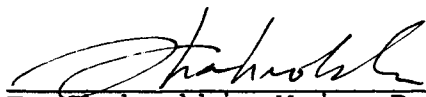


To the Graduate Council:

I am submitting herewith a thesis written by Charles David Vanhorne Rowan entitled "A Lineament Analysis of Two Selected Areas of Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Engineering Science.

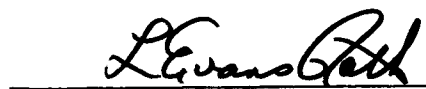

F. Shahrokhi, Major Professor

We have read this thesis
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Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

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A LINEAMENT ANALYSIS OF TWO SELECTED
AREAS OF TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Charles David Vanhorne Rowan

March 1980

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ABSTRACT

It has long been the problem of the exploration geologist to find sites of mineral and energy sources that have the potential for economic development.

At present, those involved in active exploration waste much time, personal energy, and natural resources on unproductive sites. Therefore, it is proposed that a new exploration tool, lineament analysis, be used and tested as having the potential to locate prime exploration targets.

Lineament analysis was performed on two sites. One site in eastern Tennessee has known zinc mineralization and operating mines. The other site in middle Tennessee has recently been discovered to also have zinc mineralization, and this may, hopefully, be in economically recoverable quantities.

The analysis of the known eastern site showed that lineament analysis was able to pick out the sites of known mineralization, thus eliminating for the exploration geologist many of the unproductive areas and saving money, time, and natural resources.

Finally, lineament analysis was applied to the middle Tennessee area and the sites having the most potential for future exploration were located and recorded.

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CHAPTER I

INTRODUCTION

Mineral and Energy Source Location

For some time there has been concern over the world's supply of minerals and energy. In particular, this situation has been a primary trouble of the exploration geologist. Many exploration geologists today feel that most of the world's larger mineral deposits and energy sources have already been found, because of their size and relatively shallow depth of occurrence. This leaves undiscovered smaller exploration targets which can also occur at considerable depth below the earth's surface, thus making them very difficult to locate. In order to locate these undiscovered mineral deposits and energy sources, the exploration geologist needs to use all methods of site location and all sources of information and literature which may be available.

Mineral deposits and energy sources are found by extensive and exhaustive study. In nature these mineral deposits and energy sources very rarely occur as a matter of chance. In fact, there is usually a pattern to the location of the deposit. Until the pattern is found out, deposits may look to be randomly located.

Through the use of geologic and topographic maps together with good field geology, the use of current, up-to-date geophysical methods and the laboratory analysis of field samples, a deposition pattern may be discovered. When a pattern is found out and its parameters are delineated, the exploration geologist looks for two or more of these parameters together to see if they will indicate a prime location for an exploration site. This is achieved by initiating an exploration program. Such a program will extend over a period of several years and will be of considerable cost in a single regional area.

Some steps in the exploration program are:

1. The finding of a promising site and checking into the literature for all important data.
2. An initial field reconnaissance survey to delineate smaller areas of importance.
3. The undertaking of a program of regional exploration to further delineate the sites.
4. The acquisition of detailed geologic mapping, extensive sampling, and geochemical analysis.
5. The acquisition of further data through a geophysical survey and test drilling at selected sites.
6. The implementation of a program of systematic drilling with extensive core sampling and evaluation of the core.

7. Hopefully, the above steps will locate a new site of extensive mineralization, which will lead to subsurface exploration, an outlining of a deposit, the determination of ore reserves, and a development into a full-scale mining operation.

The Idea of Lineament Analysis

The problem is locating potential sites and finding new areas of mineralization without wasting valuable time, money, and resources on unfavorable sites. This brings about the use of lineament analysis as a new method or tool by the exploration geologist.

It has been known to geologists that many mineral provinces and mining districts occur along linear trends as mineralized belts (Sabins, 1978). The individual mines of these mineralized belts are commonly located at the intersections of fracture systems or lineament systems. Sometimes, these fractures are mineralized and filled with mineral wealth, and sometimes the fractures serve as collection paths for say, oil and gas. The lineament systems themselves are an important part of regional structure. It is thought that the repeated deformation of the earth's crust renews deep penetrating fractures in the crust, which allow the passing of heat flow, magmatic fluids, and ore-bearing fluids (Smith, 1977). During repeated orogeny these deep penetrating fracture lineaments

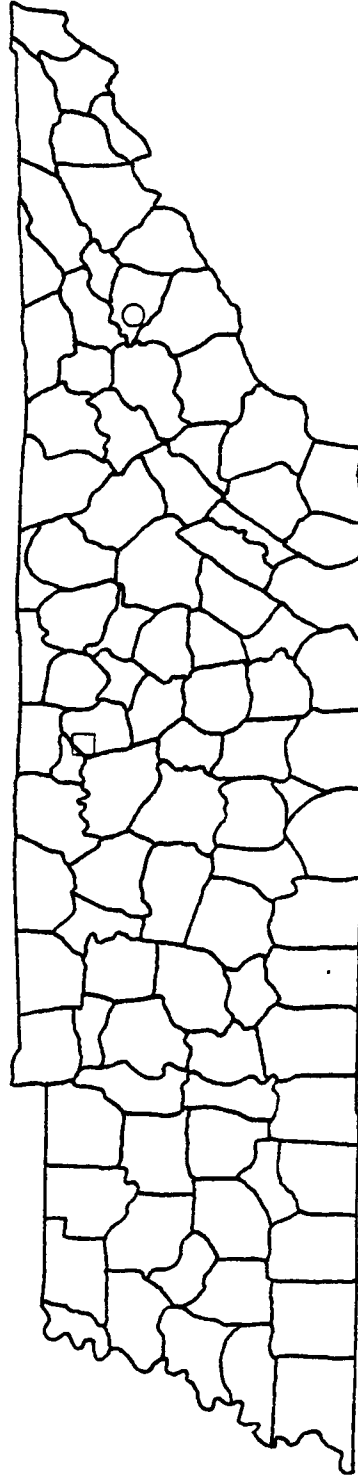
are master channels for ore-bearing fluids and may tap the sources of these fluids underlying the earth's crust. Also, ore deposits which were formed in earlier times in the earth's history could be remobilized and moved about by later orogenies through these master channels. Therefore, it is proposed that a regional analysis of lineaments would be an excellent starting point for an exploration program.

The Study of Two Areas

To prove this, two areas have been studied for lineaments. Area I is an area of known mineralization and known mining operations in eastern Tennessee. Area II is a site in middle Tennessee which shows favorable potential as an exploration target (see Figure 1).

Lineament analysis was applied to Area I and the results were used to indicate sites in Area II which have potential as targets for exploration.

O - Area I
□ - Area II



Scale: 1:4.17 million

Figure 1. Map of Tennessee showing the location of the two areas studied.

CHAPTER II

LINEAMENTS

What Are Lineaments?

A lineament is an expression on the earth's surface. It is any line that appears to be controlled by structural factors. A lineament may be a structural alignment, a topographic alignment, an expression of vegetation, a lithological boundary, a drainage pattern, an expression of soils or of soil moisture, or of any combination of the above. Lineaments may also be seen through thick overburden where the actual cause of the lineament is deeply buried. Lineaments may be either curved or straight features. Some lineaments may represent the traces of faults, while others represent very subtle shearing. Since the fault traces are very easily seen as compared to the shearing, a great deal of care must be taken during the actual interpretation so as not to miss the more subtle lineaments.

Lineaments may be seen in all types and scales of imagery, and often it is very useful to interpret the same area for lineaments on different scale imageries during different seasons, as one particular scale-season combination may show better, as well as more, results than the remaining imagery.

Gravity and Magnetic Lineaments

Lineaments may also be seen on gravity and magnetic maps. These lineaments are just as valuable as the terrain lineaments seen in imagery, and the two used together may complement one another.

Transcurrent and Wrench Fault Lineaments

For the purpose of exploration, it has been found that the use of lineaments which represent transcurrent and wrench faults is very helpful.

Transcurrent and wrench faults are high-angle, strike-slip faults of major importance. The earth's crust has moved laterally in opposite directions along this type of faulting, and wrench and transcurrent faults are the same, except that the transcurrent faults are very much longer than the wrench faults.

Nu Patterns

When looking for lineaments, certain patterns have been found to be more desirable than others. The pattern of chief interest is where an arcuate lineament intersects a straight lineament and forms what is called a Nu pattern (Peterson, 1979) (see Figure 2). The straight part of the Nu pattern is the wrench fault, while the arcuate portions are conjugate sets of shears which have strike-slip movement.

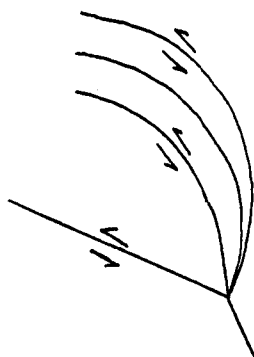


Figure 2. Nu pattern.

Source: Rex Peterson, "Oil and Gas Exploration by Pattern Recognition of Lineament Assemblages Associated with Bends in Wrench Faults," Vol. II, Proceedings of the Thirteenth International Symposium on Remote Sensing of the Environment (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1979), p. 1010.

Nu patterns may be of any size and several Nu patterns may overlap. Within a single Nu pattern the arcuate portion is usually structurally high. When several Nu patterns overlap they will have a structurally high portion which will be common to all of them.

CHAPTER III

LINEAMENT ANALYSIS

Finding Lineaments

Since the lineaments being sought initially are regional in sense, the use of imagery that is of medium- to small-scale is required. Having picked targets on this imagery, one may wish to use other larger scale imagery to better locate the exact position of the potential targets.

When suitable imagery is obtained it is worked over by a trained interpreter using various optical equipment. The working-over process is a long one and involves the interpretation of the same imagery several different times. Once an interpretation has been made, it is recorded and registered on a clear sheet of plastic film. Then the imagery is erased completely and the whole process is done over again, and again. Eventually, a composite of all the recorded lineaments is made and a final interpretation and conclusion is made from this result.

Optical Equipment

The optical equipment that may be used are magnifying glasses of both the hand-held variety and of the visor-type, and of various powers, Fresnel lenses of different powers and sizes, cylinder lenses, condensing

lenses, different lighting combinations, and different colored filters and polarizing material (see Figure 3).

The interpreter will take these optical items and use them alone or in combination to produce different effects and to obtain different perspectives of the image so as to be able to see even the most subtle lineament. One combination may be to use a red filter with a large Fresnel lens, or another may be to use two condensing lenses together with a sheet of polarized material.

There is not any set of recommended combination of equipment to be used, only whatever is found to be best for each individual interpreter. Each combination should only be used for a short period of time and then it should be changed. The reason for the different combinations of equipment and for the frequent changing is to have the effect of changing greytone level, perspective, and the size of the imagery. Also, by changing the combinations of equipment frequently, there is a reduction in eyestrain; thus, the interpreter will maintain a higher level of efficiency.

When an individual interpreter has found several equipment combinations that work for him, he will perform several interpretations on his imagery and make a composite interpretation. It is also quite helpful for two interpreters to work on the same imagery at the same time, as the two are able to check each other's lineaments.

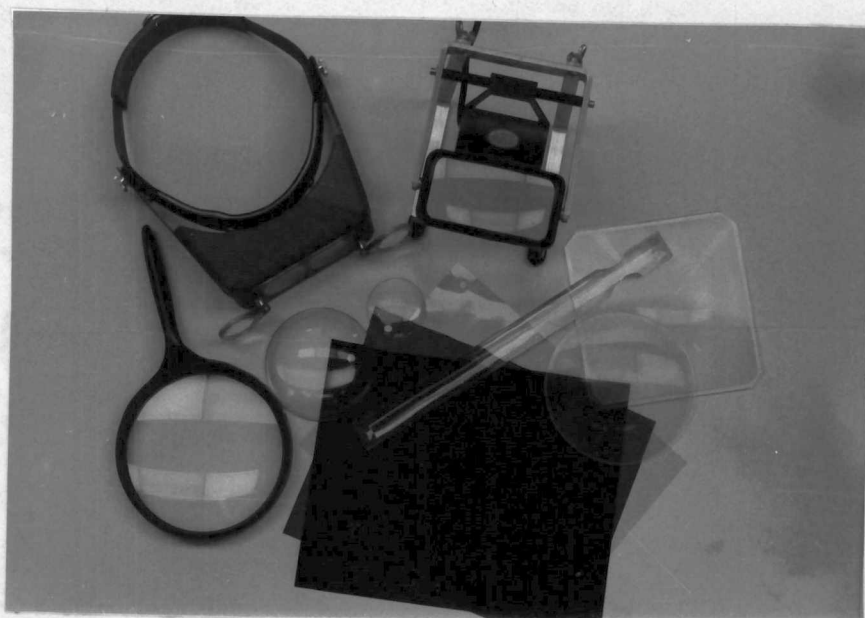


Figure 3. The optical equipment.

Interpretation of Gravity and Magnetic Lineaments

When an interpreter is working with gravity or magnetic data, the same multiple interpretation procedure is followed. The optical equipment is not needed, but it is very helpful to view the gravity and magnetic maps in three dimensions by means of stereo viewing (Gay, 1971). This stereo viewing procedure enhances the data and causes the highs and lows on the map to be placed in proper perspective, shows subtle changes in the fabric texture of contour patterns, changes in level from one area of the data to another, and shows up lineaments, many of which are regional in content.

Agreement on the Actual Interpreted Lineaments

How much agreement is there among interpreters and among different lineament interpretations of and on the same area? A measure of reproducibility has been defined (Burns, et al., 1976). It has a value of minus one when there is complete disagreement, a value of plus one when there is complete agreement, and a value of zero when there is no systematic relationship among the interpretations. By using this scale of reproducibility for the same imagery its value has been found to be of the order of 0.1 to 0.3. This result is the same as that obtained by Podwysocki, et al. (1975). This shows that there is some agreement among different annotations of the same imagery,

but it shows as well that it is not wise to accept any annotation as being reliable. For this reason, only lineaments that were seen several times as a result of several interpretations were used in the final results and conclusions of this study. The leftover lineaments were discarded and not used.

CHAPTER IV

THE ANALYSIS

The Analysis of Areas I and II

The analysis of Areas I and II was carried out by a single interpreter using the mentioned optical equipment. The interpretation process was performed several times and this operation took considerable time and effort. The final terrain lineaments that were located were compiled, and only those that were seen to reoccur in several interpretations were kept and used to make conclusions.

The actual interpretation was carried out on photomosaics constructed from 1:24,000 scale black and white aerial photographs taken during the springs of 1975 and 1977 for the Tennessee Valley Authority. There were two mosaics constructed, one for each of the areas (see Figures 4 and 5). The actual construction process was quite tedious and required considerable skill. The optimum result of the photomosaic construction would have been to produce a continuous picture of the area, without any gaps in coverage or without any lack of coincidence of say, roads or field boundaries. The good fit between individual photographs needed to produce this desired photomosaic was available for Area II; however, that was not the case for Area I. The quality of the individual photographs left

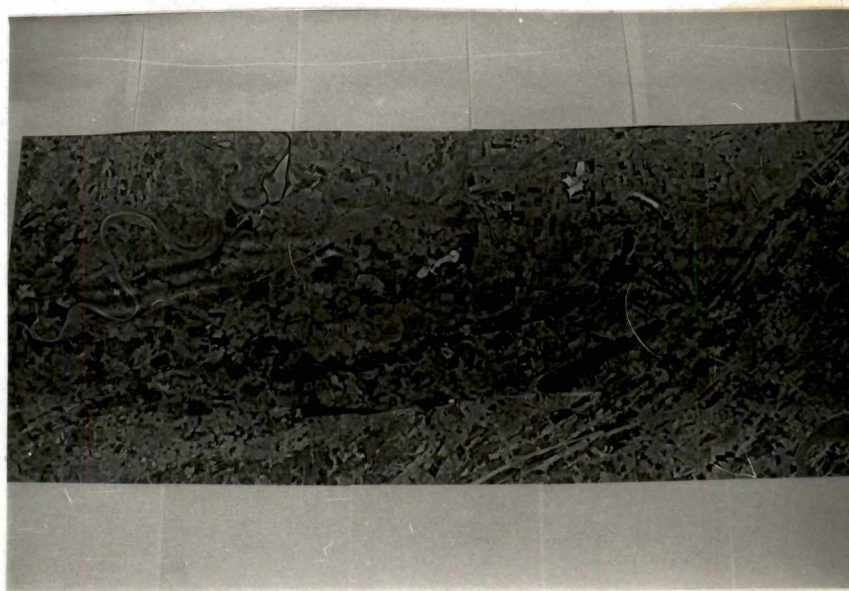


Figure 4. Photomosaic of Area I.



Figure 5. Photomosaic of Area II.

something to be desired. The main problems were a lack of overlap between adjacent flight lines, thus, causing gaps in coverage and a general lack of desirable vertical photography, thus, causing considerable edge distortion and a lack of fit between adjacent photographs in the same flight line. Although there were these problems, they were able to be overcome through the careful registration of roadways, and of stream and lake boundaries on the photo-mosaics with planimetric maps of the same area.

The Use of Gravity and Magnetic Data

On the interpretation, gravity maps of 1:500,000 scale and magnetic maps of 1:125,000 scale were also used. There were not any problems encountered through the use of these maps and they were primarily used for correlative purposes due to their small scale.

Area I

Area I, known as the Mascot-Jefferson City district, is an area in eastern Tennessee bounded by $36^{\circ} 00' 00''$ and $36^{\circ} 07' 30''$ North Latitude, and $83^{\circ} 22' 30''$ and $83^{\circ} 45' 00''$ West Longitude. The total area is approximately 181 square miles.

This area was chosen as a testing site for lineament analysis, as it is an established zinc mining district with known occurrences of ore and actual operating mines. The actual mineral occurrences were plotted onto a base

map exactly. Then the terrain lineament analysis was performed and the final composite results were compared to the actual location of the mineral occurrences. The results proved favorable for the continued usage of lineament analysis as an exploration tool. Since favorable results were obtained from Area I, lineament analysis was applied as well to Area II to try and predict future exploration targets. In this study, zinc mineralization happens to be the target; however, lineament analysis techniques together with wrench fault analysis may be used to find, besides base metals, oil and gas energy sources, uranium supplies, and water resources. The interpretation process remains the same in all incidences. The only difference will be in the location of the quantity being looked for with regard to structural position in the Nu pattern. Oil and gas would be located in structurally higher areas, while zinc would be found in structurally lower areas.

Telethermal Deposits

The Mascot-Jefferson City district is considered to be a telethermal Mississippi Valley-type ore deposit (Park, et al., 1975). A telethermal deposit is one in which the ore has been deposited by hydrothermal fluids which have migrated so far from their source that the fluids have lost most of their heat, and as well, most of their potential to react chemically with the surrounding rock. Telethermal deposits are usually formed great

distances from areas of strong tectonic activity, and from magmatic centers. The circulation of the fluids and the deposition of the ore is controlled by rock permeability. Often, ores are deposited by replacement, open space filling, and cavity filling.

The Eastern Tennessee Appalachian Strata-Bound Deposits

The Appalachian strata-bound deposits of Tennessee, like the Mascot-Jefferson City district, may have some of the following characteristics (Hoagland, 1971):

1. These deposits are in carbonate rocks of principally dolomite and dolomitized limestones. Also, there are usually some unaltered limestones present.
2. The host rocks for the ore are all similar in lithology, were all formed in a similar marine environment, and are all of Early Ordovician age.
3. These deposits all seem to be located several hundred feet below the same unconformity.
4. The major ore mineral is an iron-poor sphalerite. Galena is usually sparse or not present, and pyrite is found only as a minor accessory mineral.

5. These deposits show extensive folding and faulting. These structures are generally superimposed and have no genetic significance. This faulting and folding is the result of the Appalachian orogeny and of subsequent erosion. Consequently, these processes have been responsible for obscuring regional relationships and for preventing a reconstruction of the area's geologic history.

In addition to these factors, other important parameters of this type of deposit which the exploration geologist has to be aware of are:

1. There is a widespread dolomitization of the limestone associated with the ore depositional process. This is believed to be caused by saline waters.
2. Sphalerite was deposited in open spaces in extremely permeable zones.
3. Sphalerite that was deposited after the lithification of the host rock has been deposited due to the development of a pervasive, far-reaching karst aquifer system.
4. Mineralization was the result of the precipitation of strongly saline solutions in permeable zones established by the action of meteoric water in the formation of the aquifer system.

5. Throughout the period of deposition there was a continuing dissolution of limestone and an alteration of limestone to dolomite by saline water causing the permeability needed for the continued movement of ore solutions. In the richer ore zones there is evidence for repeated stages of dissolution, brecciation, and of ore mineral deposition.

Thus, the model for this type of Mississippi Valley deposit assumes the movement of ore solutions along paths of porosity and permeability. These paths would be permeable stratigraphic horizons and/or fracture systems. Features to look for besides the Nu pattern would be fracture intersections which might localize deposition and radial or concentric features, suggesting the presence of basement highs or collapse structures caused by the dissolution of limestone to dolomite. All of these features would be capable of being seen in a lineament analysis study.

Area II

Area II is an area in middle Tennessee bounded by 36° 13' 45" and 36° 22' 30" North Latitude and 86° 00' 00" and 86° 07' 30" West Longitude. The total area is approximately 70 square miles.

This area was chosen for study as it is part of a larger area in middle Tennessee that is now beginning to

command significant interest as a potential exploration area. In this area of middle Tennessee there are several known occurrences of zinc, and in the study area there is one known occurrence.

Middle Tennessee Deposits

The strata-bound deposits of middle Tennessee are very much like those of eastern Tennessee's Area I. These Mississippi Valley-type deposits also occur in breccias in highly fractured dolomite. There are, however, differences. In eastern Tennessee the major ore mineral is an iron-poor sphalerite, while the middle Tennessee deposits have a more iron-rich sphalerite, as well as barite, fluorite, and galena. The middle Tennessee time of ore deposition occurred later, possible as late as the Late Paleozoic age.

Other considerations of the middle Tennessee deposits are (Kyle, 1976):

1. There are early breccias near a major unconformity, but unlike the eastern Tennessee breccias, these are not mineralized.
2. The later ore-hosting breccias are not near this unconformity.
3. The fluids responsible for the ores were in equilibrium and were not responsible for the dissolution of limestone which resulted in the breccias.

4. Mineralogical studies indicate that the mineralization occurred by means of the gradual addition of reduced sulfur to a metal-bearing brine over a very long period of time.

Also, these deposits have been found to occur in fractured dolomitized limestone at depths of 1,500 to 2,000 feet, and these deposits have not undergone the effects of the Appalachian orogeny, as have the eastern Tennessee deposits.

Aside from these differences, the middle Tennessee and the eastern Tennessee deposits are considered to be genetically the same. The middle Tennessee deposits have the same porosity and permeability channelways, again exhibited as fractures and permeable stratigraphic horizons. This porosity is the center of deposition and is provided by the syndepositional conversion of limestone to dolomite, karstification before the deposition of the ore, and by the brecciation related to deposition. Thus, as in Area I, there is a case for the use of lineament analysis, and exploration sites should be able to be picked out using lineament analysis techniques.

CHAPTER V

RESULTS

Preliminary Conclusions

The results of this study proved to be highly favorable in indicating that lineament analysis should be used in the future as one of the main tools of the exploration geologist.

Trends of Area I

In Area I there were three major regional trends found to exist from imagery analysis. One trend was an east-west trend and its location was in the western portion of the study area. A second trend was a northeast-southwest trend located in the central portion of the study area. The third trend began as an east-west trend, then its western arm curved and pointed northward. This lineament trend was found in the central and eastern portions of the study area. All three of these trends were several miles long and all were quite continuous. In all three cases more than one lineament trace defined the general trend.

It should be pointed out that two of these terrain lineaments were also found by both the gravity lineament analysis and the magnetic lineament analysis.

Trends 1 and 2 were both able to be defined by both the gravity and magnetic lineaments. Trend 3 was not able to be seen on either the gravity or magnetic lineament analysis (see Figures 6 through 11).

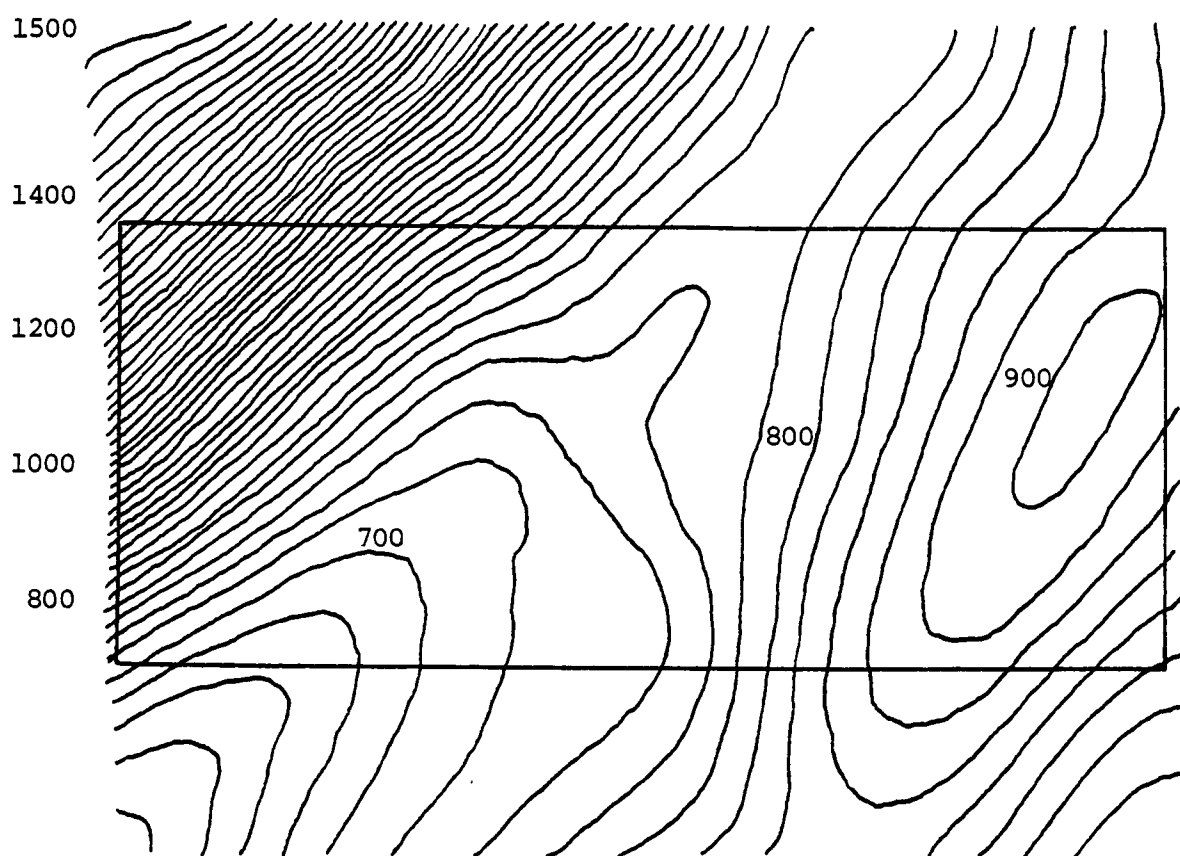
From trends 1 and 2 the value of using gravity and magnetic lineaments in conjunction with terrain lineaments was realized. However, since trend 3 was completely missed, it is not an entirely foolproof method, but may be used as a possible check.

Positions of Mineral Deposits of Area I

It was observed that most of the plotted known mineral occurrences were found either very near to or along the trace of one or the other of the three regional trends. Also, the known mineral occurrences did lie along or very, very near the observed Nu patterns and in an area of multiple intersection of lineaments. As far as the Nu patterns were concerned, the known mineral occurrences seemed to be near the nose of the Nu pattern, or along the trace of the wrench fault, or in a common structural area when there was an intersection of several Nu patterns.

Trends of Area II

In Area II, four trends were found that are of regional complexion. The first trend was a north-south trend located in the central portion of the study area.



Twenty Gamma Contour Interval

Scale: 1:125,000

Figure 6. Magnetic map of Area I.

Source: Tennessee Valley Authority, Mineral Resources Branch, Knoxville, Tennessee, 1979.

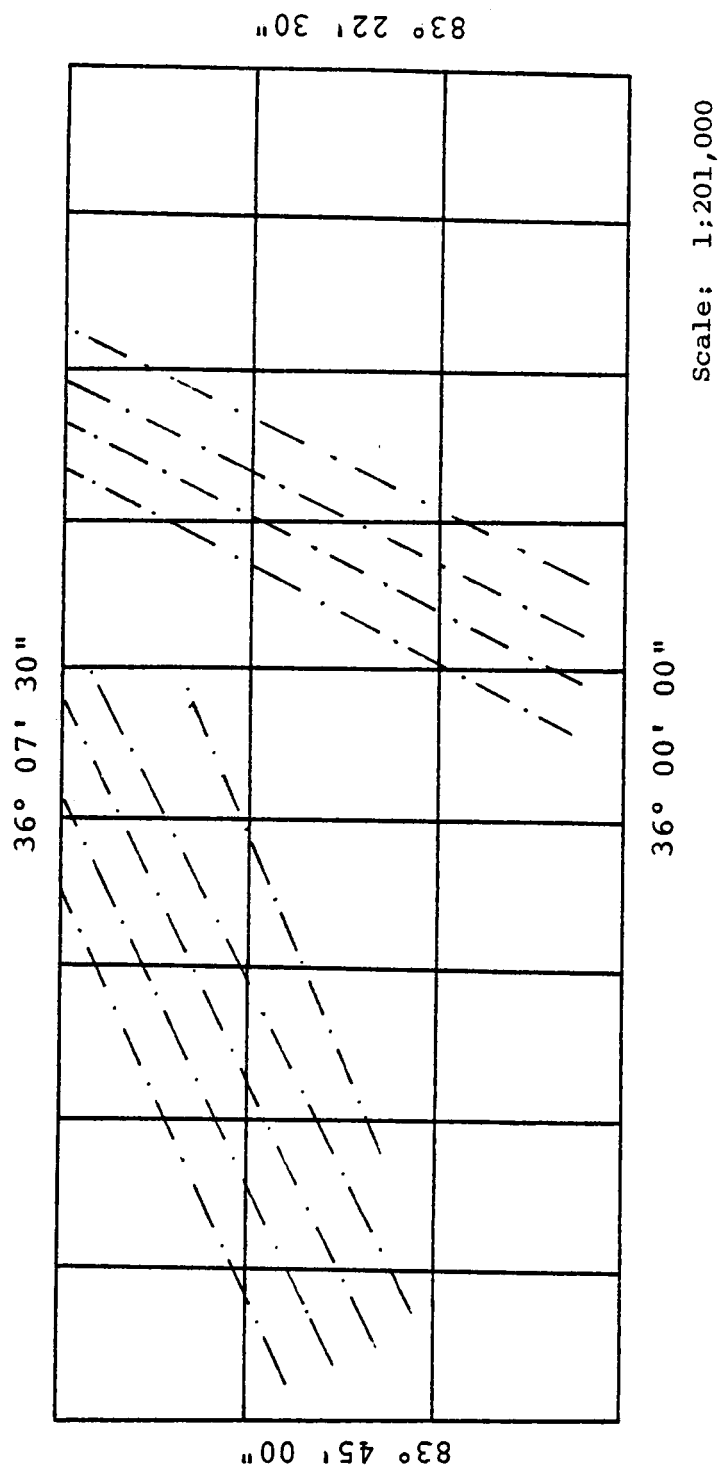
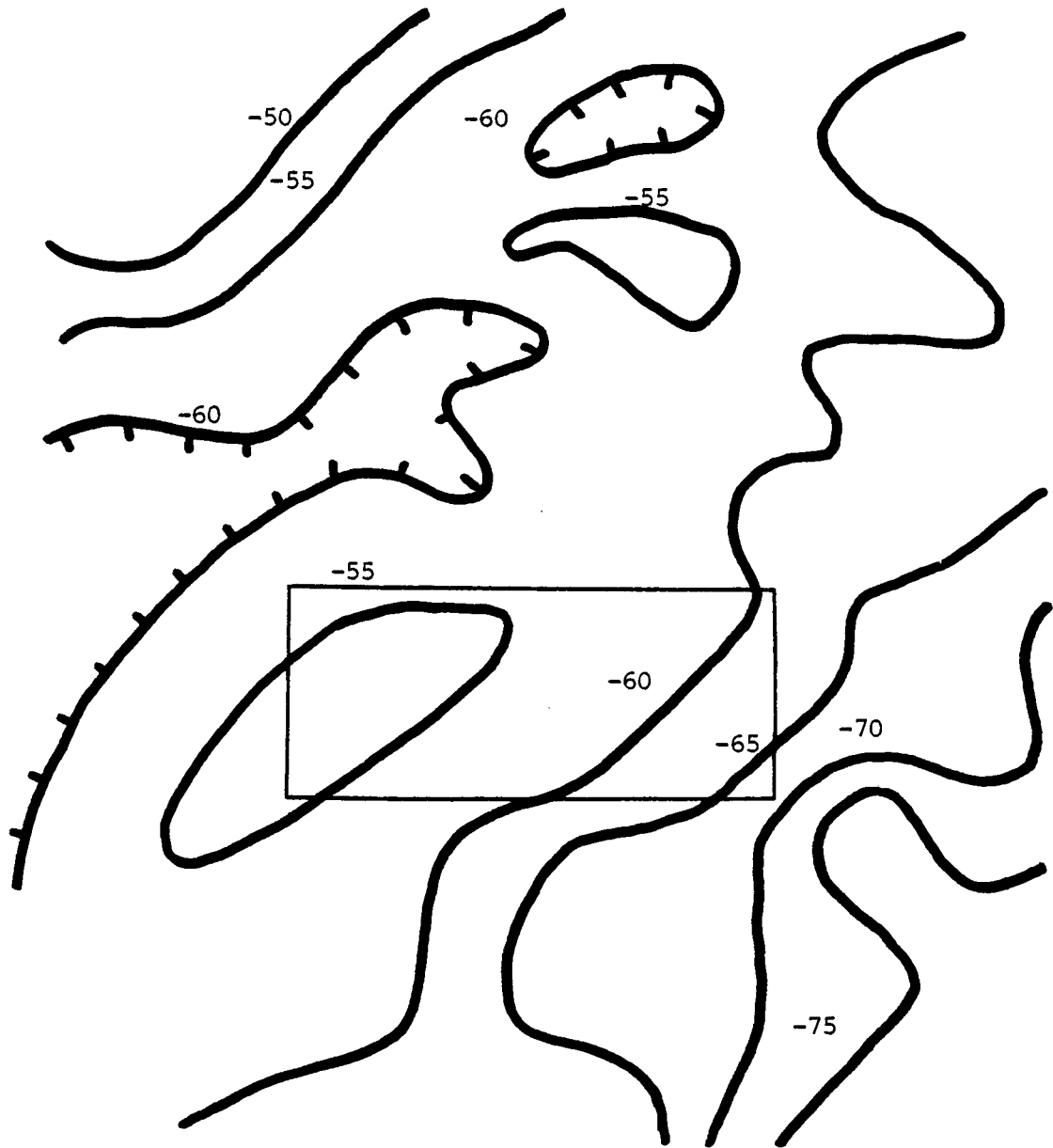


Figure 7. Observed magnetic lineaments of Area I.



Five Milligal Contour Interval

Scale: 1:500,000

Figure 8. Bouguer gravity map of Area I.

Source: Tennessee Valley Authority, Mineral Resources Branch, Knoxville, Tennessee, 1975.

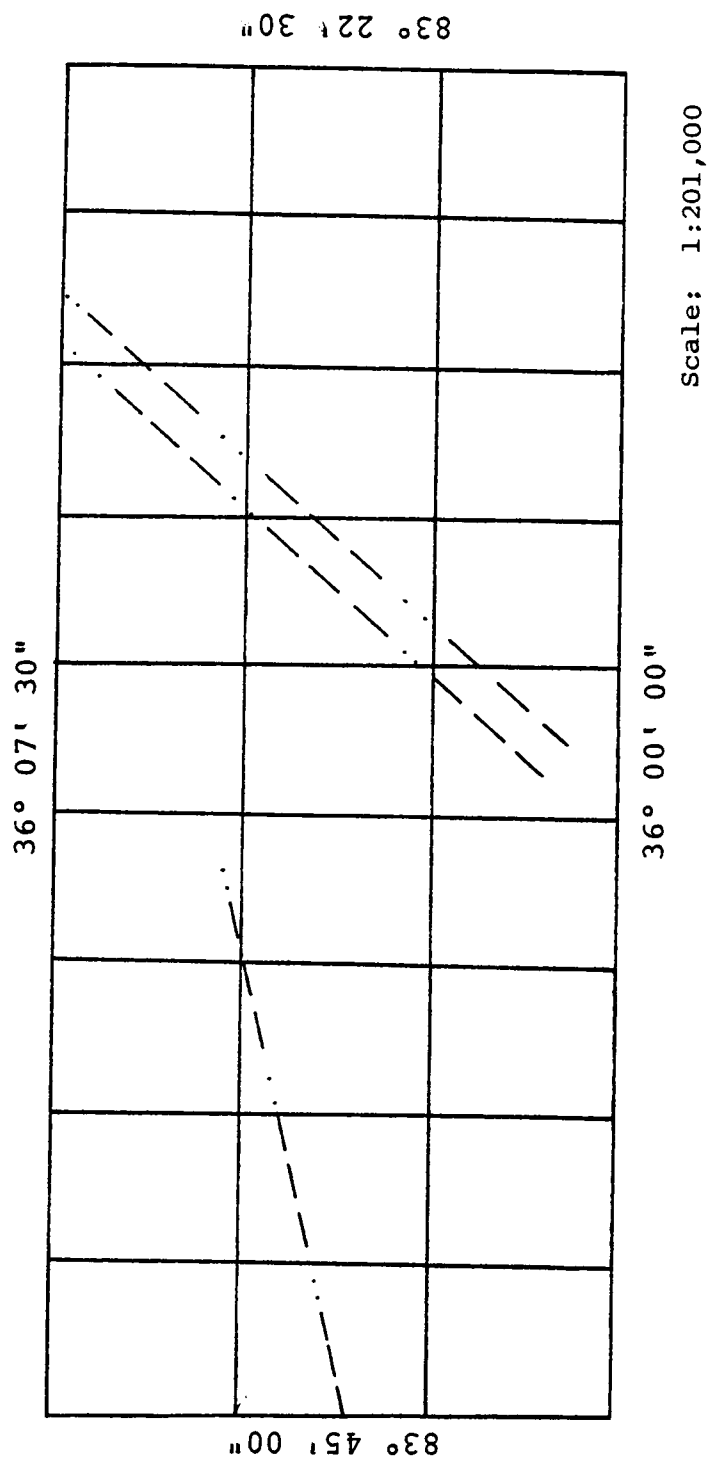


Figure 9. Observed gravity lineaments of Area I.

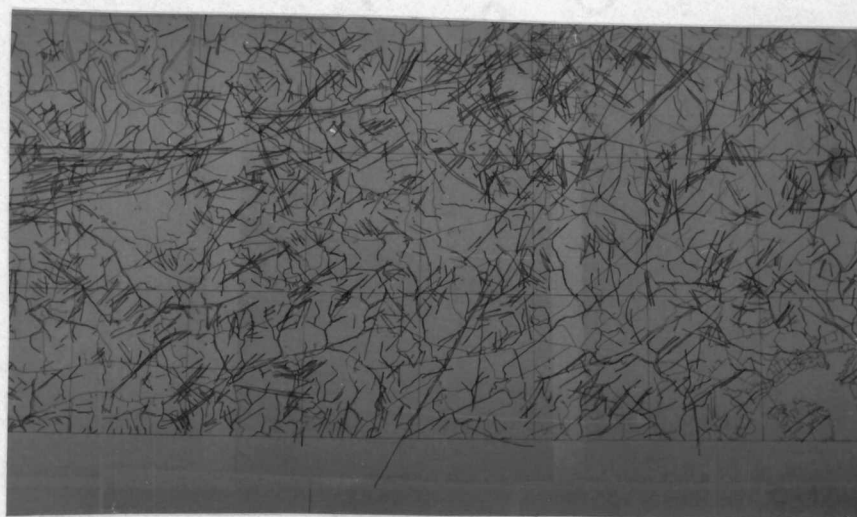


Figure 10. Observed terrain lineaments of Area I.

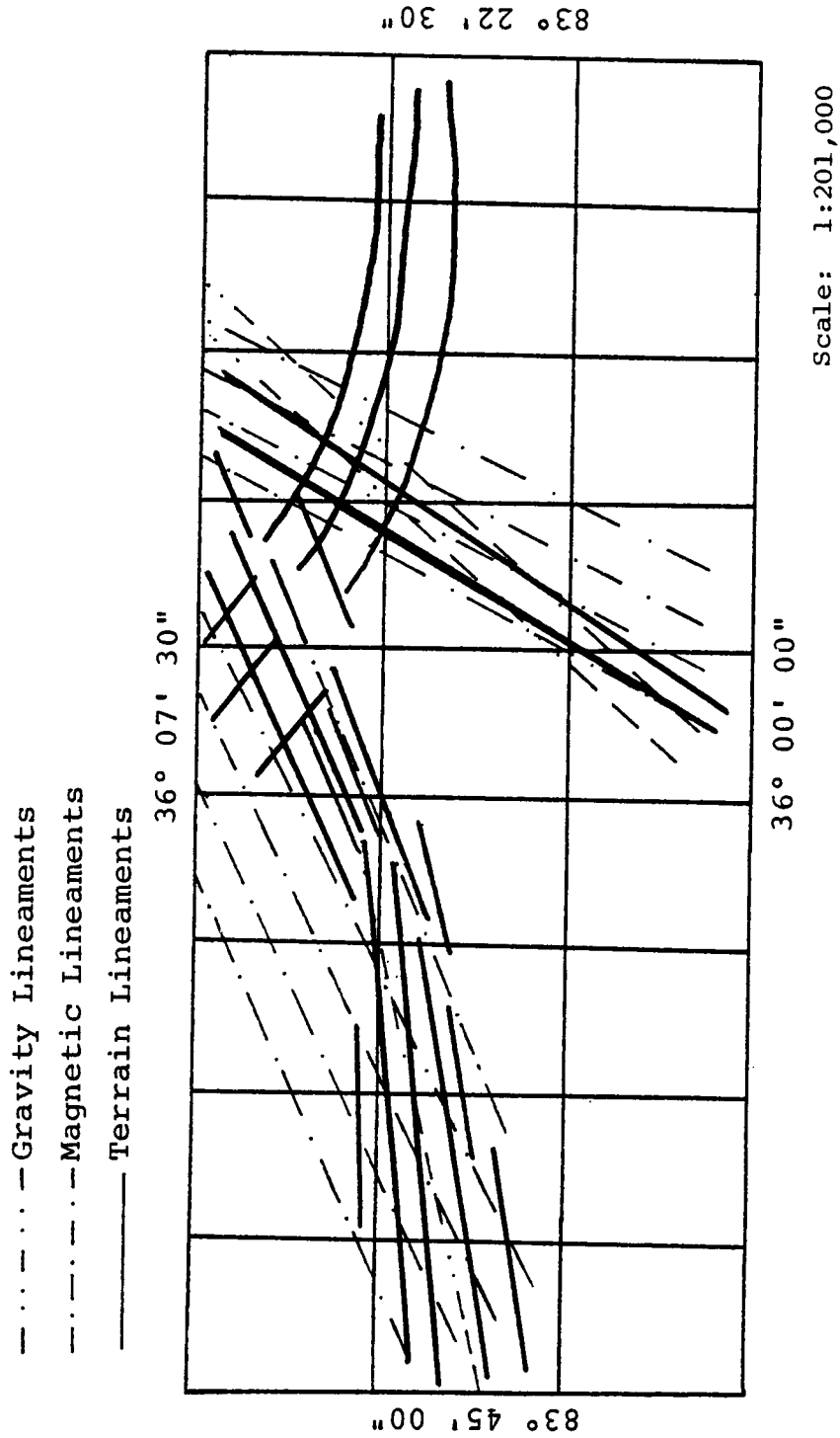


Figure 11. Composite of observed gravity, magnetic, and terrain lineaments of Area I.

This trend was observed on both the gravity and magnetic lineament analysis. In the northwest corner of the study area there was a north-northwest-south-southeast trend present, which was picked up on the gravity lineament analysis, and there was also a south-southwest-north-northeast trend, which was also seen in the magnetic analysis.

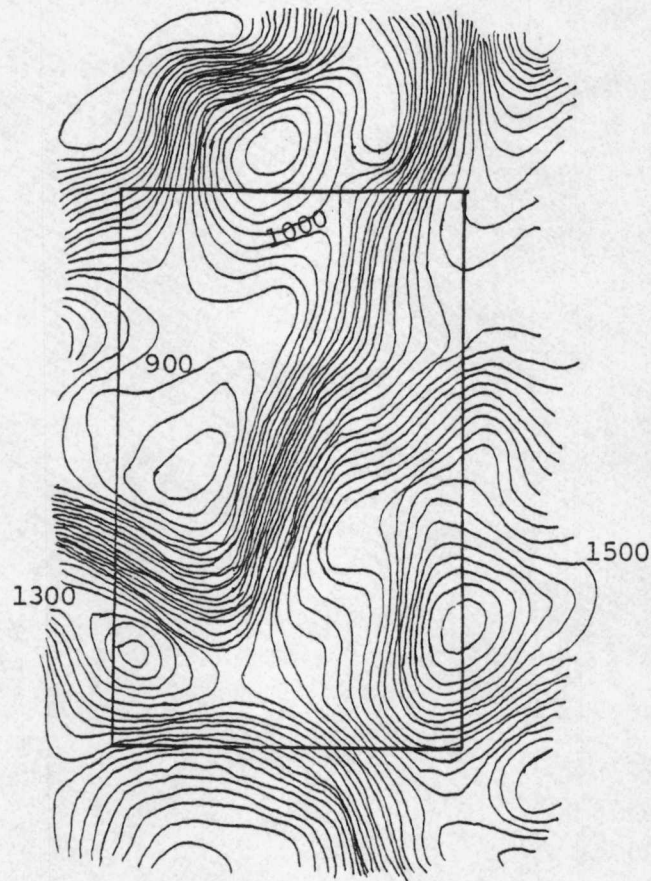
Finally, there was a northwest-southeast trend in the southwestern corner of the study area, which may also be seen in the magnetic analysis (see Figures 12 through 17).

Area II Circular Features

In Area II many circular lineament features were observed. These features possibly represent areas of doming and/or collapse structures. These features could also represent vegetation which has been metal-poisoned, or places where limestone has changed to dolomite, thus causing a change in volume and differential compaction.

Some of the circular features lie in the trace of the major regional lineaments. These circular features are also in locations where there is an intersection of the fracture patterns of many lineaments; also, Nu patterns are passing through them or are very nearby.

Therefore, for the purpose of exploration potential, these circular features must be considered as prime targets. As far as a ranking of them is concerned, for exploration



Twenty Gamma Contour Interval

Scale: 1:125,000

Figure 12. Magnetic map of Area II.

Source: Tennessee Valley Authority, Mineral Resources Branch, Knoxville, Tennessee, 1979.

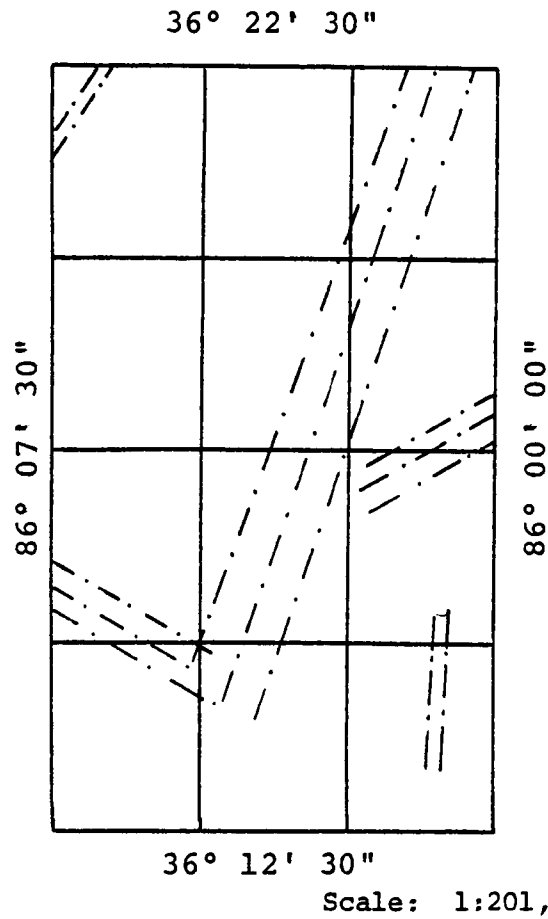
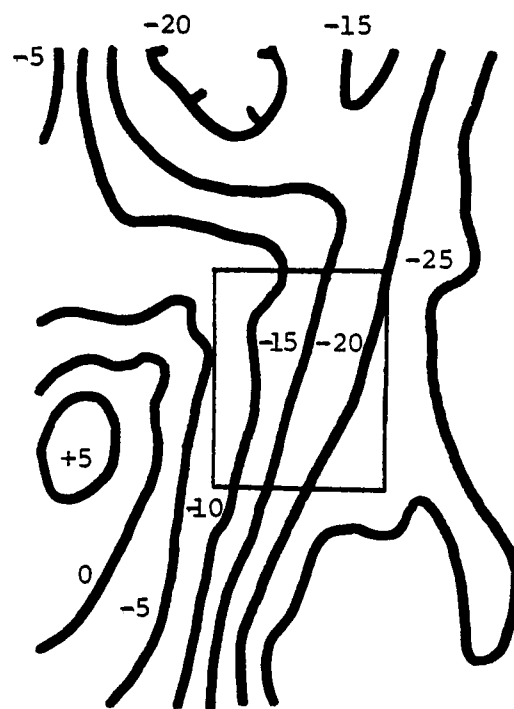


Figure 13. Observed magnetic lineaments of Area II.



Five Milligal Contour Interval

Scale: 1:500,000

Figure 14. Bouguer gravity map of Area II.

Source; Tennessee Valley Authority, Mineral Resources Branch, Knoxville, Tennessee, 1975.

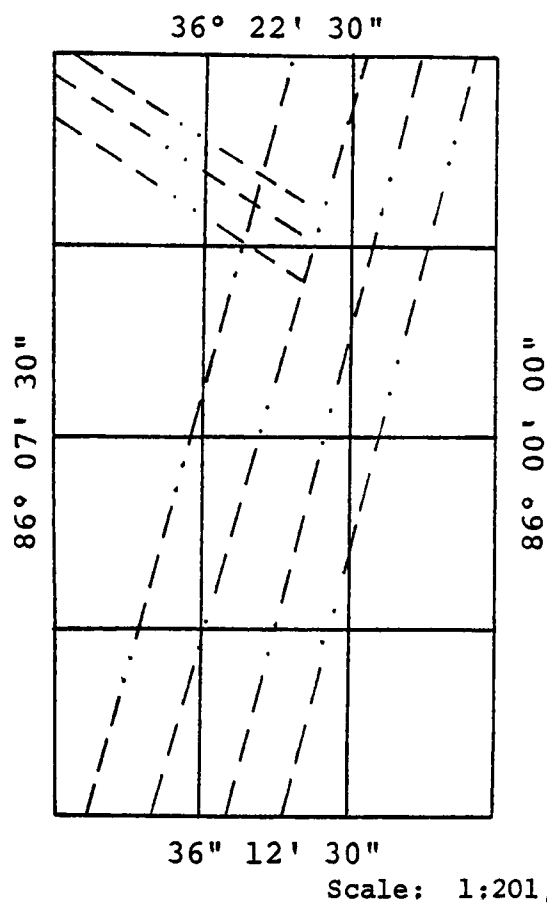
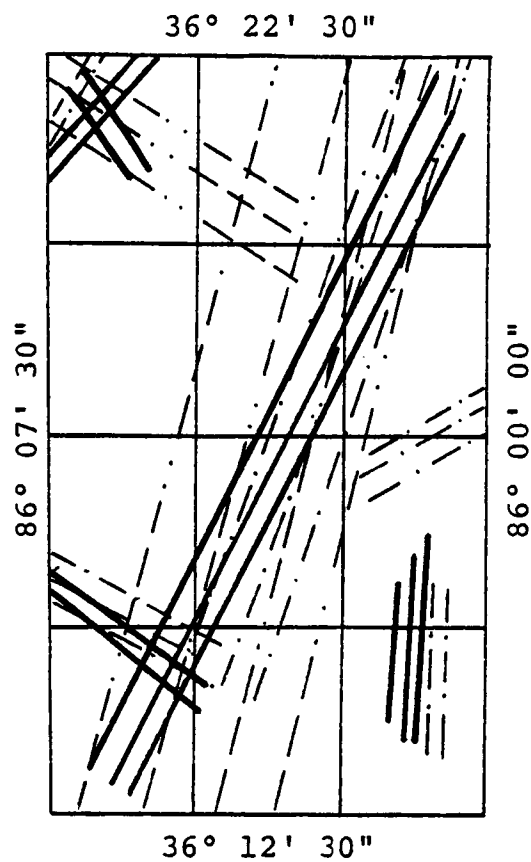


Figure 15, Observed gravity lineaments of Area II.



Figure 16. Observed terrain lineaments of Area II.

--- Gravity Lineaments
--- Magnetic Lineaments
--- Terrain Lineaments



Scale: 1:201,000

Figure 17. Composite of observed gravity, magnetic, and terrain lineaments of Area II.

potential the circular features which have Nu patterns running through them, or which are very close to the noses of Nu patterns, should be given top priority. The next priority would be to circular features at the intersection of many lineaments, and last priority to circular features which stand by themselves (see Figure 18).

Conclusions

The aim of this study was to determine if lineaments could be detected, and if so, could they be used by the exploration geologist as a tool.

The results obtained from Area I do, indeed, show a correlation between known mineral occurrences and the observed terrain lineaments. The problem of the exploration geologist has been to be able to pick exploration targets of greatest potential and not to pick bad targets. By using the results of a thorough lineament analysis, good targets will be able to be located. This will cut down greatly in expense and will save valuable time.

The method used for analysis is a very simple and inexpensive one. It does not require complicated equipment, and the equipment used may be afforded easily, even by individuals.

Imagery is usually available for almost any given area in a variety of forms and in many different scales. The personnel used for the interpretation must be trained,

- Potential Site for Exploration
- × - Location of Known Mineralization

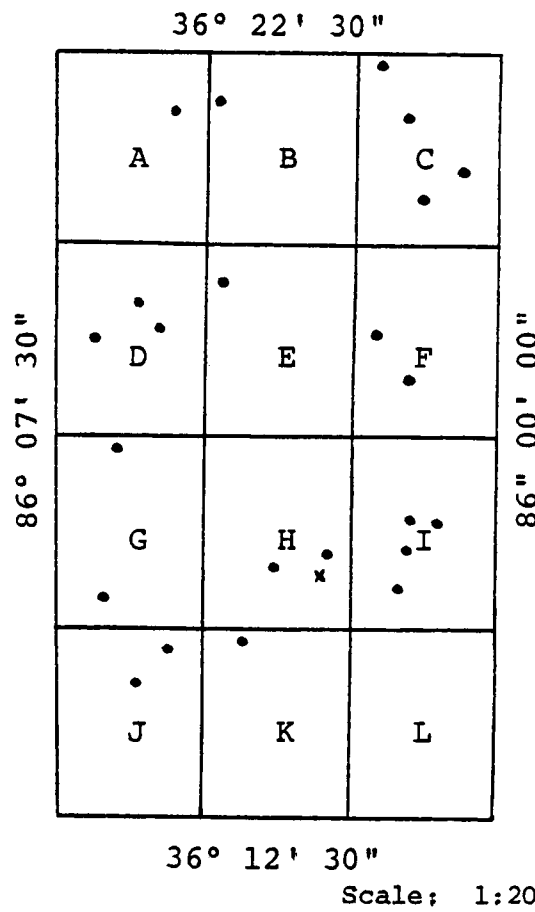


Figure 18, Position of sites having the most potential for mineral exploration, as picked from the lineament analysis in Area II.

but this is not a difficult task. The amount of time spent in interpretation may seem long and tedious; however, when compared to the time now being spent by exploration companies out in the field using conventional methods, it is small. It is advised that more than one interpreter should be used in a single area and interpretation project.

The use of magnetic and gravity lineaments has also been demonstrated. These are useful in seeing major regional lineaments; however, they are not a completely foolproof method and should be used only for correlative purposes.

Finally, lineament analysis techniques are not meant to be used by themselves alone, but should be used together and along with other geophysical and geological methods. In a time of desperation and with a lack of other information they may be used alone, but better results will be achieved when used with other data.

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Resources Branch, Knoxville, Tennessee, 1975.

Tennessee Valley Authority. Magnetic Map. Mineral
Resources Branch, Knoxville, Tennessee, 1979.

APPENDIXES

APPENDIX A

AREA I FIGURES

Figure A-1 is a key to the location of the remaining figures in this appendix. The data are presented in numbered blocks with each block side having coordinates, so as to be positioned easily and correctly. These numbered blocks are shown in the key of Figure A-1.

Figures A-2 through A-28 contain the interpreter's results as to the position of the observed terrain lineaments which existed in the study area. These lineaments represent the lineaments which were observed through several interpretations. Lineaments which were observed in only one or two interpretations were considered to be erratic and were not used for the final results and conclusions and are not presented here.

Figures A-2 through A-28 all have a scale of 1:28,000.

List of Symbols

-  Site of known mineralization
-  An observed terrain lineament
-  Stream path or lake or river boundary
-  Nu pattern

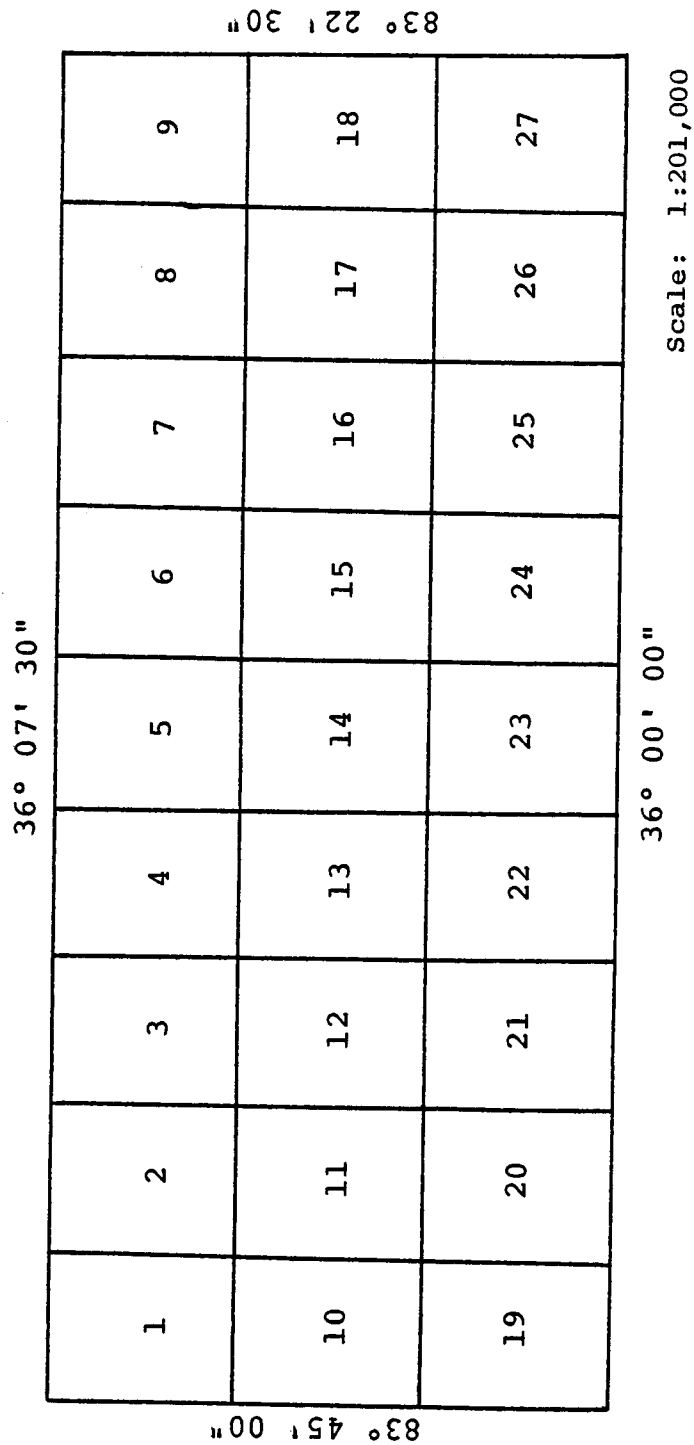


Figure A-1. Grid square key for Area I.

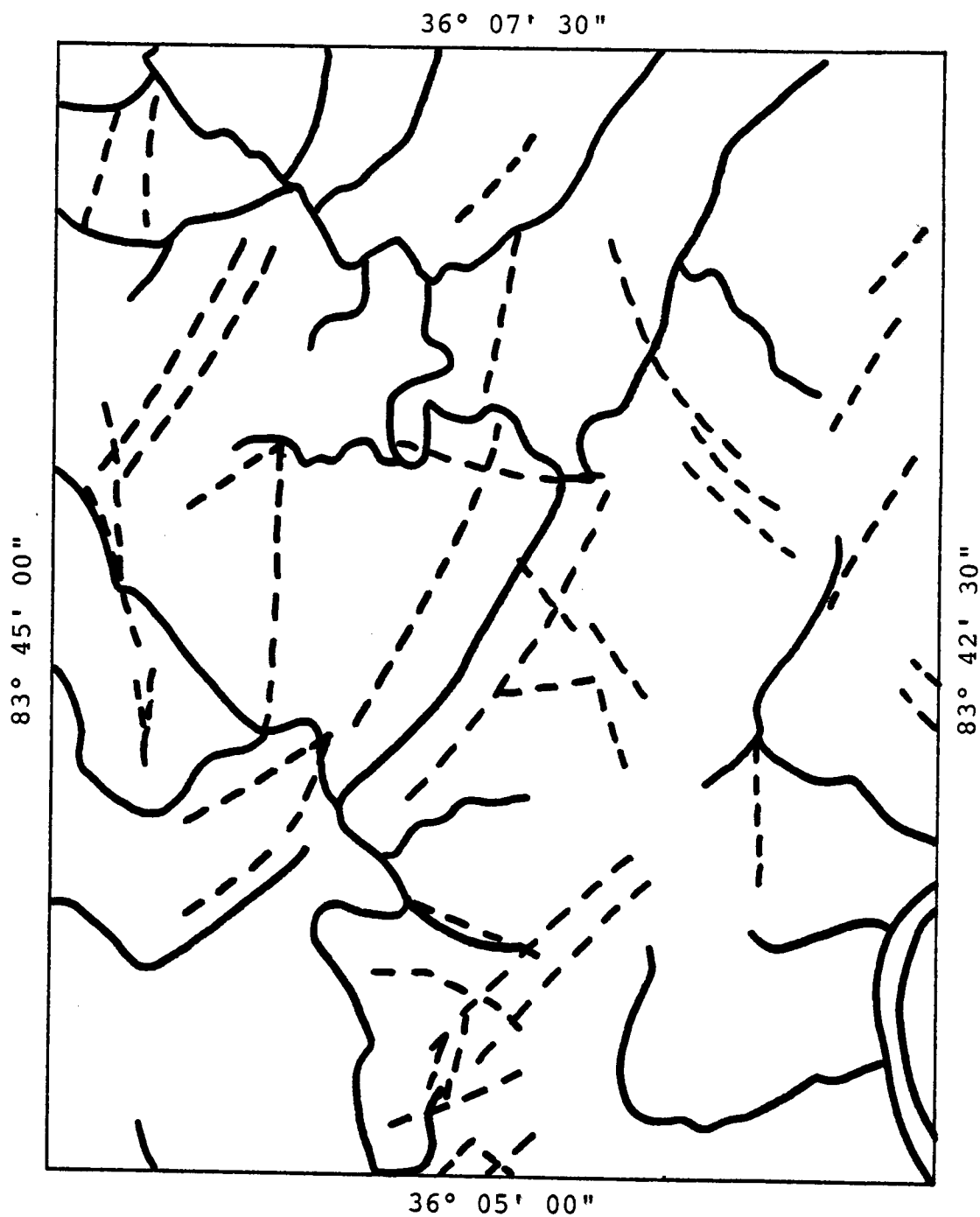


Figure A-2. Observed terrain lineaments of Area I, grid square 1.



Figure A-3. Observed terrain lineaments of Area I, grid square 2.

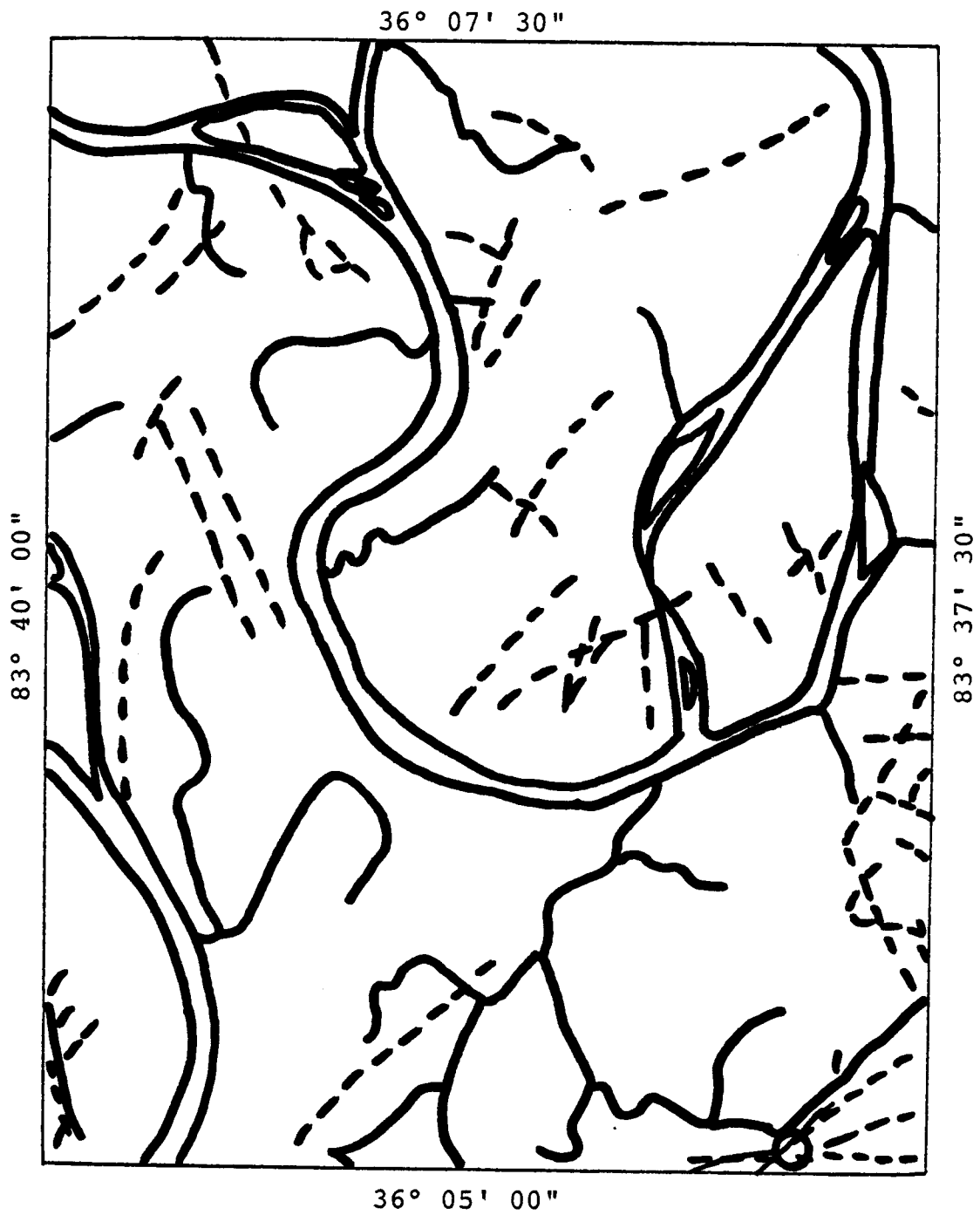


Figure A-4. Observed terrain lineaments of Area I, grid square 3.

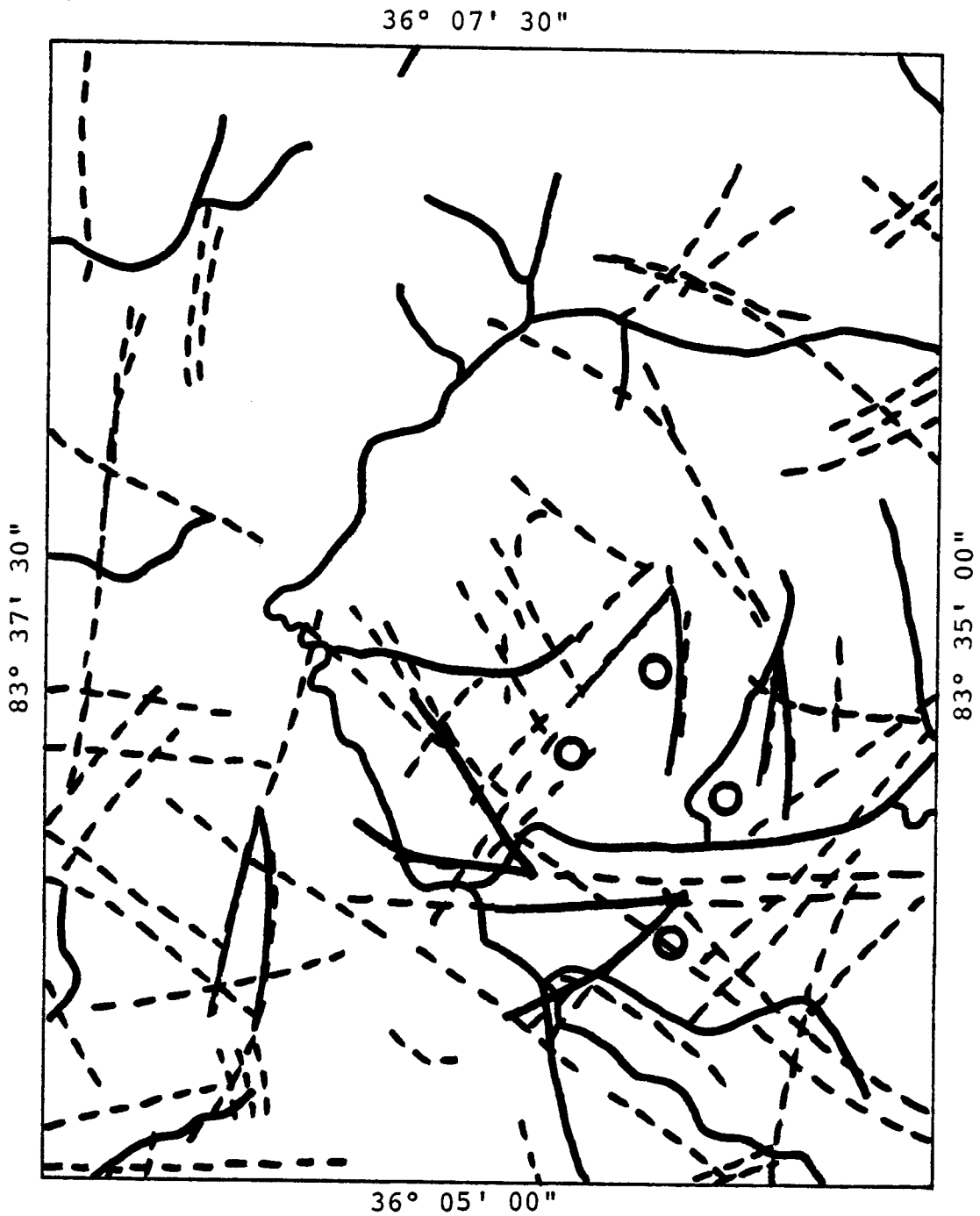


Figure A-5. Observed terrain lineaments of Area I, grid square 4.

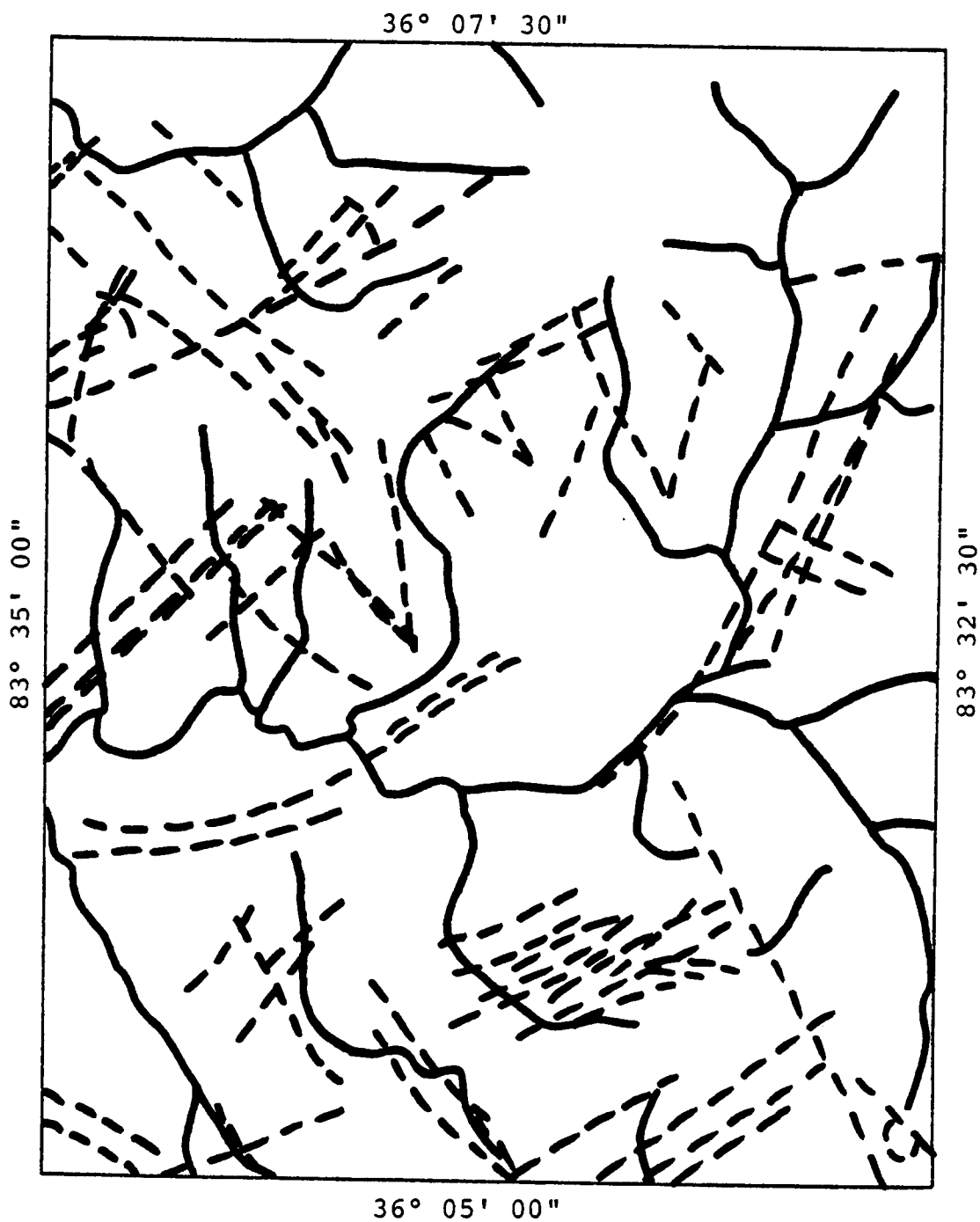


Figure A-6. Observed terrain lineaments of Area I, grid square 5.

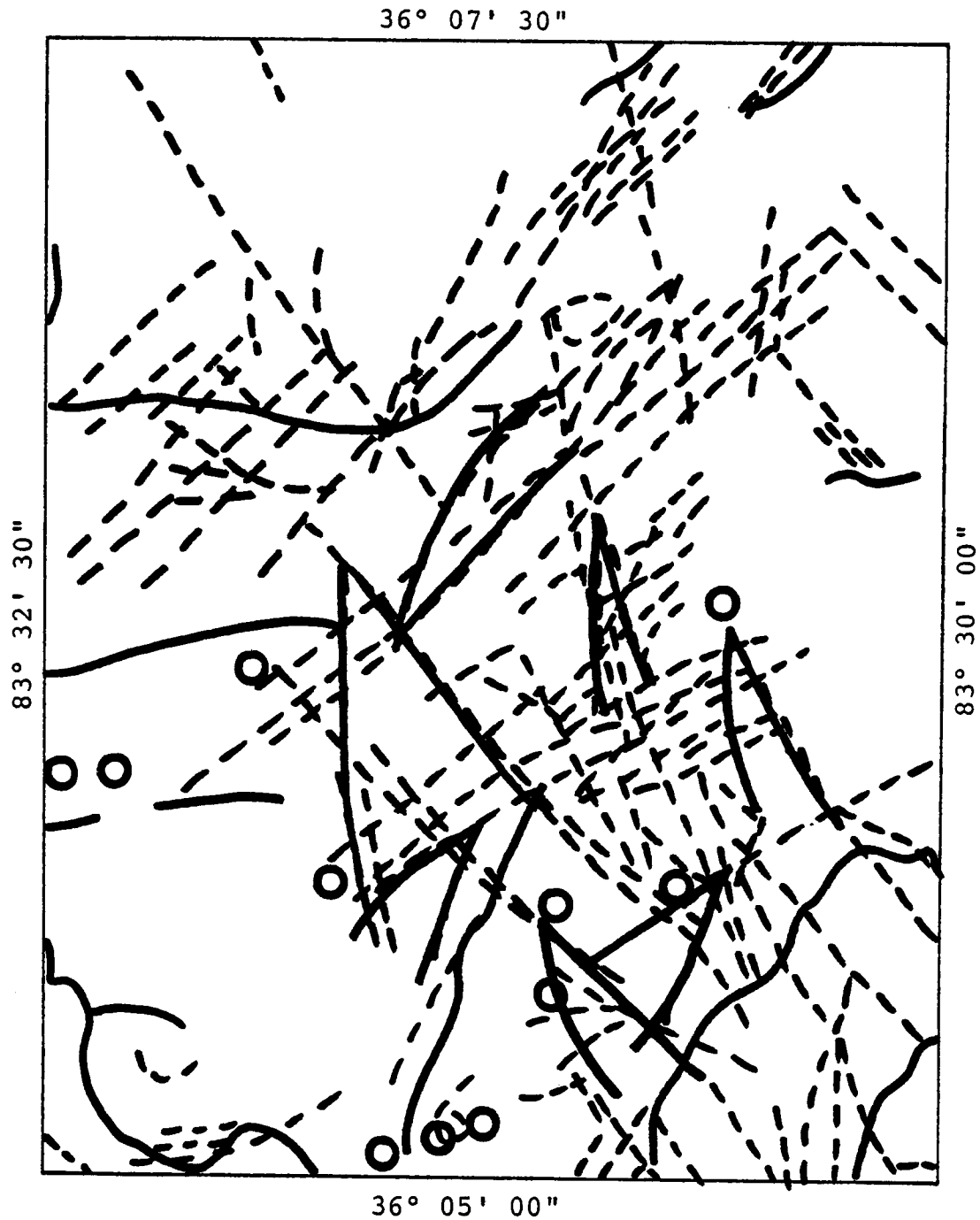


Figure A-7. Observed terrain lineaments of Area I, grid square 6.

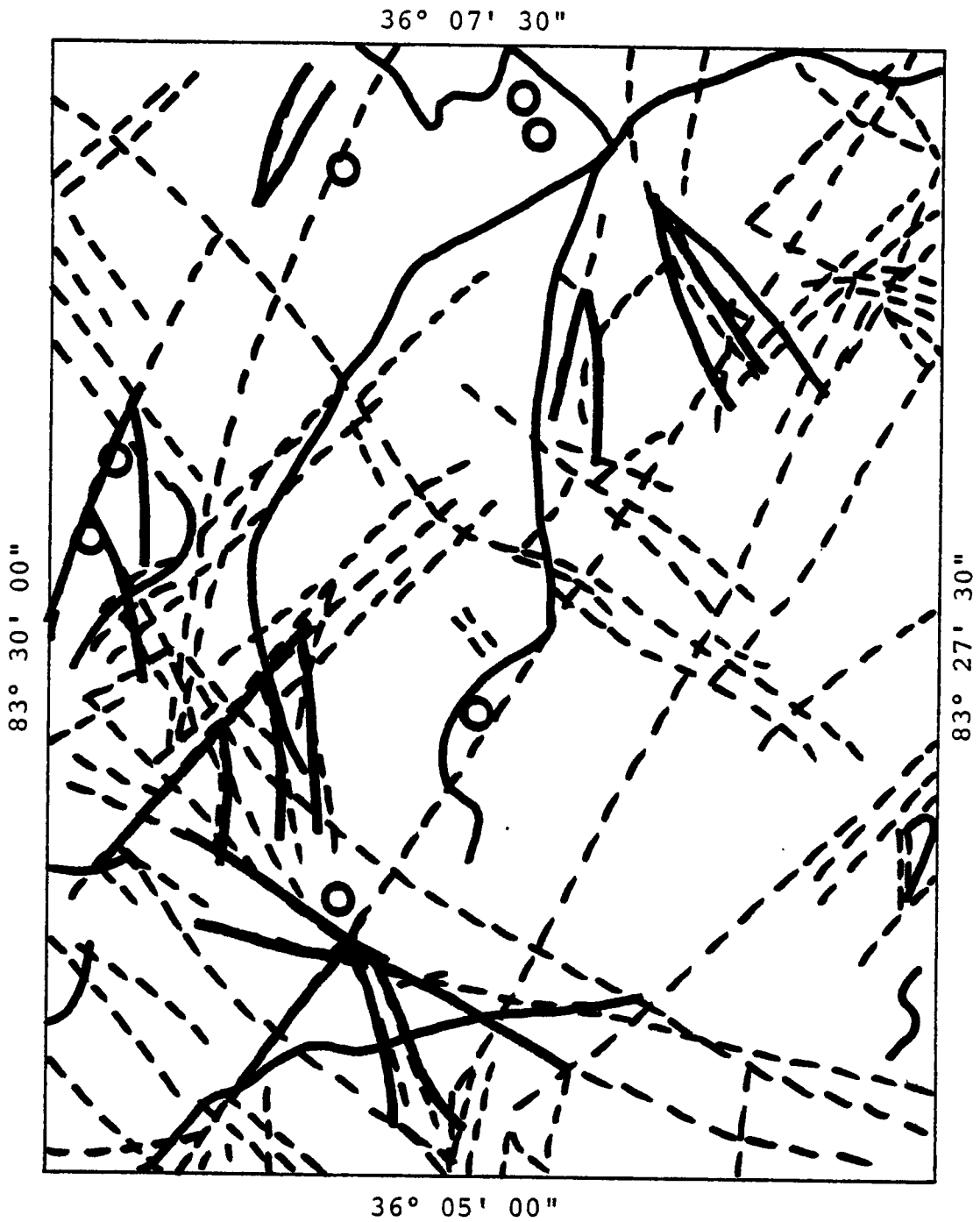


Figure A-8. Observed terrain lineaments of Area I, grid square 7.

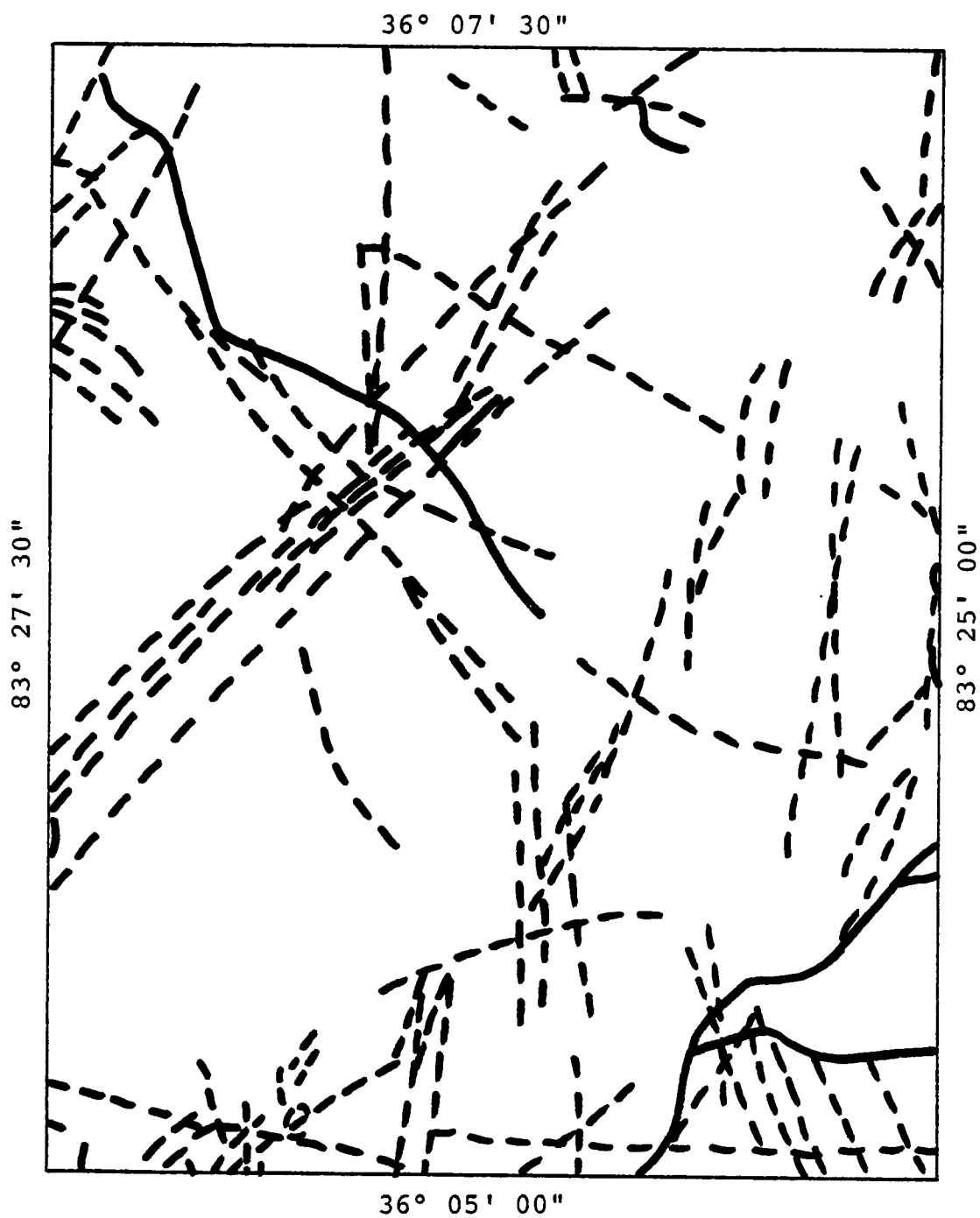


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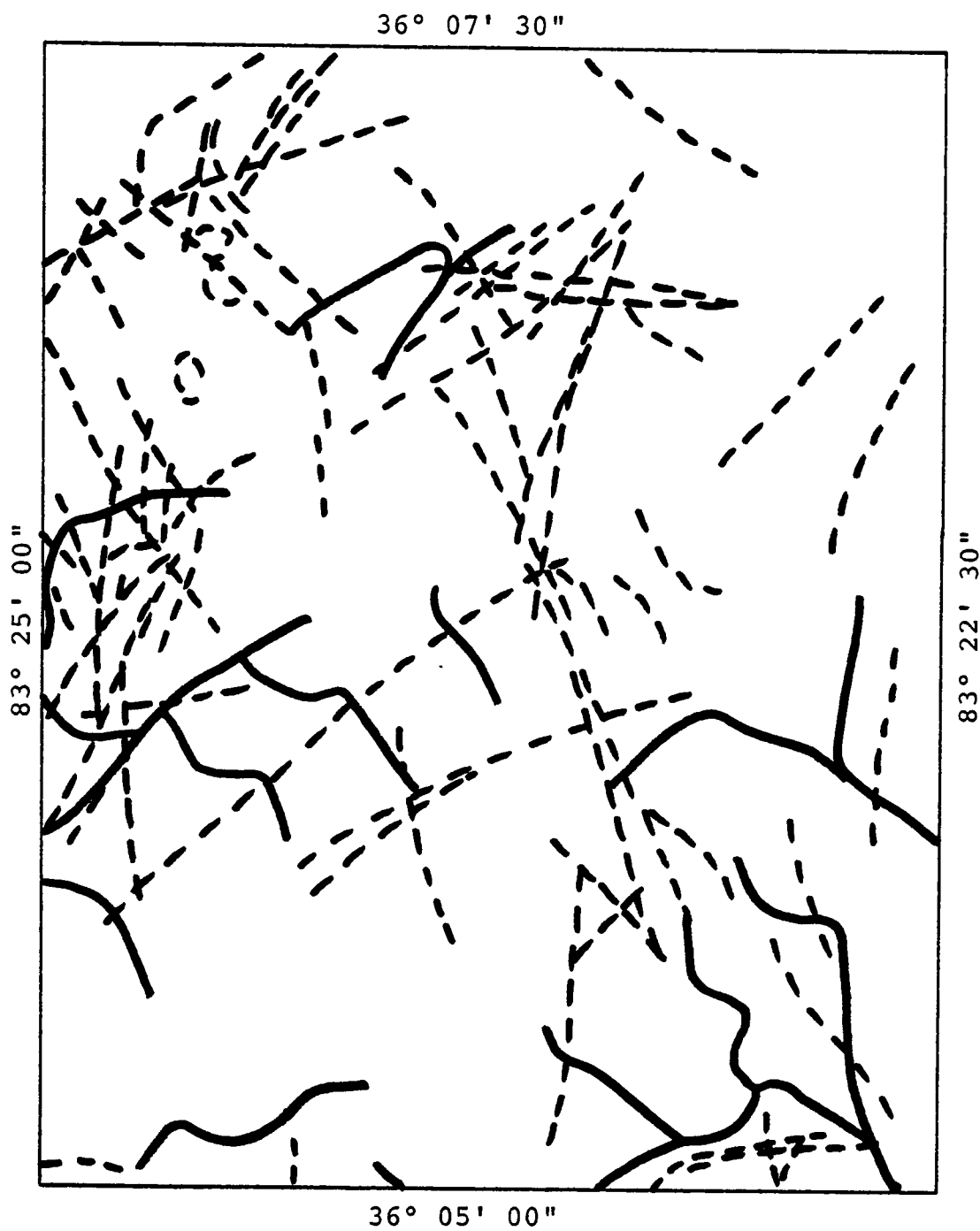


Figure A-10. Observed terrain lineaments of Area I, grid square 9.

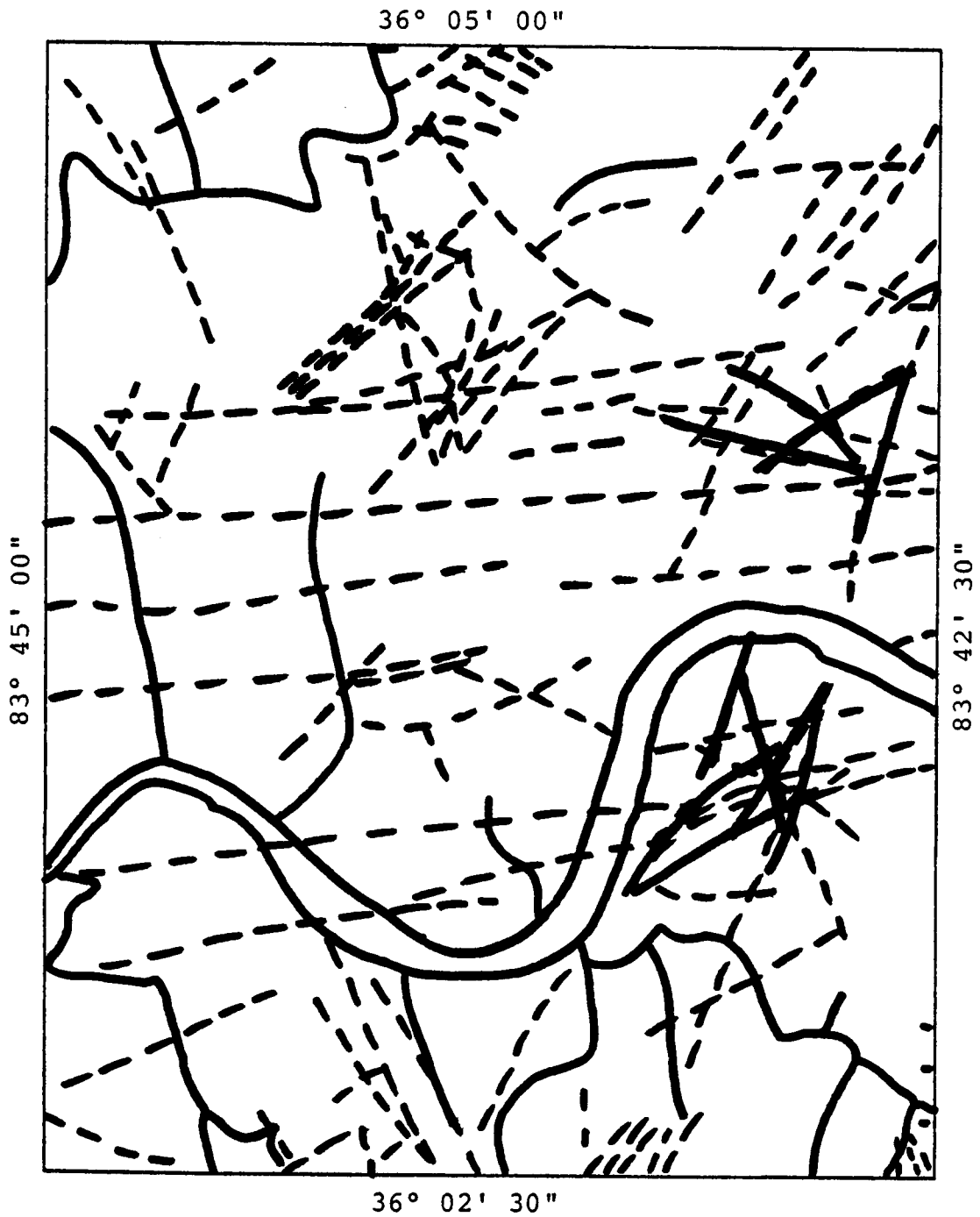


Figure A-11. Observed terrain lineaments of Area I, grid square 10.

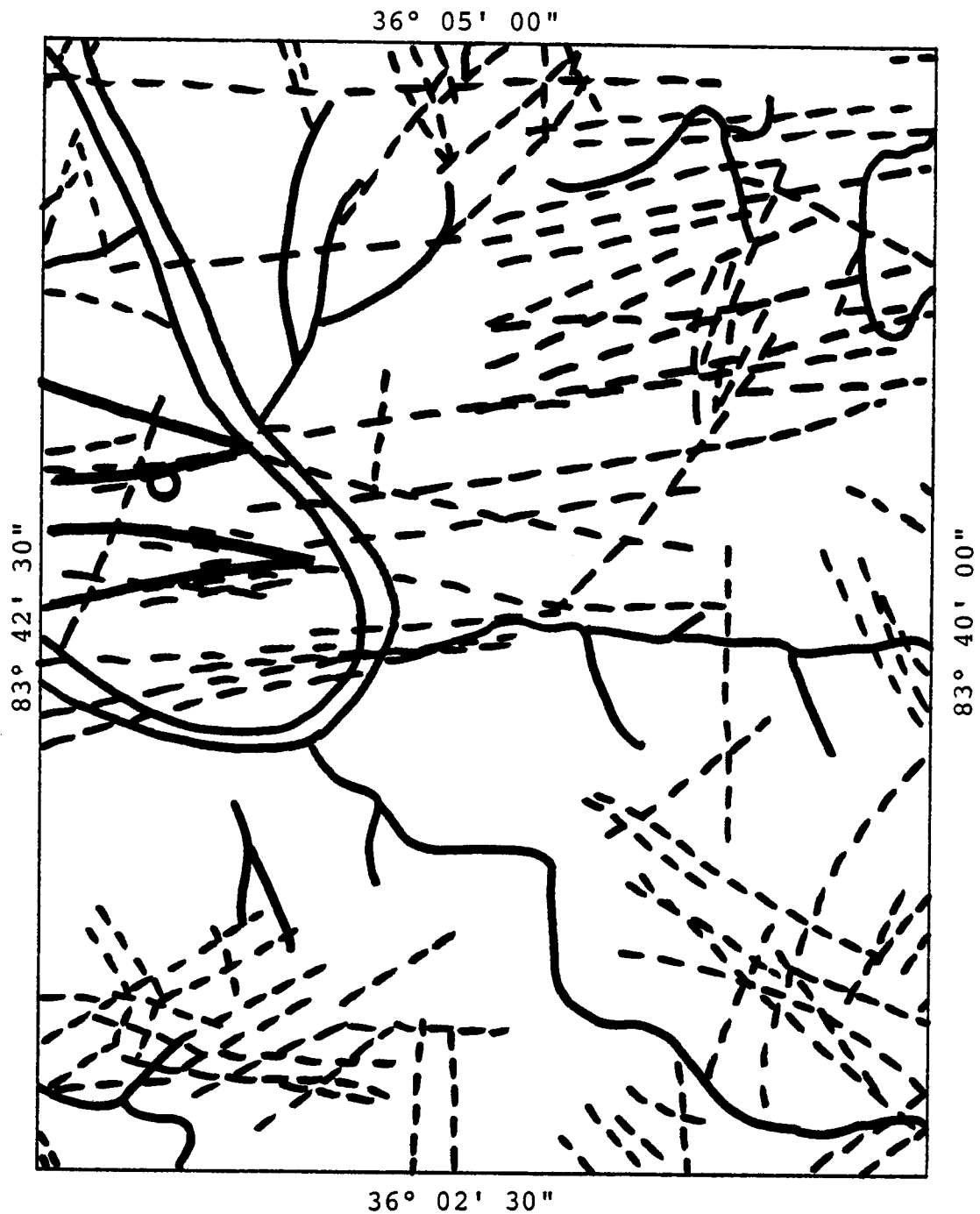


Figure A-12. Observed terrain lineaments of Area I, grid square 11.

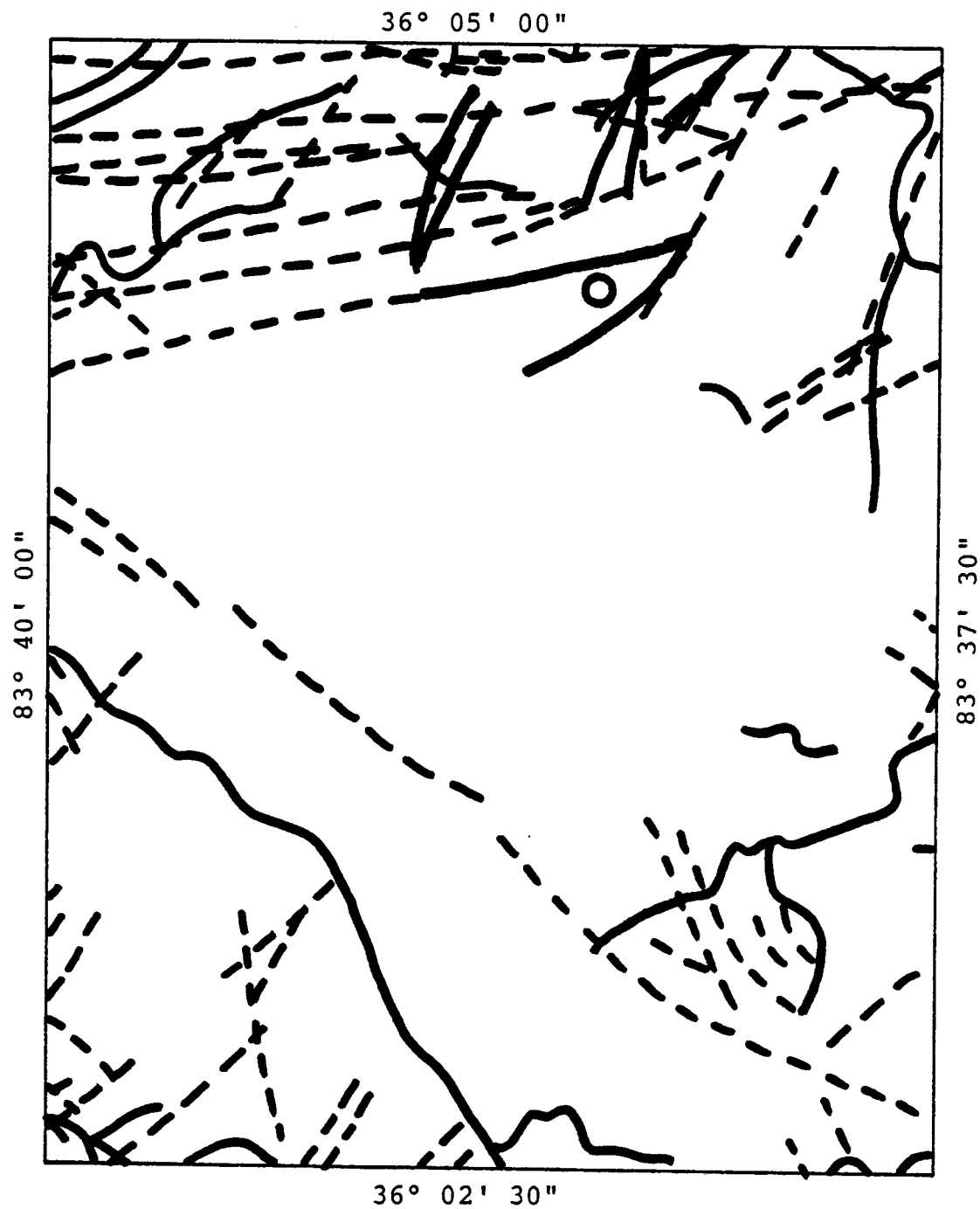


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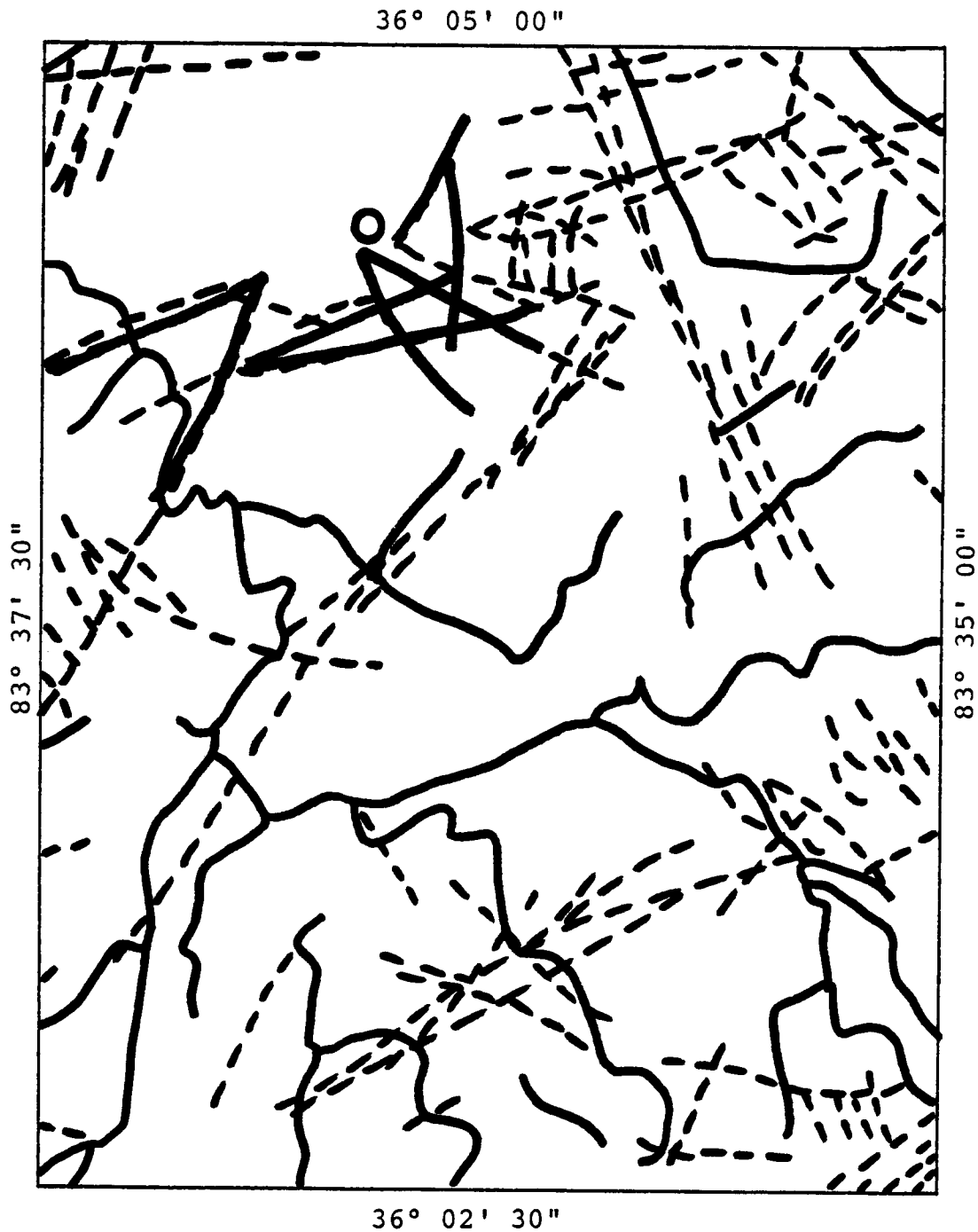


Figure A-14. Observed terrain lineaments of Area I, grid square 13.

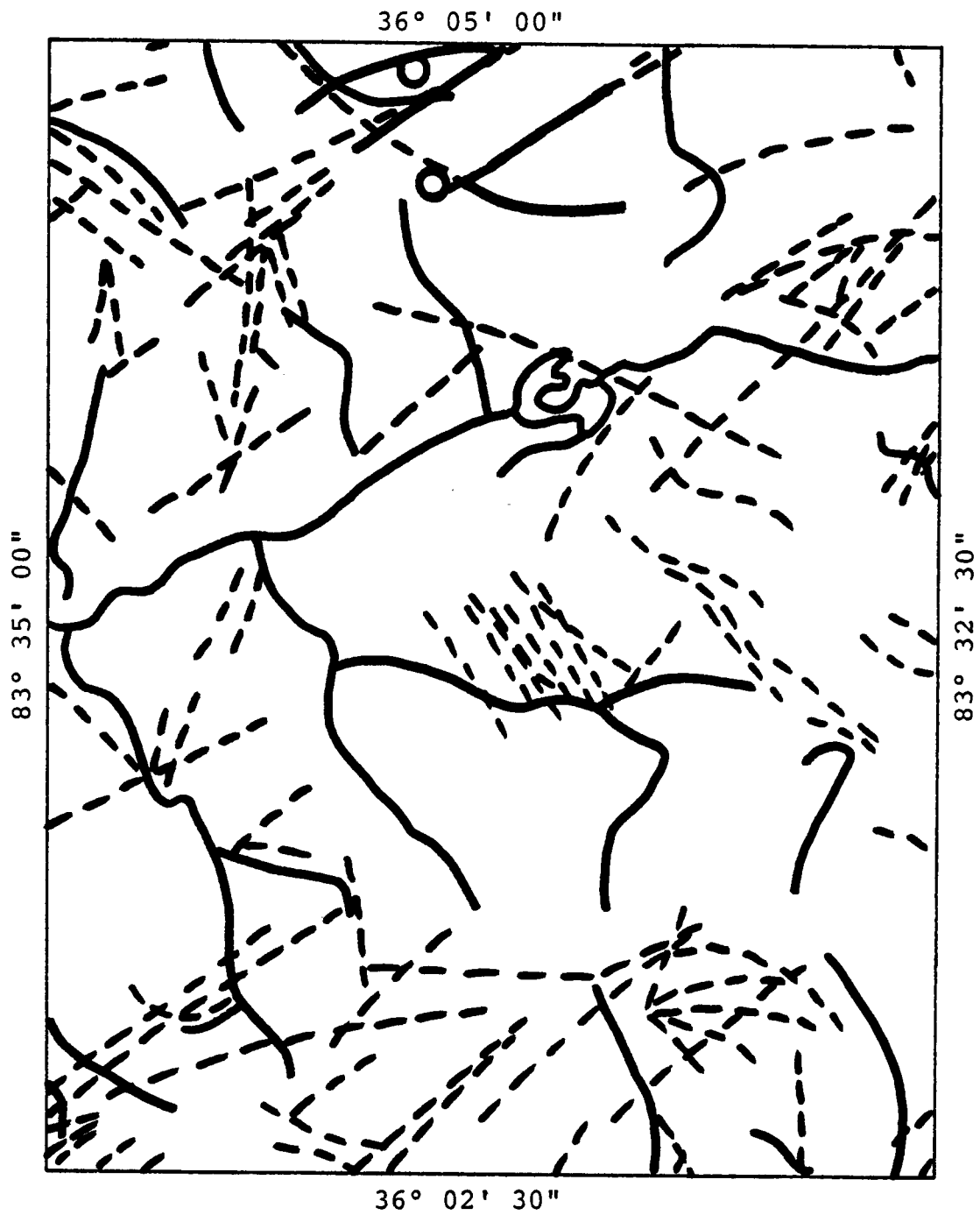


Figure A-15. Observed terrain lineaments of Area I, grid square 14.

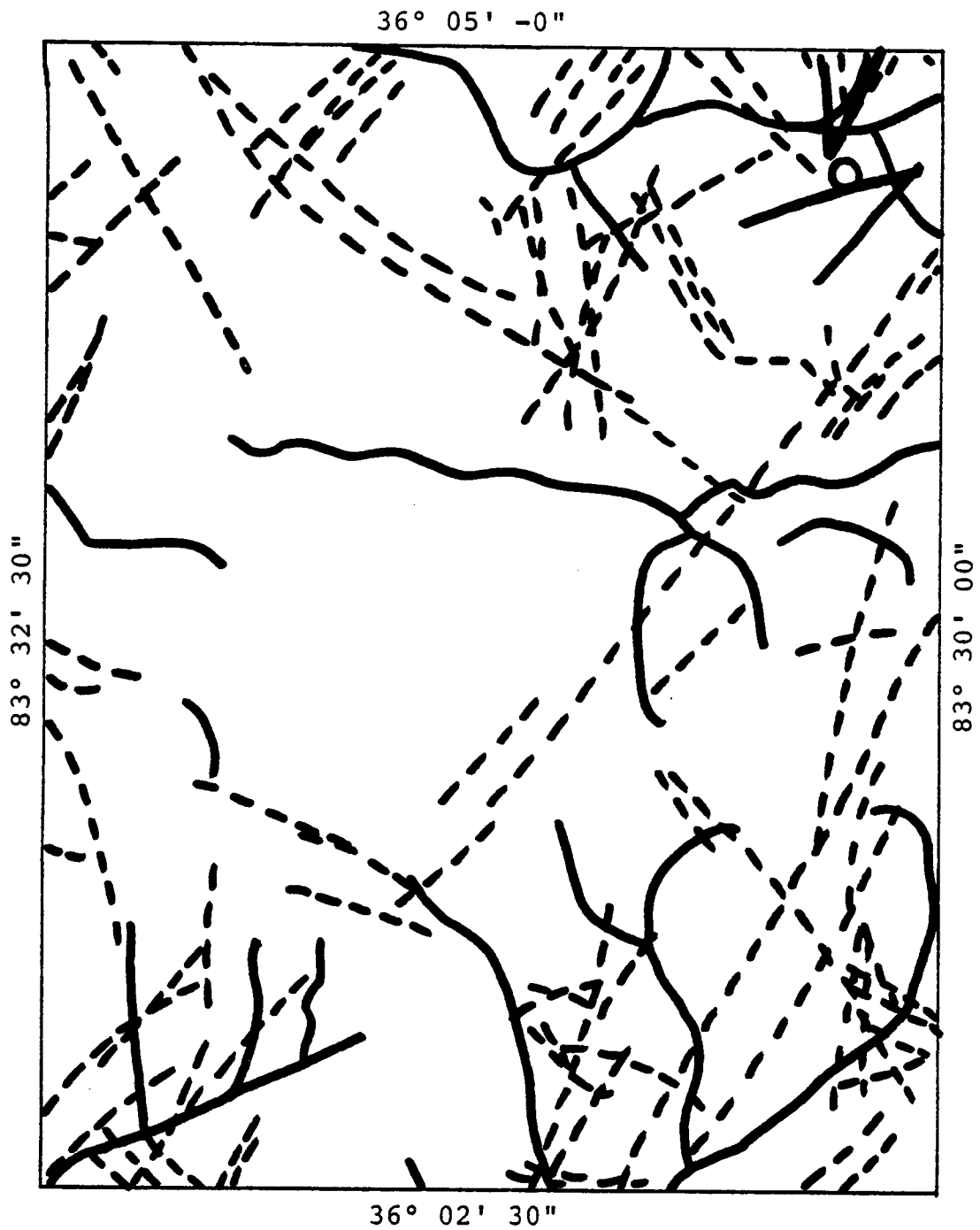


Figure A-16. Observed terrain lineaments of Area I, grid square 15.

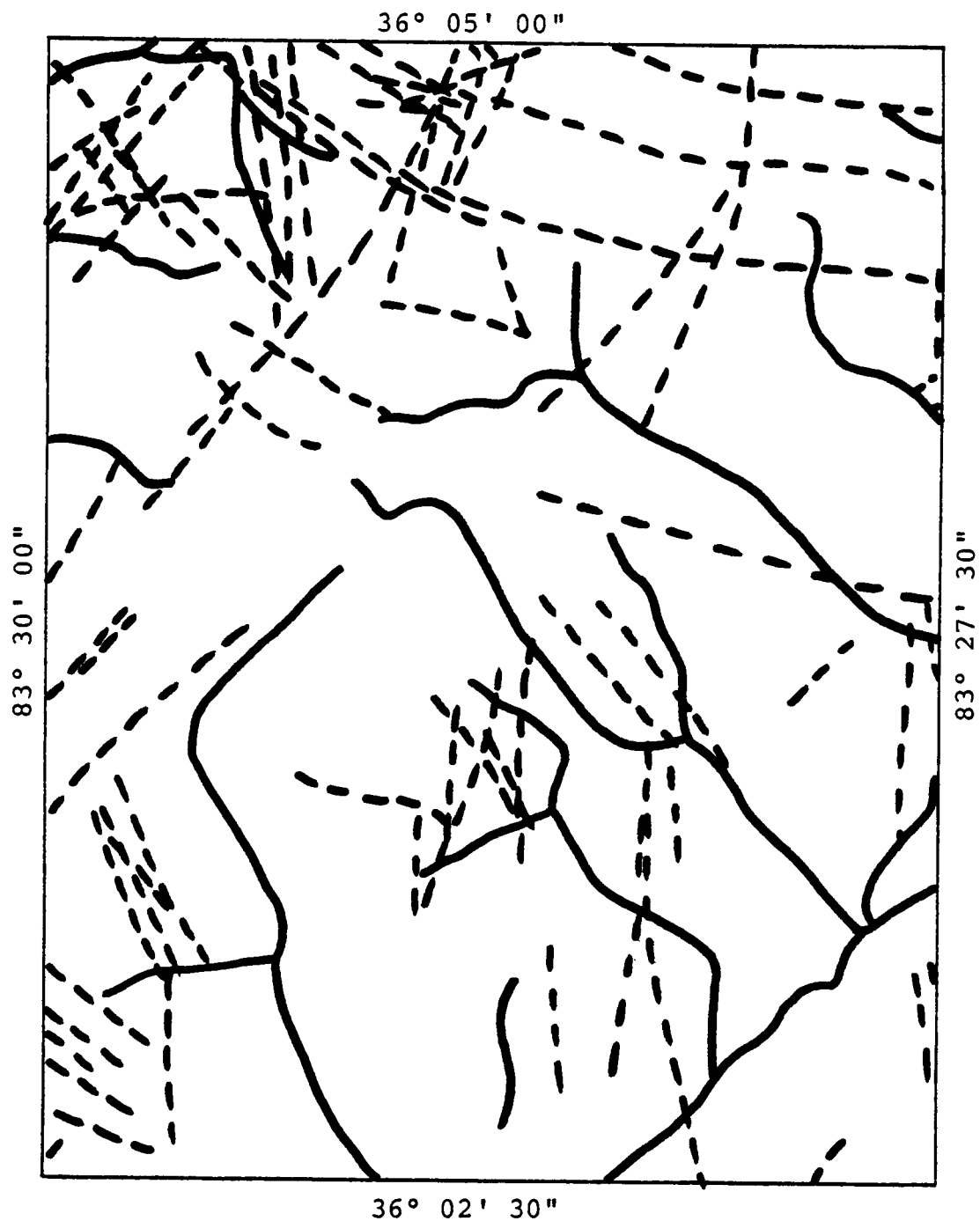


Figure A-17. Observed terrain lineaments of Area I, grid square 16.

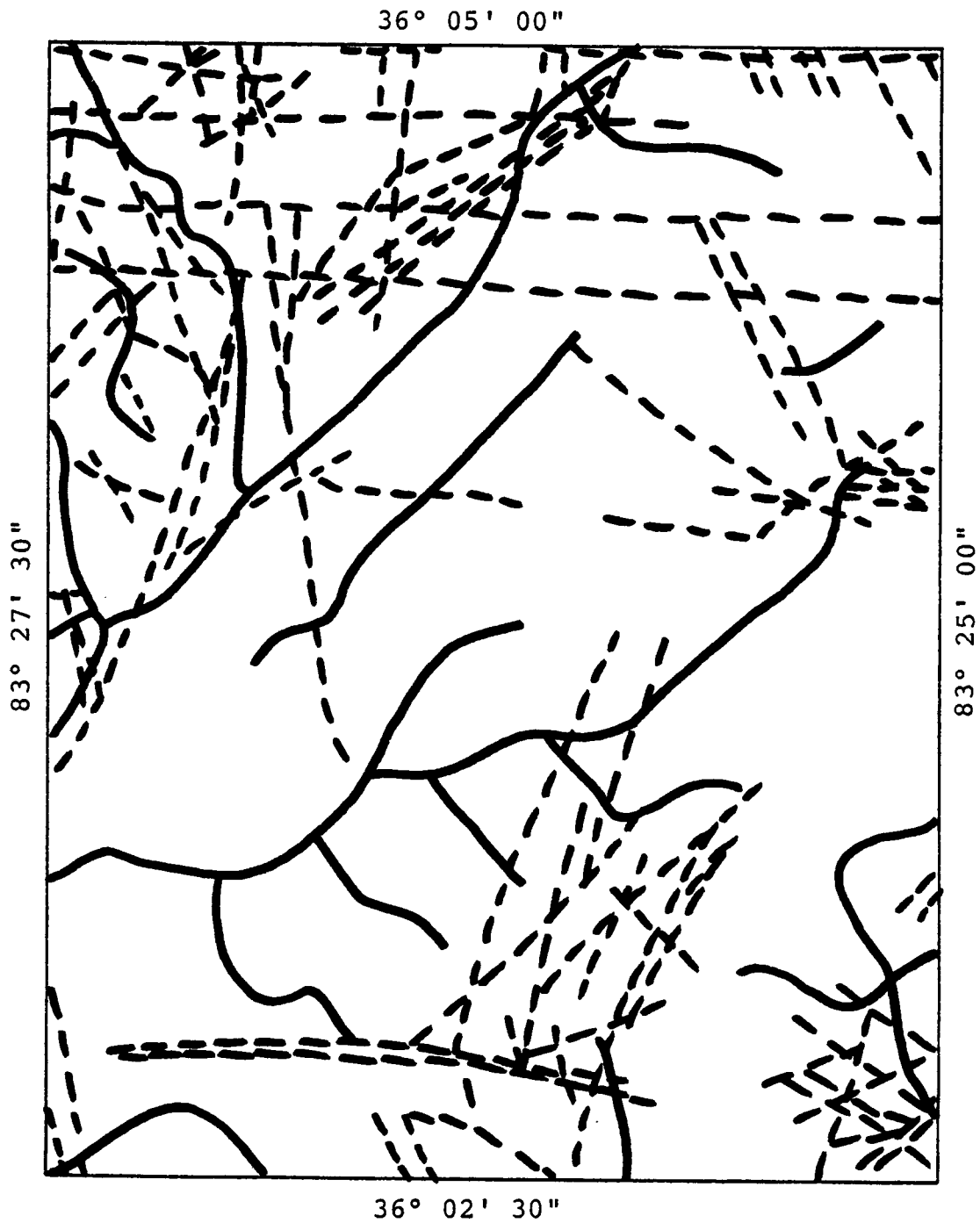


Figure A-18. Observed terrain lineaments of Area I, grid square 17.

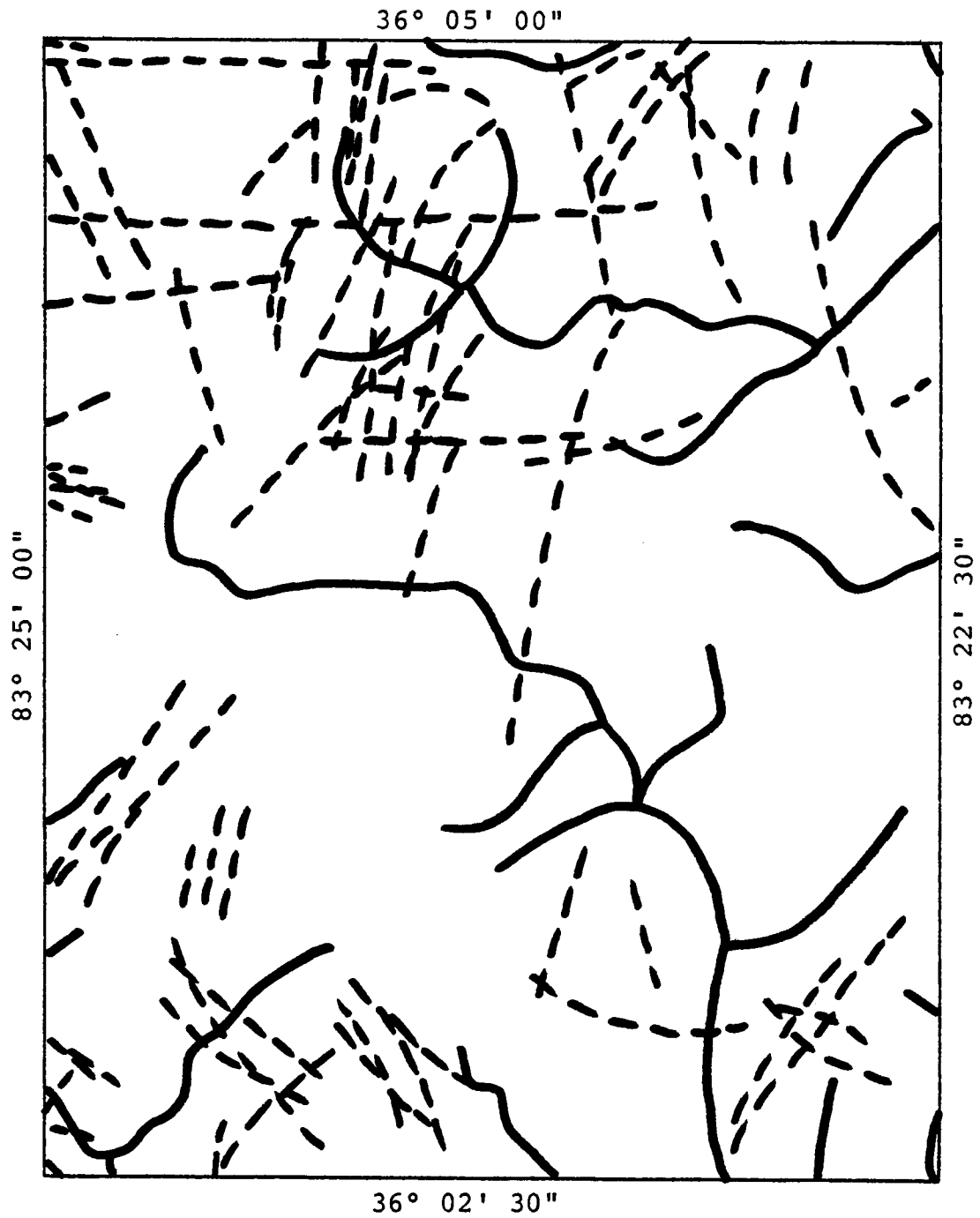


Figure A-19. Observed terrain lineaments of Area I, grid square 18.

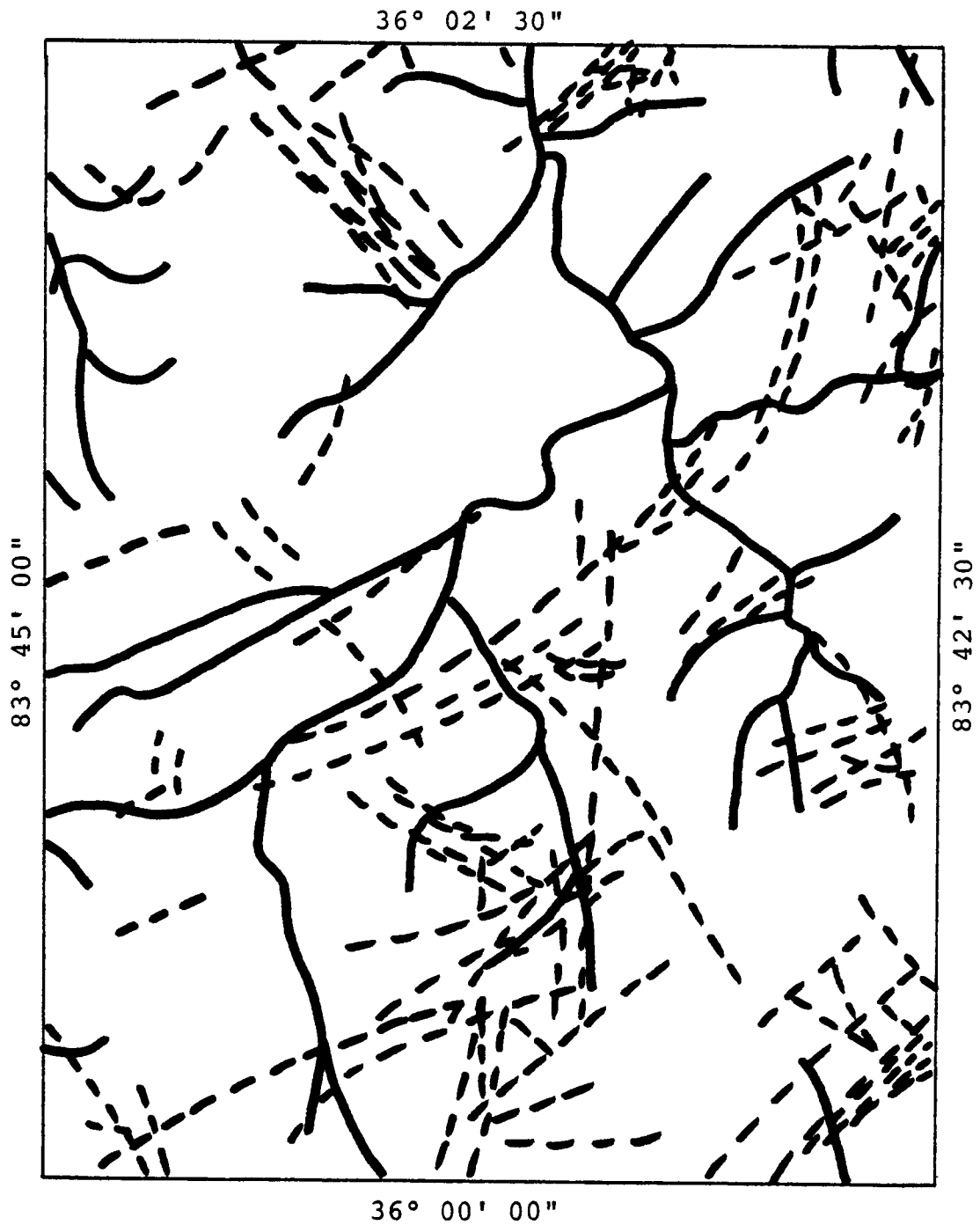


Figure A-20. Observed terrain lineaments of Area I, grid square 19.

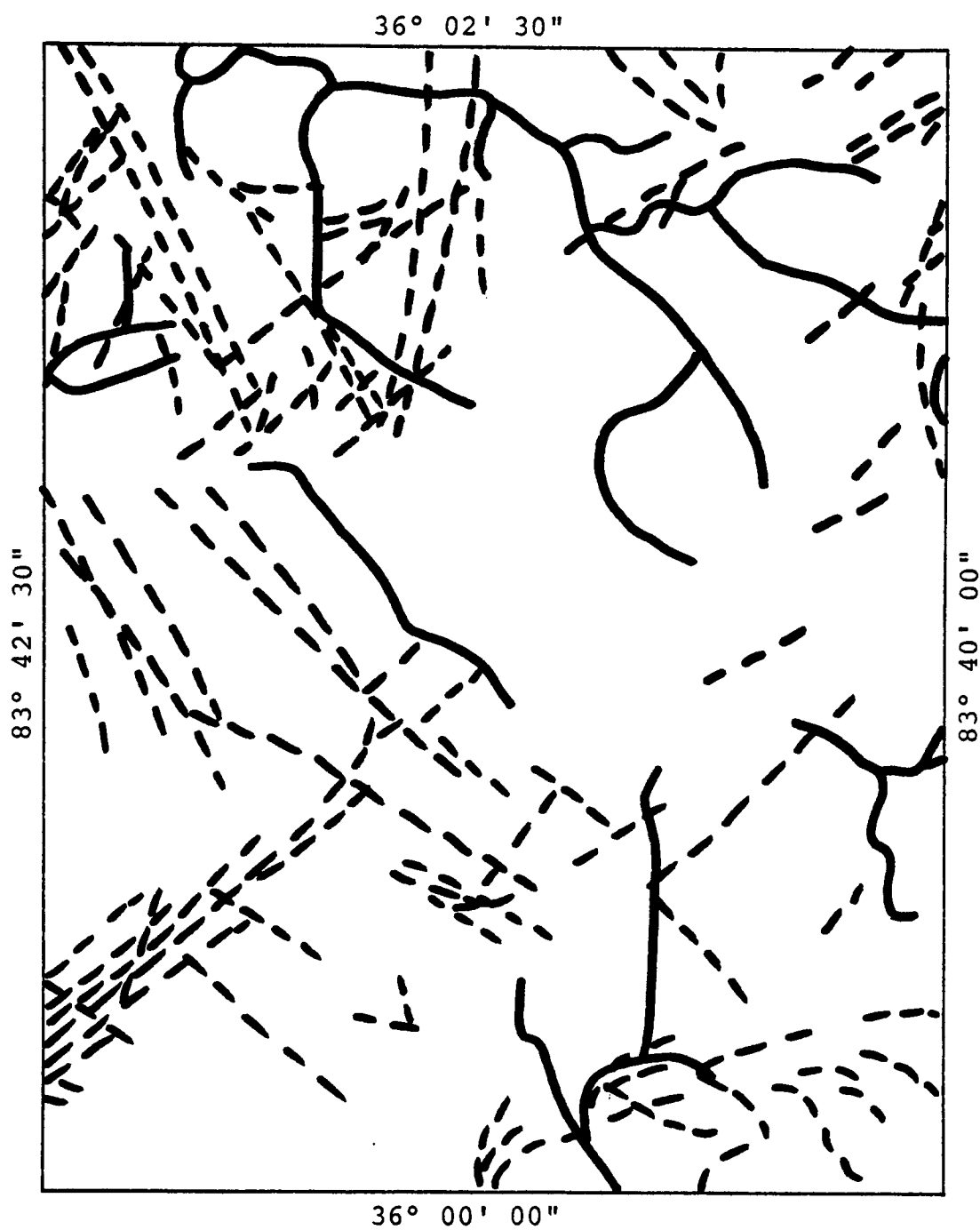


Figure A-21. Observed terrain lineaments of Area I, grid square 20.

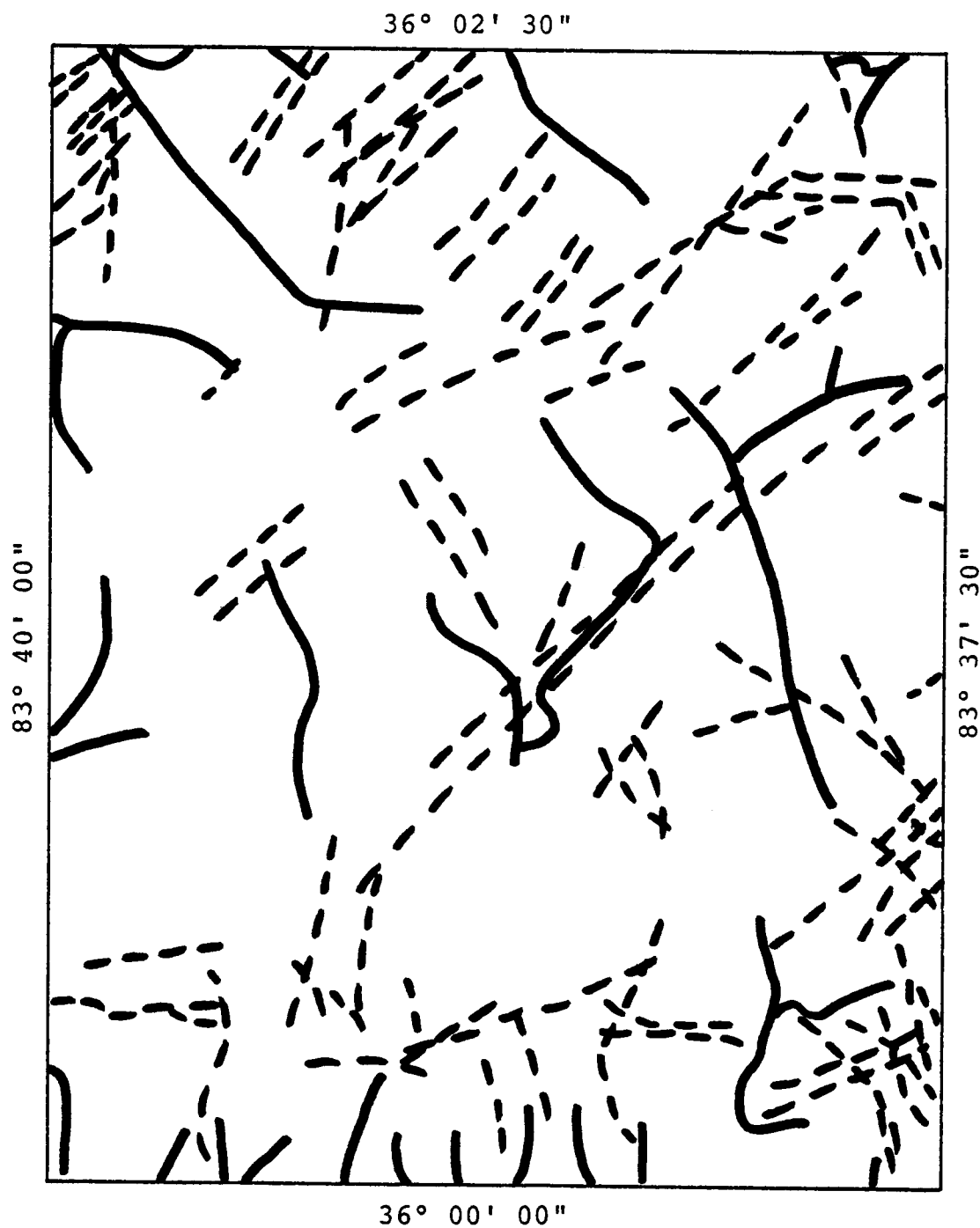


Figure A-22. Observed terrain lineaments of Area I, grid square 21.

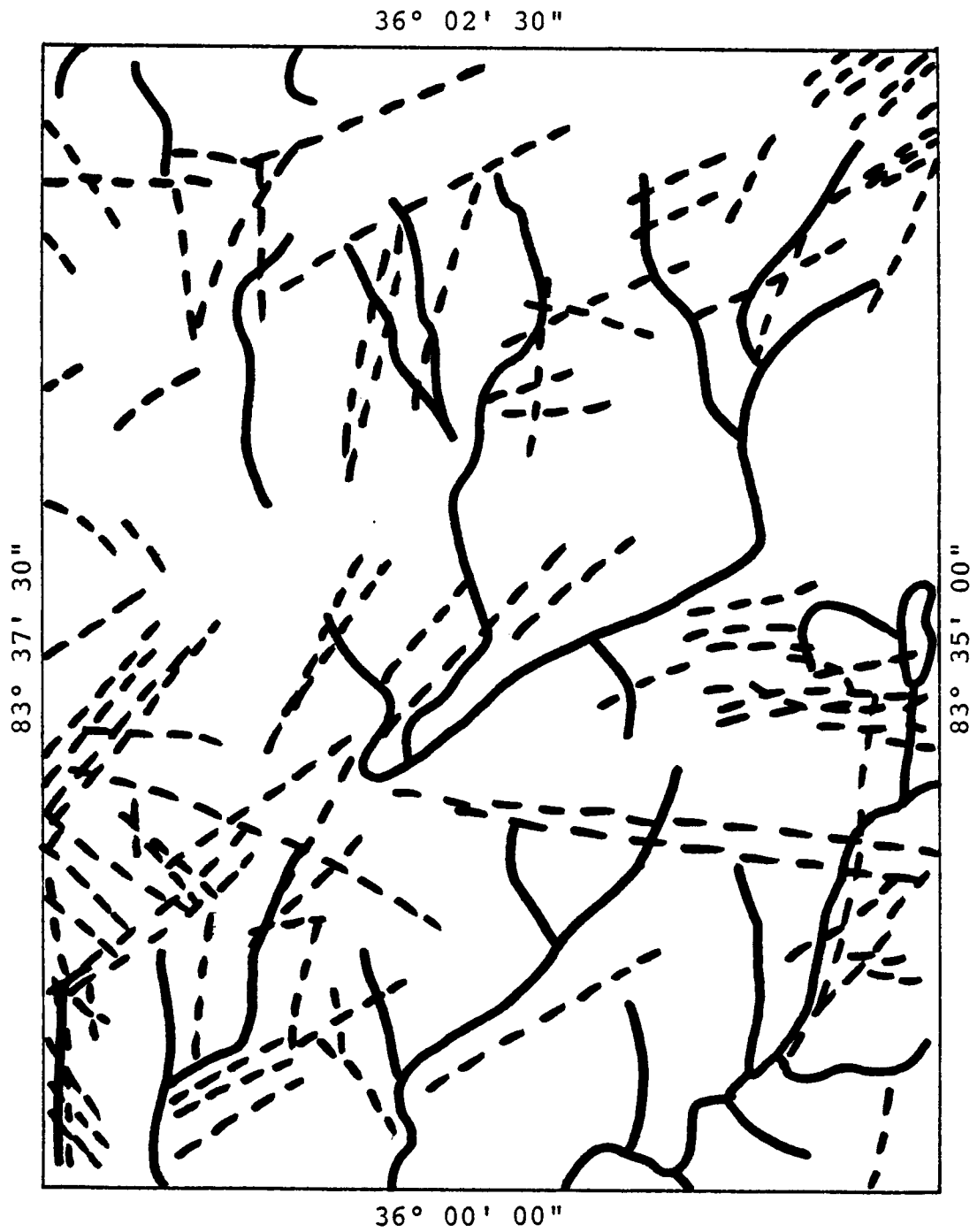


Figure A-23. Observed terrain lineaments of Area I, grid square 22.

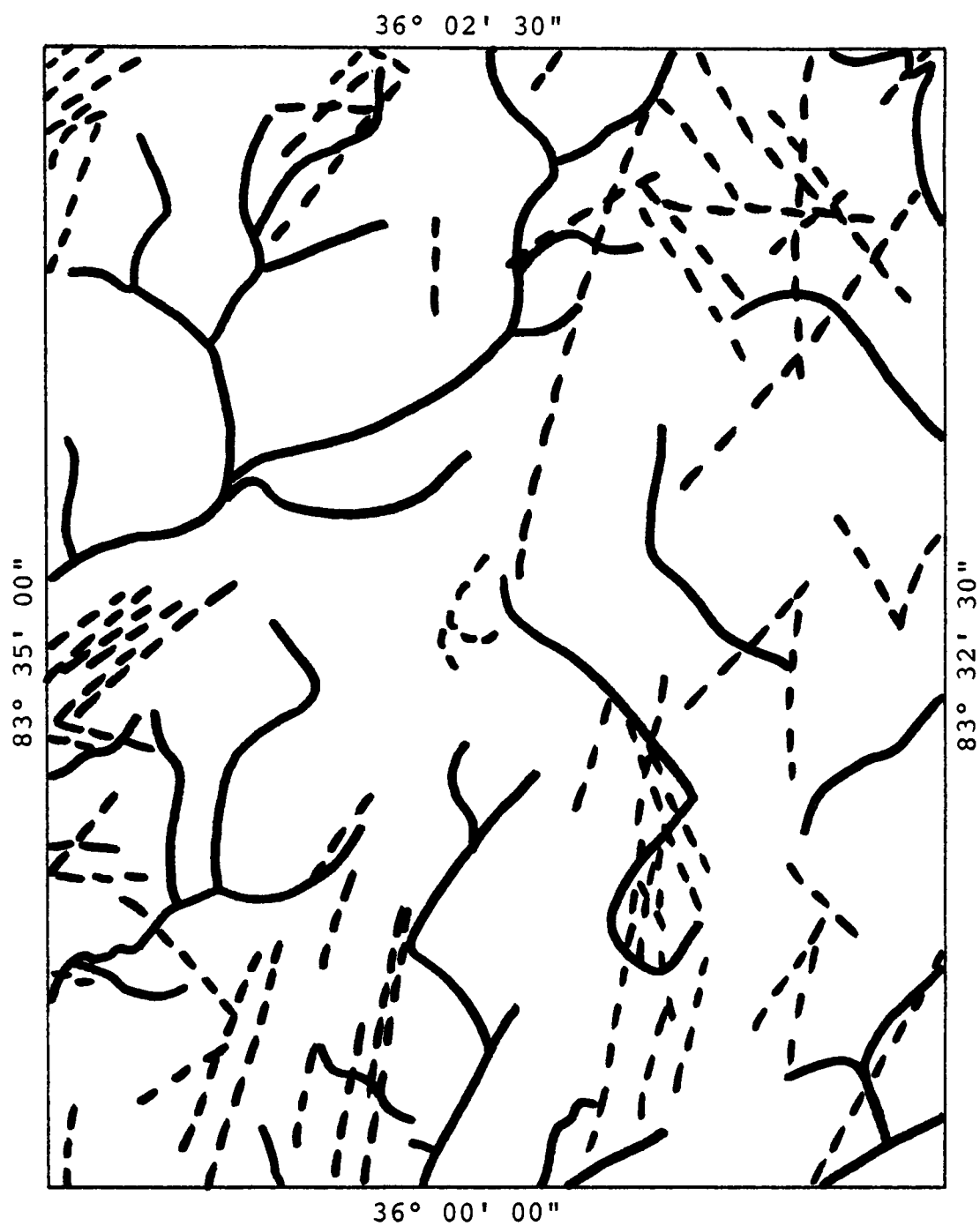


Figure A-24. Observed terrain lineaments of Area I, grid square 23.

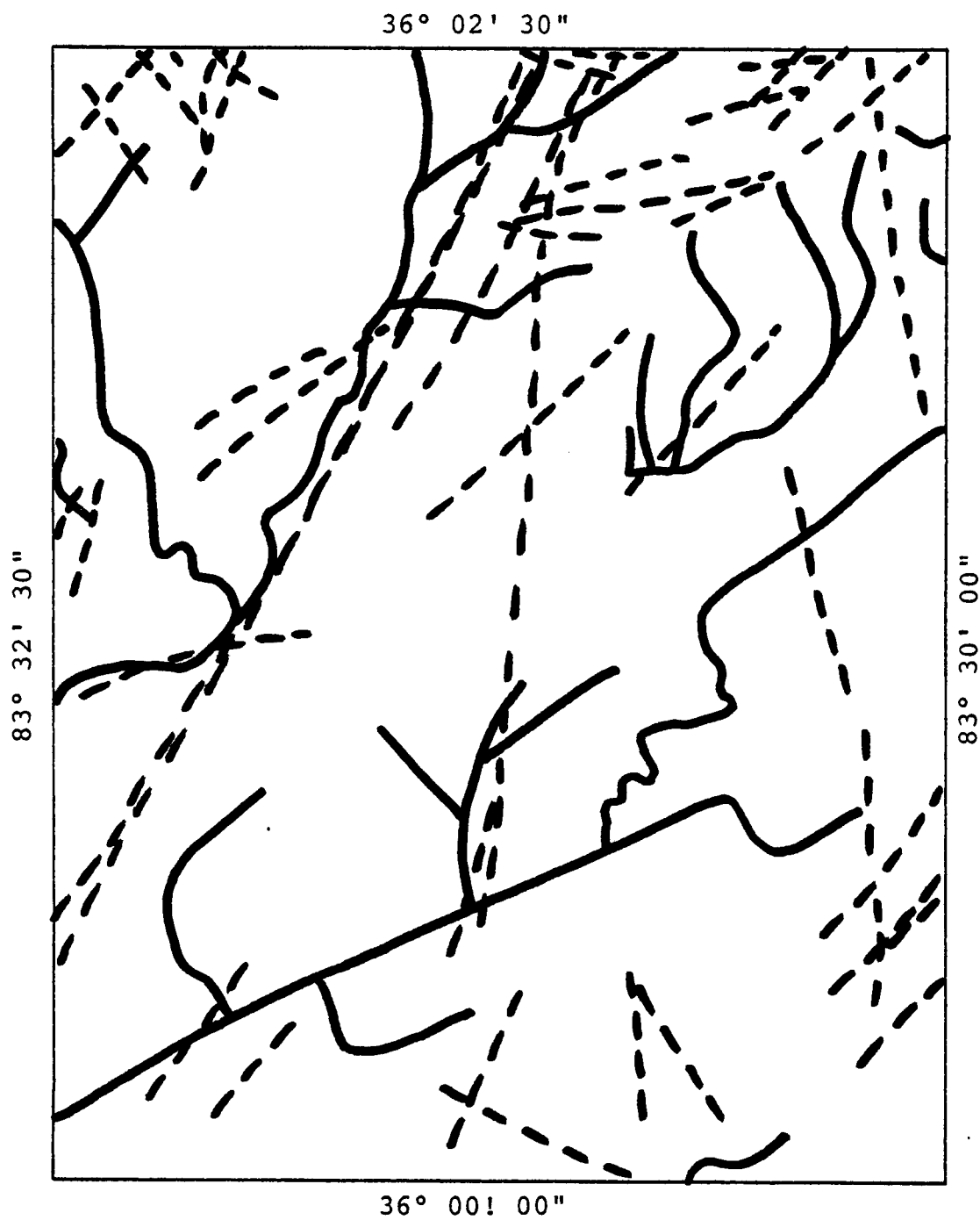


Figure A-25. Observed terrain lineaments of Area I, grid square 24.

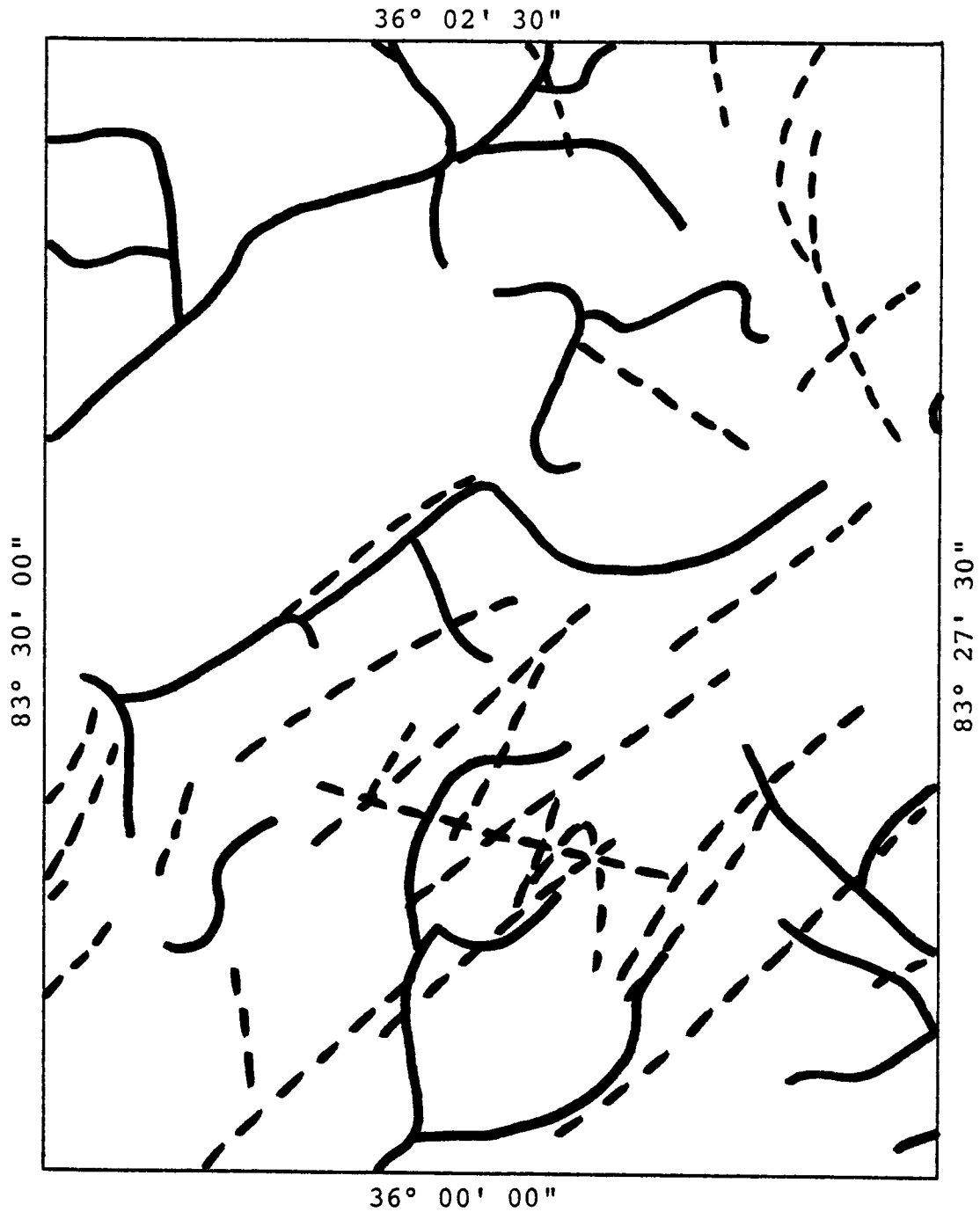


Figure A-26. Observed terrain lineaments of Area I, grid square 25.

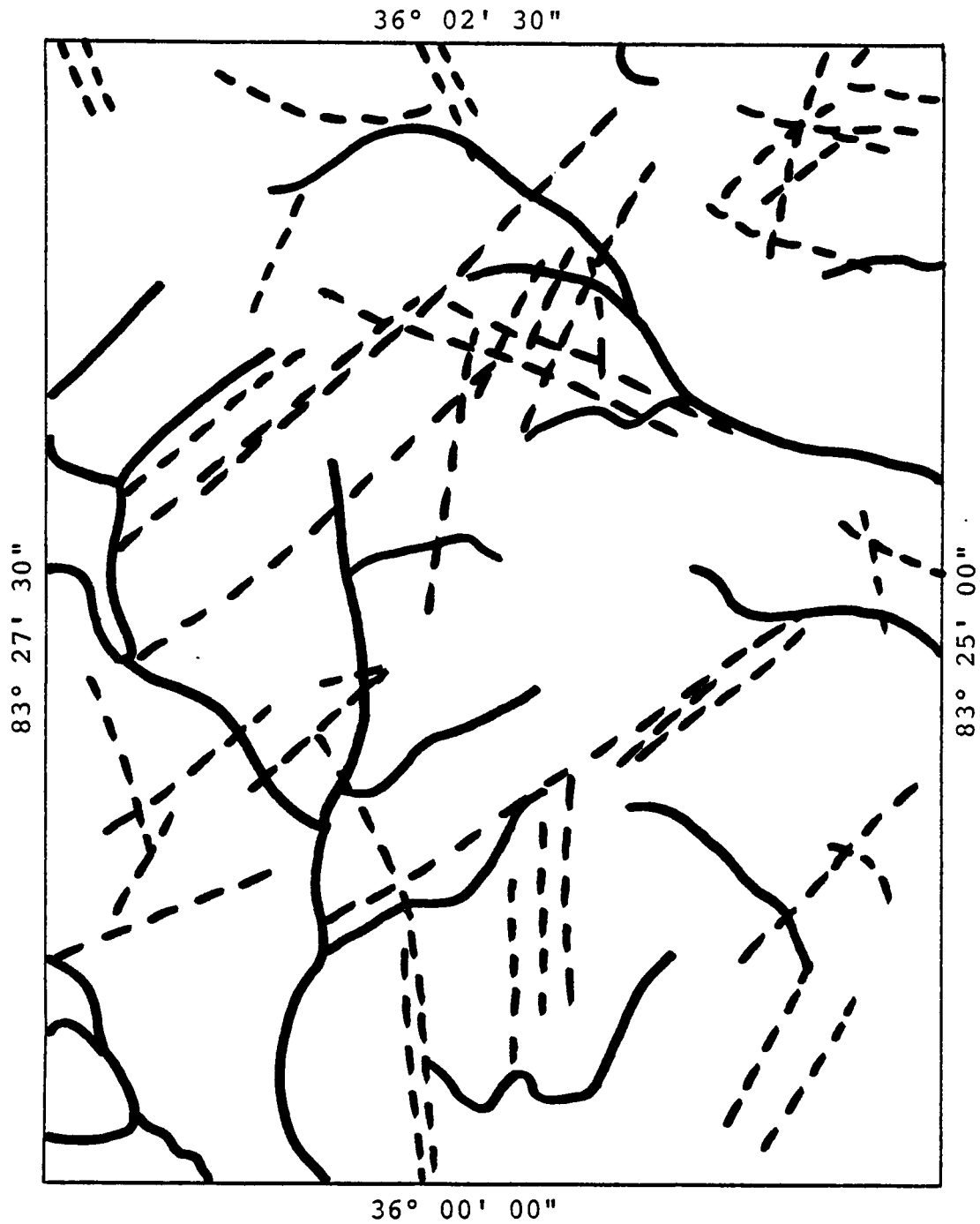


Figure A-27. Observed terrain lineaments of Area I, grid square 26.

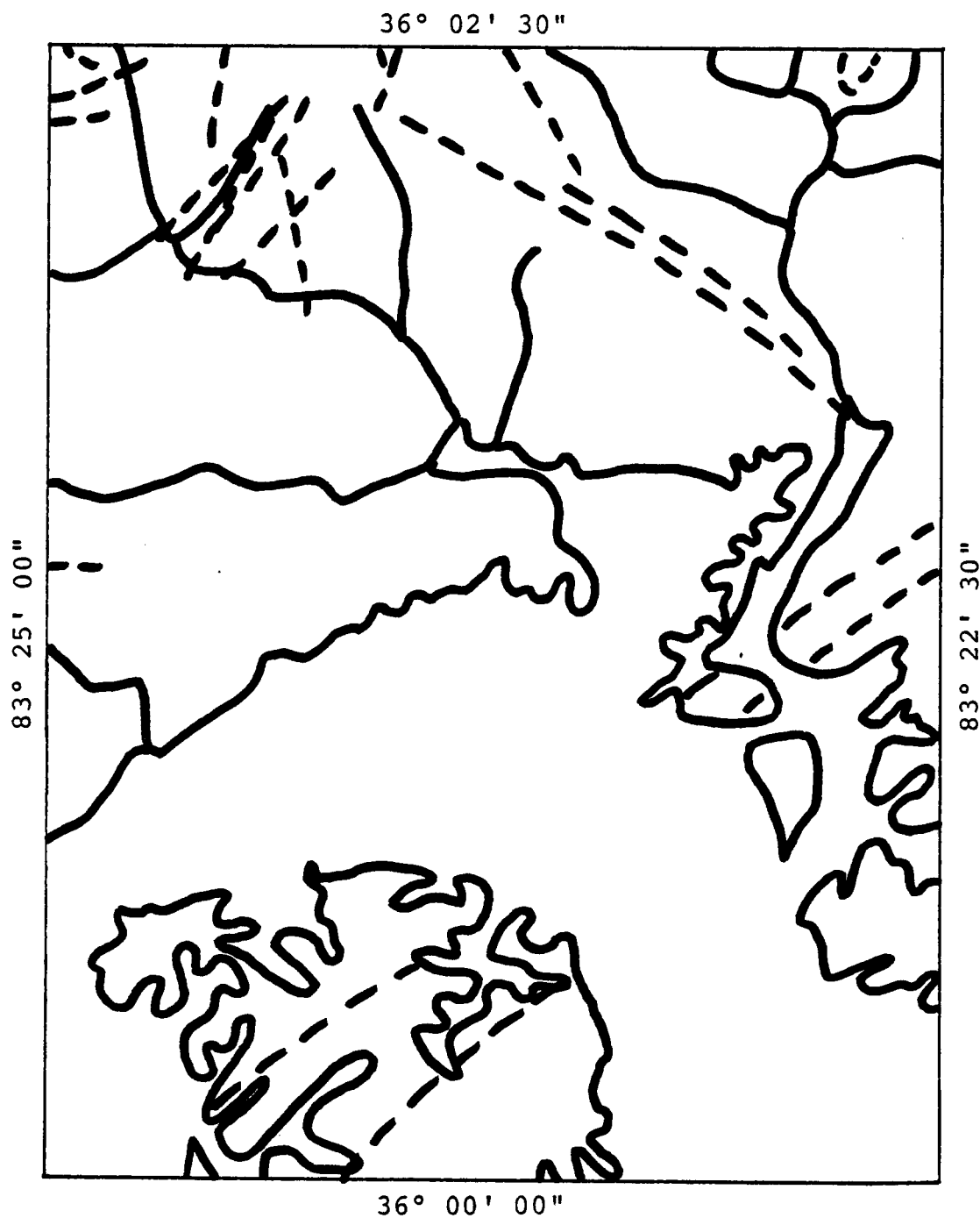


Figure A-28. Observed terrain lineaments of Area I, grid square 27.

APPENDIX B

AREA II FIGURES

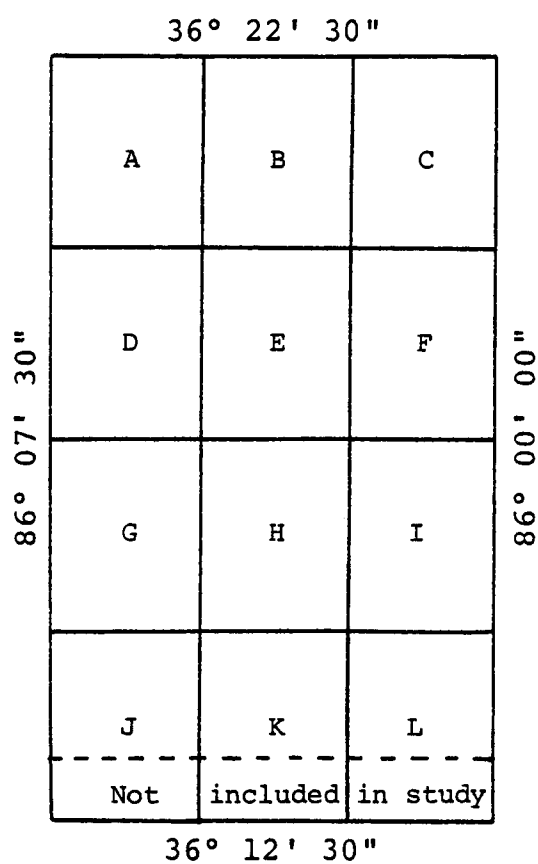
Figure B-1 is a key to the location of the remaining figures in this appendix. The data are presented in lettered blocks with each block side having coordinates, so as to be positioned easily and correctly. These lettered blocks are shown in the key of Figure B-1.

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Figures B-2 through B-13 all have a scale of 1:28,000.

List of Symbols

-  Site of known mineralization
-  Site of possible mineralization potential
-  An observed terrain lineament
-  Stream path or lake or river boundary
-  Nu pattern



Scale: 1:201,000

Figure B-1. Grid square key for Area II.

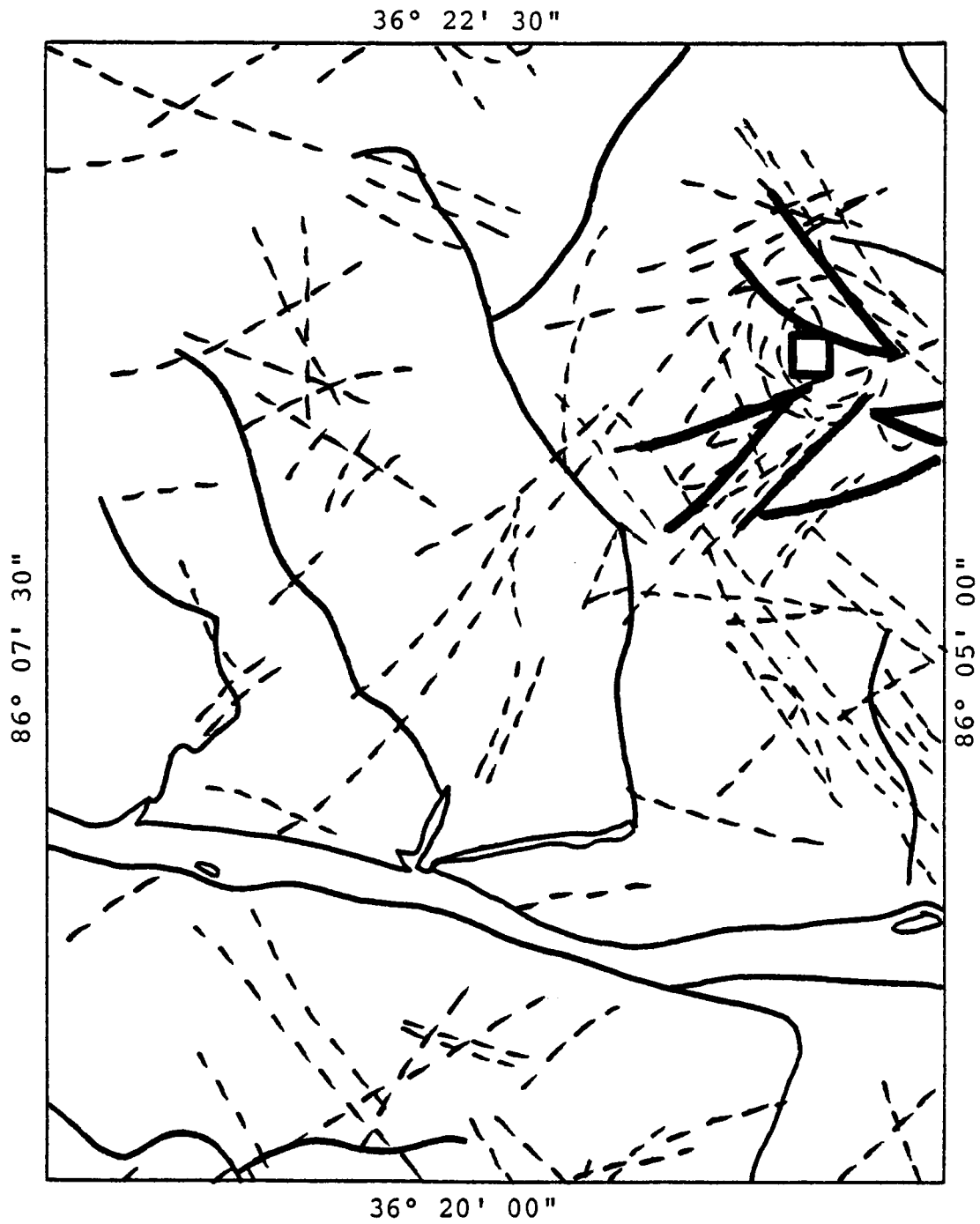


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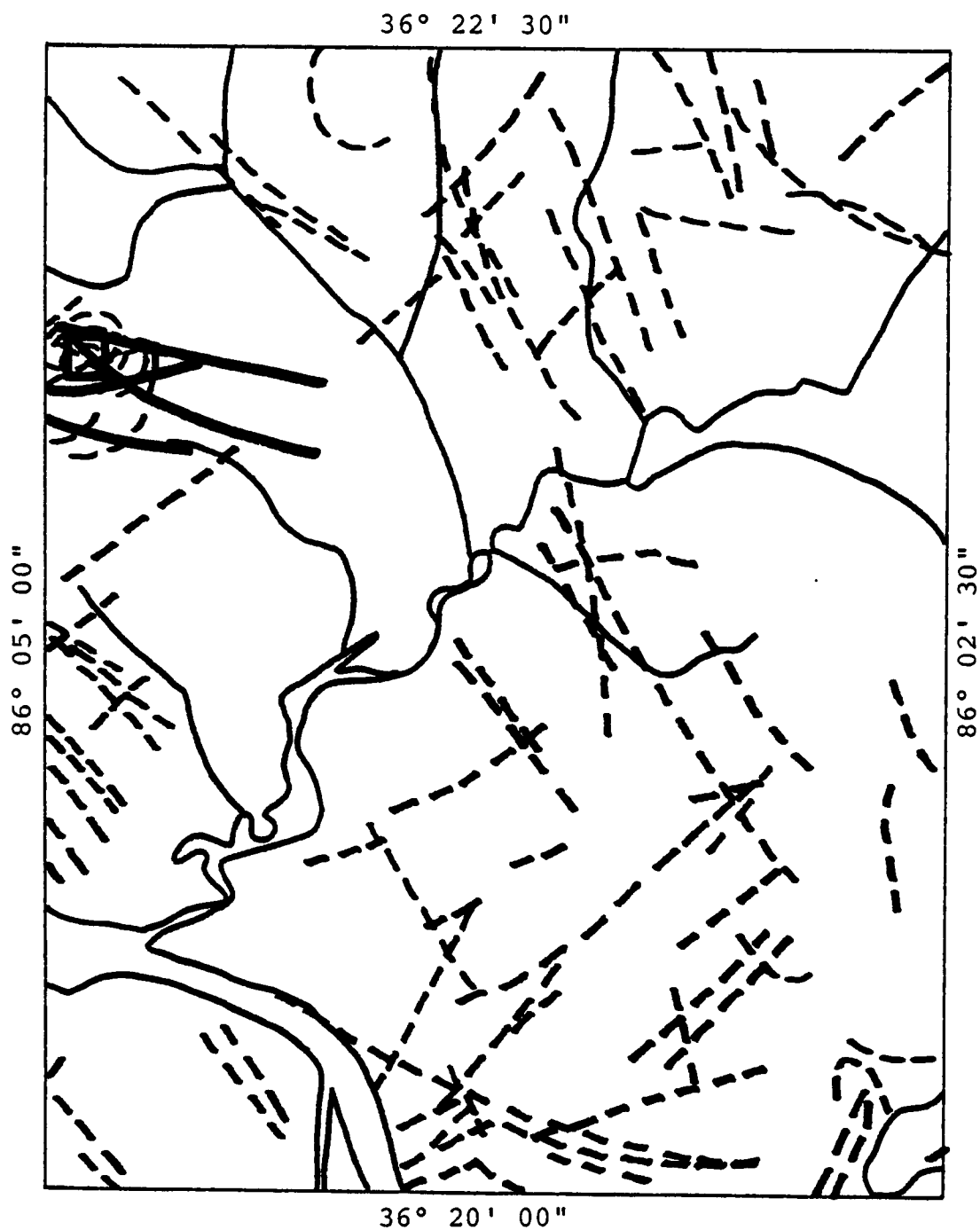


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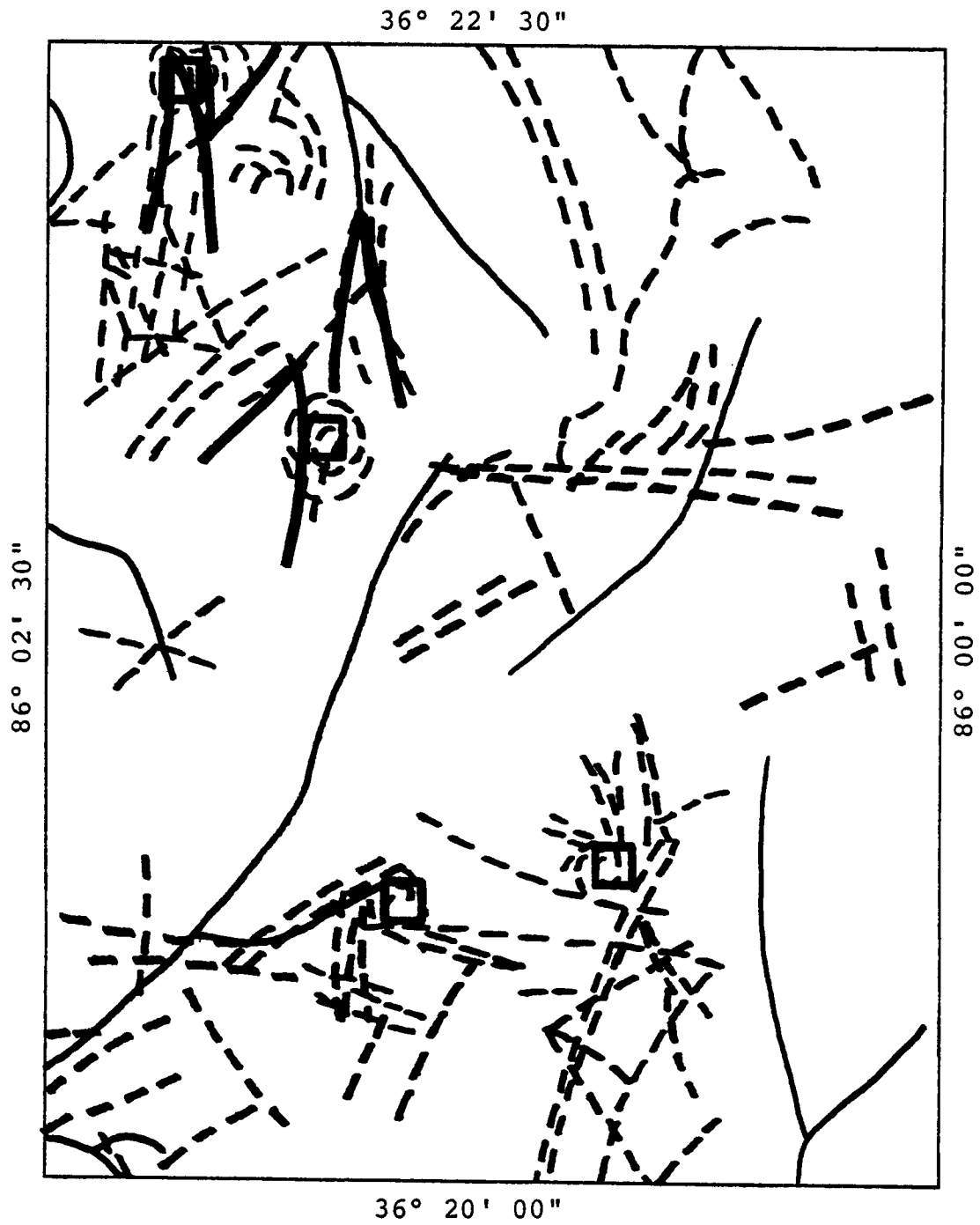


Figure B-4. Observed terrain lineaments of Area II, grid square C.

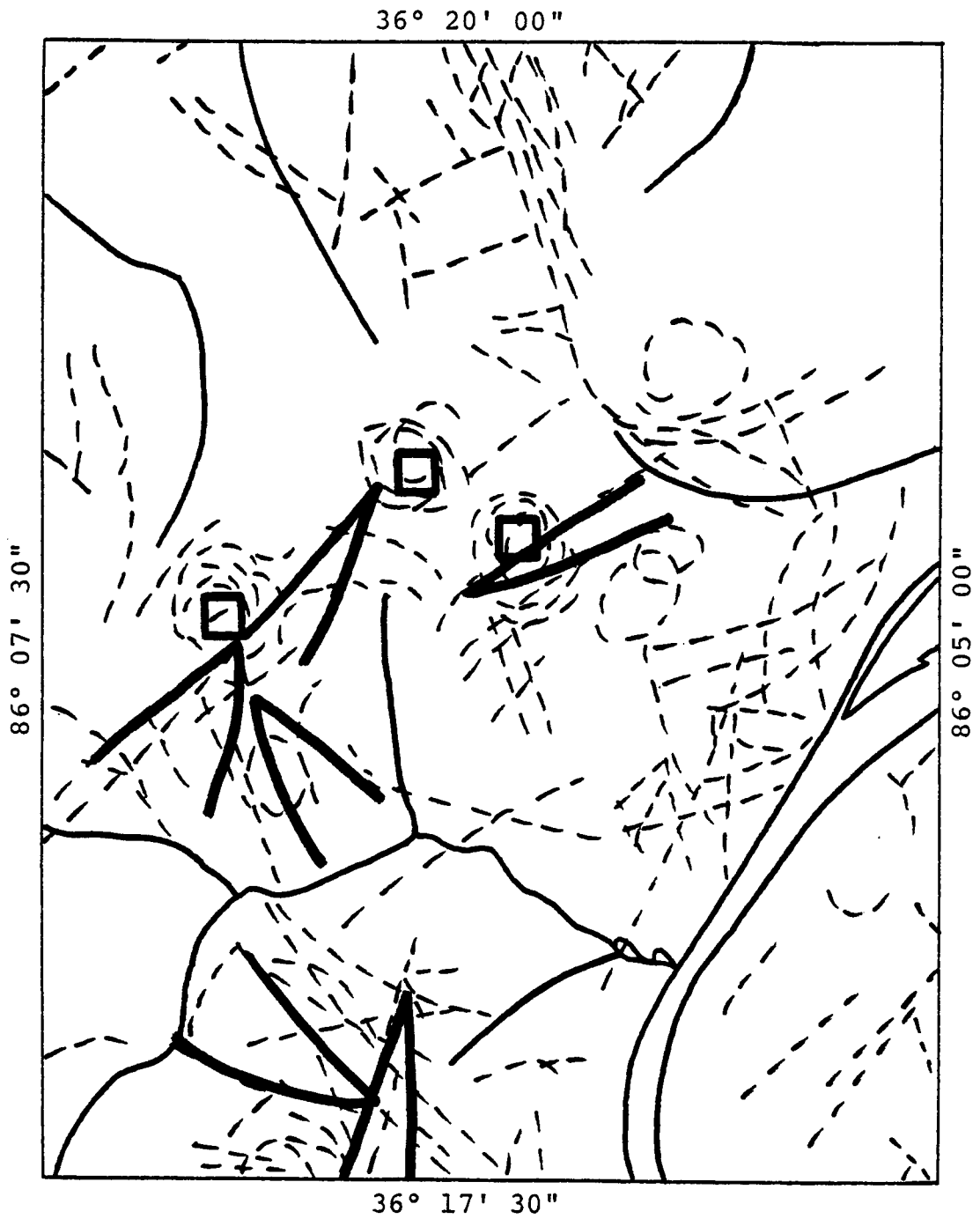


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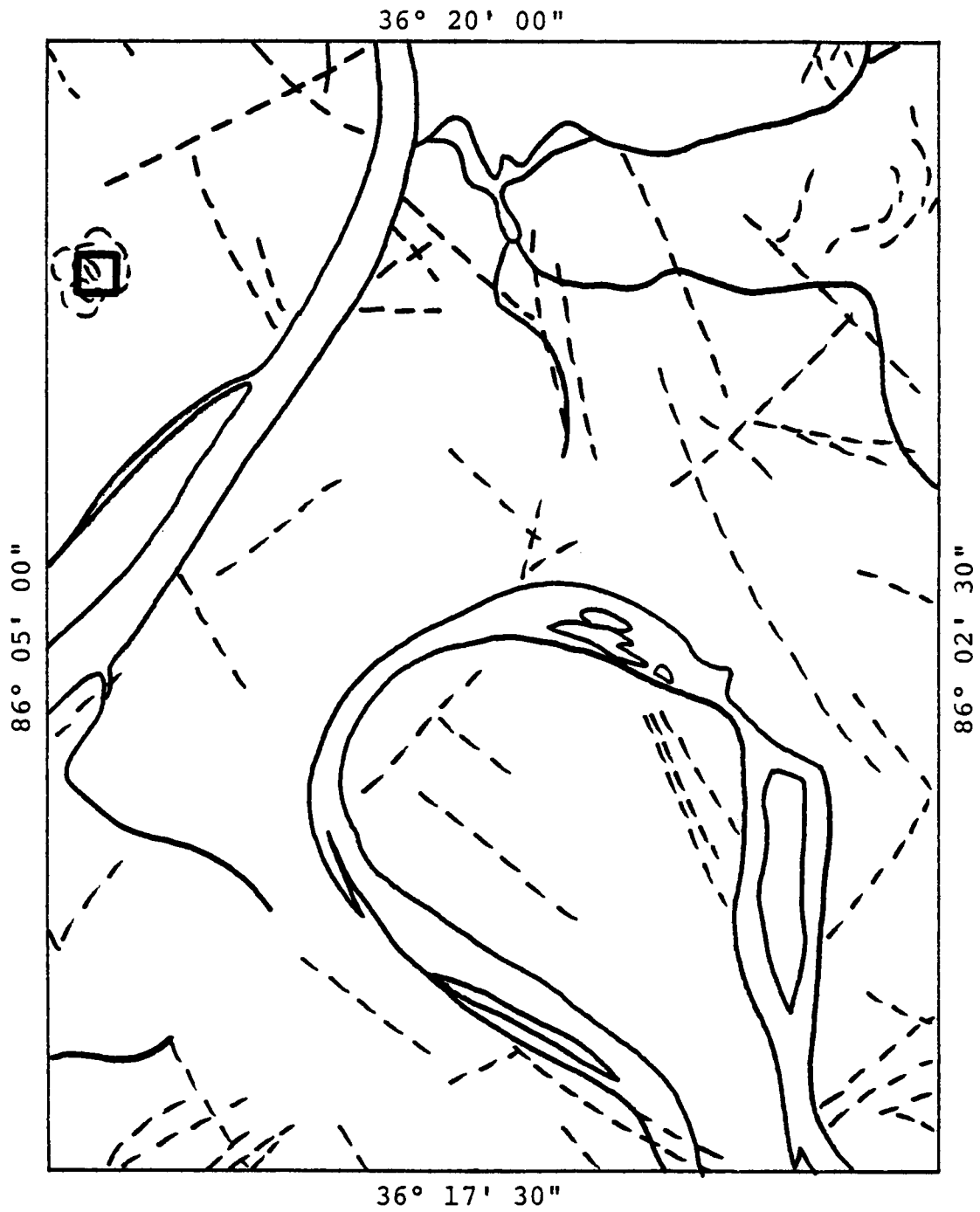


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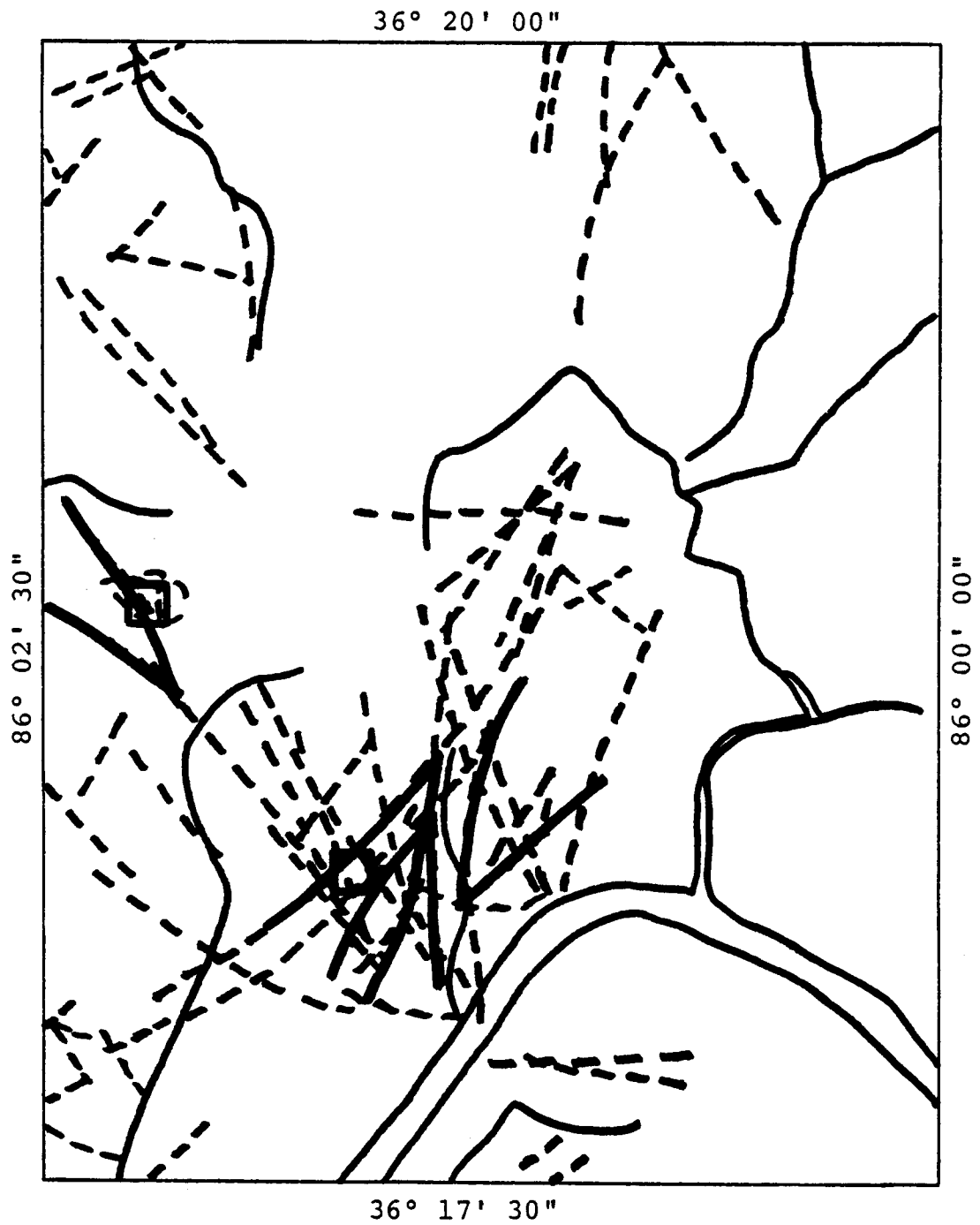


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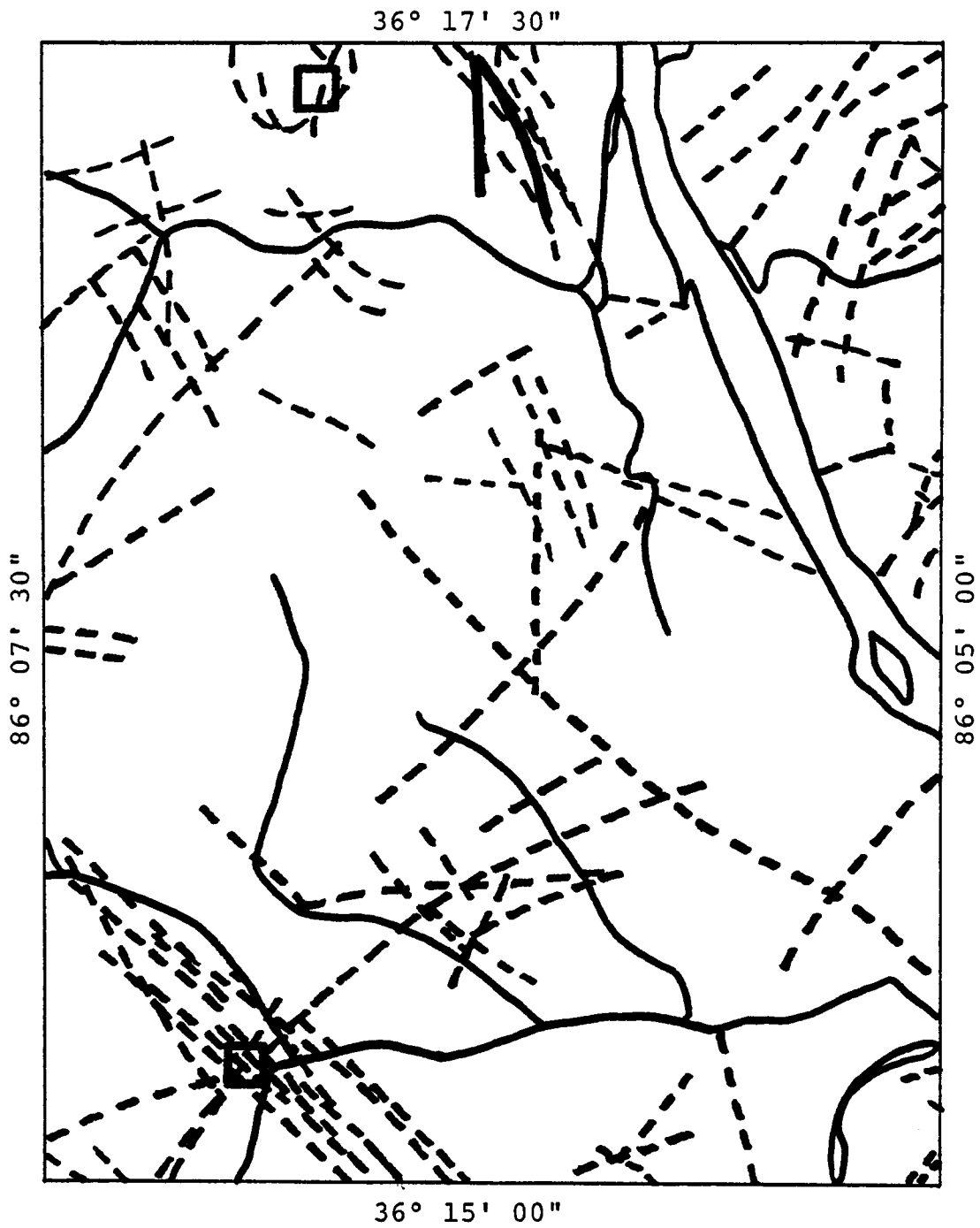


Figure B-8. Observed terrain lineaments of Area II, grid square G.



Figure B-10. Observed terrain lineaments of Area II, grid square I.

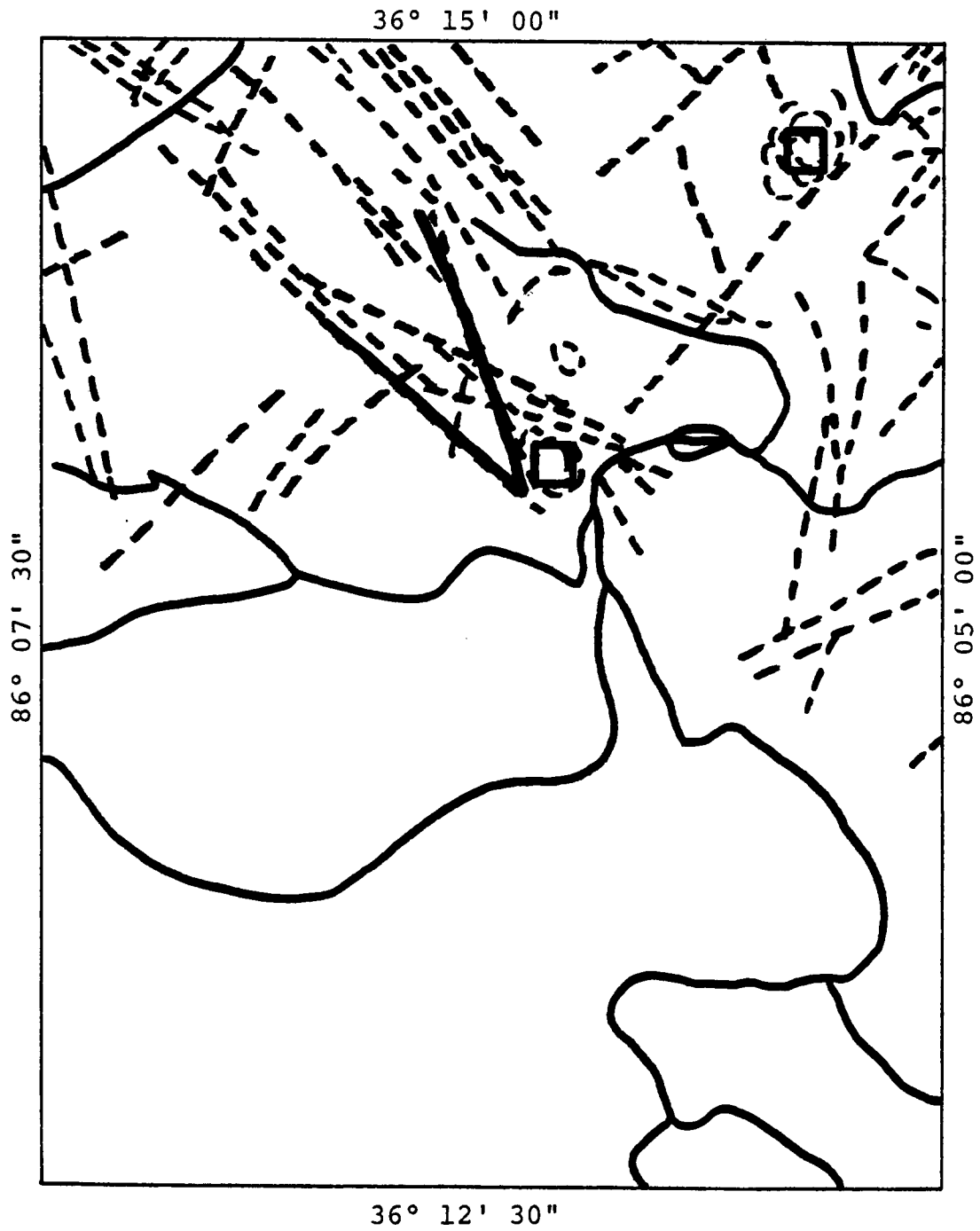


Figure B-11. Observed terrain lineaments of Area II, grid square J.



Figure B-12. Observed terrain lineaments of Area II, grid square K.

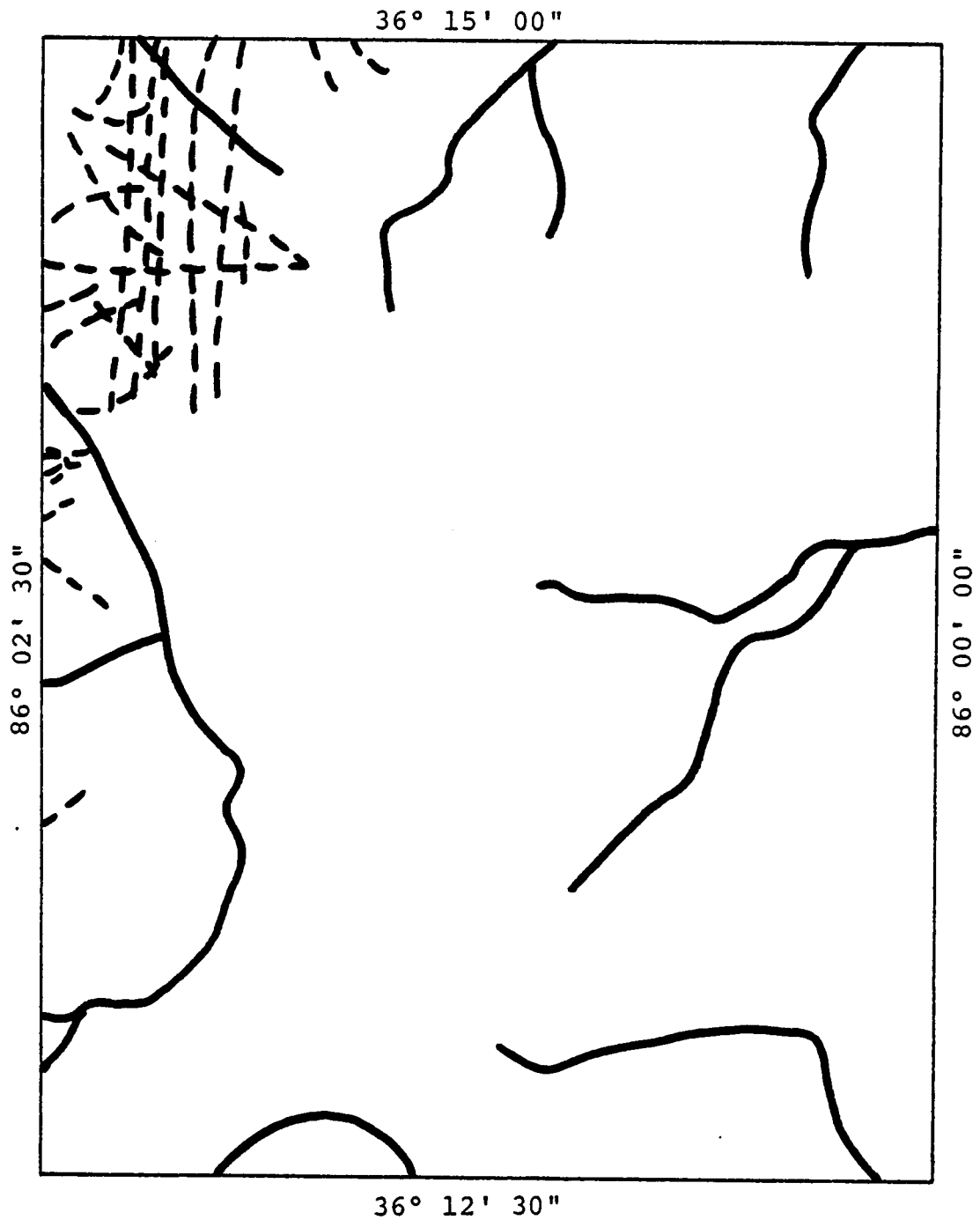


Figure B-13. Observed terrain lineaments of Area II, grid square L.

VITA

Charles David Vanhorne Rowan was born in Fredericton, New Brunswick, Canada, in April of 1955, the son of Janet E., and Charles F. Rowan. He attended elementary schools in the Fredericton area and in June, 1973 graduated from Fredericton High School. The following September he entered the University of New Brunswick at Fredericton, and in May, 1977 he received a Bachelor of Science degree in Geology. From September, 1977 to April, 1978 he continued his studies at the University of New Brunswick. In September, 1978 he accepted a graduate research assistantship at The University of Tennessee Space Institute and began study toward a Master's degree in Engineering Science.

Mr. Rowan is a member of the American Society of Photogrammetry.