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Aeromagnetic Measurements in Dixie Valley, Nevada; Implications on Basin-Range Structure

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Interpretation of an aeromagnetic survey flown during 1964 suggests that the pre-Tertiary magnetic basement under Dixie Valley, Nevada, forms an asymmetric composite graben whose inner block is approximately 5 km wide and lies under the western half of the valley at an average depth of 1.9 km. Steplike 'shelf' blocks bordering the narrow inner graben are also downthrown with respect to adjacent ranges, but to a lesser degree; the western shelf is approximately 300 meters below the surface, whereas the eastern conjugate block lies about 500 meters below the surface. The average depth of valley fill across the composite graben is approximately 765 meters. Depth estimates imply, in addition, that the eastern shelf block is broken by several NW-trending transverse faults of 300- to 600-meters displacement. The magnetic expression of contacts between a Jurassic gabbroic complex and other basement rocks can be traced across both northern and southern Dixie Valley. An absence of appreciable horizontal offset of this contact across most of the major Basin-Range faults indicates that post-Jurassic displacements have been primarily dip-slip. An apparent right lateral offset of 2–3 km may exist along the eastern side of the deepest graben block, however. Models computed from anomalies over the southern gabbro contact tend to verify earlier geologic inferences that this intrabasement complex is of lopolithic form. The apparent northward displacement of the gabbro outcrops and contact in the Clan Alpine Range from the subsurface position of gabbroic basement in eastern Dixie Valley may reflect an uplift of the range, relative to the valley block, with subsequent erosional stripping of the tapered lopolith. Satisfactory alternative solutions of an equidimensional anomaly in southeastern Dixie Valley are either a volcanic cone or an equidimensional volcanic remnant. Both computational models overlie the gabbroic complex and require a high total magnetization.

Introduction

Dixie Valley and the adjacent mountain ranges considered in this paper are located in the western part of the Basin and Range structural province and are bounded approximately by latitudes 39°20′N and 40°15′N and by longitudes 117°30′W and 118°30′W (Figure 1).

Since the earthquake of December 16, 1954, Dixie Valley and the surrounding areas have been the foci of numerous investigations. Effects of that dynamic display of tectonic activity and the availability of supplementary information contributed by investigators in the various disciplines renders Dixie Valley particularly advantageous for geophysical studies of Basin and Range structural problems.

Magnetic data were collected in Dixie Valley during 1964 for determining the structural history and subsurface geometry of that basin. Of primary concern in this investigation was the establishment and tracing, by means of magnetic measurements, of a geologic contact intersected by the major fault systems of Dixie Valley. The magnetic expression of displacements on this contact establishes whether shallow crustal faulting throughout the Cenozoic era has been principally of a normal sense, as the 1954 scarps and strain data suggest [*Slemmons*, 1957, and L. J. Meister, personal communication, 1966], or, alternatively, movement in a strike-slip sense has been of significance [*Sales*, 1966; *Romney*, 1957].

A secondary objective was to examine, through gradient analyses, the general configuration of magnetic basement under Dixie Valley, both as an aid to programming subsequent seismic refraction work and as a means of extrapolating between seismic profiles. An additional aspect, investigated through computational models, was the intrabasement geometry of a gabbroic complex exposed in adjacent mountain ranges.

Previous geological work in Dixie Valley and

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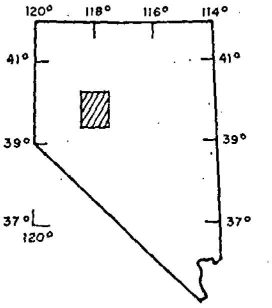

Fig. 1. Index map of Nevada showing location of the Dixie Valley area.

adjacent mountains has been primarily concerned with surface mapping, subsurface studies being limited to hydrologic investigations from shallow well data [*Cohen et al.*, 1963]. The stratigraphy and structure of the extreme north end of the project area have been discussed by *Muller et al.* [1951]. Of particular value to the present project has been recent mapping of the Stillwater Range and parts of the West Humboldt and Clan Alpine ranges by *Page* [1965] and *Speed* [1963]. Previous geophysical studies in and near the region of interest have been limited to a gravity survey of Dixie Valley [*Thompson*, 1959, and unpublished], a recent gravity survey of the Carson Sink–West Humboldt area [*Wahl*, 1965], a complete geological geophysical investigation of the Sand Springs Range, Fairview Valley, and Fourmile Flat area to the south of Dixie Valley [*Nevada Bureau of Mines*, 1963], and seismological investigations of the December 1957 earthquakes [*Romney*, 1957; *Cloud*, 1957].

COLLECTION AND REDUCTION OF DATA

Magnetic total intensity measurements were taken with a Varian model M-49 nuclear precession magnetometer adapted for aeromagnetic use. The instrument package, mounted in a light aircraft, was connected through 31 meters of suspension and transmission line to the sensing unit. It was found that this cable length effectively eliminated magnetic interference of the airplane, regardless of flight orientation. Actuation of the polarization to readout cycle was effected manually by an operator at 10-sec intervals determined by a stop watch. Station values accurate to ±5 gammas and pertinent location information were recorded by a third person in the aircraft.

Positioning of flight lines was controlled by establishing a series of ground reference points over which the pilot would fly, indicating to the recorder when these points were crossed. In the subsequent plotting of data, station points were linearly distributed between reference locations, compensating for variations in ground speed. Locations accurate to approximately ±100 meters were established by this method. With minor exceptions, flight lines were flown at a barometric elevation of 1280 ±15 meters above sea level. This elevation corresponds to an approximate height of 215 meters above the valley floor. Departures from this elevation were necessary only over isolated alluvial fans at the basinal margin.

During periods of aeromagnetic measurement, a continuous monitor of total intensity was recorded by Varian Associates in Palo Alto, California (37°30′N, 122°05′W). Diurnal and transient variations appearing on those records were compensated for in all survey data.

A linear gradient of 1.2 gammas/km in the direction N 30°E was assumed as a regional corrective factor for all magnetic data [*U. S. Coast and Geodetic Survey*, 1955]. After application of space and time dependent corrections, crossing profiles generally agreed to within 15 gammas. This value closely approaches the inherent standard deviation error in the survey, and, in view of the 50-gamma map contour interval desired, no further statistical adjustments were made to data within the survey grid.

GENERALIZED GEOLOGY AND MAGNETIC UNITS

A comparison of the mapped geology (Figure 2) with a magnetic profile flown along the crest of the Stillwater Range (Figure 3) and with the total intensity isoanomalic map of Dixie Valley (Figure 4) reveals that the numerous rock units mapped by *Page* [1965] and *Speed* [1963] in that and other ranges form three principal magnetic mega-units. The southernmost of these includes sedimentary rocks of Upper Triassic age and overlying welded tuffs, latite, and rhyolite. An average total intensity anomaly over this unit is approximately 200 gammas above the magnetic base level of 53,150 gammas observed in the area farther south [*U. S. Coast and Geodetic Survey*, 1955]. Bordering these rocks on the north, a second magnetic unit, of late Jurassic age, is composed of heterogeneous gabbroic intrusive rocks and basalt, which generate a strongly undulatory anomaly averaging approximately 500 gammas. The third magnetic unit of significance, unexposed in the ranges, borders the aforementioned gabbroic suite on the north. The magnetic expression of this mega-unit, of comparable magnitude but lower relief, suggests it is more homogeneous than the gabbroic complex.

Triassic rocks of the southern magnetic unit in the Stillwater Range are exposed generally south of latitude 39°50′N. They occur as gray-black, grayish weathering slates and phyllites. Over the greater part of the exposure, only incipient recrystallization is evident, although exceptions do occur near granite contacts. Complex deformation of these rocks precludes direct measurement of their thickness; however,

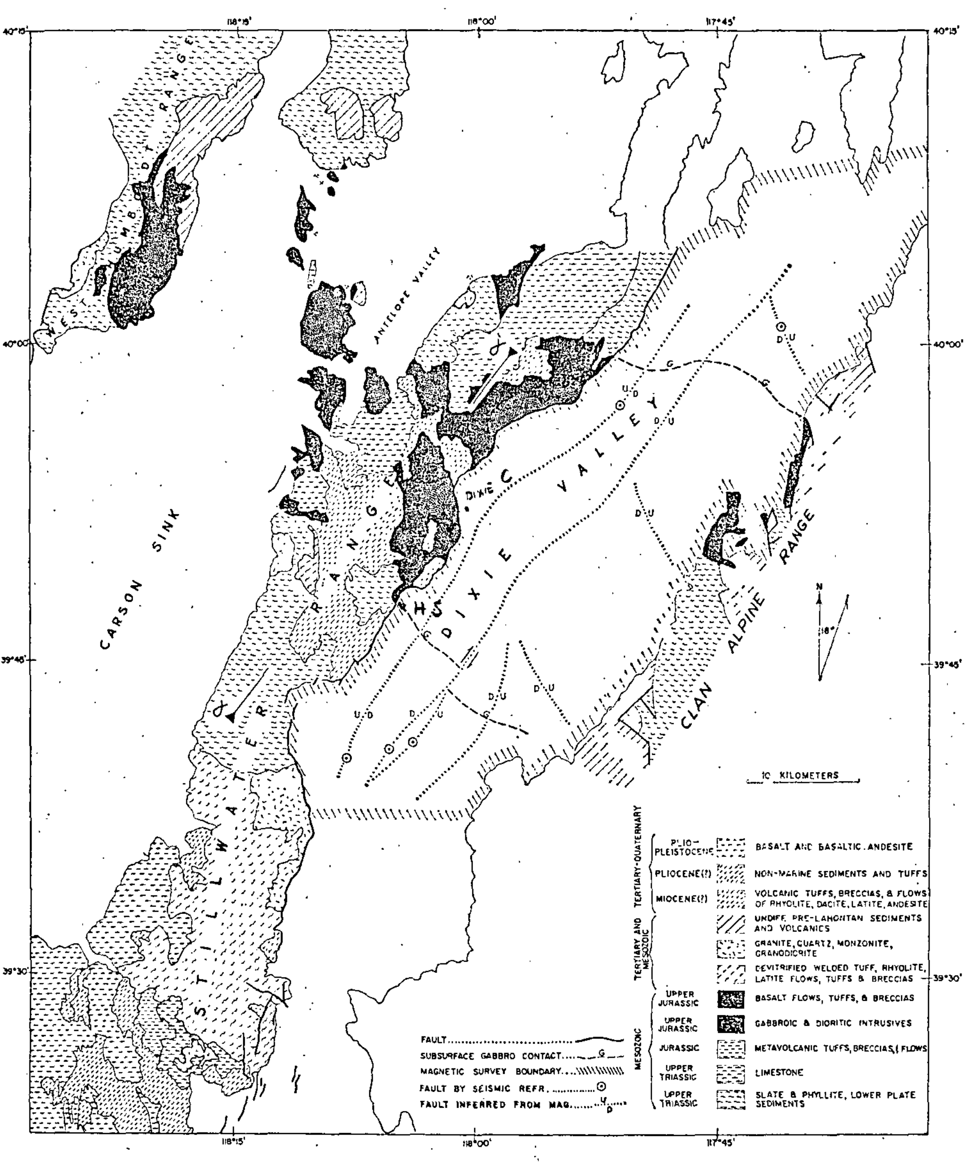

Fig. 2. Generalized geologic map of the West Humboldt, Stillwater, and Clan Alpine ranges, Nevada. Surface geology adapted from *Page* [1965] and *Speed* [1963]. Subsurface structures inferred from geophysical data. α–α' denotes location of section shown in Figure 3.

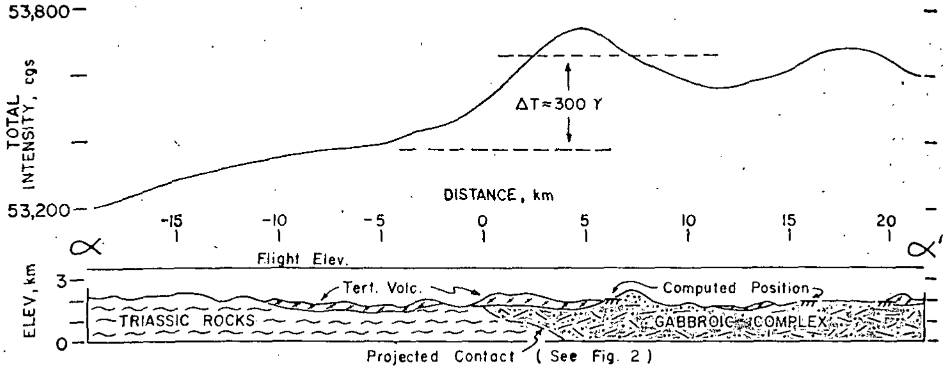

Fig. 3. Generalized geologic section and observed total intensity anomaly along the Stillwater Range, Nevada, between α and α' of Figure 2.

estimates are between 1500 and 3000 meters [*Page*, 1965]. Fossils collected in this marine unit indicate that it is of Upper Triassic age.

South of latitude 39°40′N, the Triassic slates are unconformable overlain by a number of magnetically similar volcanic units. They are shown as undifferentiated devitrified welded tuffs, rhyolite, and latite on Figure 2. Of nonmarine origin, these rocks may range in age from Late Jurassic through early Tertiary. The composite thickness of this sequence is as much as 4800 meters [*Page*, 1965].

The second magnetic mega-unit is exposed north of latitude 39°50′ in the Stillwater Range. Intrusive rocks of this unit form a heterogeneous gabbroic assemblage, which includes diorite, gabbro, picrite, anorthosite, diabase, keratophyre, and gabbroic pegmatite. Along margins of the intrusion, differentiation layering has been noted. A potassium-argon age determination from similar rocks in the West Humboldt Range indicates the complex is probably of Late Jurassic age [*Speed*, 1962*a*, *b*]. Closely associated with the intrusive gabbroic complex are large areas of altered basalt that appear to be co-genetic and perhaps contemporaneous with the intrusive suite. Speed suggests that the entire complex, of lopolithic form, was emplaced at shallow depth, locally erupting to form the associated effusives.

Along much of the Stillwater crest, the gabbroic unit is capped by Tertiary flows and pyroclastics of rhyolite, dacite, latite, and andesite. Dissection of the flows exposes a total thickness of about 550 meters. Approximating a thin plate geometry, these rocks exhibit an apparent magnetic transparency.

In Dixie Valley proper, as in many other valleys of the western Basin and Range, great thicknesses of late Cenozoic lake and stream deposits have accumulated. They range in age from Pliocene to Recent and include alluvial fan detritus, channel deposits, and lacustrine sediments. For the most part, the lake sediments consist of silt and clay, although shoreline deposits of gravel and sand exist locally. For the purpose of this investigation, complexities in this sequence are ignored; it is considered as essentially nonmagnetic valley fill.

DETERMINATION OF MAGNETIC PARAMETERS

To assign representative parameters to the various magnetic units, methods of approach were employed that depend both on inferences derived from total intensity profiles and on individual rock samples from the region. A limited number of samples were collected by the writer and by R. C. Speed from the Clan Alpine, West Humboldt, and Stillwater ranges. From cores of these specimens, volume susceptibility, magnitude of remanent magnetization, and density were determined (Appendix). High average values of remanence, particularly in the gabbroic complex, dictated the application of methods that consider that property. The general method adopted has its basis in techniques, discussed by *Green* [1960] and *Hays and Scharon* [1963], that established an *equiva-*

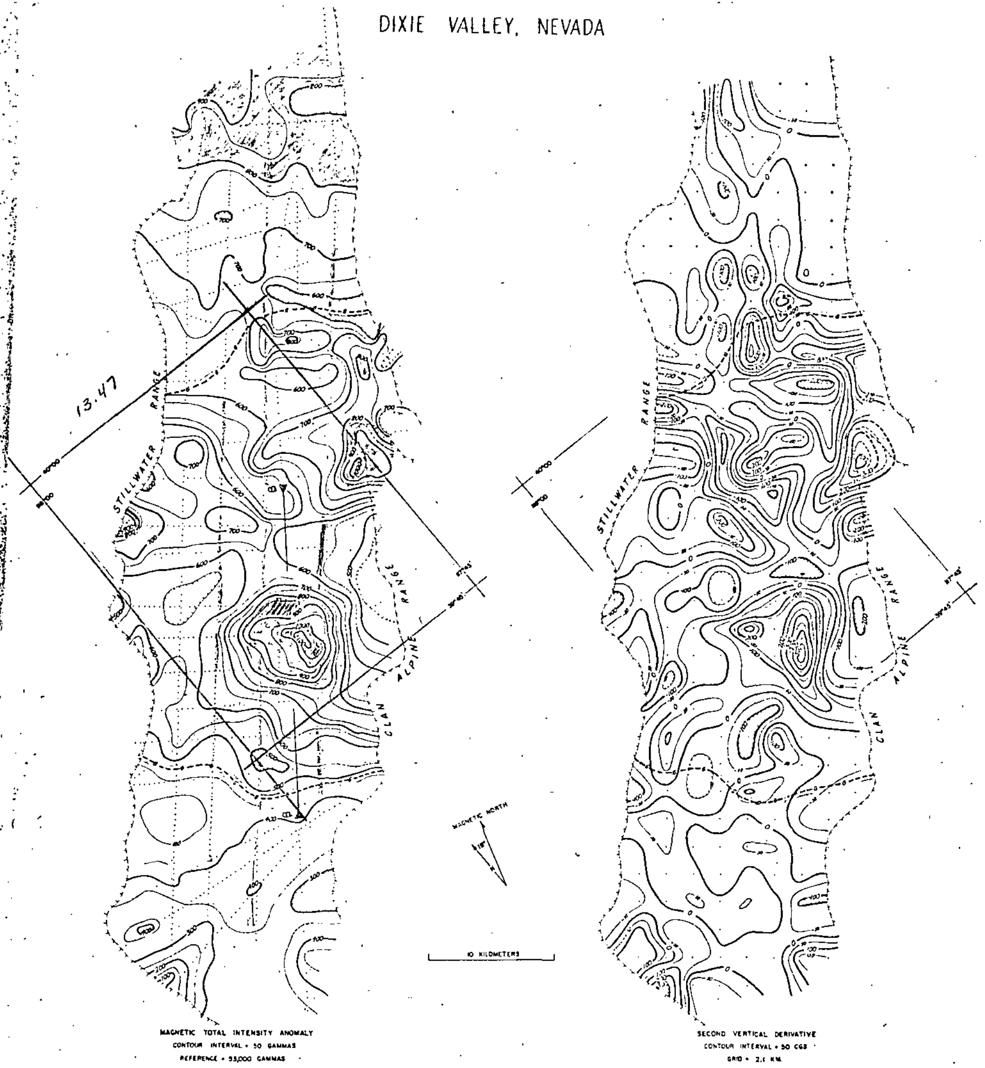

Fig. 4. Magnetic total intensity and second vertical derivative maps of Dixie Valley, Nevada. Boundary of this map shown on Figure 2.

ent susceptibility contrast between adjoining magnetic units.

Resulting magnetizations $\mathbf{J}_{1,2}$ over contiguous units 1 and 2 can be expressed by

$$\mathbf{J}_1 = \mathbf{P}_1 + K_1\mathbf{T}_0 \qquad (1)$$

$$\mathbf{J}_2 = \mathbf{P}_2 + K_2\mathbf{T}_0 \qquad (2)$$

where K is the volume susceptibility, $\mathbf{P}$ is the remanent magnetization, and $\mathbf{T}_0$ is the geomagnetic field intensity. A relative contrast of magnetization is then given by

$$\mathbf{J}_t = (\mathbf{P}_1 - \mathbf{P}_2) + (K_1 - K_2)\mathbf{T}_0 \qquad (3)$$

This relative intensity contrast is equivalent to that produced by a volume susceptibility contrast of

$$\Delta K_t = |\mathbf{J}_t|/|\mathbf{T}_0| \qquad (4)$$

in the particular case of $\mathbf{J}_t \parallel \mathbf{T}_o$. The value ΔK_t is referred to as an *equivalent* susceptibility contrast.

Application of this expression in the present study assumes that remanent components of *magnetization in all units are parallel to the* present inducing field and, further, that reversal of permanent components is not of importance in the area of interest. These assumptions are necessary in the absence of detailed paleomagnetic sampling. In addition, the Triassic slate is assumed to have negligible remanence. With these constraints on the method, equation 3 becomes

$$\mathbf{J}_t = \mathbf{P}_{gb} + (K_{gb} - K_{so})\mathbf{T}_0 \qquad (5)$$

where the subscripts *gb* and *so* refer to the gabbroic and southern magnetic units, respectively.

Using only the average anomaly over the magnetic units, we can establish a lower limiting value of either K or ΔK by means of the following expressions [*Reford*, 1964]:

$$K_t = \Delta\mathbf{T}/2\pi\mathbf{T}_0 \sin^2 i \qquad (6a)$$

$$\Delta K_t = \Delta\mathbf{T}/2\pi\mathbf{T}_0 \sin^2 i \qquad (6b)$$

where i is field inclination. Equation 6*a* determines a minimum *equivalent* susceptibilty over an infinite magnetic basement, whereas equation 6*b* provides a minimum *equivalent* susceptibility contrast between two semi-infinite magnetic bodies of differing magnetizations. The former was used in this investigation to determine a value of $K_{so} = 700 \times 10^{-6}$ cgs for the southern magnetic mega-unit. Because this value clearly represents a minimum, a K_{so} value of 1000×10^{-6} cgs was assumed for calculation of an *equivalent* contrast between the southern magnetic unit and the gabbroic complex. Insertion of this K_{so} value and an average of measured gabbro susceptibility and remanence (Appendix) into (5) yields $K_{gb-so} = 2700 \times 10^{-6}$ cgs.

If equation 6*b* and a $\Delta\mathbf{T}$ value of 300 gammas (Figures 3 and 6) are used to determine K_{gb-so}, a minimum value of 1050×10^{-6} cgs is obtained. The best value of K_{gb-so} most probably falls between this value and the value determined from the rock sample analyses; model computations in this investigation assume, therefore, an *equivalent* susceptibility contrast of 2500×10^{-6} cgs across this contact.

INTERPRETATION OF MAGNETIC DATA

Qualitative inferences. Dominating the center of the total intensity map is a broad region of sharp anomalies exhibiting numerous closures of high magnetic relief. General characteristics or 'fabric' and dipolar effects of this zone are even more discernible through an appropriate second vertical derivative filter (Figure 2). It should also be noted that the average magnetic base level over this region is approximately 300 gammas higher than over the adjoining area south of 39°45′N (Figure 3 and 4). The southernmost margin of this undulatory magnetic 'plateau' is marked by a linear gradient trending N 45°W at this latitude. Where the inflection line of this gradient intersects the Stillwater Range, it is nearly coincident with the mapped exposures of the gabbroic complex, suggesting that the high average level and magnetic topography to the north are correlative with the complex. Additional evidence of this correlation is furnished by a profile flown along the crest of the Stillwater Range, where a similar shift in magnetic level over the southern gabbroic edge is noted (Figure 3). Figures 2 and 4 show the position of the gradient inflection and inferred gabbro boundary across Dixie Valley.

Control on position of the northern contact of the complex is less exact in that a comparable shift in magnetic level is not observed. An approximate boundary can be established, however, by correlating the northernmost extent of the undulatory magnetic province with exposures of gabbro in adjacent mountains. A line indicating the inferred position of the contact trends roughly S 80°E from latitude 40°00′ in the Stillwater Range.

Extending northeasterly along the axis of Dixie Valley is a longitudinal, linear trend of anomalies of relatively high amplitude. To the west, approximately 4 km from and parallel to the east flank of the Stillwater, is a second elongate anomalic trend, which is more subdued than the first. Along these longitudinal zones, most prominent crosstrends are truncated or deflected. Coincidence of several such anomalies and their amplified counterparts on the filtered map with faults located by seismic refraction [*Meister*, 1967] implies that they may be edge effects over major subsurface fault systems. Both seismically determined locations and extrapolations of the faults are shown on Figure 2. By this interpretation, the basement under Dixie Valley is suggestive of a composite, asymmetric graben whose deepest inner block is about 5 km wide and lies under the western half of the valley. Steplike 'shelf' blocks bordering the narrow inner graben are downthrown with respect to adjacent ranges, but to a lesser degree.

In addition to the longitudinal trends, several transverse anomalies other than those discussed earlier are in evidence. They are located for the most part over the eastern shelf and trend obliquely (N 25°W) to the major features. Depth estimates on this block and coincidence with projections of faults in the Clan Alpine Range provide two lines of evidence that these anomalies are expressions of transverse faulting.

There is little magnetic indication of large strike-slip displacements along the longitudinal fault systems of Dixie Valley. This is particularly true along the western bounding fault of the valley, where no appreciable offset is noted between the aforementioned magnetic inflection line and mapped exposures of the gabbroic complex, implying that post-gabbroic displacements (since Late Jurassic) have been primarily, if not entirely, of a normal sense.

Along the central fault zone, exceptions to this generality do exist; there, several anomalies of transverse strike are deflected 2 to 3 km in a right lateral direction (Figures 2 and 4).

Basement topography. In magnetic studies of sedimentary basins, techniques of depth estimation are generally employed in order to establish basement configuration. Most such methods operate on magnetic gradients and are usually independent of rock parameters, requiring only that they remain constant within the assumed geometric model. For the reconnaissance purpose of this study and in view of the numerous dike-like bodies exposed in the neighboring ranges, the method of *Peters* [1949] was adopted for applicable profiles in Dixie Valley. The factor by which Peters' 'half-slope' index is converted to depth was empirically determined from a control profile over the Stillwater Range; a value of 1.35 was found to give representative depths along the entire profile (Figure 3).

Applying Peters' expression to depth indices from profiles parallel to usable gradients, it was possible to construct a topographic map of the magnetic basement (Figure 5). Most striking of the features revealed by this map is a longitudinal trough whose axis is approximately 6 km from and parallel to the Stillwater Range. Close spacing of depth contours along the edges of the trough lends confirmation to the fault-bounded graben mentioned above. Both the longitudinal anomalic trends and seismic fault locations fall within these closely spaced contours (Figures 4 and 5). This interpretation

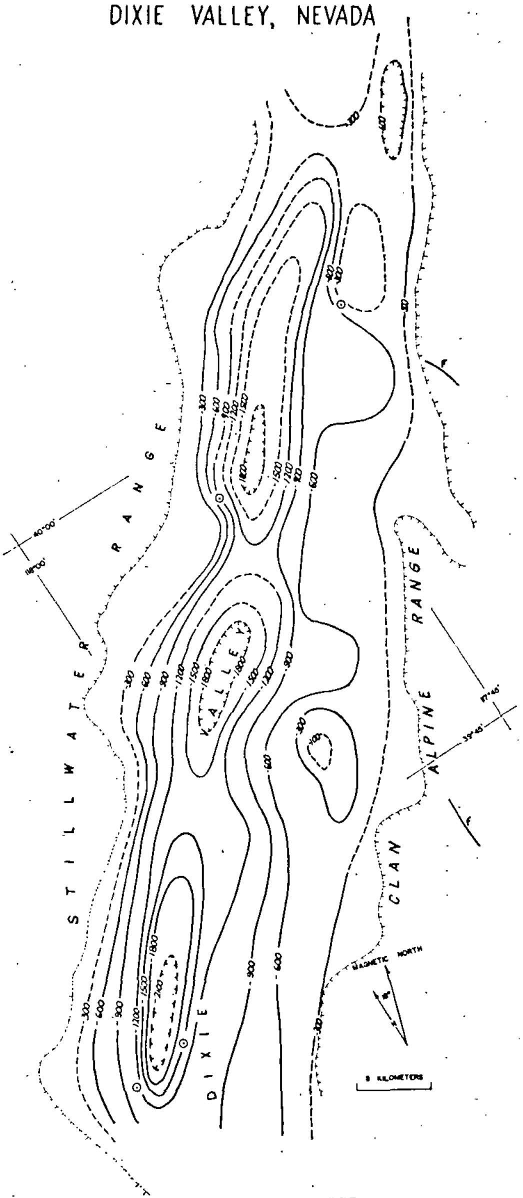

Fig. 5. Topographic map of magnetic basement (compiled from depth estimates).

agrees well with those determined independently from gravity analysis (G. A. Thompson, unpublished) and by seismic refraction studies [*Meister*, 1967].

An average of depths taken at the intersections of a 2-km grid superimposed over this map indicates that the average depth of magnetic basement across Dixie Valley is approximately 765 meters. This places the mean level of the basin floor at an elevation of 335 meters above sea level. Only the narrow inner graben, underlying much less than half the total surface area of the valley, is depressed below sea level.

Secondary features of significance on this map are the apparent transverse 'steps' in the eastern half of the valley. The most northerly of these steps trends approximately N 30°W and displays 300 to 600 meters of vertical offset. A similar deflection of depth contours is present about 20 km to the southwest, suggesting a second transverse fault with displacement in the same sense but of approximately 300 meters.

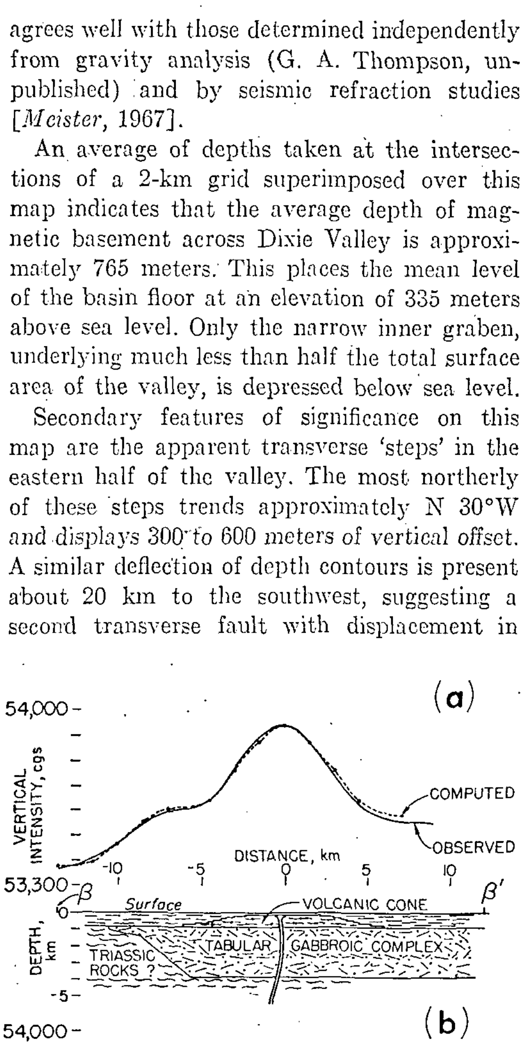

Fig. 6. Alternative solutions satisfying equidimensional anomaly in southeastern Dixie Valley. (*a*) A buried volcanic cone model. (*b*) An erosional remnant model.

Finally, the basement map clearly delineates a roughly equidimensional high in the southeast part of Dixie Valley, which coincides precisely with a closed magnetic high of 500 gammas. Application of the depth expression to the extremely steep gradients over this feature indicates its top is between 60 and 150 meters below the valley surface. A comparable depth was subsequently obtained by seismic refraction [*Meister*, 1967]. Total relief of the 'buried mountain' above the mean level of the eastern valley block is roughly 600 meters.

Model representations of the magnetic units. A secondary objective of this investigation was to test a hypothesis offered by Speed, who, on the basis of detailed surface mapping, has suggested the gabbroic complex forms an elongate northwest-trending body of lopolithic form (R. C. Speed, oral communication, 1964). To investigate this possibility, a computational analysis of a N–S profile ($\beta\beta'$ on Figures 4 and 6) over the southern edge of the complex was performed using a Pirson graticule integrator for two-dimensional bodies [*Pirson*, 1940]. Utilizing the previously calculated susceptibility contrast for this contact, a series of successive model assumption–curve comparison operations yielded the tabular model shown in Figure 6. The associated intensity curve over this model accords well with the two-dimensional component of the observed anomaly.

Existence of such a tabular body is further substantiated by indirect indications on the east side of Dixie Valley. There, the magnetic expression of the subsurface contact is over 20 km southwest of the nearest surface exposure (Figure 2). Strike-slip movement could produce a left-lateral displacement of this magnitude, although it may equally well be attributed to Clan Alpine uplift and subsequent erosional stripping of a lopolithic body. The latter interpretation is preferred by the author in view of the dip-slip or right lateral strike-slip movements exhibited by the other Basin and Range faults in the basin. An unlikely probability would be required, in addition, to explain the exact coincidence of subsurface and surface gabbro contacts observed in northeastern Dixie Valley, if strike-slip movements had occurred along the eastern border of the valley. If it is assumed that the gabbroic complex is of lopolithic form, a northward extrapolation of the lower gabbro contact shown in Figure 6 would place the depth between 3 and 5 km, implying a relative Clan Alpine uplift of comparable magnitude to produce the apparent offset.

A second investigative approach was used to study the dominant magnetic 'high' in southeastern Dixie Valley. For purposes of computation, the three-dimensional component of profile $\beta\beta'$ (Figures 4 and 6) was smoothed and reduced to vertical intensity amplitude. The resulting curve is similar to the anomaly induced by a vertical field except for the usual asymmetry of total intensity at this geomagnetic latitude, i.e., a slight southward migration of the maximum and a discernible minimum on the north. At this magnetic latitude, the peak migration of either a point pole or a point dipole is only of the order of tens of meters [*Smellie*, 1956], a negligible quantity when compared to the observed anomaly width of 12 km. As a consequence, reduction to vertical intensity, although introducing no appreciable error in solution, facilitates the use of solid angle charts developed by Nettleton for determining magnetic effects of buried vertical cylinders [*Nettleton*, 1942].

Three-dimensional models depicted in Figure 6 with associated *equivalent* susceptibilities are constructed of superposed vertical cylinders. Either model generates magnetic effects that are in close agreement with the reduced observed anomaly. Figure 6*a* attributes the equidimensional anomaly to a volcanic cone of high remanence and consequent *equivalent* susceptibility, whereas Figure 6*b* represents an erosional volcanic remnant with similar total magnetization. The *equivalent* susceptibilities indicated for these models are the ones necessary to satisfy the reduced anomaly. The feeder in Figure 6*a* is assumed to contribute a negligible magnetic effect. Both models are in reasonable agreement with gravity and seismic measurements in this area [G. A. Thompson, unpublished; *Meister*, 1967].

SUMMARY OF CONCLUSIONS

This investigation supports the interpretation that basement rocks under Dixie Valley form a composite asymmetric graben, which is roughly parallel to the valley axis. The inner graben block is approximately 5 km wide and lies under the western half of the valley at an average depth of 1.9 km. In spite of the extreme depth of this narrow feature, however, the average depth of magnetic basement under Dixie Valley is only 765 meters below the present surface. Between the main graben and the bordering mountain ranges are shelf blocks, also downthrown with respect to the ranges but to a smaller extent. The eastern shelf is broken by a series of NW-trending normal faults with smaller displacements. This general configuration is in basic agreement with seismic refraction studies and gravity measurements in the area.

The contacts of an intrabasement gabbroic complex can be traced across both northern and southern Dixie Valley. No appreciable strike-slip displacements of the southern contact are in evidence, except along the eastern side of the inner graben, where a maximum offset of 2–3 km may be present. This implies that post-Late Jurassic movements on the major fault systems have been primarily dip-slip. It is suggested that dip-slip movement on a conical fault surface is responsible for minor en echelon structures observed at the surface.

A model computed from the anomaly over the southern gabbro contact lends confirmation to an earlier suggestion that the gabbroic complex is of lopolithic form. If a body similar to the computational model is vertically displaced on a Basin and Range fault, an apparent horizontal offset of the contact may result. This mechanism is suggested to explain the apparent gabbro offset along the eastern side of Dixie Valley and requires a relative dip-slip displacement of 3 to 5 km.

Additional computational models suggest the three-dimensional anomaly in southeastern Dixie Valley may be generated by a volcanic cone or, alternatively, by an equidimensional volcanic remnant; either model requires a high *equivalent* susceptibility.

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APPENDIX. PHYSICAL PROPERTIES OF ROCK SAMPLES

Sample	Rock Type	Volume Susceptibility, cgs Units $K \times 10^6$	Permanent Magnetization, cgs Units $\|P\| \times 10^4$	Density, g/cc
		Southern Magnetic Mega-Unit		
1	Latite	100	1.76	2.51
2	Latite	910	0.00	2.49
3	Welded tuff	930	58.1	2.57
	Average	646	20.0	2.52
		Gabbroic Complex		
4	Gabbro	.002910	.0031.2	2.82
5	Gabbro	4120	21.9	2.74
6	Gabbro	680	17.3	2.82
7	Gabbro	160	0.017	2.87
8	Diabase	3570	9.79	2.81
9	Scapolitized gabbro	3330	3.94	2.70
10	Gabbro	40	0.173	2.82
11	Albitized gabbro	20	0.028	2.71
12	Anorthosite	1130	2.00	2.67
13	Peridotite	2790	12.5	2.99
14	Altered gabbro	3700	12.6	2.87
15	Hydrated basalt	420	2.22	2.71
	Average	1906	9.47	2.79

gratitude is expressed to the late Professor J. L. Soske and to Professor G. A. Thompson for their counsel and suggestions.

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