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SURFACE FEATURES ASSOCIATED WITH LINEAMENTS, EGSP AREA (COTTAGEVILLE FIELD, WEST VIRGINIA)

By
Carroll F. Knutson

April 1979

Work Performed Under Contract No. AP21-79MC10263

For
Morgantown Energy Technology Center
Morgantown, West Virginia

By
GeoEnergy Corporation
Las Vegas, Nevada

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ABSTRACT

The lineaments with discernable surface expressions are relatively small features. These features can be best seen on low altitude (large scale) imagery or on large scale (about 1:24000) topographic maps . Lineaments of this size have been positively correlated with EGSP well productivity in both the Cottageville (Jones and Ranch 1978-1) and the Big Sandy (Howard*) Fields. There is little consistency in selection of lineaments from small scale imagery.

In several areas above the Cottageville gas field water was found flowing from fracture zones that correlated with small lineaments expressed by drainage.

One spring was found on the surface above the Brown Shale Zone II in the deviated well in alignment with a drainage lineament.

Additional detailed studies of surface features including lineaments found on 1:2400 topographic maps and their correlation with productivity in the Cottageville Field Area is suggested.

*Personal Communication Dr. C.A. Komar METC

I. INTRODUCTION

This report was prepared as part of Purchase Order DG-AP21-79MC 10263 issued by the U.S. Department of Energy Morgantown Energy Technology Center.

The scope of the study defined in the P.O. was to evaluate the lineament relations in the Cottageville Field in West Virginia and the Big Sandy Field in Kentucky, and to evaluate the relationship between log characteristics shows and lineaments in the area of the DOE directional well.

The techniques used in this study were to review the available literature (as contained in – "open file information" METC (Jan. 1979), "Proceedings Seventh Appalachian Petroleum Geology Symposium" MERC/SP/76/2 (1976), "First Eastern Gas Shales Symposium" MERC/SP-77/5 (1978), "Second Eastern Gas Shales Symposium" MERC/SP-28/6 (1978) "Proceedings 3rd GRDA-EOGR Symposium" 1978) "Annual West Virginia EGSP Progress Report" (1978)). The project was discussed with Chuck Komar, Bill Oberbey, and Al Yost of METC and specific topical information was collected from them. The project was also discussed and suggestions were provided by Bob Shumaker and Henry Rauch of WVU.

After comparing the selection of lineaments by various workers and the well report from the DOE directional well. Five days were spent in the field, predominently in the Cottageville area of West Virginia, examining the surface features near some of the lineaments and near the directional well.

A discussion about information found in the literature and about the land surface are presented in the subsequent portions of this report.

II. LINEAMENTS

A. Introduction

The term lineament as used in most of the EGSP literature conforms to the recently proposed standard (O'Leary et al, 1976) which is--

> "We define the word 'lineament' in an essentially geomorphological sense, on the basis of the usage introduced by Hobbs: A lineament is a mappable simple or composite linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon."

A broad group of remote imagery was used as the basis for the lineament identification, synthetic aperature radar (SAR), multispectral scanning (MSS), Landsat, Skylab, and high and low altitude aerial photography. A number of different organizations were involved with the EGSP lineament studies. The lineaments were selected by a number of workers and in the Cottageville and Big Sandy areas correlated with Devonian shale well productivity. Thus, a good sample of representative lineaments is available for comparison.

B. Cottageville Area

The lineaments are presented on maps of various scales. The lineaments were transferred to 1:24000 scale U.S.G.S. maps and an 8½ by 11 in. area with its center near the DOE directional well was selected as the study area. The lineaments are presented as Figures 1 through 7.

Figure 1 ERIM prominent "visual" lineaments*
Figure 2 ERIM "prominent enhanced lineaments*
Figure 3 ERIM "tenuous" lineaments*
Figure 4 Composite lineaments from Rabchevsky's 1975 ERTS study
Figure 5 Composite lineaments from Rabchevsky's 1975 U2 study

*(Jackson et al 1979)

Figure 6	Composite lineaments from Werner's 1977 (1) study
Figure 7	Major lineaments from Werner's 1977 (2) study
Figure 8	Lineaments from Jones and Rauch 1978 (1)

The streams can be considered to be affected by the structural features producing the lineaments, hence these straight line stream segments are an additional lineament presentation, see Figure 9.

C. Big Sandy Area, Eastern Kentucky

Dr. J.F. Howard is finishing a study of the Vicco Quadrangle, Perry County Kentucky. This study utilizes low altitude aerial photography and the effort proposed for this report would have duplicated Howard's efforts. Hence, the decision was made to utilize Howard's study and concentrate the original work for this report in the Cottageville area.

D. Consistency of Lineament Interpretation

The problems that are occurring in lineament interpretation are well illustrated in the ERIM study (Jackson et al 1979). They had three interpreters make independent assessments of lineation in the Cottageville area, and less than 5% of the lineaments coincided between the three assessments. This is not unusual since ERIM reported another study in which less than ½% of the lineaments coincided when comparisons were made of the work of four interpreters working on landsat imagery of the Anadarko Basin in Oklahoma.

One problem that is apparant in utilizing the small scale satellite imagery is that original output must be so complexly processed that many critical features may be lost, A case of throwing the baby out with the bathwater. A "lightly" processed image of the Cottageville area is presented as Figure 10. It is probable that the processing required to take out the prominent east-"artifac" lineaments would also remove any "real" east west lineaments.

The type of machine processing done by ERIM holds promise of providing a consistant lineament output. Unfortunately, the imagery scale, parameters, etc., chosen for their study didn't produce usable results.

E. Correlation of Lineaments With Production

When the various small scale lineament studies Figures 1 through 8 are compared with the deWys et al (1977) production trend study of the Cottageville area; there is little more than a random correlation between maximum productivity trends and lineaments. However, Jones and Rauch ((2) 1978) found that there was a positive correlation between the water production and the nearness of the well to the photo lineaments they picked from large scale imagery (low altitude aerial photography). They also found (Jones and Rauch (1) 1978) that a positive correlation exists between the productivity of EGS wells and the number of nearby lineaments.

Zirk and Lahoda (1978) found a statistically significant correlation between photo lineaments (U-2- i.e. high altitude photo imagery) and the first year productivity of EGS wells in Lincoln and Wayne Counties West Virginia. However, these lineaments were not consensus, and were not necessarily drawn independently from any bias.

Ryan (1976) also evaluated side looking radar (SLR) imagery lineament proximity to ESG well productivity in the eastern Kentucky (Big Sandy) Gas Field area. A positive correlation was noted, but a high degree of statistical significance may not have been achieved (Zirk and Lahoud, 1978). Zirk and Lahoud* analyzed for statistical significance the correlation between Howard's Vicco Quadrangle lineaments, and productivity of Big Sandy ESG wells in that area. They found a significant correlation at the 0.05 level for the blue lineaments (low level aerial imagery), and no significant correlation with the red lineaments (small scale imagery).

*Written communication Dec. 7, 1978

III. FIELD EVALUATION

A. Introduction

Since the bulk of the field effort relating to this study was spent in the Cottageville area, the field evaluation remarks will be confined to a discussion of this area.

The Cottageville area is a few miles west of the surface trace of the axis of the Appalachian (Parkersburg) geosyncline (Overbey 1961). The surface bed is horizontal dipping to the southeast at less than 25 feet per mile. The state geological map shows the "Possible Cross Appalachian Fault Zone" through Cottageville having an orientation of north 30° west, and the "Probable zone of Transcurrent Faulting" passes a few miles southeast of the area and has an orientation of about North 65° east (Cardwell et al, 1968). The surface rocks in the area are discontinuous sandstones; a few limestones that often grade laterly into sandy shales, or sandstones, red shales and sandy shales, and sandy shales, and a few thin, 6 to 18 inch, coal beds. (Overbey, 1961).

B. Jointing

Except for a few recent road cuts and building excavations, the only exposed surface rocks are sandstone outcrops. Werner (1977 (2)) expressed concern that the jointing directions of these beds may not be the same as the regional trends present in the surrounding fine grained rocks. The lack of contiguous exposures of sandstones and shales in the Cottageville area precludes a comparison. In an analogous situation, where the surface formation consisted of discontinuous sandstones interbedded with fine grained rocks and were underlain by a thick sequence of organic shales and marlstones (the Piceance Basin, Western Colorado) the systematic joint direction were found to coincide in the various lithologies. However, a unique and complex series of non-systematic joints was developed in the sandstones. This complex seemed to be related to gravity forces acting on the resistant sandstone bodies. Under these circumstances the joint geometry was a function of the orientation and inclination of the free surface, the lack of support or undercutting occurring in the surrounding fine grain rocks, and the geometry of the sandstone body. The variation in direction between nonsystematic and systematic joints may have been the reason for Werner's observation (1977 (2)) that the joint or fracture directions varied between valleyside outcrops which would be expected to contain more free surface controlled nonsystematic or gravity features and valley bottom or stream bed exposures which lack a horizontally adjacent free surface.

It is important to attempt to zero in on the systematic joint or fracture phenomena, since the concept behind the examination of surface features is that they reflect fracture phenomena at depth in the Devonian Shale, and these fractures are thought to control that unit's gas productivity.

One interesting surface feature is the occurrence of fracture zones that are conduits for near-surface water flow. One of these zones located within the boundary of the Cottageville Field area is shown in Figure 11. Another illustration of water flow in parallel systematic fracture zones is shown in Figure 12. The moving water has reduced the iron oxide coating in the generally buff colored sandstone and these conduits appear as green stained zones. The orientation of the zone depicted in Figure 10 is North 10 west and north 60 east for the zones shown in Figure 12.

The orientation of stream segments was frequently seen to parallel one of the joint or fractures direction. Figures 13 and 14 present examples of joints in creek bottoms that are parallel with the stream directions. Thus, a working hypothesis is that the joints exhibit some control on stream orientation.

C. Deviated Well Area

An examination of the surface features in the deviated well area yielded a number of sandstone outcrops with measurable joint direction. The fracture rose for the area is presented in Figure 15. The greatest number of joints were near vertical and oriented near north 60 east. A spring was noted with an apparent source in joints oriented north 82 west. This near vertical joint set would intersect the deviated well at about 4500 feet, if projected vertically to an intersection with the survey of the well bore (McManus and Metzler, 1978). The section of the wellbore from 4400 ft. to total depth is located under an approximately east-west oriented straight line segment of a stream. Jones and Rauch (1978-2) found more fracturing and higher water well yield in stream valley orientations as well as higher EGS well productivities near their small lineaments.

Thus, the surface features, in the deviated well area, might cause one to predict reasonable fracture permeability in the bottom part of the well.

There doesn't appear to be any features that would lead one to predict the anomalous water production, assuming the water was from a fracture system cutting the Devonian Shale. (The water bearing fracture zones previously discussed, Figures 9 and 10, were located in a section of the field with normal gas production).

IV. Discussion of Relation Between Surface Features and EGS Production

The surface features considered in previous studies have been mostly those somewhat tenuous patterns discernable in airborne imagery (which has been highly modified or "enhanced" in many cases). This type of surface feature has proven to be ambiguous and difficult to correlate between different workers.

An interesting aspect of the problem would seem to be an attempt to correlate the EGS well productivity with topography, since this is a less ambiguous aspect of the lineament problem.

Attempting to correlate topography with EGS production is an interesting exercise, that brings into focus some of the many probles associated with the lineaments. First, topography is everywhere present in the EGSP area (as are someonés lineaments); thus a meaningful correlation probably will require more than a simple relation between proximity and productivity. Jones and Rauch (1978-2) compared lineament density, length/unit area, with productivity and achieved a significant correlation. A problem with this technique was the non rigorous location of the lineaments. The scale used in their study seemed appropriate.

Rauch will attempt to develop a set of rigorous lineament location criteria and attempt to test the consistency of location via these criteria with the aid of students in a West Virginia University graduate seminar.*

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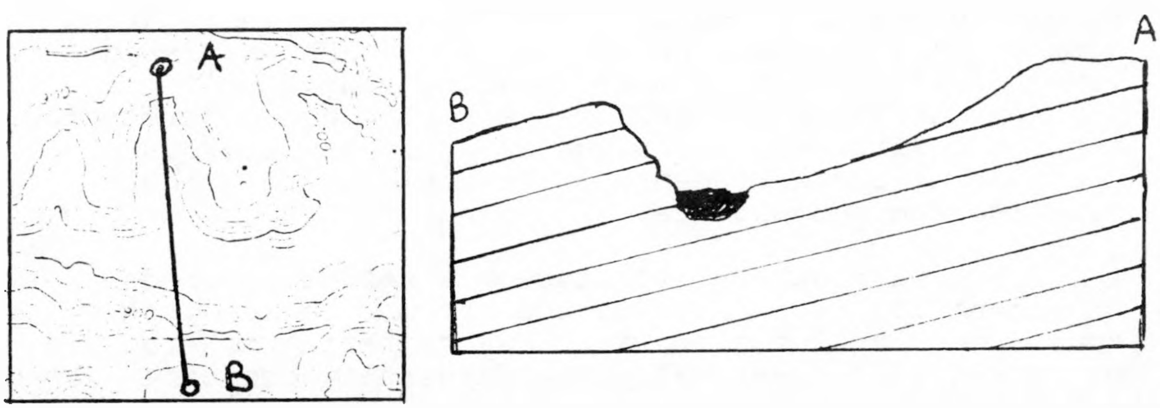
* Personal communication H. W. Rauch

Rigorous criteria probably can be applied most easily with a machine. The ERIM attempt, (Jackson et al, 1979), although not successful as far as results were concerned, seemed to exhibit promise as a software development project. Thus, it might be productive to make another attempt at machine evaluation of lineaments using a more productive base, which may be a topographic type output.

The topography is an expression of the lithology of the surface beds as well as such features as structure, jointing, faulting, impressions from former features that have been removed by erosion, etc. The topography in the Cottageville area is affected by the massive sandstone beds that are more erosion resistant than the associated siltstones and shales. The sandstones are discontinuous; and, other things being equal, erosion tends to proceed more rapidly along the margins rather than in the massive central portions of the beds. Figure 16 shows the edge of a sandstone bed in a roadcut near Cottageville Field, West Virginia.

Thus, there is a tendency for the ridges to be capped with massive sandstone, Figure 17. The ridge orientation is frequently affected by the joint directions or by erosion preferentially proceding along fractured zones such as those shown in Figure 9 and 10.

A number of topographic features in the Cottageville area seem to provide a dip direction, i.e. a measure of structural control. Valleys with tributaries on only one side frequently occur where stream direction parallels the strike direction. The stream cuts into the face of the dipping strata and the tributaries are developed on the dip slopes.



Other topographic anomalies noted in the Cottageville area are:

a) Streams consist of straight line segments.

b) Streams head opposite one another across ridges.

c) Tributaries are aligned across valleys.

d) One stream captured by a second stream.

e) Stream heads into linear valley head.

f) Numberof parallel stream segments.

g) Linear ridge segments.

One strategy would be to identify the topographic anomalies, grid the area, tabulate the number of anomalies in each grid unit i.e. construct an anomaly density map, contour the density of various types of anomalies, and compare conture maps with productivity maps from Cottageville Field.

V. Cottageville Field Model

Data from the Cottageville Field is somewhat ambiguous. This, coupled with the inherent complexity of the field, makes modeling of the field a difficult process.

If the basic assumption is made that the field is a permeability anomaly in a much more extensive shale layer, then it makes sense to attempt to correlate surface features with subsurface features that may relate to the local permeability high (for instance the assumption of pervasive sequence of stresses that have resulted in local fracturing, surface and subsurface).

During recent geological time the high permeability field area and the low permeability adjacent area would probably reach a state of pressure equilibrium. Thus the field and surrounding area could be assumed to have been at about 800 psi prior to 1930. Using the Cottageville drilling and completion information and the initial pressure information (deWys and Shumaker, 1978) a series of estimated pressure maps can be constructed, Figures 18-20. An "eyeball" comparison of cumulative production with volume of rock exhibiting pressure reduction indicates a very low porosity effected by the 800 to 300 psi pressure drop. A simple material balance can be made with a computer using a polygon well spacing, Figure 21, and matching withdrawals with flow paths and estimates of porosity. From the "eyeballed" analysis it would appear that there has been significant Devonian gas production either from multiply completed wells not listed in the data set, or there has been "leakage" into other reservoirs.

The question of natural leakage via faults of fracture zones has been considered. Werner (1977-1) suggested the correlation between one of his lineaments and low EGS well productivity may have been the results of leakage from the reservoir along lineament related permeability paths. The initial "normal" pressures that were encountered by the wells in that area suggest a more complex relationship.

The logs in the deviated well were correlated to determine if a fault might be present to explain the water production, Figure 22. A comparison of the deviated well log corrected to a true vertical relation* with wells north west and south east of the Brown Shale Zone II (location in the deviated well) certainly shows no cut out or repeated section that would indicate a fault.

* Machine processed log obtained from Al Yost, METC.

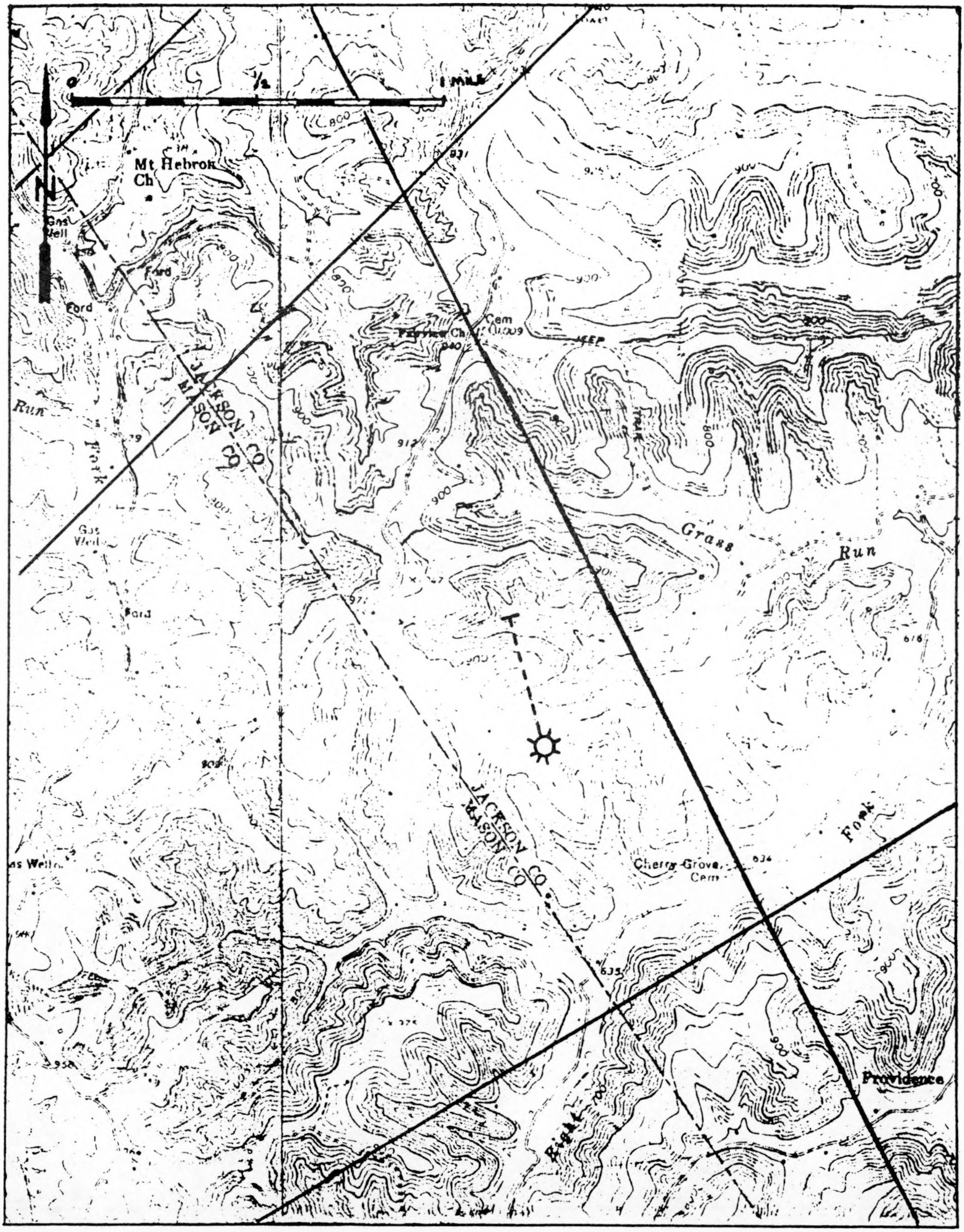


FIGURE 1. ERIM Prominent Lineaments From Visual Interpretation (Jackson et al 1979)

FIGURE 2. ERIM Enhances Prominent Lineament (Jackson et al, 1979)

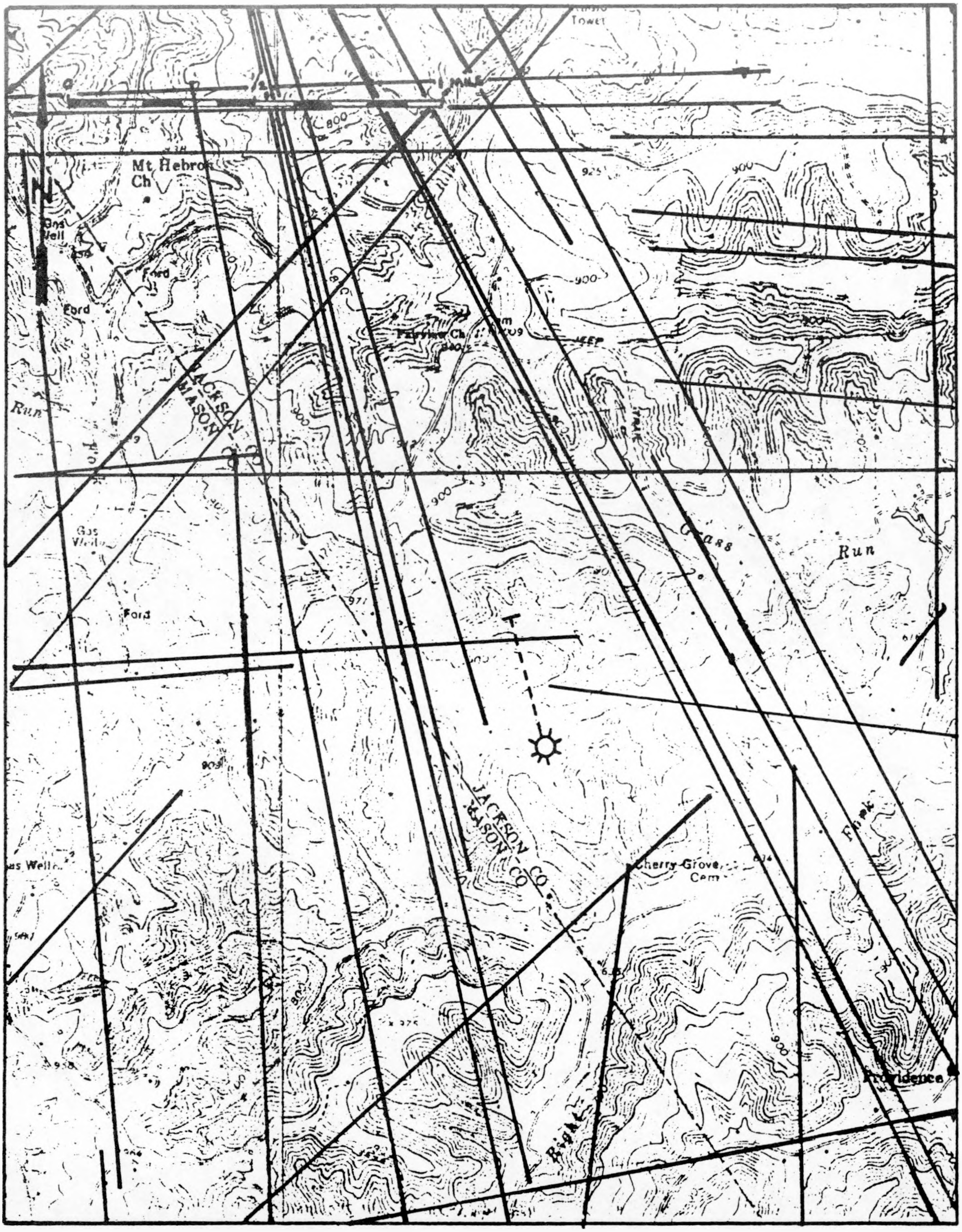


FIGURE 3. ERIM Tennous Lineament From Visul Interpretation (Jackson et al 1979)

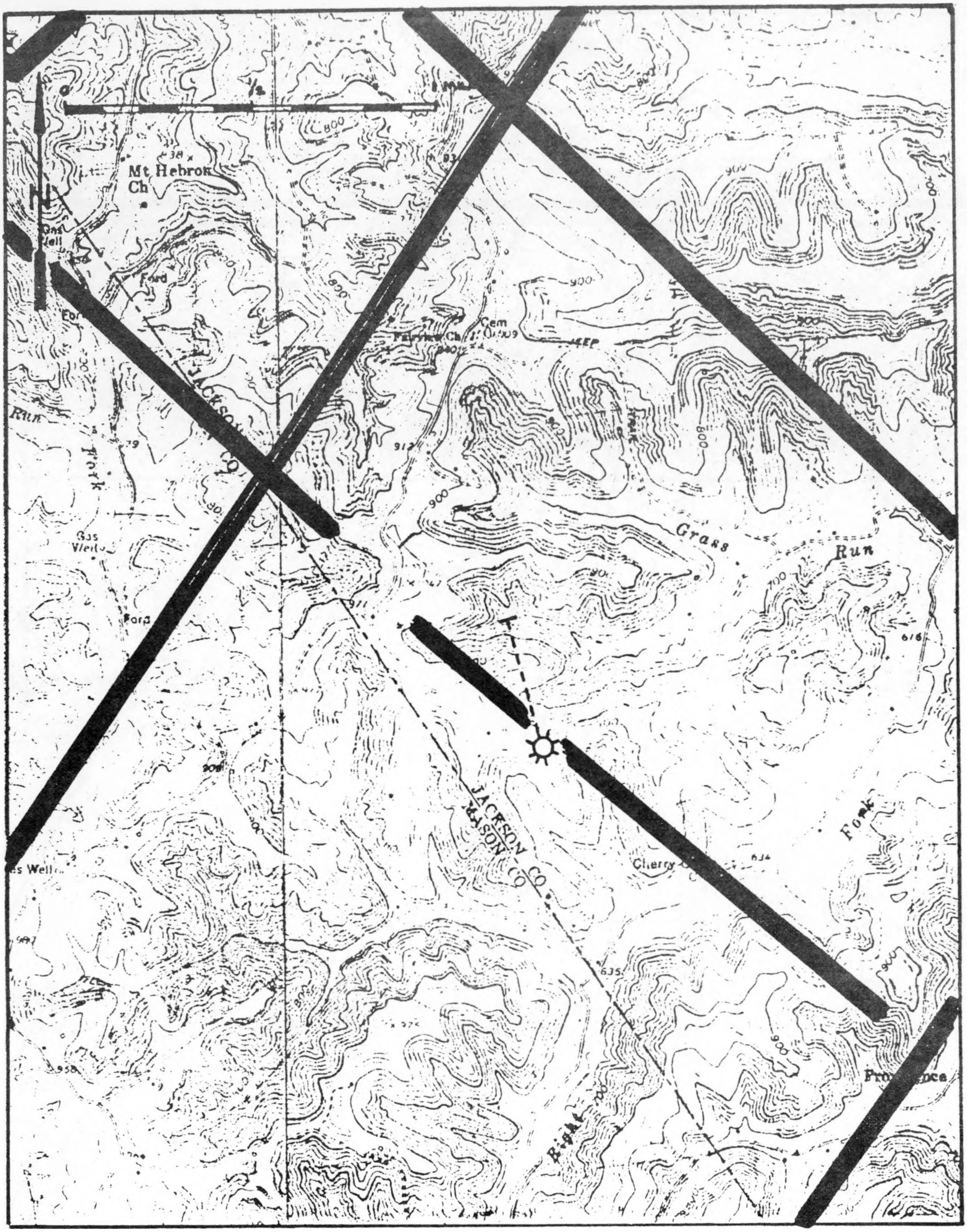


FIGURE 4. Lineaments From The Rabchevsky ERTS Study (1975)

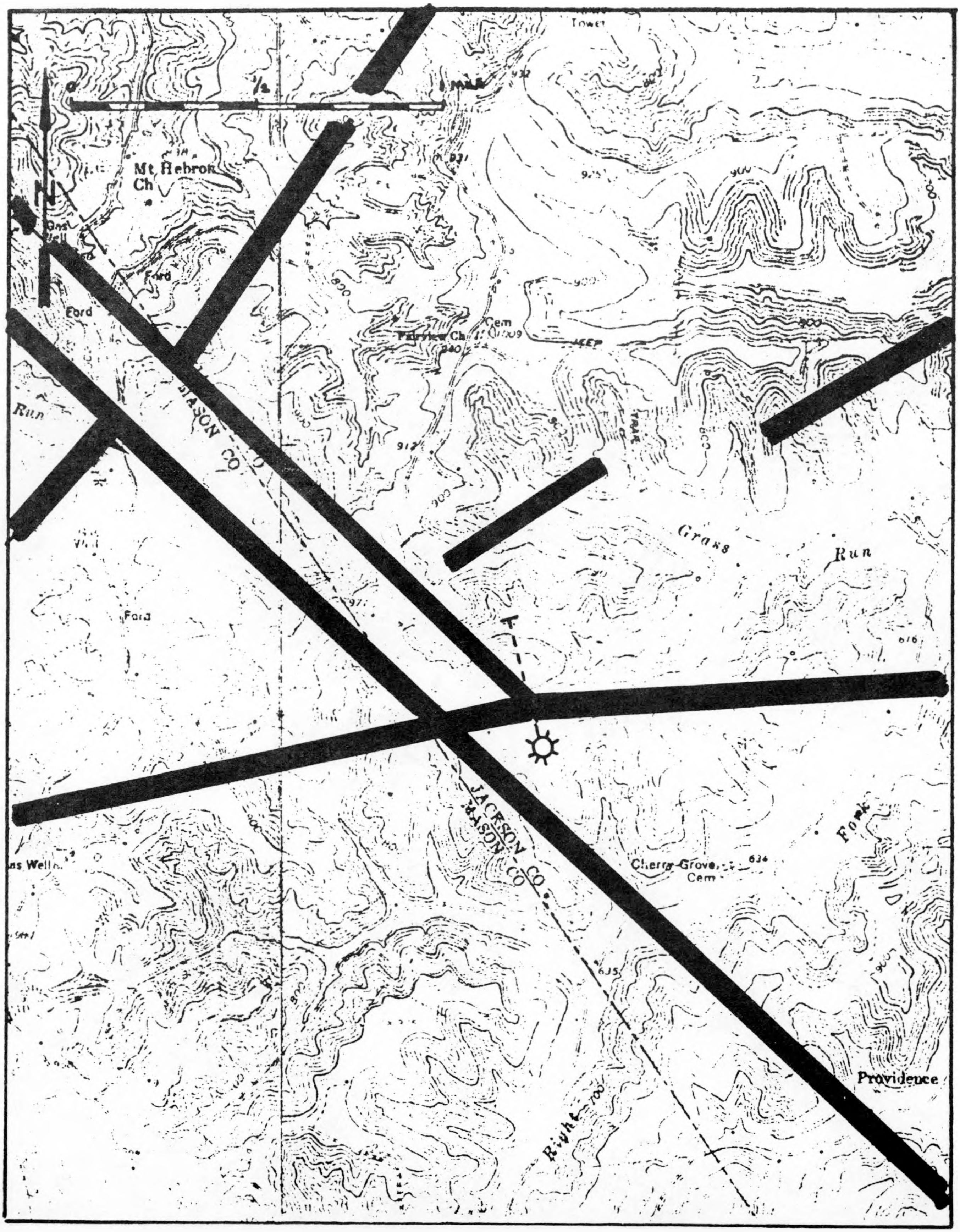


FIGURE 5. Lineaments From The Rabchevsky U-2 Study (1975)

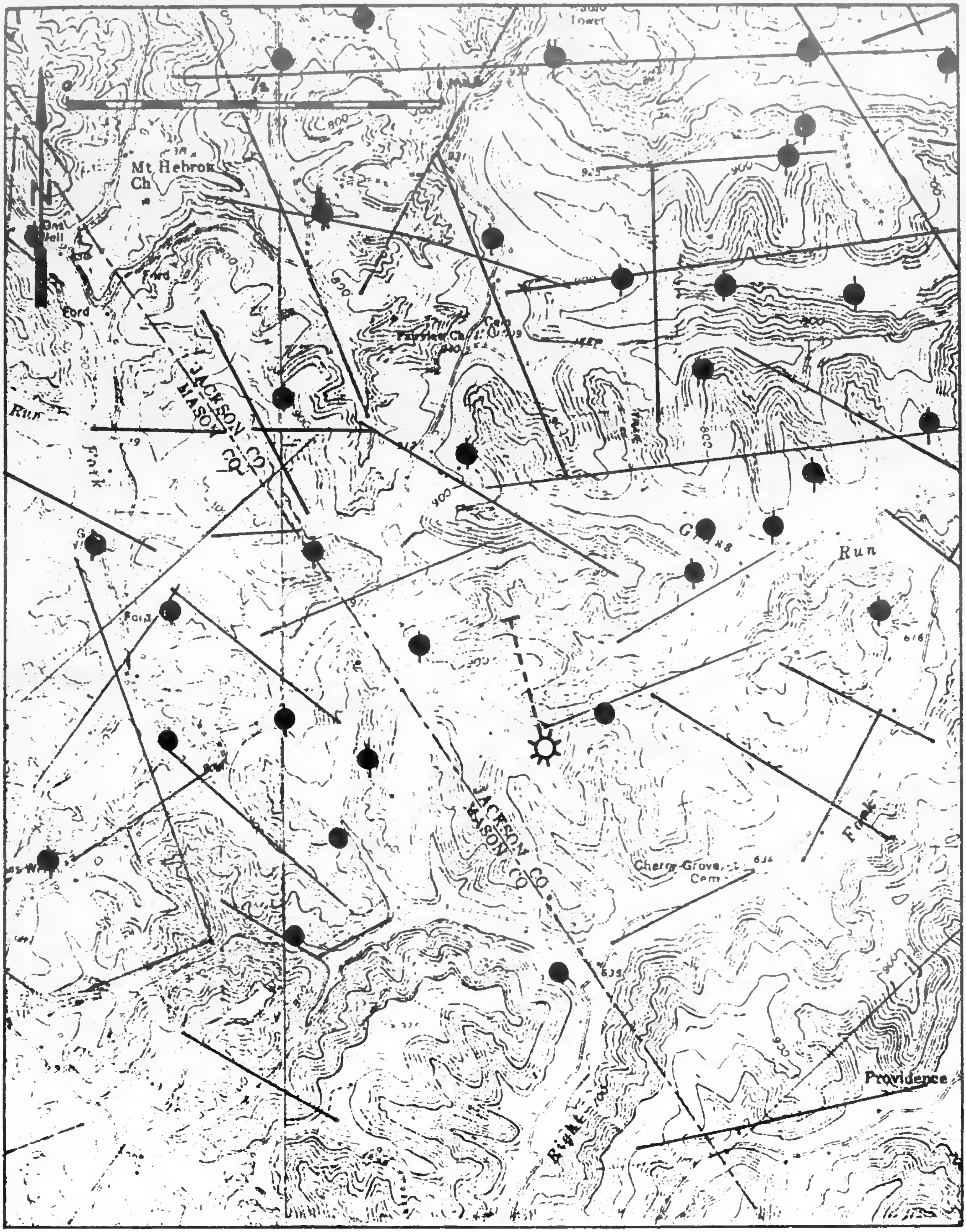


FIGURE 6. Composite Lineaments From Werners Aerial Photo Study (1977) Circles with vertical lines are Devonian shale well locations.

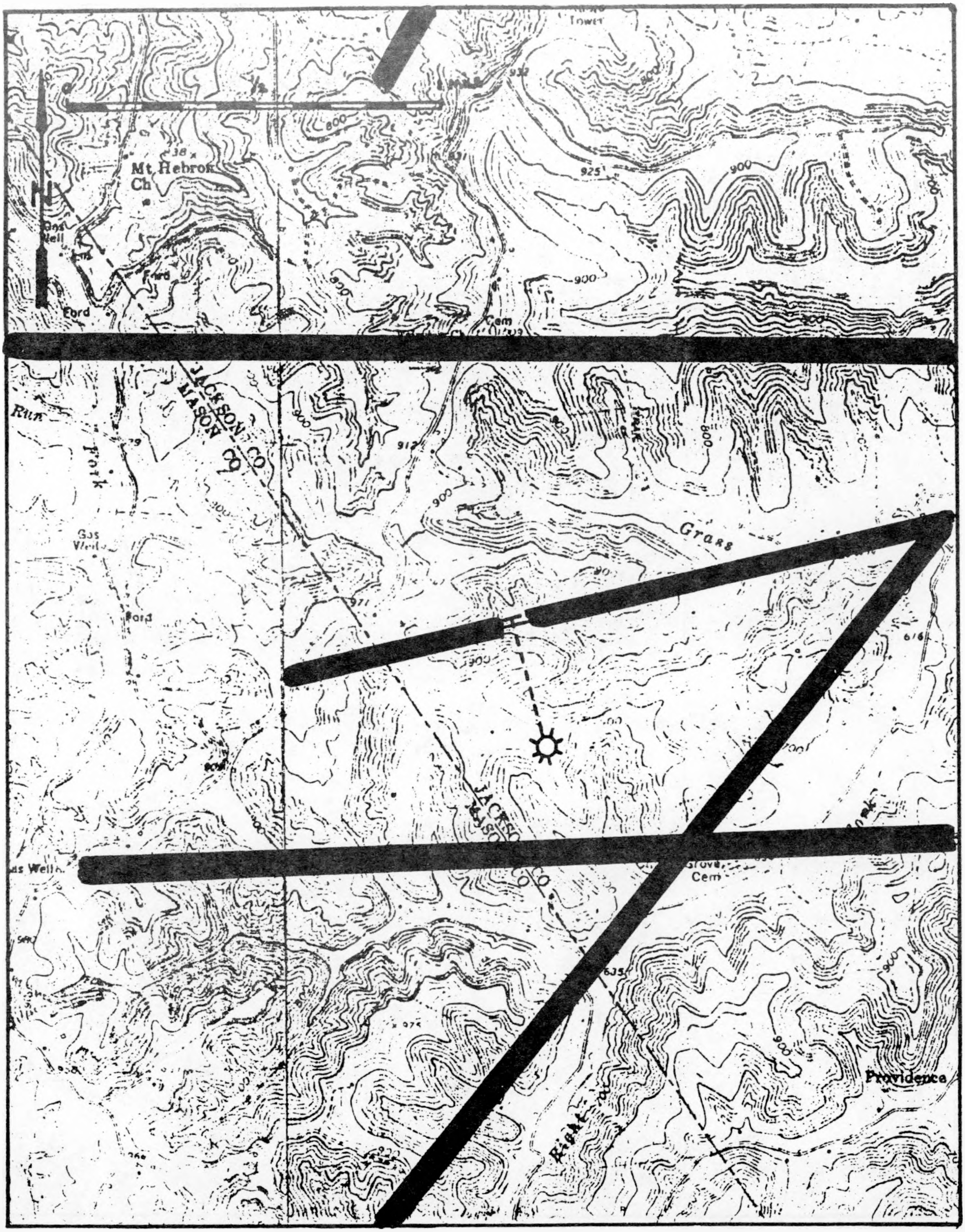


FIGURE 7. Major Lineaments From Werners Small Scale Imagery Study (1977)

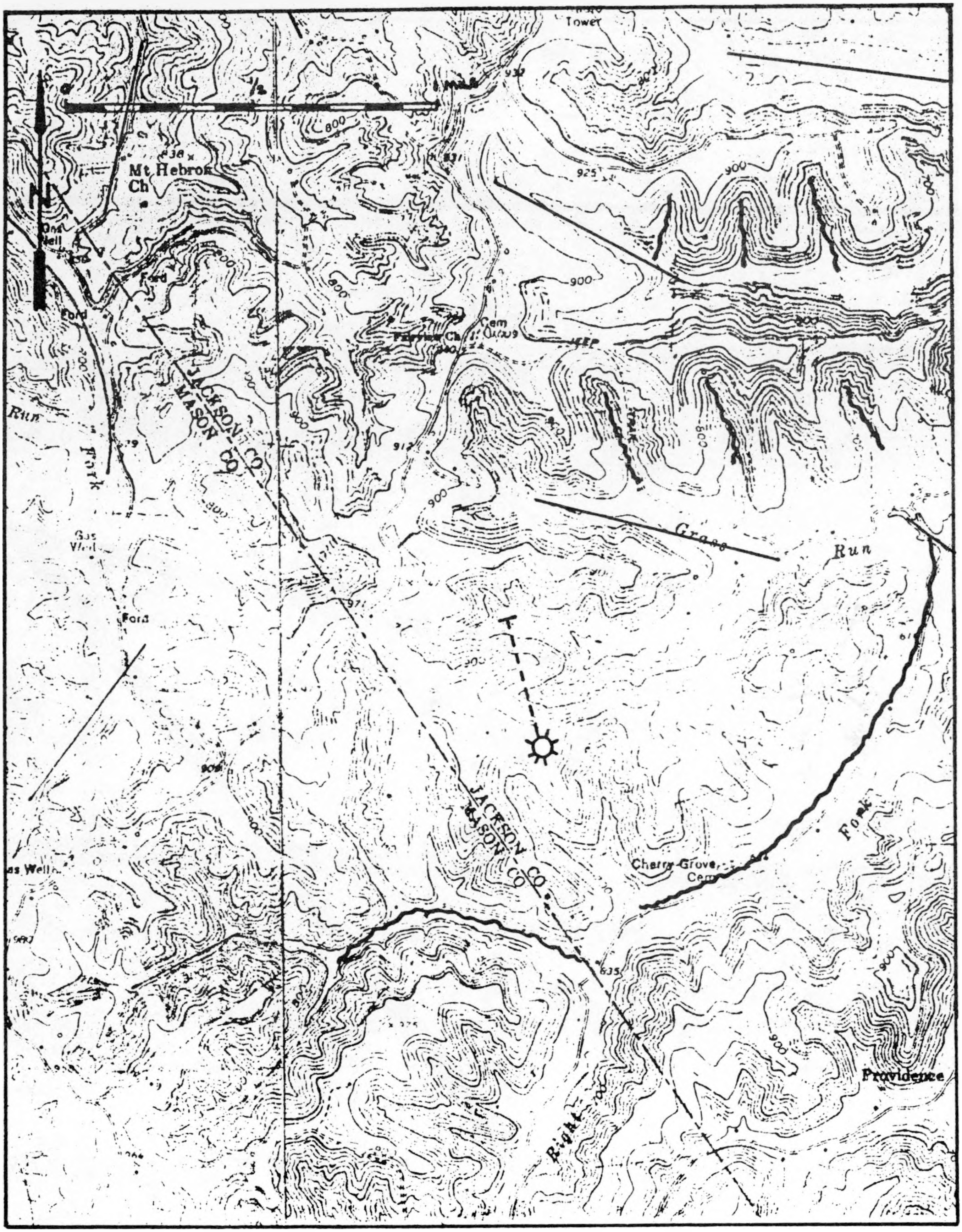


FIGURE 8. Lineaments From Jones and Rauch's Low Altitude Aerial Photo Study (1978)

FIGURE 9. Drainage Map.

FIGURE 10. ERTS Imagery Of Cottageville Area - Showing East West Scan Lines

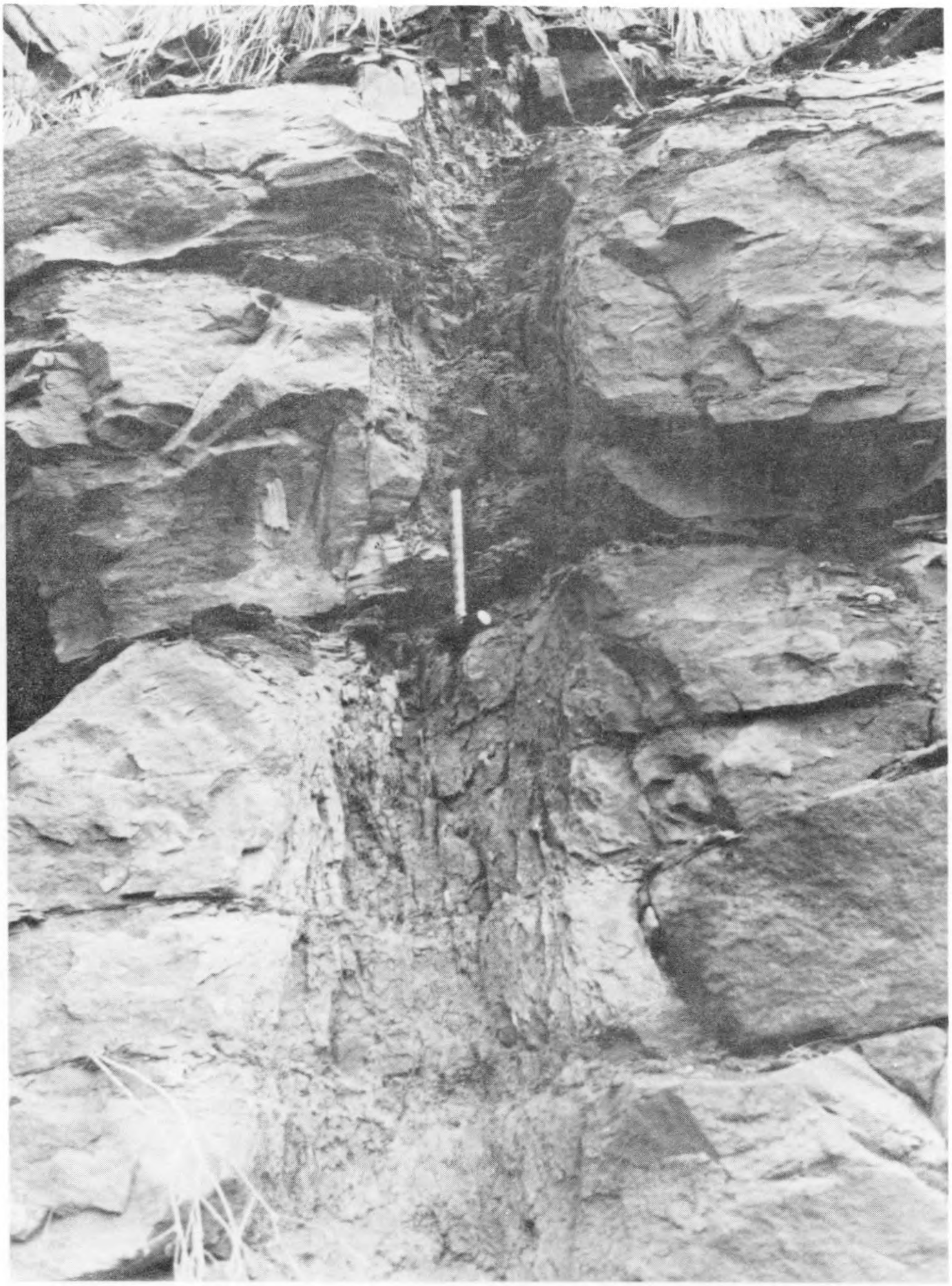


FIGURE 11. Fracture Zone Showing Discoloration Caused By Water Movement (Hammer handle 1/3 mi), Cottageville Field, West Virginia.

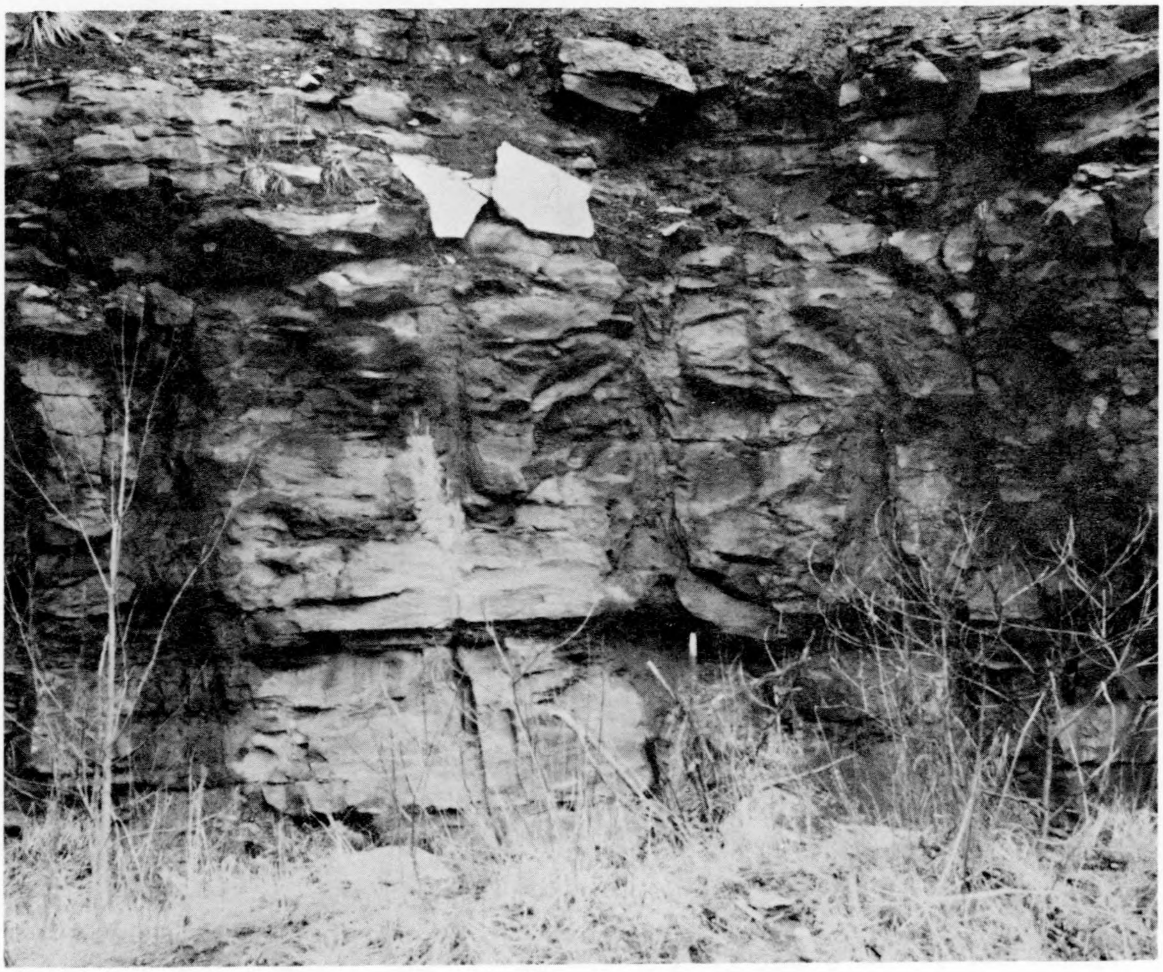


FIGURE 12. Water Flowing Through Fractured Zones Has Discolored Sandstone. South-east Portion Of Cottageville Field, West Virginia

FIGURE 13. Joint Set In Sandstone. Fractures are parallel with Stream Direction (Hammer handle 1/3 mi.long)

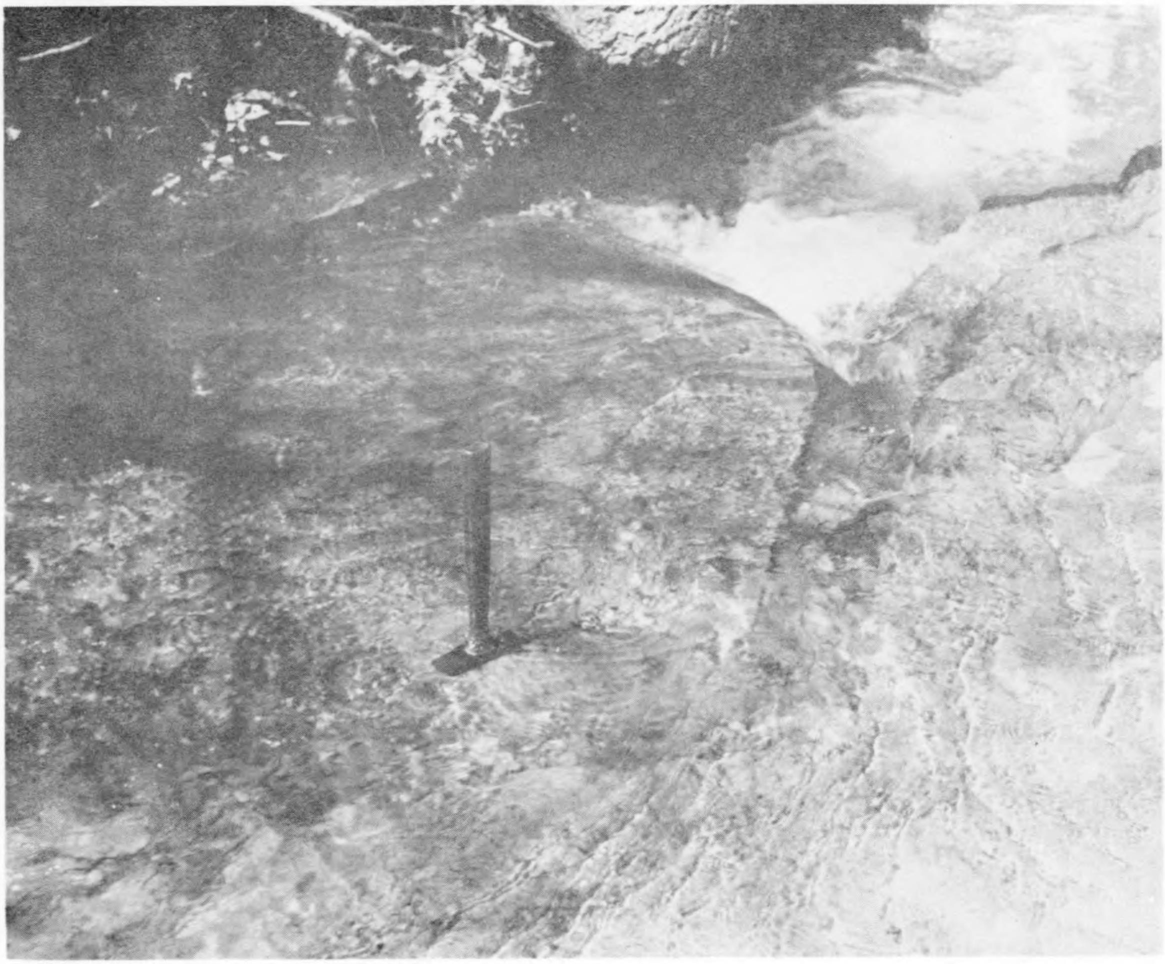


FIGURE 14. Fractured Sandstone Layer In Bottom Of Stream. Joint set parallel to stream direction near top of picture and oblique joint sets near hammer. (Handle 1/3 mi. long)

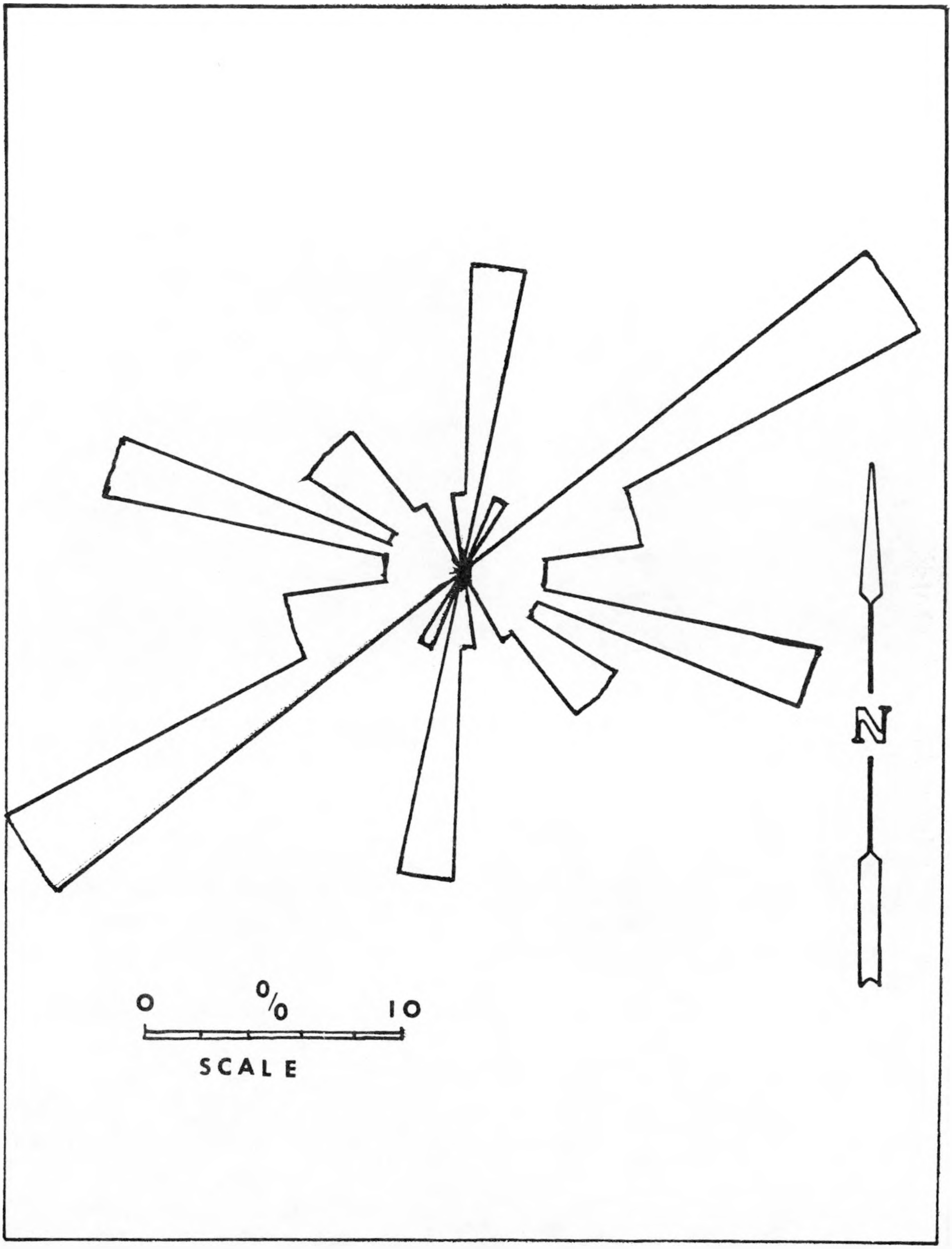


FIGURE 15. Fracture Rose Diagram From Surface Joints In Sandstone Outcrops In The Deviated Well Area.

FIGURE 16. Edge Of Massive Sandstone Lense Exposed In Roadcut Near Cottageville Field, West Virginia.

FIGURE 17. Massive Sandstone Bed Capping Ridge Near Cottageville Field, West Virginia.

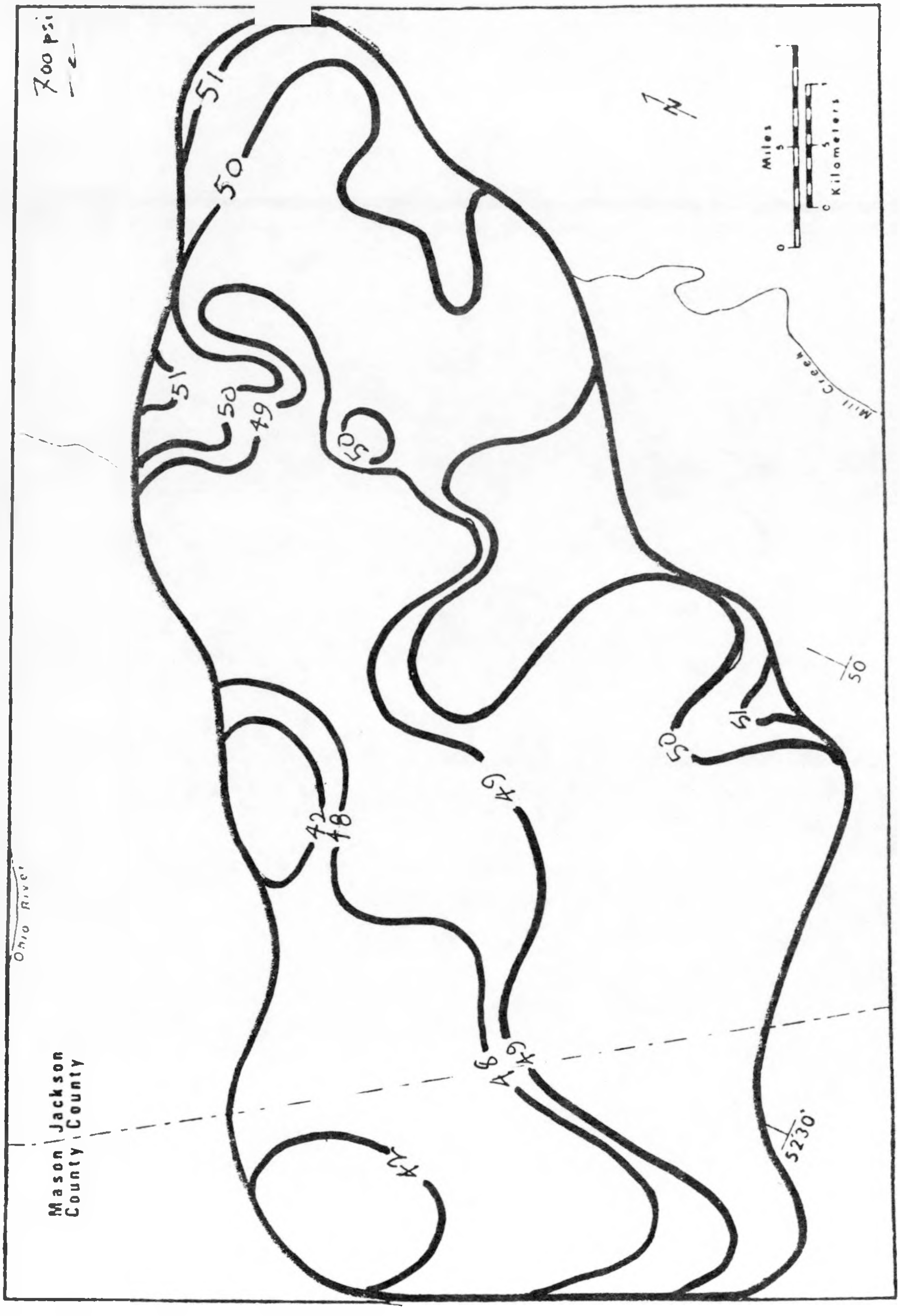


FIGURE 18. Estimated Location of 700 psi is 0 Pressure Contour 1942 (42) to 1951 (51) (Data From deWys and Shumaker, 1978)

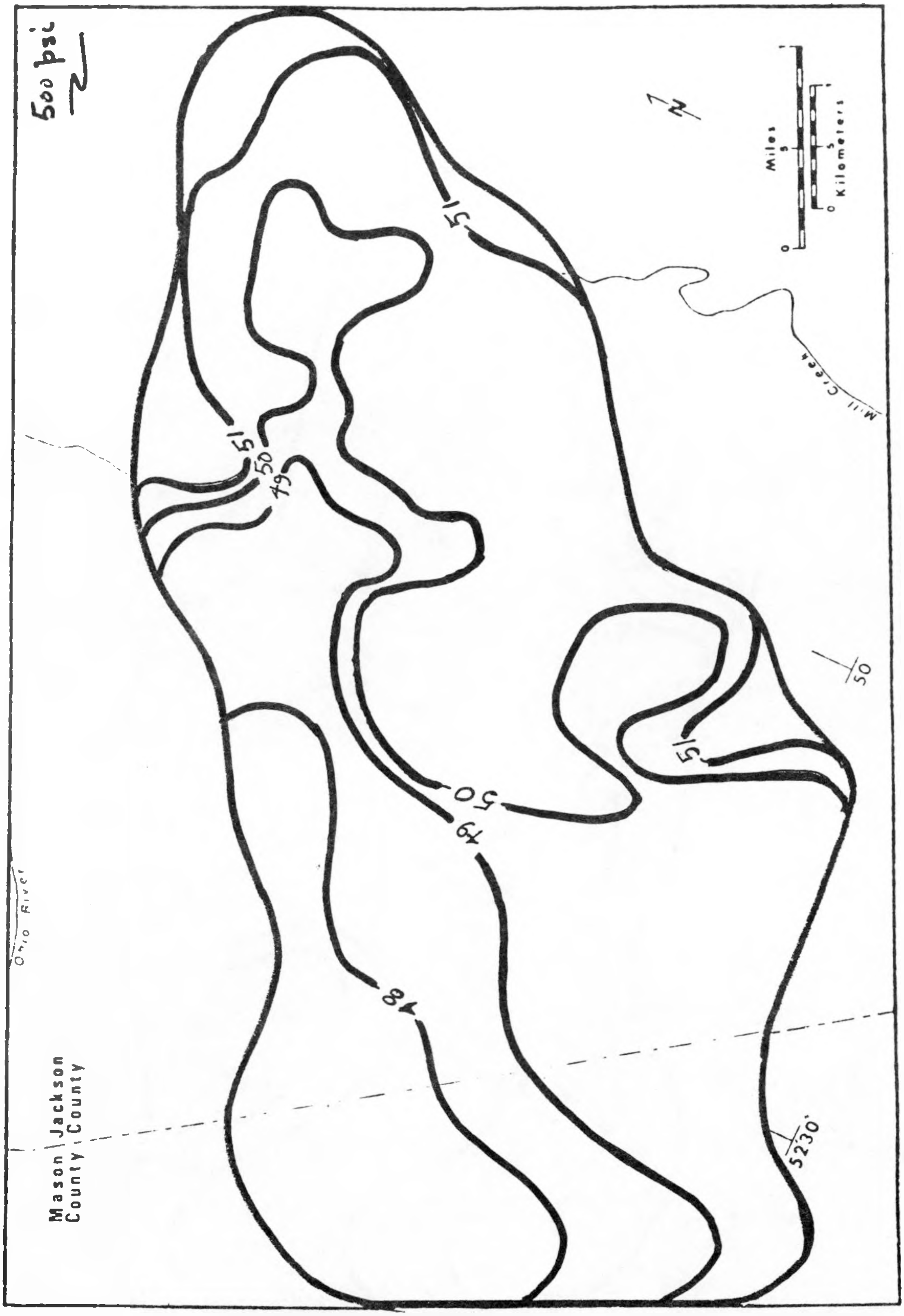


FIGURE 19. Estimated Location of 500 psi Is O Pressure Contours 1948 (48) to 1951 (51) (Data From deWys and Shumaker, 1978)

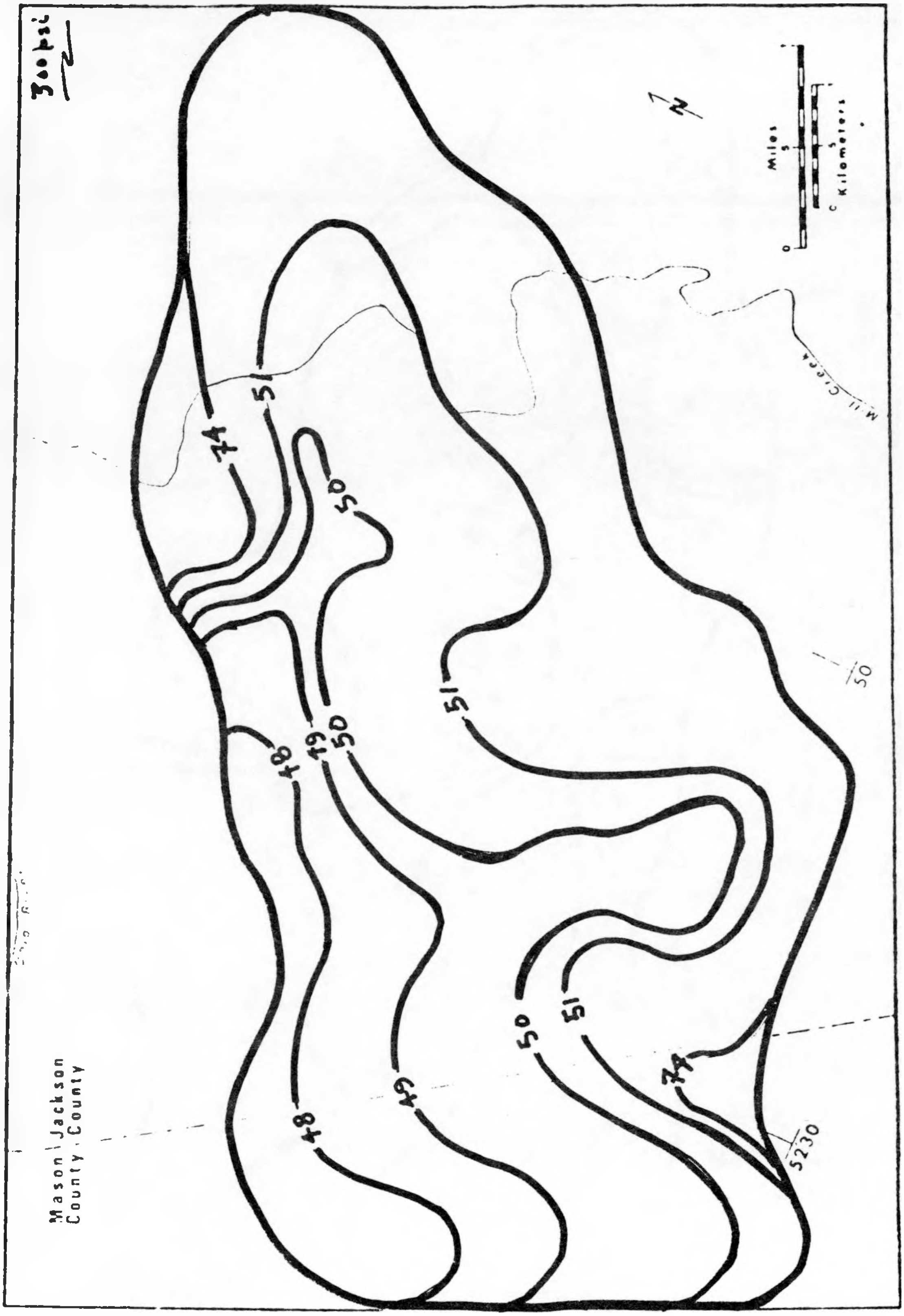


FIGURE 20. Estimated Location of 300 psi is 0 Pressure Contours, 1948 (48) to 1974 (74). (Data From deWys and Shumaker, 1978)

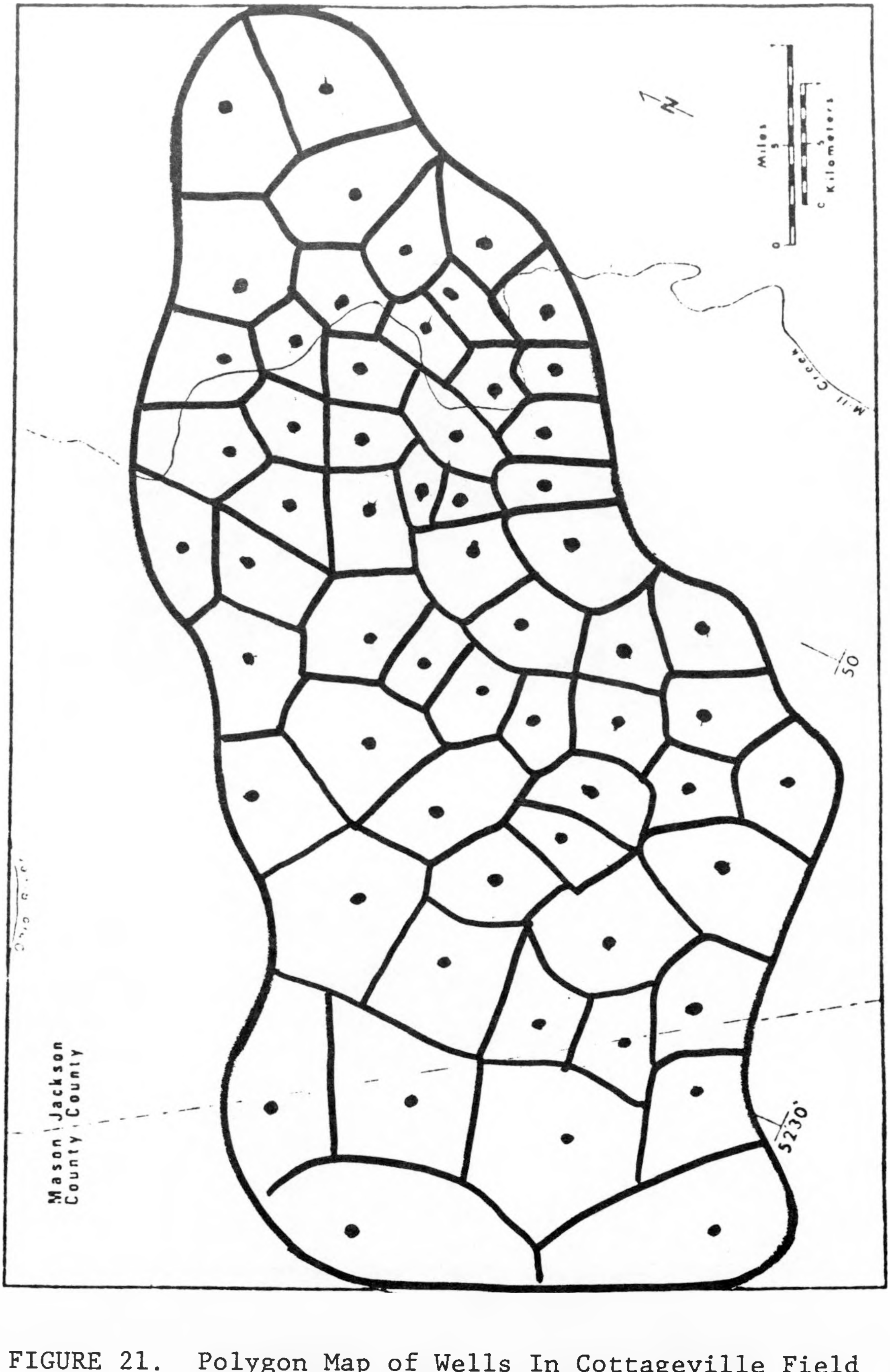


FIGURE 21. Polygon Map of Wells In Cottageville Field (Data From deWys and Shumaker,1978)

Cross Section Deviated Well Area

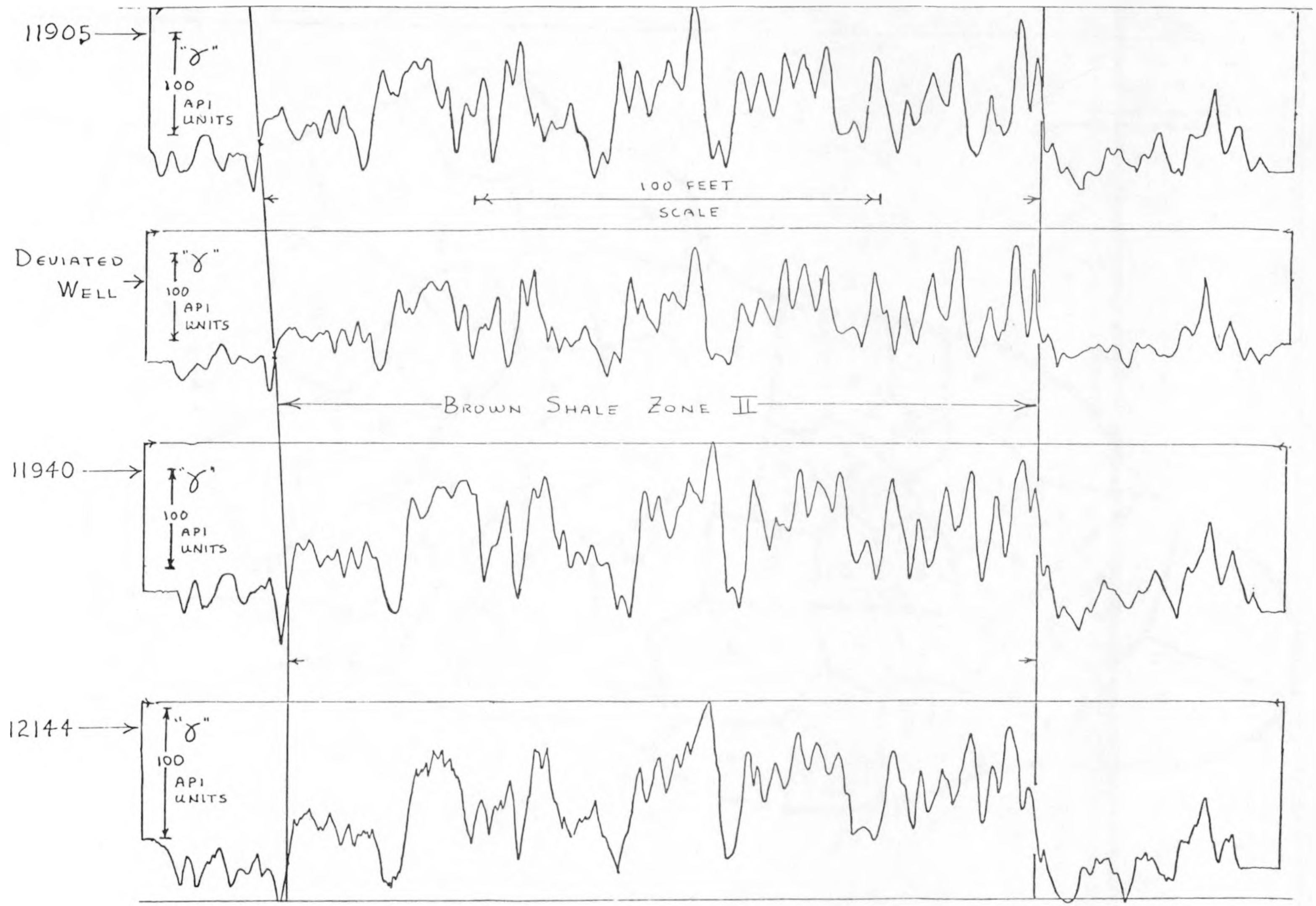


Figure 22

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