DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP MF-902

AEROMAGNETIC MAP OF NEVADA*

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INTRODUCTION

The 1:500,000 scale aeromagnetic map of Nevada (sheets 1 and 2) is a compilation of previously published or open-file maps. The direction, altitude, and flight spacing for any area may be obtained by consulting the index map. Significantly, the entire state was flown at a flight-line spacing of 8 km or less with an average spacing of approximately one mile.

The publication scale of the aeromagnetic map was specifically chosen to match that of the state geologic map. In this way, the magnetic anomalies can be compared directly with rock types exposed at the surface.

The purpose of this text is to describe the geologic significance of the aeromagnetic map and to point out major geologic features, many previously unrecognized, that it reveals.

The geology of Nevada is complex and records a history extending from the Precambrian to the Holocene. Rocks from the X, Y, and Z subdivisions of the Precambrian and from every system of the Paleozoic, Mesozoic, and Cenozoic are exposed (Stewart and Carlson, 1974).

Precambrian crystalline basement rocks, ranging in age from about 1,740 to 1,450 m.y., crop out in the southern part of the state. During the latest Precambrian and extending into the Mesozoic, the state was the site of the Cordilleran geosyncline (Roberts, 1968; Stewart and Poole, 1974). Deposition in the geosyncline was interrupted by two major orogenic events, one during the Late Devonian and Early Mississippian (the Antler orogeny), and one during the Late Permian and Early Triassic (the Sonoma orogeny) (Roberts and others, 1958; Burchfiel and Davis, 1972, 1975; Silberling, 1973). Starting in the Late Triassic and culminating in the Cretaceous, large granitic bodies were emplaced in western Nevada and locally elsewhere in Nevada. During the Sevier orogeny in the Cretaceous, major thrust faults developed in eastern Nevada, but most of the state was relatively high and in the hinterland west of this orogenic belt (Armstrong, 1968). Few events of Cenozoic age older than 43 m.y. are recorded in Nevada. Between 43 and 17 m.y. ago, igneous activity was widespread and consisted primarily of the extrusion of intermediate to silicic calc-alkaline lava flows and ash flow tuffs (Lipman and others, 1972; McKee, 1971; Noble, 1972). Subsequent to about 17 m.y. ago, basaltic rocks are abundant and apparently related to extensional tectonics that led to the development of basin and range structure in the late Cenozoic (Christiansen and Lipman, 1972).

GENERAL CHARACTER OF THE AEROMAGNETIC MAP

The aeromagnetic map of Nevada displays complex patterns of magnetic intensity that are difficult to characterize and analyze. Some linear anomalies are clearly evident, and a few can be related to well-defined geologic features. Other anomalies may be linear, but are not clearly so, and many of these are difficult to relate to known geologic trends. Other anomalies may define crudely circular patterns, but few of these can be related to known geologic features.

Some gross patterns of aeromagnetic anomalies are evident on the map. These include: (1) the greater abundance of magnetic highs in the western two-thirds of Nevada in comparison with the eastern third; (2) a concentration of arcuate east-west or west-northwest-trending positive anomalies in western Nevada between approximately latitude 36°30'N and 39°30'N; (3) a conspicuous north-northwest-trending positive anomaly between longitude 116° and 117° in north-central and northern Nevada; and (4) the general lack of positive anomalies in a north-south zone (the "quiet zone") near longitude 115° (fig. 1).

In order to analyze these and other patterns of magnetic anomalies in Nevada, we have tried to identify the source of each of the areas of high magnetic intensity (fig. 1) by direct comparison of the aeromagnetic map with geologic maps, by extrapolation from outcrops into the subsurface, or by the general character of the anomaly. The magnetic source rocks are divisible into five principal categories: (1) Precambrian metamorphic and intrusive rocks; (2) Mesozoic gabbroic rocks; (3) Mesozoic granitic rocks; (4) Tertiary calc-alkaline volcanic and intrusive rocks; and (5) Cenozoic basalt and related rocks. Singular identification of the magnetic source is not always possible, but the sources of half of the anomalies are positively identified, a quarter are identified with less certainty, and the remainder (identified with a question mark) are only tentatively identified. The distribution and geologic significance of the anomalies related to Tertiary calc-alkaline igneous rocks have been described previously (Stewart and others, 1976). A summary of the information concerning these calc-alkaline rocks and brief descriptions of the other magnetic source rocks are given below.

ANOMALIES RELATED TO PRECAMBRIAN METAMORPHIC AND INTRUSIVE ROCKS

Several major positive aeromagnetic anomalies are related to Precambrian metamorphic and intrusive rocks in southernmost Nevada (fig. 1). These anomalies are closely associated with outcrops of Precambrian crystalline rocks, the only exception being the anomaly centered in the Spring Mountains about 30 km west-southwest of Las Vegas. Cambrian to Jurassic carbonate and detrital rocks of presumed low magnetic susceptibility crop out in the area of the anomaly, and no large outcrops of intrusive rocks occur there. A Precambrian source rock for this anomaly is supported by (1) the low gradient of the magnetic contours, suggesting deep burial of the source rocks; (2) the continuation of the anomaly to the southeast into an area where Precambrian crystalline rocks crop out; and (3) the lack of any other probable source. The broad low-gradient anomalies related to Precambrian rocks in Nevada are similar to widely distributed anomalies related to similar sources in Utah (Case and Joesting, 1972; Stewart and others, 1976), where the Precambrian basement is probably exceedingly heterogeneous (Case and Joesting, 1972). A similar heterogeneity is indicated in Nevada by the great variation of magnetic intensity within a region probably everywhere underlain at depth by Precambrian crystalline rocks.

ANOMALIES RELATED TO MESOZOIC GABBROIC ROCKS

A large complex of Middle Jurassic gabbroic rock forms a lopolith in the central part of Churchill County in west-central Nevada (Willden and Speed, 1974). The lopolith is exposed in mountain ranges in an elliptical area about 65 km in a west-northwest direction and about 30 km at its widest place. Where the gabbroic rocks are exposed or near the surface, they are the source rocks of major positive aeromagnetic anomalies. The outline of the lopolith can also be traced in the subsurface on the basis of the aeromagnetic surveys (Smith, 1968; Wetterauer, 1972).

ANOMALIES RELATED TO MESOZOIC GRANITIC ROCKS

Granitic rocks, mostly quartz monzonite and granodiorite, are the source of many large aeromagnetic anomalies in Nevada. In most places, the location of the aeromagnetic anomaly and the outcrop of granitic rocks

*Prepared in cooperation with the Nevada Bureau of Mines and Geology

correspond closely. In other places, the outcrop of granitic rocks is small and the source of the magnetic anomaly less certain. The largest areas of aeromagnetic anomalies related to granitic rocks are in the western half of Nevada where outcrops of these rocks are widespread. Not all Mesozoic granitic masses in Nevada, however, produce conspicuous anomalies, and this may be because magnetization of these rocks was initially low, remanent magnetization is reversed, or the magnetization has been destroyed by hydrothermal or other types of alteration. Hydrothermal alteration appears to be the cause of the low magnetic intensity in granitic rocks in the Reese River mining district near Austin in southern Lander County (Davis and Stewart, 1970).

Other areas where large outcrops of Mesozoic granitic rocks do not produce major positive anomalies are: (1) 10-40 km north of Reno in western Washoe County; (2) the Shawave Mountains in western Pershing County; (3) 10-15 km west of the Seven Trough Range in western Pershing County; (4) the southern part of the Ruby Mountains; (5) the Kern Mountains in eastern White Pine County; (6) the southern Snake Range in eastern White Pine County; (7) parts of several plutons in western Mineral County and in Douglas and Lyon Counties; (8) parts of several plutons in western Esmeralda County; and (9) 10 km northeast of Manhattan in northern Nye County.

ANOMALIES RELATED TO TERTIARY CALC-ALKALINE IGNEOUS ROCKS

Anomalies inferred to be related to Tertiary calc-alkaline igneous rocks lie primarily between latitudes 37°N and 40°N. Anomalies in easternmost Nevada are the westward continuations of well-defined, east-west belts of aeromagnetic anomalies extending across western Utah (Stewart and others, 1976). These belts of aeromagnetic anomalies are terminated in Nevada by a north-south oriented zone of generally low magnetic relief and intensity (the "quiet zone") near longitude 115°W. West of the "quiet zone," anomalies related to calc-alkaline rocks are widespread, and, in part, occur in east-west belts that appear to be online with belts in eastern Nevada (Y-Z with A'-B', and G'-H' with I'-J').

Anomalies shown as related to Tertiary calc-alkaline rocks (fig. 1) generally occur in areas where Cenozoic intrusive rocks crop out, or can be inferred to be present at depth or in areas where Cenozoic andesitic rocks are widespread and thick. Conspicuous aeromagnetic anomalies, for example, occur over the Cactus Range in western Nye County, where both intrusive and andesitic rocks are abundant. In addition, a large aeromagnetic anomaly occurs in the area of the Timber Mountain-Oasis Valley caldera complex (Christiansen and others, 1976) in southern Nye County. The exact source of other anomalies attributed here to calc-alkaline rocks is not obvious. Many occur within large outcrop areas of ash flow tuff of presumed low magnetization, and the source of the anomaly in this case may be buried Cenozoic intrusive masses. Such an interpretation probably is not always correct, and some of these anomalies could be related instead to Mesozoic granitic rocks or to Cenozoic basaltic rocks.

ANOMALIES RELATED TO UPPER CENOZOIC BASALT AND RHYOLITE

Broad regions of northern Nevada are characterized by relatively closely spaced, high intensity positive magnetic anomalies. The style of these anomalies is similar to those in adjoining regions of southeastern Oregon and the Snake River Plain in Idaho (Eaton and others, 1975). All these areas are underlain by upper Cenozoic volcanic rocks containing abundant basalt, as well as rhyolite flows and ash-flow tuffs. Presumably, therefore, the source of the magnetic anomalies in these regions is related to the upper Cenozoic volcanic rocks or their feeder systems. In many areas, however, surface rocks are rhyolite units of presumed low magnetization or thin units of basalt that appear inadequate to produce the observed anomalies. In these areas, the anomaly is presumably caused by buried upper Cenozoic intrusive bodies.

The source rocks of the linear anomaly trending southeast in northern Nevada (the Oregon-Nevada lineament, G-H, fig. 1) can be clearly identified as basaltic and rhyolitic flow and intrusive rocks, ranging in age from 13.8 to 16.3 m.y. (Stewart and others, 1975).

QUIET ZONE

A north-south-oriented zone of generally low magnetic relief and intensity extends through Nevada near longitude 115°, and has been referred to as the "quiet zone" (Stewart and others, 1976). The areas of moderate relief near latitude 38° are more or less online with similar-appearing areas to the east and west, suggesting a near continuity of east-west aligned magnetic highs across this part of Nevada (Y-Z and A'-B', fig. 1).

A north-south-trending area of unusually low relief about 25 km wide occurs within the quiet zone between latitude 36°45' and 38°15'. This area is marked by a relatively straight north-south-trending band of low magnetic intensity along part of the western margin between latitude 37°42' and 38°08'.

The quiet zone is probably best explained as an area of relatively high heat flow where the Curie temperature is at a relatively shallow depth. Aeromagnetic anomalies, both to the east and west of the quiet zone, are produced primarily by Cenozoic igneous rocks (fig. 1), and similar rocks appear to be just as abundant within the zone as outside of it. The only area where igneous rocks are less widespread in the zone than outside is near latitude 37°, near the southernmost part of the zone. Here, the distribution of 6 to 17 m.y. old volcanic rocks is notably less than to the east or west outside of the zone. The occurrence of igneous rocks within the zone and their relatively low magnetic intensity suggest the possibility that a shallow Curie depth has caused the obliteration of the lower part of magnetic bodies. Such an interpretation explains why moderate magnetic relief occurs in the area, and yet magnetic intensity is low. The north-south-trending area of unusually low magnetic relief within the quiet zone between latitude 36°45' and 38°15' is more difficult to explain, but may be due to an even shallower Curie depth.

G. P. Eaton (oral commun., 1976) has recently noted that regional topography and gravity anomalies in the Basin and Range province in the Great Basin is bilaterally symmetrical about an axial ridge lying between 115° and 116°, and that the quiet zone lies along this axis of symmetry. He has suggested that the axis is a zone of crystal spreading related to mantle upwelling. Such an interpretation would explain the shallow Curie depth. If this interpretation is correct, the zone of crystal spreading apparently developed after 17 m.y., because Cenozoic igneous rocks older than 17 m.y. are not spatially related to the quiet zone. The magnetic intensity of rocks older than 17 m.y. within the quiet zone is less than elsewhere, but this can be attributed to destruction of magnetization due to the late Cenozoic heat flow. Igneous rocks younger than 17 m.y., on the other hand, are sparse in the quiet zone. This inverse spatial relationship suggests that spreading and high heat flow somehow inhibited volcanism. Apparently, heat flow associated with this event was high because of the relatively shallow Curie depth, but spreading was minor because no surface volcanic activity is recorded. The events that led to the development of the quiet zone appear to be related to a regional pattern of Late Cenozoic extension that is well documented in the western United States (Christiansen and Lipman, 1972; McKee, 1971; Stewart, 1971).

LINEAR TRENDS

Individual anomalies that are elongated in one direction, or groups of anomalies that are aligned, produce strong linear patterns locally in Nevada (fig. 1). Some of these linear patterns are clearly evident, whereas others are vague alignments of anomalies, and are of uncertain significance. In eastern and western Nevada, many of the linear patterns are oriented approximately east-west, whereas in northern Nevada, several are oriented north-northwest.

The origin of the east-west patterns is not obvious, but in part, they apparently represent zones of weakness in the crust, along which intrusive masses were emplaced. The east-west trends of positive anomalies in northernmost Nevada (A-B, C-D, E-F) correspond in part with the east-west trend of Jurassic and Cretaceous plutons in that part of Nevada (Coats and McKee, 1972). Other east-west trends of positive anomalies apparently related to Mesozoic granitic rocks include the following: (1) Q-R in eastern Nevada, and (2) part of S-T, almost all of U-V and W-X, part of Y-Z, part of C'-D', all of E'-F', and part of G'-H', all in western Nevada. The remaining parts of these anomalies and other east-west positive anomalies in western and eastern Nevada apparently are related to Cenozoic calc-alkaline igneous rocks. Within several incremental age intervals, Cenozoic igneous rocks in Nevada and Utah occur in east-west-trending belts (Stewart and others, 1976), and the trends of the anomalies are apparently related to the pattern of eruption of these rocks. In part, at least, the east-west zones of weakness in the crust may have localized the emplacement of both Mesozoic and Cenozoic intrusive rocks.

The alignments of some anomalies in western Nevada are somewhat arcuate or even slightly sigmoidal (Stewart and others, 1976). These occur in the Walker Lane, a northwest-trending area of right-lateral shear and large-scale drag. The magnetic trends may have been linear originally and the arcuate pattern imposed by later tectonic distortion or, in part at least, some igneous activity may have followed the structural grain of older rocks, previously distorted by right-lateral shear.

Negative aeromagnetic anomalies also occur along east-west linear trends in Nevada (M-N, O-P, fig. 1). Most of these are on the north sides of the positive anomalies and represent the negative parts of paired positive-negative anomalies expectable in the northern hemisphere. In addition, two indefinite and isolated east-west alignments of negative anomalies are shown on figure 1 in northern and central Nevada. If these two negative trends are meaningful, then the rocks here either must have been weakly magnetized originally, perhaps because of a low iron content, or the magnetization was later destroyed, perhaps by hydrothermal or other types of alteration.

Three north-northwest linear anomalies are shown on figure 1 in northern Nevada (G-H, I-J, K-L). The easternmost of these is well defined and related to intrusive and extrusive igneous rocks, ranging in age from 13.8 to 16.3 m.y. along the Oregon-Nevada lineament (Stewart and others, 1975). The western two are poorly defined, and appear to be related mainly to Mesozoic intrusive rocks.

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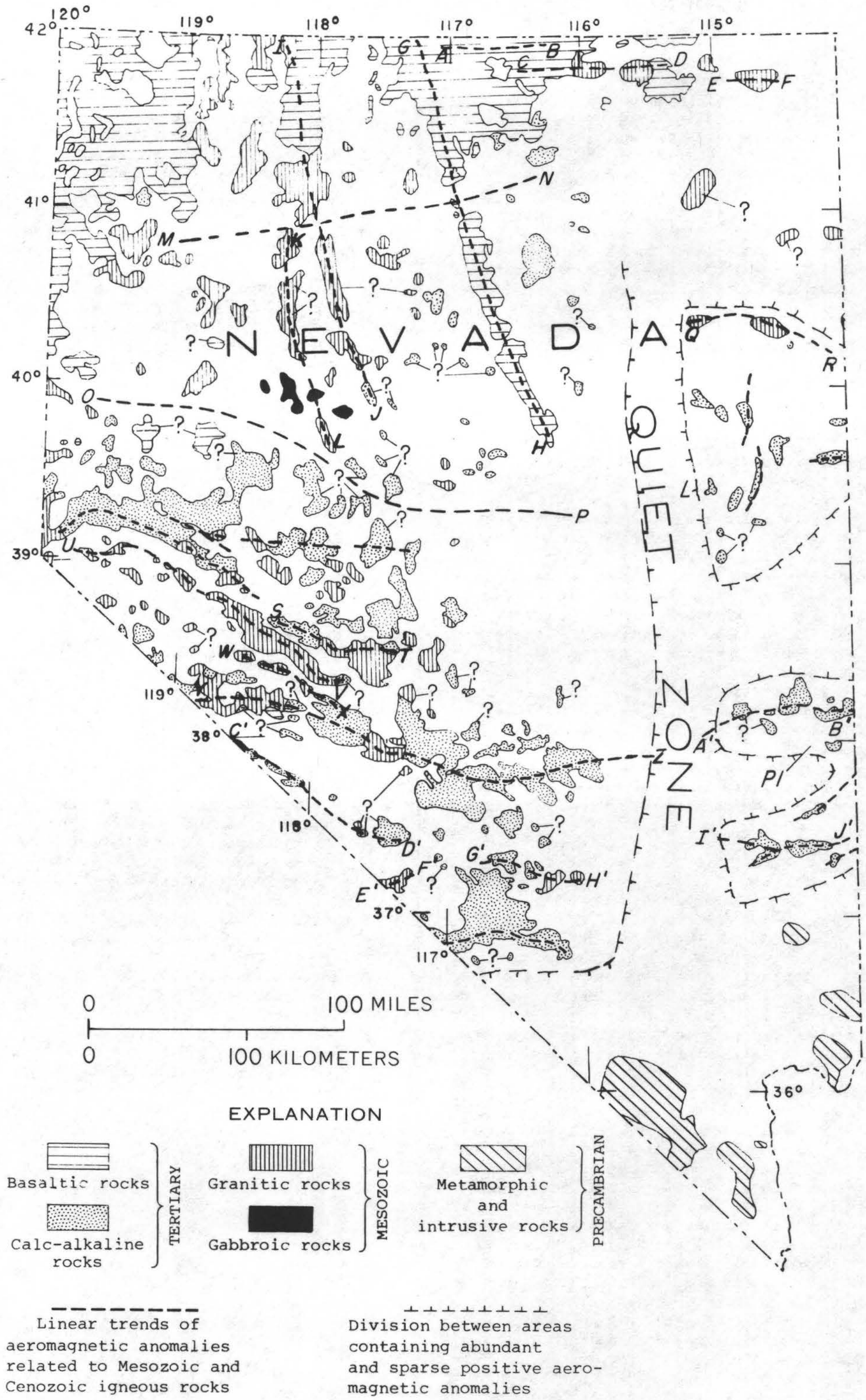

Figure 1.--Index map showing interpreted sources of magnetic highs

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