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AEROMAGNETIC INTERPRETATION OF THE MEDFRA QUADRANGLE, ALASKA

By

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INTRODUCTION

An aeromagnetic survey of the Medfra quadrangle was flown in 1978 and subsequently released in open-file (U.S. Geological Survey, 1979) at a scale of 1:250,000. The survey was flown at an altitude of 300 m above the ground along northwest-southeast flight lines spaced approximately 1.6 km apart. The profiles were originally contoured on six $1^{\circ} \times 30'$ sheets at a scale of 1:63,360 and then reduced to form the present map. Some variations in altitude of the aircraft may have occurred over hilly areas. However, comparison of the magnetic map with the topographic map indicates very little correlation between magnetic anomalies and topography and therefore any deviations from the 300 m altitude do not appear to have significant effects on the magnetic data.

In 1979, subsequent to the aeromagnetic survey, we carried out 10 separate ground magnetic traverses (fig. 1) using a hand-held proton precession magnetometer with the sensor on a 3 meter pole. The magnetic susceptibilities of bedrock exposures were determined using a hand-held susceptibility meter. The ground traverses were selected to provide additional details on specific aeromagnetic anomalies or to determine the magnetic characteristics of various geologic map units.

For descriptive purposes we have divided the aeromagnetic map of the Medfra quadrangle into three broad terranes, each having distinctive first-order magnetic characteristics. First, we will describe the broad regional features of each area and then analyze individual anomalies within each area.

Statements about the configuration of source bodies are based largely upon a comparison of observed anomaly patterns with theoretical anomaly patterns presented by Zietz and Andreasen (1967) and by Aero Service (undated). Commonly the observed anomalies do not compare closely with the theoretical anomalies. We did not have time to model the anomalies in detail, so the interpretations of source body configuration are only approximate.

Many magnetic lows in the quadrangle appear to be caused by reversed remanent magnetization in Upper Cretaceous and lower Tertiary plutonic and volcanic rocks. These rocks cooled and presumably acquired remanent magnetization in the interval 71 to 62 m.y. before present (Moll and others, 1981), during which time the earth's magnetic field reversed at least five times (Ness and others, 1980). We generally failed in an attempt to correlate the ages of reversed and normally magnetized rocks, as determined from the aeromagnetic map, with reversed and normal polarity of the earth's magnetic field. A likely reason is that the error in age determinations (typically $\pm$ 2 m.y.) is greater than the time between magnetic reversals (typically .5 to 2 m.y.). Many of the negative anomalies can be explained by reversed remanent magnetization; and it is possible that some complex anomaly patterns may be explained by reversals that occurred between times that different rock units cooled. Confirmation of these hypotheses would require magnetic studies of very accurately and precisely dated, oriented rock samples.

REGIONAL FEATURES

Terrane I -- The eastern and southeastern parts of the quadrangle are characterized by broad anomalies of less than 50 gammas relief which are interpreted to reflect a magnetic basement beneath a cover of weakly or nonmagnetic early Paleozoic and late Precambrian sedimentary rocks. The source of these deep-seated anomalies is believed to be the pelitic schist unit (Pzp€p) which is shown to be moderately magnetic in its outcrop area in the north-central part of the quadrangle. Most, if not all, of the overlying units appear to cause little magnetic relief including the calc schist (Pzp€c), chert and phyllite (Pzc), limestone and dolomite (DOld), and shaly limestone (DOsl). The quartzite, grit, and argillite unit (Pzp€q) and the sheared grit, quartzite and quartz-mica schist unit (Pzp€s) appear to be weakly magnetic.

Superimposed on the pattern of broad deep-seated anomalies are several clusters of smaller, steep-gradient anomalies which have their source in surface and near surface volcanic and intrusive bodies. One such cluster occurs in the northeastern corner of the quadrangle and clearly is related to volcanic rocks of the Sischu Mountains (TKs). Two other clusters, one centered about the Telida Mountains and the other in the vicinity of Grayling Hill, probably are caused by gabbro intrusives (KDg). Anomalies in the belt of early Paleozoic limestone and dolomite (DOld) at Stone Mountain and in the vicinity of the Nixon Fork Mine appear to be related to intrusive bodies of intermediate and mafic composition (TKm). An elongate subdued magnetic high is caused by metavolcanic rocks (Pzp€v) east of the Sulukna River.

Terrane II -- This terrane is characterized by a background of shallow-gradient low intensity anomalies upon which are superimposed scattered isolated steep-gradient anomalies. The background low intensity field is interpreted to reflect minor lateral variations in basement magnetization below a cover of nonmagnetic to weakly magnetic Paleozoic and Mesozoic carbonate and clastic sediments. The field intensity is 50-150 gammas lower than terrane I and decreases to the southwest, probably reflecting the increasing thickness of nonmagnetic Cretaceous sedimentary rock sequence (Ksu, Ksc, Kss) in that direction. All the steep-gradient anomalies appear to be caused by surface and near surface mafic and intermediate intrusive (TKcm, Tkm) and volcanic (TKc) rocks or by hornfels zones in the Cretaceous sedimentary rock units.

Terrane III -- This terrane is characterized by rugged steep-gradient anomalies with a strong northeast grain in the northwest part of the quadrangle and a northwest grain in the north-central part of the quadrangle. This pattern of anomalies reflects a mixed geologic assemblage of gently deformed Late Cretaceous-early Tertiary volcanic rocks, highly deformed Mississippian to Cretaceous volcaniclastic rocks, chert, and mafic igneous rocks and early Paleozoic or Precambrian metamorphic rocks. Two units, the pelitic schist (Pzp€p) and the volcanic rocks of the Nowitna River area (TKn) have the highest magnetic relief of any map units in the quadrangle. Anomalies in the volcaniclastic and chert units (Kvg, J℞t, PMc) in the northwest corner of the quadrangle appear in many cases to be related to mafic and intermediate intrusives rather than to the volcaniclastic and cherty rocks themselves. The calc schist unit (Pzp€c) in the north-central part of the quadrangle seems to be essentially nonmagnetic.

SPECIFIC ANOMALIES

Terrane I

Basement trends

Only a few broad trends are recognizable in the nearly flat magnetic field that characterizes large parts of terrane I. This subdued field has a faint northwest-southeast grain which parallels the flight lines and may be an artifact of diurnal variations in the magnetic field that were not properly removed in the data reduction process. This northwest-southeast grain lies at right angles to the regional strike of the bedrock and is not expressed in the bedrock outcrops.

B11 -- A broad basement low extends northeastward along the belt of early Paleozoic limestone and dolomite (DOld) from approximately lat 63°15' N. to lat 63°55' N. An inlier of undifferentiated Cretaceous shale, siltstone, and sandstone (Ksu) at Stone Mountain (T. 20 S., R. 26 E.) and a narrow sharply folded syncline of similar Cretaceous rocks extending northeastward from the Nixon Fork Mine (T. 26 S., R. 21 E.) lie along this low. Both of these Cretaceous inliers are intruded by Late Cretaceous-early Tertiary intermediate and mafic plutonic rocks. The northeastern segment of this magnetic low coincides roughly with a structural low in the limestone and dolomite (DOld) which is marked by downfaulted blocks of Silurian thin-bedded limestone and shale (see detailed geologic map by Patton and others, 1980).

B12 -- A broad 70 gammas magnetic low occurs along the east side of the Sulukna River valley at the northern edge of the quadrangle. The low is situated in the calc schist unit (PzpGc) and presumably reflects the presence of a structural depression containing a thick section of these nonmagnetic schists.

B13 -- A northeast-trending alinement of several 35 to 50 gamma lows in the southeast corner of the quadrangle may indicate a broad structural depression of the nonmagnetic chert and phyllite unit (Pzc) contrasting with the weakly magnetic sheared grit, quartzite, and quartz-mica schist unit (PzpGs) to the southeast.

Volcanic rocks

V1 -- A cluster of steep-gradient, short wave-length anomalies with a magnetic relief of as much as 300 gammas occurs in the northeast corner of the quadrangle in the volcanic rocks of the Sischu Mountains (TKs). The volcanic rocks are composed chiefly of altered rhyolite and dacite flows, domes, breccias, and tuffs, but andesitic dikes are found locally. It is not clear from the sparse outcrop data why the high magnetic anomalies are concentrated in the northern and eastern parts of the volcanic field while the remainder of the field has little or no magnetic expression. No significant differences were noted in the chemistry, petrographic character, or degree of alteration in samples collected from various parts of the volcanic field. However, much of the volcanic field is poorly exposed and the presence of more mafic or otherwise magnetic volcanic variants beneath the broad covered areas is indicated by the magnetic data.

V2 -- Three 25-50 gamma magnetic lows, which are alined along a trend that extends southwesterly from the exposed rhyolite body (TKs) at Dyckman Mountain, may represent reversely magnetized dikes or subvolcanic intrusive bodies in limestone and dolomite (DOld).

V3 -- A paired magnetic high and low of 100 gammas relief in upper Shellman Creek drainage is interpreted to represent a slablike body of subvolcanic or hypabyssal rocks dipping gently to the east-southeast, possibly related to the volcanic rocks of the Sischu Mountains (TKs).

Gabbro-Diabase

GD1 -- A 250 gamma irregularly shaped northeast-trending high situated east of Telida Mountain and an accompanying polarization low situated to the west are interpreted to have as their source a large mainly buried body of mafic intrusive rock, probably gabbro, dipping to the northwest. Several small steeply dipping gabbro bodies (KDg) occur in the Telida Mountains west of the crest of the anomaly and large gabbro bodies are exposed in this same geologic terrane on strike to the northeast in the Kantishna River quadrangle (Chapman and others, 1975). The absence of magnetic highs over most of the exposed gabbro might be explained by the destruction of magnetite within the mapped hornfels zone surrounding the granitic pluton at Telida Mountain. Alternatively, the arcuate high east of Telida Mountain may be caused by an undiscovered rock type covered by Quaternary alluvium.

This picture is complicated by the presence of a sharp magnetic low over the gabbro body at the northeast end of the granite pluton. The gabbro body, which is within the hornfels zone, must have reverse remanent magnetization.

GD2 -- A cluster of irregular highs and lows with a maximum of 150 gammas of magnetic relief on and around Munsatli Ridge also may be caused by gabbro or diabase intrusive bodies in the quartzite, grit, and argillite unit (PzpЄq). One such body of gabbro (KDg) was noted among the sparse bedrock exposures on the ridge. Alternatively, the anomalies could be caused by buried metamorphic rocks like those which cause the Msl high.

GD3 -- A cluster of 20-30 gamma highs and lows in the vicinity of Grayling Hill also appear to have as their source gabbro intrusive bodies. Three of these anomalies coincide closely with mapped exposures of gabbro (KDg).

GD4 -- An elliptical 50 gamma high and associated low 8 km northeast of Limestone Mountain appear to be caused by a mafic intrusive body in limestone and dolomite (DOld). A brief ground inspection of this locality revealed the presence of a narrow diabase intrusive body (too small to be shown on the geologic map) bordered by an altered "gossan" zone in the limestone and dolomite host rocks. The presence of the polarization low to the southeast of the high suggests a northeast dip for the intrusive body; but a steeper gradient on the northwest flank of the high suggests a southeast dip. Possibly the source has an anomalous remanent magnetization direction.

GD5 -- A similarly shaped anomaly 3 km southwest of GD4 was not investigated in the field but probably reflects the presence of another mafic intrusive body. The generally symmetric anomaly pattern suggests a steeply dipping source body.

GD6 -- A small 30 gamma anomaly 20 km northeast of Stone Mountain coincides with a narrow gabbro dike intruding the limestone and dolomite unit (DOld). An elongate high 3 km northeast of this anomaly may reflect an extension of this dike.

Monzonite

M1 -- A cluster of three 20 to 40 gamma negative anomalies, apparently caused by remanent magnetization, occur in the vicinity of Stone Mountain where heterogeneous intrusive bodies ranging from monzonite to gabbro (TKm) intrude an inlier of undifferentiated Cretaceous shale, siltstone, and sandstone (Ksu). The outcrop areas of the intrusives are bordered by an extensive hornfels zone indicating that the intrusive bodies may broaden and merge with depth. None of the anomalies coincide precisely with the outcrop areas of the intrusives. Therefore, the source of the anomalies must be either a shallow buried intrusive or mineralized zones in the sedimentary country rock.

M2 -- An intrusive body in the vicinity of the Nixon Fork Mine is reflected magnetically by several small lows and highs inside a broad subcircular low. The low is not associated with a comparable high, so it cannot be a polarization low caused by the dipole field of a magnetic body normally magnetized parallel to the present-day earth's magnetic field (for discussion of magnetic lows, see Hanna, 1969). Because the country rock surrounding the pluton is composed chiefly of limestone and dolomite, which generally are nonmagnetic and show no magnetic signature on the magnetic map, the low cannot be explained by a nonmagnetic pluton intruding magnetic country rock. The low therefore must be caused by reversed remanent magnetization. The intrusive is composed of quartz monzonite and granite (TKm) and related quartz porphyry hypabyssal bodies (TKv). The small irregular lows and highs, which are located chiefly along the contacts of the intrusive, may be related to contact metamorphic or skarn zones. The Nixon Fork Mine is a gold-copper skarn deposit located along the contact of the intrusive body and the limestone and dolomite (DOld) host rocks.

M3 -- An elliptical 50 gamma high and related polarization low are associated with a small quartz monzonite or granite stock near the head of Eagle Creek. The stock, reported in 1970 by Reed and Miller, was not visited in the field by us and its precise location is uncertain. The source of the magnetic anomaly may be either the stock itself or a mineralized zone at the contact. The uniform gradient from bottom to top of the high suggests a plug rather than a flat sheet. The prominent polarization low northwest of the high suggests that the source dips to the southeast or that it contains remanent magnetization inclined to the northwest. A small gold prospect, presumably a skarn deposit similar to the Nixon Fork Mine, is reported in the vicinity of the stock (Schwab and others, 1981).

Granite

G1 -- A large granite pluton (TKg) in the Telida Mountains is marked by a broad elliptical 60 gamma magnetic low. The low appears to reflect the nonmagnetic character of the granitic rocks in contrast to the enclosing host rocks and may in part represent a polarization low associated with the postulated gabbro caused magnetic high (GD1) that lies to the east.

G2 -- A small elliptical granite stock (TKg) located in the upper Sulukna river drainage in T. 21 S., R. 25 E. has no magnetic expression but is of interest because it contains a contact metasomatic magnetite deposit estimated to contain about 12,000 m^3 of magnetite (Throckmorton and Patton, 1978). The deposit is located 0.4 km from the nearest flight line and is not expressed in the aeromagnetic data. However, a small (10-15 gamma) positive anomaly situated at the southwest apex of the stock may represent a similar contact metasomatic deposit.

Metamorphic rocks

Ms1 -- At the northern edge of the quadrangle a cluster of moderate- to steep-gradient anomalies with up to 100 gammas of relief reflect a basement terrane composed of pelitic schist (PzpGp) and metavolcanic rocks (PzpGv). The rocks appear to comprise a broad, northeast-trending basement high separating the northern end of basement low B11 from basement low B12.

Ms2 -- A broad 40-60 gamma magnetic high occurs over sheared grit, quartzite, and quartz-mica schist (PzpGs) in the southeastern corner of the quadrangle. This broad positive anomaly probably reflects a structural high in the underlying basement rocks and a contrast between the nonmagnetic chert-phyllite unit (Pzc) and the weakly magnetic sheared grit, quartzite, and quartz-mica schist unit (PzpGs).

Anomalies of uncertain origin

U1 -- A 60 gamma low located in the alluviated lowlands of the Kuskokwim River near the southern border of the quadrangle is interpreted to represent a reversely magnetized body at a maximum depth of one kilometer. The presence of steep gradients and an elongate polarization high to the west suggests that the source body dips towards the east.

U2 -- Three 20 to 50 gamma lows in the alluviated flats of the North Fork also appear to be caused by reversely magnetized bodies.

U3 -- A cluster of small highs and lows in the alluviated lowlands of the North Fork near Little Hog Butte have an anomaly pattern similar to V1, suggesting that at this locality volcanic rocks of the Sischu Mountain-type may underlie a thin cover of unconsolidated deposits.

Terrane II

This terrane is characterized by scattered moderate to steep gradient magnetic anomalies, nearly all of which appear to have as their source either Late Cretaceous-early Tertiary volcanic and intrusive rocks (TKc, TKcm, TKg, TKm, TKv) or Cretaceous sedimentary hornfels (Ksu, Ksc, Kss). A possible basement high of pelitic schist (PzpGp) occurs in the northeastern part of this terrane.

Basement trends

Bh1 -- A broad elliptical 110 gamma northwest-trending positive magnetic anomaly in the Meadow Creek lowlands is probably caused by a susceptibility contrast within basement rocks below a cover of nonmagnetic late Paleozoic and Mesozoic sedimentary rocks. The maximum depth to the magnetic rocks, estimated from magnetic gradients, is about 3 km. The anomaly merges to the southeast with high H8, which is inferred to be caused by exposed sedimentary hornfels and associated igneous sills and plugs. By analogy, Bh1 may be caused by a buried igneous body or a buried hornfels zone associated with it. Alternatively, Bh1 may be caused by buried magnetic pelitic schist (PzpGp) like that exposed further north. At the southeast end, the magnetic high trends into an anticline in Cretaceous conglomerate (Ksc). Permo-Triassic strata (₨Ps), which rest unconformably on the pelitic schist unit on nearby Canyon Creek, are exposed in the core of the anticline.

Hornfels

H1 -- A prominent oval-shaped 500 gamma positive anomaly is located in sandstone, siltstone, and shale (Kss) hornfels near the southwest corner of the quadrangle. In order to obtain more specific details on this anomaly we made a ground magnetic traverse that extended 3 km southwesterly from benchmark Slide (profile no. 1, fig. 1). The ground profile shows anomalies of 400 and 800 gammas with gradients that indicate a maximum depth to source of about 100 m. Susceptibility meter measurements of the sedimentary hornfels yielded maximum readings of 0.2×10^{-3} cgs. Since the maximum magnetic anomaly to be expected from rocks with this susceptibility would be only 60 gammas, we conclude that the source of the anomaly is probably a shallow intrusive body beneath the hornfels rather than the hornfels itself. Likely candidates for the source are mafic and intermediate hypabyssal and plutonic rocks similar to those found in the volcanoplutonic complex (TKc, TKcm) at nearby Cloudy Mountain.

H2 -- A similar positive anomaly in Cretaceous sandstone (Ksc) occurs 20 km northeast of H1 on the south side of Page Mountain. No intrusive rocks were found at this locality but exposures of sandstone are strongly bleached and thermally altered. The similarities with H1 suggest that this anomaly may also have its source in a buried mafic or intermediate intrusive body.

H3 -- A 60 gamma positive anomaly located 10 km northeast of H2 and connected with H2 by an elongate high suggests a further continuation of the trend of intrusives. The Cretaceous bedrock at this locality is slightly altered.

H4 -- A 200 gamma cup-shaped negative anomaly approximately 5 km in diameter and two smaller 30 to 40 gamma negative anomalies are located in an isolated group of unnamed hills at the head of the Sulatna River. The hills are composed of thoroughly altered Cretaceous sedimentary hornfels (Kss) which is intruded by trachyandesite and andesite dikes and hypabyssal bodies (TKc). The extent and intensity of thermal alteration and the shape and size of the large anomaly suggest that the dikes and hypabyssal bodies may coalesce into a single large reversely magnetized body at shallow depth. The small negative anomaly east of the large anomaly is situated on the largest hypabyssal body which was mapped in these hills. The small negative anomaly northwest of the large anomaly is located in the alluviated lowlands of the Sulatna River and may represent a similar satellitic intrusive body.

H5 -- Negative anomalies in Cretaceous sedimentary hornfels (Ksu) partially ring a granitic pluton (TKg) in the Sunshine Mountains. The pluton itself, however, appears to have little or no magnetic response. The granite-hornfels contact, at least where examined along the southern and southeastern perimeter of the pluton, dips gently outward. This together with the presence of an unusually wide hornfels zone encircling the pluton suggests that the granitic body broadens with depth. The negative anomalies, which are isolated from any magnetic highs, are probably caused by reverse remanent magnetization induced in the hornfels during the intrusion of the granitic pluton when the earth's magnetic field was reversed.

H6 -- A high-low anomaly pair occurs in Cretaceous sedimentary rocks (Ksu) that have been altered locally to hornfels near the southern edge of the quadrangle. The anomaly pair can be explained by a normally magnetized tabular body dipping gently to the southeast, with its top about 700 m below the surface.

H7 -- Another high-low anomaly pair, similar to the H6 but caused by a somewhat deeper source, occurs west of H6. The deep low lying to the south of the high suggests that the source rock is reversely magnetized. There is no direct evidence that the anomaly is caused by a hornfels zone. The source could be a buried magnetic intrusive body.

H8 -- A broad magnetic high with an amplitude of about 100 gammas, which is in part an extension of basement high Bh1, occurs over Cretaceous sedimentary hornfels of the Mystery Mountains. Superimposed on the broad high are shorter wavelength highs and lows that may be influenced by the numerous sills and plugs of felsic and intermediate volcanic rocks of the Nixon Fork-upper Sulukna River area (TKv) which intrude and thermally alter the sedimentary rocks.

Volcanic-plutonic complexes

VP1 -- At Page Mountain nine small magnetic lows of 25 to 150 gammas relief are distributed in a circle surrounding a broad 20 gamma positive anomaly. Page Mountain is composed of a downfaulted circular pile of trachyandesite and basalt (TKc) with a central stock of quartz monzonite and monzonite (TKcm). The simplest explanation for the observed anomaly pattern is that the central stock cooled when the earth's magnetic field had normal polarity, and the volcanics around it cooled during a magnetic reversal. Page Mountain provides an example, however, of the difficulty of correlating magnetic anomalies with the magnetic polarity time scale, largely because the errors in potassium-argon age determinations are large compared with either the length of magnetic polarity events or the cooling time of igneous rocks. The biotite age of the normally magnetized pluton is 70.5 $\pm$ 2.6 m.y., and is very close to an estimated transition from reverse to normal field at 70 m.y. (Ness and others, 1980). The biotite age of the reversely magnetized trachyandesite surrounding the pluton is 69.8 $\pm$ 2.6 m.y. Both ages are indistinguishable from each other and from the estimated transition age, within the analytical uncertainty. Field relations, especially alteration of the volcanics by the pluton, show the pluton to be younger than the volcanics. Clearly, we cannot resolve an intrusive and cooling history from these data. Other factors to be considered are the possibility that the pluton cooled during a transition, leaving part of it normally magnetized and part reversely magnetized, accounting for its weak positive anomaly; and the possibility that the pluton is reversely magnetized, like the volcanics, but its remanent magnetization is weak and is dominated by induced magnetization parallel to the present earth's field. A further complication is that scattered intrusive bodies were mapped along the west and southwest margin of the complex within the encircling belt of magnetic lows. The magnetic anomalies of the volcanoplutonic complexes promise to yield much information, but not without careful field and laboratory study.

VP2 -- In the vicinity of benchmark Alone an elliptical-shaped magnetic high with as much as 400 gammas relief is centered over a volcanoplutonic complex (TKc). Bedrock exposures are sparse but it appears that the complex is composed chiefly of trachyandesite. A small monzonite stock occurs near a local magnetic high in the east-central part of the anomaly. The outlines of the anomaly show that the complex extends under the alluvial lowlands of the Nixon Fork well beyond the area of bedrock exposures. From the anomaly pattern we infer that most of the complex is normally magnetized, although a low penetrating the center of the high may be caused by reversely magnetized rock. The rim lows and the narrow marginal gradients suggest a flat-lying tabular body. The difference in intensity of magnetic response between this volcanoplutonic complex and the complex at Page Mountain may be explained by the fact that this complex is composed chiefly of flows which are only slightly altered, whereas the Page Mountain complex is more highly altered and consists of a mixture of both pyroclastic rocks and flows.

VP3 -- At Cloudy Mountain, at the western edge of the quadrangle, a 125 gamma high and a 325 gamma low occur within a volcanoplutonic complex (TKc) compositionally similar to the Page Mountain complex. The bulk of this complex lies in the adjoining Ophir quadrangle where no aeromagnetic data are available.

Monzonite

M4 -- At Von Frank Mountain a 220 gamma positive anomaly and an accompanying polarization low are associated with a large monzonite pluton (TKm) which intrudes Cretaceous sedimentary rock (Ksu). The pluton is a heterogeneous body ranging in composition from quartz monzonite to gabbro. The crest of the positive anomaly is located near the southern margin of the pluton where no mafic phases of the intrusive body were found. Therefore, the anomaly may be related to compositional variations within the body of the pluton that have not been recognized in the surface mapping.

M5 -- A 100 gamma elongate anomaly on the north side of Whirlwind Creek appears to coincide with a narrow northeast-trending body of monzodiorite (TKm). However, the crest of the anomalies is not centered over the intrusive but lies a short distance to the southeast between the intrusive and the Nixon Fork fault. It is possible, therefore, that the anomaly has its source in the gabbro bodies (KDg) intruded along the north side of the fault rather than the monzodiorite body.

Terrane III

Volcanic rocks

V4 -- Two curvilinear belts of steep gradient positive anomalies with 200 to 400 gammas of relief clearly outline a broad northeast-plunging syncline containing volcanic rocks of the Nowitna River area (TKn). The magnetic data are interpreted to reflect a series of normally magnetized flows at the base of the volcanic pile. The southeastern belt appears to be thinned by faulting and may be faulted out entirely northeast of the junction of the Sulatna and Nowitna Rivers.

V5 -- The middle part of the Nowitna River volcanic sequence appears to be represented by a series of reversely magnetized flows. On the magnetic map these are shown as the southwest-trending belts with as much as 850 gammas of negative relief which merge into a single belt at the southwest end of the synlcine.

V6 -- The upper part of the Nowitna River volcanic sequence is characterized magnetically by steep gradient positive anomalies with 100 to 300 gammas relief in two irregular shaped areas along the axis of the syncline.

Gabbro-diabase

GD7 -- A prominent 22-km-long northeast-trending linear positive anomaly with 250 gammas of magnetic relief appears to have as its source alined bodies of gabbro and diabase. However, field relationships of the gabbro and diabase to the surrounding cherty tuff, crystal-lithic tuffs, and volcanic breccia unit (JTRt) are obscure owing to poor exposures. A further complication is that potassium-argon age determinations (Moll and others, 1981) for the gabbro and diabase yield ages ranging from late Paleozoic to Cretaceous. It is therefore uncertain whether the gabbro and diabase represent upfaulted or upfolded slivers of older rock or are intrusive bodies within the tuff-breccia unit. A short ground magnetic traverse (profile no. 10, fig. 1) of the tuff-breccia unit near the gabbro and diabase anomaly showed only about 100 gammas of relief in contrast to nearly 1400 gammas of relief over the gabbro and diabase in anomaly GD8 (see below).

GD8 -- This 150 gamma linear anomaly also has as its source narrow northeast-trending gabbro and diabase bodies. It may, in fact, be an offset extension of the GD-7 anomaly. A ground magnetic traverse across a gabbro body shows nearly 1400 gammas of relief (profile no. 9, fig. 1).

GD9, 10 -- Northwest of GD7 and 8 are a number of small positive anomalies with 50 to 150 gammas magnetic relief. They show a strong northeasterly alinement parallel to GD7 and 8 but their amplitudes are much lower and their shapes suggest plugs rather than narrow linear bodies. Their source may be gabbro and diabase bodies, but there are no field data to support this interpretation because the bedrock in this area is largely covered by vegetation.

Monzonite

M6 -- A 500 gamma positive anomaly is caused by the monzonite pluton (TKm) that forms the core of the Cripple Creek Mountains. Two 50 to 60 gamma negative anomalies bordering the Cripple Creek Mountains on the north and east may be caused by reverse magnetization in the hornfels zone around the pluton.

Anomalies of uncertain origin

U4 -- The source of two prominent positive anomalies located northeast of the Cripple Creek Mountains is uncertain. Gradients on the northern anomaly suggest a body dipping to the southeast. No mafic intrusive bodies or alteration zones were found among the sparse exposures of the cherty tuff, crystal and lithic tuffs, and volcanic breccia unit (JTRt) in this area. However, elsewhere in this map unit small gabbro and diabase bodies have been identified, suggesting the possibility that the anomalies may reflect buried bodies of similar rock.

U5, 6, 7 -- Small steep-gradient positive and negative anomalies with as much as 225 gammas relief are scattered through the poorly exposed chert and limestone (PMc) and cherty tuff, crystal and lithic tuffs, and volcanic breccia (JT t) units in the northwest corner of the quadrangle. Several of these show a northeast-southwest elongation parallel to GD7-10. They may reflect unexposed bodies of gabbro or diabase, although the gabbro does not generally show the reversed magnetization that causes U7.

Metamorphic rocks

The magnetic anomalies associated with metamorphic rocks within Terrane III form a very complex pattern. Strong remanent magnetization with directions different from the earth's magnetic field direction are present. How parts of the schist have managed to acquire and retain a dominant component of remanent magnetization is not known. The explanations given below for the anomalies are tentative. Detailed magnetic modeling combined with field studies would be necessary to determine the configuration of the source bodies, and laboratory studies of oriented samples would be required to ascertain the direction and the nature of the remanent magnetization.

Ms3 -- A broad area in the north-central part of the quadrangle is characterized by extremely rugged, steep-gradient, high-amplitude anomalies with as much as 500 gammas relief. The highly magnetic area coincides closely with the pelitic schist unit (Pzp6p) which consists of a wide variety of metasedimentary and metamafic igneous rock including quartzite, quartz-mica schist, and greenstone. Scattered ground traverses with a susceptibility meter suggest that the metamafic igneous rocks are the most magnetic but the possibility that some of the metasedimentary rocks may contain local concentrations of magnetite cannot be ruled out.

The northern part of Ms3 (T. 18-19 S., R. 21-22 E.) is dominated by northwest-trending magnetic anomalies, indicating that the contacts between magnetic and nonmagnetic rocks strike northwest. This strike direction contrasts with the mapped east-northeast foliations. The southern part of Ms3 (T. 20-21 S., R. 22-23 E.) has roughly northeast-trending gradients between magnetic highs and lows, suggesting that contacts trend northeast, consistent with the mapped foliation directions. Of course, there is no reason that compositional changes, which the magnetic anomalies probably show, should parallel foliation.

The magnetic highs in both parts of Ms3, with the exception of the high in the southeast corner of T. 19 S., R. 21 E. (subarea C), are accompanied by lows that are deeper than normal polarization lows, and lie to the southwest or southeast of the highs. Such an anomaly configuration is clear evidence of remanent magnetization directions different from the direction of the earth's magnetic field. Using the methods of Zietz and Andreasen (1967), we estimated the configuration of anomaly sources in area Ms3. The dotted lines indicate the rough outlines of areas where the sources are likely to crop out. The breadth of the anomalies outside the boundaries of the inferred sources show that sources a-e have thicknesses that are large compared to the flight line elevation of 300 m.

Subareas a and b have magnetization approximately horizontal, directed towards the southwest. Subarea c probably has magnetization not significantly different from the earth's magnetic field, i.e., down steeply to the northeast.

A large positive anomaly (in T. 20-21 S., R. 22 E.) with an amplitude of about 900 gammas, and an associated magnetic low with an amplitude of nearly 600 gammas, occurs at the southern edge of this magnetic terrane. The magnetic high occurs over mountains composed of schist, and the low occurs over sedimentary rocks that form lower slopes and valleys. Two ground magnetometer traverses (profiles nos. 2 and 3, fig. 1) were made in the vicinity of the steep gradient separating the high from the low. The traverses showed a local high of 2300 gammas over the schist, indicating that near-surface rocks are the source of the high and the associated low. However, none of the exposed bedrock along the traverses yielded susceptibilities of more than $0.8x10^{-3}$ cgs, which is less than one-fifth of that required to explain the anomaly by induced magnetization alone. The highest readings were obtained from greenstone; the pelitic schists generally gave readings of $0.1x10^{-3}$ or less (the maximum sensitivity of the instrument). Application of the method of Zietz and Andreasen (1967) suggests that the source has an outline as shown (subarea d) and has approximately horizontal magnetization directed towards the southeast.

A somewhat similarly configured magnetic high with associated low occurs to the northeast, at Lone Indian Mountain. The source has a rough outline as shown in subarea e and a near horizontal remanent magnetization toward the southeast. A small area of metavolcanic rocks (PzpБv) overlies the pelitic schist under the eastern part of the magnetic high. A ground magnetometer traverse (profile no. 8, fig. 1) over the metavolcanic rocks within the inferred source area yielded an 800 gamma, steep gradient negative anomaly, indicating that these rocks are highly magnetic. The traverse is not long enough to say whether the rocks are normally or reversely magnetized. The exposed bedrock, chiefly a felsic metavolcanic, gave susceptibility readings as high as $1.9x10^{-3}$ cgs, about half that required to cause the aeromagnetic anomaly by induction alone.

Ms4 -- The calc-schist unit (PzpБc) which gradationally overlies the pelitic schist has little or no magnetic expression. Two short ground magnetic traverses of the calc-schist unit (profiles nos. 5 and 7, fig. 1) both showed less than 40 gammas relief. The contacts of the calc schist and pelitic schist units on the geologic map have been drawn based in part on the aeromagnetic data.

Ms5 -- An area of negative magnetic anomalies with typical amplitudes of 400 gammas occurs over pelitic schist (PzpGp) north of area Ms3 and between two areas labeled Ms4. The lows, isolated from magnetic highs, are apparently caused by reverse remanent magnetization in the schist.

A ground traverse (profile no. 4, fig. 1) was made near benchmark Our Creek at the edge of a magnetic low where a small body of granite gneiss (too small to be shown on the geologic map) intrudes the pelitic schist. The profiles show about 400 gammas of relief with the highest susceptibility readings (2.3×10^{-3} cgs) from screens of greenstone in the gneiss.

The boundary between areas Ms4 and Ms5 extends across a northeast-trending fault that borders the volcanic rocks of the Nowitna River area (TKn) on the southeast. Since the same general pattern of magnetic lows is present northwest of the fault, we infer that the volcanic rocks in this part of the volcanic field are relatively thin and are underlain at shallow depth by the pelitic schist.

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