U.S. GEOLOGICAL SURVEY

DEPARTMENT OF THE INTERIOR

GEOPHYSICAL DELINEATION OF GRANITIC PLUTONS IN NEVADA

by

V.J.S. Grauch[1], Richard J. Blakely[2], H. Richard Blank[1],
Howard W. Oliver[2], Donald Plouff[2], and David A. Ponce[2]
(co-authors listed alphabetically)

Open-File Report 88-11

1988

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards.

[1]U.S. Geological Survey, Box 25046, MS 964, Federal Center, Denver, CO 80225

[2]U.S. Geological Survey, MS 989, 345 Middlefield Rd., Menlo Park, CA 94025

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

PLATES

INTRODUCTION

This document reports the preliminary results of a study to map the lateral, near-surface extent of granitic plutons in Nevada using geologic, aeromagnetic, and gravimetric information. The study expands upon the inventory of granitic masses of Nevada compiled by Spengler and others (1979) by better defining the connections between isolated exposures of granitic rock, by estimating the subsurface limits of granitic bodies, and by identifying postulated, totally buried plutons.

The delineation of granitic plutons is part of a larger study undertaken at the request of the Bureau of Indian Affairs to evaluate the gold resource potential of Indian lands in Nevada. Granitic rocks are important in the resource evaluation because of their spatial association with disseminated gold deposits (Tooker, 1985). Granitic intrusions may have provided the heat or magmatic fluids that were involved in gold concentration. Other reasons for the spatial association are unclear, such as in places where mineralization is younger than the intrusion (at the Gold Strike deposit in north-central Nevada, for example).

Plutons were delineated primarily from an interpretative product of regional aeromagnetic data that estimates the locations of steep, shallow magnetization boundaries. These boundaries commonly occur at pluton edges and occasionally within plutons, but are associated with structural features, mafic igneous bodies, and volcanic rocks as well. Pluton edges were inferred by comparing magnetization boundaries to gravity, aeromagnetic, and geologic maps. At this stage of study, neither modeling nor field investigations were attempted in order to resolve uncertainties in pluton delineation.

SOURCES OF DATA

Aeromagnetic data used in pluton delineation were from Kucks and Hildenbrand (1987), which is a compilation of available data sets for the state of Nevada. Their compilation procedure merged many disparate surveys together to produce one consistent data set that approximates a survey flown 1000 feet above the ground across the entire state.

Gravity data used for this study were from a compilation by R. W. Saltus (U. S. Geological Survey, written communication, 1986), who removed a regional field from the data based on an Airy-Heiskanen isostatic model. Removal of a regional field aids interpretation of local features.

Mapped granitic rocks (Plate 1) were compiled primarily from Stewart and Carlson (1978), using their generalized map units, ages, and symbols. Spengler and others (1979) provided additional information in southern Nevada. Although published and unpublished geologic data are available that could improve Plate 1, it is beyond the scope of this study to synthesize this information.

DEFINITION OF GRANITIC PLUTONS

We adopted the classification of granitic rocks set forth by Spengler and others (1979). They restrict the definition of granitic rock to

> holocrystalline, quartz-bearing plutonic rock...ranging in composition from granite to diorite.... Textural characteristics are broadly defined as equigranular and porphyritic granular. Equigranular applies to rocks whose essential mineral constitutents are all of one order of size. Porphyritic granular refers to rocks in which one or more minerals are set in a finer crystalline groundmass. (p. 1)

Rocks classified as hypabyssal igneous bodies, rhyolitic intrusions, or gneiss by Stewart and Carlson (1978) or Spengler and others (1979) are not shown on Plate 1.

Plutons are defined as coherent bodies of igneous rock that have consolidated beneath the surface of the Earth. In this report, "pluton edge" refers roughly to the greatest lateral extent of a pluton in plan view. This concept will be discussed in more detail in the next section. Many of the inferred pluton boundaries on Plate 1 encompass exposures of different rock types or ages within one pluton. The discrepancies may be due to inadequate geologic or age data, or to multiple stages of magmatism that cannot be distinguished geophysically.

MAGNETIZATION BOUNDARIES

Plutons are complicated, three-dimensional bodies that probably do not have simple, geometric edges. Pluton edges are defined as the largest horizontal perimeter determined by magnetization boundaries that encompasses a plutonic body. A magnetization boundary is calculated by the horizontal-gradient method of Cordell and Grauch (1985) for aeromagnetic data.

The horizontal-gradient method is based on the mathematical properties of magnetic intensities over simple, vertical boundaries between homogeneous materials having contrasting magnetic properties. The technique locates the surface projection of these boundaries. For complicated boundaries, such as those that define the extent of a magnetic pluton, the results of the horizontal-gradient method are not easy to predict. The method is most sensitive to the parts of magnetic bodies closest to the surface and to steep sides (figure 1). In addition, for bodies with sloping sides, the deeper the top of the body, the more distant are the boundaries from the farthest subsurface extent of the body (figure 2; Blakely and Simpson, 1986). However, these problems are diminished at regional scales, such as the scale used in this study (Grauch and Cordell, 1987).

More serious problems with using the method to delineate plutons arise from variable magnetization within a pluton, which produces multiple,

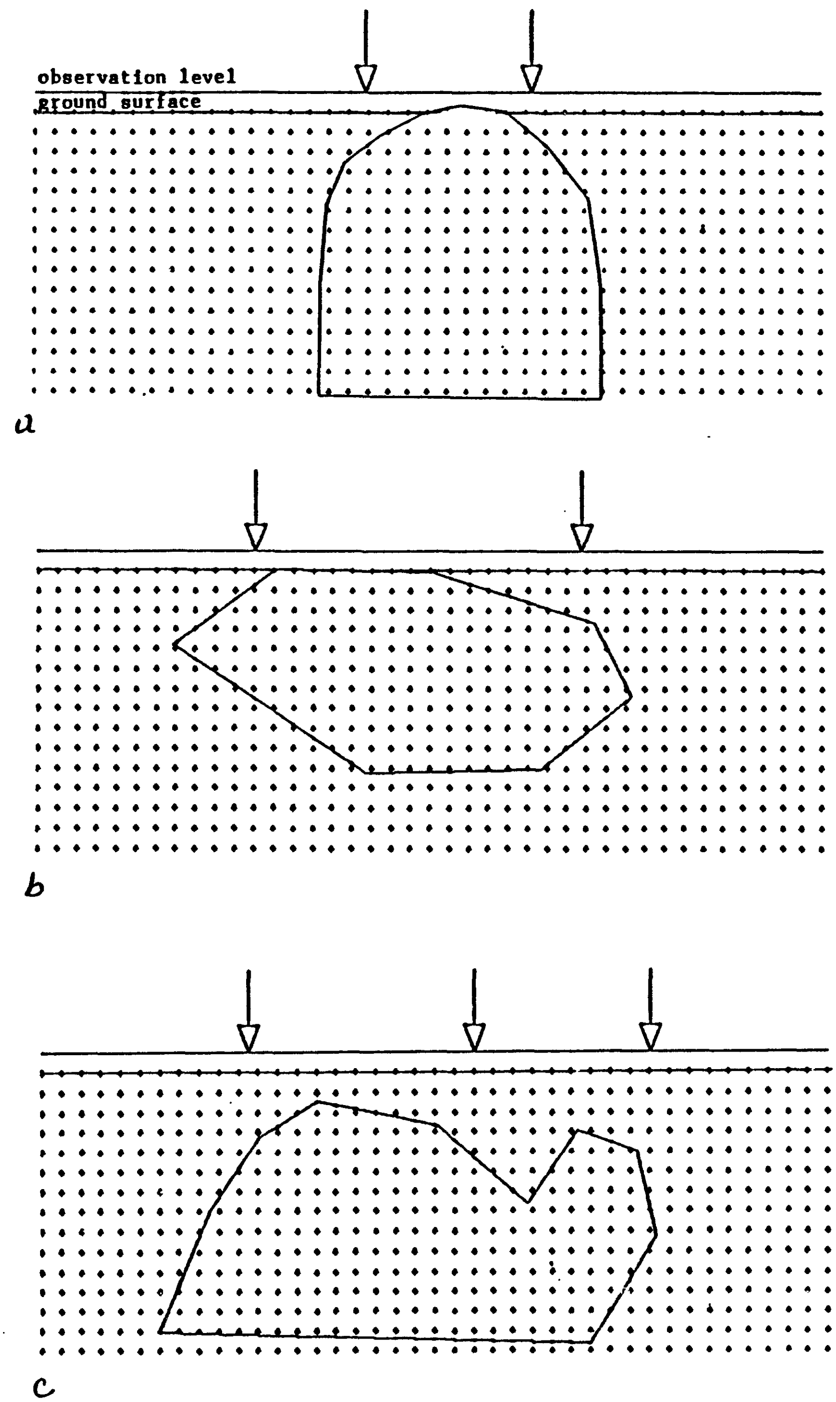

Fig. 1 -- Various two-dimensional shapes that simulate plutons and the points where magnetization boundaries, or pluton edges, would be determined (arrows). Note that boundaries are sensitive to the shallowest parts of the bodies and to steep slopes. In (c), a boundary occurs within the pluton.

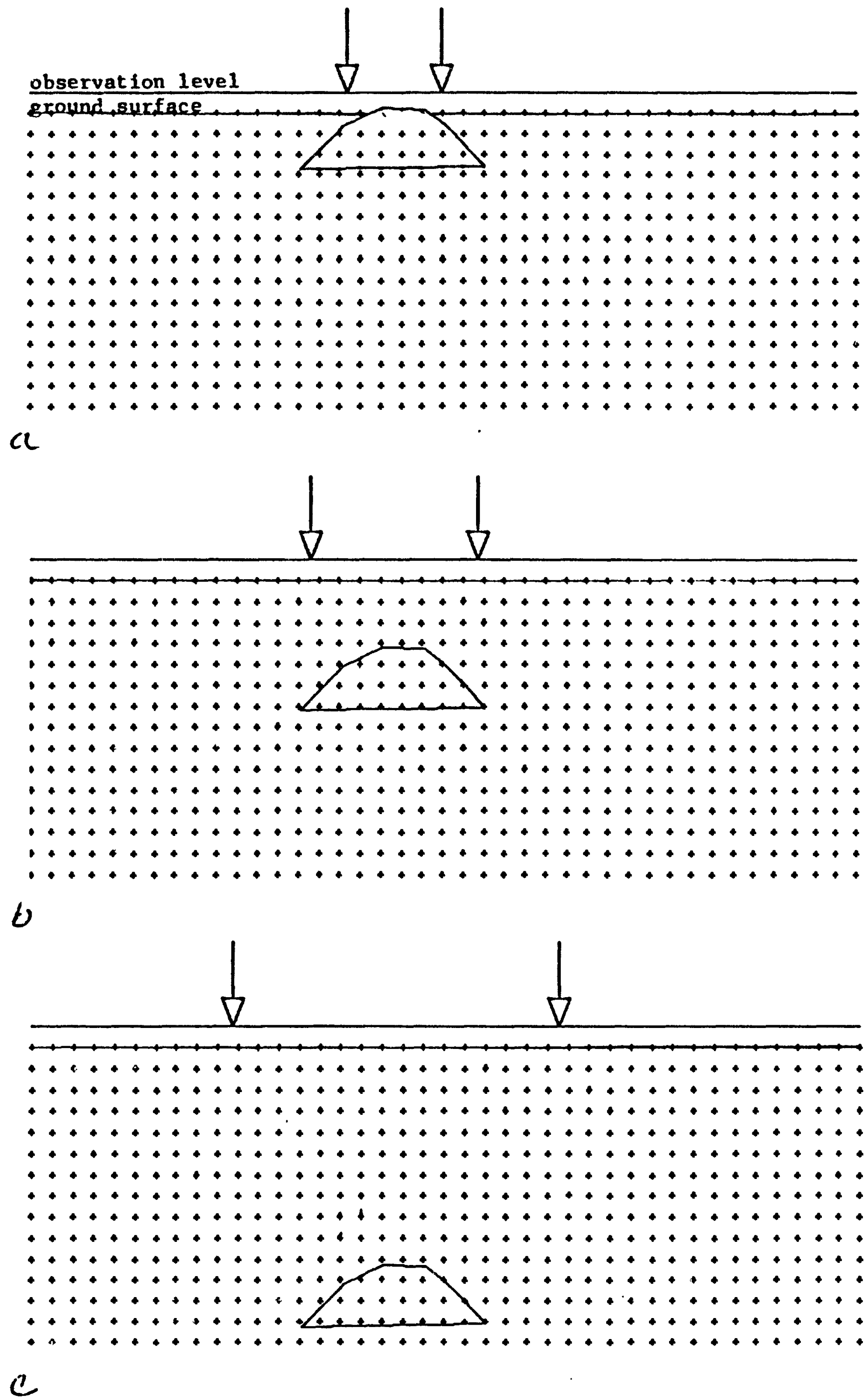

Fig. 2 -- An illustration of the effect of the depth of a pluton on the determination of pluton edges. A two-dimensional body simulating a laccolith, with its edges determined by magnetization boundaries (arrows), is shown at progressively deeper levels. Note that the arrows are farther from the body when the body is deeper.

complicated magnetization boundary patterns; and interference from the magnetic effect of proximate bodies, such as volcanic rocks, which can mask the effect of the pluton. In these problem areas, the original aeromagnetic data, gravity data, and geologic maps can help resolve pluton boundaries.

Magnetization boundaries were derived from regional aeromagnetic data for the state of Nevada (Plate 2) using an automated version of the horizontal-gradient method (Blakely and Simpson, 1986). For ease of computation, the boundaries are represented by a series of points rather than lines. The points are located by circles on Plate 2. Isolated points indicate spurious information or magnetization boundaries that are hard to resolve. Commonly, magnetization boundaries only partly encircle magnetic bodies. This problem may be related to the size of the sample grid interval, the magnetic properties of the body, and dip of the body at depth (Grauch and Cordell, 1986).

DESIGNATION OF INFERRED PLUTONS

The granitic plutons inferred for Nevada are shaded in Plate 1. Each inferred pluton was interpreted in different ways from the magnetization boundaries, the mapped granitic rocks, and aeromagnetic, gravity, and geologic maps. Some interpretations involved subjectivity.

Each inferred pluton is coded based on the confidence of its outline and its correlation with mapped granitic rocks. Solid lines along magnetization boundaries indicate confidence that the outline represents the pluton edge, although confidence is somewhat lower where there are many magnetization boundaries in one area. Plutons delineated by dashed lines are approximately located, based on either magnetic data, gravity data, or both. Dotted lines represent pluton edges that cannot be constrained by geophysical data. Most of these lines enclose mapped granitic rocks that have no geophysical anomaly in the regional data or their expression is masked by anomalies from other sources.

The inferred plutons are shaded differently based on their correlation with mapped granitic rocks (Plate 1). The criteria used for classification into five different categories are shown in Table 1.

SUMMARY AND RECOMMENDATIONS

Partially and wholly buried granitic plutons, which are commonly associated with disseminated gold deposits, were mapped within Nevada in order to help evaluate the gold resource potential of Indian Lands in the state. Their shallow lateral limits were delineated by applying a mathematical technique to regional aeromagnetic data and by comparing these results with gravity, aeromagnetic, and geologic maps. The technique estimates the locations of steep, shallow magnetization boundaries which generally occur at pluton edges.

The resulting map for Nevada shows inferred granitic plutons classified according to geophysical resolution of their boundaries and correlation with

TABLE 1. CRITERIA USED FOR CLASSIFICATION OF INFERRED PLUTONS

Classification	Criteria
Geophysical (especially aeromagnetic) expression of inferred pluton is clearly related to mapped granitic rocks.	Geophysical anomalies closely mimic the pattern of mapped rocks.
Geophysical (especially aeromagnetic) expression of inferred pluton is probably related to mapped granitic rocks.	The geophysical anomalies roughly mimic the pattern of mapped rocks and the source of these anomalies is not certain.
No geophysical expression of mapped granitic rocks.	Either no geophysical anomalies exist in the area or any pluton anomaly, if present, is masked by the effects of neighboring magnetic bodies.
Geophysical anomalies and mapped granitic rocks present ambiguous or contradictory information that cannot be resolved.	Either geophysical anomalies are not consistent over one mapped rock type, the source of the anomalies (and thus the rock type of the inferred pluton) cannot be resolved from various mapped units within the outline, or other evidence suggests that the source of the anomalies is not represented by the exposed granitic rocks.
No mapped granitic rocks are associated with the geophysical expression of the inferred pluton.	There is no evidence that the magnetic body outlined is granitic or plutonic, although the geophysical expression is similar to that over mapped granitic rocks elsewhere.

mapped granitic rocks. Some of the inferred plutons display good correlation with mapped rocks, some occur where no granitic rocks are exposed, and some mapped granitic rocks could not be discriminated geophysically.

The inferred plutons may be used as a guide to areas permissive for gold deposits. However, a better understanding of the relationship between plutons and gold requires two further studies: (1) A comparison between known gold deposits and their associated granitic rocks to determine what age and rock type is most commonly indicative of gold, and (2) better geophysical determination of the subsurface configuration of plutons in order to examine the relationship of pluton morphology to known gold deposits. The first study requires good age and petrologic data for mapped granitic rocks (lacking in many places) and a comprehensive compilation of gold-deposit data, including accurate locations and a classification scheme of their attributes. The second study requires detailed aeromagnetic and gravity data (unavailable for most areas), physical-property and petrologic studies of selected granitic rocks, and computer modeling.

ACKNOWLEDGMENTS

Many at the U. S. Geological Survey who are currently working on various projects in Nevada were consulted during the course of this study. Bob Jachens deserves special mention for his input on southernmost Nevada.

REFERENCES CITED

Blakely, R. J., and Simpson, R. W., 1986, Locating edges of source bodies from magnetic or gravity anomalies: Geophysics, v. 51, p. 1494-1498.

Cordell, L., and Grauch, V. J. S., 1985, Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico, in Hinze, W. J., ed., The Utility of Regional Gravity and Magnetic Anomaly Maps: Soc. Explor. Geophys., p. 181-197.

Grauch, V. J. S., and Cordell, L., 1987, Limitations of determining density or magnetic boundaries from the horizontal gradient of gravity or pseudogravity data: Geophysics, v. 52, no. 1, p. 118-121.

Kucks, R. P., and Hildenbrand, T. G., 1987, Description of magnetic tape containing Nevada State magnetic anomaly data: EROS Data Center, Serial number D87-270.

Spengler, R. W., Maldonado, Florian, Weir, J. E., Jr., Hanna, W. F., and Dixon, G. L., 1979, Inventory of granitic masses in the State of Nevada: U.S. Geological Survey Open-File Report 79-235, 264 pp.

Stewart, J. H., and Carlson, J. E., 1978, Geologic map of Nevada: U.S. Geological Survey Geologic Map of Nevada, scale 1:500,000.

Tooker, E. W., 1985, Discussion of the disseminated-gold-ore-occurrence model: U.S. Geological Survey Bull. 1646, p. 107-150.