CHAPTER 7

MAGNETICALLY INTERPRETED, GRANITOID PLUTONIC BODIES IN NEVADA

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INTRODUCTION

Granitoid plutons have a recognized spatial association with many mineral deposit types in Nevada, especially those containing tungsten and copper (Shawe and Stewart, 1976). Locally, the deposits may occur at pluton margins, such as skarn deposits, or may be more closely associated with dikes, veins, and apophyses that extend away from the pluton, such as various vein, porphyry copper, or carbonate-hosted precious-metal (Carlin-type) deposits (Cox and Singer, 1986; Whitney, 1989). Plutons may have provided the heat or magmatic fluids involved in mineralization, or perhaps document a long-standing focus of igneous and hydrothermal activity controlled by structure (Madrid and Bagby, 1986). Therefore, locating the margins of granitoid plutons is important for mineral exploration and resource assessment. Moreover, now that exploration has nearly exhausted possibilities in exposed areas, determination of the near-surface, buried lateral extents of granitoid plutons has become more important.

Plate 7-1, one of a series designed to support the analysis of mineral resources of Nevada, is the result of a study to interpret the near-surface, buried lateral extents of granitoid, plutonic bodies in the state. It is intended to give a broad picture of the subsurface extent of plutonic bodies and help locate general areas of interest. Plate 7-1 is a modification of Grauch and others (1988) and expands upon the work of Maldonado and others (1988), who compiled descriptions of mapped granitoid rocks and qualitatively described their aeromagnetic expressions. In the present study, not only are the lateral extents of plutonic bodies interpreted where possible, but their magnetic characters are categorized to some extent as well. The characterizations may help determine bulk compositional differences between plutons in future studies.

The interpretations are based primarily on aeromagnetic data, supplemented by gravimetric and geologic information. They were accomplished by first determining the aeromagnetic signature of mapped granitoid rocks, which are classified according to the definition set forth by Maldonado and others (1988) as "holocrystalline, quartz-bearing, plutonic rock[s] ranging in composition from granite to diorite" (p. 1). Second, where granitoid plutonic rocks are expressed by characteristic magnetic anomalies, these signatures were extrapolated to areas of no exposure. By inference, the entire area covering the mapped rocks and the extrapolated areas may be the map projection of a granitoid pluton. However, individual granitoid plutons commonly vary in composition, magnetization, or both, so that some disagreement between geological and geophysical interpretation is unavoidable. In order to allow for these discrepancies, the term *interpreted plutonic body* or *plutonic body* will be used to represent the inferred geophysical entity.

Plate 7-1 is regional in scope; neither the data available nor the interpretation approach permit local-scale accuracy. In addition, aeromagnetic data cannot reveal all plutonic bodies in Nevada, and no attempt is made to combine the interpreted plutonic bodies into geologically coherent plutons. Nevertheless, at a regional scale, the resulting map can be used to suggest connections between isolated exposures of granitoid rock and provide guidelines for the existence and lateral extent of partially or wholly concealed plutons.

Each interpreted plutonic body on plate 7-1 resulted from deductions and inferences made on a case-by-case basis from available magnetic, gravity, and geologic data. This information is too numerous and unwieldy to show at the scales used for interpretation and not informative enough at 1:1,000,000 scale, the scale of the final interpreted map. Therefore, interested readers should refer to published data sources, referenced below. It is also impossible to completely document the decisions and observations that went into each interpretation, especially considering the large number of interpretations involved and the amount of discussion with colleagues that went into each decision. Instead, the general guidelines and approach followed during interpretations will be presented, using specific cases for illustration. In addition, several interpretation problems that merit special attention are discussed briefly.

DATA SOURCES

Interpretations were made primarily from a statewide compilation of publicly available aeromagnetic data by Hildenbrand and Kucks (1988). Their compilation was merged from many disparate surveys to approximate one survey flown 1000 feet above the ground across the entire state, and thus the data for some of the surveys have been filtered. The digital data for this compilation (Kucks and Hildenbrand, 1986) allowed production of maps at 1:250,000 scale that could then be easily compared to county geologic maps. The quality and resolution of the compilation varies widely due to differences in the original surveys. Sometimes maps of the original survey data were consulted to clarify the interpretations; original surveys are referenced in Hildenbrand and Kucks (1988). In only a few cases were more detailed data available, mostly proprietary.

Gravity data used to supplement the aeromagnetic interpretations are from a statewide compilation by Saltus (1988a). Two maps derived from this data set, an isostatic residual gravity map (Saltus, 1988b) and the basement gravity map of Jachens and Moring (1990), proved the most beneficial for supplementing the aeromagnetic interpretations. The isostatic residual gravity data, resulting from removal of the effects of an Airy-Heiskanen isostatic model from the

Bouguer gravity data, enhance gravity effects of the upper crust (Simpson and others, 1986). The basement gravity map highlights variations in basement lithology that otherwise would be overwhelmed by the effects of basin and range physiography, although the results are ill constrained in many places.

The aeromagnetic interpretations relied heavily on geologic information for determination of rock type and location of geologic contacts. Because it is beyond the scope of this study to compile and synthesize all available geologic information, the amount of information was necessarily limited. The primary sources of geologic information were the state geologic map at 1:500,000 scale (Stewart and Carlson, 1978) and the county geologic maps at 1:250,000 scale. References to these and supplemental sources of geologic information are provided in the Appendix.

Contacts of granitoid rocks on plate 7-1 are from Stewart and Carlson (1978) with a few additions in southern Nevada from Maldonado and others (1988). Rocks classified as hypabyssal igneous bodies, rhyolitic intrusions, or gneiss by Stewart and Carlson (1978) are specifically excluded.

INTERPRETATION APPROACH

The lateral extents of plutonic bodies were interpreted by determining the aeromagnetic signatures of exposed granitoid rocks and extrapolating these signatures to areas of no exposure. The aeromagnetic signature of a rock unit is recognized by a certain pattern of anomalies or lack of anomalies that occurs consistently where the unit is exposed. The character of a rock unit's aeromagnetic signature is dependent on (1) the distribution, grain size, composition, and thermo-chemical history of magnetic minerals (generally magnetite) within a volume of rock; and (2) the three-dimensional shape of the rock unit (especially its topographic surface). Exposed magnetic rock units produce anomalies whose shapes correspond to the topographic form of the rock unit and commonly follow its mapped contacts, although the relation to topography in this regional-scale study may not be very apparent. Weakly magnetic rock units lack anomalies and correspond to "flat" areas on magnetic contour maps.

A few aeromagnetic signatures are typical of certain rock types. For instance, Phanerozoic sedimentary rocks are generally very weakly magnetic, so they rarely produce anomalies at the resolution of the aeromagnetic surveys used in this study (Nettleton, 1971). Therefore, any anomalies in an area are likely caused by igneous or metamorphic rocks. A pattern containing numerous small, large-magnitude anomalies with steep gradients is most likely produced by extrusive rocks (although not all extrusive rocks produce large-magnitude anomalies). The large magnitudes are primarily due to high, stable, permanent magnetizations that often arise in magnetite grains that have experienced the fast cooling and high-temperature oxidation common to extrusive rocks (Larson and others, 1969). Large-magnitude negative anomalies at regional scale are produced almost exclusively by extrusive rocks that acquired high permanent magnetizations during a reversal of the Earth's field. In contrast, the magnetization of most plutonic rocks is primarily dependant on the amount and distribution of magnetite by volume, and is measured by magnetic susceptibility.

The aeromagnetic signatures of rock units in an area are often difficult to resolve because other nearby rocks may be magnetic. The signatures may be sorted out through a series of deductions and inferences using basic principles of magnetic interpretation, knowledge of the geology of the area, recognition of aeromagnetic signatures typical of certain rock types, and other geophysical and geologic information. Gravity or other geophysical data may help indicate the subsurface extent of certain rock types and detailed geologic descriptions may indicate the relation between rock units. In this study, surface magnetic-property measurements are available in only a few places.

Through this process of elimination, deduction, and inference, the aeromagnetic signature of mapped granitoid rocks might be recognized. The next step is to extrapolate the aeromagnetic signature into neighboring areas. This process is complicated by variable magnetization within the rock unit and by Basin and Range structure. The variations in magnetization are caused by primary differences in magnetite character or concentration, commonly considered insignificant in geologic mapping, or by secondary alteration of the rocks. Basin and Range structure, which slices rock units into alternating down-dropped and uplifted blocks, affects the appearance of the rock unit's aeromagnetic signature between blocks. The magnetic field observed above the down-dropped block exhibits more subdued and broader magnetic anomalies than over the uplifted block because the lower rock is further away from the magnetometer.

The interpreted aeromagnetic signature of mapped granitoid rocks can also be used to suggest the presence of similar rocks in the subsurface, far from exposures of granitoid rock. In these situations, no mapped rock units on the surface are considered likely magnetic sources and anomalies are present that do not have the high-magnitude signature typical of extrusive rocks. In a few cases, additional geologic or geophysical information can strengthen or guide the interpretation.

Lateral Extents of Magnetic Bodies

The lateral extent of a magnetic plutonic body can generally be interpreted from its associated aeromagnetic signature, but is more precisely determined by locating its magnetization boundaries. Magnetization boundaries are nonhorizontal boundaries between rocks that have distinctly contrasting magnetic properties. They could represent faults, other geologic contacts, or abrupt limits to altered rocks. For example, a magnetization boundary would lie along the geologic contact between a magnetic igneous body and clastic sedimentary rocks.

Magnetization boundary locations are estimated by the horizontal-gradient method for magnetic data (Cordell and Grauch, 1985). This method is based on the mathematical properties of gravity and magnetic fields over simple, vertical, magnetization and density boundaries and estimates the surface projections of the boundaries at regular intervals along the projection (Blakely and Simpson, 1986). For complicated boundaries that vary in dip, like those that typify plutonic contacts, the results of the horizontal-gradient method may be difficult to interpret. The locations computed by the method are a function of the dip and depth of the boundary but at regional scales are most affected by variable magnetization and the effects of neighboring magnetic rocks (Grauch and Cordell, 1987). In general, the method is most sensitive to the steepest slopes of the boundaries that are closest to the surface, as illustrated by simplified pluton models in figure 7-1. Thus, computed magnetization boundaries are useful tools for interpreting the shallow, lateral extent of plutonic bodies. The magnetization boundaries estimated by the horizontal-gradient method for this study are presented at 1:1,000,000 scale by Grauch and others (1988). A page-size, abridged version is presented in Blakely (1988).

Some magnetization boundaries interpreted as the lateral extent of plutonic bodies cross over the mapped granitoid rocks used to interpret the bodies. The discrepancy may be due to limitations in locating magnetization boundaries, discussed above; thin-skinned, sill-like borders; a drop in magnetization; or low aeromagnetic resolution.

Lateral Extents Of Weakly Magnetic Or Masked Plutonic Bodies

The lateral extent of plutonic bodies cannot be discerned by magnetization boundaries where the body's expression is overwhelmed by the magnetic effects of neighboring rocks or where the rocks are weakly magnetic. In some cases, the extent of a magnetic plutonic body can be reasonably extrapolated into areas where its expression is masked. In other cases, the expression may be everywhere masked. Common to this situation are caldera complexes, where high-magnitude magnetic anomalies produced by volcanic rocks dominate the magnetic expression of underlying granitoid rocks. In these cases, the lateral extent of the plutonic body is drawn to follow the mapped contacts (or around the map-projection of the subsurface granitoid rocks, if applicable) with a dotted line, indicating that the subsurface lateral extent is unconstrained. If there is no information on the location of granitoid rocks, even if a pluton's existence can be geologically inferred from the presence of volcanic rocks, no plutonic body was interpreted.

The lateral extents of weakly magnetic plutonic bodies, which occur in "flat" aeromagnetic areas, also cannot be determined magnetically. Like the masked plutonic bodies, their extents are drawn to generally follow mapped granitoid contacts. The lack of magnetization may be due to a primary lack of magnetic minerals, common to ilmenite-bearing granitoid rocks, two-mica granites, and leucocratic granite; or less likely, due to secondary alteration. Hydrothermal alteration can significantly lower the magnetization over surface areas of less than 100 km^2, as demonstrated within parts of the Idaho batholith (Criss and Champion, 1984; Criss and others, 1985); secondary felsic intrusion accompanying hydrothermal alteration combined to lower magnetizations over an area of similar size in the Boulder batholith (Hanna, 1969). However, destruction of all magnetization by hydrothermal alteration for a pluton of larger volume has not been documented.

Classification Scheme

Each interpretation on plate 7-1 is coded based on its credibility and the relation of aeromagnetic anomalies to mapped granitoid rocks. The coding is accomplished through different colors and line types. Lines estimating the lateral extent of magnetic plutonic bodies are solid where they coincide with computed magnetization boundaries, dashed where they are extrapolated or inferred, and dotted where they are unconstrained by magnetic data.

The interpreted plutonic bodies are color-coded according to the scheme in the Explanation. Color categories are organized according to confidence of the interpretation and the presence of and association between mapped granitoid rocks and aeromagnetic anomalies. Across the top of the Explanation are three general categories based on the presence or absence of granitoid rocks and if present, their aeromagnetic signature: (1) granitoid plutonic rocks are mapped, and aeromagnetic anomalies are present and related to them, (2) granitoid plutonic rocks are mapped and aeromagnetic anomalies, if present, are not related to them, and (3) no granitoid plutonic rocks are mapped but aeromagnetic anomalies are suggestive of subsurface plutonic bodies. The lateral extents of plutonic bodies in the first and third categories were determined magnetically because anomalies are present. The extents of bodies in the second category cannot be determined magnetically because the anomalies, if present, do not represent the plutonic body; they are determined instead by the limits of exposures. The three main categories are further divided by certainty criteria listed along the side of the Explanation, ranging from well-constrained to speculative interpretations. The following section gives examples typical of these classifications to further clarify their determination and meaning.

ILLUSTRATIVE EXAMPLES

In order to illustrate how interpretations are made and classified, this section presents typical examples for each type of classification. The examples are organized by the three main categories of the classification scheme as outlined above, with several examples in each category to demonstrate the levels of certainty within the category. The locations of mountain ranges associated with the examples are shown on figure 7-2. Examples of atypical interpretations or special problem cases are discussed under the section on Special Problems.

Mapped Granitoid Rocks Present and Related to Anomalies

The anomaly over the Osgood Mountains is clearly related to mapped granodiorite (fig. 7-3). Therefore, the interpreted plutonic body is color-coded as dark pink in the Explanation and is well-constrained for several reasons: (1) The highest values of the anomaly correspond spatially to the mapped granodiorite; (2) the interpreted magnetization boundaries, represented by alignments of small x's on figure 7-3, roughly parallel mapped contacts in places; (3) the country rock is composed primarily of sedimentary rocks with aeromagnetic signatures that indicate very little magnetization; and (4) magnetic susceptibility measurements indicate high magnetization for the granodiorite (Grauch and Bankey, 1991) and low magnetization for most of the surrounding

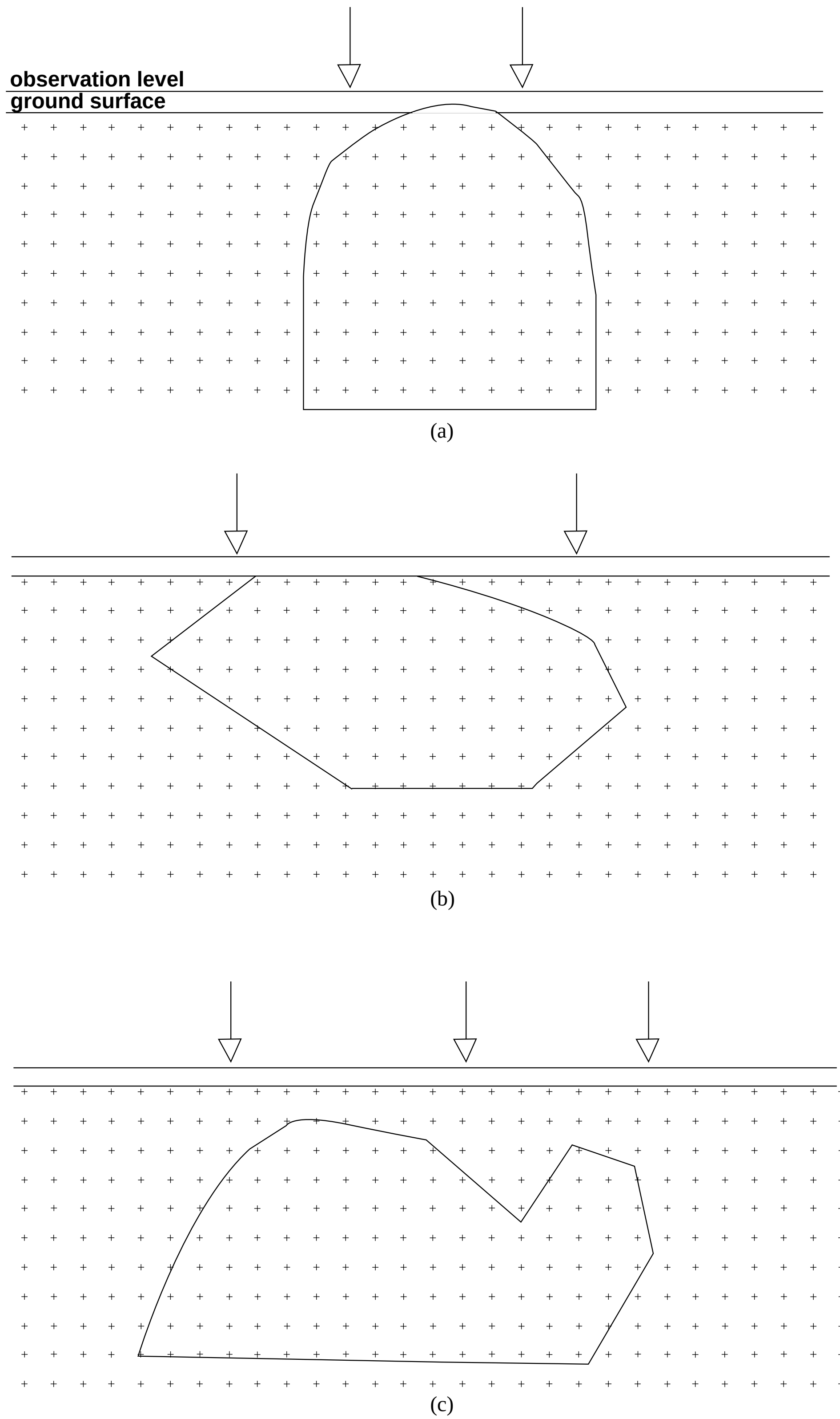

Figure 7-1. Various simple, two-dimensional shapes that simulate plutons in cross section and the points where magnetization boundaries occur (arrows), or where maximum lateral extent would be interpreted. Note that a magnetization boundary occurs within the hypothetical pluton in (c) due to its steep sides there. The interpretation of its overall lateral extent would require the aid of the original areomagnetic data.

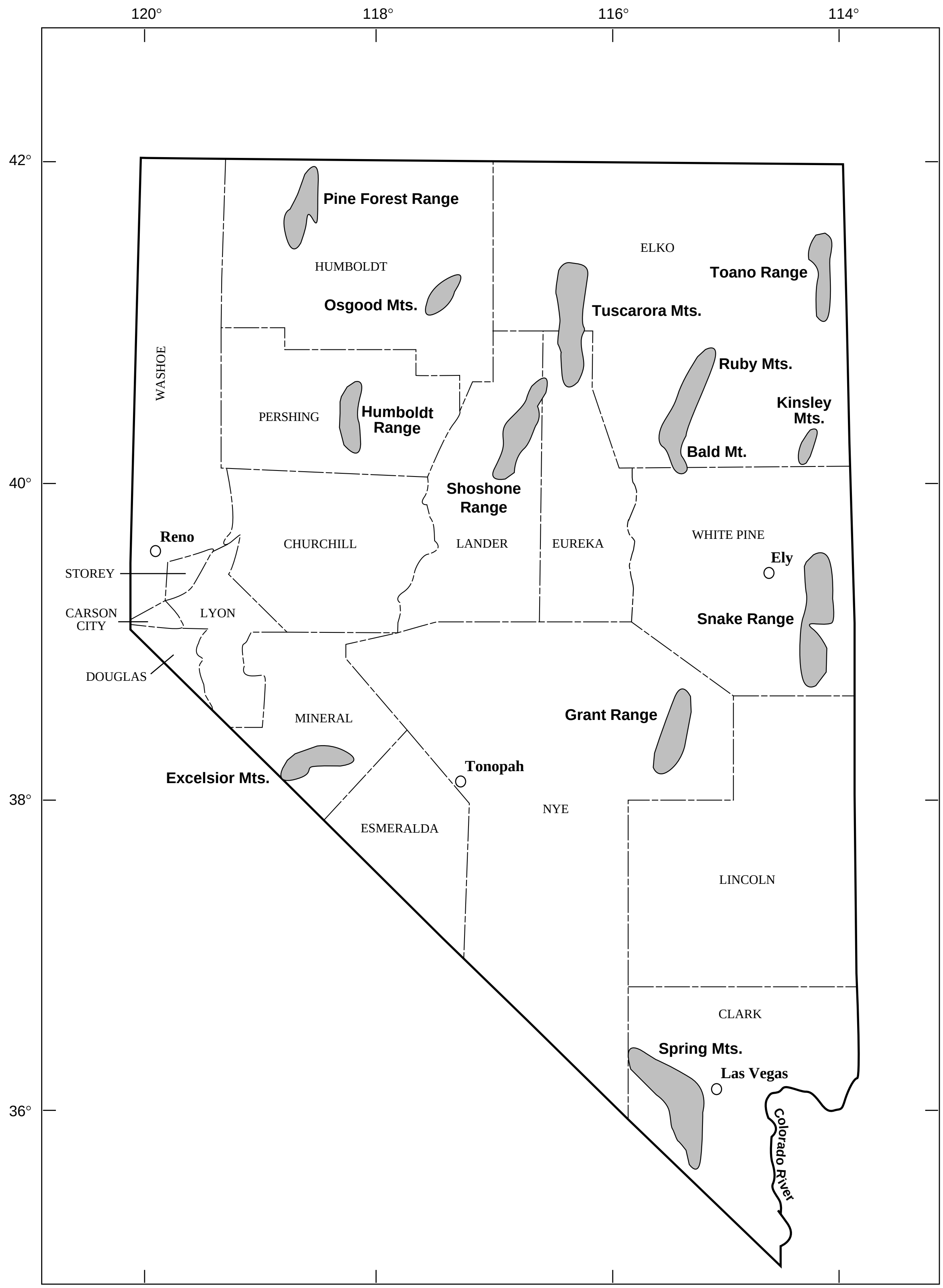

Figure 7-2. Locations of areas discussed in the text concerning examples and special problems (shaded areas).

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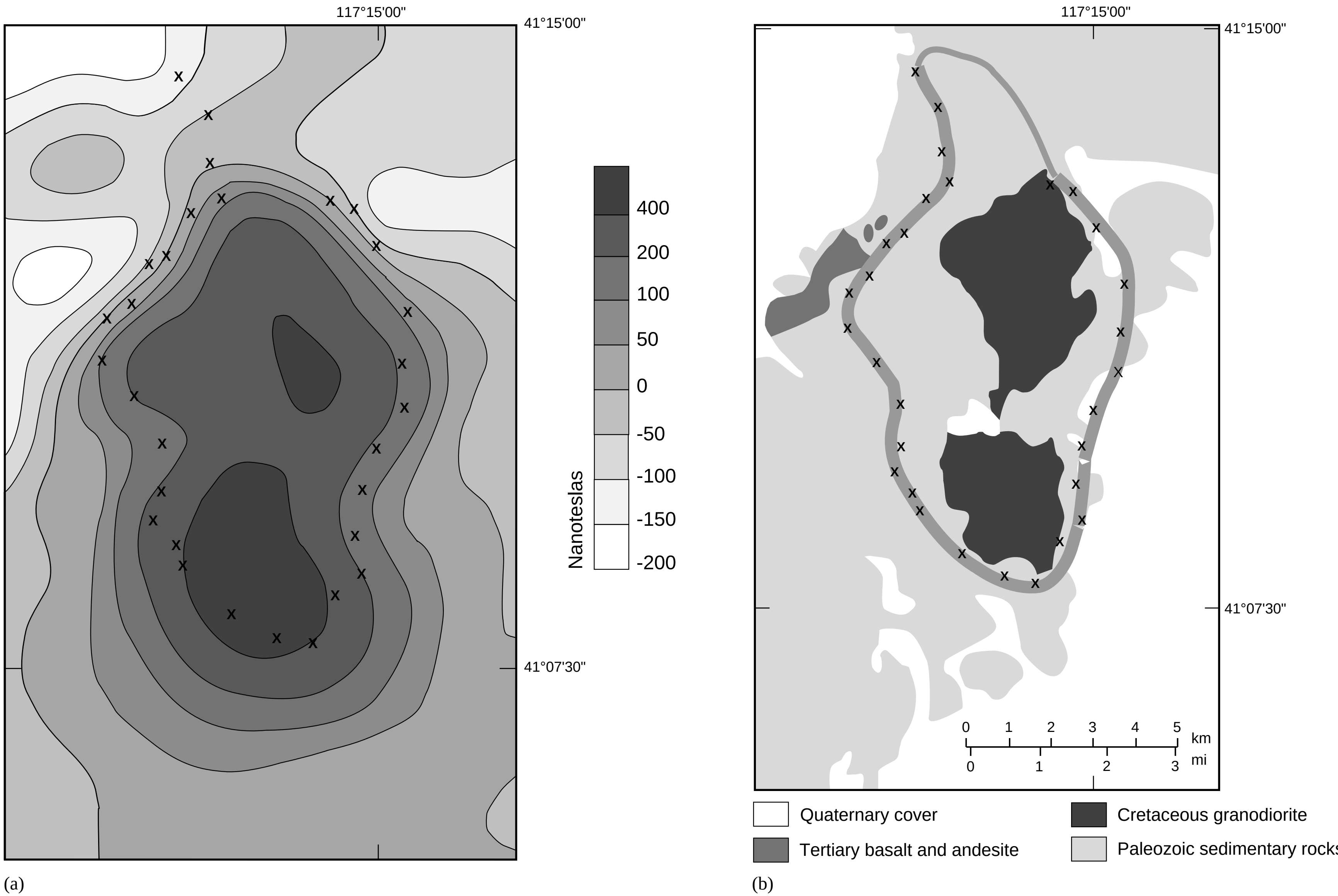

Figure 7-3. Example of a well-constrained interpretation from the Osgood Mountains (located on fig. 7-2), where an areomagnetic anomaly is clearly related to mapped granitoid rocks. A large magnitude areomagnetic anomaly (a) corresponds to mapped granodiorite (b). The small x's estimate the locations of magnetization boundaries. The green line in (b) shows the interpreted plutonic body outline, drawn thickly where well constrained and thinner where less well constrained. The interpretation is supported by analysis of more detailed data (Grauch and Bankey, 1991). Geology generalized from Willden (1964).

rocks (Grauch, unpub. field notes). Thus, where a magnetic body is inferred by the outline of the magnetization boundaries, the most likely source is the pluton, because it is the only magnetic rock type in the area. Where the magnetic body is inferred over the nonmagnetic rocks, the pluton can then be inferred in the subsurface. Inspection of more detailed aeromagnetic data (Grauch and Bankey, 1991) reinforces these observations. The magnetization boundaries indicate the near-surface limits of the plutonic body, although they might extend further to greater depths, as suggested by Grauch and Bankey (1991).

The aeromagnetic interpretation for part of the Tuscarora Mountains is less definitive than that for the Osgood Mountains, and therefore is coded by the medium pink color. North of 40°45’ on figure 7-4a (on page 7-12), a broad aeromagnetic anomaly has peaks that roughly correspond to mapped Cretaceous quartz monzonite and Tertiary granodiorite (fig. 7-4b) where they intrude rock types that are generally weakly magnetic. As Evans (1980) and Roberts (1986) have previously noted, the aeromagnetic anomaly, coupled with geologic evidence of widespread contact metamorphism, likely reflects an extensive underlying pluton. Uncertainties in the interpretation arise from (1) lack of magnetic constraint on the lateral extent of the plutonic body south of 40°45’; (2) scanty granitoid exposures; and (3) granitoid rocks of different ages. The lack of constraint south of 40°45’ arises from the moderate to high amplitude, steep-gradient, positive and negative anomalies that mask the expression of the underlying rocks. This aeromagnetic signature is typical of extrusive, not intrusive, rocks and the anomalies generally cover the area of mapped Tertiary volcanic rocks. Therefore, the magnetization boundaries in this area express volcanic features, and the lateral extent of the southern part of the interpreted plutonic body is unconstrained. The scanty exposures of granitoid rock generate uncertainty because their relation to the broad aeromagnetic anomaly is not confirmed. Because the granitoid rocks have different ages, it is uncertain whether the interpreted plutonic body is Tertiary, Cretaceous, neither, or both. Detailed, proprietary aeromagnetic data indicate that the granitoid rocks of both ages are magnetic; the interpreted plutonic body is probably a composite of both.

Interpretations are speculative where aeromagnetic anomalies and the distribution of granitoid rocks are too complicated to correlate at a regional scale; these are coded by the light pink color. For example, eighteen different intrusions (John, 1983) and three different volcanic units (Ross, 1961) are mapped in the vicinity of the Excelsior Mountains (fig. 7-5). These rock units have identifiable aeromagnetic signatures in only two locations: at about 38°10’N, 118°15’W where a strong aeromagnetic high corresponds to a circular exposure of Quaternary-Tertiary mafic volcanic rocks on a hill, and at 38°16’N, 118°25’W where hills of granite (marked as 119) correspond to a relatively flat magnetic area. Elsewhere, the geologic mapping and the aeromagnetic map suggest a complicated three-dimensional picture which cannot be resolved, especially at a regional scale. These types of problems are prevalent in western Nevada, especially elsewhere in this part of the state where geologic mapping is much more generalized than in this example.

Mapped Granitoid Rocks Present; Anomalies, if Present, Not Related

Interpreted plutonic bodies in this category tend to cover smaller and more numerous areas than the other categories because their lateral extents are determined from mapped rocks. Geophysical data do not provide enough information in between isolated rock exposures to connect them into larger areas.

A well-constrained interpretation in this category, represented by the light blue color on the Explanation, occurs in the Bald Mountain area, where granitoid rocks clearly exhibit a "flat" aeromagnetic signature. As figure 7-6 shows, mapped granitoid rocks have virtually no magnetic expression in an area of constant, low magnetic values, which indicates very weakly magnetic rocks. The highs and lows to the northeast are probably related to exposed and buried volcanic rocks. The lateral extent of interpreted plutonic bodies in this category cannot be determined magnetically. However, the "flat" aeromagnetic signature is conclusive that the rocks are only very weakly magnetic.

On the other hand, neither conclusions about the lateral extent nor the magnetization of granitoid rocks falling in the other extreme of this category can be made. This subcategory, represented by the light purple color, includes places where the aeromagnetic signature of granitoid rocks is everywhere masked by neighboring anomalies, as exemplified in the Kinsley Mountains (fig. 7-7). In this example, a quartz monzonite stock is located on the northern flank of an aeromagnetic high. The high is probably produced by volcanic rocks instead of quartz monzonite for the following two reasons, considered together: (1) Similar-magnitude high anomalies correspond well to exposed volcanic rocks, and (2) anomaly shapes do not follow the contacts of the quartz monzonite. Thus, the aeromagnetic signature of the quartz monzonite is totally masked by the signature of the volcanic rocks; that is, the quartz monzonite is not magnetic enough to deflect the anomalies produced by the nearby volcanic rocks.

No Granitoid Rocks Mapped but Anomalies Suggest Subsurface Body

Aeromagnetic anomalies that look like those over granitoid plutons elsewhere suggest the presence of totally concealed plutonic bodies. When no mapped granitoid rocks are present, such interpreted plutonic bodies are speculative by definition. The interpretations are more certain when either (1) drill-hole information indicates granitoid rocks, such as near the Gold Acres Mine in the Shoshone Range (located on fig. 7-2; Wrucke, 1985), or (2) geophysical modeling suggests a body consistent in shape and physical properties with a granitoid pluton, such as at Charleston Peak in the Spring Mountains (located on fig. 7-2; Blank, 1988; summarized by Blakely, 1988). Nevertheless, even the most speculative interpretations can target areas for further geophysical and geological investigation.

In the northern Toano range, a speculative interpretation was later corroborated by additional geologic information. As shown in figure 7-8, a broad, isolated high anomaly spans the range where no granitoid rocks were originally mapped

(Coats, 1987). This anomaly was interpreted as produced by a buried plutonic body because (1) the shape of the anomaly is reminiscent of a plutonic source; (2) the anomaly peak is located over effectively nonmagnetic Paleozoic sedimentary rocks, implying either an intrusive or pre-Paleozoic source; and (3) Tertiary volcanic rocks have a "flat" aeromagnetic expression elsewhere in the area. Two-mica granite mapped in the area (Toano Springs or Toano Range pluton) is not likely producing the anomaly at depth because it has a "flat" aeromagnetic expression where it is exposed. This indication of weakly magnetic granite is corroborated by the granite’s sparse opaque mineral assemblage (Lee and others, 1981), which implies it contains little magnetite. Later geologic mapping (Glick, 1987) revealed small exposures of Tertiary granodiorite (at the X on fig. 7-8) near the peak of the anomaly, which likely are the manifestation of the plutonic source of the anomaly. Moreover, the magnetic nature and apparent subsurface extent of the granodiorite suggest it is unrelated to the two-mica granite.

SPECIAL PROBLEMS

Every interpretation on plate 7-1 has its own unique problems, and some will probably always be debated. Some areas have enigmatic geology that affects the geophysical interpretation, such as the metamorphic core complexes in the Ruby Mountains and the Snake Range (fig. 7-2; Coney, 1979). As mentioned previously, the pluton geology of most of western Nevada is too complicated to decipher with this simple interpretation approach. In these areas, multiple pulses of magma intrusion and extrusion at various geologic times have left a very complicated surface pattern of magnetic rocks. Due to the complexity, interpretations in these areas are not only highly uncertain, but tend to oversimplify the geologic and geophysical patterns as well.

In some cases, mapped granitoid rocks are eliminated as possible sources of magnetic anomalies even though anomaly shape corresponds to surface exposures. This conclusion might follow from either (1) depth estimates to the top of magnetic sources, (2) extrapolation of known sources of characteristic anomalies from neighboring areas, or (3) incompatible rock type. Magnetic susceptibility and paleomagnetic measurements may also help eliminate possible sources, although this was never the case in this study. Examples of these situations (located on fig. 7-2) are (1) in the Ruby Mountains where depths to the top of the magnetic source, based on rough estimates and the discussion by Blakely (1988), suggest the source is below granitoid rocks mapped on the surface; (2) in the Pine Forest Range where anomalies characteristically resemble anomalies in Oregon that are produced by basalt (Bawiec and others, 1988); and (3) in the Humboldt Range, where exposed leucocratic granite is unlikely to produce the 100-400 gamma anomalies.

In another special case, an interpreted plutonic body along the Colorado River (the irregular, southeasternmost border of Nevada; fig. 7-2), is more clearly evidenced by gravity than aeromagnetic data. Gravity data and density measurements suggest Tertiary intrusive rocks that intrude Precambrian granite and metamorphic rocks produce gravity highs along the river. On the other hand, aeromagnetic anomalies and susceptibility measurements indicate many magnetic sources in the same area, some of which are mapped Tertiary granitoid rocks (R. Simpson, 1990, written commun.). The magnetic evidence is ambiguous, so the extent of the interpreted plutonic body is determined by magnetization boundaries where possible, but the general outline is guided by the gravity data of Saltus (1988b).

The overprint of Basin and Range structure presents a particularly difficult obstacle in interpreting coherent plutonic bodies across ranges. Between ranges, where a magnetic plutonic body may have been faulted down, magnetic anomalies are subdued because the magnetic sources are farther from the survey observation level. This problem is manifest in many places on plate 7-1 where interpreted plutonic bodies follow ranges, such as the Humboldt and Pine Forest Ranges (fig. 7-2). On the other hand, in a few places the interpretation could be extrapolated over a downdropped area, such as the plutonic body interpreted in the northern Grant Range (fig. 7-2) that extends into the valley to the west.

SUMMARY

Aeromagnetic interpretations of the near-surface, lateral extent of granitoid plutonic bodies in Nevada help determine areas near plutons that may be favorable for concealed deposits. The extents of plutonic bodies were interpreted through a process of inference, deduction, and extrapolation of the aeromagnetic signatures of exposed granitoid rocks, computed locations of magnetization boundaries, and gravity and geologic information. Generally, the interpretations involve varying degrees of certainty. Undoubtedly there are some plutonic bodies that were not determined at all; many may not hold up to scrutiny at local scales; and no attempt was made to combine the bodies into geologically coherent plutons. However, the resulting map contributes greatly to a regional understanding of near-surface granitoid plutons.

ACKNOWLEDGMENTS

This study began as part of a project to evaluate the gold resource potential of Nevada under the auspices of the Bureau of Indian Affairs. For that project, I coordinated the interpretation efforts of Rick Blakely, Dick Blank, Howard Oliver, Don Plouff, and Dave Ponce (USGS) and presented the results in Grauch and others (1988). Modifications to the early work, which I undertook separately, were partially funded by a USGS Office of Mineral Resources project to evaluate the mineral potential of the state. Some of the earlier interpretations were not reevaluated.

Work on the modifications benefitted from discussions with the geologists listed in the Appendix; with USGS geophysicists Dave Campbell, Bob Jachens, Howard Oliver, Rick Saltus, and Bob Simpson; with Ed de Ridder (Pearson, de Ridder, and Johnson); and especially with Steve Ludington (USGS), who offered insightful suggestions and criticisms concerning many of the interpretations. In addition, this report has been improved by the reviews of earlier drafts by Rick Blakely, Bob Jachens, and Dolores Kulik.

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APPENDIX: SOURCES OF GEOLOGIC INFORMATION

The primary sources of geologic information were the state geologic map at 1:500,000 scale (Stewart and Carlson, 1978) and county geologic maps, supplemented by Maldonado and others (1988), especially in the southern part of the state. The list below includes references to the county geologic maps and other sources of geologic information for specific areas that were consulted during the interpretation of plutonic bodies, listed by county. This list is by no means exhaustive; it was necessarily restricted due to time constraints. More up-to-date information was provided through discussions with the following geologists, all with the U.S. Geological Survey (USGS) unless otherwise noted: William Bagby, Joel Bergquist, Jefferson Chambers (Newmont Exploration Ltd.), James Evans, David John, Ronald Kistler, Edwin McKee, David Miller, Scott Minor, Robert Roback (University of Texas at Austin), James Rytuba, Geoffrey Snow (Barranca Resources), James Smith, Ted Theodore, and Ronald Willden (Mineral Exploration, Inc.).

Carson City: Moore (1969)
Churchill County: Willden and Speed (1974).
Clark County: Longwell and others (1965).
Douglas County: Moore (1969)
Elko County: Coats (1987), Coats and others (1977), Glick (1987), Howard (1980), Ketner and others (1987), Lee and others (1981), Miller and others (1987), Miller and others (1990), Taubeneck (1971), and Zoback and Anderson (1983).
Esmeralda County: Albers and Stewart (1972).
Eureka County: Evans (1980), Evans and Peterson (1986), Muffler (1964), Roberts and others (1967), and Shawe and others (1962).
Humboldt County: Bergquist and others (1987), Greene (1972), Greene and Plouff (1981), Minor (1986), Minor and others (1988), Noble and others (1970), Noble and others (1970), Roback and others (1987), Roberts (1964), Russell (1984), Smith (1973), Smith and others (1971), Taubeneck (1971), Willden (1963), and Willden (1964).
Lander County: Blake and others (1979), Roberts (1964), Stewart and others (1977) and Theodore and others (1973).
Lincoln County: Tschanz and Pampeyan (1970).
Lyon County: Moore (1969).
Mineral County: Ross (1961).
Nye County: Cornwall (1972) and Kleinhampl and Ziony (1985)
Pershing County: Johnson (1977)
Storey County: Bonham and Papke (1969)
Washoe County: Bonham and Papke (1969)
White Pine County: Hose and others (1976), and Lee and others (1981)

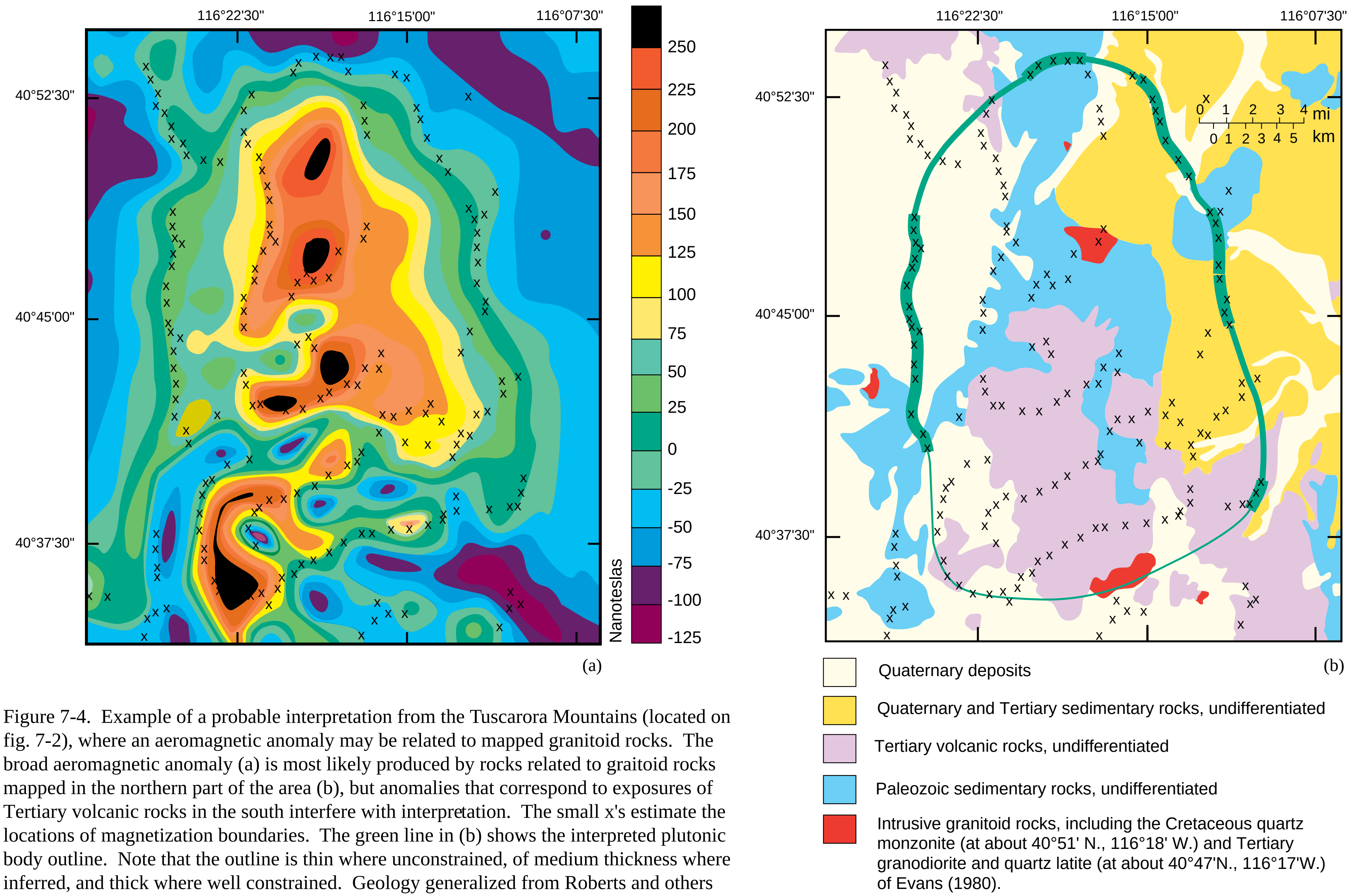

Figure 7-4. Example of a probable interpretation from the Tuscarora Mountains (located on fig. 7-2), where an aeromagnetic anomaly may be related to mapped granitoid rocks. The broad aeromagnetic anomaly (a) is most likely produced by rocks related to graitoid rocks mapped in the northern part of the area (b), but anomalies that correspond to exposures of Tertiary volcanic rocks in the south interfere with interpretation. The small x's estimate the locations of magnetization boundaries. The green line in (b) shows the interpreted plutonic body outline. Note that the outline is thin where unconstrained, of medium thickness where inferred, and thick where well constrained. Geology generalized from Roberts and others (1967) and Evans (1980).

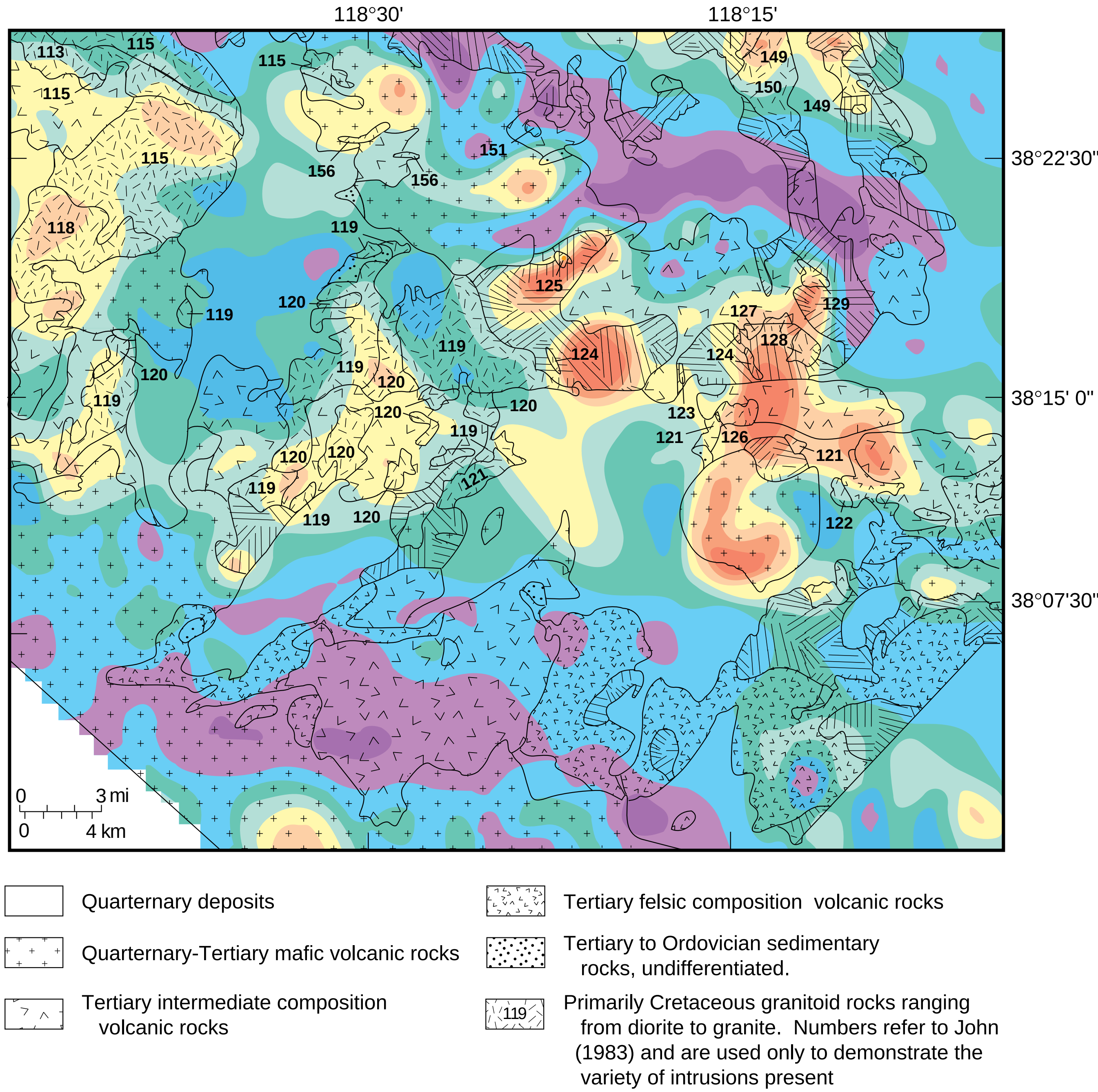

Figure 7-5. Example from the Excelsior Mountains (located on fig. 7-2) of an area where interpretation is speculative. The aeromagnetic anomalies, shown in color, show correspondence to mapped rocks in only two places (see text). The eighteen different plutons mapped by John (1983), keyed to his report by the numbers, exemplify a geologic configuration too complicated to unravel with the aeromagentic data available. Geology generalized from Ross (1961) and John (1983).

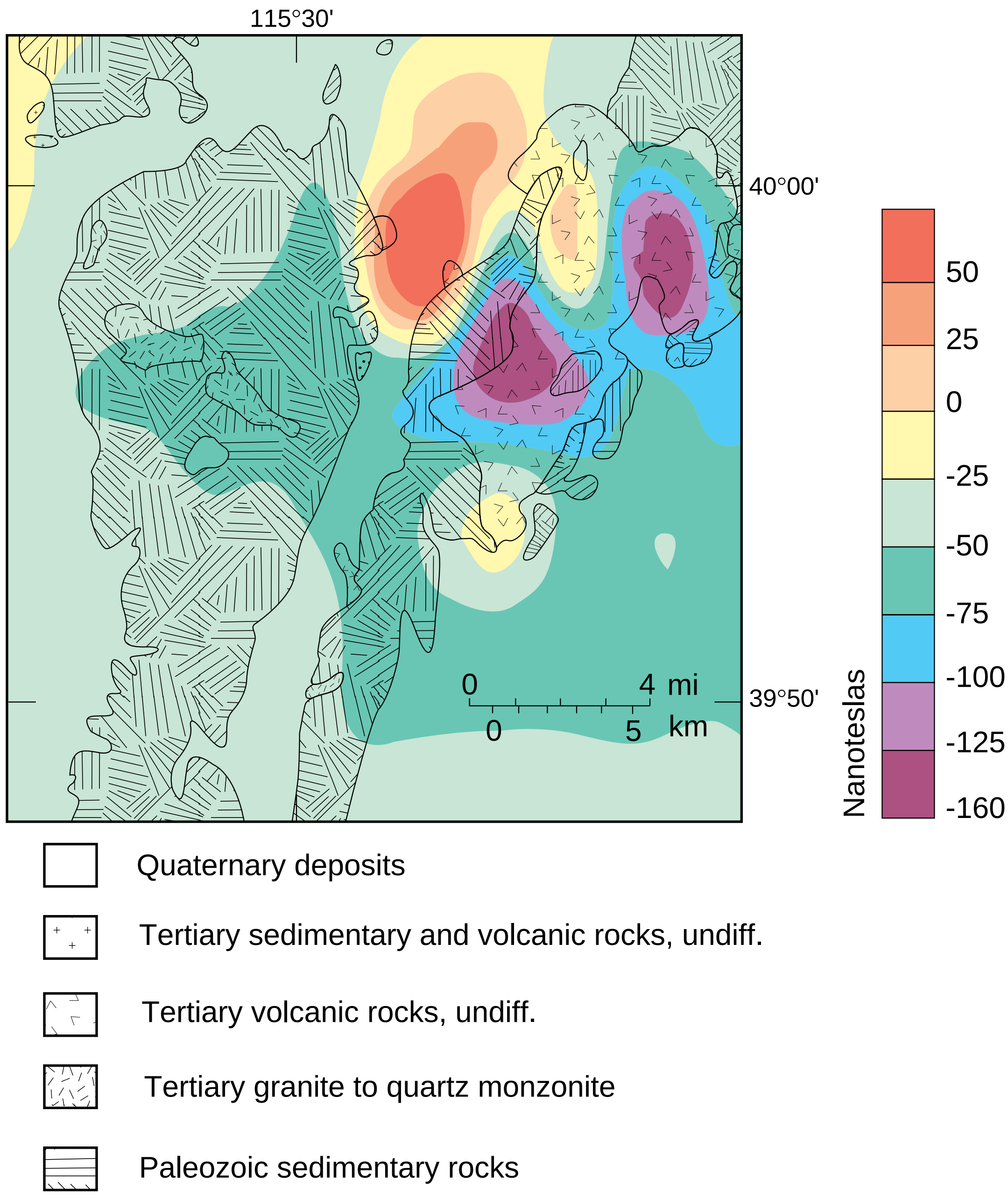

Figure 7-6. An example from Bald Mountain (located on fig. 7-2) of mapped granitoid rocks that correspond to a lack of anomalies. Anomalies, shown in color, correspond to volcanic rocks but not mapped granitoid rocks. The "flat" signature is typical of rocks that are very weakly magnetic. Geology generalized from Hose and others (1976).

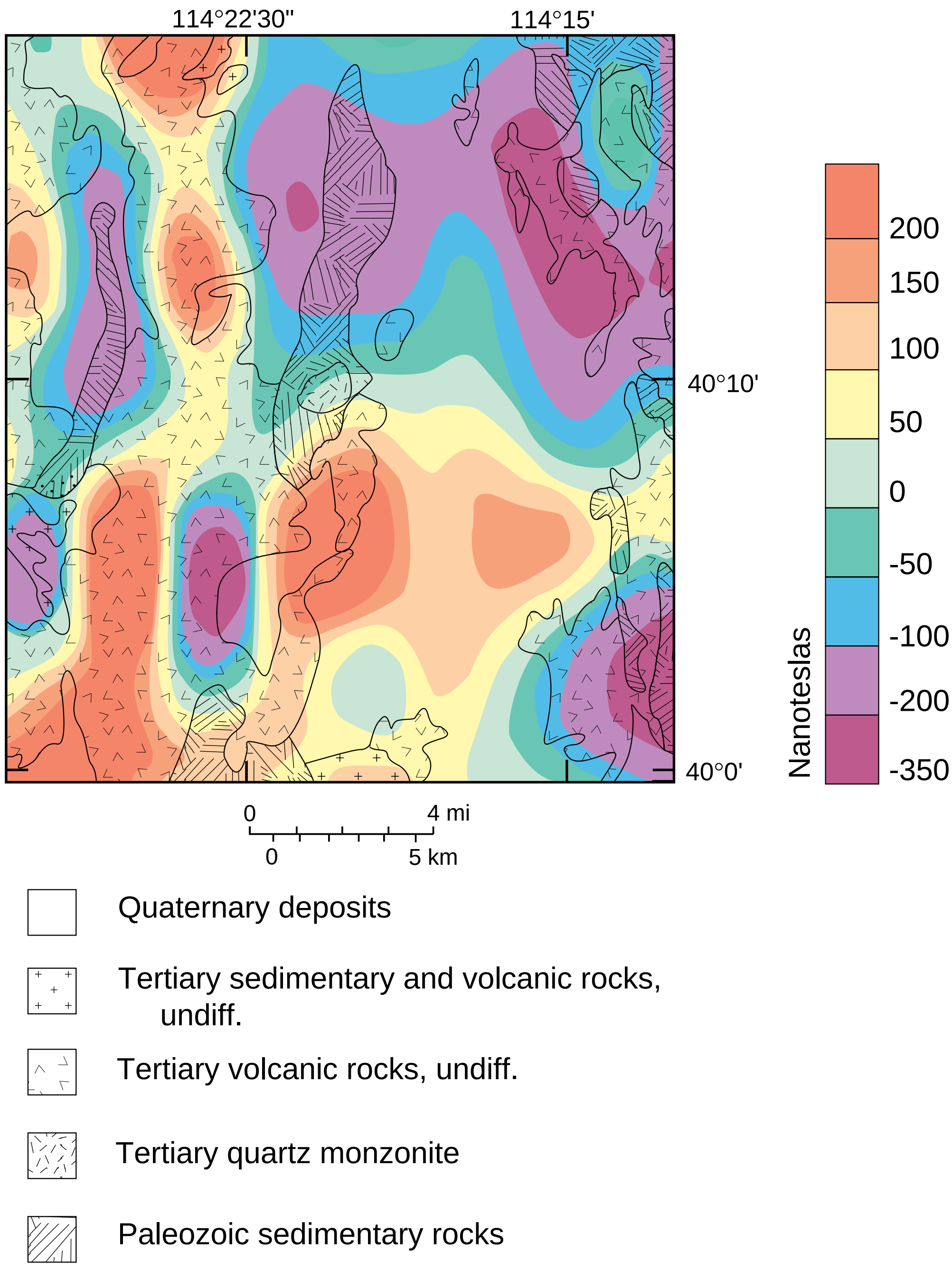

Figure 7-7. An example from the Kinsley Mountains (located on fig. 7-2) where magnetic effects of neighboring sources mask any signature of the mapped granitoid rocks. Moderate-magnitude magnetic highs and lows, shown in color, correspond to mapped volcanic rocks. The granitoid rocks are located just on the edge of a volcanic-related high anomaly and are not magnetic enough to deflect the shape of the anomaly. Geology generalized from Coats (1987) and Hose and others (1976).

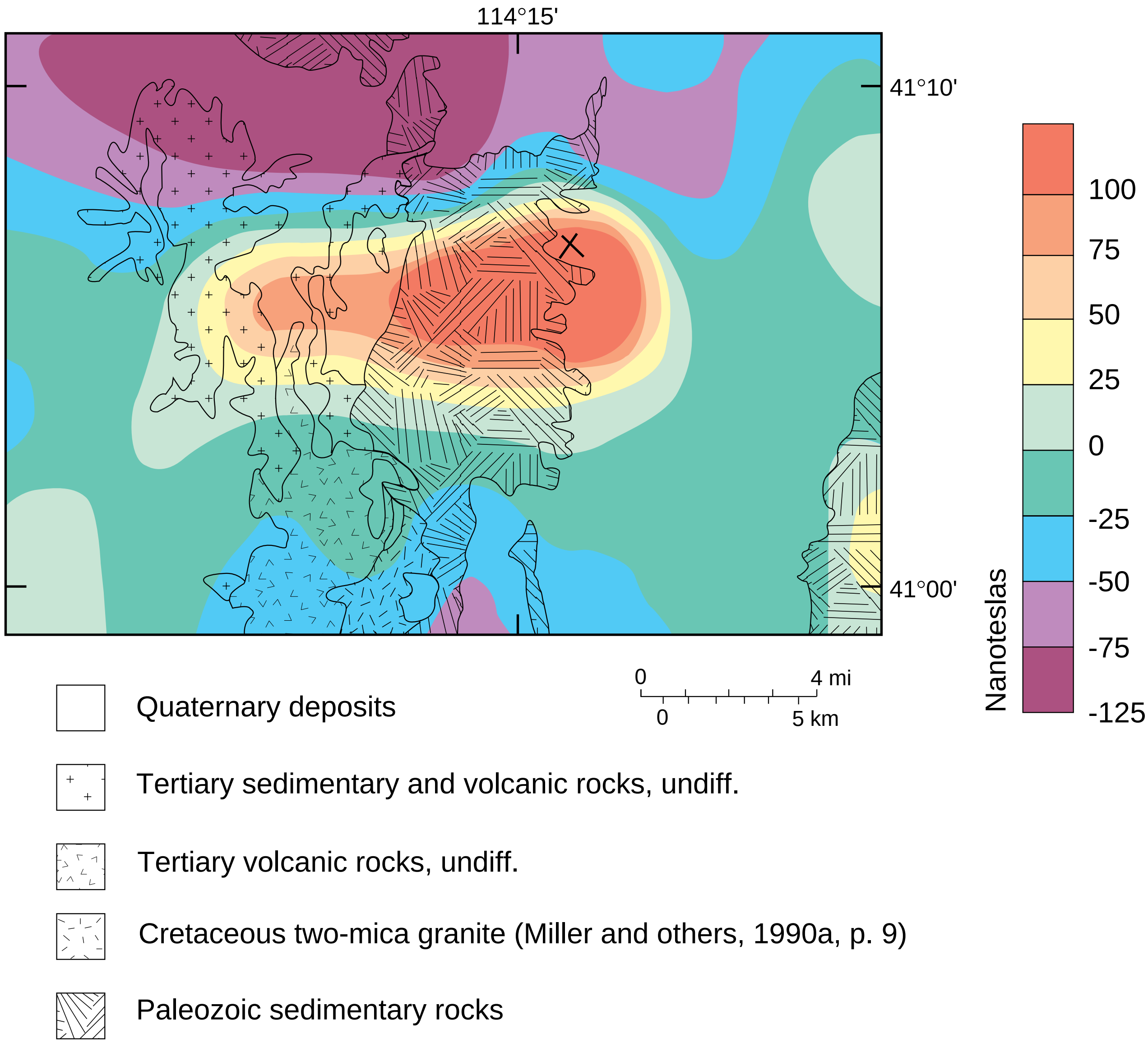

Figure 7-8. An example from the northern Toano Range (located on fig. 7-2), where a formerly speculative interpretation of a plutonic body in the absence of granitoid exposures was confirmed by new geologic mapping. The aeromagnetic high anomaly, shown in red, cannot be appropriately produced by any of the mapped rocks due to lack of correspondence to anomalies, rock type, and stratigraphic relations. Therefore, the source is probably a plutonic body. Small exposures of granodiorite, discovered at the spot marked with an X by Glick (1987), confirm the presence of a plutonic body. Its aeromagnetic signature suggests it is unrelated to mapped two-mica granite, which has a signature typical of weakly magnetic rocks, as expected from its lithology. Geology generalized from Coats (1987) except where noted.