UGR File #414
GeoEnergy Corp.
Dec. 21, 1979

GEOENERGY CORPORATION

GEOLOGY • HYDROLOGY • PETROLEUM ENGINEERING • ENVIRONMENTAL & RESOURCE EVALUATION

CORRELATION OF SURFICIAL GEOLOGIC ANOMALIES WITH GAS PRODUCTION COTTAGEVILLE FIELD, WEST VIRGINIA

UGR FILE #414

by

Lance T. Hodges

December 21, 1979

Prepared for the

U. S. Department of Energy
Nevada Operations Office
Under Purchase Order
#DE-AP21-79MC12159

SUITE A103. AIRPORT CENTER • 5030 PARADISE ROAD. LAS VEGAS. NEVADA 89119. TELEPHONE 702/739-9630

UGR File #414
GeoEnergy Corp.
Dec. 21, 1979

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Surface geomorphic features such as linear stream segments, linear ridge segments, opposed drainages, stream captures, and tributaries on one side of drainage were mapped, measured, and plotted for the Cottageville and Mount Alto topographic 7.5 minute quadrangles of West Virginia. The above anomalies were then compared for the Cottageville gas field area (production from Devonian shales), and for areas outside the gas field. While differences in orientation and density of these anomalies are present over the quadrangle areas, the differences did not seem to be related to the presence of the gas field. Because this study was limited in scope, further analysis of the surface anomalies could be useful. Use of aerial photos, including multispectral photos, and computer analysis techniques should be emphasized.

INTRODUCTION

The Cottageville gas field produces from Devonian Shales. Because obvious surficial features relating to the gas production (e.g. anticlinal domes) are not present around the Cottageville field, the reason for gas production in this specific area is still a matter for research. It is the purpose of this report to look at some less obvious surficial structural features that may give clues to the underlying geology relating to the gas production.

Remote sensing is a technique that is employed to indicate or enhance surficial features. This technique employs a broad range of technologies at various distances from the earth's surface. Most important over the years has been the use of aerial photography. The photographs can be used to examine the earth's surface directly, as in the use of stereo pairs. This type of analysis is quite subjective, and anomalies picked using this technique may depend more on individual viewers than on actual ground conditions. These photographs are also used by the U. S. Geological Survey to prepare topographic maps. During topo map construction, the basic aerial photographic negatives are utilized in complex machines in an attempt to yeild unambiguous topographic expressions.

The project covered in this report was an attempt to use the "analog" processed areal coverage as represented by the topographic maps in order to yield " more objective" drainage anomaly selections. The rationale for more "objectivity" being that the topographic mapping techniques have been tried and tested for decades, and a high degree of reproducibility is commonly achieved. And certainly, reproducibility is an aspect generally lacking in the previous remote sensing evaluation attempts made in the EGS program.

Small scale imagery is available using satellite data. This imagery gives large areal coverage and a small scale results on photos. These have been of some use in mapping larger features, such as longer lineaments, fault traces, etc. The usefulness of satellite imagery is often limited by the subjectivity of the observer, since lineament traces are often obscure. Satellite data has been of little use for the definition of short linear features. In this regard, imagery obtained from aircraft is superior.

Several studies applying various kinds of remote sensing have been made on surface features in the Cottageville area and other areas of the eastern gas shales region. Jones and Rauch (1978) correlated water well characteristics and short photolineaments (mapped from low altitude black and white photos) in the Cottageville area. They found higher water well yields close to straight stream channel or valley segments. Short photolineaments were not in general found to be associated with gas well yield, but the density of WNW photolineaments was apparently related to gas well yield. Additionally, water well yield had no relationship to Landsat or curvilinear lineaments. In one case, gas wells near a Landsat lineament had significantly lower rates.

Another study by Jackson and others (1979) used several kinds of remote sensing data, including Skylab and Landsat data, airborne radar, airborne multispectral scans, and airborne photography of the Cottageville area. Their study selected long lineaments rather than the short ones used by Jones and Rauch (1978). The most prominent longer lineaments could not be interpreted as geologic structures such as folds or faults on field checking. Jackson and others then applied a variety of optical and digital enhancement techniques to the imagery. This apparently did not help significantly in relating the lineaments to the geology or to the production of natural gas. Apparently long lineaments determined by remote sensing are not useful for evaluating either the geology or the occurrence of natural gas in the Cottageville region.

Results from short lineament analysis using either maps or photographs can be useful in gas or oil exploration, because these surface features may be the surface expression of subsurface fractures or joint sets controlling gas or oil production. Because the fractured eastern gas shales have very low permeabilities, significant shale gas production can only be obtained from fractured areas. The fractures provide a path for the otherwise trapped gas to reach the wellbore. Thus it becomes imperative in shale exploration to find areas with natural fractures of reasonable density and continuity.

Knutson (1979) in a field study in the Cottageville area found that orientation of stream segments frequently paralleled fracture or joint directions in surface sandstone outcrops.

The fractures are often indicated by surface staining resulting from water movement along the fractures. This relationship between stream segment orientation and fracture orientation was a motivating factor in the present study.

A given linear stream segment (of any length) may be superimposed on a fracture system. Tributaries to this linear segment may also be aligned with fractures, possibly those complimentary to that along the linear stream. Opposed drainages across either a stream valley or a ridge are possibly related to a fracture common to both of the opposed drainages.

In the Cottageville region, rock outcrops are very limited, mainly because of soil and vegetative cover. Drainage patterns can be used to provide structural information in addition to fracture patterns. For example, dipping beds may have a dip direction which can be determined by looking at tributaries to a linear stream segment which are concentrated on one side of the stream segment (Knutson, 1979).

This study has as a prime goal the development of an objective method of evaluating physiographic data with the hope that this type of data will correlate with gas productivity.

The bottom line of an evaluation technique is the ability to move into a new area, make an analysis, and pinpoint favorable targets. The technique should be objective enough so that any competent technician would produce consistent results. This report presents an attempt to generate an objective analytical exploration approach.

Mapping and Analysis of Drainage Anomalies

Part 1. Straight Stream Segment Anomalies

Stream segment directions may be related to subsurface fracture and joint patterns. Stream segments would likely (other factors being equal) follow fracture patterns in the surface rocks. Since fracture patterns have often been related to gas productivity, measurements on stream segments might be useful in exploring for gas.

The Cottageville gas field is located mostly in the northwest corner of the 7.5' Cottageville quadrangle. Parts of the field also lie in the Mount Alto and Ravenswood quadrangles.

Procedure:

Straight stream segments were marked on the Cottageville and Mount Alto quadrangles. To increase objectivity and limit the study, only segments marked with blue on the topographic map were marked. No straight segments less than 150 feet long were measured. Also marked off was a network of grid lines with 10,000 foot spacing, starting with the northeast corner of the Cottageville quad. The squares produced were numbered (28 squares). Data was obtained for each square. Figure 1 is an outline of the 28 numbered squares on the Cottageville and Mount Alto quadrangles. The Cottageville gas field is also outlined.

Stream segment lengths and strike directions in 10^{o} increments were measured, giving 18 data groups for each of the 28 squares. This data was plotted on 28 rose diagrams.

Figure 2 shows rose diagrams with only the four most prominent stream directions for each square (more than four directions indicate some directions of equal length). The lengths of the stream strike lines of the roses are at twice the map scale.

Some similar patterns may be noticed when comparing roses for adjacent squares on Figure 2. This may indicate that joint sets are reflected in stream segments, and that these joint sets sometimes persist over areas greater than 10^8 square feet. Similar patterns do not persist over areas larger than about 4 squares. The most prominent directions shown by Figure 2 may represent the directions of complementary joint or fracture patterns. For example, square 1 could have two complementary joint sets, 1 set oriented NNW-SSE and E-W, and the other set oriented NE - SW and NW - SE.

To show the rather local directivity of the stream segments, several squares were lumped. Figure 3 shows the roses for the most prominent stream directions resulting from this lumping. The lumping of Figure 3 separates the gas field from other areas. The parts of squares 3,5,6,7,8,9,10,21 and 23 located in the gas field were lumped. This rose is that seen in squares 5,6, 7 and 8. All other roses shown are lumpings of the four squares surrounding each rose, but not including any part of the gas field. The exception to the four-square lumping is the rose seen in squares 9 and 10, which lumps squares 7,9, and 10 (non-gas areas). It can be seen that the roses of Figure 3 do not seem to relate to adjacent roses. Apparently stream directivities (i.e. joint sets) do not persist over areas greater than about 20,000 feet on a side. The lengths of the stream strike lines of the roses are at the map scale.

There is no indication from Figures 2 or 3 why the gas field is located where it is. The rose patterns are different in the gas area from other areas, but roses outside the gas field differ from each other also.

Chi square tests using a computer should be used to detect significant differences between roses. This could be done in future more extensive study.

As a further indication of directivity of the stream segments, Figure 4 gives two peices of numerical information for each square. The upper number is the total length in 1000's of feet of all the stream segments. That is, this number gives the stream density in each square. The lower number in each square is a measure of directivity. It is the ratio of the sum of the E-W components of the stream segments divided by the sum of the N-S components. A number larger than 1 indicates dominant E-W directivity. A number less than 1 indicates dominant N-S directivity.

Square 2 has the highest stream density = length 69,000 feet/square, while square 10 has the lowest, 31,000 feet/square. The average stream density is a length of 45,800/ feet square. Squares 5 and 8 are entirely in the gas field. The average stream density here is 56,000 feet/square. (Recall each square is 10,000 feet on a side). The stream density is higher in the gas field area than the average. However, highest stream densities prevail in the northeast corner of the Cottageville quad, while lowest densities occur in the center of the Mount Alto quad. Stream density in the gas field is higher than average for the region, but is not higher than the area east of the gas field, and thus stream density cannot be regarded as a specific gas field anomaly.

Figure 4 also indicates E-W versus N-S directivities. In the gas field, directivities are dominantly E-W rather than N-S. This is not true just for the gas field however, since some squares outside the gas field in both quads have dominant E-W directivity. There seems to be some pattern to the directivity values but it is not apparently due to the presence of the gas field. Highest E-W directivity is 1.55 in square 18. Lowest E-W directivity (i.e., highest N-S directivity) is 0.57 in square 12. Overall directivity of the two quadrangles is 1.00, indicating no stream direction preferred alignment in N-S or E-W directions. This is an expected result, since the roses for the lumped squares (Figure 3) are different from each other. Thus stream directivity averaged over the two quadrangles is essentially random. There does not seem to be any relationship between stream density and directivity.

Part 2. Opposed Drainage Anomalies

Four kinds of opposed drainage anomalies were mapped: stream captures, opposed drainages across valleys and across ridges, and linear ridge segments.

Figure 5 illustrates three of these measured anomalies. Straight, unbroken lines are linear ridge segments over 4000 feet in length. The dashed and dotted lines are opposed drainages across ridges. These were noted only for drainages marked in blue on the topographic maps. While there are considerable lengths of streams marked in blue on the maps, the opposed drainages of these streams are few (7 on Figure 5). Only one of these 7 (in squares 6 and 8) is a stream capture.

The linear ridge segments of Figure 5 are not large in number, but do show interesting trends. There is a prominent approximately north-south trend for most segments in the Mount Alto quad. The trends in the Cottageville quad are less obvious but several trends are noticeable. The lower part (most productive part) of the gas field has a higher than average concentration of linear ridge segments and opposed drainages, but with the low numbers of anomalies mapped this may not be statistically significant. The linear ridge segment orientation trends in the gas field area are somewhat variable. It is not obvious from Figure 4 why gas production is concentrated in the area shown.

Because topographic maps only approximately define the geomorphology of the earth's surface, a set of aerial photos of the Cottageville (village) area were examined. The use of stereo pairs greatly facilitated visualization of drainage patterns. Opposed drainages across both valleys and ridges were marked on the aerial photos.

Figure 6 shows the opposed drainages mapped from the aerial photos. Each opposed drainage is shown by two dashes. The study was restricted to all of square 3, most of square 5, and parts of nearby squares. The northeast corner of square 5 and the southwest corner of square 3 have few anomalies because the topography is flatter and valleys are broad. Some trends may be seen in Figure 6. The most obvious is an approximate north-south trend. There are lesser trends also. Since all apparent opposed drainages were measured in this local area, this method gives many more data points than measuring opposed drainages using only the restricted (blue streams) from the topographic maps. Using the aerial photos is also inherently more accurate and meaningful, but perhaps much more subjective.

There does not seem to be any obvious connection between opposed drainages mapped in the gas field and the production of gas, when compared with the opposed drainages mapped outside the gas field, even with the increased data available with the use of aerial photos.

Part 3. Linear Streams with Asymetrical Drainage Anomalies

Linear stream segments in the study area often show more tributaries on one side of drainage than on the other, probably because of geologic structure. To record these anomalies, straight stream segments greater than 5000 feet long were marked. Segments were chosen which did not deviate more than about 10° from linearity. Valley flat areas were allowed along with stream meanders in determining straight areas. Side drainage tributaries were marked which were not greater than 45° from perpendicular to one of the linear streams marked above. The lengths of the marked side tributaries on both sides of the marked linear stream were measured, and the percentage on each side of the linear stream calculated.

Figure 7 shows the marked linear segments, along with the percentage of total side tributary length marked on the side with largest side tributary length for the Cottageville and Mount Alto quads. It can be seen that the long linear segments have only limited directional trends. There does not seem to be a pattern distinguishing the gas field area from other areas. There is also no useful detectable pattern for the percentage of tributary length on one side of drainage when comparing gas field to non gas field areas. Localized patterns may be apparent, both for the percentage value on one side, and the position of the side of the linear stream with the largest percentage.

Future Geologic Anomaly Analysis, Including Use of Computers

A computer would be useful to perform objective analysis on the data obtained in this report, particularly that of Part 1. Specifically, chi square tests can be used to test the similarity of the orientation distributions of stream segments of adjacent squares or areas. Tests for randomness of the distributions can be performed also. This last test would help determine if stream segment orientations are related to geologic structure, for example, joint sets.

Map marking, map measurements, and data collection and manipulation could be made easier and faster by using an electronic light pen which records its coordinate position on an electronic grid, and also marks the area measured on a map superimposed over the grid. Data would be input to a computer for statistical analysis as described above. Alternatively, tapes of digitized map data (limited availability) could be input directly to computer.

In addition to conventional topo or aerial photos, multispectral photos obtained from aircraft should be used because these photos often enhance features shown barely or not at all on conventional photos.

It is hoped that Landsat photographs could be used to supplement multispectral photographs obtained from aircraft. Landsat photographs have not been useful so far in geological interpretation in the Cottageville area, and should be used only in a supplementary role to the photos obtained by aircraft.

Comparative Cost Analysis of Manual versus Computer Processing

An alternative to manual evaluation on conventional topographic maps is the use of digitized map information available on tapes suitable for computer input and subsequent data measurement and analysis. All 1^{o} x 2^{o} section sized digital tapes are currently available. Some 7½' quadrangle digital tapes will soon be available from NCIC, at a price of around $26 per quad. Making individual tapes from a topo map is possible with a digitizer but is prohibitively expensive.

A digital tape processing program is currently under development (Geospectra). This program will automatically map linear features from a digital tape. The cost of mapping linear features from a tape will probably be about $1,000 per 7½' quad.

Manual marking of longer linears for a 7½' quadrangle requires about one day, at a cost of about $275 including overhead, G & A and profit. However, if linears of shorter lengths are mapped, the time involved rises appreciably, since many more linears must be mapped. If, in addition, the orientation and lengths of stream segments are measured, as in Part 1 of this report, at least 10 working days are required, at a cost of $2750. This figure does not include data analysis, which takes considerable time if done manually. An advantage of the computer processing of digital tape map data is that computer analysis of the mapped linears or other map data is facilitated. The manual method is cheaper, if only a limited amount of information (e.g., long linears) is desired. Otherwise computer processing rapidly becomes more cost effective.

Conclusions

The rose diagrams of orientation of stream segment strike lines provided the most interesting result obtained in this study. These diagrams showed that similar dominant orientations often persisted over an area somewhat larger than 10^8 square feet, but not over an area larger than 4×10^8 square feet. The dominant orientations of stream segments are probably related to complementary joint sets of the rocks in the subsurface. There did not seem to be a relationship between the orientation of these joint sets, and the location of the Cottageville gas field.

joint sets are random?

The orientations of the longest linear stream segments, of the longest linear ridges, and of opposed drainages showed some localized orientation trends in each case, but these were not apparently related to the location of the Cottageville gas field. Concentrations of tributaries on one side of drainage were mapped, but these did not show any obvious patterns that could be related to the location of the Cottageville gas field either.

Analytical techniques more sophisticated than those used in this project could perhaps detect subtle differences which may exist in these anomalies relating to the location of the Cottageville gas field. Multispectral data could be correlated with the productivity of individual wells in the gas field and could be useful in extending the work begun in this report.

Evaluation of the data might provide subtle clues to the existence of gas fields in the Eastern Devonian Shales.

REFERENCES

Jackson, P. L., Wagner, H. L., and Shuchman, R. A., 1979, Investigation of Remote Sensing for Geologic Reconnaissance Over the Cottageville, West Virginia, Eastern Gas Shale Field: U. S. Dept. of Energy, Morgantown, West Virginia, Contract DE-AC05-77ET12137, 90p.

Jones, D. S., and Rauch, H. W., 1978, Lineaments and Ground Water Quality as Exploration Tools for Ground Water and Gas in the Cottageville Area of Western West Virginia: Second Eastern Gas Shales Symposium, U. S. Dept. of Energy, v.1, p. 196-205.

Knutson, C. F., 1979, Surface Features Associated with Lineaments, E.G.S.P. area (Cottageville Field, West Virginia), U. S. Dept. of Energy, Morgantown, West Virginia, METC, P. O. DE-AP21-79MC10263, 33p.

Negus-de Wys, J. and Shumaker, R. C., 1978, Trend Analysis of Gas Production in the Cottageville Field: Second Eastern Gas Shales Symposium, U. S. Dept. of Energy, v.1, p.186-191.

Negus-de Wys, J. and Shumaker, R.C., 1978. Pilot Study of Gas Production Analysis Methods Applied to Cottageville Field: U. S. Dept. of Energy, Morgantown, West Virginia, Contract EY-76-C-05-5194.

Werner, Eberhard, 1977, Interrelationships of Photolineaments, Geological Structures, and Fracture Production of Natural Gas in the Appalachian Plateau of West Virginia: Proc. First Eastern Gas Shales Symposium, U. S. Dept. of Energy, p. 474-483.

Wescott, T.F., and Smith, A.F., 1979, Digital Image Processing and Enhancement of Landsat Data for Lineament Mapping and Natural Gas Exploration in Appalachian Region: Third Eastern Gas Shales Symposium, U. S. Dept. of Energy, p.39-49.

Zirk, W. W., and Lahoda, S. J., 1978, A Relationship Between Productivity of Gas Wells and Their Locations with Respect to Lineaments: A Statistical Analysis: U. S. Dept. of Energy, Morgantown, West Virginia, METC/CR-78/14, 36p.

UGR File #414
GeoEnergy Corp
Dec. 21, 1979

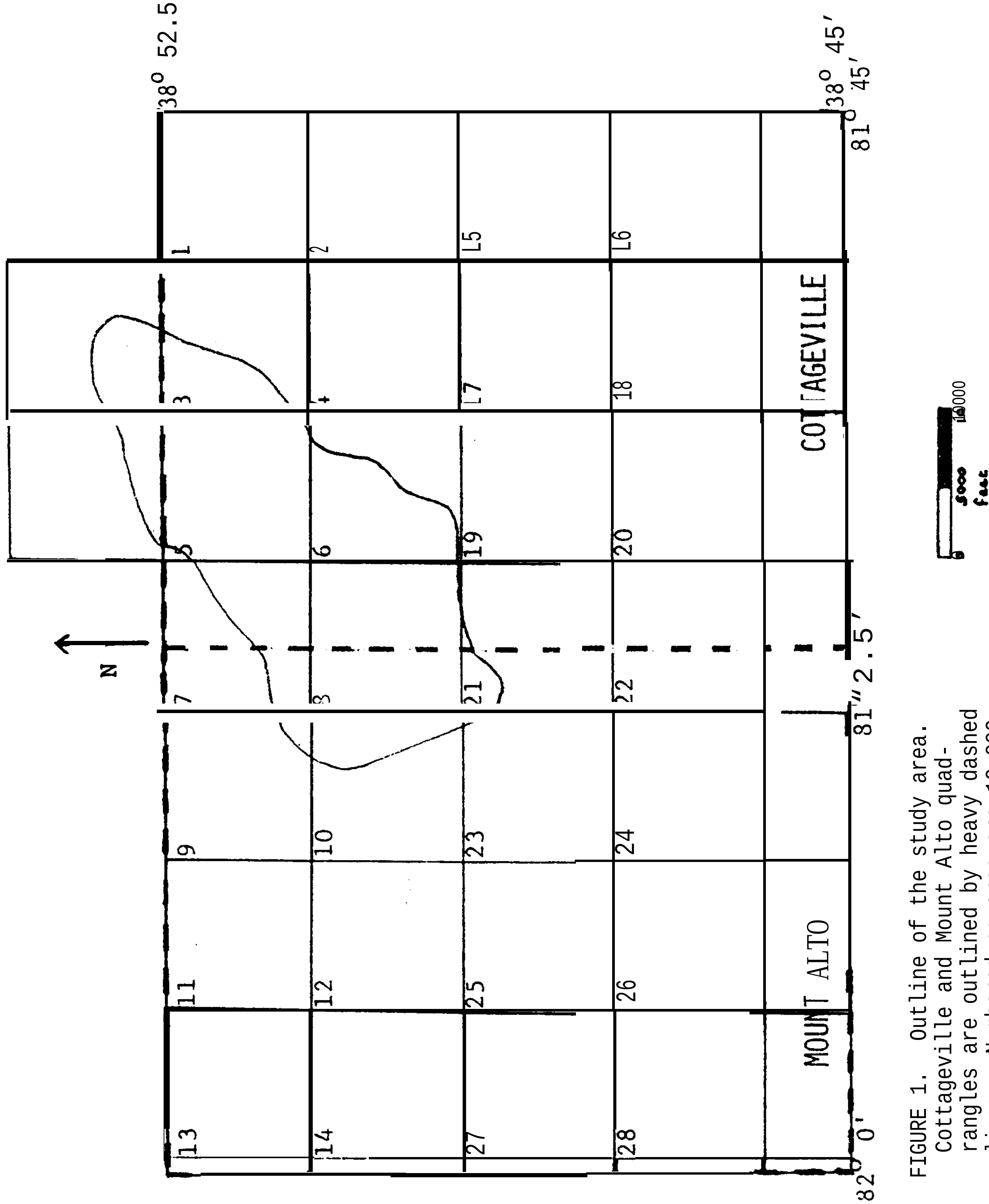


FIGURE 1. Outline of the study area. Cottageville and Mount Alto quadrangles are outlined by heavy dashed lines. Numbered squares are 10,000 feet on each side. The Cottageville gas field is outlined by the irregular wavy line.

UGR File #414
GeoEnergy Corp.
Dec. 21, 1979

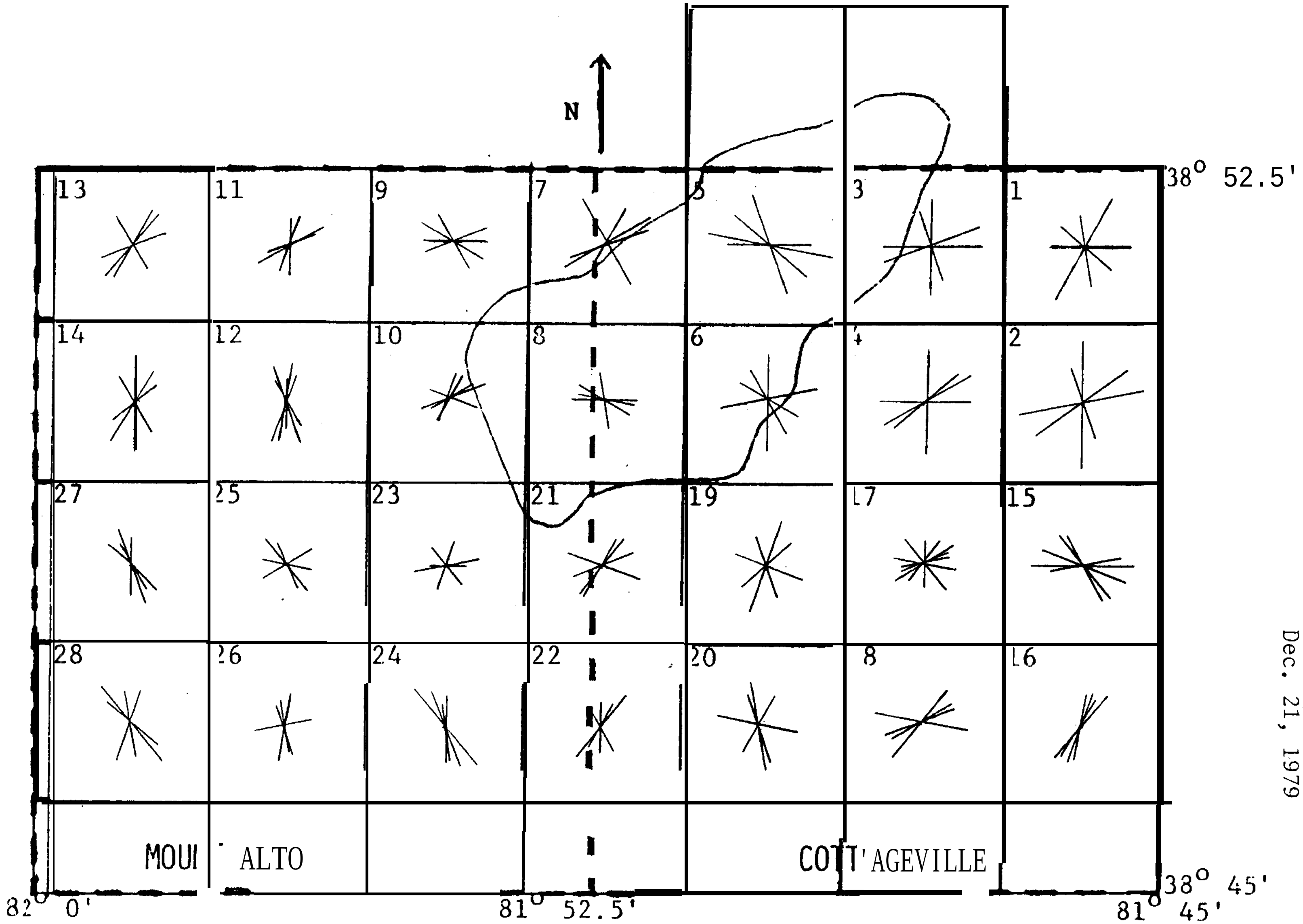
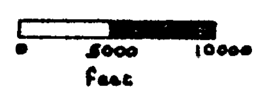


FIGURE 2. Rose diagrams of the most prominent stream segment directions for each of the 28 squares. The total length of individual rose lines is at twice the scale of the map.



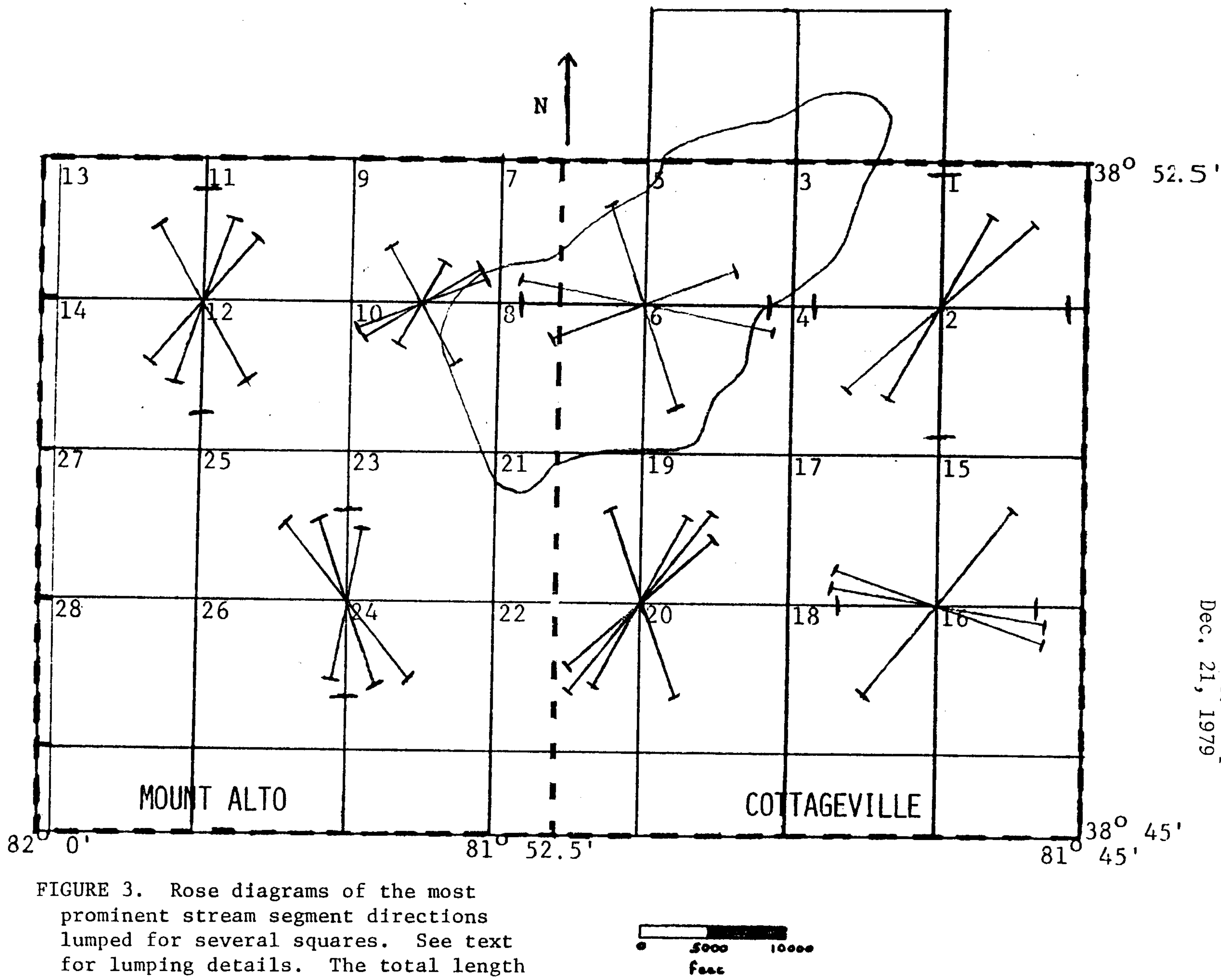
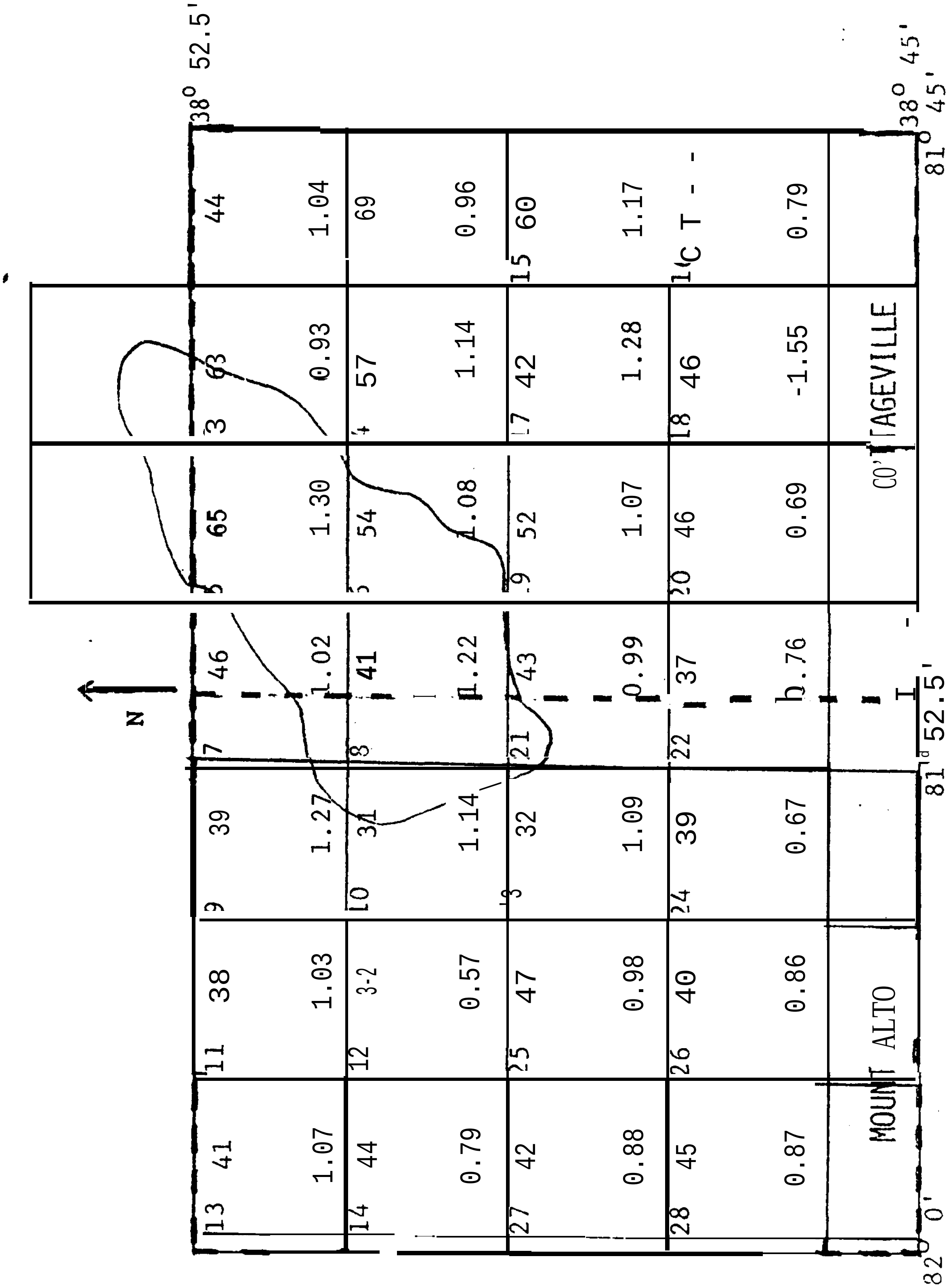


FIGURE 3. Rose diagrams of the most prominent stream segment directions lumped for several squares. See text for lumping details. The total length of individual rose lines is at the map scale.



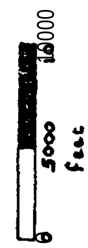


FIGURE 4. Approximate stream length in thousands of feet is given by the upper number in each numbered square. The lower number in each square is the stream directivity. Interpretation is given in the text.

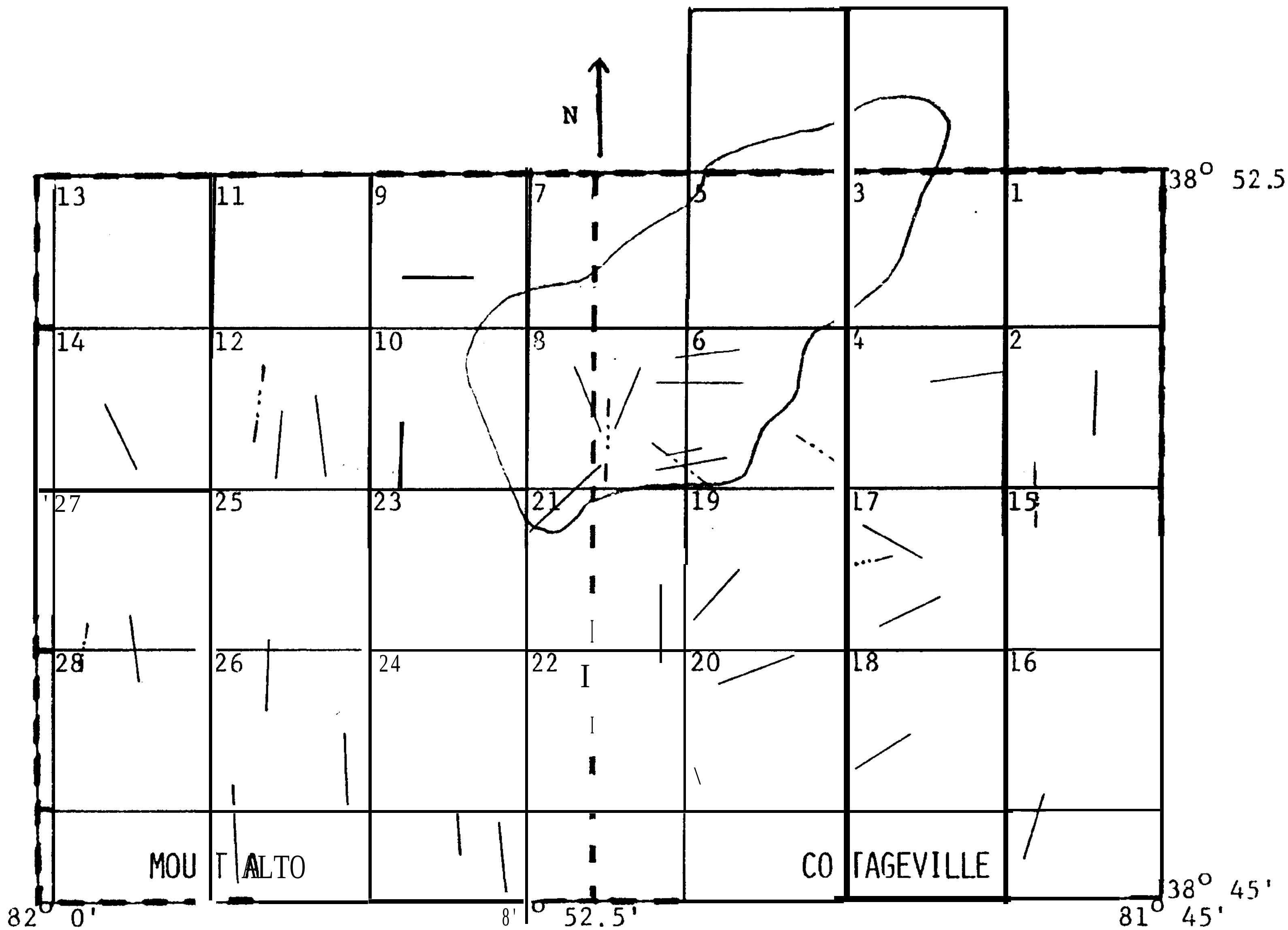


FIGURE 5. Three kinds of opposed drainage anomalies are shown. Solid unbroken lines are linear ridge segments. Dashed and dotted lines are opposed drainages across ridges. One of these (in square 6 and 8) is also a stream capture.

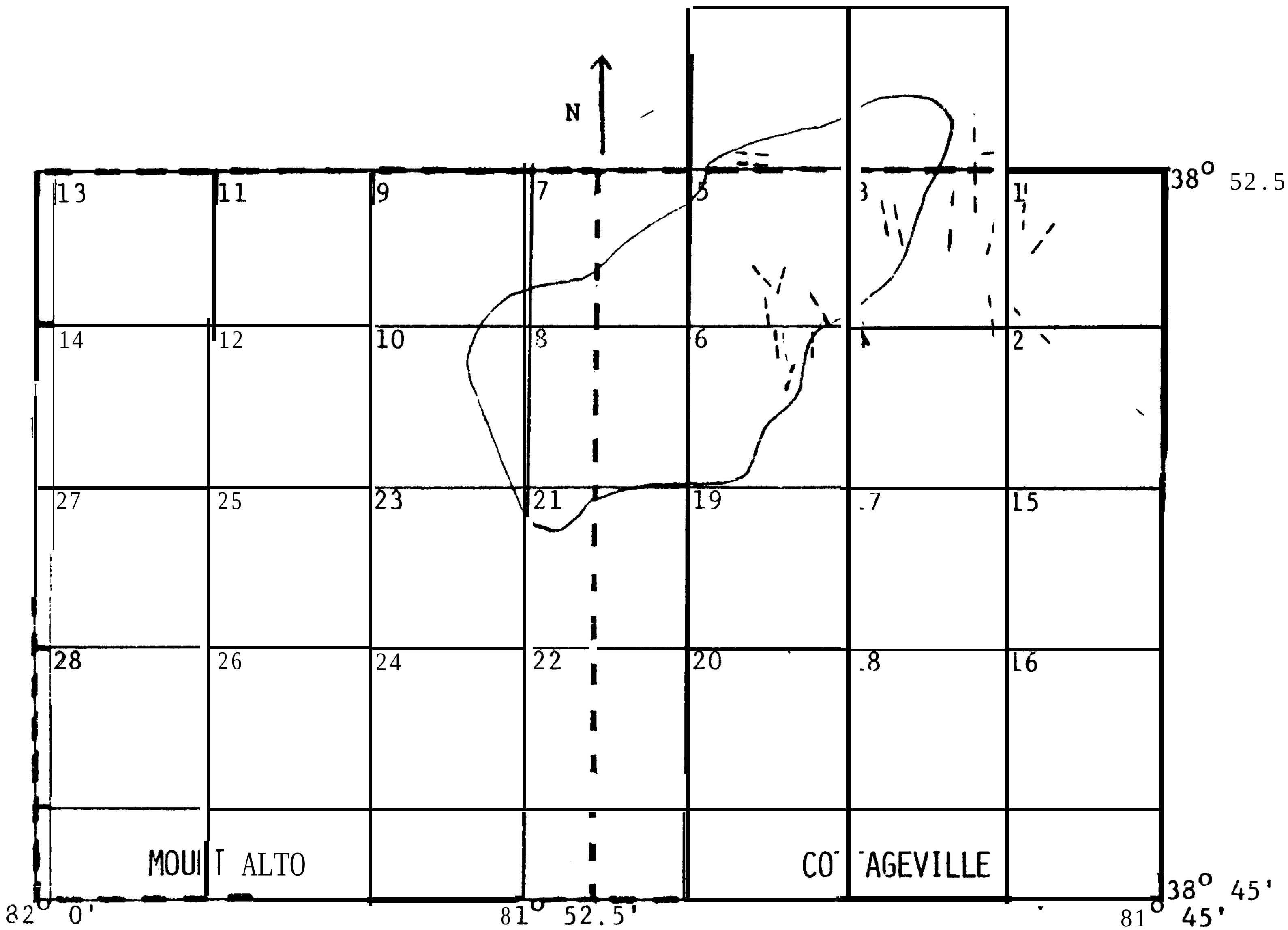


FIGURE 6. Opposed drainages across ridges and valleys mapped using aerial (stereo pairs) photos. Each pair of dashes represents an opposed drainage. The coverage is restricted to square 3 and parts of surrounding squares.

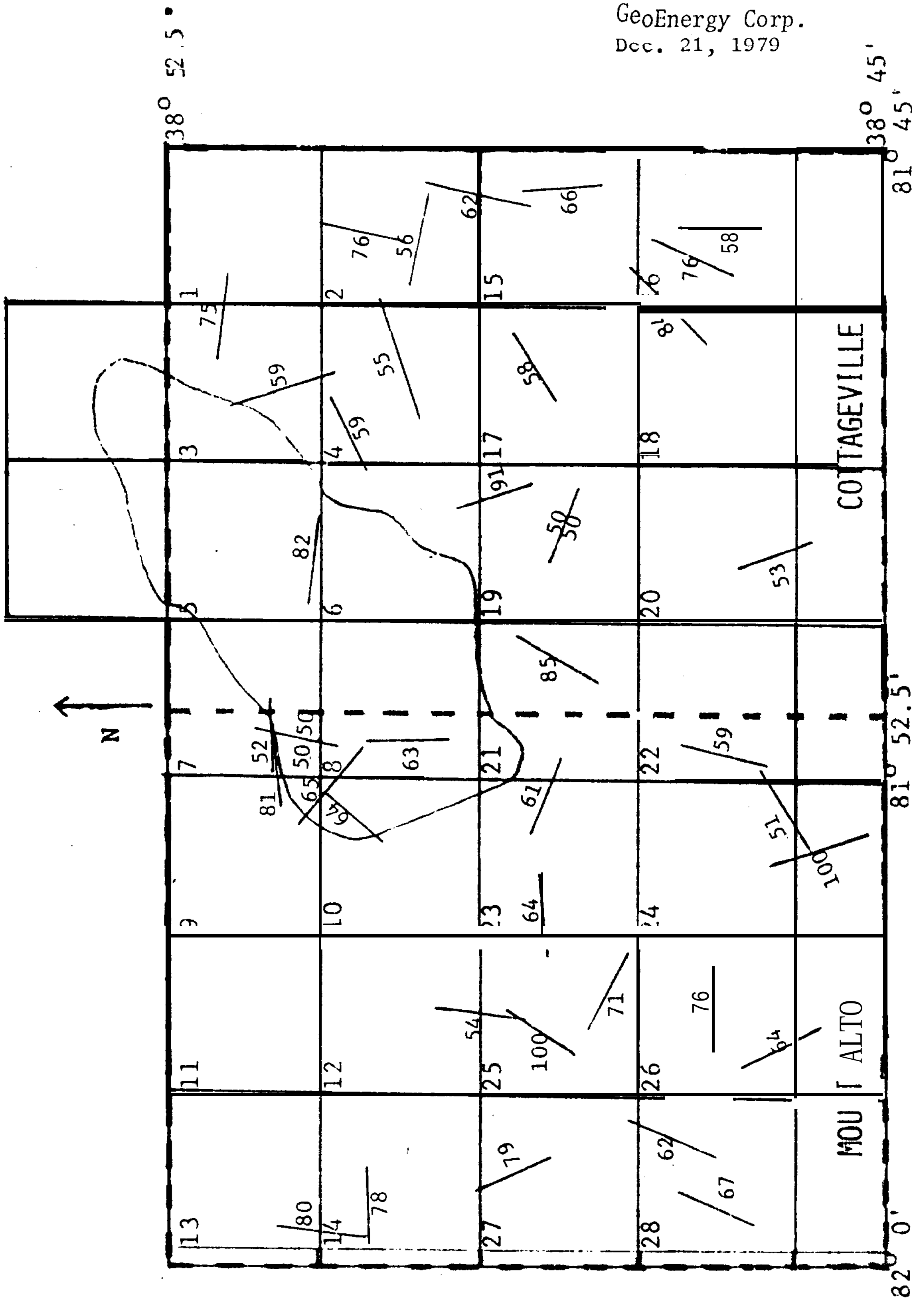


FIGURE 7. Long linear stream segments are indicated by line segments. Percentage of total tributary length which is on the dominant side of drainage is indicated by the number on the dominant side of drainage).