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THE DOMINION OBSERVATORY SEISMIC STATION AT RESOLUTE BAY, NORTHWEST TERRITORIES

BY

PETER C. BREMNER

EDMOND CLOUTIER, C.M.G., O.A., D.S.P.
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ABSTRACT

The Dominion Observatory has installed a seismograph station at Resolute Bay, Cornwallis Island, latitude 74°41'N., longitude 94°54'W. The need for such a station in the Canadian Arctic has been recognized for many years. The establishment of a joint weather station at Resolute Bay offered an opportunity for the installation. A preliminary survey of the terrain indicated that the only outcrop of bedrock was situated at a distance of 1,400 feet from the settlement. At a conference held in Ottawa it was decided that electromagnetic instruments should be used, the detectors to be on the rock outcrop, the recording unit close to the weather station. Field tests carried out at Ottawa throughout a winter season demonstrated the feasibility of this plan.

The station was installed during the summer of 1950. The seismometers were placed on concrete piers and enclosed in a heated, insulated shelter that was subsequently buried with gravel to provide an effective vault. The recording unit was housed in a double-walled, prefabricated building expecially designed for the purpose. Principal source of heat is an oil-fired space heater, but close control is made possible by the additional use of thermostats and electric heaters.

The station is equipped with Sprengnether long-period horizontal seismometers and a Sprengnether short-period vertical instrument. Records are read daily and the data are sent through Ottawa to the United States Coast and Geodetic Survey for use in epicentral determinations.

The paper outlines research investigations undertaken during the first year's operation. The first, a study of near earthquakes, shows that the eastern Arctic islands do not have frequent tremors. The second investigation attempts to associate spurious seismic disturbances with the movement of sea ice by making a careful study of the tide. A third undertaking was the successful operation of a short-period vertical seismometer on a base consisting of steel pipes driven into the frozen ground. It was established that this frozen medium could be used for transmitting seismic radiation to the detector if bedrock was not available. Finally, the occurrence of microseismic storms is discussed in relation to atmospheric disturbances.

INTRODUCTION

Up to the present a major blank space in the world network of seismic stations has been the vast Arctic regions of Canada, where transportation is difficult and where the maintenance of an isolated scientific station is prohibitively expensive. The need for such a station has been recognized by seismologists for many years, both for the study of the seismicity of the Arctic and to make possible more precise epicentral determinations of major earthquakes throughout the world. Several possible sites had been considered in the past, including Aklavik at the mouth of the Mackenzie River and Churchill at Hudson Bay, which is the terminus of a railway line. It was clear, however, from a study of Canadian geography that a location on one of the Arctic islands would be more desirable. By a fortunate chance the establishment of a major meteorological station at Resolute Bay on Cornwallis Island made available many necessary maintenance services on a co-operative basis, and the decision was accordingly made to investigate the possibility of setting up a seismic observatory near the weather station.

PRELIMINARY PREPARATION

Reconnaissance at Resolute Bay

As a first step in the project the writer travelled to Resolute Bay in the summer of 1948 to study the problems of constructing and servicing a seismic station in the Arctic. Particular attention was given to the availability of rock outcrops, to the types of buildings required to house the instruments, and to transport and maintenance problems likely to be encountered. A rock outcrop was found 1,400 feet south of the weather station. Under ordinary circumstances this would have provided a satisfactory location for the station. However, two difficulties were visualized by station personnel: first, the distance was so long that serious voltage drop would occur in the power line; second, it might be impossible to travel even so short a distance during stormy weather, which sometimes lasts for several days.

A second idea suggested itself. The ground at Resolute Bay is permanently frozen, thawing out only to a depth of about 18 inches during the summer months. This *permafrost* can be used as a satisfactory foundation for heavy equipment, provided that the level of the frozen layer is preserved. For example, the diesel generators which supply power to the station are mounted on timber cribbing extending well down into the frozen ground. This type of construction seemed to offer a possible means of obtaining a stable foundation, at least for the recorder and galvanometers, although it was doubtful that such a foundation would be satisfactory for the seismometers.

It was, therefore, recommended that the seismometers be installed on the rock outcrop, and the recording unit in a separate building close to the weather station.

Advisory Conference at Ottawa

A meeting of the Seismic Subcommittee of the Associate Committee on Geophysics of the National Research Council was held in Ottawa on April 29, 1949, to discuss the writer's report and to make specific recommendations for implementing it. In addition to the regular members of the subcommittee, Dr. Beno Gutenberg of the California Institute of Technology, Dr. Frank Press of Columbia University and Dr. E. C. Bullard of the University of Toronto were present and gave valuable assistance. It was agreed that, as suggested in the preliminary report, the seismometers should be placed on the rock outcrop and that a separate building should house the recording unit. No serious difficulties were anticipated with this arrangement although it was agreed that field tests might well be run to reveal any unforeseen complications.

The Committee considered that formation of frost in the hinges of the seismometers might lead to serious reduction in sensitivity unless the seismometer shelter were heated. If this could not be done it was suggested that some means be found to remove all moisture from the air inside the instrument cases.

Although specific instruments were not recommended, it was recognized that they would have to be fairly light because of transportation problems. As the difficulties of the installation were largely unknown it was also recommended that galvanometers of several different periods be made available.

ASSEMBLY AND TESTING OF EQUIPMENT

Following the recommendation of the Associate Committee, Sprengnether seismometers were selected because of their light weight and simplicity of operation. Orders were placed early in the autumn of 1949 and the instruments were available in time for the winter tests.

No outcrop of rock was available for these tests. A substitute was provided by a slab of concrete, 6 feet square and 1 foot deep, laid down for the purpose. The Committee had recommended that the seismometers be housed in air-tight cases. These were constructed of 16-gauge aluminium sheeting and were 20 inches wide, 18 inches high, and 28 inches long. The base of the case was made of $\frac{1}{4}$-inch steel plate and it was intended that this should be cemented directly to the rock; for purposes of the winter tests it was imbedded in the concrete slab at the time the cement was poured. The top was clamped to the base against a felt gasket, making the case moisture proof. There was a plexiglass window in the top to allow inspection of the seismometer, and an air-tight gland permitted the entry of an electrical cable. After the instruments had been installed in these special cases a simple shelter was used to protect them from the weather.

The recorder and galvanometer were housed in one of the prefabricated huts used in the seismic survey[1], and were set up on steel tables mounted on timbers set into the ground.

To connect the seismometers to the galvanometers a 1,600-foot, two-conductor cable was made up using No. 14 copper stranded wire with $\frac{1}{16}$-inch rubber insulation. The insulated wires were enclosed in a lead sheath, protected with double steel tape armour and covered with jute overall. This cable was strung along the ground, to reproduce, as much as possible, conditions to be expected at Resolute Bay.

Two instruments were used in the tests. The first was a Sprengnether short-period Series DH vertical seismometer, with the coil rewound to 700 ohms, coupled to a Micro Moll galvanometer with a period of 0·3 second. The other was a Sprengnether Series H long-period horizontal, which was tested with three different galvanometers with periods varying from 6 to 22 seconds. Since only a single cable was available at the time of the tests these various combinations were tested one after the other.

Test records were run in temperatures as low as minus 15 degrees Fahrenheit accompanied with strong winds. The short-period instrument operated quite well, but the long-period system produced a confused trace and was subject to the tilting of the concrete pier and temperature fluctuations. When the boom of the long-period seismometer was clamped in its rest position, however, a straight line trace was recorded indicating that there were no spurious currents being induced in the long connecting cables, and, further, that the galvanometers were not subject to temperature drift in the heat-controlled prefabricated building. As a result of the winter test, the concept of remote recording was considered feasible, and it was thought that the solid bedrock and a more sturdy instrument shelter would make it possible to operate the long-period seismometers, at one of the three frequencies provided by the galvanometers available. In the event that the above systems proved unsatisfactory, and also to provide instruments for other studies, two Sprengnether Series DH short-period horizontal seismometers and a Willmore seismometer

[1] Hodgson, J. H.: A Seismic Survey in the Canadian Shield, Publications of the Dominion Observatory, in preparation.

were included with the equipment. A Sprengnether three-component microseismic recorder, a chronometer, and a short wave radio receiver completed the instrumentation. Plans for a double-shell prefabricated recording building and for an instrument shelter were drawn up and orders placed for their construction. All this equipment was carefully packed for shipment and was flown to Resolute Bay by the Royal Canadian Air Force, Air Transport Command.

INSTALLATION OF THE STATION

On July 4, 1950, the writer, accompanied by Mr. R. E. Andrews, a summer assistant at the Dominion Observatory, arrived at Resolute Bay to begin construction. By this time most of the snow had melted and the ground could be worked without too much difficulty. Two buildings had to be constructed, first the shelter for the seismometers, and then the hut to contain the recording instruments.

The Seismometer Shelter

The seismometer shelter was located on the rock outcrop already mentioned. The outcrop is limestone, badly weathered, and dipping south at an angle of 10 to 15 degrees. The exposed surface is 100 feet long and 75 feet wide, and a small river 10 feet wide and 10 inches deep runs across the centre. In the early spring the river floods for a period of 2 to 3 weeks, at which time the water rises some 12 inches above the normal level. In order that the seismometers would not be under water each spring, an excavation was made 12 feet from the river bank. After removing frozen soil (a mixture of gravel and clay saturated with ice lenses) from a pit 4 feet deep, 10 feet wide, and 18 feet long, a suitable surface of rock was exposed. As the frozen ground about the excavation began to thaw, water collected on the newly exposed surface. A drainage ditch was dug along the dip of the outcrop through the soil barrier between the river and the site. A drain pipe was then made from heavy planks to permit the water to run off the outcrop to the river. Timbers 6 feet in length were bolted together and levelled to make a foundation for the instrument building. There is a large trapdoor in the top of the corridor and a stairway leading down. The shelter was set on the beam foundation and held together with lag screws.

In order to prevent water from being trapped around the beam foundation and causing heaving when it freezes, large stones were piled around the base of the building. These stones were first covered with boards and then with several feet of washed gravel. A box conduit was left to bring in the cables and the shelter was banked with gravel until the roof was level with the ground, the trapdoor previously mentioned providing entrance into the vault. A gentle grade was extended from the roof of the building out to the original ground level.

The gravel fill about this building will serve two purposes. First, it will prevent winds from shaking the shelter and consequently disturbing the seismometers. It will also provide a natural water run-off, for, although the structure is situated at the bottom of a long grade, the gravel bank around the shelter is higher than the surrounding contours. It is hoped that the frozen layer will rise under this new gravel fill making a higher contour and thus forcing the water from melting snow to flow around the vault.

FIGURE 1—Excavation through permafrost to expose bedrock for seismometer shelter.

FIGURE 2—Drain for carrying away the water from the disturbed permafrost. The large stones prevent gravel from blocking the passage of water.

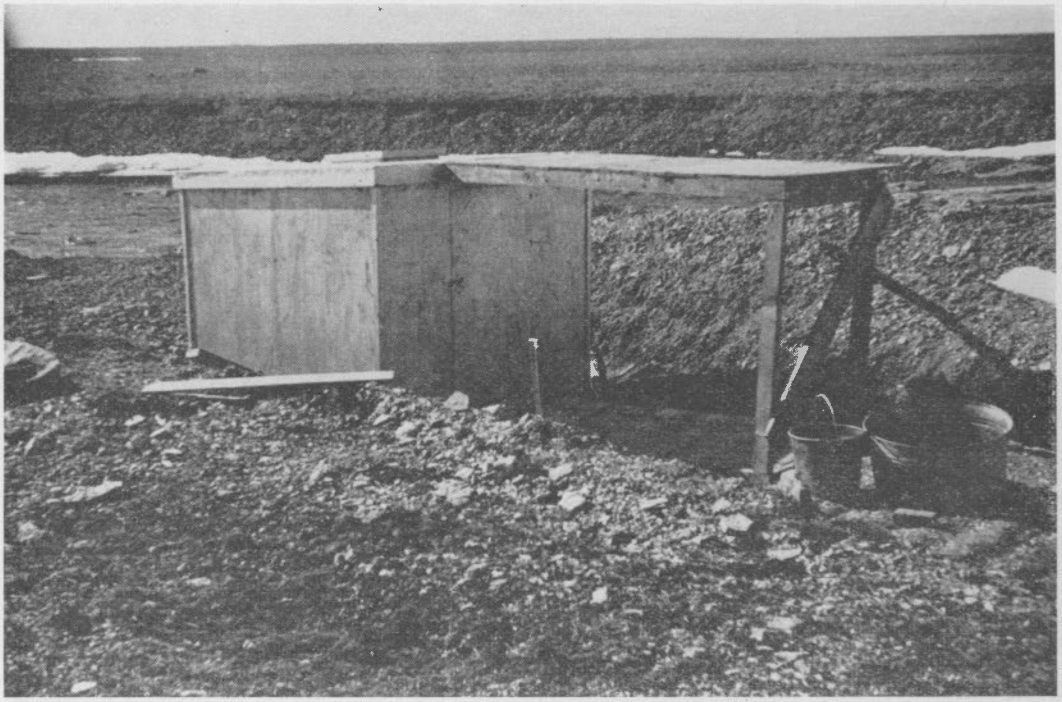

FIGURE 3—The seismometer shelter during construction. Stairs were later constructed in the section at the right to permit entrance to the vault.

FIGURE 4—The seismometer shelter buried with gravel. The trapdoor leads to the stairway mentioned in the caption of FIGURE 3.

The Recorder Hut

Attention was now directed towards the main recording building which was to be located some 175 feet southeast of the electrical power house to minimize the drop in line voltage. The outer shell of this structure was 16 feet square and had a 4-inch wall covered outside with 1-inch weather-proof plywood and backed with 2 inches of rock wool insulation held in place by insulboard. The inner shell was 8 feet square and also had a 4-inch wall made of insulboard lined with rock wool.

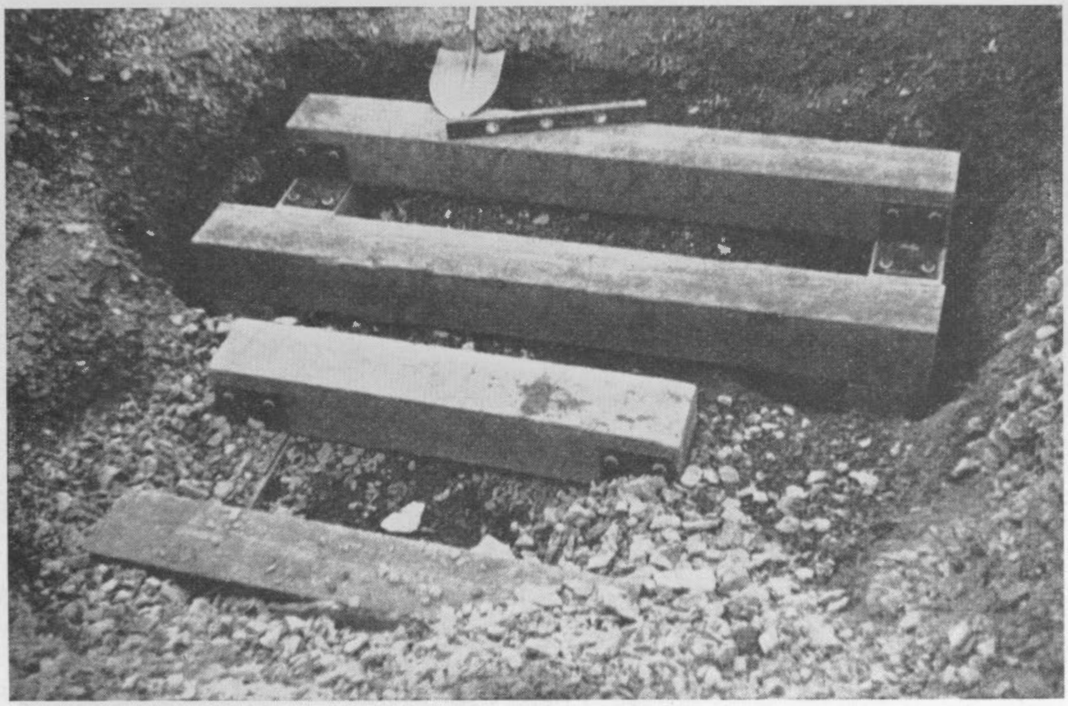

FIGURE 5—Timber cribbing, set in permafrost, to provide foundations for recording tables.

There were two important considerations connected with this part of the project: first, because of strong winds, it was desirable to have rigid foundations, separate from the building itself, for the galvanometer and recorder tables; second, the observatory must be placed on a foundation that would not be affected by frost heaving. These two objectives were achieved by setting the tables on heavy timber cribs set in the frozen ground, and by placing the building on a foundation of washed gravel, 3 feet high, that contained no clay or other materials subject to frost action. The legs of the tables pass through holes built into the floor panels. Insulboard was used to line these holes, which were then filled with rock wool insulation. The beams for the building were levelled, and the structure was assembled without any serious difficulties. A small oil stove was installed in the outer passage to assist the electric heater that controlled the temperature in the inner vault. Finally, a 4-foot gravel bank was shovelled against the outside walls to reduce the effects of wind.

Both buildings being completed, the connecting cables were now laid. The distance from the instrument shelter to the position finally selected for the recording observatory was 1,000 feet. A trench for the cables was made using a road grader with the blade

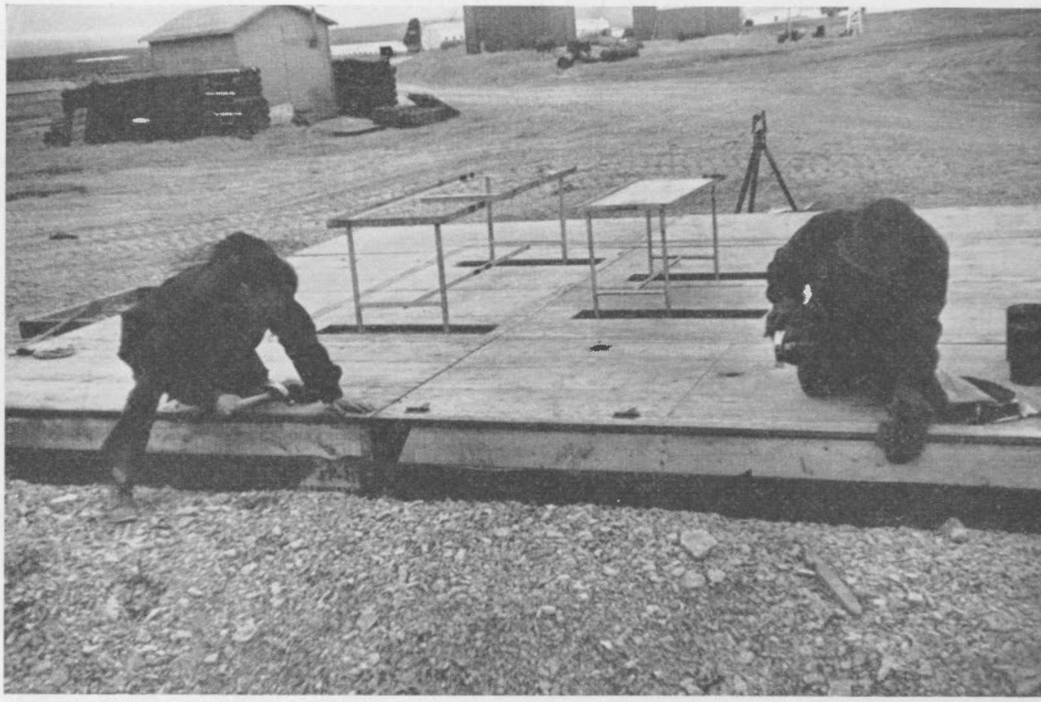

FIGURE 6—The floor of the recording building. Steel tables for the recorder and the galvanometers are shown in place. The legs of these tables are separate from the floor, and rest on the cribbing shown in FIGURE 5.

FIGURE 7—The recorder building under construction. The inside recording room has been completed and the outer protecting building is being erected.

tilted, but in many places further digging had to be done with pick and shovel. The reels of cable, 4 feet in diameter and weighing 1,600 pounds, were mounted two at a time on a sled. Two stands were made, using three sets of timbers, and a steel bar was run through the centres of the reels so that they were free to turn. The sled was pulled by a tractor and the cable laid out along the trench. In all, seven cables were laid, five seismometer connecting cables, one power line made from the ends of the seismometer cables, and one telephone line. The ends of the seismometer lines were spliced into special moisture-proof marine terminal boxes fitted with sealing glands and containing the electrical leads to the seismometers and galvanometers respectively. The trench was refilled and clearly marked with stakes to warn heavy traffic of its presence, and to assist the operator in locating the vault in the dark.

A 220-volt line was buried underground from the power house to the observatory and to the instrument shelter. It was hoped that it would not be necessary to heat the seismometer shelter but it seemed advisable to lay the power cable while the trench was open. Both structures were wired for lights and electrical outlets.

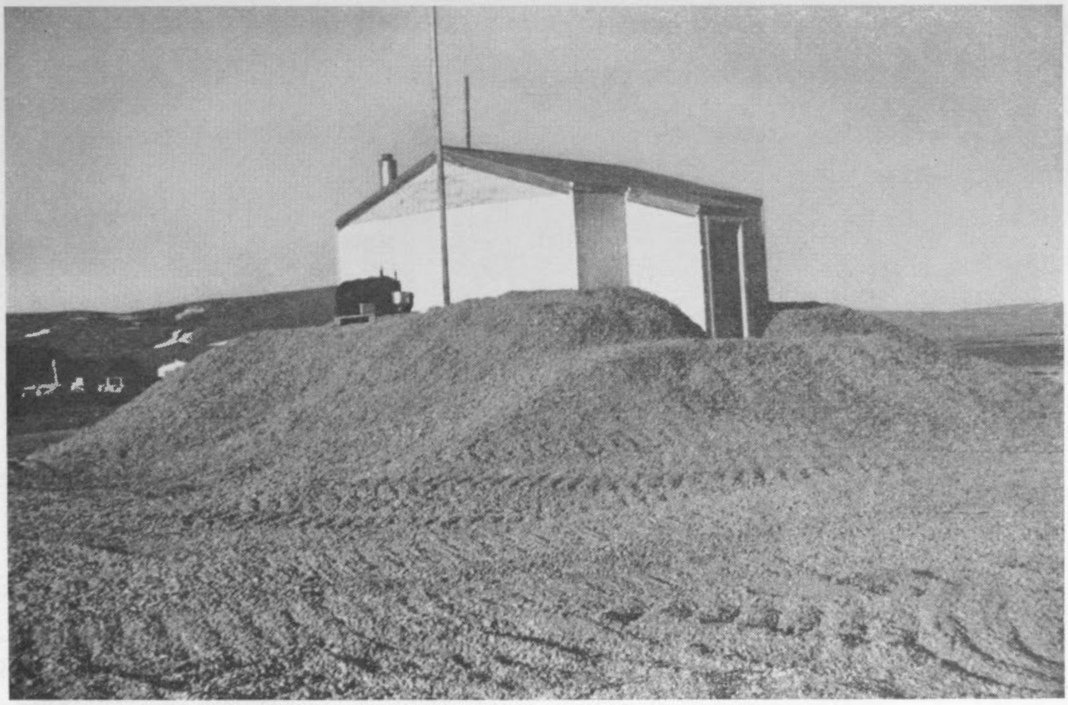

FIGURE 8—Recorder building completed. Note the oil reservoir and chimney of the oil-fired space heater.

INSTALLATION OF INSTRUMENTS

The heavy construction being completed, the installation of the seismometers and recording apparatus was begun. The short-period seismometer was set up on the bedrock and adjusted to a period of 1 second. It was connected by means of the buried cable to the Micro Moll galvanometer having a period of 0·3 second. The long-period seismometers were set up at 90 degrees to each other to record the north-south and east-west horizontal components of any earthquake that might be detected. Both were adjusted to have periods of 15 seconds and connected to galvanometers with the same periods. The trace obtained was confused by galvanometer wandering and after several days the pendulums of the seismometers had either moved considerably away from their centred positions, or were resting against the pendulum clamp. The records indicated that better temperature control and a more solid foundation for the seismometers were required.

The nature of the bedrock presented a problem in itself. The rock surface was saturated with water and badly broken; when a heavy weight was placed on the surface, small rivers of water oozed from the many fractures, outlining thin flakes of rock varying in size from pieces as small as a penny up to slabs a foot or two square. This flaky surface was stripped off, but the underlying material was in the same condition. It seemed probable that each leg of the seismometer was resting on a different island of rock. The small effect contributed by these flakes was almost entirely eliminated by pouring a concrete pier 2 feet wide, 3 feet long, and 1 foot deep for each horizontal seismometer.

Better temperature control was obtained in the instrument vault by insulating the walls with 4 inches of rock wool and lining the inside with masonite. Two 500-watt strip heaters and a thermostat set at 50° Fahrenheit were connected in series across the 220-volt line. Temperature control was further improved by insulating the instrument

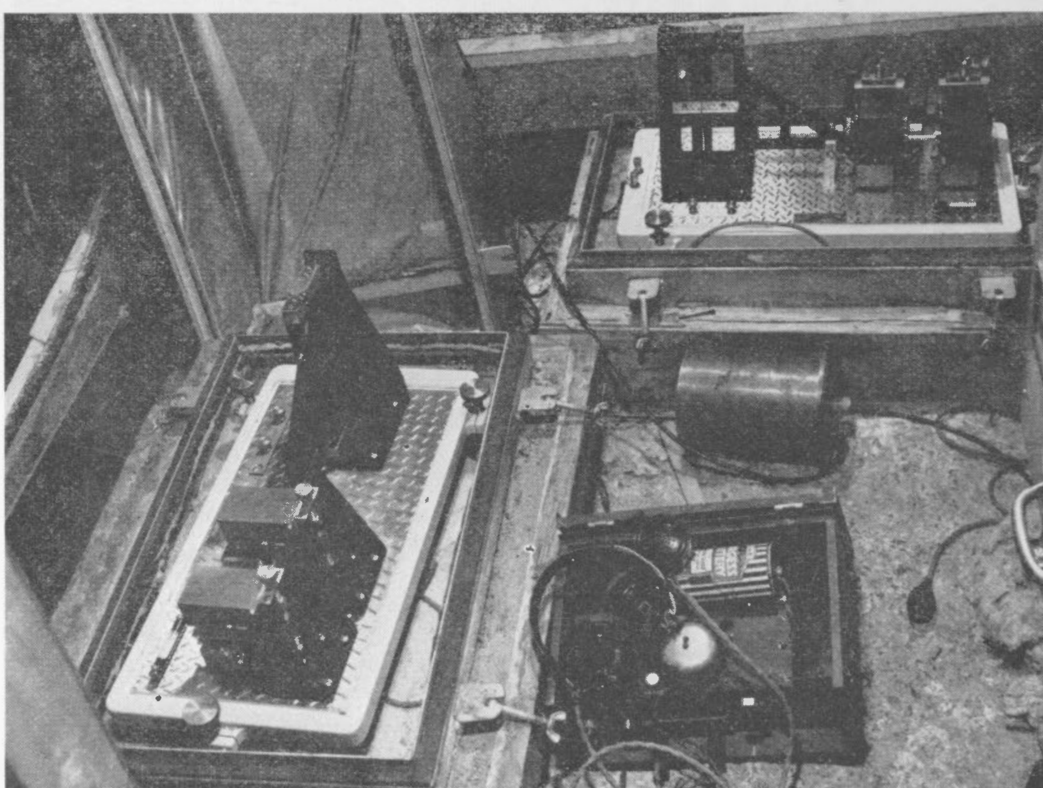

FIGURE 9—Interior of the instrument shelter. The long-period horizontal seismometers are mounted on their individual piers, the Willmore seismometer rests directly on the bedrock. The telephone for communicating with the recording building is shown in the foreground. Note the seismometer case insulated with fibreglass.

cases. The bottom was cut out of the steel base plate, and the sides were cemented into the pier. The insulated top was clamped down over the seismometer. The records obtained after the addition of temperature control and the piers were entirely different from those preceding. There was no sign of galvanometer wandering, and during two weeks the seismometer pendulums had drifted only slightly from their central position.

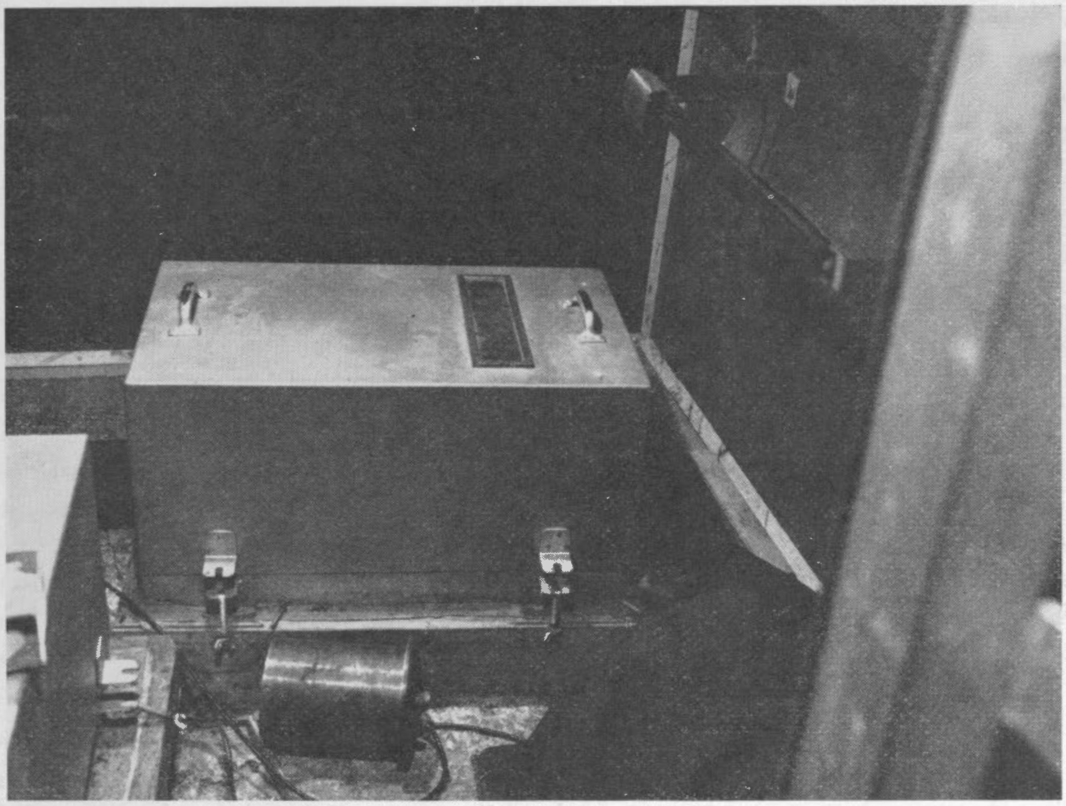

FIGURE 10—Interior of instrument shelter with insulated cases in place. Note the reflecting heater on the wall.

The instrumentation of the station was varied from time to time throughout the course of the first winter's operation. The long-period horizontals were tested with galvanometers of 6-second and 22-second periods, and the Willmore seismometer and 1·4-second Sprengnether vertical system were used at various times. The purpose of these variations was to determine the best recording system, but care was taken to keep the station in operation at all times so that its routine functions could be maintained. The 1·8-second Sprengnether horizontals were never used, as the long-period instruments proved satisfactory.

The geographical position of the instruments was accurately determined by the Topographical Survey of Canada. The co-ordinates of the bedrock on which the seismometers are set up are given as latitude 74°41′N, longitude 94°54′W. The elevation of the detectors is about 5 metres above mean sea-leavel.

THE ROUTINE OPERATION OF THE STATION

On August 29, 1950, with the completion of the installation, the first step was taken towards making Resolute Bay a first-class station for recording teleseismic disturbances. After a brief testing period, arrival times for P, S, and other clear phases were being sent to Ottawa and the United States Coast and Geodetic Survey in the form of a self-checking message. Where possible the P-phases are also classified as compressional or dilatational. Upon receipt of the Coast Survey epicentral cards the records are re-read and a bulletin prepared; the records are then sent to Ottawa for storage.

The location of the station provides an opportunity for the study of problems peculiar to that area, as for example, the seismicity and microseismic activity of the eastern Arctic islands, possible disturbances due to ice movement, and the operation of seismometers on permafrost. These topics will be dealt with in a later section in which the special investigations undertaken at the Resolute Bay Observatory are described.

As yet, there have been no difficulties with equipment which are peculiar to Arctic conditions. Once good temperature control had been established and the problems posed by the fractured bedrock had been overcome, no serious operation problems remained.

The radio time signal from WWV is used for rating the chronometer. This signal is particularly valuable as it is transmitted over a wide range of short wave frequencies, one of which can nearly always be detected with sufficient signal strength to trigger the timing relay. The signal received when the four hundred cycle note returns to indicate the beginning of a specified 5-minute period, is amplified to operate a relay in the plate circuit of the amplifying stage. This relay is in series with the lamp relays of the recorder. Consequently, both the chronometer minute marks and the WWV reference dashes are indicated consecutively on the seismogram.

Part of the error incurred when calculating arrival times arises because of variation in the cycle of the electrical power furnished to the observatory. As the recording drum is driven by a synchronous motor, the cycle of the power supply determines the rate of rotation of the drum, which in turn regulates the distance between chronometer minute marks. At Resolute the cycle varies from fifty-six to sixty-four cycles per second, depending on the line load. As these variations may occur often during a short period of time an attempt was made to obtain a more accurate sixty-cycle source.

This took the form of a power oscillator. Essentially the oscillator was a multivibrator with two stages of power amplification. The wave form was determined by careful selection of values for condensers and choke coils used in the multivibrator circuit. A bias control on the multivibrator determined the output frequency which was set at sixty cycles per second. Unfortunately, though the rate of the oscillator was more reliable than the station power, its cycle could not be held fixed but kept drifting higher with tube age. The cycle was adjusted to sixty c.p.s. by altering the bias but the steady increase finally overruled this control. Since supply problems made it impossible to change the tubes at frequent intervals, and since excessive paper speeds could not be tolerated because of the drain on the stock of photographic paper, the oscillator was discarded and the regular power supply re-installed. This system allows time to be measured to the nearest second or perhaps the nearest half-second.

It was mentioned earlier that experiments were conducted to determine the best operating period of the horizontal seismometers. Serious disadvantages were evident when using the 7- and 22-second system, but the 15-second arrangement was quite satisfactory. At the lower range, microseisms were recorded frequently with amplitudes that obscured any other seismic disturbance on the record. On the other hand, at the higher range the seismometer was unstable, being very sensitive to tilt; over a period of several weeks the boom drifted well off the calibration adjustment, often coming to rest against the boom clamp. The intermediate 15-second range was stable and for the most part free from severe microseismic disturbances.

The final instrumentation consisted of a Sprengnether short-period Series DH vertical seismometer with matching Leeds and Northrup galvanometer. The system was adjusted for critical damping, the seismometer and galvanometer operating at the same period of 1·4 seconds. In addition there are the two long-period Sprengnether Series H horizontal seismometers oriented to record the north-south and east-west components of motion. Operating under the same conditions as the short-period system, the final period of the north-south is 14·1 seconds, and of the east-west 13·5 seconds. Direction of first motions were noted, relating trace displacements to the direction of ground motion.

The table below gives the constants of the instruments.

Instrument Constants of the Resolute Bay Seismological Observatory

Component	Instrument	Period (seconds)	Magnification	First Ground Motion
Z	Sprengnether Series DH Vertical	1·4	10,000 c.a.	Compression-up seismogram
NS	Sprengnether Series H Horizontal	14·1	1,600	North-up seismogram
EW	Sprengnether Series H Horizontal	13·5	1,600	East-up seismogram

Seismograms are read once a day at the Resolute station and a radio message sent out immediately if any earthquakes have been recorded. Unless communication conditions are poor the message will arrive in Ottawa less than 24 hours after it was compiled at Resolute. At Ottawa the message is relayed at once to the United States Coast and Geodetic Survey.

Initially the messages were sent out simply as a series of numbers, but it was found that the signals were frequently garbled in transmission. Code messages were, therefore, resorted to, the code being a modification of one used some time ago by the United States Coast and Geodetic Survey. The message form is shown in Figure 11, and its use will be illustrated by an example. Suppose the following message is to be transmitted:

P 17d: 09h: 24m: 06s
S 17d: 09h: 30m: 27s
P 18d: 04h: 29m: 12s

The number of phases to be transmitted is indicated under column 16 by the number 3. The first phase is a P, indicated by the number 1 under column 17. Next follows the time in days, hours, minutes and seconds, care being taken to include a zero if any number has a single figure. The information on the second phase begins in column 26, the number 2 indicating that the phase is an S. If there had been an unidentified phase it would have been indicated by the number 3.

The numbers are divided into groups of five by the heavy vertical lines. These groups of five are written down, one under the other, in columns 1 to 5. For the section "Vertical Check" all six numbers in column 1 are added; the last number, seven, of the total twenty-seven obtained, is inserted in column 6. Only the last number of the totals is significant, the others being dropped. Thus, adding columns 2, 3, 4, and 5 respectively, we obtain the entries for columns 7, 8, 9, and 10. For the horizontal check the numbers in columns 1 to 5 are added horizontally, the first row of these providing the entry for column 11, and so on down to column 15. The last row of numbers is not added.

The complete number message is transformed to a series of five-letter words, using the key provided on the form. The complete message as received in Ottawa would read as follows:

Resolute Bay Nov. 18/51.

Pc	17	09	24	06
S	17	09	30	27
Pd	18	04	29	12

SGNTT/DAUGM/GAASW/UDKWN/DASWU/GWDSA/ATWKD/UADWW Stop.

The subscripts c and d, indicating a compression and dilatation, respectively, are not included in the self-checking code. Both the numbers and the code are sent, thereby providing a double check.

SPECIAL INVESTIGATIONS AT RESOLUTE BAY

With the completion of the instrumental installation at Resolute Bay consideration was given to the study of special problems. The seismicity of the eastern Arctic islands, seismic disturbances caused by shifting ice, and the use of perma-frozen ground as a foundation for seismometers were three topics of particular interest to this northern observatory. A qualitative study of microseisms was also undertaken for a period of 8 months. These investigations have served to emphasize the advantages and disadvantages of the present system of detectors. It is hoped that additional seismometers will soon be available to enable a more complete investigation of the topics that are discussed below.

Near Earthquakes in the Eastern Arctic Islands

Prior to the establishment of the seismic observatory at Resolute Bay, reports of near earthquakes from inhabitants of islands in the eastern Arctic suggested that the region might be quite active. During the latter part of 1949, and the first months of 1950, no less than seven reports of tremors were received from personnel at the weather station on Ellef Ringnes Island.

SEISMOLOGICAL MESSAGE

P-phase = 1
S-phase = 2
Other-phases = 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
	3	1	1	7	0																																															
	9	2	4	0	6																																															
	2	1	7	0	9																																															
	3	0	2	7	1																																															
	1	8	0	4	2																																															
	9	1	2	0	0		Vertical check of	words in message			Horizontal check of	words in rows 16 to	40 inclusive			No. of phases	Phase	day	day	hour EST	hour EST	minute	minute	second	second	Phase	day	day	hour EST	hour EST	minute	minute	second	second	Phase	day	day	hour EST	hour EST	minute	minute	second	second	Phase	day	day	hour EST	hour EST	minute	minute	second	second
Data						7	3	6	8	8	2	1	9	3	5	3	1	1	7	0	9	2	4	0	6	2	1	7	0	9	3	0	2	7	1	1	8	0	4	2	9	1	2	0	0							
Letters						S	G	N	T	T	D	A	U	G	M	G	A	A	S	W	U	D	K	W	N	D	A	S	W	U	G	W	D	S	A	A	T	W	K	D	U	A	D	W	W							

Message

Code	1	2	3	4	5	6	7	8	9	0
	A	D	G	K	M	N	S	T	U	W
	Andrew	Daniel	George	Kate	Mary	Norman	Sam	Tom	Union	William

FIGURE 11

Several systems of electro-magnetic seismographs, some of them in operation only for a period of several weeks, were installed at the station for studying local seismicity. The most satisfactory results were obtained when using a Willmore seismometer with a period of 0·3 second coupled to a Micro Moll galvanometer with a period of 0·3 second.

Although considerable activity was anticipated, the study of seismograms did not justify these expectations. Over a period of one year, five local tremors have been well recorded; other disturbances on the records may possibly be caused by local earthquakes. The P and S phases for these disturbances were well defined and additional i-phases were noted in both the P and S groups. Epicentral distances varied between 280 and 725 kilometres from the Resolute station. It may be that the earlier disturbances reported from Ellef Ringnes Island were, in fact, not earthquakes but resulted from ice shifting in the nearby bay. Though the Ellef Ringnes area has been occupied for some years, it is worth noting that all seven reports were issued over a period of 3 months from one settlement. No reports have come from other inhabitants of the eastern Arctic during the past six or seven years.

Sea Ice as a Source of Ground Noise

During the winter months at Resolute Bay the short-period records were carefully scanned for spurious activity that might be attributed to the movement of the sea ice under the influence of the tide. Though random noises were identified on the trace, there was little to indicate that this effect stemmed from tidal, or other forces, acting on the ice. Since the detectors are situated less than half a mile from the ocean, it was decided to undertake a further test during the month of May, when the sea ice attains its maximum thickness of approximately 6 or 7 feet.

The seismic detecting system used for studying ice noise was the same as that used for recording local tremors. In addition, a tide gauge equipped with a pen recorder was mounted on the ice to provide a graph of sea-level against hour of the day. The range of tide, its rate of change, and the time of low and high water were noted for each day.

An examination of the seismograms for the test period revealed bursts of high-frequency disturbances lasting from 2 to 15 seconds. The energy involved was small, for these bursts of spurious noise were seldom perceptible on the short-period Sprengnether seismometer. The number of disturbances varied from 25 to 75 a day and a count was made of the number of distinct disturbances occurring during each half-hour period. A comparison of seismic data with the tide curve suggested that the ground noise was not obviously related to the amplitude, slope, or phase change of the tide graph. The high-frequency vibrations were recorded almost entirely between 09:00 and 21:00 local time (Central Standard Time) during each day of the test period. There appeared to be no relationship between the number of disturbances recorded, and the rate of change of the tide; neither was there any indication of a change in the time during which noises were most frequent to coincide with the phase shift of the tide curve. No suitable explanation is put forward to justify these disturbances, but a longer testing period may show they are present the year round and are possibly associated with the freezing and thawing of the active layer that covers the permanently frozen ground.

Installation of Seismometers on Permafrost

Normally, seismometers are set up on concrete piers that are in contact with bedrock; on some occasions the seismometers may be mounted directly on the bedrock. In certain instances it becomes desirable to establish an observatory in a location where bedrock is not easily accessible and in such cases well-consolidated materials often prove quite satisfactory for certain types of instruments.

The Arctic climate provides yet another medium that may provide a suitable base for detectors and that, in its undisturbed state, will transmit seismic radiation almost as well as bedrock. This medium is permafrost, a frozen layer made up of constituents varying from a mixture of washed gravel and ice, to frozen muskegs saturated with ice lenses. In the eastern Arctic the permafrost almost invariably extends to bedrock and when protected from additional heat its coefficients of compressional and shear stress should be comparable to those of concrete for the purpose of installing seismometers.

Experiments were conducted with a short-period Sprengnether vertical seismometer set up on permafrost. The installation was of a temporary nature but results suggest that this medium could be used satisfactorily as a site for seismometers. Rigid contact with the permafrost was achieved by hammering three 4-foot lengths of 2½-inch pipe into the ground. The seismometer was mounted on a steel plate resting on these pipes. This crude arrangement proved adequate for recording almost all the earth tremors reported by the United States Coast and Geodetic Survey during the period that the seismometer was operating on permafrost. On removing the steel pipe some two months later, it was evident that the frost level had already risen several inches.

Since testing indicates that permafrost could be used as a base for seismometers, provided care is taken not to supply heat to the frozen layer, it is well to consider the most suitable way of constructing a surface for mounting the instruments. One method of obtaining a suitable table would be to drive steel pipes well into the frozen ground and then to pour a concrete pier around the extended pipe so as to form a slab floating above ground. Care in insulating beneath the table top so formed, and around the pipes, would allow the frost layer to rise. This type of construction would probably provide a more stable pier than one poured into a deep excavation and subjected to the forces acting at the surface of the frozen layer. No tests have been made to determine the stability of permafrost with regard to operating a long-period horizontal seismometer. Indeed, this type of pier might prove unsatisfactory for systems sensitive to tilt but should be quite suitable for most types of short-period instruments as well as for long-period vertical seismometers.

Microseismic Storms at Resolute Bay

Microseismic storms have been well recorded at Resolute Bay on the two long period Sprengnether horizontals and to a lesser extent on the short-period vertical. The variation of amplitude and period of microseisms show no relationship with changes of barometric pressure recorded at the Resolute Bay weather station. There are, however, problems and opportunities for which this station is particularly well situated.

Over the past years many mechanisms have been proposed as the cause of the microseisms; the common theme of nearly all hypotheses is that radiation is closely associated with atmospheric disturbances over large bodies of water. During much of the year, the Arctic seas are covered with ice, and the microseismic pattern to be expected at Resolute Bay was unknown.

Inspection of seismograms from Resolute Bay suggests that a definite relationship exists between microseismic storms and meteorological disturbances to the south having their low pressure areas over ice-free water. There does not seem to be any relationship between the microseismic amplitudes and the prolonged high winds so common in the Arctic. Whether this is due to the presence of the ice or to some other factor is not yet definitely established.

The study of microseisms at Resolute Bay is hampered by the lack of a long-period vertical seismometer. It is anticipated that this lack will be filled in the near future. With this in mind, arrangements are being considered to correlate observations of microseismic amplitude and period with hour of the day for a 2- or 3-month period, with similar studies to be organized at Ivigtut, Scoresby-Sund, Iceland, Bergen, Upsala, Copenhagen, Kew, and Palisades. It is hoped that important conclusions concerning microseismic mechanisms may be deduced from a progressive study of microseisms, atmospheric conditions, and other factors for this large area.

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