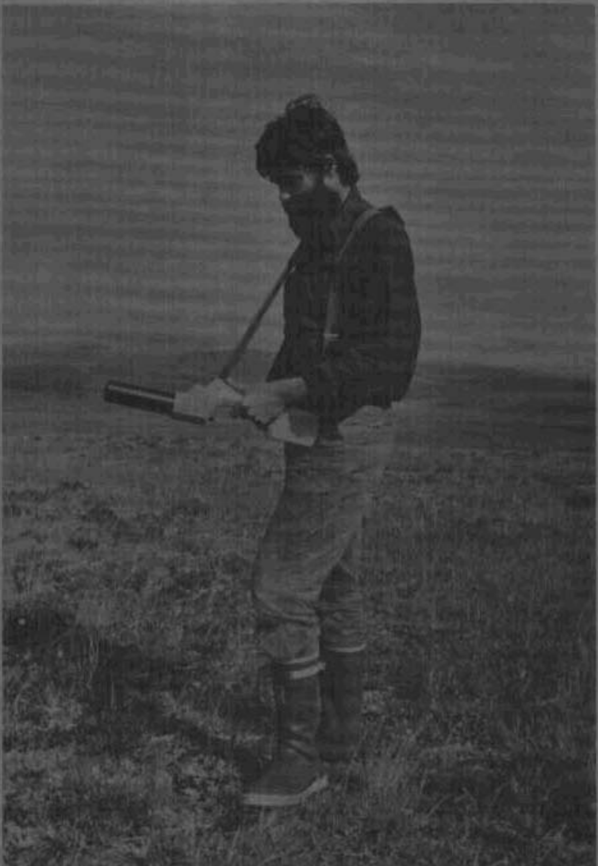
M.I.R.L. Special Paper No. 2

MAGNETOMETER AND DIRECT-CURRENT RESISTIVITY STUDIES IN ALASKA



Mineral Industry Research Laboratory
University of Alaska
Henry R. Joesting
Reprinted 1979

Foreword

Henry R. Joesting led an adventuresome and rewarding life. He was born in Baltimore and educated in chemistry and geology at Johns Hopkins University. As a geologist his work took him to the southwestern United States, Norway, Jan Mayen, and South America. In the early 1930's he met Bob Marshall, who had spent some time at Wiseman, and as a result he went to the Koyukuk district with two partners to mine. After a year he went to Fairbanks where he worked in the mines, both on the surface and underground.

About 1935 he began teaching mining and geology at the University of Alaska, and organized a course in geophysical exploration. In 1938 he returned to Johns Hopkins to finish his doctoral studies. Returning to Alaska in the spring of 1939, he went to work for the Territorial Department of Mines with the specific assignment of studying the application of geophysical exploration to Alaskan conditions. For two years he continued this work, the results of which were published by the American Institute of Mining and Metallurgical Engineers in 1941.

Henry Joesting went on to become chief of the Geophysical Branch of the U.S. Geological Survey, but his early work in Alaska still stands as an outstanding contribution to the application of geophysics to mineral exploration, especially for placer deposits. His paper is reprinted here with the permission of the Society of Mining Engineers of A.I.M.E. in the hope that more people will become acquainted with his early classical work, and will use it in the search for new placer deposits.

Cover photo by Jeff Foley.

Published by Mineral Industry Research Laboratory,
School of Mineral Industry, University of Alaska,
Fairbanks, funded in part by the Mining and Mineral
Resources Research Institute, Office of Surface
Mining, U.S. Department of Interior.

MAGNETOMETER AND DIRECT-CURRENT RESISTIVITY STUDIES IN ALASKA

By Henry R. Joesting,*Member, A.I.M.E.

During the past year and a half, the territorial Department of Mines in Alaska 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 differ considerably from those in most other regions, it was considered advisable to make a general study of the possibilities and limitation 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.

Manuscript received at the office of the Institute Dec. 2, 1940. Published by permission of B.D. Stewart, Commissioner of Mines, Alaska. *Associate Mining Engineer, Territorial Department of Mines, College, Alaska.

[1] References are at the end of the paper.

[3,4] The problems treated here are caused by 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.

INSTRUMENTS AND METHODS

Magnetic and direct-current resistivity methods were used because they are relatively simple, rapid and inexpensive and because generally they are 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]

Nonpolarizable electrodes were made from unglazed porcelain pots about 10 cm. 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 resistivity work in cold weather, a nonfreezing electrolyte consisting of equal parts of ethylene glycol and a saturated water solution of copper sulphate proved satisfactory. Stainless steel rods of 3/4-in. diameter 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 in general were 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 confirmatory 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 magnetomer has been used successfully for placer prospecting in several regions, [1,8-10] 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 measurable 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

In all, 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 places to have a probable effect on a magnetometer. Other minerals found, of minor importance because of their low susceptibility or scarcity, were iron-rich garnets, amphiboles and pyroxenes, biotite, pyrrhotite, wolframite and platinum. Table I shows the approximate magnetite content of placer concentrates grouped according to mining districts.

TABLE I. Magnetite Content of Placer Concentrates

District	Number of Creeks	Number of Samples	Approximate Percentage of Magnetite	
			Range	Mean
Chena	9	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	18

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, measurable anomalies are associated with about three-fourths of the placers in the interior camps considered. Where magnetite content of the concentrates is below about 8 per cent, anomalies may be too small to be measurable. Additional work may alter these estimates somewhat, since the data are incomplete for some districts.

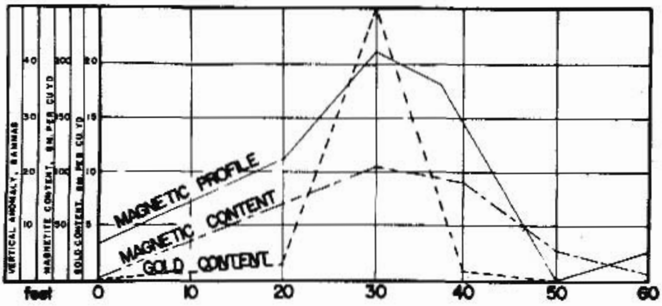


Fig. 1. Relation of Magnetic Anomally to Magnetite and Gold Content in Narrow Bench Pay Streak on Deadwood Creek, Circle District.

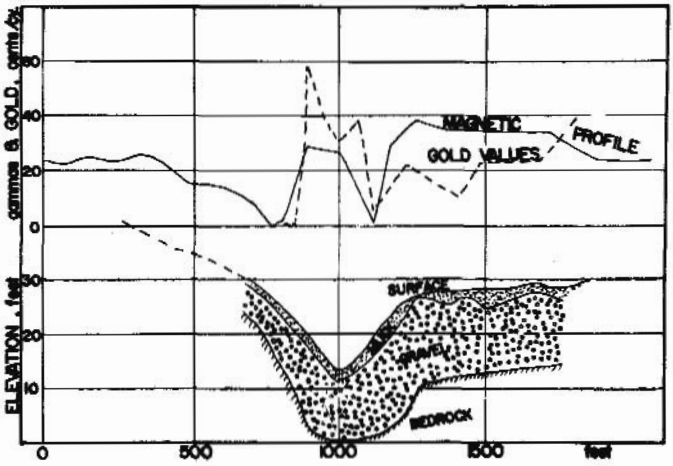


Fig. 2. Profile at Line 16, Portage Creek, Circle District.

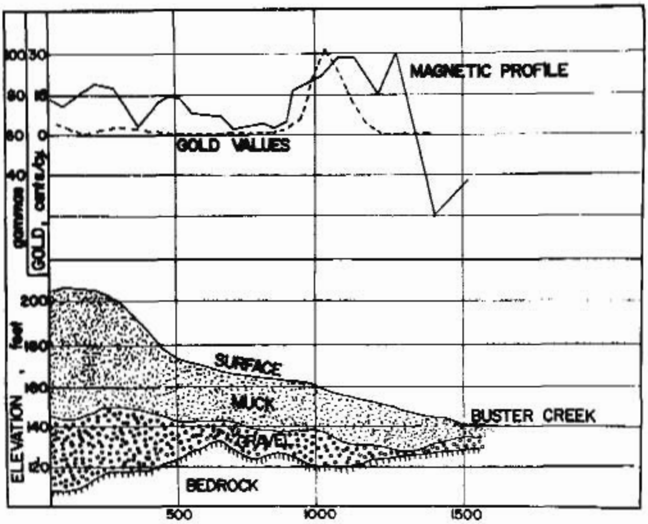


Fig. 3. Profile at Line 12, Buster Creek, Kako District.

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 pay streak. Where gold 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 unusually proportionate to the magnetite content and in most pay-streak placers are also approximately proportionate to the gold content. Fig. 1 shows a profile across a narrow bench pay streak 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 grams per cubic yard at the limits of pay and 52 grams in the richer parts. The concentrates from the limits contain about 4 per cent magnetite, compared to 6 per cent 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 content. 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.

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 pay streaks are usually regular, while those over some shallow placers are very irregular. Figs. 4 and 5 show typical profiles of deep pay streaks 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 course 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, of an anomaly caused by a thick gravel deposit in which there has been little concentration, with Fig. 4, where concentration has caused a definite pay streak.

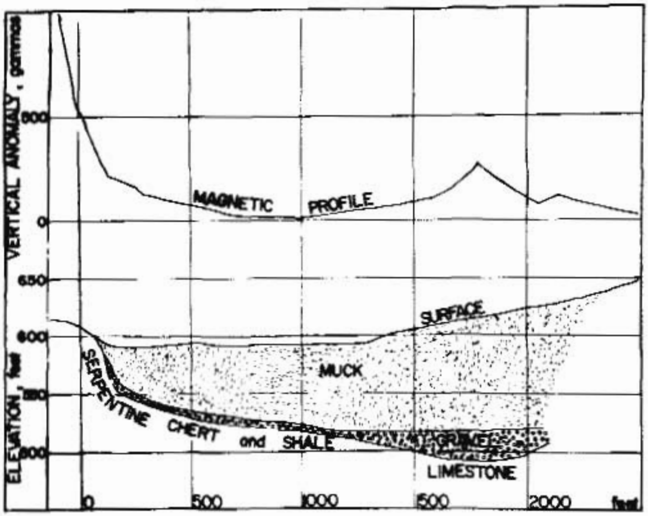


Fig. 4. Profile at Line 31, Livengood Creek, Livengood District.

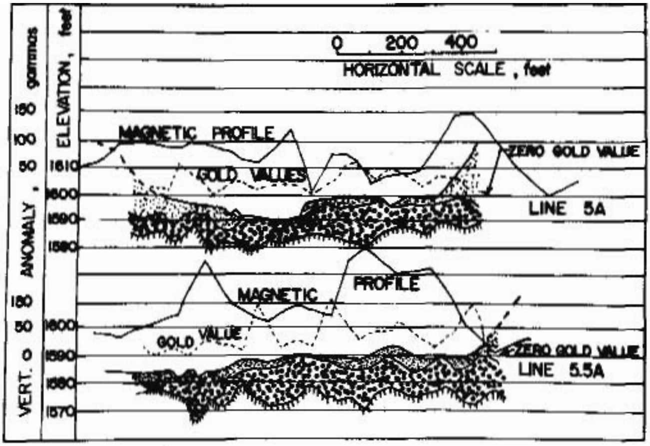


Fig. 5. Profiles of Mammoth Creek, Circle District, Showing Erratic Nature of Anomalies.

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 whether corrections could be made for their effects.

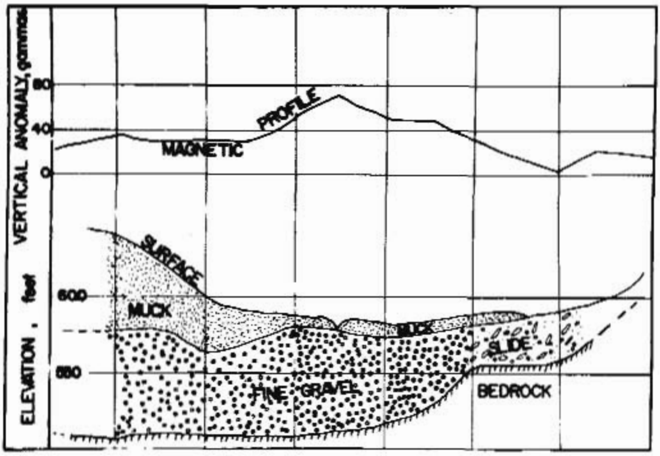


Fig. 6. Profile of Moose Creek, Fairbanks District, Showing Vertical Anomaly Caused by Thick Gravel Deposit. Drill Holes 200 Feet Apart.

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 in size, 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

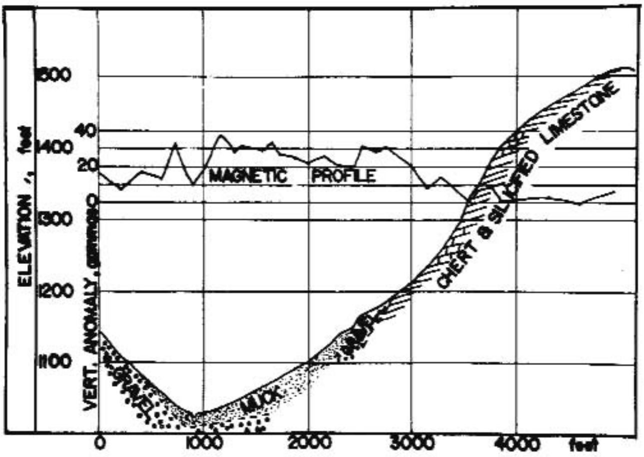


Fig. 7 Profile Across South Fork of Hess River, Livengood District.

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 sometimes be applied 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.

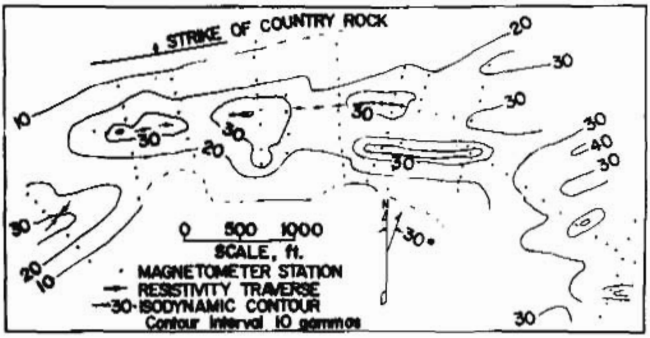


Fig. 8. Magnetometric Map of Ridge on South Side of Goldstream Creek, Fairbanks District. Sections 19 and 20, T. 1N., R. 1W.

For example, during a six weeks placer investigation in the Kako Creek area on the lower Yukon River, 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 interfer 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 possibly may 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 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 usually are 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.

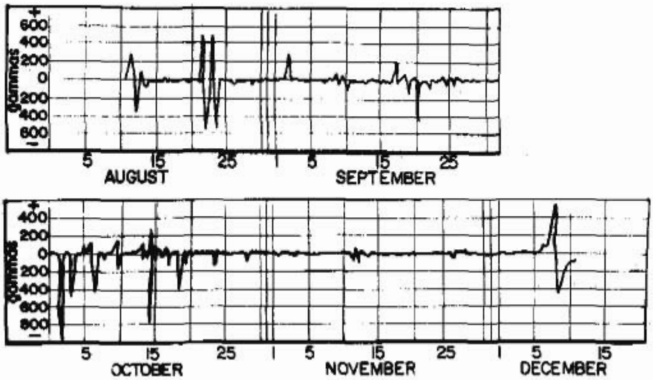


Fig. 9. Major Variations in Vertical Component of Magnetic Field, Aug. 11 to Dec. 6, 1939.

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 close enough 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.

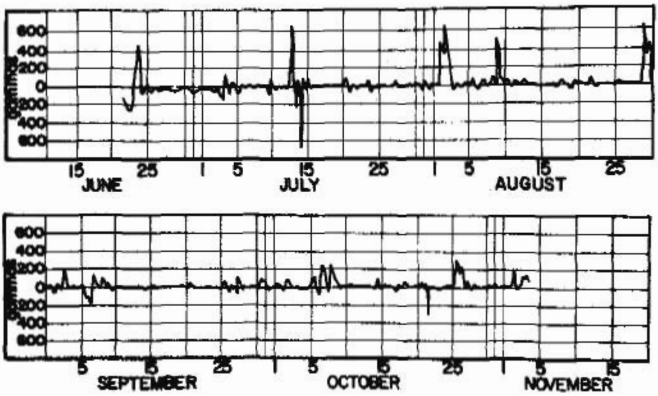


Fig. 10. Major Variations in Vertical Component of Magnetic Field, June 23 to Nov. 4, 1940.

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

Table II, taken from Sitka magnetograms, shows 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 small but irregular fluctuations, as well as magnetic storms, prevented the

TABLE II. Comparison of Quiet and Disturbed Days.

	Number of Quiet Days	Number of Disturbed Days	Total Days	Percentage of Disturbed Days
	Aug. 11 to Dec. 6, 1939			
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	91	27	118	23
	June 24 to Oct. 31, 1940			
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

measurement of vertical anomalies smaller than about 20 gammas. Although it is possible to plan field work so that little time is lost because of magnetic disturbances, nevertheless they are a serious handicap to measuring small anomalies in Alaska with field methods now in use.

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 minus 30 degrees 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 to be taken directly from the depth profiles; in other, conditions were too complicated to permit determination of the resistivity of any single layer. The results are summarized in Table III.

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 5 ft., the moisture content was more uniform and there was less variation in resistivity.

TABLE III. Resistivities of Thawed and Frozen Overburden and Bedrock

Material	Resistivity Range Ohm-cm.	Approximate Mean Resistivity, Ohm-cm.	Locality[a]
Thawed, moist silt and vegetation muck (in valleys)	3,600- 35,000	1.1 X 10^4	a,b,c
Thawed silt and residual deposits, dry on surface (on slopes)	20,000- 130,000	4.0 X 10^4	a,b,c
Frozen silt and vegetation muck	700,000- 800,000	36.4 X 10^4	a,b,c
Thawed moist sand, fine gravel and clay	22,000- 65,000	4.2 X 10^4	a,b,c
Thawed moist gravel	41,000- 71,000	5.5 X 10^4	a,b,c
Water-bearing gravel	100,000- 185,000	13.5 X 10^4	a,b,c
Frozen sand and fine gravel	630,000-2,400,000	120 X 10^4	a,b,c
Frozen gravel	780,000-4,200,000	220 X 10^4	a,b,c
Frozen surface silt at -10° C	2,000,000-3,000,000	220 X 10^4	a
Frozen surface gravel at -15° C	2,500,000-4,000,000	350 X 10^4	a
Thawed soft mica schist, chlorite schist and graphitic schist	20,000- 80,000	3.9 X 10^4	a,c
Thawed hard quartzitic schist	220,000- 300,000	26 X 10^4	a,c
Thawed conglomerate	22,000- 73,000	6.0 X 10^4	c
Frozen conglomerate	1,200,000-1,600,000	140 X 10^4	c
Thawed chert	140,00- 200,000	17 X 10^4	b
Thawed limestone	50,000- 84,000	6.5 X 10^4	b
Thawed argillite	26,000- 70,000	5.7 X 10^4	b
Thawed granite	95,000- 185,000	15 X 10^4	c
Thawed serpentine	114,000- 140,000	12 X 10^4	b
Partly frozen limestone and serpentine	270,000-1,500,000	57 X 10^4	b

[a] a, Fairbanks district; b, Livengood district; c, Circle district.

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[3] and others attribute the higher resistivity of water-bearing beds to the smaller content of dissolved salts in 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 (4.4×10^8 ohm-cm. at -4 degrees C.*). However, since 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.

*International Critical Tables, 6, 152

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 minus 30 degrees C. and the ground temperature was about minus 20 degrees C. Potentials dropped to a few millivolts when nonpolarizable 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 have been made in the regions considered here.[13] Another possible reason for some of the lower 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 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 35 ft. on the profile and dips north. Resistivities were determined every 20 ft. at electrode separations of 5, 10, and 20 ft. The May 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 1 to 3 ft., and for that reason, the apparent resistivities of the frozen ground are much lower.

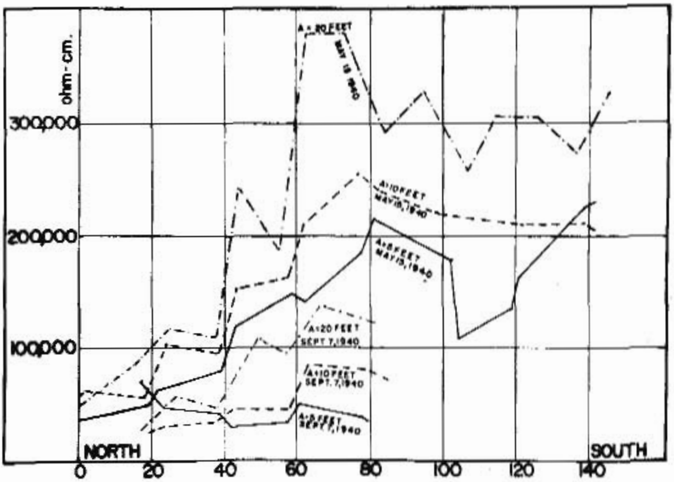


Fig. 11. Traverse Profiles showing resistivity Increase from Thawed to Permanently Frozen Ground.

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 (Figs. 12, 13 and 14). In

Fig. 12, the lower summer resistivities are caused by a 1 to 3 ft. surface layer of thawed silt. Winter resistivities are relatively low at 10 ft., 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 ft. west of line No. 1. The actual depth to the schist bedrock is not known, but it is probably between 125 and 150 ft. and increases to the south.

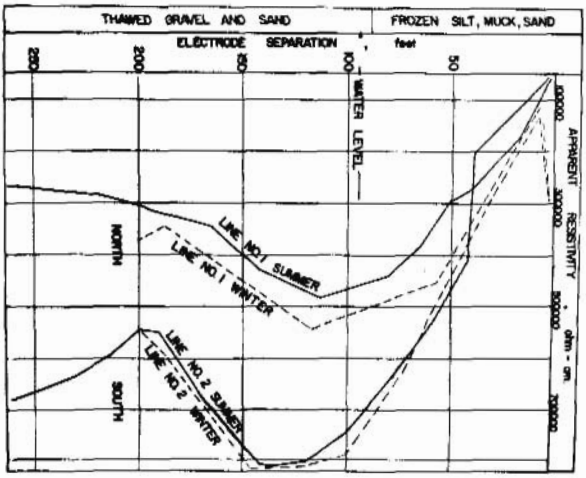


Fig. 12. Depth Profiles in Permanently Frozen Overburden, Tanana Valley, Near College, Alaska.

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 ft. N. 30 degrees east from the central electrode shows frozen silt, sand and gravel to a depth of 80 ft., except for a layer of water-bearing sand from 44 to 55 ft. Water-bearing gravel was struck at 80 ft., followed by thawed fine gravel and sand to a depth of 277 ft., where drilling

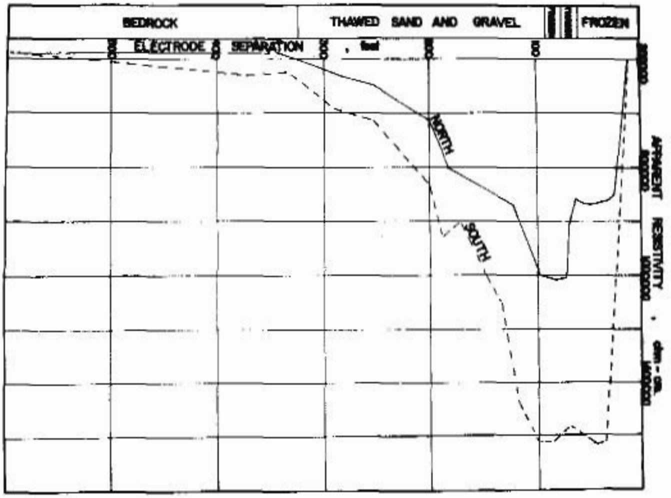


Fig. 13. Depth Profiles in Partly Frozen Overburden, Tanana Valley, East of Fairbanks.

was discontinued. Depth to schist bedrock is estimated to be over 300 ft. 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.

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, in some places approximate depths to bedrock can be determined indirectly by determining the depth of frost.

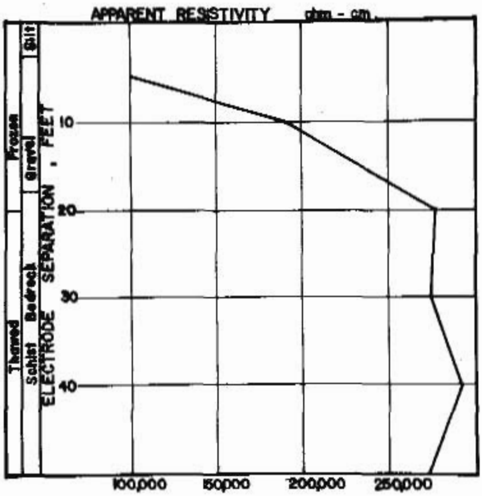


Fig. 14. Depth Profile in Permanently Frozen Ground, Mammoth Creek, Circle District.

Approximate determinations of thickness of silt and gravel were found to be possible only where conditions were fairly simple. Determinations of depths were sometimes impossible because the resistivity of the overburden was not measurably different from that of the overlying bedrock; in other places 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 ft. is not known,

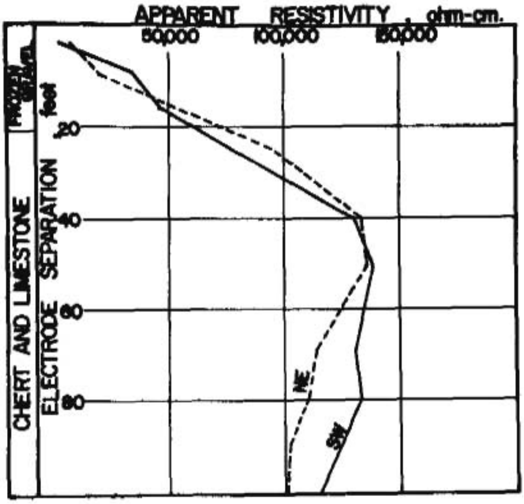


Fig. 15. Depth Profiles in Permanently Frozen Ground on Livengood Creek, Livengood District.

as it is doubtful whether frost extends 30 ft. into the 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]

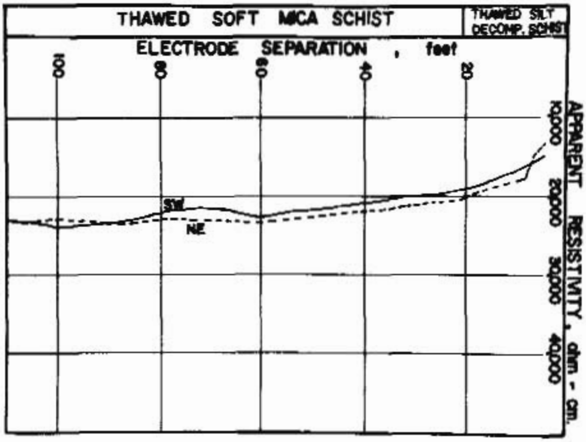


Fig. 16. Depth Profiles in Thawed Overburden and Schist Bedrock, near Goldstream Creek, Fairbanks District.

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 undersying gravel is frozen and thawed in about equal parts. Drill logs show, to the north of the central electrode, 75 ft. of frozen silt overlying 70 ft. of thawed gravel. To the east and west, the mean depths are 50 ft. of frozen silt and 115 ft. of gravel. The resistivity-depth profiles indicate that frozen ground, with occasional thawed lenses, occurs from depths of about 10 ft. to bedrock. The meaning of the resistivity maxima at 220, 260 and 270 ft. 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.

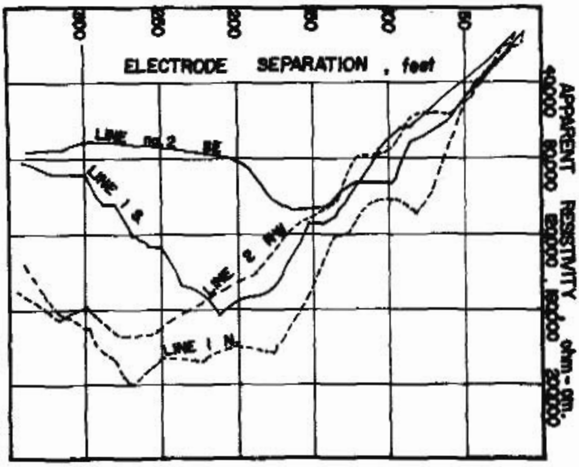


Fig. 17. Depth Profiles in Partly Frozen Overburden, Ester Creek, Fairbanks District.

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 fluvatile deposits that are partly thawed and partly frozen (see also Figs. 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.

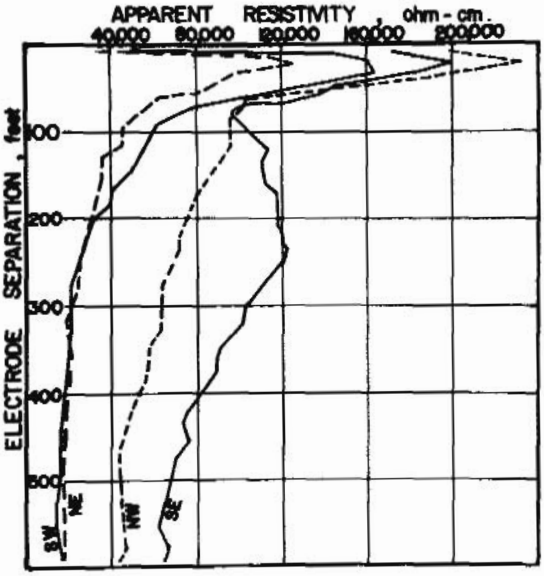


Fig. 18. Depth Profiles in Partly Frozen Overburden, Tanana Valley, Near Fairbanks.

The greatest known depth reached by drilling in the river deposits near Fairbanks was 364 ft. Since bedrock apparently was not struck, it may be at least 400 ft. below the surface in some places. According to available well logs, the ground is alternatingly thawed and frozen to a depth of about 180 ft. The proportion of thawed ground increases with depth and probably below 180 ft. it is 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 450 feet.

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, like those 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 incidentally, water, in otherwise frozen sand and gravel deposits (Fig. 11). Depth profiles can be used also for locating water under frozen deposits by determining the depth at which thawed ground is encountered (Figs. 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 found 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.

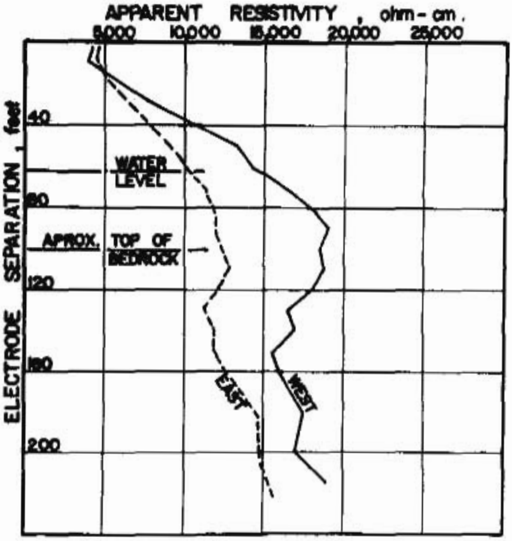


Fig. 19. Depth Profiles in Thawed Silt and Water-Bearing Gravel, Near Ester Creek, Fairbanks District.

Low-resistivity bedrock at about 110 ft. is apparently indicated by the sharp drop at that electrode spacing, which coincides with the known depth of approximately 100 ft. 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, while the high resistivity of the north line may be caused by a small mass of near-surface frost, formed in the shade of a building. Water at a depth of about 10 ft. is indicated by the south

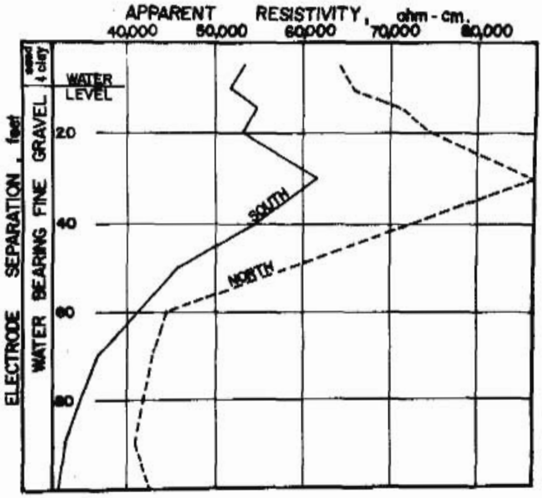


Fig. 20. Depth Profile in Shallow, Water-Bearing Gravel, Tanana Valley, near College.

resistivity line; the actual water level was found to be 9 ft. below the surface. The low temperature of the water, 3 degrees C, may partly 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 pay streaks. It is of no value in finding placers that 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 drilling or 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 bedrock.

Water-bearing deposits associated with permanently frozen ground can be indicated usually 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 later winter or early spring, when the surface resistivity is high and uniform, are more easily interpreted than those made during the late summer.

ACKNOWLEDGMENTS

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.

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