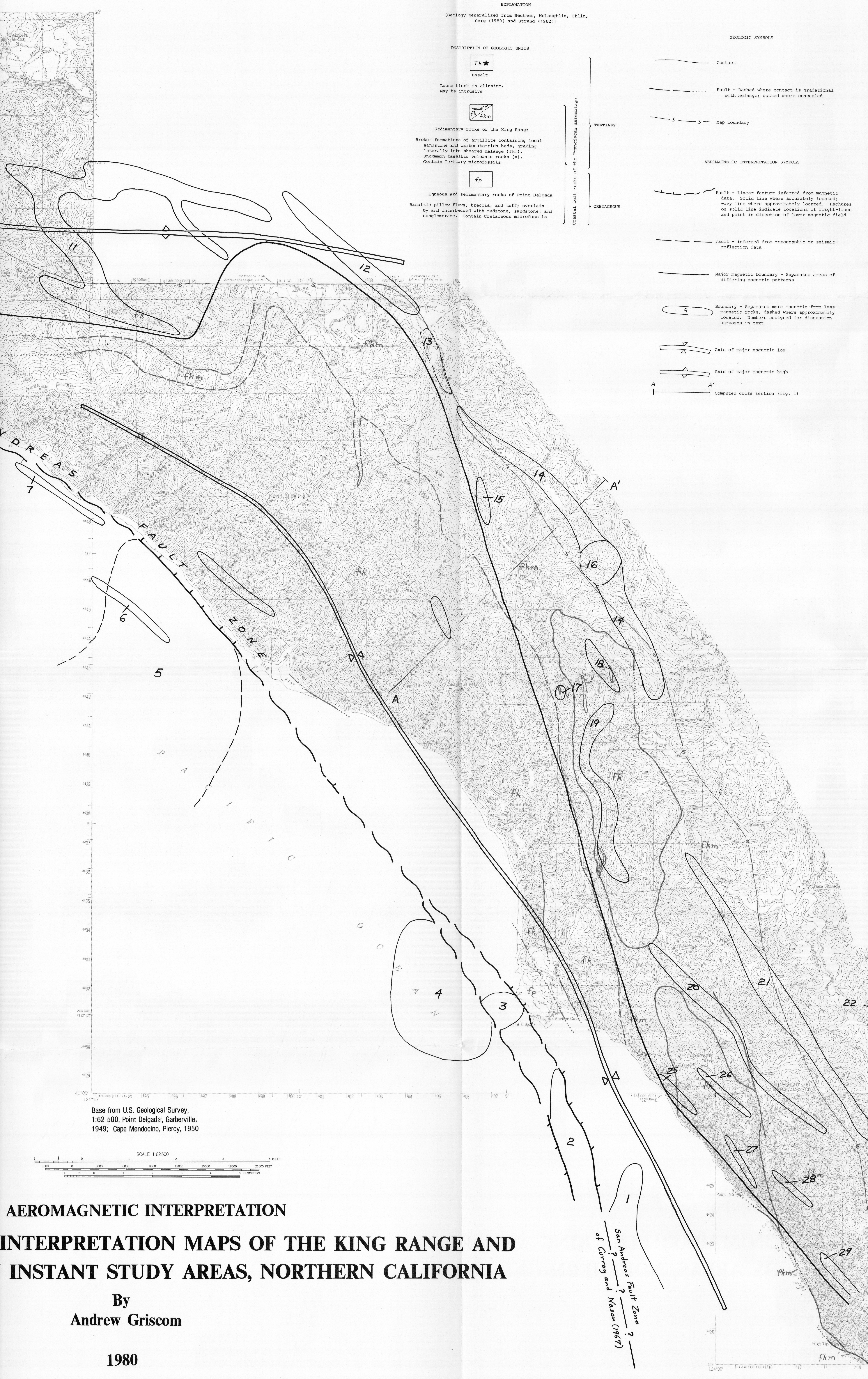
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF – 1196-B
Sheet 2 of 2



EXPLANATION

[Geology generalized from Beutner, McLaughlin, Ohlin, Sorg (1980) and Strand (1962)]

DESCRIPTION OF GEOLOGIC UNITS

Tb★

Basalt

Loose block in alluvium. May be intrusive

fk / fkm / v

Sedimentary rocks of the King Range

Broken formations of argillite containing local sandstone and carbonate-rich beds, grading laterally into sheared melange (fkm). Uncommon basaltic volcanic rocks (v). Contain Tertiary microfossils

fp

Igneous and sedimentary rocks of Point Delgada

Basaltic pillow flows, breccia, and tuff; overlain by and interbedded with mudstone, sandstone, and conglomerate. Contain Cretaceous microfossils

Coastal belt rocks of the Franciscan assemblage

TERTIARY

CRETACEOUS

GEOLOGIC SYMBOLS

Contact

Fault – Dashed where contact is gradational with melange; dotted where concealed

Map boundary

AEROMAGNETIC INTERPRETATION SYMBOLS

Fault – Linear feature inferred from magnetic data. Solid line where accurately located; wavy line where approximately located. Hachures on solid line indicate locations of flight-lines and point in direction of lower magnetic field

Fault – inferred from topographic or seismic-reflection data

Major magnetic boundary – Separates areas of differing magnetic patterns

Boundary – Separates more magnetic from less magnetic rocks; dashed where approximately located. Numbers assigned for discussion purposes in text

Axis of major magnetic low

Axis of major magnetic high

Computed cross section (fig. 1)

Aeromagnetic data and interpretation

The data for the aeromagnetic map (sheet 1) of the King Range and Chemise Mountain areas were collected in 1978 and compiled at a scale of 1:62,500. Northeast-southwest traverses were spaced at 0.8-km intervals at an altitude of 300 m above the ground surface and 600 m above the ocean because of cliffs along the shore. The contour interval is 10 or 50 γ, depending on the steepness of local gradients in the Earth's magnetic field. A regional field of approximately 5.6 γ/km was removed from the data before contouring.

The local topographic relief in much of this area frequently attains values of 500 to 1000 m. The valleys are generally narrow and steep sided. Accordingly, the fixed-wing aircraft that performed the survey did not maintain a reasonably constant altitude of 300 m above ground and may have been as low as 200 m above ridges and as high as 700 m above the valley floors. Continuously recorded altimeter data, though available for each traverse, were not examined. Comparison of the aeromagnetic with the topographic map indicates a poor correlation between magnetic anomalies and topography, and so the variations in aircraft height above ground are generally unimportant. The greatest limitation of the survey was its likely failure to detect small magnetic rock masses in the valleys because of increased distance from the aircraft.

The magnetic anomalies and patterns shown on the aeromagnetic map are caused by variations in the amount of magnetic minerals, commonly magnetite, in the different rock units and therefore are closely related to geologic features. The lithologic sources of the magnetic anomalies in this map area are not known with certainty but probably include mafic volcanic or hypabyssal rocks and, possibly, serpentinized ultramafic rocks.

The aeromagnetic interpretation map (sheet 2) was compiled from the aeromagnetic map without reference to geologic information other than the likely position of the San Andreas fault where it enters the southern and northwestern parts of the map area. At these magnetic latitudes the inclination of the Earth's magnetic field is sufficiently steep that the boundaries between magnetic and relatively nonmagnetic rock units are generally on the flanks of a given magnetic anomaly, approximately at the steepest gradient. This interpretation map contains many such interpreted boundaries drawn around characteristic magnetic anomalies. With the exception of two deep-seated magnetic anomalies (4,5, sheet 2) all these boundaries are believed to be at or very near the bedrock surface. Two other boundaries that have been drawn to separate areas of differing magnetic patterns are shown by different symbols on the interpretive map: the San Andreas fault zone, and a curvilinear line drawn east of the fault zone and crossing the entire map.

One magnetic low on the map (anomaly 24) is interpreted to reflect reverse remanent magnetization of the causative rock unit. This isolated low is considered to be below the background level of the local magnetic field. Other magnetic lows on the map, in particular those on the northeast sides of magnetic highs, are due to edge effects and have nothing to do with reverse remanent magnetization.

Geologic discussion

The geologic map of this area (sheet 2) is generalized from that of Beutner, McLaughlin, Ohlin, and Sorg (1980), which is based largely on fieldwork by E. C. Beutner before 1978 and additional later work by R. J. McLaughlin, H. N. Ohlin, and D. H. Sorg. In the discussion here and on the geologic map, Quaternary sedimentary deposits are omitted because of their negligible importance to the aeromagnetic interpretation. All the particular geologic information reported here is from the map by Beutner, McLaughlin, Ohlin, and Sorg.

In the Point Delgada area, rocks of Late Cretaceous age were assigned by Beutner, McLaughlin, Ohlin and Sorg to the coastal belt of the Franciscan assemblage. The rocks are predominantly basaltic pillow flows and breccia, tuff, and sills overlain by and partly interbedded with sheared mudstone, sandstone, and conglomerate that resemble melange and contain at least one large block of glaucophane schist. According to Beutner, McLaughlin, Ohlin, and Sorg, the volcanic rocks resemble the upper part of an ophiolite. Some of the layered rocks, which contain Cretaceous radiolarians, lie in probable fault contact to the east with younger sedimentary rocks of the coastal belt.

The rest of the King Range and Chemise Mountain areas is underlain by rocks of the coastal belt of the Franciscan assemblage, predominantly shale, siltstone, and sandstone. The rocks are generally more coherent to the west and are transected by two major belts of melange composed of graywacke blocks in a shaly matrix, generally steeply dipping and locally with folded foliation. Uncommon fragments in the melange are composed of altered pillow lavas, blueschist, limestone, and chert. Isolated boulders of altered greenstone occur in many streambeds within the area of melange. The sedimentary rocks of the King Range contain microfossils of Paleocene, Eocene, Oligocene, and Miocene age. The margins of the melange belts may be relatively abrupt fault contacts or more gradational fault or shear zones. A major antiform, overturned to the east, extends approximately north-south across the King Range at long 124°12' W.

The location of the San Andreas fault zone in this area has been a matter of conjecture. The marine seismic reflection data of Curray and Nason (1967) provide control on the position and trend of the fault near the south border of the map area, as do also Nason's (1968) geomorphic studies of the submarine topography south of Point Delgada. Mattole Canyon west of Punta Gorda on the west edge of the map area at lat 40°15' N. is a linear submarine feature, the floor of which may represent the fault. The geology, as described by McLaughlin and others (1979) and Beutner, McLaughlin, Ohlin, and Sorg (1980), precludes the presence of a major strand of the San Andreas fault zone onshore at Point Delgada.

Magnetic patterns and anomalies

Magnetic patterns

A general inspection of the magnetic anomaly patterns on the aeromagnetic map (sheet 1) discloses one series of magnetic anomalies along the southwest border of the map area and a second series of somewhat elongate anomalies in the northern and eastern parts of the area. In between is a somewhat linear area trending northwest that displays a relatively smooth magnetic field and is associated with a regional magnetic low. This linear area terminates on the southwest at a curvilinear boundary believed to represent the San Andreas fault zone (sheet 2); the area is bounded on the northeast by a somewhat arbitrarily drawn major magnetic boundary (sheet 2) that appears to correspond approximately with the southwest limits of the melange belts. This linear area correlates in general with more coherent sedimentary rocks of the King Range and Chemise Mountain areas, and the substantial thickness of the nonmagnetic unit corresponding to these rocks explains both the regional magnetic low and the smooth field. Only two minor local magnetic highs occur within this linear area.

Magnetic anomalies near the San Andreas fault zone

Anomalies 1, 2, and 3, like most of the local anomalies on the aeromagnetic map, have relatively shallow sources that must be at or near the bedrock surface, here at shallow depth beneath the sea. The source rocks of these anomalies are unknown, but the proximity of anomaly 3 to Point Delgada suggests that basalt pillows and sills similar to those exposed at the point may be the source. If these rocks represent the upper part of an ophiolite, then offshore serpentinized ultramafic rocks may also be the cause of the observed anomalies. Perhaps the specific flow units at Point Delgada are too thin or altered to have any magnetic expression on the map. Samples of mafic rocks provided by R. J. McLaughlin include specimens of: a small diabase intrusion, basalt fragments in mudstone, amd pillow basalt from Point Delgada; metabasalt (blueschist) from Wood Creek in the northern part of the map area; blueschist from Squaw Creek in the north shear zone; coarse blueschist (eclogite?) from Honeydew Creek; and manganiferous chert from Queens Peak. Measurements of magnetic susceptibility on these samples indicate that very small amounts of magnetic minerals are present because no susceptibility exceeded 30×10^{-6} e.m.u /cm^3. These rocks are too weakly magnetic to be a source of the magnetic anomalies shown on this map.

Anomalies 4 and 5 have relatively deep-seated sources (400 - 700 m below sea level) and are critical for locating the San Andreas fault zone, which must pass either close inshore northeast of the anomalies or far offshore southwest of the anomalies, in an area where seismic-reflection data indicate no disturbance of the ocean-bottom deposits (Eli Silver, oral commun. 1975). The inshore position accords better with the fault location by Curray and Nason (1967) south of Point Delgada (sheet 2) and with that inferred by Griscom (1973) at Mattole Canyon. Interpretation of the precise fault location northeast of anomaly 4 depends in part on the relation between anomalies 3 and 4. Although these two anomalies may be the same feature, alternatively anomaly 3 (which has a shallower source) may merely be fortuitously juxtaposed against anomaly 4.

Thus two possible traces for the San Andreas fault zone are shown on the map. I prefer the southwest trace passing between anomalies 3 and 4 and believe that anomaly 3 is probably caused by rocks similar to the mafic igneous rocks exposed at Point Delgada, or by related ultramafic rocks.

Anomalies 6, 7, and 8 are minor shallow linear features, whereas anomaly 9 is more equidimensional. The source rocks for these anomalies are unknown.

Magnetic anomalies northeast of the major magnetic boundary

Anomalies 10 and 11, at the north end of the map area, are the main magnetic anomalies northeast of the major magnetic boundary not associated with areas mapped as melange. Other similar features (sheet 1) are present on the magnetic gradient north of these anomalies but are not outlined on the interpretation map (sheet 2). The unknown source rocks are near or at the bedrock surface, which here is substantially covered by large landslides. One possible source could be small intrusions of Tertiary basalt (Tb). The two anomalies are superimposed on a much larger deep-seated magnetic high trending east-west across the top of the map area (sheets 1, 2). The deep-seated magnetic anomaly is an eastward extension of a magnetic high over the transform fault that extends west of Cape Mendocino (Griscom, 1973, 1980) and is not considered to be related to anomalies 10 and 11.

Anomalies 12 through 23, together with the relatively minor anomalies 25 through 29, are generally associated with the melange belts on the east side of the map area, although anomalies 18 and 19 fall in an area not mapped as melange. The overall pattern of the anomalies suggests that fairly continuous narrow belts of magnetic rocks occur within the melange. Perhaps magnetic-rock belts, though partly dismembered within the melange, nevertheless have a gross coherence expressed by the magnetic anomalies. The sources of these anomalies are probably volcanic rocks, and, indeed, anomaly 17 and part of anomaly 19 are underlain by small patches of mafic volcanic rocks. In addition, anomaly 18 appears to be associated with two small areas of volcanic rock shown on the state "Geologic map of California" (Strand, 1962). Boulders of volcanic rocks are present in stream valleys cutting the melange, and so unmapped volcanic units are probably present.

The belt formed by magnetic anomalies 13, 14, 16, and 19 has a broad gently sloping magnetic gradient on the southwest side that appears to be directly related to the anomalies. Accordingly, magnetic profile P-36 (A-A', sheets 1, 2) was selected for analysis because it has substantial amplitude, is fairly typical in form, and is not especially affected by other anomalies. Assuming uniform magnetic properties and a two-dimensional causative mass, a body was modeled (fig. 1) that gives a calculated magnetic anomaly nearly identical to that observed. This computed tabular body dips southwest at an angle of about 30°, is assumed to crop out on the northeast side of the magnetic high, and extends in the subsurface about 3 km southwest of the high to a point approximately at the major magnetic boundary. Because the anomaly has a relatively sharp crest, it was necessary to use local steeply dipping contacts near the surface before modeling the southwest dip of the slab. The general conclusion is that the gross structure of the melange belt dips southwest, probably beneath more coherent rocks of the magnetically smooth linear area. This conclusion appears to contradict the general belief that the various rocks of the Franciscan assemblage dip steeply east because they constitute a subduction complex formed at the top of an east-dipping subduction zone (Hamilton, 1978, p. 37). The computed apparent magnetic susceptibility for rock in the model is 0.27×10^{-3} e.m.u./cm^3, a value representative of weakly to moderately magnetic rocks. A sample from a greenstone boulder in the canyon at anomaly 16 possessed a magnetic susceptibility of 2.5×10^{-3} e.m.u./cm^3, and so the causative mass for anomaly 14 could be a dismembered greenstone unit diluted by a nonmagnetic matrix. Another possible cause, regarded as less likely, is a Tertiary intrusion.

Anomaly 16 may be caused by another magnetic object unrelated to anomaly 14, although its location exactly on trend with anomaly 14 suggests that the feature is simply a more magnetic part of the same object. The canyon beneath anomaly 16 was traversed on foot with a portable magnetometer; a broad anomaly of about 400 γ was measured, and the gradient on the north side suggests a source shallower than 100 m. Although abundant outcrops of nonmagnetic sedimentary rocks are present here in the canyon, no magnetic rocks were discovered other than the scarce boulders of greenstone described above.

Anomaly 24 is caused by rock possessing reversed remanent magnetization. I used a portable magnetometer to traverse the side valley of Sproul Creek that crosses the anomaly. The results confirm the existence of a magnetic low but indicate that the source rocks might be 100 m below the surface. All the exposed bedrock is composed of nonmagnetic sedimentary rocks.

References cited

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In accordance with the provisions of the Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976), the U.S. Geological Survey and the Bureau of Mines have conducted mineral surveys on certain areas that had been formally identified as "natural" and "primitive" areas before November 1, 1975. This report discusses the partial results of a mineral survey of the King Range and Chemise Mountain Instant Study Areas.

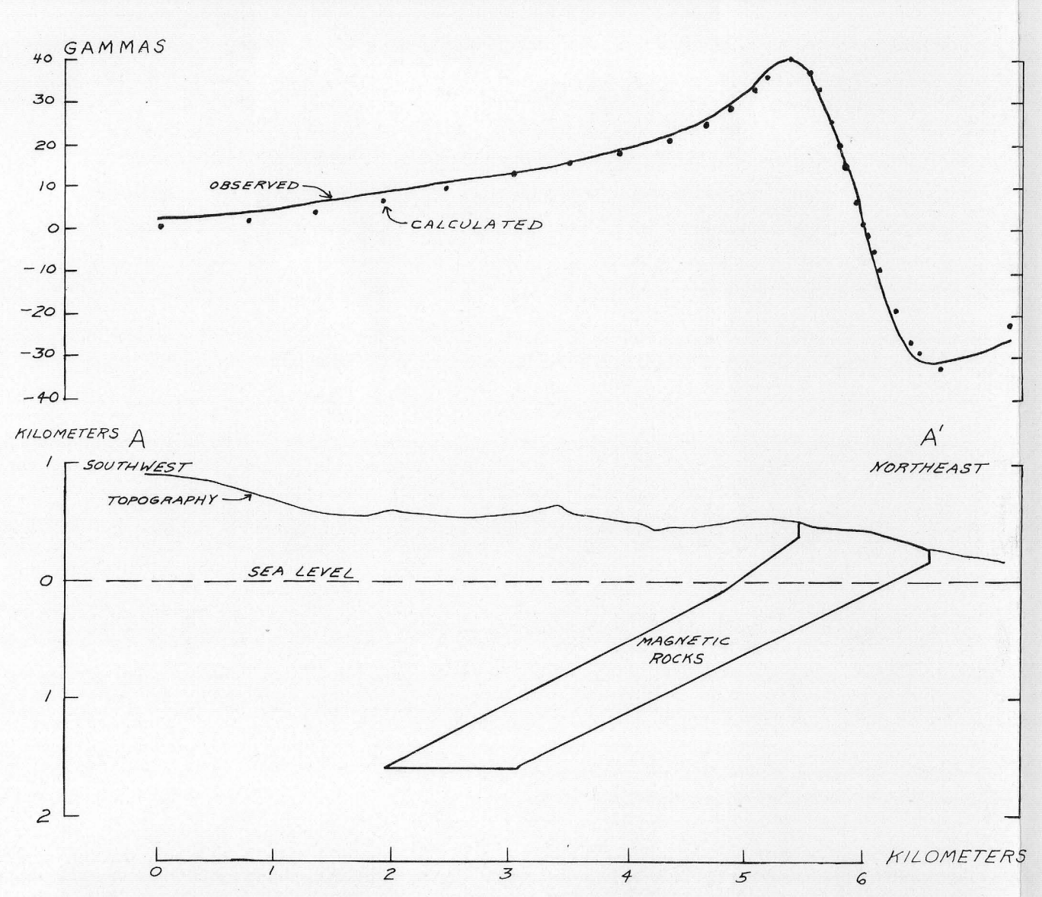

Figure 1. Calculated and observed magnetic profiles across a two-dimensional model simulating a concealed magnetic rock mass in cross section A-A' of sheet 2. See text for discussion. A regional gradient of 4.5 γ/km along the magnetic profile has been removed and the zero datum level arbitrarily determined.

Base from U.S. Geological Survey,
1:62 500, Point Delgada, Garberville,
1949; Cape Mendocino, Piercy, 1950

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

AEROMAGNETIC INTERPRETATION

AEROMAGNETIC AND INTERPRETATION MAPS OF THE KING RANGE AND CHEMISE MOUNTAIN INSTANT STUDY AREAS, NORTHERN CALIFORNIA

By

Andrew Griscom

1980

Interior—Geological Survey, Reston, Va.—1980

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