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EVIDENCE OF A MAJOR FAULT ZONE ALONG THE CALIFORNIA-
NEVADA STATE LINE, 35°30' TO 36°30' N. LATITUDE

An Application of ERTS-1 Satellite Imagery

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ABSTRACT

Geologic reconnaissance guided by analysis of ERTS-1 and Apollo 9 satellite imagery and intermediate scale photography from X-15 and U-2 aircraft has confirmed the presence of a major fault zone along the California-Nevada state line, between 35°30' and 36°30' north latitude. We suggest the name Pahrump Fault Zone for this feature after the valley in which it is best exposed. Field reconnaissance has indicated the existence of previously unreported faults cutting bedrock along range fronts, and displacing Tertiary and Quaternary basin sediments. Gravity data support the interpretation of regional structural discontinuity along this zone. Individual fault traces within the Pahrump Fault Zone form generally left-stepping en echelon patterns. These fault patterns, the apparent offset of a Laramide age thrust fault, and possible drag folding along a major fault break suggest a component of right lateral displacement. The trend and postulated movement of the Pahrump Fault Zone are similar to the adjacent Las Vegas Shear Zone and Death Valley-Furnace Creek Faults, which are parts of a regional strike slip system in the southern Basin-Range Province.

Introduction:

This report summarizes a result of research being conducted for the National Aeronautics and Space Administration on geologic applications of Earth Resources Technology Satellite (ERTS-1) imagery. The work was performed under NASA contract NAS5-21809.

The area of study was selected on the basis of the strong linear expression of Pahrump and Mesquite Valleys visible in oblique Apollo 9 satellite imagery. Although first recognized in the Apollo photography, the present investigation was guided primarily by data from ERTS-1 Multispectral Scanner (MSS) imagery. Analysis of this data has included additive color viewing and production of high resolution color composite imagery (MacGalliard & Liggett, in preparation). Research and analysis of additional satellite and aerial remote sensing data was conducted to evaluate the relative utility of various sensors and imagery scales. This research was coordinated with a program of ground-based geologic reconnaissance and mapping to evaluate imagery interpretation.

The following table lists imagery used in this investigation:

ERTS-1 NASA:	Multispectral Scanner Imagery (MSS)
	13 September 1972 Frame 1052-17484
	14 September 1972 Frame 1053-17542
	6 November 1972 Frame 1106-17495
	25 November 1972 Frame 1125-17554
Apollo-9 Satellite, NASA:	Color Ektachrome Photography
	Approximate altitude 148 miles
	12 March 1969 Frame AS9-20-3135
NIMBUS-1, NASA:	Advanced Vidicon Camera System (AVCS)
	5 September 1964 Orbit 124
X-15 Experimental Spacecraft, NASA-USAF:	Black and White Photography
	Approximate altitude 130,000 feet
	9 October 1962 Frames 081 thru 086
	Frames 089 thru 093
	Frames 095 thru 105
U-2 High Altitude Aircraft, USAF-USGS:	Black and White Photography
Mission 018V	10 July 1968 Frames 200 thru 204
Mission 018L	10 July 1968 Frames 193 thru 201
Mission 018R	10 July 1968 Frame 204
Mission 374V	6 September 1968 Frames 201 thru 204
Mission 374L	6 September 1968 Frames 194 thru 202
Mission 744V	29 November 1967 Frame 079

Regional Geology and Previous Work:

The area of study is located in the southern Basin-Range Province of southern Nevada and eastern California. A mosaic of ERTS-1 MSS frames 1125-17554, 1053-17542, 1052-17484 and 1106-17495 which cover this region is shown in Figure 1. Geographic locations within this mosaic and major structural features (Carlson & Willden, 1968) discussed in the text are shown in Figure 2.

Pahrump and Mesquite Valleys form a narrow closed basin bordered on the east and west by generally north-trending mountain ranges typical of the Basin-Range Province. Topographic relief in the area is large with elevations ranging from 2,600 feet on the valley floor to over 11,900 feet in the adjacent ranges. Climate is semi-arid and vegetation cover is sparse at lower elevations, providing excellent outcrop exposure. Geologic mapping in the vicinity of the Pahrump Fault Zone has been conducted in a number of investigations. Although several fault breaks, which form parts of the zone, have been previously mapped, the extent of faulting and its regional continuity have not previously been reported.

Longwell and others (1965) mapped the eastern portion of the Pahrump area in their study of Clark County, Nevada. They recognize a belt of thrust faults trending generally north-northeast and high angle faults trending generally northwest in the Spring Mountains east of Pahrump Valley. The thrust faults are part of a major Laramide thrust belt which can be traced the length of the western Cordillera.

Cornwall (1972) mapped the geology of Nye County, Nevada, which includes the northeastern part of Figures 1 and 2. Fleck (1967 and 1970) worked in the northern Spring Mountains where he constructed isopach maps for the Eureka Quartzite and the Laketown Dolomite and described the geometry and style of deformation of thrust faults there and elsewhere in the zone of thrusting.

Hewett (1956) mapped the Ivanpah one degree quadrangle which includes the southern portion of Figures 1 and 2. He shows several northwest trending normal faults; two of these, the Stateline and the Ivanpah Faults, are extrapolated across alluvium from south of Sandy, Nevada toward Nipton, California. These may be parts of the Pahrump Fault Zone. Clary (1967) remapped part of the Ivanpah Fault south of Sandy in the eastern Clark Mountains.

G. T. Malmberg (1967), in a study of the hydrology of the Pahrump Valley mapped a 16 mile portion of the fault break shown on our Figure 2 along the California-Nevada state line.

Burchfiel and Davis (1971) have worked extensively in the western part of the study area where they have mapped components of the Laramide thrust belt mentioned above. Burchfiel (1965) has mapped normal and strike slip faults in the Specter

Range east of Lathrop Wells, Nevada. Several smaller mapping projects and topical studies have been conducted in and near the Pahrump area. Discussion of these is beyond the scope of this paper.

Pahrump Fault Zone:

The basin formed by Pahrump, Mesquite and Stewart Valleys is an asymmetrical graben typical of much of the Basin-Range Province. Along the west side of the graben, fault scarps form the steep fronts of the Ivanpah, Kingston, Mesquite and Nopah Ranges. The Ivanpah fault of Hewett (1956) is one of these range front faults, but the extent of faulting along the ranges has not previously been reported.

Within the Tertiary and Quaternary basin sediments of Pahrump Valley, a set of two subparallel fault scarps form an essentially continuous break which can be traced for approximately 25 miles. These faults are shown as a single dashed line trending north-northwest in Figure 2. Malmberg (1967) mapped a 16 mile portion of this fault, and stated that it could be traced for 23 miles along the valley floor. He estimated the vertical displacement to be approximately 1,000 feet, west side down, based on displacement of lithologic units in the sedimentary basin deposits. The geomorphology of the fault scarps and the age of the youngest rocks cut by the faults suggest a late Quaternary or Recent Age.

Possible right lateral displacement of streams along the 25 mile long break in Pahrump Valley has been recognized, but evidence of recent lateral fault displacement is ambiguous. Similar, though less pronounced lines of springs and vegetation found in Mesquite Valley, Stewart Valley and north of Stewart Valley are also believed to be fault traces.

Strike Slip Displacement:

Several lines of evidence suggest a right lateral component of strike slip along the Pahrump Fault Zone. In the eastern Clark Mountains, south of Sandy, Nevada, Clary (1967) has mapped a syncline which plunges moderately northwestward. The syncline is in Paleozoic sedimentary rocks immediately east of the Ivanpah Fault trace, and may be the result of drag caused by right lateral strike slip on the Ivanpah Fault.

Fleck (1971) suggested that offset in exposures of the Keystone Thrust from the southern Spring Mountains to the northern Clark Mountains may be the result of large scale drag folding about a steep axis, analogous to the flexure of the ranges adjacent to the Las Vegas Shear Zone. Davis and Burchfiel (1971) attribute this offset in the thrust to folding on a gently plunging northwest trending axis. Although Fleck did not propose a "state line shear zone" he suggested that based on available evidence, such an alternate hypothesis was reasonable.

Cornwall (1972) has mapped a right lateral strike slip fault in the mountains just east of Stewart Valley. This fault trends northwest at an oblique angle to Stewart Valley (Figure 2) and may be part of the larger strike slip system.

The Montgomery Thrust Fault, approximately 10 miles northwest of Pahrump, Nevada (Figure 2), was mapped by Hamill (1966). He postulated this fault to be the equivalent of the Wheeler Pass Thrust which occupies an equivalent structural-stratigraphic position 8 miles to the southeast in the Spring Mountains. The Wheeler Pass Thrust is extrapolated southwestward for 3 miles into the alluvium of Pahrump Valley by Longwell and others (1965). If these two thrust faults are equivalents, an offset of about 8 miles on a north trending right lateral strike slip fault is required in the northeast part of Pahrump Valley. Cornwall (1972) has mapped a number of north trending faults in alluvium between the ends of the two thrusts.

Fault scarps along the western margin of Pahrump Valley, form a generally left stepping en echelon pattern as shown in Figure 2. En echelon patterns are also recognized for faults within the basin alluvium. This is particularly well shown in oblique X-15 photography which looks southward along Pahrump Valley and in U-2 photography looking northeast across the valley. These en echelon faults south and west of the town of Pahrump are too small to be shown as individual breaks at the scale of Figure 2.

Although the graben structure of Pahrump Valley indicates east-west extension, the en echelon alignment of fault scarps suggests a right lateral component of stress. Similar patterns of surface faulting were reported by Gianella and Callaghan (1934) resulting from right lateral strike slip on the Cedar Valley Fault, Nevada, and by Brown (1970) for scarps along an active portion of the San Andreas Fault, California. This geometric orientation of faults can be shown in theory to be perpendicular to the direction of extension in a dextral stress system. (See for example, Billings, 1954, p. 196f.)

Figure 3 shows the structural features of Figure 2 superposed on a regional Bouguer gravity survey (USAF, 1968). The trace of the Pahrump Fault Zone coincides with a pattern of aligned low gravity anomalies. This correlation supports the interpretation of structural control of basin development which permitted the accumulation of a thick sequence of Cenozoic sediments less dense than the underlying bedrock. Similar gravity patterns are apparent along the Las Vegas Shear Zone and the Garlock Fault. The gravity pattern along the Death Valley-Furnace Creek Fault Zone is more complex, but the coincidence of gravity trends with the fault zone indicates structural control of subsurface mass.

Regional Implications and Conclusions:

The Pahrump Fault Zone is similar in trend and postulated displacement to the Death Valley-Furnace Creek Fault Zone to the west and the Las Vegas Shear Zone to the east. There is some evidence that these three fault zones may have branches in common but more detailed field work will be required to establish such interrelationships with certainty. The three fault zones form part of a larger northwest-southeast system of right lateral strike slip known as the Walker Lane. Cumulative displacement of 80 to 120 miles within the Walker Lane has been estimated based on displacement of regional isopachs, geologic structures and sedimentary facies, as well as flexure of adjacent mountain ranges (Stewart and others, 1968).

Right lateral movement within the Walker Lane is at least in part coeval with Basin-Range normal faulting and extensive andesitic to rhyolitic volcanism centered east and northeast of Beatty, Nevada (Fleck, 1967; Kistler, 1968). The stress pattern responsible for large scale right lateral movement and possible genetic relationships between faulting and igneous activity are poorly understood. However, recognition of new strands in the strike slip system, such as the Pahrump Fault Zone, may help solve these problems by adding to our knowledge of the regional geometry of faulting.

The Pahrump Fault Zone as described in this report is a system of numerous separate fault breaks which cut both bedrock and unconsolidated alluvium. Much of the zone has subtle expression best studied by a combination of remote sensing and ground based methods. Much of the data cited in this report has come from the work of other investigators which has involved detailed ground based mapping and stratigraphy. The ERTS-1 imagery does not replace these techniques. However, it provides a unique basis for studying the regional patterns of faulting not obvious from the perspective of conventional ground based mapping. We feel the results of this study illustrate the significant applications that orbital remote sensing can have to structural geology.

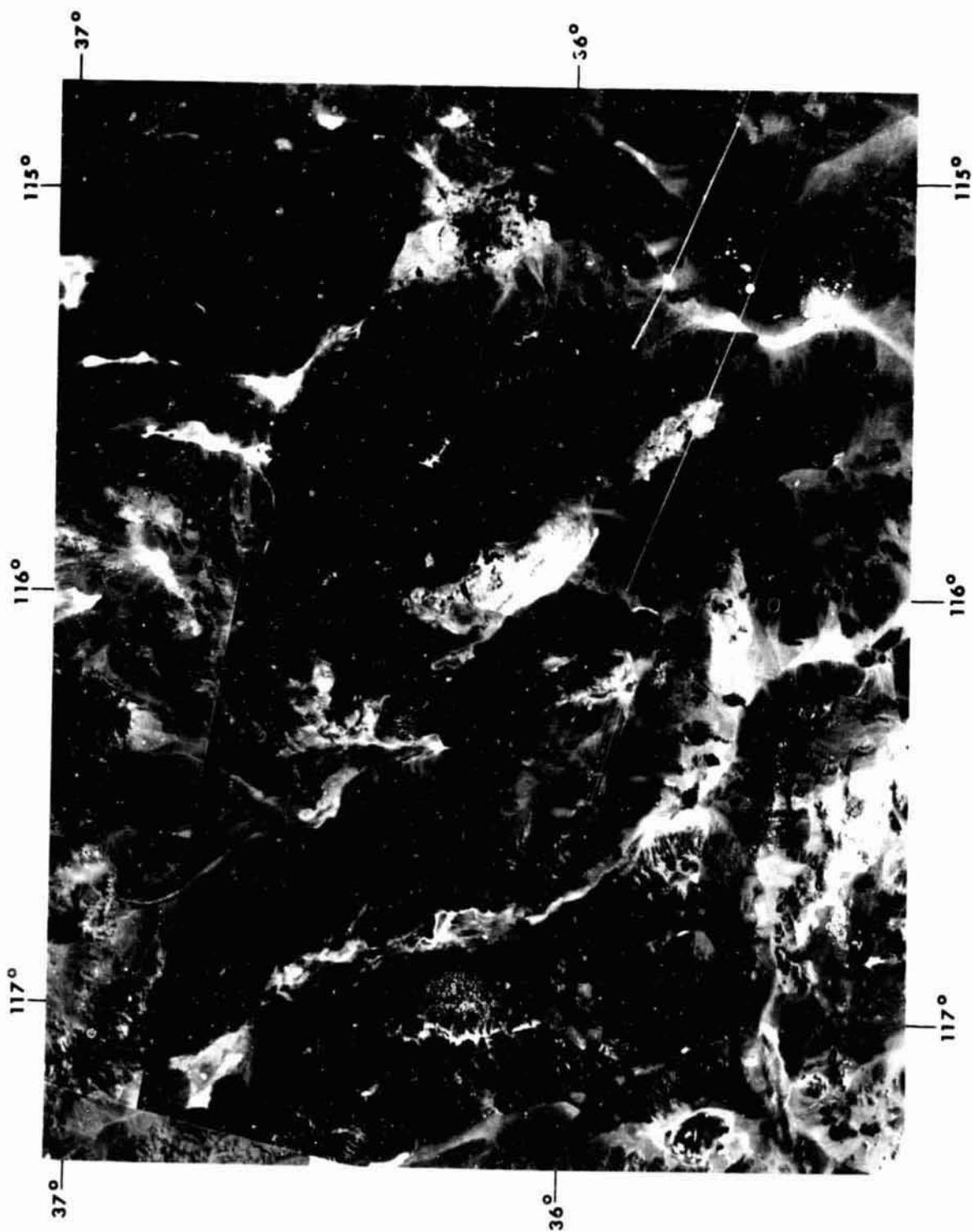


Figure 1. Mosaic of ERTS-1 MSS frames over southern Nevada and eastern California.
(Frame I. D. nos. 1052-17484, 1053-17542, 1106-17495, 1125-17554)

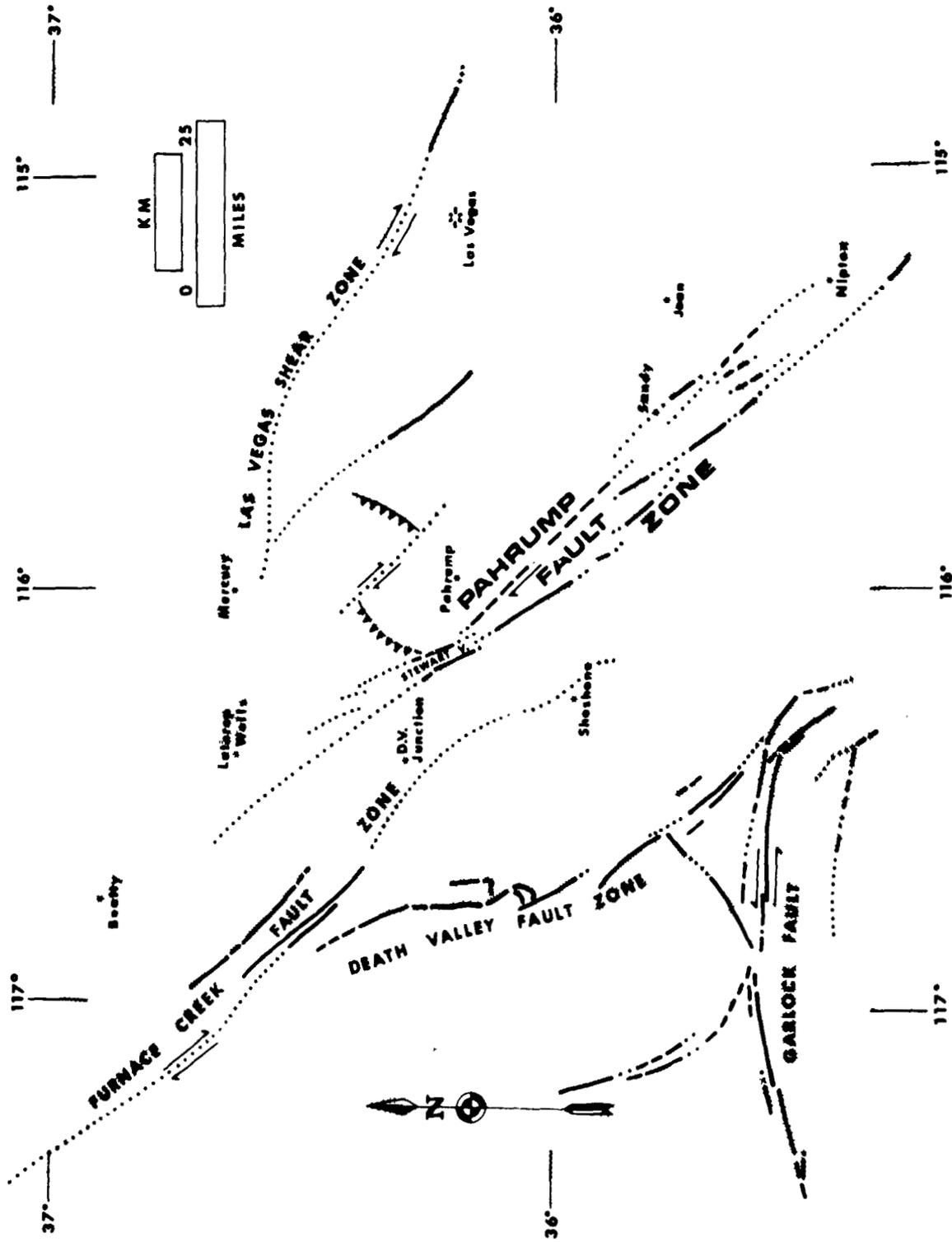


Figure 2. Major fault zones and geographic locations in the area of figure 1. Faults are dashed or dotted where approximate or inferred. Mountainous areas are shaded.

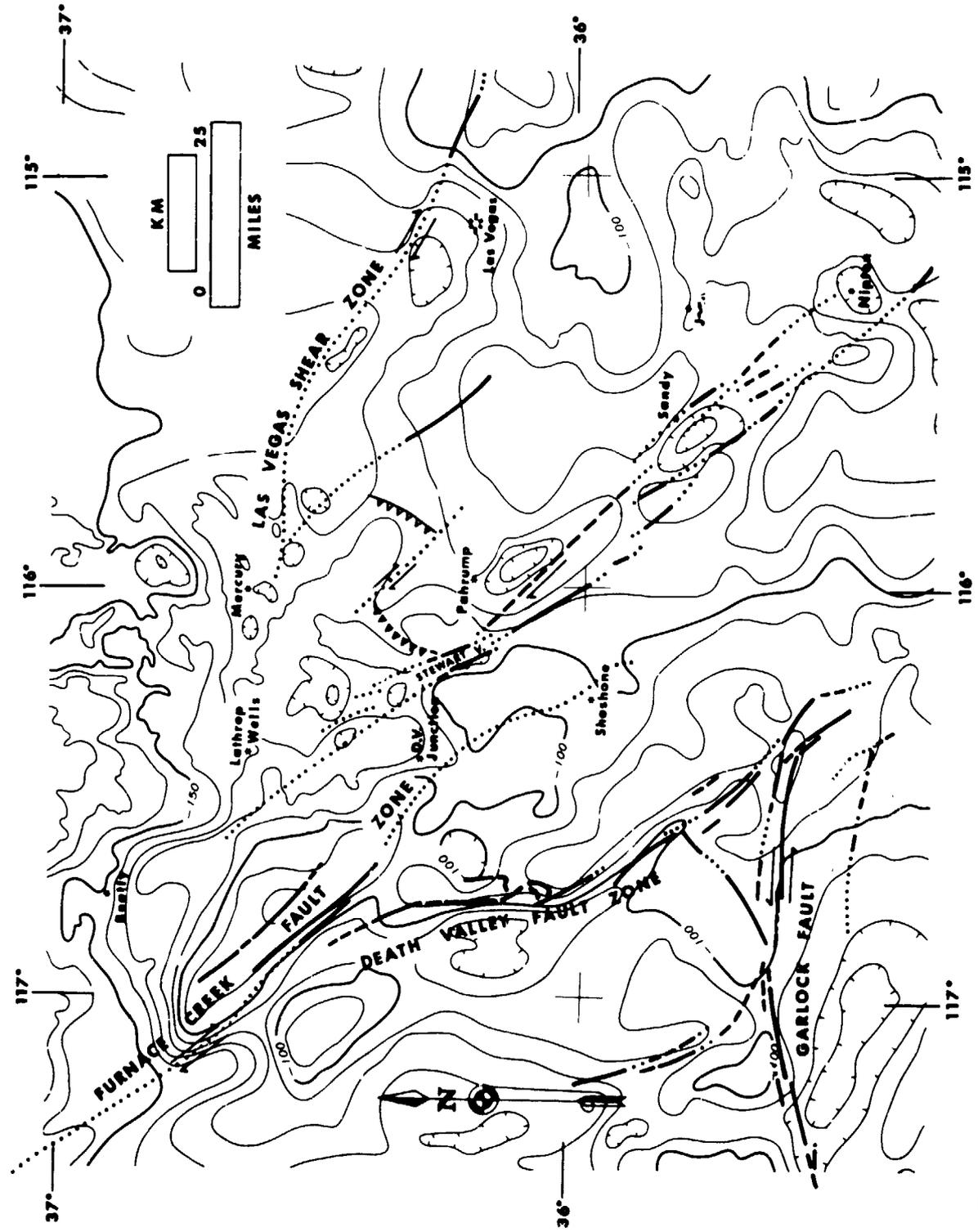


Figure 3. Fault zones of figure 2 superimposed on a regional Bouguer gravity map (USAF, 1968). Gravity contour interval is 10 milligals.

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