Department of Mines and Resources
Surveys and Engineering Branch

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Dominion Observatory

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SEISMIC RESEARCH PROGRAM
ROCK BURST PROBLEM
LAKE SHORE MINES

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Report No. 9
April 15 - June 30
1941 - 1942

Ernest A. Hodgson

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Department of Mines and Resources
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OTTAWA

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Of the eight previous reports on this work, Nos. 4 and 7 dealt solely with the operation of the surface and mine seismographs from December 19, 1939 to December 31, 1941. Report No. 6 was devoted to an account of "Experiments with Rock Specimens under Pressure; May-June, 1941". No. 8 presented a study of ten rock bursts which occurred in Lake Shore Mines during the period 1938-41 and which registered at Ottawa. The others, Nos. 1, 2, 3, and 5 carried forward a general description of the work up to April 15, 1941. The present report brings that general description up to July 1, 1942.

I. Experiments with the Microgauge:

At the time reports Nos. 5 and 6 were completed, considerable time was being devoted to testing a microgauge, designed by Mr. V. E. Hollinsworth of the Observatory staff. The gauge was used at Ottawa during May and June, 1941, for testing specimen rocks sent to Ottawa from Lake Shore Mines by Mr. Robson. The results of those tests are given in Report No. 6 which brings, in part, the general account to the end of June, 1941. During that time (April 15-June 30), at Kirkland Lake, Gibbs and Hallick carried out a series of experiments with a specimen gauge left at the mine by Hollinsworth, endeavouring to stabilize the zero and to obtain data with it in the mine.

The gauge was demonstrated at the Kingston meeting of the Royal Society of Canada (May 21-22, 1941) by Hollinsworth and Gibbs. A report was also given in a short paper to the American Geophysical Union and appears on pp. 397-399 of their Transactions for 1941 (Part II).

Experimenting continued until July 6, when Hodgson and Hollinsworth arrived at Kirkland Lake for the first visit subsequent to the pressure experiments at Ottawa. Efforts to stabilize the zero of the gauge continued until the end of the month. A report on this work, presented to Mr. Stewart under date of August 18, 1941, appears as Appendix I.

During the progress of the experiments a visit was paid to the mine by Mr. Stewart, accompanied by his wife and daughter. Small bursts were occurring rather frequently at that time in the bottom section of No. 6 shaft where miners were slashing and setting the steel. Several occurred during the visit underground on July 24 of Mr Stewart and his daughter, Dorothy.

Hodgson and Hollinsworth returned to Ottawa on August 5. Experiments with the gauge, both in the mine and in the laboratory, continued until October 15 when it was decided to abandon the method and return to a study of subaudible noises or, as then planned, supersonic noises.

II. The Mine Seismograph:

This instrument was reconditioned and was moved on August 11 to a more convenient location on the 3075'-level. It is now about 120 ft. west of the junction of 3053W drift which connects with 3052 X-cut at a point about 1500 ft. north of the north vein (see Fig. 5 of Report No. 5). The set up is shown in Figs. 1 and 2 of the present report. See also p. 2 of Appendix I.

The seismometer employed is Heiland geophone No. 357. The recorder is a commercial, 5 milliampere Esterline-Angus meter. The amplifier was built by Gibbs and is equipped with the filter described in Report No. 5, p. 17 seq. Twice each day for an overall period of about five minutes a telechron clock repeatedly applies and lifts a test weight to and from the mass of the Heiland geophone by means of the device designed and built by Gibbs and described in Report No. 7, p. 3. It is illustrated in Figs. 4 and 7 of this report. (A similar testing device is used with Heiland geophone No. 331 on the surface seismograph (see section III below). Power is obtained from the AC mine electric service, wired to the location. The records are changed once a week and are analysed by Ted Andrew. (See Report No. 7).

III. Control Panel for the Surface Seismograph:

As shown in Report No. 7, considerable lost time in recording was experienced with the surface seismograph because of lamp failures. It was recommended that an automatic warning device be designed and constructed. This was done by Mr. Gibbs. The warning device and also the control for the testing equipment described in section II above were

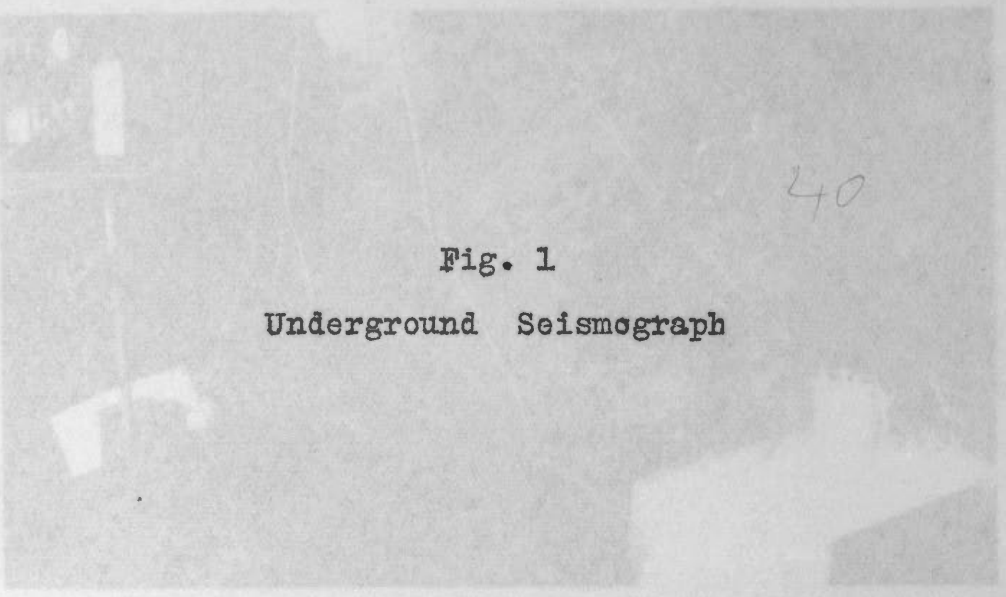

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Fig. 1

Underground Seismograph

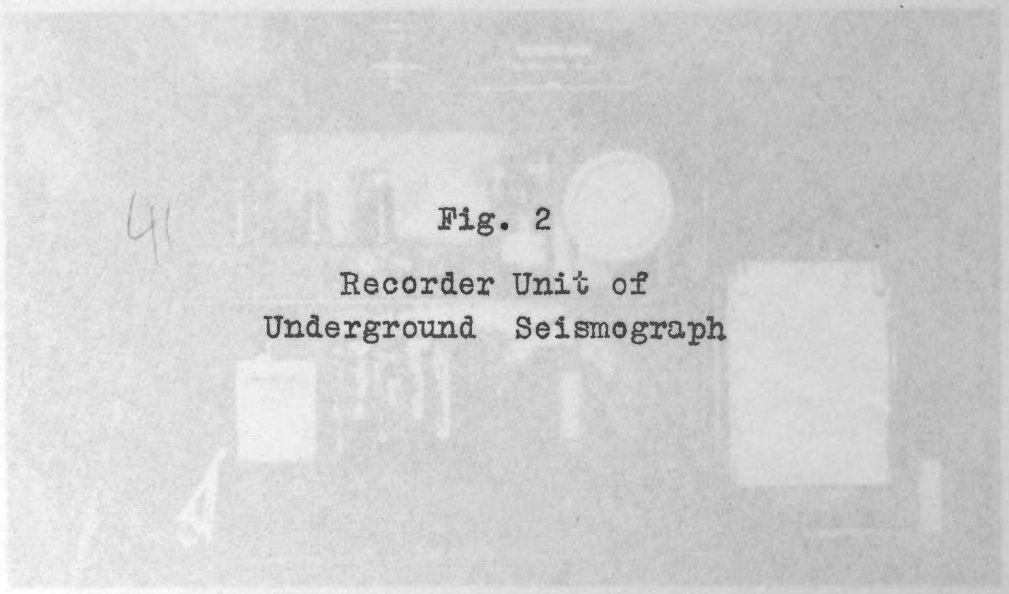

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Fig. 2

Recorder Unit of
Underground Seismograph

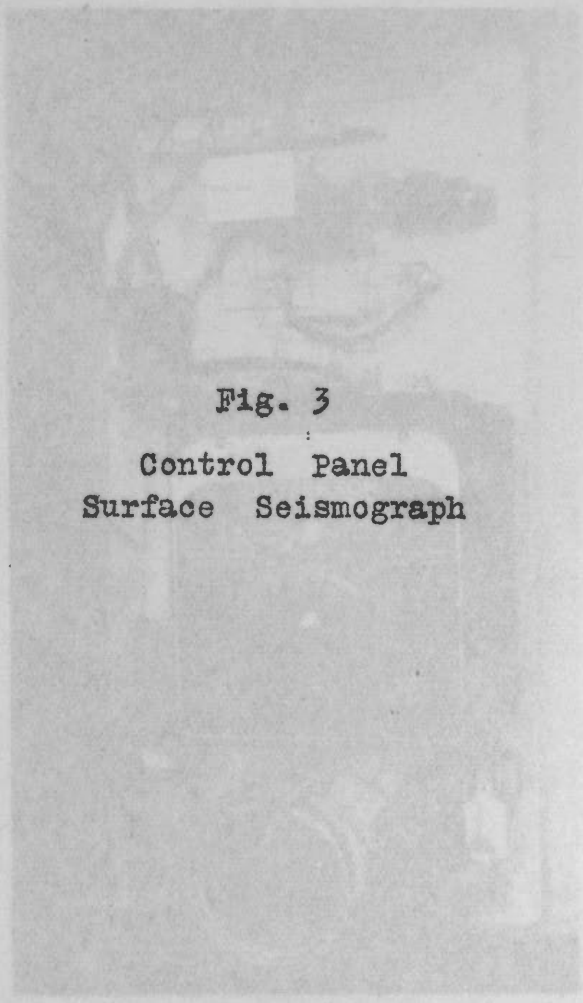
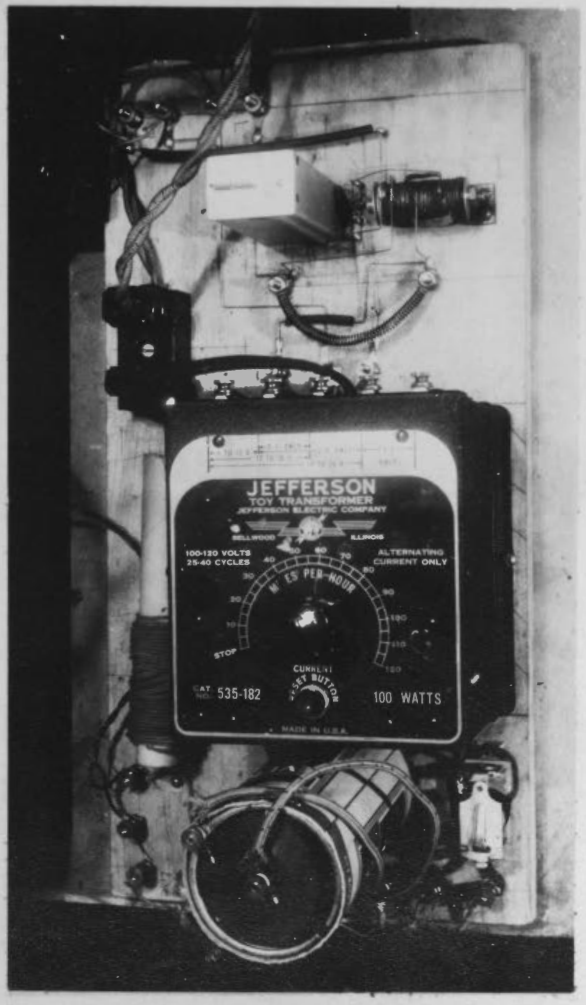
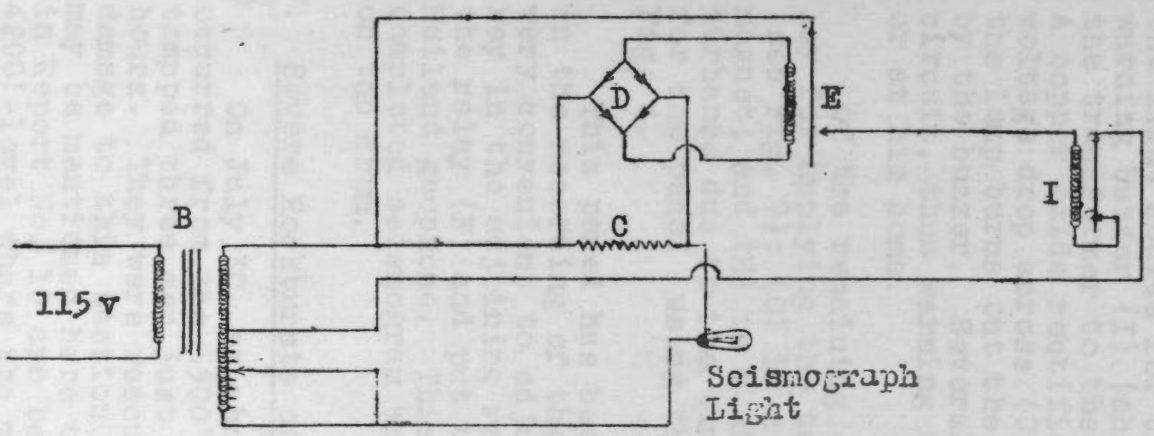
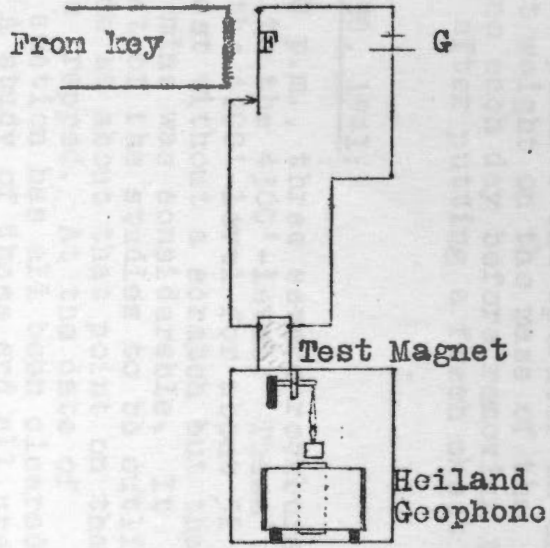


Fig. 3

Control Panel
Surface Seismograph


JEFFERSON
TOY TRANSFORMER
JEFFERSON ELECTRIC COMPANY
BELLWOOD ILLINOIS
100-120 VOLTS
25-40 CYCLES
ALTERNATING CURRENT ONLY
STOP
CURRENT RESET BUTTON
CAT. NO. 535-182
100 WATTS
MADE IN U.S.A.





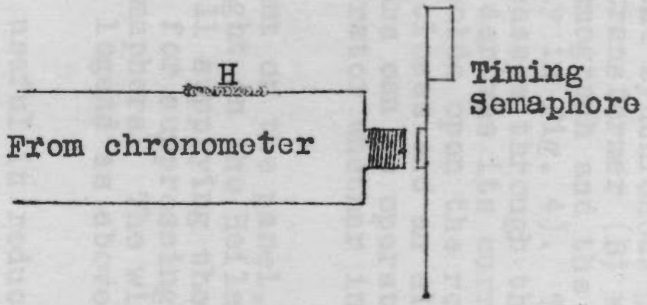


Fig. 4

Wiring of Control Panel

Surface Seismograph

mounted on a horizontal control panel on the seismograph pier. The panel is shown in Fig. 3. The 115-volt supply outlet (A) provides a power source for the synchronous motor drive of the seismograph and for the transformer (B) which supplies the light source for the seismograph and the power for the warning buzzer (I) (shown only in Fig. 4). The circuit from the transformer to the lamp passes through the resistance (C) A copper oxide rectifier (D) derives its current from the voltage drop across (C) and holds open the relay (E). If the lamp burns out the relay closes and an alarm is sounded by the buzzer. Several buzzers can be operated on the same circuit, thus warning the operator whether in the laboratory or at his home.

Of the remaining equipment on the panel, (F) is a relay for applying the test weight on the Heiland seismometer (see Fig. 7); (G) is a dry cell supplying the test weight magnet; and (H) is a RF choke for suppressing the radio disturbance due to the timing semaphore. The wiring diagram for the panel using the same legend as above appears as Fig. 4.

This panel has been most useful in reducing lost time in the recording of the surface seismograph and makes it very convenient to adjust light intensity, etc. A telegraph key in the adjoining radio room permits the operator to close the relay (F) and put the test weight on the mass of the Heiland geophone. This is done each day before removing the completed seismogram and also after putting a fresh sheet on the drum.

IV. Severe Rockbursts of July 30, 1941:

On July 30, at about 9.40 p.m., three severe rockbursts occurred from the 3900'-level to the 4300'-level. These trapped three men just above the 4200'-level for about 52 hours. They were rescued almost without a scratch but the damage to this section of the mine was considerable. It may be mentioned here that most of the studies to be outlined in Report No. 10 are being made at about that point on the 4200'-level where the men were trapped. At the date of writing (Sept. 25, 1942) this section has all been cleared up and is again being mined. A study of these and all previous rockbursts occurring in Lake Shore Mines and recorded at Ottawa is given in Report No. 8 which is being printed in the Bulletin of the Seismological Society of America (Vol. 32, No. 4) for October, 1942.

V. Study of Supersonic Vibrations:

At the time of the report to Mr. Stewart, given as Appendix I (Aug. 18, 1941), it was planned to make crystal geophones to be used as vibration pick-ups in bore holes. These were to operate through amplifiers fitted with filters to restrict the recording on Esterline-Angus meters to vibrations of supersonic order -- above the limits of audibility as well as of low intensity. The geophones and the amplifiers were constructed by Gibbs and a program of listening was begun which had just gotten under way when it was halted for a testing of the devices described in section VI below.

It is now believed that the high frequency, low intensity (supersonic) snaps probably do occur and are indicative of bursting conditions but that they could not be picked up more than two or three feet at most from their place of origin. The subaudible snaps of lower frequency, which register on the Obert equipment to be described in section VIII, travel thirty to fifty feet in many cases before being attenuated to a point where that sensitive recorder fails to pick them up. Higher frequencies would attenuate at much shorter distances.

VI. Obert Experiments:

Hodgson was in New York and Boston on business about the middle of September, 1941. While there he was able to arrange a meeting at Washington, D.C., with Dr. Leonard Obert of the U.S. Bureau of Mines who has been making a study of rockbursts in United States mines for several years. Obert has developed an instrument which records subaudible (but not supersonic) noises. These are said to indicate, by an increase in the number per minute, the imminence of a rockburst. Hodgson was so much impressed by the man and the method that he took steps to have Obert invited to try the equipment in the Frood Mine at Sudbury and at Lake Shore Mines. This was duly arranged. The visit was made to Sudbury on October 17-21 and to Kirkland Lake October 22-26. The report of the meeting of Hodgson with Obert in Washington is given in Appendix II and of the visits to Frood and Lake Shore in Appendix III.

VII. Listening Experiments:

After Obert left Lake Shore on October 26, steps were at once taken to carry through a listening program using a

geophone loaned by Obert and the amplifier (LSM-10) designed and built by Gibbs for the supersonic studies previously planned. The program was begun November 5, 1941, and continued each day (except Sundays and holidays) until June 20, 1942. At first the LSM-10 amplifier was used and later LSM-11; then, beginning May 21, the Obert recorders which had in the meantime been purchased by Lake Shore Mines as outlined in section VIII below. From time to time during the period May 21-June 20 it was necessary to use the LSM-11 due to trouble with the Obert writer coils.

Beginning November 5, listening was done on the 3825'-level, the geophone being below 3811E drift in 3906E stope and the amplifiers in the charging station on the main crosscut. These continued until May 1 when the equipment was moved to a "doghouse" on the main crosscut on the 4200'-level. During the period November 5-April 30, most of the listening was done during the afternoon blasting period 2,45 p.m. to 3.55 p.m. and nearly all by Hallick. From November 5 to November 13 Gibbs endeavoured to check Hallick's records by listening during the corresponding early morning shift. It was found, however, that this did not afford a check as, during that period, there was no early morning blasting. Gibbs then took over the afternoon listening November 26-29 and found he agreed substantially with Hallick.

From May 1 to June 20 the listening was all done during the afternoon period indicated above. Geophones were installed in several of six holes in 4201W 7. These holes were all in the south (hanging) wall, were about six feet deep and 30 feet apart. Attempts were made to record for ten minutes from each hole by means of a switch in 4201W 7 operated from the crosscut. (The holes were numbered 1 to 6. These numbers are to be retained; holes drilled subsequently for this work will be numbered consecutively.) The switch gave some trouble due to leaks on the control line; but so far as could be judged, hole 4 (or H4 as it will be designated hereafter) seemed to be the most active.

Beginning May 21 Obert recorders were used whenever possible but the writer coils burned out one after another so the LSM-11 was used for listening when the recorders were not available. The program continued until June 20. Hodgson arrived at Kirkland Lake on June 17, - his first visit since October 26, 1941. The writer coils of the Obert recorders were then all out of commission as well as

some of the six replacement coils Obert had furnished.

It was decided to discontinue the listening program on June 20 and to concentrate on getting new coils made and the Obert equipment operating as soon as possible. This was accomplished by June 30 when a regular program with the Obert recorders was begun in a doghouse constructed on the 4200'-level in 4201W 7. This doghouse was supplied with the AC mine electric service which was specially wired out to this point, some 700 feet west of the main crosscut.

A brief analysis of the listening program November 5, 1941-June 20, 1942 is given in Appendix V.

VIII. Purchase of Obert Recorders:

At the time Obert left Lake Shore (October 26, 1941) it was agreed that steps would be taken to arrange for the purchase of three complete sets. There were many difficulties. Obert had to obtain permission to have these made and to sell them, and priorities (Canadian and U.S.) had to be obtained for the materials and equipment required. By January 1, 1942, negotiations had reached the point where lack of priorities alone was holding up the program. The matter was referred to Ottawa and through the cooperation of the Department of Mines and Resources the details were laid before Mr. A. A. Walker, Assistant Director General of Priorities. It was stressed that the amount of material required was small, most of the cost ($1,000 per set) being chargeable to labour, that the opportunity for research was exceptionally good at a time when the mine was running with one shift only, and that the results of the experiments, if successful, would be of value in predicting rockbursts in the base metal mines. Full details regarding the instruments were supplied. A copy of the specifications appears as Appendix IV.

Mr. Walker arranged for the Canadian priorities about January 30 and took the papers to Washington with him on a trip which he was making at that time. The Washington priorities (A3) were granted on or about February 16 and the three complete sets completed and delivered to Lake Shore Mines on May 20. They were at once put in service and found very satisfactory except for the burning out of the writer coils - a difficulty which Obert experienced also with his own newly constructed sets and which at first was attributed to the chemical nature of the paper cores on which

they were wound. It was later found that if the air about the instruments could be kept quite dry the coils did not give further trouble. It required considerable experimenting before this was realized.

As indicated in the specifications given in Appendix IV, a complete set consists of three units which may be called (A), (B), and (C). (A) is the three-stage amplifier and attenuator, (B) is a limiting or logarithmic amplifier, and (C) the recorder proper. These are shown in the illustrations as follows: Fig. 5, a side view of a recorder or (C) unit; Fig. 6, another view of the same unit; Fig. 9, one of the alnico magnets of a (C) unit with its troublesome writer coil and part of the writing stylus; Fig. 10, the interior construction of the power pack and logarithmic amplifier or (B) unit; Fig. 11, the interior of the three-stage amplifier and attenuator; and Fig. 8, two complete sets in service underground, each set in order from left to right being units (A), (B), and C).

In Fig. 8, attention is drawn to the base of a lamp socket about the centre of the bottom of each (C) unit, the lamp being away from the observer. These lamps (50 watt mine bulbs) were found sufficient to dry the air about the coils to a point where they did not burn out. The method was first tried out by Hallick and found so successful that all units were so equipped.

In the top left hand corner of unit (A) (see Fig. 8) the input geophone cable is plugged by means of an amphenol connector. The dial shows the degree of attenuation in decibels. To the left of the connectors in the lower right hand corner two switches control the two high pass filters. The upper switch controls a 2500-cycle and the lower a 7500-cycle filter, either of which can be cut in. The sockets for plugging in earphones are to the left of the filter switches. All connections except phones are of the amphenol type.

On the front panel of unit (B) (see Fig. 8) there are, in order: a pilot lamp to show when the set is on or off; a switch for turning the set on; and a testing switch which enables the operator to determine whether the styli are operating properly (see item c of Unit No. 1, i.e. (A), in Appendix IV).

The recorder (C) (see Figs. 5 and 6) has two alnico magnets (as shown also in Fig. 9) each with writer coil and

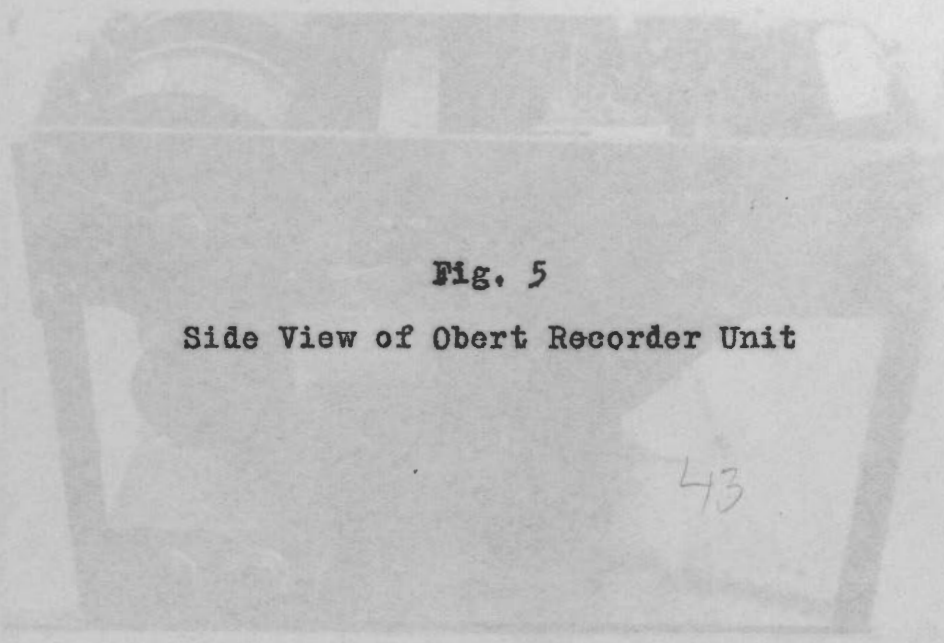


Fig. 5

Side View of Obert Recorder Unit

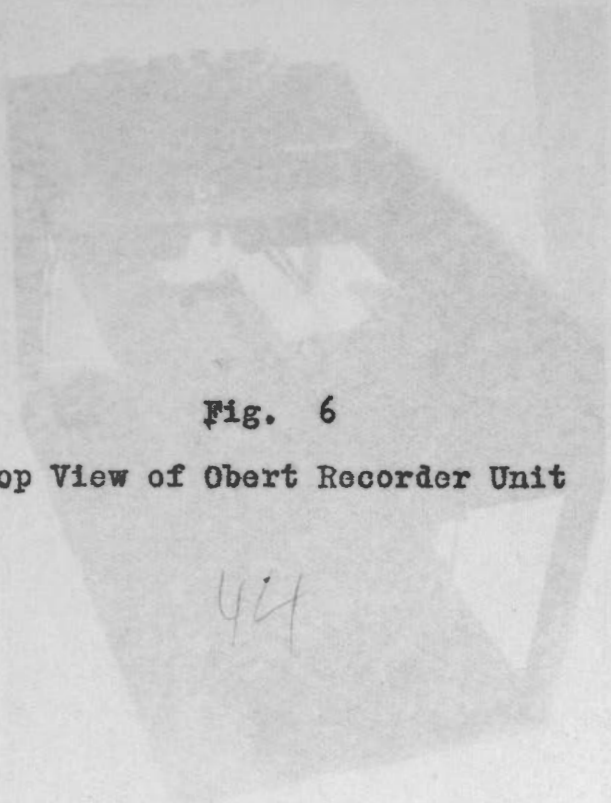


Fig. 6

Top View of Obert Recorder Unit

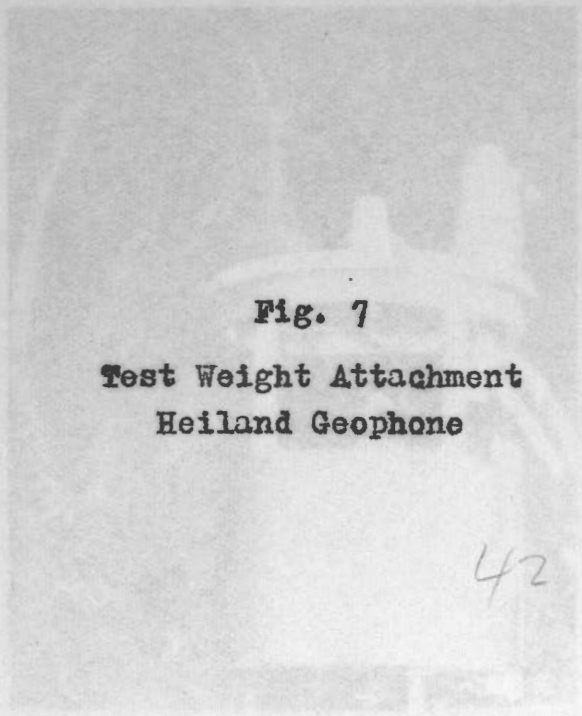
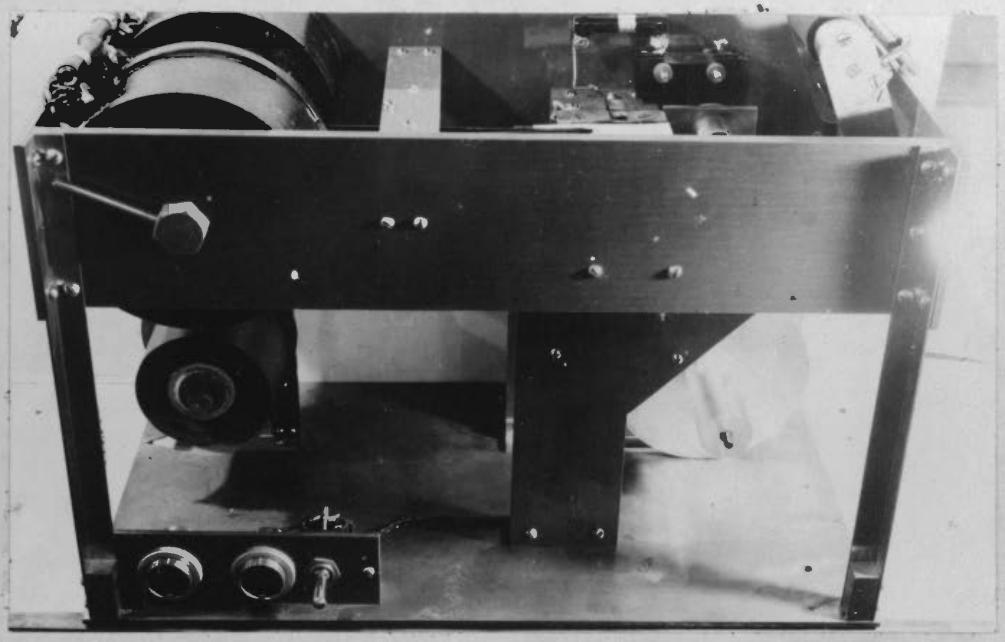


Fig. 7

Test Weight Attachment
Heiland Geophone



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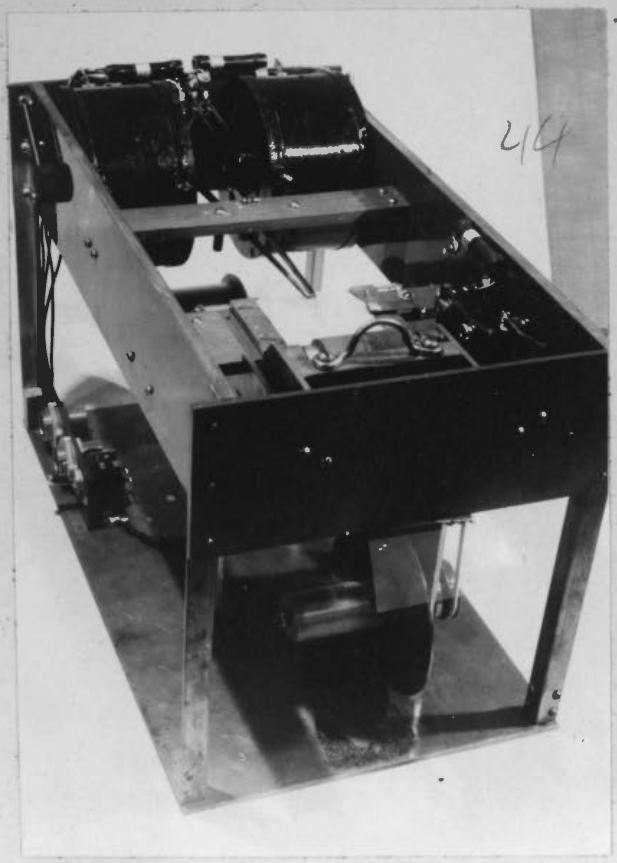

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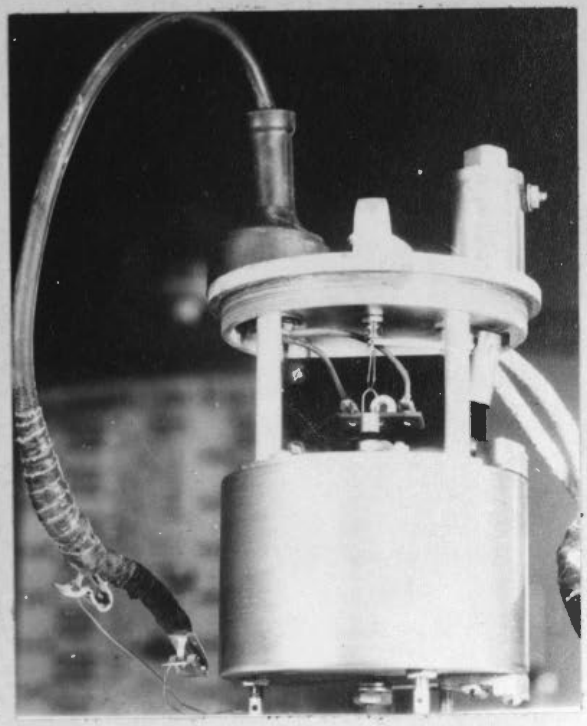

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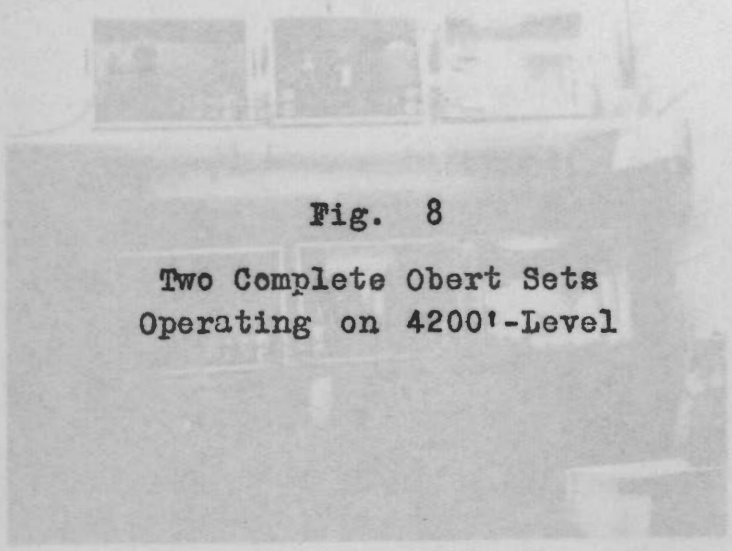


Fig. 8

Two Complete Obert Sets
Operating on 4200'-Level

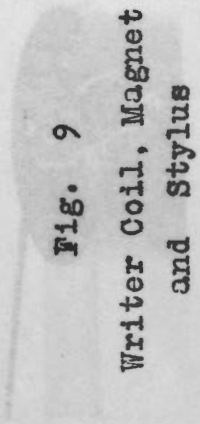


Fig. 9

Writer Coil, Magnet
and Stylus

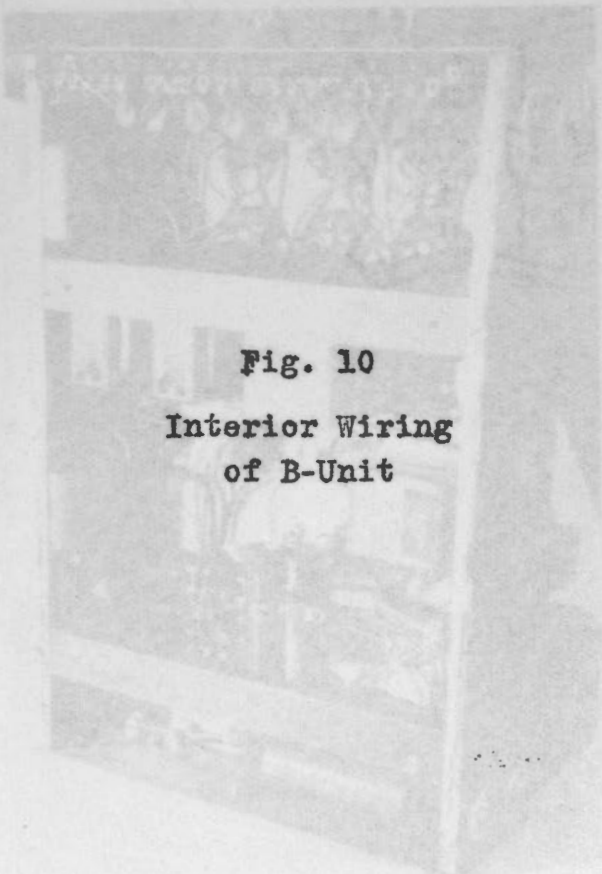


Fig. 10

Interior Wiring
of B-Unit

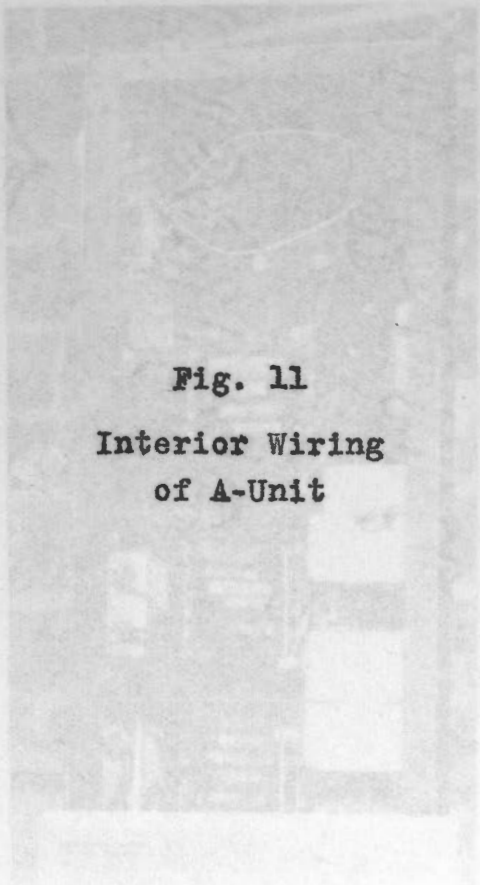
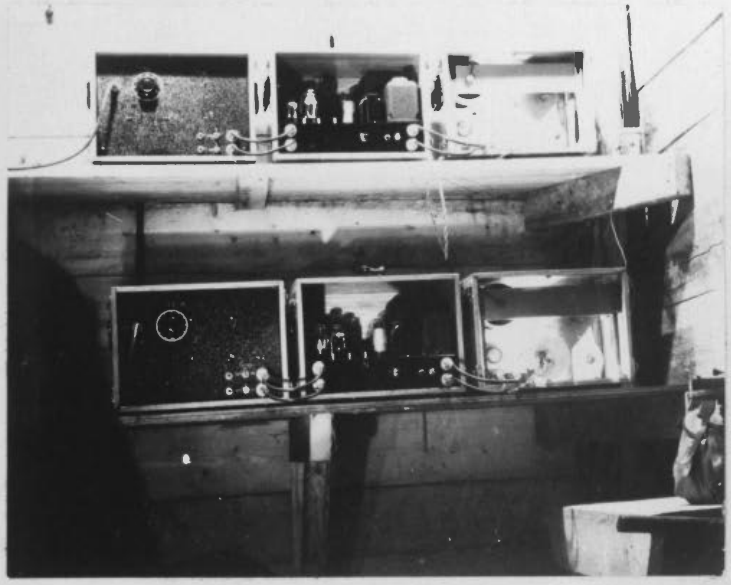
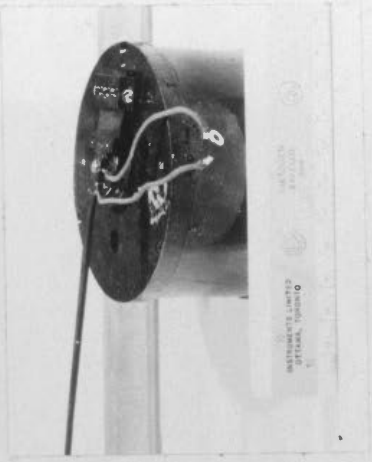
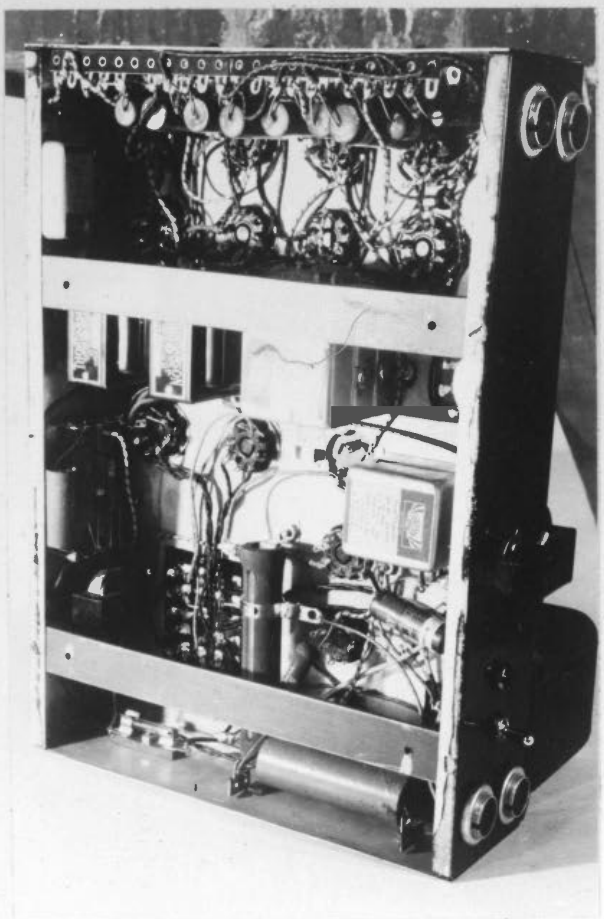


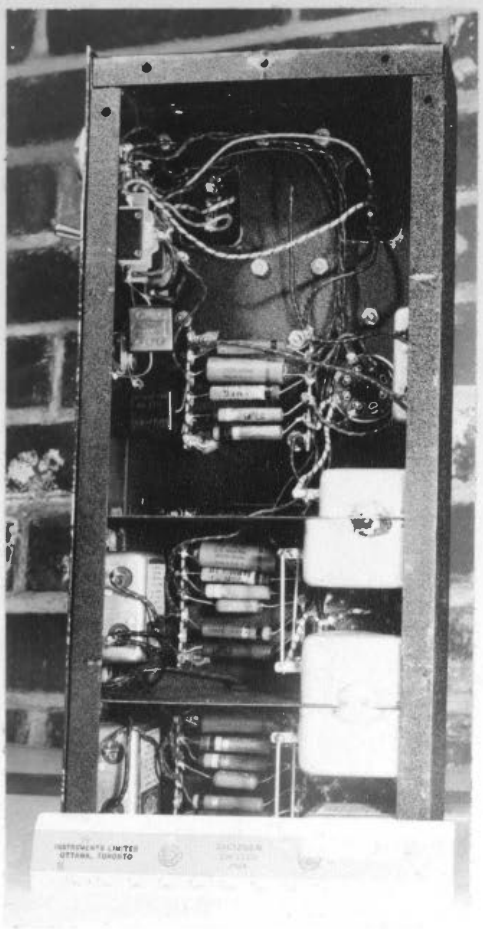
Fig. 11

Interior Wiring
of A-Unit









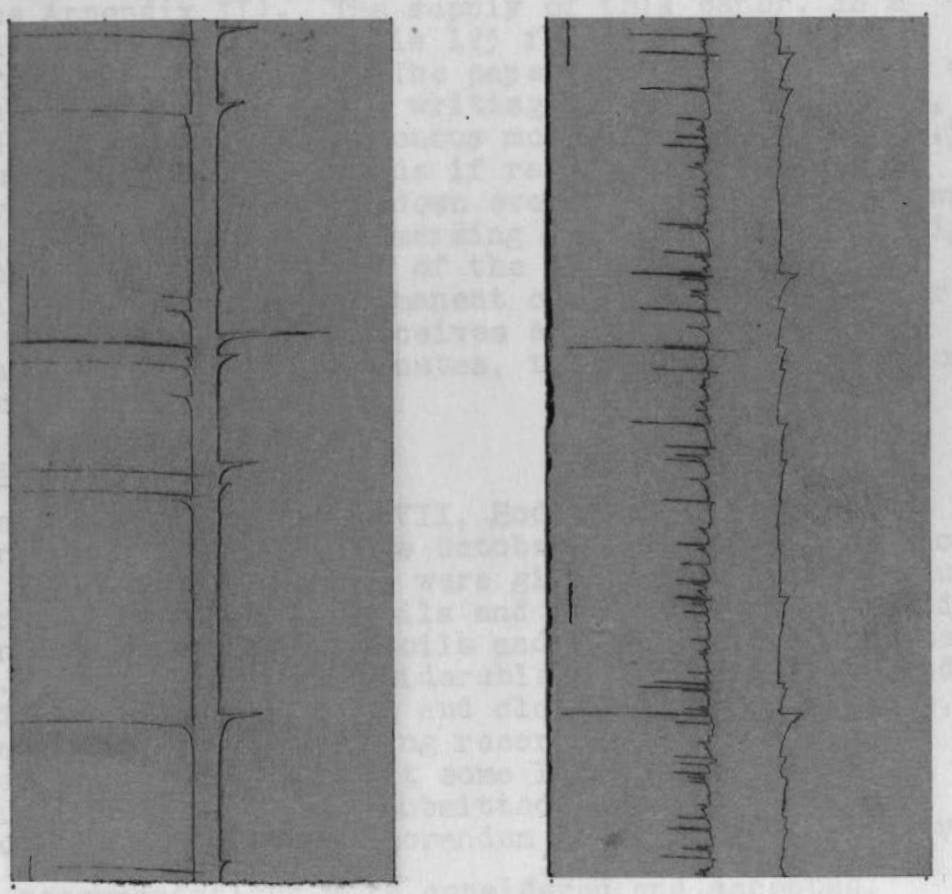


Fig. 12

Samples of Actual Records made in Lake Shore Mines on Obert Recorders using Teledeltos Paper and showing Moderately Active Conditions (left) and Acutely Active Conditions (right)

stylus. These record by means of a small current (about 7 milliamperes at about 150 volts) on a strip of Teledeltos paper (see Appendix II). The supply of this paper, in a roll 2 in. wide (a full roll is 125 ft. long) is shown in the central left of Fig. 5. The paper passes up and over a brass contact plate under the writing points of the styli, is pulled forward by a synchronous motor at the rate of 1.5 in. per min (or at other speeds if required by means of gears furnished), and thence down over a take-up drum shown in the right centre. A time-marking device is shown in Fig. 6 just above and to the right of the handle on the upper feed roller. A stylus in permanent contact with the paper near one edge of the paper receives a writing voltage for about ten seconds each two minutes, tracing a short dash on the record (see Fig. 12).

IX. Initiation of New Program:

As mentioned in section VII, Hodgson visited Lake Shore for the first time since October 26 arriving there on June 17. The Obert recorders were giving difficulty because of failures of the writing coils and Gibbs and Hallick had their hands full making new coils and getting the instruments in order. Hodgson spent considerable time underground and in a study of the maps (plans and elevations) of the mine, and in going over the listening records previously made. The situation was discussed at some length and finally a memorandum was prepared and submitted on June 26 to Mr. Blomfield. A copy of the memorandum appears as Appendix VI.

The recommendations were considered and accepted. Later Mr. Blomfield asked Hodgson to accept the responsibility for developing and carrying through the underground program, leaving Gibbs free to deal with the heavy and complex instrumental problems. Hallick was assigned to assist both. Arrangements were made with the Department of Mines and Resources to permit Hodgson to take over this responsibility and the new program began as of July 1, 1942.

Dominion Observatory,
Ottawa, Canada,
September 26, 1942.

A P P E N D I X I

Ottawa, August 18, 1941.

Memorandum:-

R. Meldrum Stewart
Dominion Astronomer

Report re Trip to Kirkland Lake, July 5 - August 5, 1941

The writer, accompanied by Mr. V. E. Hollinsworth, drove to Kirkland Lake, July 5-6, 1941, and returned August 5-6. The following report covers briefly the progress recently made in the research at Lake Shore Mines, lists the recommendations made to Mr. Blomfield at the close of the visit, and indicates the action taken with respect to these recommendations.*

1. Preliminary Mine Experiments with the Microgauge:

After three weeks spent in building and testing auxiliary equipment for use with the 25-cycle power supply of the mine, the microgauge was installed on Monday, July 28, in a bore hole at the back of the safety station at the extreme south end of the main cross cut on the 4200'-level. It showed some variation during the first three days which would seem to indicate that pressure was lessening in the azimuth of the bore hole crossed by the gauge.

The heavy triple burst occurred on Wednesday evening while the gauge itself was temporarily replaced by a reference standard designed to check the stability of the apparatus. This device had just been installed when the burst occurred. The next morning the gauge was again placed in operation. Both the check record and the gauge record on Thursday (and since to date) show that the drift of Wednesday has disappeared.

It is possible that the gauge movement--present prior to the burst and absent afterwards--may have been due to temperature effects which had become equalized by Thursday.

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* Sections 1-5 inclusive are taken directly from the report made to Mr. Blomfield on August 4 and refer to conditions as of that date.

With the short experience to date, it is impossible to say definitely.

The gauge has been run continuously since Thursday morning and shows no variation in pressure. It is known that the equipment is in good operating condition, but the only azimuth which can be checked with the single gauge does not present a complete picture of conditions.

2. Velocity Determinations:

Data obtained from Ottawa by telegraph indicate that the first burst and the last recorded, the first for twenty-four seconds, the last for forty seconds. The duration of the record at Ottawa is a rough indication of the relative intensities of the two bursts. The corrected time of occurrence of each as given below was obtained from the records of the surface seismograph at Kirkland Lake. The arrival times, given by Ottawa, are subject to slight correction when repeated scaling is done on the dry records.

Times of Occurrence	Arrival Times
$9^h\ 39^m\ 01^s$	$9^h\ 41^m\ 01^s$
9 39 09	- -- --
9 46 17	9 48 19

It thus appears that the time of transmission for the 279 miles in direct line from Lake Shore to Ottawa was about two minutes flat, the estimate being liable to correction by possibly one or two seconds when the more accurate scaling has been done on the Ottawa charts.

3. Mine Seismograph:

The mine seismograph is being moved from the extreme north end of the 3052 X-cut to a point about 120' in on the 3053W drift. It is proposed to operate it at this point for at least a year under standard conditions.

As a check on the operation, this seismograph (and also the surface instrument) is being fitted with a testing device. This is being designed and installed by Gibbs. When in operation, it will be possible to place a standard deflection on the record by simply throwing a switch on changing the charts. So long as this deflection is of standard length, it may be taken as an indication that the

entire equipment is in proper operating condition.

4. Supersonic Equipment:

All the auxiliary equipment required for this work has been completed. The mountings for the pickup crystals are being designed and built by Gibbs. When assembled, the crystals can be installed in a 1.5 in. bore hole. The crystals will be made and mounted by the Brush Development Co. of Cleveland, Ohio. When they are received, the supersonic experiments in the mine may begin at once.

5. Recommendations:

It is recommended that:

(a) The mine seismograph be operated continuously under standard checked conditions in 3053W drift and that the records continue to be correlated with those of the surface seismograph as has been done in the past.

(b) The experimental microgauge be continued in operation on the 4200'-level for at least six weeks.

(c) The microgauge be re-designed to check two azimuths mutually at right angles.

(d) Three gauge units (double azimuth) be assembled after the general pattern of the present experimental model now in operation. These should be designed for individual operation at any selected stations. It will be necessary to provide electric power (110 volt lighting circuit) at each station.

(e) The supersonic equipment be operated in the same bore hole with one of the three newly designed double gauges.

(f) The hydraulic gauge be repaired and re-installed in 3001W 8 as soon as possible, preferably as a self-recording device if that can be arranged.

6. Action Taken with Respect to Recommendations:

The recommendations were approved by Mr. Blomfield, who gave authorization for the purchase at once of all necessary equipment and urged that the gauges be constructed and placed in operation at the earliest moment consistent with efficient

construction.

Telegrams were at once despatched asking for quotations and delivery dates on the units required. As these could not be obtained at once the approximate cost quoted to Mr. Blomfield was a thousand dollars ($1,000) for each gauge. This cost is made necessary by the requirement, in the case of these experimental units, of making each complete in itself and capable of being placed independently of the others. The cost of the program immediately planned will be about five thousand dollars ($5,000) for the equipment alone. This will permit investigations to proceed at four points in the mine and also provide equipment for experimenting in the laboratory on improvements to the gauge.

At the date of this memorandum, the testing devices for the mine seismograph and the surface seismograph have been completed by Mr. Gibbs. The mine seismograph was placed in operation in 3053W drift on August 11.

The hydraulic strain gauge has been repaired - (It was broken by a burst in April last) and is being replaced in operation in 3001W 8 drift. It is proposed to make an automatic recording device for this gauge which can operate at a distance from the gauge and thus preserve a continuous record in case of a burst. The ground in 3001W 8 is badly strained and bursts occur there from time to time.

Mr. Gibbs has gone to Toronto to interview manufacturers with a view to having equipment delivered as soon as possible and to arranging that some of the construction of the gauges proper can be done commercially. The new, double, gauges are being designed by Mr. Hollinsworth and by Mr. Bird who will do most of the construction work on them.

Mr. Hollinsworth and Mr. Gibbs are trying to arrange a magneto for generating the AC necessary for use on the gauge bridge, thus making the record more free from variations due to the present power source. They are also trying to locate small motor-generator sets for supplying AC for the amplifiers, which are also affected by line voltage variations. If either or both of the modifications can be effected without too much delay, they will be used instead of the present stabilizing equipment. If not, the present type of equipment will serve for the initial investigations.

Some variations in the gauge record on 4200'-level have been reported recently from Lake Shore. These occur

at the blasting period (but not necessarily with the actual individual blasts). They are being checked to determine whether they may possibly be due to variations other than strains in the rock. It has been shown that they are not due to change in temperature or to line voltage fluctuations.

Respectfully submitted,

Ernest A. Hodgson,
Seismologist.

EAH/GMcD.

APPENDIX II

Memorandum: Conversations with Obert
Washington, September 24-25, 1941

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1. Recording Paper: The seismic equipment designed and operated by Obert uses a recording paper developed, manufactured and supplied by Western Union. It is known as "Teledeltos".

This paper has a three-layered structure. The layer next the metal drum is aluminum coloured and is probably a special conducting material. The middle layer is black and looks like asphalted roofing felt. The face layer is a bluish-white, smooth-surfaced paper, quite thin and hard. Recording is done by means of a stylus carrying a current of about 7 milliamperes at 180 to 200 volts.

The stylus is able to record clear cut lines at frequencies as great as 10 cycles per second. At a paper speed of two inches per minute, the close writing of the stylus does not confuse the record as does halation in photographic paper and blotting in the case of ink recorders.

The paper was developed by Western Union for use on their facsimile transmission work but is now manufactured and sold commercially. It comes in two grades "high" and "low" impedance. Just what these impedances are was not learned. The Western Union uses high impedance for their own work but low impedance is generally preferred for other recording. Obert uses low impedance paper exclusively.

The paper is manufactured in sheets 125' long by 30" wide. It can be supplied cut into rolls 125' long and any desired width down to half an inch. As used by Obert, the rolls are 2" wide and cost about 50¢ per roll. Care must be taken to prevent the paper feed from failing, leaving the stylus too long on one spot. This sometimes ignites the paper which burns slowly as does punk. It is not a fire hazard, except in so far as it damages the stylus and the drum.

The advantages for its use are the clear cut lines, low friction with the writing stylus, relatively low price,

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NOTE:- The text of this memorandum has been amended to include changes suggested by Dr. Obert after receiving a copy of the original draft.

no development delays, ease of handling in the light, reasonably good permanency when handled, and convenience of being able to see the results of tests and adjustments as they are being made.

The literature, price lists, etc. may be obtained by writing to: Mr. F. E. d'Humy,
Vice President in Charge Engineering,
Western Union Telegraph Co.,
60 Hudson St., New York, N.Y., U.S.A.

2. Pick-up Device: Obert uses the piezo-electric effect in his pick-up devices. These consist of Rochelle salt crystals in the usual two layer build up: two slabs of crystal separated by a conducting leaf at one potential and with connected outside conducting leaves at the other potential. The whole is built into a crystal 2.5" long, .75" wide, .25" thick. The natural frequency of the crystals is 800-900 cycles per second. The crystal is mounted "spring-board fashion" in a heavy metal cylinder.

The rounded ends of this cylinder screw into place. One end has an outlet for the electric cable. The gasket for this is designed to exclude moisture and has been markedly efficient. The whole pick-up cylinder is 7" long and a little more than 1" in diameter. It is simply laid in a drill hole. For this reason the drill holes must be blown dry and clean with compressed air. Some of the pick-up units are weighted with lead but this is not generally done. It is sometimes helpful.

The pick-ups are made in the Bureau of Mines workshop. Including the price of the crystal, they cost about $6. to $8. each for parts, exclusive of labour. This is in marked contrast to our seismic pick-ups which cost $150. in U.S. funds and over $200. laid down here.

3. Recording System: For recording, Obert uses an amplifier, filters and recorder made up at the Bureau. The recording device consists of a writer coil operating a steel stylus. This is something akin to the recording device made by Hollinsworth but in Obert's recorder the writer coil is designed to obtain high impedance. The output current from the amplifier is rectified. The amplifier is practically flat gain for the range 50 to 10,000 cycles but the system is peaked slightly by the natural frequency of the crystal pick-up.

Two recording devices are used to register the impulses from the same geophone. One operates through an integrating device which has an integrating time of a tenth of a second and will here be referred to as the A recorder. The other operates through an integrating device with an integrating time of one second and will here be referred to as the B recorder. A and B register side-by-side on the same recorder strip.

In effect, the A recorder indicates the amplitude of the maximum throw or voltage variation of a wave train, while B records the integrated energy. It is thus possible to determine from the dual record whether an impulse was from a nearby small pulse with a wide amplitude but small train or originated as a more severe shock at a greater distance which has a lower initial amplitude and a longer train. By comparing the double record from instruments at various points in the mine and also the reports from the miners, it is possible to determine approximately where all the larger pulses originate. This work of reduction and analysis is tedious and time consuming but it is done systematically and regularly and is, according to Obert, very informative.

4. Characteristics of the Mine: In the mine where most of their recent work has been done (Ahmeek Mine of the Calumet and Hecla Co. at Ahmeek in Michigan) blasting is almost entirely confined to fifteen minutes twice a day. Accordingly, the recording devices are shut off when blasting is about to begin and turned on again when it is over. The observers are thus not hampered by frequent blasting as experienced in Lake Shore Mine. All blasts set off at times other than the regular blasting cycle are reported to Obert with details as to amount of powder used and exact location in the mine and stope.

This particular mine operates only on three levels at a time, working forward, at staggered positions, three sets of stopes on each side of the shaft pillar and out to the respective boundaries. Speed of operation is relied on to keep ahead of bursting conditions. No large bursts are experienced. Small bursts occur in cycles. Injuries are suffered from time to time but, so far as known, no fatal accidents due to bursts.

Obert has found, for the single mine in which most of his work of this type has been done, that when the detected noises for the vicinity of any given pick-up become numerous -

sometimes 200-300 per ten minute interval - a burst occurs in that part of the mine within 24 hours. It is to be noted that the "noises" are quite inaudible and would pass unnoticed except as picked up with the seismic equipment. The noises are always more active for a short time after the blasting cycle.

The above occurrence pattern for mine noises is quite the opposite of what had been expected. It was thought that the frequent releases of pressure, shown by the recorded noises, would preclude the possibility of a build-up of pressure and that one should expect a burst only after a period of quiescence. Obert offers the possible explanation that the frequent noises indicate a general increase of pressure with slight releases along some of the fault faces, leading to a building up of pressure to bursting value on one or more of the blocks. This seems a reasonable explanation in view of the different occasions in which a burst has been found to follow a period of marked unrest.

This law of greater activity preceding bursts is tentatively supported by the initial plotting at Lake Shore Mines of the integrated burst activity. The larger bursts seem to fall on or near the peaks of activity. However, there has not been, as yet, a sufficient accumulation of data with equipment under uniform conditions to permit of generalization.

In testing the equipment in various parts of different mines, Obert comes to the tentative conclusion that bursts are more frequent in places where the dip is least. Steeply dipping veins do not seem to be associated with bursts. It will be interesting to see if this rule follows in Lake Shore where the dip of the veins changes somewhat with depth.

5. Characteristics of the Recording: The equipment used by Obert is much more sensitive than that used in Lake Shore Mine. This is possible because there are no blasts to disturb it. The blows of a one pound hammer on the wall of a drift 1000' distant give offsets of about 1/8" on the record. This method is used as a rough test of sensitivity.

The chief source of disturbance for their set-up is the rock drill. The drill disturbs Lake Shore equipment almost not at all. The reason is that the disturbance set up by a drill (and also, according to Obert, by ore chutes) is of high frequency, of the order of 1000 cycles per second.

Lake Shore equipment is more sensitive to frequencies about 100 cycles or less.

To eliminate the rock drill disturbance, a series of filters is used. Some records were examined in which, under like conditions except for changes in the filter, markedly different degrees of interference were recorded. It is quite a simple matter to test out the effect of various filters in a few minutes when using the Teledeltos paper. Filters are a help but will not eliminate all drilling noise.

6. Observations on Frequency: According to Obert, impact on an elastic body causes the generation of a wide spectrum of frequencies. If these be plotted, for various sources of disturbance, it will be found that the peak of the spectrum curve occurs at characteristic positions along the frequency abscissa. He is in agreement with the work done at Lake Shore which shows that blasts generate lower frequencies than do bursts but would modify the conception.

He believes that the blast and burst spectra have peaks at different frequencies but that each generates some amplitude at all frequencies. Moreover, the waves damp out in the rock at distances which vary with the frequencies. He believes that the noises with which he is working carry only twenty feet or less, and that, when he is studying the noise occurrence pattern for any pick-up, his attention is thus directed for the most part to only a small section within 20' of his equipment.

As is obvious, the amplitude of the record made by any set of equipment depends then on a variety of factors:

(1) The energy released in the various frequencies, i.e. the initial spectrum curve.

(2) The filter system employed which cuts down the intensities of certain frequencies.

(3) The gain factor of the amplifiers for various frequencies.

(4) The resonance characteristics of the pick-up and the recording mechanisms for various frequencies.

(5) The distance from source to recorder which causes higher frequencies to damp out more than the lower ones, i.e. the spectrum at the recorder.

(6) The path between source and recorder which tends to be better in some parts of a mine than in others.

Obert is of the opinion that increasing pressure probably generates "noises" at frequencies as high as 15,000 cycles per second, that equipment can be designed to pick them up and amplify them sufficiently to record, and that other noises can be filtered out. But, he believes that noises at that frequency could not carry more than two or three inches (or as many feet, at most) and that equipment so designed would obtain data from such a small volume of rock that one could not expect to learn much from the occurrence pattern. He advises the use of Y-cut quartz crystals for such work, if we decide to go on with it, as such crystals are not affected by moisture.

7. The Direct Approach to the Problem: With the experience so far gained, it has been possible to compile a good deal of information regarding mine noises, which might serve as a warning of approaching bursts. If one wishes to design the optimum in such equipment, the effect of the various factors given in Section 6 must be known in detail. In particular the frequencies generated by impacts of various types and the variation of the damping factor with frequency must be determined.

It is necessary, then, to determine the spectrum of frequencies due to impact both at the source and at various distances from that source. The variation of the damping factor with frequency must be determined for different mines and for many paths through those mines. With such information at hand, the other factors may be chosen to give optimum recording for any desired frequency.

Records will then have to be obtained in any given mine at various frequencies with optimum response characteristics in order to determine for which choice of frequency one obtains the most definite warning that a burst is impending. Obert believes that this frequency will be found close to the 1000 cycles which he has been using, but he is obtaining equipment (General Radio Sound Analyser) which will permit him to determine the frequency spectra and the damping factors.

8. Alternative Means: Obert has done considerable work in determining the elastic constants of rocks under pressure both in the laboratory and in the mine. He has found, as has Birch and others, that the velocity curve flattens markedly

after pressures definitely below bursting values have been reached. It cannot be used therefore as a means of predicting bursts but it is a useful method of determining what the pressures are in residual pillars which contain so much ore that it is desirable to take the load on artificially constructed supports prior to the removal of the native pillars.

He has developed equipment by means of which he determines the elastic constants by the vibration method used by Birch and thereby is enabled to calculate seismic velocities. He has also constructed a high speed camera so that he is able to measure velocities directly in the mine over very short paths - 1000' or less. This requires high timing accuracy. He claims to be able to measure elapsed time to .001 sec. with an accuracy of 1 per cent.

In carrying out the direct measures of seismic velocity Obert found that the electric surge due to the blasting current could be picked up by means of a short length of wire laid in the drift at the recording point a thousand feet and more away. On the basis of his experience he offers a tentative explanation of the high frequency disturbances preceding the blast frequencies as shown in Figs. 12c, 12d, and 12e, Report No. 5 of Rock Burst series. He suggests that this is due to the surge caused by the blasting current carried by the rock of the mine and picked up by the seismometers as electric currents. This does not seem likely, as the mines in which he was working are copper mines where the rock is highly conductive while the rocks at Lake Shore are by no means such good conductors.

This work on velocity determinations by both methods is useful commercially where residual pillars are to be replaced but it is also of scientific interest as throwing light on the differences of seismic velocity as measured by Leet in the field compared with velocities as computed by Birch from vibration measures of the elastic constants of rock specimens. Birch found velocities higher than Leet was able to detect in the field. This discrepancy is being lessened as more sensitive seismic equipment is being used by Leet. There is a good agreement in the two methods as used by Obert but his detectors are sensitive to much higher frequencies than are those used by Leet.

Obert would like to secure some sections of rock from deep workings of Lake Shore Mines for use in his experiments

along this line. This may be done when he comes up to Kirkland Lake for the experiments now being arranged.

Dominion Observatory,
Ottawa, Canada,
October 6, 1941.

Ernest A. Hodgson.

APPENDIX III

Memorandum of Experiments by L. A. Obert at Frood and Lake Shore

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By pre-arrangement, the writer, accompanied by V. E. Hollinsworth, drove to Sudbury on Friday, October 17, to meet Obert who was expected Saturday. On Saturday morning a visit was paid to the office of the International Nickel Co. at Copper Cliff, where contact was made with H. R. Elves, Assistant Geologist, and, later with R. D. Parker, General Superintendent, Mining and Smelting Division.

At noon, a luncheon was attended at the Copper Cliff Club with Parker as host to the Chief Mining Inspector for Ontario, Wm. Tower, and his assistants for the entire province. The group were inspecting several mines for the purpose of becoming acquainted with rock burst conditions.

Obert, accompanied by Mrs. Obert, reached Sudbury in the late afternoon of Saturday and arrangements were made for a visit early Sunday morning to Creighton mine -- one of the Inco group, about seven miles southwest of Copper Cliff. Frood mine had been quiet for some time and it was felt that the experiments could better be tried at Creighton.

The visit to this mine took up the entire morning of Sunday. The party going underground consisted of A. B. Yates, Chief Geologist, Elves, Obert, Hollinsworth and Hodgson. The initial shaft leading into this mine was inclined, so the designating numbers of the levels do not indicate the depth. The party went down a vertical shaft to a depth of about 4000'. Observations were confined to a single level.

Obert did not bring his recorders with him, so observations consisted simply in placing the pick-up in the drill hole, plugging the open end of the hole with rags to minimize air borne vibrations, and connecting with the amplifier and head sets.

Although observations were continued without interruption until about one o'clock, there was never a moment when drilling stopped. Change of shift is effected without stopping work in the mine. One rock drill or another was always in operation so that, at no time, could the gain be turned up sufficiently to listen for rock noises.

Yates had to leave for Toronto Sunday afternoon to attend

a meeting of the Rockburst Committee of the Ontario Mining Association. (Robson and Gibbs of Lake Shore were also away to this meeting). It was decided to visit Frood mine Sunday night, as this was one of the alternate Sundays when that mine was not operating. Elves agreed to have a number of holes drilled on the 2800'-level near the top of No. 6 shaft where the ground has been working for some time. Cracks, developing in the hoist room, are being measured and studied regularly.

Frood mine has two large mineralized areas with a narrow, horizontal, section connecting them -- a sort of dumb-bell form. The initial development was done at the 2800'-level and mining continued upward. While it is still being so continued, open pit mining has started on the surface and development drifts have opened below the 2800'-level, working downward.

Obert, Elves, Hollinsworth and the writer went underground at Frood in the early evening of Sunday and listened in at the prepared holes until about midnight. There were snaps from time to time, perhaps an average of four or five a minute. A few of these could be heard without the equipment but most of them were quite inaudible. Obert said that the low pitch indicated that they were coming from a distance of about a thousand feet.

This would indicate the possibility of working ground at a distant point where the more frequent, higher-pitched noises indicative of bursting conditions might be heard. Such noises do not carry more than about fifty feet. After discussing the situation with Elves, it was decided to try a listening post on the 3100'-level. The holes were to be prepared during the day on Monday and the experiments were to be tried late Monday night or rather early Tuesday morning during the offshift period.

No air or water being immediately available in the location planned, it was necessary to have the pipe fitters run in the necessary lines. They had just finished and moved out and the drillers were not yet at work when a rock burst occurred which heaved the track for a distance of about 60' along the drift, broke timber and threw out several tons of loose. The ground continued to "talk" so the drillers did not put any holes in the burst section but began drilling ten feet or so to the south and continued at intervals for several hundred feet. Similar holes were drilled to the north of the burst section. All were blown clean, ready for the experiments.

The party, consisting of A. E. Prince, Assistant to Electrical Superintendent, Elves, Obert and Hodgson, went underground at midnight Monday. The first stop was made at one of the holes on the 2800'-level. The noises were about the same as those heard the night before. They were about as frequent as they had been and were of the same low pitch, indicating a relatively distant origin.

The outfit was then moved to the 3100'-level and the first set-up made at the hole nearest the south end of the burst section. The noise was practically continuous. It sounded something like static but many snaps had the hissing, spitting sort of noise one hears around a neon sign which has a poor connection. There were about a hundred per minute by estimate. Occasionally, heavier ones were felt and could be heard without the equipment.

The pick-up was left in this hole and another placed in a hole some 75' to the south. Two amplifiers and two sets of head phones permitted the observers to listen to both places at once. It was at once apparent that the high-pitched noises were much more frequent in the hole nearer the burst section and that there was a marked lack of simultaneity in this sort of sound in the two locations. The heavier snaps were simultaneous. Occasionally one could hear a crack progressing through the rock as a crack crosses an ice-covered lake with a ripping sound.

Listening in at successively farther points going south, it was found that the high-pitched noises fell off until at about 300' there was not much more snapping than there had been heard on the 2800'-level. (The direct distance from the burst on the 3100'-level to the listening post on the 2800'-level was about 500').

While reeling in the line from the farthest hole south and while about 100' from the burst section, another burst occurred at 3.45 a.m. This heaved the track still more in the section previously effected and in addition heaved the track in the next parallel drift 44' to the east. It broke timber in both drifts and threw out several tons of loose in each drift.

The party returned to the hole first used and installed the geophone. The activity was found to be about the same as before, as nearly as one could judge. The line was then carried through the burst section to place the geophone in various holes north of the section, the amplifiers remaining

at the south end. It was found that the rock became noisier with "local" cracking as one went north. The readily audible snaps and bumps were more numerous. As the time was then about 5 a.m., it was decided to move out.

No further experiments were carried out at Frood. The remaining time was spent in examination of maps and in interviews. A start for Kirkland Lake was made early Wednesday morning, October 22, and the trip was completed at 3 p.m.

After interviews with Robson and Gibbs it was agreed that a trip underground would be arranged for Thursday morning for the purpose of selecting a place or places for the experiments. The trip underground was made at 8 o'clock Thursday. The party consisted of Robson, Selnes, Gibbs, Obert and Hodgson. The sections examined were in 3202W, 3811E, 3802E, 4301W. Some diamond drill holes in each vicinity were found which had not been partly closed by the slabbing of exposed faces. It was arranged that these should be cleaned out and experiments begun in the afternoon shortly after blasting.

The afternoon trip was made as planned, by Robson, Gibbs, Obert and Hodgson. Two holes were tried in 3811E at approximately 500' east of the main crosscut on the north vein. The nearest (farthest east) hole was about 20' west of the stoping on this vein. A few "local" noises were heard and also a few distant ones but there was very little activity. None of the sounds could be heard except with the equipment.

The party then moved to 4301W, to a point about 700' west of the main crosscut on the north vein. This is almost immediately below the large burst of July 30 last which affected the 3900', 4000', and 4200'-levels. The ground here was a good deal more noisy. Practically all of the snapping was local. None could be heard except with the equipment. Attempts to plot the snaps on a time scale show an average of about three per minute.

This occurrence pattern, in the mine with which Obert is best acquainted (Ahmeek, Mich.), would not indicate bursting conditions. Until the high-pitched snaps are recording from 20-30 per minute that ground is considered safe. However, as stressed by Obert, the significance of the occurrence pattern at Lake Shore can only be learned by continuing observations over a period sufficiently long to include a burst in the vicinity of the listening post.

Although the observations were being made in the Lake

Shore, off-shift period, drills could be heard working in Teck-Hughes mine at a distance of not less than a quarter mile. These were sufficiently disturbing to prevent an accurate counting, but Obert was of the opinion that most of the local unrest would have registered if the recorder were provided with the proper filters.

It was decided to listen in at the same position on 4301W on Friday afternoon, before, during, and after blasting. The party going underground at 2 o'clock included Robson, Gibbs, Hallick, Obert and Hodgson. The amplifiers were kept at No. 5 shaft on the 4300'-level and cables were run to the pick-up placed just below the stoping. About 1200' of cable was run out but the listening was done through 1500'. There was no impairment of the sensitivity. Matching transformers were used at each end of the cable.

It was learned that the mining in the stopes immediately above the 4300'-level had not progressed far enough for blasting at the end of the shift. However, there were other stopes higher in the mine and in the same general area to be blasted.

It was found, even before blasting, that the rock was "noisier" in this section than it had been the day before. All the noises were "local" in character. After blasting was completed, they increased in number and a few were audible. One was quite of burst proportions but it is not known whether it caused damage anywhere. Careful counting by different members of the party gave snapping noises 10-15 per minute -- at a time about an hour after blasting. Whether this indicates dangerous conditions can only be learned by experience.

On Saturday morning Robson, Gibbs and Obert went underground and selected two diamond drill holes on the 4200'-level. The more westerly of these was in the south wall of the small triangular pillar at the intersection of the north and diagonal veins with the main crosscut. The other was in 4201E about 200' east of the crosscut on the north vein. Two or three days before a small burst had heaved the track and knocked down several tons of rock on the main crosscut on this level. The relaying of the track had just been completed.

The party going underground at 2 p.m. on Saturday consisted of Gibbs, Obert and Hodgson. Robson arrived a little later joining the party about 3 p.m. Two pick-ups and two amplifiers were used with two sets of head phones, so the activity in the two holes could be compared. It was found

that the noise was nearly all "local" in character and that there was a good deal of it not simultaneous. Sometimes the west pick-up was the noisier, sometimes the east. Careful counting showed 8-22 snaps per minute at a time about half an hour after blasting had been completed.

No further experimenting was done at Lake Shore. Obert left early on Sunday morning, October 26. He left one of his geophones on loan with Gibbs, who is arranging the necessary equipment for listening. Obert wishes to obtain further noise data from Lake Shore. It is proposed that the equipment be used underground by Frank Hallick, adopting a program designed first to determine the "noisier" sections of the mine and then to follow through on one of these up to and past a burst to learn the significant occurrence pattern. It is also planned to acquire, as soon as possible, the necessary equipment to permit recording the noises.

Dominion Observatory,
Ottawa, Canada,
October 31, 1941.

Ernest A. Hodgson.

APPENDIX IV

SPECIFICATIONS FOR SUBAUDIBLE NOISE RECORDER

The subaddible noise recorders consist of the following:

Unit No. 1

a. A three stage amplifier operated from the power supply having a voltage gain of over 100,000 (from the grid of the first tube to the plate of the last tube). Linear to frequency to within 2 db. from 150 to 10,000 cycles. An attenuator (0 to 45 db. in steps of 2.5 db.) is inserted between the first and second stages.

b. A filter system consisting of a 2500 cycle and a 7500 cycle high pass section with switching arrangement so that either section can be cut in. The filters have an attenuation of 40 db. in the first half octave below cut off and an insertion loss of less than 3 db.

c. A calibration circuit operated by a switch on the amplifier panel showing the overall response (with the exception of the first two stages) of the recorder.

d. This unit is enclosed in a gumwood, copper-lined, carrying case with cover. Two 1620 and one 6P5 tubes are included.

Unit No. 2

a. A non-linear peak limiting amplifier for compressing the recording scale.

b. A one stage, low gain amplifier for independent regulation of the fast and slow recorder,

c. Two signal rectifiers and time constant circuits, one having a time constant of approximately 0.1 second and the other a time constant of approximately 1.0 second.

d. Two class B amplifiers with approximately 8 watts output.

e. A 90 to 120 volt, 25 to 60 cycle power supply (140 v.a.) having a voltage regulation such that the sensi-

tivity of the recorder does not change appreciably on a power line fluctuating by as much as 15 percent. All of the equipment is operated from this power supply.

f. This unit is contained in a gumwood case with cover. The following tubes are included: 1-6J7-G, 2-5v4G, 2-6p5-G, 2-6ZY5-G, 1-VR75 and 1-VR150.

Unit No. 3

a. This unit contains two magnetic recorders using Teledeltos paper. The paper speed is set for approximately 3 inches per minute. The recorder will operate over 8 hours on a 125 foot roll of recording paper. The recorders are driven by Telechron synchronous motors and a time mark is made on the paper every other minute. A sample record is enclosed showing the response to actual mine noises.

b. Five hundred feet of shielded two conductor microphone cable with necessary terminal connectors.

The necessary connectors for all units are furnished. Amphenol plugs are used throughout.

The price of the complete recorder is $1,000.00, F.O.B., College Park, Maryland.

A P P E N D I X V

Listening Program November 5, 1941 to June 20, 1942

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A listening program was carried out in Lake Shore Mines from November 5, 1941 to June 20, 1942. From November 5 to April 29 inclusive the work was carried out on the 3800'-level, the amplifier (LSM-10 till Feb. 9 then LSM-11) and phones being in the charging station on the main crosscut and the geophone being in stope 3906E. The operator listened from 2.45 to 3.55 p.m., entering on specially prepared forms the total number of cracks heard up to the end of each successive minute and converting the figures into cracks per minute. Listening usually began earlier than 2.45 but the same period each day was reserved for recording. The counting of the cracks was tallied with a small automatic counter. The detailed record is given in Table I. Whenever the count rises above one per minute an entry in the remarks column of the original notes nearly always reports blasting in the stope.

The listening program in 4201W 7 was carried out from May 1 to June 20 using six holes drilled 6 ft. deep in the hanging wall. The amplifier (LSM-11 and later Obert Recorders) was placed in a doghouse on the west side of the south end of the main crosscut on the 4200'-level. The time of listening was the same as before. The observations are tabulated in Table III.

It is to be observed that:

(1) Except for checking by Gibbs, practically all the listening was done by Hallick which tends to give uniformity to the series.

(2) There is a marked difference between 3906E stope and 4201W 7 drift, the latter being much the more active in ratio of about 10:1.

(3) Blasting in the vicinity of the geophones markedly increases the count, many cracks following the blasts.

(4) The average of cracks per minute is given in the table but the number occurring in each of successive minutes varies greatly. For example, on June 20 the average for 60 min. was 5.7 but the number in any one minute varied as shown in Table II.

(5) Greater cracking activity precedes and immediately follows the one small burst experienced while actually listening in on 4200'.

(6) It is concluded that recording should be attempted in the vicinity of 4201W 7.

(For tables see over)

TABLE I

Summary of Listening Observations for Stope 3906E
November 5, 1941 to April 30, 1942

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DATE	C/M	DATE	C/M	DATE	C/M	DATE	C/M	DATE	C/M	DATE	C/M
N5	3.2	D3	.3	D30	.9	J31	2.6	F28	.9	M27	.7
6	1.2	4	.3	31	1.6	F2	.2	M2	.7	28	1.0
(7)*	.5	5	.4	J2	.5	3	1.9	3	.7	30	.3
(11)	.4	6	.7	3	.4	4	1.1	4	.8	31	.8
11	1.1	8	.6	5	2.0	5	B	5	.9	A1	1.4
(12)	2.0	9	.5	6	2.0	6	.2	6	1.4	2	1.8
12	2.1	10	.5	7	.7	7	1.9	7	1.1	3	1.4
(13)	.8	11	.7	8	1.7	9	C	9	.5	4	1.6
13	1.4	12	2.5	9	.2	10	1.4	10	.4	6	.6
14	1.3	13	.5	12	.1	12	D	11	4.4H	7	.5
15	.9	15	1.0	13	A	13	.1	12	1.0	8	2.0
17	1.2	16	.4	17	.4	14	.6	13	.7	9	J
18	1.5	17	1.0	19	1.1	16	E	14	.9	10	.4
19	.9	18	.2	20	.2	17	.9	15	G	11	J
20	1.1	19	1.2	21	.5	18	.8	17	.8	13	.8
21	.9	20	.7	22	1.6	19	F	18	2.6I	14	1.0
22	.7	21	.5	23	.5	20	1.0	19	.7	15	1.4
24	.4	22	1.2	24	.3	21	.6	20	1.2	16	.9
25	.3	23	.8	26	.6	23	G	21	1.2	17	1.4
27	1.2	24	.5	27	.5	24	.6	23	1.0	18	.5
28	1.4	27	1.9	28	.3	25	.4	24	1.1	20	1.1
29	1.0	28	.9	29	1.9	26	.6	25	.5	21	1.2
D2	.4	29	1.4	30	.6	27	.2	26	1.0	22	1.2
										24	.7
										25	.8
										27	.4
										28	.1
										29	.6

NOTES

* Observations 2.45 to 3.55 a.m. indicated by brackets about the date.

A Insensitivity traced to geophone (Obert's). Replaced by one made by Hallick beginning January 17.

B No blasting in stope. Only 6 cracks in 110 mi.

C New dual amplifier installed February 9.

D Drill operating prevents good listening.

E Replaced battery.
F Geophone trouble spoils record.
G Crusher and Conveyor running.
H Several bursts.
I New section started in 3906E stope.
J Listening by Gibbs. Testing equipment.

TABLE II

C	O
1	2
2	1
3	6
4	7
5	13
6	12
7	9
8	5
9	2
10	2
11	1

C = number of cracks in a given minute.

O = number of minutes when the count was the number given in column C.

TABLE III

Summary of Listening Observations for 4201W 7
May 1 to June 20, 1942

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DATE	C/M	DATE	C/M
M1	8.1	M27	3.7
2	6.4	28	9.2
4	5.6	29	3.2
5	4.1	30	7.5
6	2.9	J1	8.3
7	2.5	2	4.8
8	6.3	3	B
9	5.2	4	7.8
11	5.5	5	5.1
12	4.4	6	8.8
13	6.2A	8	2.6
14	2.2	9	1.5
15	7.5	10	2.4
16	10.3	11	1.2
18	7.2	12	.9
19	5.0	13	2.0
20	5.2	15	5.4
21	10.1	16	11.6C
22	7.0	17	3.8
23	9.0	18	5.7
25	7.3	19	5.3
26	8.3	20	5.7

NOTES

A Heaviest snaps and greatest activity seem to be in hole No. 4.

B Testing and adjustment of equipment by Gibbs.

C Small burst occurred during listening period with great increase in activity.

APPENDIX VI

Recommendations for a Geophysical Research Program at Lake Shore Mines, Kirkland Lake, Ontario.

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The development of the various geophysical programs undertaken at Lake Shore Mines has now reached a point where it may be stated definitely that a geophysical characteristic (sub-audible snapping) exists which is probably indicative of strain conditions approaching burst proportions, and that equipment is now completed and in hand, adequate for a thorough study of this phenomenon in a selected section of the mine. The various phases of this problem must now be studied intensively and persistently.

It is therefore recommended:

1. Personnel. That the responsibility for maintaining and adapting the equipment rest with Mr. Gibbs; that the problem of developing and carrying through an underground program be given to someone thoroughly interested and qualified to carry it through; and that Mr. Hallick be assigned to assist jointly in these closely correlated programs.

2. Locale. That the study be confined to the west pillar. Initially, the investigations should cover both sides of that pillar throughout its entire elevation. As experience may dictate, the study may later be directed more particularly to key points, the existence and position of which become evident as the work progresses.

3. Recording Equipment. That three shelters be provided, one on each of three levels to be selected and that these be located in that part of the drift which is central to the pillar (within the stoped region). These shelters should be made as safe as is reasonably practicable and supplied with 110-volt electric circuit (A.C.). From these strategically placed shelters, lines can be run out to reach any selected point in the pillar, in drift or stope.

4. Listening Equipment. That a light truck be designed and built to accommodate the battery-operated listening equipment, making it easily possible to reach, on any level, the holes to be drilled for geophone installation.

5. Geophone Holes. That a considerable number of drill holes be located by survey and run out into the solid. These are to be placed wherever there is reason to suspect that strain conditions may be building up in any part of the pillar.

6. Mapping of Mine Work. That an isometric chart of the pillar be constructed by Mr. Andrew and used as a base on which to plot the progress of the mine work in the pillar. A chart, brought up to date on, say, Friday of each week is to be made available to the geophysical services on Saturday.

7. Recording Program. That records are to be obtained regularly at each of the three recording posts for such times of the day and such points on the pillar as may be found desirable from day to day.

8. Listening Program. That some part of each working day is to be spent with the listening equipment in an endeavour to track down the active section or sections of the pillar and to determine whether they are stationary or migrate as mining progresses.

9. Observing Program. That the man appointed to take charge of the underground program is to devote sufficient time to become thoroughly familiar with every part of the pillar, the stopes as well as the drifts. He is to have access to the reports of the shift bosses and they are to be instructed to bring to his attention anything which, in their opinion, has any bearing on his problem of determining the strains in the pillar. As experience may indicate, the study of sub-audible snapping is to be supplemented by records of strain gauges, scratch plates, photographic repeats, etc.

10. Reports. That, once each week, a confidential report is to be submitted, showing graphically the work done and the conclusions drawn to the then date, and adding such brief comments as seem necessary.

Lake Shore Mines
Kirkland Lake, Ont.
June 26, 1942.

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Ernest A. Hodgson

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Zack E. Gibbs