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Department of Mines and Resources
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SEISMIC RESEARCH PROGRAM
ROCK BURST PROBLEM
LAKE SHORE MINES

Report No. 12
April, 1943 - January, 1944

Ernest A. Hodgson

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Department of Mines and Resources
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FOREWORD

Due to a unique combination of circumstances, Report No. 12 has been written in a series of instalments. Parts I and II were begun in January. After being amended from time to time, they were finally mimeographed on February 24. Appendix I was prepared early in February and mimeographed also on February 24. Appendix II was mimeographed on February 22.

The series of Appendixes III-VII were composed and mimeographed during the last half of March and the first half of April. Part III was drafted and mimeographed and the report was assembled and bound during the last half of April.

As a result, there appears some lack of continuity and a certain amount of overlap. A great deal of information concerning the work has been condensed into this report, however, and even the few overlap references seem warranted as they present the subject matter concerned in different relationships to other data. The chief objection would seem to be that a busy reader may find it difficult to get a clear overall picture. For this reason, a brief but carefully prepared Summary is given as a preface.

Dominion Observatory, Ottawa,
April 25, 1944 E. A. H.

SUMMARY

The thesis of Report No. 12 may be stated formally as follows:

The experiments in the west pillar, as outlined in Report No. 11, indicate that the subaudible activity shows considerable promise as a means of predicting bursts due to the failure of rock under compression and possibly also in shear. The outstanding problem involved in applying the method to such cases seems to be that, after a burst happens in a predicted spot, the redistribution of strains may precipitate another (triggered) burst or bursts within a few minutes in some geologically related section.

There is no reason to fear that the integration of all mine noises by any given geophone during off-shift times will produce misleading records; i.e. if pressure zones develop within range of the geophone, they will be readily identified as such. No special listening qualifications are needed beyond good hearing over the entire audible range up to about 10,000 cycles per second, and patient persistence.

Equipment can be designed, programs laid out and men trained to apply the subaudible method with considerable promise of successful ability to indicate points of high strain in compression or shear and even to overcome the problem of predicting triggered bursts. But, no matter how successful it may prove, the method can only indicate danger spots, not state that a burst will occur. Possibly, experience in dealing with the indicated spots will evolve a method of estimating just how critical any such strain may be.

Recording instruments must continue to be used extensively in the research program; but, if and when the subaudible method is applied to routine protection of the mine, the instruments must be of the listening type. It requires far too much technical attention to maintain recorders in operation for such a program.

Geologic structure has a most important bearing on the applications of the subaudible method. Experiments are being designed to determine geologic structure in the block of ground now under survey on the east side of the mine and to determine its effect on the counts. It should be possible to learn how to take advantage of peculiarities in local structure, making it assist rather than hinder the application of the method.

On the east side of the mine the bursts seem to be due to sudden slips of blocks of ground along fault planes. A block hangs up due to high static friction until the pressure builds up to a point where a sudden movement results. The elastic rebound from this slip may not affect any opening, being evidenced only by the concussion, or it may shake down loose several hundreds of feet away. These have been termed slip bursts. Most of the bursts experienced on the east side during the period of this report seem to have been of this type.

These slip bursts present a difficult problem. In spite of an intensive program of experiment and a patient persistent reduction of records (all of which is indicated in detail in the report), it is not yet known whether the pressure per square inch ever builds up to a point where pre-snapping would predict a slip and it has proved difficult to determine where to locate the geophones in order to detect it if it occurs. Experiments are now being designed to enable the operator to determine the direction from which snaps reach a geophone. This should afford a means of determining the geologic structure and of getting a geophone into the point of highest activity. Whether it will ever permit the prediction of slip bursts depends largely on whether pre-burst activity actually occurs. This is the immediate problem now under attack.

Of the seventeen located bursts during the period covered by this report, all but four occurred in the block of ground now under survey. Most of the unlocated bursts (more than 120) also occurred there. Listening experience shows that the 4700'-level (east side) is a most promising laboratory

for study. There seems to be no reason to change the locale of the studies nor to break the continuity of the present routine, but the indicated experimental work should be carried on concurrently with a view to gradually modifying the program to yield more useful data.

E.A.H.

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SEISMIC RESEARCH PROGRAM

ROCK BURST PROBLEM

LAKE SHORE MINES

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Report No. 12. April, 1943, to January, 1944

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Ernest A. Hodgson

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The general account of the work was brought up to the end of March, 1943, in Report No. 11. The present issue deals with the period, April, 1943, to January, 1944, inclusive. It is divided into three sections: Part I: Revision of Theories and Deductions; Part II: Recommendations; Part III: Organization of Research Program and Routine Analyses of Data.

Part I sets forth the status, as of September 1, 1943, of the theories and deductions resulting from a study of all sources of data. The experience since gained and the steps taken, or in process of being taken, to secure answers to the questions thereby raised are then discussed. The necessary amendments to the tentative conclusions of September are next presented. The need for maintaining the research program without essential change is stated finally as the necessary deduction to be drawn from the discussion outlined.

Part II offers definite suggestions for a continuing program of research studies and also for a program of practical applications, which is now to be developed. The latter work was initiated when, early in December, 1943, Mr. C. E. McKnight, Safety Director of Lake Shore Mines, was asked to organize what may here be referred to as the Underground Service Program.

It was felt by Mr. Blomfield that the practical applications of the principles derived from the research studies should be made throughout the mine as soon as available. Mr. McKnight has undertaken the responsibility for this phase of the work. The two sets of underground studies, while having somewhat different outlooks, and being run as separate programs, will, of course, be closely co-operative.

Part III presents in some detail the set-up of equipment made on the east side of the mine, and outlines the analyses

of data carried through as a matter of regular routine. Some special instruments designed and made by Gibbs are described, as well as experiments arranged with the object of improving the technique of recording.

Part I: Revision of Theories and Deductions

(1) Status of Investigation as of September 1, 1943:

In any investigation of this type it is inevitable that impressions, theories and conclusions, held at any stage of the work, are of necessity tentative. In September, 1943, when the latest preceding reports were prepared (the radio talk of September 7, the Chicago presentation of October 6, and the published papers resulting, including that appearing in the C. I. M. M. BULLETIN for September, 1943), the conclusions then standing had been derived almost entirely from experiments conducted on the west side of the mine. These conclusions may be briefly summarized as follows:

(A) In Lake Shore Mines, rockbursts are caused entirely by the weight of superincumbent rock, unequally distributed due to the block-faulted structure and the progress of mining, i.e. there is no evidence of inherent strain surviving from its geologic history.

(B) The term "rockburst" should be extended to include any sudden release of rock strain energy, whether or not it is accompanied by evidence in the mine. These may be classified and defined as follows:

(a) Crush Bursts, due to failure of rock under compression.

(b) Strain Bursts, due to failure of rock in shear or tension.

(c) Slip Bursts, due to slippage of rock on fault planes, either exposed or far in the walls. The results of the blow, delivered by the elastic rebound from such a slip, may cause the fall of loose or the overthrow of timber and equipment, sometimes possibly quite far from the point where the impending slip

was hung up; but, on the other hand, may be evidenced only by the concussion.

(C) The snapping in the undisturbed mine (off-shift period) picked up by the Obert equipment consists of at least three classes:

(a) General Snapping (generally sounding low-pitched whether heavy or light, and sometimes heard without the equipment) registered through more than one geophone and believed to be due to slippage of breaks or faults, and to the fracturing of rock whether loose or in the wall.

(b) Local Snapping (generally sounding high-pitched whether heavy or light and almost never heard without equipment) seldom recording simultaneously on more than one recorder.

(c) Distant Local Snapping (sounding quite similar to the local type but so faint that they can be picked up, in general, only when listening with earphones, the heaviest ones alone being recorded). Local and distant-local snapping are believed to be indicative of rock yielding under strain, either compression or shear. Some minute fracturing is also probably included.

(D) For some time before a rockburst is imminent, the general snaps tend to become stronger and more frequent and then diminish in number as the pressure is built up. Moreover, the local type tends to increase, if the locus of pressure is near enough to the geophone(s) (75 ft. for recording, or 200 ft. for listening) to be registered or heard.

(E) If the incidence of local type snapping increases on several geophones and does not surpass on any one, say 20 per min. (for the early morning off-shift count), there is no localized danger in that part of the mine adequately serviced by geophones.

(F) If the count for local type surpasses 20 per min. (morning count), close observation should be made of the stope or stopes affected, especially as the listening is done in the early morning, which time

the recorders indicate as being the least active of the day.

(G) If the morning count rises to over 80 per min. (at first the limit was set at 100 per min. but early experience on the east side caused some doubt and the adopted critical value was lowered), the stope concerned should be allowed to rest; or, if worked, the next blasting should be made abnormally heavy. High counts do not necessarily indicate an impending burst, but they are an evidence of strain and should be treated with respect, especially until further experience has been gained.

(2) Development of Instrumental Lay-out on the East Side:

It must be remembered that the above was the status of conclusions as of September last. The conclusions there stated were in accord with the data available up to that time. Some experience was just being gained on the east side of the mine with geophones at the Sec. 3 line in each drift on the 4450, 4575, 4700, and 4825 levels. Most of the study there had been done with the portable listening equipment, but the recorders were just coming into service on the lower three of the above-named levels.

It was found that the morning counts were never high on any of these pick-up locations; so, after the conditions had been carefully discussed with Robson and Adamson, holes were drilled on or about the Sec. 6 line on each drift of the levels mentioned (except 4402E6). The geophones on the lower three levels were fed into the recorders on 4700 and those on 4400 were fed into a recorder on that level. The latter is not run on schedule but is used daily for listening, and is thus known to be always in adjustment for use at any strategic point, being mounted for this purpose in a special carrier box. To care for 15 geophones with only 8 recorder tracks, time switches were made by Gibbs which have worked out extremely well. These arrangements were completed about December 1, 1943, and have been in operation ever since. The coverage is not as comprehensive as could be desired; but, under the present circumstances, it was considered to be the best disposition of available equipment, and it is still so regarded by the writer and his associates.

(3) Experience with Small Slip (?) Bursts on the East Side:

Since December 1, 1943, at least four small bursts have occurred, which have been located in or near the block of country serviced and, in addition, there has been at least one other which was not definitely located but for which the evidence points to a rockburst of the slip type in or near Sec. 6E on 4400. Unfortunately, in no case to date, have the necessary conditions been fulfilled; namely, that the geophone must be within 75 ft. of the focus in order to register the local-type snaps, must be recording for some time before the burst and must continue to record through it.

But, the fact remains that, in no case, has a prior indicative increase of local-type snapping been picked up by the geophone nearest the burst. It becomes of paramount importance to record a burst under the conditions stated above. There seems to be no virtue in altering the present set-up even if it could be done. Close attention should be given to obtaining records for all possible times, at the present geophone locations.

(4) Experience with Small Strain Bursts on the East Side:

Prior to most of the above bursts, there have been evidences of very small strain bursts, which seem to have occurred in the stopes about to burst violently. On one occasion, the small burst was heard by Hallick at the stope and by Hodgson as recorded at the station. There is no doubt that many of the disturbances, which were early called "salvos", are small strain bursts in ground under critical pressure.

Such bursts should receive further study. At first they were confused with runs of ore in the ore passes. The difference in the two types of record is now known. The strain burst record begins suddenly; the ore run record begins gradually. In both there is considerable true wall snapping due to the trigger effect of the moving load. If these strain bursts prove to be of sufficient value in prediction, Gibbs can design and make simple instruments to record them. This equipment could be made up in inexpensive units, each of which would record the time of incidence, and possibly the duration, of such

disturbances, as occurring in the stope in which it was installed; but would be so insensitive as to fail to record any in an adjacent stope. If a unit were installed in each suspect stope and examined daily, the location of the strain bursts would be indicated and steps could be taken to further examine the ground concerned.

(5) Some Special Experiments now in Progress:

Further attack on the new problems confronting the investigation is being arranged as follows:

(A) The Obert Set 2, which alone has filters in service (though Set 3 on 4400 could have them connected, for one track only) has been placed tentatively on 24 hr. service in the station switch house at No. 6 shaft on the 4700'-level. It is connected by Belden cable to a geophone in H46 in 4701E4, a hole which was acutely active on several occasions in November last. Listening will be done at this set during the afternoon off-shift period (4^h-7^h), with a view to acquiring experience during this, the more active half of off-shift time. Experiments will also be run to determine the best adjustments for recording under the 24 hr. conditions. These include a variable time-constant circuit and a possible change in gain through the utilization of the further possibilities in the impedance-matching 6P5 tube, which is included in the earlier models only. (It is to be noted that, no matter how valuable the filters may prove to be, none can be obtained for the sets on 4700, presumably for the duration.) The use of Set 2 considerably increases the possibility of obtaining a record up to and through a burst.

(B) A small portable automatic hammer has been designed and built by Gibbs and will be used in an endeavour to determine which sections of the block under study are intimately related. The tapper on 4700 registers on all geophones in Sec. 3, including those on 4400, but, at Sec. 6, those in 4502E, 4701E, and 4702E fail to pick it up. Striking the wall with an ordinary hammer, on the vein beside the master tapper, registers on all the Sec. 6 lines and serves as a check that the complete hook-up for these holes is in good order.

(C) A thorough experimental study is being made of the equipment, under regular underground working conditions, with a view to coming closer to a standardization which will permit a greater degree of confidence in determining from several simultaneous records the direction and distance of the source of snaps, bursts, etc. Results to date have been very gratifying. All predictions as to the locations of bursts and salvos, made at listening time, and from the records alone, have been confirmed, if and when they were located later by other means. These experiments are progressing. Calibration of the instruments is done regularly once a week and the test records are carefully studied and filed.

(D) A laborious, tedious, but highly-desirable analysis is now under way, of the data obtained through the daily routine analyses of coincidental offsets occurring on the records. The work will take several weeks to complete, to deal with the records for November, December, and January, but will answer, once and for all, whether the routine analysis of coincidences is of any value.

(E) It has been decided to have Set 3, on 4400, run on schedule (3:15 to 6 o'clock, a.m. and p.m.) at a 20Db. setting, thus giving preference to the registration of the medium snaps to the exclusion of the very small ones. The question has been raised as to whether these larger snaps are not the more significant. This program for Set 3 should serve to answer the question, since the larger snaps record on the other levels as well permitting the correlation of all records as to time.

(6) Discussion of Some Recording Problems:

The question has been raised as to whether there are not many interfering noises which have not been identified as to source. Hodgson and Hallick have each had more than a thousand hours of actual listening experience underground; and, in addition, have made regular daily studies of the records. They are of the opinion that practically every man-made and machine-made noise of any importance can be identified on the records. At the moment there are

about two, the exact sources of which have not yet been determined. But, the fact remains, that none of these can in any way confuse the issue. They are readily identified as extraneous even on the record and are always eliminated from all counts.

Mention has already been made of the means of distinguishing between the records of rock runs and small strain bursts. It may be added that, when listening on a set which is registering a rock run, there is no difficulty in distinguishing between the offsets due to rock impacts and the snaps caused by the trigger effect of the passing load. Furthermore, it should be noted that, when watching rock runs recording on several geophone lines at the same time, it becomes clearly apparent that the only offsets occurring on the records least affected are those identified by ear as being due to snapping in the walls. The effects of impact die out at lesser distances. Moreover they are always of lower pitch than the snaps.

It has further been suggested that the counts are hopelessly confused by snaps due to the failure of broken rock in a rill or ore pass, or to the scaling off of the newly-exposed faces of openings. It is the opinion of the writer that, while these can be heard to considerable distances on the earphones, they seldom transmit sufficient energy into the walls to register on the records. Furthermore, though there are undoubtedly many in a day, they either occur in groups, as in ore runs, or they are so spread out in time that they do not sensibly interfere with the significant counts.

The experience gained at Lake Shore Mines, both on the west and on the east sides, and supported by a multitude of recorded data, indicates that:

(A) The local and distant-local types of snapping are alone indicative of strain in the rock. (There is some difference of opinion as to the relative importance of very small and medium snaps. The question should be settled by the experimental recording now being started on 4400. The plotted graphs of Fig. 9, Report No. 11, seem to the writer to be a completely satisfactory proof that the medium snaps are not as indicative as are the small ones, in spite

of the somewhat greater amount of interference which is undoubtedly present in the registration at the higher gain. Moreover, the small ones are essential if one is to locate the focus of pressure from the records.)

(B) Some, at least, of the snapping which occurs in loose rock and in slabs on the face does not transfer enough energy into the wall rock to carry more than a few feet, and so does not appreciably affect the count.

(C) Morning counts in the range, say 10- to 20, are, more or less, affected by snaps due to fracture in loose rock, but counts well below or well above that range are probably both significant.

(D) When listening, snaps can readily be distinguished as "snappy" and "dull", respectively. It is assumed that the former are due to internal yielding of the rock body and the latter to actual fractures.

(7) Amendments to the Tentative Conclusions of September, 1943:

With the further experience outlined in the preceding pages of this report, there seems to be no reason to modify the tabulated theories and conclusions (held as of September last and given at the beginning of the report) except as follows:

(A) The small strain bursts, which were recorded through on the west side of the mine, were preceded by indicative snapping when they originated close to a geophone. These show clearly for the records on the level where the burst originated, but do not register on the lines from adjacent levels. (see b_1, b_2, b_3 of Fig. 14, Report No. 11.) No indicative pre-snaps have been obtained for strain bursts registered thus far on the east side; but it is not known that, in any case, a geophone has been recording within the necessary minimum distance. The absence of such snapping prior to a burst has not been proved in any case. It is hoped that something may be done to answer this question through the choice of locations for the geophone feeding into the filter-equipped, 24 hr. recorder.

(B) There has been no record of indicative activity prior to any of the slip (?) bursts which have occurred since the equipment went into service on the east side. But in no case was there a geophone within 75 ft. of a burst and recording nearer than 8 1/2 hrs. prior to the time of its occurrence. Experience on the west side has shown that pressure may build up within a few hours. (see Fig. 13, Report No. 11.)

For a further discussion of the possible modifications see Appendix I.

(8) Conclusion:

The entire substance of the above report brings one to the following conclusion:

> It is highly desirable that the present program of listening and recording be maintained without interruption, permitting only such modifications of routine or dispositions of the time of men and instruments as shall not interfere with securing the maximum coverage in space and time until a burst is heard and/or recorded through.

Only in this way can the question of the occurrence or non-occurrence of indicative snapping be answered. It is a matter to be determined from experience, not opinion, and the necessary machinery is now in operation for that purpose.

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Part II: Recommendations

It is recommended that:

The present research program should be maintained without interruption as stated in the final paragraph of Part I, for the reasons set forth in detail in the discussion there given. In addition to the investigations with the Obert equipment, the mine seismograph should be rehabilitated

and its operation continued in 3052XC, and the surface seismograph should be overhauled and equipped with an amplifier to provide a gain of about 5X.

In addition, the following methods of investigation are suggested for the service program:

(1) The sections of the mine which have been stated to be more active than the block of country now serviced by the research lay-out should have holes drilled in the hanging wall as deeply as possible with percussion drills at intervals of about 30 ft. Some old diamond drill holes could also be utilized. These holes should be carefully cleaned, protected by plugs and numbered. They can then be serviced by means of the portable listening equipment on a regular schedule and the data gathered, tabulated and plotted and made available to all concerned.

(2) As soon as any section shows marked activity the portable recording equipment can be set up in the nearest convenient location and two or more holes placed on a recording program.

(3) An automatic tapper should be constructed to give a standard impulse, continuously at intervals of, say, three seconds. This instrument should be arranged to be easily moved from level to level and installed on steel pins located near an AC outlet in the main crosscuts at levels about 500 ft. apart from top to bottom of the mine. These would serve as sources of sound for investigating the fault pattern throughout the mine.

The following instrumental work, in addition to that indicated or implied above, is being carried out as soon as possible for use in the research program:

(1) The parts having been received, the hundred geophones, already partly constructed, are being finished and made ready to meet any emergency.

(2) Another listening set is being constructed, identical with LSM 15, for use in the research program, the original equipment having been placed at the disposal of the service program.

(3) A simple, negative-feedback amplifier is being designed and built to permit a slight increase in sensitivity in the surface seismograph. It is felt that this will permit a better study of the blasting and small burst records.

(4) Experiments are planned to provide carrier-current communication between the doghouse in 4700XC and the laboratory, both as a safety measure and also to save time when replacements or repairs are found necessary when servicing the instruments.

Kirkland Lake, Ont.
February 24, 1944.

E. A. H.
Z. E. G.

Part III: Organization of Research Program

(1) Development of Recording Program:

The previous report (No. 11) brings the account of the recording program to March 31, 1943, the date of the second large burst in the west pillar. This burst left only H32 in service. It soon became evident that the strains in the west pillar had been relieved by the bursts. Steps were then taken to initiate a recording program on the east side of the mine from the 4450'-level to the 4825'-level.

The steps by which this was done are outlined in detail in Appendix V. Tables are there given showing, by means of the record numbers involved, when each of the holes, 31 to 54 inclusive, was in service. A set of notes, chronologically arranged, indicates the steps taken and the reason for each. Appendix IV gives full details regarding the holes (H31-H54), being effectively a continuation of the list in Appendix I of Report No. 10 (H1-H30).

At the time of the closing of the present report (January 31, 1944) recording was being done regularly from 15 holes (see final table of Appendix V). In addition, some experimental recording had just begun (January 31) from one other (H46).

(2) Equipment Available for Recording:

After the second burst in the west pillar only two, single-track recorders (Nos. 2, 3) were left, No. 1 having been lost on the 3825'-level on January 29. Three new, double-track recorders (Nos. 4, 5, 6) were received from Obert in June, 1943. Gibbs remodelled (early in October) the old single-track recorder (No. 3) to two-track and adapted the other (No. 2) for use in experimental work. Thus, as of January 31, 1944, the recording equipment consisted of four, two-track sets (Nos. 3, 4, 5, 6) and one single-track, experimental model (No. 2).

At the time of the burst on January 29, 1943, all the geophones (7 in number) were lost. One was later recovered. An order for 50 crystals and 25 transformers was then of long standing. Fortunately, this equipment began to arrive, piecemeal, and enabled Gibbs to begin making geophones for immediate use. The order was finally filled completely. (The practice of ordering twice as many crystals as transformers is necessary, since the

crystals are not of uniform quality and some are broken on installation or in service and have to be replaced.) The 25 geophones made possible by the above order have all been made and are in service. Since then, six geophones were supplied by Obert to accompany the new two-track recorders.

With an expanding program in view and the experience of losses by bursts as an added incentive, it was decided (see p. 11, Report No. 11) to order 200 crystals and 100 transformers with the intention of making a further 100 geophones. This material had all been received prior to January 31, 1944, and most of the machine work has been done, an extra helper, Bruce Black, having been engaged for that purpose during the summer months (1943). These geophones are being made up as required. The pressure of other work prevents their being constructed all at once.

(3) Development of Listening Program:

During the period covered by this report, listening has been done daily (except Sundays and holidays). When Hodgson is at Lake Shore, he goes underground about 3.30 a.m. and carries out a program of listening and experimenting until the day shift comes on (6:45 in summer, 7:45 in winter). When he is not there, Hallick goes underground about 5:30 a.m. and does the listening, afterwards carrying out whatever instrument work is required before coming to surface.

When possible, listening is done over the Obert sets; but, when necessary, use is made of a portable amplifier (LSM15) which was designed and constructed by Gibbs for that purpose. It has proved most satisfactory in service, if anything a rather higher gain than the Obert sets. The amplifier weighs about 25 lbs. Together with geophone, connecting cable, and tool bag this makes a load of between 30 and 35 lbs. It is conveniently carried by means of a tump line, which makes it possible to move the equipment from level to level down the ladders of the manway. (The cage service below the 3950'-level does not begin until the shift comes on.)

A report of the listening is prepared underground each day. At first, an original and one carbon was supplied. As more copies were requested, it was finally arranged that a single copy of the report be turned over

to the office staff on arrival at surface, the carbon copy being retained by the observer. The report is then typed and copies supplied to those entitled to receive them. The form used and the nature of the notes made are indicated in Appendix III.

In general, the listening program services the same holes as the recording (see Appendix V), but the holes were put on the listening program as soon as they were drilled. It sometimes required quite a long time to instal the cables connecting the holes to the recorders. For example, H41 was drilled May 28 (see Appendix IV) and began to register (Record No. 603) on July 13 (see July table of Appendix V). During an interim of this kind, the hole in question was serviced by the portable amplifier carried to the location concerned and connected to a geophone left installed in the hole.

During the earlier part of the period covered by this report, listening at each hole was carried through for five minutes at least, the snaps being counted by means of a Veeder tally. The count was reported as "snaps per minute". When the number of holes increased to 15, it was impossible for Hallick (when working alone in the absence of Hodgson) to finish such a program, before the shift came on making listening impossible. It was found that, in many cases where the activity was low, the count could be made with sufficient accuracy in a minute, especially when the observer could, at the same time, examine the record which was running. The scheme outlined in Appendix III was then adopted, listening for a minimum of one minute and recording the snaps per minute on the scale 0+, 10-, 10, 10+, 20-, 20, etc. Where a count seems important, the count is made for a longer period than a minute.

The data on the copy of the report retained by the observer is plotted each day on the listening graphs, which are arranged on the same scheme as the recording graphs, a sample of which is shown in Fig. 4.

(4) The Master Tapper:

When working in the west pillar, considerable difficulty was experienced in getting enough simultaneous snaps to permit a synchronization of the records. Tapping on the walls on one level seldom registered from geophones

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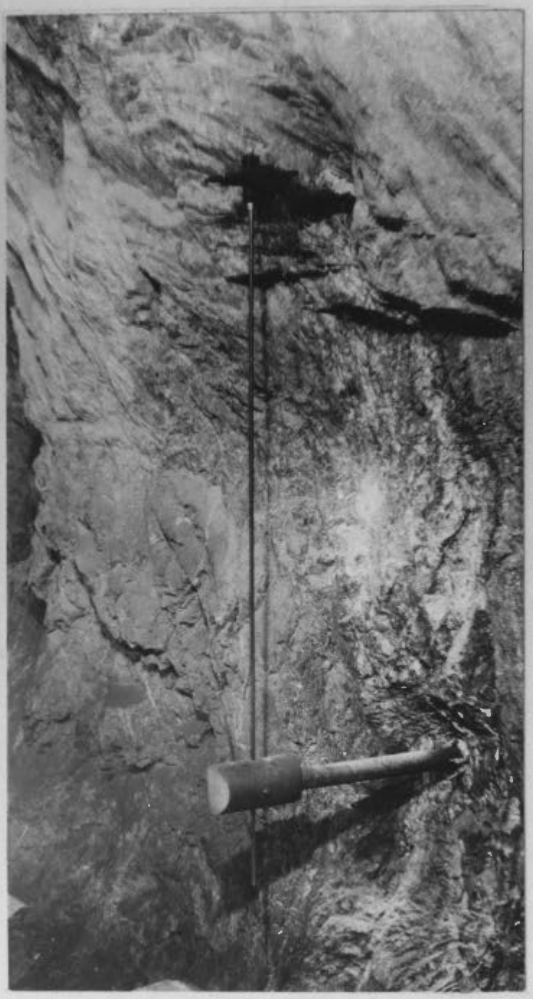
Fig. 1

Master Tapper

Fig. 2

Time-Switch



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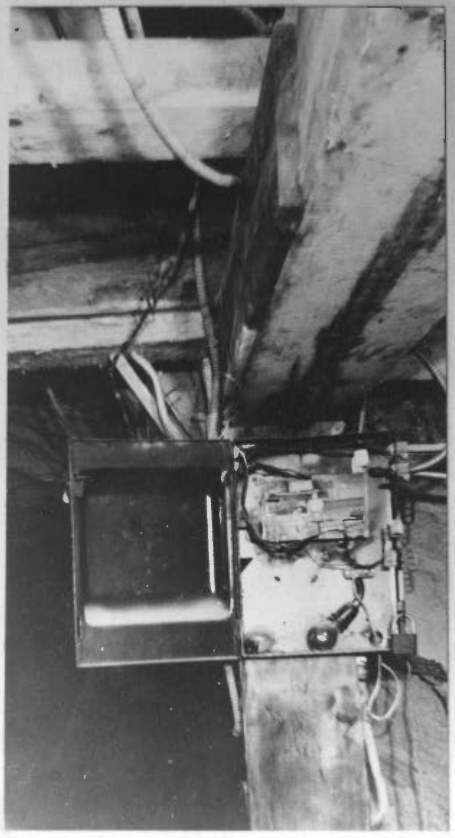
60 – Hallick placing geophone



on adjacent levels. Gibbs constructed tappers, one for each hole, which consisted of small hammers weighing an ounce or so suspended on leaf-spring bearings, each operated by a cam driven by a synchronous motor supplied with A.C. current through style B wires running from the doghouse and controlled there by a switch. However, these did not function well as there was not sufficient power in the motors.

After the doghouse was completed on 4700, it was noted that tapping on the east wall of the crosscut, opposite the door of the doghouse, on an exposed vein, registered on all the geophones. (At that time only the holes at the Sec. 3 line were in service.) Accordingly, Gibbs constructed the "master tapper" shown in Fig. 1. This tapper is a steel hammer, shaped like a croquet mallet, having a cylindrical head weighing about ten pounds and supported by a steel rod 3' long resting on a knife edge. The head was turned on the lathe about the hole through which the supporting rod is passed. This results in the faces at the ends of the cylindrical head being sections of a cylindrical surface concentric with the support, resulting in the ability to deliver a direct blow with a minimum of vibration. The knife edge rests on a ruled plate set on a steel bar let into the wall about 3'. The hammer hangs, at rest, with its face just touching another steel bar "the anvil" also let into the wall about 3', directly in the centre of the vein.

A tapper test is made by holding back the head about 1/4" (insertion of a pencil as a gauge) and allowing it to strike once, freely, when the pencil is removed. Five such taps are made. Then five more are run, using a gauge about 1" thick in place of the pencil. Five more are then made, using a gauge about 2" long. Finally, the 2" gauge is set and removed and the tapper falls are allowed to decay. See p. 2, Appendix II. A tapper test from the 1" gauge is equivalent to dropping 1 ounce from a height of 2 1/4". This gives some idea of the high conductivity of the rocks of the east side for elastic waves.

The offsets on the records, caused by the tapper test, vary according to the distance from tapper to hole. They are also a function of the efficiency of every part of the circuit concerned. The tapper fails to record for some of the more distant holes in Sec. 6. For these,

a test is made by striking the vein ten strokes with a carpenter's hammer. However, the tap record from any given hole soon becomes a matter of experience. If the easily-applied test fails to give the characteristic response for any hole, it shows that some part of the system is not in order and steps are taken at once to remedy the trouble.

(5) Calibration:

To permit the offsets on one record to be compared with those on another, it is necessary to have equally efficient transducing and amplifying equipment throughout each channel. The chief sources of variation are:

(a) the transducing efficiency of the geophone.

(b) the overall gain of the amplifier.

(c) the friction at the writing stylus.

(d) the placement of the geophone.

Steps are taken to secure comparable standard conditions for the first three of these and an optimum placement in case (d).

(A) The geophones are tested underground just before being placed in service. A dry, bootleg hole, H47, in 4702E2, about 75' from the doghouse, is used to house a particularly good geophone, G27. This geophone records daily from this hole on track 5B. It receives the tapper test daily, affording a check that the geophone is not deteriorating from its initial good quality. To test a new geophone, the procedure is as follows:

(a) Tapper test for G27 in H47 on 5B.

(b) Replace G27 by Gx (the geophone to be tested) in H47.

(c) Tapper test for Gx in H47 on 5B.

If (c) is less than (a), Gx is reset slightly more forward or back in the hole and the test repeated. If, after several trials,

it is always less than 2/3 the amplitude of (a), it is discarded.

(d) Replace Gx by G27 in H47.

(e) Tapper test for G27 in H47 on 5B.

If (a) and (e) are the same, it is assumed that G27 is back in its optimum setting. If not, G27 is reset until the test is satisfactory (see (D) below). In no test yet made, has any geophone quite equalled G27. Most of them run about 2/3 the corresponding amplitudes.

(B) The overall gain of the amplifier is tested by an oscillator, by means of which a 1000-cycle pulse, of standard duration and amplitude, is fed into the input socket and made to record. The procedure followed for this calibration is given in full in Appendix II.

(C) The friction at the writing stylus has been a problem which has been the subject of many experiments. The problem was not solved quite satisfactorily until about the end of March, 1944. It will be discussed in the next report.

(D) The placement of the geophone is a matter for experiment. If a geophone loses efficiency (due to infiltration of moisture or other cause), it is replaced by another geophone, tested as in (A) above. If the tapper test shows the circuit less efficient than it was before the former geophone failed, the new geophone is reseated by being pulled forward or pushed back a little in the hole. If the new geophone was shown by the tapper test to be comparable with the old one when it was installed, the placement experiments are expected to succeed in producing equivalent results from such tests. Sometimes they fail to be as good the day the geophone is installed; but, if it is left on its best setting, it usually has become of equal efficiency after a day in place. It is hard to say just why this should be, but experience shows it to be a fact that geophones tend to increase in efficiency, as revealed by tapper tests, after a day in service. See also Note 3, p. 6, Appendix II.

(6) Line Trouble:

Considerable trouble has been experienced from time to time, with various long connecting lines. These are nearly all made of armoured BXL cable with No. 14 wire conductors and lead shield. It is impossible to string these in a drift and have them left strictly as placed. Mining operations result in the lines being moved. Accidents happen: ore cars sway and cut cables, timbers fall and break or stretch them. If a single break occurs in the lead shield, trouble shows up as 25-cycle disturbance at the stylus as soon as moisture gets through the shield.

One of the worst cases experienced has been the line to H51 in 4701E6. This line was cut on two separate occasions by a swaying mine car. It was moved several times as chutes were built or timbers replaced. The ground potential varies considerably from point to point in this drift, with the result that it takes very little to put the line out of service.

Assuming that geophone-ground characteristics might contribute to line trouble, a series of experiments was run in November to determine the effect of various combinations of grounds in the geophone. That is: the centre tap of the transformer might or might not be grounded. The shield of the line might or might not be electrically connected to the geophone case. The crystal might or might not be grounded. After many tests of all possible combinations, it was found best to electrically connect line shield and geophone case and leave the centre tap of the transformer ungrounded. It made no difference whether the crystal was insulated or not.

Many hours have been spent keeping this and other lines in service. Add to that the many adjustments necessary to maintain the recorders at peak efficiency and the experiments required to eliminate troubles of one kind and another. The result is sufficient to show that the following must be accepted as a necessary conclusion: In any final, regular program of protection the daily checkup must be made by means of listening equipment, not recorders.

(7) Reduction of Records:

In general, three records (2 track), each about 40' long, are brought up each morning. Sometimes there is a supplementary experimental record (No. 2). Sometimes the recorder (3AB) on the 4450'-level is allowed to run on schedule if the activity is high. All these records are booked and filed (see p. 8 and Fig. 1 of Report No. 10), but only three records (6 tracks) are put through the routine reduction program. As time switches are used to connect each of two holes alternately each half hour on each track, the records give data from 12 holes. The day-by-day notes of the work are kept in a specially-designed logbook in which all daily instrumental set-ups are quickly and easily recorded in tabular form, together with covering memoranda, and in the diaries of Hallick and Hodgson. All times are recorded in Eastern War Time on the 24 hr. system beginning at midnight.

The work of reducing the records to data which can be considered typical of conditions for the holes and times concerned is tedious and somewhat difficult to outline. However, for anyone who may be interested the procedure is given in full detail in Appendix VI.

It will suffice here to note that an a.m. and p.m. recording count is obtained and plotted on a graph for each of 12 holes. A sample graph, that for January, 1944, appears as Fig. 4. Similar graphs are made of the listening counts. The blasting data (number of holes and amount of powder used) are also tabulated and plotted.

In spite of the fact that no lapse has occurred in the regular reduction of all data obtained, the fact remains that, for the period covered by this report, no case has been found where warning snaps have occurred at any hole in the east side program. There has been, however, only one occasion in that time when the recording was going on a sufficient time before the burst to permit of a preliminary record. (The bursts noted on the graphs of Fig. 4 occurred at blasting time, just as the sets turned on.) Moreover, these bursts are due to slippage on fault planes which have hung up, due to static friction, at some unknown place in the walls. The elastic rebound

at the time of the burst shakes down loose in some opening crossed by the fault affected. But, not knowing where the hang-up occurred, it cannot be known whether a geophone was near enough to record it.

This is the real problem: In the case of slip bursts, is there anywhere a build-up of pressure and a high rate of snapping before the burst? If so, how may that point be determined?

This is the most outstanding problem at the time of the closing of this report. A series of new experiments are now being undertaken to solve it. Their discussion must be reserved for the next report.

(8) Rockbursts Registered:

A tabulation of the rockbursts detected in Lake Shore Mines during the period of this report is given in Appendix VII. It is to be noted that, of the 17 bursts so localized, all but four occurred in the block of ground now under investigation. Of the unlocated bursts (more than 120 in that time), it is known from record indications that most of them occurred in that same block of ground. Listening experience shows that this section of the mine is the most consistently active. It appears from the experience so far gained that the 4700'-level is the best rockburst laboratory available in the mine at this time. There seems to be no reason to regret the choice of locale nor to wish for a more promising place to study. It has become necessary to recognize the fact of slip bursts and to direct every effort to solve the special problems connected with this type of disturbance.

(9) Technical Contacts:

Hodgson visited Mineville, N.Y., April 26-29, to see the application of the subaudible method by Obert and his staff to the removal of pillars in an iron mine. The opportunity for discussion was excellent and the exchange of ideas and experience most helpful. He also attended the meeting in Toronto on June 3, 1943, of the Rockburst Committee of the Ontario Mining Association. Contacts such as these are most stimulating, yielding new viewpoints and suggesting fresh points of attack.

Mr Douglas Donald, a graduate student of Princeton University spent about ten days at Lake Shore in June. He was gathering material for a thesis on rockbursts which he has since written.

The program at Lake Shore was inspected for several days in January by Mr. A. H. W. Busby and Mr. C. D. M. Chisholm of the Consolidated Mining and Smelting Corp. of Trail, B.C.

(10) Lectures and Papers:

During the period covered by this report the following talks on rockbursts have been given by Hodgson:

(a) Progress report "Rockburst Research" before Section IV of the Royal Society of Canada at the annual meeting in May, 1943, at Hamilton, Ont.

(b) Radio talk "What is a Rockburst" given over station CJKL (Kirkland Lake) September 7, 1943.

(c) Invitation lecture "Recent Developments in the Rockburst Problem" before the Mining Section of the National Safety Council at their annual meeting in October, at Chicago, Ill.

The papers published during the same period are as follows:

(a) "What is a Rockburst" (text of radio talk (b) above), Northern News, p. 1, Kirkland Lake, Sept. 9, 1943; also printed in Northern Miner, 102-103, Christmas Number, Toronto, 1943, and in Journal, Royal Astronomical Society of Canada, Vol. 38, No. 1, 1-16, Toronto, Jan., 1944.

(b) "Recent Developments in Rockburst Research at Lake Shore Mines", Bulletin, Canadian Institute of Mining and Metallurgy, No. 377, 313-324, Montreal, Sept., 1943; also printed with the title "Rockburst Research at Lake Shore" in The Mining Magazine, Vol. 70, No. 2, 116-118, London, Feb., 1944.

(c) "Recent Developments in the Rockburst Problem" (text of lecture (c) above), Transactions, 1943, National Safety Council (not yet in print), Chicago, 1943.

Dominion Observatory, Ottawa,
April 22, 1944

Ernest A. Hodgson.

APPENDIX I

Several points have been raised, which were not clear to those charged with inaugurating the Underground Service Program. After these points had been thoroughly discussed, the following memorandum was prepared which may be put on record as a further amendment to the conclusions of September, 1943. (see I(7) of this Report.)

(1) Basic Assumptions, to be Subjected to Experimental Test:

It must be remembered that the entire program is based on the suggestion made independently by the writer and others, that faint, sub-audible snapping may be generated in rock subjected to serious strain and that, if such snapping is found to occur, will probably indicate a focus of pressure if, as is to be anticipated, it proves to be localized. Further it may offer a means of prediction, if it develops a sufficiently long time before the pressure becomes critical. The equipment and its disposition in the mine, together with the routine and handling of data have been designed to subject the above suggestions to the test of experiment.

(2) Sub-Audible Snapping Has Been Proved to Exist and to Attenuate at Short Distances and is Tentatively Assumed to Indicate Strain:

The experiments by Obert in U.S. Mines, experience at Frood on October 20, 1942, and all subsequent work at Lake Shore Mines shows that the statement of paragraph 3, Page 3, Appendix III, of Report No. 9 is true for all the mines in which experiments have been conducted. Beyond all doubt, faint, sub-audible noises are generated sometimes in rock which is about to burst or which is presumably (not proved in every case) in a state of serious strain. There is still the question, does it always develop? At any rate, when they occur, these noises are real, not static or instrumental, and can be heard over one line when they are recording on another, when the geophones are adjacent in the lay-out. A very good example (among thousands) occurred between 5 and 5:30 a.m. on February 12. Snaps counted as distant-local type on other lines could in many cases be seen

to record on H40.

(3) Significance of the Rate of Snapping:

It is tentatively assumed that the rate of incidence of the localized high-pitched snapping varies directly with increasing strain. Linearity is not assumed; indeed, the change of rate is suspected of accelerating as the strain approaches a critical value. There has been no proof to the contrary as yet, but such noises did develop prior to the burst in 4201W10 on July 25, 1942; in 3800 and 3900 geophones in the west pillar in January 1943; and in three cases where geophones were near a point where a sill was taken out and where presumably (debatable ?) the strain was great.

(4) That Extraneous Noises are Not a Serious Handicap:

The recorders are very sensitive and one can make many different kinds of noises by many different means, which are heard and even registered at considerable distances. However, if the statements of paragraphs (2) and (3) above are accepted, these noises do not need to cause any anxiety. The occasional snapping, occurring admittedly from time to time within a radius of, say, a thousand feet of a geophone, do without doubt often register and can generally be heard in the earphones. But experience shows that these counts are never high and are far from being localized. It is tentatively assumed by the writer that, until the counts are localized and high they may be disregarded so far as the existence of strain foci is concerned, at least within the range of the geophone emplacements. There is no proof to the contrary and there is much evidence to support the assumption. So far as man-made and machine-made noises are concerned, they are easily recognized as such, both on the recorders and when heard. This includes the cases where rock runs or caves are registered and/or heard.

(5) The Routine Counts May Have Value:

It is assumed that much of the general snapping is due to the adjustment of blocks of ground of various sizes and that the continuance of such snapping is, if anything, a sign that localized pressure is not developing.

The assumption has not been proved, but it is felt that, however laborious it may be, tabulations of all counts and a study of their simultaneity from day to day should be carried through until experience has given a completely satisfactory record (or records) of a burst (or bursts). There is some indication that simultaneous snapping does decrease as localized snapping develops.

(6) Geologic Structure May Affect the Counts:

This has been proved to be the case. It is proposed to examine the geologic structure by means of the portable tapper, according to a plan developed for this express purpose. Experience would lead the writer to think that, in some cases, structure has a serious effect and that in others it has not.

As an example of the former, it may be noted that H46 is in 4701E4 and H40 is in 4701E3. Each hole is 30 ft. deep and in the south wall of the drift. They are about 135 feet (paced) apart. In November, 1943, H46 had high counts and H40 low. Now H40 has high counts and H46 low in spite of the fact that H46 is much nearer to a working stope than is H40. It would be most instructive to have a series of 30 ft. holes, drilled about 30 ft. apart, from a point about 30 ft. west of H40 to a point about 30 ft. east of H46. Then a study could be made using the portable listening equipment in these holes when the regular records showed a marked difference in the counts from the two holes.

As a further example of a hole which seems isolated, one might cite H54 (4702E6) which sometimes develops both local and general snapping which does not register well on other geophones.

To sum up: If and when geologic structure seems to be interferring with the counts, experiments should be conducted with the tapper and by drilling to determine where the geophone(s) should be installed to protect any given stope.

(7) Evidence for Prediction Lacking:

In the west pillar, localized snapping registered

in increasingly higher counts for some days prior to the burst of January 29, 1943. But on the east side, to date, there has not been a single case of a burst occurring, where a geophone was within 75 to 100 ft. and where listening or recording was going on prior to the burst.

Furthermore, the most that can be expected from this method, even if it proves as successful as can reasonably be anticipated, is that it will indicate points of critical pressure. The factors which combine to cause a burst are so many and so unknown that all one could reasonably say is that a danger point exists if the count becomes localized and active. Possibly, long experience with properly-placed equipment would help to segregate the acutely critical from the critical cases. Certainly the contribution of experienced miners must carry much weight in deciding how a focus of critical strain should be treated. The method can only state that such a focus exists and indicate when it ceases to be critical.

(8) Qualifications for Listening:

It is the considered and firm opinion of the writer that the problems raised with regard to the possible need for peculiar listening powers in observers need not be a source of great concern. The questions have suggested a special type of filter which, if successful, will be extremely useful in deciding whether the localized snapping goes up at a higher rate than the general type and it will permit an analysis of the spectrum of frequencies to find out what range is the most informative for listening and recording. But, even if fully successful, the counts can only tell where the critical points are, not whether they will burst.

Experience shows that, when the counts are high there are always present a large percentage of localized snaps, i.e. very high counts are never wholly general. All counts may rise in a certain section of the mine but only the point of critical strain will show very high counts.

Two men, equipped respectively with the present type instrument and with the hypothetical filter design, under the same circumstances, would bring back the same reports

of critical conditions which might or might not burst. But, if such points are systematically detected and are studied as to their history under various circumstances, by both miners and geophysicists, experience should, in time, permit some gradation in estimating the degree of menace to be assigned any newly detected focal point. The only qualifications a listener must have, so far as the frequency question is concerned, are good hearing and persistent patience.

Kirkland Lake, Ont.
February 24, 1944.

E. A. H.

APPENDIX II

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Calibration Routine

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Each of the four Obert Sets is to be calibrated regularly once a week. The test records are to be carefully annotated, with full notes written legibly on the actual tapes. These are then to be mounted in the covers provided, the latter being endorsed with the data required by the printed form. The tests are to be filed, serially and chronologically, in the file cases provided.

The Set to be calibrated must be thoroughly warmed up before calibration begins. The amplifiers are not to be turned off throughout the procedure. When not in actual use, the recorder should be turned off at its own switch. In the case of long interruptions, the unconnected filter switch(es) of the channel(s) not under examination may be turned off. These leave the Set warmed up but shut off the impulses to the styli and stop the motor. In the case of long interruptions to the calibration of Sets 2 and 3, the recorder switch should be turned off and the main attenuator(s) set at infinity.

A full calibration series involves:

I. Initial Test by Master Tapper.
II. Initial Test by Oscillator.
III. Adjustments of the Set (indicated as necessary by the initial tests).
IV. Final Test by Oscillator.
V. Final Test by Master Tapper.

For all tests and adjustments, the input (from geophone or oscillator as the case may be) is to be divided between the two channels by means of the special input divider which permits switching, to each of the two channels of a Set, either the standard geophone or the oscillator. This saves considerable time in making connections and permits the tests of the two channels to record simultaneously, thus facilitating comparisons.

Before making a tapper test, care must be taken to see that the hammer of the master tapper is in adjustment; the

finished face of the hammer head toward and just grazing the end of the anvil rod, and the long axis of the head parallel to and central with that of the rod. A standard tapper-test series consists of five taps in each of the first three cases below, the hammer being allowed to fall freely from the indicated initial positions and (except for the decay test) caught on the first rebound after each initial tap. For each tap, the head is to be set in position on a distance gauge, which is then to be withdrawn vertically downward, without imparting any further offset or side play to the hammer. If the tapper adjustments and the technique of gauge withdrawal are correct, there should be very little vibration in the supporting rod of the hammer, even for the 2 in. fall.

A standard tapper-test series consists of the following:

(1) Five free falls from 1/4 in. displacement.
(2) Five free falls from 1 in. displacement.
(3) Five free falls from 2 in. displacement.
(4) Decay taps from an initial 2 in. displacement.

The order of this program has been designed with some care so that a record may be preserved of the characteristics of the Set after a week's recording and before any adjustments are made, together with a record of its characteristics after all adjustments are completed. Hence the order of the routine procedure should be closely followed as outlined below.

Routine Procedure

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Before starting a calibration, make sure that there is no gross defect in the equipment and that the styli are in adjustment, having a minimum of friction with the tape and writing throughout the entire width of the throw. Then connect the standard geophone and the oscillator to the input divider and connect the latter to the A and B channels of the Set to be calibrated. With these preliminaries completed the record is to be endorsed with the Initial Annotations as follows:

(1) The date.
(2) The number of the Set under calibration.
*(3) The settings of the three dials (A and B

writer-gain potentiometers and the bias-gain potentiometer) at the front of the second (P) unit of the Set, read by means of the small mirror provided (see Notes 1 and 2).

(4) The initials of the operator.

*I. Initial Tapper Test:

With the standard geophone properly installed in H47 (see Note 3) and connected through the input divider to the warmed-up Set to be calibrated, adjust both main attenuators to 10Db., start the recorder and put on a standard tapper test series.

II. Initial Oscillator Test:

With the oscillator switched through the input divider to the Set, adjust both main attenuators to 45Db. and, on the oscillator, set the pulse-time dial at Mark 14 and the pulse-amplitude dial at Mark 26. Plug in the oscillator to the AC supply and give five distinct, standard pulses by operating the push button switch on the oscillator (see Note 4). Set both main attenuators to 40Db. and repeat the above; again resetting the attenuators and repeating for, successively, 35, 30, 25, 20, 15, 10, 5, and 0Db. (On some channels the setting at 0Db. cannot be run through, due to oscillation.) If the set is properly adjusted, the successive groups of offsets, recorded through each of the two channels, should progressively increase from 45Db. to 15Db., be about the same at 10Db. as at 15Db., and then decrease through 5Db. to 0Db.

III. Adjustments:

(1a) Switch on the standard geophone through the input divider to the Set. This must be done under regular operating conditions, i.e. before work begins in the mine. Set the main attenuators at 10Db. and record for about 10 sec. Then, with the attenuators at 10Db. and the tape running, put on a regular bias test as follows:

Increase the bias until the styli are

both in contact with the inner bumpers. Allow the record to run for 10 sec. Then slowly decrease the bias until the first stylus just leaves its inner bumper. Allow to record for 10 sec. Then further slowly decrease the bias until the second stylus just leaves its inner bumper and allow to record for 10 sec.

This series of four runs of 10 sec. each may be termed the Initial Bias Record. This gives a record of the bias setting before any adjustments have been made.

(1b) Then set the main attenuators to infinity with the recorder turned off. After increasing the bias until the styli are resting on the inner bumpers, slowly decrease the bias. The two styli should leave their inner bumpers at the same time. If they do not, the trouble may be caused by lack of balance in the pair of 6F6 tubes (the pair at the back on the left hand side of the second unit of the Set). Try interchanging them. If this does not correct the trouble, it may be necessary to try out other 6F6 tubes until a matched pair is found, which will permit the styli to leave the inner bumpers together.

As a last resort, and only if necessary, try interchanging the 6ZY5G tubes (the pair second to the back on the left hand side of the second unit of the Set). This should not make any difference. If it does, try to match a pair and, if this cannot be done, the Set will have to be brought to surface for checking.

When the Set is adjusted so that the styli begin to move out from the inner bumpers at practically the same time, start the tape and record a bias test, the attenuators being left set at infinity. This series of three runs of 10 sec. each may be called the Adjusted Bias Record.

(2) Switch on the oscillator through the input divider to the Set. If the impulses from the oscillator did not record the same through both channels for

for each of the given attenuation settings in Section II above, it may be due to lack of uniformity between the two tubes (6B8G), which may be identified as the pair of tubes nearest the front on the left hand side of the second unit of the Set. It may be necessary to replace one or both of these. If they are good, there should be some slight record at 45Db. when the writer-gain potentiometers are properly set (see paragraph next below), but a tube need not be discarded if there is no record until 40Db.

If the tubes are balanced and the writer-gain potentiometer settings are correct, the offsets at 10Db. should each be just full scale. If they are not, set each of the main attenuators successively to 10Db. (with the other at infinity) and, in each case, adjust the corresponding writer-gain potentiometer so that a standard pulse from the oscillator just barely makes the stylus tap the outer bumper. This may be termed the Adjusted Maximum. When both are adjusted, start the tape and record simultaneously this Adjusted Maximum with both attenuators at 10Db.

(3) Switch on the standard geophone through the input divider to the Set, adjust the attenuators at 10Db. and repeat the bias test. Leave the bias-gain potentiometer at this setting (see again Note 2). Due to differences in the noise level on the two channels, it is usually not possible to have the styli leave the inner bumpers together under operating conditions, but they should do so with the main attenuators set at infinity. This series of three runs of 10 sec. each may be called the Final Bias Record. This gives a record of the bias setting after all adjustments have been made.

IV. Final Oscillator Test:

With the oscillator connected and adjusted as in II above, repeat the routine of that test. If it is not satisfactory and if the suggested adjustments do not permit a satisfactory calibration, the Set must be brought to surface for checking. If the test is satisfactory,

proceed at once with V below.

*V. Final Tapper Test:

With the standard geophone connected and the attenuators adjusted as in I above, repeat the standard tapper tests there outlined.

The Final Annotations are now to be made, as follows: Write, on the tape, the final settings of the three potentiometer dials(*) and add any memoranda which should accompany the record, such as changes in tubes or major adjustments. Then re-connect the regular input geophones, set the attenuators to 10Db. and restore the Set to operation.

NOTES

(1) Throughout the above instructions, the sections marked with an asterisk are to be omitted in testing Set 3.

(2) Do not re-adjust any of the potentiometer dials at any time without completely re-calibrating the Set.

(3) Proper placement of the standard geophone requires: that all projecting wax be removed from the screw heads in the side of the geophone; that it be positioned, with screws down, at the back of the test hole (H47); and that it be well seated by being drawn forward by the cable and pushed backward with the loading pole several times over the back 12 in. of the hole. If the geophone was properly placed when installed, its setting need not be checked before calibration; and, indeed, it should be in place without further adjustment at least a day previous to calibration.

(4) In operating the push button switch on the oscillator, care must be taken to push it firmly and vertically down the full depth of its run, to hold it down longer than the pulse time and to release it suddenly. Do not try to put on the five offsets too rapidly.

(5) A complete calibration should include only the ten

essential records, namely:

Initial Annotations	Adjusted Maximum
Initial Tapper Test	Final Bias Record
Initial Oscillator Test	Final Oscillator Test
Initial Bias Record	Final Tapper Test
Adjusted Bias Record	Final Annotations.

If any extra records are included, which were made in error or as tentative tests in adjustment, cross them out in pencil as they are made. If very much tape is included in these extra records, cut out the superfluous section(s) and join up the tape before booking it for filing.

(6) In comparing offsets, it is to be noted particularly that amplitude is to be measured from the operating zero, which may be displaced from the zero near the inner bumper due to a high noise level on the line. This difference will not cause trouble except at high gain settings of the main attenuators when using the oscillator or when making tests in which the recording geophone lines are feeding the Set.

Ottawa, February 22, 1944. E.A.H.

APPENDIX III

On December 1, 1942, the practice was adopted of turning in a daily report of activity in the section of the mine under investigation. At first these notes were given only to Mr. Blomfield. The service was gradually expanded by request. At the close of the period covered by this Report a single copy is turned in to the office each morning. Typed copies of this are made and distributed to the officers concerned.

Three different forms have been used in these reports, being changed to meet new conditions or to include further data. A copy of the form used since December 27, 1943, is shown in this Appendix. The following text was supplied to each person receiving the daily reports. It will serve here to make clear the nature of the observations made during the listening period.

Explanation of Form

(1) H = Hole Numbers, arranged in the order of: (a) levels (4450,4575,4700,4825); (b) drifts (north,south); (c) sections (2,3,4,6). Except H37, all holes are in the south wall; each is 30' deep. The locations, arranged for reference convenience in serial order of hole numbers, are as follows:

Hole	Location	Hole	Location
36	4402E3	*46	4701E4
*37	4402E3	⁸47	4702E2
38	4401E3	48	4502E6
•39	4702E3	49	4401E6
40	4701E3	50	4501E6
41	4802E3	51	4701E6
42	4801E3	52	4802E6
43	4502E3	53	4801E6
44	4501E3	54	4702E6
*45	4501E4		

* Not in cable hook-up but available for use with listening equipment.

• Lost due to mining operations. ⁸ Houses current reference-geophone, and used as location for testing geophones, but run in recording set-up.

(2) Time + Period: e.g. 5:18-2 indicates that listening began at 5:18 a.m. and continued for 2 min. net (exclusive of interference or salvos which interrupted and were allowed for but not counted through).

(3) C.P.M. Count ± = Average count per minute to nearest value on scale running: 0, 0+, 10-, 10, 10+, 20-, 20, 20+, etc. where, for example, 20- means definitely less than 20 but nearer 20 than 10; 20 means so nearly 20 that one cannot say less or more; and 20+ means definitely more than 20 but nearer to 20 than to 30, etc.

(4) Type: G = General (major adjustment, registered on more than one recording line); L = Local (pressure snap from focus presumably less than 75' distant); D = Distant-local (pressure snap from a focus presumably more than 75' and less than 250' distant).

(5) Ocnce = Occurrence: C = Continuous (throughout listening period); O = Occasional (brief, isolated, intermittent); S = Sporadic (continuous for intermittent short intervals during the listening period).

(6) Enrgy = Energy: C = Crackly (lively, small, sounding like brisk pine fire); D = Dull (low-pitched, usually indicative of distant general snaps); F = Faint (usually associated with distant-local snaps); H = Heavy (having considerable energy, full scale on recorders, very loud in phones, sometimes audible without equipment but not always); S = Snappy (not necessarily loud, but lively, high-pitched snaps, usually local); T = Tearing (local snaps which sound like tearing of silk, or like similar tearing cracks running across a hard-frozen ice surface).

Note: If more than one type occurs, all will be entered, the occurrence and energy indications being in the same order. For example: L:D:G O:C:S C:F:H indicates that the snapping was made up of local type, occurring occasionally and sounding crackly; of distant-local, occurring continuously and being faint; and of general snaps occurring sporadically and sounding very sharp and loud.

(7) Interfrnce, C, O = Interference, causes and occurrence: B = Blasting; C = Crusher; E = Electrical; H = Hum (25 cycle, etc.); M = Man-made; O = Ore runs in ore passes.

not associated with filling of skip; P = Pulsations (fan, pump, etc.); S = Skip; U = Unknown cause. No entry indicates absence of all interference. Multiple causes, and their manner of occurrence are entered as explained for types in Note above.

(8) S = Salvos (presumably small strain bursts accompanied by rock falls in stopes). Number occurring while listening is here indicated. Counts do not include salvo runs.

(9) Operator's Tentative Opinion of Conditions: High counts are not the only criterion of danger indications. After a listening period, the operator is in a position to give a tentative opinion on conditions which will supplement the quoted counts. This opinion must be recognized as subject to modification after studying the records and blasting reports.

(10) Equipment Remarks: Notes indicating changes in hook-up, troubles found and corrected, etc.

(11) Record numbers (top of form) indicate those removed at close of the listening period here reported.

Lake Shore Mines, Ltd.

INTERIM ROCKBURST REPORT

Issued: ..... , 194 . Records: ..... No. .....

H	Time +Period	C.P.M. Count ±	Type	Ocnce	Enrgy	Interfrnce C	Interfrnce O	S	Remarks
38	: -								
49	: -								
36	: -								
37	: -								
	: -								
44	: -								
45	: -								
50	: -								
43	: -								
48	: -								
40	: -								
46	: -								
51	: -								
47	: -								
54	: -								
42	: -								
53	: -								
41	: -								
52	: -								

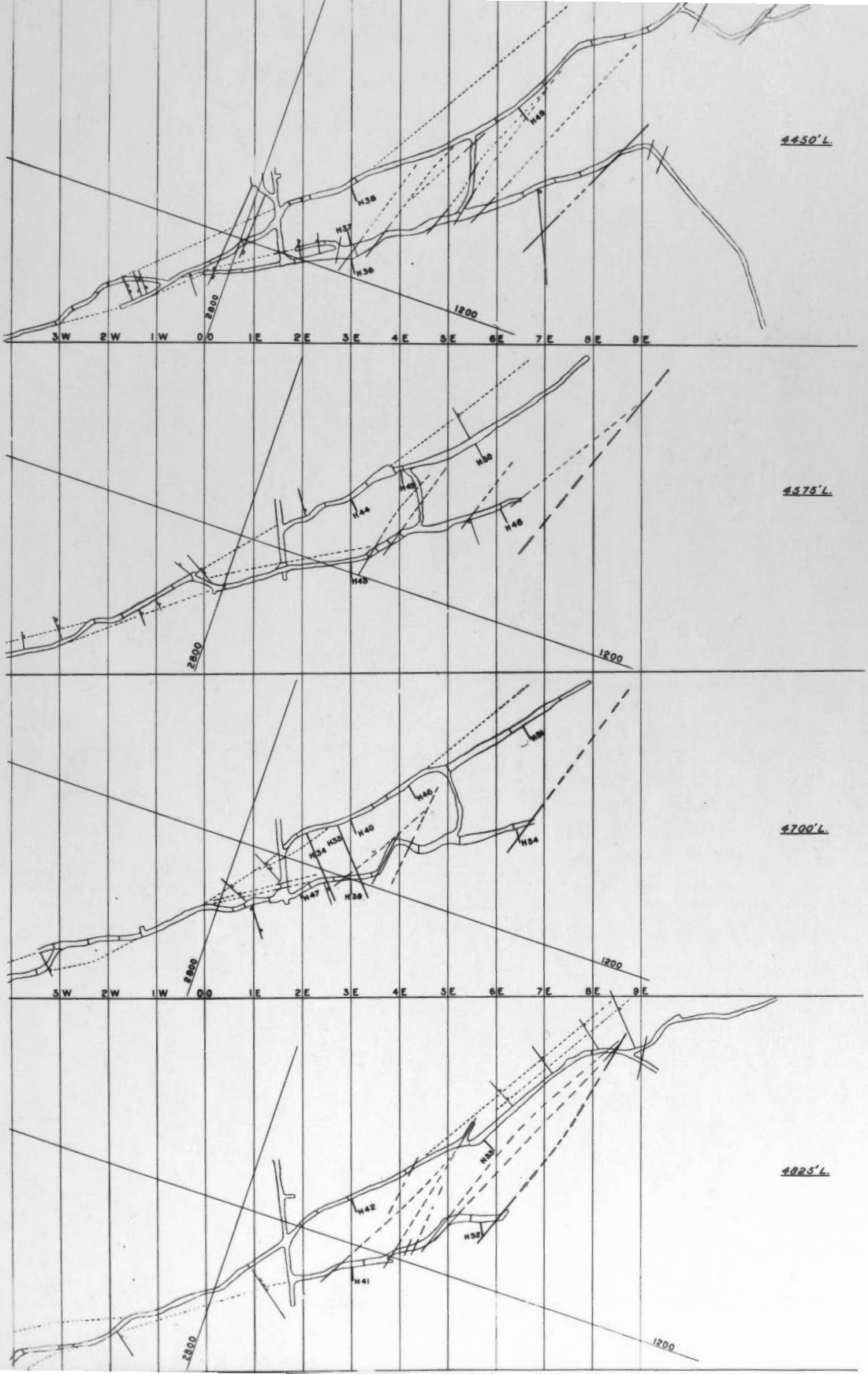
Most Active Holes: Nos. .....

Operator's Tentative Opinion of Conditions: .....

Equipment Remarks: .....

Fig. 3

Location of Holes 34-54


4450'L.
4575'L.
4700'L.
4825'L.
3W
2W
1W
0 0
1E
2E
3E
4E
5E
6E
7E
8E
9E
2800
1200
H36
H37
H38
H39
H43
H44
H45
H46
H47
H48
H49
H50
H51
H52
H53
H54
H55
H56
H41
H42

APPENDIX IV

Test Holes Assigned to Rock Burst Research

H	DD	Date	Location and Wall	Depth	Remarks
31	3744	Nov. 6'42	3908W-7-S	29' 6"	Replaced H30. A
32	3808	Feb. 7'43	4201W-5-S	51' 0"	Diagonal. B
33	3829	Feb. 28'43	3801W-6-S	51' 0"	Diagonal. C
34	3780	Jan. 15'43	4701E-2-S	140' 1"	30° up. D
35	3779	Jan. 13'43	4701E-3-S	164' 7"	30° up. E
36	3876	May 25'43	4402E-3-S	29' 0"	Fairly solid. F
37	3877	May 25'43	4402E-3-N	28' 9"	Fairly solid. G
38	3878	May 27'43	4401E-3-S	39' 5"	Broken ground. H
39	3881	May 29'43	4702E-3-S	32' 0"	Some seams. I
40	3882	May 29'43	4701E-3-S	29' 3"	Fair ground. J.
41	3879	May 28'43	4802E-3-S	30' 0"	Some seams. K
42	3880	May 28'43	4801E-3-S	32' 0"	Fair ground. L
43	3883	May 31'43	4502E-3-S	30' 0"	Good ground. M
44	3884	June 1'43	4501E-3-S	30' 7"	Broken ground. N
45	3899	June 23'43	4501E-4-S	30' 9"	Good ground. O
46	3901	June 24'43	4701E-4-S	30' 0"	Broken ground. P
47	PD	?	4702E-2-S	1' 6"	Bootleg. Q
48	3974	Nov. 20'43	4502E-6-S	30' 2"	Badly broken. R
49	3975	Nov. 20'43	4401E-6-S	30' 0"	Broken ground. S
50	3976	Nov. 23'43	4501E-6-S	30' 1"	Badly broken. T
51	3977	Nov. 23'43	4701E-6-S	30' 4"	Broken ground. U
52	3978	Nov. 23'43	4802E-6-S	30' 2"	Badly broken. V
53	3979	Nov. 24'43	4801E-6-S	30' 0"	Badly broken. W
54	3980	Nov. 26'43	4702E-6-S	30' 0"	Fair ground. X

Note: The date given is that of completion of the drilling.

A. DD3744 H31 Drilling began Nov. 6; finished Nov. 6'42.
0' - 10' Badly shattered porphyry; 12 pulls; 2" to 4" ground core at each pull.
10' - 29'6" Porphyry; not badly broken up; 7 pulls.

B. DD3808 H32 Drilling began Feb. 7; finished Feb. 7'43.
51' No log kept. Drilling done on Sunday, and hurriedly to avoid interference with regular work. Hole drilled SW at 45° angle with line of drift in effort to get geophone into ground burst on Jan. 29'43.

C. DD3829 H33 Drilling began Feb. 28; finished Feb. 28'43.

51' No log kept. See note B above, all of which applies here.

D. DD3780 H34 Drilling began Jan. 13; finished Jan. 15'43.
140'1" Porphyry; no mention of shattering. Hole run 30° up.

E. DD3779 H35 Drilling began Jan. 9; finished Jan. 13'43.
164'7" Same note as D.

F. DD3876 H36 Drilling began May 24; finished May 25'43.
0' - 5' Casing; no core recovered.
6' - 18' Porphyry; not badly shattered; most pieces 2" to 6" long; normal for porphyry; 5 pulls, with 2" to 8" of core missing at each pull.
18' - 29' Core not saved.

G. DD3877 H37 Drilling began May 25; finished May 25'43.
0' - 5' Casing; no core recovered.
6' - 28'9" Porphyry; not badly shattered; 6 pulls.

H. DD3878 H38 Drilling began May 26; finished May 27'43.
0' - 5' Casing; no core recovered.
Seam at 14"; lost water; ground badly broken to 11'; much of core ground up; water came back at 11'.
11' - 24' Core not badly broken up but about 2' lost by grinding.
24' - 39'5" Fairly solid porphyry; 3 pulls; rock sheared at 39' at a weak calcite break.

I. DD3881 H39 Drilling began May 28; finished May 29'43.
0' - 5' Casing; no core recovered.
0' - 4' Porphyry crushed and broken into small pieces; 3 pulls.
4' - 17' Highly altered porphyry with cherty break at 15'6"; 4 pulls, with a total of 17" of ground core.
17' - 32' Slightly altered porphyry; not badly broken up but with a total of 30" of ground core; 5 pulls.

J. DD3882 H40 Drilling began May 29; finished May 29'43.
0' - 5' Casing; no core recovered.
6' - 29'3" Porphyry slightly altered and not badly broken up; 11 pulls, with a total of 56" of ground core, mostly in the first 14'.

K. DD3879 H41 Drilling began May 27; finished May 28'43.
0' - 5' Casing; no core recovered.
6' - 14' Three pulls; 2'6" ground core.

L. DD3880 H42 Drilling began May 28; finished May 28'43.
0' - 5' Casing; no core recovered.
0' - 14' Fresh porphyry; not badly broken up; 6 pulls.
14' - 32' Porphyry; slightly altered; 5 pulls.

M. DD3883 H43 Drilling began May 31; finished May 31'43.
0' - 5' Casing; no core recovered.
0' - 18' Altered, slightly silicified porphyry; 10 pulls; 56" ground core.
18' - 30" Porphyry; core not badly broken up; 3 pulls; 12" ground core.

N. DD3884 H44 Drilling began May 31; finished June 1'43.
0' - 5' Casing; no core recovered.
0' - 17' Porphyry; badly broken up into pieces about 2" or less; 8 pulls; 50" ground core.
17' - 30'7" Porphyry; not badly broken up; 4 pulls; 26" ground core.

O. DD3899 H45 Drilling began June 23; finished June 23'43.
0' - 5' Casing.
0' - 18' Porphyry; not much altered or broken up; 7 pulls.
18' - 30'9" Porphyry; core recovered in good shape; 4 pulls; tight seam or crack from 24' to 26' longitudinal to core.

P. DD3901 H46 Drilling began June 24; finished June 24'43.
0' - 5' Casing.
0' - 7' Porphyry; not badly altered; 3'6" ground core (chopped); 5 pulls.
7' - 21' Porphyry; not altered but core broken into small pieces 1" to 3" long; 6 pulls.
21' - 30" Porphyry; not altered or broken up. 2 pulls.

Q. PD 1'6" H47 Due to the progress of mining, H39 was lost when cut off by sill removal. A short percussion-drill bootleg in the same drift (4702E-2-S) was used and given the number H47. At first it was intended to abandon this hole as soon as a new 30' hole could be drilled, but it was found

so useful for testing geophones that it has been retained, even in the regular recording program.

R. DD3974 H48 Drilling began Nov. 19; finished Nov. 20'43.
0' - 5' Casing.
0' - 30'2" Porphyry; badly broken up; break, with ore, at 8'6"; 20 pulls.

S. DD3975 H49 Drilling began Nov. 19; finished Nov. 20'43.
0' - 5' Casing.
0' - 12' Porphyry; slightly altered; badly broken up; 11 pulls.
12' - 30' Porphyry; not so broken; 7 pulls.

T. DD3976 H50 Drilling began Nov. 22; finished Nov. 23'43.
0' - 5' Casing.
0' - 30'1" Porphyry; badly broken up; much lost core; 26 pulls.

U. DD3977 H51 Drilling began Nov. 24; finished Nov. 25'43
0' - 5' Casing.
0' - 19' Porphyry; badly broken up; much lost core; 15 pulls.
19' - 30'4" Porphyry; less broken; 6 pulls.

V. DD3978 H52 Drilling began Nov. 22; finished Nov. 23'43.
0' - 5' Casing.
0' - 30'2" Porphyry; badly broken up; 21 pulls.

W. DD3979 H53 Drilling began Nov. 23; finished Nov. 24'43.
0' - 5' Casing.
0' - 30' Porphyry; badly broken up; 23 pulls.

X. DD3980 H54 Drilling began Nov. 26; finished Nov. 26'43.
0' - 5' Casing.
0' - 30' Porphyry; altered; not as badly broken up as other holes; calcite break at 12'6"; 17 pulls.

Note: All diamond drill holes on the east side, beginning with H36, were cased for the first five feet of hole, with 1"5 pipe cut in 6' sections, set with 1' projecting into the drift.

APPENDIX V

Recording Program from Holes 31-54

The following tables show the records obtained from holes 31-54, for the period covered by this report. The digit at the intersection of any hole line and date column is the units figure of the number of the record which began to register from that hole on that date. The hundreds and the tens digits of the number are given in the bottom (double) line, in the order reading down. A dash in any position indicates that one is to read the figure next on the left in the same line. An oblique bar through a units digit couples it to the hundreds and tens digits next on the left of those immediately below in the double line.

For example, on July 12, record 599 was begun from H43 and H44, while record 600 was begun from H39 and H40. The day before, being Sunday, the records were not changed but continued to register on, respectively, Nos. 597 and 598, which were begun on Saturday, July 10. The heavy vertical lines indicate week ends. A vacant intersection indicates that there was no record for the hole and date concerned.

NOTES

1. Holes 31 and 33 were lost in the burst of March 31, 1943.

2. Hole 32 (4201W5-S) survived the burst and continued to be serviced by the old-type, single-track recorder (No. 2). The ground on the west side was very quiet during April and May; the program on the east side began on April 27; mining operations finally made it necessary to abandon the doghouse on 4201W5. For these reasons, recording in the west pillar was discontinued, the last record being 544 on May 15.

3. The first recording with the two-track instruments began on the east side (H34, H35) on April 27. H34 and H35 are deep, diamond drill holes in 4701E. They had been drilled for ore-location purposes in January, 1943, but were found to be still in good order. As they run upward at a 30°-angle, there

was some difficulty in placing the geophones in them. They were used until a series of nine holes (H36 to H44) had been drilled at the Sec. 3 line in the east drifts of the levels from 4450' to 4825' inclusive (see Appendix IV). Initially, these holes were serviced by means of the listening equipment, pending the installation of connecting cables and the building of a doghouse in the 4700XC.

The holes on the 4450'-level (H36, H37, H38) continued to be so serviced until October 8. H37 was never connected to a recorder and was finally lost through slips on faults intersecting the hole. For recording from H36 and H38, see note 6 below.

Recording from the remaining holes of the new series was begun with record 576 from H39 on June 19, the others coming into service as fast as the installations could be completed. The last ones (H41 and H42 on the 4825'-level) began on July 13, with record 603.

4. As the activity at Sec. 3 was found to be low, two holes (H45 and H46) were drilled at Sec. 4 line in 4501E and 4701E, respectively. Time switches permitted them to record, beginning July 17 and July 24, alternatively with H44 and H40, respectively. Recording from these ceased about the end of November, as the holes H48 to H54 came into service (see note 7 below); but H46 was again used, for experimental recording, about the end of January (see note 9 below).

5. H39 (4701E3-S) was lost due to mining operations; the last record (653) was begun on August 2. In its place, a clean, percussion-drill bootleg in the same drift (at Sec. 2) was adopted and recording begun on August 4. It was, at first, intended to use this hole only until a new one could be drilled near H39, but H47, as the bootleg was numbered, is near the doghouse and was found so useful for testing geophones that it has been retained on the regular recording program.

6. Beginning October 8, a portable instrument case was placed in the crosscut on the 4450'-level, to

house recorder No. 3, which had just been made over by Gibbs from a one-track to a two-track instrument. Cables were run and holes H36 and H38 were connected to this recorder. The first record (No. 828x) was inadvertently given a number already issued to another record, hence the added designation x. The set was, at first, run only during the listening period each day, which accounts for the absence of records for the Sundays in October. A program clock was then used to turn on the set for a halfhour, a.m. and p.m., so the records were obtained on Sundays beginning about November 1. The records were changed at irregular intervals, roughly once a week, since they ran only about an hour and a half (about 10') per day. Beginning with record 997 (December 9) a new time switch permitted H49 (4401E6-S) to be run alternatively with H38.

7. A series of seven holes (H48 to H54) was drilled at approximately the Sec. 6 line in the east drifts of the levels 4450 to 4825, inclusive (see Appendix IV). Recording was begun about the end of November. Time switches were used to run each of the Sec. 6 holes alternatively with the corresponding hole at Sec. 3 in the same drift. (No hole was drilled in 4402E6 due to the very broken nature of the ground.) These holes went into service on various dates as the installations were completed, the last hole (H53) being put in operation with record 993 on December 8.

8. Record 999 was begun on December 10. This closed the first series of record numbers. The new series (records 1, 2, 3, etc.) began on December 11.

9. Beginning with record 133 (January 30), an experimental recording arrangement was started on 4700. The recorder, No. 2, old-style, single-track, equipped with filters, was connected to a geophone in H46 (4701E4-S), vacant since November 29.

10. As of January 31, 1944, a total of 1136 records had been made, all carefully annotated, analysed, booked and filed, available for reference or further study.

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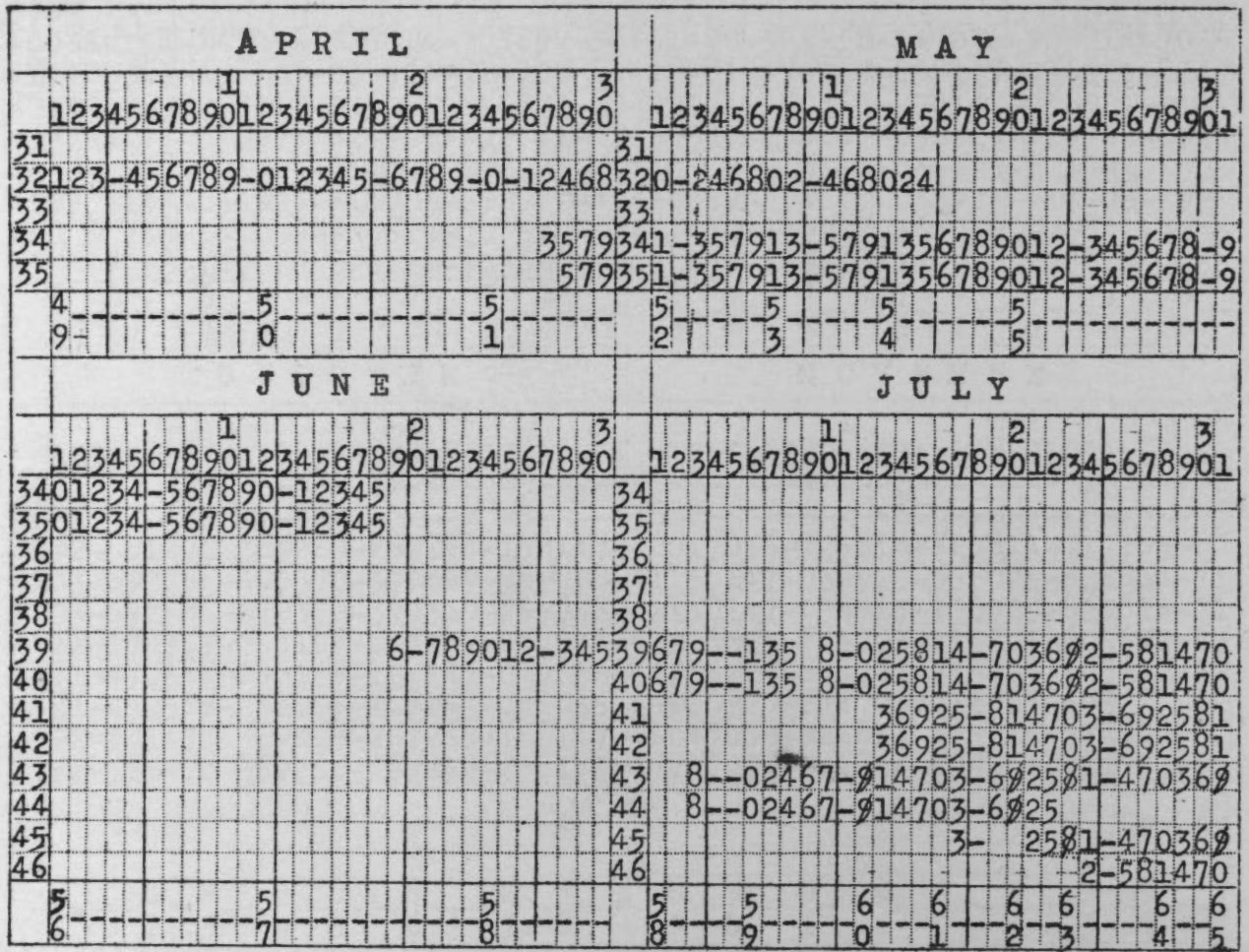
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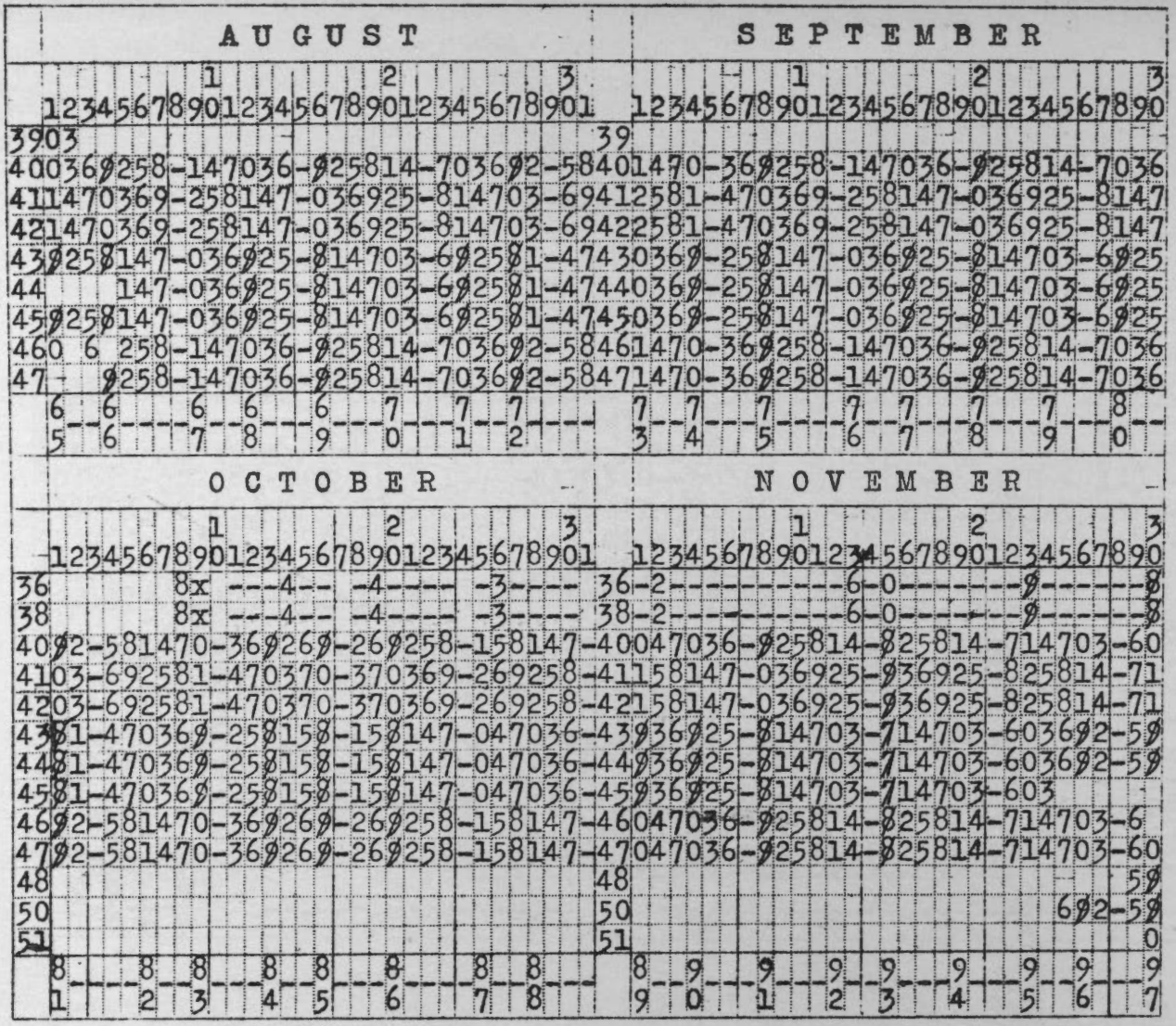
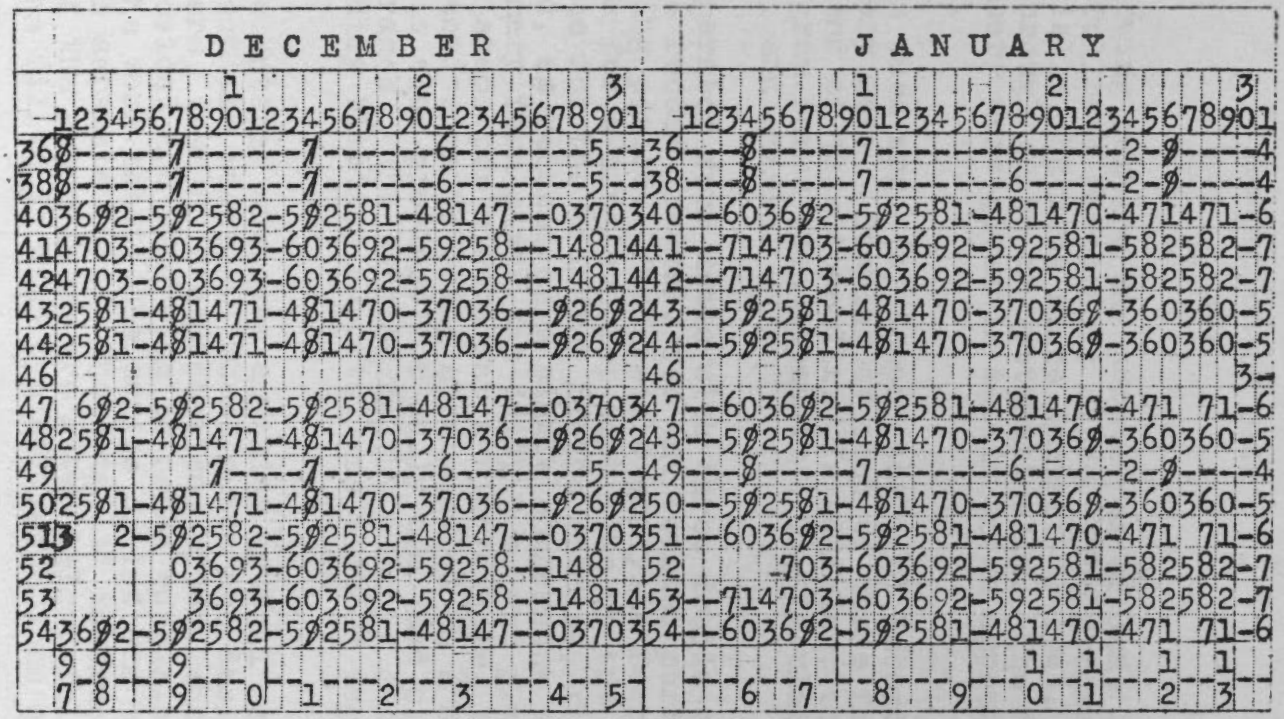
JULY


AUGUST
SEPTEMBER
OCTOBER
NOVEMBER


DECEMBER
JANUARY

APPENDIX VI

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Reduction of Data

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The following routine was adopted as of June 1, 1943, and has been followed rigorously since. The program had been substantially the same since January 1, 1943, but was not carried through quite as systematically. The reductions for January were given in detail as an appendix to Report No. 11.

The forms used are: (a) Comparator, (b) Record Analysis, (c) Summary Data. Samples of each of these forms are given at the end of this Appendix. In addition, there are listening program forms (see Appendix III), tabulations of blasting data, and graphs.

Each comparator form deals with three double-track seismograms (6 record tracks), for the counted part of a single recording period. Each record analysis form tabulates the data for a single hole, each line on the form affording space for the transfer of the entries, for the hole concerned, as reduced on a single comparator sheet. Each data summary form gives the daily a.m. and p.m. average number of snaps per minute for a single hole, the entries for an entire month being accommodated on a single form. Space is also provided for daily a.m. and p.m. listening averages. The entries on the summary data forms, as also the daily blasting reports, are plotted regularly each day.

Notes are entered wherever anything unusual occurs which can affect the records. These notes are designated by index letters, issued in alphabetical order, entered in the column provided and referring to notes appearing on the back of the same sheet, the series of letters beginning at A on each separate form. The detailed instructions for the use of the above forms are given below, followed by sample forms filled in with typical reductions of data.

Instructions

...

I. Records are first to be passed through the annotator (see p. 5, paragraph 1, Report No. 11). They are to be

carefully examined for anomalies and the following annotations are to be entered directly on the record tapes:

A. At the beginning of the record (entered, in part, when tape is placed in service on the recorder underground)

(a) Record number.
(b) Hole numbers.
(c) Set number and track letters.
(d) Geophone numbers.
(e) Attenuations.
(f) Schedule designation.

B. Throughout the entire record

(a) The beginning time and every tenth minute thereafter for each separate recording period.
(b) The ending time at each cut-off by either program clock or time switch.

C. On each period of recording

(a) Set and tracks, if not the same throughout the entire record.
(b) Hole numbers, if not the same throughout the entire record.
(c) Coincidences used for synchronizing.
(d) Periods to be omitted from the counts.
(e) Start and finish of counting times where whole recording period is not counted.

II. Records are then to be put on the comparator (see p. 4, paragraph 3, Report No. 11) with the following procedure which is to be repeated, using a separate form for each count period:

A. Enter on the top of the comparator form the beginning and ending times of the whole recording period as started and stopped by the program clock or time switch (not just the counted part). There will be only one date, since there is only a single period on any comparator sheet and periods do not run over midnight. The serial number of the comparator sheet

is to be entered in the space at the top-centre of the form, under the word "Date".

B. Enter opposite Rec. the record number for each pair of tracks. In the line next below, enter the set number and track letter for each of the two tracks on the record, and in the next line the numbers of the holes served.

C. For each two minutes of record, set the horizontal, mimeographed time lines of the comparator sheet (1".5 apart) to match time lines which are to be drawn transversely in pencil on the record tapes through the synchronized endings of corresponding time marks (3" apart), the design of the comparator taking care of the half-scale reduction.

Draw the coincidence times on the comparator sheet using a faint pencil line clear across the whole six tracks. Mark the actual coincidences as heavier sections on this faint time line. Use the first column alone where the coincidence on the track concerned is small (1/4" offset or less) and both columns where it is large. Identify one or two outstanding coincidences by letters, entered both on the record and on the form.

The first column of the last pair on each half of the form is to be used for the identifying letters, the second for a series of index letters referring to notes entered on the back of the form. If care is taken to put coincidence designations always in the first column of the last pair, and note designations always in the second, capital letters can be used in each case without causing any confusion. The letters indexing the notes should be in alphabetical order, beginning with A on each sheet; but the coincidence identification letters may be assigned at random. Indeed, random use of letters in the latter case makes it easier to find the sections of record to be correlated with a given comparator sheet when checking the work later.

D. Having completed the analysis of the coincidences for the two minutes, count all snaps for the first track in that two minutes, regardless of whether they were included as coincidences or not. Enter the number indicating the count of the "totals" in the left hand column of the pair assigned to the track concerned, in any available space within the minute boundary lines. Then count the "larges" - those more than

1/4" long - and enter this count in the right hand column of the pair. Repeat for all six tracks for the two minutes concerned.

E. Repeat C and D for each two minutes of the period selected for counting, winding forward the records, moving up the form and thrusting forward the lever so that, at its farthest position, the near edges of the comparator plates lie on the synchronized final time-lines of the records and forms for the two minutes just completed.

F. Enter the identification of the alternate minutes in the space provided at the end of each of the minute lines in the last two columns of each half of the form.

G. Total the "totals" and total the "larges" for each hole and enter these grand totals in the spaces at the end of each corresponding column in the second half of the comparator sheet.

H. Determine the fifteen possible pairs of coincidences, using the masks* 1-15 in order. Enter each as counted, in the 15 successive sections at the bottom of the right-hand half of the form.

If any track was not recording, use the masks as usual, in order, entering a dash where you would have entered a coincidence count. In other words, the dash indicates that the coincidences were not determined, not that there were none. The dashes are to be treated in the section next below, exactly as the counts would have been, and carry over into the record analysis forms as dashes, indicating that the coincidences could not be determined for the hole and count concerned.

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* Note: The masks to which reference is here made, are sheets of thin stiff cardboard the same size as the comparator forms and having two long slots cut to expose the first half of each of two columns, selected in such a manner that each mask gives one of the fifteen possible combinations of the six tracks (ABCDEF), two at a time, in the order: AB, AC, AD, AE, AF, Bc, BD, BE, BF, CD, CE, CF, DE, DF, EF. These masks simplify the counting and entering of all possible combinations of coincidences, rendering the work automatic and reducing errors.

I. In the diagonal of the 6 x 6 section square, in the lower left-hand corner of the form, from top left to bottom right, enter the number designations of the holes in the order which they have on the comparator sheets. (The track order for any given combination of recordings which is repeated from day to day should always be the same.)

J. In the remaining 5 sections of the top line (left to right) and of the left column (top to bottom) of the square, enter the first five coincidence values (numbers or dashes as may be). In the next line and next column, enter the next four. In the next line and next column, enter the next three. In the next line and next column, enter the next two. In the final line and final column, enter the remaining one. The square is now filled.

K. In the first column of spaces following the square, enter the number of minutes for which the count was made, for each of the holes respectively on the same lines in the diagonal of the square. Usually these "periods" are all the same but sometimes, for various reasons, they differ.

L. Divide the grand totals of the "totals" and the "larges" of each track by its own proper period value and set the derived "totals per minute" and "larges per minute" in the first two of the three spaces following the period entry for each hole. Subtract the second from the first and enter the value, "smalls per minute", in the third space.

Note: In designing the comparator form, care was taken to provide for counting throughout the entire half-hour recording period. This was found to be prohibitively time consuming and a count of sixteen minutes was then used. After long experience, it was found that, if care is taken to select the six minutes (not necessarily concurrent) which appear average in any half-hour recording, the counts will differ little from averages taken over the complete time. On July 13, 1943, a six-minute count was adopted as standard and a table was prepared which simplifies the divisions. At first, only the nearest whole number was entered, but as this gave no clue to relative small values, the divisions were carried to two decimal places. The plotting is done only to the nearest whole number.

III. Record data are next to be transferred to the record analysis forms. Data are transferred to the forms for the respective holes concerned, filling in each to the bottom line and beginning again on the next sheet for the same hole without any regard to termination of days, weeks, or months.

Enter on each line the record number and the dates of beginning and ending of the entire record (not just the half hour recording period). Enter the data as to set (and track), attenuation, and geophone. The epoch (E) is the middle minute of the count period. When the minutes are not concurrent, it is the middle minute of the time from the beginning of the count to the end. The actual, net count period, in minutes, is entered in the column headed P. The average "totals per minute", "larges per minute", and "smalls per minute" are taken directly from the comparator sheet and entered in the columns headed, respectively, T, L, and S. The number of the comparator sheet concerned is entered in the column headed N. The concurrent records are indicated by the holes occupied, obtained from the top of the comparator sheet (or the diagonal of the square in its lower left-hand corner). These are entered on the analysis sheet in the same order. The numbers of coincidences, in the 15 categories, are entered, in order, from the line in the square containing the hole concerned, maintaining the order of the square, but omitting the hole number cut across by the diagonal.

IV. The summary data form entries are obtained by taking, for example, the sum of all the a.m. entries for a given date ("totals", "larges", and "smalls"), dividing by the number of entries in each class and entering the resulting number in the first line for the date. (The first line is for a.m. entries, the second for p.m. entries.) The p.m. values, obtained in the same way, are entered in the second line for any given date. The values of the listening, for the same hole, a.m. and/or p.m. are entered in the spaces provided under the heading H (heard). These are to be obtained from the listening form for the date concerned (see Appendix III).

V. The data from the summary data form, the listening form and the mine reports of powder and holes used in blasting are to be entered on the graphs daily.

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Sample Data Reductions

The readings for the first afternoon count (16^h01^m-16^h31^m) on February 11, 1944, are given on comparator form No. 2393, which is here reproduced in full, just as it was originally completed. To make the sample more typical, it has been copied, in multiple, by Mrs. Grace who normally does all the reduction work. The following points may be noted, beginning with the comparator form and continuing with the other two in order:

(1) Track 5B was not recording, as indicated by the blank double column and by the note index (A) on the face of the form, and as explained in the note itself on the reverse.

(2) The strong coincidences at about 20^m and $21^m.5$ are identified by the random letters K and T, which are also used to identify the actual offsets on the record tapes, making it easy to identify corresponding times when checking the reduction.

(3) H40 shows all but one of the 29 coincidences, while H42 is at the other end of the scale (with only 13). Yet H40 is almost vertically above H42 and on the next level. They are only about 125' apart. The geophone in H40 seems to be resting on a very active block, or else on rock which is an unusually good conductor of elastic waves. H42 is not always so lacking in coincidences, but H40 is almost always uniformly high, both in counts and coincidences.

(4) The checking of coincidence patterns, after the manner briefly and partially indicated above, is very helpful and suggestive.

(5) The numbers of the successive holes (43, 44, 47, 40, 41, 42) are entered downward and to the right across the diagonal of the square. (All these holes are at the Sec. 3 line, the first pair, 43 and 44, being on the 4575'-level, the next pair on the 4700'-level, and the last pair on the 4825'-level. The first of each pair is in the south vein, the second in the north vein. This order, for example, is always maintained in the reductions when these holes are involved, a procedure which simplifies the reductions and also the daily check of conditions underground as revealed by the records.) The counts are next to be made.

(6) Taking, for example, track 6B(H43), we find that there were 20, 18, and 17 "totals" in each of the successive two minutes of counting from 19^m to 25^m, and the total of "totals" is thus 55, as entered at the bottom of the left-hand half of the first pair of columns on the right-hand side of the form. Similarly, there were 6, 4, and 6 "larges", making a total of "larges" of 16, as entered in the right-hand half of the space for grand totals for this track. These numbers, divided by the period time (6 min.), gives the values 9.17 and 2.67 to be entered in the top line to the right of the square (since H43 appears at the intersection of the diagonal and the first line) as the "totals per minute" and "larges per minute", respectively. The difference, 6.50, represents the "smalls per minute", entered in the final space on the line.

(7) The number of coincidences between, for example, 6B and 6A (H43 and H44) is 19, as may be verified by inspection of the pencilled coincidences. This accounts for the first entry in the row of fifteen sections across the very bottom of the right-hand side of the form. The number of coincidences between 6B and 5B (H43 and H47) cannot be determined (since H47 was not recording). Hence the dash in the second section. So on, with the series: (43,40) (43,41) (43,42) (44,47) (44,40) (44,41) (44,42) (47,40) (47,41) (47,42) (40,41) (40,42) (41,42), yielding the further respective entries: 26, 19, 12, -, 20, 16, 12, -, -, -, 20, 12, 12. These values are filled into the sections of the square (first five, next four, next three, etc.) as described in II-J of this Appendix. The comparator sheet has now been completed. As a sample, let us consider H41, and transfer the data to the record analysis form. There will, of course, be a form for each of the six holes. Only one is given here. Consider the last (latest) line showing entries on the sample form, following through that line from left to right.

(8) H41 was registering on Record No. 177 (see top of comparator sheet). The record ran from Feb. 11 to Feb. 12. The track was 4B (see top of comparator sheet). The attenuation (10Db) and the geophone number (34) were obtained from the record itself (see I-A of this Appendix), and are entered in the columns headed respectively Db and G.

(9) The epoch (E), or central minute about which the count was made, was 16^h22^m, (see identification of alternate minutes on the comparator sheet). The number

of minutes of count (P) was 6.

(10) Taking the line next to last in the square at the bottom left of the comparator sheet (which line has H41 on the crossing of the diagonal) the "totals per minute" (T), "larges per minute" (L), and "smalls per minute" (S) are, respectively, 7.50, 2.50, and 5.00, as given on the line concerned, to the right of the square, whence the entries shown on the record analysis form.

(11) The comparator form number (N) was 2393.

(12) The concurrently-recording holes, in order from top left to bottom right of the diagonal of the square on the comparator sheet, omitting of course H41, were, in order: 43, 44, 47, 40, 42. The coincidences are obtained from the horizontal line next to the last in the square, again omitting H41, and are, in order: 19, 16, -, 20, and 12, respectively. That is to say, for example, the number of coincidences between H41 and H40 (next to the last of each of the series as entered on the record analysis form) was 20. This may be verified by checking the pencilled coincidences of H41 and H40 on the comparator sheet. When one tries to do this, the aid given by the masks may be appreciated. They are especially convenient when comparing columns which are not adjacent. It may be noted, in passing, that when checking conditions with only the record analysis form at hand, the dash entry in the central section for the coincidences indicates that there was no record from H47, the concurrent-record entry in the central section for the holes concerned.

(13) As there was only one afternoon count for this set of holes on Feb. 11, there is no averaging to do. The values, 7.50, 2.50, and 5.00 appear, therefore, directly on the p.m. line for Feb. 11 in the monthly summary data sheet for H41, as shown.

(14) The values given in the summary data sheet are now entered on the monthly graphs for the hole concerned.

(15) All the reductions, at least four counts per day, for, in general, 12 holes (six on one time-switch contact and six on the other), are made each day and carried right through to the graphs, making all readings available and completely up to date. As

stated in the body of this Appendix, the daily blasting data and the listening counts are also plotted on their respective graphs for the month.

(16) The records are then made up into book form for easy reference (see p. 8 and Fig. 1 of Report No. 10).

The reduction of records has been illustrated in considerable detail to show how carefully all are scanned and the reduced data digested into the graphs. This has been done for a total (as of Jan. 31, 1944) of 1136 records (2352 comparator forms). Credit for practically all of this work is due to Mrs. Grace. It is of extraordinary assistance to the writer, to have this information made ready for his inspection promptly and accurately every day.

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H41 Record Analysis Form

Rec.	Fr.	To	Set	Db	G	E	P	T	L	S	N	Con.Rec.Holes	Coincidences	Remar
	Feb.	Feb.												
169	9	10	4B	1034		16:06	6	15.33	4.50	10.83	2385	43444740424	5424155 61	
169	9	10	4B	1034		4:11	6	3.67	1.00	2.67	2387	43444740421	8161919 13	
173	10	11	4B	1034		16:20	6	12.50	4.50	8.00	2389	43444740424	9515155 54	
173	10	11	4B	1034		4:24	6	3.67	.50	3.17	2391	43444740421	0 9101 3 8	
177	11	12	4B	1034		16:22	6	7.50	2.50	5.00	2393	43444740421	916 -2012	
3	2	2				5	1	5	4	5	4	2 2 2 2 2	2 2 2 2 2	
3	2	2				5	1	5	5	5	4		2 0	

H41

Summary Data for February, 1944

D	T	L	S	H	Remarks
1	3.17	.33	2.84	0+	
	6.17	2.33	3.84		
2	5.17	1.17	4.00	0+	
	11.83	3.00	8.83	10-	
3	2.67	.33	2.34	0+	
	2.50	.17	2.33	0+	
4	2.50	.33	2.17	10+	
	8.17	2.67	5.50	0+	
5	2.83	.67	2.16	6	
6	1.83	.50	1.33		
	3.50	.50	3.00		
7	1.67	.17	1.50	0+	
	11.33	.67	10.66	0+	
8	3.33	.67	2.66	0+	
	5.17	1.17	4.00	0+	
9	4.00	.83	3.17	0+	
	15.33	4.50	10.83	0+	
10	3.67	1.00	2.67	0+	
	12.50	4.50	8.00		
11	3.67	.50	3.17	0+	
	7.50	2.50	5.00		
12					
13					
14					
15					
16					

D	T	L	S	H	Remarks
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					

Computed G Checked E.A.H.

Fig. 4

Recording Program January, 1944

APPENDIX VII

Rockbursts Located in Lake Shore Mines
April, 1943 - January, 1944

	Date	No.	Time	Class	Location	Rock Displacement
A	April 7	345S	3:55 p.m.	-	4402E-5 to 4502E-5	small
B	" 9	297C	7:05 p.m.	heavy	4450E to 4825E	several hundred tons
C	June 2	346S	2:45 p.m.	-	4802E-3	25 tons
D	July 13	298C	2:30 p.m.	light	4902E-2	30 tons
E	Aug. 18	299C	2:30 p.m.	light	4801E-5	several tons
F	Sep. 29	300C	1:19 a.m.	med'm	1801W-11	50 tons
G	Oct. 5	301C	2:32 p.m.	med'm	4701E-4 to 4801E-4	160 tons
H	" 15	302C	5:45 p.m.	light	3 shft.plr	10 tons
I	" 26	303C	12:20 p.m.	heavy	3 shft.plr	more than 1000 tons
J	" 29	304C	3:00 p.m.	light	4701E-6	several tons
K	Dec. 13	305C	3:20 p.m.	med'm	4801E-7	100 tons
L	" 18	306C	3:30 p.m.	light	4502E-5	25 tons
M	Jan. 5	347S	3:30 p.m.	-	4502E-5	25 tons
N	" 10	307C	3:30 p.m.	light	4501E-5	several tons
O	" 13	348S	3:30 p.m.	-	4502E-5	10 tons
P	" 20	308C	4:35 p.m.	med'm	3501E-5 to 3811E-5	several hundred tons
Q	" 28	349S	3:30 p.m.	-	4801E-7	15 tons

7 4 16 5 11 17

The above list shows only the bursts which occurred during the period indicated and which were located and investigated in Lake Shore Mines. More than 120 bursts occurred which were of sufficient magnitude to be registered on the seismographs. (Some serious interruptions in January, 1944, to the recorder on the 3000'-level leave in doubt the exact number of bursts which might have registered.) A total of 17 bursts (5 strain, 12 crush) were surveyed and reported as above shown. All but four (B, F, H, I) occurred during or close to the afternoon blasting time in the off-shift period. All but four (E, H, I, P) occurred

in the section of the mine which is directly under investigation (east side, 4325'-level to 4950'-level). The second burst in No. 3 shaft pillar (I), on October 26, registered on the seismograph at Ottawa.