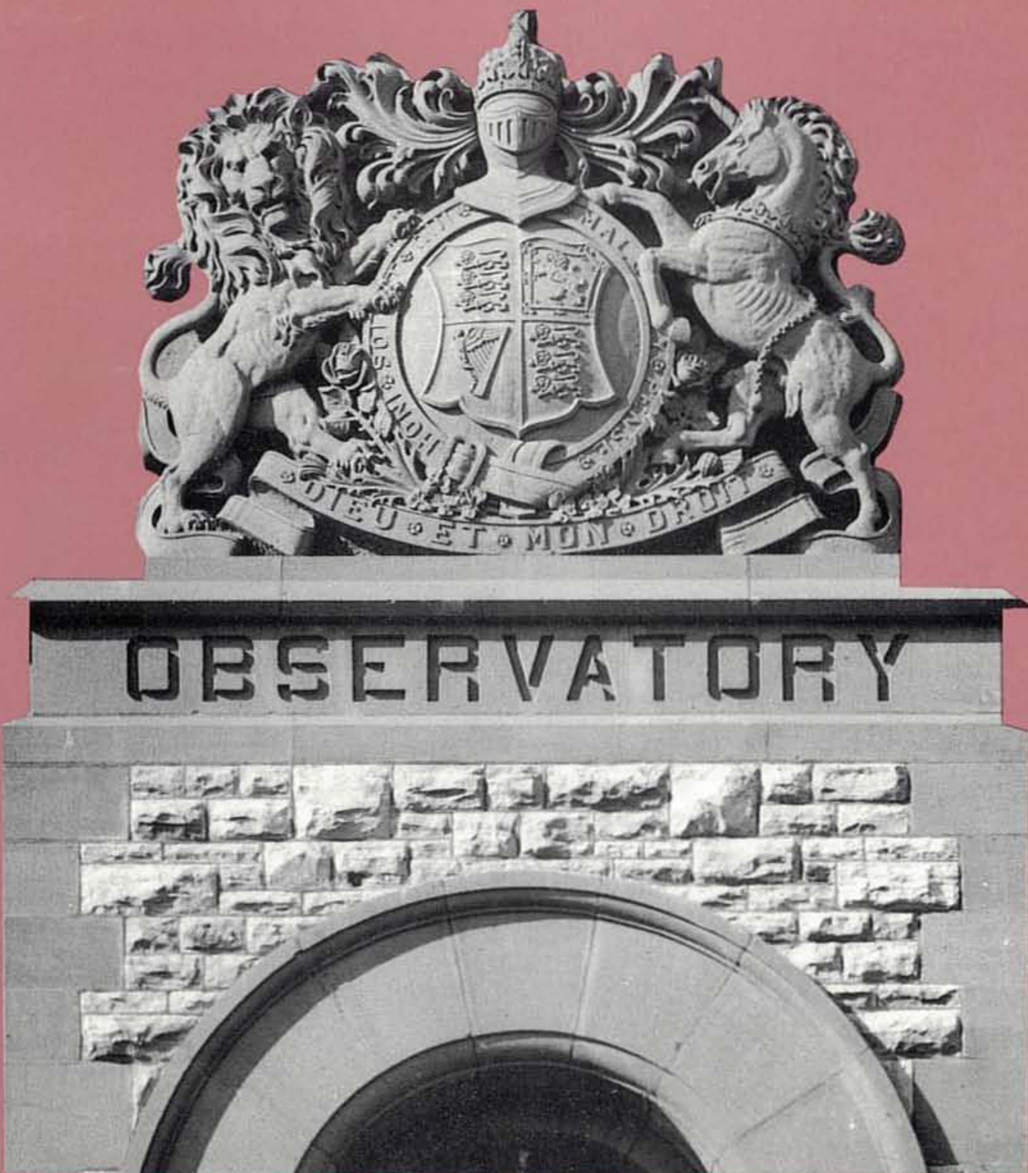
THE HEAVENS ABOVE AND THE EARTH BENEATH

A History of the Dominion Observatories



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The Heavens Above and the Earth Beneath

A History of the Dominion Observatories

Part 1

To 1946

J.H. Hodgson

1989

Cover

"The Heavens Above and the Earth Beneath" which is appropriate to the multiple mandate of the Dominion Observatories, is taken from the First Commandment, Exodus 20, 4.

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Preface

The Dominion Observatory grew out of a gradually expanding section of Astronomy in the office of the Surveyor-General. With this beginning it had its feet firmly placed on the earth, and the study of the physical properties of the earth was part of its mandate from the beginning. But its eyes were on the stars, not simply as tools for the surveyor, but also for the information they could provide about the universe and the physical laws which governed it. This two-pronged, astronomy/geophysics, approach was unusual in astronomical observatories. Still more unusual was the inclusion of astrophysical research in a government institution. Most national observatories confine themselves to the bread-and-butter issues of positional astronomy and time determination.

It is difficult to date the beginnings of the Observatory precisely, but there is no problem about its end. It expired with the transfer of Astronomy to the National Research Council on April 1, 1970. Astronomy and geophysics lived on, in the Herzberg Institute of the National Research Council, and the Earth Physics Branch of the Department of Energy, Mines and Resources respectively, but the Dominion Observatories Branch ceased to exist. It thus provides an historic entity, which these volumes attempt to explore.

This history was begun at the suggestion of Dr. J. G. Tanner, Director-General of the Earth Physics Branch, whose continuing support is gratefully acknowledged. With the 1986 amalgamation of that Branch into the Geological Survey of Canada, the lines of responsibility have become somewhat obscured, but I should like to acknowledge the support of Drs. M.J. Berry and R.P. Riddihough, and particularly of Dr. R.A. Price, who has approved publication by the Survey, through its Open File Series.

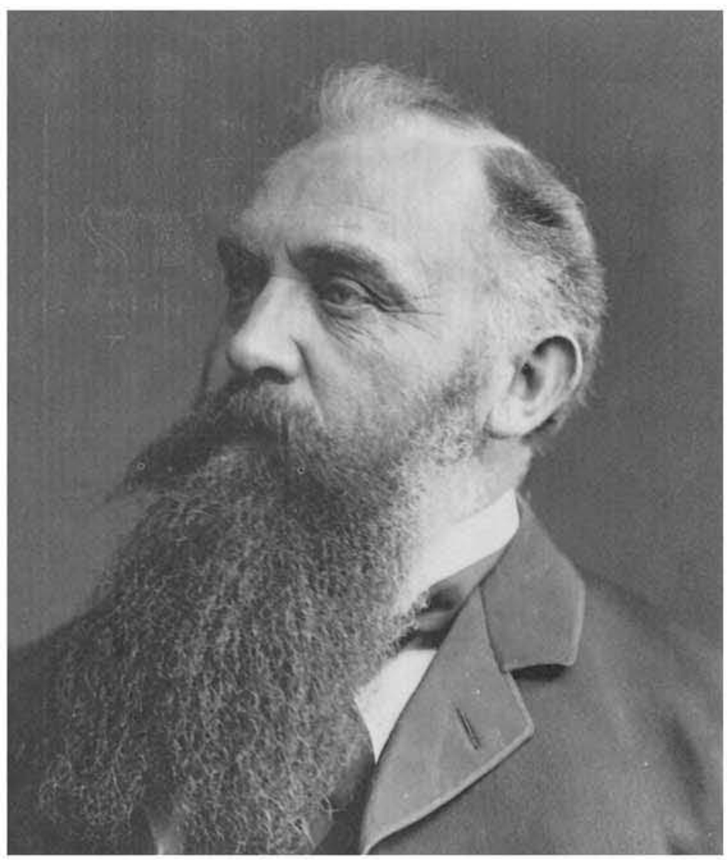
Many former colleagues have read sections relating to their particular disciplines. Some of them - Drs. Jean Petrie, Anne Stevens, K.O. Wright, Ian Halliday, Malcolm Thomson and Jack Locke - have read the entire manuscript and commented on it in most helpful detail. This professional support is very much appreciated, although I am of course responsible for any errors or obscurities which may still exist.

Charles Levesque and Louise Simpson, of the former Earth Physics Branch Library, have been assiduous in helping me in the pursuit of references; Mr. Levesque, Charles DeLaunais and Larry Newitt have searched through files of old photographs and lantern slides to produce many of the illustrations, and Dr. Alan Batten has provided many more from the archives of the Dominion Astrophysical Observatory. Those contributions are most gratefully acknowledged.

Finally I must express my very great debt to Jo-Anne Wagner who transposed my crabbed hand-written manuscript into the elegant text which you see before you.

John H. Hodgson

W.F. King, circa 1895. Detail from National Archives of Canada, PA 12444.



O.J. Klotz, circa 1895. "Yesterday I surprised Marie [Mrs. Klotz] by coming home with my 'handsome' beard in an envelope, the product of thirty years' tender nursing. When she saw me she laughed and laughed. I looked so funny, yet much improved she said, and younger". [Diaries, December 18, 1901]. National Archives of Canada, PA 12295.

I - THE FOUNDING

BACKGROUND HISTORY

Under the British North America Act the colonies of Canada, New Brunswick and Nova Scotia united to form the Dominion of Canada, which came into existence on July 1, 1867. Immediately the government of the new country began negotiations with the Hudson's Bay Company and the British Government with a view to taking over Rupert's Land and the North-Western Territory. This transfer was accomplished on July 15, 1870, part of the new area becoming the Province of Manitoba (a much smaller Manitoba than the present one), the rest being placed under territorial government. A year later, on July 20, 1871, British Columbia entered Confederation, one of the terms being that a transcontinental railroad should be built.

With the completion of these arrangements, the infant Dominion of Canada found itself with huge territories which had to be surveyed before they could be colonized and developed. For more than thirty years surveyors ranged over this new country, providing land, railway and boundary surveys. They were giants and they accomplished miracles. Their story has been splendidly told elsewhere[1], and it is not our story, but the founding fathers of the Dominion Observatory were among their numbers, and the needs of their profession influenced the form that the Observatory took.

The first survey in the new area was one to establish the boundary with the United States. Work began in 1872 with British and United States Boundary Commissions working together; a number of Canadian surveyors were attached to the British group. Their first step was to determine the geographical coordinates of a point very close to the intended boundary, at Pembina, North Dakota. This was done astronomically, which leads us to consider the role of astronomy in surveying.

Observations of Polaris provide fundamental evidence for surveyors; its azimuth defines true north, and its elevation is the co-latitude of the point of observation. The surveyor can therefore run a north-south line and check distances chained along that line by frequent measurements of latitude.

The measurement of longitude is more difficult, because it requires a knowledge of the correct time. Star catalogues give the positions of large numbers of stars, essentially telling the surveyor at what time each star will be on the zero meridian of Greenwich. If he can observe the same stars at his own meridian, and measure the time of their transit precisely, the time differences between the Greenwich transits and his own provide the hour difference in longitude; this can readily be translated into geographic coordinates. There are two requirements for precision, reliable star catalogues and accurate time, which today is provided by radio time signals.

Neither time signals nor completely reliable star catalogues existed at the end of the nineteenth century, so that the determination of longitude was more complex. Two observers were required, one at a position of known longitude, the other at the position to be determined. A dedicated telegraph line, carrying second beats from a standard clock, connected the two observers. Each observed the transit of a number of stars, the same at each place, and measured the time of transit of each precisely. The mean of the differences in transit times was the difference in longitude. Many refinements had to be observed: the timing of the transits was done with accurate chronographs; allowance was made for the delay of the time signals in the telegraph line; the personal errors of the two observers were measured and allowed for. Most importantly, the two observers measured the same transits of the same stars. Depending on the separation of the stations the difference in transit times might be a few minutes or several hours, but it was necessary to measure the same transit. If one site was clouded over, the night was lost in both places, which sometimes led to long and tedious delays, particularly since it was usual to demand up to six nights of repeated observations on the same group of stars.

With the installation of trans-Atlantic cables it was possible to tie North American longitudes directly to Greenwich. Since the first cables went to the United States, the first ties were to American observatories. As the railways spread west, the railway telegraphs could be used to bring longitude determinations to a number of American cities, Chicago among them. The surveys in western Canada were tied to Greenwich longitude by relating the longitude of Pembina to that of Chicago, the tie being made by British and Canadian observers. We need not concern ourselves with the survey of the 49th parallel, except to note that it had preceded the land surveys and so provided a base line for them; we might also note that the sub-assistant observer on the

British Commission was the 18-year old W.F. King, future director of the Dominion Observatory.

For the purpose of the land surveys a principal meridian was established ten miles west of Pembina by repeated chaining along the 49th parallel; the currently accepted longitude of this meridian is 97°27' 28.41" West. Additional meridians were established by triangulation at 94°, 102°, 106°, 110°, 114°, and 118°. These meridians were carried north by chaining, checked by frequent observations of latitude, and baselines were laid out at right angles to these at 24-mile intervals. Further subdivision into Townships and Sections followed. Within six years, that is to say by 1878, the meridians and baselines had been established from Winnipeg to the Rocky Mountains and from the International Boundary to the North Saskatchewan River. This haste was necessary because of the need to provide surveyed land for the great influx of people who were following the railroad into the new promised land, but it didn't make for great accuracy.

Accordingly a new "Special Survey" was started in 1874 to use more refined scientific procedures; in particular, it would be possible to determine longitudes astronomically, using the telegraph lines of the rapidly advancing Canadian Pacific Railway. The work continued for six years, re-surveying as far as the fifth meridian (114°W). Because the principal members of our cast, Deville, King and Klotz, were involved in the Special Survey, it will be appropriate to introduce them at this time.

Edouard Gaston Deville[2] was born in France in 1849, and educated at the French Naval School at Brest. After six years of hydrographic survey work with the French Navy he retired with the rank of Captain and, in 1874, came to Canada. He first found work as a surveyor with the Province of Quebec, but in 1880, having qualified as a Provincial Land Surveyor (PLS) and a Dominion Land Surveyor (DLS), he joined the federal surveying establishment and was assigned to the western surveys. His advancement was remarkably fast. In 1881 he was appointed Inspector of Surveys for Western Canada; in 1883 he advanced to Chief Inspector of Surveys and was transferred to Ottawa; in 1885 he succeeded to the post of Surveyor-General, an office which he held until 1922.

William Frederick King,[3] born in England in 1854, came to Canada with his parents at the age of eight. The family settled in Port Hope, Ontario. He matriculated from the local grammar school to the University of Toronto at the age of fifteen, but left the University three years later, before graduation, to join the Boundary Commission working to establish the 49th parallel. He was 18 years old, but it is reported that his supervisor "speaks very highly of the ability exhibited by Mr. King, sub-assistant astronomer, in the work entrusted to him[4]".

King returned to the University in 1874 and graduated with high honours the next year, obtaining the gold medal in mathematics. He was a brilliant student. Plaskett[5] states "His standing in the class lists was never surpassed, and his course throughout, as indicated by his obtaining seven scholarships, was an exceptionally brilliant one."

After graduation in 1875 he returned to the west as astronomic assistant on the Special Survey. Two years later he was placed in charge of the astronomic observations and continued in this capacity until 1881, at which time the Special Survey was completed. In 1883, on the advancement of Deville to the position of Chief Inspector in Ottawa, King became Inspector of Western Surveys, with headquarters in Medicine Hat; when Deville advanced to Surveyor-General King succeeded him, in Ottawa, as Chief Inspector of Surveys.

The Civil Service List for 1895 shows the permanent staff of the Topographical Survey Branch consisting of 11 people, with Deville as "Chief Clerk and Surveyor General", King as "Chief Clerk and Astronomer". The tremendous amount of field work was done by surveyors hired, year after year, on a seasonal basis. One of these surveyors, Otto Klotz, plays a major role in our story.

Otto Julius Klotz[6] was born in Preston, Ontario, in 1852. His father, also Otto Klotz, came from Kiel, Germany, to Upper Canada, in 1837. He bought a small brewery in Preston, saved his money, and bought an inn which he named "The Klotz Hotel" Although he was very successful commercially, his burning interest was in education. He was responsible for the introduction of free schools in Waterloo County and for fifty-four years served as secretary and treasurer of the school board.[7]

The young Otto Klotz inherited his father's respect for education. At the age of 13 he won a scholarship entitling him to free tuition at the Galt Grammar School, whose headmaster, Dr. Tassie, was well known as an educator and disciplinarian. Three years later Klotz matriculated to the University of Toronto in both Arts and Medicine, with a scholarship in the latter course. Despite the scholarship he chose the Arts course, with specialization in mathematics, astronomy and science. He found the teaching standards in the sciences so poor that he shortly transferred to the University of Michigan, from which he graduated in 1872. Returning to Preston he set up a private practice as a surveyor, winning his papers as a Dominion Land Surveyor (DLS) very quickly, and the more prestigious Dominion Topographic Surveyor (DTS) in 1877. In 1879 he was appointed as a

Contract Surveyor by the Canadian government and assigned to baseline work on the Special Survey.

From the time Klotz entered the Galt Grammar School until his death, he kept a diary, never missing a day except, as he frequently told people, the one he lost in crossing the date line in the Pacific. His diary is a fascinating social history and casts brilliant, if often biased, light on the events here described.

The three were very much contemporaries; Deville was three years older than Klotz, King two years younger. But because Klotz was in the "outside service" and remained there until 1892, he always occupied a lower position in the hierarchy and had less connection with the senior civil service. On the other hand he remained a working surveyor for much longer than the other two which, perhaps, gave him a more practical point of view than theirs and led to serious conflict during the founding of the Observatory.

One of Klotz' more important surveys took place in 1884. The Government set up a study to investigate the feasibility of establishing a port on Hudson Bay. Observers were placed at various points on Hudson Strait and in Hudson Bay to report on ice conditions. "At the same time Mr. Klotz was entrusted with an overland exploration survey, following the South Saskatchewan to its junction with the North Branch, thence to Cumberland House and through Cedar lake to lake Winnipeg, continuing down the Nelson to Hudson bay and York Factory; the return trip was by the canoe route of the Hudson's Bay Company up the Hayes river and through Oxford lake. The expedition comprised two Peterborough canoes and four men; it covered two thousand miles, involving eighty-seven portages. On account of the shallowness of the water about York Factory and Nelson he reported adversely to making either the terminus of any contemplated railway to Hudson bay; the commercial value of such a railway he also questioned in any event[8]." Klotz apparently carried a magnetometer with him on this survey, probably his first involvement in geophysics.

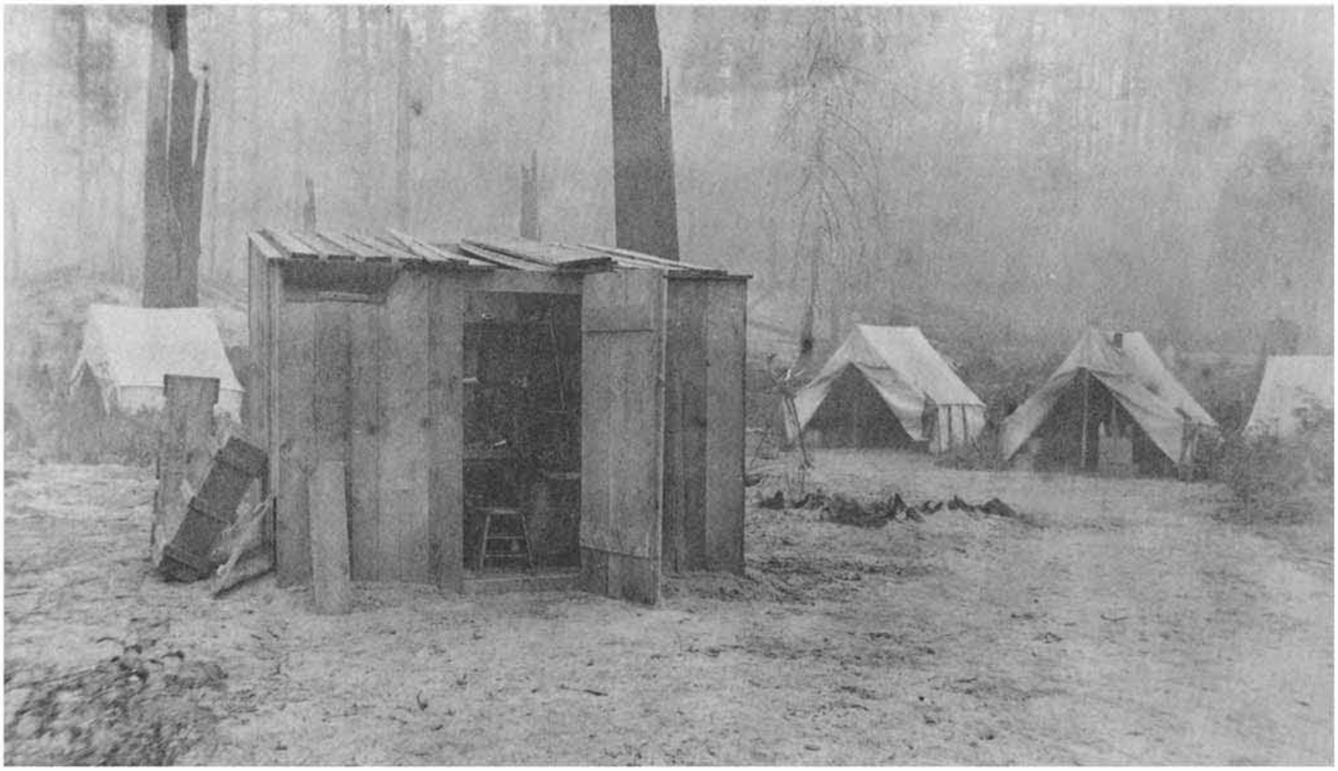
Klotz' next important assignment was connected with the survey of the "British Columbia Railway Belt" , a strip of land extending 20 miles on either side of the railroad, ceded to the Federal Government by British Columbia as one of the terms of its confederation. The surveying of these lands presented special problems. Mountain ranges made up much of the belt, but it included many fertile valleys as well. How were these to be surveyed? The easy way would have been to survey each independently, without regard to any established base, but it was decided to extend the prairie system of townships and ranges. The survey was carried out along the railroad right-of-way, and Klotz was responsible for the section from the summit of the Rocky Mountains to Revelstoke. During this field work he triangulated a number of mountain peaks, determined their elevations, and named them, one after himself. (This name did not receive official approval.) He also discovered an important trilobite fossil, which was subsequently named *Ogygopsis klotzi*.

It was not enough to establish the bench marks; their longitude had to be determined. This was the beginning of a programme very important in the history of the Observatory. In 1885 Klotz carried longitude from Seattle to Victoria and to Revelstoke, and then to a number of other points along the railroad, thereby tying his surveyed points to the continental grid; within the next two years this chain of longitudes was carried east to Port Arthur. During this work, Klotz was officially given the title "Chief of the Astronomical Observations to be conducted in British Columbia and the North West."[9]

In 1889 Klotz was given an assignment of considerable importance, and one which had a serious influence on his subsequent career. It involved the Canada-Alaska boundary. When the United States bought Alaska from Russia in 1867, the boundary line depended on a treaty between Russia and Great Britain, signed in 1825. The territory was very poorly mapped at the time that the treaty was signed, and the very imprecise terms of the pact gave rise to much controversy between Canada and the United States. One of the most serious problems concerned the boundary of the Panhandle, which was to be ten marine leagues from the coast. How to define this line with a shoreline indented by so many fiord-like inlets? Canada took the view that the line would be ten leagues inland from a general line connecting the headlands; the American position was that it followed the sinuosity of the coast. This would have denied Canada any outlet to the sea.

In 1889 Klotz was commissioned "to take a cruise along the coast with a chartered schooner to gain information in general and to ascertain what the American Govt. is doing in survey matters relative to the Boundary question".[10] He found little surveying activity going on, but he came away firmly convinced that the American position about the 10-league line was the right one and so stated in his report. This did not go down well. Two years later King was sent on a similar mission. This was a blow to Klotz who had hoped to be named as Boundary Commissioner. "This undoubtedly puts another candidate in the field"[11]. Moreover, King recommended in favour of the Canadian position.

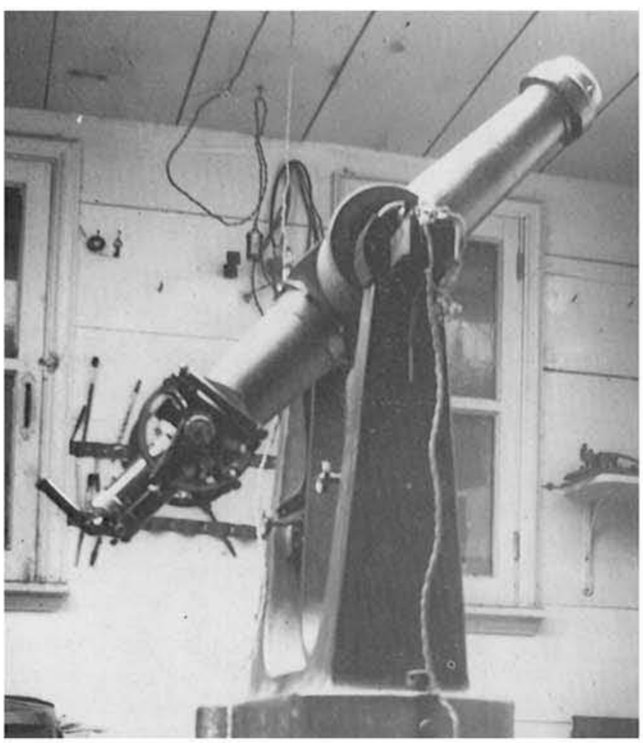
After each survey season Klotz returned to Preston, reduced his observations and produced his



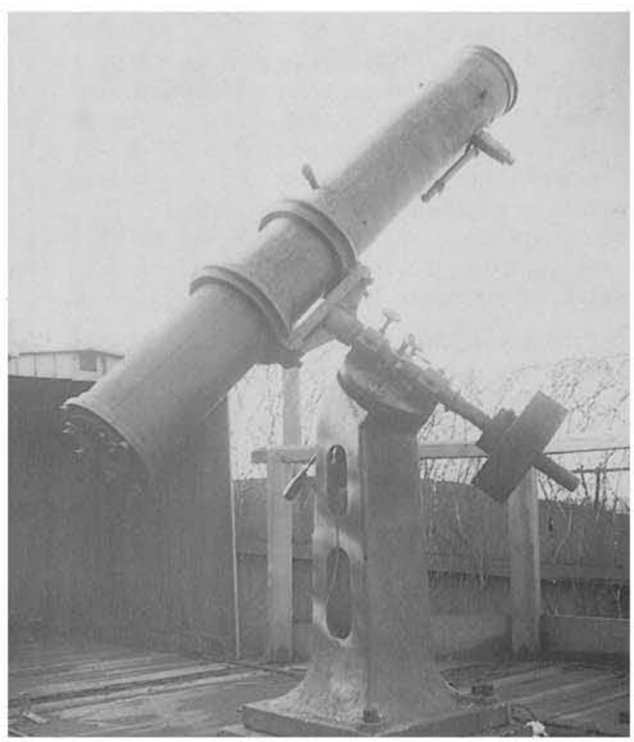
Astronomical field observatory at Revelstoke, 1886. Photo by Otto Klotz, National Archives of Canada, PA 52790.

View of Parliament Hill from the Chaudière district, showing the residence of R.J. Devlin. The two white roofs beyond the residence, on the edge of the cliff, are of the "Astronomical Laboratory". National Archives of Canada, PA 27392.

The transit house at the Cliff Street Observatory. National Archives of Canada, C 11614.



The transit telescope of the Cliff Street observatory; at far right is the chronograph used in recording star transits.



The six-inch equatorial telescope of the Cliff Street Observatory. Note the tracks for moving the shelter.

report, and continued in his private practice. "My family is better off here and enjoys comforts that income in Ottawa will be necessarily less, for here many an odd dollar I earn beside my Government pay"[12]. But despite his reluctance to move, the case for Ottawa was growing more interesting. In 1887 Deville, as Surveyor-General, recommended to his Deputy Minister[13] "that a permanent observatory be established in Ottawa for the following reasons:

1. to store and maintain in proper working order 'a number of fine and expensive astronomical instruments';
2. 'the value and accuracy of explorations in remote parts of the North West Territories could be increased by exact determinations of geographical positions by the explorers';
3. 'For the purpose of rating chronometers, testing and adjusting surveying instruments, and for examining in astronomy candidates for commissions as Dominion Topographical Surveyors ...'"

By 1890 an observatory had been erected on Cliff Street, Ottawa, and by 1891 a Physical Testing Laboratory for verifying the measurement of length was established, also on Cliff Street. The site of this old observatory is now occupied by the Supreme Court Building. At the same time King was given the title of "Chief Astronomer" of the Department. This date might well be taken as the founding date of the Dominion Observatory.

Klotz' reluctance to move was finally overcome by the Minister. Klotz was still spending time in 1891 on the reduction of his observations in the Railroad Belt, and was being paid for it on a per diem basis. The Minister objected to this and insisted that if he were to be paid he must work in Ottawa. The move was made in 1892, and by late July the family was established in their new home at 437 Albert Street, across from the present Technical High School, where Klotz lived for the rest of his life.

In view of the unpleasantness which developed later between King and Klotz it should be recorded that at the time he moved to Ottawa Klotz was looking forward very much to working with King whose interests were more akin to his own than anyone he knew. In the six months before his family arrived they spent a great deal of time together, in King's home or in Klotz' hotel room, more often the latter, discussing the work, planning for an enlarged observatory or contesting mathematical questions. For example[14] "spent the evening with W.F. King. At his suggestion I assisted him in drawing up a memorandum to the Minister in reference to his scheme or plan for the further prosecution of Exploratory Surveys in a systematic manner".

These evening sessions were convivial. "King and I almost every day do not leave the office till 5:30 p.m. then sit down for half-an-hour at the Bodega over a glass of Gaelic and soda and smoke a cigar"[15]. It wasn't unalloyed bliss. "Our chats are interesting and mutually instructive but they are in the long run a little expensive. King'll smoke 3 to 5 of my cigars and consume a few Gaelics. However he's a good fellow"[16]. A week later he reports " afterwards I was in my room, glad to have a night to myself"[17].

In addition to the enlarged intellectual resources of the Capital Klotz enjoyed the small observatory. As well as the transit instruments it had a 6-inch equatorial telescope and Klotz delighted in showing the wonders of the heavens to visitors. "In evening at Observatory. Mr. & Mrs. R.J. Devlin [a prosperous Sparks street merchant], Mr. Fisher and Miss Percival were in too. Mr. Devlin has a fine residence beside the Observatory and overlooking the Ottawa. Before returning to my hotel I enjoyed a cigar with him in his cozy library"[18].

Deville's establishment was small. That of the astronomy section was correspondingly smaller. It consisted of King and Klotz. The Surveyor-General and his staff occupied offices in the Thistle Building, at 28 Wellington Street. The location of this office will be of some interest.

In those early days the area that we now know as Confederation Square had not yet been cleared[19]. There was a full city block of buildings east of Elgin and between Sparks and Wellington streets. The Thistle Building was in this block, facing Wellington Street. Immediately to its west, in the same block, was a building occupied by the Bodega Wine Company. They owned a restaurant on the northeast corner of Wellington and Elgin, and an adjacent bar "the Bodega" facing on Elgin Street. It was in this bar that King and Klotz "sat down for a half-an-hour almost every day".

In 1901 the Surveyor-General moved to a new building on the northeast corner of Metcalfe and Slater, a building[20] "which was specially constructed to suit" his requirements. The astronomers remained in the Thistle Building until their move to the new Observatory, but the new building was almost certainly the "skyscraper" (p. 67) which the Geodetic and Boundary Commission surveyors occupied until 1914 when the new Geodetic Survey Building was completed. As for the Thistle Building, by 1908, and probably much earlier, the entire block facing Wellington Street had become the Bodega Hotel.

By 1892 the Alaska Boundary question was once again demanding attention and Klotz hoped to be put in charge and to be named the Boundary Commissioner. Instead he was assigned to a project to link Montreal and Greenwich in a longitude determination. The work was planned by astronomers from the Greenwich Observatory (H.H. Turner, of International Seismological Summary fame, was one of them) and by Professor C.H. McLeod of McGill University. Klotz was to some extent imposed on the experiment to show the federal flag, since the surveying establishment in Ottawa feared, with some reason, that McLeod was trying to establish McGill as the headquarters of national surveys. In addition to resenting his rather minor role in the operation, Klotz also felt that he was given the assignment to keep him away from Alaska and to avoid naming him as Boundary Commissioner.

Four stations were involved in the longitude determination, the principal stations at Greenwich and Montreal and intermediate ones at Waterville, Ireland, and Canso, Nova Scotia. Observers changed locations during the experiment, but only McLeod and Turner interchanged between the principal stations. For this reason theirs was the main contribution which, added to the other sources of discontent and to the fact that both his parents died during his absence in the field, made Klotz something less than enthusiastic about the assignment.

His fear about the Boundary Commissionership was borne out when he returned from the field; King had been appointed to the post. "My non-appointment I attribute to two reasons - principally to the fact that I expressed my opinion in a report to the Government that Canada had no claim to any part of the coast northward of the Portland Canal, i.e. that the inlets irrespective of their widths belonged wholly to the United States. The Deputy Minister Mr. A.M. Burgess holds differently. In the second place the Deputy feels that King has not received that pecuniary acknowledgement that he deserves ... and now embraces the opportunity of doing something for him. ... As I was not appointed I was glad to see my intimate friend King get it and not a political hanger-on."[21]

The next year, 1893, Klotz did get to go to Alaska. There were five parties, one working directly under Klotz, the others under his general supervision. The aim was a topographic survey of the Panhandle region for, in addition to the question of coastline, the topography of the mainland would bear on the decision of the Tribunal. The parties used cameras as an adjunct to surveying, a technique that had been pioneered by Deville and which was the forerunner of modern photogrammetry. Klotz spent the summer on a comfortable steamer, supplying the parties and directing the work. He also took large numbers of photographs of the Alaskan survey, a collection of photographs which seems no longer to exist.

He was back in the field the next year, but this time King was out too and had, in fact, taken Klotz' schooner and assigned him a small and most uncomfortable substitute. He wasn't having that! He found a new schooner and arranged that it should be re-decorated. When it was "I immediately quarter myself therein in the cabin specially arranged and neatly furnished for me. Everything is freshly painted and varnished, lace curtains on windows and bed, arm chairs, gold thread tablecloth, bookshelves, nickle cuspador - in short a cozy room. Kind friends have sent on board some wine, liquor, beer and cigars, these together with choice provisions and a good cook put me in a comfortable position, which I hope to enjoy, not however forgetting to discharge my duties with the utmost devotion and zeal"[22].

When they met in the course of the summer work King was a frequent visitor to the well stocked cabin.

The Canadian survey work was much appreciated; by late 1895 the U.S. Coast and Geodetic Survey was using it to produce a new map of Alaska; Mr. Burgess, the Deputy, was annoyed!

To finish with the question of the Alaska Boundary, Klotz' position was apparently vindicated in 1899 (although Thomson makes no mention of a decision on that date, the final arbitration having been made on October 20, 1903[23]). His diary entry says: "I feel that the constant position [which] I have taken since 1889 has been [vindicated] as the correct one. I have been ostracized departmentally and severely sat upon. King will return from Washington in a few days with his tail between his legs, and I here with a feather in my cap, he with many thousand dollars to his credit, I to my debt, and the Government of Canada tens and tens of thousands of dollars thrown away on the survey of S.E. Alaska"[24].

The money "thrown away" was that spent on the topographical surveys, during 1892-1894, of territory that was ultimately judged to belong to the United States. As we have seen, the U.S.C.G.S. appreciated the work. It isn't clear how King had profited, nor Klotz lost, by "many thousands of dollars".

Whether or not his position vis-a-vis Burgess, Sifton and Laurier was made difficult by his having been "right" from the beginning, he thought it was, and, in his diary, he frequently attributed career difficulties to this source.

There is one fact that makes it difficult to accept this. In 1898 he was sent on a confidential mission to Britain and Russia to track down all the pertinent papers on the British-Russian treaty of 1825 which settled their conflicting claims about the territory that was to become Alaska. He spent several weeks in London and in Saint Petersburg and compiled a file of papers that were very useful to the British-

Canadian delegation at the final boundary conference.

In 1896 the question of who was responsible for longitude determinations was settled by the Minister. King and Klotz were the responsible officers, not Deville and certainly not McLeod. They tied Ottawa to Montreal and Winnipeg to Ottawa that summer. Since Winnipeg had been tied to Seattle by the earlier work of Klotz, the trans-Canada longitude net was established, and longitude determination was recognized as a responsibility of the developing Observatory.

THE FOUNDING OF THE OBSERVATORY

From the time that the Cliff Street observatory was built and King had been appointed Chief Astronomer, lobbying seems to have been in process for the construction of a National Observatory. For example, in June, 1898, a party of members of Parliament visited the Observatory and were greeted by Klotz. One of them told him that a number of the members "will bring the inadequate condition of the Government Observatory to the attention of the House when our supplementary estimates come up." We may suppose that the members didn't dream this up on their own. However Klotz' ambitions, at least, were limited. "I told him that for my part I was not looking for a 'dome' observatory at present, but for an adequate equipment for the line of work we were at; we require at present a new chronograph and I want a half-seconds pendulum apparatus"[25].

King's ambitions were higher. The next day[26] "King came in to discuss estimates for a permanent observatory. Our idea of the equatorial [telescope] to get were the same - i.e. 10 in. My estimate was a minimum of $25,000." A few days later King was discussing possible programs in stellar photography. These few diary entries are about all the evidence we have for this preliminary skirmishing. In the major developments that were to follow we are not much better off. King left no papers, the Sifton papers lack detail, and Klotz, in his diaries, reports surprisingly little about the matter. His diary is very detailed about current events and about his involvement in extra-curricular activities, but his entries about the observatory are usually limited to "To the office". Only when some decision of King or Sifton particularly annoyed him is an event noted, and then almost invariably by pouring scorn on his superiors.

It is unfortunate that, by the time a new observatory became a possibility, relations between King and Klotz had deteriorated badly. King still came in for a glass and a cigar but he seldom told Klotz what was on his mind. On the other hand if we can believe Klotz, King was an incompetent who avoided most of the work and claimed most of the credit. Both he and the Minister, Clifford Sifton, were guided not by a true interest in furthering astronomy but by a desire for personal prestige as the responsible Minister and the potential Director. Klotz was opposed to almost everything they proposed, sometimes with reason but, in the light of hindsight, usually without.

There can be no question of the competence and dedication of King, nor of Sifton. Stewart[27,28] gives them full credit for founding the institution that we know and Plaskett[29], who worked under King's direction for many years, is extravagant in his praise of King's competence and modesty. Like Stewart, Plaskett gives King and Sifton credit for the founding of the Observatory. We cannot accept the negativism of the Klotz diaries but, in studying what he opposed, we may learn what King and Sifton were doing.

It is evident from the diaries that Klotz, even at his relatively low, 1898, position in the hierarchy, could visit the Minister for general discussions about the work. We may therefore suppose that King and Sifton enjoyed many such discussions and that when on October 29, 1898 Sifton asked King to send him a memorandum on the proposed observatory he had been well-prepared for its contents. The memorandum,[30] dated November 7, 1898, was prepared with the help of Klotz who made the estimate of building cost and supplied the attached list of observatories, U.S.A. and foreign, "from my *private* library"[31]. The fact that this wasn't acknowledged in the memorandum irked him very much.

The memorandum is given here, less the list of Observatories; it gives a very clear statement of what King and Sifton had in mind.

Department of the Interior,
Office of Chief Astronomer.

Ottawa, 7th November, 1898.

Sir,

With reference to the Ottawa astronomical observatory, I have the honor to report that the principal use of the present establishment on Cliff Street is the determination of time and longitude. It is the basal point from which have been determined a number of telegraphic longitudes, including a series extending across the continent to Victoria.

These telegraphically determined longitudes have been of use in many ways; as affording a series of points upon which the Dominion Land Surveys in the Railway Belt of British Columbia have been based; in connection with the Dominion Lands Surveys in Manitoba and the North West Territories; in connection with the international boundary, as in the case of the determination in 1896 of the longitude of Port Stanley on the north shore of Lake Erie; the interprovincial boundary between Ontario and Manitoba; and in connection with distant explorations, such as Mr. Ogilvie's survey of part of the shore of Hudson's Bay in 1890.

For all such astronomical determinations, Ottawa, as the Capital of the Dominion, forms the natural centre, and it is anticipated that it will be found advisable in future to extend the system of longitudes into Eastern Canada. Such determinations would form an essential part of any scheme of Geodetic or Coast Survey.

The observatory is used also for the determination of local time, the rating of chronometers (for use in exploratory surveys, &c.), the practising of observers, the determination of their personal equations, &c.

Besides the transit instruments, with the auxiliary apparatus, used in the above work, the observatory is furnished with a reflecting telescope for the observation of star occultations, &c. and as an exhibition instrument for the use of visitors to the observatory. Unfortunately, the situation of the building is very poor; there is a clear view to the north and south only; to the east the view is cut off by the adjacent stable, which is further most objectionable from the danger of fire and in other ways. To the south, buildings and the smoke of the city destroy the view of the most interesting portion of the sky, as the observatory stands on ground much lower than Victoria and Wellington Streets. The lot, moreover, is so narrow that there is not space alongside for the erection of a room which can be warmed in winter, a very necessary accommodation, both for the observer preparing for his observations and for keeping the electric batteries by which the recording apparatus is worked. Artificial heat cannot be used in the observing room itself. Hence the observatory cannot be used in winter at all for observations of precision.

On these grounds I recommend the erection of a new building upon a better site. At the same time I would point out the desirability of improving the equipment of the observatory so that, besides the geographical work (i.e. longitude &c. spoken of above), something could be done in the direction of the modern investigations in Physical Astronomy. The special instrument for this purpose, which would have to be procured, is an equatorially mounted telescope, driven by clock work, and fitted with attachments for micrometric measurements, and for spectroscopic photometric and photographic work.

The usefulness of such an instrument from a public standpoint may be briefly indicated as follows:

1. The scientific value of the observations which would be made with the instrument; also the collateral assistance which would be afforded to investigators in the many branches of science which are closely related to astrophysics.

2. Stimulus to science throughout the Dominion. The development of our resources calls for applications of science. The advancement of even "pure" science, often so-called in contradistinction to "practical" science, means public benefit in many directions, benefit which may be quite unforeseen by the scientific investigator, but which the history of industrial development shows is sure to follow. A Government cannot well afford to leave its interests in this direction wholly in the hands of foreign investigators, for each country has its own special problems to solve. Hence the advancement of science is a matter of national concern, worthy of careful consideration on the part of the Government.

Now Astronomy is a science which so touches other sciences, that an increase of public interest in it forwards the others, and, again, there is nothing else so capable of arousing public interest as the exhibition, through a good telescope, of the wonders of the skies. A national observatory at the Capital will assist to this end in a paramount degree, for Ottawa is a centre to which come the leaders of public opinion from all parts of Canada, so that the interest aroused will permeate all parts of the Dominion.

Astronomical investigation has been hitherto greatly neglected in Canada, although its importance is recognized everywhere else, especially in the United States, where many princely endowments of observatories have been made by wealthy men. To illustrate the attention paid to astronomy elsewhere, I append a list of eighty-five observatories in the United States, and a list of two hundred and fifty two observatories elsewhere. These lists I believe are tolerably complete. The United States list shows the result of the wide spread popular interest in this branch of investigation.

The following estimate of cost has been prepared after consulting the catalogues of many British instrument makers, and with the advantage of personal consultation with Mr. Brashear, one of the foremost instrument makers of the United States, who spent a day in Ottawa last summer. The basis of the calculation is a telescope of object glass ten inches in diameter, which appears to be a suitable size for the objects aimed at.

The cost of the telescope, with mounting, all attachments, is	$ 5,360.00
Clocks and minor instruments, and setting up the instruments say	640.00
$ 6,000.00	
Cost of dome (22 ft. diameter) with rollers, &c. - (Price from Messrs Warner & Swasey of Cleveland)	$ 3,075.00
Cost of Building, about	7,000.00
$16,075.00	

In the estimate for the building, provision has been made for office accommodation, besides the tower and pier for the large telescope and the house for the transit instruments. The material is brick. Stone would probably increase the cost.

The cost of site has not been included in the estimate.

I have the honour to be,

Sir,

Your obedient servant,

(Sgd.) W.F. King

Chief Astronomer.

Honble. Clifford Sifton,

Minister of the Interior,

City.

King and Sifton obviously had further discussions for in March, 1899, King took Klotz on a walk to Parliament Hill and showed him "the site of our new observatory. ... Who selected the site I queried - 'I' he replied, adding a minute later 'and the Minister'". Klotz was appalled ... "a knoll about a hundred feet in diameter to be the site of the Dominion, the National Observatory, in a public park ... a site ridiculously absurd, a site so utterly unsuited for laying the foundation of an institution that is to develop into something creditable"[32].

Klotz was really upset. His diary continues: "My plans have been toward laying the foundation [for] the establishment of an astronomic geodetic institute - where the work would comprise geodetic astronomy, geodesy, terrestrial magnetism, pendulum observations and standards, in short to be the division of government work that dealt with Exact Science. - And all these plans to be centered on a hundred foot knoll!!! - I thought King had higher and truer aspirations, and a greater sense of obligation to the future".

On May 23-25, 1899 Klotz attended the meetings of the Royal Society ("there is a good deal of humbug about the proceedings of the Royal Society") and heard a paper by Professor C.H. McLeod, of McGill University, in which he made a plea for the establishment of a geodetic survey[33]. The paper seems well-reasoned and very modest in its proposals but it apparently created quite a furor in the Ottawa surveying establishment. Whether they suspected that McLeod wanted the Survey to be based in McGill, or whether the Geological Survey, the Surveyor-General's Department and the proposed new Observatory were jockeying for control of the new Survey isn't clear from the diary. It was agreed that King should prepare a memorandum for the Minister. This memorandum has not survived, but the passage does show that King and Klotz were aggressive in seeking the Geodetic Survey as part of the new astronomical branch.

Meanwhile Sifton was moving quickly to get funding for the new observatory. On March 22, 1899 he requested the Minister of Public Works to provide $10,075 in the estimates to cover building costs. "The cost of the instruments and equipment will of course be covered by an estimate by this Department". The Chief Architect, D. Ewart, increased this amount to $16,000[34].

The Minister must have followed through with the estimates for the new instruments, including a 10" equatorial telescope; shortly after Parliament had recessed Klotz reports a discussion with King[35]. He "said nothing about buying the 10-inch equatorial for which Parliament just at closing provided the means and I didn't refer to it, since he said nothing to me at all about the new observatory after obtaining much information from me for his memorandum to the Minister advocating the erection of an observatory and 10-inch equatorial".

Klotz was opposed to almost everything King was trying to do. King was hurt by the disagreement and had become even more withdrawn. Klotz' objections may be divided into four categories. First of all, he objected to the proposed location of the observatory; the site was unsuitable and the available area too small. Secondly he objected to the proposed scope of the observatory; he wanted it to serve as a base for the determination of astronomic positions in Canada, as the headquarters for a trigonometric survey, and for associated field work in magnetics and gravimetry but he thought astrophysics should be excluded. Thirdly he objected to the proposed staffing, both as to their numbers and their scientific competence. Finally he objected to what he regarded as the pretentiousness of the proposed building.

These objections were obviously inter-related. If King would follow his ideas for a limited programme there would be no need for the expanded staff nor the elaborate building. On the other hand Klotz wanted a site with lots of room for expansion. It is hard to escape the conclusion that much of his carping derived from his jealousy of King.

Klotz determined to go the Minister over King's head[36]. "My conscience will not allow me to remain silent, even at the risk of incurring the Minister's displeasure, on a proposed action which I consider wrong, and if carried out will in time be condemned by others. King's motive in the premises are of course obvious to me. He is anxious to have a separate branch of the Department established and recognized - the Astronomic - of which he would be its head. The erection of an observatory provided with a good equatorial with which to reveal the wonders of the heavens to members of Parliament and other visitors would throw a certain glamour and importance on the institution. Had he raised the question of the unsuitability of any ground owned by the Gov't. it would have added materially to the appropriation necessary for carrying out the scheme, hence he undoubtedly left that question severely alone, otherwise the whole scheme would probably have fallen through. Hence the appropriation was only $16, 000, six thousand thereof for the equatorial. Such a course I could not have taken. I will either do a thing right or not at all".

Klotz had his interview with the Minister.[37] He outlined the scientific disadvantages of the proposed site, its inadequacy considering the probable future size of the National Observatory and said "that no building of whatsoever nature should be put on Government Hill which I looked upon as hallowed & sacred ground". Sifton "asked me for a suggestion as to the site, saying that the site had not yet been determined upon". Klotz concludes the entry: "when I was out of doors I felt that a burden had been removed from my heart about the observatory".

Despite the assurances of Sifton, planning continued on the basis of the Parliament Hill site. Early in September King, who was leaving on an extended trip and instructing Klotz on the problems he would face as Acting Chief Astronomer, showed him "a ground plan of the observatory to be erected on the knoll near the Western Block"[38]. Klotz went into his standard arguments against the site. "But", King replied, "if we are obliged to build away from the Gov't. grounds we will not be in touch with the Department". Klotz regarded this as a good thing: "there will not be daily telephoning and asking us for this and that information". "But", the diary continues, "this is what King personally likes, he is rather averse to continuous work, he likes to knock about the Department and hence does not like to get so far away that he cannot run from one office to the other within a minute or two. - To me the matter is too serious to treat as a personal one. For him the observatory on the Hill would cast a constant visible halo around him as Chief Astronomer".

Once King had left, Klotz, armed with his authority as Acting Chief Astronomer, called[39] "on Mr. Ewart Chief Architect to see what he had done with reference to plans for proposed observatory. I found he had made none. ... He said he had no instructions to go ahead, as no place or site had been decided upon. He said to build it on Parliament grounds the building would have to conform with the Parliament buildings. He looks on the observatory simply as an architectural problem and I of course from an astronomic and useful one".

During the remainder of 1899 the location of the new observatory continued to be a matter of contention between King and Klotz. In early January, 1900 the first plans, with front elevation, were presented for their consideration by Fenning Taylor of the Architect's Office[40]. "Looking at the gorgeous perspective I laughingly tapped Taylor's overcoat pockets - saying they didn't seem to be thick. He not understanding what I meant - I added - I thought you'd have your pockets filled with money to build such an observatory. I may say that $16,000 were ordered last year by Parliament for an observatory but goodness knows what this will cost. Taylor said 'there'll be no trouble about the money'". Later Taylor said they might make any changes in the plan of the observatory but that "Mr. Ewart doesn't want any change made in the elevation. - This then is primarily to be an architects' observatory, the astronomer counting for little or nothing. Where in the wide world was ever an observatory designed on these lines. ... However, King will lay no obstacles in the architects' way, his motto is - 'an observatory at any price - W.F. King - Director'. With the money the above will cost we could buy a suitable site, which the knoll on Government Hill is not, build and well equip a serviceable observatory with room for expansion and other buildings which will be necessary if to the astronomic work is associated as it should be with geodetic work, for which I have for so many years been laboring for its inception".

During the next few weeks he continued to lobby against the proposed site, and against the fancy architecture, this time through the Deputy Minister, Mr. Smart. Smart didn't give him much encouragement[41]. "I suppose we don't need to care, you and I won't have to pay much towards it".

He continued at the same time to oppose the purchase of an equatorial telescope, without much success apparently, because by May, 1901 the plans have increased from the 10 inch aperture of August 18, 1899 to 12 inches. Klotz thought that[42] "the whole business is more or less of a humbug, had the money voted for telescope and building ($30,000) been used to begin a well considered plan for a thorough geodetic survey of Canada, it would have been a most wise and practical outlay, but to purchase a 12-inch equatorial is practically useless. Neither King nor I (the two astronomers) have ever done any work with such an instrument, it is not in our line, but geodesy is. But there is a glamour surrounding the words observatory with a dome & large telescope that appeals to the layman including our Minister so that King two years ago filled Mr. Sifton with his idea of a large telescope, which now finds itself provided for. - As I said at that time in my diary King himself does not care to do any systematic work with it, as he does with nothing else except to gain present ends, for he is too lazy. His incentive is to have something imposing, something to strike the public eye - and then to be able to say 'I am director of the Dominion Observatory'. We certainly require an observatory in the place of the miserable shed we now have for our transit etc. Its principal functions would be for longitude work, gravity work, rating of chronometers, latitude variation and the like".

His ideas didn't carry much weight because just three weeks later[43] the plans had grown to a telescope of 15-inch aperture. I have not been able to find any documentation of this change of thinking except the diaries, but obviously Sifton and King were seeking the best. King went off immediately to Cleveland to order the instruments. Klotz' comments "The Lord knows what efficient work will have been done with it in ten years. Not much, I trow."[44]

Klotz had more influence on the site selection, his interview with Sifton apparently having impressed the Minister. A number of possibilities were investigated. One was on Concession Street (now Bronson Avenue) where it ended on the bluff overlooking the Ottawa River; a second was on a height of land near the Rideau River, apparently south of what is now Strathcona Park. Klotz rambled around Rockcliffe and liked a site which must have been close to the present RCMP headquarters. They were offered a site at the corner of Maria and Concession street (the present Laurier and Bronson) but this was refused as being too small and too rocky.

Apparently Sifton himself turned the search toward the ultimate solution for in mid-June, 1901 he told Klotz[45] "that he had tentatively chosen a site in the Experimental Farm. I said that years ago I had looked over the ground and found it suitable, only a little far from the city to go in and out. This he said would be remedied by the 'Improvement Commission' and by the extension of the electric railway. He said 'I am going to have comfortable quarters for you out there'. I thanked him that it was not to be built on Parliament Hill, which would have been wrong. He said 'You have the credit that it isn't going there, when you spoke to me after I had decided that it should go there (3 years ago) it made me think, and I found that you were right'. This was a great compliment to me. He said it was a disgrace how we (2 astronomers) were now provided and that he had told them so in the House lately and I could find it in Hansard."

The next day[46] Klotz looked "at the site tentatively chosen by the Minister. It is a knoll of less than 100 feet diameter situated between the large barn and greenhouse, the space available besides lies to the back and rapidly falls." It is impossible to locate the site from this description; there is no rapidly falling ground anywhere near the present green houses. It may have been in the Arboretum, near the present Botany Building, for there are greenhouses there and the land does drop off toward Dow's Lake. In any event the limited area made the site unsuitable. Klotz "walked about the grounds and found a more suitable place, one in which we and our successors, for I plan for the long future, can expand and build as the requirements of the progress of Canada dictate".

The following day a great delegation went out to see the site that Klotz had selected. King arrived[47] "in great state - a flunky and landau two horses", accompanied by the architect Fenning Taylor, Mrs. King and a Mrs. Simpson. Klotz had earlier delivered Mrs. Klotz to the home of his friend Dr. Saunders, the Director of the Experimental Farm, to take tea with Mrs. Saunders, and he and Saunders were on hand to meet the King party. Under Saunder's direction the party visited several possible sites, but all agreed that the one selected earlier by Klotz was the best.

The party then repaired to the Saunder's residence where, as we have seen, Mrs. Klotz was already taking tea with Mrs. Saunders and her daughter Mrs. Ford. "When Mrs. S. saw the grand equipage with flunkey driving to the door, she thought it was the governor general and party, so her daughter, Mrs. Ford and Marie [Mrs. Klotz] hustled into another room and Mrs. S. received - a shock to find a Mrs. Simpson and a Mrs. King, whom latter she didn't know, ushered in!!"

Unknown to Klotz, King phoned the news of the newly selected site to Sifton who, since he was on his way to a cabinet meeting, had an Order-in-Council passed the same day setting the site of the observatory where we now find it. Klotz found out about this a few days later when he visited the Minister. He also found out that he had not been given credit for finding the site; he corrected this oversight very promptly! In the meantime Klotz, with the assistance of his astronomic observer F.W.O. Werry, had surveyed the site and produced a plan with the observatory building located, and King had had the property photographed.

It is a bit difficult to follow the design of the building itself. In January, 1900, as already documented, Taylor had produced a plan and elevation of the proposed building; the plan was open for any modifications King and Klotz cared to make, but the elevation was sacrosanct. When the question of site had been settled[48] "King came in to my office and gave me a rough sketch of his idea of the proposed observatory. I was to have a room 18 x 15 and he one of 20 x 15."

Five days later, at the request of Sifton, Klotz[49] visited the "sub-architect J. Fenning Taylor who has the observatory draughting in hand. I found him at work on the design of King's. The radical difference between King's and mine is that his obs. is in form of a right angle with transit house toward front of one side, while mine is a straight front for the two wings of obs. with dome in the centre and transit house to side and rear of west wing. While discussing with Taylor who comes in but King, surprised to see me I suppose. King stuck to his design. I said little. After nearly two hours desultory talking Taylor suggested making an angle (150°) in the front between the two wings and immediately made a sketch thereof. I agreed and so did King. The transit house was put however along the west side of the west wing." The same day Klotz produced a site plan, with the building position laid out on it, and took it to Taylor. The detailed planning of the building could now proceed.

The specifications[50] for the new building were issued so soon after the June 1901 selection of the site that we may assume that they had been drawn with the original Parliament Hill site in mind. The front elevation was unchanged from that originally designed by the Chief Architect, and the specifications were very precise about the materials to be used. The external walls were to be of Nepean sandstone of selected and approved beds, and the trim of "approved reddish-brown Credit Valley sandstone".* There was to be a full sized coat of arms over the main door the "carving to be done by experienced carvers". Perhaps there had been some skimping in the plans for the interior, which did not match the exterior in elegance, but the pressed brick to be used as facing in all corridors and public rooms was to be uniform in quality and colour and laid with specified precision in mortar of an approved shade.

The date at which tenders were called is not recorded but tenders closed on November 27, 1901.[51] Theophile Viau submitted the lowest bid, $74,999 and on August 9, 1902 he was awarded the contract. The provision of the heating system was awarded to the Butterworth Bros.[52] under a separate contract. Construction of the "transit house" was not started until the main building was nearly completed; a contract for its construction was awarded to McGillivray and Labelle on May 16, 1904.[53] Patrick Canty represented the Department of Public Works on all three contracts as Clerk of Works.

In late July, 1902, Klotz and King positioned the building on the site. Klotz' account casts some interesting light on the trials of a public servant in 1902.[54] "In afternoon King asked me to go with him to the observatory site to observe for direction (by azimuth of sun) for giving the line for building - We drove out in a cab and took the 8" transit along. We needed a few stakes. I said I'd get them at Thaskeys' [?] - No, they are not on the patronage list, King said. All right, I'll pay for them myself, I said and got them. Had we been obliged to hunt up some obscure carpenter, who is on the list we probably would have wasted an hour of our time and the cab hire too, costing the government probably five dollars to get 20 cents worth of wood! But such are the ways of government." By August 12 "they were digging the basement of the observatory."[55]

It is pleasing to report that the unpleasantness between King and Klotz was resolved, at least temporarily, at about this time. They had been visiting a basement room in the old Supreme Court Building where Klotz was mounting his pendulum apparatus, and took the opportunity to have a chat.[56] "In a quiet way I took King to task for his treatment of me, especially since last autumn. He said that he had felt hurt by my going to the Minister and showing him our sketch plan for the observatory and

*The external trim actually used may not have been of Credit Valley sandstone. There was repeated lobbying by an Ottawa Member of Parliament, N.A. Belcourt, on behalf of quarries in the Amherst, N.S. and Sackville N.B. area. There is a general understanding today in Sackville that Wood Point sandstone was used in the Observatory, as it was for the old Toronto city Hall and the Ontario Parliament Buildings.

(Top) Klotz family portrait, 1896. All of the sons became medical doctors: Max, far right, became a very popular Ottawa surgeon, but died in 1921; Oskar, left rear, had a distinguished career as a pathologist, becoming head of the Department of Pathology and Bacteriology at the University of Toronto; Julius, foreground, had a general practice in Westboro. The only daughter, Irma, died in 1899. National Archives of Canada, PA 27800.

(Right) Diaries, January 16, 1904: "By appointment meet two half-caste Maoris ... and have a photo taken with each showing the Maori form of greeting – rubbing of noses." Reproduced, from a small photograph pasted into the Klotz Diary, by the National Archives of Canada, C131090.

that the Minister (Sifton) had asked me to show the sketch to the architect; and also that I had last autumn apparently made suggestions to one of the architect's staff for changes from King's recommendations. I told King that his inference from what he learned at the architect's office of my visit there was utterly wrong. ... We both spoke very calmly, when I finally said, 'let's drop it, shake hands King,' which we did. I told him that I looked upon myself as his right hand man, and as he will be director and superintendent of the various branches into which we may develop so I will be the assistant director and superintendent of all. We talked for about two hours and before separating for luncheon had two cocktails - each treating."

I'm not quite clear where they found cocktails in the basement of the Supreme Court. I suppose they had adjourned to the Bodega, or to the Russell Hotel, which was a favorite watering hole, but the diary doesn't say so.

In the meantime equipment had to be purchased. We have already seen that King and Sifton were planning to purchase an equatorial telescope, a decision strongly opposed by Klotz. In early June, 1901, apparently after considering a number of alternatives, King travelled to Cleveland to place an order for a 15", equatorially mounted, refractor[57]. The optical parts were fabricated by John A. Braeshear, the mounting by Warner & Swasey. A year and a half later, in early January, 1903, the telescope was completed, and Klotz travelled to Cleveland to inspect it and to supervise its packing for shipment[58]. The contract price for the telescope was $14,625.[59]

The other major piece of equipment ordered for the new Observatory was the "meridian circle" transit. Again King went against Klotz' advice in this purchase.[60] "King asked me what I thought of getting a meridian circle. I told him I was opposed to it, as this was work that was well done by the older observatories and was really outside our sphere, at present anyway. To which he replied that he had come to the same conclusion." Nevertheless the meridian circle was ordered; details will be given in a later section. Various geophysical instruments, also to be detailed later, were ordered at this time, and in September, 1902 they received "a number of control clocks from Paris."[61]

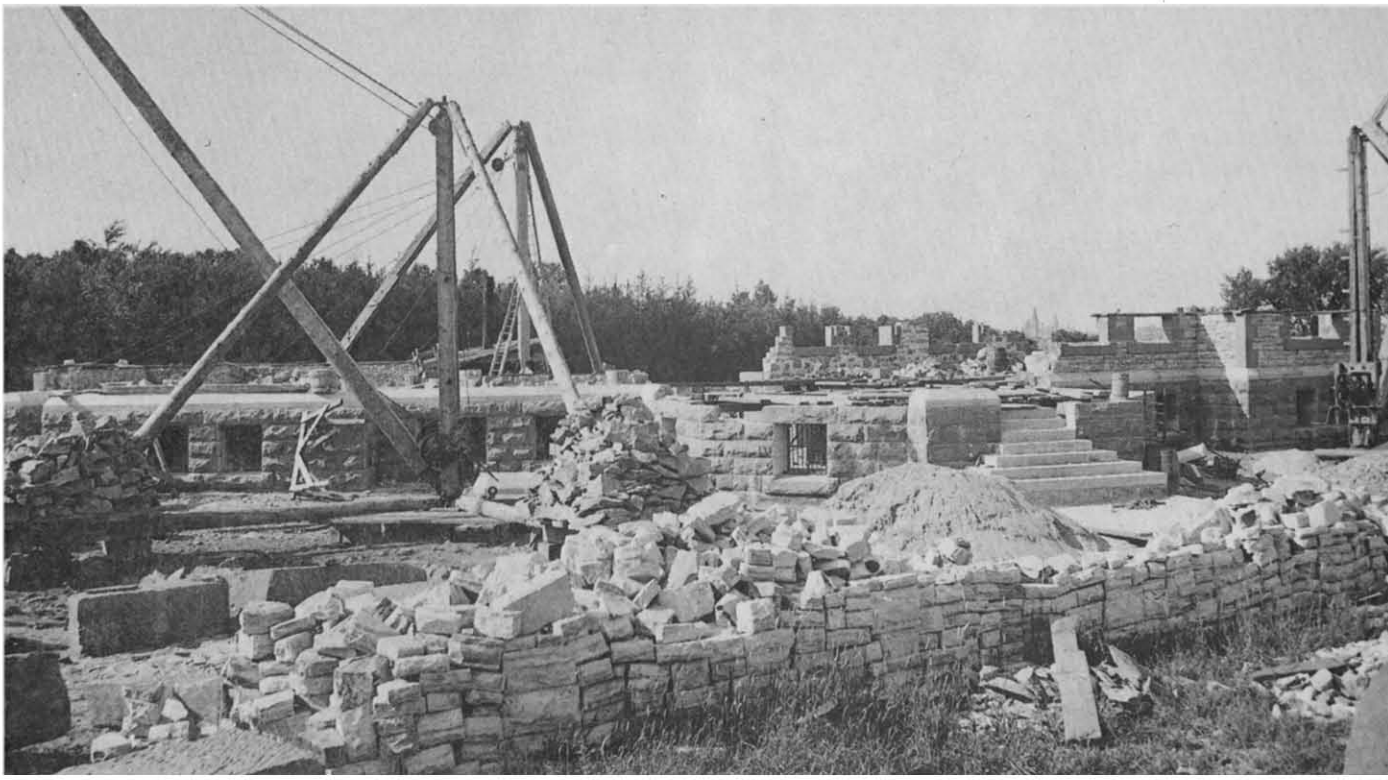
There is very little information about the actual construction of the new Observatory building. The diary reports, as we have already seen, that Klotz and King laid out the line for the building in July, 1902[62] and that excavation for the basement had started on August 12.[63] The diary contains very little more about the construction because for a year, from May 2, 1903 to April 23, 1904, Klotz was involved with very important longitude determinations. Since this was one of the major efforts in this important branch of Observatory work, some description seems in order.

In late 1902 the Telegraph Construction and Maintenance Company of Great Britain completed laying a cable from Vancouver to Norfolk Island, via Fanning Island and Fiji; from Norfolk two branches were developed, one to Queensland, Australia, the other to New Zealand. This, along with the British Cable from Britain to Glace Bay and the Canadian Pacific telegraph system across the continent was called, with pardonable pride of Empire, "the All Red Line". Just as the Atlantic cable had made possible the longitude tie between Greenwich and Montreal, so the Pacific cable allowed the tie to be carried to the antipodes. Klotz, assisted in the Pacific by F.W. O. Werry and in Vancouver by F.A. McDiarmid was responsible for the work.

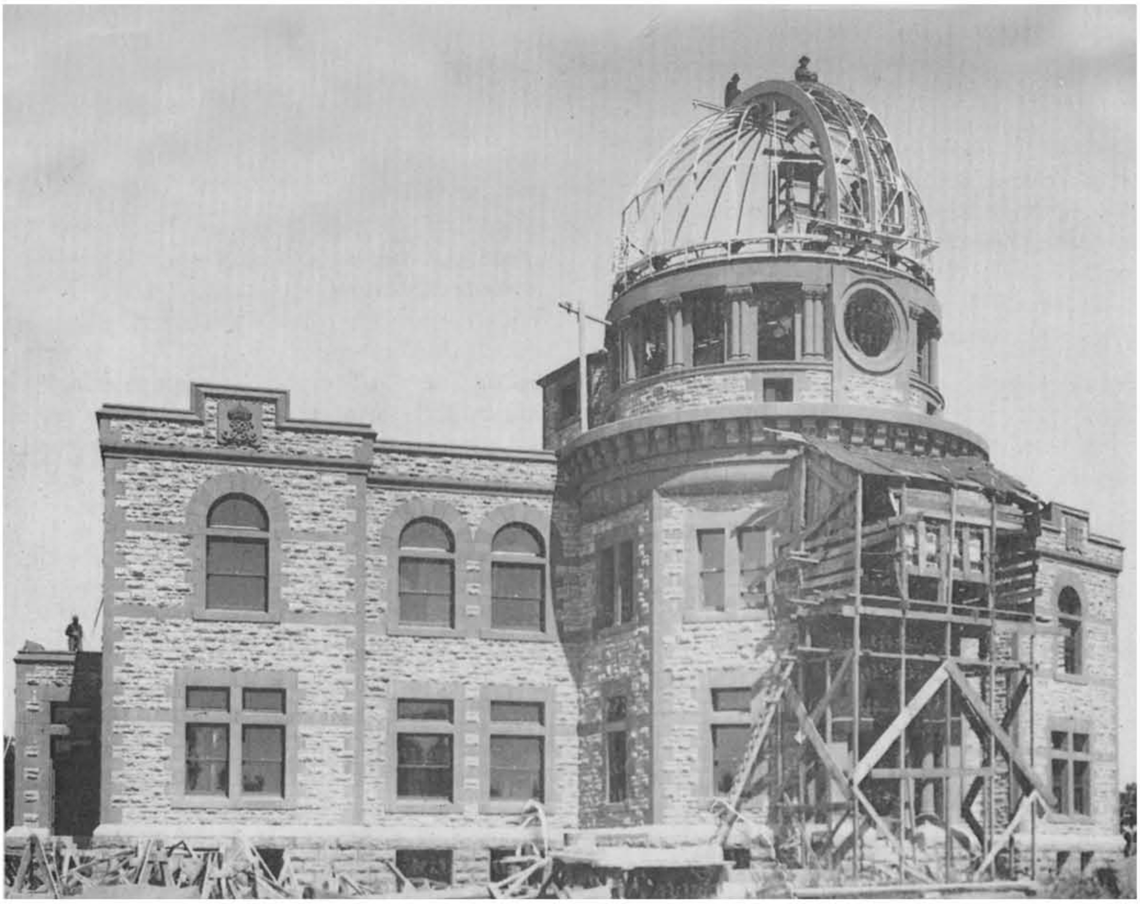
We have already seen the problems inherent in observing sufficient transits of a suitable sequence of stars at two points. Each of the three ties, Vancouver-Fanning, Fanning-Fiji and Fiji-Norfolk required about one month; Werry spent an extra 20 days on Fanning while Klotz moved from Vancouver to Fiji and Klotz spent an extra six weeks on Fiji while Werry moved from Fanning to Norfolk. Klotz occupied his time at Suva by swinging his half-second gravity pendulums, measuring the magnetic field, studying, second hand, the sex habits of the Polynesians, and being instructed in the making and drinking of kava. After the Fiji-Norfolk tie Klotz moved to and observed successively at Southport in Queensland, Sydney, Wellington, and Doubtless Bay on the North Island of New Zealand. During all this time, nearly four months, Werry remained on the bleak island of Norfolk, thinking of his hard lot and of the girl he had become engaged to before leaving Canada. Klotz had an incipient mutiny on his hands!

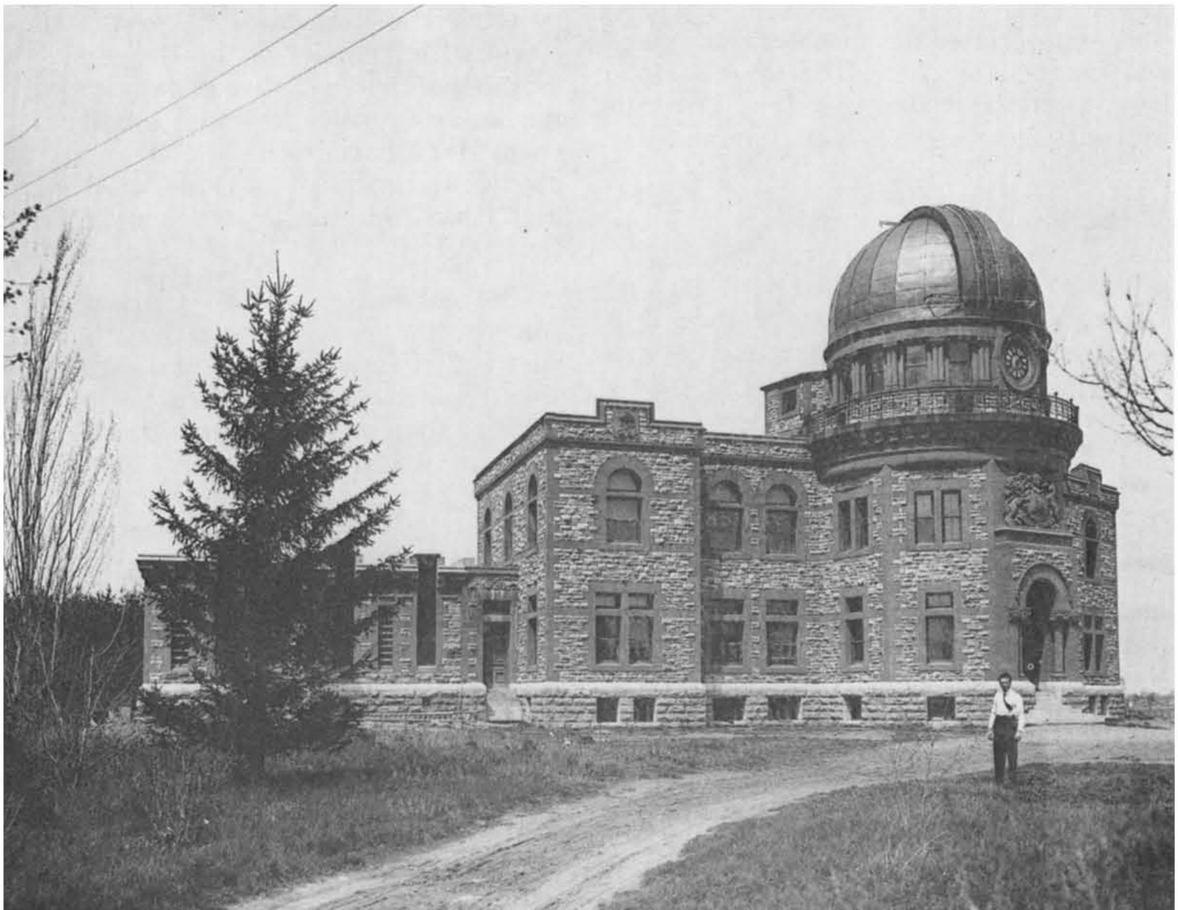
Gravity and magnetic observations were made at all the points where he observed for longitude.

The work was finished in early January, 1904. Klotz proceeded home around the world, travelling overland from Sydney to Adelaide, by boat from Adelaide to Naples, with sight-seeing stops at Perth, Colombo, Port Said and Cairo. In Cairo[64] "the hour of the day led us to the 'Mena Hotel' a fine modern hotel and built of course exclusively for tourists. On the wide piazza and sitting beside a glass of Scotch and smoking a cigarette waiting for luncheon I contemplated the great pyramid of Cheops which shows in all its hoary magnitude before us." Later: "There are several or rather two things to do here, one is to climb the pyramid (Cheops) and the other to ride a camel from there to the Sphinx close by, and on much lower ground. Both of these things I did, the



(Above and facing page) Construction
of the Observatory.





former with the assistance of three Bedouins, two pulling and one shoving."

From Naples he toured Italy, Switzerland, Germany and England before returning to Canada, visiting observatories and seismograph stations and, relations. I mention these things because, years later, shortly before he died, Klotz took a vacation and remarked in his diary that it was the first he had taken during his 30 years in the public service! [65]

When Klotz returned, the new building was well advanced but it was not until April 1905, that he moved in to his new office. We shall consider the details of the building in the next chapter.

Although we miss a written account about the Observatory's construction we have a remarkable series of photographs documenting the progress, some of which are shown on the preceding pages. The glass plates from which these were printed were originally in the collection of the Dominion Observatory but were transferred in 1977 to the National Photography Collection of the National Archives of Canada. In his notes on the collection,[66] Andrew Rogers suggests that this series of photographs was taken by J.S. Plaskett "an energetic amateur phtographer". This seems very probable and adds one more facet to our picture of this remarkable man whom we are to meet very shortly.

The $16,000 appropriated for the observatory was of course quite inadequate. The final cost for the main building, including furnishings, but not including the transit house or any instruments, was $93,800.[67]

While the building was progressing, and the major instruments were being acquired, King was also thinking of the need for staff. Just as Klotz was opposed to the expansion of the observatory into anything beyond the needs of surveying, so he was opposed to the recruitment of staff for the new disciplines. In February, 1902, during a visit to the University of Toronto,[68] "I learn that W.J. Loudon and King have been making arrangements to take three prospective graduates into our (astronomical) office, of which I have been kept in ignorance. What the men are to do the Lord knows, except to increase our staff in order to give more importance to King's position as head". Two of these men were Plaskett and Stewart who certainly found plenty to do over distinguished and influential careers. Stewart joined the staff in July, 1902, Plaskett a year later.

Robert Meldrum Stewart[69] was born in Gladstone, Manitoba, in 1878, the son of a Presbytèrian minister who, at the time of his son's birth, was engaged in missionary work and moved from place to place on the frontier. Later he returned to Ontario where he had a number of charges, which kept the family on the move. Because of this, young Stewart did not go to school until he was eleven. His father coached him in Greek, Latin and Hebrew as well as the more standard subjects of the curriculum and he entered High School at the age of eleven, attending, first, Jarvis Collegiate in Toronto, later Lisgar Collegiate in Ottawa. He matriculated with several scholarships to the University of Toronto from which he graduated in 1902 with the Gold Medal in Mathematics and Physics, and immediately joined the staff of the Astronomical Branch. He was put in charge of the "time service" and by the time the new Observatory was occupied he already had a substantial part of the organization in place. We shall return to this in the next chapter.

John Stanley Plaskett[70] had a more remarkable background. Born in 1865 on a farm near Hickson in Oxford County he was educated in the local school and in the Woodstock High School but was unable because of family responsibilities to proceed to university. For a while he stayed on the farm but left as soon as he could to work as a machinist for an engineering firm in Woodstock. From there he went to the Edison Company in Schenectady where he learned the practical fundamentals of electrical engineering. In 1889 he was transferred to the Canadian Edison Company, in Sherbrooke, Quebec, where he was responsible for installation of electrical systems. A year later he joined the staff of the Physics Department of the University of Toronto as foreman of the workshop and lecturers' assistant. In the latter capacity, through setting up the lecture-room demonstrations, he became interested in physics and enrolled as a student. He graduated with high honours in Mathematics and Physics in 1899 at the age of 34.

He continued at the University until 1903. During this period he experimented in three-colour photography and published on the subject. When he joined the Astronomical Branch in 1903 he brought to it experience as a machinist, as a practical electrical engineer and as an experimental physicist. His contribution to the development of the infant observatory was of the greatest importance, as we shall see in later sections. However, he was not hired as an astronomer. The letter from King to the Deputy Minister, requesting his appointment, survives in the Plaskett papers[71]: "Mr. Plaskett has been a mechanician for the University of Toronto for several years. I have seen some of his work, and I believe his employment here in a like capacity would be desirable. We have many instruments in use which require frequent attention and repairs. I beg to recommend Mr. Plaskett's appointment as a mechanician, at a salary of $1,100.00 per annum, to take effect on the lst July next." Some mechanician!

The diary reports two discussions with King on the subject of staffing. On February 16, 1905:[72] "In evening on my invitation W.F. King comes and we spend the time till 1:30 a.m. discussing the future plans or rather plans for the future for the work of our office - the organization of staff for our new observatory, salaries for various grades. He agreed to my suggestion, based on justice and right, that when we enter the new observatory and he assumes the title of Director, that I have that of Assistant Director and Chief Astronomer, the latter title he now holds." A month later[73] "King tells me of the approval of the scheme of organization for the new observatory of which he will be Director, I Assistant Director and Chief Astronomer; J.S. Plaskett, astronomer at $2000 an increase of $800 in his present salary as 'mechanician'!! His brother-in-law J.A. Macara is to be made 'Chief Computer' at $1800. ... With *two* secretaries, photographer, draughtsman and observers our staff is to consist of ten. - I don't think there's an office in the government where less work is done, we are overmanned and there is lack of system and order. King lets everything and everybody go at its own sweet will. But shall I 'kick' and make it unpleasant for myself, as has happened on more than one occasion. - Why invite trouble and worry?"

Things went much as King planned, although Klotz' title wasn't quite as grandiose as he had hoped. The 1905 report of the Chief Astronomer[74], gives the staff as follows.

W.F. King, B.A., LL.D, D.T.S., Chief Astronomer

<u>Correspondence and Accounts</u>

W. Simpson, secretary and accountant

J.H. Labbe, correspondence clerk

<u>Observatory Division</u>

Otto J. Klotz, LL.D, D.T.S., astronomer

J.S. Plaskett, B.A., astronomer

J. Macara, chief computer

Louis Gauthier, C.E., Keeper records

F.W.O. Werry, B.A., D.L.S. observer

R.M. Stewart, B.A., observer and superintendent of time service

W.M. Tobey, B.A., observer

J.D. Wallis, photographer

F.A. McDiarmid, B.A., observer

<u>Boundary Survey Division</u>

J.J. McArthur, D.L.S., surveyor

C.A. Bigger, D.L.S., surveyor

In addition to these positions Klotz mentions[75] a caretaker and a woman to serve them meals during the long night's observing. These were presumably "daily rate" employees, and there may well have been others.

On June 10, 1904, to mark the approaching completion of the National Observatory, Mr. King and Mr. Klotz became Dr. King and Dr. Klotz. Each was awarded the LLD degree by the University of Toronto. Klotz reports[76] that he was introduced as "the first one to girdle the world astronomically, calling me the 'Astronomical Magellan'". In the following chapters we shall see what they did with their new Observatory and their new titles.

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Dr. W.F. King.

II – THE KING ADMINISTRATION: 1905-1916

ADMINISTRATION

The new Observatory building was ready for occupancy by mid-April, 1905, and as we have seen the permanent staff totalled fourteen. Stewart[1] states that the total staff was 31, of whom at least 14 were involved in boundary survey work. No list of temporary workers survives. People like cleaners, caretakers and the like were treated as "daily rate" employees and were not included. The surveyors on the staff, permanent and temporary, did not move into the new building; we know from Klotz' diary that they were housed in a "skyscraper" in the central part of the city.

The surveyors included in the list of 14 permanent employees - Werry, Tobey, McDiarmid, McArthur and Bigger - were members of the Topographical Survey Branch, transferred to the new responsibility. Of the administrative staff, Simpson, Macara, Gauthier and Wallis had been in the Civil Service for many years, almost certainly in the Topographical Survey; Labbe seems to have been a recent addition and may have been recruited to the new job.

When the building was occupied, Plaskett was asked by King to prepare a report on the building and its equipment. He produced a detailed and informative paper[2] from which the following illustrations are taken.

The large room at the front of the east wing was then, as it has continued to be, the office of the Director. Klotz, as Assistant Director, was assigned the large office on the front of the west wing, more-or-less the mirror image of the Director's office; successive Assistant Directors - R.M. Stewart, R.E. DeLury and E.A. Hodgson - continued to occupy this office until, under the Directorship of C.S. Beals, the position of Assistant Director was abolished. Plaskett doesn't say how the remaining offices were assigned, but it is probable that those in the west wing were soon occupied by the rapidly increasing staff in positional astronomy. The "Time Service" room itself contained clocks and the mechanisms for transmitting time signals to government offices in town. The unidentified room in the east wing was probably occupied by Gauthier, the keeper of records.

There were no women on the staff. The Secretary, Simpson, was the Administrative Officer and apparently did most of the typing. From the samples that survive he was not very good at it. Klotz remarks in his diary on the absence of lady "typewriters" and attributes it to the fact that no bathroom facilities had been provided for them. On one occasion he borrowed a shorthand secretary to help him with a special job. I don't know how she managed.[3]

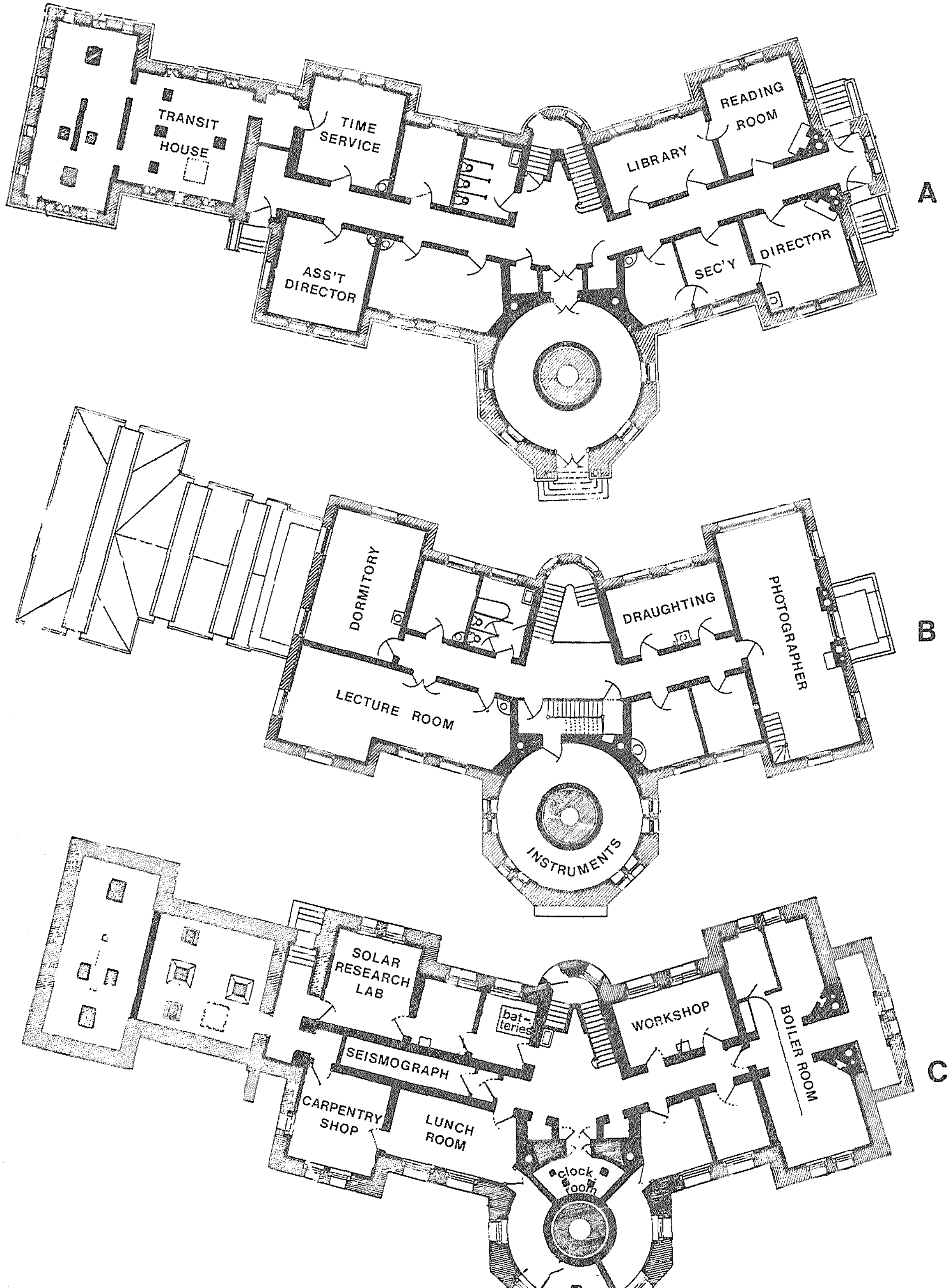
No elevator was provided in the building; the present one dates from a much later period. The entrance hall of the building proper, with its staircase, was quite a gracious space. For many years a very large potted palm stood in the re-entrant of the two sections of the stairs and scientific photographs were displayed on the walls. The very high ceiling of the hall made it an ideal place to install a Foucault pendulum.

On the floor next above, Plaskett and Macara had offices in the east wing and there was also a draughting office, the large room, later divided, at the back of the building. The photographic studio was then as it is now, except that the small office opposite the entrance was a much later addition, and that the north wall was of glass to permit exposures by natural light. Then, as now, the dark room was up a flight of stairs on a half level.

In the west wing there was a large lecture room, which has since been divided into three rooms. It was adequate for staff meetings, seminars and meetings of the Royal Astronomical Society. The remaining large room in this wing was a dormitory, where astronomers could sleep after observing or while waiting for the skies to clear. It was still in use when Malcolm Thomson joined the staff in 1930.

The "round room" on this floor had elegant steel cases with heavy, sliding, plate-glass doors, rounded in conformity with the walls. They housed the chronometers, transits and chronographs that were used in field work. These instruments were initially the responsibility of Plaskett; he maintained them, making any necessary repairs, issued them to the field officers and checked them back in. As more staff were recruited he turned this responsibility over to one of them, R.M. Motherwell.

We don't have a diagram of the dome but we should mention that, between the observing floor of the equatorial telescope and the second floor there was an intermediate floor which held a small laboratory with a dark room where the spectrograph plates could be developed. There was also a concave grating spectrograph on which sunlight was



Observatory floor plan, A-main floor, B-second floor, C-basement projected, through a window, by a heliostat placed outside on the roof.

The basement was fully utilized. The seismographs and the master clocks were located as indicated to provide constant temperature by placing them as far as possible from the external walls. This did not work as effectively as had been hoped and thermostatically-controlled electric heaters had to be used from the beginning. A pier, shown as a small square at the front of the "round room", was provided for swinging the half-second pendulums. This pier soon became the gravity base for Canada, replacing the earlier one in the old Supreme Court building.

To the south of the seismograph room there was a carpentry shop and a lunch room. Lunch was served at noon, at Government expense, to those who lived too far away to go home for lunch. Midnight snacks were also available for the astronomers who were on duty.

To the north of the seismograph room there were, reading from left to right, a solar research laboratory, a small chemical laboratory and a battery room; the batteries provided power for the clock systems. Within a few years a horizontal solar telescope was built to the north of the solar laboratory and a large spectrograph almost filled the laboratory. The mirror, driven by clockwork to follow the sun, reflecting its rays through a system of fixed mirrors on to a spectrograph slit, was called a coelostat and the housing which sheltered it, and which could be moved on rails to expose it to the sun, was always referred to as the "coelostat house". The light beam from the coelostat reached the spectrograph by passing through a tunnel under the driveway at the back of the building. This tunnel provided a substantial hump in the roadway and it was a favorite pastime of young bucks to drive very rapidly over this hump and for their young ladies to scream prettily.

The machine shop, called a workshop in the figure, was Plaskett's pride and joy. The main electrical input to the building was in this room and Plaskett had made the installation and the control panel himself; considering his training under Edison, who was better qualified? The machine shop had a[4] "10-inch by 6-foot engine lathe with all the necessary attachments, ... a Milling machine with mill 20 inches long, 7 1/2 wide and 18 inches high, ... a bench lathe ... with 8-inch swing ... supplied with a 4-inch 3-jaw universal chuck". Although Plaskett had been hired as a "mechanician" he was quickly promoted to astronomer and there was, for the first year or two, no machinist on the staff. Plaskett and Stewart each did the work required in their separate sections.

There is no information on the use of the two small rooms facing the machine shop but the one nearer the round room was used as a bindery very early in the Observatory history and continued to be so used until the Observatory acquired the Geodetic building.

The arrangement of the basement didn't remain in its initial form for long. It was found that the machine tools interfered with the seismograph and the shop was moved to a separate building, where it remained throughout the life of the Branch. When this was done the carpentry shop was moved to the vacated area; the lunch room was closed and these two rooms became the quarters for the seismological section; an additional, vertical, seismograph was acquired at the same time. In December, 1914 Klotz reports "My assistant moves into his new room, the old dining room which has been repainted and made very comfortable and Mr. Hodgson is delighted with his new quarters".[5] The dining room and, I think, the free lunches, disappeared; a gas ring and some tables were provided in the boiler room for those who wanted to prepare a lunch.

In 1914-1915 seismograph vaults were built north of the building with an entrance from the area under the transit room but the old seismograph room continued in use until the Bosch instruments were transferred to Halifax in 1938; after that it was used as a store room and was not returned to its original function as a corridor for many years.

The generous distribution of space didn't last very long. The astrophysics section of the observatory expanded rapidly: W.E. Harper joined the staff in 1906; R.M. Motherwell and Dr. R.E. DeLury in 1907; J.B. Cannon and T.H. Parker in 1908. On the positional astronomy side A.H. Swinburn joined the staff in 1905, D.B. Nugent in 1907, C.C. Smith in 1908, Dr. R.J. McDiarmid in 1911 and E.C. Arbogast in 1912. In geophysics, C.A. French became assistant in magnetics in 1906 and R.C. McCully became seismological assistant in 1912, to be replaced by E. A. Hodgson in 1914. One machinist was recruited in 1906 and a second in 1908.

During King's administration the observatory achieved and maintained a level of scientific distinction which, insofar as the Ottawa observatory was concerned, it was not to know again for more than 40 years. This was due principally to the genius and drive of J.S. Plaskett who in some ten years turned the observatory into a world centre for the study of double stars and exhausted the list of double stars available to the 15-inch telescope; he then went on to promote, develop and build the Dominion Astrophysical Observatory, the completion of which was assured by the time of King's death. Stewart and Klotz, responsible respectively for positional astronomy and geophysics, were not as brilliant as

Plaskett and were perhaps working in areas where it was impossible to shine quite so brilliantly, but they were both competent scientists and established their respective divisions on a very sound basis.

All these accomplishments will be documented in later sections; we shall be here more concerned with administrative matters and those continue to be dominated by the disagreements between King and Klotz. Before getting into these unpleasantnesses what can we say about King's abilities?

King made the primary decisions about the programmes which the new Observatory would carry out and he must have had a major input into to the design of the building which was to house them. He personally recruited two of the scientists, Plaskett and Stewart, who were to make possible the realization of his ideas, and he supported them fully. There seem to be no doubts that he made all the decisions about the 15-inch equatorial telescope and on the initial purchase of solar equipment. The events proved his decisions wise. He may have had help from Stewart in selecting the meridian circle transit, for it was ordered some two or three years after Stewart joined the staff. The idea behind the instrument proved sound even though the instrument actually delivered was faulty. Finally, he supported Plaskett expertly in lobbying for and building the Dominion Astrophysical Observatory. He filled the position of Boundary Commissioner with distinction and, as its first superintendent, launched the Geodetic Survey of Canada on a successful journey. He seems not to have been a very good administrator but he gave each section head enough autonomy that this didn't matter very much.

That's the good part, now the bad. The details come almost entirely from Klotz' diary, but it's impossible to avoid the conclusion that King treated his old friend in a shameful way. For the most part it only affected their personal relationship, but in some ways the organization itself suffered. To the latter category belongs the allocation of positions in which he favoured astronomy over geophysics. In the first few years Plaskett and Stewart were each given five professional assistants plus some technical ones, Klotz only two, of which one was not made permanent during the King years. True, a surveyor, F.A. McDiarmid, was assigned to help him in gravity, but the assistance was limited and grudgingly given. Considering the vast responsibilities in magnetics and gravity in a country with the second largest land mass in the world, this was niggardly. Oddly enough, Klotz doesn't seem to have objected to this lack of staff; his diary contains many complaints about King, but this is not one of them.

We saw in Chapter I that Klotz was not appointed Assistant Director and Chief Astronomer as he had expected upon the opening of the new Observatory. Nor was he given the salary classificaion that he felt he had been promised. This was another source of dissension. The question of classification came up again in 1908 when the Civil Service Commission began a reorganization of the entire Public Service, but Klotz was still not placed in the top category, Class A, where he thought he belonged. Shortly afterwards, possibly as part of the general reorganization, the Geodetic Survey of Canada was established as a separate entity under Dr. King's direction. King became Chief Astronomer, Boundary Commissioner and Superintendent of the Geodetic Survey. At the next level Klotz was appointed Assistant Chief Astronomer, J.J. McArthur, Assistant Boundary Commissioner and C.A. Bigger, Assistant Superintendent of the Geodetic Survey. King assured Klotz that this change in organization would ensure his advance, along with that of McArthur and Bigger, to Class A. In fact it did nothing of the sort and it was not until May, 1911, that the reclassification was approved.

In 1914 a new building, adjacent to the Observatory, was completed to house the Geodetic and Boundary Surveys. At about the same time the management of the Geodetic Survey was expanded, with five men - McArthur, Craig, Ogilvie, Bigger and Tobey - all listed as Assistant Superintendents. There is one puzzling thing about the re-organization of the Geodetic Survey, although it doesn't seem to have worried Klotz. In many ways Klotz was a more logical person to head both the Geodetic Survey and the Boundary Survey than was King, and certainly more logical than either McArthur or Bigger. Klotz was a founding President of both the Manitoba and Dominion Associations of Land Surveyors, he had been very active in pushing for a trigonometric survey of Canada and had prepared the Association briefs to the government. In his plans for the Observatory he always supported the position of the surveys and opposed the astrophysical aspects. It would seem that his position, under King, should have given him supervision of the surveys instead of, if not in addition to, the Observatory. The actual arrangement made for many difficulties during King's administration and practically ensured the separation of the surveys from the Observatory when Klotz succeeded as Director. This was certainly not a bad thing, but it does seem a little rough on Klotz.

The new organization led to, or at least was used by King as an excuse for, another problem which had very serious implications and which led to the Secretary, Simpson, being the *de facto* Assistant Director. The matter was spelled out in a letter Klotz received in March, 1910.[6] "Dr. King sent me a letter today informing me of my appointment as Assistant Chief Astronomer and of my duties, and particularly what I may *not* do, that is, have charge of the observatory during his absence, but instead the Secretary is given charge of our correspondence and the general management, while I am permitted to look after the technical work, i.e. my own work, for the others in charge of divisions know their own work. It is simply damnable, yet characteristic of a Judas and a hypocrite."

It was not just when King was away that Klotz felt out of things. King himself was secretive and files were all kept by Simpson in an early version of a central registry, and were not normally released to Klotz. Klotz was not informed of any of the major decisions affecting the Observatory. The diary teems with examples: he was not informed when the Order-in-Council appointing him Assistant Chief Astronomer was sent forward, nor when it was approved; the American Astronomical and Astrophysical Society was invited to hold its meeting in Ottawa and Klotz didn't know about it until he read it in his own copy of the Astronomical Journal; he learned from the junior staff about the proposal for the 72-inch telescope and despite his wide experience with observing in British Columbia was not consulted about possible locations. "I probably know less what is going on in the Observatory than any one including the inferior clerks. Fortunately the staff doesn't know this, as King and I are frequently together, he coming to my room. I often wonder what for, for he has nothing to say. I always regale him with cigarettes of which he generally smokes three ... and then he goes out again. The staff naturally thinks that we discuss observatory affairs, but that is practically never the case as far as King is concerned."[7] A strange and unfortunate situation!

On May 4, 1911 the Order-in-Council approving his promotion to the highest class, Al, was finally approved. "Dr. King coming to my room this afternoon I embraced the opportunity of telling him of the Order in Council and at the same time told him that I wanted now to be recognized by him as his deputy in reality and not simply in name, and as every one in the Observatory long ago thought should be so. As it now is, Simpson the Secretary runs the Observatory in Dr. King's absence. I said to King - 'Put yourself in my place'. When I asked him if he would give me full control, he said that he would have to think about it, as he was chief of various branches. I told him that I didn't want anything to do with the Geodetic Survey or Boundary Survey, but only the Observatory. We chatted then of other things and he left my room."[8] On a later occasion[9] "I again alluded to my anomalous official position as Assistant Chief Astronomer, not having any official status. He said that at present it was unavoidable, my room being so far from his, but that if he gets the building addition that he wants, my room would be next to his" and communications would be easier. In other words, one man had to be left in charge during his absence and since Simpson was Secretary to all three organizations it had to be him; and the distance from one wing of the Observatory to the other was too great for effective communication!

The problem was never resolved. By the time King died after several years of declining powers, Simpson was effectively the Director of all three services and Klotz knew little or nothing of current policy except as it affected his own work.

The work of the Observatory staff was recognized by a number of honours. King and Klotz had been awarded the honorary LLD by the University of Toronto in 1904. In 1913 Klotz received an honorary D.Sc. from the University of Michigan and Plaskett an honorary D.Sc. from the University of Pittsburgh. King was elected a Fellow of the Royal Society of Canada in 1908 and was President in 1911; Klotz and Plaskett were elected to fellowship in 1910. Klotz reports[10] "I have never been very much impressed with the Royal Society judging from the calibre of some of the members, however I feel it is an honour to have been elected to the Canadian Valhalla of Literature and Science without the slightest solicitation or intimation on my part."

The Great War had a surprisingly small effect on the operations of the Observatory. During the early years of the war, during King's administration, staff members could be granted leave-of-absence to enlist if their Department Head agreed that they need not be replaced, and their army pay could be brought up to their Civil Service pay, but only if they had been employed at the outbreak of hostilities. By the end of 1916 nine staff members had enlisted.

The war did make some very serious difficulties for Dr. Klotz. In October, 1914 his son Max,[11] a medical doctor, "called me up by 'phone and asked me whether I had heard that I had been arrested as a German spy, and that he had had many calls on the 'phone' from friends asking about it. I laughed at the silliness and absurdity of the rumor, yet felt, as Max stated too, that the rumor may have arisen or at least have been fanned by Marie's indiscretion in outspoken pro-German and anti-British sentiment, expressed to supposed friends but highly indiscreet individuals." Marie was his wife. She was the daughter of the German Consul in Ann Arbor, Michigan, and had recently returned from a visit to her parents. Being German, and living in a United States not yet committed to either side in the war, they naturally were on the side of the Fatherland. Marie's loyalties were natural but her indiscretions were unfortunate.

The rumours mounted; one of them reported that Klotz had installed a device in the Atlantic Ocean to communicate with submarines. This was his undagraph, intended to measure wave activity as part of his research into microseisms.

Fortunately Klotz had many influential friends and they rallied around him. The three daily papers, the *Citizen*, the *Journal* and the *Free Press*, refrained from printing the rumours and each wrote a strongly-worded editorial supporting Klotz and his three distinguished sons. There was more damage done within the family circle; the three boys, particularly the eldest, Max, were estranged from their mother for most of the war years. Furthermore, as we shall see later, when King died there was a great delay in appointing Klotz to succeed him. The rumours, or at least the prejudice, had not died completely.

One gets the impression from the Diaries that King's health was deteriorating rapidly during the last year or so of his life but it was not until February, 1916, that there is anything very specific. Rumours began to spread[12] that King would retire in favor of his son-in-law R.M. Motherwell. Klotz confronted King with the rumor; King said that he had no intention of retiring. A few weeks later[13] "King came to my room this afternoon, he looked miserable. We chatted about the examination [for the D.L.S. candidates], relating more or less amusing incidents of some papers, his faint smiles had a rather ghastly look. I asked him how he felt. Oh - all right, was his reply. I said why don't you throw up the whole business and spend the remainder of your years with your wife with all the comforts conducive to your health. You have all the honors you wish and have built up our two departments. I who has done his part too, may well deserve the few remaining years in charge of one of them (the Observatory). What do you say to it? ... He said 'I can't agree with you'. ... What is passing through his head these days I do not know."

Two weeks later[14] "Dr. King was not at the office yesterday afternoon or this morning and hearing he was in bed, I called on him. ... I found him in his library, looking more than miserable. ... It is difficult to say what turn his sickness will take. He looks now ready for the coffin, and yet both his father and mother passed the four-score milestone."

On April 6 King, accompanied by his brother-in-law Macara, left suddenly for "a place in New York state".[15] The place is not named in the diary; the Assistant Deputy Minister had recommended that he go to Virginia Hot Springs and his doctor had proposed the Clifton Springs Sanatorium, but he had declined both suggestions. He advised the Assistant Chief Astronomer, Dr. Klotz, of his intention only at the last minute and when asked "who is going to attend to anything outside of ordinary routine that may arise in the Observatory?" he replied "Mr. Simpson". When Klotz protested King remained obdurate. "'I am not going to quarrel now - Goodbye giving me his hand."

No sooner had King left than technical problems arose - what latitude programme was to be carried out in the summer, how the surveying staff was to be deployed for this work.[16] Simpson had no answer. Klotz went to see the Deputy,[17] who said that, while he didn't want to "butt in" he would have a talk to Simpson. He did so saying that Klotz and the quintumvirate in the Geodetic Survey were to be consulted on all technical matters. So the crisis passed.

Less than two weeks later King returned and had to be carried by ambulance to Observatory House.[18] He died less than a week later, on April 23, 1916.[19] "At 4:15 p.m. R.M. Stewart phoned to me that Dr. King had passed away but a short time before. ... I phoned to members of our staff the sad news, also to the Deputy, Mr. Cory, to the Prime Minister, Sir Robert Borden, to the two Civil Service Commissioners, Dr. A. Shutt and Dr. M.G. Larochelle, besides some old acquaintances of Dr. King. The cause of his death was cirrhosis of the liver, brought about by 40 years too free indulgence of whiskey."

"King was unassuming, retiring and reticent. His reticence, together with the title of Chief Astronomer threw a certain halo of profundity in science among Ottawa populace - at least those of the Civil Service, that was not warranted. King was an exceedingly clever mathematician of the old school - not of modern mathematics; his forte was 'the Theory of Numbers'. He was like a sponge, absorbing from others, especially at the Observatory where from each of the heads of work and research he was informed, so that he was well posted in science not from any work of his own but from us. ... King and I matriculated together at the University of Toronto in 1869, he taking a scholarship of $120 and I likewise one of $120. - In the Department of the Interior we have been associated since 1879. I inaugurated the first strictly astronomic work of the Department and Government in 1885 in connection with the latitude and longitude work in British Columbia. He has been in the Inside Service since 1881, I only since 1896, so that since 1881 he has been my superior officer, although my pay in those days was more than his. In 1887 and 1888 we were in the field together in astronomic work. King was naturally lazy, but could spurt on occasion. In the old days I would continually be at him to do this or that and would plan things, as he was an official and I was not. The observatory is as much my creation as it is his. King was always glad to get ideas and assistance from me, but when he had it, there was absolutely no gratitude, in fact the reverse. ... Yet there was no one in Ottawa that fitted into my intellectual leanings and habits better than

King. We were both fairly proficient in and fond of the Classics, of English Literature and history and poetry, also science and mathematics. ... Many a night have we sat up in my house till 2 a.m. years ago, with a midnight luncheon, talking, chatting or working at some problem, while the pipe or cigar was steaming away beside the genial bottle and soda."

The picture that these pages have drawn of Dr. King have, of necessity, derived largely from the Klotz diaries, not the most sympathetic source. I am pleased to be able to quote a more appreciative opinion from the personal papers of Dr. C.S. Beals. [National Archives MG 30, Box 323, File K]. Beals always felt that King had been greatly underrated. His efforts to ensure proper recognition led the Historic Sites and Monuments Board of Canada to erect a plaque to King at the entrance to the Observatory. At the unveiling ceremony, on June 23, 1975, Beals spoke of the "massive role [King] played in the development of science in this country, by his decisive contributions to the founding of Canadian astronomy and geophysics. King was very much aware that the heavenly bodies, in their totality provided not only markers indispensable for the work of the surveyor but also that they constituted a gigantic physical laboratory where the behaviour of atoms and molecules could be studied under conditions not available on the earth, and where many of the most vital problems of the nature of the universe could be investigated. He was conscious of the need to apply the most powerful methods of physical observations and mathematical analysis to studies of the Earth's interior, the earth's crust and means for detecting the presence of valuable minerals in the earth's crust The influence of King on the astronomy and geophysics of the present day is partly direct in that he clearly discerned future trends, and partly indirect in that he provided a base of operations and an example of what could be done by an enquiring mind using the best scientific technique of his day."

An even more explicit expression of his admiration for King is contained in a letter to J.F. Heard, dated May 1, 1972,: "I personally regard Dr. King as one of the greatest, if not actually the greatest, scientist that Canada has produced".

I have quoted these remarks to offset the limited appreciation expressed by Klotz, but, in my opinion, they are hyperbole at least as excessive as Klotz' strictures. King was a man of vision who, with the help of Sifton, established a national Observatory on a sound basis. He was somewhat lucky in the selection of his staff, one doesn't regularly get a potential FRS in hiring a machinist, but he recognized capable people and gave them the fullest support. He supported Plaskett effectively in the campaign for the Dominion Astrophyiscal Observatory, but to give him excessive credit for its establishment detracts from that due to the true genius, Plaskett. He was not a good administrator; on his death the Observatory was left in a shambles, and burdened with a number of non-productive people.

King was buried on the afternoon of April 26. The coffin was covered with a floral mantle presented by the three services which he had founded and directed. The pall-bearers were Klotz, McArthur, Fawcett, Bigger, Plaskett and Brabazon. The service was in St. George's Anglican Church, of which King had been a devoted member. "Requiescat in pace."[20]

Before the flowers had withered on his grave the wars of succession had begun.

ASTRONOMY

From the beginning there were two sorts of astronomical work carried out, one involving the 15-inch Equatorial Telescope and pursued principally by spectroscopy, the other involving the study of star positions and the determination and distribution of time. Eventually these came to be spoken of as "Astrophysics" and "Positional Astronomy", but in the early reports "The Equatorial Telescope" and "Time Service and Transit Operations" are the terms employed; I shall follow this usage.

The Equatorial Telescope

As we have already seen (page 17), the order for the 15-inch Equatorial Telescope was placed in early June, 1901, and Klotz made an inspection of the completed instrument in January, 1903. The optical parts of the instrument were made by the John A. Brashear Company of Allegheny, Pennsylvania, the mounting by the Warner and Swasey Company, of Cleveland, Ohio. The telescope came equipped with a large array of accessories. When one considers that neither King nor Klotz had had any experience with telescopes of this type it is tempting to suppose that Plaskett had had a hand in their selection; however, he did not join the staff until July 1903, after the telescope was delivered, and then as a temporary "mechanician".[21]

Plaskett has provided a very complete description of the equipment, as delivered[22], and the details of costs are given in the Report of the Auditor-General[23]. The costs totalled $13,187. The various accessories were either mounted on the frame of the telescope, using it as a guide, or they attached to the tail-piece of the telescope by a one-eighth turn screw. Of the latter equipment there was an eye-piece adapter and six eye-pieces with powers ranging from 125 to 750; a wedge photometer for the determination of stellar magnitudes was supplied for use with these eyepieces. There was also a 3-prism spectroscope, a position micrometer, supplied with its own range of five eye-pieces and a solar camera. A stellar camera, for photographing stars and nebulae, was attached to the telescope tube, opposite its place of attachment to the declination axis. Because this camera could not be used when the telescope was being used for spectroscopy or solar work, a 4 1/2-inch equatorial, manufactured by Cooke-Taylor, was also purchased. This was intended to be mounted on the Observatory roof with a removable cover, but it was some time before this was done.

Not much was done with the Equatorial Telescope during its first year. An eclipse of the sun on August 30 took most of Plaskett's time. The path of totality was to pass over the southern end of James Bay, and, running easterly, meet the Atlantic at Sandwich Bay on the Labrador coast. The Royal Astronomical Society of Canada submitted a resolution to the Prime Minister urging that the Observatory be permitted to mount an eclipse expedition and that it should provide for up to six observers from the Society. This was agreed to and Dr. King was placed "in command". It was decided that the expedition headquarters would be at North West River, on Lake Melville. In addition to the six Society representatives, Dr. King invited Mr. and Mrs. Maunder, of the Royal Observatory at Greenwich, to join the party and in his Report for 1905[24] he gives details of the experiments proposed and the equipment provided by each.

While King was "in command", Plaskett was obviously the brains of the expedition. He describes the preparations - the design and acquisition of equipment, the testing of photographic plates, the installation of the equipment - in great detail.[25] The report makes fascinating reading. It is the first indication we have of Plaskett's meticulous attention to scientific detail, coupled with a great practical ability to get things done. He designed a total of three cameras and three spectroscopes, each intended for its special purpose, and all mounted, with their axes parallel to each other, on a rigid framework. A coelostat was built to his specifications with an aperture sufficient to reflect the sun's rays into this battery of equipment; the coelostat was intended for later use in the Observatory's solar telescope. Photographic plates sensitive to various sections of the spectrum were necessary for the different experiments he proposed. "A reference to the literature on the subject of orthochromatics did not render much assistance as no precise agreement seemed to exist as to the range of sensitiveness by different dyes" so he bought "a box of every commercial orthochromatic plate obtainable in England and the United States, with some of French and German manufacture" as well as "a small quantity of each of the probably useful dyes" and conducted his own tests, all of which are detailed in the report. He says that he was helped in this work by his "previous training ... in orthochromatic and three-colour work".

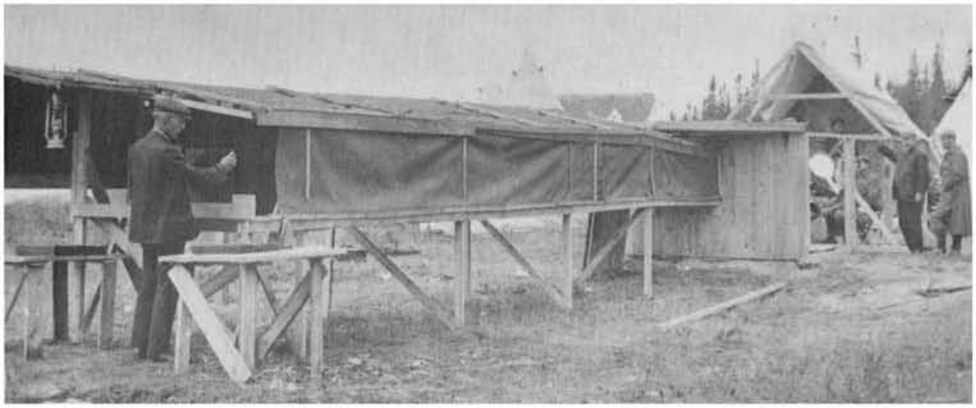
However his careful preparations were in vain; the sky was completely overcast at the time of the eclipse. "Naturally it was a bitter disappointment at having practically no result for six months' work, except the experience in preparation and the useful knowledge gained of colour sensitive plates and absorbing screens. If everything had not been in such first-class shape for the observations, if the perfection of adjustment to focus and working of the camera shutters and plate holders, if the running of the coelostat, or the quality of the specially sensitised plates had not come up to my required standard, probably I would not have felt the disappointment so keenly; but, when the prospect of obtaining some original and useful results were so good, it seemed too bad there was no chance to try."

When Plaskett returned to Ottawa from the eclipse expedition there was the report to write, very complete as we have seen, as well as the paper already quoted on the new Observatory and its equipment. It was not until November that regular observing with the equatorial telescope was begun, with Plaskett observing on Mondays, Wednesdays and Fridays, W.M. Tobey doing photometric work on Tuesdays and Thursdays, and the public viewing the heavens on Saturday nights. [Tobey was a surveyor, a D.L.S., who shortly after returned to the reduction of geodetic work and continued with the Survey throughout his career.] With this observing schedule problems with the new equipment began to emerge; Plaskett corrected them as they appeared.[26]

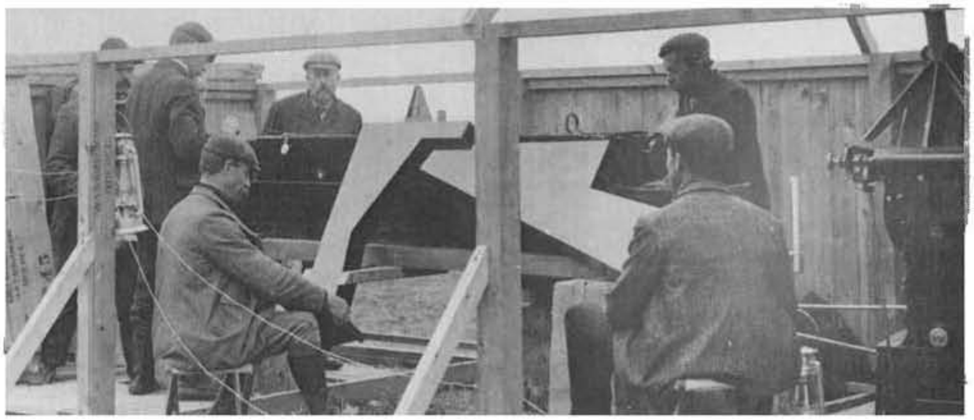
They first concerned the drive of the telescope; the driving mechanism was good over long intervals but there were short-period variations that made tracking for spectroscopic or photographic observations very difficult. These were corrected by controlling the mechanism by the Observatory's standard sidereal clock, which was done with the assistance of R.M. Stewart, and by re-cutting some of the driving gears, which Plaskett did himself in the newly-available machine shop. The enlarging lens in the solar camera produced distorted photographs; it was found that it had been corrected only for axial rays, and a new lens had to be ordered. The stellar spectroscope proved to be insufficiently rigid for the radial velocity work on which Plaskett was embarking. He made a number of changes to the optics, but principally he improved the bracing of the instrument case and enclosed it in temperature case which maintained a temperature constant to within about 3°C. The output of the spectroscope was much improved, but Plaskett wasn't satisfied. He began

The eclipse party at North West River, Labrador. Plaskett is in the centre of the front row, Professor C.A. Chant to his left. King is the man with the grizzled beard standing behind and to the left, between the second and third row.

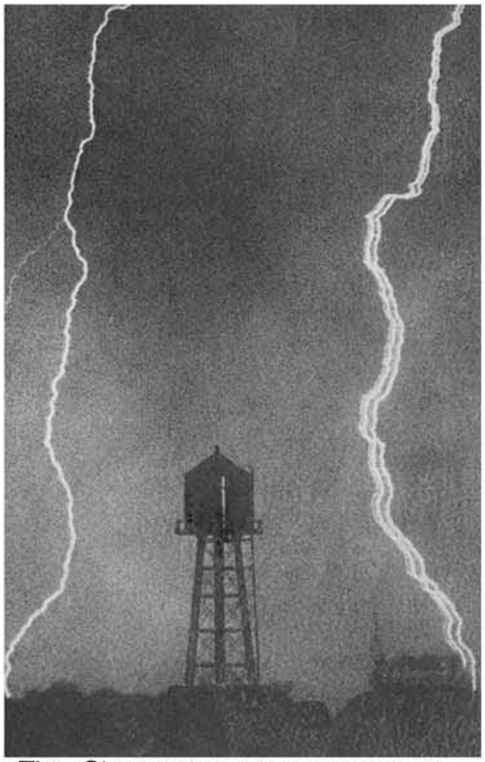
The 1905 equivalent of the pre-conference cocktail party: spruce beer at Esquimaux Point, Labrador. National Archives of Canada, PA 138914.

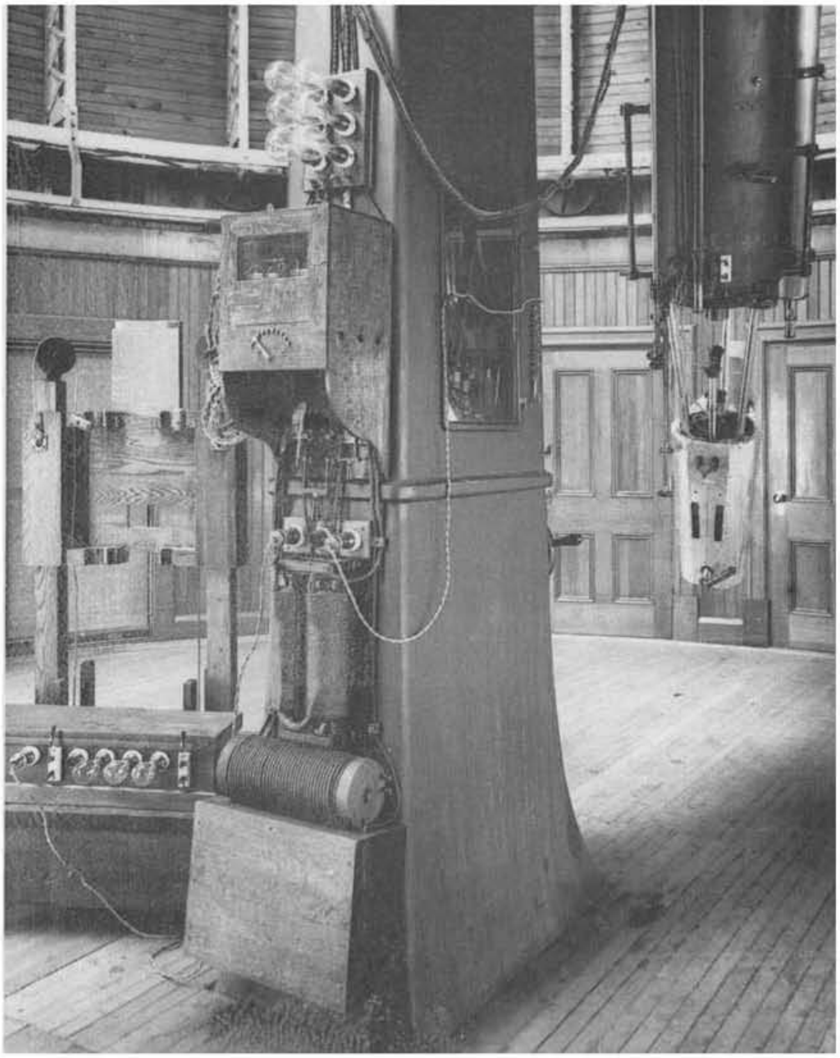


The coelostat and its shielded optical path.



The array of recording cameras and spectographs.

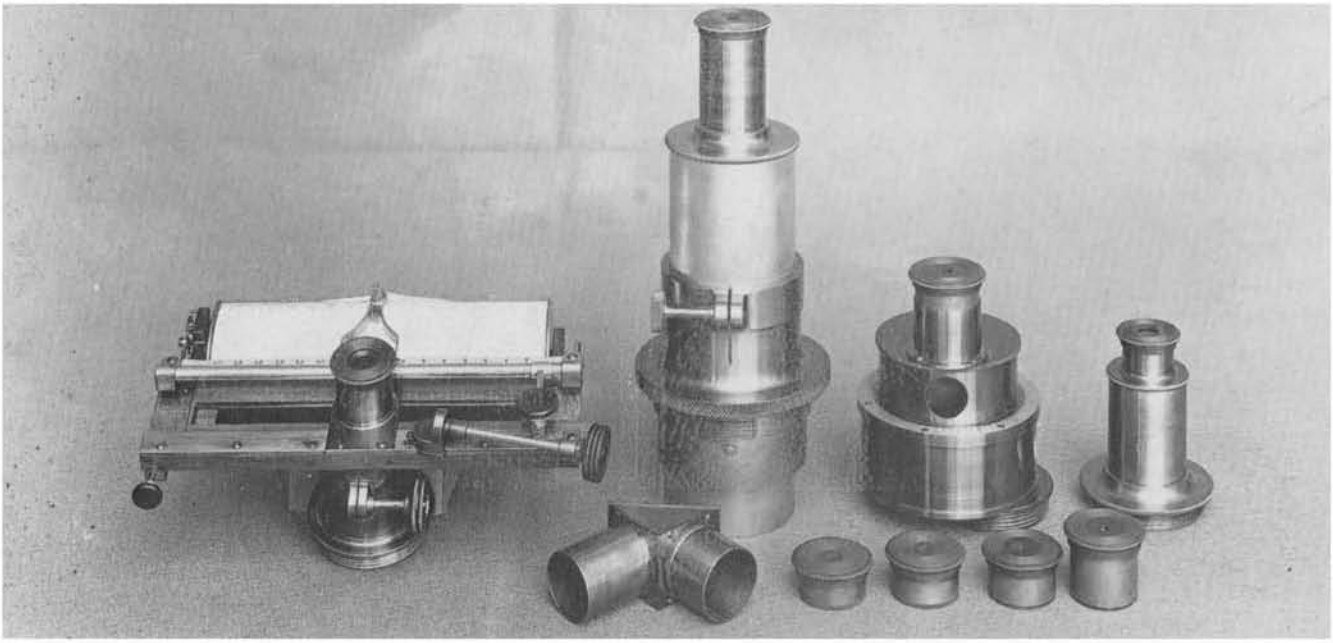




The Observatory photographer, A. Steadworthy, took a number of photographs of lightning. This example shows a storm to the south of the Observatory. For many years, large prints of these photographs hung in the main hall of the Observatory

(Right) An early photograph of the 15-inch telescope.

(Below) The eye-pieces and the position micrometer.



the design of a much more rigid one in which, in addition, temperature would be controlled to within 0. 2°C. Finally the correcting lens of the spectroscope, which was a doublet, was found to be incorrectly assembled; one of the elements had to be reversed!

With these adjustments made, Plaskett was able to begin serious observation. Initially he observed certain standard stars "which astronomers, engaged in line of sight work, have agreed to observe periodically for radial velocities. ... Such stars can then serve as objects for testing the performance of the spectrograph". The 1906 report, from which I have here been quoting, lists results for seven of these stars. Plaskett attaches an apologia to the results, pointing out that they are the first from a new telescope, made with a spectroscope not especially designed for radial velocity work.

W.E. Harper joined the Observatory staff on July 1, 1906. He was destined to have a long and distinguished career with the Branch, principally at the Dominion Astrophysical Observatory. Initially Plaskett had him measuring plates but within a month he was observing and within two years was publishing his own papers. Four more astronomers joined the staff shortly afterwards: R.M. Motherwell and R.E. DeLury in the early summer of 1907,[27] J.B. Cannon and T.H. Parker a year later.[28] They all became very productive astronomers under Plaskett's direction.

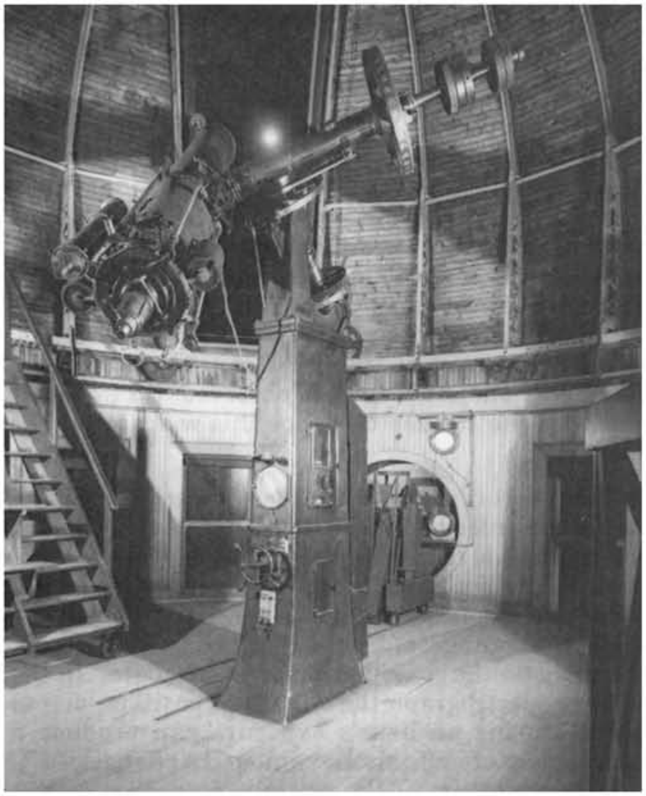
In 1907 the Government changed its fiscal year to end on March 31st instead of June 30 as had previously been the case. The Report of the Chief Astronomer for 1907[29] therefore covers only 9 months, but in these 9 months Plaskett had completed his new spectrograph which was characterised by its extreme rigidity. In a long exposure, as the telescope with its attached spectroscope tracks the star, the direction of the gravitational attraction on the spectroscope changes. If the instrument is not very rigid, the alignment of the optical path will change, with a consequent blurring of the spectral lines. This might be tolerable in some spectroscopic work, but it is intolerable in radial velocity studies, where the aim is to measure the slight shift in the lines. Plaskett was one of the first to recognize this and to provide stable supports.

It may be useful at this point to say something about the nature of radial velocity work. Everyone knows about the Doppler shift of the spectroscopic lines, toward the red if the star is receding, toward the violet if it is approaching. In the case of a double star, when the components are more or less of equal magnitude, there will be two sets of lines, one set indicating recession, the other approach, relative to a mean velocity; throughout the period of the orbiting pair this relationship will change in a systematic way. The Observatory spectrograph, which used only one prism, was not capable of resolving the two sets of lines. It is not until 1915[30] that a second spectrum is mentioned and then only to say that the matter "must be left in abeyance until our increased aperture is available". If only one star of the binary pair is of sufficient magnitude to produce a spectrum, the lines will change their position throughout the period of the orbit; by studying the variation throughout the orbit, and repeating for many orbits, the characteristics of the orbit can be determined even if only one set of lines is observed. In the early work with the 15-inch telescope this was always the case.

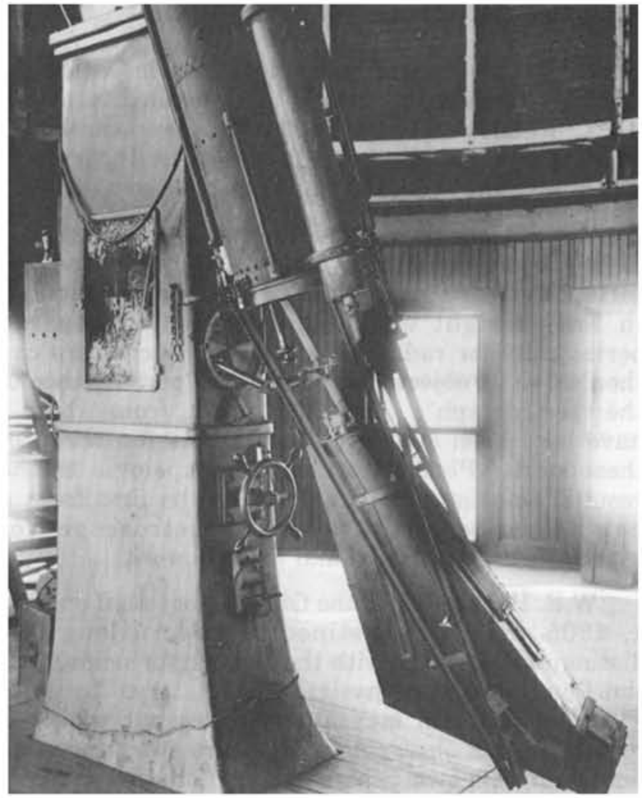
What sort of shift do the lines undergo? Plaskett gives some information on this.[31] On the Ottawa spectrograph a radial velocity of 20 km per second, which is the order of things we are dealing with, produced a displacement of the spectral lines, in the middle of the range, of from 1/900 inch to 1/2700 inch, depending on the combination of prisms used. In the ordinary spectrograph the change of position, due to flexure, during an hour's exposure can produce a displacement of half this amount, and a change of 1°C in the temperature of the prism can produce a shift equal to that which is to be measured! Thus, in addition to rigidity under changing gravity field the system must be stable thermostatically; great care was taken to ensure this. Plaskett concludes his report: "The only safe test for absence of systematic error lies in the careful measurement of a large number of plates from one star known not to be a binary, but such test has not yet been made. A few plates of the standard velocity stars have been made ... and, so far as this slight evidence can go, no trace of systematic error has been found".

Some binary pairs are sufficiently bright, and sufficiently separated, that both can be seen. In this case the angular distance between them and the direction from one to the other can be measured. Both these measures will change as the pair go through their orbit. The measurement of visual double stars was part of the Observatory program.

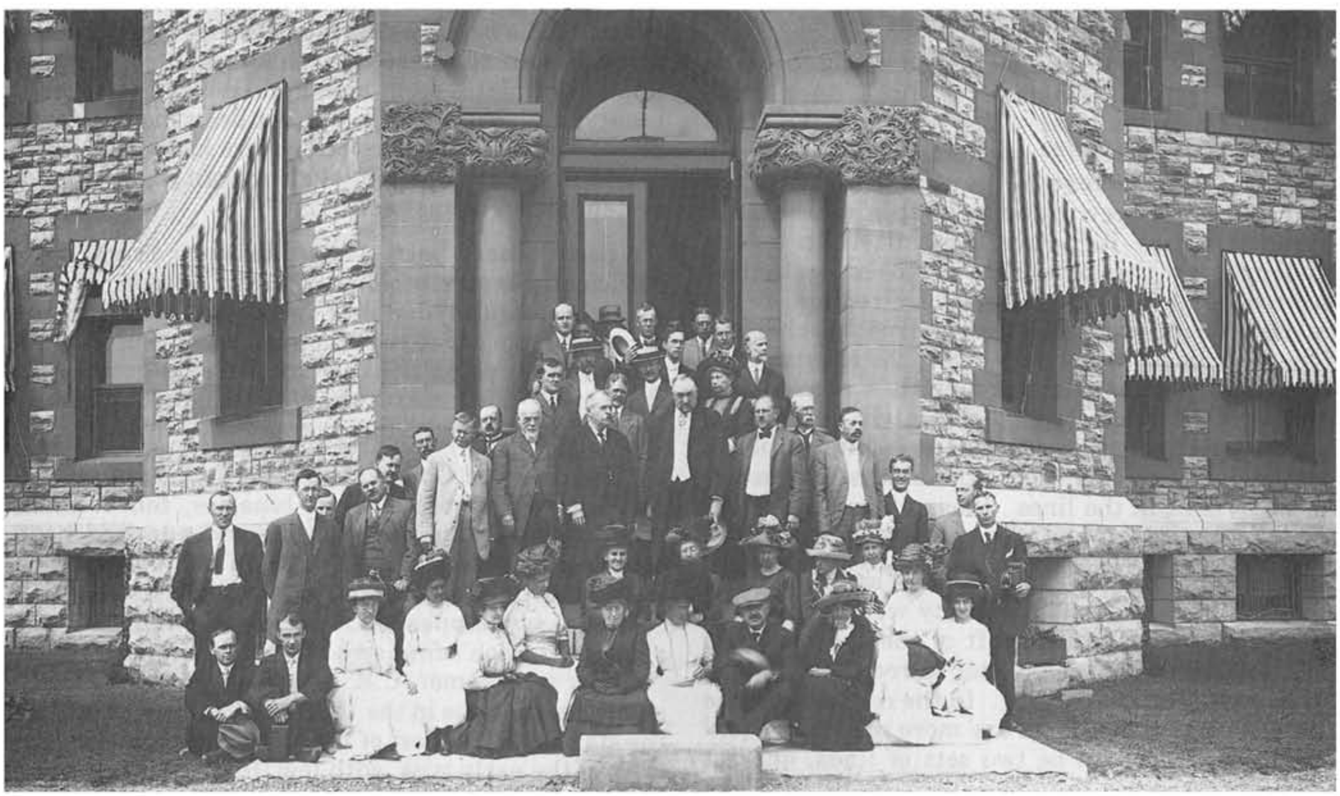
By 1907 the Observatory was firmly committed to the study of spectroscopic binaries; ten of these were under active observation and one had been completed. Much, indeed most, of the observation was done by Harper, and a new Assistant, N.B. McLean, had appeared. He seems not to have remained: I don't find any further reference to him. Another astronomer, C.R. Westland, is credited with some observations in the 1908 report. He was still on the staff in 1930. Most of the stars under observation were of the early type, with few lines, and required a large number of observations to produce statistically reliable values of velocity. The one star for which



A later photograph of the 15-inch equatorial telescope.



The new spectograph in position.



Delegates to the 1911 meeting of the Astronomical and Astrophysical Society of America; they passed the resolution which began the campaign for the 72-inch telescope.

observations were complete was written up by Harper.[32]

The 1908 Report[33] states that further use of the new spectrograph had "confirmed the good opinion formed of its performance" and not many changes were made. Some improvement was made in temperature control and a new correcting lens was installed; when it still proved to be unsatisfactory, Plaskett himself calculated the changes required and took the lens to the Brashear works for refiguring. After this the sharpness of image was improved and the exposure times required were reduced. Now the Observatory was in full production and in the year ending March 31, 1908, 736 stellar spectrograms were made on 138 nights. Work on two additional spectroscopic binaries was completed and written up by Harper.[34]

Activity was not confined to stellar spectroscopic work.[35] DeLury worked on the spectrum of an Iron-Vanadium alloy, to be used as comparison lines in the study of radial velocities, Tobey reported on observations with a new Polarizing Photometer, and Motherwell on the observation of visual double stars.

Motherwell spent the summer of 1912 at Yerkes Observatory studying photographic photometry under Professor J.A. Parkhurst, an outstanding authority in the field. When he returned, following Parkhurst's methods as much as possible, he reported on measurements of visual double stars and made many sky photographs including some of comets. This work had to be interrupted while he investigated, and corrected, aberration in the stellar camera objective. The work was also limited by the fact that the stellar camera was mounted on the side of the 15-inch equatorial telescope and used its drive system to follow the stars. Thus the 15-inch telescope could not be used when the camera was operating. For several years it was hoped to acquire a separate drive for the stellar camera. This was finally available in the summer of 1914 and was mounted in a small observatory which still exists southeast of the main observatory.[36]

With such productive assistants, Plaskett was able to turn his attention increasingly to the improvement of equipment and techniques. The 1908 Report describes experiments measuring the influence of slit width on the effectiveness of the spectrograph. They show the remarkable result that, within reasonable limits, increase of slit width, which can markedly reduce exposure time, does not lead to decrease in accuracy in the measurement of the spectral lines. He considered this matter again in a very detailed discussion "The Design of Spectrographs for Radial Velocity Determinations"[37].

King was not idle. In the 1908[38] report he develops a graphical method for the "Determination of the Orbits of Spectroscopic Binaries". The method was adopted by the Ottawa group for preliminary determination of orbits. King also wrote on "The Theory of Least Squares."[39] Both of these papers were highly mathematical, a field in which even Klotz conceded that King was pre-eminent.

With all the equipment now in good working order, production was phenomonal. The Reports of the Chief Astronomer give preliminary results on many binary systems and in the Journal of the Royal Astronomical Society of Canada there are no less than 24 papers between 1909 and 1912. As early as 1910 it began to become obvious that the list of binary stars which could be studied with a 15-inch telescope was rapidly becoming exhausted; indeed there were only two telescopes in America which could extend the observations beyond the capabilities of the Ottawa telescope. If the work was to proceed to fainter stars a much larger telescope was required. This was the impetus behind the 72-inch telescope and the Dominion Astrophysical Observatory, a subject to which I shall now turn. It should be noted that Dr. R.K. Young, who had a great deal to do with the development of the new observatory, joined the staff in 1913.[40]

The 72-inch Telescope

It is difficult to write anything original about the Dominion Astrophysical Observatory. It was Plaskett's creation and in the first issue of the Publications of the Dominion Astrophysical Observatory, he gives the whole story.[41]

By 1910 Plaskett realized[42] "that our output in radial velocity observations of spectroscopic binaries is likely to diminish materially. ... The only remedy is an increase of telescope aperture. Such an increase would not only enable us to keep up our work on spectroscopic binaries but to take part in the great work of obtaining the radial velocities of the fainter stars. ... If our Observatory could take part in such work it would place it in the first rank among observatories, and would undoubtedly give Canada a very high standing in the scientific world."

In 1910 Plaskett attended a meeting, at Mt. Wilson, of the International Union for Co-operation in Solar Research (which later developed into the International Astronomical Union). There a Committee on Co-operation in the Determination of Stellar Radial Velocities, of which he was a member, recognized that more large-aperture telescopes were urgently needed "if substantial progress in this important work was to be obtained". Furthermore, the success of the 60-inch reflector at Mt. Wilson, made it clear that large telescopes were now practical. " Upon returning to Ottawa, I brought the matter to the attention of the Chief Astronomer, Dr. W.F. King, and, as in all attempts to increase the scope and usefulness of the work of the observatory, I found him most sympathetic and eager to advance the project by all means in his power."

In 1911 the Astronomical and Astrophysical Society of America met in Ottawa and it passed a resolution "expressing the admiration of the society for the radial velocity work accomplished with the 15-inch telescope and expressing the hope that the Government would soon provide a larger telescope." It would be naive to think that such a resolution sprang spontaneously. No correspondence from this period survives, but in later periods correspondence shows that Plaskett was a maestro in orchestrating pressure on his superiors.

The American Astronomical Society (to give it the name that it shortly afterwards adopted) resolution was forwarded to the Minister, but unfortunately an election was called, there was a change of Government and a new Minister. A new resolution had to be presented. "A suitable occasion arose at the meeting of the Royal Society of Canada in May, 1912, when a resolution was introduced in Section III and was passed at a general meeting of the society", urging on the Government "the providing of a large reflecting telescope." As one would expect "This memorial was accompanied by strong letters of commendation of the project from the most eminent astronomers of Europe and America." It was presented to the Prime Minister in July 1912.

Nothing happened. "It seemed necessary, therefore, if the telescope was to be obtained, to interest members of Parliament and members of the Cabinet in the project sufficiently to have them urge its authorization on the minister. This work I, with the help of Dr. King, undertook and finally a voluntary committee of several members of Parliament . .. interviewed the [Minister] Hon. Dr. Roche on Feb. 12, 1913, and obtained his consent to make enquiries and obtain tenders for the construction of the telescope. My thanks and those of all interested in the advance of astronomy are due to Sir Edmund Osler, Mr. [F.H.] Shepherd, Mr. Arthur Meighen and the other members of the committee." Plaskett fails to mention that a strong resolution in favour of the telescope was also passed by the Royal Astronomical Society of Canada.

The Minister's approval was a conditional one: after searching the meteorological records a preliminary selection of possible sites was to be made and an observer was to "be sent to these places to test the conditions directly by astronomical observations"; enquiry was to be made "of astronomers and instrument makers in the United States, Great Britain and on the continent of Europe with a view of determining the best and most approved form of instrument, and of obtaining prices". The Minister agreed to make $10,000 available for these studies in the supplementary estimates; unfortunately he left town for an extended period without remembering to tell his staff about it, and that took a little straightening out.[43]

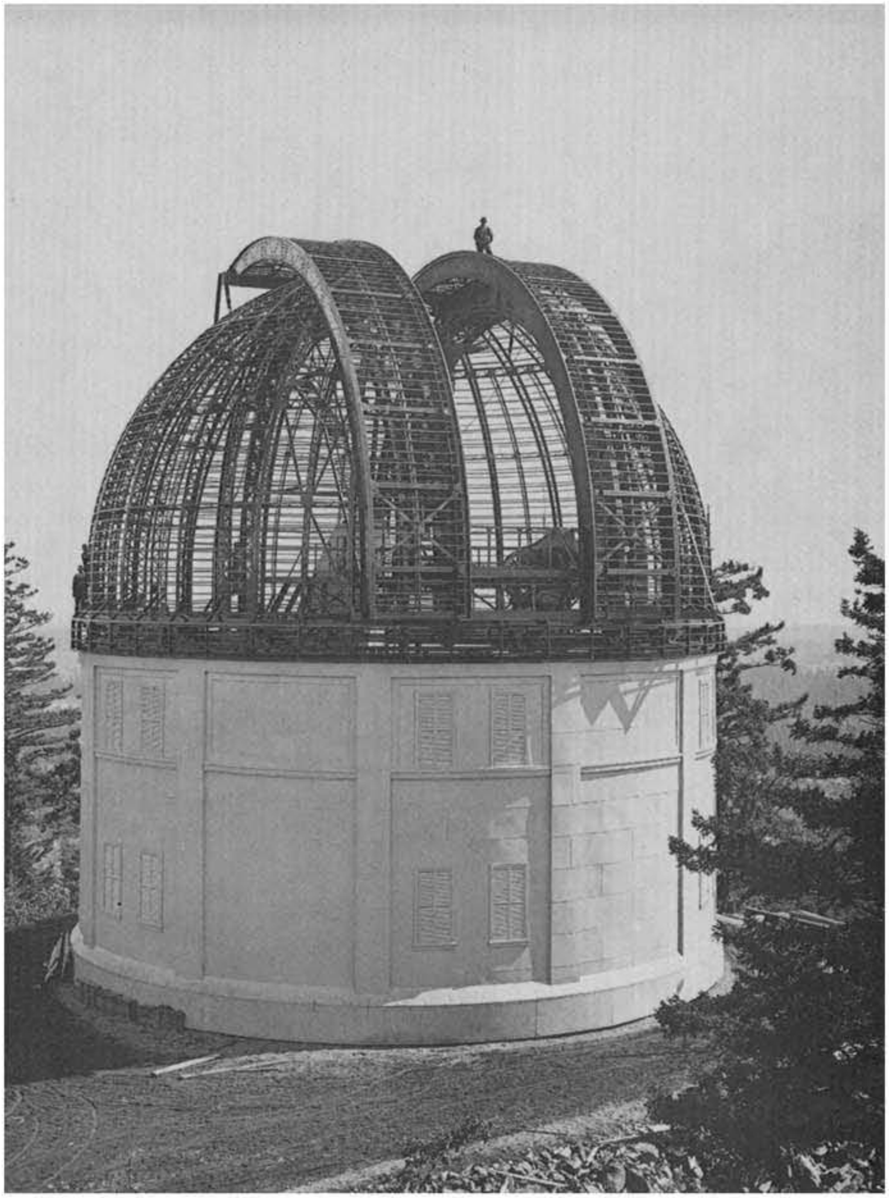
Plaskett took the first steps in fulfilling the Minister's requirements. The meteorological records suggested Medicine Hat, the Okanagan and Victoria as the three leading contenders for the location of the new telescope, and he visited these areas, en route to Mt. Hamilton and Mt. Wilson, as part of fulfilling the second requirement. From California he headed east, and visited observatories at Ann Arbor and Harvard. Astronomers everywhere were generous with their help and he arrived home with the telescope design taking shape in his mind. During his travels he also visited the works of Warner & Swasey in Cleveland and of John Brashear in Pittsburgh; as the suppliers of the 15-inch equatorial telescope, these firms were high in his esteem.

Shortly after his return the specifications were ready. He says of them "these specifications contain little radical or different from the conventional form of telescope. It did not seem wise in a large instrument like this to introduce any untried features unless with a surety of improvement." A number of firms, in the United States, Great Britain and Germany were invited to tender, on the mounting alone, the optical parts alone or for both together. There were to be two tenders, one for a telescope with a 60-inch mirror, one with a 72-inch mirror. The call for tenders was sent out in late May, 1913, the bids to be completed by August. Bids were received from four firms. On the basis of these bids King recommended to the Deputy Minister that the telescope with the 72-inch mirror be built and that the contract be awarded to the lowest tender, Warner & Swasey for the mounting and the John A. Brashear Co. for the mirror. The bids were $60,000 and $30,750 respectively, and were the lowest received.[44] The request was approved by Cabinet on October 16. The astronomical community was kept informed of progress; Klotz reports[45] that, at an evening lecture at the Observatory, King "announced the building of a reflecting telescope of 6 ft. aperture, requiring a building and dome 66 ft. in diameter. Its location is not yet settled, as it is to be placed in the most favourable (climatologically) place in Canada". King also announced plans for the telescope, with a complete listing of the specifications, in the Journal of the Royal Astronomical Society of Canada. [46]

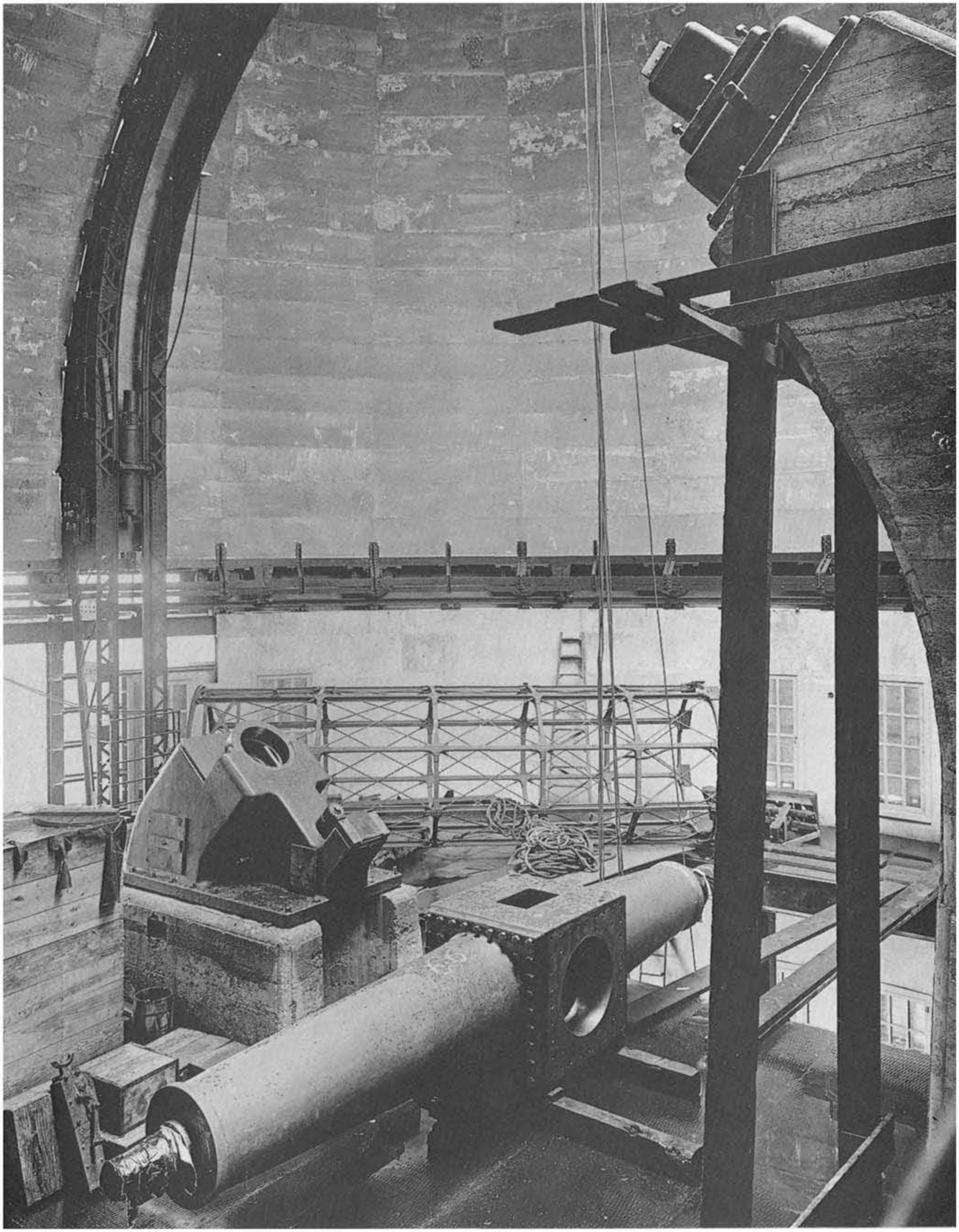
Meanwhile site testing had been going on. Originally King and Plaskett had supposed that the

Hauling the nine and one-half ton polar axis up Saanich Mountain. National Archives of Canada. PA 149324.

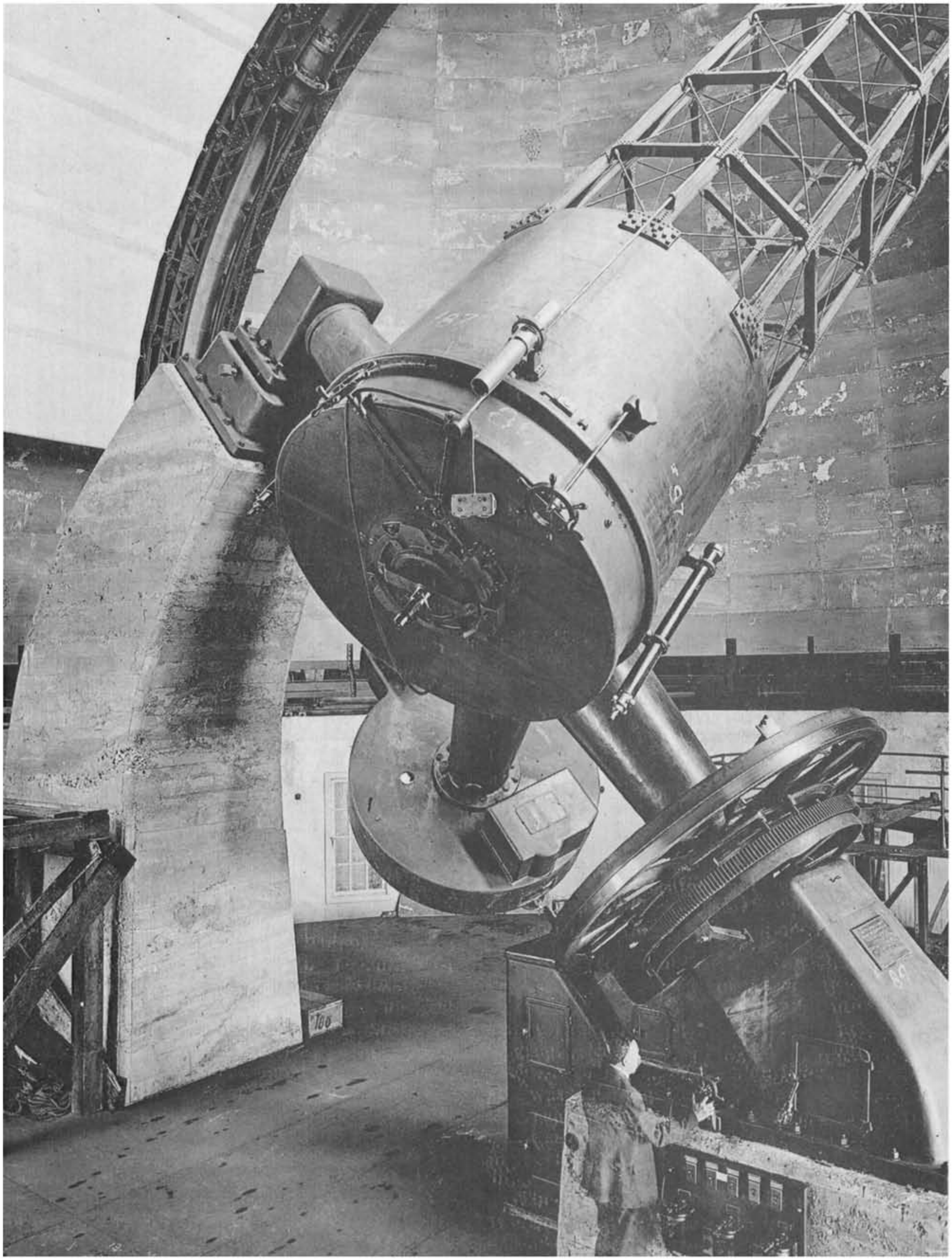
The dome of the Dominion Astrophysical Observatory under construction. National Archives of Canada, PA 149326.



The astronomer's residence under construction. This house was occupied by a succession of Directors up until the death of Dr. Petrie in 1966. It then became an office building. National Archives of Canada, PA 149322.



The telescope being assembled. National Archives of Canada, PA 149325.



Plaskett at the controls of the completed telescope. National Archives of Canada, PA 149328.

new telescope would be located at Ottawa; to build it elsewhere would have required the purchase of land and the construction of an office building and they dared not hope that the Government would accept these additional costs. However, Professor J.C. McLennan, who was instrumental in arranging for the Royal Society resolution, had insisted that it should make "provision for placing the telescope at the most suitable location, for astronomical purposes, in the Dominion". As we have already seen, meteorological information suggested Medicine Hat, the Okanagan and Victoria as the three most likely areas and W.E. Harper, Plaskett's principal assistant, had been assigned the responsibility of testing these sites for "seeing" qualities.

Harper used a 4 1/2-inch telescope in these tests and devised a system for rating the seeing on a scale of 5. On this scale Ottawa rated 2.0, Penticton 2.5 and Victoria 3.5; Medicine Hat and Banff, which was also tested, fell very much below Ottawa. Despite the fact that Victoria had about 10 per cent less clear skies than Ottawa, its superior seeing and its even temperature made it clearly superior.[47] Victoria was to be the location and "Little Saanich Mountain" about seven miles north of the city the specific site, but would the Government in Ottawa approve the location in British Columbia with the extra costs and administrative problems that it entailed?

To ensure this "it was considered desirable to see if the Government of the Province of British Columbia would assist the project in some way. The erection of such a large telescope near Victoria would be a great educational and advertising asset and if some aid could be obtained from the Province, the Dominion Government would be much more likely to sanction its location away from Ottawa." So Plaskett visited Victoria, "interviewed the Premier, Sir Richard McBride, and several members of the Government to see if they would help the project and thus make its location at Victoria more probable." The Government would; it "offered to give $10,000 toward the purchase of the site and to build a road to the summit of the hill". With this boost the Federal Government approved the location in April 1914; public announcement was withheld until the land had been acquired. However "real estate even over the rocky inaccessible summit of this hill was held at fancy prices and it was only after protracted negotiations that the 50 acres needed were obtained at $280 per acre.

Copies of the quite persuasive letters which Plaskett wrote to the Premier, in Plaskett's handwriting, survive.[48]

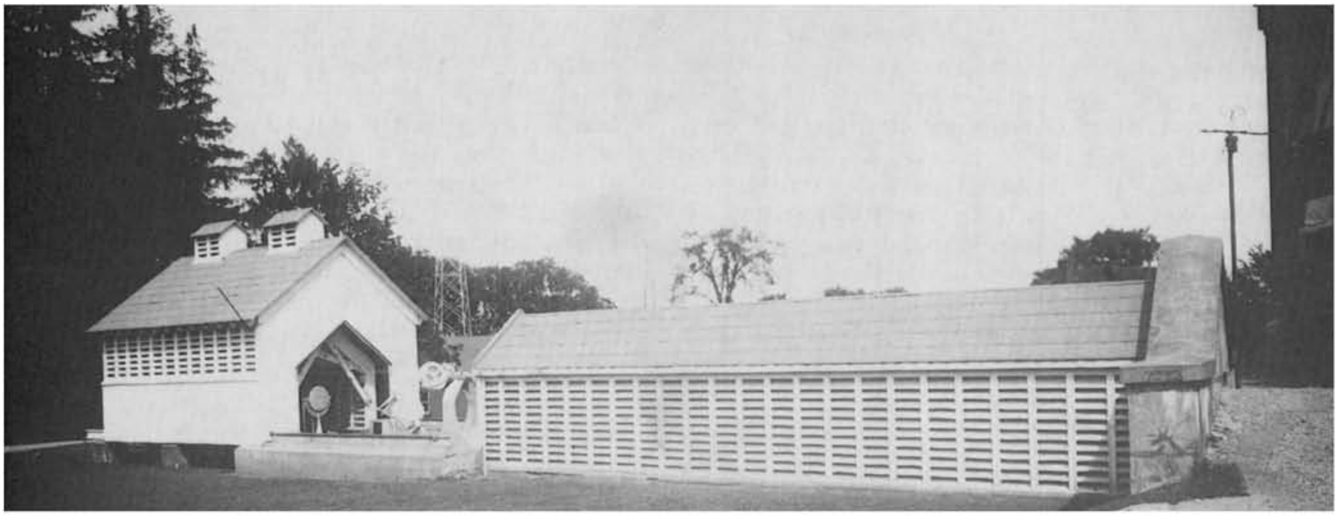
The site having been selected, the final design of the telescope mounting could proceed and the construction of the building to house the new instrument could begin. The latter was the responsibility of the Federal Department of Public Works. They let contracts locally for the construction of the building and the telescope piers, and with Warner & Swasey for the dome. Work on the former began in the early summer of 1915, of the latter in the fall of the same year. The road to the summit had been built, as promised, by the Provincial Department of Public Works in the spring of 1915 and the water supply, which proved difficult, was completed at the same time.

One must read Plaskett's account to understand how much was accomplished in the 55 months between the letting of the contract and the completion of the telescope. The dome was in place in 30 months, the telescope mounting in 36 months; only the figuring of the mirror accounted for the additional two year delay. The vast amount of heavy equipment had to be hauled up the mountain by horses, and the windlass which hoisted the units into position was horse-powered. It was a most remarkable performance! In addition to his summary paper on the 72-inch telescope, Plaskett provided progress reports in the Journal of the Royal Astronomical Society of Canada.[49]

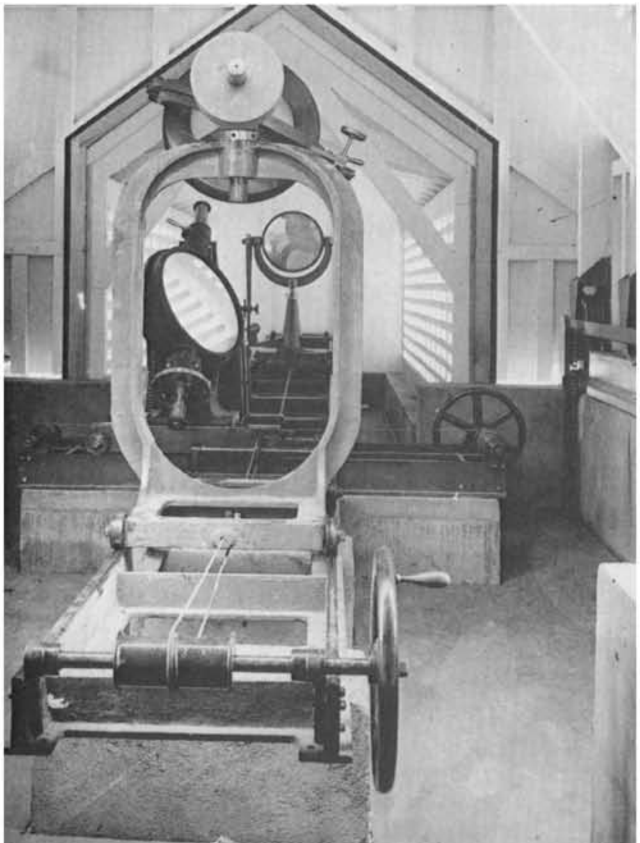
Dr. King died too soon to see the observatory completed but he must have known, as Plaskett did, that it was his steadfast support that had made it possible. With King gone the new man in Ottawa was to be Otto Klotz. There was no love lost between Klotz and Plaskett and this may be a suitable place to document some of their disagreements during the King regime.

As we have seen, Klotz was the Assistant Chief Astronomer in name only. King seldom consulted him about astronomical matters and almost never told him what was going on. When King was away the Chief Clerk, Simpson, was in charge rather than Klotz. Naturally he resented this, and as Plaskett's star became brighter the resentment grew.

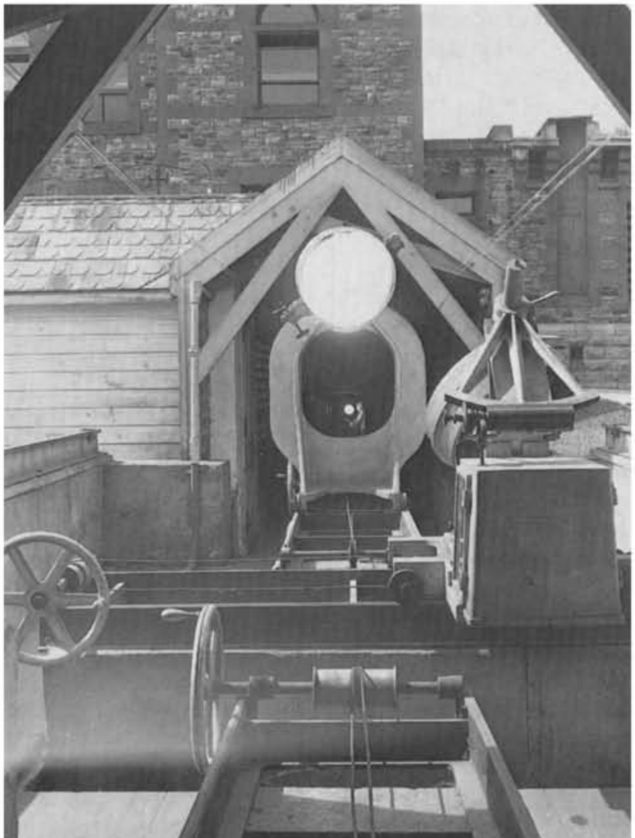
At the start he had had a good opinion of Plaskett. He speaks favourably of his work and of his abilities. In January, 1907:[50] "In afternoon Mr. J.S. Plaskett gave the first of our series of technical papers on 'The Star Image in Spectrographic Work.' It was very good and showed much aptitude for mechanical analysis in discovering sources of error in the various optical and other parts." In December, 1908[51] he proposed Plaskett as Vice-President of the Ottawa Centre of the Royal Astronomical Society of Canada. He was surprised to find opposition to Plaskett from within the Observatory. "I thought that all our staff were well disposed toward Plaskett, who has been especially favoured in every way by Dr. King, the Chief Astronomer, in promotion and getting everything he wanted, the same with his



The coelostat house opened for an observation. The light beam, after three reflections, passes along the covered pathway, under the road, to the spectrograph in the solar laboratory.



The mirror system of the coelostat. The large plane mirror in the left centre of the picture accurately follows the passage of the sun. It reflects the sun's image to the nearer, plane, mirror at the top of the picture, which reflects it to the third, most distant, mirror. This concave mirror focusses the image on the slit of the spectrograph, 80 feet distant.



Looking from the concave mirror, along the optical path, and into the laboratory.

assistant Mr. Harper whom I had proposed for Secretary. The proceedings showed me the way the wind is blowing." Was the wind blowing, or was Klotz fanning it?

Things went smoothly until the new telescope was approved. Klotz felt left out. In September, 1913,[52] he visited Napier Dennison in Victoria. "He told me Harper (of our observatory) had been here in connection with the examination of the meteorological conditions relative to the location of the new telescope. Dennison said that in his mind the selection would lie between the interior of British Columbia and Alberta. Had I been asked by Dr. King, as I should have been asked, as I have observed more than any other man in the whole region in question, having observed years ago in Victoria, Port Moody, Kamloops, Revelstoke, Field & Calgary, I would unhesitatingly select in the Kamloops region, including therein the Okanagan Valley. But King is too jealous of me to have my name associated with anything if he can avoid it. However if he can get my opinion indirectly he is glad to get it."

Not only did Klotz feel left out, Plaskett was giving himself airs. Early in 1913[53] the Director of the Allegheny Observatory, an old acquaintance of Klotz', visited the Observatory; Plaskett didn't even bring him in to say hello. In June, 1914[54] the Observatory held a reception for delegates to a meeting of the Ottawa Historical Society. King and Klotz acted as co-hosts, and their wives were mutually helpful. "Going home I was surprised to learn from Marie [Mrs. Klotz] that Mrs. King had expressed very strongly against Dr. Plaskett's recent splurge and 'impudence' in the Victoria, B.C., *Colonist*, about the new observatory for Victoria, with the 72" reflector. His putting himself in the limelight has just gone too far. He is an adept at it and that Mrs. King resents it, serves him right. Few men get as much rope as Plaskett has got from Dr. King, and Plaskett is on the road to put a noose around his neck."

In May, 1916[55] "I got an extraordinary engraved invitation from Warner & Swasey - Cleveland to be present at an exhibition of the 72" (our) telescope on the 25, and also at a luncheon to 'Dr. J.S. Plaskett, Director of the Dominion Astronomical Observatory'!! Very news to me, and I think to everybody else. Presumably it only means of our Victoria, B.C., observatory. Plaskett is an adept at advertising, and should be coralled by some patent medicine concern."

Solar Physics[56]

It will be recalled that for the eclipse expedition of 1905, a coelostat with an aperture of about 20 inches was purchased, with the intention that it would form the basis of a permanent solar telescope at the Observatory site. It was not until mid-1908 that this began to take shape, by which time it had become the responsibility of Dr. R.E. DeLury, working until 1913 under the supervision of Plaskett. The telescope lay to the north of the Observatory, housed in a shelter some 80 feet long, part of which moved back on rails to expose the coelostat to the sun. As the coelostat followed the sun, the light was reflected by a pair of mirrors along the length of the shelter, through a tunnel beneath the roadway, to form a 9-inch image of the solar disk on the spectrograph slit. Initially this was used only to illuminate the slit. Photographs of the sun were taken with the solar camera of the 15-inch equatorial until 1919; only then was a photographic attachment added to the solar telescope.

The spectrograph was 24 feet long so that it filled the Solar Laboratory and projected into the tunnel beneath the roadway. Light from the slit illuminated a lens some 23 feet away, which passed a parallel beam to a grating about a foot behind it; the light returning from the grating was focussed on a plate holder mounted directly below the slit. Prisms were used to project light from various points on two orthogonal diameters; these points included the limbs of each diameter, the four midway points between limb and centre, the centre, and four moveable points close to the centre. In addition, light from the centre of the disk passed through a tube of iodine vapour to provide a standard line; electric arcs produced other standard lines. Any selection of nine of these spectra could be recorded on a single plate. The entire spectroscope rotated on its axis, so that any pair of diameters of the sun could be studied.

Plaskett designed the telescope, DeLury the spectrograph; the optical parts for both were supplied by Brashear, the mechanical parts by a local firm, the Victoria Foundry.

The completion of the telescope was delayed by construction problems. Since the optical path passed under the roadway, any work on the roadway or on the foundation of the building interfered with it. There were several such interruptions, as we shall see later, and it was not until August, 1908, that the telescope could be tested. It was immediately found that the grating was unacceptable and a new one was ordered. While waiting for the new grating, experiments were continued with the old one by masking off those large sections which were defective.

Initially the telescope was used in the study of solar rotation as part of a program designed by the International Union for Cooperation in Solar Research. The Observatory was assigned the region of the spectrum from λ5500 to λ5700, a region "not of particular interest". It was probably just as well, because the telescope was plagued with difficulties and DeLury was still discussing the 1910-1913 rotation results in 1936! There were several sorts of problems: the new grating which arrived in 1910 was a great improvement on the original one but substantial portions of its surface still had to be masked off; the Toepfer measuring machine, used to measure the spectrograph plates, produced systematic errors which took some time to eliminate; the telescope was on the north side of the Observatory, where the building cast a shadow in the winter afternoons; all contributed to the delays.

These problems were gradually overcome and the telescope was in active use from 1911 on. During the summers of 1913, 1914 and 1915 Plaskett's son, H.H. (Harry) Plaskett was employed as a summer student and published the results of his observations. This led to some unfortunate disagreements between the Plasketts and DeLury. J.S. Plaskett and DeLury had found that the solar rotation for the years 1910 to 1912 was constant within the errors of observation, the younger Plaskett found a substantial reduction in the rate for 1913. Was this difference real, or the result of different observational techniques? DeLury believed that it was a result of the contamination of the solar spectra in passing through haze in the earth's atmosphere and investigated this effect in what he called "blended" spectra. He presented the results of his study at an Observatory seminar in December, 1916 and Plaskett, senior, made what Klotz calls "a rather savage"[57] attack on him. Discussion of the matter went on for some years and may account for the long-delayed analysis of the 1909 and 1910 observations[58] which when eventually published appears, to this layman, to be the beating of a dead horse which at best had never been particularly lively.

While the problems with the spectroscope were being resolved, the solar camera attached to the 15-inch Equatorial was used regularly for the registration of sunspots and somewhere in this period DeLury became more interested in sunspots than in the measurement of solar rotation; in particular he was interested in the 11 year cycle in sunspot activity and in the relationship to cyclical phenomena in nature. We shall return to this matter in a later section.

Time Service and Transit Operations[59]

R.M. Stewart joined the staff in July, 1902, and immediately set up an experimental time service in preparation for the move to the new building. The transit instrument in the Cliff Street observatory was used for time observations and a pair of master clocks, one sidereal, one mean time, were maintained in a basement room of the Old Supreme Court Building. The sidereal clock was connected, by wire, to a chronograph in the observatory. The transit instrument was equipped with a number of vertical lines in the focal plane. As the star image crossed these lines the observer pressed a button causing a series of signals to appear on a chronograph which also carried time marks from the master sidereal clock, the error of which could thus be determined. Since the exact relationship between mean and sidereal time was known, the correction to the mean time clock was a matter of calculation.

Slave clocks, driven by the masters in the Supreme Court Building, were set up in the Langevin Block and the Thistle Building (where the astronomical staff was housed) and these clocks, in turn, drove a number of clock dials in offices throughout the buildings. The connection between the master clock and the Thistle building could be used in reverse to advance or retard the master. Once the astronomer had scaled his chronograph record and determined the correction he could adjust the master clock without leaving his office.

When the new Observatory was occupied there was a delay of some three years in the completion of the transit room and a temporary observing hut had to be set up east of the main building. The transit was a Cooke, with a 3-inch aperture and a focal length of 35 1/2 inches. It was equipped with eleven vertical lines in the focal plane across which the passage of the star could be timed. The chronograph was one supplied by Warner and Swasey.

The clocks were housed in the basement "round room", the location being as remote from the outside walls of the building as it was possible to get; the temperature was maintained by a thermostatically controlled electric heater over which an electric fan played to keep the air in constant circulation. The vault contained four primary clocks, a Howard and a Riefler sidereal, and a Riefler and a Borrel mean time. Errors were allowed to accumulate in the sidereal primaries but the mean time primaries were regularly corrected so that they put out as accurate time as possible.

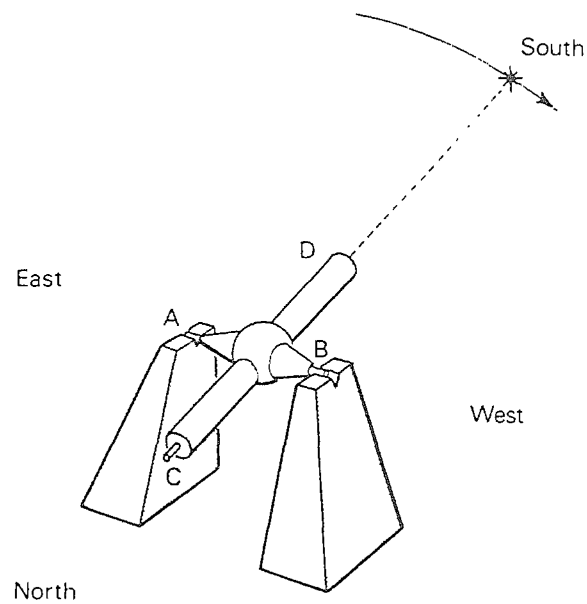
The master clocks in the vault controlled slave clocks, one sidereal, one mean time, in the Time Room. The master mean time clock also, by driving a cam with a variety of teeth, could produce second, minute or hour signals. The minute signals were used to time the seismographs, and to control a number of wall clocks throughout the Observatory and the large clock in the dome.

Four insulated wires ran from the Observatory to the downtown area. One pair controlled the time-ball on Parliament Hill which was dropped at noon as a precise time signal; the noon gun was fired manually when the observer saw the ball drop. (The dropping of a time-ball is a very old device, used on the "signal hill" of most ports; it was a signal which could be easily seen from ships in the port. The Ottawa time-ball continued in use until the wires controlling it were destroyed in the fire of 1916. The noon gun continues to this day.) The other pair of lines divided into four branches and led to clocks in four government buildings - the Parliament Buildings, the East and West Blocks and the Langevin Block - controlled by the mean-time clock in the Time Room. These slave clocks, in turn, controlled time dials in offices throughout the respective buildings. In 1905 a total of 214 such dials were in operation. The number grew to 246 in 1908 and to 276 in 1909.

These clock dials contained no movement of their own but simply an electromagnet and a device to release the hands when the electromagnet received the minute pulse from its controlling clock. The hands jumped one minute on the 60th second. The jump always made a loud, two-phased "thunk-thunk". One became accustomed to this noise very quickly and when a clock stopped working for some reason the silence of the omitted signal was deafening. The Observatory dome, and the Post Office, had large clocks, the hands of which were too heavy to operate in this way. They were operated by a small electric motor which was turned on and off once a minute by the control clock.

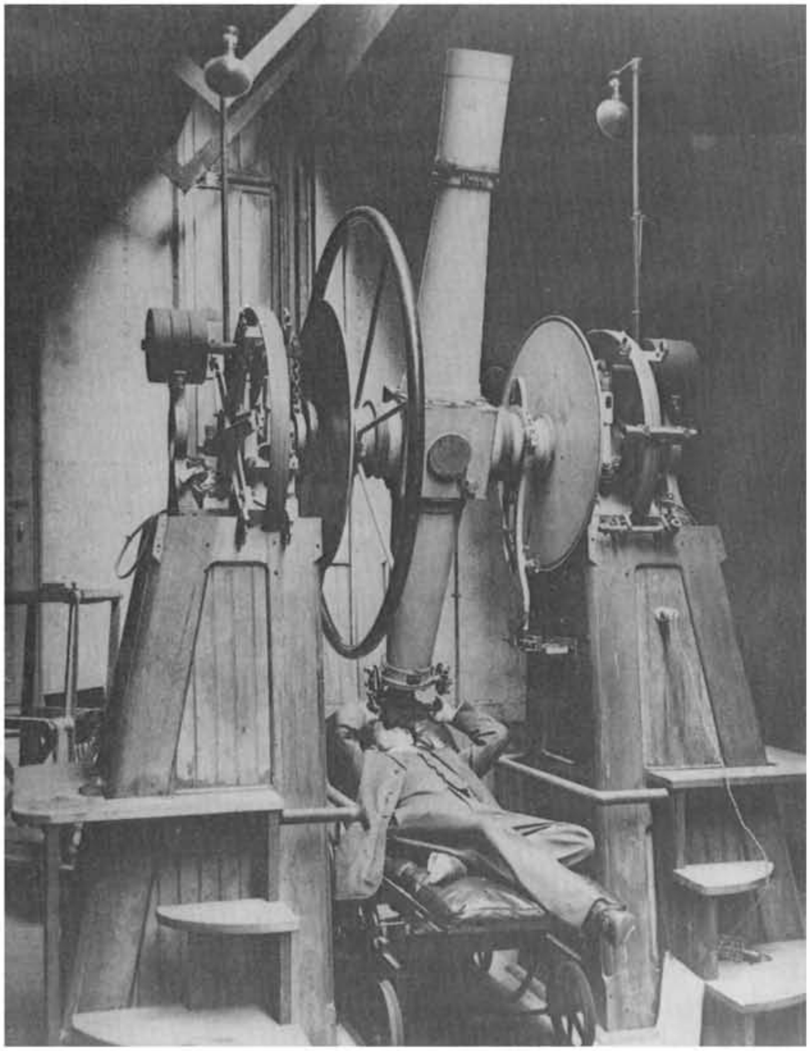
There was no major change in the system during the period of the King Administration, but constant improvements dictated by experience. By 1907 the service had been extended to the newly-completed Mint, to the Post Office, and to the Archives Building. Time signals were also being supplied to the Great North Western Telegraph Company, and occasionally to the Canadian Pacific Telegraph Company, which normally took its time from the McGill observatory. An arrangement was also available in Mr. Stewart's office to transmit the sound of a telegraph key, operated by the seconds signals, over the telephone.

The problem of better instrumentation for the observation of star transits was a two-fold one; there was serious delay in the delivery of a satisfactory instrument and there were many difficulties in the construction of the meridian annex to the building. The problems were to some extent inter-related. Until the instrument had been installed the limitations of the annex could not be recognized. We shall have to consider both problems at the one time.



The instrument involved is always referred to as the "meridian circle" or sometimes as the "meridian circle transit" and it operated on the same principles as the transits used in determining time and in establishing longitude. The accompanying figure illustrates the principle of a transit telescope. It is mounted on an east-west axis, and has only one degree of freedom - in the plane of the meridian. As stars pass across the meridian their passage can be observed and timed. The difference between the ordinary transit and the "meridian circle transit" was one of accuracy; the telescope was bigger, the mounting was more rigid, the scales for reading telescope position were much larger and, with microscope viewers, much more accurate. When the instrument was finally in satisfactory operation, in 1911, it was used in the measurement of time and in the measurement of star positions. One may ask, "what is the difference?" For the measurement of time one uses stars whose positions are accurately known; given accurate time one can then determine the positions of stars less well located. It is rather a boot-strap operation.

I have not found any record of when the order for the meridian circle was placed, but it was probably in 1904, because the contract for the meridian annex was let at that time. The London firm of Troughton and Simms was to make the instrument. Their work was most unsatisfactory. Klotz reports visiting their plant in late September, 1907,[60] at which time



J.S. Plaskett demonstrates the operation of the meridian circle transit. The observer lies on a couch which can be moved along a track to accommodate the elevation of the telescope. Note the large graduated plates on either side of the telescope, on which the elevation setting of the telescope is read. Museum of Science and Technology photograph.

(Top right) The trolley used to raise the telescope and reverse it on its pivots.

(Right) The south azimuth hut; the north hut was removed when Carling Avenue was widened to the present four lanes. These buildings housed the marks which defined the prime meridian.

delivery was almost one year overdue. The instrument was delivered about a month later, on October 28, 1907. Meanwhile work on the annex was proceeding slowly. It was originally intended to postpone building the piers until the instrument arrived but because of the delay these were built in advance. They, and the roof, were practically completed by mid-1907.

To understand the difficulties that followed we must have some idea of the instrument. It consisted of a telescope of 6-inch aperture and 7 foot focal length which was mounted on a rigid shaft pivoted at each end in a massive support. At either end of the shaft there were large circular plates, 36 inches in diameter, used to measure the declination setting of the telescope. They were inscribed in degrees and in minutes, down to 5-minute intervals, and were supplied with small microscopes for reading the scale setting. The entire system was very heavy, and to reverse it on its pivots a special trolley was provided, which ran on tracks; it could be run under the system, jacked up to lift the system from its pivots, removed and the system reversed, returned to position and jacked down to lower the system, now reversed, on to the pivots.

When the instrument arrived it was found that the piers provided were not high enough; the trolley was so tall that it would not run under the telescope system. The piers were extended and the instrument mounted. It was immediately found that the microscopes, by which the declination setting was read, did not stay in focus as the telescope was rotated on its axis. It was found that the circular plates had been bent, presumably in transit. The circles were removed and returned to the manufacturer in January, 1908. The instrument might have been used as a simple transit instrument while waiting for the return of the circles, but the building was not yet complete. Requisitions for the wiring of the annex had been with the Department of Public Works for a year and nothing had yet been done about it. The mechanism for opening the roof shutters was not yet in place and they had to be opened by hand. These matters were corrected during the winter.

When spring (1909) came it was found that all the piers, not only those that supported the meridian circle but also the collimating piers which defined the meridian, and the piers in the transit room, had been heaved by frost and some of them broken. They had to be rebuilt. Their bases were placed at a depth of 6 1/2 feet below the ground surface, and surrounded by drains of broken stone. Stewart wanted this stone extended to the ground surface but the Department of Public Works demurred. Stewart was right, the drainage was insufficient, and during the next year weeping tile was installed at the base of the piers and the stone was extended to the surface. Drainage was to a cistern of 1000 gallons capacity which could be pumped out into the city sewage system as required. This cistern still existed in the early 1960s; the secretary of the Seismological Division used it to cool a bottle of milk for her tea and Dr. Willmore fired off blasting caps in it while testing seismic field equipment.

The circles were returned in June 1908 and immediately mounted. The bending of the plates had been corrected reasonably well but it was found that, the microscopes being focussed, if the system was reversed they were out of focus. The circles were not at the same distance from the centre of the telescope! A bushing was provided to extend the axis the necessary 1/25 inch.

Serious observing could now begin, but more troubles were discovered. It was anticipated that pivot error would exist, that is that the system would not reproduce observations exactly when the instrument position was reversed. What had not been expected was that these errors would not be constant! It was found that the pivots had not been hardened and that they were wearing away with use and with every reversal of the system. What to do? It was decided to turn down the existing pivots and to install hardened steel bushings of the original diameter. The Observatory lathes were not large enough for the purpose, but one at the Royal Mint was, and the operation was successfully performed. There remained many months of testing and adjustment but the instrument was finally in reliable operation by the beginning of 1911.

In the meantime more problems had arisen with the building. Despite ventilating louvres in the walls it did not follow the outdoor temperature closely, which led to problems of refraction and consequent errors in declination measurements. These difficulties also were gradually overcome.

In order to define the azimuth, marks as far as possible north and south of the telescope were required. These marks were placed at the bottom of piers, one north of the annex near Carling Avenue, the other south close to the Farm Driveway. A telescope on each pier allowed surface marks to be lined up with the sunken basemark, and these surface marks could be viewed by the meridian circle telescope. These meridian piers were eventually housed in stone buildings, matching the main building. Initially however they were enclosed in wooden shelters.

With the instrument finally in operation, an observing programme was begun in January 1911. Initially this consisted of stars which had been or could be used in the longitude programme. The existing catalogues of the positions of these stars did not always agree and definitive measurements were required. There was a total of 2,284 stars in the programme which continued, beyond the period of this chapter, until 1923. By this time a total of 28,000 observations had been made and more than 1.5 million computations! The errors inherent in the instrument - in the pivots and in the graduated circles - as well as in the star positions had to be determined in these calculations.

The development of the instrument, and of the observing programme was the responsibility of R.M. Stewart. He was joined by D.B. Nugent and C.C. Smith in 1907. Smith only remained until 1912 when he returned to private practice as a surveyor. D. Robertson assisted in the installation of the network of clocks in the Government buildings and was responsible for their maintenance.

In the measurement of time by transit, as used particularly in longitude work, the determination of the personal error of the observer had to be obtained. It had been found that each observer was very consistent in judging the transit of stars, but that he might be consistently early or late or, indeed, consistently on time. At the beginning and end of a field season it was always necessary for the two men, the field observer and the base observer, to simultaneously observe the same sequence of stars and so discover the personal error of each and the difference between them.

Early in the 1900s a device known as the transit micrometer was introduced which reduced, or eliminated, the problem of personal error. It was attached in place of the normal eye-piece of the telescope and had a single wire or a closely spaced pair of wires which could be moved across the field of view by turning a pair of knobs. As the star came into view the knobs were turned so that the star image bisected the wires and remained there throughout the transit. During this process a commutator wheel made a series of electrical contacts to put a series of signals on the chronograph.

Another important feature of the transit micrometer was a prism arrangement that was rotated by the observer at the time of actual transit to reverse the apparent direction of motion. If the star came in from the left it also went out to the left; this was intended to eliminate a personal tendency to set too far to the left or to the right. The meridian circle instrument was equipped with this device from the beginning, and the transit instruments used in the field for longitude measurements were so modified during the first years of the decade.

It was by no means certain that the transit micrometer eliminated the personal error; if an observer had a tendency to read a star transit early or late, might he not track the star with some consistent bias? A great deal of thought was given to this matter, and indeed to the entire question of personal error.[59]

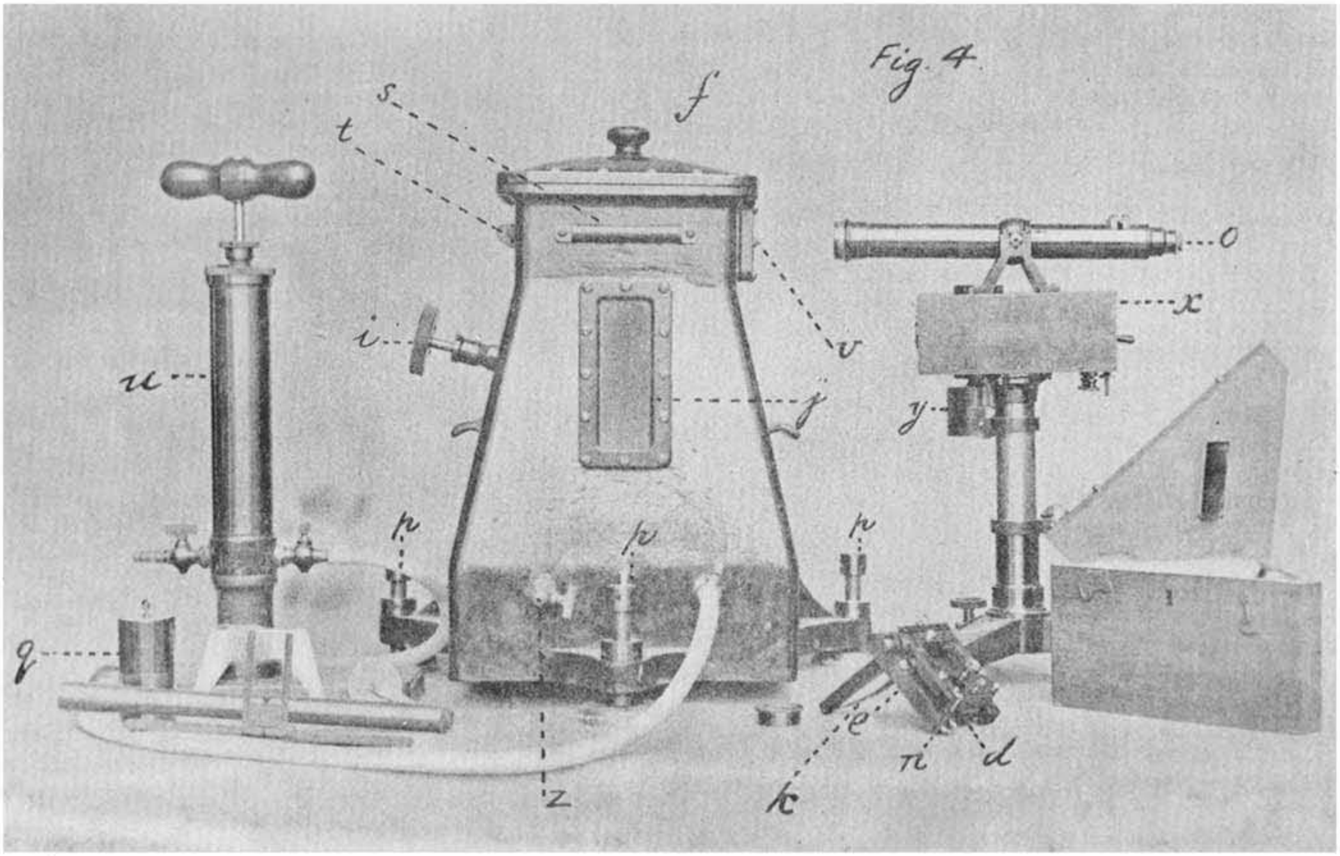
Despite the fact that the Geodetic Survey was set up in 1909, the determination of longitude by astronomical methods continued to be the responsibility of the Dominion Observatory, specifically of the "time service". During the period of the King Administration two observers, F.A. McDiarmid and W.C. Jacques, were in the field each summer, Stewart and Nugent acting as the Ottawa observers when required. The results were published annually until 1911 by J. Macara, the Observatory computer, in the Reports of the Chief Astronomer. In 1921 Stewart published a review paper[61] listing all the observations to 1919. Thirteen of the points were consolidated to form a longitude net, and the probable errors of this net were thoroughly discussed. Results for 1920 were apparently never published, but a typescript is bound into the Library copy of Vol. 5 of the Publications.

GEOPHYSICS

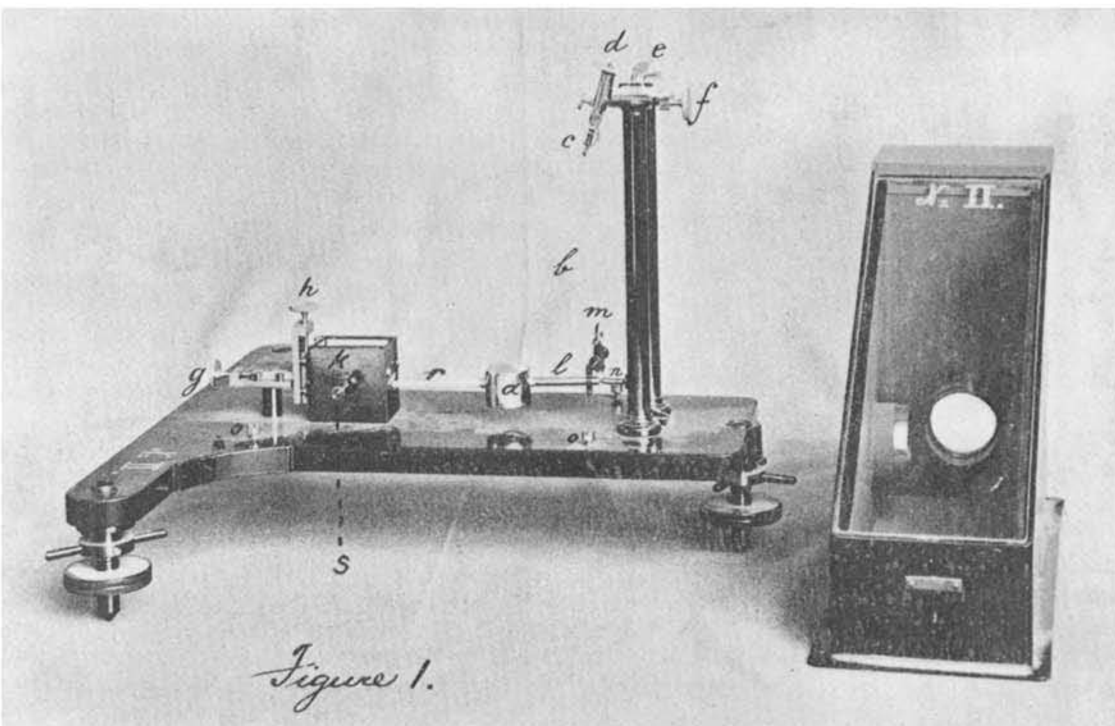
E.A. Hodgson always said that Klotz started geophysics in the Observatory to have something to manage that King didn't know anything about. Given the rivalry between the two men, this is a plausible theory, but it isn't supported by the diaries. Klotz was, as we have already seen, interested in founding[62] an "astronomic geodetic institute - where the work would comprise geodetic astronomy, geodesy, terrestrial magnetism, pendulum observations and standards, in short ... the division of government work that dealt with Exact Science," and he seems to have been interested in the magnetic and pendulum measurements because they were something one did in the field and because they contributed to man's understanding of the planet.

Gravity

Of all the geophysical disciplines it was gravity that had held Klotz' earliest interest. On a visit to the United States Coast and Geodetic Survey in Washington in 1895 he reports:[63] "Mr. Putnam then took me to the basement and showed me Dr. Mendenhall's pendulum apparatus with which he occupied, during the past season, 26 stations along or near the 39th parallel, from Washington to Utah. With this instrument absolute gravity is not determined, but only relative. As I understood from him the results of his work show that the mean density of the mass of this area above sea level is different from what had been assumed and believed." Klotz felt that measurements of gravity were an obvious extension of his longitude work. He would be able to swing the pendulums at accurately located



The Mendenhall pendulum apparatus. Two pendulums, swinging in antiphase, were housed in the central case, from which the air could be partly removed by the pump. The motion of the pendulums could be observed through a window in the case by means of the telescope.



The Bosch horizontal seismograph.

positions, while the chronometers necessary for timing the swings, and the means of correcting those chronometers, were already available in the longitude work. Also, gravity information was important to surveying. "The force of gravity is related in the same way to the latitude and longitude as the intensity of the magnetic force is related to the magnetic declination and inclination, and, as a magnetic survey would be held to be imperfect in which measurements of intensity were omitted, to the same extent must a geodetic survey be held to be imperfect in which the determinations of gravity have been omitted." Further, "as the knowledge of the constitution of the earth's crust becomes, by the aid of pendulum experiments, more perfected we shall be able to establish methods by which we can with confidence infer from the vertical attraction of mountains, etc., what their horizontal attraction, and the resulting deflection of the plumb line must be".

He lost no opportunity of pressing on King the desirability of doing gravity work, and early in 1899,[64] during a visit to the Minister, the Hon. Mr. Sifton, he told him "of the desirability of obtaining pendulum apparatus for me to use at any stations I may occupy for longitude and latitude. I briefly explained to him the value of gravity observations".

This persistence was probably unnecessary, for King must have been as aware as Klotz of the importance of the work, but, in any event, it paid off. By May, 1901 he reports[65] "I was glad to hear from King yesterday that he had ordered a half-seconds pendulum apparatus from Washington for relative gravity work. For more than a year I had urged him to obtain such for me as my latitude and longitude work takes me across the continent and I desire to do gravity work at the same time. The work to me is most fascinating and interesting. To think what mysteries of the earth are hidden in the swing of a pendulum, to observe and evolve light is truly nectar and ambrosia."

The new instruments were ready by the spring of 1902, and Klotz went to Washington to take delivery but, more importantly, to swing them on the base pier of the U.S. Coast and Geodetic Survey.[66] They were then brought to Ottawa and in early August, 1902, a Canadian gravity base was established in the basement of the old Supreme Court Building. "The place was well adapted, as there is very little traffic on the streets in the neighbourhood. ... Part of the floor in this part of the basement was removed, a cement pier, 2 feet square, was built on the limestone rock in situ, which immediately underlies the floor. The pier was enclosed within a double-walled room 8 feet square, to ensure a fairly uniform temperature, and to protect the pendulum apparatus from currents of air".[67]

Learning the technique for using this new instrument wasn't easy.[68] "At office, but most of time busy with pendulum apparatus. ... It is next to impossible for any man to set up and adjust this apparatus without seeing it done, he might read all the most minute descriptions as found in publications and yet utterly fail to get it going, with a strong probability that something would be ruined or seriously damaged." Klotz must have mastered the technique fairly effectively because by September 12[69] he was swinging his pendulums at McGill University in Montreal and by September 17 in the basement of the School of Science, University of Toronto.[70] Here he was assisted by Professor L.B. Stewart; in 1905 Professor Stewart made equivalent observations at Northwest River, Labrador.[71] These four observations are the only ones made in Canada by Canadians prior to the establishment of the Observatory proper, although A.H. Miller reports[72] that G.R. Putnam of the U.S. Coast and Geodetic Survey established two gravity stations on Baffin Island in 1896.

However, Klotz was not idle. Between May, 1903 and early January 1904, as we have seen, he was involved in carrying longitude measurements across the Pacific using the newly-laid cable to provide time connections. As part of this work he carried his pendulums. They were swung in Fiji and at Doubtless Bay, a point near the northernmost tip of the North Island of New Zealand.[71]

Despite these promising beginnings no further gravity observations were made until 1914. In 1908, Klotz says[73] "Unfortunately the new sidereal chronometers ordered were not received in time for undertaking gravity work during the past season. The chronometers of the observatory heretofore available were required for urgent longitude determinations in various parts of the Dominion". In subsequent years the problem was probably one of staff; Mr. F.A. McDiarmid, who became the gravity observer in 1914, was fully occupied until then with longitude work.

In 1914 McDiarmid was released for gravity work. A pier had been established as a gravity base ("I have had the old machine shop fitted up handsomely for it [the new vertical seismograph] and gravity observations"[74]) and in April and May McDiarmid made a tie between Washington and this new base. In addition he occupied 18 field stations in Ontario and Quebec. The work was written up in great detail[75] including a description of a new method of using an interferometer to measure, and correct for, flexure in the pendulum supports. This technique had been developed at the Coast Survey about two years earlier. McDiarmid also published a more popular paper, with descriptions of the equipment, in the Journal of the Royal Astronomical Society of Canada.[76]

In 1915 McDiarmid observed at 24 stations, spread between New Brunswick and British Columbia[77]. Some difficulties were experienced because of unexplained changes in the lengths of the pendulums. On the advice of the Coast Survey, which had recently experienced similar difficulty, the pendulums were modified by rivetting the bob to the stem.

In the conclusion of his report McDiarmid allows himself a small congratulatory remark: "Canada has now a line of gravity stations right across the continent covering more longitude than is covered by any other series of stations on the American continent ... in a few years if the gravity observations are continued, Canada will be able to supply to the world valuable scientific knowledge concerning the earth."

Alas the gravity observations were not continued, at least not for several years. We shall see later that with the death of Dr. King confusion reigned for more than a year; during this period, funds for field work were cut off. In any event McDiarmid wanted to return to survey work. Early in 1916,[78] Klotz confides to his Diary. "Called on Dr. Church about our Mr. F.A. McDiarmid who yesterday told me that the Dr. had told him that observing in cellars, basements (gravity work) was detrimental to his health, in which I took little stock, as he always looks very well in the fall when he returns from the field, and runs down in the winter when he is at home. The Dr. told me that he had examined his lungs and sputum and in so far was alright, however that he takes cold easily, saying too that cellar-air is too 'heavy', to which I replied that he is only about an hour at a time in an underground room. My own opinion is that he wants an easier job, the novelty has worn off and he has been in Washington and has had all the kudos obtainable."

Whatever his reasons, McDiarmid transferred to the Geodetic Survey.

Magnetics

Magnetic observations are the earliest form of geophysics practised in Canada. In the 1830s the British government, in order to better understand the fluctuations and variations in the earth's magnetic field, set up a number of magnetic stations throughout the Empire. One of these was established at Toronto, in 1839. In addition to "a complete set of magnetic instruments" it was equipped with transit and chronometers to maintain correct time and with a set of the most modern meteorological instruments. The station was on the campus of King's College, later the University of Toronto.

While we are chiefly interested at this point in the magnetic observations of this observatory, its meteorological observations were of even greater importance because, as they expanded, they formed the basis of the Meteorological Service of Canada. It is not by accident that that Service was responsible for the national magnetic observatory for so many years.

Magnetic observations were taken continually at the Toronto Observatory from 1841 until September 1898 at which time the instruments were moved to Agincourt, north of Toronto. The move was necessitated by the disturbances due to electric street cars.

During its early years the Observatory was directed by Lieutenant (later Sir) John Henry Lefroy. In 1843 and 1844 Lefroy took time off from his Observatory work to make a very extensive journey, by canoe, as far north and west as Lake Athabasca, Fort Simpson and Edmonton. A total of 314 stations was observed. Don W. Thomson says that Lefroy was also instrumental in having a magnetic survey on the Palliser expedition.[79] No observations of this effort seem to have survived.

In the surveying of the Dominion lands, discussed in the opening chapter, careful determination of the magnetic constants were made at many points. "The declination was generally obtained by means of a long compass needle attached to the lower plate of a transit-theodolite within a narrow box, fitting into a groove, while inclination and total force (intensity) were obtained by a Kew Dip Circle, the constants of which had been determined at the Toronto Magnetic Observatory."[80] A total of 204 observations were available from this source. The data, covering the years 1881-1890 were published in the 1898 report of the Department of the Interior.

In the next ten years additional observations became available, some made by Klotz himself, for example in connection with the longitude work on the 141st meridian, some made by the Carnegie Institution, by the United States Coast and Geodetic Survey and by the United States Lake Survey. All of the available data were tabulated by Klotz in 1909[81]; it was a sort of "cleaning up" of the cupboards before embarking on the magnetic programme of the new Observatory.

We should perhaps elaborate on the difference in function between a magnetic observatory, such as that at Toronto or Agincourt, and magnetic surveys such as those conducted by the Dominion Observatory from its earliest days. The magnetic observatory operates magnetographs which provide a continuous record of the variations in the strength, H, of the horizontal component of the earth's field, its declination, D, and its inclination, I. It also maintains instruments for determining the absolute values of these quantities, and tabulates changes on them over the years.

In making magnetic surveys the aim is to determine the values of H, D and I, or of some of them, over a broad area of the earth's surface. Since the magnetic field changes slowly with time the readings must all be reduced to the same "epoch" before a magnetic chart can be published. This can only be done by reference to the continuous observatory records. The instruments used in the field surveys must also be checked against the observatory standards at the beginning and end of each field season.

In 1907 "the observatory began systematic observations for terrestrial magnetism" and the report on this work[82] contains a detailed description of the instruments used, and the method of observation.

The system was manufactured by Tesdorpf of Stuttgart and had been used widely in Germany and on the German South Polar Expedition where it was used at sea, at headquarters for absolute measurements and on sled excursions inland. It consisted of a theodolite for the measurement of horizontal angles, a "declinatorium" with both pivot and fibre suspension, a dip circle, and a magnetometer for measuring horizontal intensity. The dip circle of the Tesdorpf system was found to be unsatisfactory at Canadian magnetic latitudes and, beginning in 1908, a Dover dip circle was used instead.

The 1907 field season was carried out by George White-Fraser, D.T.S., assisted by J.W. Menzies. They occupied 32 stations, some of them at points previously occupied by officers of the Carnegie Institution, and of course tied into Agincourt at the beginning and end of the season. The stations ranged from Sydney, Nova Scotia, to Chapleau, Ontario.[82]

The observer in 1908 was C.A. French and he occupied 21 stations, mostly in British Columbia. The results, as well as the 1907 observations of White-Fraser, are included in Klotz' summary paper already mentioned.[81] This paper also speaks of a problem which was a continuing one in making field observations. There is a diurnal variation in the magnetic field which reaches an eastern maximum in the early morning, a western maximum shortly after noon. What is the true value of the declination? By observing at 15 minute intervals around each of these maxima, or "elongations" their precise value could be determined; their mean was taken as the true value.

The year 1908 was notable for the construction on the Observatory grounds of a magnetic hut 10 x 15 feet, complete with cedar pillars for mounting the instruments. Tests were run to ensure that the electric cars, which at their closest point were 455 m distant, did not influence the instruments. The station was equipped with absolute instruments and, thereafter, field instruments were checked at this Ottawa base, as well as in Agincourt, at the beginning and end of each field season, and other parties principally from the Carnegie Institution, used it also. It never replaced Agincourt as a primary base.

In mid-May, 1909[83] Klotz went to Quebec City and arranged for the charter of a yacht, the *St. Valier*, Captain DesLauriers, to be used in a magnetic survey of the north shore of the St. Lawrence. The observers were C.A. French and J.W. Menzies, and they occupied 33 stations between Quebec and Blanc-Sablon on the strait of Belle Isle.[84]

During the 1910 season French and Menzies operated separately: "French occupied 48 stations along the line of the Canadian Pacific railway between Chapleau and Moose Jaw, a distance of 1200 miles, giving an average distance between stations of about 25 miles"; "Menzies occupied 44 stations distributed in western Ontario between Napanee and Windsor, with intervals approximately 25 miles also." French used the Tesdorph magnetometer and a Kew dip circle, Menzies a Cooke magnetometer and a Kew dip circle. It is interesting that, when observing in southern Ontario, Menzies did not observe the "elongations" of declination. Instead he made two observations at noted times; these were later corrected for daily variation on the basis of Agincourt data.

In their report on the 1910 work French and Menzies include for the first time a table showing secular variation for a number of points for the period 1906-1910.[85]

The earth was to pass through the tail of Halley's comet at 9 p.m. on May 18, 1910. The diary reports:[86] "On the strength of this information I had instructed my magnetic observer in the field (north of Lake Superior on the railway) to begin observing early in the evening for differential declination and continue same till after midnight. ... Similarly with my observer who is still here (not having gone to the field) while I myself intend to observe in my room at the observatory simply with a 7-inch compass. The other two had magnetometers".

There were no effects observed, beyond normal fluctuations of the needles. This was something of a surprise. "In the United States all sorts of electrical and magnetic disturbances were considered possible and likely so that official instruction had been given to Government vessels for compass readings, wireless stations etc. to be on the lookout. From our experience there will be much disappointment".

Beginning in 1910, and continuing through 1918, with the exception of 1917 when no field work was done, magnetic results were published in the Journal of the Royal Astronomical Society of Canada. Except for 1911 this was not a duplication. After the series "Reports of the Chief Astronomer" ceased publication in 1911, no magnetic results were published in the successor "Publications of the Dominion Observatory" until 1921 when we find " Magnetic Results, 1907-1920" by C.A. French, B.A.[88]

The Journal report for 1915 includes an intercomparison of the various magnetic instruments used, with each other, and with standard instruments at Agincourt and at the Carnegie Institution in Washington.

The field work for 1911-1918 described in the Journal, may be briefly summarized:

1911	58 stations	Winnipeg to Rocky Mountains	C.A. French
1912	60 stations	Quebec, New Brunswick and Nova Scotia	C.A. French
1913	53 stations	Quebec, Ontario, Alberta and British Columbia	C.A. French
1914	37 stations	Northern Ontario	C.A. French
1915	48 stations	Alberta and British Columbia	C.A. French
1916	55 stations	Northern Ontario	C.A. French
1918	37 stations	Re-occupation of stations	C.A. French

This re-occupation of stations was to permit an analysis of the secular variation, leading, in the 1921 paper,[88] to the reduction of all observations to the 1921.0 epoch. In the meantime, beginning in 1910, some repeat observations had been made, and the results published.

An event of lasting importance for magnetic work was announced in the Journal in 1916.[89] This was the establishment, in connection with the second International Polar Year, of the magnetic observatory at Meanook, Alberta, "for the purpose of securing photographic records of the changes in Declination or variation of the compass".

Seismology

This was a geophysical discipline in which Klotz had had no personal experience before the establishment of the Observatory but he had had a consistent interest in it for many years and it became his principal scientific field. In March, 1900,[92] he arranged for R.F. Stupart of the Meteorological Observatory, Toronto, [the Meteorological Service had acquired Milne seismographs for Victoria and Toronto as part of the world network set up by the British Association for the Advancement of Science] to give an evening "lecture in the Normal School on 'Earthquakes and the Seismograph'. The audience was small, theatres, a sparring match and other entertainments being more attractive to the large majority of our citizens, even though our lecture was free." On various other occasions[93] he profited by meetings with Stupart, or his assistant Dennison, to "talk seismograms".

In January, 1902,[94] "King again in my room discussing seismograph &c which we intend purchasing." He does not mention the selection or purchase of any instruments, but the Bosch-Omori seismographs arrived late in 1905 and were installed during the first weeks of 1906. They absorbed Klotz' time and attention.[95] "My reading is for the present concentrated on Earthquakes as the new Seismograph (two horizontal pendulums, one E&W, the other N&S) has been placed in my charge".

The seismographs were installed in what, for years, was known as the "Bosch room" made by blocking off the west corridor in the basement (see the figure on p. 26) with a brick wall at the western end and double walls, making a vestibule to provide a light trap and cut down on air currents, at the entrance. There were two piers, approximately 4 m apart, the one holding the two seismometers, the other the recorder. Recording was photographic, paper speed 15 mm per minute. The seismometers were conventional horizontal pendulums with periods of approximately 6 seconds; air damping was originally supplied, oil damping was temporarily tried in 1908, without giving satisfaction, and magnetic damping was installed in 1911.

The seismographs and recording room are described in detail in the Report of the Chief Astronomer for 1906[96]; there is a floor-plan of the room and photographs of the instruments.

The first earthquake recorded was on January 25, 1906. The diary reports:[97] "Today's papers report an earthquake in Antigua yesterday at about 1:30 a.m. which would be 3:30 here, standard time, so that my record yesterday is undoubtedly from that source, giving about 20 minutes for transmission - or at the rate of 100 miles a minute. This is the first located earthquake that I have had recorded here since I set up the instrument recently."

This was the first earthquake, but the gem was still to come. On April 18 he reports:[98] "When the seismogram was developed this morning and brought to me, I saw that a violent earthquake had taken place this morning. Word came from the city that despatches announced an earthquake from Mexico, which I doubted or disbelieved as my record showed a far greater motion of the pendulum oscillating east and west, than of the one North and South. Then came the word of a great earthquake in San Francisco (California) as having occurred at 5:13 a.m., this would be 8:13 a.m. our standard time. The first tremors were recorded here at 8-19-13, they rapidly increased in magnitude so that at 8:30 the oscillations were so violent that the light spot did not have time to record (photographically) save at the turning point, i.e. extreme of amplitude where short streaks or spots were visible. This continued for 10 minutes - till 8:40, when the amplitude lessened and the whole amplitude was recorded (photographed). I took off the sheet as usual about 10:00 a.m. to replace by another, and oscillations or tremblings were still going on. - I had a beautiful record and had the time of the record sent to our city papers. - The catastrophe in San Francisco seems to be enormous, the greater part of the city being wrecked or in flames.

After office brought the seismogram with me to show to the Deputy - Mr. Cory - and some friends whom I met."

While these earthquakes fascinated Klotz, his interest was much deeper. There were many disturbances on the records apparently not associated with earthquakes, and he turned his attention to the most obvious of these, the slow drift of the pendulum and the periodic disturbances known even then as microseisms. In his report for 1907,[99] he discusses these phenomena and actually tabulates the drift of his two horizontal pendulums, and the apparent tilt of the pier, daily for the months of March, through June, 1907. He attempts to show a relationship to steep atmospheric pressure gradients, but finds the results inconclusive.

Klotz was apparently working without an assistant in these early days, at least as far as seismology was concerned; his diary reports trips to the Observatory on Sundays and on departmental holidays "to attend to the seismograph". It is not until May, 1912[100] that he is able to report that his "assistant", Mr. R.C. McCully, for the first time looks after the seismographs on a Sunday." By that time a new seismograph had been added (March, 1912), a Spinder and Hoyer vertical, of 80 kg mass. This was installed in the room to the south of the "Bosch" room, which had originally housed the carpentry shop.

From the beginning, Klotz was fascinated by his seismographs, like a child with a new toy. "My seismograms showed a beautiful earthquake - if a scientist may so speak"[101]. On January 4, 1911[102] he located an earthquake in Persia; all American seismologists had placed it in South America. Press reports confirmed its position in Turkestan. "Score one for Ottawa".

His interest was not casual however. He read everything he could get his hands on about seismology and in his frequent trips, around the United States and to Europe, he lost no opportunity to meet seismologists and "talk seismology". What he learned was committed to paper. In the report for 1906,[96] he writes at length on earthquakes and on the science of seismology. In the 1910 Report[103] there is a comprehensive discussion of the theory of the seismographs.

Microseisms continued to interest him. He recognized their association with meteorological conditions and he listed[104] possible causes: "secular cooling of the earth; unequal heating and radiation during the day and night; statical effect of atmospheric pressure, areal or local; dynamical effect of atmospheric pressure, areal or local; precipitation, as of rain or snow." Most of these he dismisses in a single paragraph, leaving only the effects of atmospheric pressure. To study this he arranged to receive the daily weather maps, which gave the isobars at 8:00 a.m. for Canada and the United States, between latitudes 25° and 55°, and between the Atlantic and Pacific Oceans. By comparing microseismic activity with the barometric pattern he tentatively concluded that "the presence of a Low over the Gulf [of St. Lawrence] surrounded by steep or fairly steep gradients on a given morning is indicative of more or less well-marked microseisms following at Ottawa that day."[104]

He was not satisfied with this conclusion because it suggested no mechanism and because, in discarding such possible sources as wind, precipitation, variable insolation, etc., he had not had the benefit of adequate records. He took steps promptly to correct the latter deficiency. In 1907, during a trip to England, he visited the Meteorological offices in Kew and instrument manufacturers in London, and by mid-1908 he had already installed a microbaragraph, a thermograph and a "Statoscope", a French instrument which seems to have been a very sensitive microbarograph. By 1911 an anemograph had been added, with the sensing element on a tower on the roof, the recorder in Klotz' office. He published a detailed description of this latter instrument.[105]

These instruments very rapidly confirmed that there was no relationship between the microseisms and local meteorological conditions. The instruments continued in operation up until the early 1930s, and readings were routinely tabulated, but no use seems to have been made of them.

In his 1909 Report[106] Klotz outlines additional studies on the relationship between meteorological conditions and microseismic level and also on studies of mareograms recorded by the Tidal Survey on St. Paul Island, a small rocky island in Cabot Strait. These showed a secondary oscillation superposed on the regular tidal movement, but the period averaged about 4.6 minutes and there was no obvious correlation with Ottawa microseisms. He then studied mareograms from Trepassey, near Cape Race, Newfoundland, and found that the secondary oscillations here had an average period of 67.6 minutes! He had to conclude that the period of secondary oscillations was controlled by conditions local to the stations and that there was no relationship between these oscillations and Ottawa microseisms.[106]

As a result of this study he reports: "After these various examinations we arrive at the following conclusions: -

(1) Microseisms are essentially due to meteorological phenomena, that is, to barometric pressure and the accompanying gradient.

(2) The amplitude of microseims is largely a function of the steepness of the barometric gradient.

(3) Areas of low barometer with steep gradients, but west of Ottawa, have little effect in producing microseisms.

(4) Strong microseisms are almost invariably accompanied by steep gradients in the gulf, with the St. Lawrence valley, containing the Great Champlain fault, on a line of steep gradients.

(5) A well-marked low sweeping up the Atlantic coast from Florida to Newfoundland is almost invariably accompanied by marked microseisms.

(6) Microseisms are but slightly, if at all, influenced by the movements of Lows across the continent.

(7) Microseisms are not produced by local winds, frictional excitation of the earth's surface.

(8) Microseisms represent movements in vast blocks of the earth's crust, covering tens of thousands of square miles; and the period is possibly dependent on or modified by marked geological configuration and depth.

(9) Microseisms once produced may continue for a day or two when the immediate cause has passed."

Not a bad set of conclusions for 1909!

There still remained the question of how the "lows" with their steep gradients set up the microseisms. One possibility was that they caused waves which, striking on rocky shores, set the earth into vibration. This theory had many adherents, especially in Europe. At the 1909 meeting of the International Seismological Association, held in Zermatt, Switzerland, it was decided to have an instrument designed which, mounted on the seashore, would count the waves and so determine their period "so that the relationship between the latter and microseisms may be studied." The instrument was to be built by the Cambridge Scientific Instrument Company.[105]

The instrument was constructed and installed for testing at the end of the pier at Tynemouth. It gave satisfactory results, indicating a wave period of 4 to 7 seconds, well within the microseismic range, but critics questioned the North Sea location of the test. For conclusive results, they should have been made in the Atlantic, off the west coast of Norway or of Ireland. "However practical difficulties stood in the way for [so] mounting it."

Klotz determined to test it on his side of the Atlantic. An instrument, with some improvements over the prototype, was ordered in 1911 and by August, 1912, Klotz had selected a site for it at the Chebucto Head lighthouse, near Halifax, and had arranged for the lighthouse keeper to service the instrument. The instrument was installed about a year later.[107] "The instrument is 120 ft. above sea-level on the granite cliff on which stands the lighthouse. The coast hereabouts is bold and rocky. A galvanized iron pipe 625 ft. long extends from the instrument over and down the rocks into the sea. The sea-end is a 4-inch pipe, while the greater part is 1/2 inch, with short sections of 2 and 1-inch pipes between. Each wave passing over the open end causes the water to rise in the pipe, compress the air beyond, whereby the leather diaphragm is raised and electric contact made. Two dry cells give the necessary current. A small electro-magnet of a few ohms resistance actuates the armature, an arm upon which pushes a ratchet wheel one tooth ahead at every contact. This wheel has 120 teeth, and on its axis is a spiral cam with a slot. Against the cam rests the arm of the recording pen, so that as the cam revolves the arm is slowly moved latterly until at a complete revolution of the cam, that is, of 120 recorded waves, the arm falls back to zero. On the recording tape, which is 1 1/2 inches wide, two pens record; the one for the waves, the other the time-scale given by a half-seconds pendulum clock within the case. The clock records every hour at intervals on the tape of 6 cm."

No published results from the undagraph appear to exist. It was still in operation in 1915 for his Diary[108] reports that it needs a longer pipe; its opening is sometimes out of water. It did have one personal result. In 1914, when Klotz was rumoured to be a German spy, the undagraph was described as a device for communicating with U-boats!

Another instrument proposed by the International Seismological Association caused Klotz a lot of trouble. At the Manchester meetings in July, 1911 Hecker described his observations of the deformation of the earth under the influence of the moon and sun. He reported that they leave an unexplained residual, a compression North and South greater than East and West. Love suggested the tidal influence of the Atlantic and, to test this, Hecker proposed setting up "several stations - Paris, Winnipeg, a station in the Russian empire and one in southern Africa for observing for two years the deformation of the Earth under the influence of the moon".[109]

Klotz discussed this proposed programme with King who, by late October, 1911, had obtained the approval of the Deputy Minister.[110] The next day Klotz set out for Winnipeg, where he selected a site in the cellar of the Agricultural College. They estimated the cost of the recording building at between $250 and $300. Construction was to be supervised by the Provincial Department of Public Works, the cost to be borne by Ottawa. Nine months later[111] the site is described as the Normal School, rather than the Agricultural College, and the contractor's estimate was $2,307 if the room was in the existing basement, $1,919 if a new vault was built outside the building. Tenders were let.

A little more than a year later[112] Klotz was back in Winnipeg and found the vault completed but flooded waist-deep with water "I fear that I shall have to abandon mounting the instruments in this vault, it is beyond redemption". Some frustration with the whole project was beginning to creep in.[113] "I don't know what possessed Professor O. Hecker when he sent me the design for the vault to make such narrow stairs. It is with difficulty that I squeeze myself down after taking off my coat."

Klotz proposed to abandon the Winnipeg site and install the deformation instruments in Ottawa "if it be accepted by Dr. Hecker".[114] Although Ottawa was not in the centre of the continent the new location would give "the assurance that the instruments would be in competent hands which I now, having seen the instructions of the apparatus" regard as very important. King and the Minister agreed to the switch. The decision had important implications because it led to the construction of the vaults which served until the early 1960s.

A proper vault would have to be built. By November, 1913[115] "Mr. Thorpe of the Public Works, is busy getting out a plan for the underground vault or room for installing the instrument"; a week later[116] he saw the Minister "about building the two vaults at the Observatory". No mention is made of the justification for the second vault but it seemed assured. In mid-December he reports[117] "My vaults at the Observatory are now in a fair way of being built. The architect is getting out the specifications, a condition being that they must be finished before the close of the fiscal year March 31 next as we are using money appropriated for other purposes which would otherwise lapse. It is a matter of about $12, 000."

By early February, 1914,[118] he reports "A start has been made at the Observatory of my seismograph vaults. It is being done by day-work by the Government as the contractors had made too high estimates, over $20,000. Although there is a general complaint of want of work, and of many men being idle, yet the clerk of work tells me that it is difficult to get men - who want to work - four came out to the Observatory, looked at the snow and walked off again!! They deserve to starve."

They didn't make the deadline of the close of the fiscal year. As it approached he reports[119] "My northwest vault is giving much trouble as springs have been struck and we are rather in a quandary what to do, altho' we have dug a drain with a 9" pipe. The question is how to build an isolated pier and prevent the water - if accident to drain arises - from getting into the vault." Presumably since the Department of Public Works was handling the construction by day-work, costs incurred up until the end of the month could be paid immediately and the lapse of funds so minimised.

Almost a year later the vaults had still not been occupied.[120] "Today I found that water got into my vault at Observatory, apparently at the junction of the outer wall with vault. It seems as if I am not going to get the 'deformation of the Earth' instruments set up. I have them from Strassbourg since the summer of 1913!!"

Don't despair. On April 21, 1915 he reports[121] "At last the vault is fairly dry and the temperature outside sufficiently moderated that I have the three large cases unpacked containing the instruments for measuring the deformation of the Earth by the Moon. Mr. Hodgson, my assistant, and I began mounting the same. They are wholly new to me, but I expect to encounter no difficulties, except perhaps in the adjustment of the pendulums, which are light affairs and of the Zollner type of suspension."

No difficulties indeed! On July 15:[122] "Mr. Hodgson, my assistant, and I are busy with the deformation instrument. With a new instrument one is apt to be a little awkward and Hodgson managed to tear down both pendulums breaking all four suspension wires! Keep cool, we put in new ones."

They did keep cool, and they did apparently get the instrument into operation within the next few days, but Klotz never mentions it again. It was such an unstable instrument that it never produced useful records. It did respond to earthquakes but, since its paper speed was only 17 mm per hour, the records were of little use. However, they had their vaults. The deformation instruments and their vault are described by Hodgson in the Publications of the Dominion Observatory[123].

With regard to staffing, we have already seen (p. 56) that R.C. McCully joined the Seismological section in 1912. We learn from publication acknowledgements in 1912, 1913 and 1914 that he was still present. However there must have been some dissatisfaction on one side or the other for in April, 1914, the Diary reports:[124] "Early in the evening Mr. J.E. Ratz called to give me his answer whether he would accept the appointment of assistant in Seismology provided I could get the Minister's approval thereto and an initial salary of $1,600 in the Inside Service. On questioning him about his inclination for research he said he didn't know what his bent was." He didn't take the job; as J.E.R. Ross he went on to become Director of the Geodetic Survey of Canada. Credit for the epicentre locations during the latter half of 1914 was given to E.A. Hodgson, marking the beginning of his long service. W.W. Doxsee appears in 1920.

A number of local earthquakes were reported in the Diary, a slight one on June 16, 1908,[125] another on December 10, 1909.[126]. On April 28, 1913,[127] there was a much larger one. "Tonight at half-past 7 there was a distinct earthquake which I felt while reading. Marie [Mrs. Klotz] was walking about and did not notice it. Soon afterwards my phone kept ringing, being enquiries about the quake."

This earthquake was centred near Iroquois. Klotz made extensive field studies of the damage and prepared a report.[128]

A stronger local earthquake occurred on February 10, 1914.[129] "While sitting in my chair reading after luncheon, I heard a rustling in the room above me that I took at first to be the rolling of a desk but the next moment it increased in noise as if a heavy safe was being rolled along above me, shaking the glass book cases in my room, they making however decidedly less noise than overhead on the floor apparently of the upper room. It was an earthquake. In a moment the staff gathered from all parts of the building in the lower corridor to compare sensations experienced. I went down stairs and saw a nice record on the vertical so I had the record of it (smoked paper) taken off and fixed; also the photo. record of the two horizontal seismographs and had them developed. Then the telephone began to ring and enquiries poured in for the next three hours from all parts of the city and outside, as far as Montreal. Of course nearly every one wanted to know a great deal more than I could answer at the time. ... About 5 p.m. the A.D.C. of his Royal Highness the Duke of Connaught called me up ... to obtain details for the Duke, which I got together with a brief explanation of earthquakes."

No field investigation of this earthquake was attempted but a questionnaire survey was carried out. The results of this survey, along with the readings from Ottawa and Harvard, placed the epicentre a few miles north and west of Ste. Agathe.[130]

Klotz was aware of the possibility of recording blasting. In 1900 when the dam was built across the Chaudiere falls he arranged to have the time of the larger blasts noted. None of them recorded on the seismograph. The seismogram "failed to reveal the slightest trace. If there was any it was masked by the very small microseisms that were present on that day. Beside the presence of the minute microseismics two other causes militated against obtaining a record; one, the lack of compactness of the rock over that distance, and the other the very rapid oscillations that would be set up to which the seismograph could not well respond."[131] Another large blast was noted in the Diary.[132] A quantity of dynamite, used in the quarry of a cement plant in Hull, exploded on May, 1910. It produced an air wave on the barograph but no ground wave on the seismographs.

In the Report of the Chief Astronomer for 1909, Klotz includes a section on Canadian Earthquakes.[133] He mentions the earthquakes of 1663, 1791, 1860 and 1870 and tabulates local earthquakes for 1908 and 1909. The account of the 1663 earthquake given in the Jesuit Relations is reproduced, in translation. Klotz is not much impressed: "the narrators of the above anticipated the sensationalism of our 'yellow' journals, by two and a half centuries." Some years earlier he had stated in his diary: "In forenoon at the Parliamentary Library copying Jesuit Relations re the great earthquake of Feb. 5, 1663. The descriptions thereof are nearly all wild, exaggerated and visionary."[134]

Almost from the beginning Klotz had proposed a network of seismograph stations across Canada. Early in 1907 the Diary reports that he and King had had a discussion of their plans for Geophysics.[135] "I outlined to him my idea of where we should install seismometers - say Edmonton, Winnipeg, Sault Ste. Marie, Eboullement (lower Quebec), Fredericton, Halifax, and possibly at Château Bay or St. John's, Newfoundland." Nothing seems to have developed, but Klotz didn't give up. On July 20, 1912 he announces that King agrees that they should install seismograph stations at Halifax, Edmonton, Winnipeg and Vancouver, and that Klotz should visit the universities there to arrange for the stations.[136]

Klotz set off promptly on this mission. By August 2, he was in Victoria, where the Meteorological Service was planning to build a new observatory and to install a new seismograph in it. Klotz asked Napier Dennison, the meteorologist in charge, what type of instrument was planned.[137] "He could not tell me ... Stupart hadn't told him. When I asked if it wouldn't be a Wiechert, he said 'those are discarded now'." Klotz had installed a Wiechert at Ottawa a few months earlier. "I said nothing, no use wasting words on the fellow.".

It was all very well to dismiss "the fellow" so airily, but the Meteorological Service did provide a stumbing block to Klotz' plans. They operated seismographs at Toronto and Victoria which predated that at Ottawa by several years, the Director of the Service, R.F. (later Sir R.F.) Stupart was at least as ambitious for the Meteorological Services as Klotz was for the Observatory, and Dennison and Stupart had influence with the British Columbia Premier, Sir Richard McBride. He put pressure on *their* minister, Rogers, for "assistance in having a good seismological station erected at Victoria".[138] Klotz comments: "Stupart is not a scientist in the true sense of the word. The time-service and earthquakes should be under our control, but here is the difficulty, we belong to two different departments, and it would be difficult to get an officer of the Marine Dep't to report to us - I said to King that the general good should be consulted and petty departmental jealousies disregarded. I would make the officer who is to attend to the time-service and seismograph an officer of our department, even if his instruments are housed in the prospective building for the Meteorological Service."

However Klotz pressed on with his search. In Vancouver he was taken for a drive "going along the beautiful Marine Drive around Point Grey, where a clearing is being made for the Provincial University, a site I quietly eyed for a possible Observatory, magnetic and seismograph station, for the latter two the site is adapted, but less so for the first. There is higher ground available that lies above many of the fogs that at times prevail."[139]

From Victoria he went to Edmonton. He arranged to be driven to the University and to talk to its President. "Dr. Tory is a comparatively young man, and energetic. When I told him of my mission - that of possibly offering the university a seismograph, provided they would attend to it for us daily and properly, he readily consented, and said Professor Sheldon - professor of mathematics - would be glad to look after it."[140]

No attempt was made to arrange for a station at Winnipeg, they were still arranging facilities for the deformation instrument, but in Halifax[141] he "visits Dr. Stanley Mackenzie, President of Dalhousie University and chatted with him. He readily consented to have a seismograph looked after, if we placed or rather gave them one." Later in the day he met Professor Bronson, of the Department of Physics. "Professor Bronson is a young American and may be clever but lacks polish of manner and speech." I find this very amusing. When I went to Halifax in 1952 to arrange for the establishment of a new, standard, station, it was with Professor Emeritus Bronson that I dealt; he was a gracious and charming gentleman who lacked nothing of polish in either manners or speech.

A year later the contest with the Meteorological Service was still active. Klotz, in Toronto, called on Director Stupart.[142] "On enquiry I learned that the government is building a new meteorological station at Vancouver [sic; he really means Victoria] near the wireless station...and that he intends installing a photographic seismograph like ours. ... Dr. King and I wanted to corral the seismograph work at Victoria, also any astronomic work - time work - that Stupart was going to have done, it was to be under my supervision, but Stupart didn't enter into this idea. - I don't blame him."

In September, 1913,[143] he visited the site of the proposed University of Calgary, where he hoped to put a seismograph. There were, however, no buildings yet constructed.

Arrangements with Dalhousie University went satisfactorily. By July, 1915,[144] the recording room was ready and Klotz went to Halifax to inspect his undagraph and install the new seismograph. "I found the Mainka seismograph I shipped there, unpacked of course. Unfortunately the pier therefore they had built 30" high, instead of flush with the ground, and furthermore the electric lights are not yet installed ... so that I am unable to proceed with setting up the seismograph."

The diary makes no further mention of arrangements with Edmonton, but in August, 1915 [145] he was in Saskatoon where he "proceeded to the University ... and found that the pier for the seismograph was built and the instruments unpacked, which was so far very satisfactory to me. I met the president Dr. Murray too". The next day "both forenoon and afternoon I spent at the University with Professor Hogg and the seismograph, going over the detailed description of mounting with him, besides giving him information and pointers about reading seismograms and their interpretation - a practical lecture on Seismology, so that he felt confident in going ahead with the mounting." The instrument, as in Halifax, was a Mainka.

Klotz was very much research oriented. We have already seen his work on microseisms, but there were many other problems that took his fancy. In 1907[146] he obtained access to some sort of mechanical device which permitted the harmonic analysis of waves and attempted to use this to decipher the components in the long waves in some of his seismograms.

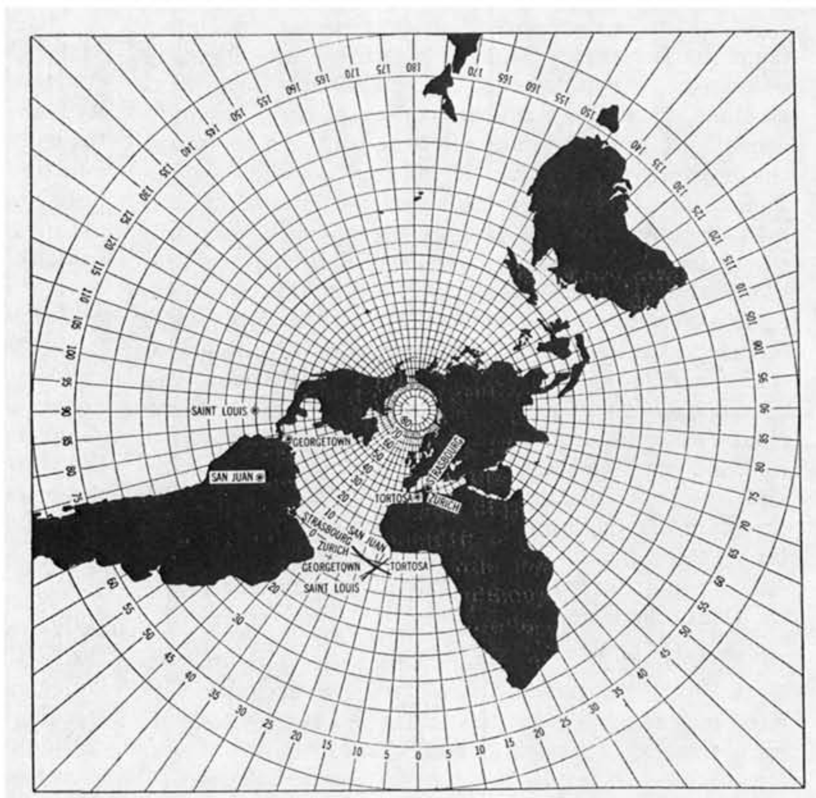
A study of more practical importance developed from his interest in locating epicentres. Having determined the distance to the epicentre from several stations, from the time differences of the "first and second preliminary phases", how was one to locate the epicentre? Initially he marked off arcs on his globe and so found the intersections. However this was clumsy and left no permanent record. He recognized that the circles he was drawing on the globe would, in the stereographic projection, plot as circles on a map. He produced a set of tables giving, for each of the principal seismograph stations of the world and for a range of epicentral distances, the distance d of the centre of the projected circle and the radius r of that circle. The method was first proposed in the Report of the Chief Astronomer for 1910,[147] and was presented in more detail in the Journal of the Royal Astronomical Society of Canada;[148] the tables were first published in the same Journal,[149] and in a slightly expanded form in the Publications of the Dominion Observatory,[150].

The Diary has an interesting sidelight on this work.[151] "The worst slip or error I ever found Dr. King make in mathematics and it is not easy to trip him he made yesterday. About a week ago I told him I was going to apply the stereographic method of projection for locating earthquakes from three stations. He remarked that a small circle would be projected as an ellipse. I said as a circle, and it ended there. Yesterday morning when I was with him speaking about some earthquake problem he again said that the small circle is projected as an ellipse and that he had computed the two axes and the eccentricity; I quietly said - into a circle, and went out. I immediately sat down and wrote out the proof for the circle, took it to his room, laid it on his table and walked out. Half an hour or so later the messenger brought me an envelope, on opening it I found that on the back of my sheet (proof) he had written - starting with 'Reductio ad absurdum' and followed by what he thought was a *crushing* (for he was in that humour to smash Klotz) proof of my error. At noon we had luncheon together. He broached the subject, by saying I make unwarranted assumptions about the similarity of two triangles. ... Having no paper in my pocket I took a plate and made a diagram and showed him the point. 'I don't know that that is true' he said. After luncheon as usual we sat together in his room for a short time. He immediately began figuring still holding to his notion about the ellipse. At last he said 'Klotz, you are right'. 'Thank you' my only remark and I led the conversation to something else. It is the worst pill he has had to swallow in any mathematical controversy with me, for King is in general a better mathematician than I am. I have filed his 'proof' of 'reductio ad absurdum' in my precious archives."

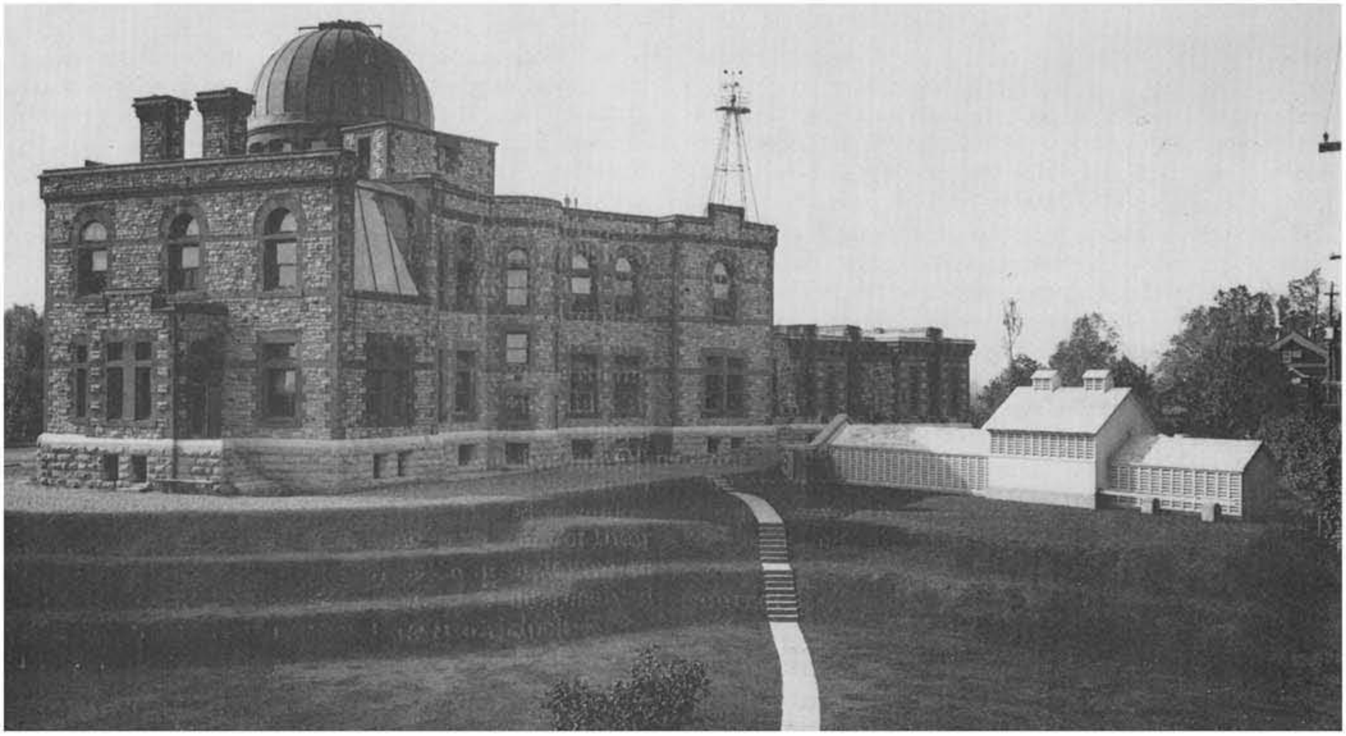
Klotz had published initial tables of travel-times in 1911,[152] but in 1916 a much more extensive compilation was issued in the Publications. [153] This was a "compilation or collection of seismological tables useful to the working seismologist". In addition to his Stereographic Projection Tables, here published for the third time although with some extensions, it contained the P tables of Mohorovicic, tables of PP-P and PPP-P derived from them; the S-P tables of Wiechert and Zoppritz; tables of S, SS-S and SSS-S derived from them; and tables of PS-P derived from the P and S tables; tables of L-P, L-S and L of his own devising; a table due to Zoppritz and Geiger giving the angle of emergence of the P-wave in terms of epicentral distances; a table giving the length of the chord and its depth of penetration corresponding to various arc distances. A set of travel-time curves were included.

The tables apparently represented the first complete compilation of existing data and they were well received. A laudatory review was published in the Bulletin of the Seismological Association of America[154] and was reprinted in the Journal of the Royal Astronomical Society of Canada.[155] Undoubtedly Klotz had a hand in bringing it to the attention of a Canadian audience.

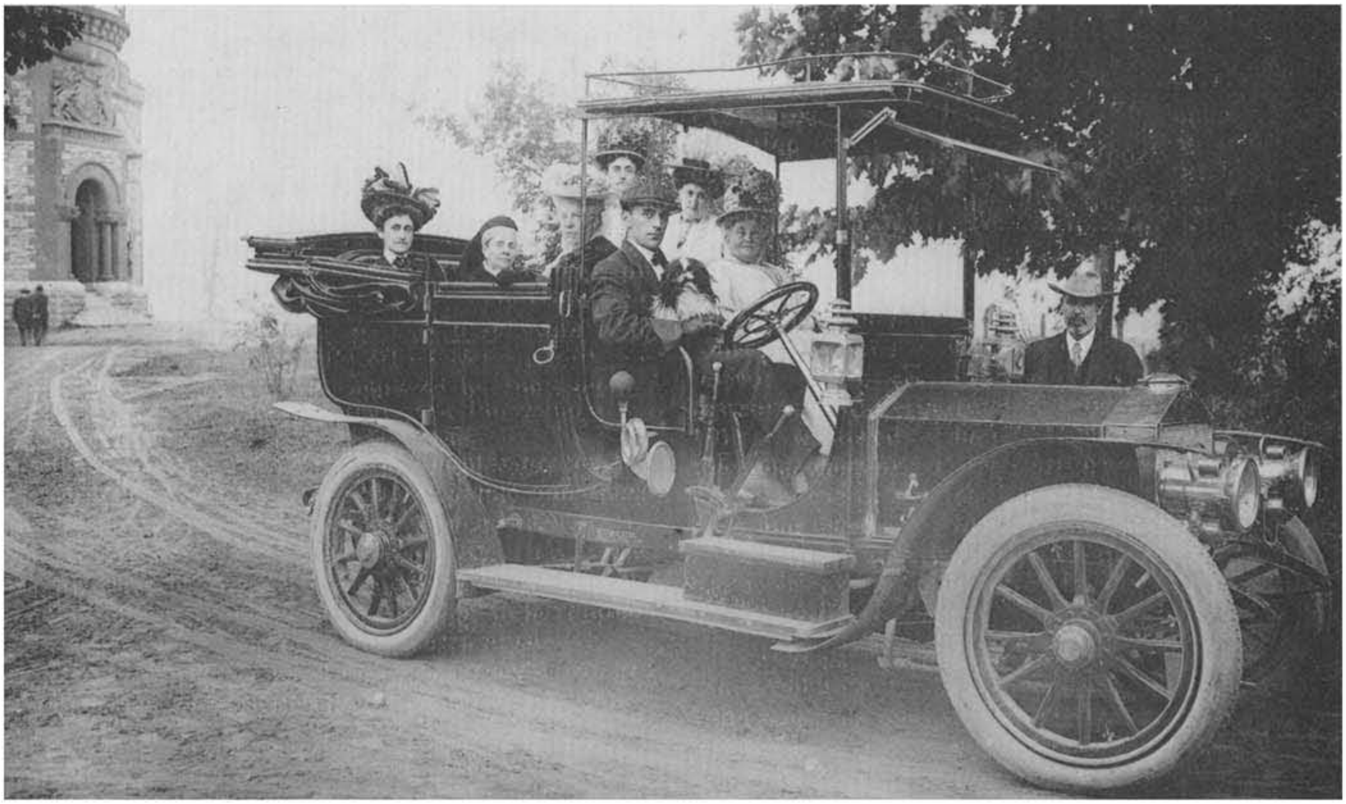
(Above) Observatory House.



(Right) The use of the stereographic projection to locate an earthquake on the Mid-Atlantic ridge.



Rear view of the Observatory, showing the glass north wall of the photograph studio, the anemograph tower, and the solar telescope. Note the steep drop-off of the terraces.



Lady Laurier and friends visit the observatory.

Klotz was brought to the stereographic projection and to his Tables, by his interest in epicentres. From the beginning he tried to get as much information from his records as possible. At the start he seemed to have some difficulty distinguishing earthquakes from microseisms (which he called earth tremors) and he contented himself with listing observed phases and giving rather chatty descriptions of the recordings.[156] In the same report he begins his study of microseisms, listing their periods of occurrence and attempting to correlate them with meteorological observations.[157] In 1909[158] he listed the seismological observations in bulletin form, giving arrival times, periods and amplitudes for P, S and L. He also, for the two largest earthquakes, whose epicentres in Messina and Bahrein were established by the damage done, tabulated observations for a number of stations and computed the velocity of P, S, and L in km/min., taking the chord as the distance for P & S, and using the arc distance for L. He also tabulated, for each station, the velocity ratios of S/P, finding it to be nearly constant. However, despite having so many observations, he makes no attempt to relocate the epicentre from teleseismic data. His investigation of microseisms continued.

The report for 1910[159] continues the "bulletin" format and introduces his work on the stereographic projection. In the 1911 Report he publishes his Tables[160] but gives his observations in "bulletin" form without any attempt to determine epicentres.

Paralleling the information in the Reports of the Chief Astronomer are notes given from time to time in the Journal of the Royal Astronomical Society of Canada in a section published with reasonable regularity under the title "Notes from the Dominion Observatory". Initially the remarks about earthquakes were chatty and descriptive rather than scientific, but by 1909 there was an obvious effort to meet the threat posed by the Meteorological Service. They had been publishing quarterly "Summaries of Weather in Canada," in which interesting earthquakes were sometimes discussed, but by 1909 each number of the Journal contained "Notes from the Meteorological Service" in which they included earthquake observations from Victoria and Toronto in bulletin form, frequently with copies of the records. The Observatory met the challenge; the listings from the Observatory became much more complete and much more professional, including estimates of distance.

In 1912 Klotz embarked on a new project, which was to be a principal effort of the Observatory for many years. The program began with the publication of the first in a series of "location" papers "Location of Epicentres for 1911".[161] His intention is clearly stated in the opening lines of the paper: "Each earthquake recorded at Ottawa, even if only some long waves (L) were recorded, was compiled with the corresponding records received here from many other stations, and if the data were sufficient, a graphical determination (stereographic method as described heretofore) of the epicentre was attempted". This programme was continued until 1920, the papers appearing annually in the Journal, under Klotz' name until 1915[162], and under Hodgson's for 1916.[163] From that point the publication of epicentre was transferred to Publications of the Dominion Observatory; the epicentres for 1917-1918 were published by Hodgson[164] and those for 1919, by W.W. Doxsee.[165] The programme was continued until 1927, although the results seem not to have been published beyond 1919. It was stopped at that time because of the activities of Turner at Oxford, which shortly led to the establishment of the International Seismological Summary.[166]

The contest between "Notes from the Dominion Observatory" and "Notes from the Meteorological Service", if it really existed, ceased once the annual publication of epicentres started. The Observatory contributions were almost entirely confined to Astrophysics and were increasingly of the form we would now call "Letters to the Editor" or "Short Notes".

SURVEYING

In the introductory chapter we saw that it was the need for tying surveys to astronomically fixed positions which led to the establishment of the Observatory. While many other responsibilities were soon added, this primary one to surveying was not lost track of. Establishment of the latitude and longitude of selected points continued to be a primary responsibility until 1923. From the beginning, however, the much more important requirement for a trigonometric survey had occupied the attention of the founders.

Klotz gives a capsule history of the developments in his diary some two months after the new Observatory had been occupied.[167] "King and I come into town early. We discuss the season's work and the proposed initiation of a systematic trigonometric survey of Canada. This survey I have advocated steadfastly for more than twenty years. The first memorandum to the Government was prepared by me some 20 years ago and signed by myself, King and a few others - a committee of the Association of Dominion Land Surveyors. There has been some scheming by other departments and persons to get hold of the proposed survey. Professor C.H. McLeod of McGill University has made himself conspicuous thro' the Royal Society of Canada, the Militia Dept. too has had an eye on the Survey, but our late or Ex-Minister Mr. Sifton stood them off in the Cabinet, and now the work is virtually assured to us (Astronomical Branch)."

In retrospect it is a little difficult to see why the trigonometrical survey should have been placed under the Astronomical Branch rather than under the Surveyor General, since the survey was really made necessary by the failure of the astronomical methods. We may quote King on this matter.[168] "Astronomical determinations serve a useful purpose in the correction of maps, when the scale of these is not too large. For the control and checking of topographical surveys they are deficient. This is due to the fact that the astronomical and geographical co-ordinates of the same point are not necessarily, nor usually, the same. ... The irregularities of the earth, both above and beneath the surface, by their attractions, cause 'local deviations of the plumb line,' so that astronomical positions, though accurate in themselves within a few feet, may show a discrepancy in comparison with survey measurements of very considerable amounts." Thus "they cannot serve as control for topographical surveys. ... This is the function of the trigonometrical survey." The survey must have come to the Observatory because King and Klotz were there rather than to ally it to the astronomical work.

In any event King pursued the matter diligently. In June 1905 he and Charles A. Bigger, who was to become Superintendent of the Geodetic Survey of Canada, visited King Mountain and selected it as a point of the primary triangle. During that summer a reconnaissance covering 3,000 square miles in the neighbourhood of Ottawa had been completed.[169] During the next year "the work ... was confined to the selection of points and the erection of towers thereat for the angular elevations".[170] Arrangements were also made for setting up a programme of precise levelling "which is a necessary concomitant of the triangulation, so as to obtain the vertical, as well as the horizontal co-ordinates of the stations. The work continued during subsequent years, proceeding east from Ottawa, but in 1909 the establishment by Order-in-Council of the Geodetic Survey of Canada, removed the subject of trigonometric surveys from our field of interest. Dr. King added the title of Superintendent of the Geodetic Survey of Canada to his existing titles of Chief Astronomer and Boundary Commissioner but the survey organizations were essentially separate from the Observatory. In 1914 they moved into a new building, the present "Seismology building", about 200 feet north-west of the main building. With the death of Dr. King in 1916 the directorates of the two organizations become completely separate.

The fact that King Mountain was selected by King as a point in the primary triangle has led to the common belief that the mountain is named after him. This is apparently not true. J.E. Ross, the then Dominion Geodesist, visited the area in 1962 and talked about the matter to a Mr. Mulvihill, aged 70. Mr. Mulvihill stated that he had lived in the area all his life and that the mountain had always been known as King Mountain.[171]

A detailed description of the work of the Geodetic Survey, at an elementary level, is given by C.A. Bigger in the Journal of the Royal Astronomical Society of Canada.[172]

As already mentioned, the determination of astronomical positions continued to be an Observatory function until 1923. Stewart tabulated and analysed the data to the close of 1919 in the Publications.[173] By this time 174 stations had been occupied and Stewart adjusted the network by least square methods and concluded that "the probable error of a single observed difference of longitude of full weight is ± . 030 sec., which corresponds to about 30 feet in the latitude of Ottawa."

It should be noted that, of the 174 stations listed in the above publication, the longitudes of 14 were determined using radio time signals.

LIFE AT THE OBSERVATORY

From the time the Experimental Farm site was selected its distance from town had been considered a problem. As already noted, (page 14), Sifton had minimized the matter saying that it "would be remedied by the 'Improvement Commission' and the extension of the electric railway. He [also] said 'I am going to have comfortable quarters for you out there'."

In this section I propose to examine the ways in which staff members adjusted to this question of distance and of other efforts to improve the amenities of the situation.

Transportation

In fact, in 1901 when Sifton made the above remark, transportation to the Experimental Farm area was not as poor as Klotz suggested, for in April, 1896, a street car line was completed via Somerset and Wellington Streets to Holland Avenue and along Holland to the western boundary of the Experimental Farm at Carling Avenue. This destination could be reached from the downtown area via Bank and Somerset Streets, or by a line that ran along Albert Street (where it passed Klotz' house) to Preston, and along Preston to a transfer point at Somerset. To judge from the diary, Klotz normally took "the cars" to the foot of Bayswater Avenue (then Fourth Street, Hintonburgh) and walked from there to the

Observatory, a street car ride of 1 1/4 miles and a walk of less than one mile.

Sanderson[174] gives some information about this Holland line which casts interesting light on social life in Ottawa at the turn of the century.

> "While the construction of the Hintonburgh line was in the making, the farseeing gentlemen in control of the O.E.Ry. followed the example of several American roads which bolstered their business through the creation of amusement parks. On November 5th, 1895 a block of ground on the West Side of Holland Avenue was purchased and later added to for a total of approximately 175 acres.
>
> "By the spring of 1896, the park was a reality. Refreshment booths, picnic tables, electrically operated swings, a merry-go-round, piano-organ, and other comforts were readied for business. On May 1, 1896, the park was declared open. Many guests each sporting a wild flower buttonhole bouquet picked from the park grounds signified their identity amongst the throng that enjoyed the opening programme and band concert.
>
> "A feature of the evening entertainment was the first public showing in Ottawa of Edison's marvellous invention 'The Vitascope'. After dark the patrons viewed pugilistic events, comedies, surf breaking, Niagara Falls, and other scenes portrayed in such realistic fashion that one columnist reporting on the performance remarked, 'if only sound had accompanied the action, one would almost believe the actors alive'.
>
> "Early in 1897, an Auditorium 115 feet by 80 feet with a stage 60 by 40 and 35 feet deep was under construction. Theatre facilities such as dressing rooms and stage paraphernalia left little to be desired from a production standpoint. The roof was high, built circular fashion, and seating capacity neared the 1,000 mark. Incandescent lamps studded the outside making the building a landmark at night.
>
> "Throughout the summer season of 1897 and for several seasons thereafter 'top notch' vaudeville performers and drama artists drew capacity crowds".

To return to the question of transportation. In the summer of 1908 the Ottawa Electric Railway entered into a contract with the Minister of Agriculture for the extension of their tracks from Holland Avenue through the Experimental Farm. In those days a planting of evergreen trees, perhaps 50 feet wide, marked the northern boundary of the Farm (remains of this grove may be seen on the Observatory grounds), and the new tracks ran between this grove and Carling Avenue to a point opposite the present Melrose Avenue. There was a stop here, with a shelter, and a pleasant and well-lighted walk ran through the grove to the main Farm gate, opposite Irving Avenue. The line turning south at the Melrose stop, ran through the fields and orchards to the present Driveway, then turned east to a loop just beyond the barns. This line was in operation by the autumn of 1909.

In the early days of the Ottawa Electric Railways the cars were all built on a single truck, which led to a rocking ride. These cars were used on "the Farm line" well into the 1920s. They had trolleys which could be moved from one end of the car to the other, and controls at either end, so that they could change direction on a single track. Such a car was the feature of a comic strip of those days, "The Toonerville Trolley that Meets All The Trains", and the Farm cars were affectionately known as "The Toonerville Trolley". These relics eventually gave way to standard street cars. By 1929 service into the Farm grounds was attracting less than 25 passengers a day, and the service was discontinued. However the cars did come to a loop opposite Melrose Avenue.

In 1914 the line running along Albert and Preston streets was continued beyond Somerset, to Carling Avenue, where it made a loop. This provided a second access to the Experimental Farm and the Observatory.

Bus service to the area began early in January, 1929; the so-called "Cross-Town" bus ran from Pretoria Bridge and followed Monkland, O'Connor, Carling, Parkdale, Wellington, to the City limits and returned by the same route.

Housing

It is not clear whether Sifton's "comfortable quarters" referred to dining and sleeping accomodation within the observatory or to residences for the astronomers, but the idea of an Observatory House, or Houses, for King and possibly for Klotz, was discussed as early as June, 1901. During the visit to the site "in great state – a flunkey and landau two horses" already mentioned, (page 14), Klotz asked Mrs. King "what she thought about the place. She emphatically gave her disapproval to any place on the Farm saying that she didn't want to bury herself alive out here, being so far from the city. This was in view that a dwelling house would be built for King (perhaps for me too) out here".[175]

Initially, in late 1904, consideration was given to buying a site "just north of the Observatory, across the Merivale Road".[176] Noting that the Merivale Road here mentioned is now Carling Avenue, the proposed site would have been on the corner of Carling and Irving Avenue, occupied for many years by the Protestant Children's Village, and now a housing development. The owner held out for $7,000 for the property and instead, an additional grant of land was obtained from the Department of Agriculture.

Very detailed specifications for the House, signed by the Chief Architect and dated 1908 survive. [176] Construction must have started fairly promptly because on August 2, 1910 Klotz reports[177] "Dr. King has now moved into his new house." The Archives file has very little to say about Observatory House during the King tenure, nor does the Klotz diary. He seems to have not been a frequent visitor there.

The idea of a second house on the Observatory grounds for the Assistant Chief Astronomer was never taken up, possibly because Klotz didn't push it. He had a very comfortable home on Albert Street, and he had no desire to leave it. When Observatory House became available to him with the death of Dr. King in 1916 he declined it in favour of R.M. Stewart.

Most of the professional staff of the Observatory lived within walking distance, on Carling Avenue or on the blocks of Irving, Fairmont or Gwynne close to Carling. These were the only streets close to the Observatory that were developed. There was only one house in the large area bounded by Sherwood Drive (which didn't yet exist) and the Queensway (which was then a railway track) and between Bayswater and Parkdale Avenues. Some Observatory staff lived in "Hintonburgh" on the streets immediately north of the railway.

For those who were not so favourably located, the Government supplied some amenities not generally available to the public servant. As we have already seen, the large west room on the second floor was a dormitory where astronomers could sleep after observing, or while waiting for skies to clear, and the nearby washroom had a large bathtub in case they felt the need of a good soak. A woman was on duty during the night to provide lunch for the working astronomers. We know this from the Diaries: in March, 1906 Klotz reports that his Foucault pendulum was disturbed by the woman preparing his lunch.[178] There were even hot meals at noon, at the Government's expense. Klotz reports:[179] "Had J.W. Reid of the Auditor General's office for luncheon at the Observatory. It was his first visit. I showed him about and he saw (and ate too) the provisions we get, of which he has to audit the accounts. It is somewhat of an innovation for the government to pay for luncheon as they do for us at the Observatory, since we have our office out here, some three miles from the city."

Staff Activities

Originally the hill from the Observatory down to Observatory House and the present Geophysics Building was much steeper, dropping in a pair of abrupt terraces and leaving a much larger area of flat ground than at present. Almost from the beginning there were tennis courts on this area and tennis was very popular. In July, 1913 the diary reports:[180] "At the moment I think the majority in the observatory have their minds more on tennis than on work. The noon rest is 1 1/2 hours of which 15 [minutes] are devoted to luncheon and the other to tennis. They play on two courts and have Senior and Junior singles and doubles. In no observatory in the world is there so much useless timber as in our observatory, but we have earnest and good workers. At present we have three additional young fellows from the Collegiate Institute - the Director's son and two chums living nearby. It is a regular pic-nic. Today I had to go to the bookbinder's room. I found beside him four others from upstairs talking tennis. Later I went to the carpenter's shop and there Fred [Dunn] had two others from upstairs 'gassing' with him".

Klotz couldn't have been quite as opposed to tennis as this passage suggests. In June, 1913, he reports:[181] "Today Dr. King and I selected a striking silver cup ($27) as a perpetual challenge cup - senior singles - lawn tennis among our observatory staff. The cup is known as the King-Klotz Challenge Cup."

In the winter there was hockey with an Observatory team playing one from the Geodetic Survey and Boundary Commission. The losing side treated at a banquet. For example in January, 1908, the diary reports:[182] "In evening attended an oyster supper at the Belmont given by the losing hockey team of our staff. Under Dr. King are the Boundary and Geodetic Surveys as well as the Observatory. As the former are housed in a tall building in the city they are called 'Sky Scrapers' while our men are called 'Star Gazers'. ... Some 40 of us sat down. Dr. King presided." The hockey banquet was an annual event; the Observatory seems always to have lost.

Seminars

In 1907 a seminar series was started at the Observatory.[183] "In afternoon Mr. J.S. Plaskett gave the first of our series of technical papers on 'The Star Image in Spectographic Work'. It was very good and showed much aptitude for mechanical analysis in discovering sources of error in the various optical and other parts." It is not clear from the diary whether the meetings were held regularly on a weekly or monthly basis; Klotz doesn't necessarily refer to them unless the subject is of particular interest to him. The papers seem to have been of two sorts, technical papers deriving from the work in hand, probably dry runs for presentation at some scientific meeting, or review papers apparently intended for the general education of the staff.

For example, in February, 1908,[184] "in afternoon I gave a lecture at the Observatory on 'Earthquakes and the Interior of the Earth' before the largest audience we have had at any lecture, quite a number of ladies were present, which was quite a compliment to me. Besides lantern slides, I used blackboard diagrams and a few models. I developed the subject matter under the headings - Density - Figure of the Earth - Variation of Latitude and finally Earthquakes; showing how each in turn told us something of the interior of the Earth. ... I spoke for nearly 1 1/2 hours and was listened to with close attention. There were some catholic priests or embryo priests present.

"As a special favor I permitted the audience to view the seismograph in the basement, as so many were curious to see the instrument that tells when the earth quakes, say in far off Asia. The seismograph room, lit with only two red lights, which I had turned on, made the scene perhaps a little more impressive while I explained the working of the instrument. - The compliments for me led me to believe that my address was a great success."

On another occasion[185] Klotz spoke on the Wegner hypothesis.

An Ottawa chapter of the Royal Astronomical Society was founded in late 1906. There were a number of problems in its formation, which will be treated elsewhere, but we should here note that almost from the beginning the monthly meetings were held at the Observatory. Most of the lectures were given by Observatory staff and it is sometimes difficult to know in the diary whether a particular lecture was in the Observatory or the Astronomical Society series.

This may be an appropriate place to mention that in the Ottawa of pre-radio, pre-television and, in the beginning, pre-movie times, public lectures were very popular. One of the leading providers of this fare was the Ottawa Literary and Scientific Society of which Klotz was a strong supporter and frequent officer. Lectures were also given in the Normal School, the Y.M.C.A., and, later, at the Public Library. Staff members of the Observatory were frequent speakers at all these series.

Public Relations

From the earliest days there was a conscious effort to make the public aware of the work of the Observatory. In his first Report after the completion of the new building King[186] says: "It may be stated here that the observatory is open to the public every day during office hours, to view the building and the instruments. In addition every Saturday evening visitors are allowed, under the supervision of one of the staff, to view the celestial bodies through the fifteen-inch equatorial telescope. These privileges are taken advantage of by many people. The number of people registering their names in the 'visitors' book' from May 31 to October 31, was 2,666."

Not only the general public visited the Observatory. The "Press of the House of Commons" accompanied by Klotz, visited the Observatory in April, 1905; Plaskett showed them the wonders of the heavens and "King had provided mineral water and Scotch."[187] On another occasion "we had a visit ... of Lady Laurier, Mrs. A.B. Aylesworth and Mrs. Thomas (of Buffalo). They wanted to see the seismograph after my telling that it recorded quakes from the other side of the world, so I took them into the basement, and of course had to turn on the light in the seismograph room to the detriment of the sensitive paper, and show the movement of the pendulums. However it's not every day that we have the premier's wife as visitor."[188]

Sometimes receptions, on behalf of the Royal Astronomical Society, or "At Homes" were held in the Observatory.[189] These continued into the 1930s. As a high-school student, I was frequently pressed into service to demonstrate some aspect or other of elementary physics, the reflection and refraction of light for example. The attendance was large and the people were interested. Sandwiches, cake and coffee were served.

There were other attempts at public relations, particularly by Klotz, since the public was always interested in earthquakes. He sent prints of the San Francisco earthquake records to the local newspapers and the Ottawa *Free Press* reproduced it. He was always glad to supply information on earthquakes, and he was deluged with calls after local earthquakes. Perhaps the publicity was more for Klotz than for the Observatory, but both profited.

Learned Societies

Canadian Societies

There were two Canadian societies which had great importance for the Observatory. We shall consider first the Royal Astronomical Society of Canada.

Late in December, 1906:[190] "a public meeting was called at the Carnegie Library for forming an Astronomical Society. Mr. R.M. Stewart of our Observatory was especially anxious that such a society be formed and he with Mr. Plaskett had consulted me about it and making it an appendage of the Toronto Society which has the title of the Royal Astronomical Society of Canada. I must admit that I am not keen in any event for such a society for it only means work for a few as instructors of the public, and as for playing second fiddle to Toronto when we have the only real observatory in Canada I objected. My views were communicated personally by our Dr. King to the Toronto officials and they at once said that they'd change the constitution so that we would be on an equal footing with Toronto, each a section of the R.A.S. - When the inevitable is going to happen it is best not only to bow thereto, but to assist and take an active part. So I prepared the various resolutions to be submitted and made out the roll to be signed by such as desired to join, in fact arranged the details of the meeting with Dr. King as chairman.

"At 8-15 some 25 gathered, and I arose and said a few words in proposing Dr. King chairman. He then explained the object of the meeting and what should first be done (as I had told him to do). - By resolution an astron. society was founded, then a resolution what officers should govern the same, these were carried. Then I proposed Dr. King for president and he was elected; Mr. Plaskett proposed me for Vice-President, and I was elected. Plaskett was elected secretary; R.M. Stewart treasurer and Jas. Pope, A.H. McDougall and F.A. McDiarmid members of Council. The next motion was that the Council prepare a Constitution and By-Laws for the Society and finally the roll was signed by 25. Thus was launched the first astronomical society of Ottawa. I don't like its popular character, i.e. that we who are engaged in active work are to become public schoolmasters. I don't think the game is worth the candle. ... However I did not wish to appear as a back number or effete in this matter of organizing a society and hence spoke encouragingly about it. But really my heart is not in it."

Things moved quickly. On December 31, Klotz reports a meeting of the Council of the RASC Ottawa Centre "to discuss its Constitution and By-Laws which have been drawn up by me."[191] Apparently however the Ottawa constitution was not acceptable to the Toronto group. More than ten months after it had been drawn up,[192] "in evening a committee meeting of the Astron. Soc. We have trouble in getting the Toronto people to recognize that they are only a section like ourselves of the Royal Ast. Soc. of Canada in drawing up our new Constitution and By-Laws as they submitted to us. They want...the National Observatory to play second fiddle to Toronto."

Things were at an impasse but in February, 1908, the diary reports:[193] "Dr. King returns from Toronto whither he and Mr. Plaskett had gone to discuss the future status of the Royal Astron. Society of Canada, we here having taken a decided stand against the new proposed Constitution in which Toronto would occupy a superior and we an inferior position. Things had gone so far that we were on the point of cutting loose altogether, Toronto was as usual trying to play 'hog'. They however became alarmed when they saw our calm and determined attitude and asked for personal interview, which took place Tuesday eve. ... He gave me an account of the Toronto conference and that things were arranged mutually agreeable, there to be *no* sections, only the General Society and meetings to be held wherever a group of members desire."

I have not found any publication of the new Constitution but the Journal of the Society reports on an Ottawa meeting of the Society with the President, Dr. W.F. King, in the chair.[194] "The President then explained the new constitution and pointed out the changes it made necessary in the procedure and in the by-laws of the local organization." We may conclude that a mutually acceptable Constitution had been officially accepted even though the Journal didn't see fit to publish it. It did publish[195] a list of officers, of the Society and of the Ottawa, Peterborough and Hamilton Centres, together with a complete list of members.

The diary reports no more squabbles with the Toronto "hogs".

Members of the observatory were very much involved also with the Royal Society of Canada. King was elected a Fellow in 1908, Klotz and Plaskett in 1910. Because of the death of the King, Edward VII, in May, the meetings of the Society were held in September that year. Klotz was presented to the Society by Dr. Bell Dawson, the President of Section III.[196] "I have never been very much impressed with the Royal Society judging from the calibre of some of the members, however I feel it is an honour to have been elected to the Canadian Valhalla of Literature and Science without the slightest solicitation or intimation on my part." He may not have been impressed at the honour but a year later he voted against a motion which would have diluted the honour by creating 40 new members.

Today, when every scientific splinter has its own association or section, it is difficult to realize how little scientific communication there was in Canada. The Royal Astronomical Society gave astronomers a forum and a meeting place, and the surveyors were well served by the various provincial and national associations, but for most scientists in Canada the annual meetings of the Royal Society provided the only opportunity for them to meet their fellows. The Observatory made full use of it. For example, at the 1909 meetings, held in Ottawa, of 17 papers presented to Section III, 10 were from the Observatory.

American Societies

The position was somewhat better in the United States than in Canada. The Astronomical and Astrophysical Society of America, shortly to become the American Astronomical Society, held annual meetings at one or other of the principal observatories. Most of the Observatory astronomers were members of it, and Klotz and Plaskett in particular attended the annual meetings fairly regularly. We have already seen the influence the Society had in the matter of the 72-inch telescope.

There was not any equivalent society in the United States for geophysics, but the American Association for the Advancement of Science had a Seismological Council. Klotz attended the Association meeting every two or three years and reports in 1907 that he had been a Fellow for 18 years. At the 1907 meeting the Council drafted a resolution which was passed by the Association in plenary session "asking the U.S. Government to make an appropriation for Seismology and put same in the hands of the Weather Bureau, which on account of its stations and trained observers scattered over the country is in the best position to assume the work." [197]

Klotz attended the AAAS. meeting at Berkeley in August 1915[198] and was able to attend the final meeting of the "American Seismological Association." The Seismological Society of America, to give it its proper title, had been established in 1910 under the impetus of the San Francisco earthquake. It is difficult to believe that Klotz was not a member from the beginning, although there is no mention of the Society in his diary. He had certainly not attended any earlier meetings.

He wasn't much impressed with his first meeting. "Four papers were presented in all of which I was one of the few who took part in the discussion. There was no paper on modern seismology and I took the Secretary, Prof. Townly, to task for such a meagre performance saying 'you Californian people founded the association, fund a quarterly, elect officers, nearly all Californians, your state is the seismic region of the United States, and when we come from the East to the meeting, you don't present a single paper on seismology, I speak quite frankly! - Townly said 'You are quite right. I shall make use of what you said'."

It is interesting that some 14 years later a group of eastern seismologists, including Klotz' successor Hodgson, frustrated at the continued domination of the Society by Californians and at the ineffectiveness of Secretary Townly, established the Eastern Section of the Society.

International Associations

International Astronomical Union

We have already noted (p. 37) that in 1910 Plaskett attended a meeting of the International Union for Co-operation in Solar Research; it is there stated that this union eventually developed into the International Astronomical Union. These are the only references I have found to the IAU during the period of the King Administration.

International Seismological Association

While the Meteorological Service had been operating Milne seismographs at Toronto and Victoria since the beginning of the century, it was the new, more sensitive, Ottawa station that attracted international attention, and in 1907 Klotz received a letter inviting Canada to become a member of the International Seismological Association, and to send a delegate to the approaching meeting in The Hague. King accepted the idea of membership, and arranged for an Order-in-Council to be passed to this effect, but he was opposed to sending Klotz as a delegate and, as the pressure built up, justified his position by pointing out that the Order-in-Council said nothing about a delegate. Klotz finally asked permission to go at his own expense. At this point King gave in, but, to save face, arranged that Klotz should go to Europe to look at instruments and attend the meetings of the Association only incidentally. "The main thing for me is to be allowed to go, they may designate my mission by any name. However *my* mission is Seismology, pure and simple."[199]

It was not quite as simple as that. Canada had joined the Association and Klotz was going to the meeting, but he had not been designated by the Canadian government as their official delegate. Upon arriving in The Hague he explained the situation to the Secretary, Kovesligethy; however, when he went to register at the opening session he found that he had been entered in the Association list as the Canadian delegate. This was very important because the events began with meetings of the Permanent Commission, composed only of delegates. These opened on the 21st of September and continued through the 23rd, under the Chairmanship of the President, Professor Palazzo of Italy.

One of the first matters of business was the establishment of a committee to report on a competition on seismological instruments. Klotz was placed on this committee, along with Galitzin, Omori, Hecker, Mainka and Rosenthal. Heady company for the new boy![200] "It was quite a compliment to pay to me and to Canada, the youngest of the accessions to the Association." Later in the day "there followed a lengthy discussion on the study of the micro-seisms. To my surprise I found that little more was known of them than I knew, so I ventured to address the meeting." Later a committee was set up to recommend on the preparation of a catalogue of earthquakes. Klotz was also placed on this committee, which was chaired by Professor Forel "a nice old gentleman but rather verbose."[201] The two committees kept him busy.

The meetings of the Association, as opposed to the Permanent Commission, began on September 24, and were opened with suitable formality by the Dutch Minister of Colonies. There were a number of papers and Klotz acted as deputy chairman, but he was not much impressed.[201] "The Society is not yet well ordered, neither in the presentation of papers or in matters of business, for both too much time is wasted. For each paper an abstract should be in the hands of the members, so that the salient points leading to discussion might be known. As it is, a paper is read to which few pay attention, partly because it is in a language that they cannot readily follow, or that it is of no particular interest to them."

The presentation of papers seems to have required only one morning. On the next day there was sight-seeing and in the evening a banquet given by the Government. "After the banquet Van der Stok said to me we must go to the Club and have your national drink. So quite a party, a dozen or so ... repaired to the Club where we all drank Canadian Club and Soda. Vive le Canada made the rounds."[202]

On departing from The Hague, Klotz visited a large number of seismograph stations and observatories throughout Germany. He arrived back in Ottawa, via London, on October 19.

Klotz was now established as a member of two committees and was recognized by the Association as a member of the Permanent Commission. There was to be a meeting of the Permanent Commission in Zermatt, Switzerland, in September 1909 and Klotz was anxious to get his position regularized. The matter came to a head in late June, 1909, when Klotz, having been given the Seismology file by the Secretary Simpson to look up an order for seismograph paper, inadvertently saw some correspondence between Schuster, current President of the Association, and King. Schuster "in writing to King about a delegate mentions that he understands that Klotz is going to attend ... and that he does not wish to have the irregularity of the Hague repeated at Zermatt. ... King in his reply does not refer to me at all, only says that the Order in Council passed (July 1907) only covered joining the Association but no provision for a delegate and further suggests himself as member of the Permanent Commission and to participate simply by correspondence. Keep Klotz out!"[203]

That night he asked King to spend the evening with him. "After having spoken of this and that over a glass or two and cigars" Klotz referred to the forthcoming Zermatt meeting, stressed how important it was for Canada to be represented, pointed out how much had been gained by his attendance at The Hague and asked King frankly what the position was. "King does not know that I by pure accident saw this correspondence and I of course did not allude to it."

"He asked me when I wanted to go. I said toward the end of August as the meeting is in the last week in August and beginning of September. He said 'all right, you may go', I thanked him cordially. We continued our chat, roaming over wide fields and topics."

However, going to Zermatt was one thing, going as an official delegate was another. As the time of departure approached Klotz asked King for a letter stating to the General Secretary that Klotz represented Canada on the Permanent Commission.[204] "To this he demurred saying that the Order in Council of July 1907 expressly stated that Canada did not intend then to have a representative. He then got the file and read to me a letter from the President Prof. A. Schuster received some months ago about me, but of which he had never told me anything. ... [This is the correspondence referred to above]. When King had read the letter, I expressed my surprise and humiliation thereat, saying I was disgraced and that it was awful. I asked him to place himself in my position. After sitting in silence for some time I left the room."

"A half hour later he came to my room with a draft letter to the General Secretary. I read it and found that in it he had made me a delegate, the formal ratification to follow by Order-in-Council. I thanked him for it and he left with the draft."

The Zermatt meetings opened on August 30. Klotz was accompanied by his wife, Marie. It was an occasion for Klotz to meet many European seismologists who were now, after The Hague meeting, old friends. Meetings of his two committees, on Instruments and on a Catalogue, were held, and Klotz was placed on a third committee dealing with the "'Central Bureau at Strasburg', a most important one, as much dissatisfaction exists about its management."[205] These responsibilities kept him very busy. A number of technical discussions were held, one on microseisms in which Klotz took a major part. The meetings finished at noon on September 2, there were excursions in the afternoon. Before returning to Canada, where they arrived on October 9, the Klotz visited a number of observatories and spent some time with their German relatives.

The next meeting, of the Permanent Committee and the full Association, was to be held in Manchester, England, in July 1911. There seems to have been no doubt that Klotz would attend. But there was another cloud in the sky. "A Victoria man, Dennison of the Meteorological Service, has stirred up the people there to have an observatory etc., and wants to go to Manchester as delegate for Canada, and the Minister ... apparently has approved of it. He is of course perfectly oblivious of the fact that our Department joined the International Seismological Society 5 years ago and pays $200. annually thereto, and furthermore that I have been heretofore the accredited delegate, that I belong to various committees of the Society, that on the programme already printed I appear for two 'papers'."[206] Klotz visited "Mr. J.A. Côté, Ass't Dep. Minister, re living allowance, $10 a day, on my proposed visit to Europe"[206] and arranged for an Order-in-Council. "The scheme with the proposed Order-in-Council - which Mr. Côté immediately ordered to be made out - is two fold, not only will it state my living allowance but also that it is *as delegate*, a very important matter - I afterwards called on Mr. P. Marchand who is to draw the Order-in-Council to make sure of the wording." So, that snake was scotched.

King not only approved of Klotz going to the meetings, he concurred in Klotz' suggestion that the Association hold its next meeting in Canada.[207] "I have little hope that it would be accepted but it would show the progressive spirit of Canada". With King's blessing, Klotz "saw Mr. W.W. Cory our Deputy Minister about ... my inviting the International Seismological Association to meet in Canada for their next meeting. ... Mr. Cory after reading the memo immediately wrote 'approved' in the margin, saying 'Canada wants to keep up with the procession' in which I heartily concurred."[208]

Klotz arrived in Manchester on July 15 and again was amongst old friends.[209] "In the evening many of us gathered in the German restaurant around a long table, each facing a stein of Munchner. These are the times around which centre the interest and value of international scientific meetings. Here we exchange ideas, pick up valuable material and stock our scientific larder with food to carry home, repaying many fold times the cost of the visit. To say the least such gatherings are most enjoyable."

The meetings opened on July 18. After the introductory formalities Hecker spoke on the desirability of deploying a network of instruments, one in Winnipeg, to measure the deformation of the earth under the influence of the moon. We have earlier seen the fiasco which this became in Canada. Then Klotz spoke about the desirability of standardizing the form of bulletins and a committee with Klotz as chairman was established to report on this.

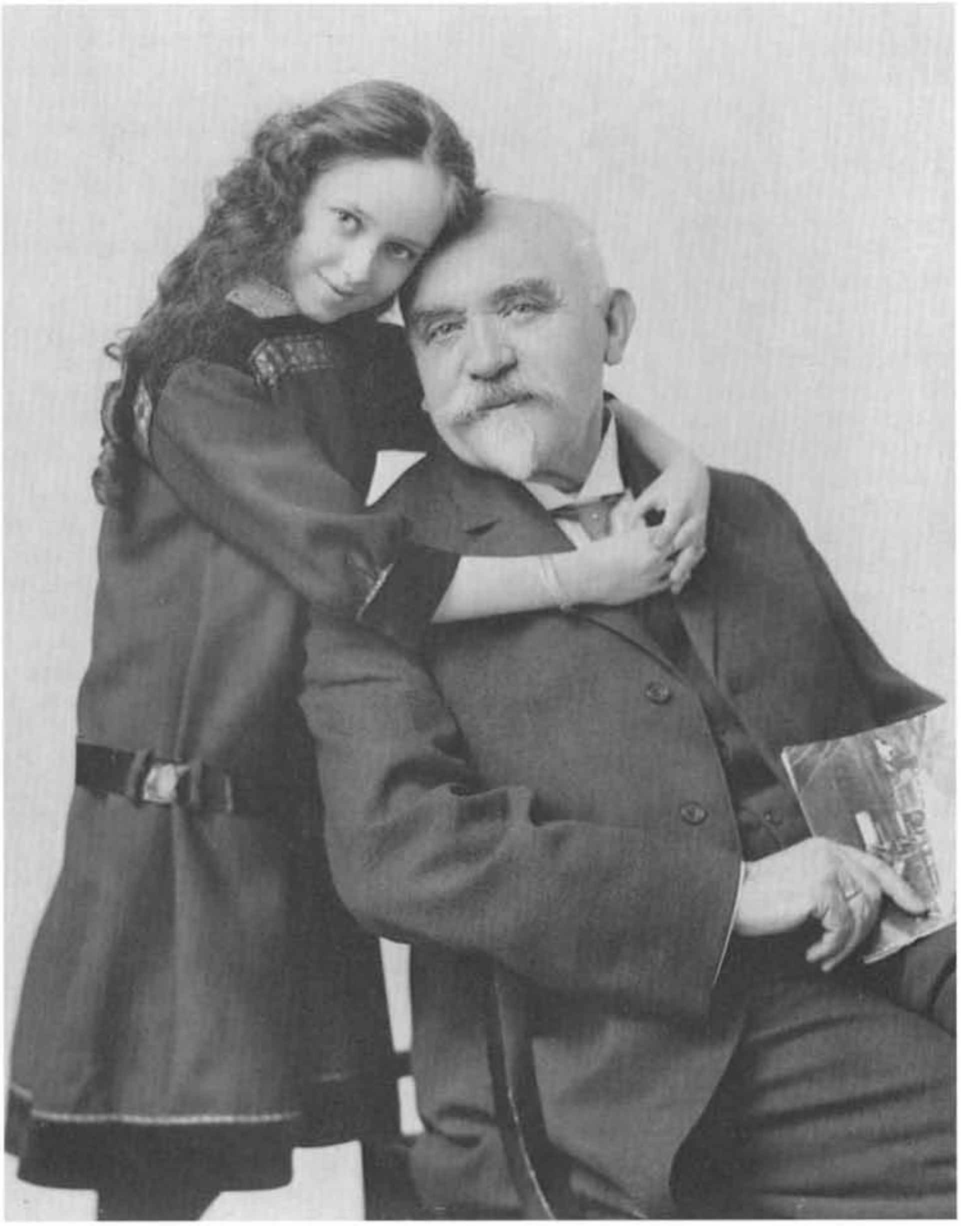
Committee meetings took up much of the time, Klotz was now on four of them, but in addition there were many interesting papers. Galitzin demonstrated his new vertical seismograph and read a paper showing how, with his three components, he was able to locate the epicentre from a single station. Wiechert spoke on the interior of the earth.[210] "He believes now in three layers, respectively at 1200, 1600 and 2400 km in depth." Klotz read a paper describing his use of meteorological instruments in an attempt to correlate atmospheric disturbances and movements of the seismograph, and Professor Schuster described an instrument, the undagraph subsequently installed in Canada, for counting waves.

There was a reception by the Mayor of Manchester. "The most of us were of course in frock or Prince Albert."[211] President and Mrs. Schuster gave a garden party.[212] "It was of the usual form as with us - music and refreshments. There was not much style, and many of the gentlemen were not in frock coats, and still less in silk hats." The University tendered a banquet in its Refectory.[213] "The banquet was similar as with us. Of wines were served sherry, Chambertin and Champagne. ... After the banquet there was a formal toast list ... Prince Galitzen proposed an extra toast to Prof. Jno. Milne in a very acceptable manner, and Milne made a characteristic reply, full of humor. A good story of his was where a young woman on a bicycle fell exhausted at his gate. He took her to his verandah, where she learned who her host was. She expressed her great interest in earthquakes, especially in big earthquakes, at which Milne manifested his astonishment. She explained that she had much of her money invested in cement works, and that big earthquakes generally meant a great demand for cement in reconstruction!!"

When it came to selecting the location of the next meeting Canada lost out to Russia, despite the fact that Klotz[214] "told them that geodesists - the earth measurers - have found that it is no farther from Europe to Canada than from Canada to Europe." Galitzin was elected President and the meetings were to be in St. Petersburg.

As usual Klotz took an extended tour of the Continent before returning to Canada. He arrived home on September 4.

He began preparing King for the 1914 meetings in May; to improve his case he also proposed to observe a total eclipse of the sun at Kiev on August 21, on his way to St. Petersburg. King apparently



Klotz with his grand-daughter Dorothea, the "little hero", March, 1914. National Archives of Canada, PA 43037.

made no objections. In mid-June he visited the Assistant Deputy Minister, J.A. Côté, to seek his approval.[215] It happened that Mr. Côté himself had a favor to ask, that Klotz support the appointment of his son to the position, shortly to become vacant, of Secretary of the Board of Examiners for Dominion Land Surveyor. "So apparently I fell into Côtés arms at a psychological moment. But 'there's method in my madness'. I let Côté tell his wishes to which I readily gave my good will. When this was disposed of, I incidentally mentioned that I was going to Russia, and that an Order-in-Council would of course be necessary again, giving me $10 a day living allowance above travelling expenses. ... Everything worked like a charm, and in a very matter of fact way."

He made elaborate plans for the trip. His eldest son, Dr. Max Klotz, a distinguished surgeon, was already in Germany with his daughter Dorothea. Max's younger brother Oskar, a pathologist currently on the staff of McGill University, was also in Germany, accompanied by his wife Stella. Klotz' wife, Marie, declined to make the trip, so he invited Max's wife, Maud, to accompany him; she was a jolly person of whom he was very fond, and he looked forward to the trip.

They sailed from New York on July 30, but they went to New York two days early so that Maud could see the sights. One evening they went[216] "to the Winter Garden - a very large theatre, the garden part was by no means obvious." "Maud was just saturated with delight at what we saw during the three hours." He was obviously enjoying himself too; he forgot to mention until a day later[217] "a most important event in world history. Driving to the station I bought the afternoon papers and found in big red letters - War Declared -, war between Austria and Serbia, as a consequence of the unsatisfactory reply Serbia made to Austria following the recent assassination of the heir Prince Ferdinand and his wife at Sarajevo. What this may lead to in European affairs no man can foretell. ... We may be on the eve of a war such as the world has never seen. My Russian plans may be wholly upset, however I am not worrying."

They sailed on July 30. On August 2 they learned that[218] "war has actually broken out, Russia and Germany having entered the field. Nearly all - not I - are very much concerned, how they will get back. My concern is more how, if at all, I shall get into Russia to observe the eclipse at Kiev on the 21st and later attend the two meetings in St. Petersburg." By August 4, Germany had entered Poland, and France Alsace; in the evening they learned that England had declared war against Germany. "It seems a crime - a most unnatural crime for England whose ruling family for 150 years has been the German House of Hanover to battle against Germany, and to be allied with her enemy of nearly a thousand years - France."[219] Klotz was to be very much torn between his loyalty and love for Britain and his attachment to the Fatherland, only one generation removed.

They docked at Liverpool in August 8 and proceeded to London where they were very relieved to find Oskar and Stella. They had been on the last train to leave Germany. No one knew anything about Max and little Dorothea. Klotz visited the Hon. Geo. H. Perley, the acting High Commissioner, whom he knew well, asking for help in finding Max.[220] "He said that there were hundreds of Canadians and many more American similarly and worse situated in Germany, as they were unfamiliar with the language." The lost ones showed up unharmed on the 12th. They had been "eight days on the trip, and little Dorothea stood the siege like a little hero. Max was arrested or stopped half a dozen times, but always got out of the scrape, his perfect command of German standing him in good stead."[221]

So, the family was re-united; the next thing was to get home. Everyone except Klotz himself was able to book passage on August 21, and he got away on September 3. Both ships arrived safely. While they were waiting, they enjoyed themselves. They went to Windsor, to Regent Park Zoo where Dorothea fed the elephants, to Bath, to Hampton Court and to Cambridge. By the time Klotz left, the Germans were within 60 miles of Paris!

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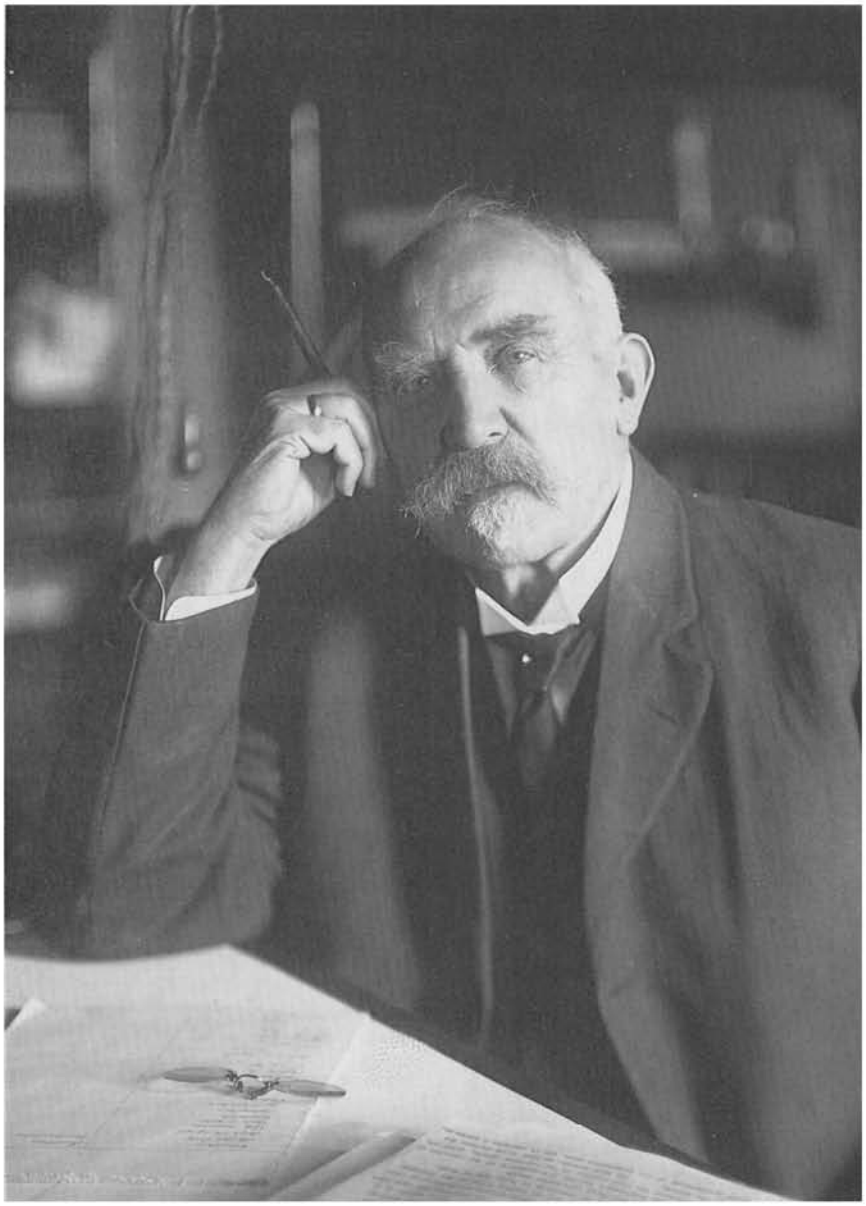


Dr. Otto J. Klotz.

III – THE KLOTZ ADMINISTRATION: 1917-1923

ADMINISTRATION

The Interregnum, 1916-1917

In ordinary times the succession of Klotz to the directorship would have been a routine matter, quickly accomplished. But the times were not normal. The world was in the depths of war and hatred of "the Hun" dominated popular thinking. The appointment of someone with a strong German background was politically dangerous for the Government.

Klotz was intensely loyal to Canada and had a sincere admiration for Britain, but as a first generation Canadian, with relatives still living in Germany, he was bound to feel some ambivalence. This he carefully concealed, after the first few weeks of the war even from his diary, but his wife, Marie, could not so easily dissemble. Daughter of the German Consul in Ann Arbor, her ties to Germany were direct and strong and she was frequently indiscreet in voicing her opinions. Klotz was supported by many distinguished members of Ottawa society but the Union government, under Borden, was very nervous about appointing him to a senior position. Perhaps they were right; a country which demanded that the name of Berlin be changed to Kitchener was probably not in the mood to condone the appointment of such a suspect character.

Aside from the question of who should be director, what should he be Director of? Should the Observatory, the Geodetic Survey and the Boundary Commission continue under a single director or should they become separate entities? The surveying part of the organization had become increasingly divorced from the Observatory during King's tenure and there seems to have been very little interest in keeping them together. Klotz was critical of the "incompetents" who were appointed temporarily to positions of responsibility in the Surveys, comparing their qualifications unfavorably with his own, but his diary shows no real ambition in that direction.

There was another question of organization, which concerned the relationship of the Victoria Observatory to the Ottawa one. While King lived the understanding was, that while the scientific work in Victoria would be under the direction of Dr. Plaskett, for administrative purposes the observatory there would be under Dr. King. Because Plaskett admired King and worked well with him, he had never objected to the arrangement. However he had no use for Klotz and was determined that the arrangement would not continue.

In the vacuum created by the Government's vacillation, the Secretary, Simpson, was the *de facto* Director just as, under King, he had been the *de facto* Assistant Director of all three services. This temporary appointment was apparently official. The Museum of Science and Technology has recently received a number of mementos of Willibert Simpson, including an obituary notice apparently written by himself, with blanks for the essential details. This material has been made available to me by Mrs. Mary Gray. It shows that he sketched attractively, was a competent versifier and that despite his handicap was an ardent outdoors man. He seems to be a much more attractive person than Klotz allows; nevertheless the principal facts of the relationship are confirmed.

Simpson was stricken with infantile paralysis in childhood and used crutches all his life. After holding a number of clerical positions in commerce he was appointed as secretary to W.F. King in 1893, and assisted King in the management of the western surveys for several years. "The Dominion Astronomical Observatory was completed and ready for occupation in 1905, when Mr. Simpson was appointed as Secretary and Accountant. ... From this time on in the absence of the Chief Astronomer and Director, he continued acting for him with full Departmental authority.

"His greatly revered Chief died on the 23rd of April, 1916, when Mr. Simpson, having previously acted for a month or more, was continued in charge by the then Minister ... to carry on his late Director's tripartite position.

"He continued as Acting Chief Astronomer and Director of the Observatory for over a year - till Dr. Otto J. Klotz succeeded to the position in 1917."

We could indulge in a good deal of amateur psychology about the crippled boy who grew up with delusions of grandeur but, whatever the reason, there can be no doubt that he expected to be promoted to the position of Director. In the 17 months of indecision he *was* the Director, and very nearly destroyed the organizations that he aspired to lead.

It seems clear from the Diary, although Klotz doesn't draw the inference specifically, that Simpson was aided in his machinations by the Deputy

Minister Cory, who according to Klotz was "an ignoramus, a pure political appointee".[1] This is probably a harsh judgement, but Cory certainly agreed with Simpson that scientists were not to be trusted to manage their own affairs and was in no hurry to change the arrangement. Klotz could only watch the observatory deteriorate without being able to do anything about it.

Simpson was[2] "a martinet of the mean kind, and the men resent his over officiousness" so that "the few men who were lukewarm toward me [Klotz] in the beginning are now wishing that I were in charge".[3] "His main forte appears to be to disallow everything on the plea of economy. In May he refused McDiarmid an advance for field work - gravity work - so no gravity work is being done. ... He refused getting some Militia maps for Tobey, necessary for his triangulation computations, refused to have some maps mounted for Gauthier, etc. etc. - chaos - but it is the Minister's own brewing".

The 1916 field season in Gravity was lost, but worse was to come. Early in 1917[4] "Mr. Simpson came to my room, with my report of the geophysical branch for the annual report to the Royal Astr. Soc. England, and had scored out my reference to the projected work of this year in magnetic and gravity, saying he had discussed the matter in the 'estimates' with the Deputy (Cory) and had made no provision for the expenses, had cut especially the Geodetic Survey, in all some $62,000. - I said very little, only that it was absurd. - What are Mr. French, Mr. McDiarmid (the two experts) to do? - 'I don't know' was the reply." He may not have known, but he had some ideas: the next day he proposed that French be seconded to the Seed Grains Branch; when that didn't work he proposed transferring him to the astronomical section.[5]

Klotz went to the Minister[6] to protest against Simpson's cuts. The Minister was sympathetic and asked Klotz to send him a memo. The memo was prepared and submitted to headquarters promptly. Nothing happened for a week. Then on January 15:[7] " This afternoon (5 p.m.) mail at the office brought me an unofficial envelope with simply 'Dr. Klotz' on, which on opening contained my letter to the Minister of last week...stamped thereon 'Minister's Office - received January 15', also a memo dated Jan. 10 signed 'W.S.' (Simpson, our Secretary) making a savage onslaught on my recommendation to the Minister about continuing this year the Magnetic & Gravity surveys. - The whole thing is a mystery to me."

He went to see Mitchell, the Minister's private secretary, and showed him the envelope with its mysterious contents.[8] "He looked at them...and became very angry, a few 'damns' leaving his lips. 'You should never have seen this, Dr.,' he said. 'Too bad, too bad' etc. etc. He said he'd keep the letters, when I mildly suggested that I thought they were mine he said - no, they belong to the Minister - 'You don't want these things, Dr., you are too big a man for that, - forget it.'".

Klotz refers to Simpson's "savage onslaught" as a 'draft memo'. Someone, the Minister, Mitchell, or the Deputy Minister Cory had referred Klotz' memorandum to Simpson to draft a reply for the Minister. Klotz suspected that it was the Minister himself, but, whichever of the three it was, Simpson had friends in high places. The other half of the mystery, who had "leaked" the documents to Klotz, was never solved.

The money for the surveys was not restored and in March Klotz agreed to the transfer of F.A. McDiarmid, his gravity expert, to the Geodetic Survey.[9]

On March 27 the Minister's office announced the appointment of McArthur as Acting Superintendent of the Geodetic Survey and of Plaskett as Director of the Victoria Observatory. This action implied a decision about the separation of the different parts of the organization, but no general announcement was made about the matter.

A memorandum survives from this period[10] which shows how Plaskett, with Simpson's connivance, managed to attain this independent status. The memorandum is worth quoting completely.

12th March, 1917

Memorandum:

Mr. Cory,

In reply to your memorandum of the 5th instant, I submit herewith a memorandum by Dr. Plaskett in regard to the organization required for the Dominion Astrophysical Observatory at Victoria. So far as I can see, I think his proposed establishment is a good one and in the interests of our Department. His proposal that the new Observatory be given an independent organization appeals to me most strongly.

I can see no more reason why the work at the Victoria Observatory should be directed from Ottawa than that the work here should be directed from Victoria. The work of both institutions is highly specialized, different in character, and should I think be managed, in each case, by a resident director. The title of Chief Astronomer might well be allowed to pass with Dr. King, who was *the* Chief Astronomer and whose position, as I have always maintained, cannot now be filled.

Any attempt to control the work or finances of the Observatory at Victoria by a director of the Observatory here will inevitably lead to friction. It would be the throwing of a wrench into the machinery that is just commencing to revolve under the careful guidance of the practically free hand that has heretofore been accorded to Dr. Plaskett. It was he who conceived and carried out the project, and to have his enthusiasm damped and his efforts for the progress of his life's work hampered by a director here, possibly unsympathetic, and with an imperfect knowledge of his work, would make a most anomalous and undesirable condition.

An independent organization of the Observatory at Victoria as one of the "Scientific Institutions" of the Department of the Interior should create no practical difficulty in the matter of estimates, as all explanations will most likely have to be transmitted by correspondence and might just as well be sent direct to the Accounts Branch.

A similar condition to the one proposed already exists in England, where the Government maintains, independently, the Observatory at Greenwich and the Observatory at the Cape of Good Hope. I am told that the Astronomer Royal at Greenwich has absolutely no jurisdiction over the Astronomer Royal at the Cape, and for many years the latter - Sir David Gill - was by far the more eminent man.

Dr. Plaskett is generally recognized abroad as our most eminent astronomer in Canada, and the esteem in which he is held here has recently been shown by his election, in succession to the late Dr. King, as Honorary President of the Royal Astronomical Society of Canada. His success in building up the astronomical work of this Observatory to its present high standing in the scientific world and his successful management of the new giant telescope appear to me to point to him only as the one who should have direction of its work. To make him responsible to anyone but the Department directly would seem to me to be a serious mistake and a great injustice to him.

The above memorandum was signed by Simpson "for Chief Astronomer". It is interesting to notice that he is replying to a request from the Deputy Minister, which confirms that he was regarded as the Acting Director by head office. Whether Plaskett wrote the memorandum or not he certainly influenced its recommendations very strongly and it is undoubtedly this memorandum and its attached organizational chart, which led to the appointment of Plaskett as Director of an independent Dominion Astrophysical Observatory, on March 27. At the same time the transfer of one of the Ottawa astronomers, Dr. R.K. Young was approved. The decision gave Plaskett complete control of the Victoria observatory, subject to the supervision of the Deputy.

A second example of Simpson's perfidy began to unroll in late April, as Plaskett was preparing to transfer to Victoria. "Mr. Motherwell came to my room to unburden himself, as matters were going from bad to worse at the Observatory. The immediate issue was that Dr. Plaskett was taking and packing up instruments - measuring devices, etc. - for the Victoria observatory which belong here and are needed here."[11] Klotz advised Motherwell to see the Minister or his private secretary Mitchell.

Motherwell did so and reported back that Mitchell was surprised to hear that the instruments were being taken but didn't do anything to correct the situation. DeLury and Cannon joined the discussion and agreed to prepare a memorandum to the Minister, asking that no instruments be allowed to leave the observatory without their specific permission. When Plaskett heard of this proposed memorandum he acted quickly. He showed them a memorandum that he had written to Simpson asking permission to take certain specified instruments; Simpson had approved the memorandum and forwarded to the Deputy who had approved it in turn. Klotz was appalled.[12] "When before was such scandalous proceeding recorded! Consulting the Secretary about the use of instruments in an observatory, and asking for permission for removal without the knowledge of the men who were at that time using the instruments or some of them. The Deputy's action is either out of stupidity or connivance - more probably the latter." Motherwell hurried to see Mitchell who admitted that he knew about the memo and referred him to Deputy Minister Cory; Cory said that he had better get back to the Observatory, that Simpson was looking for him and that he was absent without approval!

The three astronomers locked the remaining instruments in their desks and went to see the Deputy. [13] "In this morning's interview Mr. Cory said that Dr. Plaskett had told him that there was to be *no* astrophysical work done here hereafter and it was on the strength of this statement that he was appointed Director of the Victoria observatory. Motherwell nearly collapsed on hearing this falsehood, and Plaskett knows it to be a falsehood, for the late director Dr. King intended the work here to go on as before, besides he intended to be director of both observatories, Plaskett Superintendent of the western one."

The three astronomers then agreed to prepare a memorandum for the Minister, contesting the assertion that astrophysics was finished at the Ottawa observatory, and documenting the intention which had existed before Dr. King's death that the Victoria observatory should be a branch of the Ottawa one. The three men left the memorandum with Mitchell and took a copy to the Deputy, where they found Plaskett. Dr. DeLury told Klotz what happened.[14] "He was quite elated at the result. The main thing that he showed up Plaskett, before Cory and the other three including Plaskett, to be a liar, as by Plaskett's letter of April 16 he told Cory that the instruments (specified) were not used and no astrophysical work would be done etc. DeLury took delight in repeating before me just how he said it and how he said it - pointing with finger at Plaskett ... Plaskett turned white and couldn't say anything". The battle was won, in theory at least.

Plaskett's understanding of what had happened was quite different. Apparently it had been agreed only that the instruments, particularly the Repsold Measuring Engine, should remain in Ottawa for three months to permit the completion of current work. In mid-1917 Motherwell asked for an extension. Plaskett's reply gives his interpretation of events: [15] "It was distinctly understood and agreed by all parties concerned, at the meeting in the Deputy Minister's office, that you and DeLury were to have the use of the machines for three months. Had I expected that extensions would be asked or difficulties raised, I would not have made this concession, for you know as well as I that the Deputy was about to confirm his permission for me to take the machines."

In most of the controversies between Plaskett and the lesser mortals of the Ottawa staff, my sympathies have been with Plaskett. He was a near-genius bothered by small people, he was carrying a tremendous load almost single handed and the interests of the new observatory were primary in his mind. But in this case I have to agree with Klotz that there was a very definite attempt to destroy astrophysics in Ottawa. With the large budget he had been given for the new telescope it is ridiculous to suppose that he couldn't have bought his own measuring machines. He was just being bloody-minded! He may have been thinking that, without him, there would be no work done in Ottawa. As we shall see, he wouldn't have been far wrong, but the judgement was premature.

A letter from Plaskett to Klotz, about a year later, suggests that Plaskett was not the only one being bloody-minded. Apparently the measuring machine had been sent to Victoria on loan and Klotz had requested its return. "So far as the Repsold Engine was concerned it was purchased by Dr. King at my request for the Astrophysical work, was never used or hardly even looked at by anyone but myself, and I used it constantly for about three years, and it was only upon the prospect of its removal that it was urgently required for some newly projected work. It seems to me scarcely natural to expect that just at the time I am needing it the most, I should think it ought to be returned to Ottawa."[16]

During these carryings on increasing pressure was put on the Government to appoint Klotz as Director. The appointment would have to be made by Prime Minister Borden, with the advice of the Minister, Dr. Roche. Roche in turn was strongly influenced by his private secretary, J.G. Mitchell who, as was quite proper in his position, saw everything in a political light. He certainly believed that the appointment would be politically unpopular. Many prominent Ottawans made representations to the Minister on Klotz' behalf, and told Klotz about it afterwards, among them Ahearn and Soper the engineers and industrialists who owned the Ottawa Electric Railway and one of the power companies. C.A. Magrath, Chairman of the International Joint Commission, interested himself in the matter, approaching both Borden and Roche where he accomplished nothing; he characterized the two of them as "incompetents and cowards".[17] A number of members of parliament, many of them put on by McGrath, visited Roche. The arguments of the members from Waterloo County were particularly telling; they pointed out that to refuse an appointment to one of the most distinguished sons of the large German community there would have very negative political consequences.

Klotz himself finally went to the Minister, first advising the Members of Parliament who were campaigning for him that he proposed to do so "which so far these 15 months I had not done. They approved thereof. - So I called and after waiting his pleasure for nearly an hour I was admitted. I began by saying 'Dr. Roche I have never approached you on my own behalf although others ... have done so on their own initiative and without my knowledge at the time, and from all I subsequently heard the same reply as interpreted from the interview with you 'Dr. don't worry'. This was so far gratifying and satisfactory, but nothing further having been heard, and things at the Observatory are in a most unsatisfactory condition, going from bad to worse, and that it was high time a head be appointed. I told him that a year or more ago a petition was to have been presented by the staff of both buildings requesting my appointment to the three offices held by Dr. King, but was shelved on the suggestion of your secretary (J.G. Mitchell) etc. etc. Dr. Roche said he was surprised to hear that things were unsatisfactory, he thought they were running now smoothly since he had appointed McArthur for the 'season' in charge of the Geodetic Survey. We talked some more and he finally said that he would consult the Premier (Sir Robert Borden) who I said knew me probably better than he (Dr. Roche) did. - And I bade him adieu. - What the upshot will be I know not, anyway I have disabused his mind that things are satisfactory and running smoothly at the Observatory." [18] It seems very likely that the Minister intended to appoint Klotz "at the right psychological moment". [19]

In the meantime, however, as we shall document later, both the Observatory and the Geodetic Survey were in chaos. Increasingly the staff felt that it must do something about it. In early July Klotz reports[20] "Motherwell intends with the other technical officers of the Observatory to send a joint signed memorandum to the Minister stating the situation and requesting the appointment of a head (myself)". A week later[21] "Mr. Stewart gave me a copy of the letter to the Minister to read, which he and Mr. Macara had presented to him this forenoon. ... It covered a little over two pages and set forth the very undesirable situation of affairs at the Observatory, and that silence on the subject was no longer possible in the interest of the Observatory and of the work. It was very well composed and wound up with 'that the appointment as Director of the man who is the logical direct successor to that office, and who has for a number of years filled the position of Assistant Chief Astronomer, would meet with the unanimous support, not only of our own Scientific staff, but we believe, of the scientific world at large'. This splendid memorandum prepared by R.M. Stewart was signed by him, J. Macara, W.E. Harper, C. A. French, D.B. Nugent, W.C. Jaques, Dr. DeLury, J.B. Cannon, R.M. Motherwell, Dr. R.J. McDiarmid, W.A. Dier, D. Robertson, G.D. Gibson, J.D. Wallis - the whole scientific staff". It was also signed by E.A. Hodgson, although Klotz forgot to include him.

This approach to the Minister bore fruit, although not precipitately. Klotz heard the good news first on September 28 when he visited the Deputy, Mr. Cory, on another matter.[22] "I sat down and the first thing he said was 'allow me to congratulate you on your appointment as Director, and may you live long to enjoy it.' - I was almost speechless - I looked at him - grasped his hand and said 'Thank you Mr. Cory'. ... He asked me for the present to keep this to myself as things were not quite ready, or something to that effect." Klotz obeyed this injunction, but the staff found out anyway. Gagnon, a messenger, got a call from "a friend of his in the Accountant's branch ... you've got a new chief - Gagnon asked 'Simpson' - 'No, Dr. Klotz' - I thought you knew, I guess I shouldn't have said anything, and hung up the phone." Shortly afterwards other calls came in as one headquarters official after the other heard the news and passed it on.

The official announcement was made the next day. [23] "At 12:30 Simpson returns to the Observatory, comes to my room and under great obvious nervous tension, congratulates me upon my appointment as Chief Astronomer, which he had hoped for long ago!! 'Thank you, Bert', leaving him to wrestle with his conscience. Then he said - will you be coming to the other room (meaning the vacant Director's) - Yes, I'll be there Monday during mail hours, for your sake (as his room adjoins). - Well, Dr. Klotz, under the circumstances I am going to go over to the other building (geodetic). - As I always stay here Saturday afternoon I might look about the Director's room, desk etc. and you have the keys. ... 'Mrs. King kept the old keys, as she said she wanted to have the pleasure of handing them over to her husband's successor, but I have had a new lock put on! - Can one conceive anything meaner."

"I was now alone in the Director's -my- room, I sat down in the chair of my predecessor, Dr. W.F. King, and a flood of thoughts and memories rushed through my mind. ... I saw the panorama of 32 years unfold itself in clear outline, and I felt - at last the goal of my ambitions, or rather the crowning event of a long life of honest endeavor and work is found in the achievement of the position of DIRECTOR OF THE DOMINION ASTRONOMICAL OBSERVATORY."

Relations with the Geodetic Survey

The question of whether or not to separate the Geodetic Survey from the Observatory was settled by the appointment of Klotz as the Director of the latter, and of the appointments at about the same time of Noel Ogilvie as Superintendent of the Geodetic Survey and of McArthur as Boundary Commissioner. These latter appointments must have occasioned some problems for the Department. There had been five Assistant Superintendents under King - McArthur, Craig, Ogilvie, Bigger and Tobey. From the beginning McArthur opted for the Boundary Commissionership despite the fact that the position was likely to lapse within a few years as the boundary questions were settled. Of the remaining contestants, Klotz regarded Tobey, who was in charge of the mathematical reduction of the observations, as the most able scientist of the group, but recognized that his personality was not very suitable for the senior job. Tobey himself did not so much want the job as he wanted to ensure that Bigger didn't get it. This was an attitude, according to Klotz, that many of the staff shared; apparently Bigger was a most abrasive character, quite incapable of generating any branch loyalty. On the whole, Klotz was initially content with the Ogilvie appointment. "Of real Geodesy Mr. Ogilvie is woefully ignorant although he has done considerable triangulation. ... However he is a pretty level-headed young man and with able assistants and proper treatment of them he will it is hoped make a success of his office. His capacity I know as he passed through my hands in the examination for Dominion Land Surveyor".[24] He was to change this appraisal later.

The first administrative task that Klotz faced was the division of the facilities between the three now-separate organizations. A meeting of the three chiefs was held in Klotz' office.[24] It was agreed that Simpson would go through the files, separating them into three appropriate sections. He not only separated them, he purged the Observatory section of things he didn't want Klotz to see. Klotz was indifferent "for I am more concerned with progressive work than in feretting out infamies".[25] The machine shop, the book bindery, the carpentry shop and the photographic facilities were to remain under the Observatory but were to provide their services to the surveying branches. The maps collected in connection with the boundary surveys, and the cases which contained them, were to go to McArthur. Klotz would supervise a partition of the library insofar as this was possible.

These arrangements were concurred in by the Deputy Minister and continued in operation for many years, despite occasional efforts of Ogilvie to change them. The arrangements for payment for work done had to be sharpened from time to time.

The next problem was one of dividing the budget. The total budget proposed by the three, now independant, directors was

Boundary Survey	$ 60,495
Geodetic Survey	135,000
Ottawa Observatory	34,000
Victoria Observatory	7,500
	$236,995

They were told that the total estimates for 1918 must not exceed the 1917 budget of the earlier branch, $197,000. Klotz and Ogilvie disagreed on how this was to be accomplished:

	Klotz	Ogilvie
Boundary Survey	$ 60,495	$ 60,495
Geodetic Survey	104,505	111,505
Observatories	24,500	25,000
	7,500	
	$197,000	$197,000

Klotz claiming that the reduction should be in proportion to the original estimates, Ogilvie that the Observatories should be reduced to their actual 1917 expenditure. The controversy would not concern us except that the figure of the 1917 expenditures was supplied to Ogilvie by Simpson who was now firmly in the anti-Observatory corner. Simpson (but not Klotz) was summoned to the Deputy Minister's office to discuss the figures and the Deputy Minister thereupon accepted the Ogilvie proposal. Later, when Klotz finally got access to his own files, he found that the 1917 expenditures for the Observatories actually totalled $31,000.

Simpson, the files purged, finally left the Observatory building.[26] "Today Simpson came to my room handed over all the keys of the Observatory that the late Dr. King had and said 'Good Bye'. He told me that he regretted that he knew nothing of the petition by the Technical staff to the Minister asking in the interest of the work and Observatory that a Director be appointed, and requesting that I be appointed, for he said he would gladly have signed it as he had urged my appointment!!! If, that isn't the height of hypocrisy and bare-faced lying! I simply smiled and said 'yes!'"

Other attacks by Ogilvie soon followed, and Klotz sensed Simpson's fine Italian hand behind them. Ogilvie had placed items in his 1918 estimates for Gravity and Magnetics and for Astronomic work, and backed these entries with memoranda to the Deputy, one of which requested the transfer of all transit instruments to the Geodetic Survey, on the grounds that the determination of latitude and longitude was their responsibility. Klotz learned of these memoranda, not directly from Ogilvie, but from the Departmental treasurer, and was able to head them off.[27]

There was no question that Ogilvie was out to build an empire. The Deputy Minister told Klotz in confidence that Ogilvie, supported by W.H. Boyd, topographer of the Geological Survey, had proposed to him that the Geodetic Survey should take over the topographic work.[28] Two years later the head of the Hydrographic Survey complained to the Deputy of rumours that Ogilvie was proposing to take over his Branch.[29] However, problems with the Geodetic Survey were very much reduced in early 1921 when Deville was made a senior advisor, we would now call him an Assistant Deputy Minister, responsible for all surveys in the Department. This meant that Ogilvie had a knowledgeable supervisor. Klotz was very pleased at the arrangement. His only wish was that Deville were supervisor of *all* surveys in the government services, not only of those in the Department of the Interior.

Relations with the Victoria Observatory

The appointment of Plaskett as Director of the Victoria Observatory in late March, 1917, even though it was based on the false premise that astrophysics was dead in Ottawa, implied its separation from the Dominion Observatory in Ottawa. Klotz seems to have accepted the separation. Plaskett paid a formal call on him in October to congratulate him on his appointment as Director and all went smoothly, although Klotz calls Plaskett a "hypocrite" in recording the event.[30] Although Klotz issued an order[31] that nothing was to be sent to Victoria without his permission he later approved the transfer of the Repsold measuring machine on the agreement of the Deputy Minister that he was to order a new one for the Ottawa observatory.[32]

Early in 1919 a serious rift developed over the question of publications. Publications of both observatories had been held up during the war for reasons of economy and there was a substantial backlog awaiting printing. Plaskett submitted a lengthy manuscript by R.K. Young "Tables for Converting Right Ascension and Declination to Latitude and Longitude". The Editorial Committee on Governmental Publications felt that "even to a novice in astronomy the tables have clearly no bearing upon the work of the Observatory" and referred the paper to Klotz for an opinion.[33] Klotz advised that the tables were of much less importance than the research results awaiting release and suggested that the Carnegie Institution might consider publishing them along with the many other mathematical and astronomical tables which it had issued.

When the word of Klotz' interference (not really a fair word since his opinion had been solicited by the appropriate authority) reached Victoria, Plaskett was furious and dashed off a personal letter to the Deputy Minister.[34]

> "I am taking this opportunity of expressing my feelings in regard to Dr. Klotz's endeavours to belittle and discredit the work here, some of which you have probably noticed. I resent Dr. Klotz being consulted about any of the affairs of this observatory. In the first place he has no personal knowledge of the work or methods as his astronomical training was along an entirely different line; secondly he has no sympathy with astrophysical work, especially if done here; and finally his actions show he must be jealous of the institution and its equipment and opportunities. Under such circumstances you can imagine how reliable an opinion he would be likely to give on any matter connected with this observatory. As I understand it, the components of the Astronomical Branch, the two observatories and the Geodetic and Boundary Surveys, are on the same footing, their chiefs of equal status. In that case Dr. Klotz has no more right to pass judgement on the work of this observatory than I do to decide on the merits of the work at Ottawa, and I emphatically protest against his having any chance to burk or belittle the work at Victoria. I would very much like to be on friendly terms with him and to have the observatories cooperate in a friendly spirit, which would be very much to the advantage of both. Immediately after Dr. Klotz's appointment I congratulated him cordially and expressed the hope that we might work together in a friendly way. There is no reason for any rivalry, the work of the two institutions does not need to clash in any way, and goodness knows there is plenty of work for both to do. But this matter of the publication is not the only example of his methods which I have noticed and I am sure you will have seen others. I suppose I need not be surprised after Dr. King's experience, of which you probably know more than I do, but I think it is a pity there can not be a spirit of friendly cooperation."

It is clear from the foregoing that there is another point of view on the King-Klotz difficulties than that expressed in the Diaries.

Plaskett followed his personal letter to the Deputy with an official memorandum:[35]

> "I would point out further that apparently Dr. Klotz's opinions in regard to the relative importance of research and tables have undergone a complete reversal in three years. There appeared, in 1916 in Vol. III, No. 2, Publications of the Dominion Observatory, Seismological Tables by Dr. Klotz. These were avowedly, according to the foreword, 'a compilation or collection' and were intended to serve a similar purpose to those under discussion, namely to save computational labor. They were, at his insistence, given precedence over original research work of the observatory whose publication had been commenced before these tables were handed in. Moreover, one third of these tables were a repetition of Vol. 1, No. 1 of the same publications only a few columns corresponding to more stations being added."

Plaskett not only castigated Klotz, but he got his claque - "four of the most eminent astronomers in America" to write in favour of the publication of the tables. All was to no avail; the Deputy insisted that the Carnegie Institution be asked to consider their publication.

One matter of potential discord was settled to the satisfaction of all. In September 1919 the Deputy Minister had decreed that the observatories were to be known as "Dominion Observatory (Ottawa)" and "Dominion Observatory (Victoria)".[36] When the first publication from the Victoria observatory reached the Editorial Committee of Governmental Publications, they objected to the arrangement, apparently on the grounds that it did not make for an attractive Publications title page. A new directive was issued.[37] "It has been finally decided to make the name of the Observatory at Victoria 'The Dominion Astrophysical Observatory'". This was a happy arrangement, agreeable to all.

A very much more serious matter began to develop in mid-1920. The Minister called for a reorganization of the Department, one aim of which was to reduce, through consolidation, the number of Branches by 50 percent. The task was given to an Advisory Technical Board which seems to have been made up of all the Branch Directors; certainly Klotz, McArthur and Ogilvie were on it. At a meeting in mid-July Klotz was asked why the Dominion Astrophysical Observatory was not under the Dominion Observatory. "I gave in a few words the genesis of that Observatory, that it was to be a branch of the Dominion Observatory but the untimely death of Dr. King and the following year of chaos brought about the appointment of Dr. Plaskett as director at Victoria." [38] A committee, not including Klotz, was appointed to report on the matter. This committee eventually made a strong recommendation that the two Branches should be consolidated.

The Deputy Minister, Cory, wrote a personal letter to Plaskett,[39] telling him of this recommendation, saying that its acceptance was almost inevitable and asking him for any suggestions "so that we could avoid making this move an undue hardship on you." This letter, unfortunately went astray, and Cory sent a copy some weeks later.

Plaskett went into action: he sent a telegram of protest[40] in which he asked that a decision be postponed until May when he was planning to be in Ottawa; he wrote a three-page memorandum[41] and accompanied it by a long personal letter to Cory;[42] he wrote to five distinguished scientists[43] asking them to write to Cory giving their evaluation of the work of the Victoria Observatory and their opinion of the proposed amalgamation.

Both in his memorandum and in his personal letter to the Deputy Minister Plaskett stressed the impossibility of supervising the work of the Victoria observatory from a distance of 3000 miles and the complete incompetence of Klotz to do so. A pertinent paragraph of the memorandum follows.[41]

> "Even more absurd does the proposal seem when the records in scientific work of the two institutions are contrasted. Comparing in the first place the work of this observatory with other large observatories doing similar work. The radial velocities of 570 stars have been determined and nearly 150 spectroscopic binaries have been discovered at this observatory in less than three years. In the five or six of the largest observatories in the world engaged in similar work for from 10 to 25 years there have been obtained altogether the velocities of about 2000 stars and about 600 binaries have been discovered, only 4 times the number obtained here in 3 years with a very small staff. This record is absolutely unapproached by any observatory in the world and one of which Canadians may well be proud. Comparing in the second place the records of the two Canadian observatories, which may best be done by the publications issued, this observatory besides the major work above described has issued 20 separate publications each of high class while 5 more are in press. In the same times, to the best of my knowledge, the Ottawa observatory, *with a five fold greater staff*, has published 23 numbers of which only one has been prepared by the present staff, 16 being prepared by two members of my staff before their transference from Ottawa and 6 by Mr. Cannon transferred to the Geodetic Survey in July 1919. While undoubtedly other valuable work has been done at Ottawa, this comparison surely suffices to show the very high plane on which the work is being conducted here and to indicate the absurdity of supposing that any increase in efficiency can be effected by the supervision of a Chief Astronomer whose undivided attention is evidently required in Ottawa. On the contrary interference from such a source is bound to result in decreased efficiency and in loss of the high morale so strikingly in evidence at this observatory."

The five distinguished scientists - J.C. McLennan, University of Toronto, S.A. Mitchell, University of Virginia, Sir F.W. Dyson, Astronomer Royal, Greenwich Observatory, H.F. Newell, Cambridge University, George E. Hale, Mt. Wilson Observatory - all came through, as requested, with supportive letters, but all was in vain. On May 25 a special meeting of the Advisory Technical Board was held to give Plaskett an opportunity to protest against the proposed re-organization. Plaskett came armed with copies of all their publications and photographs of the observatory, three of the supporting letters, from Hale, Mitchell and McLennan were read by the Chairman, and Plaskett addressed the meeting for thirty minutes. [44] The sense of the meeting was expressed by J.B. Challies that "with all the evidence submitted he still held that the responsible and visible head should be in Ottawa as is the case in all other branches." The diary continues "I was glad when Challies informed Plaskett that Dr. Klotz had nothing to do in this movement for coordination. Plaskett replied 'I'm glad to know that'". A vote was called, Plaskett being invited to vote, and the reorganization was accepted by a vote of 9 to 2, Plaskett and Ogilvie being opposed.

A few days later Plaskett and Klotz met in Klotz' office to define the new relationship.[45] Klotz invited Plaskett to draft the agreement. The next day[46] Klotz persuaded him that his draft was too verbose and got him to agree to a simple statement "leaving the scientific work wholly in his hands, while administration and all official correspondence was to go through me."

The two Directors jointly signed the following memorandum.[51]

MEMORANDUM. 31st May, 1921.

Mr. Cory:

In conjunction with the resolution of Advisory Technical Board recently passed confirming the former one of August 1920 with reference to the administration of the Dominion Astrophysical Observatory at Victoria, we beg to recommend that the administrative functions, apart from the scientific investigations and researches, be, for the convenience and to meet the desire of the Department, placed in the hands of the Director of the Dominion Observatory at Ottawa, through whom all official correspondence shall be made.

The scientific programme to be wholly in the hands of the Director of the Dominion Astrophysical Observatory, who however will keep the Director of the Dominion Observatory informed of the programme of work so that the latter can at any time furnish instant information when required to the Department.

Respectfully submitted,

Director Dominion Observatory,

Director Dominion Astrophysical Observatory.

Mr. W.W. Cory, C.M.G.,
Deputy Minister of the Interior,
Ottawa.

Plaskett still didn't quite trust Klotz. He sent *his* draft to Cory as a Memorandum.[48]

MEMORANDUM,

Mr. Cory.

In order to avoid future misunderstanding, this joint memorandum places in concrete form the arrangement arrived at by the directors of the observatories at Ottawa and Victoria in regard to the coordination of the administrative affairs of the two institutions.

It is agreed that, -

1. All official correspondence and all requisitions for apparatus and supplies previously made direct to the department from Victoria shall, in future, be carried on through Dr. Klotz, the director of the Dominion Observatory, Ottawa, who will thence be in a position to give any additional information required about the Dominion Astrophysical Observatory and to act in an advisory capacity with the department;

2. Appropriations for the two observatories are to be allotted separately as at present and each observatory, subject to the approval of the Deputy Minister, is to be entitled to the use of the full amount allotted to it.

3. General maintenance expenses at Victoria are to be met from advances to the director, as at present, and accounted for by him.

4. The names of the two observatories and the titles and forms of their respective publications already well established are to remain unchanged.

5. Each director is to have independent control of the programme of scientific work, of the personnel, activities and discipline of the staff, and of the editing of the

publications of the respective observatories as hitherto, but will, at the same time, be ready to cooperate and coordinate the work where possible and advisable.

The spirit and purpose of these conditions is to make the coordination of the administrative affairs of the two observatories beneficial to the progress of astronomy in Canada without limiting the independent scientific control so essential to the true progress of research.

Respectfully submitted,

Only the second item was changed with the passage of time; under later administrations the estimates of the Dominion Astrophysical Observatory were subject to the total requirements of the Branch, although each observatory continued to be entitled to the use of the full amount allotted to it.

Problems of Personnel

Relations with the Geodetic Survey and with the Victoria observatory, and the administrative modifications that these entailed, were matters forced on Klotz by circumstances and were not necessarily part of his management philosophy. What was this philosophy?

Klotz welcomed the loss of the surveying function and was prepared to accept the existence of the Victoria observatory as a separate entity, but he was not prepared to lose the other field disciplines - gravity, magnetics, longitude determinations - to the one or to leave the scientific honours to the other. The problem however was one of staff. Plaskett was pressing for the transfer of all those engaged in stellar spectroscopy and if that work was to continue in Ottawa, even on a limited basis, new positions would have to be established and new astronomers attracted. His gravity observer had been transferred, with position, to the Geodetic Survey and his seismologist had never been made permanent (transferred from the "outside" to the "inside" service in the jargon of the day) and was considering resignation. Ten of his staff were on active service overseas and many of those that remained were, in his view, incompetent.

First, the astrophysicists. There were five of these: Plaskett, Harper, Cannon, Parker and Young. Of these, Plaskett had been lost to the work of the Ottawa observatory from the time that the new telescope was approved, and Young made the transfer early in 1917, during the hiatus between King's death and Klotz' appointment. Parker was overseas. Plaskett pressed for the transfer of Harper throughout 1918 but accepted the fact that Cannon was reluctant to make the transfer. "Unless he wants to come out here for the work's sake, I do not wish his transfer, as I wish my staff to consist only of enthusiastic workers".[49]

Harper was somewhat reluctant to transfer. He had a fine new house on Fairmont Avenue, a young family, and a chance to become number one in Ottawa astrophysics. On the other hand he recognized the opportunities for important work with the new telescope. Pressure was applied. The Deputy Minister received a letter from the Member for Esquimalt urging the transfer. "The letter was undoubtedly written by Dr. Plaskett, for the details about astronomic work - radial velocity work could be written by no other than Plaskett".[50] Harper felt that he should receive an increase in salary and wanted to be named Assistant Director. Plaskett said that his salary was adequate and that there was no justification for an Assistant Director in a three-man establishment. Finally the Deputy Minister agreed that he should be paid a housing allowance of $50 a month. This convinced him. Klotz agreed to the transfer[51] and in April, 1919, Harper left for the coast.

Cannon not only declined to move to Victoria, he asked to be transferred to the Geodetic Survey and when Parker returned from the wars in May, 1919 he made a similar request. Klotz gives no reason for their defection. Were they unwilling to work under his direction or did they realize the limitations imposed by their small telescope? In any event they were gone by mid-1919.

However, replacements were at hand. In February, 1919,[52] Klotz was assigned a new position for an astronomer and the competition was won by C.C. Smith. [53] Smith had been on the staff in the early days of the Observatory, but had left to return to private practice as a surveyor; he now returned to the staff where he had a long and distinguished career. In June[54] Klotz arranged for a new permanent position for an assistant astronomer. The position was won by a young Toronto astronomer, J.P. Henderson. Next[55] he recruited Dr. F. Henroteau "a Belgian but who has been in the U.S. for the past four years at the Lick Observatory, at Ann Arbor and recently at the Allegheny Observatory at Pittsburgh. He has had a good deal of experience in spectroscopy and parallax work, especially the former". Henroteau and Henderson went to work on the 15-inch equatorial, joining Motherwell who continued his photometric work. Smith joined the group in positional astronomy, led by Stewart, (who was given the additional responsibility of Assistant Director in early 1918) which included D.B. Nugent, R.J. McDiarmid and, still on military service, W.S. McClenahan and E.C. Arbogast. DeLury continued with the solar work, assisted, on his return from military service, by John O'Connor. By the end of 1919 Klotz could feel some security in his astronomy staff although he recognized that not all of them were pulling their weight.

In geophysics things were much worse off, and this in spite of the fact that geophysics had been Klotz' responsibility from its inception. His gravity observer had transferred to the Geodetic Survey, he had in C.A. French a well-trained and productive observer in magnetism, and in E.A. Hodgson a discontented seismologist. Hodgson had joined the service as a temporary (in "outside" service) in 1914 with the promise of a permanent position and increased salary in the immediate future. In 1919 he was still waiting for the permanency and the raise; in the meantime he had built a large house and acquired a large mortgage in anticipation of the event and he was over-extended. He accepted a position in the Toronto Technical School; Klotz saw the Deputy and got the promise of a $200 retroactive raise; Hodgson got out of his Toronto commitment; six weeks later the raise hadn't materialized and Klotz found that the Minister had killed it without letting him know; Hodgson accepted a three-week appointment as a supply teacher in the Galt Collegiate Institute; Klotz saw the Minister and got the $200 retroactive raise approved; Hodgson, unimpressed, accepted a permanent position as Mathematics Master at Galt and sold his house.

Once the horse had been stolen the Department acted with dispatch in locking the door. The Minister approved a position in the "inside" service for a seismologist and a competition was arranged. Hodgson was invited to apply but declined and the position was won by a Dr. R.C. Searle, who then declined the offer; he had accepted a position in the Department of Physics at the University of Western Ontario. Another competition, another winner - C.S. Allin - another refusal. A third competition, a third winner - W.G. Spencer - an acceptance! But Spencer proved unsatisfactory in the job and had to be let go. Finally, with the records piling up and bulletins unissued, a deal was struck.[56] Hodgson was to be paid $50 per month for reading the seismograms and preparing a bulletin, a new position of senior seismologist with a salary range of $2400-$3120 [Hodgson had been making $1600] was to be established, the position to be held open for Hodgson until the end of the school year.

Hodgson won the competition but made some conditions which Klotz doesn't detail but describes as "impossible".[57] According to family tradition these included:

(i) Hodgson was to be named head of an independent division.

(ii) He was to be exempt throughout his career of any need to "sign the book" to register his attendance.

(iii) He was to be granted leave with pay to pursue a PhD.

Klotz reports[58] seeing the Chairman of the Civil Service Commission who said he would do what he could. Again, family tradition has it that the Government capitulated. Certainly Hodgson never again signed the book until Beals became Director, and then only as a favour to Beals.

Hodgson was back on the job by early July, 1920.

It may be mentioned here that Hodgson's stipulation that he be granted educational leave with pay was met. During the summer of 1921 he attended summer school at the University of Chicago, and he was a full-time student at Saint Louis University from 1930 to 1932, earning his PhD. This was the beginning of the Observatory's very satisfactory programme of educational leave.

Meantime other recruiting had gone more smoothly. A position was established for a Gravity expert and for Assistants in Magnetics and Seismology. Klotz was particularly pleased about the Gravity position. [59] "I receive the cheerful news that the Minister has authorized the appointment of a Gravity Specialist for the Observatory. This is killing two birds with one stone - I get the specialist and the Deputy gets a good position for a protégé of his - a Manitoba man - Mr. E.H. [*sic*] Miller who again calls on me. He impressed me favourably - is an honor graduate in mathematics and physics, a Rhodes Scholar, has put in 3 years at Oxford two years in post graduate work in Physics at Madison and has a very good and honourable war record."

Boards were held for the new positions and were won by A.H. Miller, in gravity, B.R. Hooper in magnetics and W.W. Doxsee in seismology. The diary says nothing more about Hooper but a year later,[60] "Our new assistant magnetician Russell Madill B.A. assumed his duties. He seems a 'likely' young man." In the meantime Major J.A. Pearce spent the summer of 1920 as a field magnetician. After attending graduate school Pearce joined the staff of the Dominion Astrophysical Observatory where he had a distinguished career, ultimately becoming Director.

Klotz gives fewer details about the support staff, but there was substantial reorganization here. He forced retirement on his photographer, J.D. Wallis, who had been very satisfactory but who, at 83, was slowing down, and on J. Macara, the late Dr. King's brother-in-law, aged 66, who had been incapacitated for months with sciatica. Apparently retirement at 65 was not mandatory; Klotz himself was 67 at the time. He arranged transfers for some of his incompetent support staff, got Orvill Sills established as Secretary, a position he held until the arrival of Dr. Beals. L.P. Christensen won a competition as Assistant Machinist.

These arrangements were complicated by the return of men from overseas; they had "veteran's preference" and, while the return of many of them was anxiously awaited, others had a long history of incompetence and had to be, somehow, shunted off to other branches. With one or two exceptions he accomplished this successfully. It is also interesting to record that the first woman to work in the Observatory worked for one day, in 1919, as a replacement: "Both my typists are now laid up in bed so that I had the loan of a Miss Macdonald to do some typing - the first time a woman ever typed in the Observatory."[61]

It will be apparent from the foregoing that the question of promotions and classifications was still handled in a pretty unprofessional way, with little standardization. The Civil Service Commission was in place but not necessarily in control, but it was trying to do something. A Committee for the Reorganization and Classification of the Outside Service was in operation by early 1918. "Great good could come from this committee in unifying salaries for similar services".[62] The newly-formed National Research Council, which was not controlled by the Commission, was taking the lead in trying to standardise the salaries of senior management. These attempts were not very productive however and the problems of reclassification and salary adjustment were tedious and time consuming. Klotz had another problem: there were a substantial number of unproductive people on the staff, both at the professional and support level, and he was not very successful in weeding them out even when the Prime Minister ordered a staff reduction. "I have some timber at the Observatory which I want to get rid of, but fear will have difficulty - 'what does it matter to you - you are not paying the salary he is a decent fellow and has a family to support' such is a statement one meets. Friends will intercede, the wife may come and beg. - It is easier for the Prime Minister to issue an order for weeding out, than it is for Chiefs to wield the axe."[63]

One solution was to raise the salaries of the good workers and to leave the drones where they were, but attempts in this direction always led to appeals, particularly by returned soldiers who were supported by their veteran's association. Even if their appeal was lost, the bad feelings that were engendered continued to make life difficult for everyone.

Building and Grounds

Almost immediately on becoming Director, Klotz and his wife, Marie, considered moving to Observatory House. They visited it on two occasions and Marie was not much impressed. He sought funds for its refurbishing. "One thing is certain - the house will be made decently habitable - no frills - or else I'll remain in my cosy house at 439 Albert Street in town." [64] In fact, decently habitable or not, Marie didn't want it, and it was agreed that the Assistant Director, R.M. Stewart, would move in once the refurbishing was complete. This was accomplished, and the move made late in 1919;[65] immediately an additional list of improvements was submitted.

All was well until the cold weather started. The house was completely un-insulated and inadequately heated and when the exterior temperature got to -20°F, the interior temperature would drop to 45°. This was not a new matter. The Kings had found the house very cold despite burning as much as 27 tons of coal a year. But Stewart had four small daughters, one of them seriously ill. A second furnace was requisitioned and refused. Stewart decided to put electric heaters in the more frequented rooms but found the wiring inadequate. This was apparently rectified before the winter of 1921-1922. Mr. Stewart continued to occupy the house until the arrival of Dr. Beals.

The need for increased space for the Observatory staff has been a continuing problem and it is interesting to learn that King was pressing for "a one storey addition on the east side of the building", essentially for library purposes, in early 1914.[66] The addition was approved, plans prepared and the money voted but over-runs on the Geodetic Building meant that the money had to be deflected there. Then the war intervened and the addition was postponed.

By 1920 the library had extended itself into the hallways and the "bookstacks in the library itself are so crowded, that the Chief Architect some time ago on inspection compared the narrow passages to 'rabbit warrens'".[66] The re-scheduling of the addition became a major item in Klotz' plans.

In fact the addition was never made but the project came into conflict with the building programme at Victoria and led to some acrimony. The original plans for the Dominion Astrophysical Observatory had called for an office building, a house for the Director and four houses for the observers. Of these only one observer's house had been built and it was occupied by the Director. Plaskett pressed for the completion of the building programme; in addition he wanted a tennis court which, on account of the

(Left) The sundial, with its planting.

(Below) A view to the north-east from the Observatory roof, taken in the mid-1920s. The "red barn" in the foreground housed the standards laboratory of the Geodetic Survey, in which their chaining tapes were calibrated. The tall mast is one of those built about 1922 to support the antenna used in the receipt of time signals. The small white building housed the Ottawa magnetic station; the machine shop is seen behind it. Under a magnifying glass, the small figures to the left of the machine shop are seen to be playing horseshoes.

unevenness of the terrain, would have to be made of wood planking.

None of this work had been done by the time the Victoria Observatory reverted to the administrative control of the Ottawa one, so that it became a matter for Klotz' decision. No one questioned the need for a proper office building. The three astronomers were working in the Observatory building itself, in cramped quarters beneath the observing floor. The space was inadequate, lighting was inadequate, and the need to heat the quarters in winter had an adverse effect on the instruments on the floor above. The need for housing was less clear; Plaskett was occupying the house, already built, destined for one of the astronomers, Young was living in the city and getting back and forth by a trolley which passed the foot of the hill; Harper could do the same. Klotz therefore recommended the Victoria office building as a top priority but insisted that the Ottawa extension should come before the additional housing. His attitude was not appreciated by Plaskett. In the event, of all the proposed construction, only that of the Victoria office building was carried out, and that not until 1924.[67]

One other matter of grounds maintenance remains, that of the sundial at the front of the Observatory. This had been designed by Klotz and it had been understood that the areas between the hour lines were to be occupied by flowers. This apparently had not been done. One of his first acts after becoming director was to visit the government greenhouses in Majors Hill park. He chatted up the green-house keeper, gave him a cigar, and ensured a free supply of plants for his sundial.[68] I recall that in those early days it made a splendid display!

DOMINION ASTROPHYSICAL OBSERVATORY

By the end of 1916 the telescope and dome were in place, awaiting only the arrival of the mirror. Plaskett returned to Ottawa leaving T.T. Hutchison, who had been hired as an engineer to assist in the construction, and who was to remain for many years as an observing assistant, in charge.

The mirror was not completed until April 1918. It was then shipped, by rail, in the cast iron cell in which it had been ground and arrived six days later. In another week it had been installed and the first star spectrum obtained "which is, I think," says Plaskett, "a record-breaking performance for such a large telescope".[69] The first plate was taken on May 6, 1918.

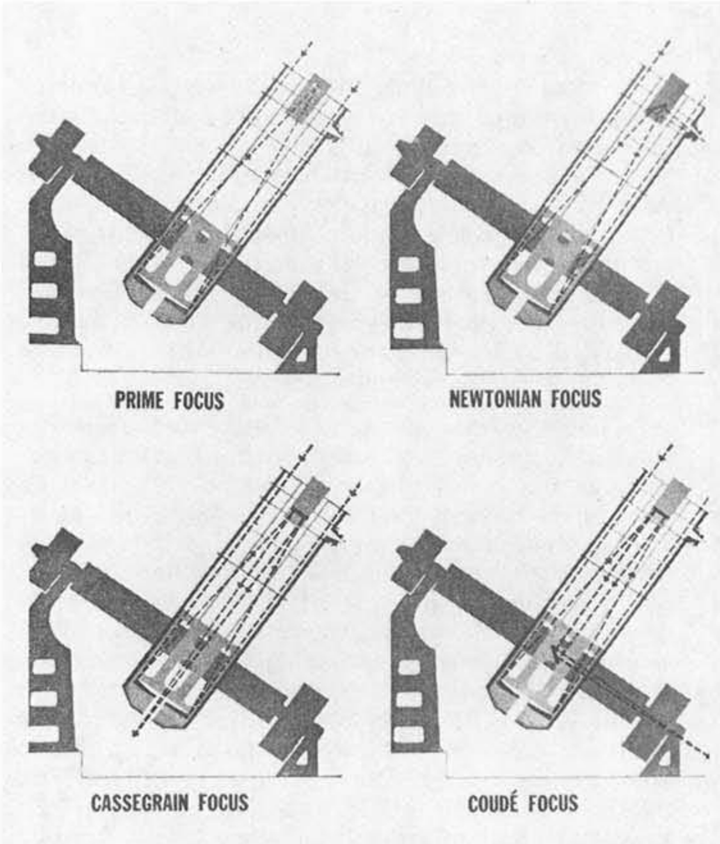
The telescope and its auxiliary equipment are described very clearly by Plaskett and there is no point in attempting any detailed appraisal here. The design was conventional. "It did not seem wise in a large instrument like this to introduce any untried features unless with a surety of improvement." One modification that was introduced was in the bearings supporting the polar and declination axes. Ballbearing races were used here, for the first time in a large telescope. Another innovation concerned the method of inter-changing the several mirrors needed to convert from one operational mode to another. In conventional design the upper end of the telescope had a number of removable sections, each with its own mirror. The new telescope had a fixed upper end and a device for interchanging the mirrors themselves.

The design of the spectrograph attracted a great deal of Plaskett's attention. We saw earlier that, for radial velocity work, flexure of the spectrograph must be kept to a minimum. To accomplish this the universal form of spectroscope in use at most observatories, which could be used with different dispersions and at different regions of the spectrum, was abandoned in favour of a rigid fixed form in which one, two or three prisms could be used with appropriate cameras. This spectrograph was supported in a very rigid box which was in turn covered with a temperature case. This case, lined with 1/2 inch felt, was heated by three different circuits of wire attached to the felt, the circuits being used in any required combination to maintain the desired temperature. Tests of the instrument showed that flexure and temperature variation could have only a negligible effect on the radial velocity results.

The actual construction of the spectrograph might have been delayed due to the war, because the glass which Plaskett wanted for the prisms was manufactured in Germany and was unobtainable. Fortunately the University of Toronto had a prism of the proper size made of the desired glass and Professor Chant lent this to Victoria. After the war the three prisms became available but because the radial velocity work did not require the two- or three-prism mode, they were not immediately installed.

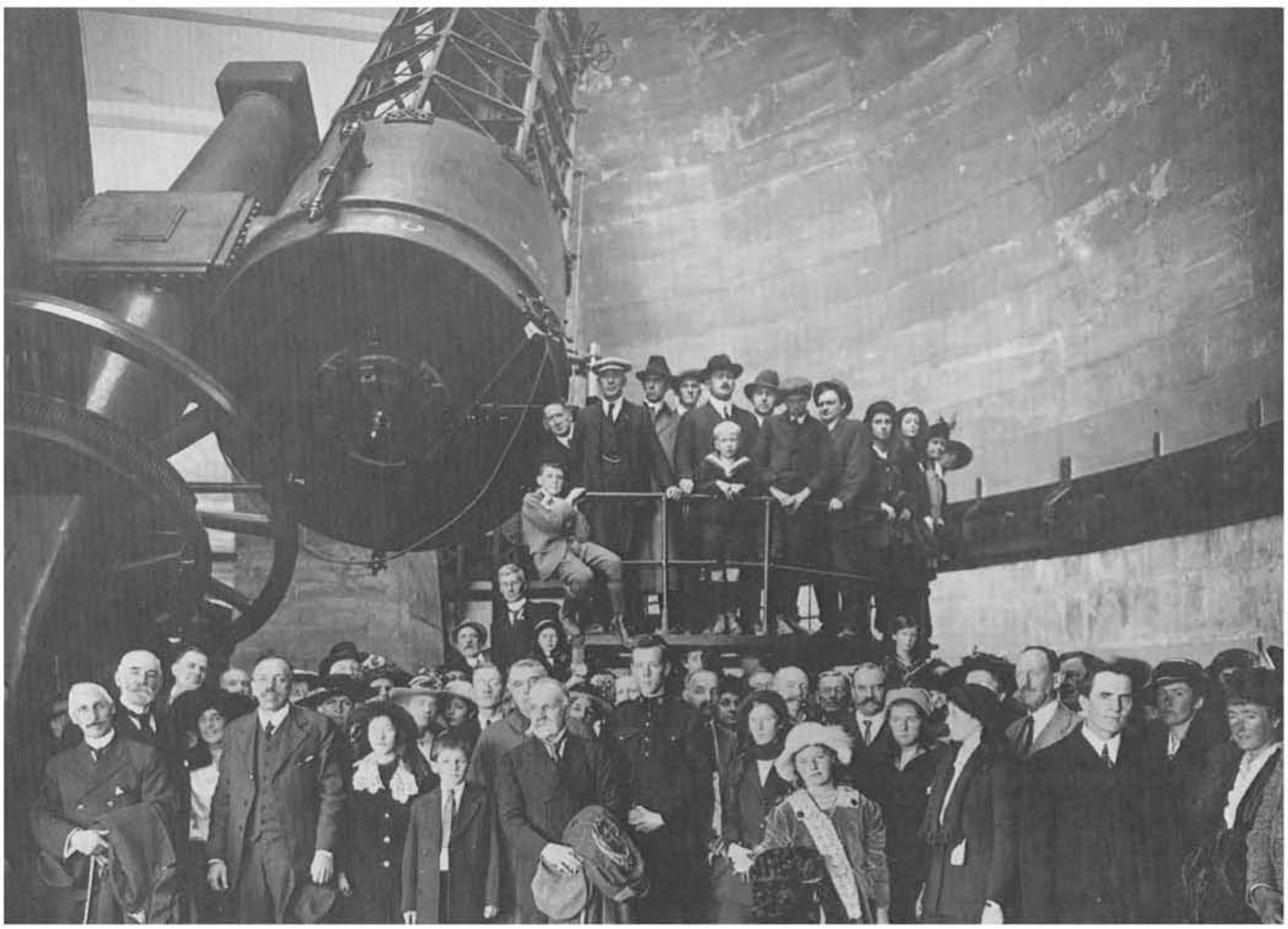
Early in 1922 an ultraviolet spectrograph was received; this instrument was installed at the prime focus. It does not seem to have been much used in the period under review.

An informal opening of the new observatory was held in mid-June, 1918. The date was dictated by an astronomical phenomonon, an eclipse of the sun which was to be total in the State of Washington, about 150 miles south of Victoria. Because many astronomers would be in the area, Plaskett suggested that they be invited to Victoria to see the new telescope. This was done, and in a letter to Cory, Plaskett reports: [71]



(Left) The various operational modes of a reflecting telescope. The Victoria 72-inch telescope could not be used in the Coudé configuration. From Baker [73]

(Below) The opening ceremonies of the Dominion Astrophysical Observatory. Plaskett is the gentleman, fifth from the left in the front row, holding his hat. National Archives of Canada, PA 149323.



"There were short addresses by Dr. Campbell, Director of the Lick Observatory, and by Drs. Brashear and Swasey, who are eminent scientists as well as the Presidents of the firms who built the telescope. There were also introductory remarks by myself and a short dedicatory address by the Lieutenant Governor, who at the close of the addresses, and as representative of the Crown, declared the Observatory open for its work.... The guests, who included the members of the Provincial Government, the chief representatives of the Dominion in Victoria, and other prominent citizens, then had the opportunity to look through the telescope, and were served with light refreshments."

This is perhaps a suitable place to mention one very serious omission in Plaskett's planning: he did not provide for a machine shop, nor for a machinist. He apparently thought that the spectograph which he had designed would last forever. Throughout his Directorship, any necessary shop work was done in the city by S.S. Girling. After Plaskett's retirement, a shop was set up and Girling hired, although originally as a night assistant (K.O. Wright, personal communication).

Despite the opening, the Observatory was not in full operation. Plaskett and Young, who had been on location from the time the telescope became operational, could not keep up with the full potential of the instrument and it took some time to get additional staff. Plaskett was anxious to have Harper join him, but, as we have already seen, this was not accomplished until April, 1919. Plaskett's son Harry who, after demobilization, had taken a short course under Professor A. Fowler at the Imperial College of Science, London, joined the staff in October 1919. These four astronomers, with the support of a Clerk-Stenographer and a Caretaker-Chauffeur were the entire staff of the Observatory throughout the Klotz Administration. Shortly before Klotz' death in 1923 extensive negotiations were under way for the transfer of Dr. R. J. McDiarmid from the Ottawa staff. We shall return to this matter later.

The amount of work they got through is incredible! In a memorandum to the Deputy Minister in February, 1921[72] Plaskett states that, considering the different times at which the various astronomers joined the staff there had been 102 astronomer-months worked in the 33 months since the commissioning of the telescope. During this period 5500 stellar spectrograms were obtained and 5200 measured and reduced; the radial velocities of 450 stars were determined; 140 spectroscopic binaries were discovered and the orbits of 18 of them were computed. By the time of Klotz' death almost two Volumes of the Publications of the Dominion Astrophysical Observatory had been published, totalling 46 separate papers. Most of the results were published in addition in the Journal of the Royal Astronomical Society of Canada. This duplication, which would be frowned on today, was probably requested by the Journal for which the sources of material were then very limited.

The programme of radial velocity measurements was not a random one. After consultation with other astronomers working in the field some 800 stars were selected from BOSS' Preliminary General Catalogue. The stars selected were in the magnitude range 5.5 to 8.0 and their proper motions, that is the motion at right angles to the line of sight, had all been determined. By measuring the radial motion it would then be possible to establish their true motion in space. The programme was planned jointly with Mount Wilson, the only other observatory with a sufficiently powerful telescope, and it was pursued with great energy, Plaskett and Young being involved from the beginning, Harper and H.H. Plaskett from their arrivals on, respectively, April 22 and October 4, 1919. The results of the Victoria section of the programme were given in a paper "The Radial Velocities of 594 Stars".[73] In the course of the work a large number of binary stars were discovered.[74]

Almost all of Volume 1 of the Publications, and much of Volume 2, is taken up with analyses of binary orbits. There are three levels to which these studies may be taken. When the spectrum of only one of the stars is available it is possible to compute the period and eccentricity of the relative orbit, the maximum orbital velocity and the velocity of the centre of mass, but the actual dimensions of the orbit depend on its inclination to the line of sight, normally unknown, and the total mass of the system is a function of the inclination and of the ratio of the two components, again an unknown factor. When the spectra of both components are available it is possible to reduce the complexity to one involving inclination alone and this may be regarded as the second level of sophistication. When the inclination of the orbit is known, which it may be in the case of visual binaries, or when it is zero as in the case of eclipsing binaries, all the properties of the orbit, the masses and densities of the orbiting stars and the distance of the system, may be obtained. This is obviously of the utmost importance in providing direct measurement of stellar masses.

Seventeen of the binaries studied in the first two volumes of the Publications belong to the first level, where only a single spectrum is available, and where it is possible to determine the dimensions of the orbit only in terms of the angle of inclination and the total mass as a function of the mass ratio. Eight of the studies were based on the spectra of both components and involve the inclination as the only unknown. Finally eight of the papers were of the third level of sophistication and provided complete solutions. It is a curious fact that all of these papers are by the Director, curious in view of the fact that each investigator was supposed to have priority on the binary stars which he had discovered. Perhaps these were not stars in the principal programme.

On the completion of this initial programme a second one was drawn up involving some 1500 stars in the magnitude range 5.5 to 5.6 but, as Plaskett puts it[75] "it was felt desirable, before actively undertaking a programme of this magnitude, to finish up some smaller pieces of work which had arisen in the course of the previous programme". These "smaller pieces of work" became larger and larger as they were pursued and, as far as I can find, the second, formal, programme was never seriously attempted.

One of these studies was made by Young. It had been known for several years that certain spectral lines, the H and K lines of calcium, did not always shift backwards and forwards as the stars in a binary rotated about each other. Young made a study of stars which showed this peculiarity and showed that they all belonged to the same spectral class, B, and he speculated that the phenomonon was due to a cloud of gas of limited dimensions surrounding the star and typical of stars of that particular temperature.[76]

What are "spectral classes of stars"? About 1885 Harvard Observatory began to study and classify the spectra of large numbers of stars by placing a prism in front of the telescope lens so that, instead of points on the photographic plate, one found small spectra of the brighter stars. It was found that these spectra formed a continuous sequence characterized particularly by the rise and decline in the strength of the hydrogen line and by the appearance of the lines of other elements at different stages in the sequence. The types came to be known by the letters O,B,A,F,G,K and M and there was a decimal separation between the classes so that B5, say, was half way in character between B and A while B8 was much closer in characteristics to A than to B.

At the time of which we are writing it was generally believed that the sequence from O to K represented an ageing of the star, and O type stars were called "early", G, K and M "late". Later it became clear that as a star matured its maximum temperature was limited by its mass and that mature stars might fit directly into any position in the sequence; the terms "early" and "late" do not necessarily have an exact meaning, but they continue to be used. The sun is a star of class G2 and stars of class G are sometimes referred to as Solar-type stars.

Modern values of the temperature of the various classes are as follows:[77]

O5	50,000°K
B0	25,000
B5	15,600
A0	11,000
A5	8,700
F0	7,600
F5	6,600
G0	6,000
G5	5,520
K0	5,120
K5	4,400
M0	3,600

The excitation and eventually the ionization of the atoms in the stellar material increases with increasing temperature. It is this which leads to changes in the spectrum, and in turn it is the spectra which allow the determination of temperature.

The O-type stars are of particular interest since, because of their high temperature, they provide conditions that cannot be met in the laboratory. This aspect of the stars particularly appealed to H.H. Plaskett, whose interest in astrophysics was that of a spectroscopist rather than an astronomer. In 1922 he published a paper analysing the spectra of three O-type stars in great detail, explaining the lines found in terms of the current theories of atomic physics and using them to deduce the physical conditions within the stars.[78]

Two years later J.S. Plaskett reported on an extensive programme in which the spectrograms of 80 suspected O-type stars were obtained, the spectral class adjusted where necessary, and the radial velocities of 47 O-type stars (and of 23 B-types) measured.[79] A principal problem of these stars is that their spectra contain very strong H and K absorption lines; a widely distributed and nearly stationary gaseous medium containing ionized calcium, through which the stars moved, was proposed to explain these lines. The paper also includes the discussion of a particular class of O-type stars, the Wolf Rayet stars, which will play an increasingly important role in the work of the

Observatory in the years to come. In the course of this work Plaskett discovered a spectroscopic binary about four times more massive than any previously known. He says smugly in the Annual Report:[80] "The interesting character of the results was given world-wide newspaper publicity and directed widespread attention to the observatory". Not so much to the observatory as to its director. Plaskett's name was so closely associated with the star that Klotz and Stewart believed, incorrectly, that he had named it after himself, a fact that shocked their scientific souls to the core.[81]

In his work on the physical properties of stars H. H. Plaskett needed to know the relative intensities of the various spectral lines as precisely as possible and he spent a great deal of effort over a three-year period in perfecting and testing the "wedge" method by which the spectrum was converted into something resembling "a range of mountains" in which the heights of the crests and valleys were proportional to the intensities of the corresponding line. A major paper was prepared on this work.[82]

The bootstrap methods by which astrophysicists determine the distances of stars have intrigued me from the day when Professor Millman first unrolled them for me during his class in Elementary Astronomy. The process starts with the near stars and involves a standard surveying technique. When a surveyor wishes to measure the distance to a mountain, he establishes a baseline of known length and, sighting on the mountain from each end of the baseline in turn, measures the angles between the line-of-sight and the baseline. Given the base and the two angles, the triangle can be solved to give the distance of the mountain and the angle subtended at the mountain by the baseline.

Astronomers do exactly the same thing to determine the distance of the nearer stars. They observe the stars at times separated by six months, so that the observing points are separated by twice the radius of the earth's orbit. Their base line is thus two "astronomical units" and half the angle this base subtends at the star is known as its "parallax"; this can readily be transposed into distance.

The error in the determination of a stellar parallax is about 0.005 seconds of arc and is of course independent of the distance of the star. For the nearest star the probable error is about 1%, but the probable error increases very rapidly with the distance of the star and only a limited number of stellar distances can be determined in this way. The next step in the logic involves magnitude.

The apparent brightness of a star depends on two things, its absolute brightness, or absolute magnitude, and its distance, since the apparent brightness decreases as the square of the distance. The apparent magnitude may readily be determined, indeed it has been determined for many thousands of stars. If we could find the absolute magnitude of a star we could determine its distance.

About the time that the first programme at Victoria had been completed a method had been found at Mt. Wilson to determine absolute magnitude. It depended on the empirical discovery that the intensities of certain lines in stellar spectra correlate with the absolute luminosity of the star. The reason for this is intuitively evident. If there are two stars of the same class, and therefore of the same temperature, one a giant and one a dwarf, the giant star will appear brighter because of its larger surface area. But the masses of the diffused giant and the condensed dwarf are much the same, and therefore the surface gravity, and surface pressure, are much lower on the giant. This allows the ionization of elements of low ionization potential, and the corresponding lines appear, indications of the low pressure and low surface gravity of a giant star of high luminosity.

Harper and Young determined to apply the method to as many stars as possible. They first studied the spectra of stars of known parallax to discover which lines in each star class were the most definitive and they applied their findings to a total of 1105 stars. In their paper they list their absolute magnitudes, compare them with magnitudes determined at Mt. Wilson, where these are available, and publish the spectrographic parallaxes.[83] In the course of this monumental work they had to determine the radial velocities of 125 stars not previously studied, and these were published.[84]

While the telescope was used almost entirely for spectroscopic work, some photographs of nebulae and clusters were made in the early days of the telescope as a demonstration of its excellence. Four stellar transparencies were sent to the Royal Astronomical Society of London and the enthusiastic response was reported to the Deputy Minister, who had also received a set. Klotz was invited to the Deputy's office to see them and found them very fine.[85] Other non-scheduled work included a spectrographic study of two novae, one in Aquila, one in Cygnus.

A total eclipse of the sun in September, 1923 was to be visible in Australia and Professor C.A. Chant, of the University of Toronto requested that Dr. Young be permitted to join him in observing it. The specific aim of the Canadian expedition was to investigate whether the rays of light from suitably located stars were bent by the gravitational action of the sun in passing close to it. Permission was granted for Young to join the expedition, the sun was observed under good conditions, and the bending was established; the importance of the observation was of course that it confirmed a basic conclusion of Einstein's theory.[86] Unfortunately for the prestige of the Canadians, other, more famous, astronomers also observed the phenomenon but Plaskett made good public relations use of Young's work as we shall see presently.

The impressive publication record has been mentioned. Plaskett recognized the importance of publication not only to the scientific reputation of the Observatory but also to maintaining its position in the consciousness of the Ottawa mandarins. In letters to the Deputy, to the Minister or to the Chairman of the Civil Service Commission, the publication record is stressed. When the second volume of the Publications of the Dominion Astronomical Observatory was completed, a bound set of the two volumes was sent to the Prime Minister, W. L. Mackenzie King, who acknowledged the gift warmly.[87] Nor was Plaskett's publication zeal limited to the scientist and the Ottawa establishment. A very attractive booklet was produced in 1923 giving the history of the Victoria observatory, describing the telescope and discussing the observing programme in layman's terms.

Another subject in the correspondence of this period concerns the acquisition of additional acreage on the observatory hill. A Richard Colville, who held 131 wooded areas in the area, of which 90 were on the hill itself, offered the land to the Government as early as 1918.[88] If they were not interested he was prepared to sell the timber from the land and to develop it where possible, for agriculture. Plaskett was not enthusiastic about the purchase, although in late 1920 he recommended the purchase of a small parcel of 7 or 8 acres southwest of the Observatory and some 600 feet distant from it.[89] This was approved[90] but before anything could be done about it Colville was pressing for the sale of 65 acres for $3,000. Considering that they had had to pay $280 an acre for the original purchase this was a bargain and Plaskett recommended strongly that the purchase be made.[91] In the meantime Colville was not prepared to consider the now- approved offer for the 8 acres. This stalemate does not seem to have been resolved during the period of Klotz' administration.

It will be apparent from everything we have said about the Dominion Astrophysical Observatory that Plaskett was a master of public relations. He was not above what would appear to many as sycophancy. When his Minister, Meighen, became Prime Minister he wrote him a letter of congratulation, to which Meighen replied.[92] When W.L.M. King, the Leader of the Opposition, was planning to visit Vancouver, Plaskett wrote him a cordial letter inviting him to visit the Observatory. King replied most courteously, regretting his inability to accept. Every bit of publicity, favourable notices in scientific journals or popular interviews in the local press, were brought to the attention of the people in Ottawa.

While the main thrust was to publicity for the Observatory, Plaskett was not at all reluctant to encourage publicity for himself; indeed he seems to have regarded himself and his observatory as two facets of the same personality. It was his observatory and his whole life. I'm not sure that he should be accused of immodesty. If a person is very good and has made a monumental contribution, is it immodest to be aware of it? I think not. The scientific world agreed with him as his election to Fellowship in the Royal Society of Canada in 1910 and the Royal Society of London in 1923 attests. Almost simultaneously with the latter honour was the conferring of a Doctor of Science by the University of Toronto.

Prime Minister King, in congratulating Plaskett on his F.R.S., put the matter very well: "The honour is one of which our country as a whole may well be proud, for your distinguished services have helped to bring not less fame and credit to the Dominion than to yourself".[93]

DOMINION OBSERVATORY ASTRONOMY

The Equatorial Telescope

We have seen (p. 90) that by 1919 the entire staff of the Equatorial Division had transferred either to Victoria or to the Geodetic Survey, and that Klotz had recruited two replacements, J.P. Henderson and F. Henroteau. Henderson had been recruited on the advice of Professor C.A. Chant, of the University of Toronto. He had had no experience in stellar spectroscopy but was highly regarded by Chant and was set to work to learn the new field. Shortly afterwards Dr. Henroteau arrived, and the two worked together as a team, Henroteau being the senior man responsible for the programme. What was to be done? The list of stars which could profitably be studied along the lines of the previous work was exhausted. Attention was turned to a class of stars which presented a number of unsolved problems and of which there were several examples of sufficient magnitude to be studied by the 15-inch telescope. These stars showed a very short period cyclic variation in radial velocity, of the order of a fraction of a day; the variation was less regular than that of the ordinary spectroscopic binaries. When the programme started there were only four of these stars known, and the class was named the beta Canis Majoris type after the first such system discovered.

The first step was to seek for more examples within the light-gathering capabilities of the telescope, and a search was made throughout the catalogue of early class B stars. The benefits were not limited to the list of new short-period binaries discovered. A series of publications, under the general title of "A Spectrographic Study of Early Class B Stars", described the spectral characteristics of all the stars studied.[94]. J.P. Henderson was a joint author on the first paper and his help was acknowledged in the second. Thereafter his help is not mentioned and Klotz reports that they had had a falling out. In any event, as we shall see, Henderson had developed new interests and accepted new responsibilities.

Henroteau describes the method of the research. "An observing program was drawn up and each star on the program was followed for several complete nights, as many spectrograms as possible being taken in close succession, so as to provide a continuous record covering a complete period of variation, or even several complete periods if possible".[95] As a result of this programme twenty of these short-period systems were discovered. The brightest of these were studied at intervals over the next several years to refine the measurements. In the case of one of the stars, Sigma Scorpii, it was found that a longer period variation existed in addition to the short one. This longer period indicated a motion of the centre of mass of the binary system, in addition to the movement of the binary pair. The work on this star was an extension of studies Henroteau had made at Lick before coming to Ottawa.[96]

The next step in the study was to search for variations in the intensity of specific spectra. It is not clear when this work was begun but it seems to have been after 1923. Description of it is therefore left to the next chapter.

Photographic Photometry

As stated earlier, the provision initially made for photometry, of having a camera operating through an 8" doublet attached to the 15" equatorial, had not proven satisfactory. The use of the telescope had to be divided between spectroscopy and photometry, and it was not possible to make an exposure through the meridian. A new drive was commissioned through the John A. Brashear Company and was delivered in 1912; however, the building to house it was not available until 1914. This building, which still exists, stands southeast of the main building and is made of similar material. Octagonal in shape, it has a 14-foot dome. The support of the drive extended through a lower area used as a dark room into an observing floor which could be reached via a circular staircase and a trap door.[97]

The drive carried an array of instruments: an 8-inch doublet with a 41-inch focal length; a 6-inch doublet with a 30-inch focal length; a guiding telescope of 4.5-inch aperture and 52.5-inch focal length; and a Zeiss Tessar lens of 3.3-inch aperture and 11.0-inch focal length. There were two prisms, of 15° and 25° which could be mounted on the 8 inch doublet to produce small spectra on the photographic plate.

The method of determining the luminosity of the stars, which Motherwell had studied during his sojourn in Yerkes in 1912, was to adjust the telescope to be slightly out of focus. The star images produced on the plates were then disks instead of points and their intensities could be measured by a microphotometer. The work required a great deal of care because the image on the photographic plate could be affected by so many variables - the type of plate used and its possible deviation from specifications, the variable absorption of light by the atmosphere, the fogging of the plate by the general illumination of the sky, aberrations in the telescope-camera combination. The aberrations of the system could be measured and allowed for. To provide some control of the other factors a "sensitometer box" was used to calibrate the plates. This box contained twenty closely packed open tubes of graded diameters and the plate was pressed against one end of the tubes. The whole device was mounted on a plate which was rotated by an electric motor, the open end of the tubes being pointed at the pole star, with one or more sheets of opal glass intervening. The rotation overcame any possible variation in the opacity of the opal glass. When the plate was developed, the intensity of the spots, measured by a microphotometer, could be related to the known diameter of the tubes to produce a calibration curve for the plate.

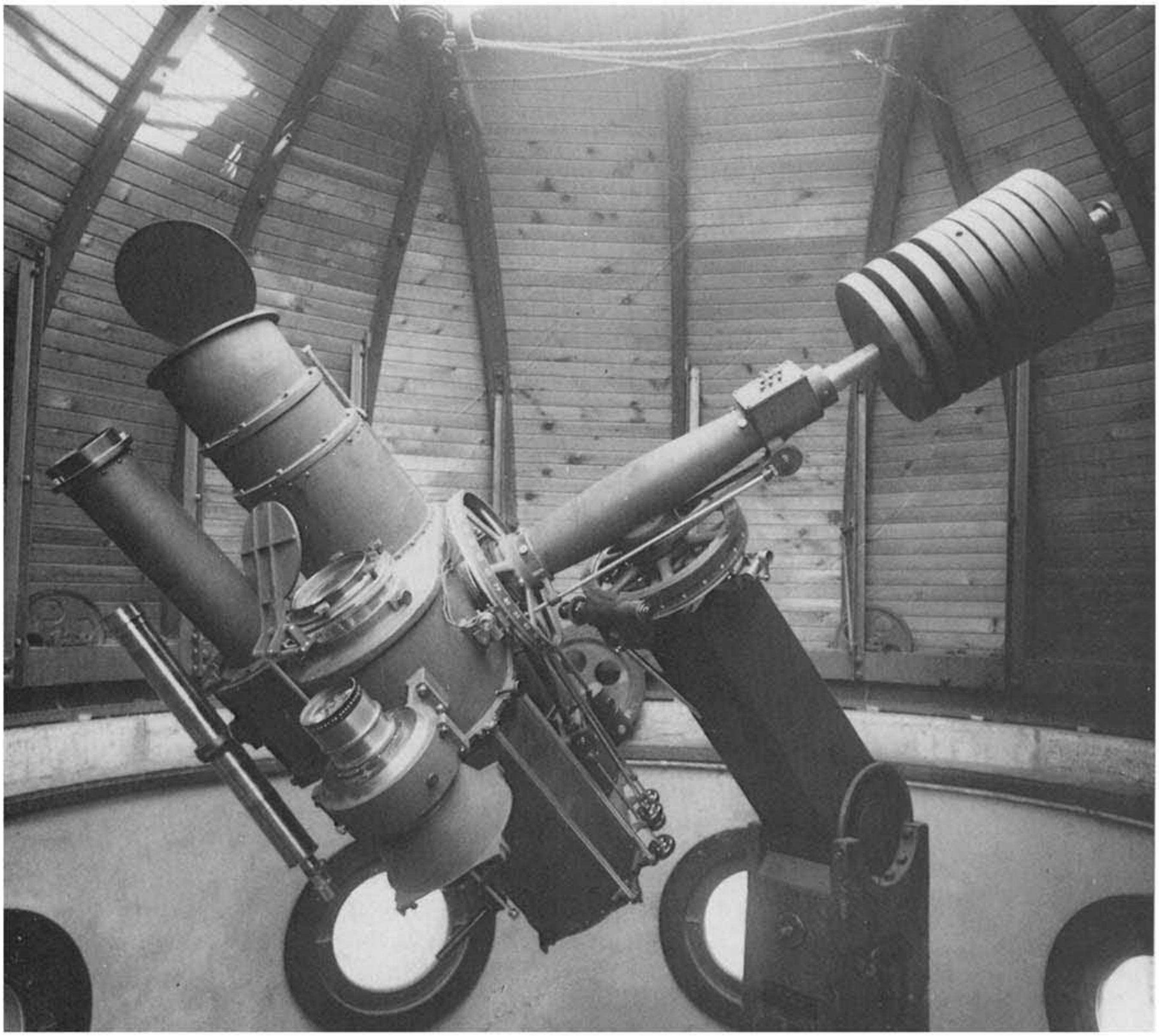
Observing the appropriate precautions Motherwell exposed 26 plates between 1917 and 1921. Since there were many stars on each plate he was able to deduce the magnitudes of 119 stars; as many of the plates overlapped the region of other plates he was able to repeat the measurements, sometimes as often as seven times. In his publication the stars are listed by a catalogue (B.D.) number but Motherwell gives no reason for selecting the particular stars nor the particular star fields photographed.[98]

Solar Physics

Only one addition seems to have been made to the solar telescope during the Klotz administration. This

(Left) The small observatory built in 1914 to house the photometric telescope.

(Below) The 8-inch doublet and auxiliary instruments used in photometric astronomy.



was a new camera, incorporated into the coelostat system. Up until late 1919 solar photographs were taken with the 15-inch equatorial telescope, the camera used providing a picture of the sun approximately seven inches in diameter. Position lines mounted on graduated rings defined the East-West line and the solar equatorial line. Late in 1919 a camera mounted on the solar spectrograph began to be used. It produced a nine-inch image of the sun which, in the matter of definition was not always as good as the earlier ones. This was due to the effects of temperature on the coelostat mirrors and on the air along the horizontal light path.

DeLury was very active in publication during the Klotz years. A list of his publications, prepared at the times of his election to the Royal Society of Canada, shows no less than twenty papers, three in the Astrophysical Journal, thirteen in the Publication of the American Astronomical Society, two in the Journal of the Royal Astronomical Society, and two others. These papers dealt largely with the rotation of the sun, but they also showed a growing interest in the possible relationship between apparently disparate natural phenomena. For example one paper deals with a possible relationship between the numbers of meteors and the quantities of nitrogen compounds in freshly fallen rain and snow, another with an apparent relationship between Chinese earthquakes and tree growth in California. By the early 1920s papers began to appear relating natural phenomena, such as weather and bird populations, to sunspot numbers.

In 1922 the first number in a volume of the Publications devoted exclusively to solar physics appeared.[99] It contained a very detailed description of the equipment. Additional numbers[100] appeared in 1923, in which he returned, using the data obtained in 1911-1912, to the effects of "blended" spectra, the matter of such controversy with the Plasketts. One of the papers he published in the Astrophysical Journal in 1918 also dealt with this subject. It annoyed J.S. Plaskett very much; he felt that DeLury was taking unfair advantage of his son Harry, who was on active service overseas, while "DeLury who might have gone as he had no family ties, sits at home in comfort and safety and writes this unfair criticism". [101]

During this period DeLury was assisted by John O'Connor, and included him as co-author in many of his papers. O'Connor was a remarkable man, much more so than those of us who knew him only as he approached retirement appreciated. He was a high school graduate who had never been to university and he joined the staff shortly before the first war. He took part in the seminars and gave papers which Klotz praised highly in his diary. He enlisted early in the war and remained in active service for the duration when he returned to the Observatory to work with DeLury. When it was proposed to drop him during the depression, Stewart defended him fiercely in comparison with other, university, men. He continued to work in Solar Physics until DeLury's retirement, at which time he was transferred to seismology as a reader, but he continued to take sun photographs on every clear day until DeLury's replacement, Jack Locke, arrived.

Meridian Circle Operations, the Time Service and Longitude Determinations

There is nothing new to report on the Meridian Circle work during the Klotz administration. The observing programme which had been initiated in 1911, of those star positions required for the longitude programme, continued through 1923 and therefore essentially covered the period of the Klotz regime. A new programme, recommended by the Commission of Meridian Astronomy at the 1922 meetings of the International Astronomical Union, did not get underway until January 1924, immediately after Klotz' death. The results of the 1911-1923 programme were not reduced. It was not until after the Second World War, under the Beals' Administration, that they were published.

Nor was there much change in the distribution of correct time by conventional methods. The Observatory continued to supply time to government buildings through dedicated lines and the service was extended to meet the needs of the expanding public service. Between 1915 and 1926 the number of clocks serviced increased from 333 to 561. Time continued to be supplied to the Ottawa Electric Railway and to leading jewellers, and was delivered on demand to both Canadian Pacific and Canadian National Telegraphs. However McGill University was the official source of the telegraph companies' time.

The one area in which there was tremendous advance was in the use of radio time signals, both in the intercomparison of time between observatories and in their field use in longitude determinations. The entire development is very well covered by M.M. Thomson to whose book "The Beginning of the Long Dash" [102] the reader is referred and to which these notes are much indebted.

The first use of radio was in longitude work, in the summer of 1914, at locations north of Lake Temiskaming in the head waters of the Ottawa river. Arrangements had been made to transmit chronometer beats from a government transmitting station near Kingston. These signals were not detected but satisfactory signals were received from United States stations at Arlington, Virginia, and Sayville, New York, and the longitudes of four points were determined. In order that these longitudes should be based on Ottawa, rather than on Washington, it was necessary for Ottawa to observe the same signals and to correct the Washington signals to the Ottawa base. This precaution was always observed.

Field work continued in 1915 with the occupation of nine stations, but by 1916 the pressures of the war reduced the programme to one station and it was then abandoned. When it was revived, in 1921, the equipment in use had undergone a major improvement, from "crystal" sets to the use of vacuum tubes. There had also been a change of personnel, with the arrival of J.P. Henderson.

Henderson had been recruited to work with the 15-inch equatorial, and while he carried out these duties for some time, he devoted much of his energies and all of his spare time to the new science of radio and to its practical application. In 1921 and 1922 he had an opportunity to demonstrate the effectiveness of the new receivers.

Oil had been discovered on the Mackenzie River, sixty miles north of Fort Norman, and it was necessary, in allotting claims, to tie the survey to the meridians and base lines used in the agricultural area to the south. The tie was made by a stadia line joining the existing surveys to the new fields, a distance of about 1000 miles, but because of the errors inherent in the work it was necessary to establish the latitude and longitude of a number of base points. This was to be the responsibility of the Observatory.

There were three members in the party: Henderson who was responsible for the radio operation, H.S. Swinburn who made the astronomic observations, and A. H. Miller who took advantage of the opportunity provided by precise location and accurate time to make the first pendulum observations in northern Canada. Five stations were occupied in 1921, four in 1922. Henderson observed time signals from San Francisco, San Diego, the Canal Zone and Washington on a regular basis (Ottawa was observing the Washington signals to check on any differences between the two national standards) and between these signals received news bulletins. These were made available to the locals, and when the party was travelling by steamer the bulletins were put up on the noticeboard. One scoop that Henderson made was to report on the results of the heavyweight title bout between Dempsey and Carpentier. These two seasons marked the end of the Observatory involvement in longitude measurements for survey purposes and in 1924 the regular work was taken over by the Geodetic Survey.

From the experience gained in the Mackenzie expeditions Henderson designed and constructed three radio receivers for use by surveyors of the Topographical Survey. This was followed by a "vest-pocket" long-wave receiver which could be used for longitude observations without adding excessive weight. It was in use for many years. Other receivers were made for the gravity observers and for the various seismograph stations.

As transmitters become more powerful and receivers more effective, time signals could be received from observatories in Washington, Paris and Hamburg. Comparison showed systematic difference between the various national standards, due to the use of different stars in the observation or of different methods in the reduction of the data. These differences were quickly corrected, but it was to the credit of the new techniques that they were discovered.

Thomson[102] reports that radio time signals began to be transmitted by the Dominion Observatory in 1923. Klotz had authorized the erection of very tall antennae masts sometime earlier.[103] The signals consisted of a short interval of second pulses. To attract listeners to the station and to allow them to "tune in", Henderson played phonograph records as part of his programme. People living near the Observatory objected to this; their not-very-selective receivers were swamped by the local signals and they were not able to receive KDKA in Pittsburgh, which was the ambition of everyone who owned a set.

Radio time signals raised the question of which source of time should have precedence in Canada. The Ottawa observatory had by far the most sophisticated meridian transit, but a lesser accuracy would suffice for most purposes. Transit observations continued in St. John, New Brunswick, until well into the 1930s and their time was broadly circulated throughout the Maritime provinces. McGill University continued to supply time signals to the telegraph companies; their time was based on transit observations augmented by radio comparison with Arlington. The Meteorological Service apparently continued its transit work, and maintained its own time, in Toronto well into the 1930s and in Victoria into the early 1920s, at which time it came to depend on radio transmissions from San Francisco and Arlington. Klotz very strongly opposed the use of "foreign" time in western Canada, proposing that Dominion Observatory signals be transmitted by the telegraph lines, but nothing came of this. The distribution of time was to remain fragmented for another 15 years.

GEOPHYSICS

Gravity

As we have already seen, the gravity work suffered severely after the death of Dr. King. Simpson and the Deputy Minister Cory agreed that there should be no money for field work and Klotz, in the limbo of his pre-appointment year, could do nothing about it. McDiarmid, discouraged and apparently somewhat disenchanted with gravity work anyway, was released to the Geodetic Survey at the start of the 1917 field season. A new position was not made available for gravity work until 1920, at which point it was quickly filled by A.H. Miller.

Miller was a Manitoba boy who, on graduation from St. John's College, was awarded a Rhodes Scholarship. With this he attended Oxford and was awarded a B.A. in 1910. He returned to Canada, attended McGill for one year, and then spent two years of graduate work at the University of Wisconsin. The war intervened and he enlisted in the artillery and saw three years of active service. With the end of hostilities he returned to Oxford where in 1919 he was awarded the M. A. degree. He returned to Canada just in time to fill the newly-created position in Gravity. He reported for work in mid-June, 1920, and left immediately for Manitoba to be married. When he returned with his bride they were entertained by Dr. and Mrs. Klotz: "For tea we had Mr. and Mrs. A.H. Miller, recently married. ... We found her pleasant and very agreeable",[104] a judgement with which a generation of Observatory staff would agree.

Miller lost no time in getting down to work. His first task was to make a new tie between Washington and Ottawa. This was done in March and April, 1921. The tie had been made earlier in 1902, by Klotz, to the base in the old Supreme Court building, and in 1914, by McDiarmid, to the new base in the Observatory basement. Miller's results agreed with McDiarmid's within .004 dynes, and a weighted average of the Ottawa value was set at 980.618 cm/sec/sec.

Next, Miller joined Swinburn and Henderson on the expedition to the Mackenzie basin, already described in connection with the longitude measurements. The work began in Peace River which was a railway terminus and the end of a telegraph line. It was thus possible to use the telegraphed time signals from Ottawa as well as the radio signals from Annapolis and to compare the results. The pendulum periods obtained by the two standards agreed within five points in the seventh decimal place. This lent great confidence in the subsequent measurements. In Peace River he tried swinging his pendulums in a tent but found the temperature variations unacceptable. Fortunately he was always able to find a cellar or a sturdy log building to house the experiments and they maintained temperatures to within 1°.

Five stations were occupied during the summer, and the pendulums were swung in Ottawa at the beginning and end of the season to check for any changes. The results of the Washington-Ottawa tie and for the five Arctic stations were published.[105] Before discussing them it will be well to review the various methods used in the reduction of gravity observations.

The first reduction is the "Free Air" one which supposes that the observing point is isolated in the air at the appropriate elevation above a spherical earth stripped to sea level. The value of gravity at sea level is calculated for the latitude of the station, the effect of the increased distance of the observing point above the centre of the earth is computed, and the sum is the calculated value of gravity at the point. The difference, Observed - Computed, is equal to the Free Air Anomaly.

A more sophisticated calculation supposes that the station is placed on an infinite uniform disk of material with a thickness equal to the elevation of the station above sea level. The "Bouguer" anomaly is the difference between the value observed and that so calculated.

One would have expected that the free-air correction, which was, on land, postulating too little material below the station would produce too small a value of gravity and that the Bouguer correction, which postulated too much material, would produce too large a one. This was not found, and Hayford and Bowie, of the United States Coast and Geodetic Survey developed a theory of isostasy to account for the observation. They supposed that there was some level of "compensation" within the earth at which all crustal columns of unit area weighed the same: if there were mountains or dense geologic layers placing an extra load on the surface, this was compensated for by lighter material below; if there were deficiencies, as in ocean deeps, they were compensated for by heavier material. On the basis of all gravity observations throughout the world they estimated the depth of compensation to be 113.7 km and they produced tables giving the value of the compensation. To apply these corrections they developed a chart which divided the whole surface of the earth into 33 zones; the observing station was placed at the mid-point, the mean elevation in each zone was calculated, and their tables gave the total correction, for topography and for isostasy, of each square, the sum to be applied to the value of sea-level gravity. Again the difference between the observed value and the calculated one was the anomaly, in this case the "isostatic" anomaly.

When Miller reduced the observations for the 1921 field season he was not certain of the elevation of his stations, so he did not attempt to determine the isostatic anomalies; he contented himself with free-air ones. However he did list the principal facts for all the observations made in Canada since 1914 and gave all three anomalies for the observations made earlier than 1921.

In 1922 the longitude work in the Mackenzie basin continued, and Miller was there with his pendulums. By the end of the field surveys a line of levels had been carried north from the existing surveys to the vicinity of Great Slave Lake and Miller felt more confidence in his elevations along the river. Sketch maps of the topography in the vicinity of his stations were prepared and, using the relief map of Canada which had been published in 1915, he applied the topographic corrections and calculated the Hayford anomalies for all nine of his arctic stations, the five occupied in 1921 and the four additional ones of 1922. He also calculated the best value for the depth of compensation in the area - 91 km, with a probable error of 29 km.[106] We should perhaps list the stations occupied during the programme:

Peace River

Chipewyam

Resolution

Simpson

Liard River

Norman

Good Hope

Arctic Red River

Miller published a popular description about the expeditions which makes interesting reading.[107]

Klotz had been thinking about purchasing a torsion balance for some time and the order was placed late in 1921.[108] It was to be made by Professor O. Hecker in Jena, and during his visit to Europe in connection with the meetings of the I.A.U. and the I.U.G.G. he visited Hecker and saw the instrument. The diary makes some interesting comments in connection with the torsion balance. Klotz, who was confined to his home for much of 1923, the last year of his life, was visited by Miller who described his recently completed field work and discussed with his chief the reduction of the observations. "I gave him instructions to get out preliminary results for the pendulum observations - lacking details in the meantime for corrections for 'topography' - to be applied later, so that he can begin his experimental work with the torsion-balance I had constructed by Professor Hecker in Jena for the determination of differential gravity, a method evolved some years ago by Baron Eotvos of Hungary. It is the first instrument of its kind in America and I inspected it last April in Jena with Professor Hecker. I am saying little about its applicability in the determination of oil deposits in our Northwest, although I used that argument - quite legitimate - to secure the construction of the instrument in Germany. Miller will have to master the manipulation of the instrument without my personal supervision. However the ass't director - Mr. Stewart - will familiarize himself also with the apparatus and render assistance. To further our scientific work we must always be able to show some practical bearing that is connected therewith and in this I believe I am a pretty good adept."[109] Things haven't changed much!

The torsion balance does not seem to have been used during 1923 so its description is reserved to a later chapter.

Magnetics

The cancellation of appropriations for field work in 1917 also affected the magnetic work, but fortunately Klotz was able to prevent the transfer of his magnetician, C.A. French, and so it was possible to mount a field season in 1918, when the budget had been restored. This season, as well as those for 1919 and 1920 was devoted to reoccupying stations for the determination of secular variation. Thirty-seven stations were reoccupied in 1918 and second stations were established at four of the points where the existing stations seemed likely to become unsuitable in the future. The figures for 1919 were 58 stations re-occupied with secondary stations established at six places. In 1920, when two observers were available, 50 stations were occupied. The second observer was J.A. Pearce.

The magnetic results for the years 1918-1920, declination, inclination and horizontal intensity, were, as had been the custom for several years, reported in the Journals of the Royal Astronomical Society of Canada.[110] In 1921 French published a major paper discussing the magnetic results for 1907-1920.[111] The paper includes stations observed by the Meteorological Service of Canada and by the Carnegie Institution. It lists the instruments used in each field season, describes the methods used in determining the geographical coordinates of each observing station, and the observing techniques and reduction procedures for the magnetic data. In 1919 and 1920 corrections for daily variations were based on the variations shown at both Agincourt and Meanook.

The most important contribution is the listing of observations for repeat stations and, based on these observations, the reduction for all stations to the epoch 1921.0. The results are given in tabular form, arranged by longitude, and cover 506 stations. Station descriptions for all of these stations are included.

With the arrival of R.G. Madill, in April 1921, there were two permanent magneticians on the staff. In 1921 observations were confined to the settled areas of eastern and central Canada, French observing 29 stations from Louisburg to Matane, Madill 17 stations from Megantic to Bancroft. Mr. Madill, like Mr. Hodgson in an earlier period, had initial difficulties. Klotz reports[112] that Madill, working in Prescott, had broken a deflecting bar and a thermometer and that Mr. French had had to be sent to his rescue. During the next two years observations were much more dispersed, French occupying stations between the Peace River and Aklavik on the Mackenzie, and also along the railroad lines in Saskatchewan and Alberta, Madill covering portions of northern Saskatchewan and Manitoba and reaching as far as Hudson Bay. Wherever possible stations established earlier by the Meteorological Service of Canada or by the Carnegie Institution were reoccupied. The results of the three seasons were published under the joint authorship of the two men.[113]

We discussed earlier (p. 54) the problem posed in making field measurements by the daily variation in the field. There the solution was to measure the extreme "extensions" and to take a mean. Where the station was close to a magnetic observatory, either Agincourt or Meanook, observations were timed and a correction applied later on the basis of the observatory fluctuations.

When observations began in the Arctic these methods proved inadequate, partly because of the distance from a base station, partly because of the increase in the daily variation at points within the auroral zone. Each observer kept detailed records of the declination variations on three pre-selected days a year; these were compared with the diurnal variations at Meanook and hourly corrections were computed for three different geographical groupings of stations. Details are given in the report.[113]

In the 1923 season each party was equipped with a wireless receiving set to determine chronometer correction. Reception proved satisfactory everywhere, and the receivers became a standard field item.

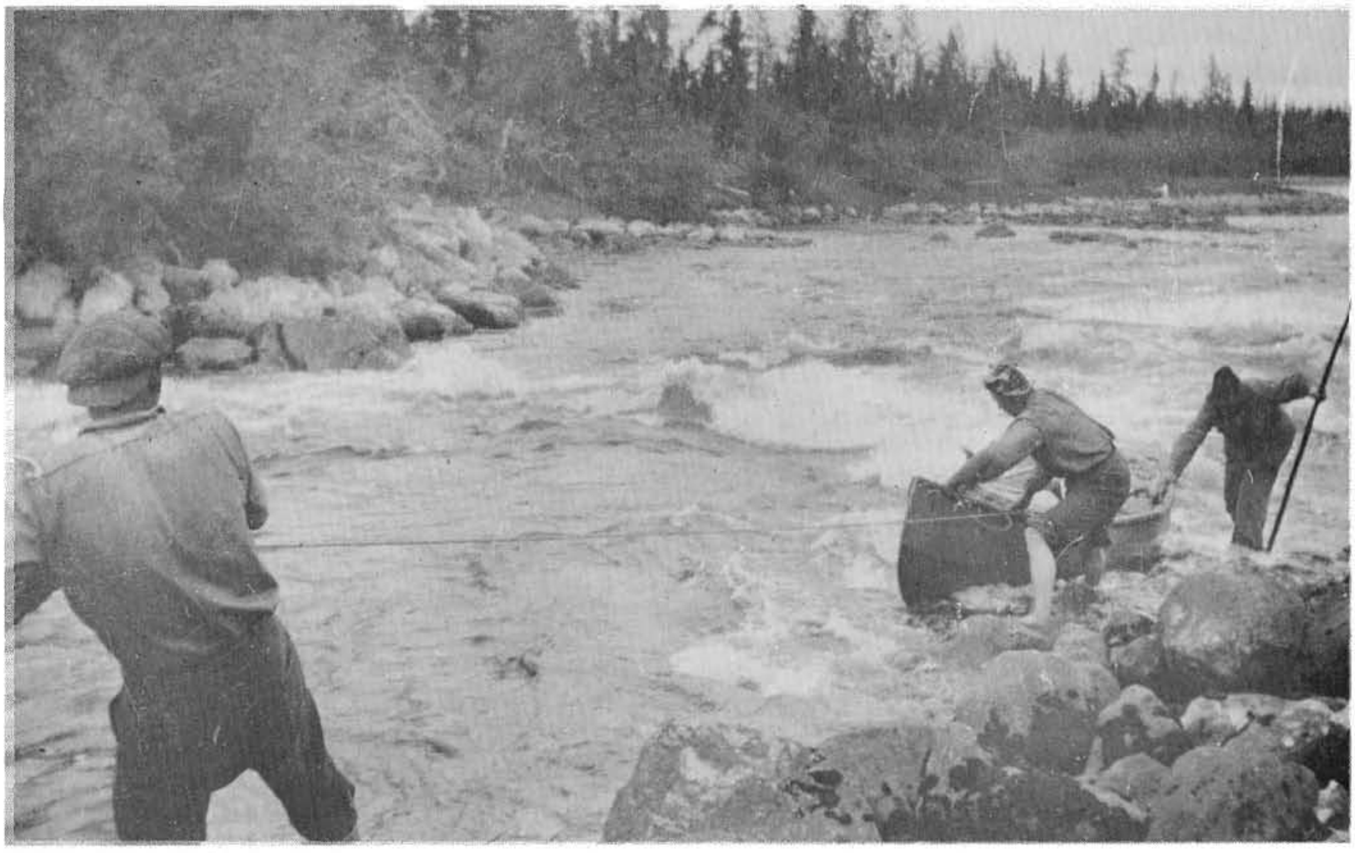
As in every field season, observations were made at Ottawa and Agincourt at the beginning and end of the season. The Ottawa standard instruments were checked against those at Agincourt and Washington at regular intervals.

French reports[114] that, on two occasions, June, 1918 and September, 1922, the Division cooperated with the Carnegie Institution in studying whether there were any magnetic effects associated with an eclipse of the sun. In both cases the study was a failure because of strong magnetic storms covering the period of the eclipse.

Seismology

The seismological work did not suffer the set-backs imposed on the other geophysical disciplines by the Secretary, Simpson, between the time of King's death and the appointment of Klotz. The operation of the stations at Ottawa, Halifax and Saskatoon continued without interruption, epicentres were located for all earthquakes recorded, and bulletins were issued regularly and with commendable promptness. The seismologist, E.A. Hodgson, as has already been documented, left the service for a year, but this was accomplished without prejudice to the output of the section. On his return a position for an Assistant Seismologist was established as part of the general strengthening of the geophysical work and this position was filled by W.W. Doxsee in June, 1920.

There was a gradual improvement in instrumentation. Experiments began in September, 1918, to use electric motors to drive the Bosch seismographs, whose mechanical drive was erratic. As part of the experiment, Stewart ran tests on the reliability of the mains frequency. Nothing seems to have come of these experiments; the mechanical drive continued in use for many years. The Wiechert vertical seismograph, which had been installed in 1912, had never been completely satisfactory. In 1921 it was rebuilt and provided with an extra insulating case and improved temperature controls. The operation was much better.[115] At about the same time orders had been placed for two Milne-Shaw seismographs. According to Hodgson[116] the first of these arrived in May, 1922 the second in December of the same year. There must have been some delay in unpacking them. Klotz, who was confined to his home by illness reports in late October, 1922: "Mr. Hodgson called at one o'clock to discuss a few seismological affairs as our new component from England has arrived. Unfortunately the wrong one but we can make it do".[117] A very mysterious remark that; how can a component be the wrong one? In any event the new instruments were in the vaults and in operation by the beginning of 1923.



On the magnetic surveys on northern Manitoba, 1922.

On the magnetic survey along the Hudson Bay Railway, 1922.

Glen Madill preparing dinner, 1923.

The magnetic station at Nueltin Lake, 1923.

Hodgson states[116] that Klotz had intended to select seismographs for his new vaults when he went to the St. Petersburg meetings of the International Seismological Association in 1914. Those meetings were of course cancelled because of the war; otherwise Ottawa might very well have been equipped with Galitzen seismographs instead of the Milne-Shaw instruments ultimately selected.

There were no changes in the instrumentation of the outside stations although Hodgson reports[116] that the Halifax instrument was moved from one location to another shortly after its installation and that the Saskatoon instrument was transferred to the new Physics building in 1921.

The difficulties encountered with the "deformation" instruments have already been documented, but some good did come from them. They were extremely sensitive to tilt. One day, in October, 1916, a heater which was used to control the temperature of the vault was inadvertently turned off, and the next morning the records showed regular oscillation of the pier as it cooled. In a paper describing the phenomenon[118] Hodgson suggests that the same tilting effect should exist in any pier which suffers temperature fluctuations and should be taken account of when piers are constructed for gravity or astronomic observations. He also suggests that the differential heating of land masses, such as mountains, might be a cause of some microseisms. The publication is chiefly of interest for its description of the deformation instruments and its analysis of their sensitivity to tilt.

In "Activities of the Astronomical Branch",[116] Hodgson describes a series of experiments involving the new Milne-Shaw seismographs, without saying clearly what the aim of the experiments was. My recollection is that they represented an attempt to determine the direction of approach of microseisms and they seem to make sense only within this context.

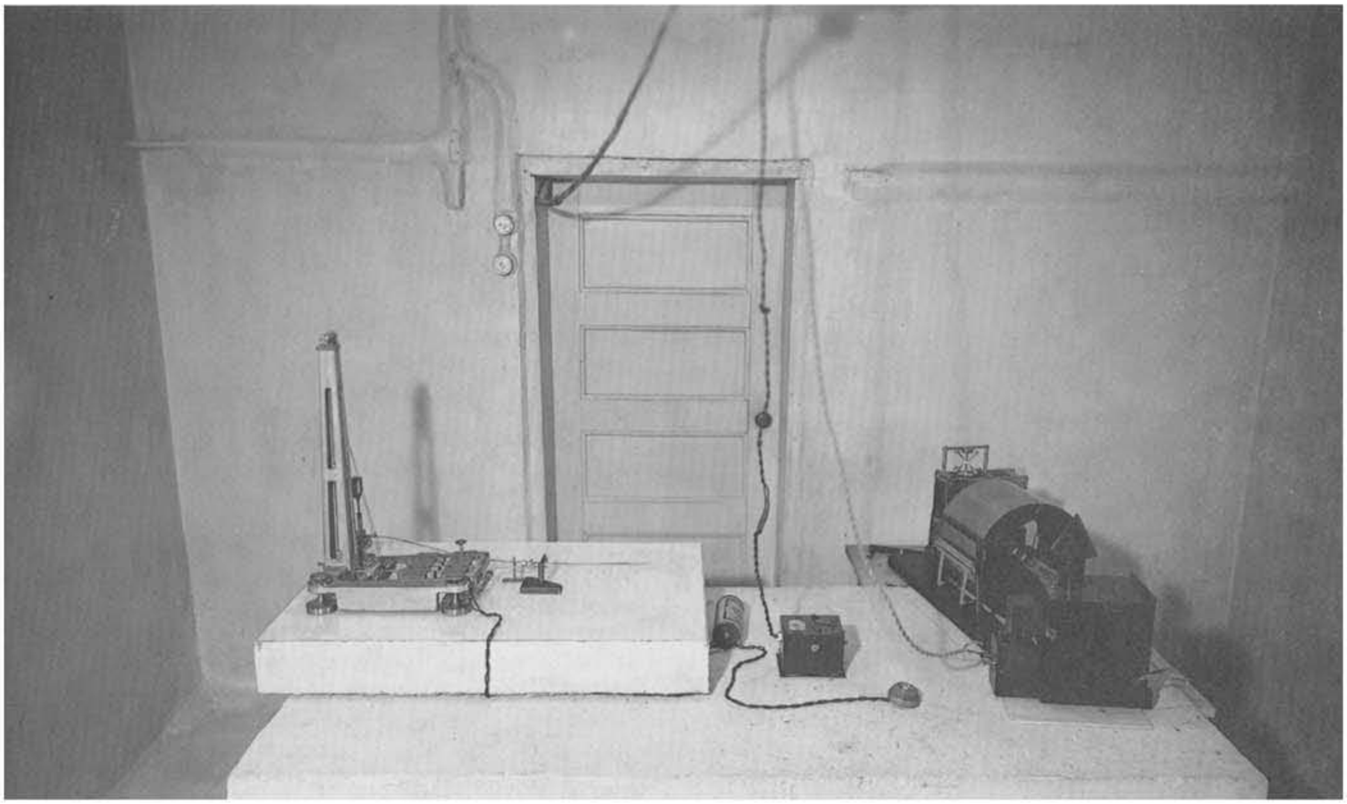
The first step in the experiment was to show that the two instruments when mounted in the same azimuth would produce identical records. These experiments were conducted in the Ottawa vaults and showed that the records of recorded earthquakes were identical, even if the damping constants were allowed to differ substantially. Next, one of the instruments was transferred to Shirleys Bay, at a distance of about 11 miles from Ottawa, and operated in a tent for about six weeks during the summer of 1923. Constant wind and an inadequate foundation made the records almost useless. Hodgson doesn't say how they operated a photographically-recording instrument in a tent.

The next step was to move the "field" seismograph to a more stable location. This was selected at the Kemptville Agricultural School. A pier was built on the cement floor of the basement which was itself laid on solid rock. "A series of experiments was run for nearly six weeks, during which time an unusually large number of severe earthquakes were registered. It was found, to our surprise, that the earthquakes registered remarkably similar wave trains at the two stations. Waves could be identified with certainty for tens of minutes. ... It had been hoped that it would be possible to identify wave trains of microseisms. A remarkably fine micro storm was recorded while the instruments were operating but it was quite impossible to identify wave trains."[116]

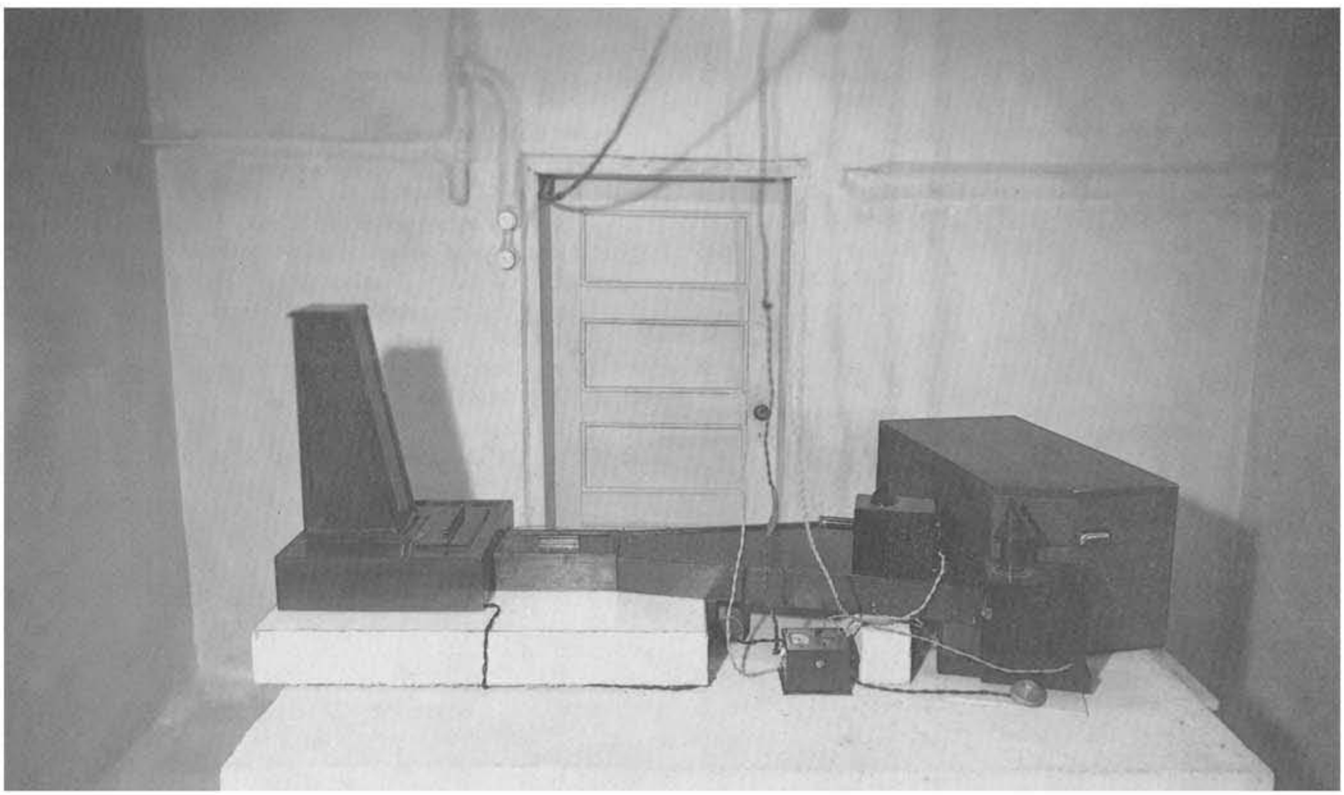
The field stations, at Shirleys Bay and at Kemptville, were operated by Doxsee. Radio time signals were recorded on the seismogram but not directly; Doxsee listened to the signals and placed them on the record by tapping a telegraph key. The indefatigable J.P. Henderson was monitoring the same signals in Ottawa so that the two time systems were synchronized.

The remark quoted above, that "it had been hoped ... to identify wave trains of microseisms" is not an explicit statement of aim but these experiments appear to have anticipated by some twenty years the efforts of Ramirez to track microseisms by means of a tripartite arrangement of seismographs. Hodgson had one more idea along these lines. He had a large steel vat constructed on which a steel plate three inches thick and two feet in diameter floated in a bath of mercury. One of the seismometers was mounted on this plate and its orientation could be changed simply by rotating the plate. To ensure that the distance to the recorder remained constant a large cast-iron arc was provided along which the recorder could slide to accomodate the rotating seismometer. The idea was to rotate the system to determine the azimuth of maximum amplitude and hence to define the direction of approach. There is no evidence that the experiment was ever carried out.

The responsibilities of Administration left Dr. Klotz little time for scientific work, but he seems to have supervised Hodgson's work fairly closely and he continued to represent the Observatory on international committees and on boards of societies. We shall return to this matter presently. One area of research that continued to interest him concerned the frequency analysis of seismic waves. We have already noted (p. 61) some earlier work in this field. Later he met a Professor Wilson, of Cleveland, who expressed a desire to analyze some actual seismograms. Klotz sent him a selection. In June, 1918[119] Wilson sent him some results of his preliminary analysis, and Klotz selected some additional seismograms for study and sent them to Wilson[120]. The analyses came back 18 months



The Milne Shaw seismograph, above without its protective cover, below with the cover in place.



later.[121] None of Wilson's work seems to have been published and the diary says nothing specific about the results. When Klotz visited Europe in 1922, to attend meetings of the International Unions of Astronomy and of Geophysics, he saw in Zurich a 40-element harmonic analyser, but time was running out on him, and he was not able to pursue this interest.

The diary records a very interesting sidelight late in 1918.[122] "Today I obtained reproductions of the part of the seismogram of Nov. 9 and also of Nov. 11 in which were recorded the signals announcing the abdication of the Kaiser, and of the Armistice; the time of the former was 3-37-42 p.m. Nov. 9, and of the latter 3:10:48 a.m. Nov. 11. Our local paper '*The Citizen*' had arranged and notified the public that the former event would be signalized by two 'blinks' of the electric light, and the latter by four blinks. As our seismograph registered photographically by use of the electric light, any blinking of the light would of course be shown - as it is shown. It sounds of course a little queer to say that the abdication of the Kaiser was recorded on the seismograph, which of course is true, but not due to a seismic shock but to the momentary cutting off of the light. Nevertheless the record is unique and probably the only one of its kind in America, possibly in the world. I gave the first copy to Mr. Cory and the next to Mr. Wilson Southam of the *Citizen*, who was more than pleased to receive it."

He didn't limit himself to these two copies but apparently distributed copies to some seismograph stations. Many years later Professor Perry Byerly, who was retiring and tidying up the accumulated debris of his years in the same office, found a copy of the "seismogram" of the Armistice and sent it to me. It arrived shortly before Armistice day, and I sent it to the *Citizen*, with a letter of explanation. The record, and story, were featured on the front page of their Armistice Day Edition.

LEARNED SOCIETIES

One of Klotz' first actions on becoming Director was to re-establish the Observatory seminars, in what he called the Observatory Club. This gave the young staff members an opportunity to gain experience in presenting their work in public. Observatory staff, both in Ottawa and in Victoria, continued to be the principal support of the local centres of the Royal Astronomical Society, and their papers were a major source of material for its Journal. The Society was not really a professional one, and indeed there were few, if any, professional scientific societies yet established in Canada. This position continued to be filled by the Royal Society of Canada and by its several sections. The staff of both the Ottawa and Victoria Observatories attended the meetings regularly and presented papers.

More important perhaps to the working scientists were the professional societies flourishing in the United States, in which their membership was welcome. The American Association for the Advancement of Science met annually, and there was usually some representative from the Observatory in attendance. In 1921 it met in Toronto and nine staff members attended and presented papers. There must have been some raised eyebrows in headquarters. Klotz found it necessary to support the large list:

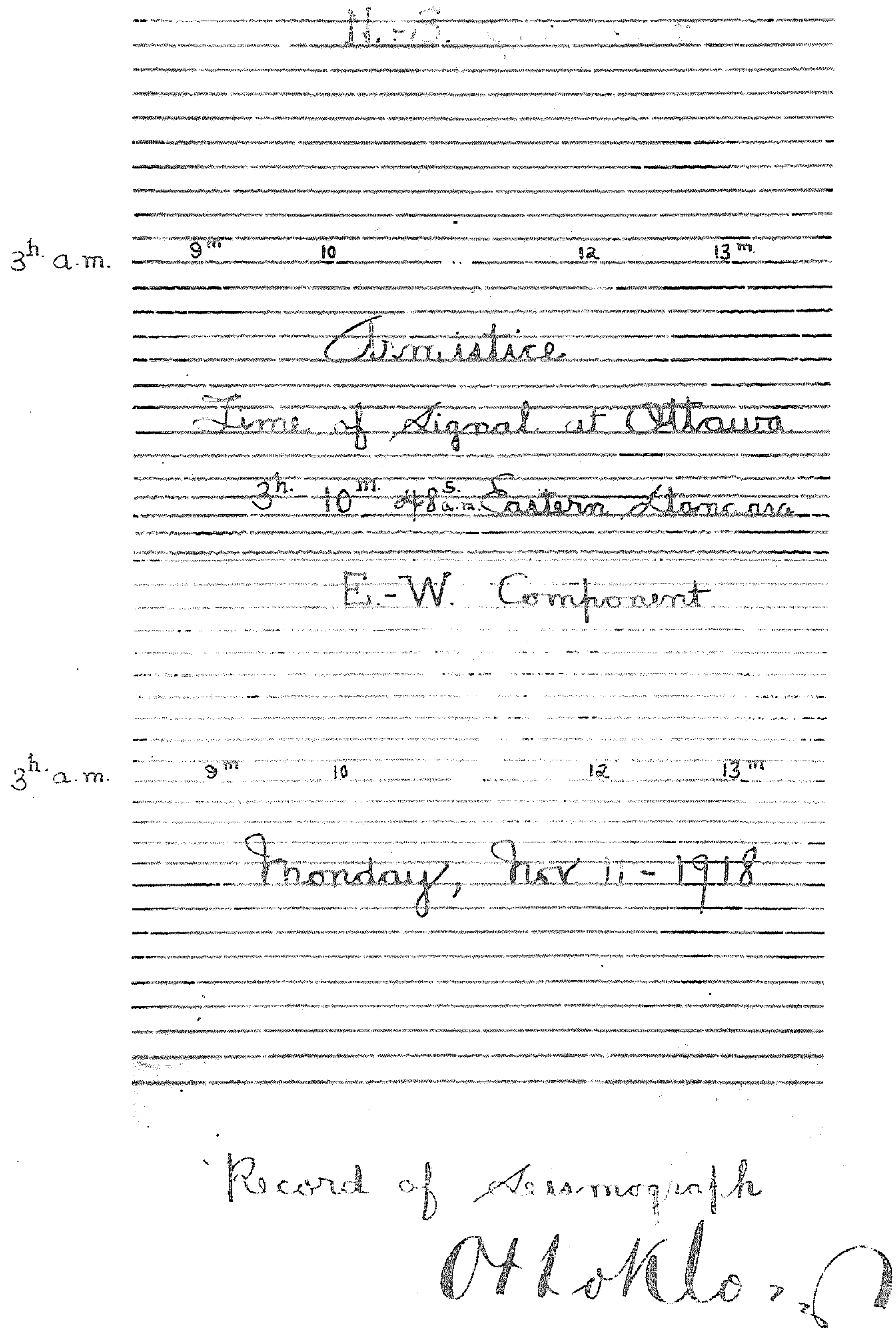
> "The scientist, shut up within his four walls, although supplied with the best apparatus and all the scientific literature, will fail in his highest achievement if he is prevented from contact with the human element of scientific confrères."[123]

The American Astronomical Association for the astronomers, and the Seismological Society of America for seismologists were strongly supported by members of both Observatories. Klotz became Vice-President of the former for 1920-1922 and President of the latter in 1920. He was not able to attend any of the seismological meetings, and carried out his duties by correspondence.

At the close of the war there was a reorganization of international science if for no other reason than that the pre-war organizations were dominated by Germany, a situation that the victorious allies were not prepared to have continue. Meetings were held in Brussels at which an International Research Council was established and, under it, International Unions of Astronomy, Geodesy and Geophysics, and Chemistry. A number of other unions were proposed. Provision was made for sections of Geodesy, Seismology, Meteorology, Terrestrial Magnetism and Electricity and of Oceanography within the IUGG. Canada was invited to join these several organizations. The government asked the newly-formed National Research Council to advise it; President Macallum had already asked Dr. Klotz for his opinion and the Council's recommendations followed them closely. Membership in the Council and in its Unions of Astronomy and of Geodesy and Geophysics was recommended, with National Committees to be set up as follows:

For the International Astronomical Union (IAU):

> The Director of the Dominion Observatory, ex-officio,
>
> The Director of the Dominion Astrophysical Observatory, ex-officio,
>
> Three representatives of the Royal Society of Canada to be selected not necessarily from its own membership,



The seismograph record of the signing of the Armistice, November 11, 1918.

Six representatives of the Royal Astronomical Society.

For the International Union of Geodesy and Geophysics (IUGG):

The Director of the Dominion Observatory, ex-officio,

The Surveyor General, ex-officio,

The Director of the Meteorological Service, ex-officio,

The Director of the Geological Survey, ex-officio,

The Superintendent of the Geodetic Survey, ex-officio,

The Superintendent of Tidal and Current Surveys, ex-officio,

The Chief Hydrographer of the Naval Service Department, ex-officio,

Four representatives of the Royal Society of Canada.

The Royal Society named as its representatives the Magnetician and Seismologist from the Observatory, plus two professors, L.B. Stewart of Toronto and R.W. Brock of U.B.C.

While this was going on Plaskett independently, and without knowledge of developments in Ottawa, learned of the formation of the new IAU and wrote to the Deputy Minister,[124] drawing his attention to the matter and suggesting that he (Plaskett) was the appropriate person to represent Canada on any organizing committee. Informed by Cory of the current action of the Research Council he wrote to its President, Macallum, apparently (the letter doesn't survive) objecting to the make-up of the national committee and asking that Harper, Young and H.H. Plaskett should all be named to it. Macallum suggested that they could be named among the six representatives of the Royal Astronomical Society or the three representatives of the Royal Society.[125] Plaskett seems to have accepted the situation.

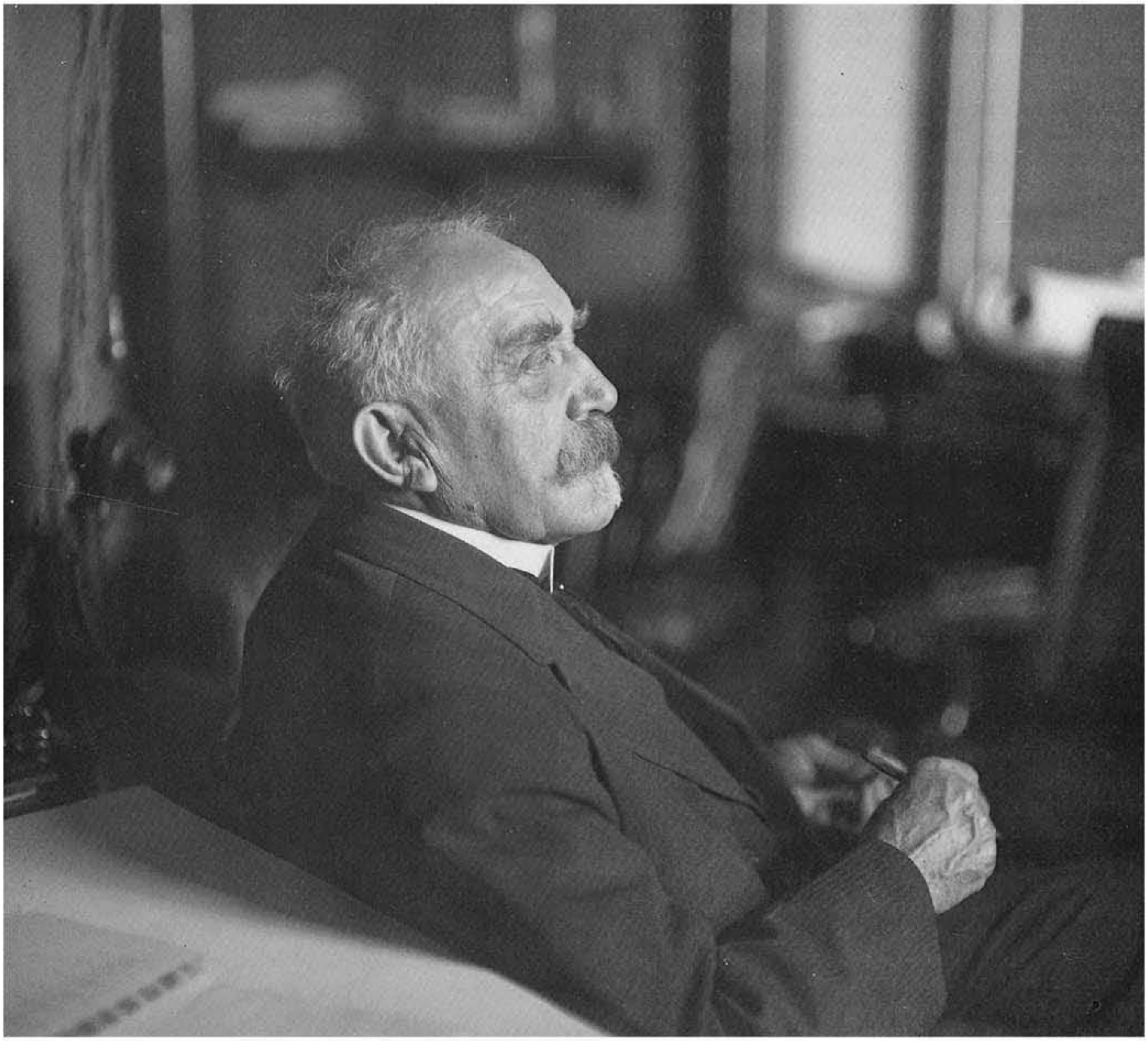
Once the Research Council recommendations about the Committees had been accepted by the government, developments moved rapidly. Deville convened an organizational meeting of the Committee for the IUGG at which he was made permanent chairman and C.A. French secretary, and Deville and Klotz were instructed to draft a constitution.[126] Two days later a meeting was held in Klotz' office to organize the Committee for the IAU. Klotz was elected chairman, DeLury Secretary, and Klotz and Chant were named to draft a constitution.[127] A year later both national committees met in connection with the Royal Society meetings to make it easier for members outside of Ottawa to attend.

The first meetings of both the IAU and the IUGG were to be held in Rome in the spring of 1922 and it was necessary to propose delegates to these meetings. The committee for the IUGG named six delegates, Klotz and Deville among them although, as Klotz observed, "the probability of six being concurred in by the Government is about as probable as a collision with the moon."[128]

The committee for the IAU voted on its delegates by mail; Dr. Klotz was their first choice, Dr. Young the second. Plaskett wrote a very strong personal memorandum to the Deputy about this. He did not object to Klotz but was very offended that his subordinate Young should have been named.[129] In the event, it didn't matter: the government named Deville as the delegate to the IUGG, Klotz as the delegate to the IAU.

The meetings of the two Unions were held, in Rome, concurrently in early May, 1922, and Klotz was able to attend the meetings of both the IAU and of the embryo International Association of Seismology. Before the new seismological organization could be established, the old one had to be dissolved and a final meeting was held for this purpose in Strasbourg on April 24-25. Klotz was a member of the committee which drafted the resolution of dissolution. The retiring chairman, Schuster of Great Britain, appeared to Klotz to intend that in the new organization Canada and other countries of the Empire would be represented by the "mother" country and would not adhere in their own right. When he met Turner, the official British delegate, a few days later in Rome he told him "that I did not intend to have Canada sidetracked, as appeared to me was intended last week in Strasbourg."[130]

At the organizational meeting of the new Association the attempt to sidetrack the colonies was not carried out; perhaps Klotz had imagined it. When as the meeting started, Klotz proposed that Turner take the chair, he intended this as a temporary chairmanship but it was taken as a nomination of the new President and accepted as such; Professor Rothé of Strasbourg was named secretary. Turner must have been expecting to be elected, he had a Presidential address ready, but as he began to read it his voice failed and he called on Klotz to complete the reading. He did so, "Toward the end he made some bitter and quite uncalled for remarks about Germany, which had I known I would have declined reading the address."[131] It was an embarassing moment for Klotz and seems to have disillusioned him, at least temporarily, about the new organization. He declined to become a member of a



One of the last photographs of Otto Klotz.

committee on microseisms and remarks "I take no stock in this organization".[131]

Before the meetings broke up he made an opportunity "to give Professor Turner my mind about his presidential address which I read for him and in which he referred in rather bitter terms to Germany. I said to him 'If you are going to use your official position as president for political propaganda I shall have nothing to do with the section, you'll get no telegrams from me nor any seismological data'. ... I told him my government would support my attitude. He was a little flustered and said I had misinterpreted his object. 'Cut it out from the printed report', and he said he would".[132]

Deville and Klotz made official reports to the Deputy Minister on their respective missions.[133]

CLOSING COMMENTS ON THE KLOTZ ADMINISTRATION

As usual, Klotz' travels were not limited to attending the meetings that were the excuse. On the way to Rome he spent an active four days in Britain and a week in Germany; after the meetings he attended the celebrations marking the 700th anniversary of the founding of the University of Padua, as a representative of the Royal Astronomical Society of Canada, visited Venice and Milan, spent an additional nine days in Germany, three days in Brussels and an energetic week in England, dining every night in his favorite restaurant, Frascatis. When he finally arrived home, seeing the Ziegfield Follies in New York on a three-day stay there ("Probably the best thing was a cowboy twirling a rope, sometimes two at a time, talking all the time making local hits, or hits at government measures")[134] he had been absent for an energetic and happy three months. As he embarked at Liverpool for the trip home he soliloquized on his happy state. Admitting that his needs were simple "I have not sought pleasure or amusement ... a good dinner, good music and genial surroundings are or were the extent of my modest desires",[135] he found his condition good. "I am in the pink of health ... I have not suffered one moments indisposition. Physical exercise I was told some years ago ... to avoid, and I have done so, but in this trip there were almost daily some unavoidable demands made in walking, in climbing stairs at stations, and etc. that seem to have been most satisfactory, so if anything I am fitter than when I left." Yet within a week of his return he was reporting trouble with his heart.

This was not a new thing. Since mid-1918 his heart had been "in evidence more than he liked". His son Max, a distinguished local surgeon, examined him. "Max said there was nothing particularly serious, it was a case of arterio-sclerosis, and said - eat less and don't smoke too much ... occasionally two ounces of rye or scotch".[136] Max re-examined him the following year and decided that he should be examined by a specialist.[137] The specialist, Dr. Lyman, said that there was to be no more walking to or from work; when he wasn't satisfied with the progress in a month he prescribed bed rest for several weeks. This wasn't conducive to good cheer. "Perhaps as I write this Charon has already started paddling for my shore and will soon be awaiting me with his boat." But he survived this dismal period and the death of his son Max, served as President of the Seismological Society of America, Vice-President of the American Astronomical Society and President of Section III of the Royal Society and put in the hectic three month tour of Europe described above.

This time there was no such miraculous recovery. He had to remain in bed for fairly extensive periods; when he was able to go to the office he had to be driven there and back and could remain for limited periods only. By mid-October a nurse was in attendance each day, more to save his wife's strength than because his condition was critical. However at one point he got so weak that he had to dictate his diary to the nurse. Mr. Stewart, the Assistant Director, was in charge at the Observatory; he and the various Division Chiefs visited Klotz at his bedside, reported on their work and left major decisions to him. J.P. Henderson installed a $100 wireless set for his listening pleasure.

This went on all winter. He had two doctors, a young one who wanted to get him up and about, an older one who insisted on complete bedrest. Between them they got him back on his feet by spring, and by mid-April, 1923, and for most of the summer, he was able to go to the office for half days, driven by one or other member of the staff. He maintained his interest in the scientific work and in his family, and continued this limited activity until mid-autumn. From that time on he was increasingly confined to his bed. The last entry in his diary in his own hand was on December 22. In a different writing, presumably that of his son Oskar, there was a final entry on December 28:

> Otto Klotz, the author of these diaries, died in his home 437 Albert St., in the City of Ottawa, at 5 o'clock in the afternoon of December 28, - 1923."

We have quoted Klotz' appraisal of Dr. King, and he himself deserves no less. What can we say about him as a person and as a Director? He was a much more important person in the life of the nation and of the city than these notes reveal, usually because of his organizational abilities. He was, for example, a founder of the Manitoba Association of Land Surveyors. He was chairman of the meeting which established the Association of Dominion Land Surveyors, and he drew up the memorial to the federal government which led to its establishment. He was elected its first President. In this capacity he proposed the establishment of a triangulation survey and drew up the Association memorial to the government. When the Ontario Association of Provincial Land Surveyors was proposed it was Klotz who was first speaker. Along with Deville and King he was for many years an examiner for the D.L.S. certification.

When he came to Ottawa he was active in many organizations. He was a strong supporter of the Literary and Scientific Society, was its president at various times, and a frequent speaker. When the Society finally was dissolved because of lack of interest it was Klotz who closed its office and distributed its resources to successor bodies. He was active in the Canadian Club and was President one year. He was a founder of the University of Toronto Club of Ottawa which grew into the Alumni Federation, and of the University Club. When the Ottawa Centre of the Royal Astronomical Society was founded it was Klotz who drew up the Constitution and who supported King in defending the Centre against the Toronto chauvinists. For many years he led the campaign for the establishment of a Public Library, fighting the indifference of the people and the attempts of Aldermen to turn it into a patronage matter (or, at one point, to put a swimming pool in the basement). It was he who wrote to Andrew Carnegie to solicit the money to build the library and he was widely acclaimed, and still is, as the father of the Ottawa Public Library.

Aside from these organizational matters he was a very popular person and something of a bon vivant. He was a member of the Rideau Club, a frequent visitor at Rideau Hall, one of the first to dine in the new and most elegant Chateau Laurier. He was a family man, greatly devoted to his children and his grandchildren, and presiding with the greatest flair and pleasure at family parties. Visitors to the Observatory and new staff members were always invited to his home, a thing that seldom happened with Dr. King.

When we turn to his contribution to the Observatory his own diary shows the limits of his contribution. He was opposed to the purchase both of the equatorial telescope and of the meridian transit and was less than enchanted with the development of the Victoria Observatory yet he always insisted that he was a founder of the Observatory, sometimes almost that he was *the* founder. He was jealous of his dignity and of receiving credit for his contributions to a degree which was almost paranoic and this led him into quarrels with King and with Plaskett which severely limited his effectiveness as Assistant Director. When he became Director much of his staff defected to the Geodetic Survey, which must indicate some lack of respect, but the remaining staff was loyal and he built up their numbers and supported them fully.

As a surveyor he was one of the leaders in opening the west. As a scientist his major contribution was the trans-Pacific longitude tie, and his tables, particularly the use of stereographic mapping in which he seems to have pioneered. These contributions show his great ability as an organizer and the energy he brought to anything he undertook. His work on microseisms including the installation of meteorological instruments in Ottawa and the marograph in Nova Scotia, was quite advanced for its time; I would say that no further advances were made in the subject until the 1940's.

He was vain about his appearance; with his beard and his frock coats he looked like King Edward and was pleased when people said so. He was vain about his possessions, about his library, about his literary tastes. He regarded novels as a waste of time and didn't read one until he was in his sixties; then he read a number of the more turgid Russian ones as part of a project to write about Russia and the Russians. He was vain about his diary and of the fact that the only day he had missed was the day he lost in crossing the date line in the Pacific. He was not only vain, he was pompous; perhaps the two go together. When a year or two ago I asked Dr. Pearce, who had worked for Klotz as a young man, what he was like: "Oh, he was a pompous ass". Perhaps the people who liked Klotz regarded him as dignified, those who didn't regarded him as pompous.

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R. Meldrum Stewart. This picture dates from the mid-1920s.

IV THE STEWART ADMINISTRATION 1924-1946

ADMINISTRATION

Unlike the King-Klotz transition, there were no problems involved in the succession of Stewart to the Directorship. The only possible contender for the position was Plaskett, and he wasn't interested. Life with the 72-inch telescope was too challenging. Within days of Klotz' death he was writing to Stewart. [1] "The news of Dr. Klotz' death came as a shock to me as I had no expectation but that he would get around to the office again after a rest at home. I regret very much his untimely death, for he was still mentally alert, and consider it a great loss to Canada, to the observatory and to the community in which he lived. I do not know of any one who can quite take his peculiar place in Canadian Science".

Not exactly fulsome praise! He continues: "The main purpose of this personal letter is, however, to express the hope that there will be no obstacles to your prompt promotion to the directorship of the observatory. Certainly no one else in the observatory or department should even enter serious consideration for the position and I hope the Department will view the matter in the same light."

It did. His appointment was confirmed toward the end of May. Oskar Klotz, Professor of Pathology at the University of Toronto and son of Otto, wrote to congratulate Stewart: "I am doubly pleased that this position has come to you, not only because of our long standing friendship, but also as I know it was the hope and wish of my father that you should become his successor".[2]

Stewart's tenure was to be long but most difficult. When he took office the Government was still practising the restraint that post-war debts had demanded; before this attitude had completely disappeared Canada, and the world, had slipped into the depression from which it was saved by the Second World War. Each of these phases posed difficulties for an organization dedicated to "pure" science. We shall treat the three phases separately.

1924-1930

We saw in the last chapter that Klotz had been slowly building up the staff in geophysics and that, by recruitment of Henroteau and Henderson, he had been trying to return the 15" telescope to a useful life. These latter efforts were only partly successful. The two men didn't get along very well and, in any event, Henderson soon made himself indispensable to the Time Service through his mastery of the new techniques of radio.

One of Stewart's first actions on his appointment was to prepare a memorandum for the Deputy Minister on the Observatory staff.[3] He proposed a reorganization into seven divisions, which he spelled with a small d, perhaps in recognition of the fact that only one of them had more than three staff members and that two divisions had only one. Each division head was to be promoted to "Research Astronomer" and Dr. DeLury, the head of Solar Physics, was to serve also as Assistant Director. One new staff member was proposed, an assistant in the Gravity Division. A number of positions were vacant.

The proposed organization was as follows.

	Scientific Staff
Director	R. Meldrum Stewart
Solar Physics Division	Dr. R.E. DeLury, Chief C.R. Westland J.L. O'Connor
Meridian Work & Time Service	C.C. Smith, Chief D.B. Nugent, Astronomer Dr. R.J. McDiarmid, Astronomer W.S. McClenahan, Assistant Astronomer A.H. Swinburn, Assistant Astronomer J.P. Henderson, Assistant Astronomer W.C. Jaques, Computer E.C. Arbogast, Computer D. Robertson, Longitude Exchange Operator W.A. Dier, Electrical Engineer
Astrophysics Division	Dr. F. Henroteau, Chief J.F. Fredette, Assistant Astronomer R. Callander, Assistant Astronomer
Photographic Photometry	R.M. Motherwell, Chief
Seismology	E.A. Hodgson, Chief W.W. Doxsee
Terrestrial Magnetism	C.A. French, Chief R.G. Madill
Gravity	A.H. Miller, Chief Vacant, Assistant
	Secretarial and Office Staff
Secretarial	O. Sills, Head Clerk J.F. Dolan, Senior Clerk

	Vacant, Messenger Vacant, Clerk Stenographer Vacant, Clerk Stenographer
Library	J.H. L'Abbé, Librarian Vacant, Clerk
Editorial	A.W. Grant, Editor Vacant, Draughtsman S. Wilhams, Engineering Clerk
	Mechanical Staff
Machine Shop	L. Christensen, Instrument Maker Vacant, Assistant
Carpentry Shop	F.J. Dunn, Carpenter
Photographic	A. Steadworthy, Senior Photographer J.G. Dickson, Assistant Photographer
Library	A.E. Shore, Bookbinder
Time Service	J.M. Walker, Watchmaker Thos. Hackett, Night Watchman

In his memorandum Stewart discussed nearly all the positions and their incumbents. It is remarkable that every one was doing a good job; there were no incompetents. Klotz had been under no such illusion; there are many references in the Diary to staff members who were not pulling their weight and some attempts to discipline them. Patronage was still a potent force in the Civil Service of 1924 and there was little that could be done. Perhaps Stewart was only cooperating with the inevitable.

There were a number of staff changes at Victoria, coincident with, but unconnected to, the change of administration in Ottawa. R.K. Young resigned from the staff in 1924 to take a position at the University of Toronto. No reason for the move is apparent. He was certainly well thought of by Plaskett. "I would like to say that he has given splendid service to the observatory and that I do not see how he can be adequately replaced. He has a happy blend of mathematical ability, experimental skill and manual dexterity, combined with originality and initiative very rarely met with in one individual and his going is a great loss to the observatory."[4] He was replaced by J.A. Pearce who was to have a distinguished career in the observatory, for many years as its Director.

At the same time Plaskett was feeling the need to increase his staff. There were interesting and important things to do, and he felt that the telescope was not being used to its full capacity. The Deputy Minister was sympathetic but he insisted that the additional staff should be obtained by transfer. One transfer was made, of S.N. Hill from the Topographic Survey. He worked as a computer and read spectrograms on occasion, saving much time for the astronomers, and sometimes publishing the results under his own name, he was helpful in the library and acted as draughtsman, but he never became an effective observer. Since he had been reasonably senior in the Topographic hierarchy his salary on transfer was higher than these duties justified and, when money was tight, as in 1932, Plaskett looked at that salary with greedy eyes. However Hill remained on the staff, serving very effectively in his limited capacity, until 1934.

Even before Klotz' death, Plaskett had been trying to arrange for the transfer of Dr. R.J. McDiarmid, who held a doctorate from Princeton and had had substantial experience in both photometric and radial velocity work. Plaskett was about to embark on an involved study of B-type stars, similar to the work he had just completed on the O-type stars, but because of the much larger number of these stars he felt that the programme would take too long for a single-handed attack. At first McDiarmid was interested, but then he vaccilated, asking for advancements in rank and salary that Plaskett found unreasonable. The transfer never took place.

Plaskett now felt that he had made an honest effort to meet the Deputy's request that positions be filled by transfer and the Deputy agreed. A position was established and a Canadian with suitable training, C.S. Beals, became available. A graduate of Acadia University, he was a student of F.A. Fowler's at the Imperial College, London, and was highly recommended by his supervisor. He was appointed to the staff in 1928. A year or two later he was joined by R.O. Redman. It may be that, before Beals became available, the position was briefly filled by W.H. Christie, for he has papers in the Publications dated 1925, 1926 and 1927, and one in the Journal of the Royal Astronomical Society of Canada for 1929. This same number of the Journal announces that he is leaving the observatory to take a position at Mount Wilson.

Beals was working in somewhat the same area as H. H. Plaskett, interpreting the results of stellar spectroscopy in terms of atomic physics, and the additional strength in this field was something that both Plasketts welcomed. Again, however, the net gain in staff was short lived. Late in September the younger Plaskett received an offer of a temporary lectureship at Harvard. He accepted and at the suggestion of Plaskett *père*, the Department made up the difference between his government salary and the lectureship. This temporary position gave way to a permanent one a year later and Plaskett did not return to Victoria. His position was ultimately filled by R.O. Redman.

By 1930 Stewart had made real gains in building up the staff.[5] A Secretary-Typist, Miss K. Nevins, and an Assistant Astronomer Malcolm M. Thomson, had been added to the Time Service, but the Longitude Exchange Operator Robertson had disappeared, probably transferred to the Geodetic Survey. Miriam S. Burland had replaced Fredette in the Astrophysics division and Callender had been transferred to the staff of Photographic Photometry. A third professional, S. Gold, and a stenographer, Miss G. McDonald, had been added to the Seismology division, and a professional assistant, W. G. Hughson, had joined the Gravity division. Two clerks, J. P. Sanche and S. I. Saxby, and a stenographer, Miss G. O'Boyle, had been added to the administrative staff. An Assistant Instrument Maker, A. Bird, had joined the machine shop, A. Steadworthy had retired and J. G. Dickson had become Senior Photographer. There were five positions vacant, three for junior professionals, one for a clerk and one for a draughtsman.

A comparable advance had been made at Victoria:

	1924	1930
Director	J.S. Plaskett	J.S. Plaskett
Assistant Director	W.E. Harper	W.E. Harper
Astronomer, Grade 4	R.K. Young	J.A. Pearce
Astronomer, Grade 3	H.H. Plaskett	S.N. Hill
Astronomer, Grade 2		C.S. Beals
Astronomer, Grade 2		R.O. Redman
Astronomer, Grade 1		Vacant
Astronomical Assistant, Grade 2	T.T. Hutchison	T.T. Hutchison
Clerk, Grade 4	? (filled)	Miss L.M. Blake
Caretaker-Chauffeur	H. Little	H. Little

Credit for the planning of the Victoria staff, and for the care with which the members were selected, belongs entirely to Plaskett, but as the intermediary between Plaskett and the Department, Stewart had an important part to play and obviously played it well.

A most important innovation had appeared by 1930, the establishment of four "seasonal" positions in Ottawa and two in Victoria. This is the first appearance of "summer assistants".

We clearly must give Stewart full marks for developing the staff during this six-year period and we must also acknowledge that the Dominion Astrophysical Observatory and the geophysical divisions received a fair share of the new positions. The latter had not been the case under King and had only begun to be rectified under Klotz.

He also had some success in construction. The office building at the Dominion Astrophysical Observatory, which had been begun during the Klotz directorship, was completed, and a vault was built, in Ottawa, to house the master clocks. Plaskett continued to press for a Director's residence and, to a lesser extent, for two additional residences for astronomers; Stewart continued to support him in this but gave a higher priority to the extension of the library in Ottawa. By 1929, Stewart was asking not only for additional space for the library but also for offices.[6] His requirements had almost doubled.

While Plaskett never did get his Director's residence and his additional astronomer's houses, his methods of seeking them are worth describing. For example, in a flurry of activity in connection with the 1927 estimates he wrote an official request through Stewart, a "personal" letter to the Deputy Minister and a letter to the Prime Minister, Mackenzie King.[7] He was sure, he said, that Mr. King would understand that the present house "intended for an astronomer ... is quite inadequate in accomodation and altogether unsuitable for the entertaining required of the director of this famous observatory or the lodging of distinguished scientific visitors who frequently come to see the telescope and study the methods and work of this observatory." He points out that the observatory "is an institution which has already established a world wide reputation and of which the Government may well be proud" and feels "sure that the Prime Minister of Canada, outside of his sympathy with scientific research, would like to see the observatory made a complete and model institution unsurpassed in the Empire."

King copied the letters to the Ministers of Public Works and of the Interior, on whose behalf the Deputy had to tick Plaskett off for going over his head.[8] None of these projects was approved. However, an extension was made to the Director's house in 1932, to accomodate the Astronomer Royal on an official visit to Victoria (K.O. Wright, personal communication).

Despite Plaskett's great objection to being placed under the nominal supervision of the Ottawa director, the situation worked well. There had been very little friction between Plaskett and Klotz; with one noteworthy exception, to be described later, there was even less between Plaskett and Stewart. When Plaskett heard of Klotz's death he wrote a personal letter to the Deputy Minister, W. W. Cory, thanking him for past support and expressing the hope that it would continue. "If I can feel assured of yours and the Department's continued sympathetic support of our scientific work, I will be the more content to leave the future administrative status of the observatory and its connection with the Department to be arranged as you think will be for the best interests of both. Naturally I would like to be informed beforehand of anything that concerns the interest of the observatory and to have an opportunity of presenting my views before the final decision is reached."[9] Cory replied, "I have recommended that Mr. Stewart be promoted to the position here and anticipate that there will be no difficulty about the matters you mention in your letter. I know that Mr. Stewart has always impressed me with his desire for friendly co-operation in the work which you both have so much at heart. You may rest assured that your scientific work will not be interfered with."[10]

This exchange of personal correspondence was typical of the period. Almost every problem was presented to the Deputy by this route as well as officially, through Stewart. Sometimes it was only directed on a personal basis and Stewart (or, earlier, Klotz) would be asked to comment on something that he had not been aware of. It is a poor way to run an organization and it is surprising that Cory (or Klotz or Stewart, for that matter) tolerated it.

Klotz had faced most of the problems involved in the separation of the Geodetic Survey from the Observatories, fighting off Ogilvie's frequent attempts to expand his empire. One source of friction remained: who was to be responsible for longitude determination? Klotz had been adamant that it was an astronomical matter and that it had been a primary reason for the establishment of an astronomical observatory. Klotz himself had been a Canadian pioneer in the field and he was not going to relinquish the responsibility.

Once Klotz was gone Ogilvie struck again. By now it was not a direct confrontation between the two directors. In 1921 Deville had been appointed Director-General of Surveys and the Geodetic Survey was one of the organizations making up his Bureau of Surveys. He expressed the opinion "that one organization should carry out the field work and that it might be possible by co-operation, which perhaps had been lacking in the past, to settle the matter on a proper basis."[11] He began negotiations with both parties.

Ogilvie took the position that all work in the field should be done by the Geodetic Survey but that the Observatory should be recognized as the base point of all the longitude work and that the observations *within* the Observatory itself should be done by Observatory staff. Stewart took the position that a single organization "should have full responsibility for the work and therefore full control. Whether that organization is the Observatory or the Surveys Bureau is immaterial, so long as the work is well done."[12] He went on to urge that, because of its expertise in astronomy and in the use of wireless telegraphy only the Observatory could see the work well done.

The Deputy Minister, Cory, asked Stewart how the matter was handled in other countries and Stewart forwarded a review.[13] He concluded that "the practice varies in different countries, though in the majority this work is done by observatories where such exist, and in all by organizations which have a complete and extensive astronomical equipment. Perhaps the outstanding fact is that in no case are individual operations, such as the determination of a longitude, entrusted to institutions which have not in their own organization the means and equipment for performing the complete operation."

He goes on: "I can only add that the prospect of again taking over this work in its entirety, especially in view of Mr. Ogilvie's opposition, is not ... a pleasing one to me personally. ... I have no particular wish for further responsibilities if these would involve friction with another branch."

The Deputy, with the advice of Deville, ruled against the Observatory and the determination of longitude became the responsibility of the Geodetic Survey. However, this wasn't quite the end of the matter, as will be seen later (p. 159).

1931-1939

When the New York Stock Market crashed on October 29, 1929, the effect on Canada was almost immediate, but it took some time for the shock to reach the Public Service. The Prime Minister, King, believed that Canada could avoid the worst of its effects by keeping a balanced budget and a sound dollar. Throughout the early months of 1930 his hopes seemed to be borne out but, as the year advanced, things worsened rapidly. In a general election on July 28, the Conservatives under R.B. Bennett were returned with a clear majority of 29 seats.

This is not the place to document the disasters of the Bennett administration, but in those pre-Keynesian years the idea of curing a depression by spending money to create purchasing power had not been heard of, and would have been discarded by Bennett if it had been. He aimed to cut expenditures to the bone, and the Public Service was an obvious target. In April, 1931, Stewart learned that "a list has been prepared which is intended to designate a first installment of those whose services it is proposed to dispense with at the Dominion Observatory."[14] The list contained eight names; three of the four stenographers which Stewart had been able to provide, one junior clerk, the bookbinder, and three professionals, M. M. Thomson, S. Gold and Miss M.S. Burland. These were the most recently engaged members of the professional staff; indeed, except for the bookbinder, all the names were of people recruited during Stewart's regime. The bookbinder was 59 years old and had 41 years of service and was, presumably, to be let go on these grounds.

Stewart presented a strong memorandum[14] to the Deputy Minister defending the importance of those positions, and their incumbents, to the work of the Observatory; he also pressed his case in a direct interview with the Minister. He was apparently reasonably successful, for a staff list dated 1932-33 contains the names of all but two of the eight people, a stenographer and a junior clerk.[15]

The next blow occurred a few days later when he was forced to write to the Photographer, J. G. Dickson: "It is regretted that the reduction in the amount available for the continuing work of this Department makes it necessary to terminate your service *from and after today*."[16] The italics are mine; no notice whatever to a permanent civil servant who had given good service! Stewart appended a note: "Please accept also my personal regrets." Perhaps Dickson was not a "permanent" although his personnel file shows that he was made permanent on April 1, 1929. Whatever the justification for it, he was replaced immediately by Major G.H.A. Collins who was transferred from the National Development Bureau. Collins, who was a veteran of both the Boer and Great Wars, remained on the staff until July, 1949 when he was retired at age 70.

The Department continued to press for a reduction of staff, but apparently Stewart was able to convince the Deputy that the blow should fall on its less productive members. In February, 1932, a new Deputy Minister, H.H. Rowatt, sent a list of four such staff members, three professionals and one senior clerk, whose employment was to be terminated by the end of the fiscal year.[17] Since Stewart had made the selection he was not going to protest the action, but very shortly the four had marshalled enough support that Rowatt wrote that "some objections have been taken to their being selected for retirement in preference to such younger members of the staff as Miss Burland and Messrs. Thomson, Gold and O'Connor." [18]

Stewart provided a strong defence. In his response[18] he says of two of the people he proposed to let go "The heads of the divisions concerned are in thorough agreement with me that they are the least competent men in their respective divisions. It is particularly the case with scientific positions, much more so than for those of an administrative or clerical nature, that the success of the whole institution depends to a large degree on the ability, initiative, and enthusiasm of individual members of the staff. Men lacking in these quantities, or who look on their positions mainly as a means to a livelihood, while they may frequently be successful in other lines, are never a real success in scientific work. It is precisely these qualities that Messrs. --- and --- lack."

As for the third professional, he and Mr. O'Connor "are in the same division - Solar Physics. ... Mr. --- had the initial advantage of a university education and survey experience, which Mr. O'Connor lacked. Notwithstanding this handicap, Mr. O'Connor has, over a period of years, applied himself with such diligence and taken such an interest in making a success of his work that he has made himself practically indispensable, while Mr. --- has been content to carry out such work as assigned to him without any particular vision or ambition."

"With regard to Miss Burland, Mr. Thomson, and Mr. Gold, they are keen young investigators, with specialized education and abreast of the times ... and are already essential units in the divisions in which they are working."

The Deputy discussed the matter with the Minister and wrote.[19] "It is remarked that the fact still remains that these three officers are reasonably efficient and that they are in category 2 whereas some of the employees retained are in category 4. I would appreciate any further observations which you may care to make. If you feel that you are unable to revise the decision the Minister will give you an opportunity to discuss the whole matter."

Stewart blasted back:[19] "the selection was made on the basis of efficiency, and ... on this basis no other selection could reasonably have been made. That the Department definitely and officially considers this as the primary requirement is confirmed by yours of March 5. Of course, if the criterion were to be, not enthusiasm for their work, but enthusiasm in securing recommendations that their service be continued, the selection might be quite different."

All was in vain.[20] A pair of memoranda were received from the Deputy; the first stated that the three most senior of the men in contention should be re-instated, the second that S. Gold and M. M. Thomson were to be let go at the end of June.

Stewart's response came promptly.[21] "I beg to report that the presence of Messrs. --- and --- [two of the three men involved] at the Observatory will not only be of no advantage to the institution, but will be a detriment. Notwithstanding the fact, therefore, that I am constrained to pay their salaries out of my appropriation, I would respectfully request that they be stationed in some other branch. It is of course possible that under new circumstances they may give the service which they have failed to give at the Observatory."

I have quoted this correspondence so extensively because it seems to me to have been an extremely courageous act for Stewart to have so defied the Deputy Minister and the Minister in defense of his principles and of his staff. He was 54 years old at the time and might very well have found himself pensioned off like so many of his staff.

As for Gold and Thomson, Stewart proposed that he be permitted to make cuts in his budget of an amount equivalent to their salaries in order to retain them. This permission was granted "on the distinct understanding that the necessary work of the Dominion Observatory must be carried out without over expending the appropriation."[22]

As the depression deepened, its effects began to be felt in Victoria. At the end of 1931 the Department decided to cut back drastically on the number of motor vehicles it operated, and the Victoria observatory automobile was one to go. Plaskett was furious, dashed off letters and telegrams of protest, but to no avail. The car must go, supplies could be brought from town by staff members who, after all, were receiving $50 a month housing allowance and might be expected to do something for it, and the Post Office would be asked to deliver the mail to the observatory offices. It was left to Plaskett to initiate discussions with the local Post Office officials. Apparently they felt that the decision would have to be made in Ottawa. This led to the one example of unpleasantness between the two Directors which has already been adverted to (p. 125). Plaskett wrote to Stewart[23] "I assumed, therefore, that the negotiations would be arranged between the two departments, particularly as they had been initiated at Ottawa without your having deemed it either necessary or courteous to consult the director here about what arrangements it would be advisable to make for the necessary transport when the observatory car was discontinued after less than 48 hours notice."

"A similar method is apparently being followed, as judged by your recent letter, in your recommendation for the delivery of mail and parcels and it is hard to consider it as anything but insulting to an efficient officer to have his business thus settled without the courtesy of consultation or any apparent consideration of the difficulties of transport at this distance and the personal loss caused by the recent removal of a long established system of communication. I am merely informed by wire that arrangements are being made for the transport of mail as if that comprised the sole purpose of the observatory car. As they cannot know the local conditions at head office, I can only infer that the proposals must have been based on the meagre knowledge you obtained in one short visit to the observatory. I cannot believe that the situation is properly understood by the Department or else the inconvenience and expense of alternative methods to that proposed by me, and the injustice of trying to settle this matter without reference to the director would have been realized."

He sent a copy of the memorandum to the Deputy Minister with an accompanying personal letter suggesting[24] that "owing to the indirect and, as I have always maintained, unjustifiable method of conducting the departmental business of this institution through the director of another observatory" the Deputy might not understand the situation.

Stewart didn't reply until February 25.[25] "Yours of February 3 was received in due course. I wish to thank you for your kind personal references and for your expressions of appreciation of my efforts in your behalf, particularly as contained in the first two paragraphs of your letter. Such sentiments could not fail to produce a most favourable reaction not only on myself but on the Deputy Minister and the Minister."

"It appears that you have entirely failed to realize the government's view of the seriousness of the economic situation, and the fact that the many favours that you have received in the past, both for yourself and members of your family, cannot be expected to continue under such conditions." Stern words!

Worse was soon to follow. Just hours before the estimates for 1932-33 were to be tabled in the House, the votes for both observatories were cut drastically by Treasury Board, that for Victoria from $25,170 to $20,600;[26] I have not found the exact figures for Ottawa but the cut was slightly over 25%.[27] Part of this reduction was to be accomplished by a government-wide cancellation of statutory increases and salary reductions of 10%, but a substantial amount remained to be found. At first it was feared that at least one staff member would have to be sacrificed but the Minister intervened and decreed that other savings must be made.[27] They were. Summer assistants were dispensed with, publication was postponed or replaced by papers in scientific journals and a 50% reduction in housing allowances was imposed. The gentlemen receiving this allowance - Drs. Harper, Pearce and Beals - were not very happy about the reduction and the money was found elsewhere. [28] About the same time the Minister approved a payment to Plaskett of 10¢ a mile for the use of his personal car on Observatory business.

The 10% salary cut imposed on the Public Service was never, as far as I can find, returned. When statutory increases were again allowed, they were applied to the lowered base. Considering the suffering that was going on throughout the country, with unemployment in excess of half a million and with the destruction of agriculture in the west, this was a very small price for public servants to pay.

Indeed, to this point, the Observatory had suffered relatively little. Comparing the staff lists for 1932-33 with that for 1930 there are changes but a net reduction of only two positions. Apparently some people with greater seniority, or political influence, had replaced the original staff (as in the case of Collins replacing Dickson) and the position of draughtsmen had been filled.

Things got worse. In August, 1933, Gold, Hughson and Saxby were let go,[29] thus negating the efforts that Stewart had made to build up the seismology and gravity divisions and the administrative section with competent younger people. It was to be many years before these losses were made up.

Another casualty of the period, about which the surviving files are quite inadequate, was Dr. F. Henroteau, the chief of the Astrophysics division. In a memorandum of mid-June 1932 we find the terse statement:[30] "Mr. Henroteau is being suspended for five months without pay." He retired on July 25, 1933, apparently without ever returning to work. At the start of the war he wrote to Stewart from a still-neutral Belgium,[31] offering his services in any capacity that would help Canada or Britain's war effort.

In its 1933 budget the Government undertook to reduce controllable expenditures by $14 million. This was a large amount of money in 1933. One way in which they proposed to effect savings was to insist that all public servants 65 years or older should be retired. We who are used to mandatory retirement at age 65 will regard this as an unnecessary step, but apparently mandatory retirement was not very strictly enforced in those days. We have seen, for example, that Klotz died in office at the age of 71 and there is quite charming correspondence concerning the observatory photographer, J. D. Wallis, asking that his retirement be deferred until the end of the fiscal year. Mr. Wallis was 83 years old and the deferrment was granted! At any rate the government had decided to enforce the regulations unless it could be shown that the public interest would suffer if the service of an incumbent were terminated. Stewart received a memorandum reminding him that Dr. Plaskett and W. S. Dier were subject to the new regulations.[33] Dier was the electrical engineer responsible for maintaining the clocks which the Time Service operated throughout public buildings and Stewart already had a replacement being trained. He asked for an extension of time to permit the completion of this training.[34]

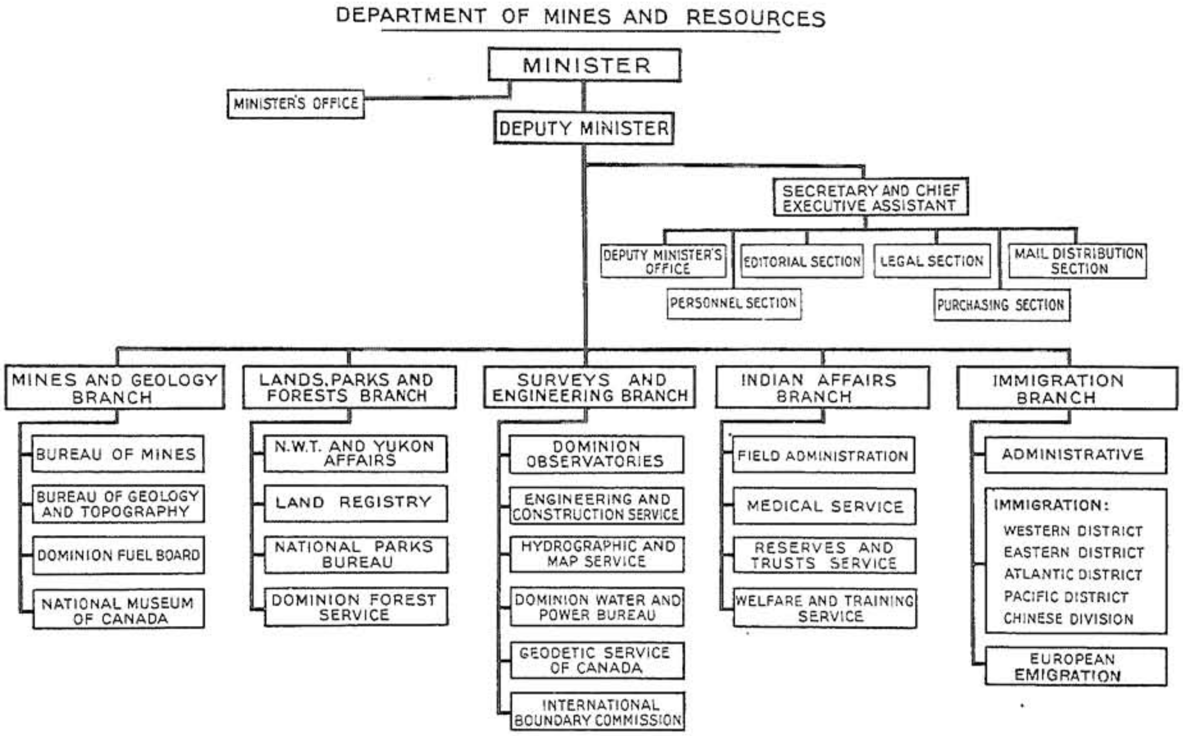
Plaskett was 68, and there was little Stewart could do to defend his retention. He pointed out however that[35] "in the case of an institution such as the Dominion Astrophysical Observatory, continuity of policy and program are essential to success ... it is felt, therefore, that to retire the Director, Dr. Plaskett, on two or three weeks notice, without an opportunity to arrange for the rounding out and completion of the investigations in which he is personally engaged, as well as to give the benefit of his long experience in planning for future work with the Assistant Director...would not be in the public interest." He suggested that Plaskett be retained until March 1, 1934, but that he be notified of the proposed date. He goes on: "though on account of his high qualifications and long experience, I should still have some hesitancy in certifying that the public interest would not suffer if his services were then terminated." In his obituary notice of Plaskett,[36] Beals gives his retirement date as 1935, but no correspondence remains to show how this extension was obtained.

Plaskett was succeeded as Director by his Assistant, W. E. Harper, and J. A. Pearce became the new Assistant Director.

This apparently completes the staff reductions which the Observatory suffered. A staff list dated April 1, 1936 survives and the only employees that have disappeared since 1932 are the four discussed above - Gold, Hughson, Saxby and Henroteau. Of the three people that Stewart worked so hard to get rid of, one has transferred to the Geodetic Survey, the other two are on the 1936 list; whether they were actually working at the Observatory or merely carried on the Observatory pay list as Stewart had requested, is not clear. Dier, who was supposed to have retired in 1933, is still with us in 1936. At Victoria, staff numbers were unchanged. Hill and Redman had left, Petrie and McKellar had joined the staff. One step in this sequence is missing. In 1934, Dr. Frank Hogg who had joined the staff late in 1930, resigned to accept an appointment at the University of Toronto. When he left, Plaskett was considering filling his position either by R.M. Petrie or by A. McKellar, both of whom had worked as summer assistants. In the event, Hill retired at about the same time and he was able to engage both men.

The return to some sort of normalcy may have been the result of a change of government. The Liberals, under Mackenzie King, won the general election of 1935 with an overwhelming majority and began the modest application of the Keynesian economic policies which King had studied while in opposition. Whatever the reason for the change, there is a definite up-turn in the spirit of correspondence.

Stewart had done a remarkable and courageous job in protecting his staff through the depths of the Depression. His budget had been drastically cut. Ridiculous economies had had to be practised. For



Organizational chart, Department of Mines and Resources.

The staffs of the Dominion Observatory and the Geodetic Survey, November 1939. National Archives of Canada, PA 149301.

example there was a phone in Stewart's office and one other phone, in the rotunda, for all other staff members. Perhaps Stewart enjoyed the rituals of the economy. I remember that my father travelled to Montreal on some government business involving McGill University. He checked into his hotel and telephoned the professor he was to visit. When, on his return, he turned in his expense account, Stewart refused to authorize the expenditure of 10 cents for this call; Mr. Hodgson could have phoned from the pay phone in the lobby for a nickel!

Nevertheless, let us give the man credit; he kept the organization alive.

In 1936 there was a major reorganization of government departments. Among other things, the Department of the Interior disappeared and a new, larger, Department of Mines and Resources was established. The Meterological Service was transferred from the Department of Marine and Fisheries to the Department of Transport and its geophysical responsibilities, the magnetic stations at Agincourt and Meanook and the seismograph stations at Victoria and Toronto, were transferred to the Dominion Observatory. The organization chart of the new Department appears on the facing page.

The Observatories became a unit within the Surveys and Engineering Branch and they reported to a Director, J. M. Wardle, who was a professional engineer. This is the first time that the responsible senior officer had been more than an administrator. It meant, however, that the titles of the erstwhile Directors under him had to be changed, and Stewart became the "Dominion Astronomer", the Assistant Director DeLury became "First Assistant" and the Director and Assistant Director at Victoria became "Head Astronomer" and "First Assistant" respectively.

There is some amusing correspondence about this. Apparently the change in title was made while Victoria had some new letter-head paper on order and the new paper had the old title. When Stewart wrote pointing this out, Harper was away and the letter sat on the secretary's desk. "Shortly thereafter J.S.P. came in and he and the secretary had a great chuckle over it; of course anything that might carry the implication of demotion would be a tasty morsel to both."[37] The letter continues in such a way as to suggest that Plaskett was not as uniformly beloved as tradition would have us believe. "Everything goes smoothly apart from the visits of J.S.P. Thank goodness the blocked conditions of the roads has kept him at home the past two or three weeks."

The transfer of the geophysical responsibilities of the Meteorological Service to the Observatory also involved a transfer of staff. W.E.W. Jackson and W.E. Ross of the Agincourt observatory and H.E. Cook, the Observer at Meanook, remained in those locations but became members of the Observatory staff. A third new name appears in the Magnetic Division, F. Furnell, but it is not clear whether he had come from the Meteorological Service. Apparently a seismologist was gained at the same time. A W.G. Carroll appears very briefly at this time, but was transferred back to the Department of Transport, leaving his position available to the Observatory. It was apparently this position that Morris J.S. Innes filled in 1938.

It will be informative, before closing this section, to compare the staff list for the 1939-40 estimates with that already referred to for 1936. We have five new employees, four in the Magnetic division and one in seismology, as a result of the transfer from the Meteorological Service. The two remaining "poor" employees that Stewart had been trying to get rid of for so long were finally dropped at the end of the 1938-39 year. A number of temporary positions have appeared, V.E. Hollinsworth as Supervisor of Time Service, a clerk and two stenographers. In Victoria, K.O. Wright appears as a temporary and there is one additional, vacant, position for an Astronomical Assistant.

On the whole, things seemed to be looking up again.

I have not found lists of the Observatory appropriations through the Depression and post-Depression years, but in a 1940 memorandum Stewart says[38] "we had ... in the last few years suffered reductions in appropriations of nearly one-third." This is a figure that we must keep in mind as we evaluate the scientific work of the period. First, however, we must document the effects of the next blow! On September 1 the German armies marched into Poland, on September 3 Britain and France declared war, and on September 10 a hastily convened parliament brought Canada into the war at the side of Britain.

1939-1946

The war affected government scientific departments in three ways. Young staff members enlisted in the services and were lost for the duration; staff members with special skills that could be applied to the more immediate problems of war were seconded to other departments; decreasing budgets limited the work and even resulted in the laying off of staff. All of these factors operated, to varying degrees, in the Observatories. There were not very many people of military age on the staff. In Ottawa only three men, Morris Innes, Malcolm Thomson and Ted Hollinsworth, were under 40, and of these Innes enlisted in the R.C.A.F. in March 1940 and Thomson enlisted as a navigation officer in the R. C.A.F. Special Reserve in November, 1942. Hollinsworth, who by now was responsible for the maintenance of the Time Service could not be spared from his duties. In Victoria there were three people under 40, Petrie, McKellar and Wright, and immediately after the war started[39] Pearce offered their services and his own, in any capacity in which they could be useful. It was agreed that such highly trained physicists would be more valuable in the support of the war effort than in actually fighting the war.

A memorandum was circulated by the Civil Service Commission asking for lists of people who were available for secondment to other departments, with their field of specialization.[40] Stewart replied promptly and generously and, as a result, A.H. Miller and R. M. Motherwell were on loan to the National Research Council in connection with work for Munitions and Supply from late June, 1940. Motherwell died only three months after the transfer and Miller returned to the Observatory in November, 1942, for health reasons. The chief machinist, L. Christensen, was also seconded to Munitions and Supply to act as a Gauge Production Representative to factories seeking to supply these items.

In Victoria, McKellar was released temporarily in late 1941 to teach at the University of British Columbia, replacing a Professor Mann who, in turn was on loan to the National Research Council. Later in 1942, the Radiation Laboratory of the University of California, through its director Ernest O. Laurence, made an effort to enlist McKellar to their staff. However Dr. R.W. Boyle, head of the Division of Physics and Electrical Engineering at NRC, wanted McKellar in his optics laboratory, and this wish prevailed. In January, 1944, McKellar moved to NRC which seconded him to the Directorate of Operational Research, Royal Canadian Navy.

Petrie also was in much demand, particularly by the University of British Columbia. There was a reluctance on the part of Pearce and Stewart to lose a second senior member of their staff, and the pressure was resisted. However when the National Research Council asked for his secondment that was another matter, and he was released, through them, to the Royal Canadian Navy for a period of about two years ending in September, 1945. He held the rank of Lieutenant-Commander, served with the mine detection unit and was awarded the M.B.E. for the work he did there. McKellar served in a similar capacity.

In May, 1940, Stewart was told by the Minister "that certain reductions had to be made in appropriations, and that the only way we could meet these reductions was by retirement of the staff." To fight this decision during wartime would have been unpatriotic and Stewart "accepted the situation cheerfully (at least as cheerfully as we could - perhaps too cheerfully) and proceeded to make the necessary retirements".[41]

Two people, both division chiefs, were to be retired, C.A. French and R.M. Motherwell. They were probably chosen because they were the most senior both in age and in salary and so represented the largest saving with the smallest personnel sacrifice. The retirements were to take place about the first of June but the loan of Motherwell to NRC allowed him to avoid it. Then another factor entered; since NRC was paying the salaries of Miller and Motherwell, the saving on their salaries met the necessary reduction in the appropriations and there was no need to proceed with the retirement of French. Stewart argued forcefully on his behalf.[41] "As for Mr. French himself, I can say no more than that he is one of our oldest and most valued employees, and that the lack of his services in our magnetic work has already caused us considerable difficulties, and is likely to cause more. As you know, magnetic work is particularly important in war time, especially in view of our rapidly expanding naval and air services, for which a knowledge of magnetic declinations along the coasts and indeed over the whole country is essential. Instead of cutting down on this work we should be expanding it. Skilled scientific men are not picked up overnight; they require years of training. What we should do to ensure the future of this essential work is not only to recall Mr. French, but to employ in addition a young man to be trained during the next few years against the day when Mr. French must retire on account of age."

His pleas were in vain; Mr. French's retirement was allowed to stand.

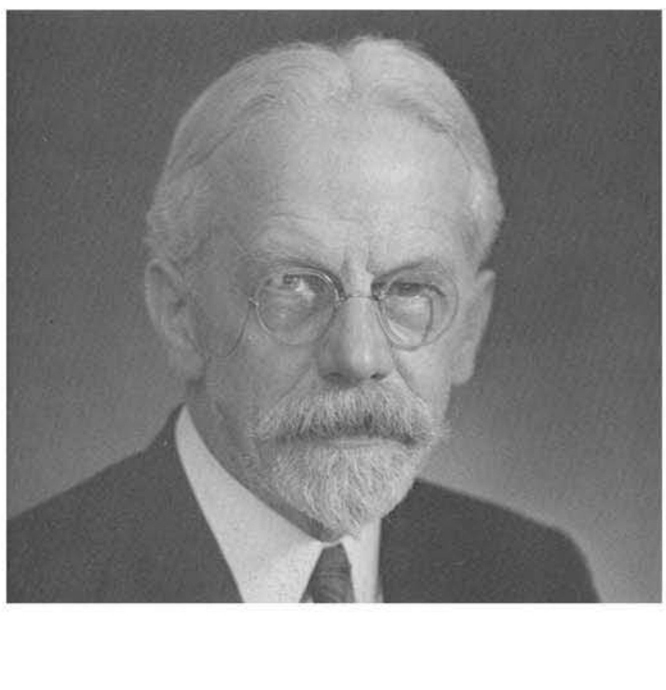
One other change in personnel should be noted: Miss M.S. Burland was transferred to the Seismological Division to replace Morris Innes and work with the 15-inch telescope was discontinued.

For the first time, in connection with the cuts in appropriations caused by the war, I find some actual figures of what these appropriations were;[42]

1939-1940	$116,800
1940-1941	104,853
1941-1942	95,470
1942-1943	95,370
1943-1944	97,910
1944-1945	102,490
1945-1946	111,105

(Above) A reception at the Observatory, April 1946. From left to right J.M. Wardle (?), J.E.R. Ross, (Director of Geodetic Survey), R.M. Stewart, P.M. Millman and M.J.S. Innes.

(Right) R. Meldrum Stewart at about the time of his retirement.



Dr. J.S. Plaskett

A group from an IAU conference visit the Dominion Astrophysical Observatory in August, 1932. Plaskett, as the host, is front row, centre; Pearce, Hogg, Beals and Harper are in the second last row. Dr. Helen Hogg and Mrs. Beals will be seen on a line reaching "southeast" from Beals.

these figures do not include the appropriation for the Dominion Astrophysical Observatory. In 1939-1940 it was $30,575, in 1940-1941, $27,575.

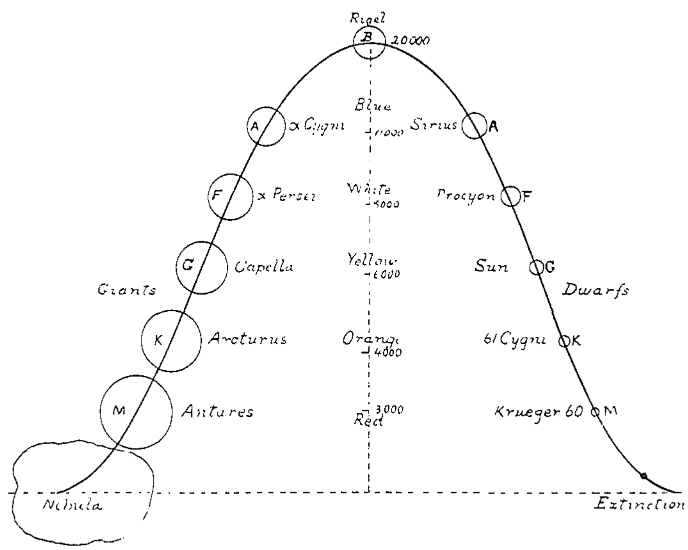
A salary list survives for 1939-1940[43]; for the Ottawa observatory it totals $104,575, for Victoria, $25,020. By transferring Miller and Motherwell to the NRC vote and retiring French, the Ottawa salary list would total $93,055 in 1940-1941 but the Victoria total would remain unchanged. This means that in 1940-1941 the Dominion Observatory had $11,798 and the Dominion Astrophysical Observatory $2,555 to spend on such non-salary items as supplies, equipment and field expenses. The Ottawa figure would be reduced to $2,415 in 1941-1942 and $2,315 in 1942-1943. These figures are incredible! Even if we go to the pre-war level of 1939-1940 and restore Miller, Motherwell and French to the staff, the free funds available are only $12,224 for Ottawa, $5,550 for Victoria. One would not have thought that this was sufficient to mount one field party in Ottawa or to buy the photographic plates in Victoria. My father's story that during most of his career the Seismological division seldom had as much as $100 to spend on equipment becomes believable.

The observatories, both in Ottawa and Victoria, contributed as much as possible to the war effort but most of these contributions can better be described in later sections. Here we might mention some training courses. In Ottawa J.P. Henderson and Glen Madill gave courses in navigation and Stewart received a very nice letter of thanks from the United Kingdom Air Liaison Mission.[44] In Victoria courses in practical astronomy were given to the Officer's Training Corps and on "Gases in Warfare" and on the construction of gas masks, to groups of Air Raid Wardens.

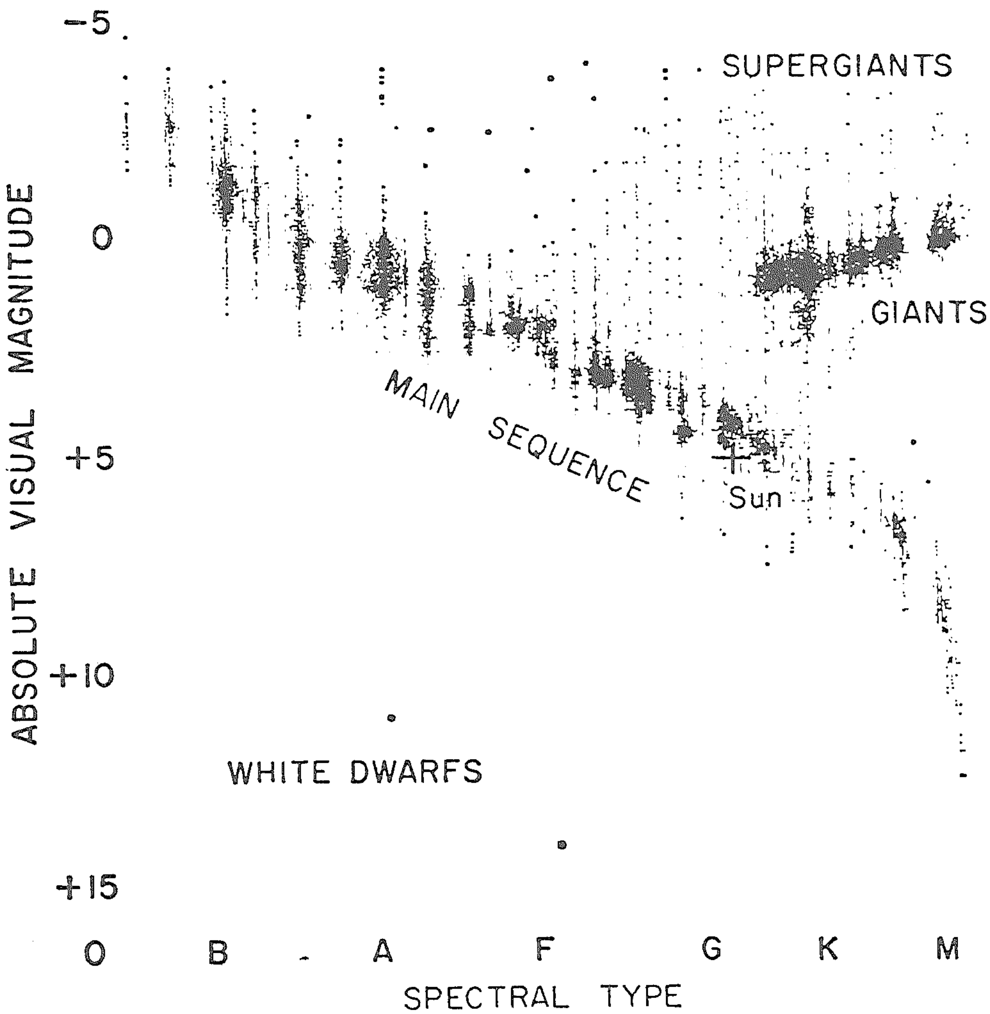
The European War ended on May 6, 1945, the Pacific War on August 14 and demobilization began at once. Thomson and Innes returned to the staff. Sometime during the war a position had been established for an assistant in gravity, at a salary scale somewhat higher than the position Innes had occupied in seismology. He transferred to the new position; the position in seismology was filled by W. G. Milne. There were a number of other additions to the staff in the closing days of the Stewart administration. Dr. P.M. Millman joined the astrophysics group on his demobilization from the Air Force, E.G. Woolsey was recruited to the Positional Astronomy Division, and J.E. Clark, A.A. Onhauser and P.H. Serson to the Geomagnetic Division.[45]

DOMINION ASTROPHYSICAL OBSERVATORY

As we have seen, there were a number of staff changes in Victoria more or less coincident with, though unrelated to, the change of administration in Ottawa. There were also changes in the programme in Victoria, but those were natural developments of earlier work and the time coincidence has no significance. This is worth stating for it illustrates the fact that the interference by Ottawa, which Plaskett had so much feared, never materialized.



The Observatory programme was increasingly dedicated to two ends, to understand the evolution of stars and to learn about their motions through space. There is a very interesting paper by Plaskett from this period[46] which outlines the then current thinking. The above figure is from that paper. Stars were formed by the accretion of matter in spiral nebulae and, under the action of their own gravitation, gradually become compressed with consequent rising of their temperature, eventually to a point where they became visible as red stars, red "giants" in fact, because they would still be very large and very tenuous. The condensation and the increase of density and temperature would continue and as the star became hotter its spectral class would change, from M to K and from K to G, and so on. When it reached a temperature of 20,000° and appeared as a blue star the process of condensation could no longer raise, or even sustain, the temperature, and as the stars shrank into "dwarfs",



Spectrum – Luminosity Diagram, 47.

their temperature dropped and they moved from one spectral class to the next in reverse order.

In order to attain to Class B, the star would have to have a very large mass, and those that had smaller masses could attain only to a lower class before declining in the dwarf phase. On the other hand, those rare stars with even greater masses then the B-Class could attain even greater temperatures than the blue stars, and these constituted the O-class.

This theory of stellar evolution, although it was soundly based on theoretical studies of Jeans and Eddington, did not stand the test of time. Things were much more complex than it suggested, but it had an important influence on astrophysical research for it was obviously of the greatest importance to study the different classes, to understand the numbers of stars in each class, their masses, densities, temperatures and motion in space. One of the most powerful tools in this study was the investigation of binary stars. Jeans had shown theoretically that, as the stars condensed, they rotated, and as they continued to diminish in radius they would become unstable and separate to form binary systems. It was therefore important to know what percentage of stars were binary, how this varied with spectral class, and what the separation of the stars and the dimensions of their orbits were. In those rare cases where a complete solution was possible and the actual masses of the stars could be obtained, the information was of the utmost significance.

It was at about this time, when the absolute magnitudes of a large number of stars had been determined, that a new way was developed to demonstrate the numbers and distribution of stars of the various Classes. This is illustrated on the facing page. When the absolute magnitude, or luminosity, was plotted against spectral type, the points mostly fell in a broad diagonal band. Stars which were so located were said to be in the "main sequence" . Some stars fell above the main sequence bands, meaning that they were unusually luminous for their spectral class, and these were called "giants" or " supergiants" depending on how far above the band they lay. Other stars had abnormally low luminosity and lay below the line. They were called "dwarfs". Later the term "dwarf" became much more loosely used and was applied to all main sequence stars of low luminosity.

The study of absolute magnitudes and related parallaxes, completed in 1924 by Young and Harper,[48] had concerned late stars, types F to M. A new programme was instituted in 1925 applying the same methods to all A-type stars for which parallaxes were known. This programme was never completed in the form originally intended. Harper found that estimating relative line intensities by eye was not adequate and no recording microphotometer was available. In any event equivalent programmes were being carried out elsewhere, so the programme was dropped. The radial velocities of 917 stars obtained during the work were published in 1937.[49] Harper also found time to publish the radial velocities of 477 stars of classes F to M which had accumulated over the years in one programme or another.[50]

In the course of these investigations many spectroscopic binaries were discovered and the orbits determined: Volume III of the Publications contains papers defining the orbits of 17 binaries in which only one of the spectra was observed, of 15 in which both spectra were observed and one in which both spectra were observed and in which a photometric orbit was available. This paper was by Pearce.[51] He was able to determine all the properties of the system including its parallax. While most of the other papers in the volume are by senior members of the staff, two of them are by Christie, as already noted, and one is by a summer student, R.M. Petrie.

Meanwhile Plaskett, having completed his study of the O-type stars[52] began a parallel programme involving all B-type stars brighter than magnitude 7.5 and lying north of -10°. The observing portion of the programme in which he was assisted by Pearce, continued until 1930 by which time 3500 spectra of 550 stars had been obtained, several stars had been re-classified from B to O class and 135 new binaries had been discovered. As the main programme was nearing completion it was extended to include some stars of classes B5 to O fainter than magnitude 7.5.

The absorption H and K lines of calcium were a prominent feature of the spectra of the B stars as they had been for the O. In his 1924 paper Plaskett had suggested the existence of a widely distributed and nearly stationary gaseous matter containing ionized calcium, through which the O-type stars moved rapidly in all directions. Apparently on the basis of this paper, Eddington made an "elegant theoretical treatment of the nature and physical properties of the diffuse gaseous material in the galaxy".[53] Once the programme on the O- and B-type stars had been completed many more data were available and Plaskett and Pearce returned to the question of interstellar matter, armed with the sophisticated theory provided by Eddington. They were able to show that, on a statistical basis, this matter was uniformly distributed through space and that it shared in the general rotation of the galaxy.

The ultimate aim of Plaskett's work on the O and B stars was to establish the fact that the galaxy rotated and to determine its dimensions and its rate of rotation. Why the O and B stars; why not all stars, or a weighted sample of all types? There had been suggestions that the galaxy was not a single system, but that there were a number of systems within it, moving independently. The O and B stars are brighter and can be seen to greater distances than most late-type starts. Hence they can define the galaxy better. Furthermore, earlier work had found an anomaly in the motion of these stars which could be interpreted as a movement away from the centre of the galaxy. To investigate this so-called K term was an important part of the research. It should perhaps be stated here that the study of the B stars continued to be a major research effort of the Observatory for many years, and a most fruitful one. We shall return to this matter later.[54]

Plaskett and Pearce tackled these questions in four papers which make up a dedicated volume of the Publications of the Dominion Astrophysical Observatory. The first paper gives "The Radial Velocities of 523 O- and B-Type Stars Obtained at Victoria, 1923-1929".[55] The tabulation includes the velocity of the calcium lines where they were present; it was found that stellar calcium lines could be confused with those due to interstellar material in stars cooler than about B5 and care had to be taken in interpreting these lines. A second paper provides "A Catalogue of the Radial Velocities of the O and B Type Stars".[56] The catalogue included stars observed at other observatories. The third paper which considered "The Problems of the Diffuse Matter in the Galaxy"[53] has been summarized above. The fourth paper brought the research to a conclusion: "The Motions of the O and B-Type Stars and the Scale of the Galaxy".[57]

This is a most complex paper, impossible to summarize in an account such as this. The methods were not new, but the authors had vastly more data available than previous investigators. We may only state their conclusions. The galaxy has a diameter of 30,000 parsecs (9.2 x 10^{17} km), a total mass 16.5 x 10^{10} times that of the sun and it is rotating with a period of 224 million years. The mysterious K term was very much reduced in magnitude and was satisfactorily explained as consistent with a displacement forecast by the theory of relativity. Finally, the paper compares our galaxy with the Andromeda Nebula and finds the two similar in dimensions and in surface brightness.

The Volume constitutes a monumental work, pursued with careful planning over many years, and one that brought great prestige to the authors and to the Observatory.

The fact that our galaxy was a spiral nebula was by this time well accepted although the comparability of dimensions and brightness with the Andromeda Nebula was a new bit of corroborating evidence. If stars are formed by condensation within these nebulae/galaxies it is important to know as much as possible about the other nebulae. As early as 1924, H.H. Plaskett was involved in such studies and two papers involving both observation and detailed theoretical considerations of nebulae were published. [58] The Publications include a related paper, obviously a very important one, by H. Zanstra,[59] a Dutch astrophysicist who spent one summer at Victoria.

In February, 1928, H.H. Plaskett took up a lectureship at Harvard University. The appointment was initially for one year but it was extended, and the younger Plaskett left the staff of the Dominion Astrophysical Observatory for good. His stay at Harvard was not long; in 1932 he was appointed Savilian Professor of Astronomy at Oxford University. He returned to Victoria frequently for short periods. We have already noted the appointment of Beals to the staff at about the same time. In recommending Beals' appointment Plaskett had noted the similarity of his interest to those of H.H. Plaskett but stated "there is easily room for another man and it is certainly the most promising field in modern astronomy." In the event, it was a most fortunate appointment; there must have been very little overlap between the two men, and it meant that the point of view of the laboratory spectroscopist was not lost to the Observatory.

Beal's first research had to do with the Wolf Rayet stars. These are O-type stars which show very broad atomic emission bands. How were these bands to be explained? In his study of the O-type stars Plaskett included 14 of the brightest Wolf Rayet stars; Beals extended the study to include all the stars of this class which could be observed at Victoria. From the large body of data thus acquired he was able to propose a new spectral classification especially adapted to these stars. He showed that the bands are due to a widening caused by a Doppler effect, that is due to a motion of the star or of its radiating envelope, and pointed out the similarity to the broad emission bands in novae, which are explained by the violent ejection of luminous gases from the star. By analogy he proposed that the broad bands in the Wolf Rayet stars were due to the continuous ejection of material by radiation pressure, a phenomenon that could only occur under very favourable combination of the temperature of the photosphere and the value of gravity at the stellar surface.[60]

Another addition to the staff at this time was R. O. Redman. At the suggestion of Plaskett he made a study of galactic rotation based on late, K-type, giant stars; Plaskett had noted that the centre of galactic rotation determined from the early-type stars seemed not to fit the later types. Redman determined the radial velocities of 225 K stars and confirmed, in a general way, that the results differed from those of

Plaskett and Pearce, although there were many unsolved puzzles.[61] He returned to the matter in a second paper[62] in which the radial velocities of an additional 224 K-type stars are given. However the results of the study continue to be puzzling; the results for the younger, and nearer, stars were not compatible with those for the early types. This may well have been due to the fact that differential rotation was more difficult to detect in these nearer stars.

This second paper, dated 1931, was submitted from the Solar Physics Observatory at Cambridge where Redman had been appointed Assistant Director. He returned to Victoria as a Voluntary Assistant for six weeks in the summer of 1934.

The papers of Volume IV of the Publications which have not already been discussed dealt for the most part with the spectra of binary stars, but there seems to be a difference in the approach from earlier volumes. The stars selected are of particular interest, either because of unusual spectra, unusual orbital periods or because they were eclipsing binaries. To continue the analysis given of earlier volumes, 18 of the studies involved binaries in which the spectrum of only one star was available, 6 involved stars where both spectra were observed, and one was an eclipsing binary in which all properties of the system could be determined. This paper was by Redman.[63] The volume includes papers by two summer students, R.M. Petrie and P.M. Millman. Volume IV covers the period to the end of 1930.

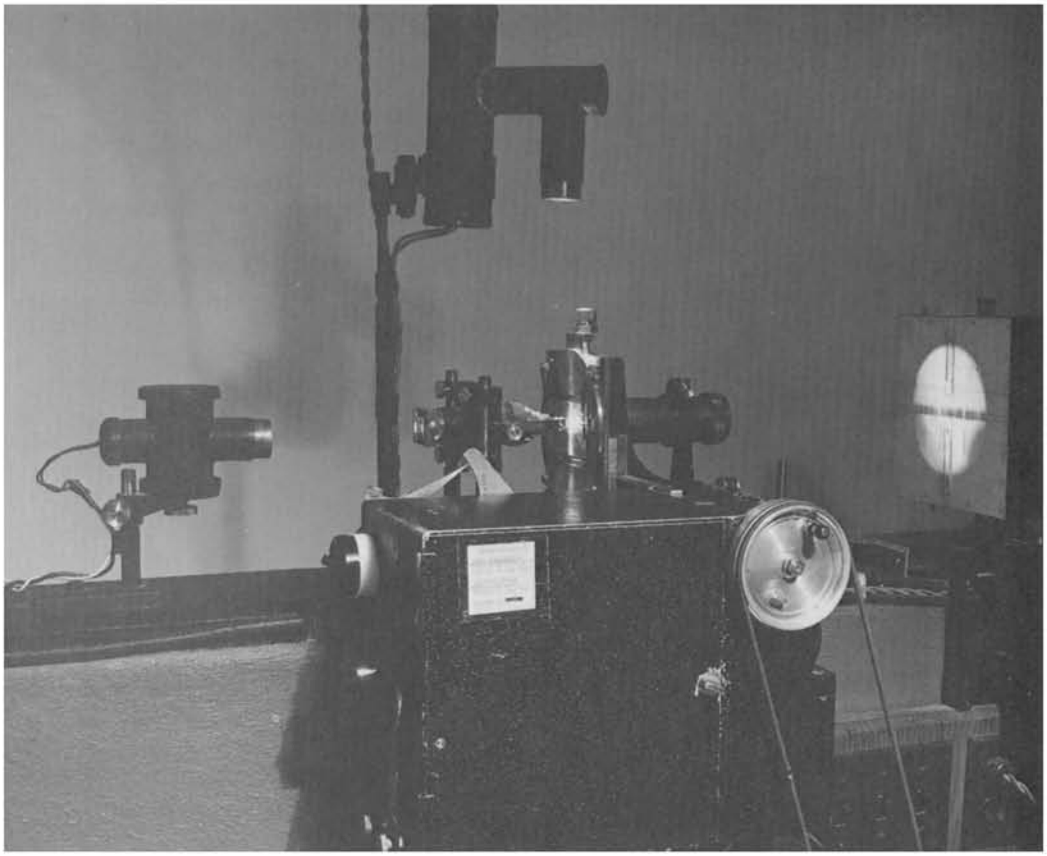
About the time that Redman resigned, Frank S. Hogg joined the staff, perhaps appointed in Redman's position. Hogg was from Preston, Ontario, and he was inspired to study astronomy by E.A Hodgson who was his mathematics master at Galt Collegiate during the year that Hodgson was a fugitive from the Public Service. He held a B.A. from Toronto and a Ph.D from Harvard, and he was accompanied by his astronomer wife, Helen B. Sawyer. They didn't remain long in Victoria. Hogg was interested in studying emission spectra with low dispersions, and his results while at Victoria were inconclusive and led to no publications, but Mrs. Hogg made important contributions during their stay there, to which we shall presently return.

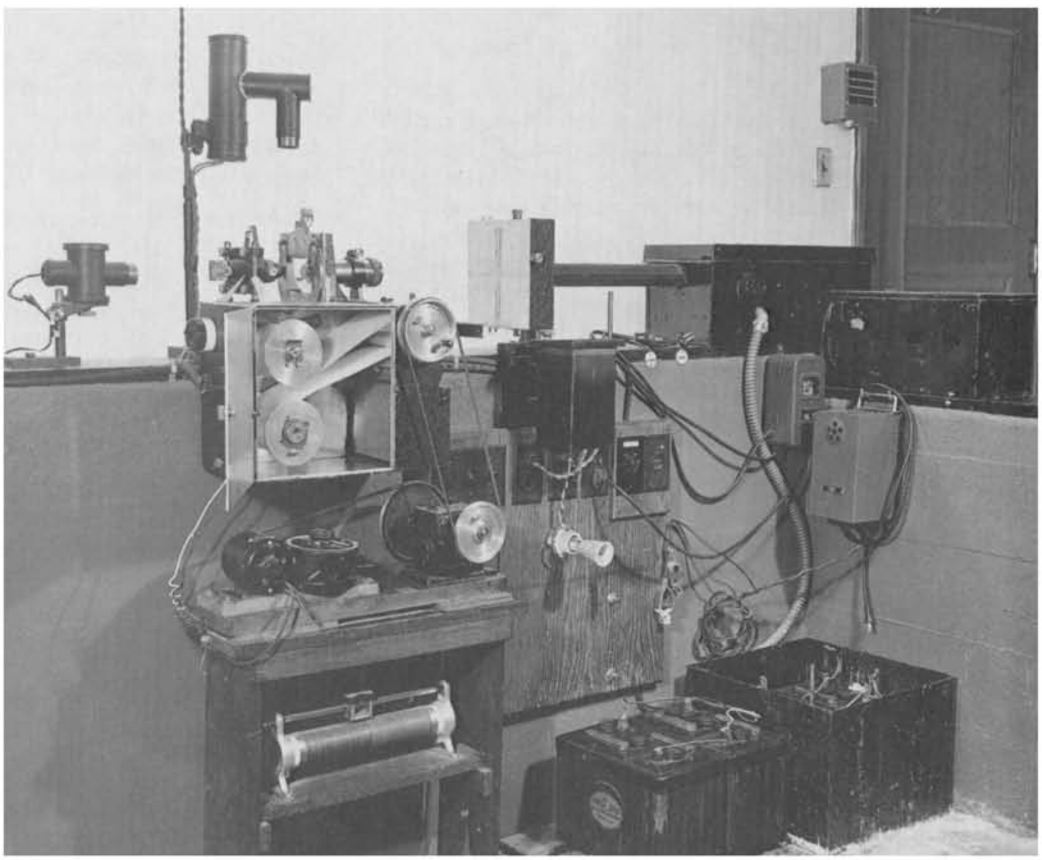
Nothing has been said in these notes about the problem of spectroscopic standards against which the lines in the stellar spectra could be compared. In measuring the radial velocity of a star it is the shift of the spectral line from its normal position that defines the velocity. What is the normal position? There are two aspects to this problem.

The first concerns the accurate position of the lines in the comparison spectrum. In 1930 Beals, who had worked on this problem during his years at the Imperial College, London, began a programme to establish the wavelengths of certain oxygen and nitrogen lines in the central section of the visual region. Since he wished to include his observations from London, it was necessary to construct a laboratory spectrograph which would, as nearly as possible, duplicate the one there. This was done, using a plane grating already available at the Observatory and a slit, prism and lens purchased for the purpose. The instrument was designed by Beals and constructed by Girling in his shop in the city. The source of the spectra were discharge tubes filled with oxygen at low pressure and, for nitrogen, with atmospheric air. A total of 85 lines was measured. There were some consistent differences between the Victoria results and earlier ones made at the Imperial College, which were resolved in favour of the Victoria values.[64]

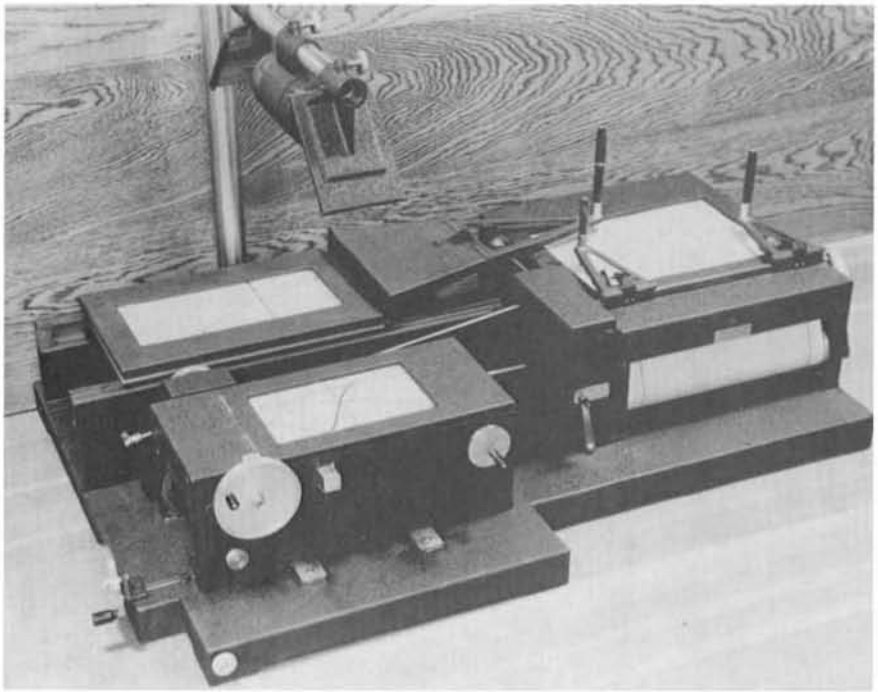
The second aspect of the "standards" problem relates to the lines in the stellar spectra. Unlike the laboratory lines in the comparison spectra, the stellar lines are seldom pure. They may represent a blend of two or more lines, for example of titanium and iron, which fall so closely together that they can't be separated. They may show widening due to motion in the stellar atmosphere or due to rotation of the star. A line which appears satisfactory in a spectrogram of low dispersion may be useless if the dispersion is great. It was therefore necessary to select lines for each spectral class, and for each range of dispersion, which could be positively identified and whose "zero-velocity" position could be precisely located. A constant effort was made in this direction, the results of which, to 1936, were summarized by Harper.[65] It was a subject which was to recur.

At the same time Beals was continuing his study of the Wolf Rayet stars, this time by spectrophotometric methods. This marks a departure of the greatest importance and seems worthy of a digression. The complete analysis of a spectrum requires not only a study of what lines are present and a precise measurement of their position, but also a knowledge of their comparative intensities, their widths, and the intensity profile across this width. This field of study is known as spectrophotometry, and it seems to have become important in the mid-1920's. In 1923 H.H. Plaskett (p. 98) developed a wedge method for displaying intensities as a profile of hills and valleys. In 1928 Henroteau was working with Professor Douglas at McGill, using a Moll microphotometer, and in 1930 or 1931 the Dominion Observatory purchased a Moll instrument for itself. No equivalent instrument was available at the Dominion Astrophysical Observatory until the mid-1930's. We saw (p. 137) that Harper was unable to carry out a proposed study on the absolute magnitude of A-type stars because, for these stars, the eye

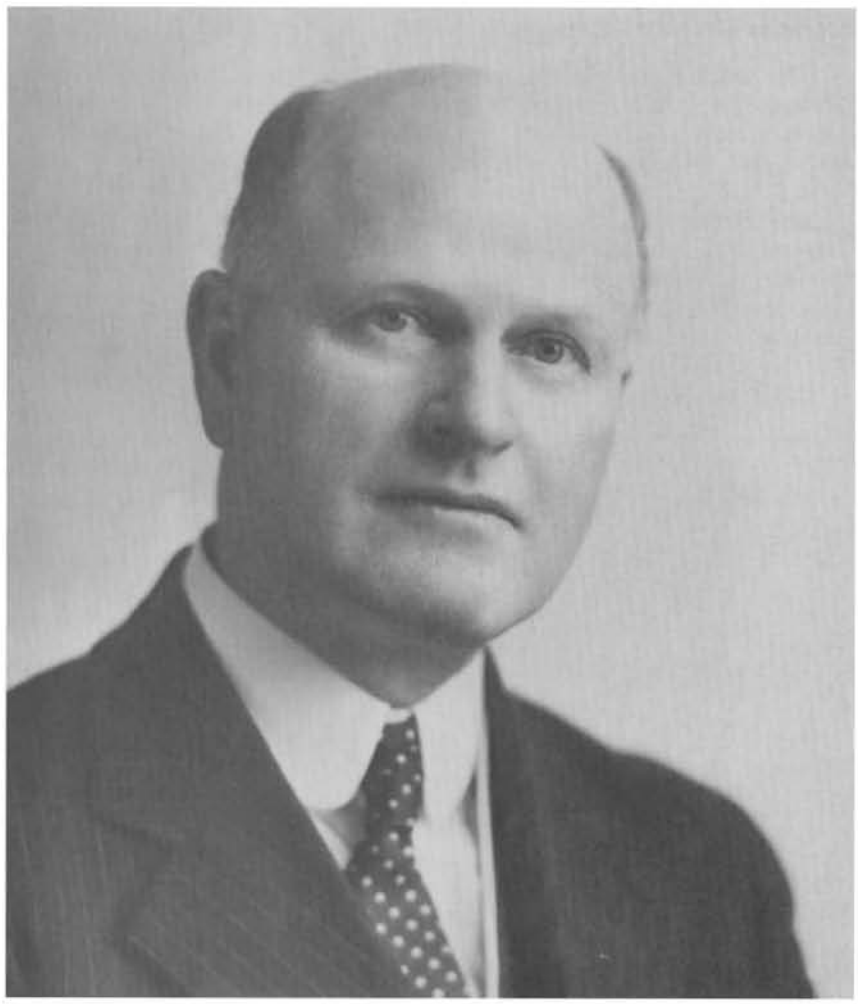




The Beals Microphotometer, above in operation in a darkened room, below opened to show the details. The recorder, with its photographic paper, is in the left centre of the photograph; the plate holder is at the centre of the device immediately above. An image of the illuminated slit is focussed on the plate, the transmitted beam is focussed on the white screen where it is further limited by an adjustable slit. The photoelectric cell lies behind this slit. Official Photograph, Dominion Astrophysical Observatory.



The Beals Intensitometer. The calibration curve is etched on a glass plate at the upper left, the record from the microphotometer is mounted on the reel at the lower left. As the curve is scanned the calibration values are synchronised with it and the true intensity curve is traced on the moving record to the right. National Archives of Canada, PA 149321.



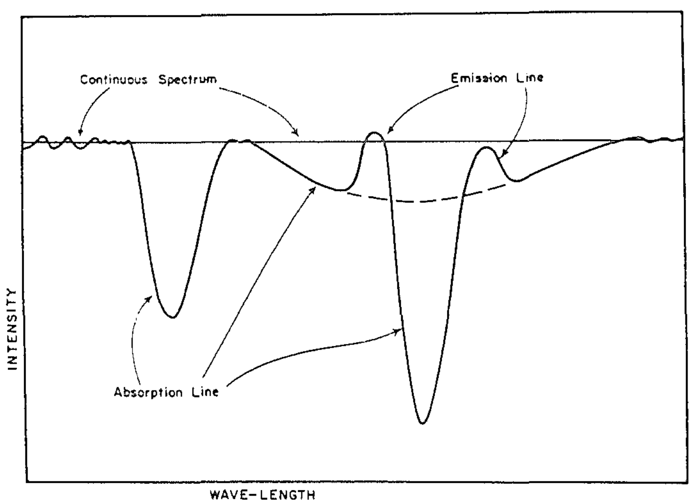
Dr. W.E. Harper, Director of the Dominion Astrophysical Observatory, 1935-1940.

proved inadequate for estimating relative line intensities, and because no microphotometer was available.

Beals felt the need for such an instrument in his work on the Wolf Rayet stars and he designed it and had it built by Girling. A light beam illuminated a slit, the image of which was focussed on the photographic plate with its spectrum. The light passing through the plate fell on a photoelectric cell, the resulting current was amplified and drove a galvanometer which recorded on photographic paper. As the spectrum was moved across the slit image, the recording paper moved in synchronization, with a speed 20, 100 or 200 times as great.[66]

The output of the microphotometer is not a measure of the true intensities because the technique takes no account of factors such as the variation in colour sensitivity of the photographic plate. A calibration spectrum must be recorded on each plate and each point on the microphotometer tracing must be transformed according to a "characteristic curve". In 1944 Beals perfected a device which made the transformation mechanically.[67] The instrument was known as an "Intensitometer".

The following figure provides a schematic representation of an intensity tracing from a stellar spectrogram. All stellar spectra consist of a continuum, in which the intensity of light radiated by the star's atmosphere varies, slowly, with wave length; this continuum is broken by dark lines due to absorption of the radiation from the star's surface by atoms in the cooler upper stellar atmosphere. It may also contain bright lines due to the direct, unabsorbed, radiation of particular frequences.



It will be recalled that in his earlier[60] paper Beals had proposed that the broad bands observed in the spectra of Wolf Rayet stars were due to the continuous ejection of material from the star, and had compared the process with that in novae. When the photometric measurements became available he found that, whereas in novae the intensity curve was flat-topped across the width of its band, in the Wolf Rayet stars the contours were rounded in almost all cases. Apparently the velocity of ejection of atoms varies, and the frequency of the velocities is different across the width of the band. In the earlier paper he had proposed a classification for the Wolf Rayet stars; here he checked his classification by measuring the total intensity in the several bands in stars of the various classes. Finally he made estimates of the temperatures of the Wolf Rayet stars (50,000° to 100,000°) and in two novae (20,000° to 65,000°).[69]

Helen Sawyer Hogg, who had come to the Observatory with her husband in 1930, had been a student of Shapley's at Harvard and had worked with him on the study of globular clusters. Earlier, Shapley had studied some 70 of these and had determined their distance by a method that involved Cepheid variables. It had been shown that the brightness of these variable stars was a function of their period, and once the intrinsic brightness of near Cepheids of known parallax had been determined that of the distant ones could be established simply from their period. Knowing this, the distance of the star could be calculated by methods we have already discussed.

Based on his study of the globular clusters Shapley had constructed a model of the galaxy which conformed reasonably well with that determined from stellar motions except in dimensions; it was much larger. This could be explained as due to an error in the Cepheid "measuring scale" and before coming to Victoria Mrs. Hogg had been working with Shapley on a revision of his work. To extend this work, the identification of as many Cepheids as possible in globular clusters, and the determination of the period of their light-curves, was obviously a matter of great importance.

Although Mrs. Hogg was not on the staff, she was granted observing time on the telescope to photograph a number of globular clusters. This was the first use of the telescope for direct photography aside from a few demonstration photographs when it was commissioned. She was assisted in her observations by her husband, Dr. F.S. Hogg, and accompanied by her infant daughter, Sally, sleeping peacefully in a basket on the observing floor. In a first paper[70] she reports on the globular cluster Messier 2, in which she discovered six new variable stars and determined the periods of these and of 11 already known. In a later paper, published after she and her husband, and Sally, had moved to Toronto, she reports on 132 new variable stars discovered in the plates of 5 other globular clusters.[71]

In a paper published in 1958[72] Odgers tells us that there are three sorts of Cepheid variables and that "ignorance of this fact led in the past to many erroneous distance determinations". The classical Cepheids, of which δ Cephei is the prototype, have a long period variation, of the order of days, and lie in the plane of the galaxy. They have one luminosity-period relationship. Another sort of long period variable, of which W Virginis is the prototype, lie in the galaxy but in its spherical part, outside the galactic plane. None of them is close enough to provide a reliable measure of parallax. Furthermore, while they have a luminosity-period relationship similar to the δ Cephei type, it has a different zero point; it was the failure to recognize this which led to early errors. Finally there are the short period variables, with periods a matter of hours, of which RR Lyrae is typical. Although they lie outside our galaxy, in globular clusters, they fit the same luminosity-distance curve as the δ Cepheids, extending it to the shorter periods. They are bright enough to permit a reliable estimate of distance.

For all the Cepheid variables there is a related variation of radial velocity, with the maximum brightness correlating with the maximum outward velocity of the stellar envelope.

This may be a good place for a short digression on star clusters. At a very elementary level, two types are recognized. Both of them fit the definition given by Baker[73] as "assemblages of stars having their members less widely separated than are the stars around them. They are not temporary congestions in the celestial traffic; the stars in each group are moving together, so that the clusters maintain their identities for a very long time. Because the members of a cluster are all practically at the same distance from us, they may be compared fairly one with another."

The first class of clusters are known as "galactic" clusters because, for the most part, they lie in, or close to, the galactic plane. They are so close to us that the individual stars can be distinguished and in many cases they are close enough that the proper motions of the individual stars can be measured. When this is possible we can project the trajectories of the stars backwards in time to define the point at which the stars were formed and the cluster started on its way. Conversely, given this "convergent point", the distance of any star for which the proper motion is known may be accurately determined.

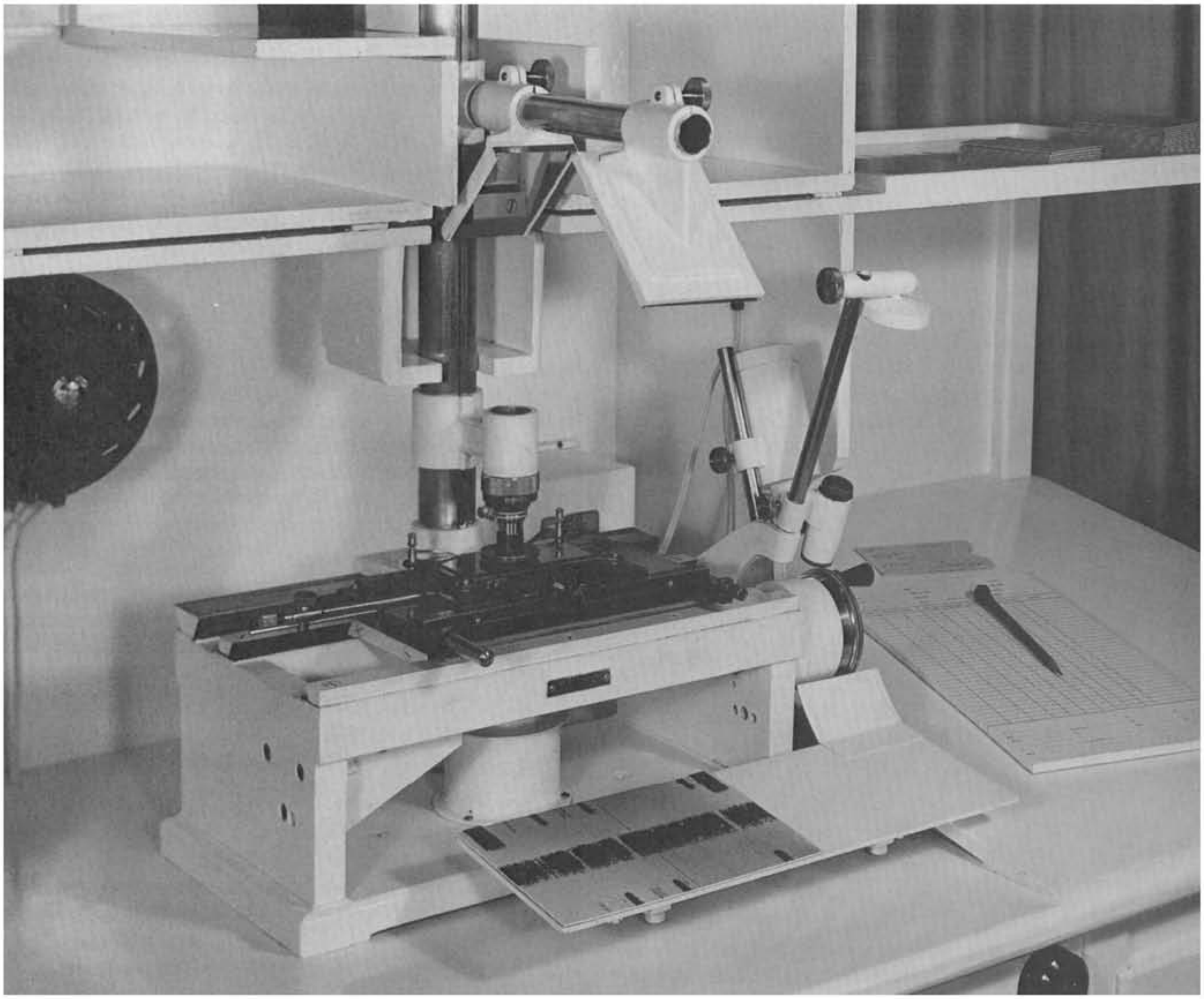
The "globular" clusters which Mrs. Hogg was working are much larger accumulations of stars, both in volume and in the number of stars, and they are generally much more distant than the galactic clusters. Most lie outside the galactic plane, many of them outside our galaxy, and there is some evidence that they revolve about the galactic centre in highly eccentric orbits, something like comets revolving about the sun.

In addition to the papers already discussed, Volume VI of the Publications contained studies of a large number of binary stars in which, to continue our classification, 10 involved the spectra of only one of the stars, 9 involved two spectra, and 1 eclipsing binary, with two spectra available, permitted a complete solution. The Volume also contains a re-determination of the orbits of 64 binaries published earlier, based on additional data secured over the years, and a detailed study, involving all of the staff members, of the Nova Lacertae, 1936.

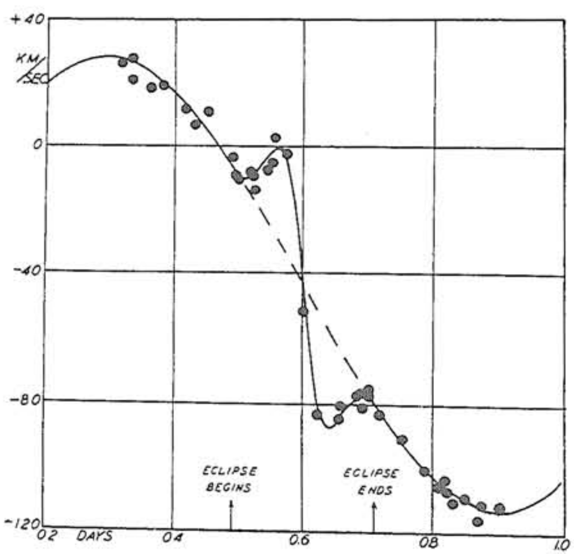
The conclusion of Volume VI coincides reasonably well with the retirement of Plaskett. We saw in an earlier section that this was made necessary by the government decision to enforce retirement at age 65. As his retirement approached, many honours were showered on him, of which I am aware of the following: The Bruce Medal, of the Astronomical Society of the Pacific; the Flavelle Medal of the Royal Society of Canada; an LLD from McGill University; the Rumford Medal of the American Academy of Arts and Sciences, Boston, Mass.; the Henry Draper Medal of the National Academy of Sciences, Washington, D.C.; the Gold Medal of the Royal Astronomical Society of London; an LLD from Queen's University; a CBE in the Honours List of New Year's Day, 1935.

There were a number of staff changes more or less coincident with Plaskett's retirement. The existing staff all moved up one step, Harper becoming Director and Pearce Assistant Director. Hill retired because of ill health and Hogg left to join the faculty of the Department of Astronomy at the University of Toronto where the new 74-inch David Dunlap telescope was reaching completion. Their positions were taken by R. M. Petrie and Andrew McKellar, both of whom had been employed as summer assistants at the Observatory. Petrie had obtained his Doctorate in Astronomy at the University of Michigan, McKellar his, in Spectroscopy, from the University of California. A year later, in 1936, K.O. Wright joined the staff. A graduate of the University of Toronto, he had taken graduate work at the University of Michigan; his Ph.D was granted in 1940.

One other staff change should be recorded. Guy H. Blanchet who had been Astronomical



Petrie's projection machine for radial-velocity measurements. The photograph plate is mounted on a micrometer shown in the centre of the photograph. Light passing through the plate is focussed by a microscope which, by means of a pair of mirrors, projects the image to the viewing screen below and in front of the instrument. As the micrometer plate is moved the spectral lines can be lined up, one after the other, with a fine marker on the viewing screen; the corresponding micrometer readings are projected on an adjacent screen. Official photograph, Dominion Astrophysical Observatory.



ROTATION-EFFECT UPON RADIAL VELOCITIES IN RZ CASSIOPIAE

Assistant since July, 1936, resigned in 1938 and was replaced by Walter H. Stilwell.

In reading the Annual Reports, one is struck by an increase in the pace of the work at this time, particularly in its attention to instrumental improvements. This is probably due to the arrival of the new blood rather than to the change in the Director. One thing is interesting: the programme to study A-type stars, begun by Harper in 1924, has been announced each year as "nearing completion"; the first Annual Report prepared by Harper reports it as " in abeyance".

Annual Reports of the Observatory give useful information on instrumental improvements. The years given are Annual Report years, which cover a one-year period beginning April 1 of the preceeding year. In 1934 the primary mirror of the telescope was sent to Mount Wilson to be aluminized; this was so satisfactory that the secondary mirror was sent the following year and in 1943 equipment for aluminizing the mirrors was acquired by Victoria. In 1935 a slitless spectroscope was acquired for work with faint stars and a rotating sector device for plate calibration was perfected. In 1936 tests were conducted on the photographic plates available, to define which were best for various purposes. Also in 1936 the photoelectric microphotometer designed some years earlier by Beals, was converted to direct recording.

Work on modernizing the dome continued over a number of years. Controls were centralized and the wheels on which the dome rotated were reground. In 1940 the ground floor of the dome building, beneath the observing floor, was completely re-organized to provide better facilities for the observers.

The problem of plate calibration continued to receive a lot of attention. The blackening of a photographic plate is a very non-linear response to the intensity of the incident light. The relationship between the two must be established. This could be done by exposing with a standard lamp for a standard time at a succession of distances from a prism and recording the resultant spectrum on the plates under test. The intensity of the incident light was assumed to follow the inverse square law. Alternatively the lamp could be fixed in position and the exposure made through a succession of slits of differing widths. Petrie and McKellar[74] developed a system in which exposure was through a rapidly rotating disk in which sections of a succession of angles had been out.

In 1937 a 4-inch plane grating was acquired for the spectrograph which increased the dispersion by a factor of about two. The modified instrument was so satisfactory that in 1938 a second grating, possessing a very strong second order, was added to the complement of available tools. It produced an additional 3-fold improvement in dispersion.[75]

In 1937 Petrie perfected a device for projecting a star spectrum and its calibration spectrum on a screen, which greatly reduced the strain of measuring plates. A series of tests by Petrie and other staff members showed the new system to be as accurate as the older ones.[76]

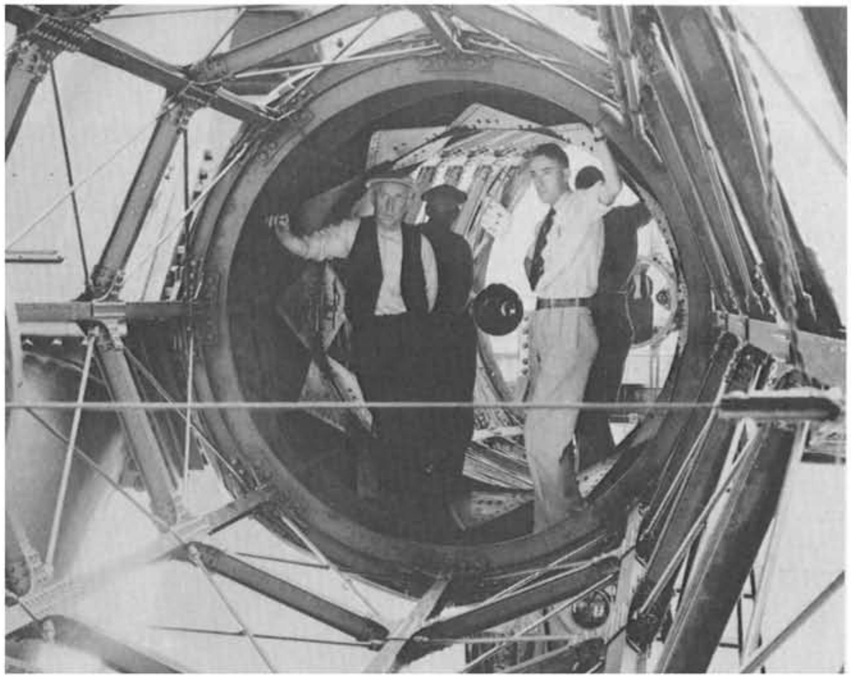
The 1939 report describes an anti-fogging device which had been installed on the telescope. Two platinum thermometers, forming the arms of a Wheatstone Bridge, controlled heat applied to the mirror to keep it at outside temperature.

In 1937 a stellar photometer was constructed to study the light variation in stars. The light was focussed on a caesium photoelectric cell and the output of the cell was amplified for direct recording. It is interesting that this marks the first use of a photometer at the Dominion Astrophysical Observatory. The photometer provides the most accurate method of determining the magnitude of a star, but magnitudes could be measured using much smaller telescopes than the 72-inch, and published values had been accepted. It also permits the determination of the *colour index* of a star. This is the difference in magnitude as measured at two different colours, usually blue and visual. Since a red star appears brighter in yellow light than in blue, and therefore has a numerically lower magnitude, red stars generally have a positive index, blue stars a negative one. A scale has been developed in which the index is set to zero for stars of class A_0. Stars earlier than A_0 have an increasingly negative index, stars later an increasingly positive one. Measurement of the colour index is a very accurate way of placing a star in its proper spectral class *unless* interstellar matter intervenes to redden the star's light. In that case, the difference between the class as determined by the colour index and by spectroscopy provides a measure of interstellar absorption.

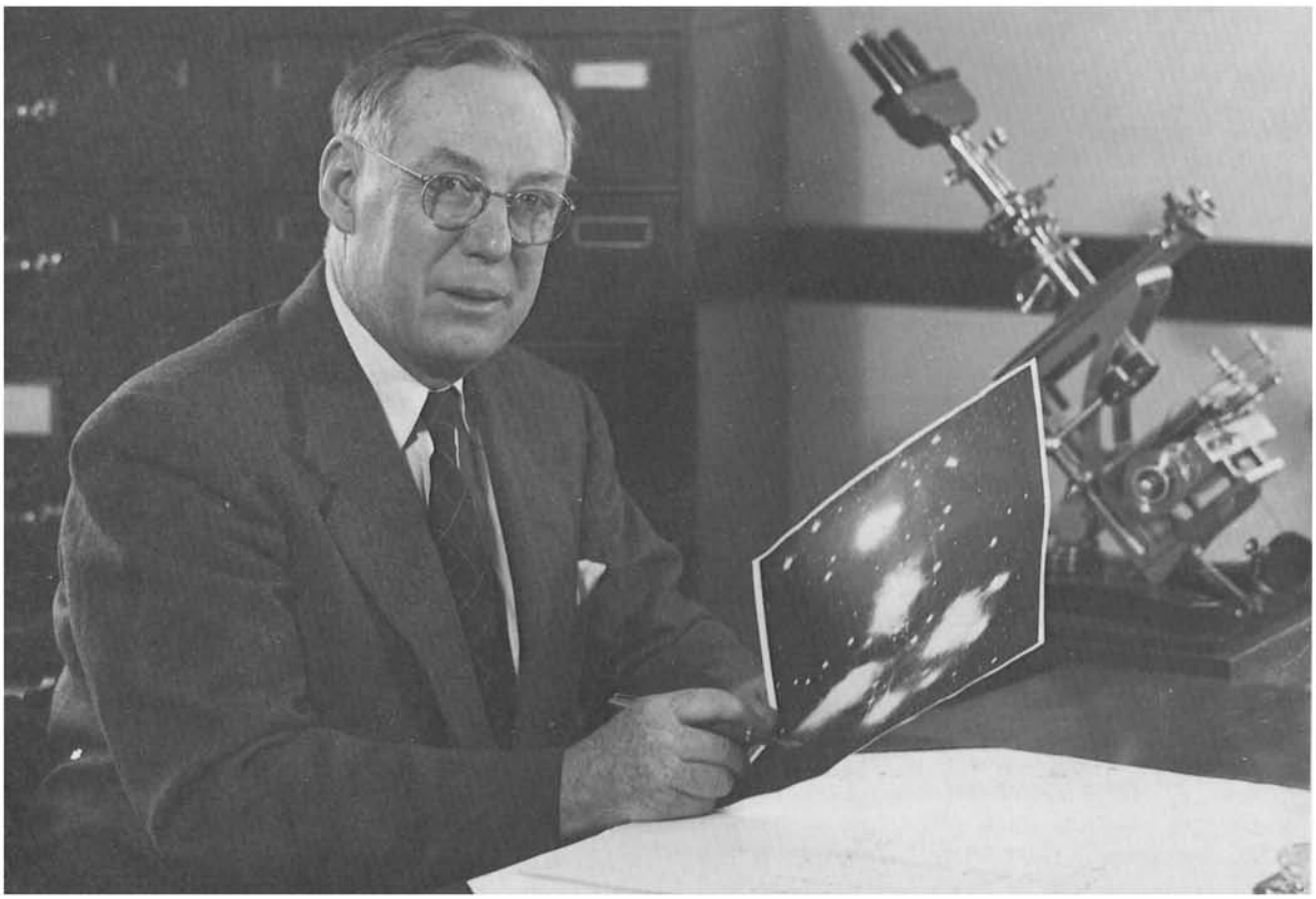
There is a more precise measure than colour index, known as colour gradient, which is defined as

$$G = \frac{2.30 \, log \, I_1/I_2}{1/\lambda_1 - 1/\lambda_2}$$

I_l and I_2 might for example be intensities measured in red and blue light respectively; a gradient may be determined for any part of the spectrum. The size and sign of the quantity G may be related to the temperature and the chemical composition of the stellar atmosphere.[77]



Dr. Andrew McKellar, right, within the tube of the 72 inch telescope, circa 1930. National Archives of Canada, PA-149318.



Dr. J.A. Pearce, Director of the Dominion. Astrophysical Observatory, 1940-1951. He is inspecting a photograph of the Pleiades cluster.

The research work of this period seems to a non-astronomer to be more complex and more dedicated to the interests of the individual astronomer than to any general observatory programme. Wright (personal communication) confirms this. "Under Plaskett, observatory programmes were the 'thing', but later each astronomer was allowed considerable leeway if his ideas were good." One such study was by Beals, who became very much involved in the investigation of a group of stars named after the type-star, P Cygni. This star had been a nova in 1600 and had settled to a constant magnitude by 1677. It has a very distinctive spectrum with emission bands, similar in many ways to that of recent novae and to the Wolf Rayet stars; its study was thus a natural extension of Beals' earlier work. Over the course of some five years Beals observed all the stars of this class which could be reached from Victoria and came to the conclusion that they and the Wolf Rayet stars formed a new sequence similar in many ways to the various stages in the life of a nova.[78]

Petrie continued the Observatory interest in binary systems but brought more sophisticated analysis to it. He considered the effect of the rotation of the members of an eclipsing binary system on the apparent velocities of approach and recession. The figure on page 144 illustrates the effect. The star being eclipsed is rotating on its axis in the same sense as the rotation of the binary pair. Before mid-eclipse its receding hemisphere is uncovered, its approaching hemisphere partly eclipsed; this adds an effect of recession to the observed radial velocity. After the mid-position of the eclipse the effect is reversed. Petrie developed formulae for evaluating this effect and showed that a knowledge of the rotation velocities would permit the determination of the diameters and masses of both components even if the spectrum of only one of the components was available.[79]

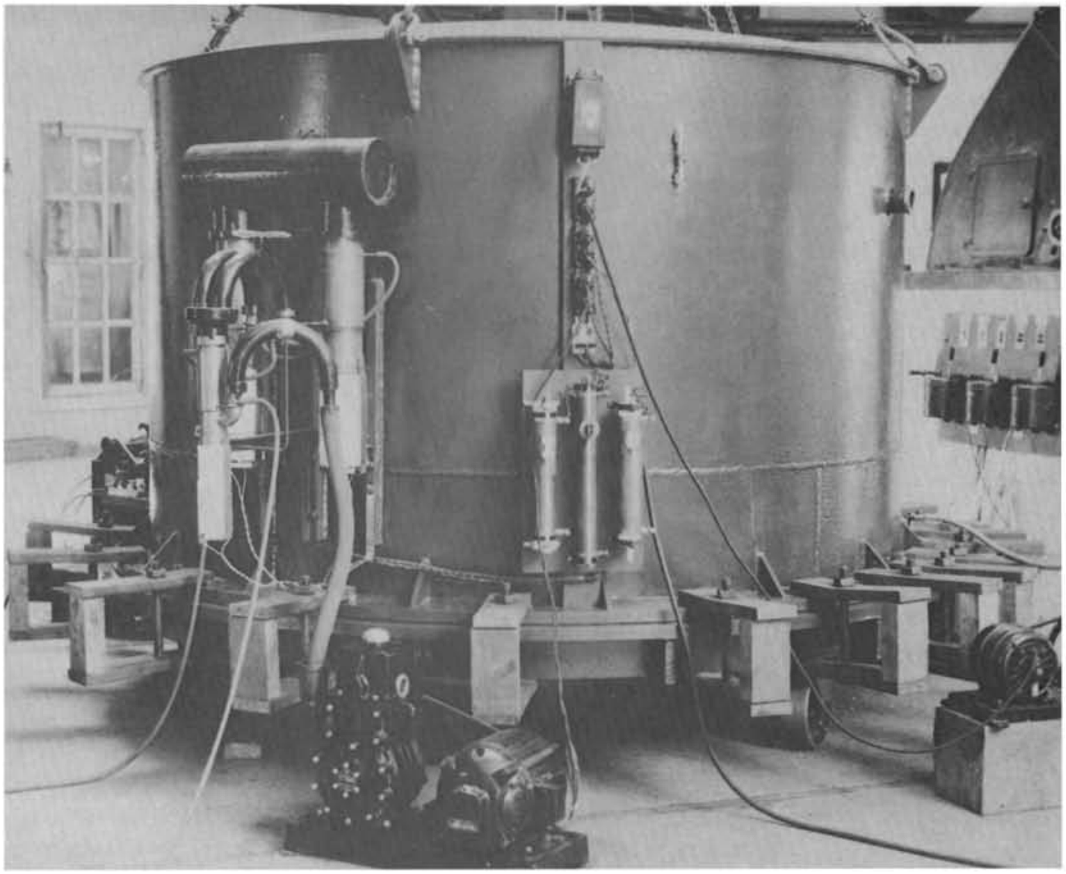
Petrie next turned his attention to measuring the magnitude differences in spectroscopic binaries in which both spectra are available, using the microphotometer recently built by Beals. He developed a theory to explain the varying intensity profile as the lines from the two stars moved together and separated in accordance with the rotation of the binary system, and to derive from it the magnitude difference of the two stars. Since the magnitude of the binary pair is known this permits a calculation of the magnitude of each component.

For many such binary stars the parallax is known so that magnitudes can be translated into luminosities. Assuming a mass-luminosity ratio, the masses may be computed and, since for double-line binaries the masses are known in terms of the inclination, a knowledge of the inclination follows. Alternatively, knowing the temperatures of the component stars from their spectral classes, formulae giving the relationship between magnitude, radii and temperature may be developed to give radii from which, and the mass ratio, a density ratio may be determined. These extensions from the original data are increasingly tentative, but Petrie tested the method on 23 stars of various spectral classes including 6 eclipsing binaries for which the masses, and hence the mass differences, were known. The method proved reliable and Petrie announced his intention of extending it to larger groups of stars.[80] It is interesting that Petrie acknowledges the assistance of the Dominion Astronomer, Stewart, in the critical reading of the mathematical aspects of the paper.

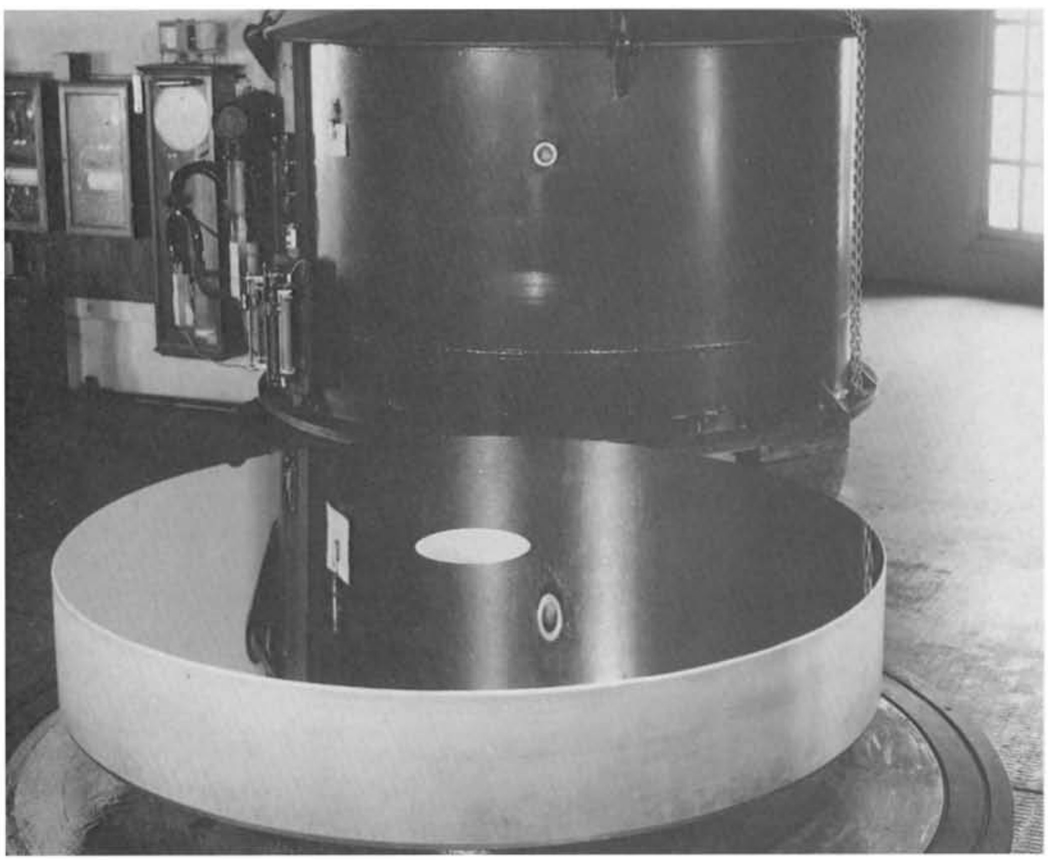
Volume VII of the Publications contains a number of papers on spectroscopic orbits. It is difficult to know which of these should be assigned to the period of the Harper directorship, to which I am here confining myself, because during the war years publication was stopped for some time and a spate of papers appeared in 1947. However it seems reasonable to assign papers up to No. 16 to the Harper years. Of these papers, 5 were based on the spectrum of only one star (although in one case there was evidence of a third body) and 4 were based on two spectra. In these latter cases, application of Petrie's method, described above, permitted the determination of all the elements of the system.

While McKellar contributed to other programmes, his chief efforts were as a molecular spectroscopist. He published a major paper on the mass ratio of lithium isotopes, a continuation of work that he had been doing as a graduate student.[81] In a paper of more purely astrophysical interest[82] he identifies certain molecular lines in the spectrum of a B star as being due to diatomic molecules in interstellar space, provides a table of absorption lines clearly identified as of interstellar origin, and speculates on other lines, as yet unidentified. This paper is regarded by astronomers as of the utmost importance. Petrie[83] speaks of "his brilliant ... demonstration of the presence of molecules in interstellar space," and Wright (personal communication) describes the paper as of "major importance." Ian Halliday (personal communication) says of it: "McKellar found a temperature of 2.3 K from the rotational spectra of interstallar CN. At that time the cosmological significance of its relation to the Big Bang was not realized, but when the radio astronomers found it decades later, at 2.7 K, it was worth a Nobel Prize."

Beals also was much interested in interstellar material. In the Observatory study of the nova Lacertae 1936[84] he contributed an estimate of the distance of the star. Arguing that the intensity of the interstellar H and K lines should increase with the



McKellar's aluminizing tank for the 72-inch mirror.



The mirror after aluminizing.

increasing distance of the star whose light was being absorbed, he studied their intensities in the spectra of a large number of stars of known, and various, distances. He was able to construct a smooth curve relating intensity to distance and to use this curve to estimate the distance of the nova.

While the H and K lines were the brightest interstellar lines others were found by various investigators. These lines were normally quite sharp, sharper than the stellar absorption lines themselves. Beals found however that when he examined them with higher dispersion they were frequently double, or even multiple which he interpreted as due to differential motion of different volumes of the interstellar material. At about the same time he investigated some very broad interstellar bands, which had been discovered at Mt. Wilson, and added to their numbers. It was difficult to find a model for interstellar material which explained both the sharp lines and the broad bands.

Harper was a delegate to the Stockholm meetings of the International Astronomical Union in 1938. He profited by his presence in Europe to visit a number of observatories and during his post-congress travels he contracted pneumonia. In a Europe busily preparing for war he had to be removed from Germany to Denmark by ambulance, from Denmark to England by boat. When he returned to Canada his health was quite broken and, while he attempted to resume his observatory duties, he died in office in early June, 1940 at the age of 62.

He was succeeded as "Head Astronomer" by J.A. Pearce; Beals became "First Assistant". Everyone advanced, so that there was an open position at the bottom of the ladder. This was filled briefly by Elizabeth Walker, who resigned to marry the Astronomical Assistant, Stillwell. She was replaced by Jean K. McDonald. Stillwell who had been assisting the Geodetic Survey during the war, transferred to that organization at its conclusion. Mr. S.S. Girling, who had assisted in the construction of much of the Observatory equipment at his machine shop in the city, finally joined the organization as instrument maker in 1943.

This is a suitable time to record the death, on October 17, 1941, of Dr. J.S. Plaskett, a little more than a year after that of Harper. It was fitting that the two should go so closely together. As Pearce says: "Intimately associated for over thirty years at the Canadian Government Observatories, their numerous and important researches in stellar motions received worldwide recognition."[85] In the preparation of these notes I have been overwhelmingly impressed by the imagination and drive that Plaskett brought to his work and I would subscribe to a judgement ascribed to Petrie, "that Plaskett was arguably the most distinguished scientist that Canada has produced."[86] He was ably assisted in his work by W.E. Harper.

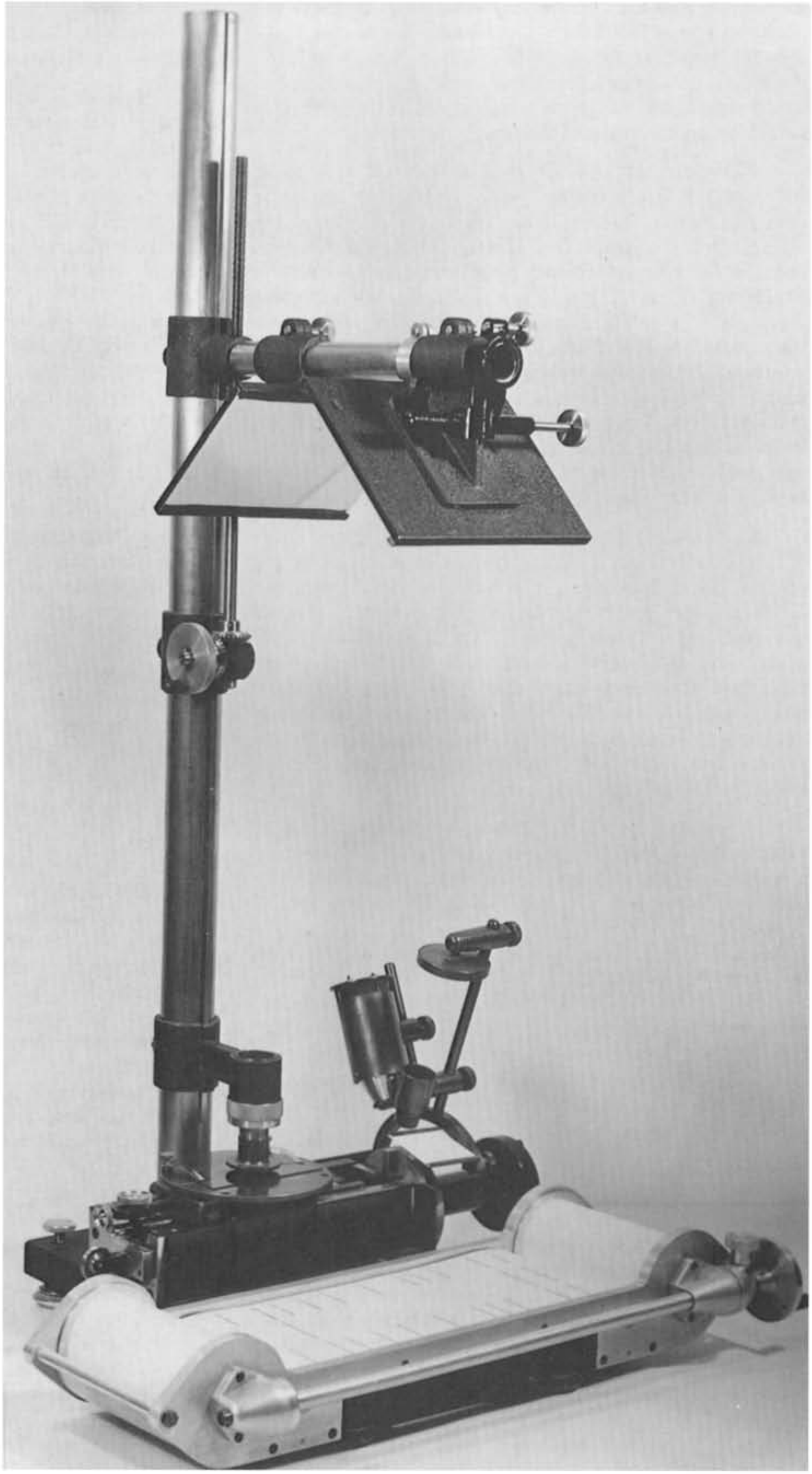
I hope that these pages have paid adequate tribute to the work and genius of John Stanley Plaskett, but they have not said much about his personality, for the simple reason that there are few left who knew him well. I am pleased to make up this lack from some notes that Beals made for an informal, after dinner, talk, which have recently become available in his personal papers [National Archives, MG 30, Box 323, File IJ]: "Shrewd and brainy as all get out but had, at the same time, a strain of refreshing naivety and ingenuousness that was most attractive. Wonderful sense of humour with a high-pitched and infectious cackling laugh. So far as possible a man without jealousy or malice. Delighted with the honours heaped upon him, but totally devoid of pompousness or affectation."

The accession of the new management pretty well coincided with the beginnings of the war, and we may discuss the effects of the war before considering the work that was done during the remaining years of the Stewart administration. The effects on staff have already been documented (p. 132).

The ability of the Observatory to aluminize mirrors was fully utilized by the Navy in aluminizing the mirrors and reflectors used in their signalling apparatus.

One interesting development of the period concerns the 72-inch mirror. Early in 1942 it was realized that military installations in western Canada might be bombed by the Japanese; the proximity of the Observatory to both naval and air bases raised the possibility that the mirror might be damaged. What to do? Military authorities suggested that if bombing seemed probable the mirror should be transported inland to Kamloops, Penticton, or some such location; the astronomers felt that the risk of damage by dismantling and transportation was greater than from possible bombs. They suggested that the mirror should be lowered to a position beneath the telescope pier. Plans were drawn for covers to protect both the primary and secondary mirrors, but I have not found any record that these were ever constructed. By May, 1942, Pearce was reporting to Stewart: "The paper today contains the news of another naval engagement in the Pacific in which the U.S.A sunk several Japanese boats. Every Naval victory in the Pacific lessens the probability of enemy action on our coast."[87] Wright agrees that the mirror was not removed from the telescope at any time during the war, although it was considered. However, as a camouflage test, the dome was painted brown and grey, and several posts were put up to represent trees. (Wright, personal communication).

Petrie's Projection Comparator, used to measure stellar radial velocities. The photograph plate, with its comparison and stellar spectra, is attached to the circular disk lying at the base, and to the front, of the upright. The plate is illuminated from below and the lines are projected by a fixed lens to the mirrors and so to the white paper in the foreground on which the standard lines have been drawn. The scale of the image is adjusted by moving the mirrors, and the plate is set to match the comparison lines with the standards. To measure the shift in any line of the stellar spectrum the plate is moved by a micrometer screw until the spectral line is bisected by the ruled line; the micrometer reading is a direct measure of the shift. The lower picture shows the instrument in operation.



A more serious casualty of the war were the Publications of the Dominion Astrophysical Observatory. Nothing was published between early 1942 and 1947, and it is difficult to assign a date to work described in the rush of papers issued in 1947 and 1948. Fortunately Pearce published two reports in the Journal of the Royal Astronomical Society of Canada, describing the work of the Observatory for 1940 and 1941[85] and 1942-1945.[88] The following descriptions depend very much on these reports.

Pearce's description of the improvements to instruments in the period 1940-1945 duplicates a number of changes already reported, on the basis of Annual Reports, for the years 1935-1940. Probably these were continuing developments, begun in the earlier period, completed in the latter. One basic improvement of great importance was the completion in 1943 of an 84-inch aluminizing chamber designed by McKellar and the new machinist Girling. Tests designed by Beals showed a reflectivity of 82.6% for the aluminized coat as compared with 65% for a fresh deposit of silver; spectra of the 11th magnitude could now be achieved. There was a marked improvement in the ultraviolet.

The Littrow arrangement of the spectrograph, mentioned earlier, was completed, with contributions from Beals, Petrie and McKellar and the shop assistance of Girling. In this mounting, in which the collimator also serves as a camera lens, one, two or three prisms could be used, with a reflecting plate to return the beam through the prism train; alternatively either of the 4-inch gratings could be used, and this mode became the principal one. The case of the spectrograph had to be re-designed to retain freedom from flexure.[89] The optical parts of the new arrangement were treated with low-reflection coatings after extensive testing had proved their worth.[90]

The Intensitometer mentioned in an earlier section was also perfected during the war years.[67] This instrument permitted the microphotometer tracing of a spectrum to be mechanically translated into an intensity curve.

Petrie had developed a projection measuring machine in 1937 (page 145). In a 1948 paper[91] he describes a Projection Comparator which takes the process one step farther. A highly magnified image of the spectrogram is projected on a screen on which the lines of the comparison spectrum, and the lines corresponding to zero radial velocity are ruled. The amplified image and the drawn lines being to exactly the same scales, it is only necessary to measure the displacement needed to superimpose the lines. This is accomplished by having the plate bearing the spectrum mounted on the platform of a micrometer.

Several modifications and refurbishings were applied to the telescope including a motor and gear system to facilitate focussing at the Cassegrain focus.

The ultraviolet spectrograph, which seems to have been used very little in the past, was redesigned by Girling for use at the Cassegrain focus; it had previously had to be mounted at the prime focus, not an easy operation.

The overlapping of the claims of the Annual Reports, 1935-1940, and Pearce's reports for 1940-1945, noted in connection with the development of instruments, extended to the research work of the Observatory. For example, Petrie's application of spectrophotometry to binaries, with the determination of the actual masses of the member stars, is claimed for both periods. This is of small importance; the method was certainly developed in the former period, applied and extended in the latter. In his 1942 Report, Pearce announces "a new programme embracing studies of all Class B stars north of the celestial equator and fainter than 7th magnitude". This programme was to form an important part of R.M. Petrie's major study of Class B stars.

We have already noted (p. 142) the development of the microphotometer as a tool of astrophysical research. It became more and more important. The width of the lines or bands, the variation of luminosity across them, the sharpness or fuzziness of their edges were the matters attracting attention and these properties were being explained in terms of the rotation of the star, its temperature, its atmosphere and the movements within the atmosphere.

One method of studying stellar atmospheres depends on comparing the intensity of the absorption lines with a "curve of growth". This is a theoretical curve, relating spectral line intensity to the abundance of various atoms in a stellar atmosphere of specific pressure and temperature. By comparing observations with sets of curves, the most appropriate values for pressure and temperature and hence of the abundance of the various atoms, may be selected.

A second method of studying stellar atmospheres is through the use of models, where exact numerical representations of pressure and temperature gradients are assumed and the strength of absorption lines predicted. Computations are very laborious, even for simple atmospheres, and this method did not find its fullest application until the development of electronic computers, which occurred somewhat later in our story. However both methods of investigation were used.

Beals' interest in the Wolf Rayet stars and the P-Cygni stars, both of which showed emission lines, led him to concentrate on particular stars which appeared to represent a bridge between the classes, always interpreting his findings in terms of the structure, temperature and movement of the stellar atmosphere. The interest in these stars continued until his transfer to Ottawa in 1946. During his first year in Ottawa he found time to prepare a major paper on "The Spectra of the P-Cygni Stars."[92]

The P-Cygni stars are characterized by emission lines usually somewhat displaced to the red, accompanied by the related absorption line displaced to the violet. Beals studied in detail the spectra of all such stars which could be observed from Victoria and analysed published descriptions of the spectra of similar stars in the southern sky, and showed that much variation existed but that the variations represented a series grading from the earlier O-type stars with emission lines, through the P-Cygni type stars and into the Wolf Rayet stars. The general phenomenon was due to motion in a shell of outward moving gas, somewhat larger than the star itself. The absorption lines originated in that shell of gases in the observer-star line of sight, the emission lines from the remainder of the envelope. Differences throughout the series could be explained as due to the increasing temperature as one moved to earlier spectral types.

Wright continued the work done in his doctoral thesis,[93] specializing in the spectrophotometry of solar type stars, using very large dispersions and interpreting his findings in terms of the stellar atmospheres. Since one of his stars was the sun itself, the only star in which the disk could be observed, the theoretical developments were tied firmly to verifiable facts. Two important papers, dealing with the "curves of growth" of atoms in one of these stars were published.[94] He suggests stratification in the stellar atmospheres, even for differently charged atoms of the same element.

Petrie made an extensive investigation into the absorption line intensities of O-type stars measuring the intensity ratios of various lines and relating these to the spectral classification. From the variation in the ratio of ionized to neutral helium he was able to estimate the temperatures of the stars. These ranged from 36,300°K for 05 to 28,600°K for B0.[95]

McKellar pursued his work on the molecular bands, studying the intensities of CN, CH and C2 in the spectra of three R-type stars and determining the temperatures of the stars from his data.[96] Later he determined the relative abundance of the carbon isotopes C^{12} and C^{13} from the spectra of 21 R-type stars. He relates variations in the ratio to the particular stage of the star in its development.[97] This work will be discussed in more detail later.

An extensive paper[98] by A. Pannekoek, of the Astronomic Institute of Amsterdam, Holland, giving the line intensities observed in the spectra of seven late-type stars (F3 to G6) and of the sky in the region, appeared in 1946. This work was based on plates taken by H.H. Plaskett in 1924, and by the author during a visit to the Observatory in 1929!

In an earlier section (page 145) a stellar photometer was mentioned. This instrument, which used a caesium photo-electric cell, was designed by Beals and was tested, with Petrie's help, by comparing its measurement of colour intensities with that determined by spectrophotometric methods. Having passed these tests it was used to determine the photoelectric colour indices (see page 145) of 250 0- and B-type stars for which colour gradients had already been measured in Greenwich. I cannot find the results of this research, reported by Pearce, in either the Publications or the Journal.

I commented earlier that the ultraviolet spectrograph, which had been acquired in the early days of the Observatory, seems not to have been used much. After it had been transferred to the Cassegrain focus, William Petrie, of the Department of Physics of the University of Saskatchewan, (younger brother of R.M. Petrie) used the spectrograph to study the colour temperature of a number of Wolf Rayet, O and B stars. The results were inconclusive.[99]

Publications during this period give evidence of a good deal of cooperation with universities, particularly with the University of Saskatchewan where William Petrie was a professor. Students and staff from the University of Alberta and Washington University are also represented in the Publications, and Pearce reports that Anne Underhill, who was shortly to become a member of the staff, was awarded her Master's degree by the University of British Columbia for work done, in part, at the Observatory.[100]

McKellar made a number of studies of the spectra of comets which threw some light on the mechanism producing their emission lines and suggested the existence of various polyatomic molecules.

Interest in spectroscopic binaries remained high, but, following the trend of recent years, attention was focussed on stars of particular interest and, in all cases where the two spectra were available, relative luminosity studies were used to define the masses of each member star. In the remaining part of Volume VII, four of the five binary stars studies were in this category.

An increased interest in the radial velocities of stars in clusters should be reported. Pearce worked on the Pleiades cluster, studying the radial velocities of 71 stars, and determining the motion of the cluster.[101] Stillwell studied the Taurus cluster and refuted an earlier suggestion that the cluster contained an anomalous number of binary stars.[102]

The problem of "standard" wavelengths (see page 139) continued to be a source of concern. There was evidence that the standards in use at the various large observatories were not consistent since there were statistically valid differences in their radial velocities. The "K" term in calculations of the rotation of the galaxy (page 138) remained stubbornly different from zero and there was at least the possibility that this was due to errors in the standard wavelengths employed. In 1946 Petrie turned his attention once again to this matter, with the assistance of Dr. Jean McDonald.

If one is talking about stellar, zero-velocity, wavelength standards, where do we find the zero-velocity star? There is no such thing, but the sun, the moon, the planets and some asteroids do have motions, relative to the earth, that are accurately known and the sun is a star of known type - G2. Therefore, with suitable calculations one can establish the required lines for a G2 star. A first paper[103] considered standards for stars in the range F4 to K8, for high and moderate dispersions. There were two sources of data. If double stars could be found in which one star was of class G2 then the velocity of that binary could be determined. The velocity of the second member thus became known and if it were of some class other than G2 its spectrum could be examined for standard lines. Secondly, as we have seen, stellar clusters are made up of stars all travelling at about the same velocity. If stars of type G2 could be found in a cluster, the "standard" velocity of the cluster could be established and the spectra of stars of other classes could be searched for standard lines. The work of Pearce on the Pleiades cluster and of Stillwell on the Taurus cluster, were related to the needs of Petrie's research on spectrographic standards.

Once standards for stars in the range F4 to K8 were established the methods could be extended to other classes and this was done; to A stars, using high dispersion;[104] to A stars using low dispersion;[105] to solar type stars, with low dispersion.[106]

This brings us to the close of the Stewart administration, but the pursuit of standard wavelengths was to continue: for F- to M-type stars, using low dispersion by Wright;[107] and for B-type stars, using low dispersion, by Petrie.[108] This latter paper completed the programme of establishing standard wavelengths. Specifically, Petrie states "there is little need for extensive work ... for high dispersion spectra [of B-stars], where many prominent lines are sensibly free from blends and laboratory wave-lengths may be adapted for them at once."

DOMINION OBSERVATORY

ASTRONOMY

The Equatorial Telescope

Henroteau's search for short-period variables of the beta Canis Majoris type (p. 100) had led to the discovery of twenty stars which could be placed in this class. Some of them showed additional properties but "the general characteristic of all the stars of this type was found to be the existence of a radial velocity variation of very short period, upon which was superposed a variation of longer period, often of the order of a month or more. The short period variation appeared to be analagous to the Cepheids, and possibly due to pulsation in a single body; it appeared likely that the longer period was due to real orbital motion."[109]

The work thus led Henroteau to consider the Cepheids in general. This was a class of stars characterized by short period variation in luminosity, and they had been extensively studied. The definition of a Cepheid had gradually been broadened and so increased the number of stars included in the class. As a first task Henroteau made a list of these stars; they totalled 92, although many of them were too faint to be studied by the Ottawa telescope. He proceeded to observe as many of these as systematically as possible. He produced a major paper[110] in which, after reviewing the literature very thoroughly, he gives the Ottawa spectrographic observations on seven stars and includes photometric data on two of them; he then discusses the photographic light curves of eight stars which were apparently true Cepheids in the sense that they showed no binary characteristics. These light curves were obtained by photographing rather wide areas of the sky with the short-focus camera, standard equipment with the 15-inch equatorial. The stars being studied were compared with non-pulsating stars of known magnitude appearing in the same plate. Strangely, Motherwell, who was supposed to be responsible for the photometric work is not mentioned in the paper, but the assistance of two astronomers, J.F. Frédette and R. Callander, is acknowledged. The paper was published in 1924; the work should probably be included under the Klotz administrations and he should be given credit for recruiting Frédette and Callander, of whom we have not previously heard.

The title of the paper quoted, "The Cepheid Problem" indicates Henroteau's deep interest in the subject, and within a year he was doing something about it on an international scale. Because the variations to be studied had such short periods it was very difficult for a single observatory to study them. Daylight and uncertain weather conditions made it impossible to collect adequate data on a single cycle, with the result that numbers of cycles were averaged and, in so doing, possible variations from cycle to cycle were lost sight of. Henroteau and a French astronomer Grouiller proposed an international programme. As many observers as possible would be enlisted in the study: the varying magnitude of selected Cepheids would be compared to certain standard stars and reported to Lyon Observatory, to be analyzed by Grouiller; the magnitude of these standard stars would be determined by other observatories with suitable photometric equipment and reported to Ottawa.

The proposal was submitted by Henroteau to the committee on variable stars of the International Astronomical Union at their meeting in Cambridge, England, in July, 1925. It was accepted. [Henroteau attended the meeting as part of a vacation trip to his native Belgium. Stewart and Plaskett were the official Departmental delegates.] There is something very strange here. By 1925, we are well into the Stewart administration, in which Motherwell had been named a division chief, of equal status to Henroteau. The work proposed in the international programme is entirely photometric and yet Motherwell's name is not associated with it. If Stewart had made the proposal, protocol would have been observed, but Henroteau? Perhaps the incident is indicative of why Henroteau was not popular with his fellow workers.

Frédette left the observatory in 1927 and was replaced by Miss Miriam Burland. At about the same time Callander was transferred to the Photographic Photometry division and was replaced by D. A. Barlow. Miss Burland was assigned to work on the new photoelectric photometer.

Meanwhile, for the next year or two Henroteau was extremely active in spectroscopic work, studying spectroscopic binaries and in particular the Cepheids and psuedo-Cepheids. A number of papers appear in the Publications and in the Journal of the Royal Astronomical Society of Canada.[111]

Information could be obtained from stellar spectra not only about the changing radial velocity of the Cepheids but also of the physical changes accompanying the pulsation. This required a study not only of the changing positions of the spectral lines but also of their relative intensities, and the changes therein. Henroteau began a cooperative study with Professor A. Vibert Douglas of McGill University, using a Moll thermopile microphotometer. The work continued for several years. I am aware of only one paper[112] but I have not searched the literature. This paper was published in 1929. In 1930 or 1931, the Observatory acquired its own Moll microphotometer but, as we have seen, Henroteau left the staff in mysterious circumstances in mid-1932, and the report for the fiscal year 1932-1933 states that "spectroscopic work with the fifteen-inch equatorial has been practically discontinued owing to the fact that the available field in that direction for a telescope of this size has been pretty well exhausted."

A photo-electric photometer was purchased in 1927 and came into regular use in 1928. This instrument was attached to the fifteen inch equatorial in place of the spectroscope and measured the total intensity of the light coming from a star. By observing continuously, or at frequent intervals, it could produce a light curve and so was particularly useful in the study of the short period Cepheid variables. It was operated from the beginning by Miriam Burland. As far as I can find, nothing has been published about the results and only the Annual Reports give an idea of how extensively it was used. According to those reports (giving the year of publication and therefore covering a period from April 1 of the proceeding year to March 31 of the year given) the instrument was tested, and a few preliminary observations made, in 1927, was used extensively (89 observations) in 1929, was rebuilt in 1930 to improve the sensitivity but was apparently not satisfactory. In 1931 a new instrument was built employing "a new electrometer which is simpler, more sensitive, and more accurate than the former string electrometer." By 1933 this instrument was making over 400 observations per year and the programme continued at a gradually decreasing rate until the early 1940s when it was dropped completely. Miss Burland was transferred to the Seismological division to replace Innes who had enlisted. Apparently she made occasional observations after that time but from 1943 the reports state simply that there are no programs involving the fifteen-inch equatorial. We should state that the reports do mention some spectrographic work after the departure of Henroteau, apparently involving the reworking of old plates with the Moll microphotometer. The instrument proved unsatisfactory; the lenses were adjusted and work was continued with it up until 1939. I can find no publications, and no indication of who was doing the work.

Plaskett's dictum, that there would be no astrophysics done in Ottawa after this departure, took some time to come true, but true it did become!

Photographic Photometry

As we saw in the preceding section, Henroteau had committed Motherwell to a major international programme in which he himself would be involved only to a minor degree. Motherwell seems to have made a real effort to meet his obligations but I have not been able to find any publication by him describing the work other than the section on Photographic Photometry in the 1930 "Activities of the Dominion Observatory."[113] Beyond 1930 we must depend on the Annual Reports.

The method of determining photometric intensities, due to Parkhurst and described in an earlier section, was to set the camera slightly out of focus so that the star images were disks rather than points and to compare the relative intensity of the images with that of stars of known magnitude. The method was easy to apply, but the fogging of the plates due to the lights of the city made the calibration of the plates questionable and in the 1930 paper Motherwell reports that a thermopile was used shortly after 1924 for measuring photographic plates. This method was not a new one; it was used at Harvard, and by European astronomers. The experiment was not a success. Motherwell reports in 1930 that "we hope to have the thermopile method in operation within a year and to obtain magnitudes much more accurately."

Motherwell embarked promptly on the international programme, established by the IAU; 167 Cepheid variables were selected by the committee, and several observatories in various parts of the world agreed to cooperate in observing these variables and also in determining the magnitudes of comparison stars in their fields. Ottawa assumed responsibility for 67 of these fields.

Motherwell states: "A photograph of the variable field was taken on the same plate as a Leavitt field which contained stars of known magnitude and, from comparison of the diameters, the magnitudes in the variable field were determined." By 1926 Ottawa had photographed 60 of its assigned fields at least once. The plates of 20 fields had been measured and the resulting magnitudes sent out to the cooperating observatories. The work continued and by 1928 the study of 18 fields had been completed and work was well advanced on the remaining 49.

In order to maintain the parallel programme of studying the variation of the Cepheids in detail, a new equatorial mounting was acquired, carrying three cameras, with space for a fourth. This was operated by Callender, newly transferred from Henroteau's group, and by 1928 he had exposed over 1,000 plates in this programme as well as contributing several hundred plates to the programme of photographing the fields of the selected Cepheids.

Other observatories were not as active in the programme as Ottawa, and in 1928 the programme was reorganized, apparently to concentrate on the fields uncompleted in the initial programme, although new stars were added. Ottawa still was responsible for 67 fields, and by the time of the 1930 paper 53 of the fields had been completed and numerous plates had been taken for the variable on the new list.

From the Annual Reports we know that work on the programme continued up until the start of the war, when Motherwell was seconded to the National Research Council, although the amount of work decreased steadily year by year. The 1933 Report states that the triple camera was no longer in use due to shortage of staff; this suggests that Callender was a victim of the depression cut-backs, probably in 1932. Nothing seems to have been published for these later years and there is no mention of the distribution of data to the cooperating observatories. From 1943 onwards, the division is not mentioned in the Reports.

The division was also responsible for photographing comets. Reid's comet of May, 1921, and the Pons-Winnecke comet of 1928 were photographed frequently and a search was always made for any newly discovered comet.

Meteor Observations

A beginning was made during the Stewart administration on the observation of meteors. This was a cooperative venture in which the lead was taken by Peter Millman. Millman who was on the staff of the University of Toronto interested himself particularly in meteors. In 1934 he began editing a feature of the Journal of the Royal Astronomical Society of Canada called "Meteor News" and he was very active in organizing astronomers in observing meteor showers. The first reference I have found to Dominion Observatory cooperation in his programme is in 1934 when M.M. Thomson, M.S. Burland and W.B. Knowles observed the Perseid shower. Thomson and Burland observed the Perseids annually although their report on the 1936 shower makes it clear that the effort was on behalf of the Ottawa Centre of the Royal Astronomical Society. During that year the Centre observed in three places - Ottawa, Hull and Golden Lake - and they took photographs in addition to the visual count. The participation of the Ottawa Centre in the Perseid programme seems to have been an annual event from that time forward, with Malcolm Thomson and Miriam Burland always in charge of the Ottawa Centre effort. They report annually in the Journal.

Millman joined the staff of the Dominion Observatory at the close of the war (July, 1946) and meteor observing became a regular part of the

Malcolm Thomson at the observing position of the broken-type Cooke transit.

observatory programme. These developments will be covered in Volume II.

Positional Astronomy and Time Service[114]

When Meldrum Stewart became Director of the Observatory in 1924, he was succeeded as head of the Positional Astronomy division by C. C. Smith. Smith had been an early recruit to the staff, in 1908, but had resigned in 1912 to enter private practice as a Land Surveyor in British Columbia. He returned to the Observatory in 1919, became Chief of the Division in 1924 and continued in that capacity until his retirement in 1937. He was succeeded by D. B. Nugent, a long-term member of the staff who, in turn, retired in 1944 to be followed by W. S. McClenahan.

There were no radical departures in the programme of the division until very near the end of the Stewart administration when thought began to be given to building a Photographic Zenith Telescope (P.Z.T.). Observations were taken with the meridian circle transit on every clear night, initially as part of two different programmes. The first had to do with time, and involved the observation of certain stars whose positions had been well-determined and the rapid transfer of these observations into corrections to be applied to the master clocks. The second programme aimed at the improvement of the catalogue position of a large number of other stars. This programme had actually began in the closing months of the Klotz regime, having been agreed on by the IAU at its 1922, Rome, meeting at which Klotz was the Canadian delegate. There it was agreed that a list of fundamental stars, compiled by astronomers Backlund and Hough and published in the *Connaissance de Temps* for 1914, would be observed by all observatories suitably equipped in order to improve their catalogue positions. The Observatory began this programme in 1924 and continued it until 1935 at which time 10,600 observations for right ascension and declination had been completed; the eye and object ends of the telescope were then interchanged and a programme of re-measuring all the stars in the new positions was begun! Two years later a vast catalogue of 33,342 stars was published by Boss which seemed to suggest that there was no need to go on with the programme on which every one had worked so hard. Some modifications were made. Observations of the sun and planets, which had been made regularly since the beginning of the programme, and which were necessary to define the coordinate system of the stars, were stopped. Reference would be to a framework of standard stars. With the outbreak of the war even the reduced programme could not be maintained and the numbers of observations gradually dwindled.

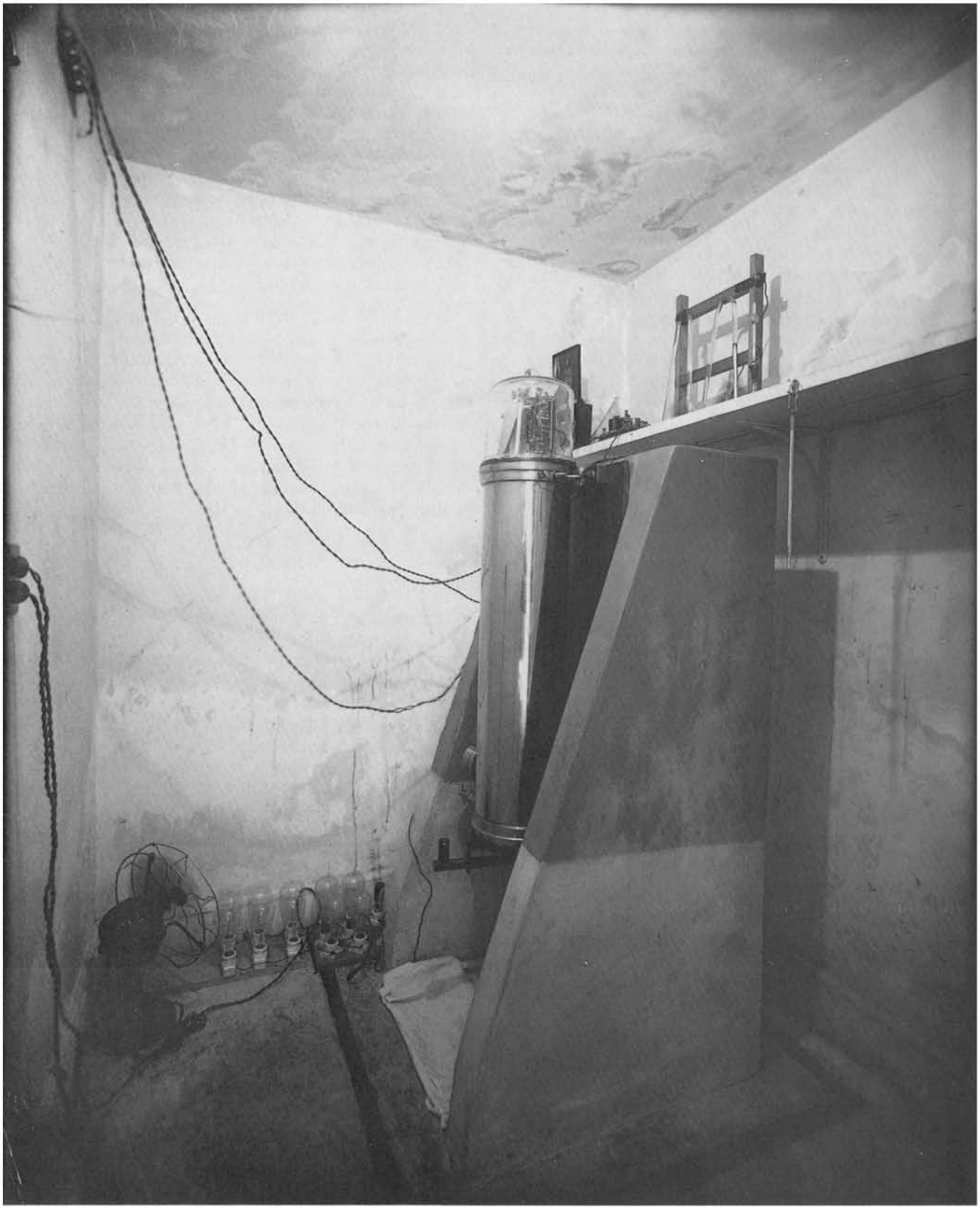
During all these years no results had been published. The Annual Reports are filled with wishful comments that "computations are continuing slowly", or "are progressing" but nothing was brought to the publication stage. This was partly due to the shortage of personnel, but it was also due to the vast number of computations which must be made and the meticulous corrections required - for errors of the pivots, of the graduation circles, in the micrometer, and the personal errors of the observers. These things could not be analysed adequately until the programme was completed.

In 1949 McClenahan published the meridian circle results for 1911-1923, containing a catalogue of 2, 436 stars.[115] He was much assisted in this work by E. G. Woolsey, who had joined the staff in 1946; Thomson[116] says that publication was "largely due to the assistance given by E. G. Woolsey and R. W. Tanner". In 1952 McClenahan extended the publication to 1935[117] and in 1954, with Woolsey and Tanner as co-authors, to 1950;[118] in 1957 Woolsey and Tanner extended it to 1953.[119]

The instrument continued in operation until December 1962 so we shall be returning to the subject in a later chapter.

Until 1935 the meridian circle transit was used for time measurements as well as for determining star positions. For the time measurements of course the observations were very quickly reduced so that an appropriate time correction could be applied to the master clocks. By 1930 Smith had begun to suspect that there were errors in the meridian circle observations which, while they could be eliminated over a long series of observations, could not be corrected in the day-to-day operations needed for time checks. He started observing with a 3-inch Cooke transit, as well as with the larger instrument and it became apparent in a year or two that there were consistent differences. In 1933 he introduced a broken-type transit into the experiments as well, and by 1935 he was convinced of the superiority of the broken-type transit, over both the straight Cooke transit and the meridian circle.

Thomson suggests[116] that the reason the Cooke transit was better than the meridian circle was that it was reversed at the mid-transit of the star and so eliminated collimation error. In the broken-type transit a prism or mirror in the optical path deflects the star image at right angles through the axis of the support. This made for a fixed position for the observer, whatever might be the azimuth of the star, with lower fatigue for the observer and smaller errors. Smith was so impressed that he had a standard Cooke transit converted to a broken-type in the machine shop, and this became the standard



The Shortt synchronome clock in the clock vault, 1930.

instrument for observing for time. He published a paper on the conversion.[120]

As already described, (p. 126) the responsibility for longitude determination had been transferred to the Geodetic Survey in 1924, but that was not quite the end of it. In 1924, at a meeting in Cambridge, England, the International Astronomical Union decided to make a new determination of longitude ties between Europe, North and South America, and Asia. It was felt that transmission of time by radio would eliminate some of the errors in the earlier efforts, in which cables and telegraph wires had been used, and that the accuracy of the new measurements might be sufficient, if repeated from time to time, to detect the continental drift that Wegener was suggesting. There were to be two principal lines, to which other stations could be tied: Greenwich-Ottawa-Vancouver-Tokyo, and Greenwich-Algiers-Zikawei-San Diego. Since the programme had originated in the IAU rather than in the IUGG there was no question about which Canadian agency was responsible - it was the Observatory. The measurements were made in 1926.

Smith and Swinburn occupied the Vancouver station at Brockton Point, in Stanley Park. Smith had a straight Cooke transit, Swinburn a broken-type Heyde transit and J. P. Henderson was there to provide the radio signals. According to Thomson[121], A. H. Miller took advantage of the time signals to make a pendulum determination at Vancouver. Thomson does not say who made the simultaneous observations in Ottawa, nor have I been able to find out. The results were computed promptly and submitted to the IAU in late October, 1926. The longitude of Ottawa was reduced by 0.012 seconds (of time), that of Vancouver by 0. 005 seconds, but the probable errors of the observations were such that no changes were made to the accepted values.

The programme was repeated in 1933 with Smith (using his converted broken-type Cooke) and Swinburn in Vancouver, McClenahan, (with a broken-type Heyde transit) and McDiarmid (using the meridian circle) in Ottawa. A truly southern line of stations - Cape of Good Hope, Adelaide, Wellington and Buenos Aires was included in the 1933 experiment. To tie the two lines together a group of equatorial stars was observed by everyone. Time signals, on an agreed to basis, were observed by Thomson in Ottawa and Henderson in Vancouver. A total of 87 stations participated in the experiment. When all the data had been collected by the *Bureau International de l'Heure*, in Paris, and all possible sources of error had been eliminated, the results were not sufficiently accurate to detect any possible "drift" of the continents in the seven years since the earlier experiment.[122]

The observers were always much concerned about their personal error equations (see page 50) and it was particularly important in these international programmes to determine them accurately. A "personal equation" machine was designed and built in the Ottawa shops. It consisted of a pin-hole light source which could traverse the field of the transit, making exact contacts as the "star" traversed the field; these could be compared with the signals recorded from the micrometer. The validity of the results was questioned since they did not agree with findings based on actual observations, and it seems not to have been extensively used.

We turn now to the matter of master clocks which maintained "Dominion Observatory Time" and which were corrected by the nightly astronomic observations. These clocks were maintained in an inner basement room (see page 46) which was intended to minimize temperature effects, and were mounted on piers which reduced vibrations. Over the years the complement of clocks increased, with newer, more accurate clocks replacing the earlier ones, and irregularities due to both vibration and temperature fluctuations began to appear. From the early 1920s Klotz, and then Stewart, were pressing for a new clock vault. This was finally completed in 1927, under the north lawn of the observatory; it was approached by a door on the lower side of the terrace. Massive piers, separated from the floor, and provided with embedded steel plate for the attachment of the clocks, provided protection against vibration and double walls and a thermostatic control system guarded against temperature variations.

The two primary Riefler clocks were installed in the new vault and a Shortt synchronome clock was purchased to augment them in 1930. This clock proved to be so superior to the old ones that it quickly became the primary sidereal clock, the Rieflers being reduced to secondary status. The Shortt clock had a master in the vault, and a slave in the Time Room and proved to have an accuracy of 0.04 seconds. Thomson, whose book should be read by anyone interested in the fascinating business of gradually improving time keeping, gives a detailed description of the Shortt clock.[123]

The accuracy of the new clock inspired Stewart to design a "time machine" which, through systems of gears, transformed the sidereal time of the Shortt slave into mean time; this mean time was used to control a system of shafts, with gears and ratchets, which could send out signals at every hour, every minute and every second and could turn on circuits to "clients" such as the railways and the CBC network to give them time signals at agreed times. Another set of contacts controlled the radio signals being sent out over CHU. To modern eyes, conditioned to microchips, the machine had a rather "Rube

J.P. Henderson, left, with C.S. Beals, in front of the "time machine", April 1947.

A close-up of the machine.

Goldberg" appearance, but it was a marvel of design and precise machining. Thomson[124] estimates that its construction occupied two full years of machine shop time. It was so successful that a second, standby, system was built. The pair gave excellent service up until 1951, when they were defeated by obsolescence and crystal clocks took over. This however carries us beyond the bounds of our present chapter.

The division had been very much involved in the developing science of electronics, nowhere more so than in problems of radio transmission. The use of radio time signals for longitude determinations had begun under King and was well established under the Klotz administration. The monitoring of Washington, Paris and Hamburg signals, and the radio transmission of Ottawa time, also began under Klotz. This service improved steadily; by 1927 time signals were being monitored from Rugby, England and by 1933 signals were regularly being received from Argentina and Brazil. The 1934 Annual Report states that 2,844 comparison has been made in the year and that a search of any differences, and their cause, was under way.

Henderson published a comprehensive article on "Wireless Time Signals and their Applications" in 1928[125] and the Journal of the Royal Astronomical Society of Canada regularly carried listings of "Wireless Time Signals Observed at Ottawa", under Stewart's name. These listed all of the signals received, gave the apparent error of the transmitting station and the error of the Ottawa master clock. In 1930 Smith published a complete listing of wireless time signals observed in Ottawa from 1921 to 1926 inclusive.[126]

As we have seen, the transmission of time by the Observatory began in an informal way during the Klotz administration. By 1929 regular, day-time transmission had been established with the call letters VE90B, and by 1933 there were low-power transmitters in operation at 20.4, 40.8 and 90 meters. International agreements in 1934 caused these wavelengths to be changed to 20.41, 40.82 and 90.00; at the same time frequency rather than wavelength became the official way of designating a transmitter characteristic. The new wavelengths corresponded to frequencies of 3332, 7350 and 14,700 kilohertz. In 1938 the call letters of the station were changed to CHU and the frequencies were adjusted to 3,330, 7,335 and 14,570 kilohertz, frequencies with which we are all familiar.

The distribution of time was not much changed over the years, except that the number of clocks controlled in the government offices steadily increased. By 1940, for example the number of these had grown to 700. In the depth of the Depression when it was proposed to retire Mr. Dier, who was responsible for the maintenance of the clock network, the Department suggested that the care of the clocks be turned over to the Department of Public Works who, after all, were maintaining the buildings in which the clocks were mounted. Stewart strongly opposed this[127] and, as we saw earlier, Dier was not forced to retire and the Observatory continued to control the system.

During the war, official Ottawa became very distressed to learn that there was no "official" time in Canada. This was soon rectified. An Order-in Council was passed on August 18, 1941:

> "THEREFORE, the Deputy of His Excellency the Governor General in Council, on the recommendation of the Minister Of Mines and Resources, is pleased to order that the time determined at the said Dominion Observatory, and which is broadcast by standard and shortwave radio daily, be and is hereby designated as official time for Dominion official purposes."

A 1949 paper by Thomson on "Canada's Time Service" [128] coincides reasonably closely with the close of the Stewart years and the close of the present chapter. He concludes: "there is no doubt that the modern methods of photographic observation and crystal-clock time keeping are likely eventually to result in increased accuracy." We leave the division of Positional Astronomy and the Time Service on the threshold of this new era.

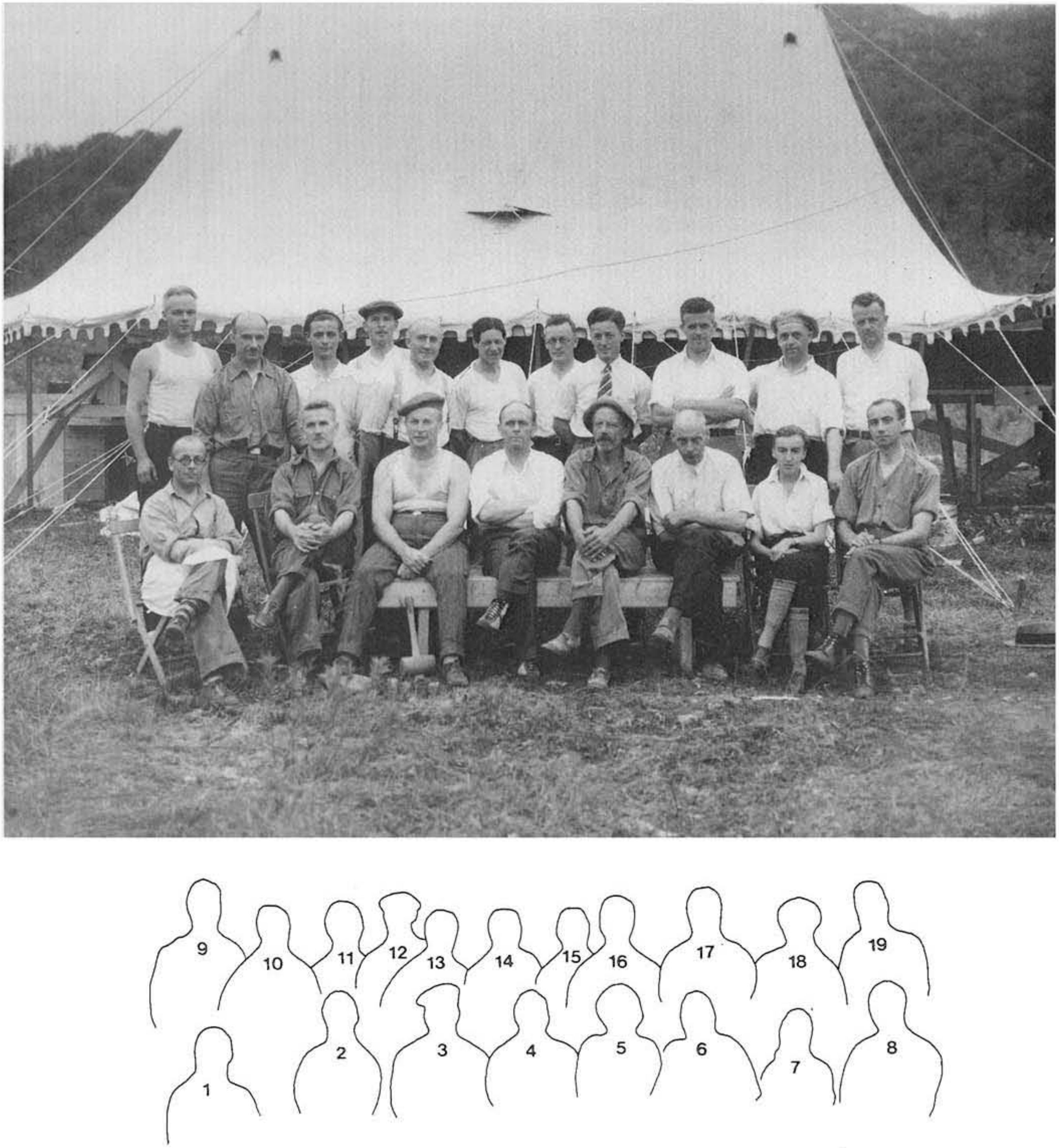
Solar Physics

DeLury and his assistant John O'Connor, more probably the latter, were assiduous in taking solar spectra and direct photographs of the sun. From the beginning of the period, the Annual Reports always list the number of solar spectrograms taken "each comprising nine strips of spectrum, using various combinations from centre, limb, and midway positions, with comparison spectra of electric arc and iodine."

Nothing seems to have been done with these combination spectograms, nor indeed with the photographs, beyond counting the number of sunspots. DeLury's time was taken up with the re-measurement of the spectra from 1909 to 1916, and with the attempt to track down all the sources of error and to define the effect of blended spectra. To help in the work he designed a "spectrocomparator" which made the readings of spectrograms easier and more accurate, and he produced tables and designed equipment which allowed the rapid determination of the coordinates of positions on the sun's disk, and of the contribution of solar rotation, terrestrial rotation

(Above) Arthur Bird, left, and L. "Chris" Christensen in the Observatory Machine Shop. These two men built the many pieces of equipment developed during the Stewart and early Beals administrations.

(Right) V.E. Hollinsworth, with the first Observatory crystal clock, 1947.



Observatory staff on the eclipse expedition of 1932. Identifications, where I can make them, are as follows: 1 Hector Gauthier, 3 Robert Motherwell, 4 Ralph Delury, 5 Meldrum Stewart, 6 Charles Smith, 7 Miriam Burland, 8 J.P. Henderson, 9 John O'Connor, 10 Dick McDiarmid, 14 Art Bird, 15 Bill Doxsee, 17 Bill McClenahan, 18 E.C. (Arby) Arbogast. Photograph from the National Museum of Science and Technology.

and the movement of the earth around the sun to the sun's apparent velocity of rotation. All this equipment was built in the Observatory machine shop. These instruments are described in Part I of the Publications, Vol 6, a volume that was reserved exclusively for Solar Physics.[129]

It was not until 1936 that "Part II Solar Rotation" was ready for the press, not until 1940 that it actually appeared.[130] Then it only discussed the rotation results for 1909 and 1910. Even for this limited study, the conclusions were not very substantive. They did not support the then popular theory that the velocity of rotation increased with increased elevation in the sun's atmosphere, but the consistency of the observations was not sufficient to definitely disprove the theory.

In 1939, DeLury considered the problem of solar rotation on a broader basis, considering all spectroscopic results including his own, as well as velocities determined from observing the movement of sunspots. Combining all observations he proposed a law which related the velocity of solar rotation to solar latitude.[131]

As a layman, I find it difficult to understand why DeLury spent so much time analysing data from the two years during which the equipment was still in its "breaking-in" period. Would it not have been better to have measured the plates which proliferated throughout the Klotz era when most sources of error had been recognized or eliminated? It may have been because the task had been assigned by the International Union for Co-operation in Solar Research as part of an international study of solar rotation, but surely the problems must have been long since solved by 1940.

One may also ask why it took so long. The reason is almost certainly DeLury's increasing preoccupation with the effects of sunspots on terrestrial phenomona. In his section of the 1930 report "Activities of the Astronomical Branch"[132] many correlations with sunspot activity, in particular with the 11 year cycle, are listed: the relationship to aurora and magnetic storms; to the "melting" of the caps of Mars; to variations in the growth rate of trees, both living and pre-glacial; to the numbers of grasshoppers and grouse; to commodity prices in Great Britain and Ireland. He was fascinated by the subject, and lectured and published about it to naturalist societies and similar organizations. He established a considerable public interest, and was consulted about the effect of the current cycle on commercial possibilities in muskrat farming and logging. He published a major paper in the Journal of the Royal Astronomical Society of Canada.[133]

This fascination seems natural to one who knew Ralph DeLury. He was a very gentle man, a childless widower who lived with his sister in a large house on Fairmount Avenue, surrounded by bird and squirrel feeders. He was much disliked by neighbourhood ladies because of his aversion to cats. Cats killed birds so DeLury killed cats. He kept a 22-calibre rifle, with silencer and telescopic sights, always available. When he killed a cat he buried it in the bottom of the garden. I have been told that the people who bought the house after his death found this cat cemetery, with dozens of skeletons. He was also an ardent nature photographer. Once, in the dead of winter, I, as a small boy of perhaps eight, accompanied him on a photographic expedition. This consisted in standing, shivering, up to my waist in snow, while he stalked some chickadees with a large Graflex box camera. He was active in naturalist societies and in lecturing, on nature, to young people. A lovely man, but not a great scientist!

DeLury retired just a few months after Stewart, in 1946. His retirement brought an end to an era in the Solar Physics work. The recruitment of Dr. Jack Locke early in the Beals' administration marked a new beginning.

This is as good a place as any to speak of the various solar eclipses which occurred during the Stewart administration. The first was on January 24, 1925 and was total over much of Canada, in particular in southern Ontario. The observatory decided against visual or photographic observing of it, since the chances of obtaining clear skies was only about 50% and since the University of Toronto would have a photographic party in the field. Instead they concentrated on magnetic effects, including the influence on radio transmission. The party was set up, under the direction of Mr. Stewart, a few miles south of Hamilton, in a tent inadequately heated by a non-magnetic copper stove. Madill and French observed the declination every minute for the six hours bracketting totality; to provide a control, similar measurements were taken on the preceding and following days.[134] J. P. Henderson[134] studied the effects on radio reception. It was found, as expected, that the effect was similar to night conditions.[135]

The next eclipse, on August 31, 1932, was total in eastern Canada. The observatory sent an expedition to St. Alexis-des-Monts, P.Q., in the path of totality, but the sky was completely overcast.

On July 9, 1945 a total eclipse was visible in the northwestern United States and in central Canada; the path of totality entered Canada at the Montana-Saskatchewan border and passed over Hudson Bay. No expedition to observe it was mounted by the Observatory. The Fels Planetarium of Philadelphia had an observing party in Wolseley, Saskatchewan and it was observed by amateurs at various points along its path,[136] and by P.M. Millman from an RCAF aircraft.

GEOPHYSICS

Gravity

Having completed the analysis of the 1921-1922 observations, Miller was anxious to extend the coverage in Western Canada with a view to "narrowing the gap between Canadian work in the Mackenzie River basin and that of the United States Coast and Geodetic Survey south of the International Boundary, and in relation to the requirements of isostatic investigation for the continent as a whole".[137] During the field seasons of 1924, 1925 and 1926 48 pendulum stations were observed ranging from Riverton, Manitoba to Masset in British Columbia and reaching as far north as The Pas, Manitoba, Prince Albert, Saskatchewan, Waterways and Grand Prairie, Alberta and Stewart, British Columbia. There were substantial numbers of observations in the foothills and mountain areas. The results were published and discussed in great detail in 1929.[138] Hayford anomalies were computed, and analysed to determine the level of isostatic compensation (85 to 114 km). They were also analysed in relation to the underlying geologic formations where there was some evidence that Mesozoic stations exhibited positive anomalies, Tertiary stations negative ones. For the first time, mention is made of Airy's method of compensation, but it was dismissed as being unlikely to produce anomalies significantly different from Hayford's.

The publication was accompanied by two maps, one showing the geology of western Canada with the gravity stations superposed, the other showing the Hayford anomalies for western Canada and adjacent areas of the United States, contoured, and with areas of negative and positive anomalies indicated in colour. The most positive station was Victoria; since Seattle had a high negative anomaly, the gradient across the Strait of Juan de Fuca was very high.

A letter survives[139] in which Bowie, with Hayford a "father" of isostasy, congratulates the Observatory on this work. The great man says: "I think that the gravity survey, made out in the mountains of western Canada, and the results of the isostatic reductions furnish definite information that isostasy is true. Of course many of us have believed it for a long time but, when one can go into a mountain area, as Mr. Miller has done, and show that isostasy is true to a remarkable degree, even the few outstanding opponents of isostasy must succumb to the evidence".

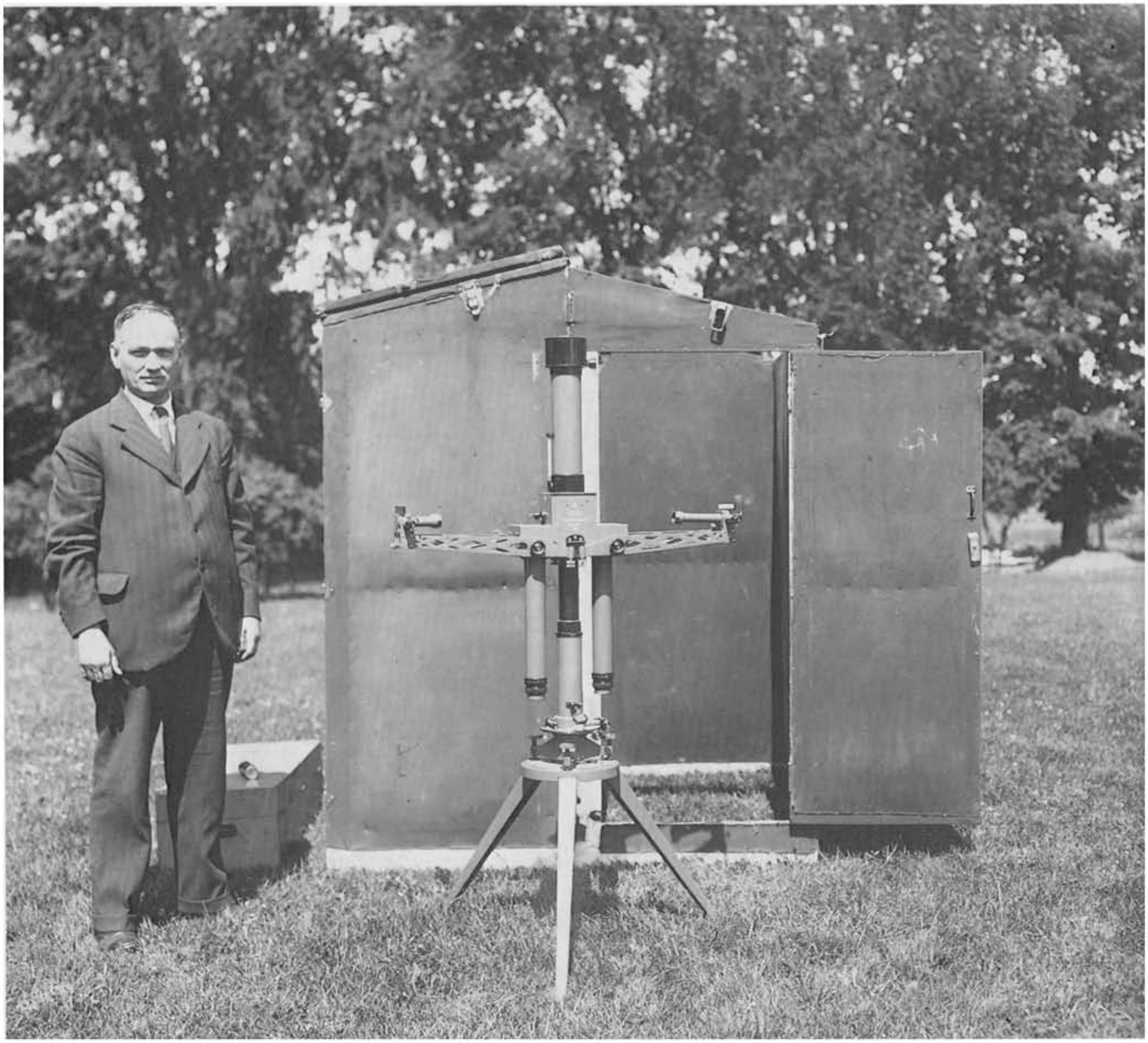
Miller now turned his attention to Eastern Canada. In 1927 six stations were observed in Ontario, one in Quebec and nine in Western Canada; in 1928 one station was observed in Quebec; in 1930 eight stations were observed in Ontario, six in Quebec. In the meantime however more important business had intruded. In 1928, Miller took the Ottawa pendulums to Europe, swinging them first in Ottawa, in June, in Greenwich in August and in Potsdam in September. I suspect that the one Quebec observation in 1928, as listed above, which was at McGill University, was made while Miller was waiting for his boat. The pendulums were swung again at their Ottawa base in January, 1929, in Washington during February and finally in Ottawa in March, thus completing the tie of the three national bases to the international standard at Potsdam. Miller's results[140] differed little from the previously accepted values. His value for Greenwich agreed to the third decimal place, for Washington it was about 0.006 cm/sec. greater, and for Ottawa, which had previously only been tied to Washington, a difference of +0.004. The new Ottawa value was 980. 622 cm/sec/sec.

With this international tie completed Miller was able to turn his attention once again to the gravity field in Canada and in 1934 he published a large paper bringing the analysis up to the end of the 1930 observations.[141] Since the value of g at the Canadian base, Ottawa, had been changed, it was necessary to republish the gravity values from earlier papers: there were 29 new stations to report, a total of 128.

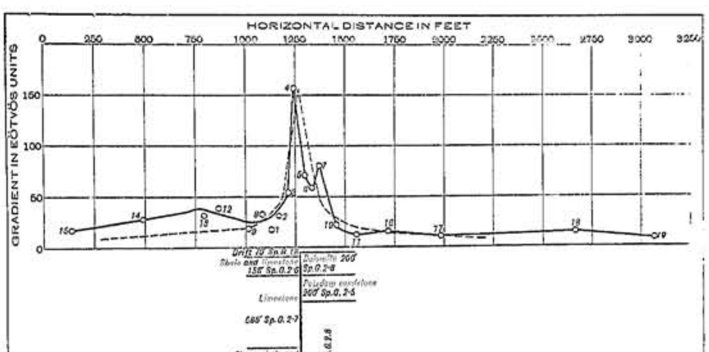
The Airy method of isostatic compensation, which had been only hinted at in the 1929 paper, is here thoroughly investigated. It differed from the Hayford system in that, where Hayford and Bowie assumed that compensation was accomplished at a uniform depth through density variations, Airy postulated that compensation was accomplished at varying depths with constant density. The Canadian results tended to support Airy.

The paper included a map of Hayford anomalies not only for those parts of Canada where the surveys had been completed, but also for the continental United States.

When Miller travelled to Europe in 1928 his mandate was not only to make a comparison of gravity values but to investigate "in collaboration with the Department of Mines, Ottawa, modern European methods of geophysical prospecting. ... Visits were made ... to the Geodetic Institute, Potsdam; the Geological Survey of Prussia, Berlin; the Baron Roland Eotvos Institute, Budapest; the Dutch Shell Company, The Hague; and several



A.H. Miller with the torsion balance and its portable hut.



The gravity gradient over the Hull-Gloucester fault.

British institutions including the Geological Survey of Great Britain".[142]

The Geological Survey had been experimenting with geophysical methods for some years, with the collaboration of Professors Eve and Keyes of McGill University and of Professor Gilchrist of Toronto. Miller's contribution was to be principally with the torsion balance and the magnetometer. We saw in an earlier chapter that Klotz had ordered a torsion balance in 1921, from Professor Hecker, in Jena, and that this instrument was delivered shortly before his death. Miller tells us[143] that in fact two instruments had been obtained from Hecker, that they had proven unsatisfactory and had to be returned to the manufacturers and were not returned in working condition until 1928. They seem not to have been used in the joint work of the Observatory and the Geological Survey. Instead a Suss and an Askania torsion balance and four Askania magnetometers, two vertical and two horizontal, were purchased for the joint work. Miller clearly states that the Suss instrument was the property of the Observatory but ascribes no ownership to the other equipment. Suss was the technician who had worked with Eotvos in the development of the torsion balance and of the torsion fibres needed for it.

The torsion balance was developed by the Hungarian, Baron Roland von Eotvos, and became a major tool of geophysical prospecting in the late 1920s and early 1930s. In modern terms it was an unwieldy instrument, standing some five feet high and requiring to be mounted in a portable hut to provide protection from wind and temperature fluctuations.

The instrument consisted of a horizontal beam with a mass at either end, one on the beam, the other suspended from it, the whole system suspended by a torsion fibre. In operation, the beam was set in a particular azimuth, released, and the torsion in the suspending fibre necessary to produce equilibrium noted. The beam was then reset, through a sequence of five azimuths and the measurements repeated. Since in each position it took about an hour for the beam to come to rest, the better instruments had two beams, necessitating only three sets of observations. The measurements could be interpreted in terms of two quantities, the gradient of gravity at the point and the curvature of the equipotential surface. Knowing the curvature of the surface and the gradient at right angles to that curvature, maps showing the contours (isogams) of the surface could be constructed. These of course were related to structure; it was up to the geologist to decide whether the structure was favourable for mineral concentration. Miller published a very good analysis of the theory of the torsion balance.[143]

The first tests were made in 1929 over three different faults in the vicinity of Ottawa. The first of these was the Hull-Gloucester fault, which had a very thin drift cover and which had an estimated throw of 1,000 feet with an equivalent difference in sedimentary thickness on the two sides. Plots of both gravity gradient and differential curvature correlated very well with the known position of the fault. Magnetic traverses did not indicate its position. Next, two traverses were made across the Hazeldean fault, about three miles apart. This fault had thicker drift cover and a throw of about half the amount of the Hull-Gloucester fault. Again the fault position was defined by the torsion balance, although less dramatically than in the earlier case. Here the magnetometer surveys were useful in defining the fault position. The second traverse of the Hazeldean fault was made in 1930. Work on these three faults was described by Miller as part of a larger study on prospecting methods.[144]

In 1930, in addition to completing the work on the Hazeldean fault, Miller assisted by G. P. Halton[145] began work on the asbestos and chromite deposits at Thetford, Quebec, work which was continued for the next two field seasons, and carried out studies over a pyrite deposit in Renfrew County. This area was chosen because the ore body had been fairly well defined by drilling and because of the very rough topography of the area. Could the topographic effects be eliminated in the final gravity map? They could be, and the map did give a good indication of the position of the ore body. The magnetic survey also defined the known ore body and indicated an extension not heretofore suspected, although the anomaly apparently was not due to the pyrite, but to a closely associated rock.[144]

Experiments over the serpentine belts, near Thetford, Quebec, were limited to the magnetometer and extended over the three field seasons 1930-1932. The geology of the area is very complex and, while deposits of both asbestos and chromite were often associated with magnetic anomalies, many anomalies were not associated with mineralization. Miller concluded that "in view of the complicated nature of the magnetic field within the intrusive, the magnetometer can hardly be of much value in the direct location of asbestos or chromite".[144]

In 1931, in cooperation with the Ontario Department of Mines and the Ontario Research Foundation, Miller made a torsion balance study of the Onakawana lignite formation of the Moose River Basin in Ontario. At the same time R. H. Hawkins, of the Geological Survey, made measurements with a vertical magnetometer. The lignite occurs in beds of variable thickness and limited extent, overlain by 50 to 150 feet of boulder clay, 10 feet of marine clay and 5 feet of muskeg. Miller made four miles of traverse,

Miller with the Atlas gravity meter, circa 1946.

with 79 stations at 100 metre intervals, forming three profiles. The lignite deposits were clearly defined as negative gravity anomalies. Hawkins made 82 magnetometer observations which showed no correlation with the deposits.[144]

While he was in the area Miller made some preliminary investigation of siderite deposits at Grand Rapids on the Mattagami River, using both vertical and horizontal magnetometers. This preliminary study suggested that the magnetometer might be useful in defining the extent of the deposits, and in 1933 a grid was laid out over the general area of the deposit and 600 observation were taken with the vertical magnetometer. At the same time 73 stations were occupied by the torsion balance. The results and their interpretations were quite complicated, but Miller's final conclusion was that neither the magnetometer nor the torsion balance was likely to prove useful in defining such deposits.[144]

Study next turned, in collaboration with the Geological Survey and the Provincial Geologist of New Brunswick, to a buried "granite" ridge near Moncton, New Brunswick. The ridge consists of pre-Carboniferous igneous and metamorphic rocks, and oil and gas shows had been obtained in holes drilled to the overlying Carboniferous sediments. Could geophysics define the boundaries of the ridge?

In 1932 five magnetometer traverses were made across the ridge, involving 200 stations made by a "super dip" operated by G.W.H. Norman of the Geological Survey and 150 stations made by Miller using both vertical and horizontal magnetometers. In 1935, Miller made three traverses, involving 131 stations, with the torsion balance and took vertical magnetometer readings at the same time. Both magnetic and gravity methods were successful in mapping the ridge, the magnetic rather more so than the gravity.[144]

Finally, in 1934, and again in cooperation with Norman, a study was made of the Malagash salt deposits. These deposits lie in a complicated series of Carboniferous strata at a depth of about 1,000 feet. Since the density of the salt is substantially less than that of the surrounding rock it seemed probable that the torsion balance could define the boundaries of the deposit. This proved correct. An area of about 3/4 of a square mile was covered with 233 torsion balance stations and an excellent isogamic map was produced which defined the known deposits very well and suggested possible extensions. [144]

The work in 1935 seems to have been the last in which the torsion balance was used. This may have been due to the pressure of pendulum work or to the fact that the Survey regarded the "testing" programme as complete. It may also reflect the fact that the time of the torsion balance was coming to a close. There are occasional references to "more modern apparatus" throughout the various reports; people were obviously anticipating the perfection of the gravity meters currently under development.

Miller reviewed all the work and provided a number of detailed anomaly analyses in the Publications;[144] he was joined in some parts of the publication by G. W. H. Norman. At the same time the Geological Survey was reviewing the results of its extensive study of geophysical prospecting in a series of papers and internal reports.

As we shall see later, an earthquake of Richter magnitude 6 occurred at Temiskaming, Quebec, late in 1935. Initially it was thought that the earthquake had a focus deeper than normal and it was suggested that there might be some displacement of material at depth which might have caused, or been caused by, the earthquake. There were three pendulum stations within 100 miles of the epicentre - at Mattawa, New Liskeard and Sudbury. It was decided to re-occupy these stations to see whether any changes had occurred. To guard against the possibility that something had happened to the pendulums since the original occupation of the stations, three control stations sufficiently far from the epicentre to be beyond the influence of the earthquake - Kingston, Ste. Anne de Bellevue and Montreal - were also re-occupied. No changes in gravity were detected.[146]

Further pendulum observations were made in 1937 and 1938.[147] The Annual Report for 1938[148] states that the five stations occupied in 1937 "were established with a high order of precision and are intended to serve as base stations in these areas [Newfoundland and Quebec] when a more modern apparatus becomes available for gravity investigations." Miller makes no mention of this in the paper referred to above and I myself fail to see how a higher order of precision than normal could be achieved.

In 1938 20 pendulum stations were occupied, forming three traverses across the Appalachian region. In these traverses the isostatic anomalies were, for the most part, negative, a fact which Miller attributed to lower-than-normal surface densities In addition to the standard isostatic (Hayford-Bowie) reduction the paper gives Free Air, Bouguer and Airy anomalies and also those using a method of Venning-Meinesz.[147]

We have already seen that the Gravity Division had suffered from the Depression and would suffer from the war. Hughson who had joined the staff in 1926 was let go in 1933 and Miller was by himself from then on. In 1941 he was seconded to the National Research Council and did not return until late in 1942, somewhat broken in health. In 1943[149] he returned to work on the buried "granite" ridge near Moncton, New Brunswick completing a torsion balance traverse 33 miles long and magnetic traverses over 100 miles long. The next summer, 1944, he was back in New Brunswick,[150] this time using a gravity meter lent by the Humble Oil Company. The season's work, given the flexibility of the instrument, was much broader and covered much of the Carboniferous basin in the province and extended into adjacent areas of Nova Scotia and the Gaspé. The results of these were not discussed in the Observatory publications until 1953 when Garland provided a complete review and analysis of gravity results in the Maritime Provinces.[151] However it is clear that Miller was pleased with the gravity meter. "The results obtained ... were highly satisfatory. ... In all 513 gravity meter stations were established in a period of two and one-half months. The time consumed in establishing such stations is thus almost negligible compared to that required for pendulum occupation and the accuracy is excellent, provided the instrument can be standardized fairly frequently at previously established pendulum stations."[150]

In 1945,[152] 562 gravity meter stations were observed in southern Ontario, Quebec and the Maritime Provinces using an instrument lent by the American Geophysical Union. This is probably the same gravity meter that had been used during the previous summer. The Humble Oil Company had made a number of gravity meters available to the American Geophysical Union to be assigned as they saw fit and one of these went to the Observatory. The Annual Report speaks of the preparation of Bouguer anomaly maps and of attempts at their interpretation. This is the first use I have detected of the Bouguer, as opposed to one or other of the isostatic, anomalies. It indicates a change of interest from the theoretical to the applied aspects of gravity work since the Bouguer anomaly is more sensitive to local structure. I have not found these maps in the Publications but in 1950 Garland published "Interpretation of Gravimetric and Magnetic Anomalies on Traverses in the Canadian Shield in Northern Ontario"[153] which includes the 1945 data as well as some taken in 1946 and 1947 using an Atlas Exploration Company gravity meter.

As Miller had stated in 1944,[150] pendulum bases were necessary for the calibration of gravity meters. In the late winter of 1946 the Canadian Army mounted an expedition to test equipment under Arctic conditions. It was known as Exercise Muskox, and was under the direction of Col. J.T. Wilson. Morris Innes was a member of the expedition, and made gravity and magnetic observations. Eight pendulum stations were established in northwestern Canada, between Hudson Bay and the Mackenzie River, as far north as latitude 69.[152] In 1946 pendulum stations were established in northern Ontario, northern Manitoba, southern Saskatchewan, southern Alberta, the Gaspé peninsula and Nova Scotia.[154] During the same year "two traverses by automobile with the new gravity meter purchased in the spring of 1946" resulted in a gravity profile of the prairie region."

The base stations established in 1946 are discussed by Innes and Thompson as part of a larger paper published in 1953.[155]

Magnetics

The attached table summarizes the field work of the Magnetic Division for the period of the Stewart administration. The entries up until the end of 1937 are from published papers[156] but I have not been able to find any publication covering the remaining years. The entries for 1938-1946 are taken from the Annual Departmental reports which are often very sketchy in details.

The table exhibits the vicissitudes, already documented, which struck the Observatory during the Stewart administration. Up until 1931 the field seasons were very productive, amazingly so when we remember that there were only two magneticians - French and Madill - on the staff, and the amount of hard, unremitting slugging that was involved can scarcely be exaggerated. Madill published a very interesting description of field work on these pre-aeroplane days.[157]

The 1925 field season included a number of stations in Labrador and one in Newfoundland, which were not yet part of Canada. This was done because of the almost impossible logistical problems of making observations in eastern Quebec in the area adjacent to the Quebec-Labrador border. It was much easier to observe along the Labrador coast although it was necessary to obtain the approval of the Newfoundland government through the Department of External Affairs in Ottawa.

In 1928 a magnetic observer was attached to the Hudson Strait Expedition of the Department of Marine, and in 1934 and 1937 an observer accompanied the Eastern Arctic Patrol, on the *Nascopie* in 1934, and the *Fort Severn* and *Nascopie* in 1937. In all of these expeditions the observer would go ashore at each stop, set up a station and attempt to complete the observations before the ship was ready to move on. Sometimes he couldn't, but usually he did.

When the Depression struck, the magnetic division shared the general suffering. There was no field work done in 1932 or 1933 although the division sprang back more quickly than the country did, with

Summary of magnetic field work, 1924-1946

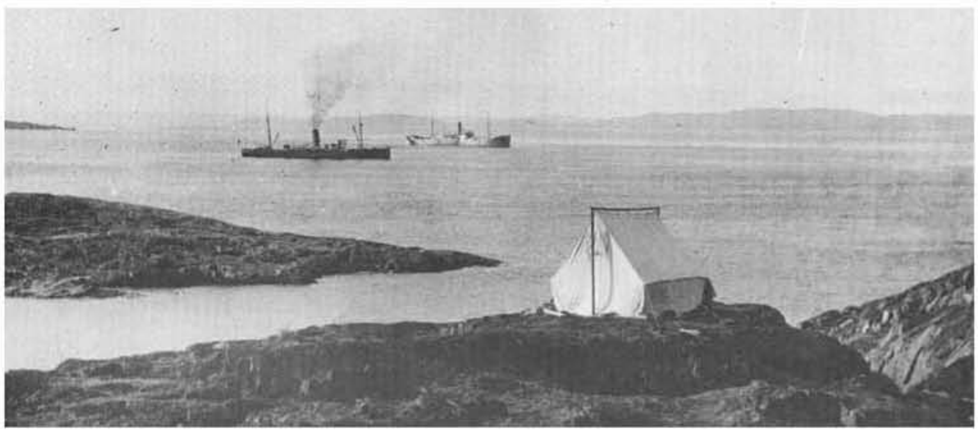
Year	Station occupa-tions	Locali-ities	Repeat local-ities	Remarks
1924	23	20	10	Eight stations in the Arctic, four being exact and two approximate repeats. Fifteen in British Columbia, fourteen along the coast, four being repeat stations.
1925	32	(28)	26	Eastern Canada and Labrador.
1926	40	(35)	31	Eastern and East-Central Canada.
1927	72	69	56	Ten stations along north shore of Lake Erie; sixty-two between longitudes 98°W. and 138°W., and between the Canada-United States boundary and latitude 56°N.
1928	11	8	7	Stations located in Quebec and Ontario between longitudes 71°W. and 82°W., and latitudes 45°N. and 50°N.
1928	6	5	1	Stations in the region of Hudson Strait. The station representing the repeat locality is at Port Burwell, and is an approximate re-location of station B occupied in 1914 by the Carnegie Institution.
1929	11	11	8	Ten stations along the water-route between Sioux Lookout and James Bay by way of Lac Seul, Root River, Lake St. Joseph, and Albany River, and the repeat station at Ottawa.
1930	47	47	47	Forty-four stations between longitudes 75°W. and 116°W., and between the Canada-United States boundary and latitude 53°N.; and three in northern Manitoba.
1931	35	34	34	Twenty-three stations in the southern parts of Ontario and Quebec, and in the Maritime Provinces; twelve in Western Canada, nine being along the water-route to the Arctic by way of Chipewyan.
1932	3	3	1	Two stations, Rivière aux Ecorces and Ayer's Cliff, established at the time of the total solar eclipse in August, and the repeat station at Ottawa.
1933	1	1	1	The repeat station at Ottawa.
1934	33	28	28	With the exception of Ottawa all stations in Alberta, British Columbia, and Yukon.
1934	15	15	5	Two stations in Labrador, three in Quebec, and ten in the Northwest Territories.
1935	33	28	26	Fifteen stations in Quebec and Ontario, and eighteen in the Prairie Provinces.
1936	16	16	13	Stations located between longitudes 59°. 9W. and 97°.2W., and latitudes 44°.6N. and 50°.1N.
1937	18	18	16	Stations in area between longitudes 65°W. and 84°.3W. and latitudes 42°N and 46°. 5N.

Summary of magnetic field work, 1924-1946 cont'd.

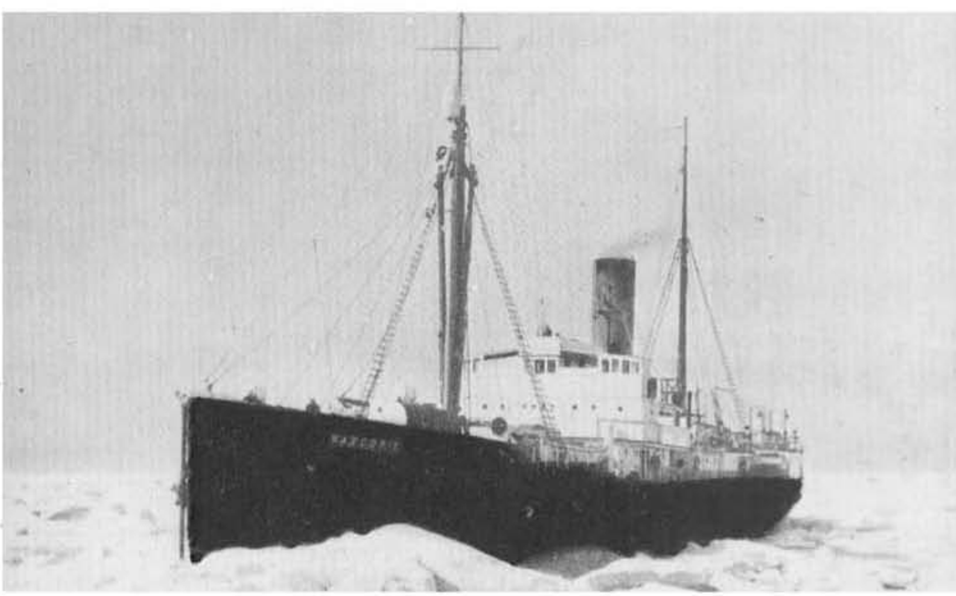
Year	Station occupations	Localities	Repeat localities	Remarks
1937	18	18	16	Stations in area between longitudes 65°W. and 84°.3W. and latitudes 42°N and 46°. 5N.
1937	13	13	10	Stations in Northern Canada between longitudes 62°W and 101°W., and latitudes 54°N and 67°N. Two of the repeat stations, Chesterfield and Baker Lake, were established by the Meteorological Service of Canada during the International Polar Year.
1938	20	-	17	Eighteen along Canada-U.S. border, between 85°W. and 120°W. Two in Northern Ontario.
1939	8	-	-	Seven in British Columbia, one in Ontario.
1940	3	-	12	Arctic, in cooperation with British-Canadian Arctic Expedition.
1941	11	-	-	Field work as required by Royal Canadian Navy and Royal Navy. Seven stations in Newfoundland, three in Nova Scotia, one in Ontario.
1942	5	-	5	In Arctic (?).
1943	4	-	3	Mackenzie River; 786 measurements of declination, at 193 different locations, made by survey officers of the Geodetic Service.
1944	12	-	12	Ontario and Quebec; 1228 declination observations made by survey officers of Geodetic Service.
1945	48	23	25	Throughout Canada; 600 declination observations by officers of Geodetic Service.
	8	8	-	Arctic, as part of an aerial magnetic-gravity survey.
1946	8	2	6	Arctic, in vicinity of North Magnetic Pole from steamship *Nascopie*.
	17	17		Northern Canada, during Exercise Muskox.
	550	550		Vertical force stations in Western Canada; 600 declination observations by officers of Geodetic Service.

Portaging magnetic party equipment, Perch Ripple, Ontario, 1929.

High and dry on the North Bluff Shoals, 1929.



Magnetic station, Diana Bay, Hudson Strait, 1928.



The *Nascopie* in James Bay, 1934.

active field seasons from 1934 until 1938. Field work was again very much reduced during the war years, partly because of the early retirement of French in 1940, partly because efforts were channelled into war-related work. The pace picked up immediately in 1945 with the staff additions noted on p. 135, and improved transportation.

Increasingly, from 1924, the programme aimed at determining secular variation through the re-occupation of earlier stations, including those established by the Carnegie Institution, the Meteorological Service of Canada and, in a few instances, the Topographical Survey. The programme of repeat stations seems to have been dictated to some extent by the International Association of Terrestrial Magnetism and Electricity; I have not found earlier reference to this but reports to this Association in 1936 and in 1939 make it clear that the Observatory was following, in addition to its own plans, recommendations of the Association.

As the field work became more remote from the magnetic observatories, particularly as it moved into the auroral zone and the vicinity of the north magnetic pole, the problem of determining the true magnetic values from the daily variations became more difficult and led to a change of observing procedures. Observations for inclination and total force continued to be averaged over the 12-hour period from 7 to 18 hours, Local Mean Time, but the declination was observed and averaged over a 24-hour period. The hope was to obtain not only an average that would screen out the short-period variations so prevalent in the Arctic, but to study the nature of these variations over as broad an area as possible.

Agincourt and Meanook had been very well run under the Meteorological Service and the publication of their observations was reasonably up to date. Data to the end of 1937 were supplied by Jackson in 1958.[158] From that time on, publication fell very seriously in arrears and it was not until 1962 that publication of the post-takeover observations began.[159] By 1970 observations for Meanook had been published to 1954, for Agincourt to 1949.

The instruments used in the field had to be re-calibrated at the beginning and end of the field season at Agincourt and also at the secondary base in Ottawa. By 1936 this base station was becoming too badly disturbed by the encroaching city to be useful and steps were instituted to establish a new base station at Long Island, near Manotick. This base, consisting of two non-magnetic huts, was completed in 1938 and the Ottawa base was abandoned.

Although the field programme was much reduced during the war years, Madill, working almost completely by himself, made a number of important contributions to the war effort. Early in the war the Ontario Hughes-Owens Company obtained a contract to manufacture magnetic compasses for both the Royal Navy and the Royal Canadian Navy. Madill made a detailed traverse of the proposed site of their magnetic testing laboratory and a LeCour Magnetometer was apparently lent to them for the duration of the war. Both the Canadian and British navies required more detailed magnetic information than was then available in Newfoundland and along the eastern coast of Labrador and a special field programme was mounted in 1941. Ten stations were occupied, apparently about half being repeats so that detailed information on secular variation could be supplied. During the same year detailed surveys - latitude, longitude and magnetic elements - were supplied for "two strategic harbours in Newfoundland."

Until 1932 the publication of magnetic charts was the responsibility of the Topographic Survey. By the start of the war this arrangement had changed. A chart of declination for 1940.0 was issued by Surveys and Engineering Branch.[160] Madill supplied "general magnetic data and lines of annual change in declination". By 1942.0 the responsibility was a Dominion Observatory one. In December, 1942,[161] Madill submitted to the Geodetic Survey a north polar isomagnetic chart for the epoch 1942.5; the letter of submission was accompanied by a two page memorandum of the sources available and of the methods used. The work involved must have been formidable. He even had to draw the chart himself. "Since all the work in connection with the drawing of the chart - as well as the preparation of the necessary data - has been done by myself, it lacks the finished touches of the draughtsman's art."

With the close of the war there was an increased demand for accurate magnetic charts of the Arctic. The first requirement was to determine the position of the north magnetic pole. The method for locating the magnetic pole has been very well stated by Madill: [162] "The only way to fix accurately the position of the magnetic pole is to compute first a position using data from stations not too distant. The declination data will establish the centre of convergence of the magnetic meridians, the inclination data will establish the point where the dip should be 90 degrees and the horizontal force data will establish its vanishing point. The next step is to surround the area indicated with magnetic stations which will further restrict the pole area. The mean pole point must then be found by an intensive ground survey in case the earth's magnetic field is deformed by the presence of certain geological formations."

The determination of the pole position and of its rate of migration took a number of years, and the story will be told in Volume II. However, much of the initial work of locating the pole was done during the last years of the Stewart administration. Serson, in 1945, observed at Coppermine and Cambridge Bay, which he reached by Canso aircraft, and at Fort Ross which he visited with the R.M.S. *Nascopie*. In 1946 Innes, as a member of Exercise Muskox, made observations at seventeen points along the traverse, which reached as far north as Denmark Bay. During the summer of 1946 observations were made at 14 additional points during the cruise of the *Nascopie*. When all these data were analyzed, they suggested that the pole was in northwestern Somerset Island or northeastern Prince of Wales Island.

At the same time Madill was endeavouring to expand the observations in the Arctic and to study the secular variation. He arranged with the Bureau of Geology and Topography that their officers, working in the Arctic, would measure declination wherever possible, according to set standards. With these observations, and those that had accumulated in the earlier programs of the Carnegie Institute, the Meteorological Service and the Observatory, Madill was able to produce[163] a listing of declinations for stations north of latitude 60°N., covering the period 1938-1947. In this paper he gives a re-location of the north magnetic pole at 73°N., 100°W. This location is based in part on the general declination data, in part on the field work which we have described. The pole position compares with that established by Amundsen in 1904: 70.5°N, 97°W.[164]

While the Observatory took no direct part in the Second International Polar Year (September 1, 1932 to September 1, 1933), it was very important for magnetic work in Canada. According to Andrew Thomson, [165] the Meanook Observatory, which was at that time the closest permanent magnetic observatory to the north magnetic pole, received "three sets of La Cour magnetographs for recording, in complete detail, the changes occurring in the earth's magnetic field." A party was set up at Chesterfield Inlet, about 450 miles from the north magnetic pole, for the study of a vast array of phenomona in meteorology and terrestrial physics. He mentions specifically the measurements of earth currents, solar radiation and atmospheric electric potential, but says nothing about magnetic measurements. The staff of the station consisted of Frank Davies, Balfour Currie, S. J. McVeigh and John Rea.

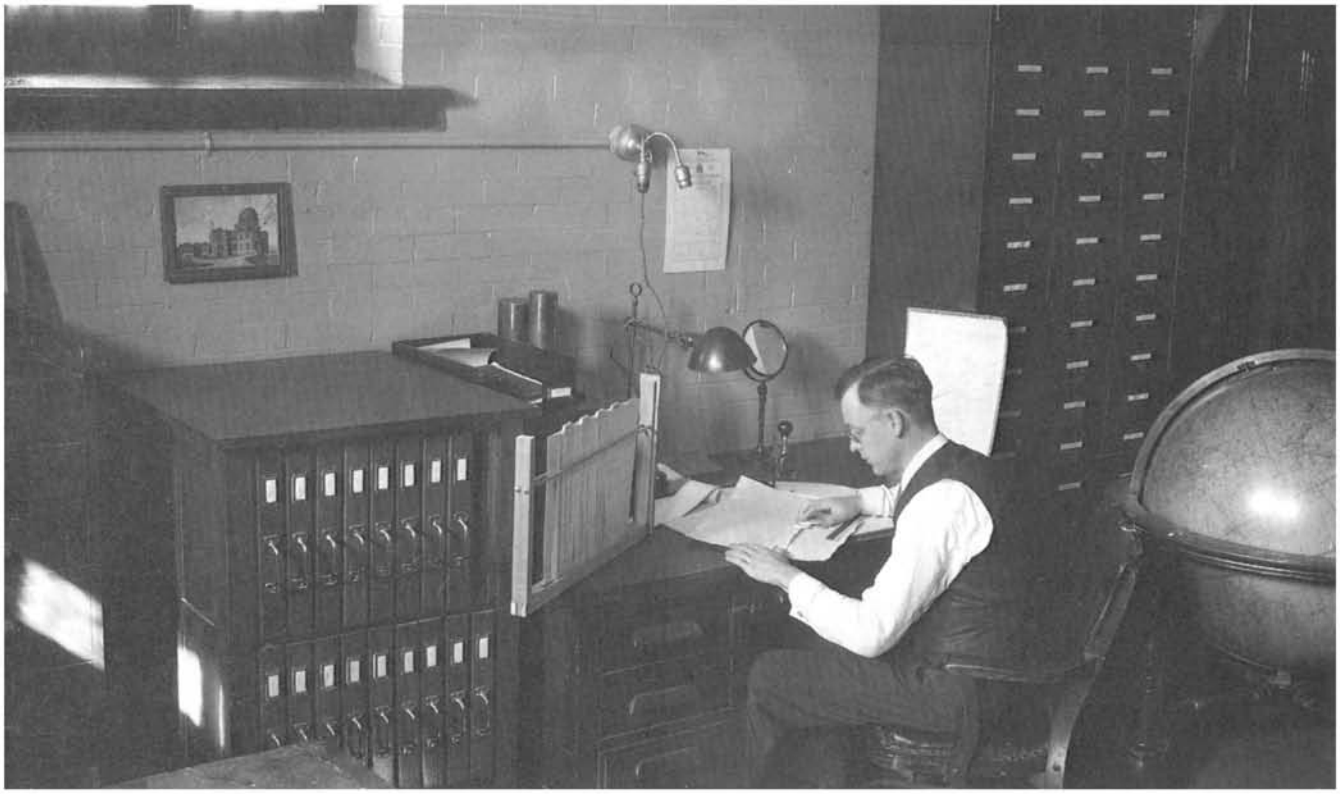
There was strong pressure from the Association of Terrestrial Magnetism and Electricity to have the station at Chesterfield Inlet maintained permanently, particularly as a magnetic observatory. The Director of the Meteorological Service supported this idea, pointing out that the station would provide improved data for the correction of magnetic observations in the Arctic. His superiors in the Marine Department were not able to support the idea and the station was closed, the magnetic instrument being part of those inherited by the Observatory in the re-organization of 1936.

Seismology

As we have already seen, E. A. Hodgson was named head of the seismology division in the reorganization that Stewart initiated on becoming Director. In addition to Hodgson the staff included W. W. Doxsee and the equipment consisted of the Bosch-Omori horizontal seismographs, the Wiechert vertical, and the Milne-Shaw horizontals purchased in 1922. The undagraph at Chebucto Head and the meteorological instruments in Ottawa were still in operation although there is no evidence that the data they produced were being used. In Halifax and in Saskatoon Mainka horizontals were operated by Dalhousie University and the University of Saskatchewan respectively.

On taking charge, Hodgson's first concern was to organize the office.[166] Operational files and technical material were partly in the Administration files, partly in the Divisional ones, but much of it was with Klotz' personal papers. There were no routines established for the maintenance of instruments or for the publication of data. Or at least, so Hodgson thought. I must say that my father was a slave of "system" and an office which seemed chaotic to him might well have been reasonably orderly. In any event he made a major effort to introduce systems to everything, and this occupied his first year as head. It was at this time that the filing of seismograms in heavy manila folders, carefully identifed, and the establishment of specially-built filing cases was instituted. A more important innovation was the development of a system of "earthquake data cards". These had ample room for a complete analysis of the seismograms for a single 'quake and this material was summarized in a standard way along the leading edge of the card. Tabs on the cards fitted into slots in a container in such a way that the edges of many cards could be read, and photographed, at once. At a glance, knowing the code, one could pick out the earthquakes that satisfied any particular interest - well developed surface waves, for example. It was "System" Hodgson's very clever anticipation of punched cards, and it attracted a good deal of attention. A set of the files was prepared for exhibition at the Prague meeting (1927) of the International Association of Seismology, and the method was demonstrated to the 1926 meetings of the American Geophysical Union and of the Eastern Section of the Seismological Socity of America.

As part of the reoganization it was decided to eliminate the "determinations of epicentre" series,



W.W. Doxsee with the files of earthquake data cards.

which had been running for so long. H. H. Turner was now supervising similar work at Oxford and the United States Coast and Geodetic Survey had announced a programme for the "preliminary" location of all large earthquakes; these efforts made the Observatory publications redundant and the series was ended at the close of 1927.

In the days before the epicentral programme of the United States Coast and Geodetic Survey an organization called Science Service played an important rôle in seismology. This organization, which published authoritative reports on current research for distribution to various newspapers and journals, collected telegraph reports on the larger earthquakes, and passed the assembled data to the U.S.C.G.S. and to the Jesuit Seismological Association. When these organizations had agreed on an epicentre the information about the earthquake was distributed, by telegraph, to its subscribers. From the beginning the Observatory cooperated in this programme, which flowed naturally into the ultimate U. S.C.G.S. one.

At about the same time a routine was set up to report all large earthquakes recorded at the Observatory to the local papers. Whether the Observatory had earlier been victimized by newspaper sensationalism or simply to guard against it, a severely constricted format was used: "The Dominion Observatory today recorded a - (moderate or large) earthquake. The first preliminary tremors arrived at -" and so on. The papers normally transcribed them verbatim.

Hodgson was asked to visit Harvard University in 1927 to recommend on the reorganization of its seismological station along the lines established in Ottawa. One of the results of this contact was that the young Harvard seismologist, L. Don Leet, did his doctoral thesis work at Ottawa, on the subject of surface waves; he used the "earthquake data cards" to select the appropriate seismograms. His thesis was published by the Observatory.[167]

At the close of 1925 Hodgson attended the meetings of the American Association for the Advancement of Science, in Kansas City. There he met two other Directors of the Seismological Society of America, Heck, of the U.S.C.G.S., and Macelwane of Saint Louis University. There had been considerable dissatisfaction with the management of the Society, dominated as it was by Californian seismologists, and when they realized that three Directors constituted a quorum, they convened a meeting of the Board and established an "Eastern Section of the Seismological Society of America." The new Section had to have a publications, but it had no money. It was agreed that Hodgson would edit a "Bibliographical Bulletin", and that this would be distributed, in mimeographed form, by the Dominion Observatory. This bulletin filled a very real need and seismologists in many countries collaborated by sending material to the Editor. In 1929 the Eastern Section realized that it could not support the work and the Observatory took over the responsibility, issuing the Bibliography of Seismology four times a year in dedicated volumes of the Publications. The Bulletin of the Seismological Society of America republished the mimeographed numbers.[168]

The Bibliography was continued under a succession of Editors until 1964, at which time it was taken over by the International Seismological Centre. Long before that time it had become something of an albatross around the neck of the Division but every attempt to dislodge it brought objections from the seismological community.

The years of the Stewart administration were exciting ones for the Seismology Division, not because of the generosity of the Department but rather of nature, which provided a splendid series of damaging earthquakes. The first of these occurred on February 28, 1925, (local time; March 1, G.M.T.) and was centred near La Malbaie on the Saint Lawrence River. We know that Klotz had been aware of the seismic potential of eastern Canada; he had read, and belittled, the accounts of the 1663 earthquake and had investigated at least three local shocks. However this knowledge seems to have been lost in the confusion of files already alluded to, and such a large earthquake was quite unexpected. However, the Seismological Division reacted competently. From the Milne-Shaw records they were able to measure not only an S-P, and hence a distance, but also an azimuth, and within a matter of hours had issued a statement to the press placing the epicentre as "probably near the mouth of the Saguenay River." Since other observatories were placing the epicentre "near New York City - probably in the direction of Washington," and "near the Great Lakes" this was quite an accomplishment.

Hodgson made a number of trips to the epicentral area and to more distant locations where damage had been reported. He circulated questionnaires to postmasters throughout eastern Canada and collected press clippings which gave some indication of intensities. The United States Coast and Geodetic Survey collected similar data in the United States and these were turned over to the Observatory. Original seismograms from 18 stations, in North America and Europe, were collected and analysed by Doxsee, along with data from bulletins, to provide an epicentre. As a result of all these studies Hodgson placed the epicentre in the Saint Lawrence River about mid-way between Rivière Ouelle and La

E.A. Hodgson during the investigation of the 1925 earthquake. Much important information was obtained from damaged tombstones.

A row of tombstones; most of the distant ones have been tipped over, the one in the middle distance has shifed horizontally on its base, while the vertical pillars on the stone in the foreground have rotated.

This stone, in the cemetery at Rivière Ouelle, was lifted vertically off its pins, indicating that it was in the immediate epicentral area.

Malbaie. Modern research has moved the epicentre only slightly, and has assigned it a magnitude of 7.0.

There were many aftershocks felt and as quickly as possible a Milne-Shaw seismograph was purchased, second-hand, from McGill University and installed in the basement of the Agriculture Station at Ste. Anne-de-la-Pocatière. It was maintained there for something less than two years. The cooperation of the Geodetic Survey was sought in re-levelling an earlier line between Levis and Rivière du Loup and the Hydrographic Survey provided an analysis of tide gauge records along the St. Lawrence. While the changes indicated by both studies were very small they did suggest the possibility of permanent movement in the vicinity of the epicentre.

Hodgson prepared a very complete report on all aspects of his investigation, including detailed descriptions of the nature and distribution of the damage. When the manuscript was submitted for publication, political pressure was brought to bear by Quebec members to stop this, since publicity about the earthquake might hamper industrial development. This pressure was successful; the paper was not published until it was resurrected by Dr. Beals when he took over Stewart's office in 1948![169] Fortunately a number of papers did appear in contemporary journals, so that the scientific community was aware of the work which had been done. These included a discussion of the effect of the earthquake on tombstones, some of which were rotated in very puzzling ways,[170] and a complete summary of all known data in the Bulletin of the Seismological Society of America.[171] Impressed by the potential for widespread earthquake damage due to the large areas of marine clays, which could flow like water under certain conditions, he published a paper "The Marine Clays of Eastern Canada and their Relation to Earthquake Hazards"[172] which was in such demand over the years that it was reissued in 1951 as a Contribution from the Dominion Observatory.

There had been considerable, though not serious, damage in Shawinigan Falls, and the Shawinigan Water and Power Company was concerned about possible seismic risks to its dams. They consulted Hodgson who said, quite properly, that the existing distribution of seismograph stations was quite inadequate to define this risk. The Company proposed to rectify this: they would pay for the purchase and installation of two stations, at points to be selected by Hodgson, if the Observatory would be responsible for their operation. The proposal was gratefully accepted and the stations, at Shawnigan Falls and at Seven Falls (near Beaupré) were in operation by late 1927. They were equipped with the latest, Wood-Anderson, short-period seismographs. These were probably the first short-period instruments in eastern North America. In addition the Milne-Shaw was moved from Ste. Anne-de-la-Pocatière to Seven Falls. Part of the arrangement with the Company was that monthly reports should be submitted listing the earthquakes recorded by the Quebec stations. These reports were continued for many years.

The next excitement was provided on the Grand Banks. On November 18, 1929 an earthquake occurred just beyond the continental shelf; modern research gives it a magnitude of 7.2. It caused a tsunami which struck the south shore of Newfoundland in the vicinity of Placentia Bay. Twenty-seven lives were lost and there was great property damage. In addition to the damage caused by the tsunami a large number of breaks were caused in transatlantic cables, of which there are very many in the vicinity. Since the cable companies were able to supply the exact times of the breaks, it was possible to show that these occurred sequentially. Many years later Ewing and Heezen were able to use these data to establish the existence of turbidity currents.

No field study was attempted, since questionnaires showed that there was little earthquake damage on land and since other agencies had surveyed the tsunami damage. The questionnaire survey was, once again, a joint effort of the Observatory and of the U.S.C.G.S. and showed a maximum Rossi-Forel intensity of 6 on land. Seismograms were collected from around the world, a total of 89, and Doxsee determined the epicentre to be at 44°.5 N., 55°.0 W.[173] Although he did not publish the data on first motion he recorded it in his notes and many years later I was able to attempt a fault-plane solution based on his observations. The data were inadequate to provide a definite solution but did suggest a fault in the general direction of the Cabot Strait.

Doxsee produced his report promptly, but alas it too suffered delay. Apparently it got lost in the considerable confusion of the Director's office until it too was discovered by Dr. Beals and sent to press some 18 years late!

As we have seen, the Observatory was aware of the importance of geophysics in the search for minerals, and Miller had been cooperating with the Geological Survey and others in investigating the importance of gravity and magnetic methods. The methods and equipment of earthquake seismology were not readily adaptable to exploration, but Hodgson made an effort to understand the new techniques. In 1930 he spent some time with a seismic party in the Turner Valley; in 1937 he visited an experimental seismic party being operated in Arkansas by his old colleague Leet; and in 1939 he studied the operations of a Western Petroleum Company seismograph crew operating near Lethbridge. Internal reports and some popular papers were prepared on these new methods.

Hodgson spent the academic seasons of 1930-1932 at Saint Louis University where he was awarded the PhD for a thesis on the Tango, Japan, earthquake of 1927.[174] His studies contributed much of the data used by Macelwane in producing his travel-time tables, forerunners of the "J-B Tables". Macelwane's lectures on "Geodynamics" were intended to be the basis of a textbook, very much overdue, to be published by Wileys. By the time Hodgson had straightened out his lecture notes he had essentially written Macelwane's book for him and he agreed to produce the manuscript and see it through the press. Macelwane was appreciative. "So great is the share of credit that is due to Doctor Hodgson for some parts of the work that it would be impossible, short of joint authorship, either fittingly to acknowledge the debt, or adequately to express the gratitude I owe to him." The book was published in 1936.[175]

During Hodgson's absence, the work of the Division was handled by Doxsee and Gold, but Gold was let go about a year after Hodgson's return and there was no replacement until 1938. A number of tasks developed during that period. The first was occasioned by the next major earthquake in eastern Canada, at Temiskaming, Quebec, on November 1, 1935. Modern research assigns a magnitude 6.2 to this earthquake. Hodgson investigated the earthquake in the field.[176] He also collected seismograms from around the world and, under his direction, the author analysed these records to locate the instrumental epicentre. The results were never published.

The method used in locating the epicentre was one, then in general use, due to Geiger. It consisted of selecting an epicentre and computing the distance Δ and the azimuth to each recording station; the epicentre, ψ, γ, was then perturbed by a finite amount, the distances and azimuths re-computed, and the differences used to approximate to $d\Delta/d\psi$ and $d\Delta/d\gamma$, quantities required in the Geiger method. Since the distances and azimuths had to be calculated using 9-place logarithms, a method that allowed perhaps four stations to be computed per day, it was a tedious business. At the suggestion of Mr. Stewart, I simply differentiated the formulae relating Δ, ψ and γ in spherical trigonometry and came up with instant formulae for the required quantities. A paper, my first, resulted.[177] It attracted a good deal of attention; how could such a simple matter have escaped so many smart men for so long?. Unfortunately the fame was short lived because other methods of locating epicentres were adopted at about that time.

The occurrence of the Temiskaming earthquake in an area not previously considered seismic pointed to the need for a more efficient seismological network and in 1937 a Benioff vertical seismograph was installed in Ottawa. This instrument operated both long- and short-period galvanometers from a single mass and so provided a replacement for the antiquated Weichert vertical and a high-magnification short-period instrument for the better recording of local earthquakes. At about the same time the reorganization described earlier occurred, in which the seismograph stations at Victoria and Toronto became part of the Observatory network. Initially the transfer was not of much benefit; the location of the Toronto instrument in the basement of a university residence was far from ideal and there was difficulty in getting the instruments attended to on a regular basis. The station at Toronto was closed in 1942; the instruments were removed to Ottawa for overhaul and were installed in Saskatoon in 1942 and 1945. The Bosch instruments were moved from Ottawa to Halifax in 1938. By 1939, new seismograph vaults had been constructed at the Dominion Astrophysical Observatory and some time in 1940 the instruments, two Milne-Shaws and a Wiechert vertical, were transferred there from the meteorological observatory at Gonzales Heights. K.O. Wright assumed responsibility for their operation.

These improvements in the Canadian network were accompanied by similar advances in the United States, particularly by the installation of numerous Benioff seismographs. This made possible the more efficient recording and location of local earthquakes, and in 1939 the North Eastern Seismological Association (NESA) was formed to provide cooperation in the study of the seismicity of the region. Data were collected by Weston College, epicentres were located, and regular bulletins were forwarded to Ottawa for mimeographing and distribution to the member stations.

At the request of Professor E.F. Burton, Hodgson gave a week-long course in seismology in the Physics Department at Toronto during the autumn of 1936. This was part of Burton's effort to broaden the scope of geophysics in Toronto, from the purely applied interests of Professor Lachlan Gilchrist. The next step was to arrange for the training of students by the Observatory, and in 1938 three graduate students spent several weeks in Ottawa, working in rotation in the three geophysical divisions. One of these students was M.J.S. Innes. After taking his master's degree in 1938 he joined the staff of the Seismological Division. Unfortunately the experiment in extracurricular training was not continued.

The selection of Hodgson to give the Toronto course was a natural one. He had a reputation for being able to present complex scientific matters in a very clear way; Klotz had commented on this many times in the diary. Because of this ability he was in considerable demand as speaker to scientific and engineering groups, and many of his more important papers originated in this way. One of these, "The Structure of the Earth as Revealed by Seismology"[178], was presented to the Engineering Institute of Canada and won him their Gzowski Medal. His publication list includes no fewer than twelve papers of this review type, aimed at lay audiences.

On December 27, 1938 a rockburst occurred in Lake Shore Mines, Kirkland Lake, which recorded on the Benioff seismograph at Ottawa. This event had a strong influence on the work of the Seismological Division for the next several years. Realizing that rockbursts were, in essence, local earthquakes constrained to lie in a very small area, Hodgson visited the mine to arrange for the establishment of a station, at the mine, to time the bursts at their source. This was quickly arranged, and at the company expense, but a much larger programme developed, aimed at finding a method of forecasting the bursts. It occupied Hodgson for the next six years.

During mining operations voids are created in the ore body and in the country rock and, no matter how carefully these are back-filled, the pressure on the remaining rock builds up. Weak rock simply crumbles under this pressure, but more competent rocks, such as those at Kirkland Lake, accept the pressure, which builds up until a breaking point is reached, releasing the energy in a sharp, violent burst. Since large sections of the mine could be destroyed in a burst, the economic cost was high, but the principal anxiety was for the safety of the miners. Could some way be found to forewarn of bursts so that the miners could be moved out of the danger area before the burst occured?

Hodgson spent somewhat more than half his time in Kirkland Lake between 1939 and 1945; the mine paid the salaries of two assistants and a clerk and provided all the instruments and equipment.

A number of different methods were attempted. A strain gauge was developed for insertion in a bore hole but proved difficult to operate in underground conditions. V.E. Hollinsworth, of the Observatory Time Service, who had designed a microgauge for the rapid testing of machined parts, adapted it to measure convergence in a bore hole. While it worked excellently in laboratory tests, power fluctuations and the excessive moisture and acidic conditions underground made it impractical. Attempts were made to measure the velocity of seismic waves in the mine rock, in the hope that increasing pressure would result in measurable velocity change. With the large volumes of void in the rock it was impossible to find direct lines of solid rock along which to measure velocity; the shortest seismic path might not be the direct one, and the results were of no value. Measurements were made of the frequencies of mine noises - mine cars, ore chute runs, blasting and bursts - and filters were designed to permit the optimum recording of bursts, even very small ones. This was done with a seismograph installed underground; a standard short-period instrument was in continuous operation on the surface for recording the times of the larger bursts.

Finally, in 1942, the programme concentrated on what were called microseismims, sub-audible snapping noises that could be picked up by crystal microphones placed in bore holes, and recorded on high speed recorders or heard with ear phones. It was found, and indeed had been found in other mines, that these increased in frequency with increasing pressure and that the increase accelerated rapidly as the bursting point approached. This would seem to have provided a direct means of forecast. Unfortunately it did not work in Lake Shore Mines where because of the geometry of the mine workings and the nature of the rock and its fractures, the pressure would shift rapidly from one part of the mine to another. The microseismim numbers would build up, indicating increasing pressure, and then would drop as the pressure moved to some other part of the mine. Short of providing listening posts, and listeners, throughout the entire mine, there was no way to keep track of the migration of pressure. There was another problem: because of the war the amount of ore being mined was drastically reduced; this reduced the pressure build up and the number of bursts. After many months of alternating encouragements and disappointments the programme was abandoned by mutual consent on October 31, 1945.

The rockburst research was described in a series of mimeographed reports which were re-issued, with some editing, in the Publications.[179].

The original purpose, to provide data for the study of crustal structure, was not lost sight of. The seismograph was operated at the mine throughout the entire programme and was moved to a new location in the immediate vicinity at the close of the programme. Thirteen rock bursts were recorded at Ottawa; two of these recorded at Shawinigan Falls and one at Weston, Massachusetts. These records were analysed by the author as a Master's Thesis at the University of Toronto and provided the first controlled crustal investigation in Canada.[180] On the basis of this work a more detailed programme was proposed and, as we shall see later, accepted.

Before the rockburst programme had been completed, nature provided another in the series of earthquakes in Eastern Canada, this time in the St. Lawrence River, between Cornwall, Ontario, and Messina, New York. The date was September 4, 1944 (local time; September 5 GMT) and the magnitude 5.7. Hodgson made a field study of the epicentral area,[181] sent out a questionnaire to collect data on intensity, and collected the original seismograms from North American stations, but was unable, because of his commitments in Kirkland Lake, to complete the research. This was eventually carried out by W.G. Milne,[182].

After the Cornwall earthquake, Hodgson published a most important paper "Industrial Earthquake Hazards in Eastern Canada" which summed up a lifetime of study of Canadian earthquakes.[183]

The next earthquake, on June 23, 1946 was located near Campbell River, British Columbia. It was of great importance, for it was the first major earthquake (magnitude 7) on Canada's west coast in many years, and it demonstrated the marked inadequacy of the seismic network. Steps were immediately taken to rectify this, but it was not until June, 1948, that a Benioff vertical seismograph was installed at Victoria.

Hodgson made a very thorough field investigation of the earthquake[184] and arranged for the collection of the seismograms, but again it remained for W.G. Milne to complete the analysis.[185]

The so-called "Seismic Survey in the Canadian Shield" had its beginning during the closing months of the Stewart Administration. J.H. Hodgson had proposed it in 1947, in the paper analysing the rockburst travel-times,[180] but this was before the days of NRC or NSERC grants, the Observatory had no money to support it, and funding of the programme seemed improbable. L.D. Leet, seismologist at Harvard, heard of this and proposed to his colleagues Francis Birch and M.P. Billings that a grant be sought from the Geological Society of America. Preliminary steps had been taken in this direction when the author's supervisor, J. Tuzo Wilson, stepped on to the scene. He had recently become the founding Chairman of the NRC Associate Committee on Geodesy and Geophysics, and he placed the matter on their agenda; the project was strongly endorsed. I was invited to attend the next meeting and to describe the project in detail. Again the committee gave strong support and Wilson went to senior officers of the Department of Mines and Resources, armed with this support. They declined to provide financing. Next, he approached officers of the NRC who, tentatively, agreed to support the project. Faced with the possibility of losing seismology to NRC, the Mines and Resources officials capitulated. This was one of the first of the innumerable services rendered to geophysics by Professor Wilson! The work itself was largely conducted after Stewart's retirement and will be treated in the next chapter.

LEARNED SOCIETIES

The situation with respect to professional societies in Canada changed somewhat during the Stewart years, but their dramatic growth came a little later. The Canadian Association of Physicists was established about 1945 and there were some other organizations, such as the Canadian Institute of Mining and Metallurgy for geophysicists and the Royal Astronomical Society of Canada for the Astronomers, in which Observatory staff could meet people of congenial interests. The Royal Society continued to be a major vehicle of scientific contact. A number of senior staff members attended its meetings regularly and the number elected to Fellowship grew steadily - Stewart in 1924, Pearce in 1931, Beals in 1933, Hodgson in 1936, DeLury in 1938, Petrie in 1940, McKellar in 1942 and Miller in 1947.

While the contacts provided by the Royal Society were important, it was necessary to go to the United States to meet people of like disciplines: for the Astronomers the American Astronomical Society and the Astronomical Society of the Pacific; for geophysicists the American Geophysical Union or the Seismological Society of America. Attendance at meetings of the American Association for the Advancement of Science was also common.

Klotz had been a member of the Seismological Society of America from its inception and was elected a Director in 1916. Hodgson was elected to the Board in 1926. He continued in that capacity for many years, being President for two terms, 1941-42 and 1942-43. In all that time he was never able to attend a meeting of the Society and in 1952 he was replaced on the board by the writer, who continued to be a Director until 1963. The change of Hodgsons was engineered by the Secretary, Perry Byerly, who felt that I might be more regular in attendance. My name was substituted on the ballot in place of my father's, and Byerly always said that I was elected because the members thought they were voting for the senior Hodgson!

While E.A. Hodgson was not able to attend meetings of the parent society, he was very active in the offspring which he had helped father, its Eastern Section. He ran through its offices early in its history, being Chairman in 1929, and he almost always attended its meetings. In 1935, and again in 1951, the Section met in Ottawa.

The American Association for the Advancement of Science met in Toronto in 1921 and in Ottawa in 1938. On both occasions the Royal Astronomical Society held joint meetings with Section D (Astronomy), of which Stewart was Chairman in 1938. At the same time, although retired, Plaskett was President of the Pacific Division of the Association, and he had held other offices throughout his career, including that of Chairman of Section D in 1928.

Going farther afield, the British Association for the Advancement of Science met in Toronto in 1924 and Plaskett was elected a Fellow of the Royal Society of London in 1923. He was not able to attend Society meetings and sign the register until 1925. We shall see more about this presently.

Klotz had been Chairman of the Canadian Committee for the International Astronomical Union, and his death made its reorganization necessary. This was done early in 1925. Plaskett was anxious that the Committee should not be overloaded with people from the Ottawa staff. At the time of the 1922 meeting the committee had passed over Plaskett to select his assistant, Young, along with Klotz, as delegate to the Rome meeting, and Plaskett attributed this to the "ancient though unjustified unfriendliness among your staff toward me".[186] Wright (personal communication) advises that from the start of the Stewart administration the Chairman and Secretary alternated between the Dominion Observatory and the Dominion Astrophysical Observatory, and that there were enough members from each organization to ensure a quorum wherever the meetings were held. Stewart and Plaskett, along with some non-government personnel, were named as delegates to the forthcoming meetings in Cambridge. Being named was one thing, getting to the meetings was another; apparently the minister objected to spending the money to send any delegate and Plaskett was desperate to go. A series of memoranda to Deputy Minister Cory of increasing urgency followed at monthly intervals. The urgency arose from the fact that "the distinction of F.R.S. given to me in 1923, entails the obligation of attendance in London, not later than the fourth meeting after election, to be formally admitted and to sign the roll and declaration of the Royal Society".[187] All was to no avail. Was it a question of choice between Stewart and himself? In a memorandum dated March 13, 1925 he faces this question, refers to it as "entirely a friendly rivalry and I would be the last to enter into invidious comparisons. You must know, for I have previously spoken to you on the matter, that I have a high admiration for Mr. Stewart's ability, and I have always spoken of him in the highest terms."

He continues. "Nevertheless, there is no getting beyond the fact that men of science the world over look upon me as the foremost astronomer of Canada and I believe will almost unanimously expect me to be an official representative of Canada at the Cambridge meeting. Incontestable evidence of this has been furnished by the most eminent scientific court, the Royal Society of England whose Fellowship is only conferred for outstanding eminence in science. Other distinctions at home and abroad (see attached copy) only serve to emphasize this estimate which can no longer hence be considered any matter of opinion either of Mr. Stewart or myself."

I have quoted this paragraph in full because it is typical of the sort of outpouring that developed when he was balked of his desires - as for example for a grander house or an enlarged office building or to keep the official automobile when all others were losing theirs. He was not a modest man although, to adapt Churchill's remark about Atlee, he had a lot to be immodest about.

By late March Cory was able to report success but he defended Stewart:[188] "I can assure you that from what I have seen of Mr. R. Meldrum Stewart, I feel confident that in the matter of ability he can hold his own with any engaged in his chosen sphere of activity. It may be that his diffident manner has prevented him from getting the advertising that has accrued to others, but I am proud indeed to have him at the head of our Observatory here."

Touché, Dr. Plaskett!

In the event, Stewart also attended the meetings, along with McLennan and Chant from the University of Toronto, and Henroteau who, as mentioned earlier, was able to attend as part of his European vacation.

Plaskett was grateful and said so, but he also expressed the hope that his per diem allowance would be generous.[189] "The special advantage of an adequate per diem allowance is that it enables a good impression to be made without haggling or worry over petty details and although I doubt whether I can equal such a past master as Dr. Klotz on the social side, I believe I can adequately meet the needs socially and am sure I can scientifically."

Indeed he did, and he was delighted with his reception.[190] Instead of being housed in one of the dormitories he was "entertained by the Vice Chancellor of the University of Cambridge, the highest officer of the University." At the final dinner at Trinity College he sat at the head table and "at a celebration of the 250th Anniversary of the Royal

Retirement party for R. Meldrum Stewart, August 14, 1946.

Observatory we had the high honour of being presented to the King and Queen."

The Union met at Leiden in 1928, with Plaskett, Chant and Professor Buchanan of Vancouver in attendance; in 1932 in Cambridge, Mass.; in 1935 in Paris when Stewart, Plaskett and Chant attended and in Stockholm in 1938 with Plaskett, Harper, Chant and Professor and Mrs. Hogg being the Canadian representatives. No meetings were held during the war and in 1947 a letter[191] reminded Canada that dues to the Union had not been paid between 1941 and 1947 and that the amount due was $2,058.

It was also necessary to reorganize the National Committee for the International Union of Geodesy and Geophysics. Deville had been Chairman of the committee and had represented Canada at the 1922 meetings in Rome, but he died in 1924. A reorganization meeting was held in 1926, Noel Ogilvie, Superintendent of the Geodetic Survey, was elected Chairman, Hodgson Secretary. Sections were set up paralleling the Associations making up the Union; French was Convenor of that on Terrestrial Magnetism and Electricity, Hodgson of Seismology. The committee was fairly large but normally only Ottawa members attended the meetings. These were very infrequent and were usually held before the meetings of the Union to name delegates. As Chairman, Ogilvie always headed the list and was invariably the only government-sponsored delegate. In 1926 Stewart made a strong recommendation that Hodgson be sent to the 1927 meetings in Prague. The request was refused, with the promise that he would probably be able to go to the next meeting. When that time came, in connection with the Stockholm meetings in 1930, Hodgson's application was again refused. The various section convenors had to content themselves with sending reports to the meetings, while Ogilvie, made the triennial processions to Europe.

In 1939 the meetings were to be held in Washington on September 4-15. Stewart recommended that six delegates be sent from the Observatory - himself, Hodgson, Miller, French, Jackson and Madill. Approval was granted for four of these to attend. I do not have a record of who was selected, but in a group photograph of the meeting I recognize Stewart, Hodgson, Miller and Madill. The meetings were much reduced in scope because of the war, which began while some of the delegates were at sea, en route to the meetings.

Like the IAU, the IUGG held no further meetings until after the war.

When, shortly after the war, the National Research Council Associate Committee on Geodesy and Geophysics was established under the Chairmanship of J.T. Wilson, the existing National Committee for the IUGG was absorbed into it, Noel Ogilvie being named Honorary Chairman, and the various Section Chairmen being named to the NRC committee. Since most of them were already members, this was only a formality.

One more association should be mentioned. In 1932 the Fifth Pacific Science Congress was held, in Victoria and Vancouver, under the auspices of the National Research Council. The meetings were very successful. Dr. H.M. Tory acted as President of the Congress and he was supported by a large team, of which most senior members of the Observatory staff were members. Two of these acted as Committee Chairman, Plaskett for Astronomy and Hodgson for Seismology and Volcanology.

It is gratifying to report that Hodgson finally got sent to a meeting beyond the limits of eastern Canada and the United States. He was a delegate to the 1949 meetings of the Pacific Science Congress in New Zealand.

CLOSING COMMENTS ON THE STEWART ADMINISTRATION

Meldrum Stewart retired on August 15, 1946, after 44 years' service, 22 of them as Director. He was 67. Thomson tells us[192] that he "had agreed to remain at this post two years beyond the normal age of retirement, and for patriotic reasons had declined even to take time off for annual leave". Delury served as Acting Director until late November, when he too retired.

What can we say of Stewart, as a scientist and as Director? His scientific contribution was important. It was he who planned and developed the Positional Astronomy division, and the excellence of its work over the years is a tribute to its founder. He had broad scientific interests and a great facility in mathematics and was always available to assist his staff.

As Director he had to contend with Government constraints throughout his term of office, saw his budgets reduced to unworkable levels, his staff denied advancement and, even over his most determined opposition, some of his bright junior staff sacrificed on the altar of political expediency.

Other Directors were facing the same problems; were their organizations reduced to the same level, and was their staff morale equally depressed? The Dominion Astrophysics Observatory lived through the same difficulties, but the staff maintained their interest and their output. It may be argued that they had, in the 72-inch telescope, a world-class instrument which permitted them to do world-class work, but I don't think that this is the whole reason. Stewart was not an inspiring leader.

Whatever the cause, the correction was placed in the hands of a Victoria astrophysicist, Dr. C.S. Beals. He became Director in 1947, Dr. E.A. Hodgson Assistant Director, and a new era had begun.

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Cover

"The Heavens Above and the Earth Beneath" which is appropriate to the multiple mandate of the Dominion Observatories, is taken from the Second Commandment, Exodus 20, 4.

CORRECTIONS AND ADDITIONS TO PART 1

Page ii – The Title "The Heavens Above and the Earth Beneath" is taken from the Second Commandment, not the First. The reference to Exodus 20, 4 is correct.

Page 1 – Fifth paragraph. Mr. DeLaunais' name is Richard, not Charles.

Page 8 – LH Column, Line 1. The underlined section should read:

He resisted suggestions that he should move to Ottawa. "My family is better off here and enjoys comforts that in a city are denied with the same income. My income in Ottawa will be necessarily less, for here many an odd dollar I earn beside my Government pay"12.

Page 59 – Right column, fourth paragraph. The dam across the Chaudiere Falls was built in 1908, not 1900.

Page 146 – Top photograph. K.O. Wright has identified the man with McKellar as Tom Hutcheson.

Page 163 – M.M. Thomson has made some additional identifications: 2 C.R. Westland; 12 J.E.R. Ross; 13 F.J. Dunn; 16 "Chris" Christensen; 19 Bill Hughson(?).

Back Cover – When this photograph was published the unidentified figure, third from the left in the front row, was thought to be R.K. Young. Dr. Peter Millman pointed out to me that the blackboard carries a number of Chinese characters. Klotz reports that a Dr. H.E. Johns, an Englishman working at "Union College, China", spent several weeks at the Observatory in 1918. The unidentified figure is probably Johns, and the occasion a seminar in which he spoke of his work in China.

THE SCIENTIFIC STAFF OF THE DOMINION OBSERVATORY, c.a. 1915

Front:

W.E. Harper, D.B. Nugent (R.K. Young?), R.M. Motherwell

Back:

E.A. Hodgson, J.B. Cannon, R.J. McDiarmid, C.A. French, R.E. Delury