Principal facts and preliminary interpretation
for gravity profiles and continuous magnetometer profiles
in Surprise Valley, California

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards

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Introduction

These geophysical data were collected in order to investigate faults and thickness of alluvium near hot spring areas in the Surprise Valley area of northeastern California. Surprise Valley lies on the western edge of the Basin and Range province and appears to be a typical basin in a north-trending block-faulted structure. It is flanked on the west by the Warner Range, a westerly dipping block of Tertiary sediments and volcanic rocks and on the east (along the California-Nevada border) by the Hays Canyon Range, composed of similar rocks. Surprise Valley has no outlet and within the valley are three shallow alkali lakes, Lower, Middle, and Upper Alkali Lakes.

Simple Bouguer gravity anomaly values are reported here for 191 gravity stations in the Surprise Valley area. The stations are located between 41°35' and 41°42' north latitude and between 120°00' and 120°15' west longitude. The data provide six gravity profiles (Figs. 1 to 6) the location of which is shown in Fig. 7. In addition there is a gravity map of Surprise Valley, scale 1:62,500, by J. Gimlett (Fig. 8, sheets 1 and 2). This gravity map is part of an unpublished report and is available from the California Department of Water Resources at a scale of 1:31,250.

The magnetic data consist of 12 magnetic profiles (Figs. 9-13) collected with a continuously recording truck-mounted magnetometer. An index map (Fig. 14) shows the location of the profiles, which were collected in the general vicinity of the gravity profiles.
Gravity data

The gravity data were collected with LaCoste-Romberg Meter 130 along roads at a station spacing of 100-200 m. Elevations were surveyed with an alidade and are accurate to ±0.7 m absolute and to ±0.03 m relative to adjacent stations. The datum for each profile is a bench mark or spot elevation on the profile. Local terrain corrections relative to adjacent stations are negligible so that relative accuracy of adjacent stations is about ±0.03 mgal. The stations are referenced to the Alturas Base Station 14 of Chapman (1966, p. 18).

Gravity data format

The principal facts for all 191 gravity stations are listed in table 1. Each data column is described below.

1. **STATION column** - An alphanumeric combination of up to 5 characters used for station identification.

2. **LATITUDE and LONGITUDE columns** - Values are listed in degrees and minutes to the nearest hundredth of a minute. These values were determined from U.S. Geological Survey topographic quadrangle maps at a scale of 1:24,000. Values were checked for errors by obtaining a computer plot of the stations and comparing this to the hand-plotted stations.

3. **ELEV. column** - The station elevation is in feet to the nearest tenth.

4. **OBSV. GRAV. column** - Each station's observed gravity value is reported to the nearest hundredth of a milligal.

5. **THEO-GRAV column** - The theoretical gravity value for each station is determined by the formulae given under number 6.
6. **FAA column** - The free air gravity anomaly values for each station are listed to the nearest hundredth of a milligal. The formula used in calculating these values is:

\[
FAA = O.G - T.G + (0.09411549 - 0.000137789 \sin^2 \theta)E - 0.0000000067E^2
\]

where FAA is the free air anomaly in milligals

O.G. is the observed gravity in milligals

T.G. is the theoretical gravity in milligals

obtained by the International Gravity Formula of 1950

\[
T.G = 978049[1 + 0.0052884 \sin^2 \theta - 0.0000059 \sin^2(2\theta)]
\]

\( \theta \) is latitude

E is elevation in feet.

7. **BA1 column** - The listed simple Bouguer anomaly values were determined to the nearest hundredth of a milligal for a crustal density of 2.67 g/cm³ according to the formula:

\[
BA1 = FAA - 0.12774 \times 2.67E
\]

8. The remaining columns (CC, TC, CBA1, CBA2) relate to the calculation of terrain corrections and therefore are irrelevant to this report, being artifacts of the computer program.

**Preliminary gravity interpretation**

After reduction to simple Bouguer anomalies, the gravity profiles provide us with information on the distribution of rock masses with various densities beneath the surface. The steep gravity gradient down to the east in the profiles on the west side of the valley is the result of the large thick mass of low-density valley fill in the center of Surprise Valley. Superimposed on this gradient are various smaller features of geologic
significance. Inflection points are likely to be the location of concealed faults and such features are identified on the profiles.

Of considerable interest are the small gravity highs (0.5 mgal) associated with faults on profiles 1, 2, and 3 (Fig. 1, 2, and 3, respectively). The phrase, "FAULT(?)", indicates a fault deduced from the gravity profile. The features are only 500 to 1000 feet (150 to 300 m) wide and, because of their small width and narrow marginal gradients, must be caused by density differences within 300 to 500 feet (100 to 150 m) of the surface. The association of these anomalies exclusively with faults containing hot waters suggests that the high are caused by partial cementation of the alluvium at the faults which increases the alluvium density by filling some of the pore space with silica or calcium carbonate. The results indicate that in some areas detailed gravity profiles can be used to follow faults through areas of thick alluvium if there are hot saline waters depositing material in the pore space of the alluvium.

Also noted on the gravity profiles are faults taken from plate 21 of Bulletin 98 of the California Department of Water Resources (1963). Some of these faults have no expression on the gravity profiles and must be either very minor or nonexistent. On profile 2 (Fig. 2) at Lake City the Surprise Valley Fault is crossed without even an inflection of 0.1 mgal. Vertical offset of only 100 feet (30 m) in a shallow concealed fault at this location would cause an effect of at least 0.6 mgal (for density contrast of 0.5 g/cm$^3$) so that the fault cannot exist here.
Conclusions

1. Small gravity highs are associated with faults containing hot saline water and are probably caused by local density increase due to cementation of alluvium.

2. Such gravity highs may be useful guides to hot saline water circulating in areas of thick alluvium.

3. Small gravity highs over the Lake City fault in the center of the valley suggest that the fault contains hot saline water and that the fault acts as a connection between the hot spring areas on the east and west sides of the valley.

4. Inflection points on gravity profiles confirm the existence of previously deduced faults.

5. Lack of inflection points on certain gravity profiles deny the existence of previously deduced faults, especially the Surprise Valley Fault near Lake City.

Gravity map

The gravity map, Fig. 8, sheets 1 and 2, was surveyed by J. I. Gimlett for the California Department of Water Resources in 1960 and is unpublished. Details of the survey are described in Bulletin 98, California Department of Water Resources (1963). The data are simple Bouguer anomalies but the lack of terrain corrections is not particularly important because much of Surprise Valley is extremely level. Gimlett calculated various two-dimensional gravity profiles across the valley in order to locate concealed faults and to determine the depth of the valley fill. Geologic cross-sections based upon these calculated profiles were published in
Bulletin 98 as figures 20 and 21. A manuscript basement contour map was prepared by Gimlett but is not available at present from the California Division of Water Resources, although the inferred faults are shown in plate 21 of Bulletin 98, California Department of Water Resources (1963).

Magnetic profiles

The magnetic profiles were collected along roads by a continuously recording truck-mounted flux-gate magnetometer mounted approximately 13 ft (4 m) above the ground. The data tapes are photographically reduced to a scale of approximately 1:70,500 so that they may be compared easily with the traverse map Fig. 14 (scale 1:62,500). Full scale on the tapes (i.e., from 1 to 11) is 2000 gammas. Location points are the hand-numbered tic marks on the pen tracing along the top of the tapes and are also plotted on the traverse map.

Occasional datum shifts on the magnetic profiles are necessary in order that the recorder stay on scale and are indicated on the records by a four-digit push-button setting (pbs) number. The first digit refers to the number of 2000-gamma increments which have been added to the basic instrument datum level (48,4000 gammas); the second digit refers to the number of 400-gamma increments; the third digit refers to the number of 100-gamma increments; and the fourth digit refers to the number of 20-gamma increments. The sum of the four products (increment value times number of increments) added to the basic instrument datum (48,400 gammas) gives the approximate absolute value of the earth's field when added in turn to the reading on the tape trace.
The magnetic records, in addition to the magnetic effects of nearby rocks, document a variety of man-made magnetic anomalies. Anomalies of the latter type include culverts, bridges, vehicles, certain fences, water pipes, etc. In general such anomalies are distinguished as a very sharp, short-wavelength spike which may be positive or negative depending on the relative locations of source and magnetometer. The instrument operator crossed out or flagged most of these man-made features on the record, at the time of the magnetic survey, but man-made effects can totally obscure the natural magnetic record, especially near or in towns and cities (see Fig. 9 showing effects at Cedarville and Lake City).

The highly magnetic Tertiary volcanic rocks which form the surrounding mountains of Surprise Valley also underlie the non-magnetic alluvium and lake deposits of the valley itself. Where this alluvial material is more than a few hundred feet thick, the effect of the underlying magnetic volcanic rocks is subdued so that only the longer wavelength magnetic anomalies are perceived on the record. Thus an abrupt change from a jagged short-wavelength record to a smooth record implies a sudden change of the position of the volcanic rocks from a near-surface location to one of considerable depth. Such an abrupt change is therefore considered to be good evidence for a steeply dipping fault contact. A more gradual change from rough to smooth record is for similar reasons interpreted as a gently dipping contact, more likely a depositional contact of alluvium on volcanic rocks.

The magnetic profiles have been annotated to indicate the interpreted faults and contacts. A careful study of the geophysically located contacts
shows in general a reasonably good agreement with the known geology but also shows some places where the contacts on the geologic map (Bulletin 98, plate 21, California Department of Water Resources) can be better located or, in a few cases, where they are incorrect.

Another type of magnetic feature is observed on the magnetic records taken over areas of thick alluvium in the center of the valley. The alluvium that came from the west side of the valley has a higher amplitude magnetic "noise" associated with it than that of the eastern alluvium. The explanation is not clear but perhaps there are magnetic boulders of volcanic rock near the surface of the western alluvium.

A different and very significant area of magnetic "noise" can be observed on the magnetic record of traverse S-4 (Fig. 10, documentation point 5) in the area where the traverse crosses the Lake City fault. These small magnetic anomalies are associated with an area of small gravity anomalies and are caused by minor amounts of magnetic minerals at depths of less than 200 feet in the alluvium. The associations indicate that perhaps chemical reactions of the hot saline waters have generated these small amounts of magnetic minerals near the fault in the otherwise non-magnetic alluvium. Such anomalies could be used to trace the fault zone across the valley. The data suggest that the Lake City fault in the alluvium is actually a zone about 2000 feet wide.

Conclusions

1. Traverses across Lake City Fault (Traverse S-4, Fig. 10) in the center of valley indicate several minor shallow magnetic features and noise which are associated with minor gravity anomalies. It
is suspected that chemical reactions of the hot saline waters have generated minor local amounts of magnetic minerals in the otherwise non-magnetic alluvium near the faults. The data suggest that the Lake City fault is actually a zone about 2000 feet wide with at least two major strands. Another similar area of noise is observed on traverse S-3, Fig. 10, and is not located on a known fault.

2. Alluvium on the west side of the valley is "noisier" magnetically. See traverses S-4, S-11, and S-12, Figs. 10 and 13. Perhaps this alluvium contains magnetic boulders.

3. Various faults, especially on the east side of the valley, are visible in the magnetic records and in general confirm the geologic map.
   a. The faults on each side of the narrow buried horst of volcanic rocks extending south for 15 miles along the east side of Middle Alkali Lake are clearly defined in traverse S-9, Fig. 12.
   b. Several crossings of the southeast extension of the Lake City fault (east of Surprise Valley) indicate the presence of this fault on the magnetic record of traverse S-9, Fig. 12.
   c. The fault shown on the geologic map as defining the west edge of the small horst of exposed volcanic rocks at the radio facility probably does not exist and in any event does not offset the contact between alluvium and volcanic rocks. The magnetic data (and also the gravity data) show that the more
significant contact lies some 1600 feet farther west and
dips west at a sufficiently low angle to imply a sedimentary
rather than a fault contact between the alluvium and volcanic
rocks.
References Cited


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S-10, S-11, S-12

Fig. 13