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STRUCTURAL GEOLOGIC ANALYSIS OF NEVADA USING ERTS-1 IMAGES: A PRELIMINARY REPORT

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ABSTRACT

Structural analysis of Nevada using ERTS-I images shows several previously unrecognized lineaments which may be the surface manifestations of major fault or fracture zones. Principle trends are NE, NW, NNE-NNW, and ENE. Two lineament zones, the Walker Lane and Midas Trench lineament system, transect the predominantly NNE-NNW trending mountain ranges for more than 500 km. 50 circular features have been delineated. Comparison with known Tertiary volcanic centers and reference to geologic maps suggest 8 new centers.

Preferred distribution of mines and Tertiary volcanic centers along some of the major lineaments suggests a genetic relationship. The intersection of three previously unmapped lineaments in northwestern Nevada is the location of a highly productive metallogenic district. In the Walker Lane, ENE-trending lineaments appear to be related to the occurrence of productive ore deposits.

INTRODUCTION

ERTS images provide information which is pertinent to several aspects of geologic exploration, but structural analysis is benefited particularly by these synoptic views of complex terrain. Lineaments indicative of zones of weakness and circular features suggestive of volcanic or intrusive activity can be delineated efficiently and analyzed in regional context. These types of data are important for understanding the geologic evolution of large regions and are directly applicable to mineral exploration.

This report briefly describes preliminary results of an evaluation of ERTS images of part of Nevada. The main objective of this experiment (NASA SR 9648) is to develop structural and radiometric analysis techniques for geologic exploration from satellite platforms. Radiometric analysis has been limited thus far to visual comparison of the Multispectral Scanner (MSS) bands, mainly to identify areas for detailed analysis. Because some of these results are reported elsewhere (Rowan, 1972), this paper is restricted to the structural analysis aspects of the experiment.

Structural Analysis

The topography of Nevada is characterized by north-northeast- to north-northwest-trending block-faulted mountain ranges and intermontane basins, typical of the Basin and Range physiographic province. In many places the ranges are transected and bounded by escarpments which, along with linear zones of rock and soil contrast and many elements of the drainage system, form an intricate lineament pattern. Alinement of these lineaments over great distances is known to be the surficial manifestation of fracture and fault zones which form part of the tectonic framework of this geologically and economically important region.

To the north and along the southwestern border of the state, the Basin and Range pattern gives way to volcanic landforms. Volcanic activity has also been very important throughout the remainder of the study area. Volcanic features are commonly marked by circular or eliptical topography and radial drainage.

Because ore deposits are commonly localized by fault and fracture zones and volcanic centers, our structural studies have concentrated thus far on delineation and initial analysis of lineaments and circular (and elliptical) features. Review of published geologic maps and reports shows that several of these structural features have not been previously recognized. Comparison of the areal distributions of the major lineaments and circular features with mining areas in Nevada suggests a genetic relationship. The preliminary nature of this work must be emphasized, however, as statistical analysis and field studies have not been conducted and many aspects of this experiment have not been integrated into this evaluation.

Lineaments

Lineament analysis of the study area (fig. 1) was initiated on individual images and then expanded areally by the use of mosaics at the 1:1,000,000 scale. Although lineaments as short as 2-3 km have been mapped in considerable detail for most of the area, only those longer than 75 km are discussed here. The major lineament pattern is dominated by four general directions: NNE-NNW; NW; NE; and ENE (fig. 1). Although all of these directions are represented throughout the study area, the densities and magnitudes vary geographically. In the southwest, generally NW-trending lineaments mark the Walker Lane along the Nevada-California border. ENE-trending lineaments which are continuous for more than 100 km occur almost exclusively in this area. NE-trending lineaments are subordinate in the southern part of the study area. In marked contrast, the pattern in the north is dominated by a zone of NE-trending lineaments which is continuous for approximately 500 km. We refer to this prominent feature as the "Midas Trench lineament" because of its apparent association with the topographic depression (A, fig. 1) near Midas, Nev. The fourth prevalent lineament direction in the study area, NNE-NNW, represents faults which most commonly bound, but locally transect, the mountain ranges. The geographic distribution of these lineaments is reasonably uniform. In addition to these four prominent trends, four WNW-trending lineaments are equally spaced, some 200 km apart, between the Walker Lane and the northern boundary of the area.

The Walker Lane is a major northwest-trending zone of right-lateral transcurrent faulting, known to extend through southern Nevada from Pyramid Lake to Las Vegas (Shawe, 1965; Stewart and others, 1968). Gianella and Callaghan (1934) first recognized this zone from right-lateral displacements in the Cedar Mountains caused by the earthquake of December 20, 1932. Billingsley and Locke (1941) named the regional lineament the "Walker Line," later changed to the "Walker Lane" by Locke and others (1940).

Most evident on the ERTS-I imagery of Nevada is the NW-trending topographic discontinuity across southern Nevada, marking a distinct change in trend of mountain ranges. North of the break, the ranges trend NNW-NNE, whereas south of the break, the ranges trend predominantly northwest. Lineaments mapped by eye on the imagery suggest a zone of faulting along this discontinuity.

The two NW-trending lineaments lying south and southwest of Pyramid Lake (B, fig. 1) are mapped by Bonham (1969), and Gimlett (1967), respectively, as right-lateral strike-slip faults. We propose that these faults are part of the Walker Lane system. Continuing southeast of Pyramid Lake, two parallel NW-striking lineaments on the order of 65 km in length pass east of Walker Lake (C, fig. 1). The northeasterly one is documented as the Battle's Wells fault and the southwesterly one as the Soda Springs Valley fault (Nielson, 1965), both right-lateral strike-slip faults. Albers and Stewart (1965) propose three NW-trending right-lateral faults continuing southeast into Esmeralda County. In addition, they map another right-lateral fault (F, fig. 1) trending ENE across the northwestern part of the county; we extend this lineament approximately 175 km eastward. Right-lateral strike-slip faulting along the more northerly trending lineament south of Goldfield (D, fig. 1) is suggested by Gianella and Callaghan (1939), Locke and others (1940) and Ekren and others (1971).

The Midas Trench lineament zone is much more poorly known than the Walker Lane mainly because only small parts of the area have been mapped in detail. The most conspicuous segments of the Midas Trench lineament are linear topographic depressions near Midas (A, fig. 1) and the escarpment to the northwest (F, fig. 1) which separates the Owyhee Desert on the northwest from the mountain ranges to the southeast. Northeastward projection of this escarpment falls along straight segments of streams in the high mountains.

Geologic maps are available for only relatively small parts of the northeastern area transected by this lineament. In the Rowland quadrangle, one of the main structural features is the N.40°-70°E.-striking Trail Gulch fault which Bushnell (1967) believes has right-lateral displacement. Coats (1964) maps ENE-trending normal faults in the adjacent Jarbidge quadrangle, and a major ENE-trending normal fault is described by Decker (1962, pl. 1) in the Bull Run quadrangle to the southwest of the Rowland and Jarbidge quadrangles. In summary, NE-trending faults are major tectonic features in this part of the area, but the sense of movement is not clear.

To the southwest, this lineament assumes a slightly less distinct character. The alinement of steep-sided canyon and ridges, however, strongly suggests continuation of this zone to the vicinity of Pyramid Lake and Carson City where it intersects the Walker Lane.

Reconnaissance geologic maps covering the southwestern extension of the Midas Trench lineament zone neither deny nor support the significance attached herein to the feature. Although NE- and ENE-trending faults are mapped along this projected segment (Tatlock, 1969), intensity and magnitude and sense of displacement are difficult to assess. Shawe (1965) suggests on the basis of topographic map patterns a major transverse lineament which approximates the location of the Midas Trench lineament. He believes that this lineament represents a first-order left-lateral strike-slip fault.

Other lines of evidence suggest that this lineament may represent a major crustal feature. Projection northeast beyond the present study area results in coincidence with the southeast border of the somewhat anomalous Snake River Plains; continued projection intersects the volcanic area of Yellowstone National Park. Magnetic data compiled at the 1:1,000,000 scale show a NE-trending total intensity anomaly which extends from north-central Nevada through Yellowstone National Park and beyond (Isidore Zietz, oral communication). The Midas Trench lineament is the southeastern boundary of this anomaly in northern Nevada and along the Snake River Plains.

Two other lineaments are noteworthy. Several topographic escarpments 10-20 km long aline to form a major lineament (G, fig. 1) which is orthogonal to the Midas Trench lineament. This lineament is marked by a distinct positive magnetic anomaly for approximately 200 km (Mabey, 1966; Robinson, 1970). Mafic dikes intruded along a zone of structural weakness apparently account for this anomaly (Robinson, 1970). In the northwestern part of the state, two slightly offset NW-trending lineaments (H, fig. 1) transect the generally N-trending ranges for approximately 200 km. The area of offset is near the probable intersection with the projected Midas Trench lineament.

Circular Features

Visual analysis of ERTS images has resulted in delineation of 50 circular or elliptical features (fig. 2) which are presumed to be volcanic or intrusive centers. Most of these features occur along the Walker Lane and in the north-central part of the state near the Basin and Range-Snake River Plains boundary. A comparison with the 78 Tertiary volcanic centers mapped in the study area by Albers and Kleinhampl (1970) indicates some good agreement between the proposed and known volcanic centers (fig. 2). Although this comparison is complicated by several factors, such as scale and topographic expression versus actual vent areas, it is useful for locating previously unrecognized centers. Thirty of the known Tertiary centers fall within or on the edge of the proposed centers. On the other hand, 21 do not correlate at all with the Tertiary data of Albers and Kleinhampl. Although 7 of these 21 proposed volcanic centers are, according to available geologic maps, not composed of Tertiary volcanic rocks, the remaining 14 have significant areas underlain by Tertiary extrusive rocks (fig. 2). Judging from the diameter and structural relations indicated at the 14 proposed Tertiary volcanic centers, 8 appear to be major centers. These possible major centers are designated by the letter "T" in figure 2.

Structural control of Tertiary volcanism in the Walker Lane is suggested by the coincidence of centers with this NW-trending fault zone and by the alinement of centers along (NW) and across (ENE) this zone (fig. 2). Alinement of centers along the northeastern part of Midas Trench lineament is reasonably convincing. Many centers, however, seem to have no obvious relationship with the main lineaments.

Distribution of Ore Deposits

The existence of metallogenic belts in the western United States has been debated vigorously for many years. Considerable disagreement still exists concerning the relative importance of various geological variables (such as host rocks, depositional environment, tectonic and volcanic activity), but most workers emphasize the spatial and temporal relationship of ore deposits and structural and igneous activity. Although the structural significance of the lineaments mapped here is not clear, a genetic relationship is implied by the coincidence of productive ore bodies and some major lineaments.

The distribution of productive silver, gold, copper, lead, and zinc mining areas as compiled by Jerome and Cook (1967) appears at first glance to be nearly random, except perhaps for a concentration along the Walker Lane (fig. 3). However, comparison of major lineaments delineated on ERTS images with mining districts (fig. 3) shows that several important districts are located at lineament intersections (fig. 3). Productive districts occur preferentially along the northeastern part of the Midas Trench lineament zone, and numerous highly productive areas are concentrated where this lineament intersects the NW-trending lineament designated "H" in figure 1.

Mineralized areas in the Walker Lane occur chiefly as vein deposits along faults in Tertiary rocks (Roberts, 1966). Although the Walker Lane is basically a zone of NW-trending wrench faults, correlations shown in figure 3 strongly suggest that ENE-trending lineaments also played a role in localizing producti.e deposits. For example, along the lineament designated "I" in fig. 3 there are 14 productive mines; many other areas are situated along similarly oriented lineaments in this part of the area. Numerous volcanic centers are also located along this lineament.

A genetic relationship between Tertiary volcanic activity segregation of ore deposits is indicated reasonably clearly where pr ve mines occur in the proximity of isolated proposed centers (fig. Assessment of the role of Tertiary volcanism is more difficult where c are situated along lineaments because of the strong correlation of mines and lineaments. Some of these centers appear to localize the ore deposits particularly where the mines occur exclusively at the volcanic center. A few of the alined centers however have no associated productive mines.

SUMMARY

Although tentative, the results of this study demonstrate the potential of ERTS images for regional structural analysis. Most of the major lineaments mapped in this study were either previously unrecognized or known only locally. Concentration of known ore bodies along some of the lineaments and at intersections strongly suggests a genetic relationship. Tertiary volcanic centers are alined similarly but seem to be less important in the segregation of these metallic ore deposits. Careful geologic analyses using geophysical, geochemical, and structural techniques are needed to evaluate the full significance of these preliminary results.

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C

Fig. 1 - ERTS-I mosaic of MSS-5 images obtained in Sept. 1972 showing major lineaments in Nevada, the study area; dashed line shows eastern limit of the area. (Mosaic prepared by Aerial Photographers of Nevada for the University of Nevada, Reno.)

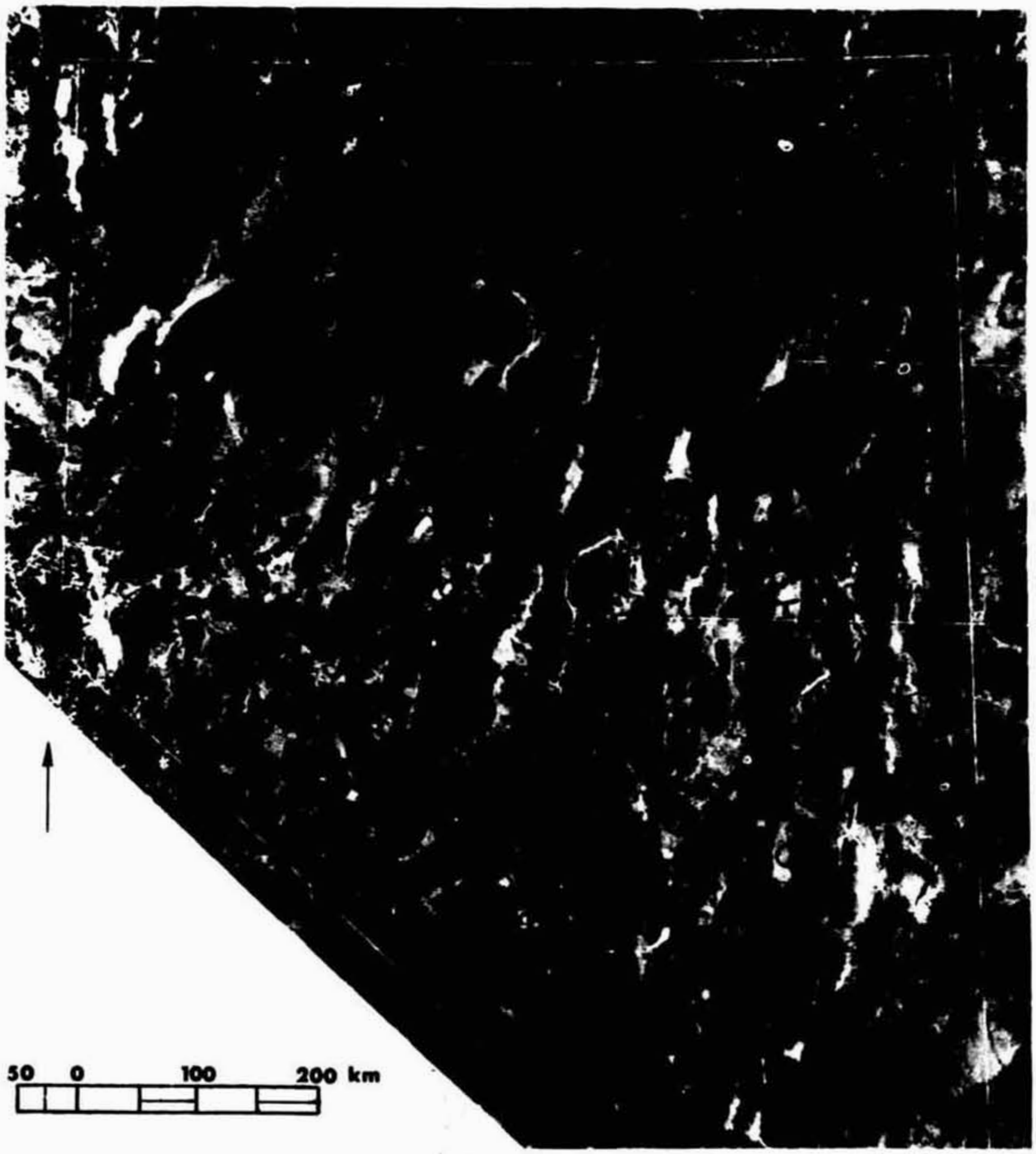

Fig. 2 - Sept. 1972 ERTS-I image mosaic of Nevada showing circular and elliptical features (dashed lines) and Tertiary volcanic centers of Albers and Kleinhampl (1970) (solid lines, ⌖ for calderas). Proposed major Tertiary volcanic centers are designated by "T."

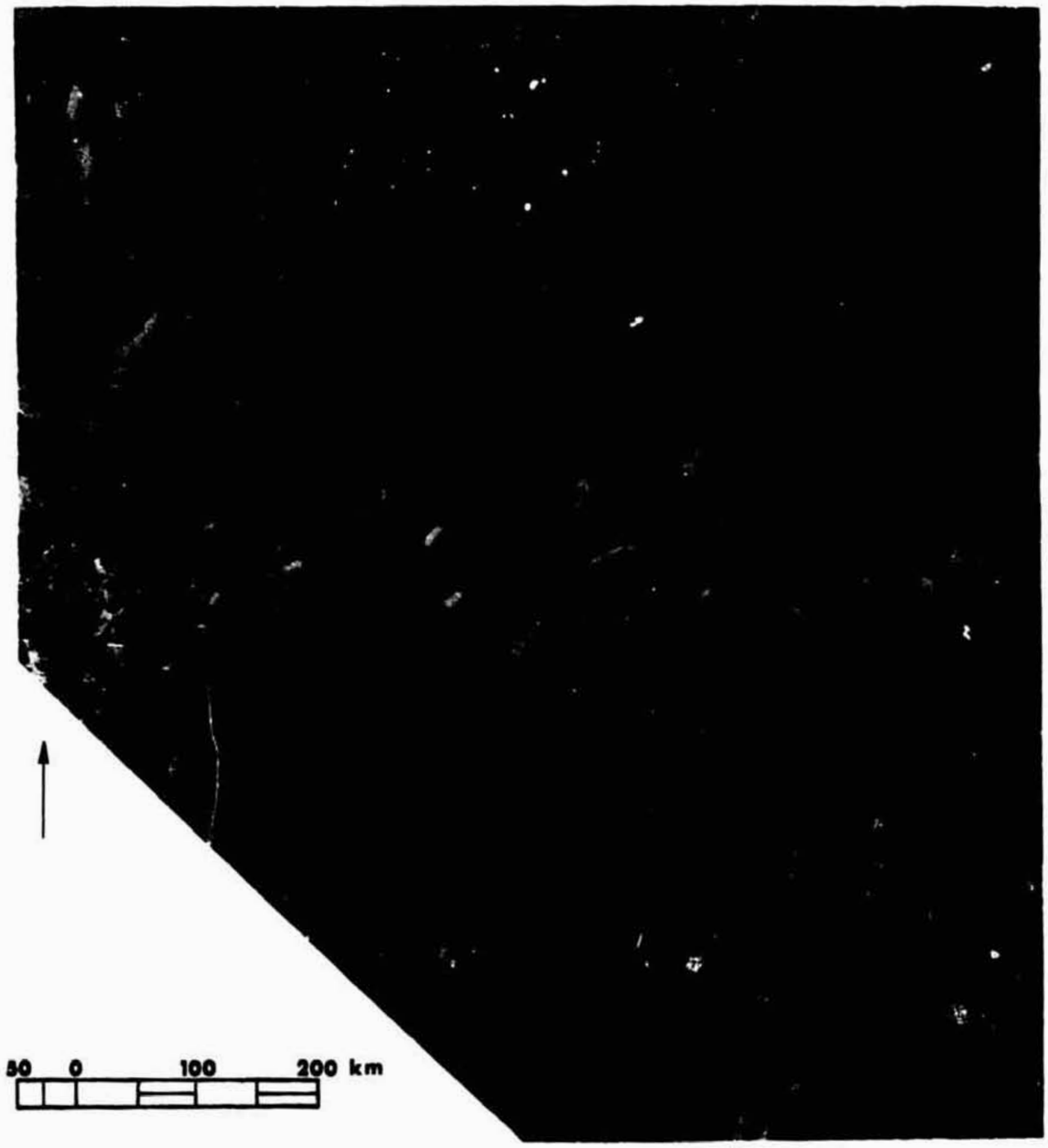

Fig. 3 - Sept. 1972 ERTS-I image mosaic of Nevada showing major lineaments, circular and elliptical features, and silver, gold, copper, lead, and zinc mines. Production levels of mines (Jerome and Cook, 1967): • - less than $100 thousand; • - $100 thousand to $1 million; ● - $1 million to $100 million; ● - more than $1 billion.