REMOTE SENSING AND SURFACE GEOCHEMICAL STUDY OF RAILROAD VALLEY NYE COUNTY, NEVADA*

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ABSTRACT

A remote sensing and soil gas geochemical survey has been completed in Railroad Valley, Nevada for Japex Geoscience Institute, Inc., Tokyo Japan. The initial survey was designed around an existing stuctural model published by Foster and Dolly (1979). This study provides a test of this model with remote sensing and geochemical information. Combined interpretation, using SAR, TM and TM enhanced images has suggested a series of major fracture lines which define regional fault and fracture systems. Many fracture lines cross the valley graben and may reflect structural subdivisions within the graben blocks, some of these confirm structural divisions identified by Foster and Dolly.

There appears to be a reasonable correlation between the mapped fracture systems, the geochemical anomalies, and the existing oil fields, although any one set of data alone does not delineate the fields. A comparison of the geochemical data with the oil fields and remote sensing interpretations shows good correlations with the presently identified fields. Light hydrocarbon magnitude and compositional anomalies appear to reflect preferential migration along certain fracture systems on the flanks of the valley updip from the oil reservoirs. Although direct soil gas anomalies do not occur over the reservoirs, valley boundary faults adjacent to the reservoirs do exhibit a significant flux of hydrocarbons updip from all the presently known accumulations.

*Presented at the Fourth Thematic Conference: "Remote Sensing for Exploration Geology", San Francisco, California, April 1-4, 1985.

INTRODUCTION

The objective of this study is to determine whether or not geochemical anomalies occur at locations that can be predicted by any of the proposed structural models of Railroad Valley reservoirs, and to establish the relationship of structures to interpretations from remote sensing data in Railroad Valley. The four principal elements in this project are: 1) the analysis and interpretation of remote sensing data; 2) geological field checking of the interpretations, 3) the field collection and analysis of geochemical data, and 4) the integration of the geological, remote sensing, and geochemical data.

GENERAL GEOLOGY

Although the Basin and Range Province has been sparsely explored for oil and gas, surface macroseeps are known, and shows of oil and gas have been encountered in many exploratory wells. Railroad Valley has been the most actively explored valley within the Great Basin since the discovery of the Eagle Springs Field in 1954. It currently has four producing fields: Eagle Springs, Trap Spring, Bacon Flat and Grant Canyon, from which over 10 million barrels of oil have been produced. The Trap Spring and Eagle Springs fields are combination stratigraphic, truncation subcrop fault traps, which also may be true of the subeconomic Currant discovery. Production occurs from matrix and fracture porosity in reservoirs in the lacustrine Sheep Pass Formation (Cretaceous and Eocene) and the Garrett Ranch volcanic group (Oligocene), (Dolly 1979). The most unique feature of these fields is that production occurs from the highest position on the lowermost fault block at the basin margin. On the adjacent higher fault blocks the reservoir beds were removed or altered by erosion during Basin and Range deformation (Foster 1979). The Grant Canyon and Bacon Flat fields are also located in structurally low, intermediate fault blocks, with production reported to be from the Middle Devonian Simonson dolomite (McCaslin, 1984). It has not been reported whether production is confined to fractured zones or to primary porosity in the dolomite or whether the Sheep Pass Formation and Garrett Volcanic Ranch Group are present and/or productive in this area. The sources of the oils in Railroad Valley are probably a combination of the Late Cretaceous-Eocene Sheep Pass Formation and Mississippian Chainman shale with the additional possibility of a varying degree of mixing from these sources within any particular reservoir (Picard, 1960).

REMOTE SENSING

The remote sensing study of Railroad Valley was based on the examination of imagery derived from Synthetic Aperture Radar (SAR) and the Landsat 4 Thematic Mapper. Emphasis was placed on mapping rectilinear elements in the terrane as these commonly are fracture zones and faults and their areal patterns delineate the structural frameworks of a region.

Fracture zones and faults are commonly favorable lines along which to place geochemical sample sites because of the increased fracture porosity along these lines to depth.

Curvilinear, oval and circular features were also noted in particular on the TM imagery. In several examples circular elements were found to correspond directly to intrusions and flexures in the mountains, flanking Railroad Valley. In other examples, as in the pediments and bajados of the Valley itself, it is not always clear what these remote sensing features represent.

SAR - Synthetic Aperture Radar

The SAR imagery interpreted for this project was purchased from Aero Service. Its primary use in the interpretation was the radar mosaic of the region produced at a scale of 1:250,000 was used for interpretation. Flight altitude was 32,000 feet and flight direction eastwest, with a south look direction. This look direction is roughly complementary to the sum angle and azimuth of the TM imagery and aided in delineating structures on north-facing slopes.

In as much as radar imagery primarily delneates topography, the mosaic was studied for linear elements in the topography. Many such linear elements such as canyons, ridges, and alignments of discrete topographic features are found in the mountains. Within the valley linear elements are found as extensive scarpes or ridges of low relief, drainage alignments and abrupt distinctive changes in the fabric of the topography over an area or across a line.

The radar features mapped, whether rectilinear, curvilinear, oval or circular are believed to correspond to zones of a higher level of structural activity. Most commonly this is manifested by an increased density of fracturing along a line and in the direction of the line and to depth. This results in the selective development of distinctive topographic features having structural significance.

The rectilinear elements mapped form a very regular network in which northeast and northwest - trending lines predominate (See Fig. 1).

LANDSAT

Landsat imagery used in the mapping and interpretation of structural and morphological features of interest in Railroad Valley was provided by Japex Geoscience Institute, Inc., sponsor of the project. Images used for interpretation were Thematic Mapper (TM) images covering the main (central) region of Railroad Valley, at a scale of 1:124,500 and Polaroid prints of CRT displays of enhanced images. Black and white images were also provided in each of the TM spectral bands 1-5 and 7 with the exception of Data from band 6 (Thermal IR Emission) which was too poor a quality for interpretation and two composite color images of combined spectral bands 2, 3 and 4.

Much more information than had been initially anticipated was derived from the several images studied. The linear features mapped from all sources appear totally compatible with respect to azimuthal distribution and, to a large extent, with respect to areal distribution and location of specific features. It was found, however, that each image provided a different aspect of the area and in each case, additional data. As a result there is not necessarily a direct correspondence of features mapped from one image to another. The pattern of linear features is fairly complex but not random. Elements of the pattern fall generally into well-defined azimuthal groupings of about N45E , N65E , E-W , N60W , N40W , N25W , and N-S (these values are + 5^{o}). Within the NE and NW trending sets there is also a tendency for a grouping into sub-equally spaced belts within the set. These require study to determine if they correspond to the larger Landsat lineaments apparent on Landsat regional mosaics.

Three sets of CRT color composite images were generated by Japex to further enhance Landsat (TM) features in areas of low topographic relief and high (and narrow range) reflectance values such as the pediments, bajadas and the playa of Railroad Valley. Of the three sets of data generated, the TDCS set yielded a maximum amount of useful structural information with respect to visual inspection. Within the TDCS data set the discrimination of lithologic and soil differences of significance was excellent and allowed the recognition and mapping of a number of previously unrecognized morpho-structural elements in the playa and sand dune areas of the central part of the valley. It is apparent from the TDCS images that the primary trend of the main graben of the valley is about NNE and not N-S, although there are important N-S structural elements which appear in the northern part of the valley, as well as N-W. These data, viewed in conjunction with those from the regional mosaics suggests that the central (and probably deepest) part of the Railroad Valley graben underlies the playa of the valley (Figure 2).

Active Structural Lines: In mapping the several color and black and white images, it was noted that there were several well-defined regional lines or zones which appear to be comprised of a series of closely-spaced, small-order features. They are particularly apparent in the playa and bajada areas but are also readily defined as continuing features in the pediments and mountains east and west of the valley. They follow generally the azimuthal lines displayed by the smaller order features but, those striking NW, NE and in the south about E-W clearly cross mountains and valleys without consideration for the local structural geometries. The fact that they are so well displayed in the imagery suggests recent structural activity along their lines.

Composite Structural Lines: In studying the maps showing the linear features derived from the radar and Thematic Mapper imagery it became apparent that many of the shorter lines lie in narrow belts which can be readily defined visually. An overlay was placed on each of the three interpretive maps, and the boundaries of the belts drawn. The three sets of data were then compiled on a single sheet and are shown on Fig. 3.

The features of this map show what may be considered the larger-scale composite TM lineaments of the mapped area. This map is of particular interest in that it shows that although a number of the composite lineaments are fully defined on a single image, several are composed of segments, each segment of which is defined on a single set of data. In particular these are lines crossing the valley in the NE-SW direction. In this example it is clearly illustrated how a single linear structural element may have aspects which are not totally defined by a single type of remote sensor.

A comparison of the remote sensing features mapped show a number of coincidences of ASL's and linear belts. Where this occurs it provides an added dimension to the structural inferences of the lineament. Taken together the linear features compiled from this unique combination of remote sensing data outline the primary structural framework of the mapped area.

GEOCHEMISTRY AND REMOTE SENSING INTERPRETATION

The geocnemical 4' probe technique used for this study is the same as that described by Matthews, Jones and Richers (1984) at the 1984 Symposium held in Colorado Springs, Co. The composition of Railroad Valley C2/C3 data as compared to 4 foot probe surveys at Patrick Draw, Wyoming and Lost River, West Virginia show a close similarity to Patrick Draw predicting an oil potential for this area (Figure 4). Contoured geochemical data reveals a number of well defined magnitude anomalies which seem to be indirectly related to the petroleum production in Railroad Valley (Figure 5). The anomalies for the most part lie on the edges of the graben blocks and along the valley boundary faults. An examination of the location of these anomalies versus composite structural lines from all the remote sensing data shows that the high magnitude samples were collected near linear systems which are probably a result of local or regional fracturing. These anomalies reflect up-dip migration of light hydrocarbons along fault and fracture planes which are an active component of continuing basin formation. The hydrocarbons which originate at depth in the basin where source formations are undergoing maturation probably are channeled along existing fracture systems. As shown in the idealized migration model (Figure 6), the updip seepage is also constrained to migrate through permeable sand and gravel valley fill formations as the gases migrate toward the valley margins. When the seepage gas comes in contact with fractures related to basin and range normal faulting it appears to be communicated to the surface along these pathways (Figure 6). This relationship is apparent in the vicinity of the Eagle Springs Grant Canyon and, Bacon Flat oil fields. The Trap Springs field has a direct propane anomally over the northern half of the field which continues onto the adjacent uplifted block. This geochemical anomaly may be related to direct vertical migration along the mapped faults of this fractured reservoir.

High magnitude geochemical anomalies have also been identified over shallow buried pediment surfaces and along the edges of structural blocks as identified by Foster (1979),(Figure 7). These structures appear to be bound by the active structural lines as identified by remote sensing data. The fractures and faults of this type are controlled by both the size and shape of the graben blocks. An examination of the strike of these linear features suggests that the majority of the high magnitude geochemical sites lie along lineaments several of which can be shown to be actual faults defined by the Palezoic blocks. The intersections of one or more linear elements also show high magnitudes in some cases. The linear features do not show anomalous values in all areas and seem to be dependent on an active source of light hydrocarbons. The northeast part of the geochemical survey area, in the vicinity of Currant is very closely correlated to divisions as defined by the lineaments. Geochemical anomalies at currant are sectioned off and bounded by these active structural lines.

High magnitude geochemical sites are also located on pediment surfaces far removed from the valley bounding faults that control updip migration of gases. The anomalies are over shallow buried Paleozoic blocks which may have limited hydrocarbon potential, such as sites at the southeastern limit of the survey area. These sites are located over Ordivician and possibly even Cambrian formations from which there is little source rock potential. The source of the measured hydrocarbons above the perdiment surfaces is probably lateral migration along fracture systems that extend into the adjacent ranges from the basin bounding blocks. Hydrocarbons from mature subsurface formations apparently migrate along the fractures which are probably also closely related to the localization of oil in reservoirs. As noted, this lateral migration extends into the adjacent pediment areas.

CONCLUSIONS

Remote sensing imagery is able to identify major fault and fracture systems which are related to the structural development of Railroad Valley. These systems define individual structural blocks which are confirmed by near surface geochemical data. Geochemical magnitude anomalies are located along fractures and faults updip from the oil fields and other prospective areas of the valley. Anomalies over pediment surfaces may reflect fracture migrated gas which probably originates in the graben structures. A combination of remote sensing and soil gas sampling appears to identify major near surface gas migration pathways in this complexly faulted valley. A model for interpretation is suggested by this study.

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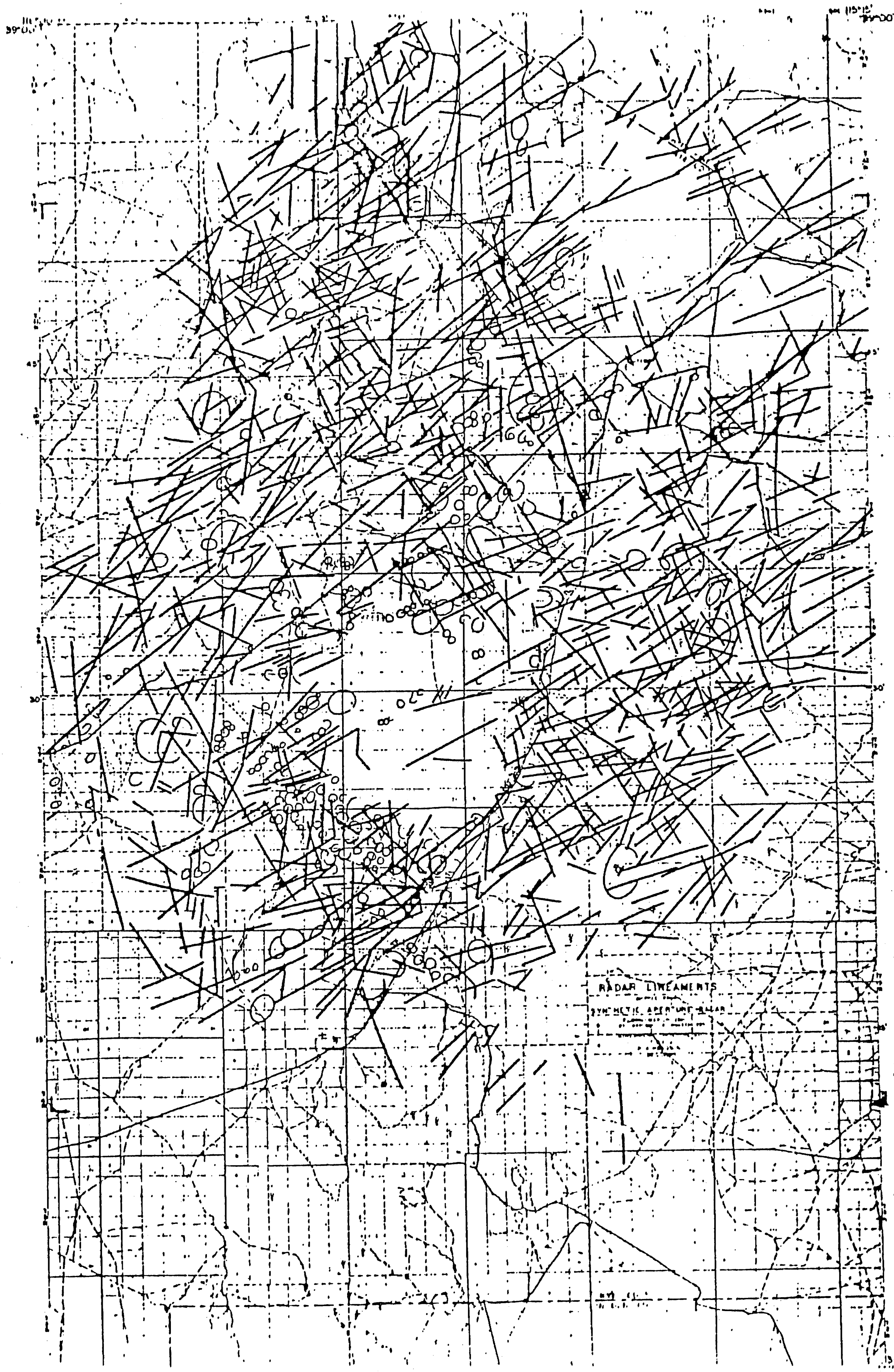
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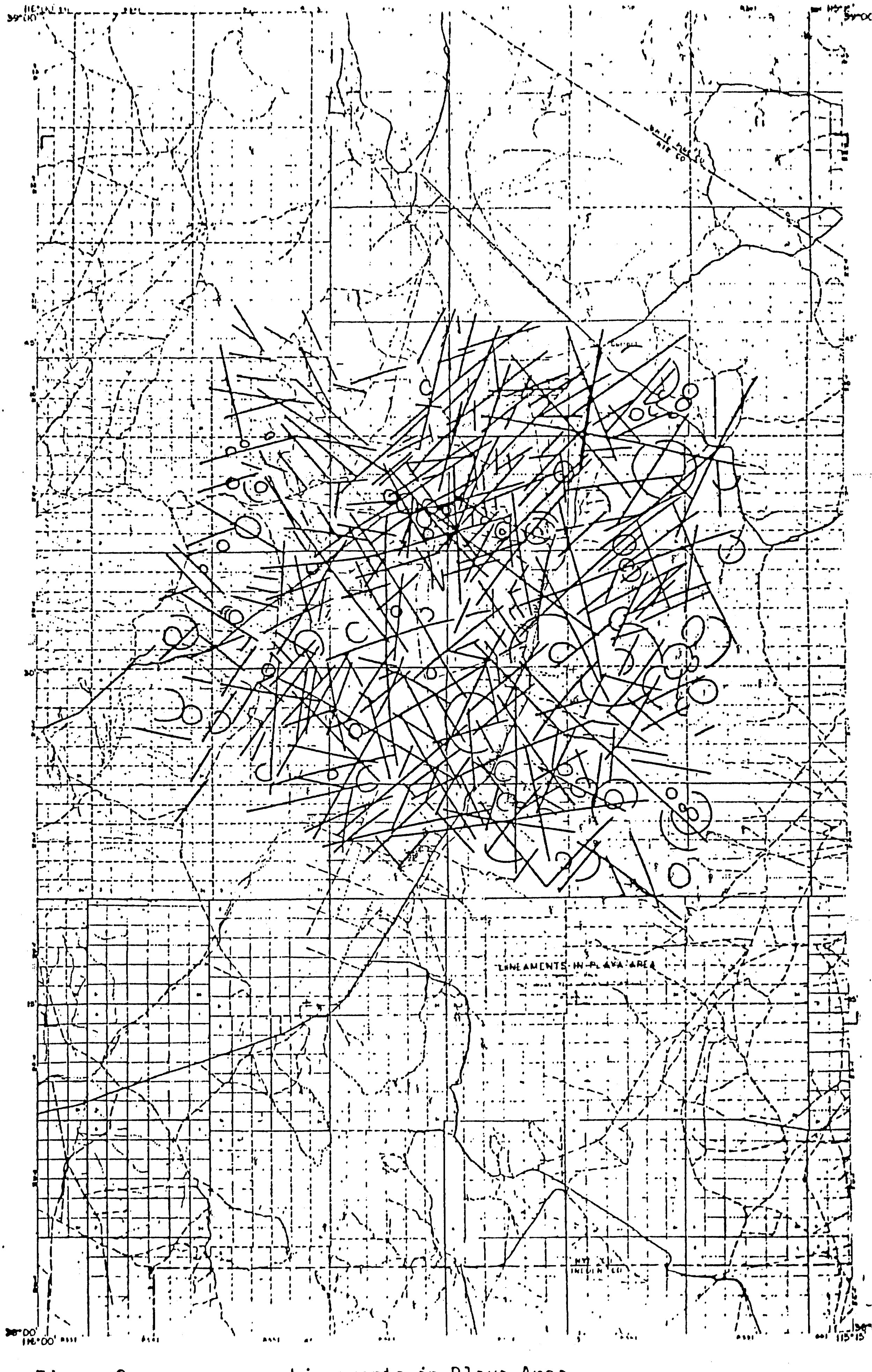

Figure 2. Lineaments in Playa Area

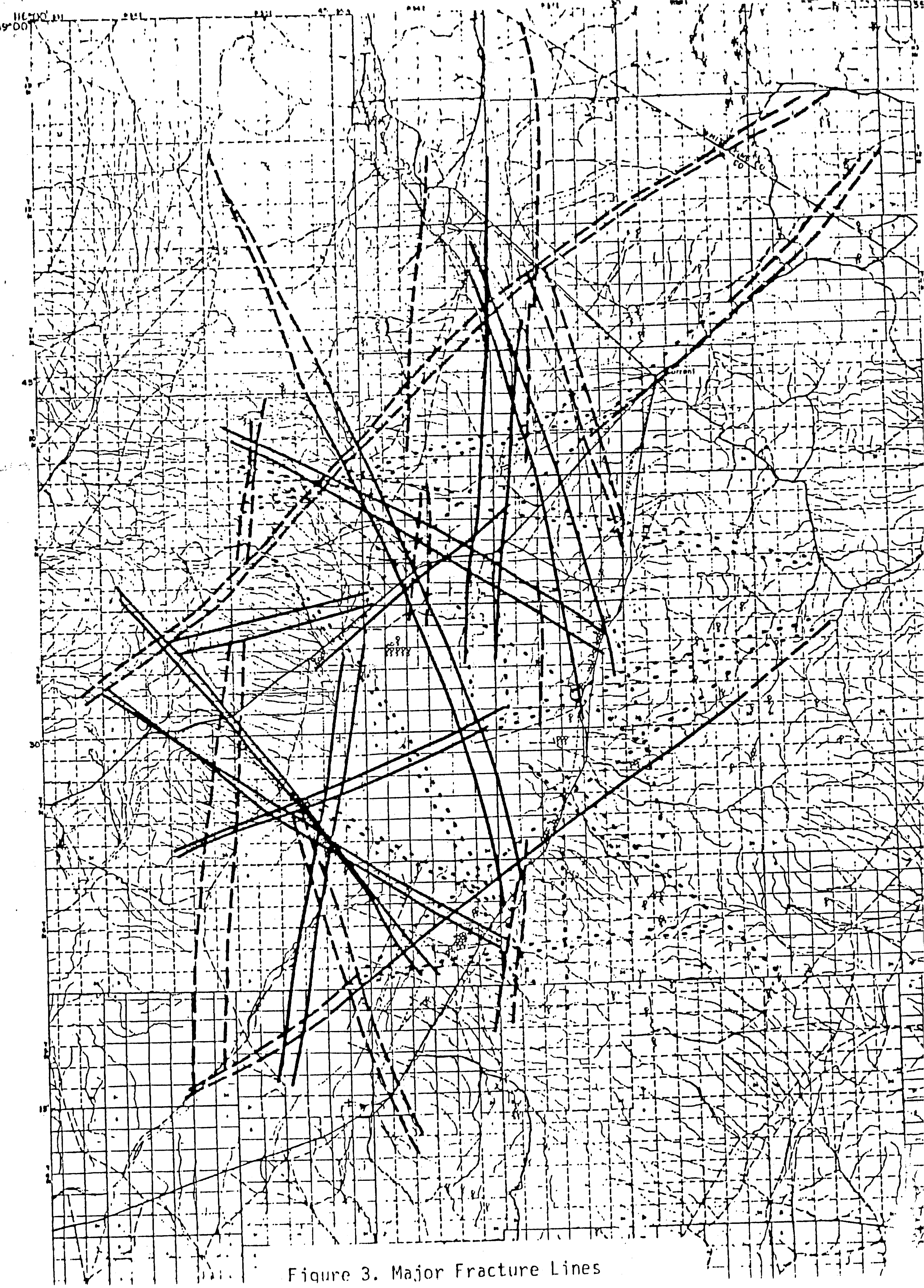

Figure 3. Major Fracture Lines

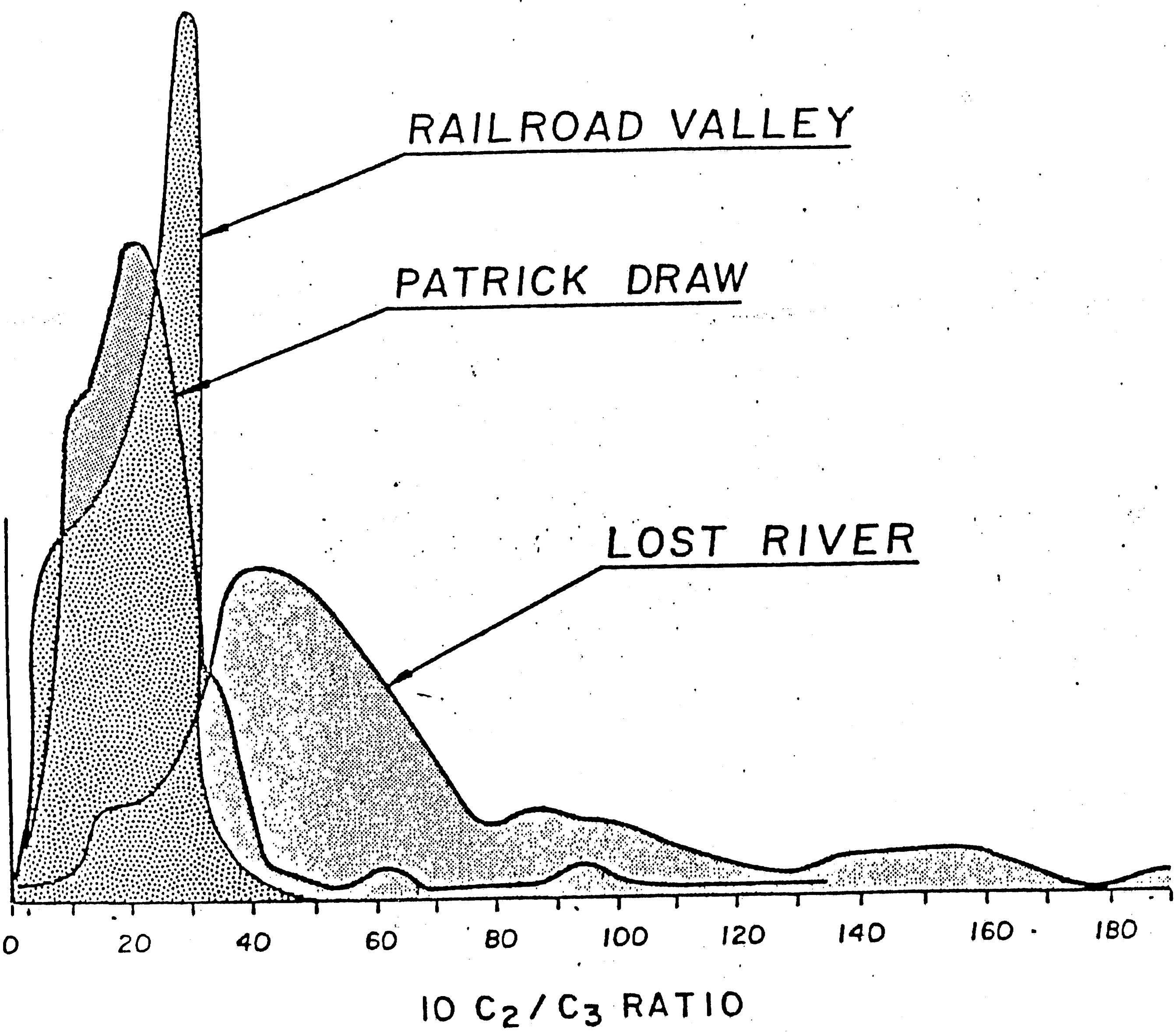

FIGURE 4 . Ethane to Propane Ratio (C2-C3): Probe Data from Railroad Valley, Nevada; Patrick Draw; Sweetwater County, Wyoming and Lost River in Hardy County, West Virginia.

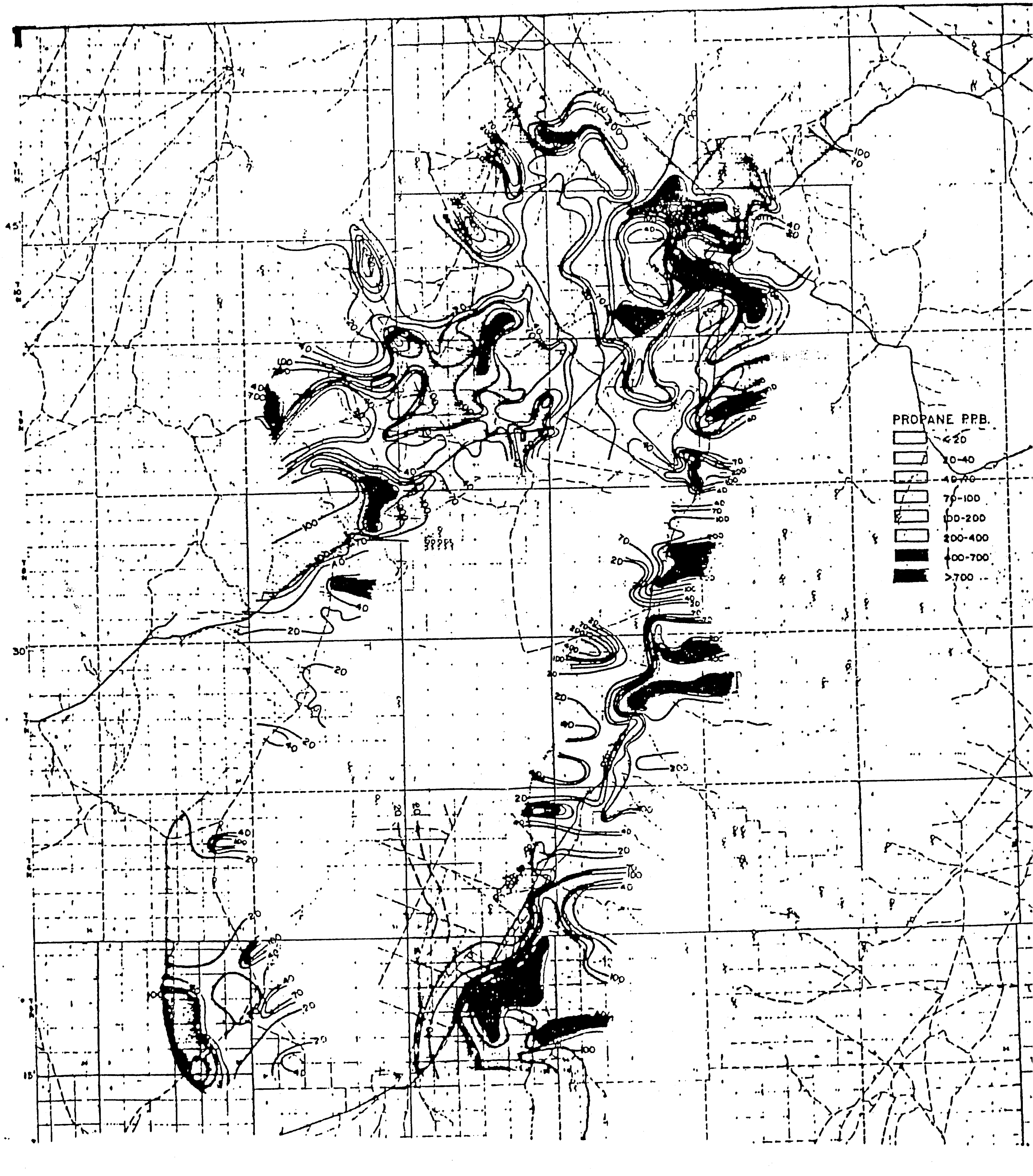

Figure 5. Contoured Propane Magnitude Data

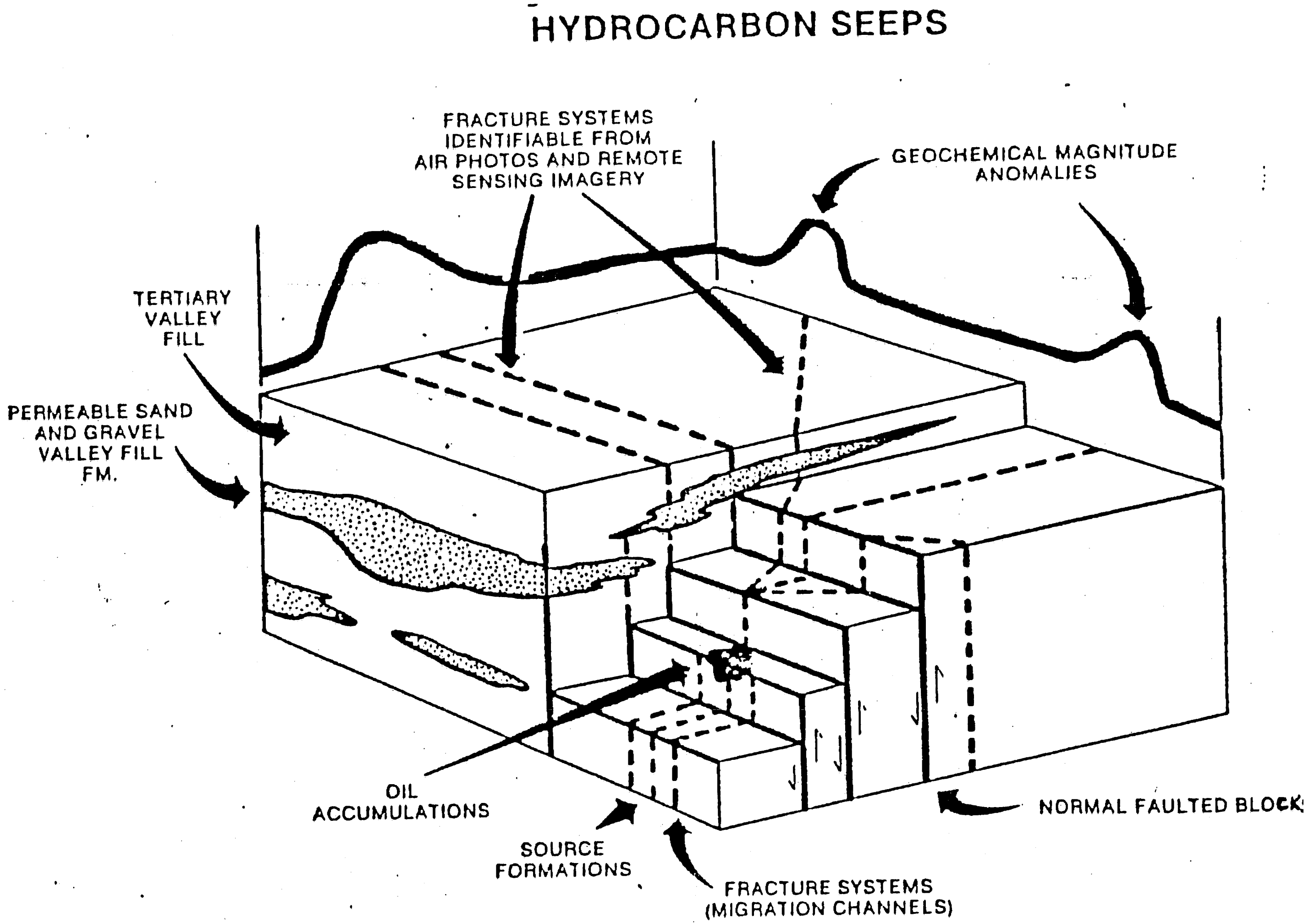
HYDROCARBON SEEPS
FRACTURE SYSTEMS IDENTIFIABLE FROM AIR PHOTOS AND REMOTE SENSING IMAGERY
GEOCHEMICAL MAGNITUDE ANOMALIES
TERTIARY VALLEY FILL
PERMEABLE SAND AND GRAVEL VALLEY FILL FM.
OIL ACCUMULATIONS
SOURCE FORMATIONS
FRACTURE SYSTEMS (MIGRATION CHANNELS)
NORMAL FAULTED BLOCKS

Figure 6.

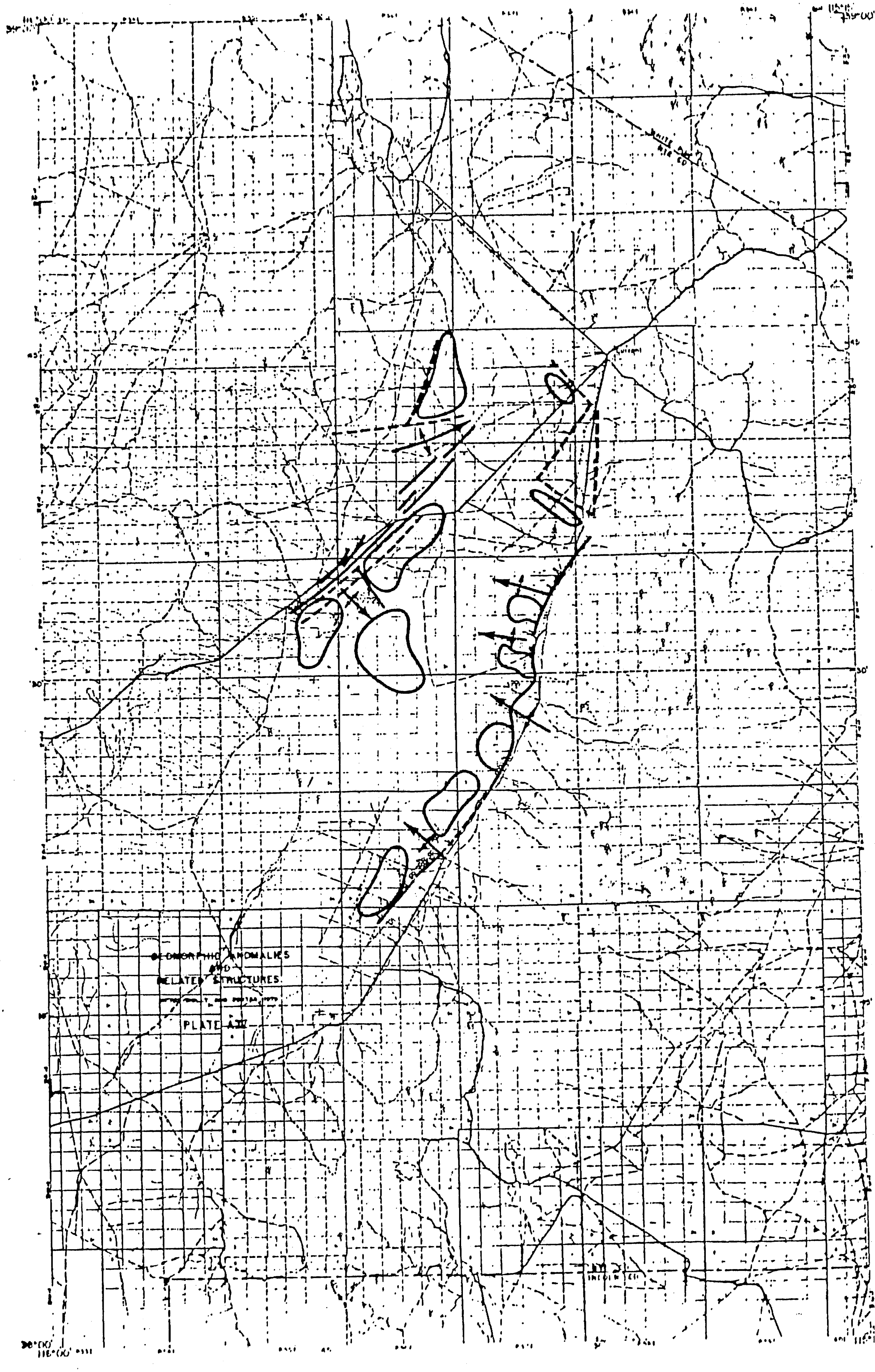

Figure 7 Geomorphic Anomalies and Related Structures