Aeromagnetic Interpretation of the Goodnews and Hagemeister Island quadrangles region, southwestern Alaska

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Report includes text and 2 map sheets, scale 1:250,000

AEROMAGNETIC DATA AND INTERPRETATION

The aeromagnetic map of the Goodnews-Hagemeister Island quadrangles region was prepared in 1971 and subsequently released by the State of Alaska in a series of 4 open-file maps (Alaska Div. Geology and Geophysics, 1972a, 1973b, 1973c, 1973d) at a scale of 1:250,000. These 4 maps have been assembled together for this report. The data were collected along east-west traverses spaced at 1.2-km intervals and from an altitude of 300 m above the ground. Compilation was originally in the form of 30- by 15-minute quadrangles at a scale of 1:63,360; these quadrangles have been combined and reduced to form the present map. Contour interval is 10, 20, 100, or 500 gammas, depending upon the steepness of local gradients in the Earth's magnetic field. A regional field (updated IGRF, 1965) was removed by computer from the data before contouring and 5000 gammas added arbitrarily to all values.

The local topographic relief for much of this area rarely exceeds 1,000 m and in general the fixed-wing aircraft that performed the survey probably maintained a reasonably constant altitude of 300 m above ground. In areas of substantial relief the aircraft flew approximately 300 m above the ridge crests and 500 to 1000 m above the valley floors. Continuous recording altimeter data are available for each traverse. Where an area of high relief is composed of magnetic rocks, a local magnetic anomaly is generated by the topography. These magnetic anomalies caused by topography may be superimposed upon even larger magnetic anomalies generated by the same magnetic rocks extending to unknown depths below the surface. Thus within broad magnetically high areas there may be local magnetic highs and lows over ridges and valleys respectively. The most extreme relief of 3000 m is found in the northeast portion of the map area where several broad magnetic highs show local small-scale complexities in the magnetic pattern. These local complexities in some cases appear to correlate with the topography and therefore are considered to be topographic effects.

The magnetic anomalies and patterns on the magnetic map are caused by variations in the amount of magnetic minerals, commonly magnetite, in the various rock units and are therefore closely related to geologic features. Probably at least 95 percent of the magnetic anomalies in this map area are caused by igneous rocks, plutonic and volcanic, or by serpentinized ultramafic rocks. As discussed below, a small but uncertain number of the anomalies are probably caused by the contact-metamorphosed rocks in the metamorphic aureoles of the plutons.

The aeromagnetic interpretation map (sheet 2) was compiled by the following procedure: a preliminary interpretation map was constructed using only the magnetic map and not referring to the geologic map, then the interpretation was compared with the geologic map and refined by modification of boundaries and by addition of a few more anomaly boundaries and interpreted faults. At these magnetic latitudes, boundaries between magnetic and relatively nonmagnetic rock units are in general located on the flanks of the magnetic anomaly, approximately at the steepest gradient. The aeromagnetic interpretation map contains many such interpreted boundaries drawn around characteristic magnetic anomalies. In addition a few boundaries in the southwest portion of the map are drawn to separate relatively flat magnetic areas from rather irregular areas. Many of these interpreted boundaries correspond approximately to mapped geologic contacts shown on the generalized geologic map. Other boundaries may represent rock units that have not yet been located by geologic mapping. In addition, many of the boundaries are concealed by extensive Quaternary alluvial deposits, particularly in the northwest and southeast portions of the map and also in the broad river valleys of the central portion. These boundaries are believed to be exposed at the top surface of the bedrock. A different sort of concealed boundary is shown by a separate map symbol on sheet 2 and is believed to be in general significantly deeper than the upper surface of the bedrock, being located commonly at depths in excess of 1 km below the ground surface. Long linear magnetic boundaries, which may truncate other magnetic lineaments, are interpreted as faults and are so indicated on the interpretation map. Minor discrepancies between mapped geology and aeromagnetic interpretation are to be expected at this map scale; they may arise from errors in aircraft location (this survey was compiled in part on older, less accurate, maps), from the semiquantitative nature of the magnetic interpretation, and from the reconnaissance nature of the geologic mapping.

Certain magnetic lows on the map are interpreted to be the result of reverse remanent magnetization of the associated rock units and are indicated by a capital letter "R". These lows are relatively isolated and are considered to be below the local background level of the magnetic field, which on this map is set arbitrarily at 5000 gammas. As discussed below, these lows are caused by volcanic, plutonic, and metamorphic rocks in different parts of the map area. Other magnetic lows, in particular those on the north, northeast, and northwest sides of the major magnetic highs, are the result of edge effects and have nothing to do with reverse remanent magnetization.

In the following sections the magnetic expression of the various rock units is discussed in sequence, starting with the oldest.

Ultramafic rocks (Jurassic)

In general serpentinized ultramafic rocks are associated with certain of the large amplitude magnetic anomalies that have steep narrow magnetic gradients. The cause of such anomalies is for the most part identified by comparison with the geologic map, and the anomalies are labeled with the letter "U". A few small occurrences of ultramafic rocks near the west border of the map lack aeromagnetic anomalies and are interpreted to be thin. Most of the serpentinite masses appear to be near faults.

INTRUSIVE ROCKS

Gabbroic rocks (Jurassic)

High-amplitude magnetic anomalies occur over most, but not all, of the gabbro plutons in the southwest portion of the map and are labeled "Ga". Three similar anomalies in this area have concealed sources and are labeled "Ga" with a subscript "C". One of these concealed features is associated with contact-metamorphosed country rocks that provide supporting evidence for a concealed pluton. At least two gabbro bodies, 4 to 6 km in length do not have any associated magnetic anomalies and are therefore mineralogically different, lacking abundant magnetite.

Assemblages of mafic and ultramafic rocks (Jurassic)

In the western half of the map are several areas where mafic and ultramafic rocks are found in close association. Large magnetic anomalies occur over these rocks but it is commonly not possible to separate the magnetic expressions of the different rock types which may include mafic volcanic rocks also. Such anomalies are labeled with the symbol "MU".

These anomalies are of particular interest because they form major magnetic lineaments up to 60 km in length. Although mafic and ultramafic rocks have not been mapped along the entire length of the linear magnetic features, their continuity suggests the same cause for the entire anomaly. The linear form supports the geologic inference that these rock assemblages may be ophiolites, associations of mafic and ultramafic rocks that usually occur in belts. Possibly other magnetic lineaments shown on the interpretive map in this area are caused by these same rock types but the features are not so labeled because there is no supporting geologic evidence.

Granitic rocks (Tertiary and Cretaceous)

Many prominent subcircular magnetic anomalies are caused by stocks of granitic rocks. A significant characteristic of these anomalies is the substantial width of the magnetic gradients on the anomaly flanks. These widths commonly exceed 3 km and, where wide, suggest outward-dipping contacts for the intrusive rocks. Most of the known plutons have associated magnetic anomalies with the exception of a few, usually small, bodies along the east border of the map. Concealed granite and gabbro plutons have similar anomalies and are arbitrarily distinguished by association with outcropping adjacent plutons.

Some of the plutons evidently possess intense reversed remanent magnetizations because of their association with reversed magnetic anomalies (labeled "R"). Other subcircular reversed anomalies on this map are probably caused by similar plutons with reverse remanent magnetization, the rocks either being concealed or not yet mapped.

The two largest northern plutons and one in the southeast corner have more complex magnetic patterns which include reversed magnetic anomalies ("R") as well as normal highs (G). Some of the reversed anomalies appear to border a central high and to be located for the most part over contact-metamorphosed country rocks. Elsewhere, detailed studies in the Talkeetna Quadrangle, Alaska (Griscom, unpublished data), have demonstrated the presence of reversed remanent magnetization in contact-metamorphosed sedimentary rocks. Perhaps the same explanation is true for the contact-metamorphosed rocks in the Goodnews-Hagemeister area but it is also possible that reversely magnetized granite underlies these country rocks at shallow depth.

Four prominent subcircular highs in the north central portion of the map have no known associated granitic rocks and are interpreted to be caused by concealed plutons (labeled "G_c"). The widths of steepest anomaly gradients suggest approximate burial depths of 1 km or less below the surface (Vacquier and others, 1951). One unusual subcircular magnetic low (labeled "R_c") in the north center of the map is approximately 6 km wide and has a source depth of 2-3 km. It is probably caused by a granitic pluton with reversed remanent magnetization. In the southeast corner of the map a possible granitic pluton (labeled "G_c") is concealed beneath the Quaternary deposits of the Nushagak Peninsula.

Narogarum Complex (Tertiary

This intrusive-extrusive complex consists of an area of dikes, sills, and volcanic rocks about 8 km in diameter in the approximate center of the map. An irregularly patterned area (labeled "V") of small magnetic highs and lows has been outlined on the map. This pattern is typical for weakly magnetic volcanic rocks.

Felsic intrusive rocks (Tertiary)

The felsic intrusive rocks in the south center of the map are so weakly magnetic that they do not appear to cause any mangetic anomalies.

VOLCANIC, SEDIMENTARY, AND METAMORPHIC ROCKS

Precambrian rocks

The northeast half of the belt of Precambrian crystalline rocks is associated for the most part with a relatively smooth magnetic field. The smoothness implies that the rocks are nearly non-magnetic and that they may be very thin. The geologic map indicates these rocks to be thin thrust slices containing windows which expose Cretaceous sedimentary rocks. The magnetic field over the southwestern half of the Precambrian belt is composed of various linear magnetic highs and lows, indicating the presence of magnetic rock units. The linear magnetic anomalies are generally of rather low amplitude and have relatively narrow gradients on the flanks; both of these characteristics suggest the possibility that the Precambrian rocks of this half too may be a thin thrust slice possibly lying upon non-magnetic Cretaceous sedimentary rocks. The northwest border of this same half of the Precambrian belt meets the smooth magnetic area of the concealed, presumably Cretaceous (see section below) rocks with so little disturbance of the magnetic field that it seems unlikely the Precambrian rocks at this location have significant thickness. Furthermore, at the southeast contact of this Precambrian unit there is one 15-km belt of magnetic anomalies (labeled both "MU" and "U") that appears to possess a wide magnetic gradient extending more than 3 km to the northwest of this contact. It is interpreted that these northwest extensions of the magnetic anomalies imply the presence of the causative magnetic rocks beneath the Precambrian of the map area and appears generally to contain a larger percentage of magnetic rocks to the west. Volcanic rock units, particularly massive flows and pillow basalts, may be the cause of some linear magnetic highs but there are difficulties in correlation of anomalies with geology. In the area northwest of the Goodnews fault less than 10% of the known outcrops of volcanic rocks have associated magnetic anomalies. Correlation is somewhat better southeast of the Goodnews fault but even here less than 50% of the known outcrops of volcanic rocks have associated magnetic anomalies. Evidently the cause of the linear magnetic highs is not known with certainty. Unexplained equidimensional magnetic highs may well be caused by intrusions while linear high-amplitude anomalies may be caused at least in part by serpentinized ultramafic rocks, especially those parallel to the interpreted thrust southeast of the Goodnews fault.

Volcanic and sedimentary rocks (Jurassic)

On the west half of Hagemeister Island, mafic flows of lower Jurassic age cause distinct magnetic highs that cannot be clearly differentiated from the highs over the associated granitic pluton.

The southwest end of a large belt of interbedded Jurassic volcanic and sedimentary rocks is exposed in the extreme northwest portion of the map area where no magnetic data are available. However, magnetic profiles across these rocks where exposed in the Bethel quadrangle, 25 km farther north (Dempsey, Meuschke, and Andreasen, 1957; Hoare and Coonrad, 1959) indicate many magnetic anomalies, 200-400 γ in amplitude, measured approximately 300 m above the ground. Extrapolation of this geology along strike to the southwest into the Goodnews quadrangle suggests that the large area of irregular magnetic anomalies (labeled V_C) in the extreme northwest corner is probably caused by this unit. Interpretation of these concealed magnetic rocks is complicated by the fact that magnetic Tertiary volcanic rocks (see below) are probably lying upon the eroded surface of this Jurassic unit and are probably causing the reversed anomalies (V_{Rc}) in this area. These reversed anomalies locally conceal the magnetic expression of the deeper rocks. The form of the southeast boundary of the concealed magnetic Jurassic rocks provides additional useful information because a wide magnetic gradient extends down to the southeast from the interpreted boundary. This wide gradient indicates that the boundary dips southeast to great depth and that the magnetic source rocks are truly basement and not merely a veneer of Tertiary volcanic rocks. The irregular non-linear magnetic pattern associated with these Jurassic volcanic and sedimentary rocks is unlike any other pattern on this map and suggests a different terrane.

Kulakak Graywacke (Jurassic)

This sedimentary unit is associated with areas of relatively smooth magnetic field, particularly in the southeast corner of the map area. The unit must be nearly non-magnetic and presumably contains almost no massive volcanic rocks.

Volcanic and sedimentary rocks (Cretaceous to Jurassic)

The rock unit covers almost half the geologic map and is characterized by numerous linear magnetic highs, some of which are up to 40 km long and are especially abundant in the south center of the map near the Hagemeister and the Togiak-Tikchik faults. At least one exposure of ultramafic rocks is known, and massive layers of steeply dipping volcanic rocks are distributed irregularly through the unit. A correlation problem exists here similar to that of the unit termed "Mesozoic and Paleozoic rocks undivided" because less than 50% of the known volcanic rock occurrences correlate with areas of magnetic highs. In particular, none of the linear anomalies near the Hagemeister and the Togiak-Tikchik faults can at present be shown to be caused by volcanic rocks although it seems likely that these rocks are indeed the cause. Perhaps the very low grade regional metamorphism of the basalts destroys the magnetite and thus is responsible for their common lack of magnetic expression. However, the correlation problem is not understood.

The regular linear magnetic patterns near the Hagemeister and Togiak-Tikchik faults are very different from the irregular swirled magnetic patterns found over this rock unit farther to the southwest. The two areas must be very different both in tectonic style and also in lithology. The geologic map indicates a significant concentration of gabbro and ultramafic rocks in the area to the southwest whereas such rocks are scarce near the pair of faults.

Cretaceous sedimentary rocks.

The unit termed "tuffs and sedimentary rocks" (Kts) in the north center of the map is nearly non-magnetic except for a few linear magnetic highs near the southeast margin where in contact with volcanic and sedimentary rock of Cretaceous to Jurassic age. The implication is that a few massive flows are present in the lower portion of this unit but that they are absent higher up stratigraphically. The remaining Cretaceous sedimentary units appear to have no associated magnetic anomalies.

The rocks of the Kuskokwim Group possess the smoothest magnetic expression in any part of the magnetic map. This unit is exposed at the north border of the map and forms a major belt, about 12 km wide, which extends toward the southwest along the northwest side of the Precambrian rocks and then disappears beneath the Quaternary cover in a place where the belt is associated with a broad smooth magnetic low. This magnetic low extends farther to the southwest and ultimately crosses the entire northwest corner of the aeromagnetic map. Accordingly the low is interpreted to represent the southwest continuation of the belt of Kuskokwim Group rocks which therefore extends completely across the northwest corner of the map. The Kuskokwim Group also underlies much of the area of Precambrian rocks, which are believed to form a thin thrust slice.

Volcanic rock (Tertiary)

In the south portion of the map, Tertiary volcanic rocks cause a few small magnetic anomalies on the mainland, where the rocks are flat-lying and relatively thin. On the east side of Hagemeister Island the Tertiary volcanic rocks dip steeply east and therefore cause elongate linear magnetic highs and lows.

rocks and therefore that the contact is here probably a thrust fault dipping to the northwest. However, 25 km northeast along this contact, the abrupt northwest border of a linear magnetic high suggests a normal fault, so the contact structure in detail is complex. In conclusion the magnetic data are taken to indicate that all of the Precambrian rocks are probably thin thrust slices completely detached from any source.

The northeast half of the Precambrian belt is associated with a broad linear magnetic high (labeled C_1), the source of which cannot be the Precambrian rocks because the anomaly extends across Cretaceous rocks as well. The source of the anomaly is concealed at depths of 1-2 km below the surface, judging by the horizontal extent of the steepest gradients (Vacquier, and others, 1951) on the northwest side. Approximately 10 km north of the north edge of the map on strike with the magnetic high are a series of aeromagnetic profiles (nos. 5A, 6, 7, and 8) which cross the magnetic high (Dempsey, Meuschke, and Andreasen, 1957). These profiles show that the concealed causative rocks of the anomaly become progressively shallower to the northeast and ultimately crop out at lines 7 and 8 as a restricted area (25 by 10 km) of magnetic schist and metachert inferred to be Ordovician(?) to Devonian(?) in age (Hoare, and Coonrad, 1959) and locally containing masses of serpentine. The Cretaceous Kuskokwim Group (see below) overlies this unit unconformably on the southeast side.

Mesozoic and Paleozoic rocks undivided

Linear magnetic anomalies interspersed with magnetically flat areas characterize this undivided rock unit, which is located in the west half

At the northwest corner of the map magnetic highs are observed over Tertiary volcanic rocks. The alluvium-covered area further to the west contains major magnetic lows (labeled "V_{Rc}") resulting from rocks with reverse remanent magnetization. Such patterns are almost invariably caused by flat-lying volcanic rocks and are here interpreted to be caused by Tertiary volcanic rocks. The adjacent irregularly patterned area labeled "V_c" may also contain some magnetic anomalies caused by Tertiary volcanic rocks but as explained above much of the pattern is thought to be caused by the volcanic and sedimentary rocks of Jurassic age.

Togiak Basalt (Quaternary)

These basalts are located between or adjacent to the Hagemeister and Togiak-Tikchik faults. The associated magnetic anomalies tend to be more irregular in shape than the linear highs caused by the adjacent Mesozoic volcanic rocks, probably because the basalts are flat-lying. The large linear anomaly at the shore between the two faults may be in part cuased by concealed Mesozoic volcanic rocks, or, alternatively, may be the result of flow ponding of the Togiak Basalt in a linear former valley. The rocks are very thin along the seacoast 10 km farther south, thus explaining the very low amplitude (910-20 gammas) of the associated anomalies.

FAULTS

Numerous faults are shown on the interpretation map. The normal faults are identified either as linear boundaries of magnetic anomalies (faults generally parallel to structural trends) and distinctively patterned areas or as linear features that terminate two or more linear magnetic anomalies (cross faults). A few faults are interpreted to be thrust faults. These thrusts are located on the northwest flanks of linear magnetic anomalies that appear to be caused by tabular masses of magnetic rocks dipping southeast at relatively small angles. Interpretation of thrusts has been conservative and has attempted to avoid gently dipping volcanic rocks interstratified with sedimentary rocks. An interpretation of the Precambrian rocks as a rootless thrust plate is described in the section on that rock unit. Many of the interpreted faults correspond with faults shown on the geologic map and many others have no mapped geologic counterpart. In addition the aeromagnetic map serves to confirm certain faults deduced from the geology. For example, the Togiak-Tikchik Fault is clearly expressed in the south half of the aeromagnetic map and is shown on the interpretive map; conversely, although the northern portion of the fault is not shown on the interpretive map, comparison between the aeromagnetic map and the geologic map indicates that the fault separates areas of differing magnetic pattern and is thus supported by the aeromagnetic data.

The Togiak-Tikchik and Hagemeister Faults are part of a more complex fault system, 10-20 km wide, concealed beneath alluvium in the southern half of the map but well-exposed on the aeromagnetic data. The faults appear to pass through an area of linear magnetic anomalies caused by volcanic rocks from the geologic map unit titled volcanic and sedimentary rock of Lower Cretaceous to Middle Jurassic age. These linear anomalies extend 10-20 km beyond the faults on each side and thus offer a crude estimate of possible strike-slip motion on this major fault system. On the east side of the system the north border of linear anomalies is at approximately lat. 59°21'N; on the west side the north border is more difficult to determine but is probably no further north than lat 59°30'N. The implication is that at most there is 13 km of right-lateral displacement on the fault system.

The aeromagnetic data raise questions concerning certain faults shown on the geologic map. The Goodnews Fault is expressed clearly in the aeromagnetic pattern on the west side of the map but in the central area the fault appears to cut across the center of a linear magnetic anomaly about 10 km long. The problem is not resolved, because there are no known intrusions younger than the fault. Similar magnetic problems are caused by the Buchia Ridge Fault, the northeast extension of which transects two linear magnetic highs trending north-south.

MINERAL DEPOSITS

The aeromagnetic map amplifies and extends certain information on the geologic map and thus outlines additional areas of possible mineralization. The various concealed plutons may be locations for mineralization although the exposed magnetic plutons are in general not known to contain mineral deposits. Two magnetic anomalies believed to be caused by granitic plutons are associated with certain geochemical anomalies (Hessin and others, 1978a,b,c,d,e). The magnetic high in the southwest quarter of T.9S, R.65W displays geochemical anomalies in zinc, lead, copper, arsenic, molybdenum, and tungsten. The sharp magnetic low of lat 59°30'N, 10 km west of the east border of the map, is associated with geochemical anomalies of arsenic and molybdenum.

The ultramafic rocks interpreted from the aeromagnetic data should be considered as possible sources for chromium, nickel, or platinum, while the belts of mafic and ultramafic rocks (MU) may in addition be the location of copper deposits.

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AEROMAGNETIC INTERPRETATION SYMBOLS

Fault inferred from aeromagnetic data; dashed where approximately located

Thrust fault inferred from aeromagnetic data

Boundary between magnetic and less magnetic rocks, dashed where approximately located. Either crops out or is near surface

Covered boundary between magnetic and less magnetic rocks. Location approximate. May be at depths in excess of 1 km

C_2 — Magnetic anomaly caused by a concealed source. Subscript is a label for discussion purposes.

R R_C — Magnetic anomaly caused by rocks with reverse remanent magnetization. Most of these anomalies are associated with granitic plutons. Subscript "C" if rocks concealed

G G_C — Magnetic anomaly believed to be caused by a granitic pluton. Subscript "C" if pluton is concealed

Ga Ga_C — Magnetic anomaly believed to be caused by gabbroic rocks; subscript "C" if rocks concealed

MU MU_C — Magnetic anomaly believed to be caused by an assemblage of mafic and ultramafic rocks; subscript "C" if rocks concealed. Many of these assemblages are probably ophiolites

U — Magnetic anomaly believed to be caused by ultramafic rocks

V V_R V_{RC} — Magnetic anomaly believed to be caused by volcanic rocks; subscript "C" if rocks concealed. Subscript "R" if anomaly caused by reverse remanent magnetization