REPORT NO 1

SEISMOGRAPH INSTALLATION

LAKE SHORE MINES, KIRKLAND LAKE

Ernest A. Hodgson

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AT

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SEISMOGRAPH INSTALLATION
AT
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Ernest A. Hodgson

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On December 19, 1939, a specially-designed Heiland vertical seismograph was placed in operation at Kirkland Lake, Ontario, under the joint auspices of Lake Shore Mines and the Dominion Observatory, Department of Mines and Resources, Ottawa. The primary object of this installation is the accurate timing of the rockbursts that occur from time to time at the mine and are sometimes sufficiently severe to be recorded at Ottawa or even as far away as Boston. The present memorandum is designed to place on record the events and discussions leading to the establishment of the Kirkland Lake station, to describe the equipment and its location as of December 31 1939, and to indicate the routine as initiated at that time.

1. Correlation of Rock Bursts and Ottawa Seismograms. On December 27, 1938, at about 10:50 p.m., E.S.T. a severe rockburst occurred at Lake Shore Mines. Mr. C. E. McKnight, Safety Director of that organization, telephoned to the Observatory asking whether the shock had been recorded at Ottawa and whether an earthquake occurred at the time of the burst. It was found that the record was quite pronounced on the short-period (vertical) Benioff seismograph. A copy of this record appears as Fig. 1. It was decided that Ernest A. Hodgson, seismologist at the Observatory, should go to Kirkland Lake to learn what he could of the burst.

Hodgson left for Kirkland Lake on the evening of January 1, and remained there until the afternoon of January 6. While there, he made various attempts to determine the exact time of the burst; as, for example, by endeavouring to locate someone who could remember the exact point in a network radio program when the burst was felt. Every attempt to time the burst, by this or other means, failed.

The site of the burst was visited on January 5. It was slightly above the 2700 ft. level. About 160 ft. of drift was affected, 98' being closed solidly by the burst. It is of special interest to note that broken rock resulting from a burst is coated with a fine white dust indicating that part of the rock disintegrated at the instant of the release from strain. Rock broken by blasting does not exhibit this dust coating. The data for the position of this burst were given later by the mine authorities. They appear as Appendix I, together with the Ottawa readings.

(1)

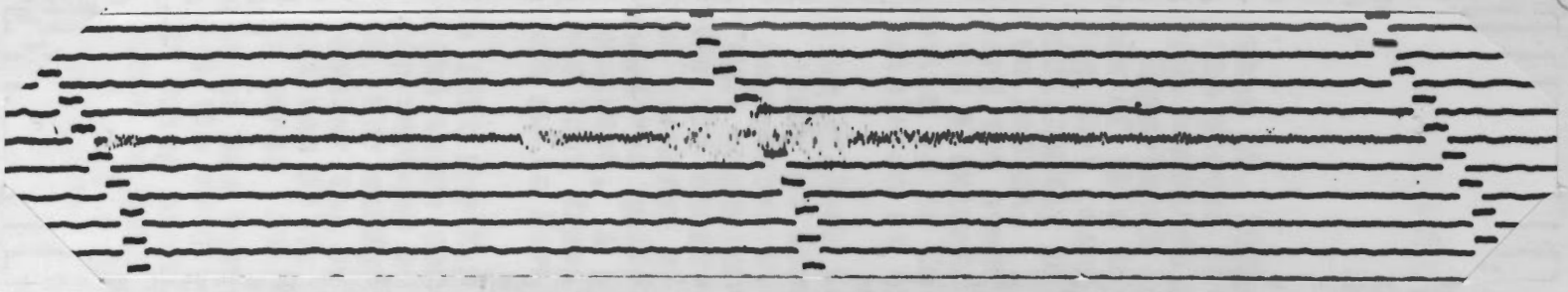

Figure 1 Ottawa Short-period Benioff Record of Lake Shore Burst of Dec. 27'38

(2)

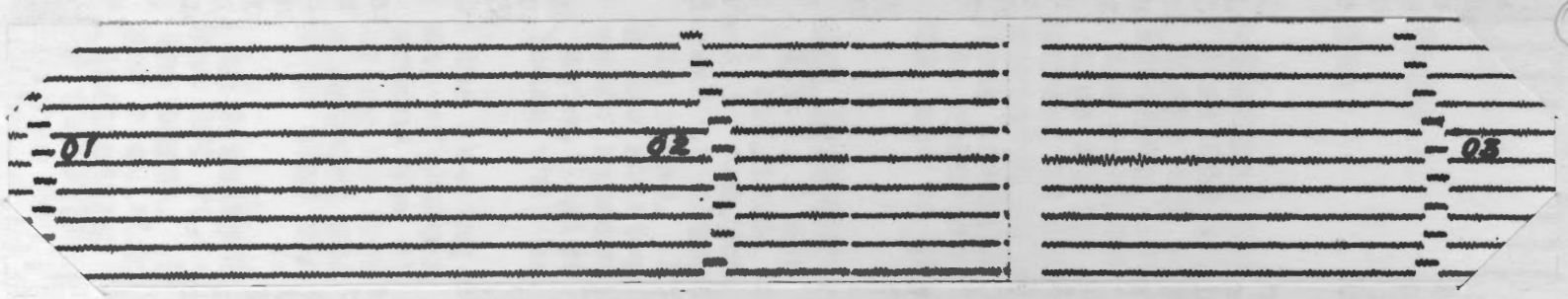

Figure 2 Ottawa Short-period Benioff Record of Blast near New Haven
(40,000 lbs. of dynamite)

Examination of the seismograms establishes the fact that no (other) earthquake occurred at the time of the burst. We must consider the burst as being itself an earthquake. The mechanism of the release of energy is exactly the same whether the storage of that energy was due to natural or to artificial causes. Moreover, the energy release in a severe burst is very great.

It is interesting to compare (Figs. 1 and 2) the record at Ottawa (Δ= 279 mi.) of the Kirkland Lake burst of December 27, 1938, with the record at Ottawa (Δ= 315 mi.) of a blast of 45,000 lbs. of dynamite in a trap-rock quarry near New Haven, Conn. The distances are nearly the same but the energy release in the former is evidently much the greater.

Lake Shore Mines furnished a list of the larger rockbursts which had occurred up to that of December 27, 1938. These are given as Appendix II. On checking these at Ottawa the following report was sent to Mr. Todd under date of January 11, 1939.

> "You will note that the records of two instruments were checked -- the short-period vertical Benioff at Ottawa and the short-period horizontal Wood-Anderson at Shawinigan Falls. The Ottawa Benioff was not in operation previous to April 5, 1937. It was then run experimentally for a couple of months or so, the recording sometimes interrupted to permit changes in the set-up. For this reason we have no records to check blasts numbered 1-5. The instrument was also temporarily out of commission for Nos. 16 and 17 (July 19, and September 9, 1938).
>
> "The net result of the check-up is that the only record obtained at Ottawa is that of December 27, 1938. Those recorded at Shawinigan Falls are those of January 5, 1937, July 19, 1938, and December 27, 1938. Presumably, the first two of these would have recorded at Ottawa had the Benioff been in operation at the time."

Requests for seismograms were sent out to those seismograph stations within a radius of 600 miles at which short-period seismographs were operating during the period covered by the tabulation of rockbursts given in Appendix II. It was found that none of these bursts were recorded except that for December 27, 1938, which was just visible as a trace on the Weston short-period Benioff record. The arcual (computed) distance from Kirkland Lake to Weston is 580 miles.

It is of interest to tabulate here the computed arcual distances from Kirkland Lake to those stations, equipped with short-period seismographs, that might be expected to record the largest of the bursts at Lake Shore Mines. They are as follows:

Station	Degrees	Km.	Mi.
Ottawa	4°02'42"	449.0	279.1
Shawinigan Falls	5 11 06	575.5	357.8
Buffalo	5 16 58	586.4	364.5
Burlington	6 06 38	678.3	421.6
Seven Falls	6 17 32	698.4	434.2
Williamstown	7 14 28	803.8	499.6
Harvard	8 12 24	910.9	566.3
Weston	8 25 06	934.4	580.9
Fordham	8 30 58	945.3	587.6
Georgetown	9 29 54	1054.4	655.4
Cincinnati	9 34 14	1062.3	660.4

It may be noted in passing that on February 8 inquiries were received at Ottawa from Mr. P. J. Shenon of the International Nickel Company at Copper Cliff, Ont., asking whether shocks felt at Sudbury had been registered at Ottawa. The times given were February 6 at 12:20 a.m.; February 7 about 8 p.m.; and February 8 about 5 p.m. Some spalling of rock occurred in the mine. Examination of the records disclosed that only the first of these tremors was recorded. This was a slight trace only from 12:23:45 to 12:24 a.m. February 6. No doubt rockbursts occur from time to time in the deeper levels of all hard-rock mines in the Ontario-Quebec mining area. Prior to the check-up with Lake Shore Mines none of these have been correlated with any of the many slight traces recorded on the short-period seismograph at Ottawa.

It should be noted that the short-period Benioff seismograph (vertical component only) was installed at Ottawa on April 5, 1937, but was run experimentally only, with many lapses of recording until about July, 1937, since when the operation has been practically continuous. No horizontal short-period seismographs are, as yet, operating at Ottawa but it is hoped to have, in addition to the vertical, both horizontal components of short-period Benioffs in operation early in 1940.

Subsequent to December 27, 1938, and prior to December 19, 1939, the larger rockbursts occurring at Lake Shore Mines were reported to Ottawa. The list of these, together with the readings of those which recorded at Ottawa, are given in Appendix III. It is to be noted that eight bursts have been reported from Lake Shore Mines and have been recorded with phase differentiation at Ottawa.

2. Initial Discussions and Correspondence. At Kirkland Lake, in January, 1939, Mr. E. W. Todd Manager of Lake Shore Mines, discussed with Hodgson the possibilities of establishing a seismograph at Kirkland Lake. The offer was then made, verbally, that Lake Shore Mines would finance the establishment of a seismograph station at Kirkland Lake and would purchase the equipment

provide quarters, electricity and water services, and daily attendance; on the condition that the Observatory would supervise the selection of instruments and their installation, would provide continued supply of photographic paper and developer, and such technical assistance as might from time to time, be required. The Observatory was also to analyse the records and issue regular reports to Lake Shore Mines. The seismograms were to become the property of the Observatory.

The Observatory officials stressed the point that the establishment of a single seismograph at Kirkland Lake would be of considerable scientific value; but that, so far as the value in rockburst prediction is concerned, the instrument could only be expected to record their times of occurrence and their relative intensities. This is specifically set forth in a letter from Mr. Stewart to Mr. Todd under date of January 11, 1939. This letter is quoted in full in Appendix IV.

In the same letter were tabulated the various conditions that would have to be met by a seismograph chosen to operate under the exacting conditions obtaining at Kirkland Lake. The unusual amount of ground unrest due to traffic and heavy machinery, together with the presence of power transmission lines made it somewhat problematical whether any type of seismograph could be used to advantage. It was quite possible that when the sensitivity had been raised high enough to record the bursts the local surface unrest would spoil the record. A requirement in addition to those listed in the above letter is evidently essential -- the sensitivity should be readily adjusted.

In a letter to Mr. Stewart dated January 14 Mr. Todd confirmed the verbal agreement and acknowledged the limitations outlined in the letter of January 11. His letter is quoted in this report as a continuance of Appendix IV.

3. Selection of Seismograph and Radio Equipment. Correspondence was initiated by the Observatory, immediately following the letters discussed above, with those seismologists best qualified by experience to advise on the selection of a seismograph. The results of that correspondence were tabulated in a memorandum, submitted to Mr. Stewart under date of March 30. This memorandum is given as Appendix V. It was forwarded to Mr. Todd in a letter from Mr. Stewart, dated April 14. In that letter, Mr. Todd was asked whether the alternating current supply at Kirkland Lake would be satisfactory as a chronograph drive. Mr. Todd's reply to the above letter is dated April 17. In it, he guarantees the purchase of equipment and undertakes the cost of installation. He decides against the use of A.C. for the chronograph drive because of shutdowns due to thunder storms, etc.

Under date of April 25, the necessary authorization was obtained from the Department. A proposal was made by Mr. Stewart

to Mr. Todd, under date of March 6, that Lake Shore Mines reimburse the Department for the cost of the seismograph and radio outfit, this equipment to become and remain the property of the Department and to be left at the Mines as long as required. The authority from the Department guarantees to leave the instruments at the Mine "at least ten years or longer if conditions so require". This arrangement was agreed to by Mr. Todd in a letter dated May 8.

The order was placed with Heiland Research Corporation under date of June 5, 1939 (Requisition No. 27865, Order No. 14889). It calls for:

One special rockburst recorder, including:

1 Type SE-400-P vibration detector and

1 special recording camera complete with galvanometer system, timer and driving motor.

The cost was given as $655.00 based on a quotation received from Heiland Research Corporation under date of May 3. The various items are listed as follows (taken from Heiland letters of February 14 and April 12): Detector $150.00, Permanent Magnet Frame $75.00, Transformer $5.00, Single Galvanometer $50.00, Camera $375.00.

The radio equipment was ordered on June 8, 1939 (Requisition No. 27866, Order No. 23160). It calls for the following equipment through the Canadian Marconi Company, Montreal:

1 National Standard HRO receiver table model, complete with 2.5-volt tubes and four sets of coils covering the range 1.7 m.c. to 30 m.c.	$299.50
1 Speaker for above	23.50
1 Power supply unit for above: 110 volt, 25 cycles	36.50
1 set of coils 100 to 200 k.c.	30.00
	$389.50

Less discounts of 50% and 10% making net $175.28

This radio equipment was supplemented under date of November 4, 1939 (Requisition No. 30836, Order No. 28413) addressed also to the Canadian Marconi Company, Montreal and calling (with respect to the Kirkland Lake installation only) for 2 sets coils 900 - 2000 k.c. $18.00 (net.)

The initial radio equipment was received about July 8, 1939. It was tested under various conditions and by different operators throughout the summer and fall. The seismograph was received at the Observatory on October 31, 1939.

4. Testing the Equipment at Ottawa. On setting up and testing the equipment at Ottawa it was found that the timing contacts on the seismograph were incorrectly placed. The worm screw for

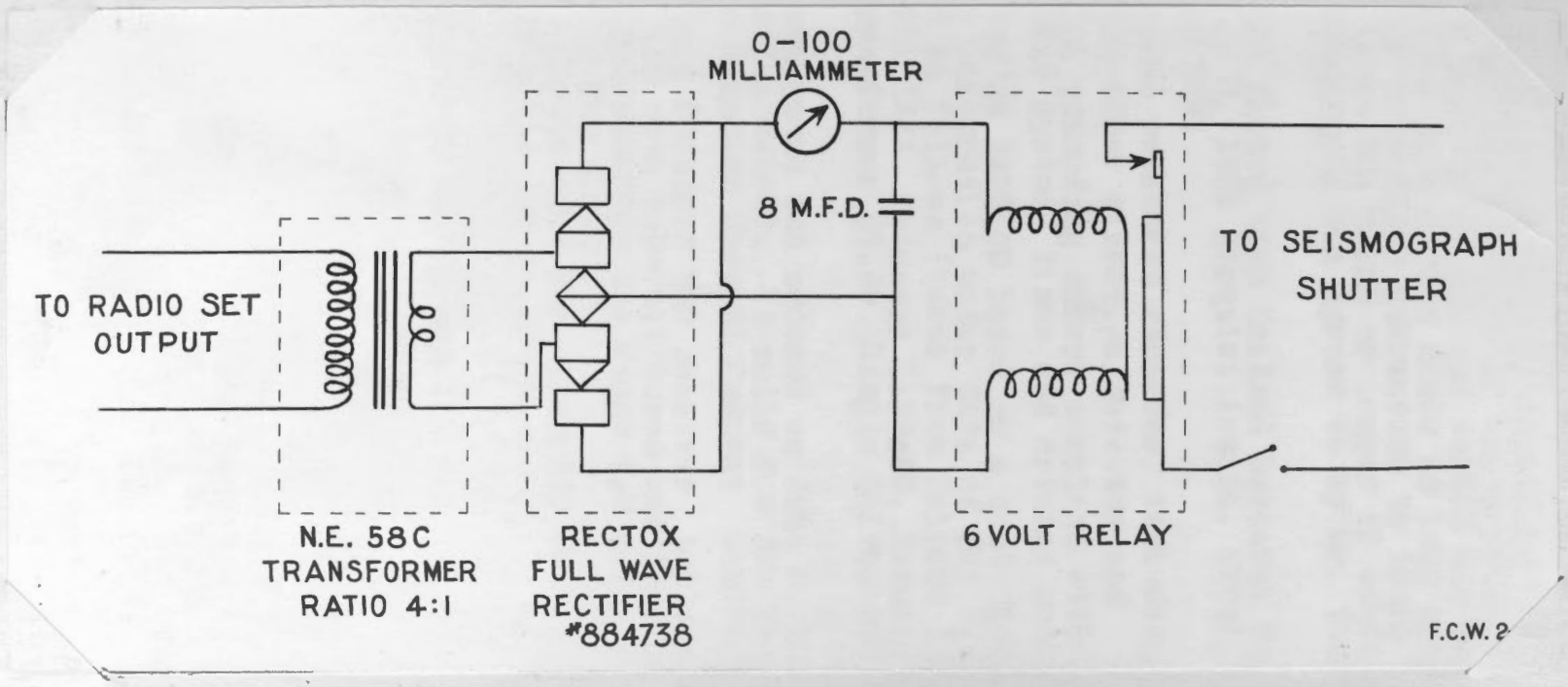

Figure 3. Wiring Diagram of Automatic Time-signal Relay

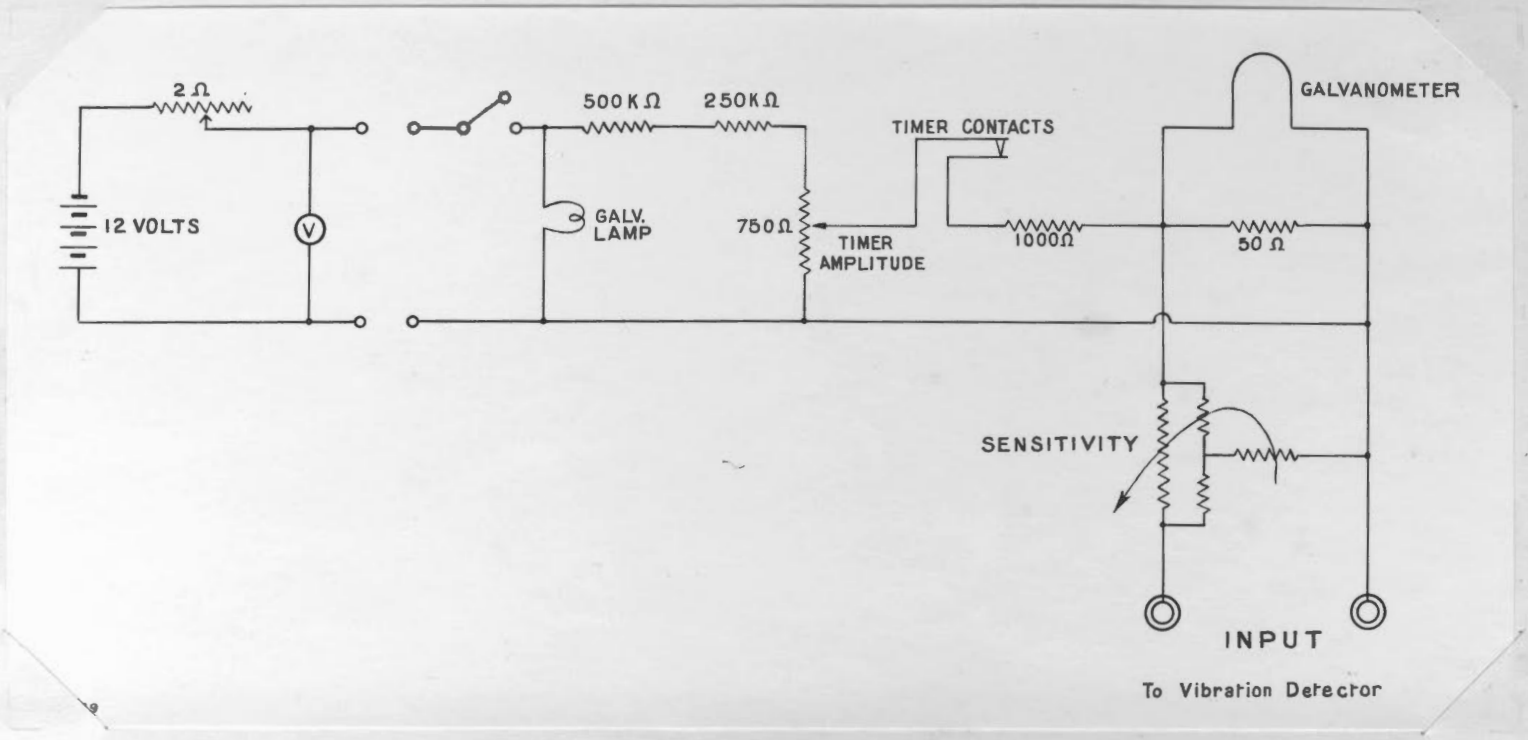

Figure 4. Wiring Diagram of Seismograph

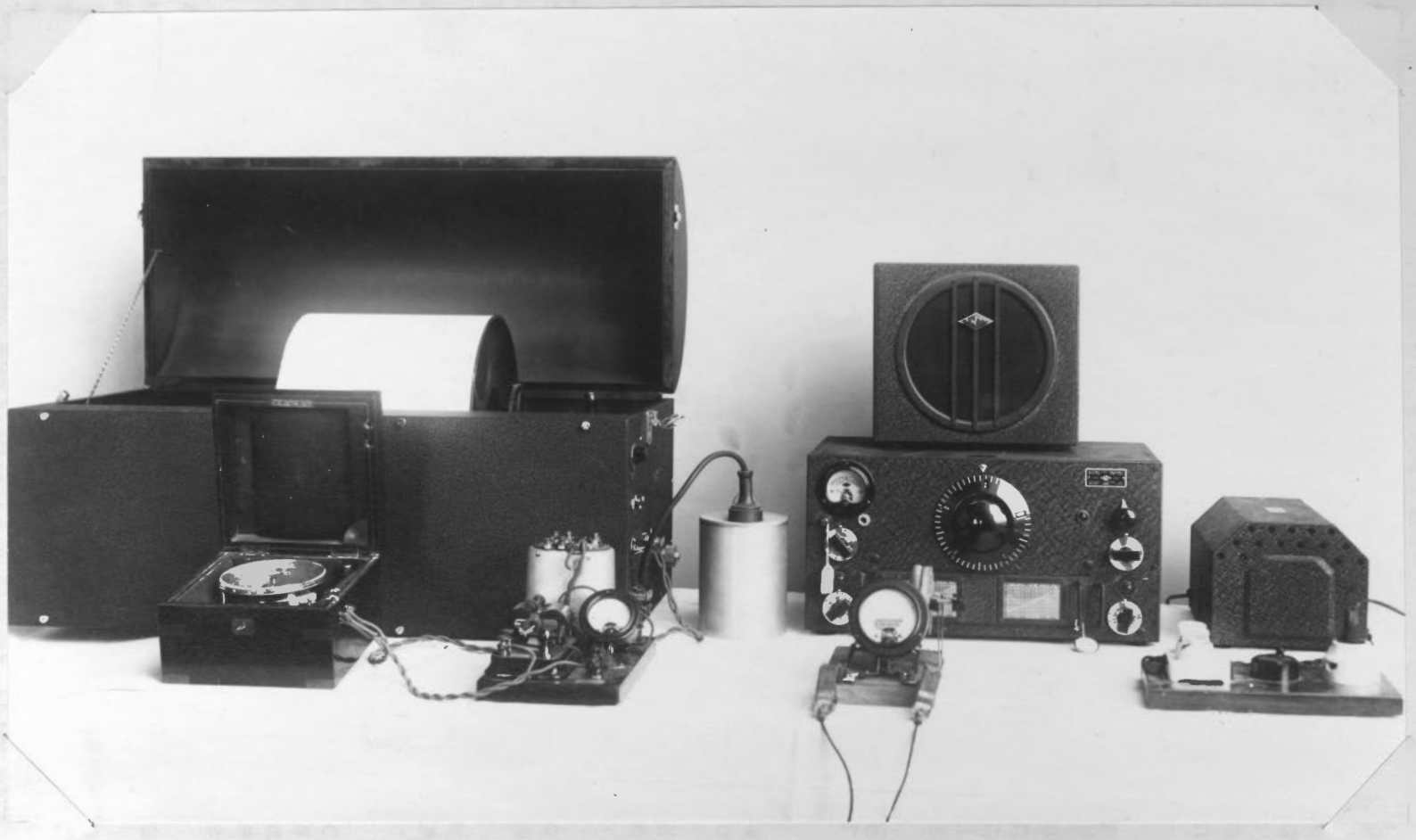

Figure 5. Complete Equipment at Ottawa

the lateral drive was found to give an insufficient length of record. A new screw was made and installed. The light source was found to be a lamp difficult to obtain and expensive. The only one supplied burned out the first day. New ones could be obtained only in the United States and at a net cost of about four dollars. The camera was modified to use the standard seismograph lamps in general use in our Canadian stations. All the machine work necessary to the alterations was done in the Observatory machine shop by Mr. Christensen.

Correspondence was begun with Lake Shore Mines regarding the preparation of a site. Under dates of November 2, 6, 20, and 30 full details were sent to Mr. Geo. T. Honer of Lake Shore Mines, who was designated by Mr. Todd to be responsible for this phase of the work. The change-over to the standard lamp required that the current supply be 10 volts D.C. instead of 4.3 volts. This would require two car batteries instead of the one which had previously been indicated. Provision would have to be made to keep these batteries fully charged against a current drain of 3.5 amps. instead of the .6 amps. for the earlier arrangement.

On experimenting with the seismograph with all the alterations completed it was found that, since the standard lamps are brighter, we can use a slower emulsion than that recommended by the manufacturers. This is a distinct advantage, as the fast emulsion is difficult to handle without finger marks and fogging. It was found difficult to place the large sheets (9 7/8" x 38") on the drum smoothly and with the crease for the clamping jaws in exactly the right place. A board with metal ends was made (See A in Fig. 11) by means of which the operator can crease the ends of the sheet, in red light or darkness, before putting it on the drum.

To permit the automatic registration of radio signals, a recording relay was constructed at the Observatory by Mr. J. P. Henderson (See A in Fig. 5). The construction of this relay is shown in diagram form in Fig. 3.

The wiring diagram of the seismograph camera is shown in Fig. 4 and the complete equipment as set up at Ottawa is shown in Fig. 5. To expose the new lamp installation it is necessary to remove the front plate of the camera. This is shown in Fig. 6. A close-up of the galvanometer end with the controls is shown in Fig. 7.

The experimental work with the equipment and the numerous adjustments, changes, and additions which were required delayed the installation. This work was carried on without interruption from November 1 to December 10. Mr. Hodgson left for Kirkland Lake Sunday evening, December 10, arriving there 1.30 p.m. Monday, December 11. Some last minute changes were made in the camera Monday and Tuesday. The equipment was shipped from Ottawa

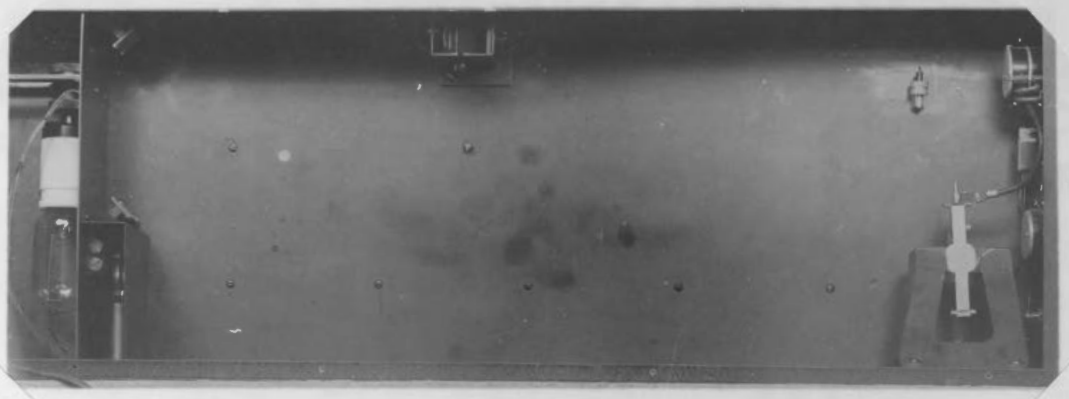

Figure 6. Front of Camera with New Lamp Installation

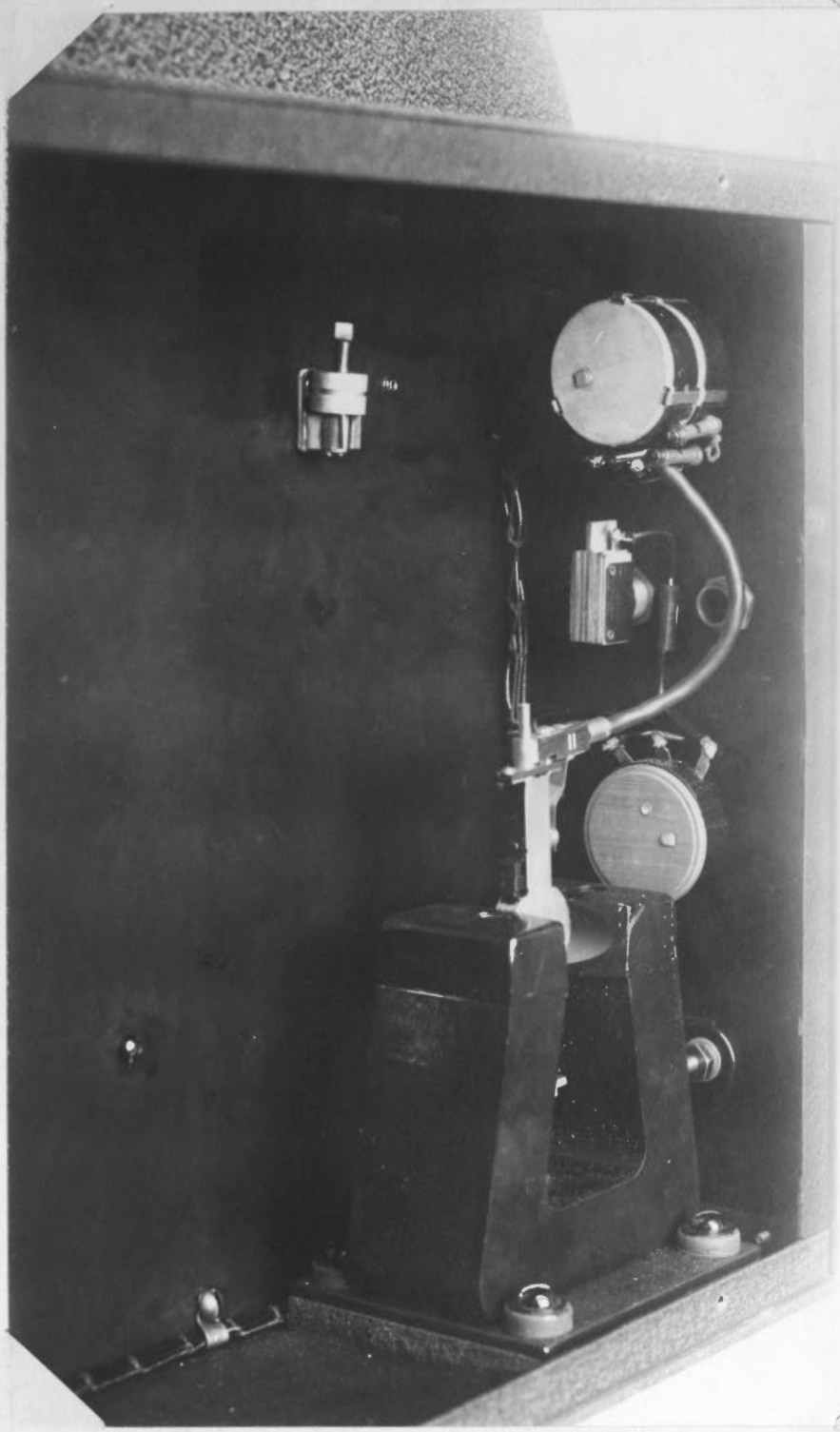

Figure 7. Close-up of Galvanometer and Controls

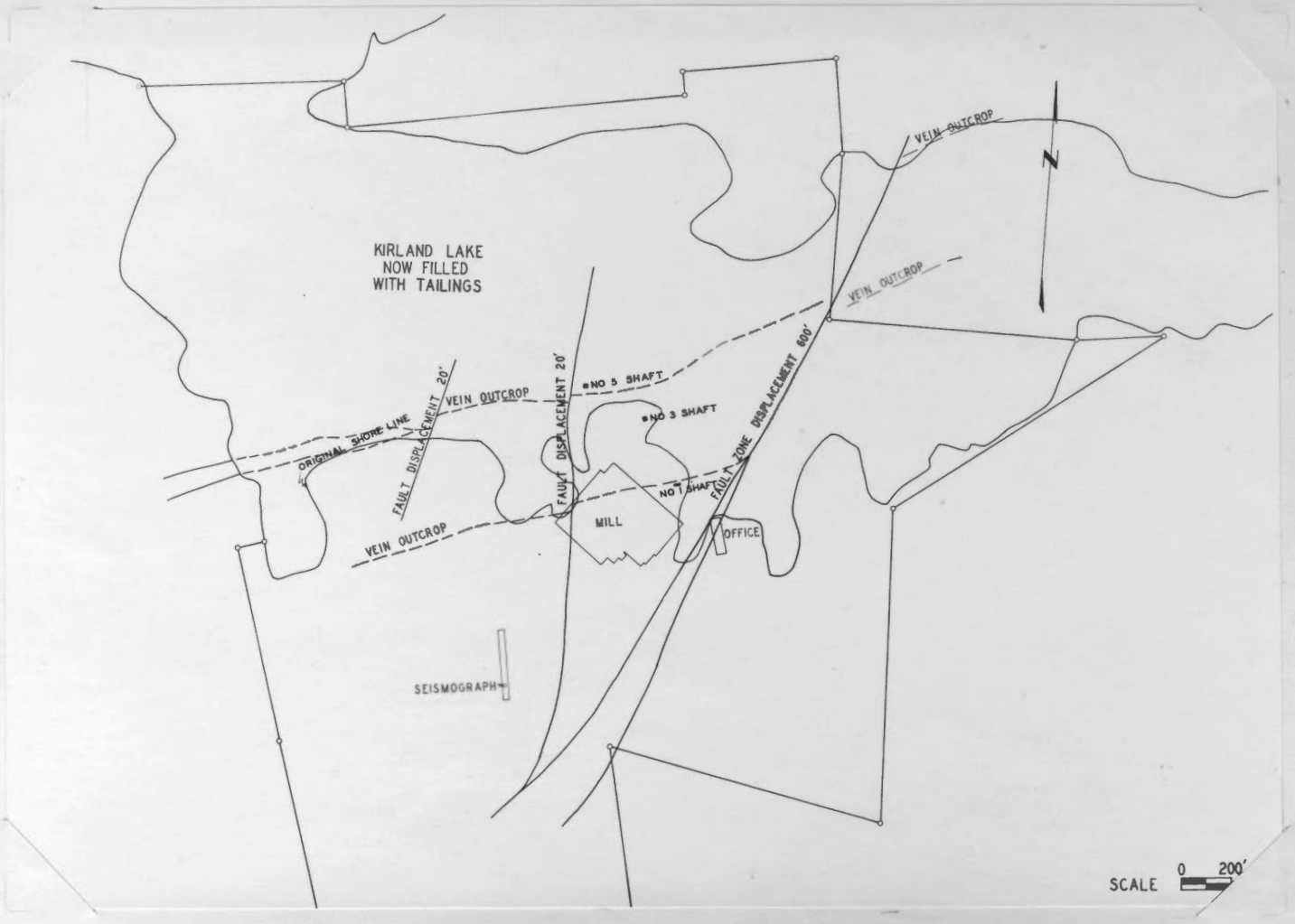

Figure 8. Position of Set-up at Kirkland Lake

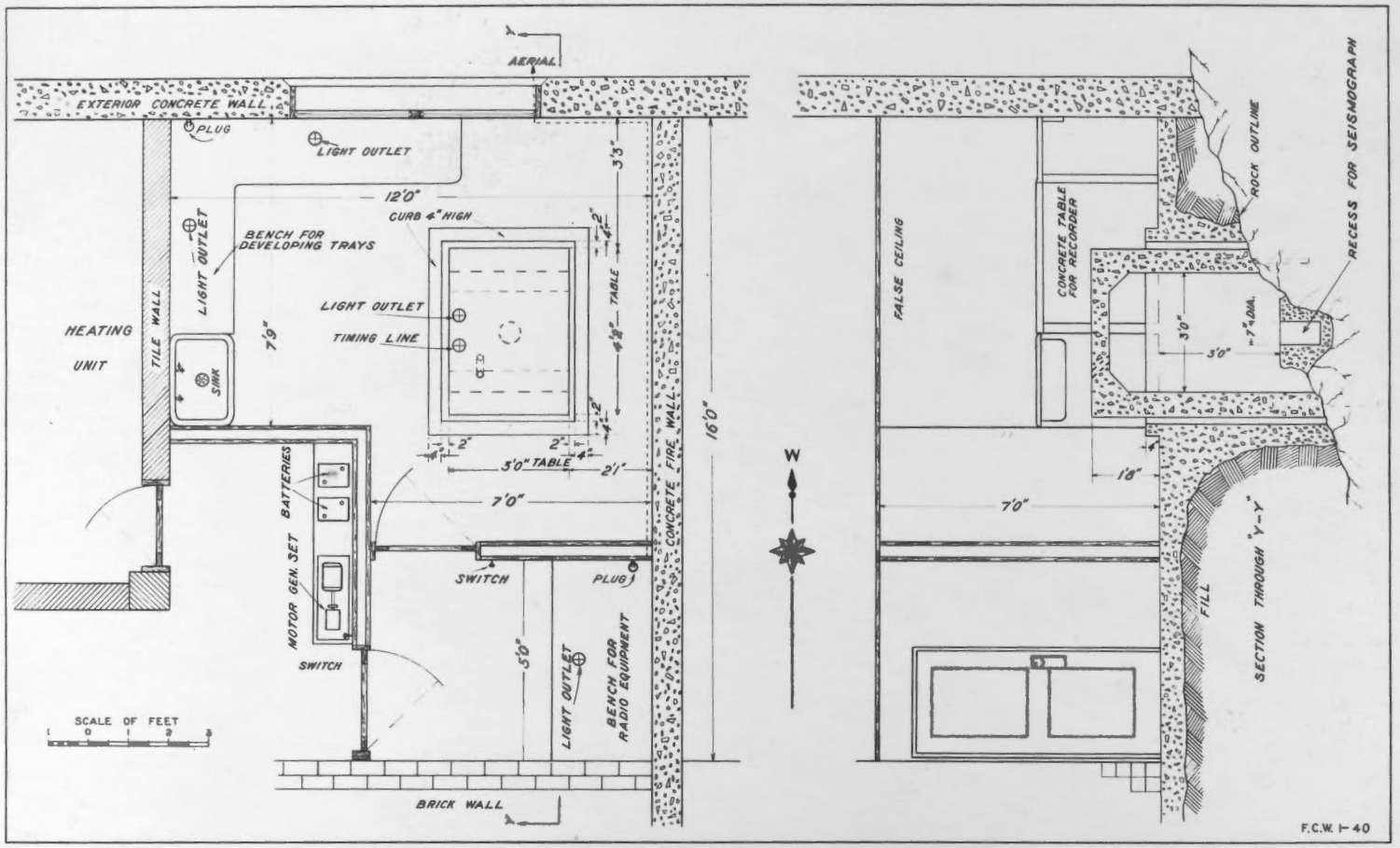

Figure 9. Diagram of Recording Room at Kirkland Lake

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Wednesday, December 13, and reached Kirkland Lake Saturday, December 17, being delivered at the site chosen for the recording room late that same evening.

5. Choice of Site and Preparation of Recording Room. Prior to Hodgson's arrival at Kirkland Lake, no site had been prepared for the reception of the seismograph. The choice of a site presented some difficulties. Three possibilities were considered: a section of the basement under the shipping room at the back of the office building; a corner of a disused hoist room; and a basement room in a long row of residences known as the Accommodation Building, about 1200 ft. south-west of the office building. The seismograph, if placed at the first of these sites, would have had to contend with mechanical disturbances from a heavy freight elevator and with electrical disturbances from a large transformer and a motor generator. The second was out of the question, the hoist in an adjoining building shaking the floor quite markedly. The third was chosen. There was some slight apprehension that disturbances from a gymnasium in the Accommodation Building immediately over the proposed seismograph room might be troublesome. Mr. Todd offered to construct a special building half a mile or more distant if required, but Hodgson did not think the expense was warranted. The position of the site chosen, with respect to the other buildings of Lake Shore Mines, is shown in the map marked Fig. 8. (Furnished through the courtesy of Lake Shore Mines.)

The work of preparing the room was begun Tuesday morning, December 12. The instruments were moved in Monday, December 18, and the first record was put on at 11:35 a.m., E.S.T., Tuesday, December 19. It was found possible to have men working in the room (painting, etc.) while recording was going on; so such work continued until after Christmas. Recording was practically continuous after December 19. The basement room chosen is immediately under the gymnasium and was being used for the storage of furniture. The preparation of the room entailed a great deal of labour. Sometimes as many as fifteen men were working on the job at one time and never less than two. Some work was done at night. The crews worked overtime on Saturday afternoon and evening and all day Sunday. Compressed air was piped in for the drill. The work was done with the greatest possible dispatch and efficiency. A diagram of the room, showing plan and elevation, appears as Fig. 9. (Furnished through the courtesy of Lake Shore Mines and draughted for photographic copying by Mr. Frank C. Weskett of the Observatory staff.)

After the furniture had been cleared away, some old partitions were torn down and the sections of frame partition shown in the plan were built. The brick, tile, and concrete walls are part of the original basement walls. An anteroom 5' by 7' was prepared for the radio and time recording instruments. This equipment, in place on the bench in this room, is

shown in Fig. 10. The larger room was given over to the recording pier and the sink, bench, etc. for developing the records. The ceilings and all frame walls were lined with "Ten-test". All the walls, floors, pier, and ceilings were finally primed and painted, all joints being cemented light-tight.

The seismograph room was made quite light proof. The window was sealed and filled with wall board and afterwards painted. A hot water pipe and a cold water pipe, which cross this room from north to south about the west edge of the pier, were encased in insulating material to keep the room from becoming too warm from the former and to prevent condensation from the latter. It is to be noted that the two room arrangement permits the operator to enter the seismograph room by a light trap, preventing stray light from the outer cellar from fogging any exposed photographic paper in the inner room.

The electric wiring was all done prior to the sheeting and is, of course, of excellent standard quality. A porcelain wall plug is provided in each room together with four single-socket, drop-line ceiling fixtures with porcelain, key sockets, three in the seismograph room and one in the radio room. A switch outside the radio room door controls the ceiling light in the radio room. A switch in the radio room to the right of the communicating door controls the two outlets over the developing bench but not the one over the seismograph pier which is controlled only by its key. Small (25 watt) ruby glass bulbs are used in the seismograph room.

The position for the seismometer was chosen to be a cylindrical hole in bed rock some 3 ft. below the floor level and in the centre of a recorder pier constructed of reinforced concrete in the form of an inverted U. A hole about 5' x 6' was dug to rock to enclose the position shown for the pier. The rock, when exposed, was found to be hard and unbroken. It lies about 2 ft. below the floor at the west end of the pier and 3 ft. below at the east end. A seismometer hole, about 10" in diameter and 12" deep, was drilled and chipped out. A cylindrical form 7" in diameter and 12" deep was set in the hole and concrete cast about it, the concrete being well grouted to the clean, chipped rock and finished level on top. A rectangular form was made about 4" wider and 4" longer than the finished pier. This form was set centrally in the excavation and back-filled to close off all excavated space, providing a rectangular hole with smooth concrete walls. These walls were carried 4" higher than the floor and a curb 4" wide was constructed to prevent any water that might get on the floor from entering the hole. In this hole, forms were set to construct a pier, with stout, reinforced, vertical slabs at the east and west ends and a smooth hard-trowelled level top 3' x 4'2".

Figure 10. Radio Desk at Kirkland Lake

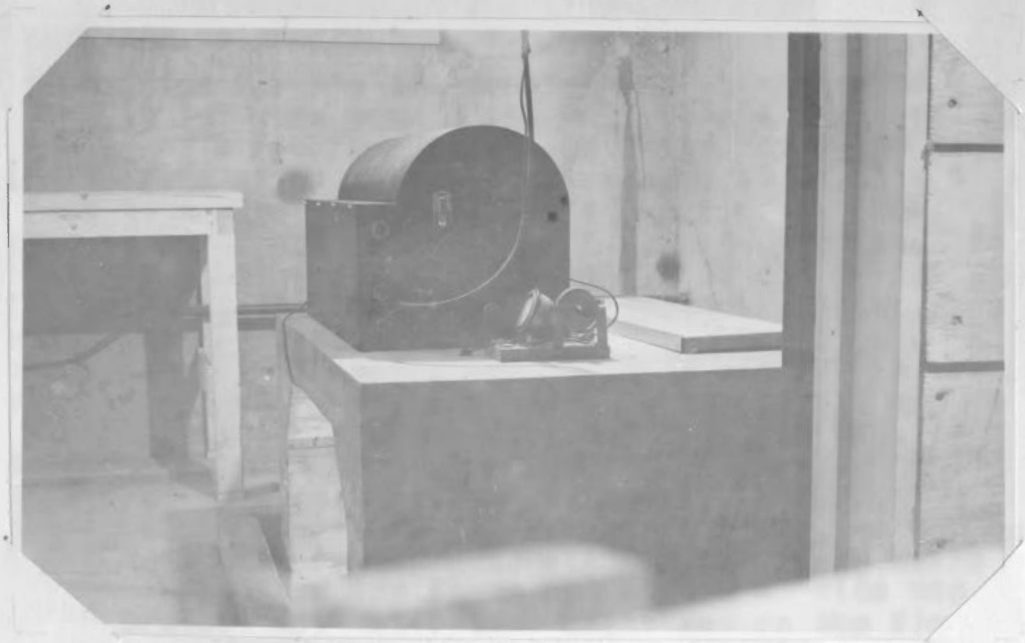

Figure 11. Camera on Pier at Kirkland Lake

Figure 12. Seismometer Emplacement at Kirkland Lake

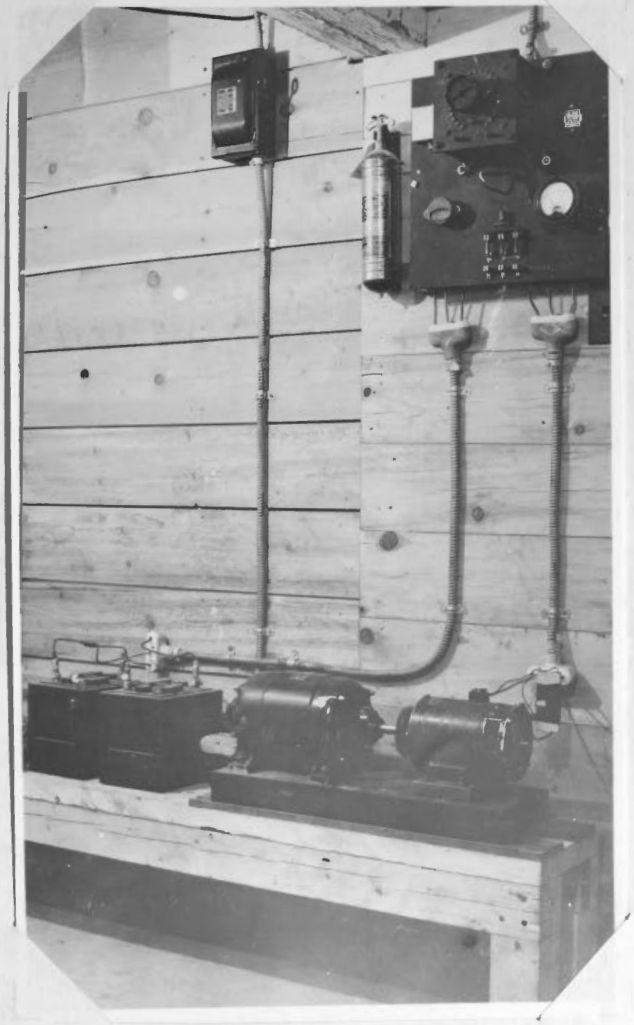

Figure 13. Generator Set and Batteries

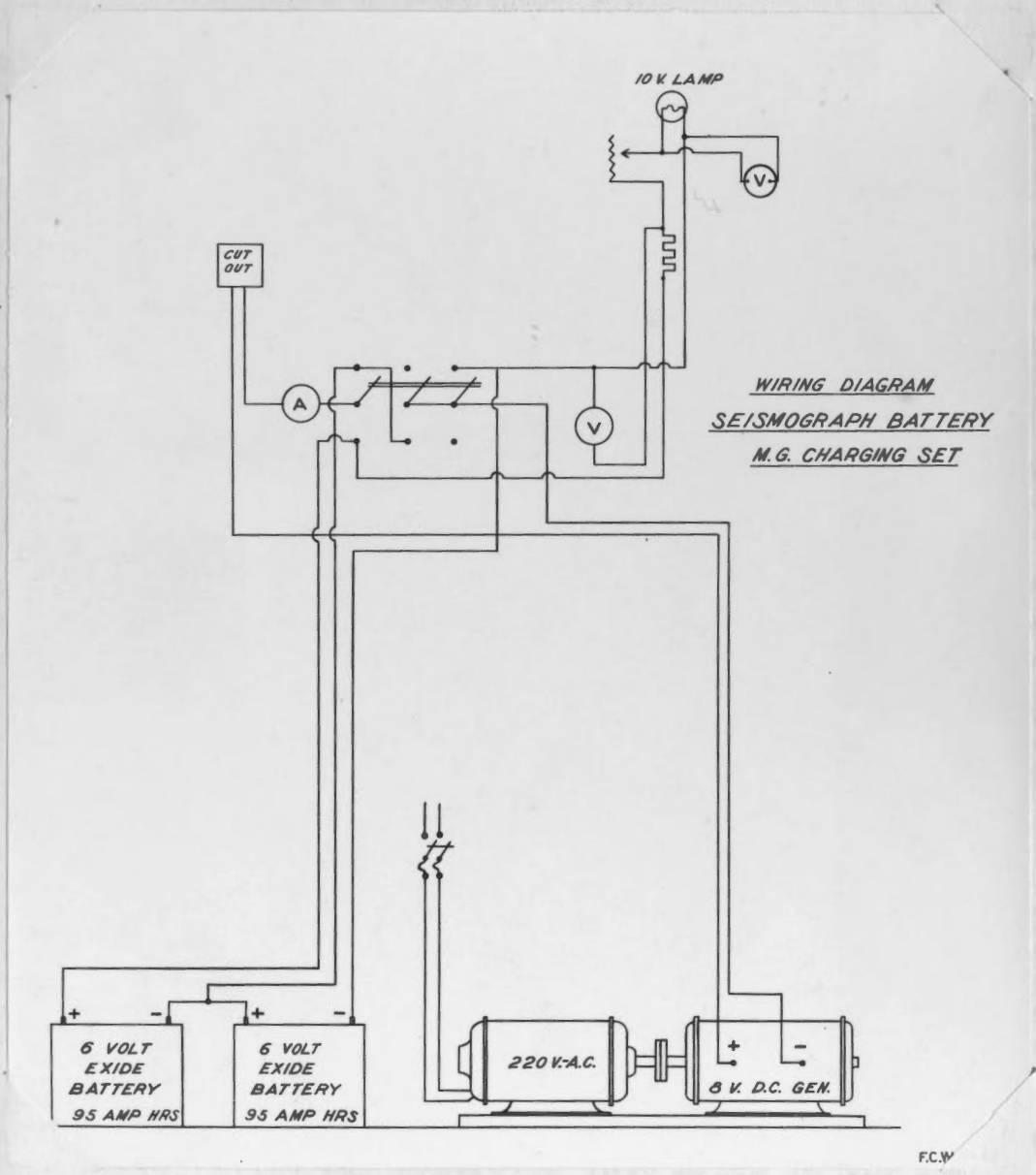

Figure 14
Wiring Diagram of Generator Set
for Camera Lamp Supply

A piece of inch pipe was set in the concrete near the east end to permit the passage of the twisted, double cord, (No. 14) rubber-insulated cable from the seismometer to the camera.

The pier is shown in Fig. 11 and the emplacement for the seismometer is shown in Fig. 12. In the former illustration the recorder is shown in position, the crimping board for creasing the sheets lies behind the recorder and a rheostat and voltmeter at the right hand end provide a control for regulating the light intensity. In the latter illustration, the observer is looking downward through the centre of the pier from the south side. The exposed rock surface is shown. The seismometer is in the hole provided. It is "frozen" to the bottom of the hole by about an inch of plaster of paris and is packed about with sand. The lifting cord is shown and the cable leading up to the camera appears at the right of the picture. A sink was put in as indicated and hot and cold water were laid down. The cold water pipe is provided with an extra valve tap at the side with a pipe outlet on which is fastened a long, soft-rubber hose for carrying water to any part of the bench. The bench is given a gentle slope south for the west extension of the L and east for the south part of the L. A raised wooden edge was built on the outer side of the bench and the whole top covered with galvanized iron sheeting soldered at all joints. Three enamelled developing trays, 12" x 40" x 3" (with pouring lip at one corner), were furnished by the Observatory. These were made by Vilas Enamel Products Ltd., Cowansville, Que. (Requisition No. 30847, Order No. 28417, November 6, 1939).

To the west of the seismograph room lies a long garage with a driveway between it and the Accommodation Building. About 50 ft. south of the back end of this garage a pole was set for an aerial. A form about 3' x 3' x 2' was built and set over a horizontal chipped face on the side of a rocky hill that rises to the south of the garage. Two vertical sections of steel I-beam were set in place, and steel reinforcing rods were set in the rock and carried up into the forms. Concrete was poured, making a heavy rectangular base with the two sections of I-beam projecting about 3 ft. A pole, 35 ft high, made of 3-inch piping was set up on the concrete, clamped between the faces of the I beam and guyed with heavy wires fastened to bolts wedged and concreted into holes in the rock. A pulley at the top of the pole had a steel rope run through it for raising the aerial. A similar pole was set some 300 ft., approximately NNW of the one described. An aerial about 150 ft. long was strung between heavy insulators at the ends of the pulley cables. The lead-in was carried through the seismograph room to a convenient terminal in the radio room. A ground was found on the water pipes of the Accommodation Building.

To supply current for the camera lamp two, new, Exide, 6-volt car batteries were supplied by Lake Shore Mines. As first set up these charged alternately, on alternate days, by means of the 6-volt motor generator set shown in Fig. 13, the wiring of which is shown in Fig. 14. In use, this equipment was awkward in that the operator had to remember to reverse the switch each day, the voltage varied making the record line variable in intensity, the batteries tended to run down due to the heavy (3.5 amp.) constant drain, and the presence of the motor generator set so close to the seismograph introduced interference which was either mechanical or electrical or both. Accordingly, a new 12-volt generator was ordered and, later, installed (January 17, 1940). This set was placed at the extreme south end of the basement of the Accommodation Building, at least 100 ft. distant from the seismograph, and set on an outcrop of bed rock. It is still too soon to say whether all interference has been overcome but it will certainly be possible to "float" the batteries, keeping them always fully charged with no voltage variation at the camera lamp.

6. Routine at Lake Shore Mines. The daily routine at Lake Shore Mines requires about half an hour. Normally the operator interrupts the actual recording for only three or four minutes. Sheets are changed about 1 p.m. Arriving at the station the operator tunes in NAA (Arlington), adjusts the relay so that it will operate smoothly without recording the static, and, at about 12:55 closes the knife switch on the relay. (See A, Fig. 5) The signals are allowed to beat, up to and including the long one o'clock note. During this time, the radio set must be watched constantly and necessary adjustments made from time to time in order to keep the relay operating smoothly.

If the sheets are changed at any other hour, the operator endeavours to pick up the Observatory continuous signals (CHU). Sometimes these come in very well but it is often difficult to tune them in through the static with sufficient sharpness to operate the relay. In such cases the operator records the signal picked up by ear by means of the key shown in Fig. 10.

The record sheet is then changed, the clockwork of the driving mechanism for the drum is wound and the seismograph is again in operation. The sheet just removed is developed, fixed, and washed. It is laid face down when very wet on a cheesecloth rack and allowed to dry slowly. The time breaks are then identified and the sheet annotated. All offsets are checked with a soft pencil and identified where possible. Every few days the completed sheets are sent to Ottawa in special mailing tubes provided by the Observatory.

7. Analysis of the Records and Preparation of Report. The seismograms are carefully examined at the Observatory, all annotations being examined and checked. For the information of all concerned and to serve as an index to the records, the report form shown in Table I is kept up to date in manuscript, the completed forms being mimeographed later to form part of the routine monthly report. As entered on the forms, memoranda regarding the records are rendered compact and informative by means of upper case letters, mnemonically assigned according to the list in Table II. Other short notes may be written in full in the remarks column. Longer notes are indicated by lower case letters in order. The notes indicated on any sheet are placed as footnotes on the same sheet.

Small disturbances, that are, in all probability, rockbursts in Lake Shore Mines or on adjacent property but have not been positively identified, are simply listed as to the number occurring on any sheet, the number being followed by a question mark (as 4?). When a rockburst has been identified as such, it is entered in the bursts column with no question mark following and the corrected time of the burst is given in a footnote which is indexed by a lower case letter in the remarks column.

Each radio time check is used to obtain the corresponding chronometer correction. These corrections (+ indicating chrometer slow, - indicating chronometer fast) are entered in the column provided on the form and are plotted on cross section paper. The time correction for any required point on a record is read off from the graph. These graphs, together with full notes on the operation and a set of the completed forms of Table I, are kept in a log book at Ottawa. A log book is provided also for use at Lake Shore Mines. It is kept in the radio room and all relevant notes are to be entered there at once, as they occur to the operator when engaged in the regular routine.

When a rockburst occurs at Lake Shore Mines and is registered on seismographs at outside points, or when earthquakes occur sufficiently close to Kirkland Lake to record both at Lake Shore Mines and on other seismographs, the disturbances will be assigned a serial number in the Ottawa consolidated reports for Canada. A complete set of these reports as they are issued will be sent to Lake Shore Mines for filing and reference.

The Kirkland Lake seismograph sheets are numbered serially. They are endorsed at Ottawa on the face side at the right hand end of the sheet with a numbering machine. A date stamp is used to endorse the dates of beginning and ending. The records are filed in large heavy envelopes, half a month to an envelope, and stored in steel filing cases in such a way that any envelope may be taken from the file without disturbing the others. The system of analysis forms and filing envelopes permits ready reference to all data obtained at the Kirkland Lake station.

8. Further Rock Burst Research Proposed. When the seismograph installation had been completed at Lake Shore Mines (December 20, 1939) Mr. Todd discussed with Mr. Hodgson the possibilities of further research on rockbursts. It is possible that a rockburst in any given section might be predicted. The possible ways of doing this which have so far been suggested are as follows:

(a) If a sensitive seismometer were installed in the area under observation and were to record continuously, the chronological pattern of the heavy rumbling noises preceding a burst might be learned by experience and serve as a basis for predicting later bursts.

(b) If the pick-up used were a sensitive microphone with its amplifier provided with a wave trap to cut out the rumbling, it is believed by some observers that high pitch (perhaps ultrasonic) crackling might be found to precede bursts, in a chronological pattern which would have to be learned by experience.

(c) It is proved that the velocity of sound in rock increases with pressure. It is now possible to measure such velocities, over such short distances as the lengths of rock face concerned, with the necessary precision to indicate the change in velocity due to increasing pressure. The velocity at bursting conditions has been found experimentally in the laboratory. If velocities were frequently measured at the suspected point in the mine, the approach to critical conditions could be observed.

(d) It is possible that continuous registration of temperature creep, by means of thermo-couples and amplifiers, might yield some indication, by its time pattern, of the approach of a burst.

(e) The use of strain meters to produce continuous records of the displacements in suspected areas might yield some prediction data.

(f) Reference marks could be installed on known fault faces in the mine. The separation of these could be measured at regular intervals, say daily, and would serve to indicate the activity along these faults.

After the discussion, Mr. Todd proposed that further rockburst research be attempted at Lake Shore Mines under the supervision of Mr. Hodgson. The latter was asked to suggest the name of a man who could be employed by Lake Shore Mines and who would be qualified by training and experience to take charge of the actual operations at the mine. He suggested Mr. Zack E. Gibbs, who

was then, presumably, at Harvard University. Finally, subject to approval by Mr. Stewart and by the Department, Mr. Todd agreed to make an offer through Hodgson to Gibbs for his services for the month of March, 1940, with a view to conducting a preliminary survey of the possibilities.

The proposal was approved, tentatively, by Mr. Stewart and, at Hodgson's request, Mr. Todd made his proposal in writing under date of December 29, 1939. A copy of this letter appears in Appendix VI. The proposed research was referred to the Department and approval was granted under date of January 12, 1940. Steps were at once taken to secure the services of Mr. Gibbs. He was finally located at San Marino, Cal., and, after some exchange of telegrams, was engaged on January 27.

The time intervening to March 1 will be utilized as far as possible in obtaining data on methods and instruments. It is hoped that the time in March can be devoted to actual experimenting with tentatively arranged equipment in Lake Shore Mines. If a research plan can be agreed on by the end of that time, the required equipment can then be built and arrangements made for its continued use at Kirkland Lake.

Ernest A. Hodgson.

Dominion Observatory,
Department of Mines and Resources,
Ottawa, January 31, 1940.

APPENDIX I

LOCATION DATA ROCK BURST DECEMBER 27, 1938.

1. Geographical co-ordinates of centre point of No. 3 Shaft, N. 48°- 08'- 56".95 W. 80°- 02'- 42".72

2. Azimuth and distance from above point to centre of burst of December 27th 1938, N. 80°- 58'- 36" E. 213.8 feet

3. Elevation of No. 3 Shaft Collar - 1051.0 (Sea-level datum)

4. Distance below collar of No. 3 Shaft to point nearest the centre of burst of December 27, 1938, 2,683 feet.

The readings for the Ottawa record of the rockburst of December 27 are as follows:

H - 11 49.9 p.m. E.S.T.	S* = 11 51 50
P_n = 11 50 52	F = 11 53.5
P* = 11 51 01	Δ = 415 km. (258 mi.)
S_n = 11 51 37	

These readings are based on Joliat's Tables for nearby earthquakes. Evidently these tables require revision for conditions between Kirkland Lake and Ottawa for the computed arcual distance between these two places is 279 mi.

APPENDIX II

CORRELATION WITH SEISMOGRAMS AT OTTAWA AND SHAWINIGAN FALLS OF THE LARGER ROCK BURSTS AT LAKE SHORE MINES MARCH 20, 1936, to DECEMBER 27, 1938

****

Short Period Benioff: Ottawa

1.	March 20, 1936	: 3.25 p.m.	No records available
2.	December 3, 1936	: 9.45 a.m.	" " "
3.	December 16,1936	: 3.25 p.m.	" " "
4.	January 5, 1937	: 7.30 p.m.	" " "
5.	April 27, 1937	: 2.40 p.m.	" " "
6.	June 13, 1937	: 6.30 a.m.	No trace found
7.	June 16, 1937	:11.00 p.m.	Questionable slight trace at 9-59-45 (might be the burst if K-L time as given were Daylight Saving).
8.	August 14, 1937	:10.20 p.m.	No time breaks on record. Various faint traces but nothing definite at 9.20± or 10,20±
9.	September 4, 1937	:11.20 p.m.	No time breaks on record. Various faint traces but nothing definite at 10.20± or 11.20±
10.	November 26, 1937	:10.15 p.m.	Possible faint traces at 10.15 but clock beats and heavy microseisms prevent any certainty.
11.	December 24, 1937	: 5.00 a.m.	Microseisms and clock beats. No certainty of traces possible.
12.	April 6, 1938	: 3.15 a.m.	Very heavy microseisms. No trace.
13.	May 11, 1938	: 9.15 p.m.	Very heavy microseisms. No trace.
14.	May 20, 1938	:12.45 p.m.	Microseisms present. No trace at 11.45 a.m.± or 12.45 p.m.± 11.45 p.m.± or 12.45 a.m.± (May 21) but sharp "local" type at 1-45-22 p.m. May 20. However two others much same at 11-03-23 a.m. May 20 and at 3.03 p.m. May 20.
15.	July 4, 1938	: 3.30 p.m.	No trace at 2.30 p.m. or 3.30 p.m Small microseisms present.
16.	July 19, 1938	: 7.19 a.m.	No Benioff record available.
17.	September 9, 1938	: 6.40 a.m.	" " " "
18.	October 2, 1938	: 2.30 a.m.	Small microseisms. No trace of burst.
19.	October 14, 1938	: 2.40 a.m.	Small microseisms. No trace of burst.

20.	November 17, 1938: 9.10 a.m.	Some gear trouble and small micros. No trace of burst.
21.	December 27, 1938:11.50 p.m.	Well recorded, beginning at 11-50-52 and continuing for a little more than two minutes. Maximum recorded amplitude 6 mm.

Short Period Wood-Anderson : Shawinigan Falls

1.	March 20, 1936 : 3.25 p.m.	No trace of burst on record.
2.	December 3, 1936 : 9.45 a.m.	" " " " " "
3.	December 16, 1936: 3.25 p.m.	" " " " " "
4.	January 5, 1937 : 7.30 p.m.	Fairly good record of burst. Begins at 7-30-17 and continues for about a minute.
5.	April 27, 1937 : 2.40 p.m.	No trace of burst on record.
6.	June 13, 1937 : 6.30 a.m.	" " " " " "
7.	June 16, 1937 :11.00 p.m.	" " " " " "
8.	August 14, 1937 :10.20 p.m.	" " " " " "
9.	September 4, 1937:11.20 p.m.	" " " " " "
10.	November 26, 1937:10.15 p.m.	" " " " " "
11.	December 24, 1937: 5.00 a.m.	" " " " " "
12.	April 6, 1938 : 3.15 a.m.	" " " " " "
13.	May 11, 1938 : 9.15 p.m.	" " " " " "
14.	May 20, 1938 :12.45 p.m.	" " " " " "
15.	July 4, 1938 : 3.30 p.m.	" " " " " "
16.	July 19, 1938 : 7.19 a.m.	Trace at 7.28 a.m. Continues slightly less than a minute. Not legible.
17.	September 9, 1938: 6.40 a.m.	No trace of burst on record.
18.	October 2, 1938 : 2.30 a.m.	Faint traces which may have been due to the burst. Quite illegible.
19.	October 14, 1938 : 2.40 a.m.	No trace of burst on record.
20.	November 17, 1938: 9.10 a.m.	" " " " " "
21.	December 27, 1938:11.50 p.m.	Trace at 11-52-09. Continues for about a minute. Illegible.

NOTE:-

All records to which Daylight time might have applied were examined also an hour earlier than the time given. No traces, other than those listed above, were found.

APPENDIX III

ROCK BURSTS AT LAKE SHORE MINES
December 28, 1938 to December 18, 1939

*****

The first section of each entry gives the report as received from Lake Shore Mines. The times given in this first section are approximate only. The latter section shows the nature of the reception at Ottawa with the full readings of those tremors that were registered.

1. February 19 4-02 p.m. E.S.T. Medium intensity. A single faint trace 4-06-25 to 4-07-05 p.m. E.S.T. February 19. May be due to other causes.

2. February 7 1-25 p.m. E.S.T. Felt at Lake Shore but no damage in Lake Shore Mines and none reported from adjoining properties.

Ottawa readings:

H = 1-25-26.6 p.m.	e = 1-27-15.5
ePn?= 1-26-25	e = 1-27-23
e = 1-27-02	F = 1-27.8
eSn?= 1-27-10	Δ = 415 km. (258 mi.)

3. March 11 8-14 p.m. E.S.T. Very heavy. Disturbed large section of the mine covering a vertical distance of 500 ft. and a horizontal distance of 400 ft. Centred at 686 ft. south 80°14' east, from centre of No. 3 Shaft at a vertical depth of between 3450 ft. and 3575 ft.

Ottawa readings:

H = 8-14-11.6 p.m.	S* = 8-16-06.5
P_n = 8-15-10	F = 8-17
P* = 8-15-18	Δ = 415 km. (258 mi.)
S_n = 8-15-55	

4. March 26 4-50 a.m. E.S.T. Heavy burst. Location of apparent centre from No. 3 Shaft is 604 ft. south 26°50' W.

Ottawa checked records show light traces only 5-08-01 to 5-10.5 a.m. E.S.T. March 26. May be due to other causes.

APPENDIX III (Continued)

5. March 28 1-07 p.m. E.S.T. Location of apparent centre from No. 3 Shaft is 936 ft. south 86°00' east.

Ottawa readings:

H = 1-09.0 p.m. E.S.T. i = 1-11-33.5
i(P*) = 1-10-40 F = 1-11.8
i(S_n) = 1-11-17 Δ = 445 km. (276 mi.)
i(S*) = 1-11-30

6. April 30 4-03 p.m. E.S.T. Severe rocking motion. Some slight trace in mine but not sufficient to account for surface tremors. No trace at Ottawa or Shawinigan Falls.

7. August 31 (a) 2-50 a.m. E.S.T. medium intensity
(b) 3-00 a.m. E.S.T. heavy intensity
(c) 3-04 a.m. E.S.T. medium intensity

Followed by more tremors.
Approximate centre of disturbance from No. 3 Shaft 600 ft. south 80° east, at depth 3575 ft.

Ottawa readings:

H = 2-51-59 a.m. E.S.T. i = 2-53-55
P_n = 2-52-57 i = 2-53-58
P* = 2-53-05 F = 2-55
S_n = 2-53-42 Δ = 415 km. (258 mi.)

.....

H = 3-02-00 a.m. E.S.T. i = 3-03-58
P_n = 3-02-59 i = 3-04-00
P* = 3-03-07 F = 3-06
S_n = 3-03-44
i = 3-03-50 Δ = 415 km. (258 mi.)

There was no trace of the third disturbance. The record shows the second to have been more severe than the first.

8. September 2 (a) 2-40 a.m. E.S.T. medium intensity
(b) 1-45 p.m. E.S.T. medium intensity

The bursts at about same locality as those of August 31 but approximately 300 ft. deeper.

Ottawa readings:

H = 1-44-55 p.m. E.S.T. i = 1-46-52
P_n = 1-45-53 F = 1-48
i = 1-46-02
S_n = 1-46-38 Δ = 415 km. (258 mi.)

No trace of the first of the above bursts was found on the Ottawa records.

APPENDIX III (Continued)

9. September 19 (a) 10-55 p.m. E.S.T. Heavy intensity
(b) 11-25 p.m. E.S.T. Heavy intensity
Followed by some fifteen smaller bursts not sufficiently severe to register at Ottawa. Bursts occurred between the 1400 and 2500 ft. levels.

Ottawa readings;

H = 10-54-44.5 p.m. E.S.T. iS^*=10-56-46
iP_n = 10-55-46 iS_g=10-57-00
iP^* = 10-55-55 F =11-07
iS_n = 10-56-33,5 Δ = 440 km. (275 mi.)

.....

i - 11-08-10
i - 11-08-47
i - 11-09.0
F - 11-11

It is just possible that an earthquake, represented by the readings of the first set above, occurred somewhat north of Kirkland Lake and that the rockbursts were set off at the mine as a consequence of the disturbance.

APPENDIX IV

STEWART - TODD CORRESPONDENCE, JANUARY, 1939,
RE
PROPOSED SEISMOGRAPH STATION AT LAKE SHORE MINES

******

Ottawa, January 11, 1939.

Mr. E. W. Todd,
Manager,
Lake Shore Mine,
Kirkland Lake, Ont.

Dear Mr. Todd,

On his return from Kirkland Lake, Dr. Hodgson informed us of your generous and welcome offer to purchase and operate a seismograph at Lake Shore Mine provided we would advise as to its purchase, supervise its installation, and make use of its records.

We have sent you a report on the check of your list of rock blasts with our records. It is disappointing to find so few of them recorded. However, three of them have been reasonably well recorded in the past two years.

The study of the rock bursts is one of unusual interest. If they were timed accurately at the mine, by means of a seismograph and radio equipment, and could be registered at least at some of the nearer short-period instruments of the NESA network, they would furnish an exceptionally precise means of determining crustal structure for the unique conditions of the Canadian Shield. Just what other information might be obtained from such a study it is impossible to say. All we can be certain of at the moment is that they would all be recorded as to time and their relative intensity would be indicated.

If, under the circumstances outlined, you still feel inclined to place the instrument at the mine we shall be very pleased to take the matter up with our Department and recommend co-operation. It is a bit difficult to decide what type of instrument to recommend. We have to choose one which:

(1) Will not be too much affected by routine traffic.
(2) Will be sensitive enough to record all bursts large and small.
(3) Will not be put out of operating condition by even the largest of the bursts.
(4) Will not be affected by power lines in the vicinity.

(5) Can be operated with a minimum of experienced attention.
(6) Can be purchased at a minimum of expense.
(7) Can be furnished by the manufacturer without too much delay.

Before advising the purchase of any particular instrument we should like to correspond with several men whose advice we should value in this connection.

I trust that the information we have asked for in another letter mailed today can be furnished without too much trouble. We should be glad to learn your reaction to our report on the possibility of recording the bursts, and the value of their study should a seismograph be installed at Lake Shore Mine.

Sincerely yours,

R. Meldrum Stewart,
Dominion Astronomer.

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LAKE SHORE MINE,
KIRKLAND LAKE, January 14 1939.

Dr. R. Meldrum Stewart,
Dominion Astronomer,
Department of Mines and Resources,
Ottawa, Ontario.

Dear Dr. Stewart,

Referring to your letter of January 11th, I wish to confirm my statement to Dr. Hodgson that Lake Shore Mines will be glad to cooperate with your department in any way possible in connection with the recording of rock-bursts. I also wish to confirm our offer to put in a seismograph here, in accordance with what you consider to be the proper specifications.

While we hope that we shall have no more rock-bursts sufficiently intense to produce quakes that will record in Ottawa, I am under the impression that our hopes will not be realized and that as long as this mine operates there will be from time to time release in pressure which will take the form of a burst.

I appreciate the scientific value of the information that may be obtained. From results obtained in India and South Africa I do not believe that we shall be able to forecast individual

rock-bursts with the seismograph, but since settlement of the ground seems to take place in cycles it may be that the seismograph will tell us when a period of general settlement is about to take place.

As you point out, there are a number of factors to consider in the choice of an instrument, and this will no doubt take you considerable time. I shall be away in the South during the month of February and will return early in March. You will probably not be ready to proceed before that time.

Yours sincerely,

E. W. Todd
Superintendent.

APPENDIX V

MEMORANDUM OF DATA RE SEISMOGRAPH SUITABLE FOR KIRKLAND LAKE (MARCH 30, 1939)

******

Inquiries were sent to C. A. Heiland at Golden, Colo., H. E. McComb, U.S.C.G.S., Washington, D.C., L. B. Slichter, Massachusetts Institute of Technology, Cambridge, Mass., and the American Instrument Co., Washington, D.C. The following summaries give the gist of the information received:

C. A. Heiland: Seismic survey geophone recommended with electric pick-up. The items quoted are as follows:

Detector	$150.00
Permanent Magnet Frame	75.00
Electromagnet Frame	130.00
Transformer	5.00
Single Galvanometer	50.00
	$410.00

In addition one would require a camera recorder. This can be built by Heiland but the cost is not stated. Also a chronometer and a radio set would be required. The total cost of such equipment without any provision for a room in which to house it would be approximately $1,000.00. Heiland remarks: "I doubt whether a mechanical seismograph would be suitable on account of the high frequency impulse produced by a burst at close range."

H. E. McComb: Recommends a heavy Wood-Anderson seismograph, a mechanical type with optical magnification. His quotation is as follows:

Single Component W-A Seismometer	$300.00
Henson Recorder (or American Instrument Co. recorder if they will build a smaller unit)	350.00
Reed control, if commercial power is not reliable	520.00
Marine chronometers or reliable pendulum clock with circuit makers for time marks on gram	400.00
Storage batteries and chargers	100.00
Automatic radio receivers for placing time signals directly on the grams	110.00
	$1780.00

This quotation is complete except for the room accommodation. However, with a good chronometer, it is likely that the reed control could be omitted and it is possible that a cheaper drum might be available. The total cost would therefore be in the neighbourhood of $1,200.00.

Mr. McComb does not recommend the U.S.C.G.S. accelerographs.

L. B. Slichter: Does not quote the price of the complete M.I.T. three-component instruments but says they could furnish a single component for $150.00. They are planning a special camera which could run for six or seven days. He does not indicate the film speed; it is probably too slow for the purpose intended. It is likely that much time would be lost in waiting for this equipment and by the time it was all assembled the price would be comparable with those quoted above.

American Instrument Co.: No reply received. Only the price of recorder drums was requested. This company issued a catalogue, Bulletin No. 1600, February, 1932, giving details for a McComb-Romberg Seismograph and listing drums and a Seth-Thomas clock for timing. No prices are given but Instruments Ltd., Ottawa, are agents for this company. It is possible that one of their drums might slightly reduce the price quoted.

Conclusion: Having regard to the cost and to the peculiar nature of the problem it would seem that more money should be spent to obtain a good drum, chronometer, and radio equipment. Almost any seismograph of proper period and sufficiently rugged to withstand the shocks would do.

In view of the fact that Heiland could supply the entire equipment and thus guarantee the efficiency of the entire installation, it would seem advisable to purchase their equipment. The cost would thus be between $1,000 and $1,200 complete except for the housing of the installation.

APPENDIX VI

LETTER FROM MR. TODD, DECEMBER 29, 1939, PROPOSING CONTINUED RESEARCH

******

LAKE SHORE MINES LIMITED
KIRKLAND LAKE December 29, 1939.

Dr. R. Meldrum Stewart,
Dominion Astronomer,
Dominion Observatory,
Ottawa, Ontario.

Dear Doctor Stewart:

We are very appreciative of the efforts of Dr. Hodgson in connection with the excellent seismograph installation now in operation at Lake Shore. It is realized that this instrument will provide a record of rock-bursts and will be of great interest from a purely scientific point of view.

In my estimation, however, there is a real need to carry the work further, along the line of underground installation, which will offer some hope of providing practical clues to help in the understanding of the stresses set up in the rock preceding bursting. While it is realized that considerable work has been done along this line in other parts of the world, nevertheless I do believe that a first class physicist, working under the direction of Dr. Hodgson, might in time learn something of extreme practical, as well as scientific value in connection with our particular conditions. If your Department would undertake this work, I would consider Dr. Hodgson much better qualified to choose the man than we are at Lake Shore. All of the cost of the work suggested would, of course, be borne by our company.

I would point out that the question of rock-bursts will, in future, become increasingly important as more and more Canadian mines reach depths at which these phenomena are likely to occur. No real work involving the application of the principles of seismology has so far been attempted in the mines in Canada, and I believe that your Department could make a real contribution by undertaking such work at the present time.

Yours sincerely
LAKE SHORE MINES, LIMITED
E. W. Todd
Superintendent.

KIRKLAND LAKE SEISMOGRAM RECORD

December, 1939.

No.	Rec'd	On Time	On Date	Off Time	Off Date	Time Correction Value	Time Correction Amount	Bursts	Quakes	Remarks	
1	30:12	11-35 a.m.	19:12	4-16 p.m.	19:12	3	+110.^{s} :12	1	-	B,a.	H
2	"	5-00 p.m.	19:12	9-45 p.m.	19:12	0	-	-	-	G,R+.	H
3	"	9-52 p.m.	19:12	9-42 a.m.	20:12	3	+107. :22	-	-	B,F.	H
4	"	9-46 a.m.	20:12	3-31 p.m.	20:12	3	+104.5 :13	-	-	B,F,S,C.	H
5	"	4-21 p.m.	20:12	9-01 p.m.	20:12	0	-	-	-	F. Light off 5-12 to 5-25 -- no record	H
6	"	9-45 p.m.	20:12	9-44 a.m.	21:12	3	+104. :22	-	-	(F),Is,R-, Sensitivity set at 0 by mistake.	H
7	"	9-52 a.m.	21:12	11-14 a.m.	22:12	0	-	-	-	Iv,B.	H,B
8	"	-	22:12	-	23:12	-	-	-	-	Sheet destroyed. Spoiled in developing.	?
9	"	11-11 a.m.	23:12	1-04 p.m.	24:12	2	+ 88.5 :22	-	-	B,b.	R
10	"	1-09 p.m.	24:12	1-14 p.m.	25:12	0	-	-	-	S. Could not get NAA signals at noon.	R
11	"	?	25:12	?	26:12	0	-	-	-	Iw. Chronometer connection broken. No time marks.	?
12	1940	12-01 p.m.	26:12	12-35 p.m.	27:12	2	+ 81. :14	-	-	Iv. CHU signal by key. No trace Turkey quake.	B
13	5:1	12-49 p.m.	27:12	12-10 p.m.	28:12	1	+ 77. :13	3?	-	B.	B
14	"	12-46 p.m.	28:12	12-21 p.m.	29:12	1	+ 74.5 :13	-	-	G?,C,(Iv).	B
15	"	12-26 p.m.	29:12	11-38 a.m.	30:12	1	+ 70. :13	-	-	G,B,(F),(C),Is.	?
16	"	11-45 a.m.	30:12	12-23 p.m.	31:12	1	+ 67. :13	1	-	B,(C),c. Good line intensity.	?
17	"	12-30 p.m.	31:12	12-40 p.m.	1:1	1	+ 62.5 :13	1?	-	C,	R

a Well-marked burst, felt generally in Kirkland Lake, recorded at 12-53-14 a.m., January 19.

b Two sharp offsets 10-12 to 10-14 p.m., December 23.

c Small burst, reported by mine captain and registered at 9-41-45 p.m., December 30.

TABLE 1A

KIRKLAND LAKE SEISMOGRAM RECORD

January, 1940.

No.	Rec'd	On Time	On Date	Off Time	Off Date	Time Correction Value	Time Correction Amount	Bursts	Quakes	Remarks	
18	5:1	12-44 p.m.	1:1	11 a.m.ca.	2:1	1	+ 59.5 :13	-	-	Batteries ran down. Record fails after 11 a.m.	R
19	13:1	12-41 p.m.	2:1	1-02 p.m.	3:1	2	+ 51.5 :13	1?	-	S,(Iw),B,BT. Light out 3-02 to 3-55 p.m., January 2.	B
20	"	1-07 p.m.	3:1	1-16 p.m.	4:1	3	+ 46.5 :13	1?	-	(Iw),B,BT.	B
21	"	1-22 p.m.	4:1	1-05 p.m.	5:1	0	-	-	-	Clutch not completely engaged. No record.	B
22	"	1-10 p.m.	5:1	11-25 a.m.	6:1	1	+ 44.5 :14	2?	-	B,(G), Iw.	B
23	"	11-31 a.m.	6:1	1-02 p.m.	7:1	3	+ 37.5 :13	1+?	-	B,C,(G),a. Very good light-spot intensity.	?
24	"	1-06 p.m.	7:1	1-03 p.m.	8:1	3	+ 33. :13	1?	-	Is,C,B,G.	?
25	"	1-09 p.m.	8:1	1-03 p.m.	9:1	3	+ 30. :13	2?	-	(Is),B,BT. Very nice rate on clock drive.	B
26	"	1-09 p.m.	9:1	1-01 p.m.	10:1	1	+ 26.5 :13	4?	-	B,G,BT.	B
27	23:1	1-06 p.m.	10:1	1-02 p.m.	11:1	3	+ 23. :13	3?	-	B. Effective light-spot intensity.	?
28	"	1-06 p.m.	11:1	1-05 p.m.	12:1	-	-	-	-	No record. Clutch out. Breaking in new man.	B
29	"	1-09 p.m.	12:1	12-40 p.m.	13:1	1	+ 20.5 :14	1?	-	G.B.C. CHU time signal.	B
30	"	12-47 p.m.	13:1	12-32 p.m.	14:1	1	+ 17. :13	-	-	B,G,Is (corrected after 1-47 p.m.), b.	A+R
31	"	12-37 p.m.	14:1	1-02 p.m.	15:1	2	+ 10.5 :13	1?	-	Iw, (G). Second of two time comparisons used.	B
32	"	1-08 p.m.	15:1	1-03 p.m.	16:1	3	+ 7. :13	1?	-	S,Is,B,(G). Well-marked blasting. Shaft No. 4	B
33	"	1-09 p.m.	16:1	1-09 p.m.	17:1	3	+ 4. :13	1?	-	C,B,G. Bubble blank due to developing (small).	B
34	"	1-13 p.m.	17:1	1-04 p.m.	18:1	3	0 :13	1+2?	-	F,B,c. Change to 12-volt charger.	B

a Small, but well-marked, burst at 5-09-50 a.m., January 7.

b Dance and card party in the gymnasium on evening of January 13.

c Fairly well-marked burst at 10-17-43 p.m., January 17. Was "not located in the mine".

TABLE 1B

TABLE II

KIRKLAND LAKE SEISMOGRAM RECORD

****

(1) Dates are recorded as Day : Month

e.g. 19 : 12 indicates December 19.

(2) Value of the time signal is given by a number in the scale 0 - 3 with the following signification

3 - excellent; 2 - fair; 1 - doubtful; 0 - lacking altogether.

(3) Time correction + / - means clock slow / fast.

(4) Amount of time correction is given in seconds and is followed by the hour (on the 24-hour system beginning at midnight) nearest to which the correction was obtained. If the correction was obtained on the first day of the record the hour is not underlined. If it was obtained on the second day of the record it is underlined. Thus: $+110^{s}$: 13 means that the clock was found to be 110 sec. slow at 1 p.m. on the second day of the record.

(5) In the remarks column the following letters indicate comments most likely to be used repeatedly:

B - Blasting at Lake Shore.

BT, BW - Blasting at Tech Hughes / Wright Hargreaves.

C - Charging equipment resonance interference.

F - Finger marks on record.

S - Stain from developer on record.

R± - Rate of driving clock accelerated / retarded.

G - Some interference from gymnasium (badminton or dancing).

Is, Iw, Iv - Light intensity too strong / too weak / or variable (due to variations in voltage).

a, b, c, etc. - Index letters to footnotes to tabulation.

( ) - Brackets on any letter denote that the fault reported is relatively small.

B, R, H, etc. at the end of the remarks line indicate the operator whose initials appear on the record as Butterfield / Robson / Hodgson, etc.