DEPARTMENT OF MINES
RECEIVED
OCT 26 1939
JUNEAU, ALASKA

TERRITORY OF ALASKA

DEPARTMENT OF MINES

College, ~~FAIRBANKS~~, ALASKA
Oct. 13, 1939.

Mr. B. D. Stewart,
Commissioner of Mines, Juneau, Alaska.

Dear Mr. Stewart:

I have been somewhat remiss lately in keeping you informed of our activities. The main reason is that it has seemed best to get in as much field work as possible before the really cold weather comes. We have not had any bad weather yet, excepting one cold, windy spell while we were on Deadwood Creek.

We returned from the Circle District Sept. 23, have since worked about a week and a half on Happy Creek and around Fairbanks, and have been running a magnetic survey on Bedrock Creek, tributary to Cleary Creek, since Oct. 6. While we are out here we intend to spend a few days running traverses over some of the granitic outcrops around Pedro Dome to see if they can be outlined by means of the magnetometer.

The geoscope was used as much as possible before freezeup, as winter conditions will necessitate some changes in the outfit, as well as some experimenting to determine if it is practical to use during cold weather. Ervin Bramhall, Professor of Physics at the U. of A., has promised to lend us a more sensitive galvanometer to replace the one we have been using, which is not sufficiently sensitive for use on snow covered or frozen surfaces. It will be necessary to mix some sort of antifreeze with the copper sulfate solution in the non-polarizable electrodes, and devise a method ~~for~~ to prevent the batteries in the geoscope from freezing. For the latter I had thought of trying hanging some pieces of wool blanket around the sides of the instrument, long enough to reach the ground, and hanging a small oil heater or Coleman lantern from a hook fastened under the planetable tripod. A thermometer stuck through the instrument panel will tell us how much heat to apply. I think that dry cells will function in temperatures above 15°F, or thereabouts, so a great deal of heat will not be necessary, especially if the instrument is warm at the start of the day. For permanent winter operations a small motor-generator set probably would be the best source of current, but the method proposed should be satisfactory and won't cost anything for new equipment. Methods similar to those we are using have never been tried out under cold weather conditions, to my knowledge, but they should work. In some respects results may be better than those obtained during the summer, as surface conditions will be quite uniform. Incidently it will be easy to determine the depth of temporary, or winter frost by resistivity methods.

I am enclosing a letter from Mr. Gebhardt, Observer in Charge at the Sitka Magnetic Observatory, in which he mentions the possibility of the C. and G. Survey establishing an observatory in the interior, and also something about a portable magnetograph which they are developing. Some method of obtaining a continuous record of the fluctuations in the earth's magnetic field intensity would be a great aid to magnetic prospecting in the interior. At present we check back hourly to a base station during magnetic surveys. An observatory in the vicinity would eliminate the need of this, would enable more accurate corrections for diurnal variation to be made, and would permit work to be carried on during more disturbed magnetic conditions.

A year ago the C. and G. Survey was considering establishing an observatory at the U. of A., but the plan apparently was dropped. Last winter in Washington I heard that the unpleasant experiences of the Biological Survey at College sort of made the C. and G. Survey wary of establishing themselves there. I wonder if the Dept. of Mines could cooperate in some way in helping to bring an observatory to the interior. Perhaps if they understood that besides getting data that they need, they would be aiding other geophysical work, they would take quicker action.

Since seeing you last we finished up on Portage Creek and ran magnetic and resistivity surveys on Deadwood and Mammoth Creeks in the Circle District and on Happy Creek in the Fairbanks District. In addition, deep resistivity runs were made on the Circle Springs airfield and on a field of Bentley's Dairy near Fairbanks. The first indicates that what is probably the Tertiary conglomerate extends from depths of from 90 to 110 feet, to at least 520 feet deep. The Fairbanks test gave no indication of bedrock at 600 feet, the greatest depth reached. I would like to make some additional deep runs near Fairbanks, where the deepest wells reach below sealevel but have not hit bedrock. Two days were spent investigating the very high surface potentials that are always found in ground covered with moss and peat. Samples of moss were taken for subsequent determinations of their acidity.

The results have not been worked up in final form, but the resistivity work on Portage, Deadwood and Happy Creeks gave good results that checked with known conditions. On Mammoth Creek the main break appears to be at the base of the frozen ground rather than at the top of bedrock. Possibly the break at top of bedrock will show up better when the curves are subjected to mathematical analysis, but an offhand interpretation, with no drill logs to check against, would place all depths several feet too great. With occasional drill holes for checking purposes, I believe that Mammoth Creek could be profiled fairly accurately. Good magnetometer results were obtained on Deadwood and Happy Creeks, with clear cut agreements with known values. On Mammoth Creek there is general agreement with drill values, but there are a number of discrepencies. That is, individual drill holes may show low values where the magnetic survey indicates good values, and vice versa. These discrepencies may be due to the fact the Mammoth creek gold is coarse and of spotted occurrence. The 4" airplane drill used to prospect the creek could not be expected to give accurate results in each hole, although the average values as determined by drilling might agree with recovered values. On lower Portage Creek the pay is scattered, according to drilling and magnetometer results. A line run on upper Portage where the pay is said to be more confined, gave results that agree with the prospecting data available. The small magnetic anomalies on Portage Creek indicate that positive magnetometric results are more difficult to obtain than on most of the other creeks tested.

To date the following creeks and areas have been tested by magnetic and resistivity surveys: Ester (resistivity only), Wolf, Happy, Cleary Hill, Livengood, Hess, Portage, Deadwood and Mammoth. In connection with the magnetic work samples of gravel and bedrock were taken wherever possible for subsequent quantitative determination of magnetic mineral content. Resistivity work also has been done on problems that are of indirect importance to prospecting including (1) study of frozen and thawed muck, gravel and bedrock in order to determine constants or typical resistivity values for various types of deposits, (2) determination of existance and depth of underground water, (3) delineation of frozen and thawed areas (4) tracing buried sewar pipes (5) study of abnormal earth currents in moss covered ground and in areas of alternately frozen and thawed overburden and (6) deep tests to determine depths of overburden in the Tanana valley near Fairbanks and in the old Yukon valley near Circle Springs. A small amount of magnetic work also has been done on faults and igneous intrusions. A good part of the work outlined above necessarily has been of a preliminary nature. The main effort at this stage of the work has been to obtain a conception of the extent to which magnetic and resistivity methods may be applied to the solution of problems related to prospecting, rather than to make an exhaustive study of any one problem. I believe this is in accord with your plans.

Although we have not yet been able to work up all of the results, the magnetic work can be evaluated in a preliminary way and some conclusions drawn as to the extent to which magnetometric methods may be applied in placer prospecting. On Deadwood, Mammoth Livengood and Happy Creeks magnetic anomalies of from 50 to 200 gammas were obtained. These may be classed as moderate sized anomalies in placer work in interior Alaska. They are directly related to concentrations of heavy placer materials; thus these creeks should be relatively easy to prospect by magnetometric methods. On Wolf and Portage Creeks the anomalies were smaller but are directly related to the placer deposits. The measurement of small anomalies requires greater accuracy and detail. The work on Hess Creek gave negative results, which agrees with the available prospecting data.

From this season's work, as well as from past work, it appears that the majority of the placer deposits of interior Alaska are amenable to prospecting by magnetometric methods. The magnetic anomalies are in general moderate to small, but are readily measurable by means of existing magnetic field balances. Placer deposits that probably cannot be outlined by this method are those that are very deep and at the same time contain a relatively small amount of magnetic sands. Occasionally, large magnetic anomalies related to changes in bedrock are encountered. These may be separated from anomalies due to placers by detailed magnetic work and by correct geologic interpretation. Apparently all placers contain some magnetic sands, but the amount may vary greatly in different deposits. The size of the magnetic anomaly is directly proportional to the amount of magnetic material and inversely proportional to the square of the depth of the deposit. Thus, shallow creeks will in general give better results, but ground up to at least 200 feet deep can be prospected if there is a definite pay streak. The depths on Happy and Livengood Creeks are from about 100 to 120 feet, and very good results were obtained.

As is well known, the main advantage of the magnetometer method lies in the rapidity with which a given area can be covered. From 30 to 50 stations per day of magnetometric work can be occupied with our present equipment. The average number of stations per day of total elapsed time will be from 15 to 25. This includes preliminary examinations, brushing out and surveying lines, calculations and report. The speed can be increased about 60% by using a separate base instrument, Subsequent checking by drills or prospect shafts is necessary, but the amount of this type of prospecting usually can be greatly reduced.

The main difficulty attending magnetic prospecting in Alaska is that due to magnetic storms. Because of the relative proximity of the north magnetic pole, irregularities in the intensity of the earths magnetic field are more frequent and of greater magnitude than in lower latitudes. During magnetic storms fluctuations in the field intensity occur over periods of a few hours to a day or more. As the fluctuations often are quite rapid and irregular, and may be of greater magnitude than the anomalies to be measured, it is impossible to obtain correct results during these periods with the equipment on hand. During the summer, magnetic storms have occurred on the average of about once a week. They usually are less frequent during the winter and should decrease in frequency and intensity during the next several years, corresponding to a period of decreasing sunspot activity. When the magnetograms are received from Sitka, some idea may be obtained as to the number of days during which unfavorable magnetic conditions may be expected to prevail.

When conditions are normal there is a small, fairly regular diurnal variation in the earths magnetic field intensity. An approximate correction can be made for this by checking back hourly to a base station, during a magnetic survey. By using a second magnetometer, conveniently located at a base station, to record diurnal variation, the necessity for frequent checks is eliminated, and measurements can also be taken during disturbed conditions, provided the disturbances are not too violent. A magnetic observatory within 50 to 100 miles of the work would serve the same purpose. The magnetograms from Sitka give a check on magnetic storms but the distance is too great to indicate minor fluctuations in the interior.

During magnetic storms, fluctuations in the earth's field intensity often are too rapid and irregular to permit corrections to be made from a base station instrument. A method which I have used for very accurate work could be used up here during magstorms. It consists of taking simultaneous observations with two similar instruments set up at the station interval used, say 50 to 200 feet apart. A simultaneous set of readings is obtained, the rear instrument is moved ahead the desired distance, and the instruments are again read simultaneously, and the traverse continues by the rear instrument leapfrogging ahead after each set of readings. In this manner fluctuations in the earth's field are eliminated and variations in intensity due to variations in magnetic susceptibility of the underlying materials are measured directly.

Any additional investigations should be along the following lines:

(1) Field work to obtain more data on the localities where magnetic methods may be applied to placer prospecting, and the extent to which it may be relied on. This would include magnetic surveys to determine placer and bedrock anomalies, collection of gravel and bedrock samples and areal and structural geologic studies for the purpose of checking and correlating magnetic interpretations.

(2) Rough quantitative determinations of magnetic mineral-gold ratios in various parts of the same placer deposit, as well as in different deposits, to "calibrate" magnetometer results and to determine more as to the reliability and accuracy of this criterion.

(3) Rough quantitative determinations of magnetic mineral content of bedrock samples.

(4) Study of the extent to which the magnetic method can be used to outline structural features, as faults, contacts, veins and intrusions.

(5) Study of costs and the extent to which drilling and shaft sinking can be eliminated in placer prospecting.

A good start has been made along all of these lines, although less has been done on (3) and (4) than on the others.

It is more difficult at present to evaluate the resistivity work, as there are more theoretical considerations to take into account than in the magnetic work, and as we have not had time at night to work up the results into final form. In general, depths to unconformities can be determined with a reasonable degree of accuracy (within about 10%) when conditions are not too complex and when the strata are more or less horizontal. The presence of both horizontal and vertical changes, as when patches of thawed ground cut across bedding in frozen ground, may cause erroneous interpretations of depth, unless measurements are made in considerable detail. It appears to be easily possible to distinguish between thawed and frozen ground at any depths at which we have worked. Ground that is partly frozen and partly thawed can also be detected. Depths to waterbearing beds and the presence or absence of underground water can be determined according to several tests run this summer. Resistivity methods can be used for the location of faults, contacts and orebodies, where there is sufficient difference between the materials in question, or when the bodies in question are large. Specifically, this means in the case of a fault, that there must be some difference in resistivity between the rocks on each side of the fault, or there must be a zone of gouge in the fault zone. One or both of these conditions are usually satisfied. Gold quartz veins may be located if they contain a considerable amount of sulfides. The method is of no value for the location of small quartz veins containing practically no sulfides, unless they happen to lie on contacts or fault planes. The difficulty lies in interpretation of the small differences in resistivity obtained from these veins. The same results may be due to slight changes in the country rock. In general all interpretation becomes more difficult as the depth increases. When measurements are made of resistivity changes in very large bodies, as in determinations of depths to gravel or to bedrock, or depths of frozen ground, measurements to depths of at least 200 feet can be made successfully, ~~made~~. In locating faults or veins, where the relative volume of the body is less, the depth of overburden through which they can be measured must be correspondingly less. Probably 25 feet is the maximum depth in this region.

The field work has been conducted so that little time was lost in making resistivity surveys. Several weeks were required for the assistants to thoroughly learn their duties before they could reach normal oprating speed. Occasional slight changes in technique were made to increase speed or to fit changes in conditions. One day was lost on Portage Creek when some spliced wires started to leak after several hours rain. It was necessary to find the leaks and rewrap the splices.

From four to five days were lost by me because of the necessity of repairing and calibrating the magnetometer, after it was found to have been improperly reconditioned at the Colo. School of Mines and again after it was dropped on Deadwood Creek. Since then no time has been lost due to improper functioning of the instrument. Magnetic storms have stopped magnetometer field work a number of times this season, but this does not represent time lost, as brushing and laying out lines, etc., can be done during these times.

The advent of cold weather has slowed down field work slightly, but after we are accustomed to the different conditions we should make about the same speed as in warm weather. The necessity of moving faster will partly offset the disadvantages of heavy clothes and gloves.

The geophysical work that I had planned for this fall, beside getting the resistivity equipment ready for cold weather, consists of resistivity work on lower Goldstream, additional work on contacts between frozen and thawed ground and on natural earth ~~curre~~ currents. From work done this summer, it looks as though frozen and thawed areas might be traceable by the abnormally large earth currents which apparently exist at the contact of permanently frozen with thawed ground. The erratic surface potentials caused by decaying moss have hitherto masked the deeper lying earth currents. It may be that now when the moss is frozen, the surface currents will have disappeared. I also want to do some magnetic work on the Birch Creek schist, where we have already done resistivity work, to determine the anomalies that can be expected from bedrock changes. Some additional work should be done on the granitic intrusions to confirm our preliminary results. All of this work can be done from College.

During the shortest days I had planned to prepare a report and if time is available would like to work up some of the gravel and bedrock samples collected this summer. Bill Burns has a petrographic and a binocular microscope and I have the rest of the necessary equipment. Field work can be resumed in the early spring, say in February or March, when the days are longer, if it is your intention to continue this work.

I would like to know how long I will be able to retain Ernie Wolff, my assistant. As things appear at present I can use him for about two more months, of which about five weeks would be field work and three weeks office work. If field work is resumed in the spring I would like to have him again. ✓ OK

Regarding mining activities, I am forwarding under separate cover the data on mining operations I was able to visit. Bill Shoddy gave me some data on operating costs of machinery on Portage Creek and promised me more when he gets to Fairbanks. Louie Smith has promised complete cost data when it is worked up. I have sent him a letter to remind him of his promise.

As you had surmised, the outlook for the Circle District does not appear to be too good. The larger outfits that did well are the Berry, on Eagle and Mammoth Creeks, Paul Menzal on upper Porcupine, Fred Johnston on Harrison and the dredges on Coal and Woodchopper Creeks. The Deadwood Creek Mining Co. (two plants) and the Mastodon Creek Mining Co. lost money. Mastodon Creek is said to be worked out, but there has been no prospecting to confirm this. Archie Laird who operates the Mastodon Creek dragline plant has been in the Koyukuk looking for ground on which to put his plant. The continuation of operations on Deadwood Creek depends partly on the results of prospecting this winter. The upper workings on Deadwood were yielding better returns at the end of the season and may prove profitable next year. The Portage Creek outfit produced about $55,000 this season but apparently have lost money because of very high upkeep costs on machinery, caused by extremely difficult bedrock conditions. It is likely that considerable fine gold was lost due to excessive leakage of oil from the dragline A film of oil was visible at all times in the drain.

The outfits on Independence Creek had a poor season due mainly to lack of water. In general the production of the small hydraulic outfits was low. The Half Dollar Mining Co, on Half and Bottom Dollar Creeks, had a good season under Harold Myers, the new manager, producing about $15,000.

The fact that no promising new ground has been found makes it appear likely that the production of the Circle District will continue to decline. The F. E. Co. gave up the ground that they were drilling on lower Harrison Creek, but it is possible that Fred Johnston will be able to work it profitably. Reports indicate that that large low grade proposition on Clums Fork, mentioned bo us by Louie Smith and which contains pyritized bedrock, is not prospecting sufficiently high to be workable. There apparently is very little additional prospecting being carried on in the district.

I spent several hours looking over the Nome Creek dredging operation and was able to obtain farily complete data. The ground runs only about 30¢ per cu. yd., but conditions are favorable in every other respect, and the operation should be successful if the values hold up. Prospecting with a light drill indicated values of only about 10¢ per cu. yd. The ground is too wet for accurate prospecting by drill, but when sufficient yardage is dredged a drill factor may be obtainable.

In looking over this letter, which turned out to be much longer than expected, I see that it could be better arranged. In the future I hope to be able to keep you informed of our activities in smaller doses. The results of our work on Bedrock Creek will be sent in shortly. Mr. Wyer, in charge at Cleary Hill, is much interested in the possibility of using magnetometers in the Hot Springs country. I told him that we would help him in every possible way.

Sincerely yours,

Henry R. Joesting.

Henry R. Joesting.

POST-OFFICE ADDRESS: Magn , Sitka.

TELEGRAPH ADDRESS: Sitka, Alaska.

EXPRESS ADDRESS:

DEPARTMENT OF COMMERCE

U. S. COAST AND GEODETIC SURVEY

September 18, 1939.

Dr. Henry R. Joesting,
Department of Mines,
College, Alaska.

Dear Dr. Joesting:

Your letter requesting blue-print copies of our magnetograms starting Auguust 11th was received the other day.

I have forwarded your request to the office for copies of the grams, and will not be able to already forward any until we receive the approval. However there is no reason why it should not be approved again this year. I have seen the photographer who did the work last year but found that he will be unable to undertake the blue-printing this year. He has started a small print-shop in connection with his photographic work, and all of his time is taken-up. However, there are a couple of surveyors in town, who have been trying to get a start; and have been doing some printing of small tracings etc. They will do the work, but at a slightly higher figure than was asked last year. The price this year, or the lowest we have been able to obtain, is 20¢ each. Will this be satisfactory?

I have turned the grams for August over to them, and they will print them as soon as we get a little sunshine. Mr. Hagen has implied that he would prefer to forward his bills for each month of magnetograms.

There has been considerable talk of an observatory in the interior; and with the added interest in geophysical work it may be such that they will again serious consider an observatory. I understand the the instrument shop in the office is working on a small portable magnetograph for installation at various places for a continuous record of the three components. In another year or so this outfit may have been perfected to the point where it could be succesfully used in the field in place of a base station as is the practice at present.

I certainly envy Bramhall his field work this past summer. It is a long jump from the old methods of gas boats, to his present speedy travel by airplane. From what meager reports we have had of the progress, it seems to have been a very interestin trip.

Best wishes for success with your present program; it sounds very interesting.

Sincerely yours,
Robert E. Gebhardt
Robdrt E. Gebhardt.

1939 ~~Ed~~ Guddf... Livengood

Experimental Magnetometer Survey of Bedrock Creek, Fairbanks District, Alaska.

The magnetometer survey described herein was made as part of the experimental geophysical program of the Territorial Department of Mines. The data obtained are the property of the Department of Mines and may be published only in the report on geophysical investigations carried out by the Department of Mines during the latter part of 1939.

Description of Survey.

12 lines were laid out, approximately 200 feet apart and crossing the valley of Bedrock Creek at right angles. A Brunton compass and 100 foot tape were used. Stations to be occupied by the magnetometer were laid off on each line at 50 foot intervals. Profiles of the lines were run with hand level and rod. Each 100 foot station is marked by a blazed stake on which the numbers of the line and of the station appear. Stations between the 100 foot stations are not marked. Line 2, the first line, is located near the mouth of Bedrock Creek, about 100 feet above the tailings pond of the Cleary Hill Mines mill. Line 11, the last line, is about 500 feet above the Wackwitz mill. 141 magnetometer stations on the 10 cross lines were occupied.

The magnetometer used is of the type known as a vertical field balance, or vertical variometer, and is designed to measure variations in the vertical component of the earth's magnetic field. Its sensitivity is 24 gammas per scale division, or 2.4 gammas per 0.1 scale division.

Preliminary Investigations.

The profiles of the creek indicate the assymetric shape of the valley, with the stream flowing against the steeper left limit hillside. The probable location of placer deposits is on the right side of the creek, in the lower valley and on remnants of higher right limit benches. Any remaining high benches evidently are small, discontinuous and with a bedrock floor sloping toward the creek nearly as steeply as the present surface.

It was apparent from the large amount of iron on the right limit hillside in the form of machinery, waterpipes, junkpiles, etc., that magnetic results indicative of subsurface conditions could not be obtained. The small amount of direct current carried by the phone line on the right limit hillside also would aid in giving false results in its immediate vicinity.

Because the surface of the ground was frozen and snow covered, it was not practicable to pan the small cuts and prospect dumps found on the creek, and thus no estimate of the ratio of placer gold to magnetic content of the gravel could be made. Samples of the surface gravel of the present creek bed and of the bedrock surface of the Wackwitz placer cut contained a moderately large amount of magnetite. From this it is inferred that any placer concentrations should cause relatively large, positive magnetic anomalies, or "magnetic highs", especially as the overburden is shallow.

Interpretation of Vertical Magnetic Anomalies.

Vertical magnetic anomalies are variations from the normal value of the vertical component of the earth's magnetic field intensity. They may be caused by either shallow or deep seated variations in the composition of the earth's crustal material. The positive anomalies often associated with placer deposits are local in extent and quite irregular, compared with those due to deep seated causes. Thus anomalies on the surface of bedrock, due to placer deposits, may be distinguished by from those caused by changes in the bedrock by taking into consideration the geologic structure of the region and by running magnetic traverses over the bedrock where no placer deposits occur.

The anomalies found are shown on the accompanying map of Bedrock Creek. They are subject to small corrections when the daily magnetograms giving diuranl variation are received from the Sitka Magnetic Observatory. The magnetic highs are smaller than anticipated, considering the relatively large amont of magnetite in the surface gravel. This is interpreted to mean that there has been relatively little sorting and concentration of heavy minerals and gold, such as occurred in true "paystreak" creeks. The irregular nature of the anomalies and their lack of continuity from one cross line to the next indicates that the ground is spotted, and a continuous run of gold is not likely to be found. No attempt has been made to interpret the anomalies found high on the right limit benches, as too few trustworthy readings could be obtained, due to the previously mentioned interfering causes. However, the highs found at station 6, line 10, and at station 6, line 11, may be worthy of investigation, as they cross the structural trend of the country rock.

The placer gold in the creek probably has been transported a relatively short distance from its sources, consequently the gold-magnetite ratio cannot be expected to hold as consistently as in creeks where there has been more sorting and concentration of heavy minerals and gold. The magnetic highs indicate the locations of the greatest concentrations of magnetite, but the largest high may not indicate a greater concentration of gold than a smaller high in some other part of the creek. Lacking data from prospect holes and cuts, it is not possible to evaluate the ground or to state which of the areas contain the most gold. The highs in this case merely indicate the best places to prospect, and any individual high should indicate the location of the richest ground in that area.

The locations that are considered most favorable are indicated on the map as I, II, III, and IV. I is considered the most desirable location, and IV the least desirable. V and VI are also marked but their interpretation is doubtful. It is possible that better prospects may be found between the cross lines where no magnetic observations were made.

Conclusions and Recommendations

If placer gold is found in paying quantities in Bedrock Creek it probably will be irregularly distributed, or spotted. It is doubtful if a large production can be expected. The conditions for obtaining reliable results by means of a magnetic survey are less favorable than on creeks with a more continuous run of gold, but the present survey should indicate the favorable places to prospect, and eliminate the unfavorable places. It is therefore concluded that it would be worthwhile to check the magnetic survey by means of prospect shafts or drillholes. In the event that such prospecting is done it would be desirable for the sake of extending interpretations to do a small amount of additional magnetic work.

Henry R. Joesting,
Assoc. Mining Engineer,
Territorial Department of Mines.

TERRITORY OF ALASKA

DEPARTMENT OF MINES

College, ~~JUNEAU~~, ALASKA
Oct. 17, 1939.

Mr. R. E. Wyer,
Cleary Hill Mines, Inc.,
Fairbanks, Alaska.

Dear Mr. Wyer:

Enclosed is a brief report of the experimental magnetometric survey of Bedrock Creek. Mr. McNair has received the map accompanying the report and is copying it for your use.

I believe it best to consider the results of this work as confidential for the present. They eventually will be published, together with the results of the other geophysical work done this summer, in a publication of the Department of Mines.

The Department of Mines will be grateful for any subsequent information you can furnish relative to the correctness of the interpretations of the magnetic survey. If Bedrock Creek is prospected I would like to be on hand part of the time. One or two holes with reliable data would enable me to revise and extend the interpretations, and would increase the value of the survey.

The following breakdown of the time required to complete the work on Bedrock Creek may interest you.

Brushing and surveying 10 lines, running profiles	2 1/2 days
Occupying 141 magnetometer stations	4 3/4 "
Office work (calculations, maps, interpretations)	2 1/2 "
Total time (approximately) for two men	10 days

Total number of separate magnetometer stations occupied	141
Av. no. stations per day of actual observing time	30
Av. no. stations per day of total elapsed time	14

The above does not include night work. We have spent an average of two hours each night on calculations.

The operating speed will increase somewhat in warmer weather and where ground conditions are better. Considerable time was also lost during this survey because of the unusually erratic nature of the earth's magnetic field, necessitating a larger number of checks back to the base station. Because of the heavy cover of partly frozen moss on Bedrock Creek, an average time of two minutes longer was taken to occupy each station, as compared to other ground where more normal conditions prevail. Where a bulldozer is available, time and money may be saved by stripping the brush and moss along the survey lines. This eliminates brushing and enables the survey to be made more quickly and accurately.

With two instruments (one for measuring diurnal variation), from 40 to 45 stations per day of actual running time could be obtained under similar conditions. On a larger scale survey under average conditions this figure could be increased slightly. The time to obtain a set of readings depends partly on the size of the magnetic anomalies encountered, as well as on ground conditions and the distance between stations. Under optimum conditions I have obtained over 50 stations per day with a single instrument and about 80 with two instruments.

The spacing of stations depends on conditions. On Bedrock Creek, because of the apparent spotted nature of the ground and the probability that any pay occurs in a narrow zone, the stations were spaced closely. (50 feet) Additional detail between the lines would be desirable for a more complete picture, but probably is not advisable under the circumstances. In a region where the pay zone is wider and more continuous, stations spaced at 100 to 200 feet and 500 to 1000 feet between lines would be suitable for the preliminary survey. After the probable pay zone is tentatively outlined, it should be detailed by magnetometer stations spaced about 100 feet apart in the form of a grid. At about this stage in the survey drilling or pitting should be started at places indicated by the the magnetic survey, for the purpose of checking and calibrating the magnetic readings.

The cost per station on a moderately large scale magnetometer survey in Alaska will run from $1.00 to $1.50, if the work is well planned and executed. This includes all costs excepting the initial cost and maintenance of the instruments. Maintenance cost will depend on the care with which the instruments are handled and the experience of the party chief. Costs in Alaska will be considerably higher than in the States or in the tropics.

I feel it necessary to advise you that considerable experience is required in order to obtain reasonably correct readings without too great a loss of time. Even more experience is necessary to correctly interpret the readings in the light of what geologic data is available.

In the event that you plan to use magnetometers for placer prospecting, I will be glad to help you in any way possible in my capacity as Associate Engineer for the Department of Mines.

Very truly yours,

Henry R. Joesting
Assoc. Mining Engineer.

MR MISC

MAGNETOMETER AND DIRECT CURRENT RESISTIVITY STUDIES IN ALASKA *

By Harry R. Joesting,* College, Alaska

---

* Published by permission of B. D. Stewart, Commissioner of Mines.
* Associate Mining Engineer, Territorial Department of Mines.

During the past year and a half, the Territorial Department of Mines has conducted a modest experimental program for the purpose of determining the extent to which magnetic and resistivity methods can be used in interior Alaska in connection with prospecting, mining and geological studies. Since little information is available concerning previous work, (1,2)‡ and since conditions

---

‡Superior numbers in parentheses refer to bibliography at end of paper.

---

are considerably different from those in most other regions, it was considered advisable to make a general study of the possibilities and limitations of the two methods, rather than a detailed study of any single problem.

PROBLEMS

One of the most serious handicaps to prospecting and geological study in interior Alaska, especially in the mature regions, is a cover of unconsolidated deposits ranging in thickness from a few feet to several hundred feet. These deposits, some of which are permanently frozen, consist of silt with varying proportions of vegetation and windblown material in the valleys and of residual deposits on the hills. (3,4) The problems treated here result from the existence of this overburden:

1. Location of buried placers.

2. Determination of depth and areal distribution of permanently frozen and of thawed unconsolidated deposits.

3. Location of water-bearing beds under unconsolidated deposits.

NOV 29

INSTRUMENTS AND METHODS

Magnetic and direct current resistivity methods were used because they are relatively simple, rapid and inexpensive and because they are generally well suited to the study of the problems indicated. The instruments used were a vertical Schmidt-type magnetometer and a direct current resistivity instrument similar to those used by the Geophysical Branch of the U. S. Geological Survey. (5)

For placer surveys with the magnetometer, a sensitivity of about 25 gammas per scale division was found suitable. For resistivity studies of frozen and thawed overburden and of underground water, the Lee Partitioning Method (6) was found to be most generally suitable. In the Lee Method a central potential electrode is placed midway between the two potential electrodes of the Wenner four-electrode configuration.(7)

Non-polarizable electrodes were made from unglazed porcelain pots about 10cm. high and 5 cm. in diameter. In order to retard evaporation of the electrolyte the sides of the pots were glazed, inside and out, with clear Duco lacquer. For cold weather resistivity work, a non-freezing electrolyte consisting of equal parts of ethylene glycol and a saturated water solution of copper sulfate proved satisfactory. Three-quarter inch stainless steel rods made excellent current electrodes because their bright finish enabled good ground contacts to be made.

Most of the field work was done during the summer and autumn, although some winter field work was done in order to try out various methods under cold weather conditions; in addition, some swampy areas were more easily worked during the winter. Field methods were in general similar to those used in other regions. Winter work, although slower because of low temperatures and short daylight periods, was found to be entirely practicable.

Mining and prospecting information was obtained when available, for purposes of checking geophysical interpretations. As a rule, interpretations were made entirely independently of these data. Much of the information was given in confidence; hence in some cases it was necessary to omit comfirmatory or contradictory data from the graphs showing the results of geophysical measurements.

LOCATION OF BURIED PLACERS

The vertical magnetometer appears to be well suited to locating buried placers, since magnetic black sands are commonly associated with placer gold. The magnetometer method has been used successfully for placer prospecting in several regions, (1,8,9,10) but from the information available it was not possible to determine whether it is of widespread value for this purpose, or of value only in a few isolated instances.

In order to determine in a relatively short time the probable applicability of magnetic methods to a large proportion of the placers in interior Alaska, data were obtained concerning:

1. The proportion of placers that contain magnetic minerals in amounts sufficient to cause measureable vertical anomalies.

2. The relations that exist between vertical anomalies, magnetic mineral content and gold content of placers.

3. The effects of anomalies associated with bedrock changes and other causes, on measurement and recognition of placer anomalies.

4. The effect of irregularities in the earth's magnetic field on measurement of placer anomalies.

Magnetic Minerals in Placers

110 samples of placer concentrates, taken from 54 creeks, were examined in the laboratory, and field tests of placer gravels were made in most of the camps in the interior. Magnetic minerals, the most important of which was magnetite, were found in all the samples. Magnetic picotite or chromite, and ilmenite were abundant enough in a few cases to have a probable effect on a magnetometer. Other minerals found, but which are of minor importance because of their low susceptibility or scarcity, are iron rich garnets, amphiboles and pyroxenes, biotite, pyrrhotite, wolframite and platinum.

Table 1 shows the approximate magnetite content of placer concentrates grouped according to mining districts.

Table I.

District	Number of Creeks	Number of Samples	Approx. Percent of Magnetite Range	Approx. Percent of Magnetite Mean
Chena	6	7	5-15	8
Circle	9	18	1-38	5
Fairbanks	21	49	6-58	14
Koyukuk	3	6	0.5-8	4
Livengood	8	15	15-80	36
Poorman	2	2	20-30	25
Marshall	5	13	6-30	10

Traverses were then run over representative placers in an attempt to determine the relation between magnetite content and vertical anomalies. The results indicate that under favorable conditions measureable anomalies are associated with about three-quarters of the placers in the interior camps considered. Where magnetite content of the concentrates is below about eight percent, anomalies may be too small to be measureable. Additional work may alter these estimates somewhat, since the data are incomplete in the case of some districts.

Relations between Vertical Anomalies, Magnetite Content and Gold Content of Placers.

Panning tests show that gold and magnetite occur in roughly proportionate amounts only where there is a well defined, fairly uniform paystreak. Where values are spotted and the gravel is poorly sorted there is often little or no correspondence between the amounts of gold and magnetite. In poorly concentrated placers magnetite is likely to be distributed all along the channel of deposition, whereas most of the gold is deposited a short distance below its source.

Vertical anomalies are usually proportionate to the magnetite content, and in most paystreak placers are also approximately proportionate to the gold values. Fig. 1 shows a profile across a narrow bench paystreak where the vertical anomaly, magnetite content and gold values are in unusually close agreement. The relations are more typically illustrated in Figs. 2 and 3. On Portage Creek, (Fig. 2), the magnetite content of the gravel averages 21 gm. per cubic yard at the limits of pay and 52 gm. in the richer parts. The concentrates from the limits contain about 4 percent magnetite, compared to 6 percent in the richer parts. The same general relations hold in other moderately well defined placers.

In poorly concentrated placers, or in placers where gold is spotted in occurrence, there is little or no relation between anomalies and gold values. However, it is often possible to determine the approximate position of the placer channel, provided that sufficient magnetite is present, although nothing can be determined concerning the distribution of gold within the channel.

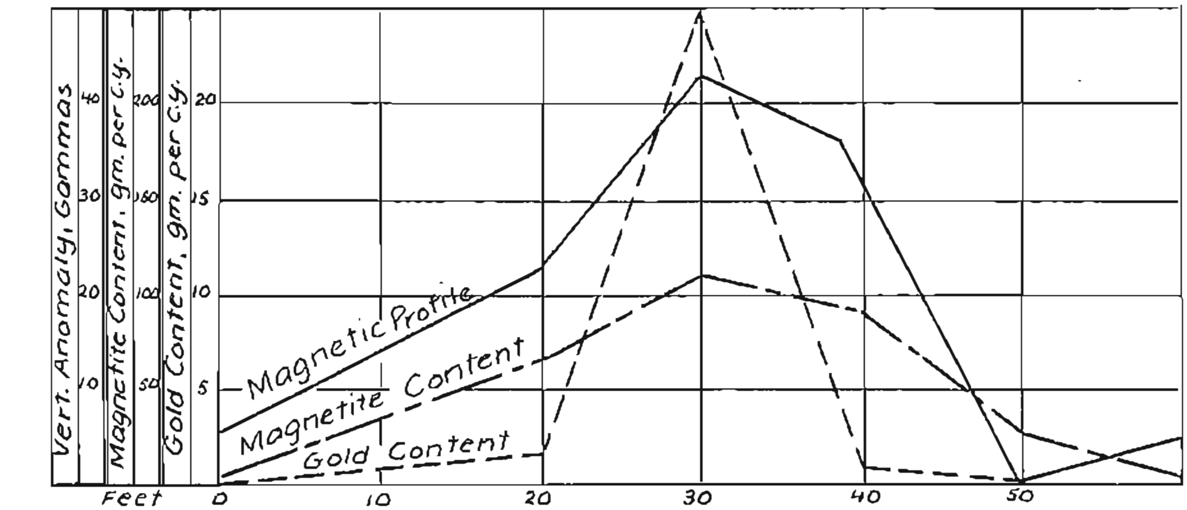


Fig. 1 _ Profile across narrow bench paystreak on Deadwood Creek, Circle District.

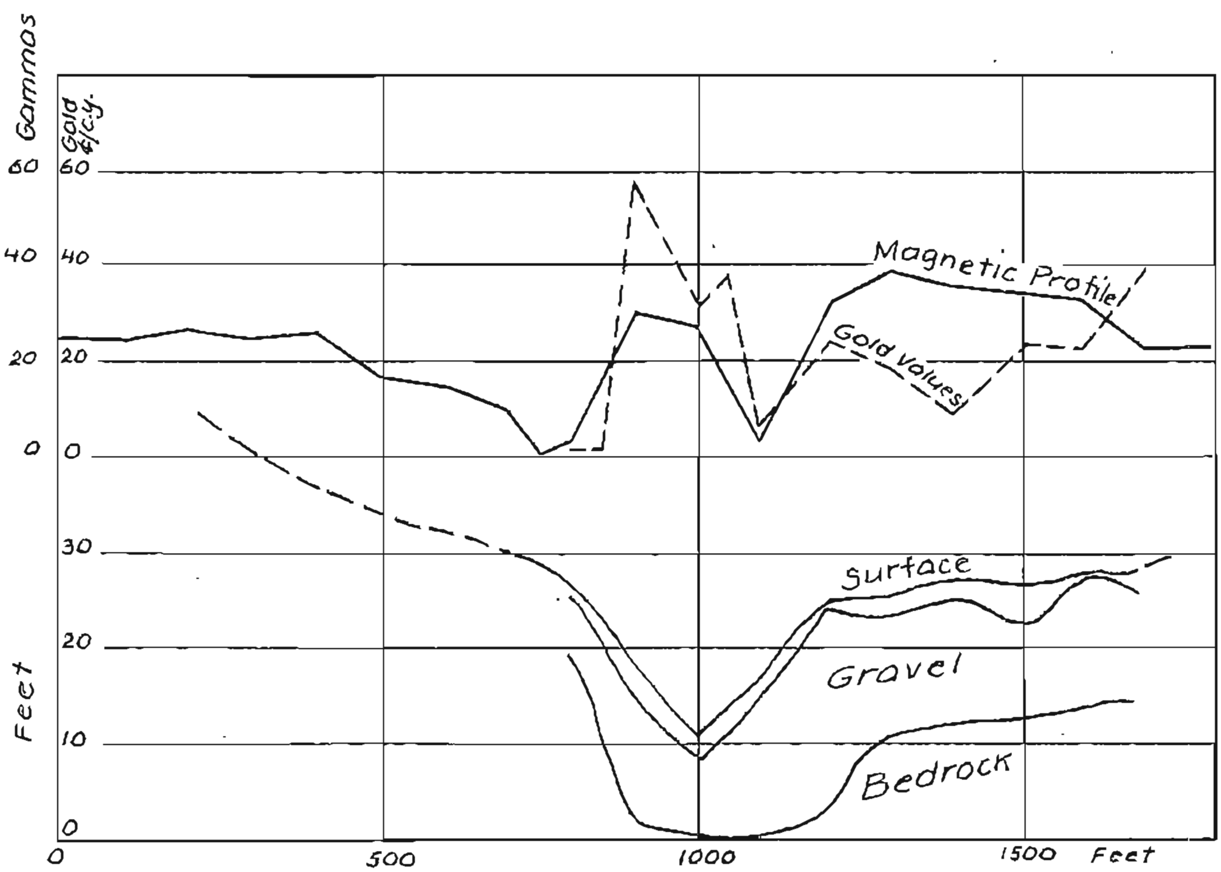


Fig. 2. — Profile at Line 16, Portage Creek, Circle District.

Following P5

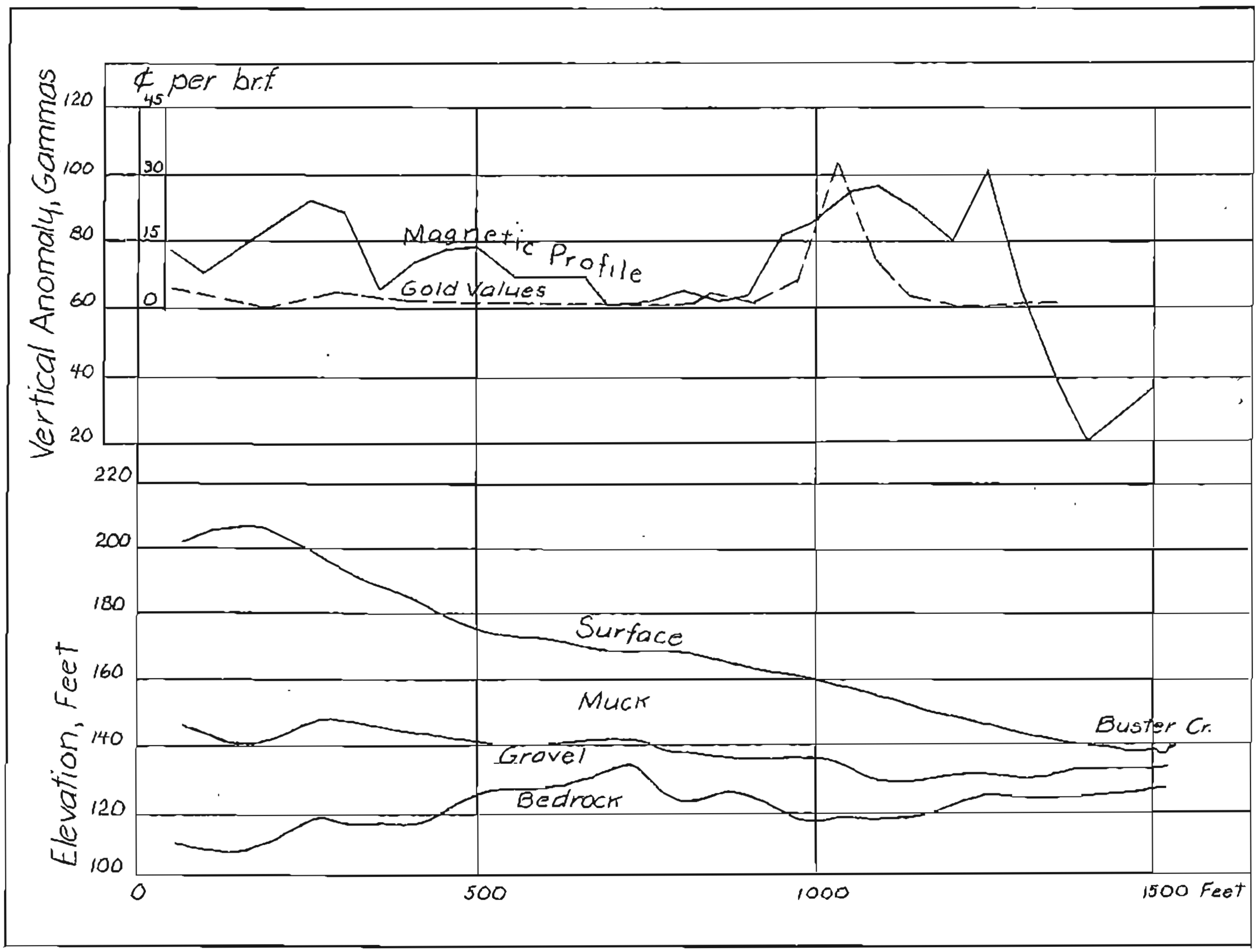


Fig. 3. — Profile at Line 12, Buster Creek, Kako District.

Vertical placer anomalies have been found to range from less than 10 to over 300 gammas. Most of them are under 100 gammas and therefore, must be classed as small anomalies. They are in general positive; those over deep placers and over uniform paystreaks are usually regular, while those over some shallow placers are very irregular. Figs. 4 and 5 show typical profiles of deep paystreaks and of shallow spotted placers. The irregular anomalies found over some shallow placers may be caused by lodestone or boulders with magnetic fields opposed to the earth's field. Several placers with irregular anomalies were found to contain coarse lodestone.

Thick gravel deposits with no marked concentration of magnetite may show anomalies similar in appearance to those caused by deeply buried placers where the concentration of magnetite is largely on bedrock. This is illustrated by a comparison of Fig. 6, where the anomaly is caused by a thick gravel deposit in which there has been little concentration, with Fig. 4, where concentration has resulted in a definite paystreak.

Following P 6

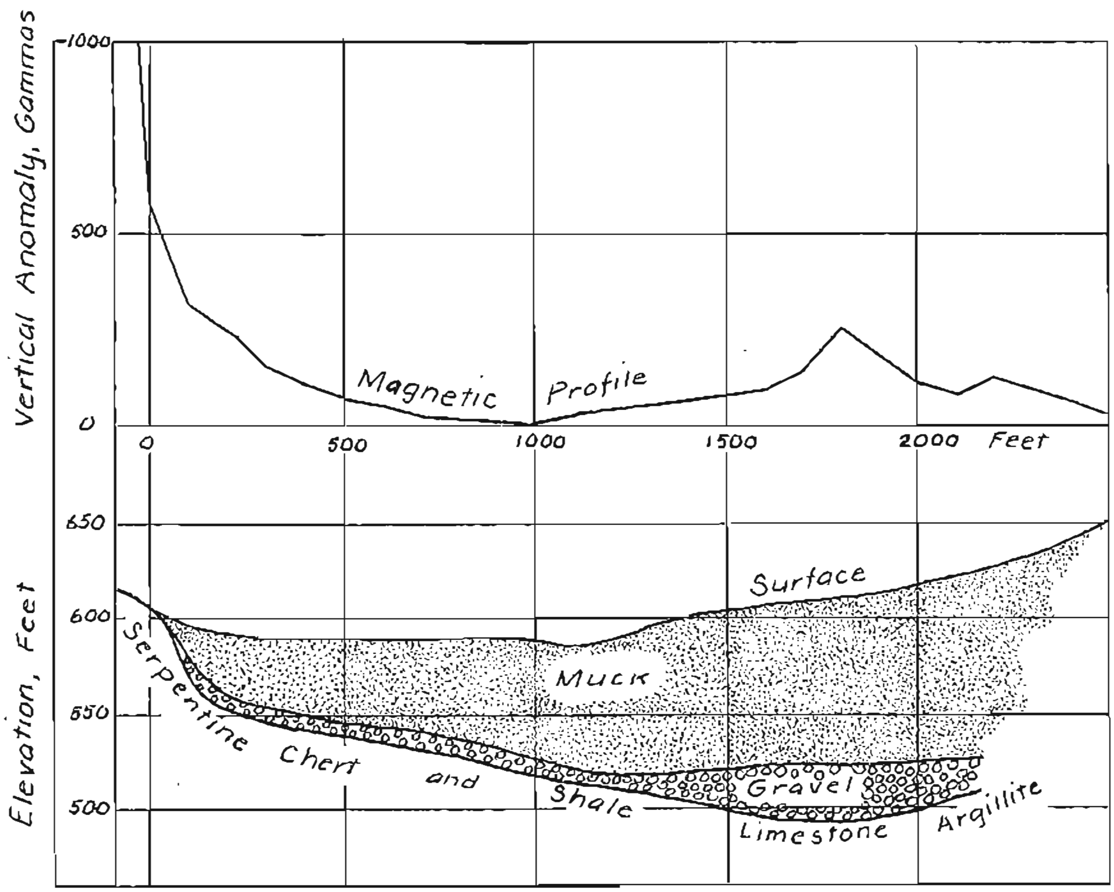


Fig. 4. __ Profile at Line 31, Livengood Creek, Livengood District.

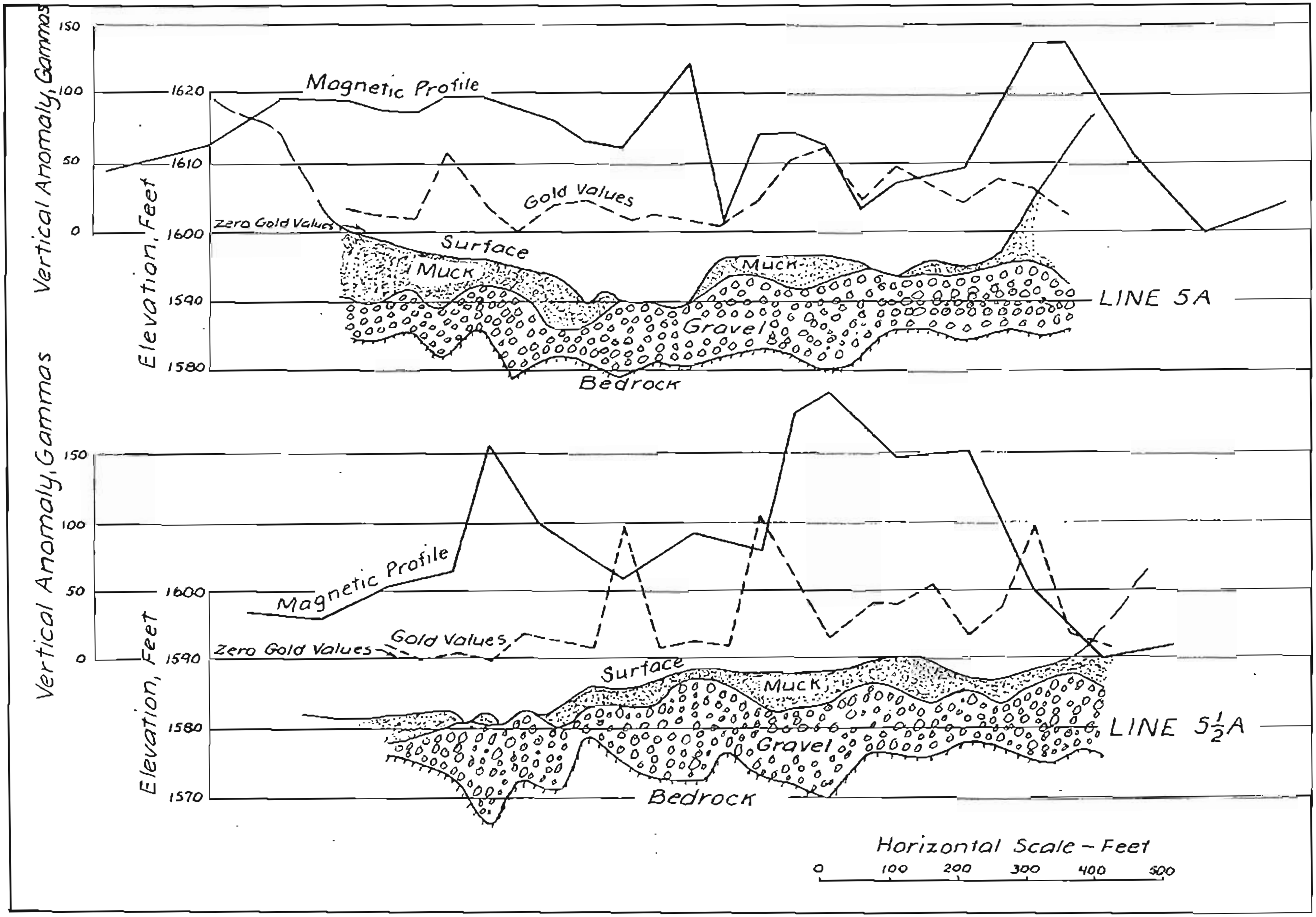


Fig. 5. – Profiles across Mammoth Creek, Circle District, showing erratic nature of vertical anomalies.

Following P 6

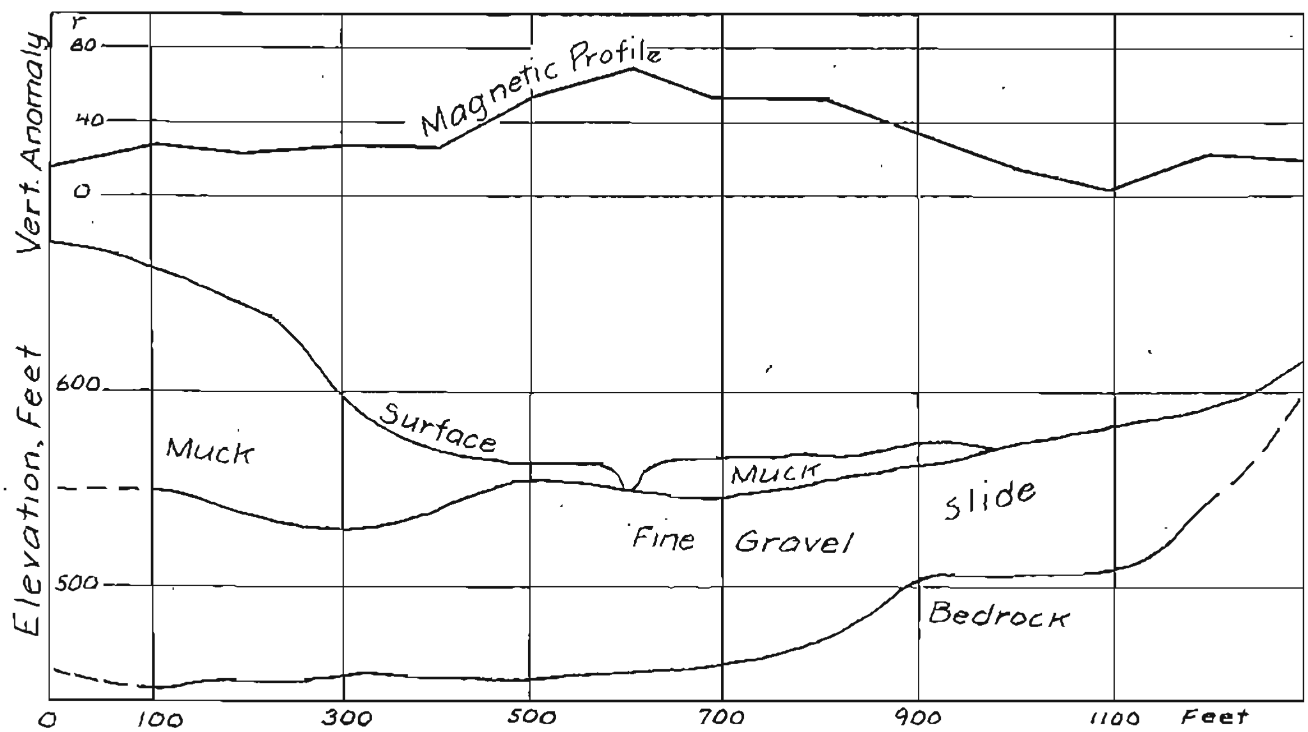


Fig. 6. — Profile across Moose Creek, Fairbanks District, showing vertical anomaly caused by a thick gravel deposit. Drill holes 200 feet apart.

Bedrock and Other Anomalies Not Associated with Placers

Since placer anomalies are small, magnetic surveys for locating placers must be carried out either where bedrock anomalies are very small or where suitable corrections can be made. A number of traverses were run in areas adjacent to placers and on ridges where no placer anomalies exist, in order to learn something of the size and shape of anomalies over various consolidated formations and to determine if corrections could be made for their effects.

As might be anticipated, the smallest anomalies were found to be associated with fine grained sedimentary rocks and the largest with basic igneous rocks. Anomalies associated with acidic intrusives were found to be small to moderate sized, depending partly on the size of the intrusive. The pre-Cambrian schist, which is the most widespread bedrock in interior Alaska, usually causes relatively small anomalies. Fig. 7 shows a typical traverse profile across chert and limestone bedrock, overlain to the southwest by a poorly concentrated, low-grade placer. The erratic placer anomalies are readily distinguishable from the smaller and more uniform bedrock anomalies. Fig. 8 shows an isodynamic contour map of an area of pre-Cambrian schist. The anomalies, which are small and uniform, are fairly typical of those found over the schist in the Fairbanks and Circle Districts.

Corrections for the effects of bedrock anomalies may be applied in some cases in determining placer anomalies. Generally, however, bedrock anomalies large enough to mask placer anomalies are not sufficiently uniform to permit corrections to be made. The practice has been, therefore, to determine the position and magnitude of bedrock anomalies and then search for placer anomalies where bedrock anomalies are unlikely to interfere. For example, during a six week's placer investigation in the Koko Creek area on the lower Yukon River,

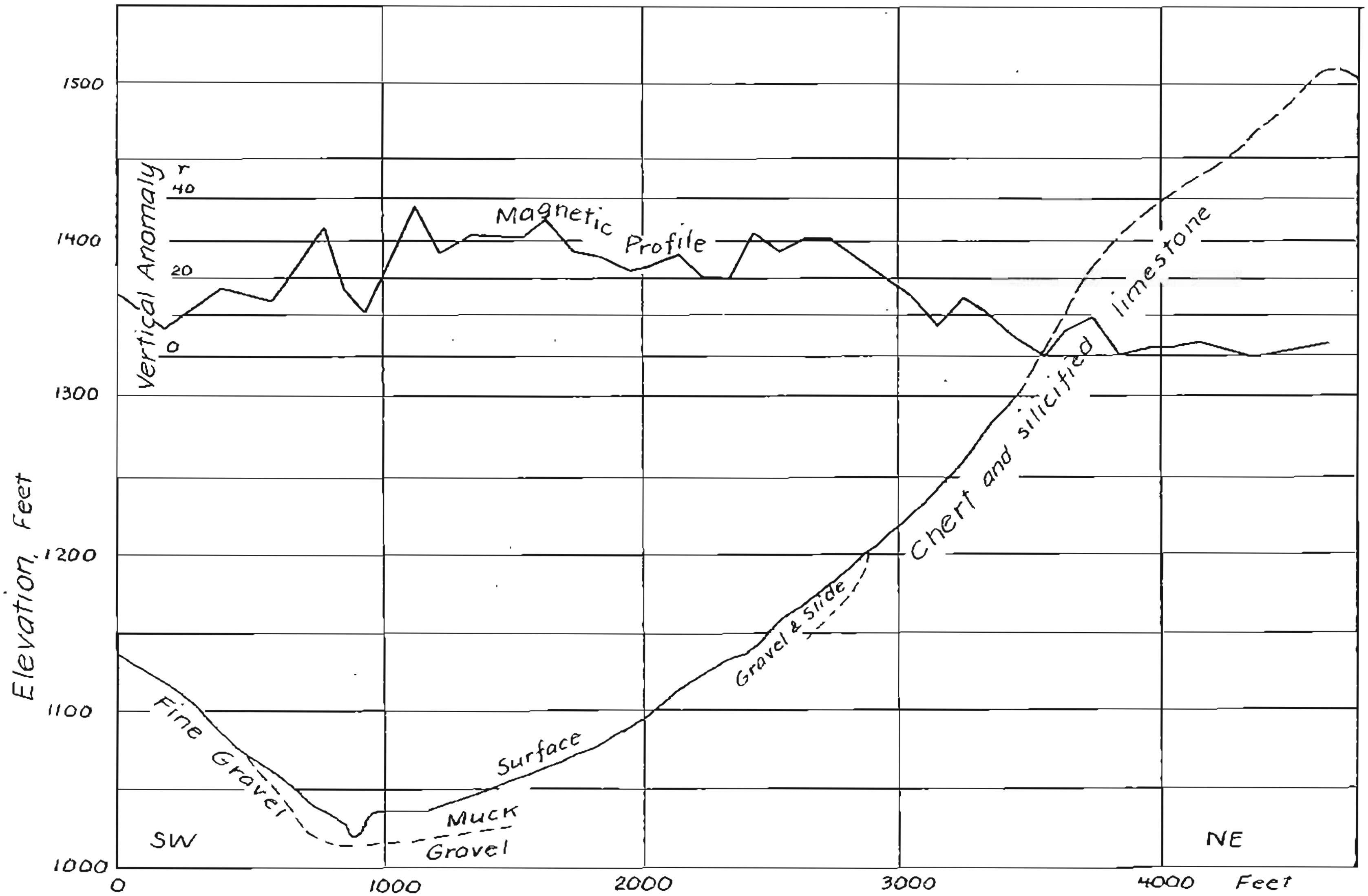


Fig. 7. — Profile across South Fork of Hess River, Livengood District.

Following P7

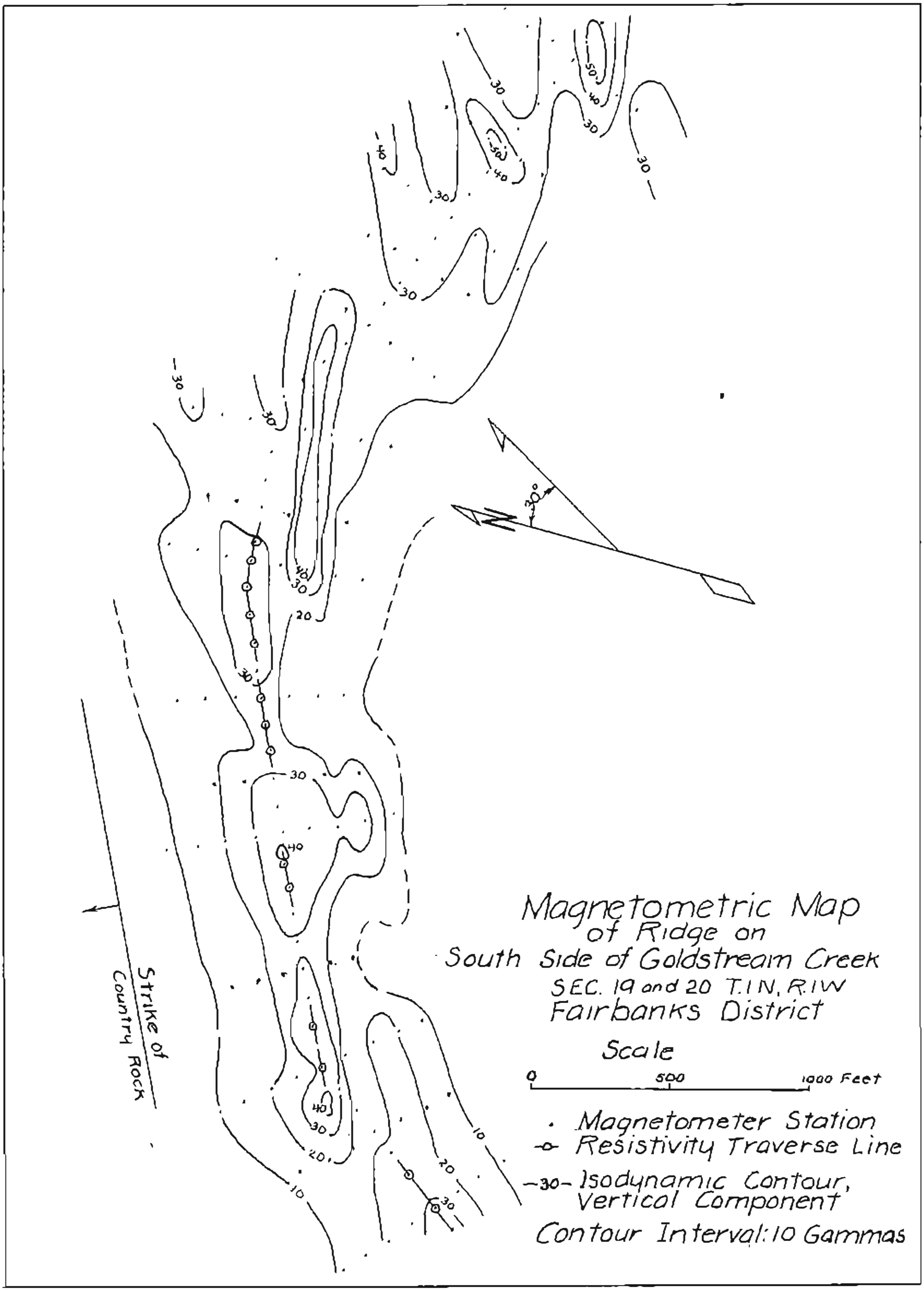


Fig. 8.

about half the time was spent in locating areas of highly magnetic greenstone that cross areas of magnetically uniform sediments. The more detailed magnetometric survey for placers was carried out only where sedimentary bedrock was found to occur.

Sedimentary rocks and metamorphosed sediments have been found to be magnetically more uniform along their strike than across their strike, consequently bedrock anomalies are unlikely to interfere where placers lie across the strike of bedrock. On the other hand, it may be difficult to distinguish between bedrock and placer anomalies where the placer channel parallels the strike of bedrock.

Silt overburden apparently has a low and relatively uniform susceptibility, nevertheless, small anomalies result from abrupt changes in slope, such as occur at silt benches or where deep, narrow gullies are cut into the overburden. They are termed here topographic anomalies, and may possibly be caused by magnetic screening, or distortion of the field to conform to the surface. Because of topographic anomalies, the vertical intensity decreases slightly at the bottom of benches and gullies, and increases along the sides. The size and shape of these anomalies apparently depends on the surface configuration as well as on the magnetic susceptibility of the overburden. The largest topographic anomaly measured is 45 gammas; usually they do not exceed 20 gammas. Approximate corrections are necessary in determining placer anomalies when the latter are likely to be small, or when topographic and placer anomalies are likely to coincide in position. Since for a given type of surface irregularity topographic anomalies are likely to be uniform within limited areas, these corrections can be readily made on the basis of field measurements.

Vertical magnetic profiles across narrow, steep-sided valleys also show some anomalies similar in form and origin to those caused by narrow gullies in overburden, and for this reason the vertical intensity along the ridges and valley sides may be higher than in the valley floor. Corrections are usually unnecessary for this type of topographic anomaly, since it seldom coincides in position with that associated with placers.

Irregular Variations in the Earth's Field.

Magnetic storms are comparatively frequent and intense in high latitudes. In interior Alaska they may cause changes of 500 gammas or more within a few minutes in the vertical component. Figs. 9 and 10, condensed from magnetograms supplied by the Sitka Magnetic Observatory and from field data, show the major fluctuations in the earth's field intensity during parts of the 1939 and 1940 field seasons.

Since only one vertical magnetometer was available, it was not possible to measure placer anomalies during even slight disturbances. An effort was made to correlate changes in vertical intensity at Sitka with those near Fairbanks, but the agreement was not sufficiently close to enable corrections to be applied to field measurements on the basis of the Sitka magnetograms. Finally, through the cooperation of the Sitka Observatory, forecasts of magnetic conditions were obtained which enabled calm periods to be utilized exclusively for measuring small anomalies. In addition, copies of daily magnetograms were supplied in order that an approximate check could be maintained on the diurnal variation curves obtained in the field from hourly readings at base stations.

The principal disadvantage of measuring small anomalies with a single instrument is that much time is lost because of the necessity of frequent base station readings. Although the results are somewhat less accurate than when a

Following P9

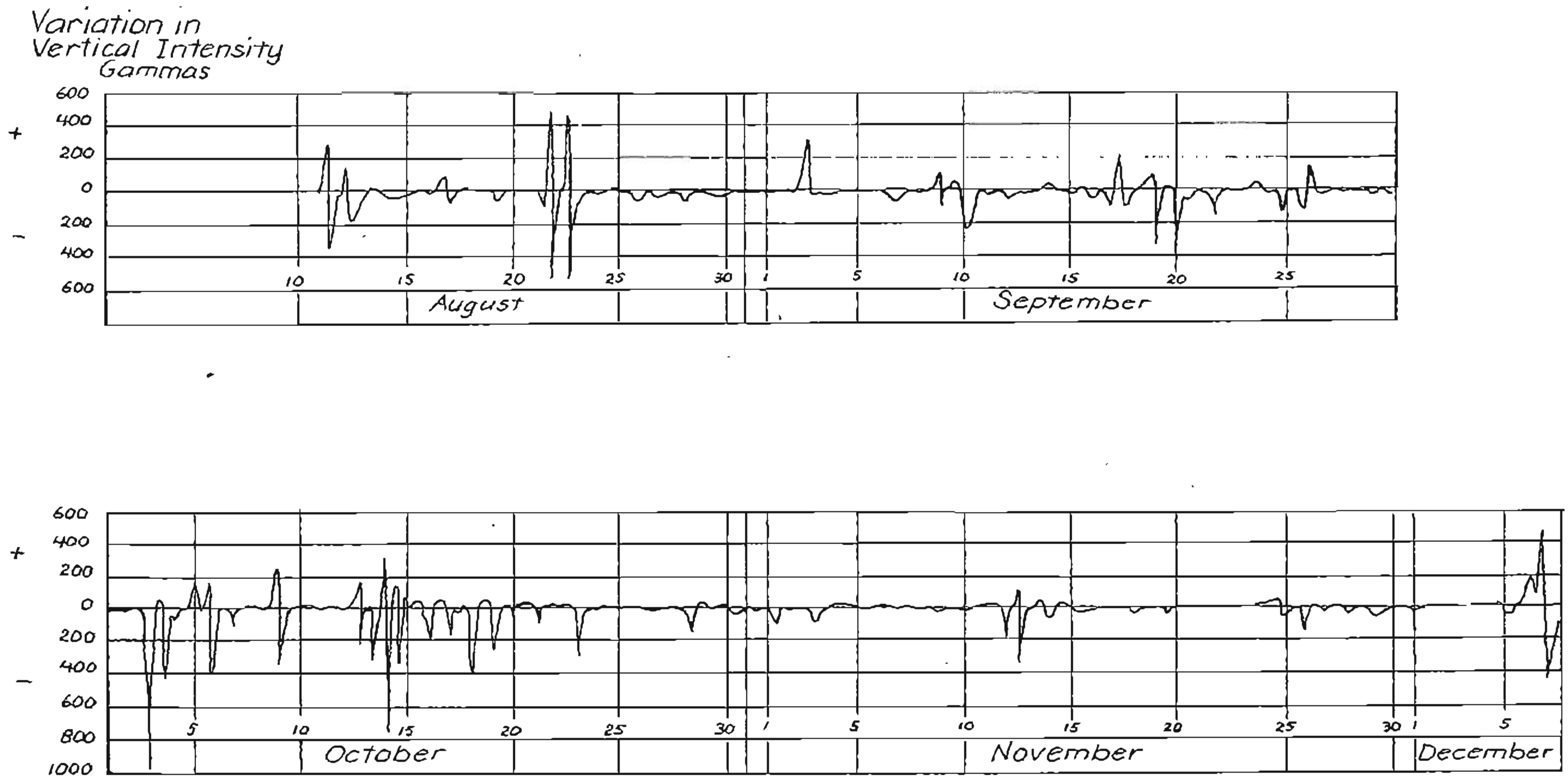


Fig. 9. — Major variations in the vertical component of the magnetic field; Aug. 11 - Dec. 6, 1939.

Following P 9

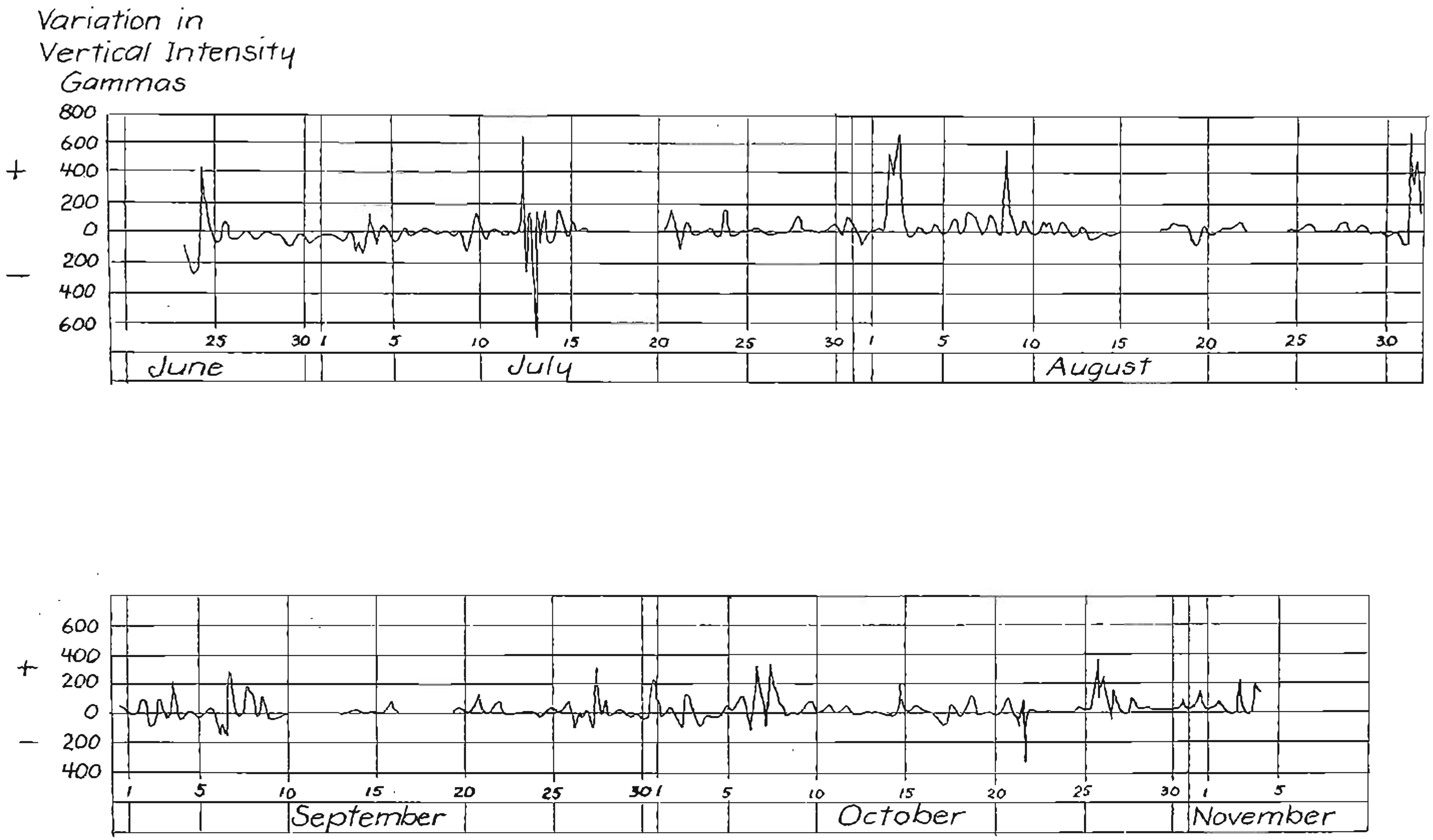


Fig. 10. — Major variations in the vertical component of the magnetic field;

June 23 - Nov. 4, 1940.

separate base instrument is used, the maximum error under most conditions was about 10 gammas, and the mean error was generally not over 6 gammas. This accuracy is sufficient for measuring most placer anomalies.

Tables 2 and 3, taken from Sitka magnetograms, show the relative number of quiet and disturbed days during parts of the field seasons of 1939 and 1940. Days or fractions of days during which changes in vertical intensity were small and uniform are considered quiet; disturbed days include those during which small but irregular fluctuations, as well as magnetic storms, prevented the measurement of vertical anomalies smaller than about 20 gammas. Although it is possible to plan field work so that little time is lost ~~during~~ because of magnetic disturbances, nevertheless they are a serious handicap to measuring small anomalies in Alaska with field methods now in use.

Table 2. - Comparison of Quiet and Disturbed Days: Aug. 11 - Dec. 6, 1939.

Month	Number of Quiet Days	Number of Disturbed Days	Total Days	Percentage of Disturbed Days
August	14	7	21	33
September	23	7	30	23
October	22	9	31	29
November	27	3	30	10
December	5	1	6	17
Total	93	25	118	21

Table 3. - Comparison of Quiet and Disturbed Days: June 24 - Oct. 31, 1940.

Month	Number of Quiet Days	Number of Disturbed Days	Total Days	Percentage of Disturbed Days
June	4	3	7	43
July	15	16	31	52
August	22	9	31	29
September	21	9	30	30
October	23	8	31	26
Total	85	45	130	35

THAWED AND PERMANENTLY FROZEN OVERBURDEN

In order to determine the resistivities of various unconsolidated and consolidated rocks, about 400 field measurements were made in the Fairbanks, Livengood and Circle Districts, where subsurface conditions were known through drilling or mining operations. Most of the resistivity measurements were made during the summer months when the surface was more or less thawed, but some in the Fairbanks District were made during midwinter at temperatures as low as − 30° C.

Resistivities were calculated by Roman's method [11, 12] when the depth profiles approximated theoretical two-layer curves. In some cases resistivities were sufficiently uniform so that they could be taken directly from the depth profiles. In other cases conditions were too complicated to permit determining the resistivity of any single layer. The results are summarized in Table 4.

Table 4

Material	Resistivity Range, ohm-cm	Approximate Mean Resistivity, ohm-cm	Locality*
Thawed, moist silt and vegetation muck (in valleys)	3,600 - 35,000	1.1×10^4	a,b,c,
Thawed silt and residual deposits, dry on surface (on slopes)	20,000 - 190,000	4.0×10^4	a,b,c
Frozen silt and vegetation muck	200,000 - 800,000	26.4×10^4	a,b,c
Thawed moist sand, fine gravel and clay	22,000 - 65,000	4.2×10^4	a,b,c
Thawed moist gravel	41,000 - 71,000	5.5×10^4	a,b,c
Water-bearing gravel	100,000 - 185,000	13.5×10^4	a,b,c
Frozen sand and fine gravel	630,000 - 2,400,000	120×10^4	a,b,c
Frozen gravel	780,000 - 4,100,000	220×10^4	a,b,c
Frozen surface silt at -10°C	2,000,000 - 3,000,000	220×10^4	a
Frozen surface gravel at -15°C	2,500,000 - 4,000,000	350×10^4	a
Thawed soft mica-, chlorite-, and graphitic-schist	20,000 - 80,000	3.9×10^4	a,c
Thawed hard quartzitic schist	200,000 - 500,000	16×10^4	a,c
Thawed conglomerate	22,000 - 70,000	6.0×10^4	c
Frozen conglomerate	1,200,000 - 1,600,000	140×10^4	c
Thawed chert	140,000 - 200,000	17×10^4	b
Thawed limestone	60,000 - 84,000	6.5×10^4	b
Thawed argillite	26,000 - 70,000	5.7×10^4	b
Thawed granite	95,000 - 186,000	15×10^4	c
Thawed serpentine	114,000 - 140,000	12×10^4	b
Partly frozen limestone and serpentine	270,000 - 1,500,000	57×10^4	b

*a - Fairbanks District; b - Livengood District; c - Circle District

Variations in the moisture content of the near-surface material were responsible for the wide resistivity range of thawed unconsolidated deposits. At depths greater than five feet the moisture content was more uniform and there was less variation in resistivity.

Thawed, moist silt appears to have higher resistivity than comparable material in lower latitudes. This may be due to the comparatively small amount of clay in much of the overburden and to lower ground temperatures. Rock weathering in interior Alaska is accomplished principally by freezing and thawing; in addition this process plays an important part in the transportation of rock debris. Chemical and biochemical processes are unimportant because of low temperature, scant rainfall and restricted underground circulation. The result is that much of the overburden consists of unaltered, comminuted rock fragments with relatively small amounts of clay.

Thawed, moist gravel has a higher resistivity than thawed silt, and water-bearing gravel has a higher resistivity than moist gravel. Lee (5) and others attribute the higher resistivity of water-bearing beds to the smaller content of dissolved salts of water with unrestricted circulation. In addition, many of the moist gravel deposits investigated contain more fine material than the water-bearing gravel, which apparently lowers their resistivities.

Although the resistivities of frozen silt and gravel are from 20 to 50 times those of their thawed counterparts, much higher values might be anticipated in view of the resistivity of pure ice (4.4×10^6 ohm-cm.).** However, since

---

*International Critical Tables, vol. 6, 152.
No information was available to the author when this paper was written concerning the resistivities of dilute electrolytes in the frozen state.

---

the ice in permanently frozen ground is not pure, it is probable that electrolysis, or some analogous process, plays a part in the conduction of current, with the result that resistivity is lower than if conduction were entirely ohmic. As it is difficult to conceive of electrolytic conduction through a solid, it may be necessary to postulate the existence, in the frozen silt, of minute layers or cells of liquid electrolyte in equilibrium with the ice. Evidence that electrolytic processes are active at temperatures far below freezing was obtained when iron rods were driven a few inches into frozen silt. Potentials as high as 0.3 volt were set up between pairs of rods in midwinter when the air temperature was -30°C and the ground temperature was about -20°C. Potentials dropped to a few millivolts when non-polarizable electrodes were substituted for the iron rods.

The wide range in resistivity of frozen silt and muck may be partly explained by temperature differences in different deposits. It is known that temperature differences exist, but no measurements ~~are known to~~ have been made in the regions considered here.* Another possible reason for some of the lower

*See E. Leffingwell, U. S. Geol. Survey, Prof. Paper 109, 1919, pp. 179-243, for a discussion of frozen ground on the northern coast of Alaska.

values is that occasional thawed parts may occur in some of the ground reported to be completely frozen on the basis of drill logs. It is often difficult to detect thawed patches, or partly thawed ground, by churn drilling.

Frozen and thawed ground can readily be differentiated by resistivity measurements. Traverse profiles are suitable for determining the areal distribution of frozen ground, while ~~vertical~~ depth profiles enable the approximate depth to be determined. Fig. 11 shows typical resistivity traverse profiles, extending from thawed silt and fine gravel on the north to similar frozen deposits on the south. The contact is at 85 feet on the profile and dips north. Resistivities were determined every 20 feet at electrode separations of 5, 10, and 20 feet. The

Following P 15

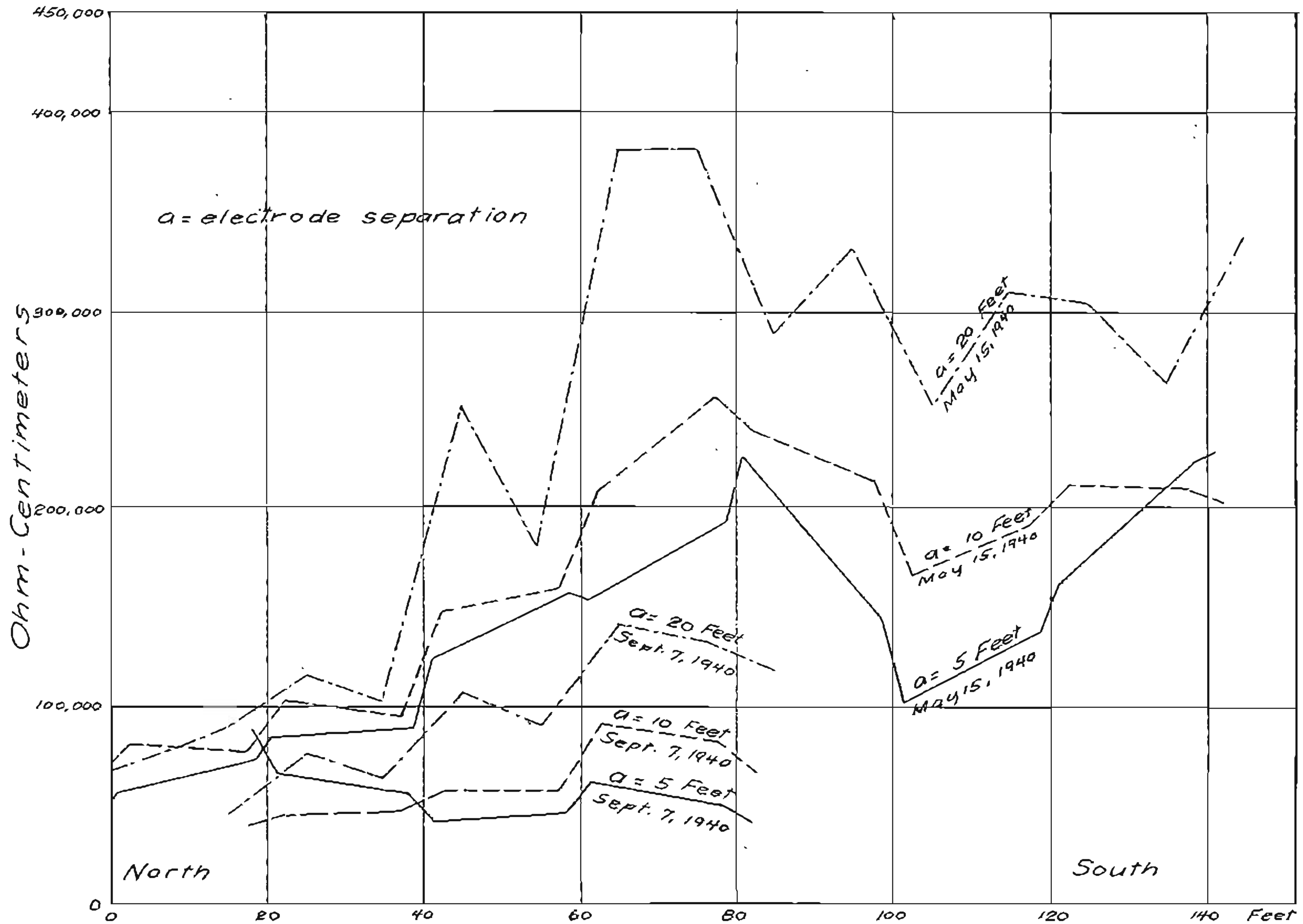


Fig. 11. — Traverse profiles showing resistivity increase from thawed to permanently frozen ground.

May 16 profiles were run when the thawed surface layer was only a few inches thick. By Sept. 7, when the second traverse was run, the surface thaw had extended to depths of one to three feet, and for this reason, the apparent resistivities of the frozen ground are much lower.

Approximate depths of permanent frost are usually obtainable from resistivity-depth profiles because there is a sharp decrease in resistivity when the electrode spacing approaches the depth at which thawed ground is encountered. This is illustrated in Figures 12, 13, and 14. In Fig. 12 the lower summer resistivities are caused by a one to three-foot surface layer of thawed silt. Winter resistivities are relatively low at 10 feet because in December, when the measurements were made, the bottom of seasonal frost had not reached the top of permanent frost. Actual depths to thawed ground and to water were obtained from the log of a well driven 150 feet west of Line No. 1. The actual depth to the schist bedrock is not known, but it is probably between 125 and 150 feet and increases to the south.

Fig. 13 is shown principally because the apparent resistivity is the highest obtained in this investigation. The resistivity of the upper layer is calculated to be approximately 7,000,000 ohm-cm., but because of the steep slope of the resistivity depth curve, this value may be somewhat in error. The log of a well located 500 feet, N 30° E from the central electrode shows frozen silt, sand and gravel to a depth of 80 feet, excepting for water-bearing sand from 44 to 55 feet. Water-bearing gravel was struck at 80 feet, followed by thawed fine gravel and sand to a depth of 277 feet, where drilling was discontinued. Depth to schist bedrock is estimated to be over 300 feet. In view of the lenticular nature of river deposits, the north resistivity-depth curve, which is closer to the well, is in good agreement with known conditions.

Follo in P16

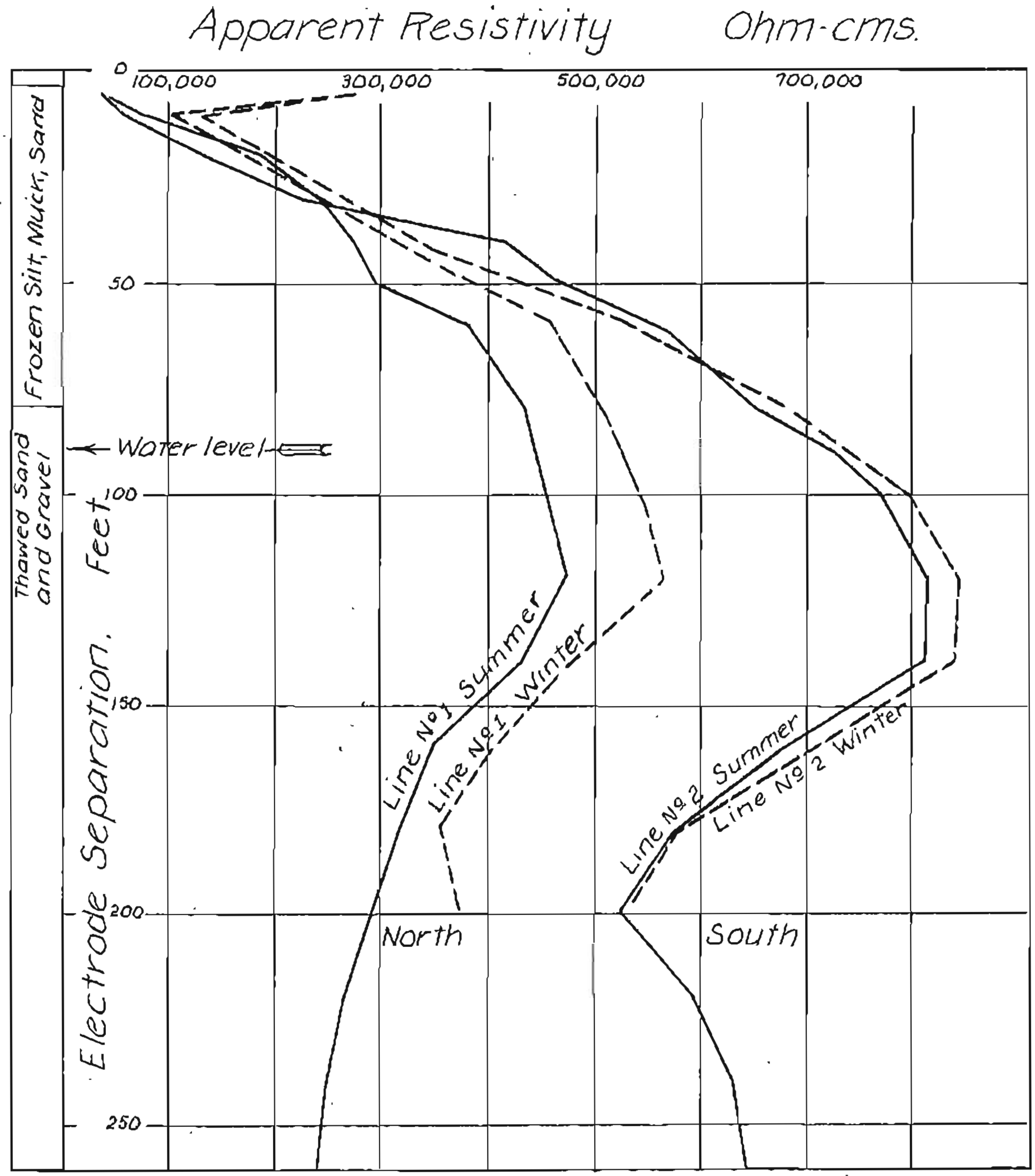
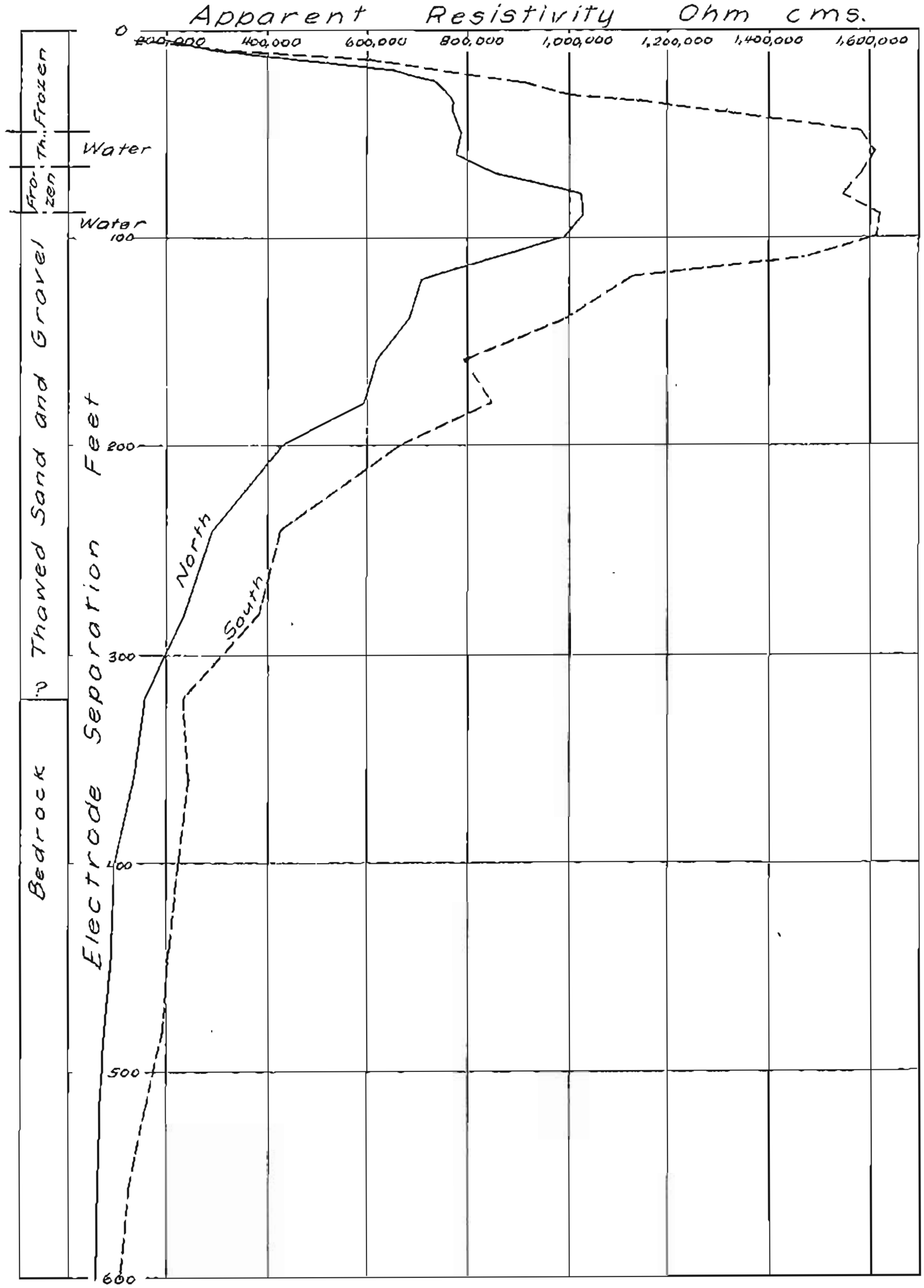


Fig. 12. – Depth profiles in permanently frozen overburden; Tanana Valley, near College.

12

Following P16



overburden;

Fig. 13. — Depth profiles in partly frozen sand and gravel, Tanana Valley, east of Fairbanks.

Following 016

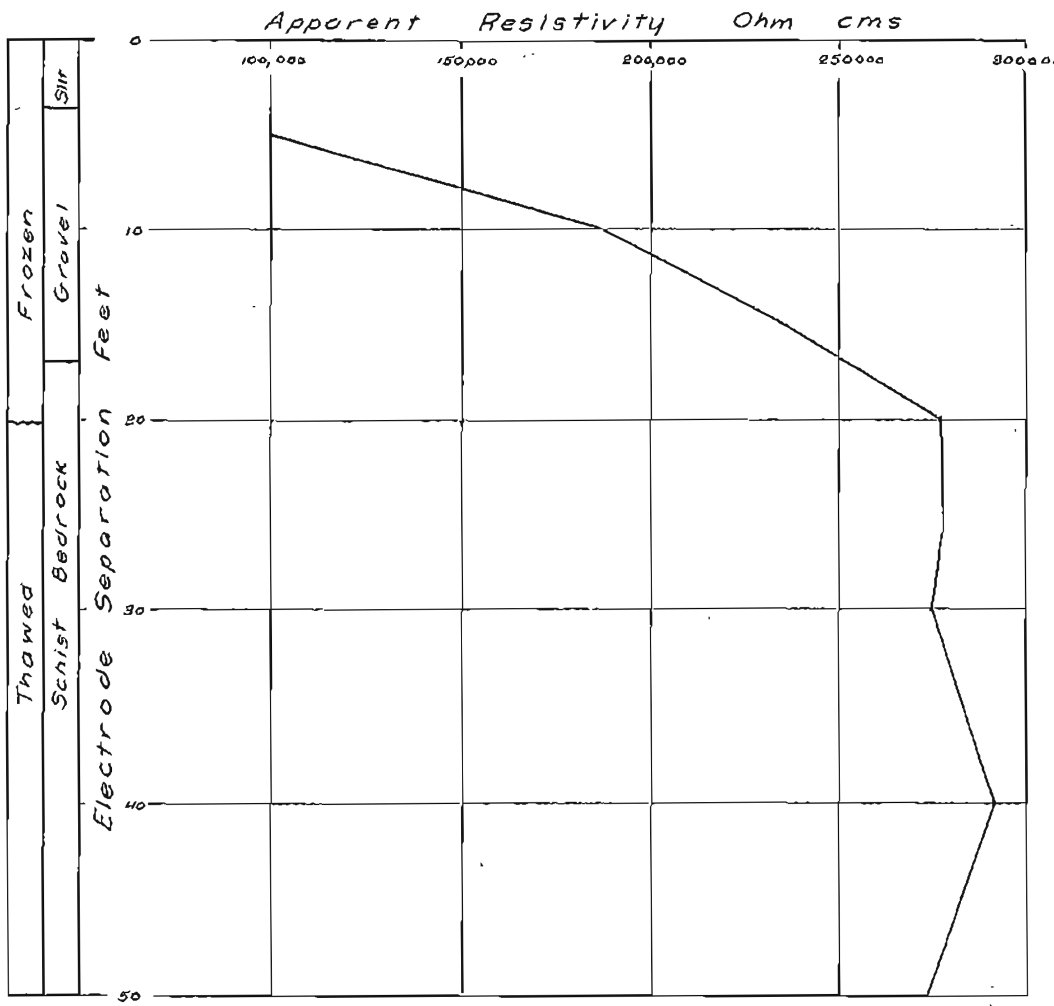


Fig. 14. — Depth profile in permanently frozen ground on Mammoth Creek, Circle District.

Fig. 14 shows the mean of four closely agreeing sets of resistivity measurements made in four directions from the same point. Here the break in the curve occurs not at the stratigraphic break, but at the lower boundary of frost. As frost seldom extends far into bedrock covered by thick overburden, approximate depths to bedrock can be determined indirectly in some cases by determining the depth of frost.

Approximate determinations of thickness of silt and gravel were found to be possible only where conditions were fairly simple. Determinations of depths were in some cases impossible because the resistivity of the overburden was not measurably different from that of the overlying bedrock; in other cases the lack of horizontal uniformity confused the interpretation of depth-profiles.

Fig. 15 illustrates the case where there is no apparent break between overburden and bedrock. The meaning of the break at an electrode-separation of 50 feet is not known, as it is doubtful if frost extends 30 feet into bedrock. In Fig. 16, although there is no abrupt change in resistivity when the electrode-separation equals depth to bedrock, a satisfactory determination of the thickness of the upper layer is obtained by the use of Roman's superposition method. (10)

Irregularities in resistivity are caused by the lenticular nature of the unconsolidated deposits and by the frequent occurrence of irregular masses of frozen ground. Fig. 17 illustrates the effect of lack of horizontal uniformity that occurs in many of the deeper placers. Here the schist bedrock surface is irregular and so deeply decomposed that depths are known only approximately. The silt overburden is mostly frozen, while the underlying gravel is frozen and thawed in about equal parts. Drill logs show, to the north of the central electrode; 75 feet of frozen silt overlying 100 to 105 feet of frozen gravel,

Following P 17

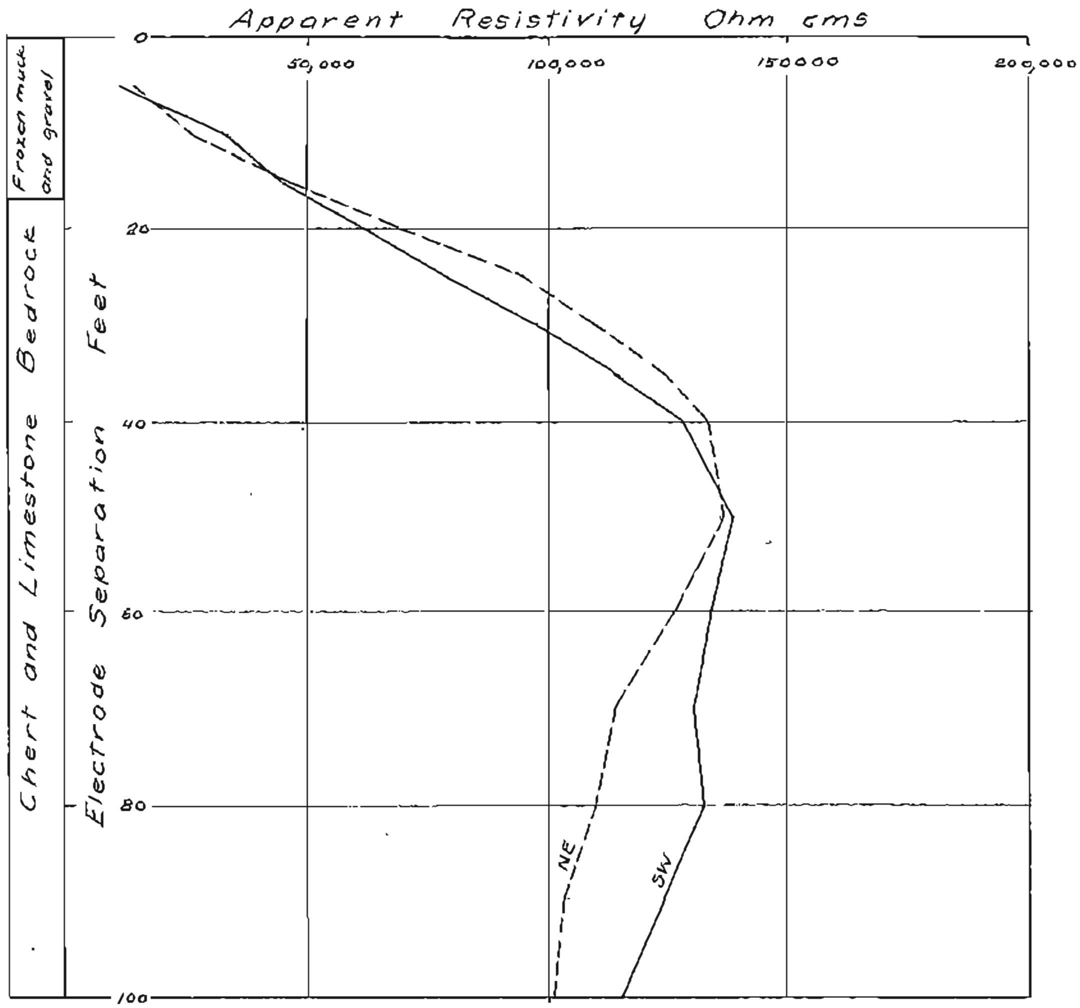


Fig. 15. — Depth profiles in permanently frozen ground on Livengood Creek, Livengood District.

Fairbanks, P 17

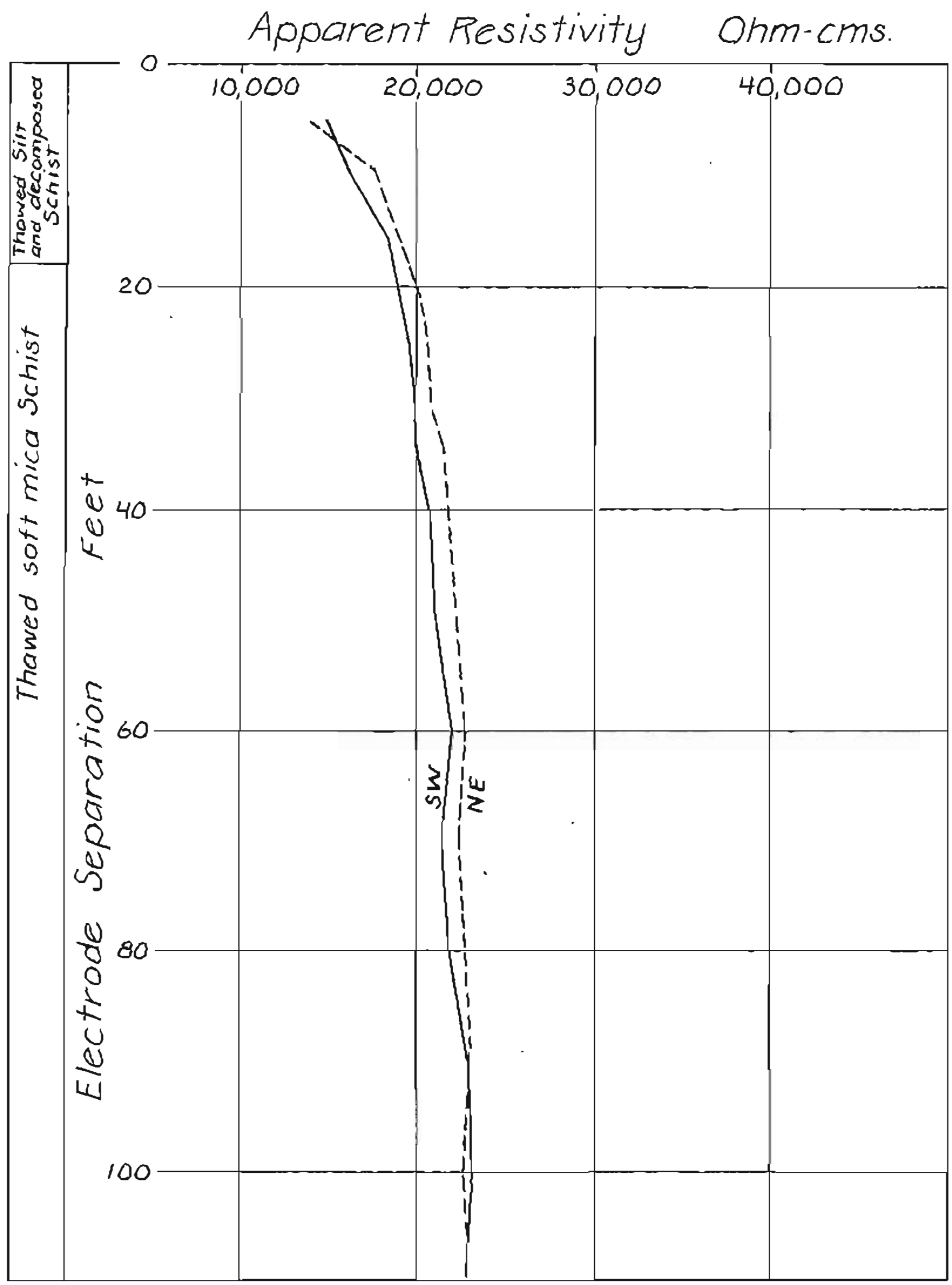


Fig. 16. — Depth profiles in thawed overburden and schist bedrock; near Goldstream Creek, Fairbanks District.

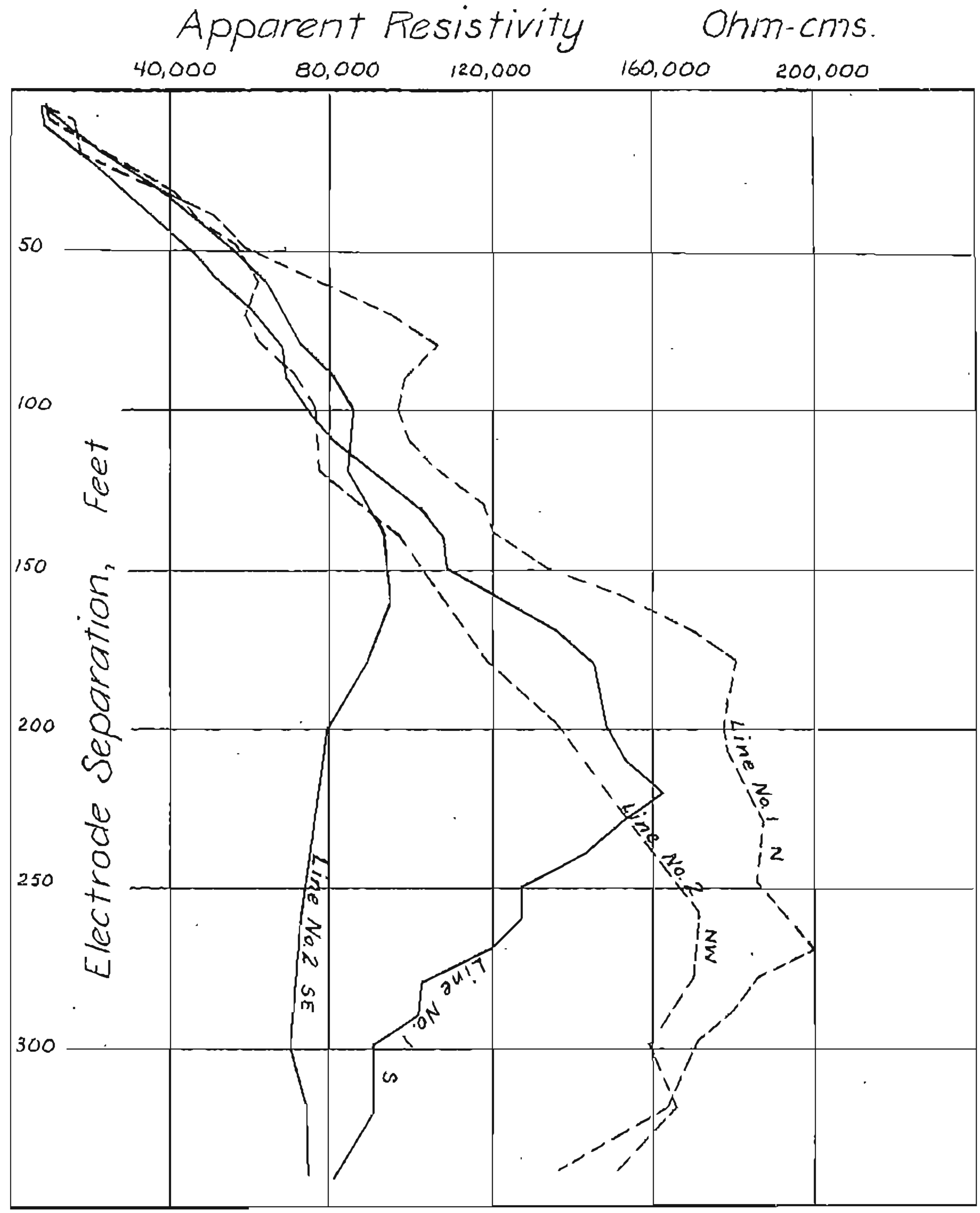


Fig.17. — Depth profiles in partly frozen overburden; Ester Creek, Fairbanks District.

and to the south: 70 feet of frozen silt overlying 70 feet of thawed gravel. To the east and west the mean depths are: 50 feet of frozen silt and 115 feet of gravel. The resistivity-depth profiles indicate that frozen ground, with occasional thawed lenses, occurs from depths of about 10 feet to bedrock. The meaning of the resistivity-maxima at 220, 260, and 270 feet is not known. Although some of the changes in slope can be correlated with drill data, the determination of depths without the aid of nearby drill holes would be extremely hazardous.

In Fig. 18 are shown two of a series of depth-profiles obtained in the Tanana Valley near Fairbanks. They indicate some possible uses of resistivity measurements in studying thick fluviatile deposits that are partly thawed and partly frozen (see also Figures 12 and 13). Although there is considerable small-scale horizontal variation, when large masses of these deposits are measured there is sufficient lateral uniformity in resistivity to enable approximate depth determinations to be made.

The greatest known depth reached by drilling in the river deposits near Fairbanks was 364 feet. Since bedrock was apparently not struck, it may be at least 400 feet below the surface in some places. According to available well logs, the ground is alternatingly thawed and frozen to a depth of about 180 feet. The proportion of thawed ground increases with depth and below 180 feet it is probably entirely thawed. Shallow water-bearing gravels are encountered in areas where the surface is thawed and in addition, a lower water level occurs at depths of about 80 to 100 feet.

Resistivity-depth profiles obtained near Fairbanks are substantially in agreement with well-logs concerning the depth and distribution of frozen ground. Indications of bedrock, which have not been checked by drilling, have been obtained at depths of from about 300 to 460 feet.

Following P18

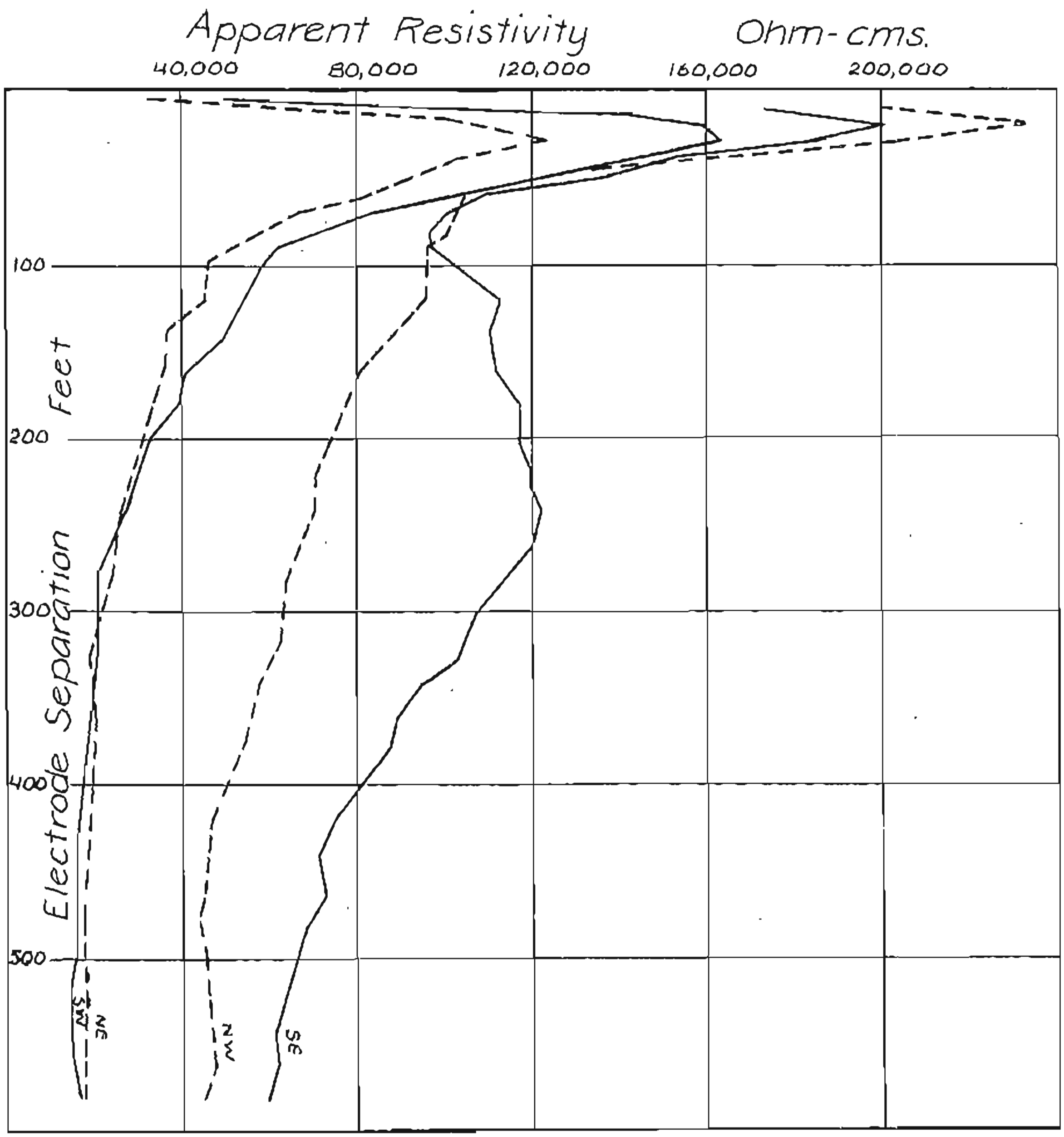


Fig. 18. — Depth profiles in partly frozen overburden; Tanana Valley, near Fairbanks.

UNDERGROUND WATER

Where silt and gravel deposits are thick the underlying gravel is more likely to be thawed than the silt. Thawed gravel layers are also common in thick river deposits, such as occur near Fairbanks. As a rule, thawed gravel deposits are water-bearing. Therefore, resistivity traverse profiles afford a simple and rapid means of locating thawed areas, and incidently water, in otherwise frozen sand and gravel deposits (see Fig. 11). Depth profiles can likewise be used for locating water under frozen deposits by determining the depth at which thawed ground is encountered. (see Figures 12, 13, and 18)

Where the ground is thawed, the problem of locating underground water is more difficult because of the frequent lack of uniformity in the overlying beds and because the differences in resistivity are not as great as between thawed and frozen beds. Under favorable conditions, however, water-bearing gravel can be located at considerable depths. Fig. 19 shows one of several depth profiles taken over a gravel and silt-filled creek channel. The low surface-resistivity is typical of thawed, wet silt, and the increased resistivity at greater depths is characteristic of thick water-bearing gravel beds. Low-resistivity bedrock at about 110 feet is apparently indicated by the sharp drop at that electrode spacing, which coincides with the known depth of approximately 100 feet. The presence of abundant water was later confirmed by drilling.

Fig. 20 shows a depth profile run in July where the water level is at a shallow depth. A dry sandy surface accounts for the high surface-resistivities,

Following P19

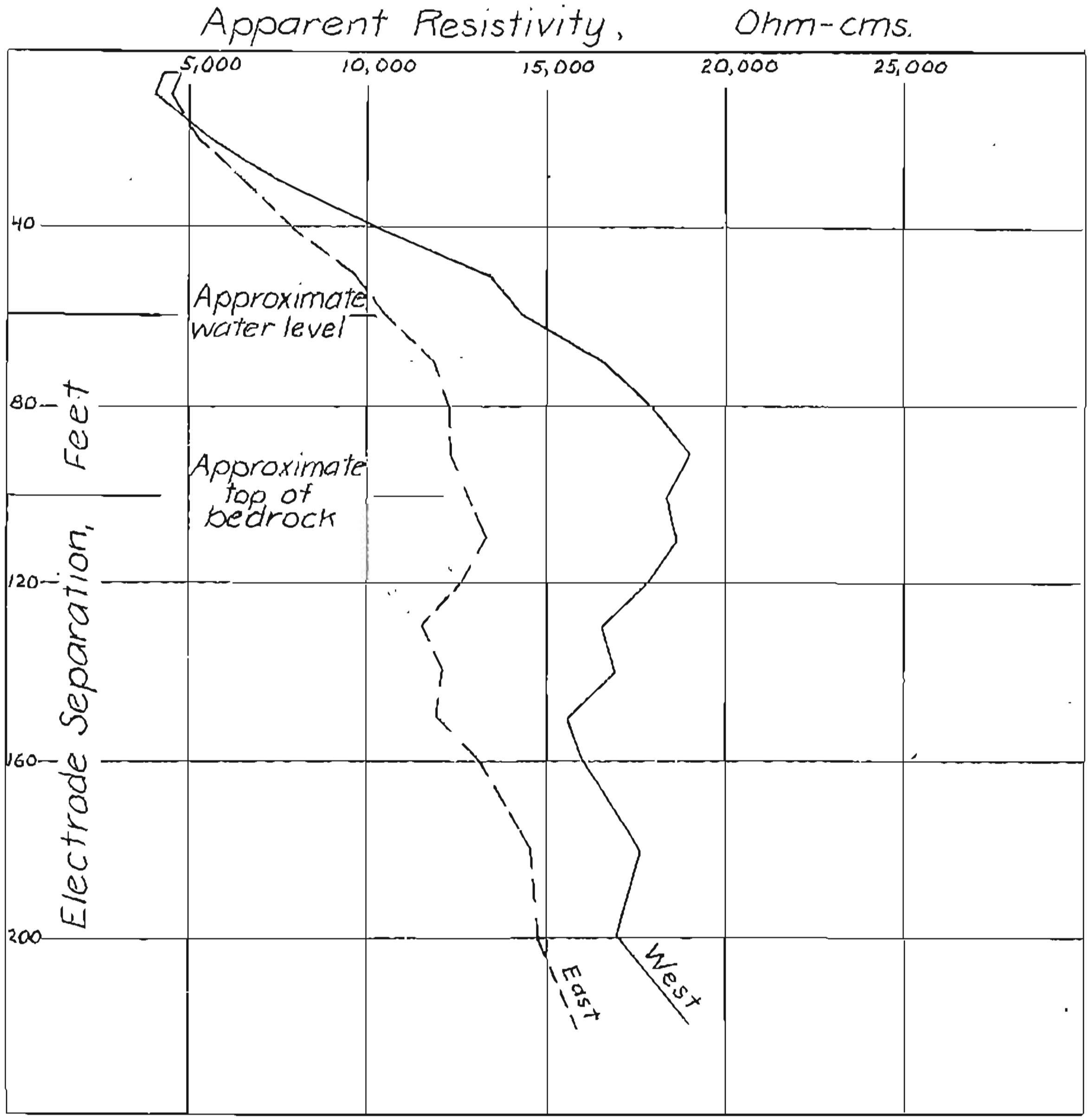


Fig. 19. — Depth profiles in thawed silt and water-bearing gravel; near Ester Creek, Fairbanks District.

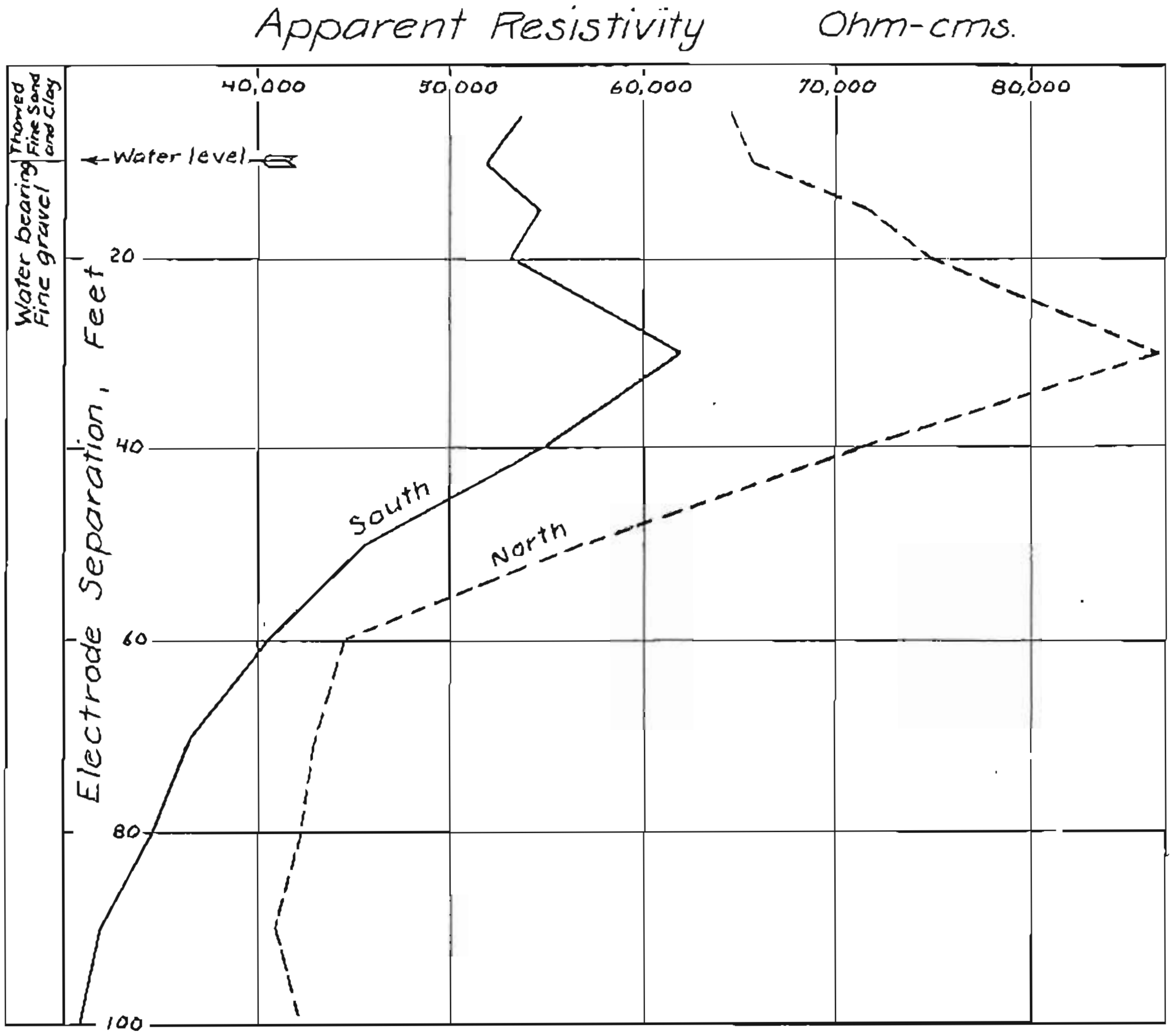


Fig. 20. — Depth profiles in shallow, water-bearing gravel; Tanana Valley, near College.

Fig 20 Depth profiles in shallow, water-bearing gravel; Tanana Valley, near College.

while the high resistivity of the north line may be caused partly by a small mass of near-surface frost, formed in the shade of a building. Water at a depth of about 10 feet is indicated by the south resistivity line; the actual water level was found to be 8 feet below the surface. The low temperature of the water, 8°C., may partially account for the high resistivity of the south line.

CONCLUSIONS.

When supported by geological and mineralogical data, the magnetometric method is of value in preliminary prospecting for about half of the gold placers in interior Alaska. It is most successful where placers, containing sufficient magnetite, are concentrated in paystreaks. It is of no value in locating placers which contain insufficient magnetite or those with which large bedrock anomalies are associated. Although the magnetometric method cannot be used for evaluating placer ground, it often makes unnecessary much of the relatively slow and expensive shaft prospecting, particularly in barren areas.

Because of the great differences in resistivity between frozen and thawed material, the direct-current resistivity method offers a rapid and reliable means of determining the areal extent and approximate depth of permanently frozen unconsolidated deposits. Determinations of depths to bedrock were not entirely satisfactory owing mainly to the frequent lack of lateral uniformity in the overburden and in bedrock.

Water-bearing deposits associated with permanently frozen ground can usually be indicated by locating thawed areas or strata. When the overburden is thawed, the presence of water can be determined under favorable conditions.

The Gish-Rooney empirical rule - which states that the depth to a discontinuity is equal to the electrode separation corresponding to the break in the resistivity-depth profile - was found to be of more general value than depth calculations based on theoretical considerations. The empirical rule usually held where high-resistivity surface layers were encountered, consequently, measurements made during the late winter or early spring, when the surface resistivity is high and uniform, are more easily interpreted than those made during the late summer.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to F. W. Lee and J. H. Swartz of the Geophysical Branch of the U. S. Geological Survey for invaluable assistance given preliminary to undertaking this investigation; to R. E. Gebhardt, Observer in Charge at the Sitka Magnetic Observatory for furnishing daily magnetograms and magnetic forecasts; and to J. B. Mertie, Jr., of the Alaska Branch of the U. S. Geological Survey, for supplying about 60 samples of placer concentrates. He is also indebted to Al Malden, Ernest Wolff, and Erwin Clahassey, students or former students at the University of Alaska, for assistance in carrying out the work; and to the miners and prospectors, too numerous to mention by name, who cheerfully furnished hospitality when needed and information when requested.

BIBLIOGRAPHY

1 J. C. Boswell: Application of Geomagnetics to Placer Exploration; Univ. of Alaska, 1929. Unpublished thesis submitted for B. S. in Mining and Geology.

2 Ted Mathews: Application of Geo-Resistivity to Placer Exploration; Univ. of Alaska, 1938. Unpublished thesis submitted for Bachelor of Mining Engineering.

3 P. S. Smith: Areal Geology of Alaska. U. S. Geol. Survey, Prof. Paper 192, 1939. pp. 66-72.

4 J. B. Mertie, Jr.: The Yukon-Tanana Region, Alaska. U. S. Geol. Survey, Bull. 872, 1937. pp. 183-198.

5 F. W. Lee: U. S. Bur. Mines Inf. Circular 6899, 1936, pp. 10-14.

6 F. W. Lee: U. S. Bur. Mines Inf. Circular 6171, 1929.

7 F. Wenner: U. S. Bur. Stds. Bull. 258, 1916.

8 C. A. Heiland: Magnetometric Investigations of Placer Deposits near Golden, Colo., A. I. M. E. (1929) Geophysical Prospecting.

9 J. J. Jakosky and C. H. Wilson: Geophysical Studies in Placer and Water Supply Problems, A. I. M. E. Tech. Publication 515, 1934.

10 Dart Wantland: Comparison of Geophysical Surveys at the Roscoe Placer, Jefferson County, Colo.; Colo. Sch. Mines Quart., 32, Jan. 1937.

11 Irwin Roman: How to Compute Tables for Determining Electrical Resistivity of Underlying Beds and their Application to Geophysical Problems. U. S. Bur. Mines Tech. Paper 502, 1931.

12 Irwin Roman: Some Interpretations of Earth-resistivity Data. A. I. M. E. (1934) Geophysical Prospecting.

As far as has been determined, the concentration of magnetite in placers results in positive vertical anomalies. The form of the anomaly appears to be determined by the amount and distribution of the magnetite through the gravel, and by the depth of the deposit. Gold, when present in the parent-rocks, will concentrate with the magnetite; thus placer gold may be indirectly located by the measurement of anomalies. However, because of variations in the proportions of magnetite and gold, they may not indicate the location of the richest ground, and actual gold values can be determined only by direct prospecting. Correlation of anomalies with prospecting data will in many cases permit approximate evaluations to be made in adjacent unprospected areas.

c. Size of vertical magnetic anomalies.

Vertical anomalies associated with the placers of interior Alaska ~~placers~~ have been found to vary from less than ~~under~~ ten gammas to several hundred gammas. ~~There doubtless are other~~ Placers with larger anomalies doubtless exist, and platinum placers should in general show larger anomalies than gold placers.

The size of placer anomalies depends on several factors ~~in~~ other than ~~addition to~~ the amount of magnetite; among them ~~which~~ are the depth of the deposit, the thickness of gravel, and the distribution of magnetite through the gravel. Thus, anomalies associated with shallow placers are generally larger and more erratic than those associated with placers covered by deep overburden; and a thick gravel deposit with no marked concentration of magnetite or gold may show anomalies similar in appearance and magnitude to those caused by a deeply buried deposit in which ~~where~~ the concentration of magnetite is largely on bedrock. This is illustrated by a comparison of Fig. 5, showing vertical anomalies due to a thick gravel deposit in which there has been little concentration, with Fig. 3, where concentration has resulted in a definite paystreak. ~~It will be noted, however, that in both cases the magnetic profile indicates the location of the best ground~~.

The minimum measurable anomaly depends on the sensitivity of the magnetometer and the accuracy of measurements and corrections. Magnetic surveys have been made in which the maximum error does not exceed two gammas. With the equipment available for this investigation ~~work~~ the maximum error is not over ten gammas and under favorable conditions is less than six gammas.

The minimum anomaly that can be interpreted depends not only on the accuracy of measurements, but on the association of magnetite and gold and on the availability of data that will enable the investigator to ~~ability of~~ correct for anomalies not caused by

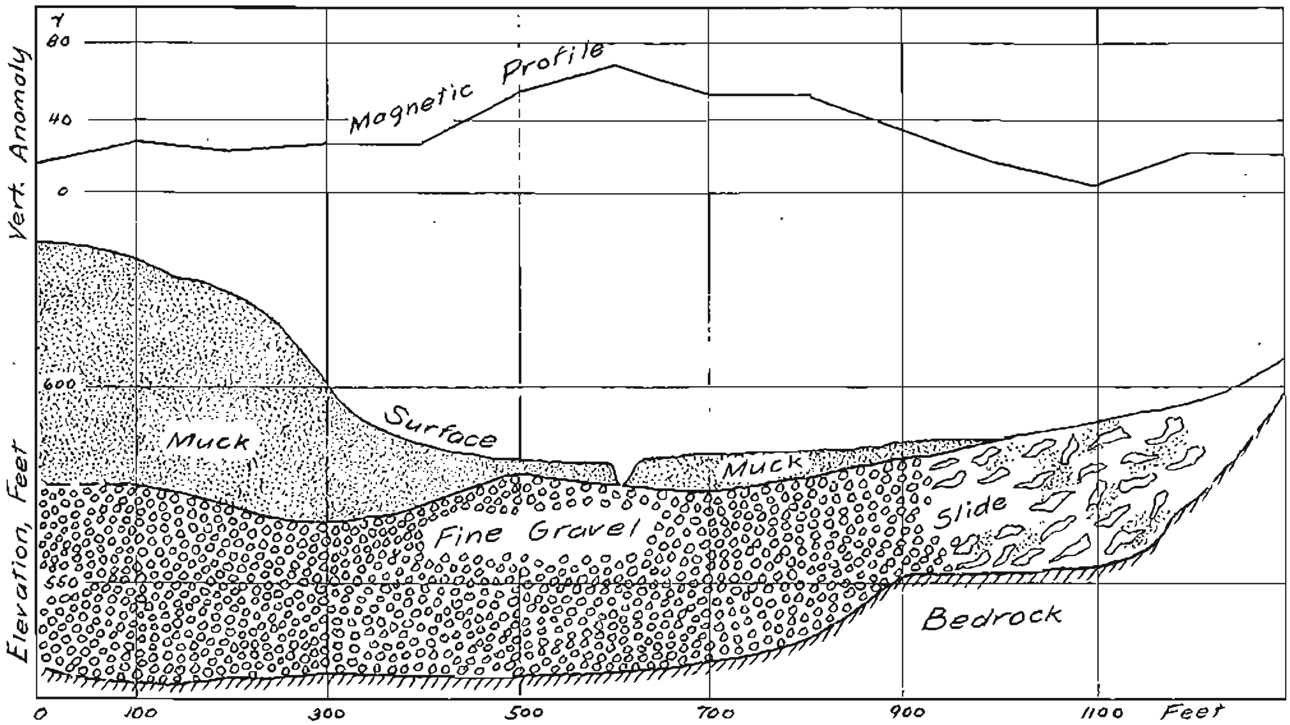


Fig. 5. — Traverse profile of Moose Creek, Fairbanks District, showing vertical anomalies caused by a thick deposit of poorly sorted gravel. Drill holes spaced 200 feet apart.

the placer, such as those due to changes in bedrock and overburden. Where a fairly constant magnetite-gold ratio~~s~~ holds, at least laterally in the deposit, and where bedrock is magnetically uniform, or where corrections can be made for anomalies, a relatively small placer anomaly may be identified. As a general rule the minimum interpretable anomaly must be ~~is~~ at least several times the maximum error in any measurement, because of variation in the magnetite-gold ratio~~s~~ and errors in correcting for bedrock anomalies. Small anomalies necessitate more careful and detailed measurements and more checking by means of shafts or drill holes.

The maximum depth at which placers may be detected by magnetic methods depends mainly on the amount of magnetite present in the gravel. The maximum depth encountered in this work was slightly over 100 feet, on Livengood Creek. The anomalies here are relatively large and this placer could doubtless be detected at much greater depths. On the other hand, under unfavorable conditions, the maximum depth at which placers may be outlined probably is not over 20 feet. The difficulties of measuring and correctly interpreting anomalies are proportional to the depths of the deposits, other factors being equal.

There is no doubt that the anomalies associated with some placers are too small to be measured, or are obscured by other anomalies. But it is equally certain that in most cases measurable anomalies exist. Their correct interpretation depends largely on the ability and experience of the ~~magnetometer~~ geophysical prospector.

d. Bedrock and other anomalies not associated with placers.

Changes in composition of bedrock usually are accompanied by magnetic anomalies. In some areas the bedrock anomalies are large enough to mask those due to placer concentrations, and corrections must be made for them. Bedrock anomalies may be determined in areas surrounding the supposed placer, as on hillsides and ridges where gravel deposits are unlikely to exist. If they are small compared to the placer anomalies they may be disregarded; if large, they must be correlated with the areal and structural geology of the region and projected across the placer. Moreover, some Account should be taken of the differences in depths of overburden in the area containing the placer and in the adjacent areas, as the effect of bedrock will decrease with increased depth. In addition, it has been found that the bedrock under many placers is more deeply decomposed than on the hillsides and ridges, and the decomposed bedrock apparently contains less magnetite than the corresponding fresh bedrock, ~~due to~~ because of alteration of the magnetite to limonite. While this serves to make bedrock anomalies under placers smaller and less abrupt, it also decreases the accuracy of corrections. Because of the many unknown factors and because it seldom is possible to accurately project bedrock anomalies for any distance, these corrections ~~were~~ are usually only approximations.

Sedimentary rocks or metamorphosed sediemtns have been found to be magnetically more uniform along the strike than across the strike, consequently, corrections for bedrock anomalies may be seldom unnecessary for placers which lie across the strike of the bedrock. These corrections may be difficult to apply when the placer parallels the strike of the bedrock, but it is seldom that this parallelism holds for any c nsiderable distance.

A number of magnetometric traverses were run in order to determine the effect of bedrock features such as veins, faults, and intrusions. They are discussed in the section on buried bedrock features. Bedding changes in the schist, which is the country rock ~~found~~ in most of the Fairbanks District usually were accompanied by small vertical anomalies. Fig. 6 shows the vertical anomalies encountered over mica-schist covered by a thin layer of silt and slide. The general parallelism of the isogonic lines and the strike of the schist is evident. Fig. 7 shows a typical traverse profile run N 60° E across the South Fork of the Hess River. For the latter survey, vertical intensity corrections necessitated by latitude and longitude changes were taken from "Alaska Magnetic Tables and Charts for 1930".[1] The anomalies associated with the country rock,

[1] Serial No. 570, U. S. Coast and Geodetic Survey.

which is Livengood Chert, are small. The gravel anomalies, while slightly larger, also are small and are in agreement with available prospecting data. Gold in small quantities is said to be scattered through the gravel near the present stream channel.

As far as has been determined, sedimentary rocks and metamorphosed sediments are fairly uniform magnetically, although considerable variation may be anticipated in some metamorphic rocks. ~~Prospect shafts are said to indicate that the gold does not occur in workable amounts or in definite concentration~~. Igneous intrusions of the granitic type may be accompanied by small to moderate anomalies, while basic intrusions usually cause larger anomalies due to their larger content of magnetic minerals.

Ordinarily, rocks with large magnetite content, and hence high magnetic susceptibility, will give rise to positive vertical anomalies. Occasionally, however, large negative anomalies are found apparently associated with rocks of high susceptibility.

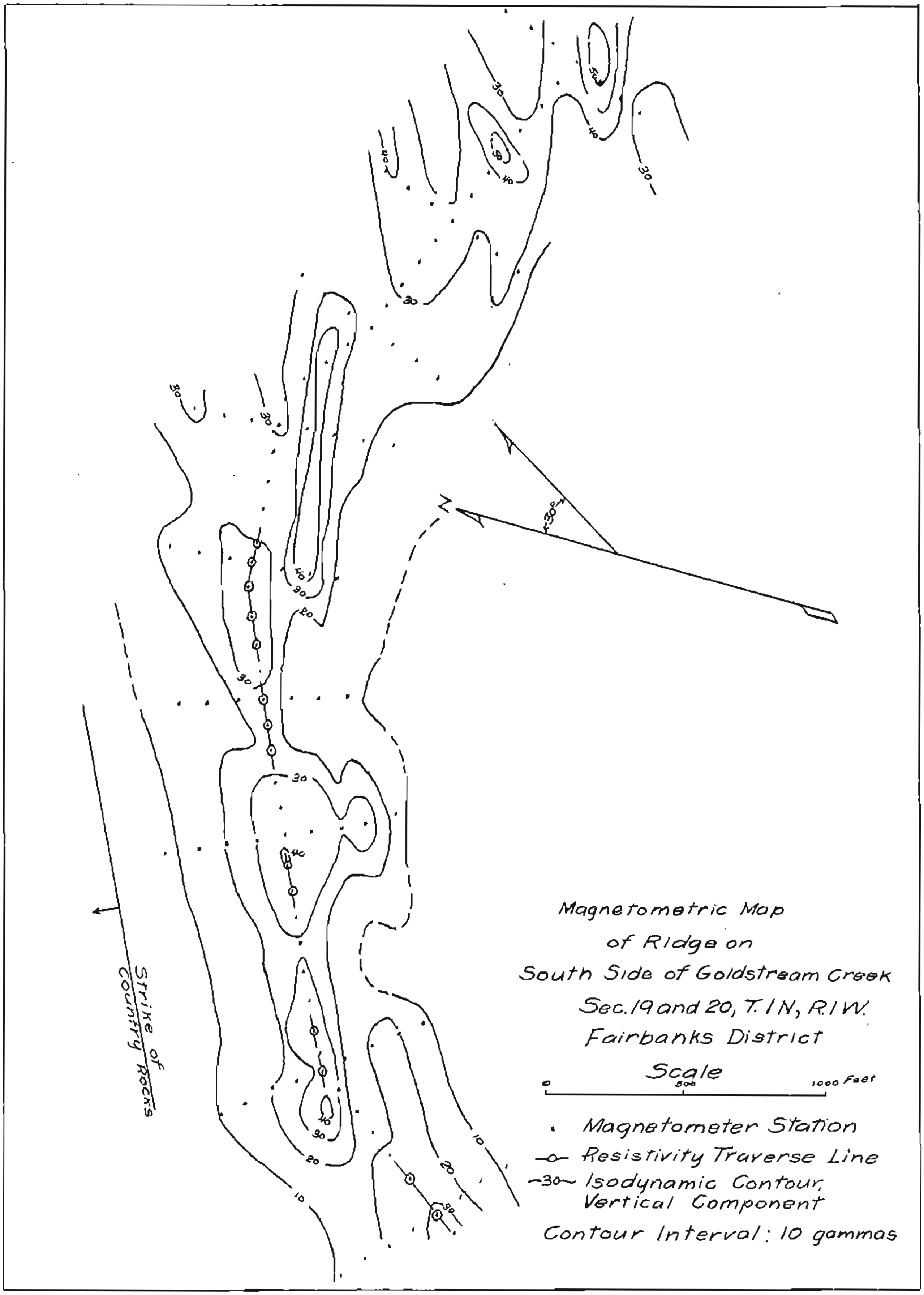

Magnetometric Map
of Ridge on
South Side of Goldstream Creek
Sec. 19 and 20, T. 1 N, R. 1 W.
Fairbanks District
Scale
0
500
1000 Feet
Magnetometer Station
Resistivity Traverse Line
-30- Isodynamic Contour, Vertical Component
Contour Interval: 10 gammas
Strike of Country Rocks
N
30°

Fig. 6.

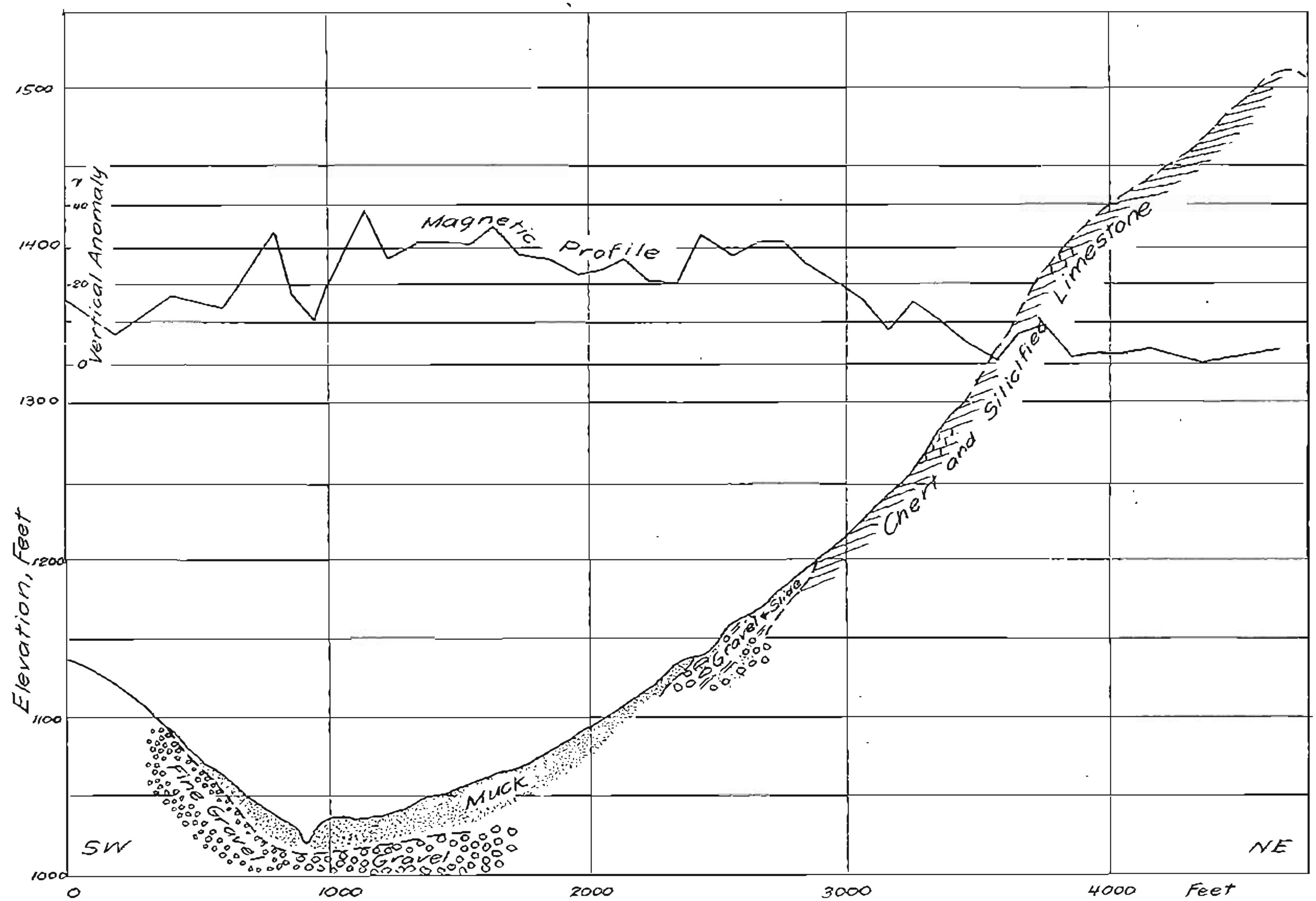


Fig. 7. — Profile across South Fork of Hess River, Livengood District.

A negative anomaly amounting to several hundred gammas was found on Deadwood Creek, in the Circle District. Because of insufficient time to determine its areal extent and a lack of nearby rock outcrops it was not correlated with the local geology. Negative anomalies may be associated with rocks less magnetic than the surrounding rocks, or with rocks whose polarity is opposed to that the normal earth field.

Large or consistent bedrock anomalies ordinarily are recognizable and approximate corrections can be made for them, but preliminary experience in correlating anomalies with known placers and bedrock changes is necessary in any new region. The only rule for distinguishing placer from bedrock anomalies is that shallow placer anomalies often are erratic, while bedrock anomalies usually are relatively consistent. ~~As with all rules, there are exceptions to this one.~~

As far as has been determined, the magnetite content and consequently the magnetic susceptibility of the silt and muck overburden is low and uniform, compared to the gravel deposits and the adjacent country rock. Apparently only the finer particles of magnetite occur in this type of overburden, indicating that there has been some sorting on the basis of grain size. It is also likely that the finer magnetite, especially that near the surface, is more readily altered to non-magnetic limonite than the generally coarser magnetite in the placers.

Vertical anomalies associated with silt and muck overburden have been found to be small. Variations in thickness of overburden have no appreciable effect on anomalies when the surface is fairly uniform, aside from the indirect effect of changing the distances to the more magnetic underlying formations. However, topographic corrections are sometimes necessary in determining anomalies associated with deep placers, when the surface is highly irregular. The so-called muck benches, particularly where they are cut by narrow, deep valleys, are often sufficiently magnetic to have a slight effect on vertical anomalies and must be corrected for if placer anomalies are small. Approximate corrections may be made on the basis of field measurements similar to those for determining bedrock anomalies; that is, a number of determinations of the topographic anomalies are made where other factors are uniform. They should be correlated with available data on ~~depth to bedrock and~~ thickness of gravel and of overburden, and in most cases may simply be subtracted from the vertical anomalies.

In connection with local surface irregularities, such as small, narrow and relatively deep valleys, there may be some magnetic screening, or distortion of the field to conform with the surface. This would increase the vertical intensity along the sides and decrease it along the bottom of a narrow valley, and theoretically, corrections could not be made by simply subtracting topographic anomalies as determined by magnetometer readings. However, these anomalies are so small, and the effect of screening is apparently so slight, that no serious error is introduced.

Occasionally, unconsolidated overburden with relatively high susceptibility may be encountered, as on upper Happy Creek in the Fairbanks District. The overburden here is from 15 to 100 feet thick, ~~and~~ the upper part consisting largely of mica- and chlorite-schist slide, some of which is only slightly altered. The creek has cut through the overburden on the left side of the valley, leaving several poorly defined benches on the opposite side. The uppermost bench, which is best preserved, is traversed by numerous, deep tributary valleys, separated by narrow ridges.

In Fig. 8, which shows a portion of the upper Happy Creek valley, the edge of the bench is close to the survey line 6...6, and the tributary valleys cutting the bench are represented by intermittent ~~a~~ streams which flow west ~~in a westerly direction~~ to the main creek. Local magnetic highs are associated with the ridges and with remnants of lower benches, such as occur near station H 12 and L 15. Several conical remnants of talus, one of which is near station G 14, also give rise to magnetic highs. The differences in elevation of these minor topographic features is from 10 to 20 feet, and the slopes are fairly steep. The lines of equal magnetic intensity somewhat resemble topographic form lines.

Traverse profiles of lower Happy Creek indicated that vertical anomalies of 59 to 80 gammas are associated with a more or less continuous left limit paystreak, which has been drift-mined intermittently for many years. Other profiles across the upper creek indicated that a poorly defined left limit placer concentration continues to the upper creek and crosses the area shown in Fig. 8. However, despite the shallower overburden in the upper valley, the anomalies are smaller, apparently because of less concentration.

The detailed magnetometer survey showed that in the upper valley the topographic anomalies are larger than the placer anomalies, and are proportional both to the change in elevation and to the narrowness and steepness of the tributary valleys. Approximate topographic corrections were made by graphic subtraction of topographic anomalies along each traverse line. Corrections were made in the same way for a bedrock anomaly which extends south from C 8 and C 9 into the steep right limit hillside.

The corrected magnetic map of the area (Fig. 9), shows the apparent anomalies due to placer concentration. Since ~~As~~ the placer

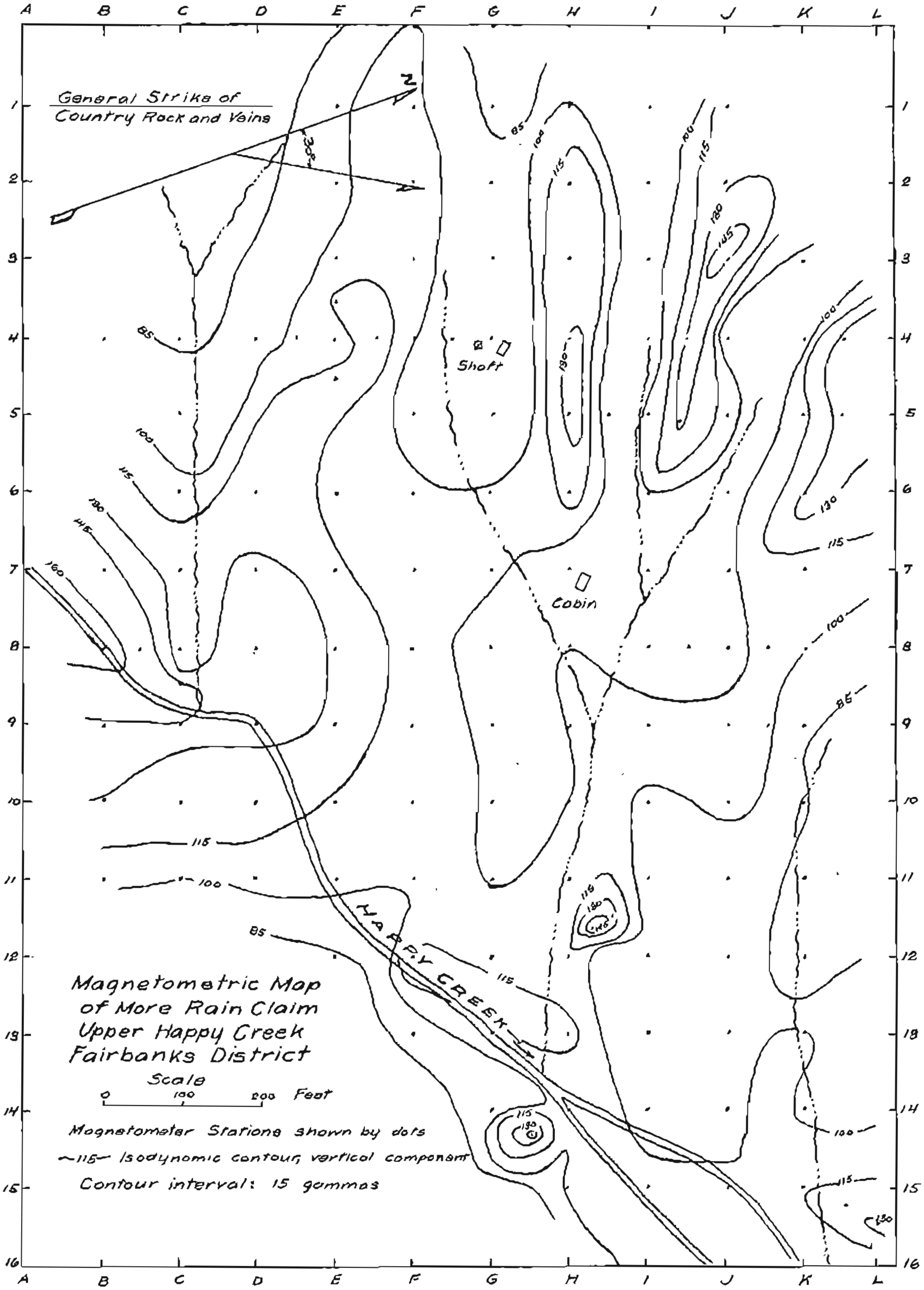
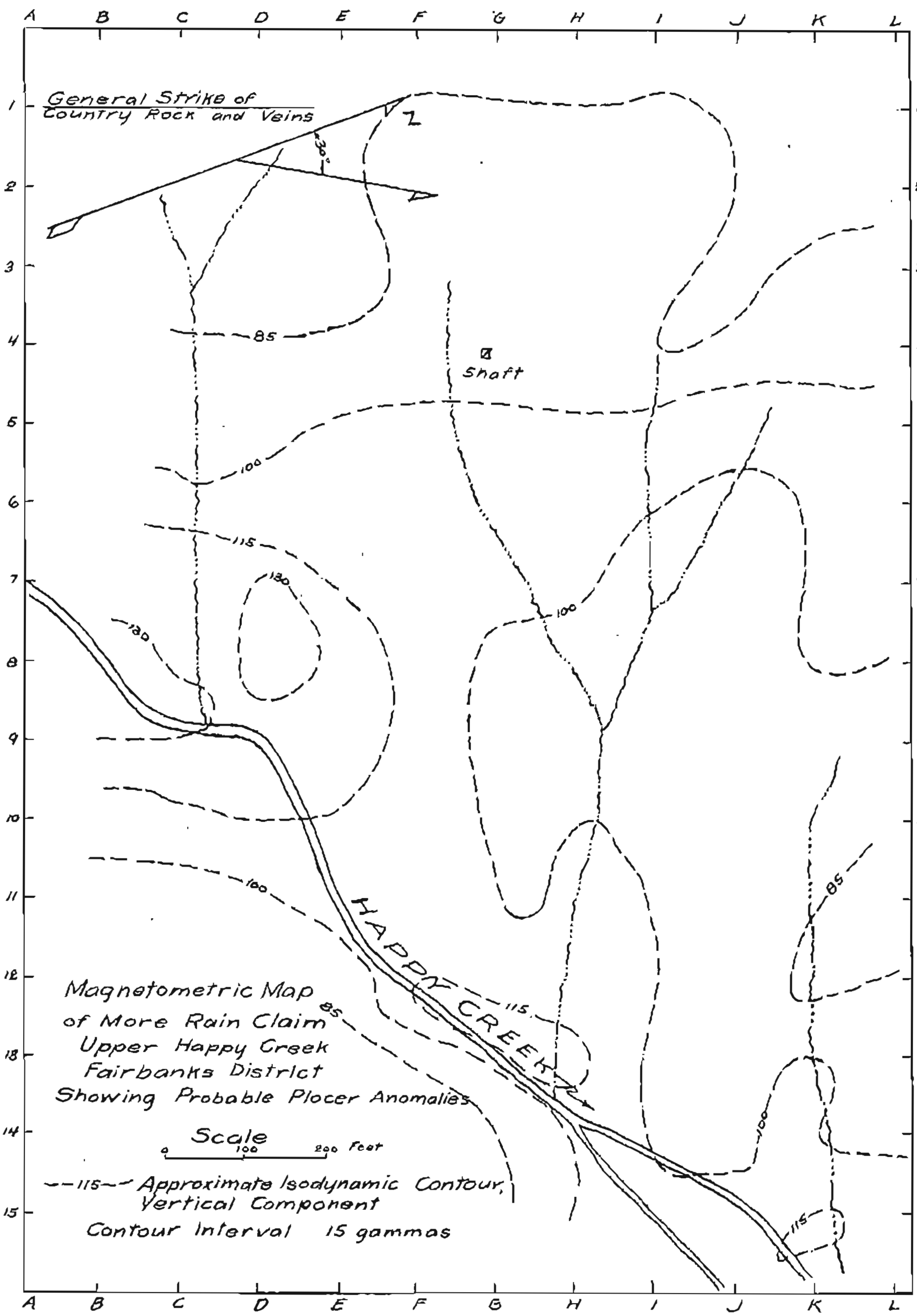

General Strike of
Country Rock and Veins
Shaft
Cabin
HAPPY CREEK
Magnetometric Map
of More Rain Claim
Upper Happy Creek
Fairbanks District
Scale
0 100 200 Feet
Magnetometer Stations shown by dots
~115~ Isodynamic contour, vertical component
Contour interval: 15 gammas

Fig. 8.



A
B
C
D
E
F
G
H
I
J
K
L
General Strike of Country Rock and Veins
85
Shaft
100
115
130
100
HAPPY CREEK
115
100
85
115
Magnetometric Map of More Rain Claim Upper Happy Creek Fairbanks District Showing Probable Placer Anomalies
Scale
0
100
200 Feet
115 Approximate Isodynamic Contour, Vertical Component
Contour Interval 15 gammas

Fig. 9.

anomalies are small and since there are several unknown factors, interpretation is uncertain and subject to revision when additional data is available. There is evidence of placer concentration along the left limit bench, and to check the small positive anomaly in the northeastern part of the area shown in Fig. 9, a shaft was sunk near station G 4 and drifts were run along bedrock. From two to five feet of poorly sorted gravel was found in this area containing an average of 30 cents in gold per square foot of bedrock. The ground is hardly rich enough for drifting ~~ground~~. The values are spotted and the gold is ~~little~~ only slightly worn. The gold-bearing gravel is replaced by barren bedrock slide and silt about 50 feet southwest of the shaft, the edge of the gravel being approximately indicated by the 85 gamma isodynamic line. The presence of water prevented drifts from being run southwest, toward the creek.

Other anomalies, apparently associated with reconcentrations of the bench placer, are found in the present creek channel, near the mouths of the tributary streams. Because of the complex geomorphology of the district it is doubtful if the present tributaries were instrumental in the reconcentration. The anomalies in the present creek channel are small in area and magnitude, and compare unfavorably with the anomalies associated with workable ground on lower Happy Creek. They have not been checked by shafts, as the ground is said to be wet.

Upper Happy Creek is one of the less favorable areas for placer prospecting by magnetometer. There is no true paystreak and placer anomalies are small because the poorly concentrated gravel contains relatively small amounts of magnetite. In addition, topographic anomalies are unusually large. The method of correcting for the anomalies which mask placer anomalies is admittedly inexact, especially where data on the character of the overburden and bedrock are not available. However, it has been found to be sufficiently correct, even under conditions existing on Happy Creek, to permit outlining the more favorable areas. The necessity of checking interpretations based on magnetometric data is obvious. In upper Happy Creek they serve only as a general guide to subsequent direct prospecting and give no information concerning gold values.

The problem of determining placer anomalies is frequently complicated by the presence of certain artificial disturbances. Iron tools and machinery, for instance, are always present on creeks that have been mined or prospected, and magnetometer stations must be located so that they will not be affected by them. Direct current power lines, particularly those with grounded returns, and telegraph and telephone lines are other sources of serious magnetic disturbance; fortunately they are not common in interior Alaska.

Large machinery on the surface may be avoided, but small objects such as old shovels and the ubiquitous tin can are soon covered by vegetation and silt, or by snow in winter, and may cause unsuspected errors if magnetometer stations are located near them. Wheelbarrows, tools and pipe in old placer drifts may cause large errors, particularly in shallow ground and in places where anomalies are small. Iron and steel are often polarized and may increase or decrease vertical intensity, depending on their orientation. The flow of water through hydraulic pipe may also change the direction and intensity of the associated magnetic field.

The location of artificial sources of disturbance on the surface should be known, and magnetometer stations should be placed outside of their zone of influence. Abandoned placer drifts should be mapped if possible, before making a magnetometer survey and doubtful readings over them discarded, as it is impossible to correct for the effect of an unknown amount of iron. Since magnetic objects above or below a vertical magnetometer have a much greater effect than those on the same level, tools buried underground may cause proportionately larger errors than those on the surface. For example, a shovel placed in a tunnel 30 feet directly below the magnetometer caused a maximum change of 20 gammas in vertical intensity, while the same shovel when level with the instrument had no appreciable effect at a distance of 15 feet.

The following table gives the approximate distances that should separate a vertical magnetometer station from iron objects.

Table II

Watches, knives and other small objects	15-25 feet
Wire fences	50 feet
Small cased wells	100-150 feet
Pipe lines, boilers, iron tanks	200-500 feet
Railroads, mills	500 feet

An automobile should not be closer than 150 feet if it is standing to the magnetic north or south of the instrument, or 200 feet if it is to the east or west.

e. Diurnal variation and magnetic storms.

Anomalies associated with placers are local changes in the earth's field intensity that are caused by variations in the magnetic content of placer gravels. These anomalies are constant with respect to time, but vary according to the position on the earth's surface. There are other variations in intensity and direction of the magnetic field that are essentially functions of time and that are the same in all parts of any locality. Corrections must be made for these variations when determining relatively small anomalies.

Variations that are functions of time are both periodic and irregular. Periodic variations include diurnal, annual, and secular changes in the earth field, of which only the diurnal variation is large enough to affect determinations of small anomalies. Irregular variations, when they are of considerable magnitude, are known as magnetic storms.

Diurnal variation is a fairly regular, daily variation in the intensity of the field from its mean value, and is chiefly a function of local time. In interior Alaska the vertical component of the magnetic field ordinarily reaches a maximum due to diurnal variation at about noon and a minimum at about 6 P. M. The total variation may be from 10 to 40 gammas. The rate of change is most rapid in the fore- and afternoon and least rapid about noon and midnight.

Magnetic storms are sudden, large and irregular changes in the magnetic field. They usually are more intense in high latitudes, and in interior Alaska may cause changes in the vertical component of 500 gammas or more within a few minutes. Correspondingly large changes occur simultaneously in the other magnetic elements. The causes of magnetic storms are not fully understood and it is impossible to predict their occurence or character except in a general way. There is no apparent relation between magnetic and atmospheric stomms. They appear to be associated with sunspots, auroral displays and earth-durrent irregularities. During violent magnetic storms, radio and telegraphic communication is adversely affected.

Sunspots and related phenomena are cyclic in character, with a period of about 11 years between maxima. The activity gradually increases to a maximum in violence and frequency and similarly decreases. During the past several years there has been maximum activity, and during the next several years there should be a decline in the frequency and violence of magnetic storms. A shorter and less well defined cycle which governs magnetic storms appears to be associated with the 28-day period of rotation of the sun about its axis. Magnetic storms usually subside when the sunspot is turned away from the earth and reappear when the sunspot is again visible. It is of course possible for magnetic storms related to other sunspots to occur in the interim. A daily cycle, dependent on the rotation of the earth, but not related to ordinary diurnal variation, is also evident at times. Thus, during magnetic storms lasting for several days, periods of maximum and of minimum disturbance occur at about the same time each day. In planning magnetometric surveys it is important to take these cycles into account, so that full use may be made of favorable periods.

Fig. 10, copied from magnetograms obtained from the Sitka Magnetic Observatory, shows variations in the vertical component of the earth's field during a normal quiet day, and during a magnetic storm of moderate intensity. Fig. 11 shows the major variations during a period of 118 days, from August 10 to December 6, 1939, and is a condensation of Sitka magnetograms and of field data ob-

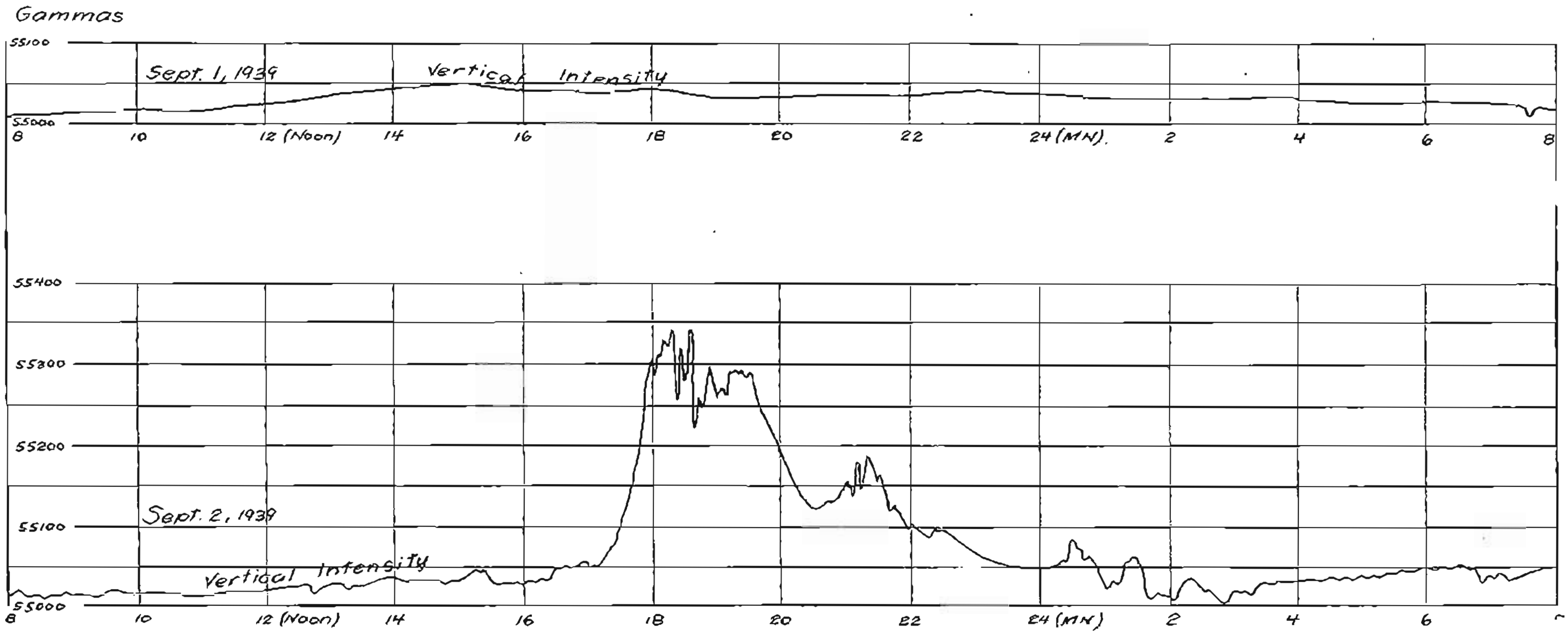


Fig. 10.— Variations in Vertical intensity during a magnetically calm day and during a disturbed day.

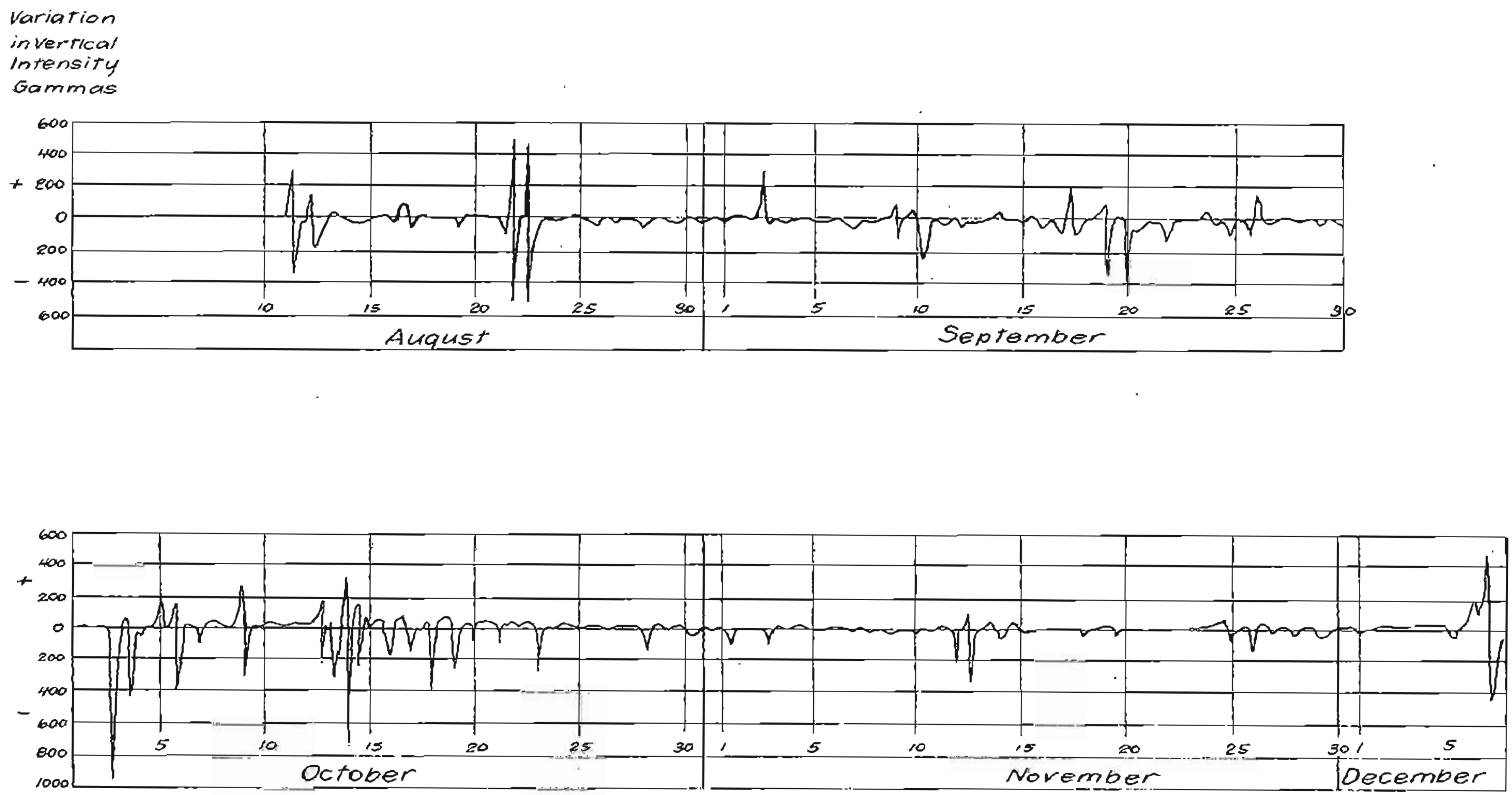


Fig. 11. — Major variations in the vertical component of the magnetic field; August 11 - December 6, 1939.

MR Misc
Joesting 1940

RESULTS OF THE GEOPHYSICAL PROGRAM OF THE DEPARTMENT OF MINES - DECEMBER, 1940.

Omit The experimental geophysical program was initiated in July, 1939, so that a year and a half ~~have~~ has been devoted mainly to this work. If the preliminary explanations are omitted from the accompanying paper, entitled "Some Results of the Experimental Geophysical Program of the Territorial Department of Mines", it may then be considered to summarize the results of all the work done excepting that done on underground water.

(Side heading) Underground Water

It was found possible to determine the location and approximate depth of water-bearing gravel under permanently frozen ground wherever tried, therefore it is probably safe to say that it is possible in the majority of cases. The greatest depths at which ~~at which~~ water was indicated by resistivity methods was about 100 feet, but under conditions encountered so far it should be possible to obtain reliable indications to depths of several hundred feet. In determining the presence of water under frozen, unconsolidated deposits, advantage was taken of the great difference in resistivity between frozen and thawed material. The resistivity method in this case ~~does not~~ indicates the presence of thawed ground, rather than the actual presence of water, therefore a knowledge of local stratigraphy was found to be helpful in interpreting the resistivity measurements. As a rule, however, thawed spots, or layers, in unconsolidated ground are likely to be water-bearing gravel.

Where the overburden is thawed, the problem of determining the location and approximate depth of water-bearing gravel is more difficult, excepting where the gravel is very thick, or close to the surface. Under favorable conditions water has been located under thawed ground at depths of 80 to 100 feet. The resistivity of water-bearing gravel is higher than that of merely moist gravel or silt, but is much lower than that of frozen deposits.

During the 1939 field season most attention was paid to learning something of the possibilities and limitations of the geophysical methods used, while during the 1940 season more attention was paid to the correlation of geological and geophysical data. A case in point is the work done on Ester Dome, in the Fairbanks district, during which as much information as possible was gotten from a few natural bedrock exposures and from what prospect trenches and pits were already there, and during which magnetometer and resistivity surveys furnished supplementary information where no bedrock exposures could be found. Although this work was not been completed, enough was learned to show that the general procedure is well suited to interior Alaska regions.

Omit

Insert p. 6 of [illegible]

(Side Heading)

THE ~~USE OF GEOPHYSICS IN PROSPECTING FOR~~ BASE METAL ORE DEPOSITS.

Of the various geophysical exploration methods available, the magnetic and electrical methods are of greatest value in prospecting for base metal ore deposits. The method used depends on conditions as determined by preliminary geological studies. Often it is necessary to use more than one method to obtain conclusive results.

Magnetic methods can be used to locate deposits, the magnetic properties of which are measureably different from the surrounding rocks. They are of special value in finding highly magnetic deposits, such as magnetite, ilmenite, chromite and pyrrhotite, but are also useful where the positions of ore deposits are determined by geologic structures. Rapid traverses over highly magnetic deposits can be made ~~by~~ with a dip needle, or with one of the less sensitive magnetic field balances. Where detailed and precise measurements are necessary, ~~the~~ Schmidt-type field balance - ~~such as th~~ similar to the one used by the Department of Mines for magnetic surveys in interior Alaska - should be used.

Most Electrical methods depend for their operation upon the creation of an electric field of force in the subsurface. This field may be produced either by passing a direct, or alternating, current through the ground by means of conductors in contact with the surface; or by sending in electromagnetic, ~~mxxradim~~ (radio) waves without making contact with the surface. These methods utilize the differences that ~~ex~~ exist between the electrical properties of relatively good conductors, as base metal ore deposits; and poor conductors, as siliceous rocks surrounding ore deposits.

The direct current resistivity method used by the Department of Mines is capable of obtaining information at comparatively great depths, but is slower than some of the less powerful methods. For rapid reconnaissance surveys, any one of the several low-powered radio methods should be useful in prospecting for large deposits in southeastern Alaska. ~~measuring resistivity measurements~~

Henry R. Joesting,
Assoc. Mining Engineer,
Juneau, Alaska.
December 13, 1940.

UNIVERSITY OF ALASKA
K F A R

B. D. [illegible]

Subject: An Episode of Gold

Sponsor: School of Mines

Speaker: John Newcomb

Announcer: Everett R. Erickson

Date: November 9, 1940

Hour: 12:00 - 12:15

****

Control Room: Announce - "The University of Alaska program."

****

Erickson: The administrative and the academic divisions of the University of Alaska bring to you their thirty-fifth radio broadcast and the fourth in the series "An Episode of Gold."

****

Erickson: "The Influence of Glaciation on Gold Prospecting in Alaska" is the subject of a report prepared by the School of Mines. The report will be read by John Newcomb, a student.

****

Erickson: You have been listening to a discussion concerning the influence of glaciation on gold prospecting in Alaska.

****

Erickson: One week from today you will hear the fifth of the series of "An Episode of Gold," Dr. Henry Joesting, Associate Engineer in the Territorial Department of Mines, will discuss the geophysical methods of prospecting.

Submitted by

Everett R. Erickson

Everett R. Erickson

D. D. Stewart

~~UNIVERSITY OF ALASKA~~
~~K F A R~~

2

~~Some Results~~ of the Experimental Geophysical Program of the Territorial Department of Mines ~~[Broadcast No. 1-16, 1940, 12-12:15 P.M.]~~

By Henry R. Joesting
Associate Mining Engineer and Geophysicist.

About a year and a half ago the Territorial Department of Mines inaugurated a modest experimental geophysical program. ~~for~~ The purpose of ~~determining~~ this program was to determine to what extent geophysical methods ~~can~~ could be used as aids to mining and prospecting in Alaska. ~~In this talk, I am going to discuss briefly~~ The following discussion outlines briefly some of the gold mining and prospecting problems to which geophysical methods have been applied, and also ~~to tell something~~ presents of the results of the experimental ~~geophysical~~ work done by the Department of Mines.

First, ~~however~~, it ~~might be~~ is well to define the terms geophysics and geophysical prospecting. Geophysics means, literally, earth physics. It is an extremely broad science, since it has to do with measurement and interpretation of all physical phenomena encountered in or on the earth, in the sea and in the atmosphere surrounding the earth. For convenience, geophysics is divided into several branches, some of which are important enough to be considered as separate sciences. Some of the important branches are meteorology, oceanography, geodesy and geophysical prospecting.

Geophysical prospecting is concerned with measuring and interpreting differences in physical properties that exist between mineral deposits and their enclosing rocks, particularly when their presence is not indicated by surface outcrops.

There are four general geophysical methods in common use; namely, ~~the~~ magnetic, electrical, gravimetric and seismic. Each method depends on the existence of measureable differences between the mineral deposits and the adjacent rocks in magnetic permeability, electrical conductivity, density or elasticity. The choice of geophysical method depends on the particular prospecting problem and also on such factors as the cost and the time required to get results. If the supposed deposit is relatively shallow and easy to prospect by ordinary methods, then the geophysical method must be simple and inexpensive to be of any practical use. On the other hand, if the deposit is deep and prospecting is expensive, it is possible to use more elaborate geophysical methods and still save time and money.

The magnetic and the electrical methods were chosen by the Department of Mines for its initial experimental work because these methods are applicable to the study of most of the important prospecting and mining problems encountered in Interior Alaska; also the cost of instruments and of field work is comparatively low. They offer the additional advantages of speed and simplicity of operation. Therefore, these two methods stand the best chance of being of eventual general use to the small, as well as to the large operator and prospector.

Now, having briefly reviewed the various geophysical prospecting methods available, let us look into some of the problems connected with gold prospecting and mining to which geophysical methods might be applied. ~~Most of these problems in interior~~

In interior Alaska, most of these problems are connected with ~~Alaska result from~~ the muck, silt, and residual deposits that cover a large part of the country, particularly in the mature regions. Many of the deposits are permanently frozen; others are thawed. They range in thickness from a few feet to several hundred feet and constitute the principal handicap to prospecting for both lodes and placers.

Omit

~~Obviously, the problems that may be profitably attacked by geophysical methods are those resulting from the presence of overburden. They are to a large extent unique to interior Alaska and to geographically similar regions.~~ The most important of the ~~these~~ problems on which geophysical work has been done are ~~are~~: first, the location of buried placers; second, the location of buried lodes, and of faults, contacts and intrusions that may have a bearing on mineralization; and third, the determination of depth of thawed and permanently frozen overburden and the distribution of permanently frozen ground.

insert ¶

(Side heading) "Placer deposits"

For locating and outlining buried placers the magnetic method appears to be best adapted. The instrument used for this work is known as the magnetic field balance, or vertical magnetometer. It is not only extremely sensitive, but surveys made with this type of instrument are rapid and inexpensive. The magnetometer can be used for prospecting for placer gold because magnetic minerals, or black sands, are commonly associated with the gold. Thus, in many cases, placers may be outlined simply by finding the maximum concentration of black sands.

Now, it is well known to everyone who has done any placer prospecting or mining that the amount of magnetic black sand varies in different placers. Some rich placers contain very little black sand, while the reverse is true with respect to some low grade ones. And, since magnetic minerals are much more widespread than gold, black sand occurs in many gravel deposits that are entirely barren of gold. The presence of both gold and magnetic minerals in placers depends primarily on an adequate bedrock source of both materials. For this reason, prospecting for placers with a magnetometer should be confined to mineralized regions.

In order to determine in a reasonably short time the applicability of the magnetic method to placer prospecting in interior Alaska as a whole, about 110 samples of concentrates from 54 creeks were examined. Magnetic minerals, the most important of which was magnetite, were found in all the samples, in amounts ranging from 1 to over 50%. Magnetometer surveys were then run over several placers to determine the relations between magnetic mineral content and its effect on the magnetometer. Considerable panning was also done to ascertain whether magnetic minerals and gold were generally concentrated in the same parts of placers.

It was found that the presence of relatively small amounts of black sand can be detected by the magnetometer, although of course more black sand is necessary in deep, than in shallow placers. Considered on the basis of black sand content alone, about 75% of the placers in the interior can be located by magnetometer surveys. However, other factors, chief of which is occasional irregularities in the magnetic properties of bedrock, reduce this figure to an estimated 50%.

Where the paystreak is well defined and more or less uniform, the amount of black sand has been found to be proportionate to the gold content, and these placers can be outlined with considerable accuracy. On the other hand, where the gravel is not well sorted and there is no true paystreak, the placer can at best be only approximately outlined. From data gathered in this experimental work and from a knowledge of the geology, it is now possible to predict whether or not magnetic methods can be used successfully in any region in the interior. I should mention, however, that the method does not eliminate regular prospecting, but it does in some cases eliminate much prospecting in barren ground. The low cost and rapidity of magnetometer surveys make them worth trying whenever drilling or shaft sinking is difficult or expensive.

(Slide Reading) "Gold Prices"!

The geophysicist is up against a difficult problem in devising a method for detecting or tracing buried gold-quartz veins. Most gold-quartz veins are small and their physical properties are often not materially different from those of the country rock. Even in a vein assaying two or three ounces to the ton, the amount of gold is too small to be detected directly by any known geophysical method. However, worthwhile results may often be obtained by utilizing a combination of geology and geophysics.

The position of a vein may be controlled by faulting, or by the contact of two dissimilar rocks, or it may bear a definite relation to intrusions of igneous rocks. In many cases it is possible to trace these structural features by one or more geophysical methods. For example, there is often sufficient difference in the magnetic properties of rocks on opposite sides of a fault so that it can be traced by a magnetometer survey. Similarly, igneous rocks can be located, and in general any contact of dissimilar rocks can be traced through differences in magnetic properties, and in this manner the presence of quartz veins can often be indicated.

An electrical method that measures the conductivity of buried formations has been used successfully for tracing fault zones and veins occurring in faults. Fault zones usually contain breccia and gouge and this material will conduct an electric current more readily than the undisturbed rock on both sides of the fault.

Both magnetic and electrical methods have been used by the Department of Mines for the purpose of tracing bedrock features with which quartz veins are associated, ~~associated with quartz veins~~. As a rule, it has been found necessary to start the geophysical surveys where conditions are already known, after which the survey is extended to unknown areas. Geophysical prospecting for lodes can be used most advantageously to supplement geological work and in connection with direct prospecting. As with placer investigations, the primary aim is not to eliminate direct prospecting entirely, but merely to reduce the amount of this slower and more expensive type of work that is so often done in unfavorable areas.

Insert par. re Ester Dome work. This follows by "Base Metal Ore Deposits"

Sub-heading: "Frozen ground and depth of overburden"

Besides the work on buried placers and lodes, the Department of Mines has carried on experimental work for the purpose of developing geophysical methods to determine the location and extent of permanently frozen ground and also to determine depths

of muck & gravel overburden.
~~to bedrock in both thawed and frozen ground.~~

It was found that frozen muck and gravel are extremely poor conductors of electricity compared to their thawed counterparts. Advantage is taken of these differences in conductivity to develop a rapid and ~~an~~ inexpensive method of finding the extent and depth of frozen deposits. Considerable attention has also been paid to the problem of finding the thickness of muck and gravel in both thawed and permanently frozen areas. It is possible at present to determine depths when conditions are fairly simple, but where depths are over about 50 feet, and where both frozen and thawed ground are encountered, results have not been uniformly satisfactory.

Insert, "Underground Water"

~~I have tried to show that much of~~ ~~in this brief talk~~ the geophysical work being done by the Department of Mines is still in an experimental stage; nevertheless, enough has been accomplished to prove that geophysics has a definite and an important place in gold both placer and lode prospecting, and mining and in the detection and estimation of the extent of base-metal ore deposits.

Omit

I have noticed that in general, ~~and with some notable exceptions,~~ most people can be placed in two groups as regards their attitude toward geophysical prospecting. One group, the superoptomists, confidently expects miracles and believes that the geophysicist can look into the bowels of the earth and tell exactly what is there. These people are doomed to disappointment ~~and in addition are likely to be taken in by frauds~~. The other group discounts the possibility of geophysical methods being of any help whatsoever in prospecting or mining. Some in this group are opposed to anything they don't understand, whereas others are just natually reactionary and opposed to change. The true state of affairs lies somewhere between these widely divergent views. Geophysical methods have in many cases speeded up prospecting and made it less expensive, but they have not eliminated the need for prospecting with pick and shovel or with drills and they are not likely to do so in the near future.

Henry A. Joesting
Assoc. Mining Engineer
Department of Mines
College, Nov, 16, 1940

In undertaking this work two alternative methods of
~~I might say here that I had the choice of two methods of working:~~
procedure were considered:
We either could have concentrated on one single problem, or we could have made a broad study of all of the important problems. In view of the fact that very little previous geophysical work had been done, compared to the immense amount done in the States and in other countries, the second method was chosen: that is, a general study was made of all of the more important problems.

Bureau Stuff 1940

Resistivity of Underlying Beds and their Application to Geophysical Problems: U. S. Bureau Mines Tech. Paper 502, 1931.
Irwin Roman, Some Interpretations of Earth-resistivity Data: A. I. M. E. volume on Geophysical Prospecting, 1934, pp. 183-197.

Table

Material	Apparent Resistivity Range, ohm-cm.	Mean Apparent Resistivity, ohm-cm/	Locality[1]
Thawed, moist silt and vegetation muck (in valleys)	3,600 - 35,000	1.1×10^4	a,b,c
Thawed silt and slide, dry on surface (onslopes)	50,000- 190,000	8.0×10^4	a,b,c
Frozen silt and vegetation muck	135,000 - 600,000	26.4×10^4	a,b,c
Thawed moist sand, fine gravel and clay	22,000 - 65,000	4.2×10^4	a,b,c
Thawed moist gravel	41,000 - 71,000	5.5×10^4	a,b,c
Water-bearing gravel	100,000 - 195,000	13.5×10^4	a,b,c
Frozen sand and fine gravel	630,000 - 2,400,000	120×10^4	a,b,c
Frozen gravel	780,000 - 4,100,000	220×10^4	a,b,c
Frozen surface silt at -10°C	2,000,000 - 3,000,000	220×10^4	a
Frozen surface gravel at -15°C	2,000,000 - 4,000,000	300×10^4	a
Thawed soft mica-, chlorite-, and graphitic schist	20,000 - 80,000	3.9×10^4	a,c
Thawed hard quartzitic schist	200,000 - 300,000	16×10^4	a,c
Thawed conglomerate	22,000 - 70,000	6.0×10^4	c
Frozen conglomerate	1,200,00 - 1,600,000	140×10^4	c
Thawed chert	140,000 - 200,000	17×10^4	b
Thawed limestone	50,000 - 84,000	6.5×10^4	b
Thawed argillite	26,000 - 70,000	5.7×10^4	b
Thawed granite	95,000 - 185,000	15×10^4	c
Thawed serpentine	114,000- 140,000	12×10^4	b
Partly frozen limestone and serpentine	270,000 - 1,500,000	57×10^4	b

[1] a - Fairbanks District; b - Livengood District; c - Circle District.

tained in interior Alaska. The ~~curve~~ graph indicates that magnetic conditions improved during November and December. In general, magnetic disturbances during any year are at a minimum from November to February, and reach a maximum from May to August. March, April, September, and October are intermediate in this respect. The daily and 28-day cycles that govern magnetic storms are also apparent in Fig. 11, but the scale is too small to show diurnal variation.

During relatively quiet periods corrections for variations can be made so that small anomalies are measurable, but during stormy periods, when irregular fluctuations may be considerably greater than the anomalies, magnetometric field work cannot be carried out by present methods. Tables III and IV show the relative number of quiet and disturbed days during the latter part of 1939 and during the summer of 1938. Complete records for the summer of 1938 were not available when this report was written and the stated percentages of disturbed day may, as a result, be somewhat in error. During the disturbed days, which include those during which small, but irregular fluctuations, as well as magnetic storms occurred, small anomalies could not be determined with sufficient accuracy.

Table IIIComparison of Quiet and Disturbed Days: Aug. 11 - Dec. 6, 1939

Month	Number of Quiet Days	Number of Disturbed Days	Total Days	Percentage of Disturbed Days
August	14	7	21	33%
September	25	5	30	18%
October	22	9	31	29%
November	27	3	30	10%
December	5	1	6	17%
Total	93	25	118	21% (average)

Table IV Comparison of Quiet and Disturbed Days: May - August, 1938

Month	Number of Quiet Days	Number of Disturbed Days	Total Days	Percentage of Disturbed Days
May	10	5	15	33%
June	15	9	24	37%
July	8	10	18	56%
August	6	3	9	33%
Total	39	27	66	41% (average)

Since only one magnetometer was available for this investigation, corrections for variations were made by taking hourly readings at a base station, conveniently located in the area being surveyed. From these readings sufficiently accurate corrections could be applied to readings taken during the interval between the base-station readings, if the variation was small or if the rate of change was uniform. Magnetograms obtained from Sitka permitted an approximate check to be made on the occurrence of sudden changes between the hourly base-station readings, but because of the distance, the variations at Sitka do not correspond exactly to those in interior Alaska. When the reading at a new station was considerably different from those at preceding stations, an immediate check reading was taken at the base-station or at a preceding station, to ascertain whether the difference was caused by an anomaly or by a sudden fluctuation in the earth's field. In this manner the error at any station resulting from incorrect determination of diurnal variation and from changes in the constants of the instrument, was not over 5 gammas, and under favorable conditions was as low as 2 gammas. The maximum total error was below 10 gammas and on some surveys was 6 gammas.

It is evident that the field procedure described is uneconomical. The necessity for frequent check readings decreases the speed of the survey and increases the cost per station. The usual method, when small anomalies are to be measured, is to employ two instruments. One instrument occupies a base station, where readings are taken at 5 or 10-minute intervals, while the magnetic survey is made with the other instrument. Automatic recording magnetometers, which keep a continuous record of variations, are also available. The use of a base-station instrument enables more accurate corrections for variations to be made, and by eliminating the necessity of taking hourly base-station readings with the surveying magnetometer, it increases the speed of field work. A magnetic observatory in interior Alaska, by keeping a continuous record of variations, would serve the same purpose as a base-station instrument.

Even when a base-station instrument is used, placer anomalies cannot be measured during magnetic storms. However, the time need not be entirely lost, as other work connected with the survey may be done when magnetic conditions are unfavorable. This work includes investigation of surface exposures and prospect holes, gathering of data related to thickness of overburden and gravel, collection and study of gravel and bedrock samples, location of magnetometer stations, and calculation of results, activities which occupy at least half of the time in most surveys. Nevertheless, the irregular magnetic conditions which exist in Alaska seriously handicap magnetometric prospecting, especially when it is necessary to measure small anomalies.

Buried Bedrock Features

A preliminary study was made to determine the usefulness of the vertical magnetometer in outlining and tracing various bedrock features, such as faults, igneous intrusions, and veins. The magnetometer has been successfully used to study similar problems in other parts of the world, but as far as is known it has ~~they have~~ not been used before in interior Alaska. Where applicable, the relatively low cost of magnetometer surveys should make them of considerable value, especially in regions where unconsolidated overburden is prevalent.

The magnetometer will, in general, reveal changes in the composition of rocks, since such changes are usually accompanied by changes in their magnetic properties, and consequently by vertical anomalies. The magnitudes of the vertical anomalies are governed by the masses of the rocks involved, as well as by the differences in their magnetic properties. Measurable anomalies, consequently, will usually be associated with large igneous intrusions, the magnetic properties of which may be only slightly different from those of the intruded rock, whereas a narrow dike of the same composition would cause much smaller anomalies. For this reason small masses, such as veins, may be traced only if their magnetic properties are considerably different from those of the country rock. Variations in composition within a rock formation may also result in measurable anomalies, as shown in Fig. 6, where bedding changes and the strike of the schist are reflected by changes in vertical intensity. Similarly, displacement of rock masses through faulting may bring into contack rocks with different magnetic properties. As a rule, the size of anomalies related to faults will be more or less proportionate to the amount of displacement, since faults with large displacements are more likely to bring dissimilar rocks into contact than small ones.

The results of reconnaissance magnetometer surveys over various types of geologic structures are given below. Since little detailed work was done, they should be regarded merely as indications of the applicability of the magnetometer to these problems.

The profile across Livengood Creek (Fig. 3) shows a large vertical anomaly resulting from the presence of serpentine in contact with relatively non-magnetic chert and shale. The total vertical anomaly, which is not shown in Fig. 3, is several thousand gammas. In measuring very large anomalies, such as those which are often associated with basic igneous rocks and with other rocks of high magnetite content, it is not necessary to apply corrections for diurnal variation, and field measurements can be made more rapidly because less care is necessary in obtaining magnetometer readings.

A north-south profile across part of a quartz-diorite intrusion in mica-schist is shown in Fig 12. The overburden, which is approximately 5 to 15 feet thick, consists of float and fine rock material, covered with moss. The traverse was run in the winter, when it was not possible to collect samples of the intrusion and of the country rock. The approximate location of the contact was determined previously from examination of prospect holes and float. The anomaly associated with the intrusion is fairly small, as would be anticipated from a rock mass with magnetic properties not greatly different from those of the surrounding rock. As in the measurement of all small anomalies, corrections must be made for diurnal variation.

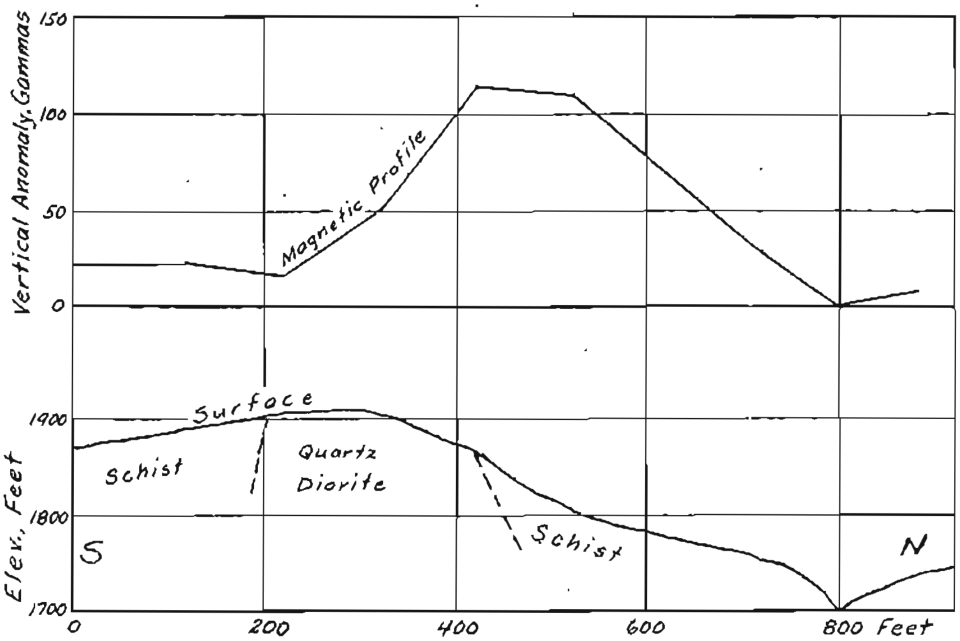


Fig. 12.— Profile showing vertical anomaly associated with quartz-diorite intrusion in schist. Pedro Dome, Fairbanks District.

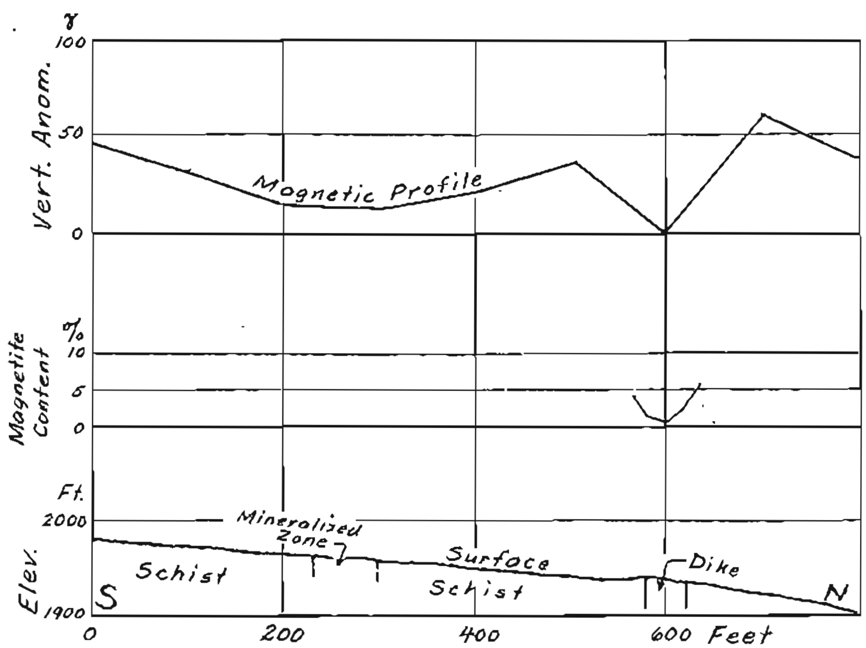


Fig. 13. — Profile across altered quartz-feldspar dike in schist, showing relations between vertical intensity and magnetite content of rocks. Head of Cleary Creek, Fairbanks District.

The occurrence of a magnetic high over the north contact of the intrusion might indicate a slight segregation of magnetic minerals along that contact, or might mean that this contact dips less steeply than the south contact. A detailed magnetic survey, together with a geologic study of available exposures, would be necessary before definite statements could be made concerning the nature of the contacts.

Fig. 13 shows a negative anomaly over a large altered aplite dike near the head of Cleary Creek, in the Fairbanks District. The dike rock consists almost entirely of quartz and decomposed feldspar, and has a gneissic texture. The small negative anomaly is caused by the low magnetite content of the dike rock, compared to that of the mica-schist country rock. The middle part of the dike, which is about 40 feet wide, contains only 0.45% magnetite, compared to a magnetite content of 2 to 3% near the walls. The country rock a few ~~several~~ feet from the dike walls contains from 4 to 6% magnetite, as determined from several samples. The close relationship between magnetite content and vertical anomalies is shown in the profile. Other profiles, run near by where the overburden was estimated to be about 10 feet thick, showed similar vertical anomalies, and it is apparent that the dike could be outlined by means of a detailed magnetometer survey. However, as is generally the case where small anomalies are concenred, it would be necessary to start such a survey where magnetic results can be correlated with known conditions, before extending it to unknown regions.

The vertical anomalies associated with a steeply dipping fault in mica-schist are shown in Fig. 14. The displacement of the fault is not known, but is probably at least 200 feet. The over-

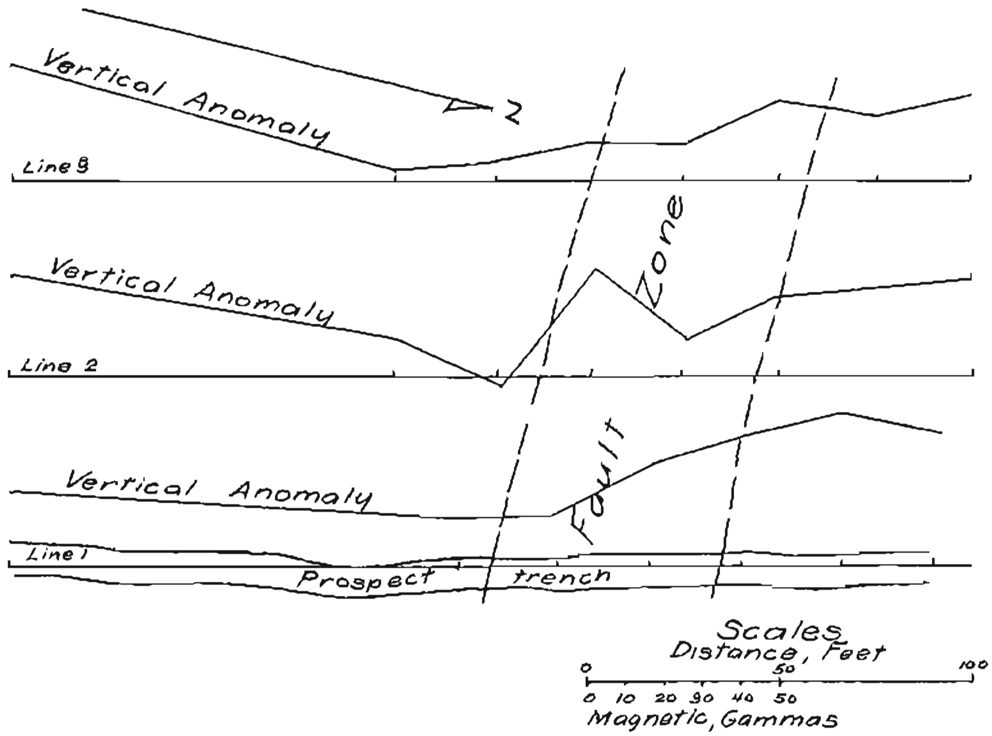


Fig. 14. — Sketch map showing vertical anomalies associated with fault zone at mouth of Bedrock Creek, Fairbanks District.

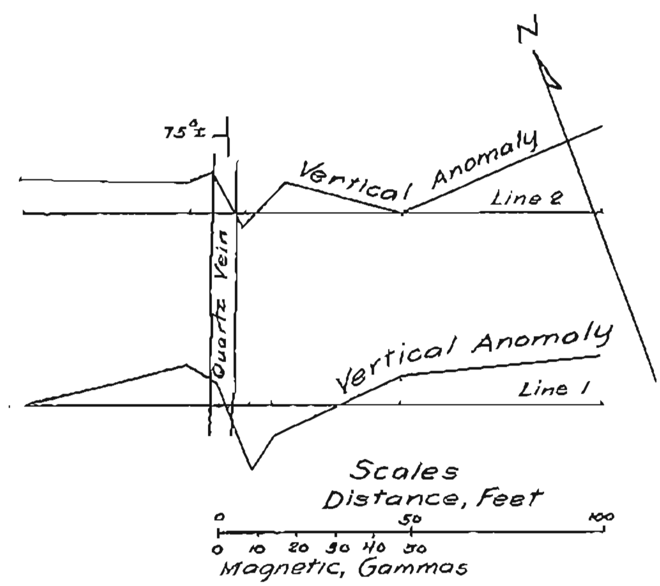


Fig. 15. — Sketch map showing vertical anomalies associated with large quartz vein on east side of Ester Dome, Fairbanks District.

burden varies in thickness from about 7 to 15 feet. The small anomalies associated with this fault would require a detailed and accurate magnetic survey in order to determine its approximate direction, and would require a comparison of anomalies where conditions are known with those where overburden covers the consolidated rocks. Since the approximate direction of the fault shown in Fig. 14 can be determined from a knowledge of the geology of the area, the practical value of a magnetic survey for the purpose of tracing this fault is doubtful. It is likewise doubtful if magnetic methods are particularly applicable to tracing most of the relatively small faults that are associated with the gold-quartz veins in the Fairbanks District, since the anomalies associated with them are generally small, and their ~~general~~ characteristics are known from underground mining.

Magnetometer traverses were run over several small gold-quartz veins of the type found in the Fairbanks District. In most cases the vertical anomalies directly associated with the veins were smaller than those resulting from normal variations in the country rock, and as a rule no interpretable results were obtainable when the small veins were covered by more than a few feet of overburden. The anomalies, when large enough to measure, were found to be negative for the most part, apparently because of the small amount of magnetite in the veins compared to the country rock. Their small magnitudes are undoubtedly due to the small masses of the veins, which in most cases were not over a foot thick. It is not likely that the vertical magnetometer will be of much value in prospecting for gold-quartz veins, unless special conditions prevail. A very large vein or mineralized zone may be traceable under moderate depth of overburden, as may any vein, regardless of size, if it lies along the contact of dissimilar rock, or if its position is determined by structural conditions with which ~~with~~ measureable anomalies are associated.

Fig. 15 shows the relations existing over a barren quartz vein, 4 feet thick, and covered by from one to about 6 feet of overburden. This particular vein is apparently traceable by magnetometric methods because of unusually favorable conditions. It is large and contains practically no magnetite, whereas the schistose country rock is moderately magnetic; furthermore the overburden is comparatively shallow.

Conclusions

The results of this preliminary investigation indicate that magnetic methods may in many cases be an important aid to direct methods of prospecting and to geological studies in interior Alaska. While they cannot replace drilling or related prospecting methods for the purpose of evaluating mineral deposits, they can in many cases replace direct prospecting for the purpose of locating mineral deposits. In general, the role of magnetometric surveys in prospecting is to furnish inexpensive information which will aid in outlining favorable areas and in eliminating unfavorable areas. They may also be a useful supplement to geological studies in determining factors which control ore deposition.

The interpretation of magnetometric data involves considerably more than the location of magnetic highs. The complete anomaly and the relations of magnetic highs and lows must be taken into consideration. The form of anomalies and their relation to the deposit or structure causing them is governed by many factors, among which are the shape, size, depth, orientation and magnetic permeability of the deposit or structure. Residual magnetism, if present, will also affect the form of the anomalies. Thus, while the significance of certain types of anomalies may be indicated by comparison with mathematically ideal cases, as a rule there are too many unknown factors to permit final interpretations on the basis of theoretical considerations alone. It is important, therefore, to correlate magnetic anomalies with available geologic data, in order to determine their significance with certainty. In practice, interpretations are made first where conditions are best known, subsequently they are extended to adjacent areas.

The vertical magnetometer apparently is useful, to a greater or lesser extent, in prospecting the majority of interior Alaskan placers. Their shape and position makes the interpretation of placer anomalies comparatively simple, so that where measureable anomalies occur, placers can be located from magnetometric and surface data alone. As stated previously, subsequent prospecting is necessary for purposes of evaluating the ground and determining the limits of pay. Since most placer anomalies are relatively small, corrections must be made for other anomalies and for variations in the earth's field which otherwise would interfere with their determination. Placer anomalies are generally positive, but locally the vertical intensity over shallow placers may be less than that over the adjacent areas.

Magnetometric methods are applicable to the study of many problems related to the geology and mineralization of consolidated rocks. The extent of their applicability depends on the rock masses, as well as on their differences in magnetic permeability. Gold-quartz veins, because of their relatively small masses, can seldom be located directly.

The irregular variations in the earth's magnetic field, characteristic of high latitudes, increase the difficulty and expense of measuring small anomalies. This difficulty could be overcome by the development of instruments and measuring technique adapted to Alaskan conditions.

Because of smaller variations in the earth's field during the winter, this period is the most suitable time for measuring small anomalies, despite the fact that cold weather decreases the speed of field work. The chief disadvantage of winter work is that surface studies cannot be made in connection with the magnetometric survey.

The Applications of Direct-Current Resistivity Methods

Resistivity methods are based on the existence of differences in the electrical conductivity of different rocks and minerals. In practice it is convenient to express electrical conductivity in the form of resistivity, which is the reciprocal of specific conductivity. In this report resistivities;are give in ohm-cm., that is, the resistivity of one centimeter cube of the substance in question, when measured between two opposite faces.

The direct-current resistivity method has been used for various types of subsurface exploration, such as the search for metalliferous deposits and the determination of depth to bedrock and to underground water.[1] It is probably best suited to investigations where the disconformities are approximately horizontal, but it has also been used successfully for the purpose of tracing more or less vertical disconformities, such as steeply dipping faults and contacts between formations. In this investigation the practicability of the method was tested on a variety of problems, chief of which were the outlining of areas of permanently frozen ground, determination of depth of overburden and location of underground water. Most of the work was done on permanently frozen ground, since this material constitutes an important portion of the overburden in interior Alaska, and since relatively little is known of its depth and areal distribution. The study of structural features of the bedrock received

---

[1] For descriptions of various applications of resistivity methods see: Colorado School of Mines Quarterly, Vol. 24, No. 1, March 1929, and Vol. 32, No. 1, Jan. 1937; Canadian Department of Mines Memoir 165, 1931, and Memoir 170, 1932; American Geophysical Union Trans. of 1939, Part III, pp. 280-298, 1939; and the geophysical publications of the U. S. Bureau of Mines and of the Am. Inst. Min. and Met. Eng.

relatively little attention, partly because of lack of time and partly because magnetometric methods are usually better suited to this type of investigation.

The passage of current through poor conductors such as rocks is effected almost entirely by the migration of ions contained in the water that permeates the subsurface, and for this reason the resistivity of both consolidated and unconsolidated rocks depends to a great extent on the moisture content. Wet, swampy overburden generally has a low resistivity, while that of well drained, relatively dry material is high. Similarly, porous rocks or rocks traversed by numerous cracks or joints containing moisture have a lower resistivity than dense, hard rocks.

Small samples of dry rocks may have resistivities as high as 10" ohm-cm., whereas the resistivity of similar rocks, measured in situ will seldom be greater than a few hundred thousand ohm-cm. Hence laboratory determinations of resistivities may be misleading unless accompanied by descriptions of conditions under which the measurements were made.

Preliminary determinations in the Fairbanks District indicated that the apparent resistivities differ considerably from those of approximately similar material in lower latitudes. It was decided, therefore, to make field measurements in a number of localities for the purpose of determining the resistivities of the various types of material encountered in interior Alaska. Several hundred measurements were made in the Fairbanks, Livengood and Circle Districts, where subsurface conditions were known. The apparent resistivities of each type of material were calculated by Romans Method[1]. The results are summarized in Table .

---

1 Irwin Roman, How to Compute Tables for Determining Electrical

Both smaller and larger apparent resistivities than those tabulated were obtained from individual determinations, since in determining the resistivity range of each material, the mean of a number of determinations made in each small area was taken as the apparent resistivity of the material in that area. The values represent the results of from 10 to over 50 measurements of each type of material, usually made in a number of localities and therefore may be considered to be typical for the various materials on which measurements were made. However, somewhat different values may be obtained in other localities where conditions may differ from those encountered in this investigation.

The large variations in the resistivities of thawed silt are accounted for by variations in the moisture content of the near-surface material. In general the surface in valleys and on level ground remains moist or wet throughout the summer, while on well drained hillsides and ridges the surface may be nearly dry much of the time. At depths greater that 5 feet, where the moisture content is ~~apparently~~ more uniform than at the surface, there was less variation in resistivity and the values were usually close to 11,000 ohm-cm.

Fine gravel has a lower apparent resistivity than coarse material, possibly because the moisture in the fine gravel contains a higher proportion of dissolved salts. The resistivity of gravel and sand was found to decrease with increased moisture content until the saturation point was approached, while the resistivity of gravel saturated with water was considerably higher. The high resistivity of water-bearing gravel, compared with that of merely moist gravel, is attributed to the smaller proportion of dissolved salts in the former.

The resistivities of thawed unconsolidated overburden are higher than those of moist overburden in lower latitudes. These high values are apparently the result of different conditions which control erosion and deposition, together with lower temperatures of the near-surface material. Rock weathering in interior Alaska is accomplished principally by freezing and thawing, and this process also plays an important part in the transportation of rock debris from the hillsides to the valleys. Chemical and biochemical ~~bacterial~~ processes play a minor role in rock weathering, because of low temperature, scant rainfall and restricted underground circulation of water. The result is that much of the overburden consists of unaltered, comminuted rock fragments and contains relatively small amounts of dissolved salts and clay. Because current is conducted through moist material mainly by electrolysis, smaller amounts of dissolved salts result in higher resistivities. Similarly, the low temperature of the overburden increases its resistivity, since the resistance of an electrolyte to the passage of a current increases with decreased temeprature.

Magnetometric Survey Methods and Costs

A brief description of the methods used in making a magnetometric survey in Interior Alaska will be necessary at this point, since certain problems and conditions peculiar to this region are not discussed in the excellent general treatises on the use of the magnetometer.[1]

---

[1] J. W. Joyce, Manual on Geophysical Prospecting with the Magnetometer: American Askania Corp., Houston, Texas, 1938.

C. A. Heiland, Construction, Theory and Application of Magnetic Field Balances: Bull. Am. Assoc. Petroleum Geol., vol. 10, 1926, pp. 1189-1200.

M. C. Alexanian, Practical Rules for the Use of the Magnetometer in Geophysical Prospecting: U. S. Bureau of Mines Information Circular 6527, 1931, Translated by W. Ayvazoglou.

Placer Prospecting Methods

Prospecting for buried placers with the aid of the magnetometer involves the collection and correlation of data obtained from geologic investigations, magnetometric surveys, and direct prospecting. The importance of the magnetometric data, compared with that obtained from other sources, depends primarily on how closely the magnetic anomalies indicate the location of the placer and the variations in gold values within the placer. The various steps in this method are, then, the preliminary geologic study, the magnetometric survey, the preliminary interpretation of anomalies, direct prospecting and the final interpretation of anomalies.

Assuming a knowledge of the geology of the region as a whole, a more detailed study of the locality seledted for prospecting should predede the magnetometric survey, in order to determine as much as possible concerning bedrock structure, the sources of gold and of magnetic minerals, and the physiographic factors affecting the deposition of placers. In many areas, the amount of information derivable from a surface study is limited, because of the presence of unconsolidated overburden, but it is seldom that some information cannot be obtained concerning the strike and dip of bedrock, the approximate location of contacts, and the general strike of faults and veins. Dumps from old prospect holes, if present, will furnish data on bedrock, gravel, and approximate depth of overburden. Mineralogical studies of placer gravel will often furnish information concerning bedrock changes and sources of gold and other economic minerals. The relative amounts of magnetic minerals in the gravel and the bedrock should be determined when samples are available.

Reconnaissance traverses should then be run to determine if measurable anomalies are associated with placer concentrations. The traverse lines, may be spaced 1000 feet or more apart, and should be located where bedrock anomalies are small. The spacing of the magnetometer stations on the traverse lines is governed by the probable width of the paystreak. The interval between stations should be short enough so that important anomalies will not be missed, but also long enough to permit covering the area with a minimum number of magnetometer readings. Intervals of 100 to 200 feet are usually suitable.

If measurable anomalies, apparently associated with a placer, are found, additional traverses should be run in order to determine their approximate extent. The traverse lines may be spaced from 200 to 500 feet apart, and the station interval may be from 50 to 200 feet, depending on the lateral extent of the anomalies. A detailed survey should then be made of the area containing the supposed placer, by means of a network or checkerboard of magnetometer stations. The stations should be placed so that the form and extent of the anomaly can be delineated. By limiting these detailed measurements to areas that show placer anomalies, much time can be saved. In addition, detailed measurements should be made over known changes in bedrock that may cross the placer, and certain traverse lines should be extended far enough on both sides of the placer so that the position and magnitude of unsuspected bedrock anomalies can be determined. The effects of local topographic anomalies should be similarly determined.

Magnetometer stations need not be located with extreme precision. When only a few short traverses are to be run, the stations may be located by means of a surveyor's compass and by pacing. For most placer surveys, a surveyor's compass and a 100-foot steel tape are satisfactory. When the area covers several square miles control points--established by means of transit and tape--should be set up in order to avoid large cumulative errors. Traverse lines and networks of stations may then be laid out from these points by less exact methods. All stations should be marked by blazed stakes. The relative elevations of the stations on traverse lines, for use in plotting vertical cross-sections, may be determined with sufficient accuracy by hand leveling. In most cases, a rough topographic map should be prepared, using the elevations of the magnetometer stations for control, and showing the locations of magnetometer stations and of geologic and other pertinent features.

Preliminary interpretation is made for the purpose of determining the most favorable locations for direct prospecting. As aids to preliminary interpretation, geologic, magnetometric and topographic data should be plotted on one or more maps. Vertical magnetic anomalies may be shown by means of traverse profiles or by isodynamic contour maps, although the effectiveness of the latter method is limited because of the erratic nature of many placer anomalies. Additional traverse profiles and isodynamic contour maps, corrected for the effects of bedrock and topographic anomalies, should then be made for the purpose of determing the locations, shape and magnitude of the placer anomaly as a whole.

Direct prospecting should ordinarily be started as soon as sufficient detailed magnetometric work has been completed to permit preliminary interpretation of part of the placer anomalies, so that magnetometric and prospecting data may be correlated while the geophysicist is still in the field. If prospect holes, ~~are~~ sunk in several parts of the area showing placer anomalies, indicate that the ground is not sufficiently rich to mine, direct prospecting may be discontinued with reasonable assurance that richer ground has not been missed. That is, it is not necessary to completely crosscut the whole area, because the magnetometric interpretations, if correctly made, have justified the eliminating of the less promising parts of the placer. On the other hand, if the gold values are sufficiently high, the placer should be outlined by direct methods. Where the agreement between placer anomalies and gold values is reasonably close, detailed prospecting may be confined to determining the working limits of the placer and only an occasional check-hole is necessary in the richer ground or in the barren areas.

Final interpretation involves the correlation of geological and geophysical data with that obtained subsequently by direct prospecting. The various significant relationships--those, for example, existing between vertical anomalies, gold values, amounts of magnetite, thicknesses of gravel and overburden, and changes in bedrock-can ordinarily be represented graphically, either by means of profiles or by areal maps. In some cases, following correlation of vertical anomalies and known gold values, gold values in adjacent areas can be determined approximately from magnetometric data alone.

Methods pertaining to other problems.

The general procedure in outlining structural and other features of consolidated rocks is similar to that employed in placer prospecting. Following the preliminary geological study, the form and size of anomalies should be determined by means of magnetometer traverses, run where conditions are best known. If measurable anomalies are obtained, the survey should then be extended to unknown areas, first by traverses to outline the general direction and extent of the feature in question, and later by detailed measurements.

In the absence of sufficient geological data obtained from surface studies, prospect holes, or mine records, a unique solution may not be obtainable from magnetometric measurements alone. Logical solution of a problem will often be expedited by comparison of results with those obtained from magnetometric investigations of similar problems in other regions. The literature on geophysical prospecting contains numerous examples of magnetometer surveys, showing the forms of anomalies and their relations to subsurface bodies or structural features.[1] Where direct prospecting for the

---

[1] For a list of references see Geophysical Abstracts, issued quarterly since 1936 by the U. S. Geological Survey, and issued monthly by the U. S. Bureau of Mines prior to 1936; or Geophysical Section of the Annotated Bibliography on Economic Geology, published by Economic Geology Publishing Co., Lancaster, Pa.

---

purpose of checking magnetometric results is expensive and impractical, it may be necessary to use additional geophysical methods in order to obtain a logical solution of the problem.

The influence of climate on magnetometric methods.

The short, warm summers and long, cold winters characteristic of the subarctic regions of interior Alaska tend to impose seasonal limitations on magnetic prospecting. However, because of the more irregular magnetic conditions that prevail during the summer months, and because of difficult working conditions in many areas when the surface is thawed, magnetometer surveys may at times be carried out advantageously during cold weather.

The advantages of summer operations are that the magnetometer can be operated with greater speed, and preliminary surface studies can be made which can be checked immediately by magnetometric measurements. Similarly, anomalies can be readily checked by prospecting.

The disadvantages are that the earth's magnetic field is less uniform than in the winter, and the condition of the ground is often such that accurate measurements are difficult to obtain. Large areas, particularly in mature placer regions, are either swampy during the summer, or are covered by a thick mat of moss which is underlain by frozen much and peat. Under these conditions it may be impossible to obtain correct readings, because the instrument is disturbed by the slightest movement of the operator, or because the frozen ground in contact with the feet of the tripod permits the instrument to settle. Where a bulldozer is available, the difficulties arrising from the presence of moss and underlying frozen soil may be eliminated by stripping off the surface moss on the traverse lines, which will permit the muck to thaw sufficiently so that stable setups can be obtained. Stripping with a bulldozer offers the additional advantages of eliminating brushing and enabling the stations to be located more quickly.

The advantages of carrying out magnetometer surveys during the winter are that more accurate measurements are possible because of more uniform magnetic conditions, and that travel over much of the country is easier when the surface is frozen; in fact many regions could not be prospected at any other time because of swampy conditions.

The chief disadvantages of winter operations are that the low temperature and short days, especially in December and January, decrease the speed of the field work, and the snow-covered, frozen ground does not permit an accompanying surface study to be carried out. It has been found, however, that magnetometric measurements can be made fairly rapidly in temperatures as low as -30° F. Below -30° F., manipulation of the instrument and note taking become slower, and the cost of field work increases correspondingly. Ordinarily, the cost of field work during the early and late winter months should be only slightly higher than during warm weather, but during December and January, the combined handicap of low temperature and short days tend to increase costs considerably.

Another undesirable feature of cold weather field work is that the low temperatures cause the metal case of the magnetometer to contract at a different rate from its enamel coating, with the result that some of the enamel may peel off; However, the effect on the operation of the instrument is negligible. Trouble may also be experienced during snow storms when snow falls on the optical system of the instrument. This may be remedied by fitting a light canvas cover over the instrument that will keep the optical system free from show, and at the same time permit readings to be taken. Other precautionary measures are that the moving parts of the magnetometer must be lubricated with a light oil that will not congeal at low temperatures, and that the instrument must not be brought into a warm place during winter operations, because rapid temperature changes will permit frost or moisture to condense on the magnet system and may alter its sensitivity and other constants.

The type of investigation and local conditions are the main factors in determining the most favorable season for carrying out magnetometric surveys. Where swampy conditions make an area difficult to reach in summer, the work must necessarily be carried out when the surface is frozen. This forced postponement may be utilized to advantage if the work is planned so that the geological investigation is made in summer, and the magnetic survey in winter, since small anomalies can be measured more accurately in winter. Large anomalies can usually be advantageously investigated during the summer months, their measurement being relatively less affected by disturbed magnetic conditions, and immediate correleation of anomalies and geologic cause being possible at this time. The short autumn, from September through part of November, is usually the most favorable time for all types of magnetometric surveys, because during this period conditions are most favorable for surface investigation, and magnetic storms are less frequent than during the summer.

The speed and cost of magnetometric surveys.

The time required to complete a magnetometric survey, and the cost of the work, depend on the accessibility, surface conditions, and size of the area, as well as on the purpose of the survey. Progress will be more rapid and costs lower in easily accessible and open country, than in inaccessible, swampy, or rugged areas. The speed of the survey also depends on the station interval and the amount of detail required. Thus, in reconnaisance surveys, where the station interval is large, the cost per station is comparatively high and the cost per acre is low, while the opposite is true in detailed surveys, where the station interval is small. Other factors remaining equal, the costs per station and per acre are less for large-scale than for small-scale surveys.

In measuring moderate-sized or small anomalies, about 4 minutes are required to set up the magnetometer and complete a set of readings, under favorable conditions. When the ground is swampy or conditions are otherwise unfavorable, from 8 to 12 minutes may be required, because of difficulties encountered in setting up the instrument and keeping it level. When the station interval is about 100 feet, from 6 to 12 stations can be occupied in an hour, while the daily total will vary between 40 and 70. However, when using a single magnetometer, the daily total of new stations is usually from 30 to 50, because of the necessity of checking back to a base station.

Joyce states[1] that in the United States, "in structural geology, the field expense per acre will not run more than one or two cents, while the cost per station will vary from $1.00 to $1.50 at the most. In mining surveys the cost per acre will be much higher due to the close station interval normally used for such work, while the expense per station will be correspondingly smaller." According to the American Askania Corporation of Houston, Texas, the monthly expenses of maintaining a large, completely equipped field party in the United States is $1255.40.[2] This includes the salaries and expenses of 3 observers, and operating expenses and depreciation of 3 magnetometers, 1 automatic recording outfit, and 3 field cars. Cost are higher in

---

[1] Work cited, p. 83.
[2] Engineering and Mining Journal, Vol. 125, No. 17, 1928.

---

interior Alaska than in continental United States because of higher wages and living expenses, and because less favorable climatic and magnetic conditions decrease the speed of field work.

The field costs given here are based on the results of small-scale experimental surveys made with a single magnetometer. The field crew consisted of an observer and a recorder. Since there is no precendent regarding salaries of observers and recorders in Alaska, these have been arbitrarily fixed at the approximate rates paid by private organizations for requiring a similar degree of training. The expense of brushing out traverse lines, locating magnetometer stations, and mapping the areas, is not included in the cost data given here since this should ~~not~~ be charged partly to the preliminary surface investigation and to the direct prospecting, as well as to the magnetometric survey. The expense of maintaining a field car is included, since it was used during most of the field work.

The cost of magnetometric equipment is:[1]

1 vertical magnetometer..................................	$1,114.00
1 Helmholz coil for scale value determination...........	185.00
	$1,299.00

[1] 1939 prices of Askania equipment, F. O. B. Houston, Texas.

The cost of field work per day is:

Salary of operator	$15.00
Salary of recorder	7.00
Living expenses for two men	6.00
Maintancence cost of one field car	4.00
	$32.00

Based on the above data, the cost per station is from $0.64 to $1.07, which is higher than the commonly accepted costs of detailed sruveys in other regions. The use of two magnetometers would permit the occupation of from 10 to 20 more stations each day, which would materially reduce both the cost per station and the cost per acre.

MR Misc
Joesting 1942

THE APPLICATION OF MAGNETIC AND RESISTIVITY METHODS IN INTERIOR ALASKA

Introduction

In July, 1939, the Department of Mines inaugurated an experimental geophysical program for the purpose of determining the applications of vertical magnetometer and direct current resistivity methods to the study of problems related to prospecting and mining. ~~As~~ Since little previous work had been done, the results of which are available, and ~~as~~ since conditions are in general different from those exixting in lower latitudes, it was considered advisable to make a general study of the possibilities and limitations of the two methods, rather than a detailed study of any one problem.

Geophysical prospecting methods are indirect, as compared to the direct methods of shaft sinking or drilling. By the latter methods samples of the minerals sought are made available for direct examination, if the prospector is fortunate enough to sink in the right place. By geophysical methods on the other hand, comparative measurements of the physical properties of the subsurface are made to determine the location of unusual or anomalous conditions resulting from such things as mineral deposits, underground water, faults, or other bedrock features. The location and causes of anomalous conditions in the earth's magnetic field and in the electrical resistivity of the subsurface were chief concerns of this investigation. Because interpretations based on these indirect methods must be geologically possible, ~~Therefore~~, considerable attention was paid to gathering such geological evidence as could be obtained from bedrock exposures, prospect shafts and drilling data, for the purpose of correlating the geophysical data with that obtained by direct observation.

The value of geophysical methods in prospecting increases in proportion to the difficulty of obtaining information by other methods. ~~They~~

Where drilling or p[illegible]ing is cheap and rapid they are n[illegible] particularly applicable;

~~are not particularly applicable where drilling or pitting is cheap and rapid~~ but Where direct prospecting is slow and expensive, due, for example, to the presence of thick overburden, geophysical methods may in many cases greatly decrease prospecting time and costs. They cannot replace drilling for the purpose of evaluating ground, but they may, among other things, eliminate much drilling in unfavorable areas and give information concerning depths of overburden, attitude of bedrock, or structural features of bedrock.

This report describes the problems encountered and gives the results of the initial experimental work. Some of the problems have as yet received insufficient attention; ~~regarding~~ others have been investigated sufficiently ~~enough was learned~~ to enable conclusions to be drawn as to the applicability of the methods used. Technical terms and theoretical discussions are generally avoided, although for the sake of brevity a certain amount of technical terminology is necessary. For descriptions of general principles and methods the reader is referred to <u>Applied Geophysics</u>, by Eve and Keys, and to the geophysical publications of the U. S. Bureau of Mines and the American Institute of Mining and Metallurgical Engineers.

Acknowledgements

The suceess of this investigation depended to a great extent on the cooperation and aid of many individuals and organizations. Aid was obtained, frpm so many sources that the writer finds it difficult to make adequate acknpwledgement.

Drs. F. W. Lee and J. H. Swartz of the Geophysical Branch of the U. S. Geologioal Survey furnished specifications for construction of resistivity apparatus and much information about resistivity measurements. Drs. P. S. Smith and J. B. Mertie, Jr., of the Alaska Branch and Drs. R. C. Wells and Charles Milton of the Chemical Laboratory of the U. S. Geological Survey furnished samples of Alaskan placer concentrates to supplement those collected by the writer, as well as laboratory space and help in identification of minerals. Prof. E. H. Bramhall of the Dept. of Physics at the University of Alaska ~~Physics Department~~ made available laboratory facilities and helped in many ways in connection with the theoretical aspects of the work. Mr. R. E. Gebhardt of the Sitka Magnetic Observatory went to considerable trouble to supply copies of daily magnetograms during the periods when magnetometric field work was done.

The following mining companies and individuals kindly furnished mining ground for testing purposes, in addition to whatever information regarding the ground was available and necessary, for checking geophysical measurements: Cleary Hill Mines, Inc., Wolf Creek Mining Co., Livengood Placers, Inc., Circle Mining Co., Deadwood Mining Co., U. S. Smelting Refining and Mining Co., George Moore, and Kenneth Anderson and his mining partners. The help of others who supplied samples, information or hospitality is gratefully acknowledged.

The writer was assisted in the field and during part of the office work by Ernest Wolff, Albert Malden and Erwin Clahassey, students or former students at the University of Alaska, and is grateful for their intelligent interest and conscientiousness. In addition, the following students and graduates gave gratis assistance at various times: Robert Lyman, Will Hartman, Harry Mikami and Joe DaGrade.

The program was initiated by and carried out under the direction of Mr. B. D. Stewart, Commissioner of Mines, whose suggestions and encouragement were of invaluable aid. Other sources of information are acknowledged in appropriate places in the report.

Discussion of Problems

A large portion of interior Alaska, especially in the more mature regions, is covered by unconsolidated deposits of silt and gravel, ranging in thickness from a few feet to several hundred or more feet. The gravel deposits were laid down by processes generally similar to those operating in other regions, but the silt and muck in the valleys and the talus and rock debris on the hillsides are largely due to the action of climatic processes peculiar to Alaska and to regions of comparable geographic location. Because This barren overburden covers both lodes and placers in many places, ~~so that~~ their existence usually cannot be inferred from surface indications. It presents one of the chief difficulties to prospecting and mining.

The problems which may be profitably ~~be~~ attacked by geophysical methods are those resulting from the presence of overburden. They are to a large extent unique to interior Alaska and to geographically similar regions. The problems are:

1. Location of buried placers.
2. Tracing of buried bedrock features, such as faults, contacts, intrusions and veins.
3. Determination of depth of thawed and permanently frozen overburden and distribution of permanently frozen ground.
4. Location of underground water.

Geophysical methods may also be used for other purposes than those outlined. The indicated problems were studied because they are of especial importance in Alaska.

Choice of Methods and Instruments

There are four geophysical methods in general use, namely, magnetic, electrical, seismic, and gravimetric. The choice of methods was determined by the types of problems to which each is applicable, as well as by the costs of instruments and of field work. The magnetometer and direct current resistivity methods were chosen because they possess the advantages of being applicable to the study of a wide range of problems peculiar to interior Alaska; also instruments are comparatively inexpensive and the smaller field crews permit work to be done more cheaply. In addition, a given area can ordinarily be covered more rapidly by these methods than by other methods available. Some of the other electrical methods possess advantages similar to the direct current resistivity methods, but interpretation of data obtained by the latter method usually is simpler.

As both magnetometer and resistivity methods have been described elsewhere[1], no attempt will be made here to describe theories of operation or ~~actual~~ field methods.

---

[1] J. W. Joyce, Manual on Geophysical Prospecting with the Magnetometer: American Askania Corp., Houston, Texas, 1938

C. A. Heiland, Construction, Theory and Application of Magnetic Field Balances: Bull Am. Assoc. Petroleum Geol., vol. 10, 1926, pp. 1189-1200

J. C. Boswell, Application of Geomagnetics to Placer Exploration: U. of Alaska, 1929. Unpublished thesis submitted for degree of B. S. in Geology and Mining

Edge and Laby, Report of the Imperial Geophysical Experimental Survey: Cambridge Univ. Press, 1931

Eve and Keys, Applied Geophysics: Cambridge Univ. Press, 1933. Chapter on electrical methods.

F. W. Lee, U. S. Bureau of Mines, Information Circular 6899, 1936

Ted Mathews, Application of Geo-resistivity to Placer Exploration: U. of Alaska, 1938, Unpublished thesis submitted for degree of Bachelor of Mining Engineering.

A discussion of magnetic methods and costs in interior Alaska will be found in Appendix II. Appendix III is devoted to a similar discussion of resistivity methods.

A vertical magnetic field balance, also known as a vertical magnetometer, was used for the magnetic measurements. By means of this type of magnetometer, variations in the vertical component of the earth magnetic field, termed vertical magnetic anomlies, are measured. Magnetic anomalies are caused by variations in the magnetic permeability of the earth's crust and are associated with changes in composition of the near-surface or deeper-seated material. In a magnetic survey, the location and magnitude of anomalies are determined by means of magnetometer readings taken at appropriate places in the area. The absolute value of the vertical component of the earth field is not determined in this type of work.

The sensitivity of the magnetometer was generally kept between 20 and 30 gammas per scale division.[1] This sensitivity was found to be

---

[1] 1 gamma = 10^{-5} gauss. A uniform field having an intensity of 1 gauss will act on a unit pole with a force of 1 dyne.

---

satisfactory for measuring the anomalies ordinarily encountered. The sensitivity was determined by means of a Helmholz coil and milliammeter. In the field the sensitivity was checked for variations by standard magnets which are supplied with all field instruments of the type.

Apparent resistivity of the subsurface is determined by passing a current through the ground and measuring the potential drop at various positions on the surface. There are several commonly used spacings for the electrodes through which the current is introduced and for other electrodes by which the potential drop is measured. The spacing found most generally suitable was first suggested by Dr. F. W. Lee, and is known as the "Partitioning method".[1]

[1] F. W. Lee, U. S. Bureau of Mines, Information Circular 6171, 1929

From a knowledge of the potential distribution at the surface, changes in the resistivity of the subsurface due to changes in composition of subsurface material, may be determined, and the depths of the changes may be more or less accurately calculated.

Direct current resistivity equipment consists essentially of a source of current, usually supplied by "B" batteries; a milliammeter for measuring the current; two metal stakes or electrodes for making contact with the ground; and sufficient insulated wire to connect this equipment ~~the above~~ in series. In addition, a potentiometer, connected to two non-polarizable electrodes by insulated wire, is necessary for measurement of potential drops on the surface. The instrument used is known as a geoscope.[2] It is a modification

[2] F. W. Lee, U. S. Bureau of Mines, Information Circular 6899, 1936, pp.10-14

of the usual resistivity equipment and was designed to simplify calculations and to increase the speed of field work.

Outline of Work

Field work with the magnetometer and geoscope was carried out from July to December, 1939, in the Fairbanks, Livengood, and Circle Districts. During July, October, November, and December the field party consisted of the writer and one assistant. During August and September two additional assistants were attached to the field party.

As indicated previously, little detailed work was done. The main purpose of the program was to learn as much as possible in the time available, ~~of~~ concerning the applications of the two methods to a wide variety of problems.

Resistivity measurements were made for the purpose of outlining frozen and thawed areas and determining the thickness of overburden in the vicinity of Fairbanks and College, and on Ester, Wolf, and Happy Creeks in the Fairbanks District; on Livengood Creek and Hess River in the Livengood District; and on Portage, Deadwood, and Mammoth Creeks in the Circle District. In addition, electrical soundings at depths up to 600 feet were made in the deep overburden in the Tanana Valley near Fairbanks and in the Birch Creek Flats near Circle Springs. Other resistivity investigations included search for underground water near College and at Ester and studies of faults covered by overburden near Cleary Creek.

Magnetometer surveys were run concurrently with resistivity measurements when four men were available, and during October and November when the party consisted of two men. The magnetometer work included surveys for the purpose of locating placers on Hess River and on Livengood, Portage, Deadwood, Mammoth, Bedrock, and Happy creeks. The results of previous magnetic surveys of Moose Creek, tributary of Goldstream Creek, and Teuchet Creek, tributary of Chena River, are also reported here. In addition, surveys were made in the vicinities of Pedro and Ester Domes in the Fairbanks District to determine the effects of known faults, intrusions, quartz veins, and lithologic changes in schist bedrock.

Field work was done during both summer and winter for the purpose of comparing results obtained under different conditions.

When available, samples of placer gravel and of bedrock were collected for laboratory study in connection with the geophysical results. Bedrock structure and lithology were studied where exposures could be found, for the purpose of correlating geophysical interpretations with geological features.

Magnetograms, showing the variations in intensity of the earth magnetic field at Sitka, were obtained from the Sitka Magnetic Observatory and enabled an approximate check to be made on diurnal variation and magnetic storms in the areas where field work was carried out.

Laboratory and office work was done during part of December, 1939 and during January and February, 1940. One assistant was available during December; subsequently the writer worked alone. The laboratory and office work consisted of mineralogical studies of placer gravels and bedrock, and of drafting maps and graphs and interpretation of results. A large number of samples of concentrates supplied by the U. S. Geological Survey ~~were~~ was studied during January and February, 1939, ~~at~~ in a laboratory supplied by that organization and at the Geology Department of the Johns Hopkins University. This report was written during February and March, 1940.

The Applications of the Vertical Magnetometer

Buried Placers

Many of the older placers in interior Alaska were deposited in drainage systems whose relations to the present drainage are obscure or nonexistent. Also, in mature regions, ~~there has been considerable~~ lateral stream erosion has resulted ~~resulting~~ in wide valleys which may contain relatively narrow paystreaks. Long continued erosion, ~~and in many cases~~ or changes in the base level of erosion, has ~~have~~ resulted in placers located on raised benches or deeply buried under barren silt deposits. Consequently, excepting for placers in narrow V-shaped valleys, it usually is difficult to determine their probable location from topographic evidence. To locate them by shafts or drill holes necessitates the crosscutting of the whole valley and ordinarily a large part of the prospecting is done in barren ground.

The geophysical method that ~~which~~ appears to be best adapted to locating and outlining buried placers is the magnetometer method. The vertical field balance is one of the most sensitive portable magnetometers available, and because of the rapidity with which measurements can be made, surveys with this type of instrument are relatively inexpensive.[1]

---

[1]The Hotchkiss Superdip, which measures total magnetic anomalies instead of vertical anomalies, possesses similar advantages.

Magnetic minerals, together with other heavy rock-forming minerals, are commonly associated with placer gold. If the magnetic minerals are concentrated with the gold in sufficient amounts, then measurable magnetic anomalies should exist. The magnetometer has been used successfully for placer prospecting in several localities,[1]

---

[1]C. A. Heiland and W. H. Courtier, Magnetometric Investigations of

of Placer Deposits near Golden, Colorado. Trans. A. I. M. E.(1929) 81, Geophysical Prospecting.
J. J. Jakosky and C. H. Wilson, Geophysical Studies in Placer and Water Supply Problems, A. I. M. E. Technical Publication 515, 1934.
Dart Wantland, Comparison of Geophysical Surveys at the Roscoe Placer, Jefferson County, Colorado; Colo. School of Mines Quarterly, 32, Jan. 1937, pp.85-115
J. C. Boswell, work cited.

---

but relatively little information is available to indicate ~~as to~~ how generally it can be used, or ~~as~~ to show the proportion of successes to failures when checked by actual prospecting and mining. It also is possible that the successful applications have been emphasized more than the failures.

One of the aims of this program was to determine in a general way the applicability of the magnetometer to placer prospecting ~~to~~ in a considerable proportion of the placer regions of interior Alaska. As it was impracticable to run actual magnetometer surveys over a large number of placers of known gold content, other information was obtained to supplement the magnetometer results. The problem involved the consideration of the following questions:

A. How general is the association of magnetic minerals and placer gold?

b. What relations exist in a given placer between magnetic anomalies and the content of magnetic minerals and gold?

c. Are the anomalies that are associated with placers generally of sufficient magnitude to be measurable and interpretable?

d. Can anomalies due to changes in bedrock and other causes be distinguished from those due to placers?

e. What effect will the magnetic storms and irregular magnetic conditions characteristic of high latitudes have on the accuracy and speed of magnetic surveys?

a. Association of magnetic minerals and placer gold.

The following magnetic minerals were found in Alaskan gold-bearing gravels:[1] magnetite and other iron-bearing spinels, ilmenite, iron-rich garnets, amphiboles and pyroxenes, and locally, pyrrhotite, biotite, wolframite, and platinum. The most important of these minerals is magnetite, as it is by far the most strongly magnetic as well as one of the most widespread of all minerals. Because of its

---

[1] see Appendix I

---

high density, compact shape and stability, magnetite apparently concentrates in placers under conditions similar to those favoring the concentrates of gold. The existence of other, less magnetic minerals in placers doubtless contributes to some extent to the magnetic anomalies, but their effect cannot readily be determined. Locally, as in parts of the Livengood District, where large amounts of magnetic chromite and chrome spinel are associated with the placer gold, they may be of considerable importance.

Table I shows the percentages of magnetite in placer concentrates taken from a number of mining districts. The concentrates were obtained from paystreaks unless otherwise noted and they give a general ~~idea~~ indication of the amounts of magnetite present in placers in the districts considered.

...ven in Table I may for the most part indicate slightly ...ons of magnetite than actually occur in the placers, ... samples were concentrates obtained from sluice boxes. ...ns of the heavy, compact magnetite increase somewhat in ..., at the expense of the lighter fractions of the concen-

...method of treatment of samples is described in Appendix I. The ...e was separated by a large horseshoe magnet, which was not suffi-...ly strong to lift the ~~slightly~~ less magnetic minerals. As no convenient ...eans of grinding the samples was available, the magnetite contained in the pebbles of country rock was not separated.

~~While~~ Although the districts listed are not covered completely, it is evident that magnetite is practically a universal constituent of placers, but in amounts that vary greatly. However, allowing for varying degrees of natural concentration in different parts of the paystreaks, there is in most cases an approximate agreement in the percentages obtained from any given placer. Also, the concentrates from the Koyukuk and Circle Districts are generally low in magnetite, while those from the Livengood District are high. The concentrates from the other districts in general contain magnetite in relatively moderate amounts.

Magnetic surveys indicate that the percentages given in Table I can be used as approximate criteria of the applicability of the magnetometer to placer prospecting in the districts listed. In general, placers containing small proportions of magnetite will have small anomalies and magnetic methods will be correspondingly difficult to apply. Larger anomalies, which are easier to measure and interpret, will be associated with placers containing larger proportions of magnetite.

Magnetometric prospecting probably would not be successful in the Koyukuk District, at least on the creeks listed, because of the small proportions of magnetite and the deep overburden which covers many of the placers. In the Circle District, most of the placers, excepting those on Deadwood Creek, contain small proportions of magnetite. However, as they are generally shallow, it is likely that magnetic methods would be applicable to some extent. The majority of the placers in the Fairbanks District contain moderate proportions of magnetite. The magnetometer evidently would not be of much aid in prospecting the deep placers in this district which contain small proportions of magnetite.

Most of the samples from the Chena District were taken from low-grade gravel. The more concentrated placers probably contain higher percentages of magnetite. ~~As~~ And, since the placers are in general shallow, magnetometric methods should be applicable. This is born out by a magnetometer survey of Teuchet Creek, the results of which agreed with available prospecting data.

b. Relations between anomalies and magnetite and gold content of placers.

Magnetite is found in practically all stream gravels because of its almost universal occurrence in rocks. The occurrence of placer gold is of course restricted to regions where gold mineralization took place. Thus concentrations of magnetite, with associated magnetic anomalies, may occur in stream gravels which contain no gold. The presence of both magnetite and gold in placers depends primarily on adequate bedrock sources.

Magnetite generally occurs ~~widespread~~ throughout the regions considered here, while gold is restricted to mineralized veins or zones in the country rock. The existance of an approximately constant ratio of magnetite content to gold content of placers, ~~The association of magnetite and gold in placers~~, derived as they are from separate source~~s~~, appears to depend on long continued ~~reworking and~~ sorting of the gravel. Conditions favorable to the concentration of gold in continuous, well-defined paystreaks also favor a similar concentration of magnetite, and in general the richer portions of the paystreak will contain more magnetite than the leaner parts. Under these conditions there seems to be a general agreement, at least in limited areas, between vertical anomalies, magnetite content, and gold values. Changes in the supply of magnetite or of gold, caused by variations in the magnetite content of country rock or by the ~~placer~~ cutting of additional gold veins, will generally prevent this agreement from holding closely over the whole placer. On the other hand, in poorly sorted placers, where there has been relatively little transportation and reworking of the material, the ratio of the magnetite content to the gold content may vary widely. ~~association of the magnetite and gold is much less quantitative~~. The magnetite will be distributed all along the channel, while the gold will be deposited a short distance below its source so that ~~and~~ the rich parts of the placer are not likely to contain much more magnetite than the lean parts. However, even under these unfavorable conditions, magnetic traverse profiles run at suitable intervals across the long axis of the placer will usually indicate the approximate location of the richest ground along any given profile; but will give no information as to how the values along one profile compare with those along other profiles.

As a rule, variations in the heavy mineral content and hence the magnetite content of placer gravel, are accompanied by similar variations in gold content. In many placers containing coarse gold the heavy mineral content of small samples is a more reliable indication of gold values than the actual gold content and is often used to determine the limits of mineable ground. Similarly, it has been found that vertical anomalies usually are roughly proportional to the increase in magnetite content from the limits to the richer parts of placers and therefore are in many cases approximately proportional to the increase in gold values.

It would doubtless be more logical to compare magnetic susceptibilities of placer gravels, rather than their magnetite contents, to associated vertical anomalies as it was not practicable to determine accurately the total amount of magnetite by methods available. Some of the magnetite is held in pebbles and cobbles and can be separated only if the samples are ground to 0.5 mm., or finer. However, attempts to determine the relative susceptibilities of gravel samples with the vertical field balance did not give consistent results. Aside from errors attributable to lack of proper equipment, the apparent susceptibility varied with the orientation of the samples, probably because of the occasional presence of polarized magnetite or lodestone and of remanent magnetism in some of the pebbles. In view of the difficulty of maintaining the <u>in situ</u> orientation of incoherent samples, the determination of magnetite content was a simpler procedure, suited to the preliminary nature of the work, and the results usually were comparable to the anomalies.

In the event that more detailed work is justifiable, a simple method of determining the susceptibility of gravel probably could be devised. This would permit comparison of the magnetic properties of gravel, bedrock and overburden, which cannot be done by methods employed ~~here.~~ in this investigation.

Fig. 1 shows a traverse profile of a narrow, shallow bench paystreak on Deadwood Creek, in the Circle District. The vertical anomalies, magnetite content, and gold values are in good agreement. It should be mentioned that such complete agreement is unusual. Conditions here are more than ordinarily favorable, due partly to the short length of the traverse. Other traverse profiles of Deadwood Creek show a general agreement between gold values, as far as they are available, and vertical anomalies. The largest positive anomalies on any profile usually are over, or close to, the highest gold values. Although most of the rich pay on this creek has been worked, gold in paying quantities, ~~and~~ together with associated magnetite, remains in some parts adjacent to the old paystreaks and in cracks and joints in the blocky quartzite-schist bedrock.

Fig. 3 shows a typical traverse profile of Livengood Creek, near the town of Livengood. The gold values were determined by drilling. Data on the amount of magnetite was not available, but it ~~evidently~~ apparently concentrated with the gold. This profile is fairly typical of those obtained over placers deposited under favorable conditions, that is, where adequate amounts of magnetite and gold were available and where there was sufficient concentration to form a well defined paystreak. / where

Anomalies over placers have been found to be positive as a whole but over many shallow placers the magnetic values fluctuate sharply and bear no apparent relation to gold values as determined by drilling.

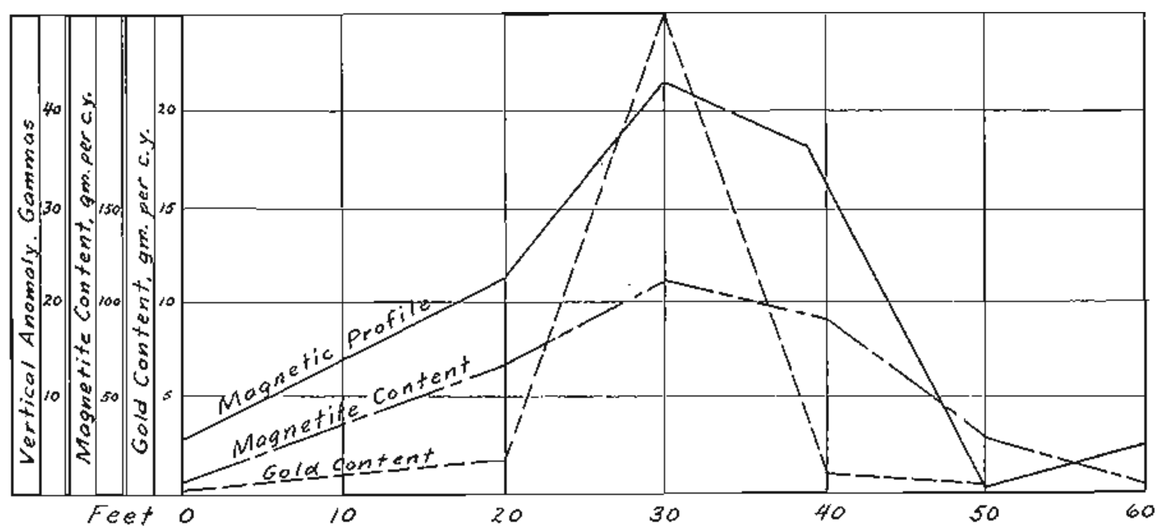


Fig. 1.— Profile showing relations between vertical anomalies, magnetite content and gold content across narrow bench paystreak on Deadwood Creek, Circle District.

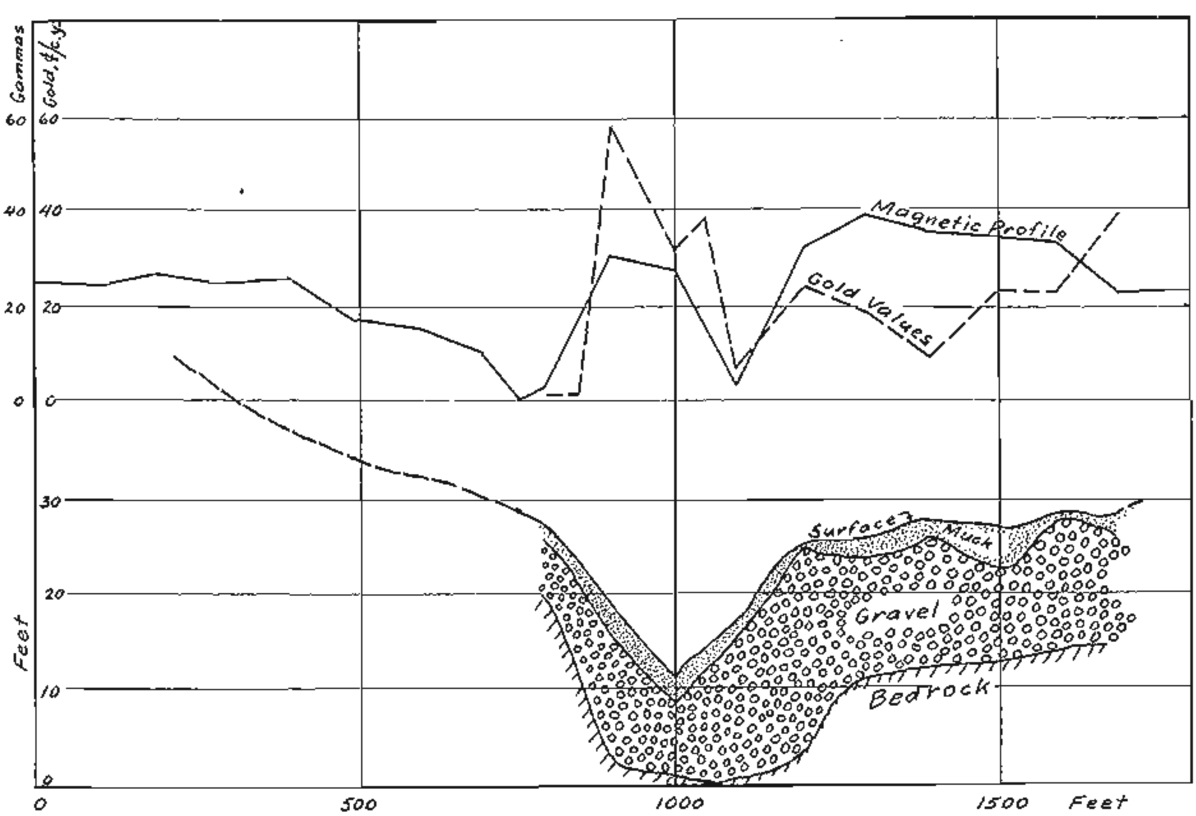


Fig. 2.— Traverse profile at Line 16, Portage Creek, Circle District.

Fig 3 Profile of [illegible] Creek survey showing position of bottom magnetic anomalies of gravel [illegible] after drilling.

Official data on depths of the core have been promised by [illegible] Planning, Inc., but have not yet been sent

H. J.

Typical traverse profiles of Portage and Mammoth Creeks in the Circle District (Figs. 2 & 4) indicate the erratic nature of the anomalies obtained over several shallow placers.

On Portage Creek it was not possible to sample the placer along the lines of the magnetometer traverses, but samples taken along the face of a nearby mining cut showed an agreement between the amounts of magnetite and gold. The gravel at the limits of the cut contained an average of 21 gm. magnetite per cu. yd., while the richer parts of the gravel averaged 52 gm. per cu. yd. A few rounded pieces of magnetite were ~~up to~~ 2 cm. in diameter. The concentrates obtained from the limits contained 4% magnetite compared to 6 % from the richer parts of the cut. The magnetite content of the Portage Creek placer is low compared to other placers and consequently relatively small anomalies were anticipated. While the amounts of magnetite as determined in the cut are not likely to hold for the entire placer, the same general relations probably are maintained and a better agreement between anomalies and gold values would be expected.

On Mammoth Creek no samples were available, but it is said that considerable magnetite, some of it coarse, is contained in the concentrates and that larger amounts of concentrates are found in the richer parts of the placer, so that here, also, a general agreement between gold values and anomalies would be anticipated.

There are several possible reasons for the lack of agreement, namely: erroneous gold values as indicated by any single drill hole, presence in the gravel of polarized magnetite (lodestone), with magnetic field opposed to the earth field, presence of near surface boulders with remanent magnetism opposed to the earth field and local erratic variations in the magnetic properties of bedrock. The last possibility may be ruled out in the cases cited, as traverses over the adjacent country

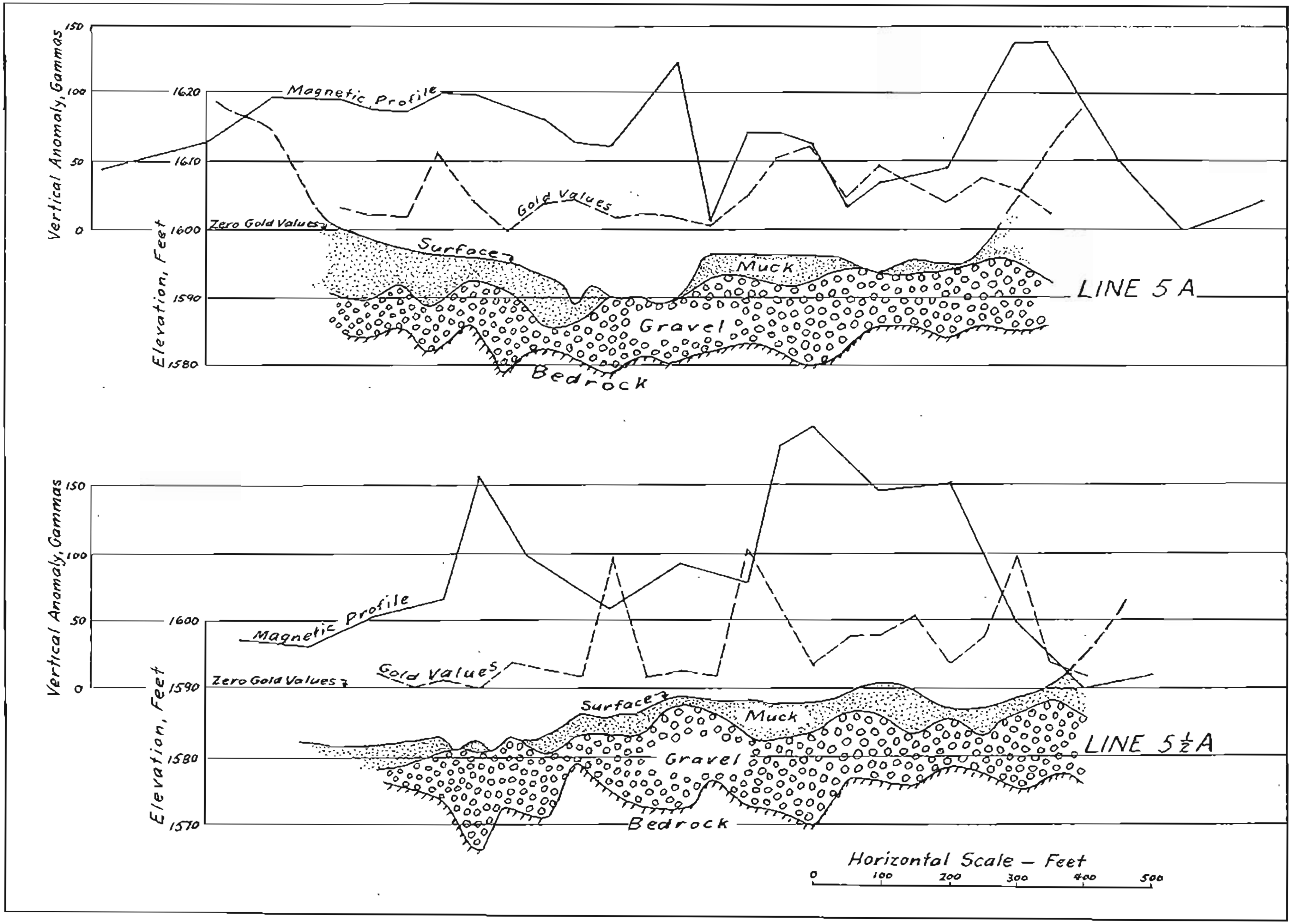


Fig. 4.— Typical traverse profiles of Mammoth Creek, Circle District, showing erratic vertical amomalies.

rock indicate uniform magnetic conditions.

Small drills were used in prospecting the two creeks, and as the gold in both placers is fairly coarse, the values as calculated from any single drillhole may in many cases not represent the actual values in the immediate vicinity. For this reason, agreement or non-agreement between values indicated by individual drill holes ~~drillholes~~ and corresponding anomalies may be partly fortuitous.

Polarized magnetite occurs in a number of placers in the interior and while there is reason to believe that lodestone will in general tend to deposit so that its magnetic field coincides with that of the earth, occasional coarse pieces may be deposited with more or less reversed polarity. Unfortunately, it would not be a simple matter to determine the orientation of lodestone in placers.

The presence of near-surface boulders or cobbles with remanent magnetic field more or less opposed to the earth field may be the most ~~commonest~~ common cause of ~~usualy reason for~~ erratic anomalies over shallow placers. Their effect on the vertical intensity would be relatively large because they are closer to the surface than the usual placer concentration. The effect of local near-surface irregularities could be minimized by closer spacing of stations.

Although ~~While~~ the reasons for erratic anomalies are not definitely known, they may be interpreted as an indication of shallow placers, after other possibilities have been eliminated. Anomalies associated with deeper placers usually are more uniform, possibly because the magnetometer readings are influenced by larger volumes of gravel and because the silt and muck overburden is magnetically uniform.