GEOLOGY AND PRODUCING CHARACTERISTICS OF CERTAIN DEVONIAN BROWN SHALES IN THE MIDWAY-EXTRA FIELD, PUTNAM COUNTY, WEST VIRGINIA

UGR FILE # 442

Thesis

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by
William W. Schaefer

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William W. Schaefer

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ABSTRACT

The Midway-Extra Field produces from the Lower Huron Shale (Brown shale) Member of the Ohio Shale with an. average reserve of 434 million cubic feet per well. The total average thickness of the Brown shale is 400 feet, thickening to the east with a loss of total radioactive intensity. Commercial production is limited to a narrow band of fractured shales with open porosity located in the synclinal portion of the field. A series of structural and open flow maps with cross sections indicate production trends and future areas to-explore. Expanded drilling programs are now underway due to the low risks involved and high rate of Ye--turn on investments (16.5%).

INTRODUCTION

The shortages of natural gas during the winter of 1977-78 have emphasized the naticn's dwindling gas reserves, Recent public attention has been focused on the development of the Devonian shale reserves to supplementourenergy needs. While many factors affect reserve figures, recoverable reserves of the shales are largely dependent upon the monetary value of the gas to the consumer, Gas valued to the producer at $3/MCF at the well head is becoming a realistic near-term cost figure. This increase would boost total current recoverable reserves of the shale', based at $1.75/MCF, from under 8 trillion cubic feet to 16 trillion cubic feet for the Appalachian basin (Kuuskraa, et al, 1978). Commercial Devonian Brownshale production in West Virginia is currently limited to the mid-western and southwestern portion of the state, Until recently, the geology of the Devonian shales has been given relatively little study, although as early as the 1930's, Brown shale production was known to be related to fracture porosity (Lafferty, 1935). Until recent years, well locations were based on available acreage and on empirical production trends with many wells being completed in the shale as a secondary target.

The general purpose of this study is to relate the geology of a Devonian Brown shale field (Midway-Extra) to the production trends in and outside the field, The spe-

cific objectives of this study are tor

(1) Describe the historical development of the Midway-Extra Field.

(2) Describe the stratigraphy and structure of the field.

(3) Analyze well and production data and develop an exploration method to predict future shale production in and outside of the field,

(4) Review the economics of drilling and completing a typical shale well from the viewpoint of the indepsndent gas producer and to analyze the implications of this review to the consumer,

The Midway-Extra Field (figure 1) was selected for this study because of the writer's working experience within the field which has proven to 'be important in evaluating well records and interpreting production data, The study was limited to the data available to the independent producers, such as: well records, production data, and wire--Line logs. Subsurface mapping was based on radioactive logs and well record data, as reported to the Stat; of West Virginia, Wire-line logs from thirty-six wells (figure 2) were used in the study and included gamma-ray, density, and gas entry (temperature and noise detection) logs. Cumulative production records, by year, for 71 wells within the study area were furnished by Devon Corporation (figure 3). A Hewlett-Packard 9830A calculater with mass memory

FIGURE 1

INDEX MAP OF SOUTHWESTERN WEST VIRGINIA

One inch equals approximately 10.7 miles

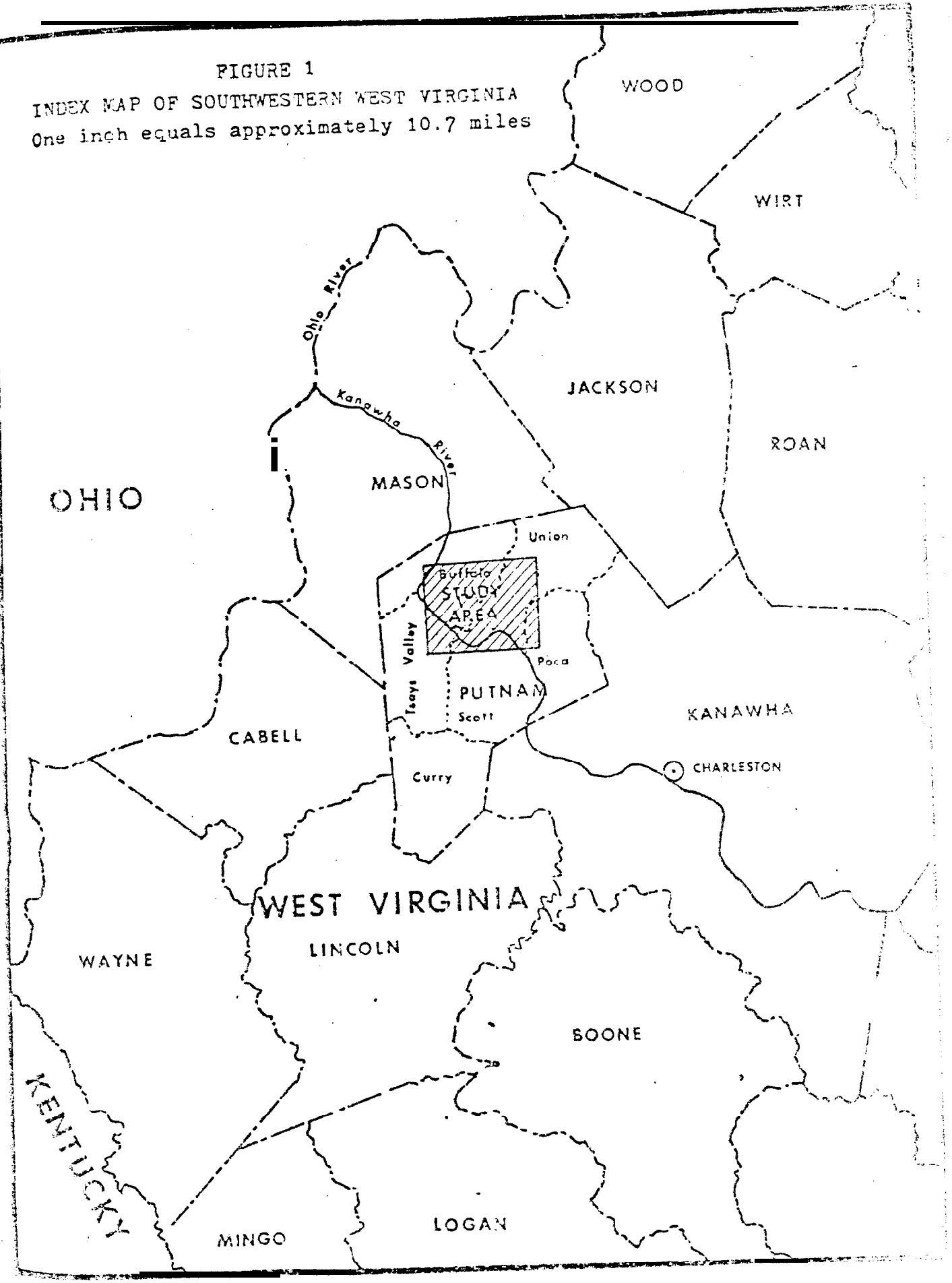


FIGURE 2

AVAILABLE WIRE-LINE LOG DATA

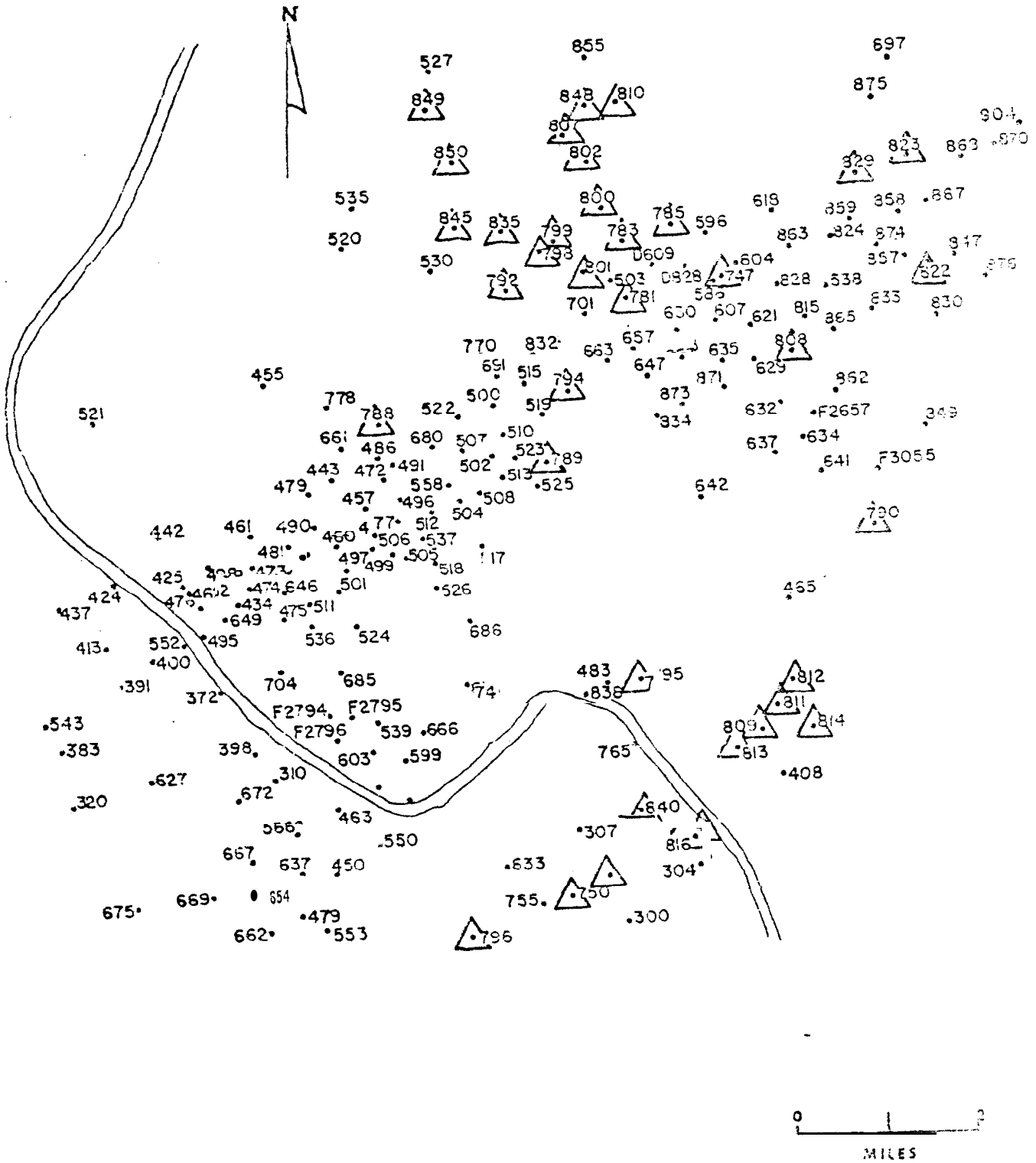
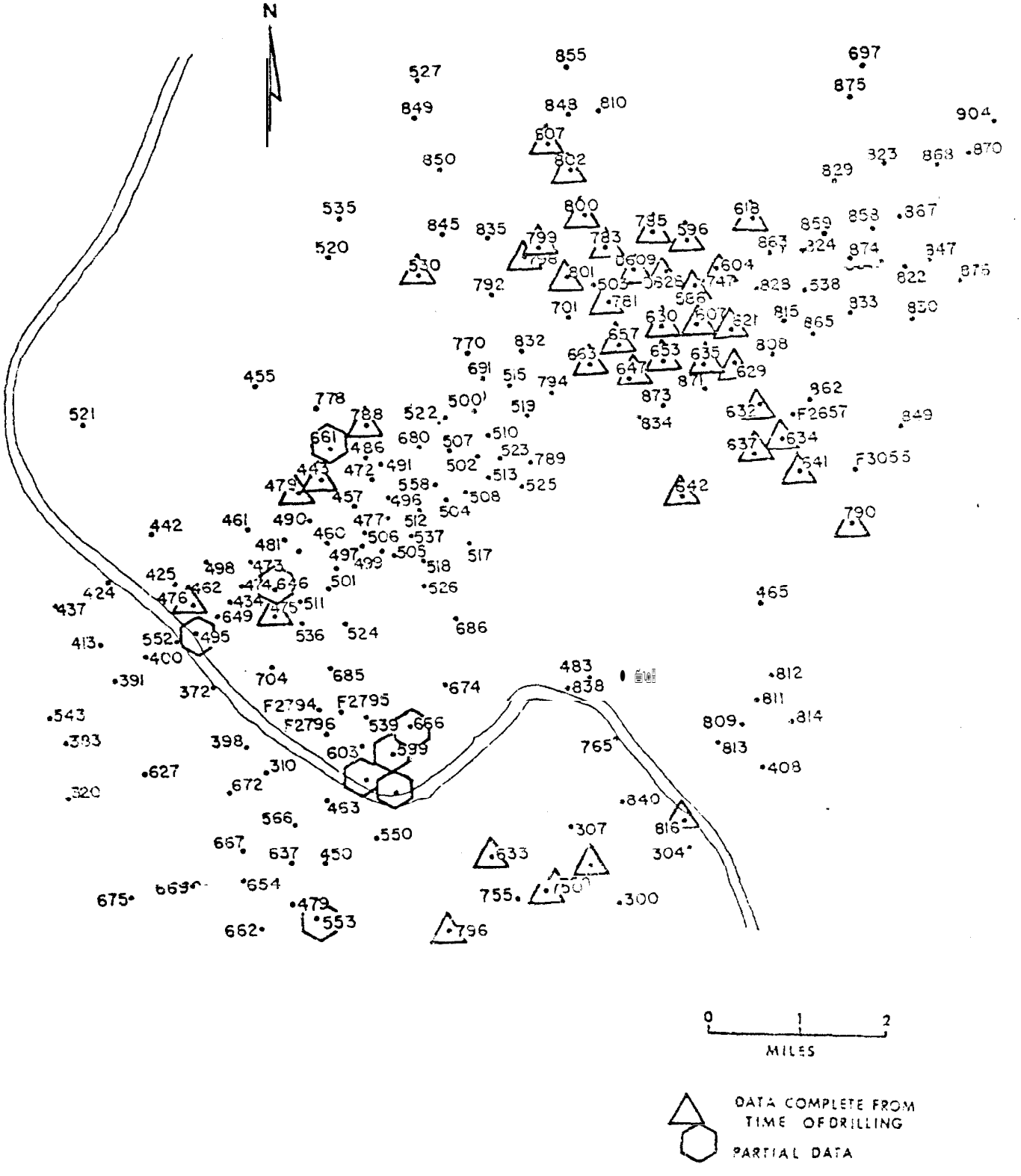


FIGURE 3

WELLS WITH AVAILABLE PRODUCTION DATA



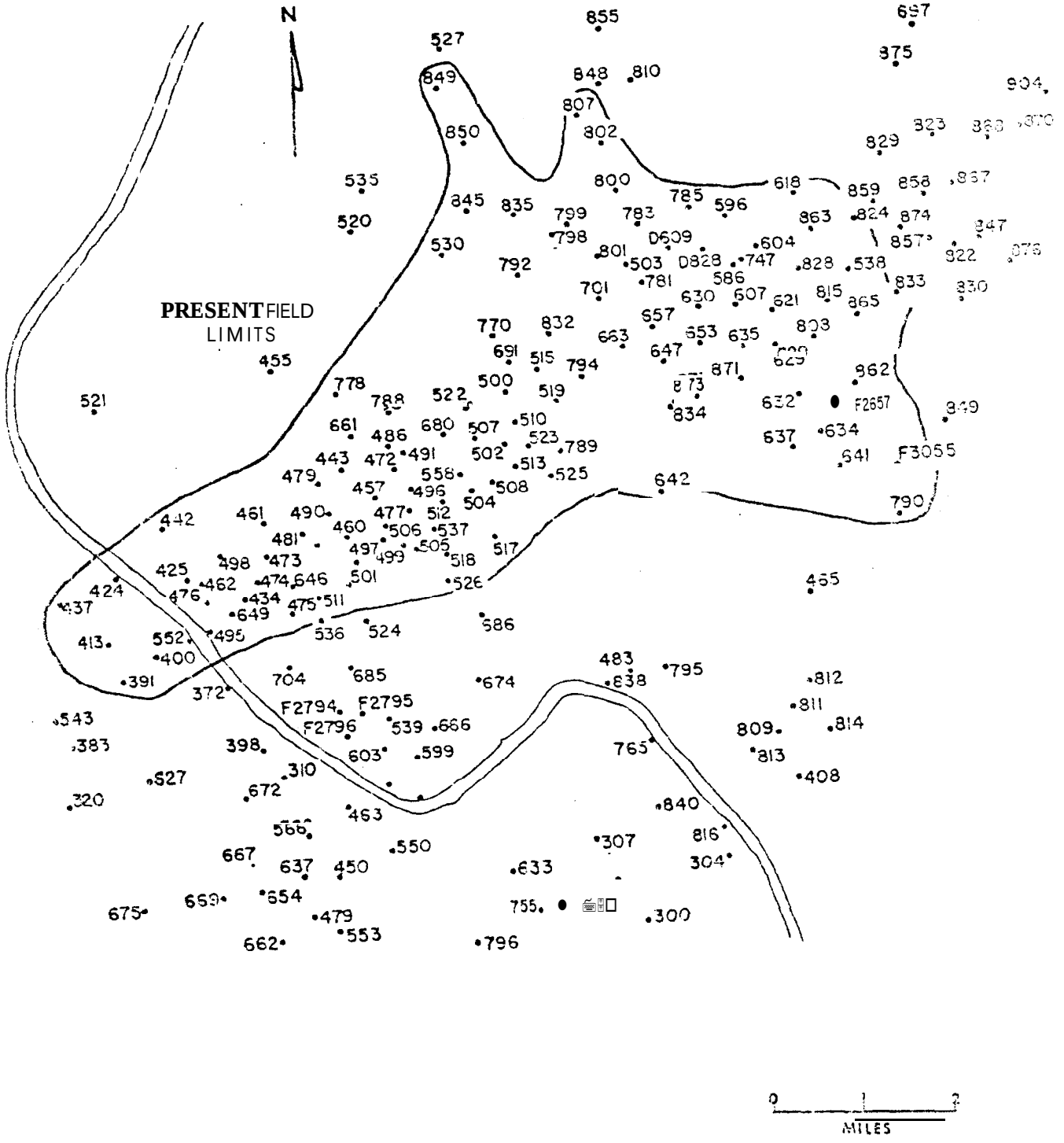
drive was made available for evaluating production data by Union Oil and Gas, Incorporated.

LOCATION

Located in Putnam County, West Virginia, the Midway-Extra Field is defined by a band of 99 gas wells producing primarily from the Devonian Brown shales. The field as outlined on the Oil and Gas Fields Map of West Virginia (Cardwell, et al, 1976) begins in Teays Valley District, south of the Kanawha River, and extends in a northeast direction into Buffalo and Union Districts (figure 4). Midway-Extra is approximately 12 miles long and 4½ miles wide, and has a total of 34,560 acres tasted for Brown shale production, of which only 14,300 acres are producing. Walls used in the study with their respective state permit numbers are shown in figure 4. Wells without state permit numbers are designated with an F or D prefix.

FIGURE 4

INDEX MAP WITH PRESENT FIELD LIMITS



HISTORICAL DEVELOPMENT

The first well in the study area to be completed in the Devonian Brown shale was drilled in 1947 by Teaves Oil and Gas, Inc., PUT-372-P, the Vintroux Heirs, The reported open flow after shot was 150,000 cubic feet per day. The well was abandoned in 1975, when production ceased due to deteriorating well-bore conditions and the influx of water, V. C. Smith, Management drilled. an Oriskany Sandstone test, PUT-391 (VCS #1), in 1948, approximately one mile south of the town of Midway, West Virginia. The reported natural open flow was 150,000 cubic feet per day. After shooting the Oriskany Sandstone, lower Brown shale, and middle Brown shale sections of the Devonian, the open flow was 926,000 cubic feet per day. When liner and tubing were run just through the Brown shale in 1973, there was little or no change in well production. This indicates that primary production from this well is from the Brown shale. In 1949, V. C. Smith, Management completed the VCS $2, PUT-400, through the lower Brown shale as an offset to the VCS #1. The open flow, -after shooting, was given as 313,000 cubic feet per day,

Gf the 104 yells drilled within the producing margin of the field, 51 percent were drilled from the period 1947 to 1952 (figure 5). This drilling completed the southwest portion or Midway section of the field (figure 6). From

FIGURE 5

NUMBER OF WELLS DRILLED PER YEAR

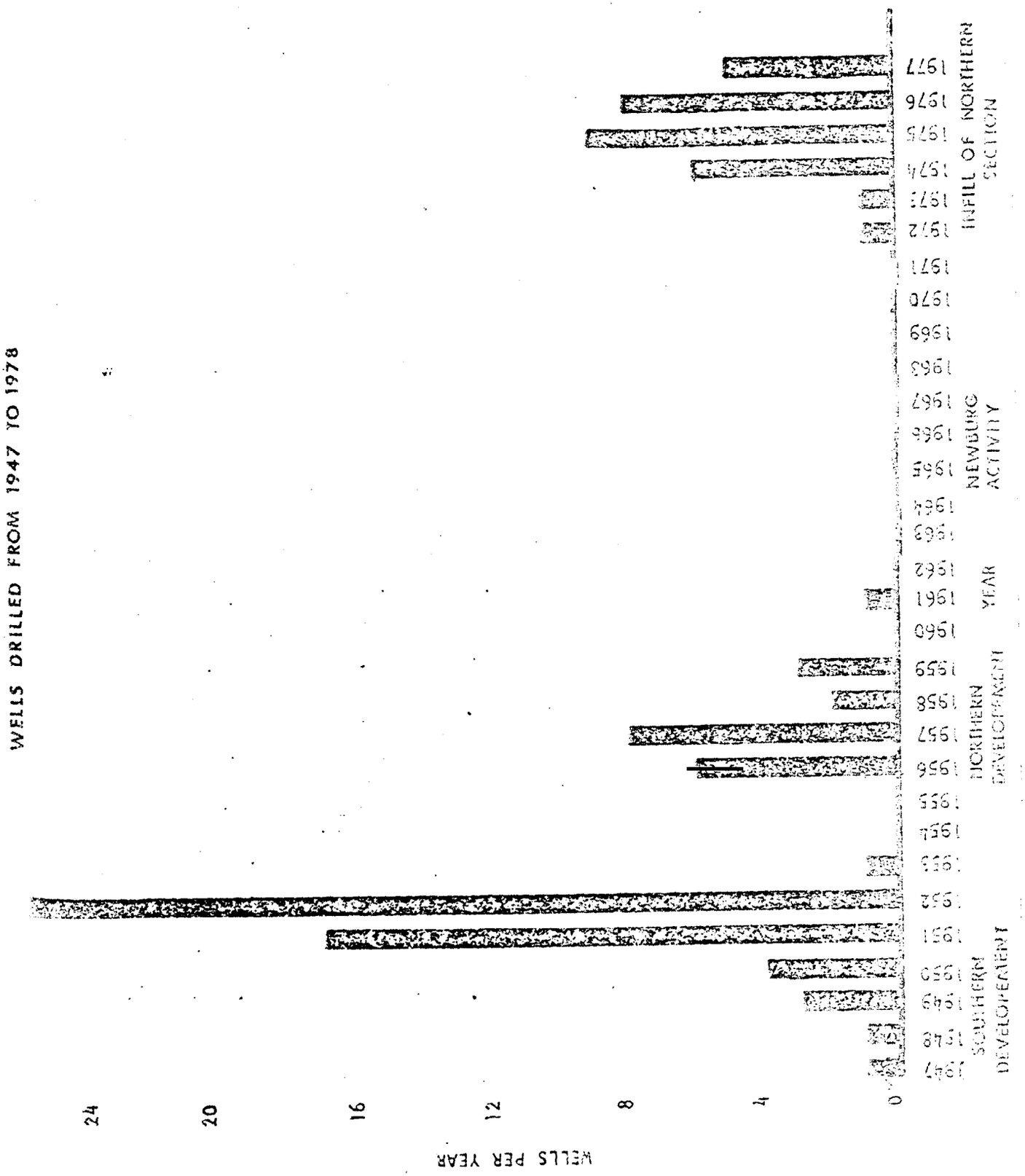
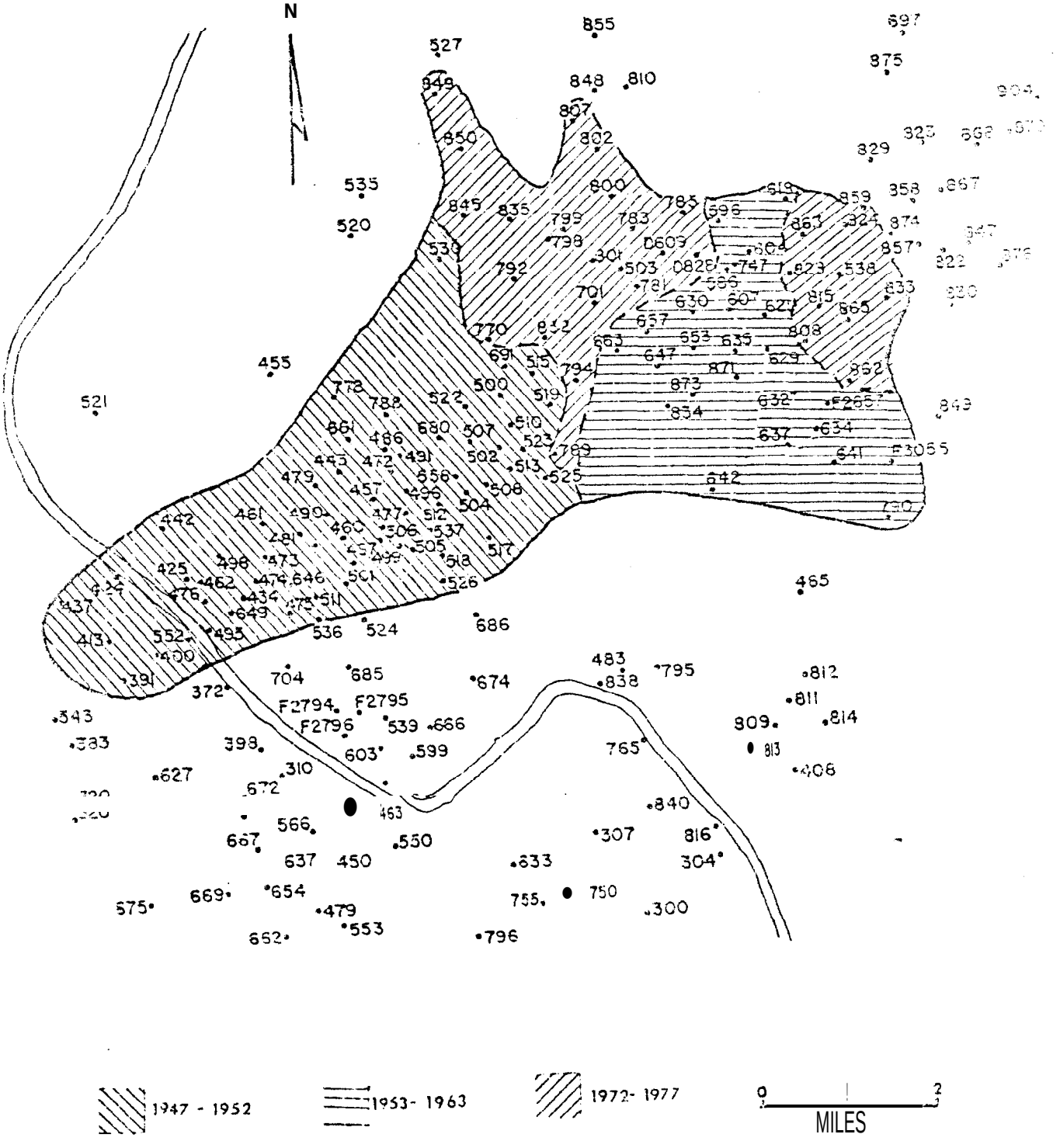


FIGURE 6

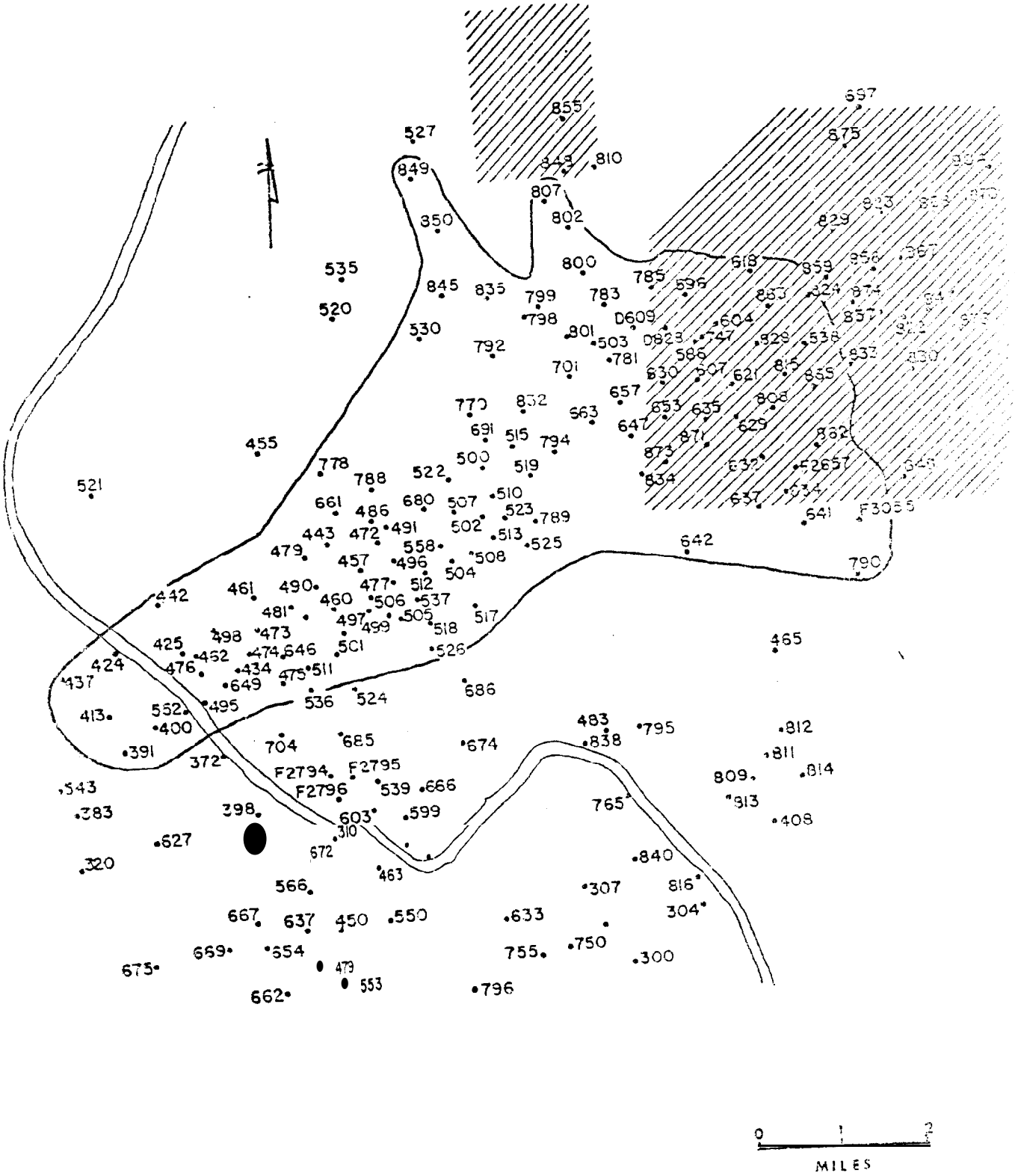
DEVELOPMENT OF THE FIELD



1953 through 1961, drilling concentrated in the northern section of the fieid (Extra section). For a ten-year period, 1962 through 1971, drilling ceased in the field because of the availability of gas from the more prolific Newburg and Oriskany Sandstone discoveries and because of the availability of less expensive interstate gas. Thirty wells were completed in the six year period, 1972 through 1977 (figures 5 and 6). Current drilling activity is concentrating in the Extra section of the field with 40 development and step-out wells expected to be completed by the end of 1978 {figure 7).

Factors which have influenced the current drilling activity are: (1) increases in intra-state gas prices, (2) the potential long-range reserves at low drilling and operating costs, (3) the low geological risks involved, (4) access to existing pipelines, and (5) competitive leasing action by operators.

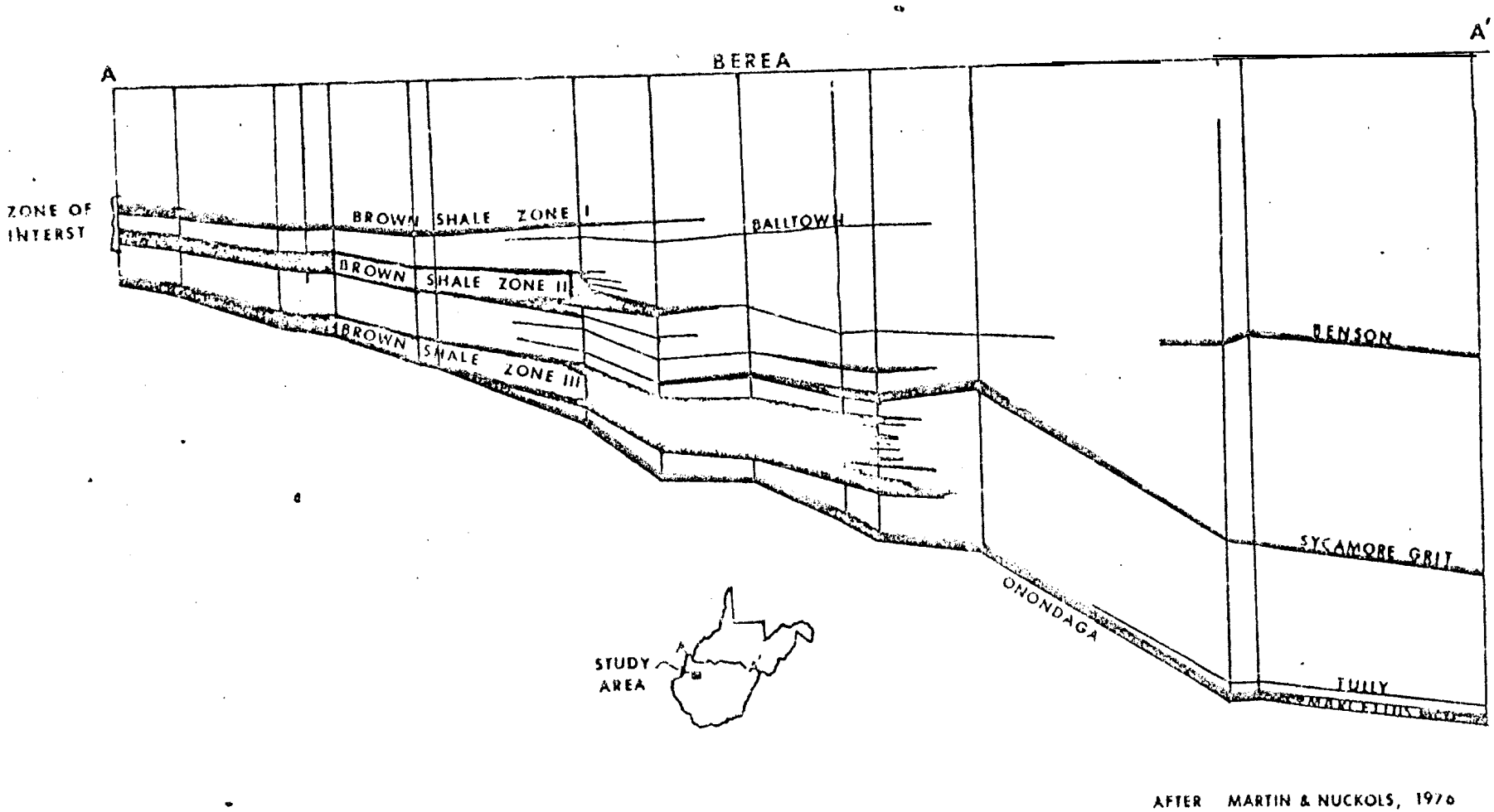
FIGURE 7
DRILLING ACTIVITY IN 1978



STRATIGRAPHY

The Devonian shale of this study is considered to be that shale found between the Onondaga Limestone (Middle Devonian) and the Berea Sandstone (basal Mississippian).

The Devonian Brown shales as referred to throughout this paper form only a small part of the total Devonian shale section. They are those zones of highly radioactive, low-density shales found within the middle portions of the Devonian shales, and are equivalent to the Lower Huron Shale Member of the Ohio Shale (Patchen, 1978). Figure 8 is a cross section through western West Virginia (Martin 2nd Nuckols,1976) which shows the stratigraphic relationship of the shales to the interbedded sands, silts, and shales of the east-central portion of the state. The Devonian brown shales, Zones I and II of Martin and Nuckols (1976), are equivalent to the Brown shale intervals studied and are Upper Devonian in age (figure 8). The Brown shales are easily correlated in western West Virginia, but eastward, in western Calhoun County, they begin to interfinger with a predominate gray shale facies and correlations are tenuous. The thickness of the tot21 Devonian shale section ranges from less than 1000 feet {figure 9) in theextremewestern counties of the state to over 3200 feet in eastern Kanawha County (Bagnall 2nd Ryan, 1976). The entire Devonian shale

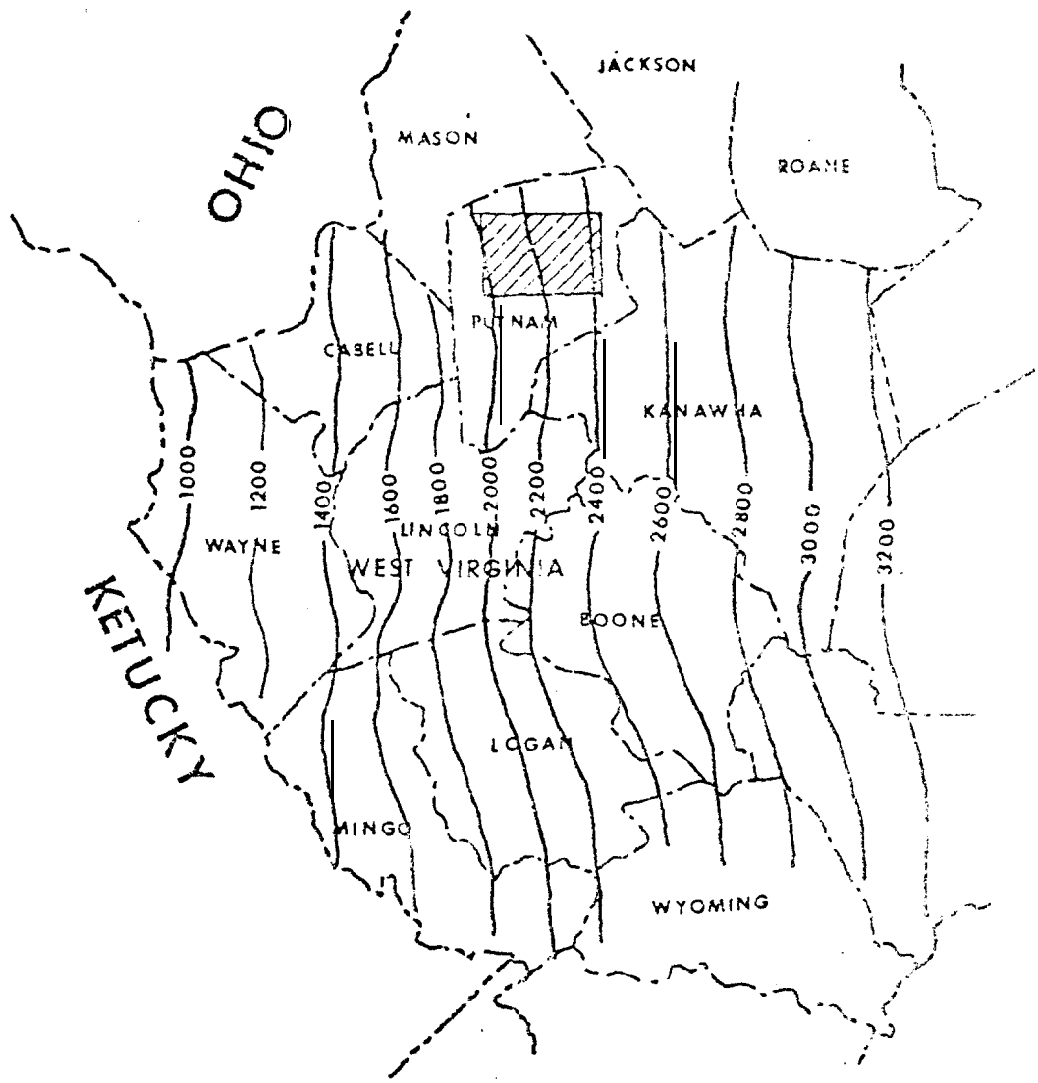


AFTER MARTIN & NUCKOLS, 1976

DEVONIAN SHALE CORRELATIONS

FIGURE 8

FIGURE 9



THICKNESS OF THE DEVONIAN SHALE IN SOUTHWESTERN WEST VIRGINIA

CI = 200'

AFTER BAGNALL & RYAN, 1976

STUDY AREA

section changes facies eastward, generally becoming more coarse in grain size. The regional thickness of the Brown shales is difficult to determine east of the study area as the organic shales rapidly change to interbedded gray shales and silts. The limited area of this study excludes most of these regional stratigraphic problems.

The Brown shales are well defined on radiation logs and drillers can readily select these shales so that drillers' logs are quite reliable, The Brown shale zone Is picked from radiation logs (figure 10) by a contrasting increase in the gamma-ray count and a decrease in the bulk density, The Brown shales have gamma-ray counts of over 200 API units, and are generally 40-50 API units greater than the gamma-ray counts of the shales and silty shales above and below, Bulk density for the Brown shales ranges from 2.65 to less than 2.5 grams per cubic centimeter depending primarily upon the kerogen content, hydrocarbon concentration, and the degree of fracturing. The shades of brown color imparted to the shales are due to the varying degrees of organic, hydrocarbon, and kerogen content. The colors vary from light brown to black.

The Brown shales range from less that! 375 feet in the eastern part of the study area to over 475 feet in the northeastern part (figure 11). The percent of Brown shale; (net percent) to total thickness of the interval as defined by drillers' logs, varies from 45 percent in the east

FIGURE 10 TYPE GAMMA-RAY/DENSITY LOG OF THE DEVONIAN SHALE

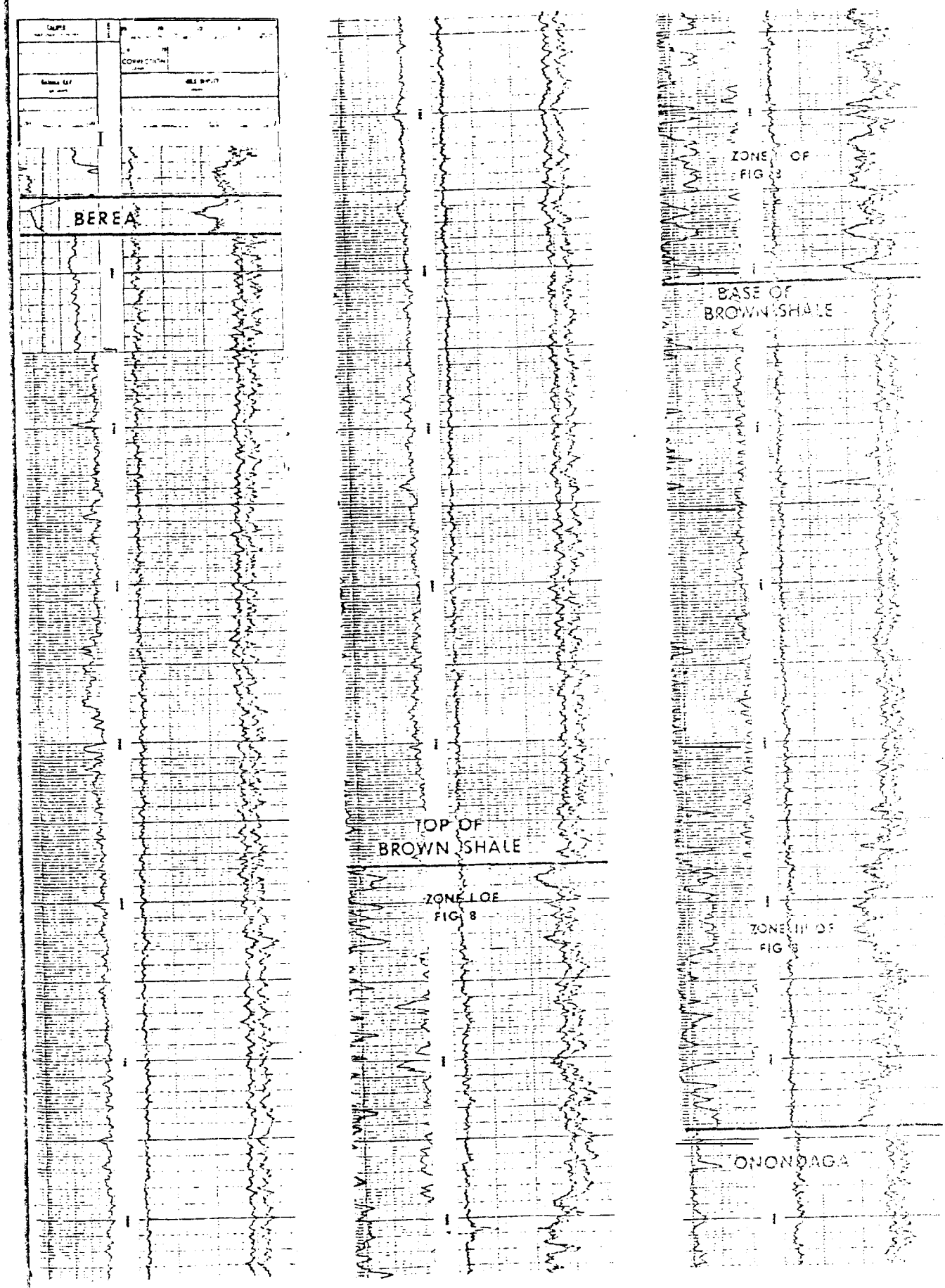
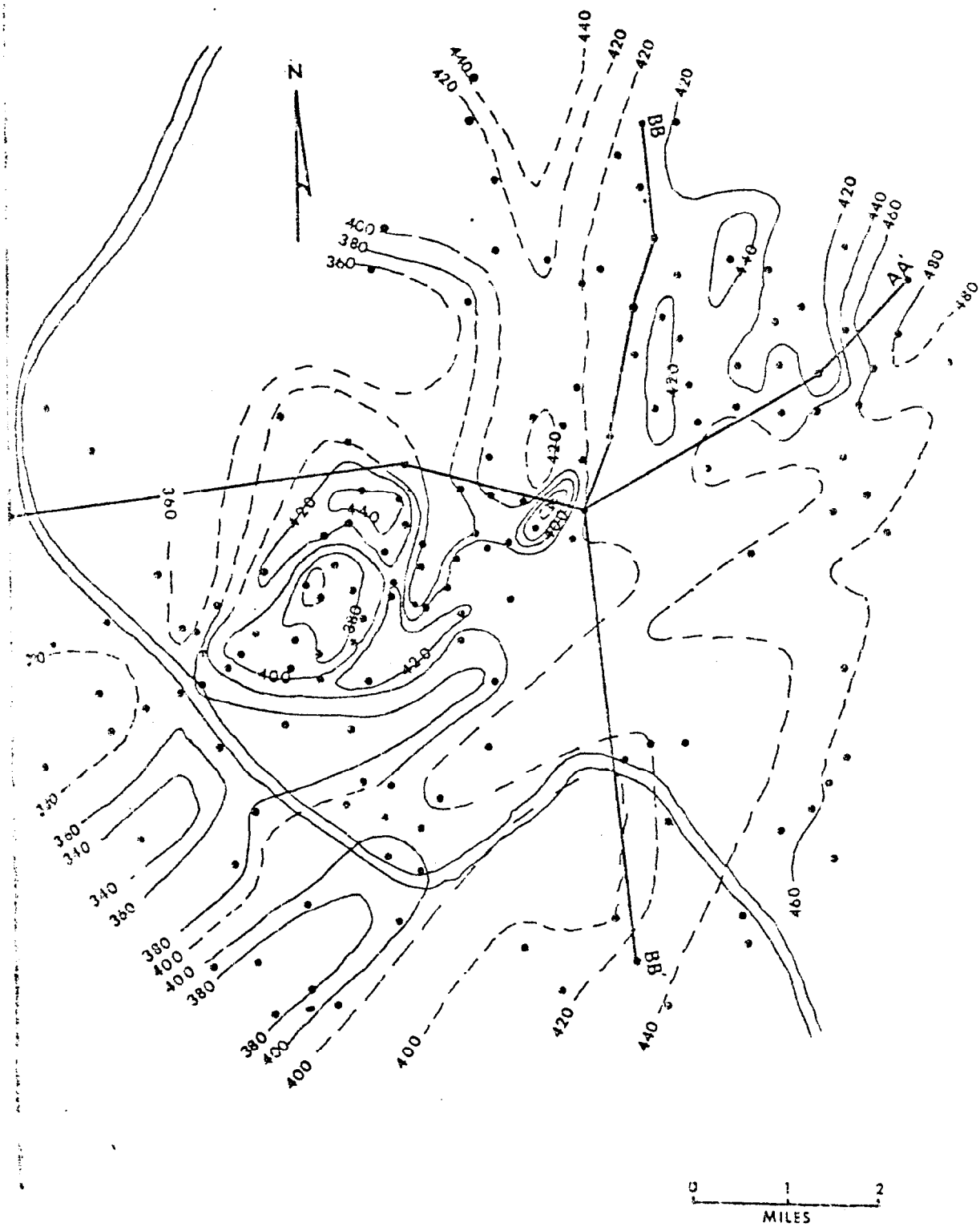


FIGURE 11

LOWER HURON ISOPACH MAP



to over 75 percent in the western portions of the study area. Most of the observed thickening is found in the upper two-thirds of the section between lines 7 and j of figure 12. The Brown shale zones are generally considered to be associated with periods of relatively lower rates of clastic sedimentation, whereas the interbedded gray shales are associated with periods of higher rates of clastic sedimentation. This is illustrated in figure 13 as the unit between the correlation lines 3 and 4 of the cross-section.

Grillers' logs indicate that the shales grade from a thin, dark, kerogen-rich (high API gamma-ray count) area in the west to a thick gray shale in the eastern section. In the cross-section (figure 14) the facies change is noted by the decreased gamma-ray intensity in the Brown shales towards the east. Cable tool records also indicate the facies change by reporting the lower two Brown shale zones in the east (lines 1 to 3 and 4 to 5, figure 12) as one zone in the west (lines 1 to 5, figure 12). As indicated, the gray shales (lines 6 to 7, figure 12) are associated with thickened intervals for approximately the same period of time, thus indicating a more rapid rate of sedimentation. The rate of sedimentation as indicated by facies and thickness figures is comparitively uniform in the north-south direction, but there appears to be a slight thickening to the south (figure 13).

A compilation of all the drillers' logs (figure 15)

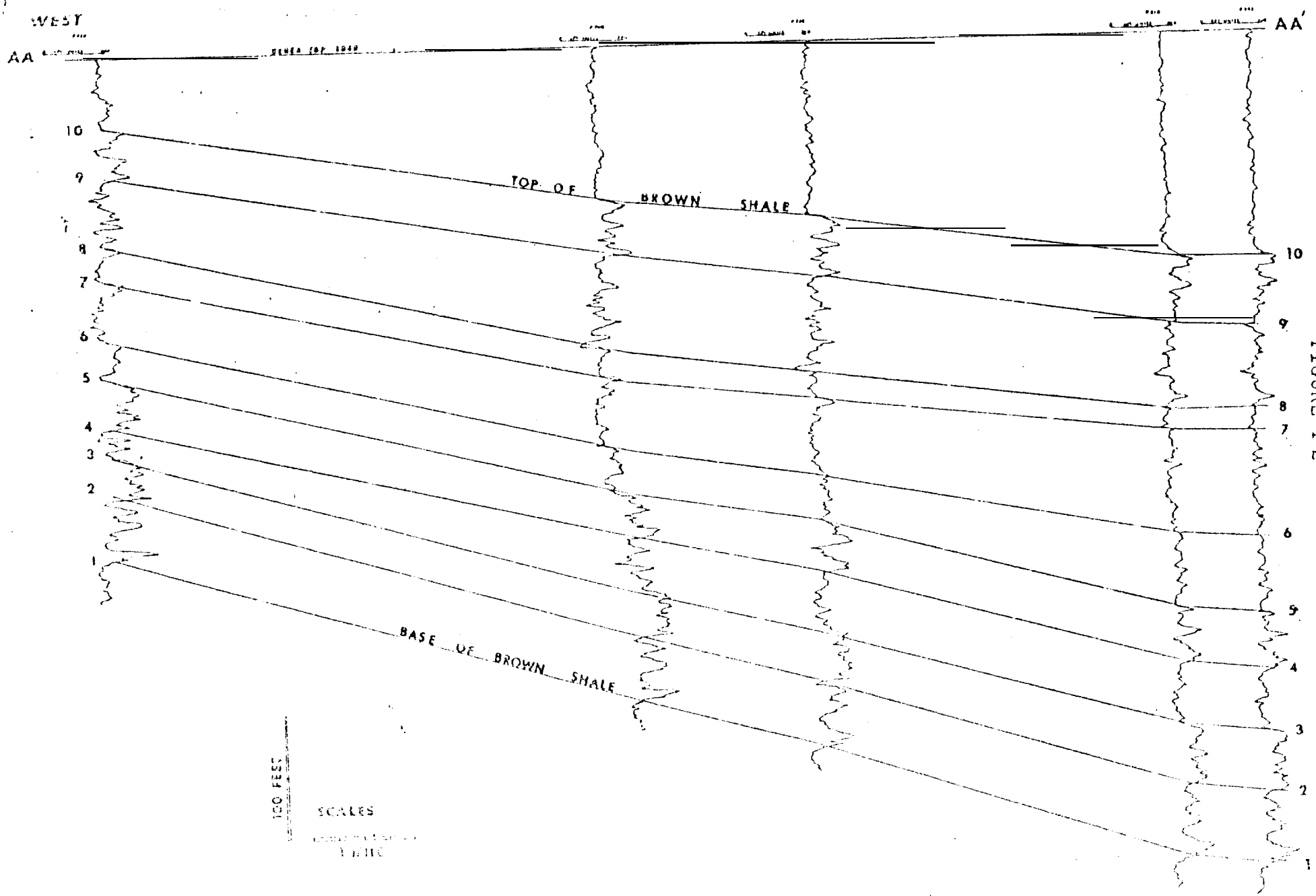


FIGURE 12

BROWN SHALE CROSS-SECTION AA-AA'

FIGURE 13

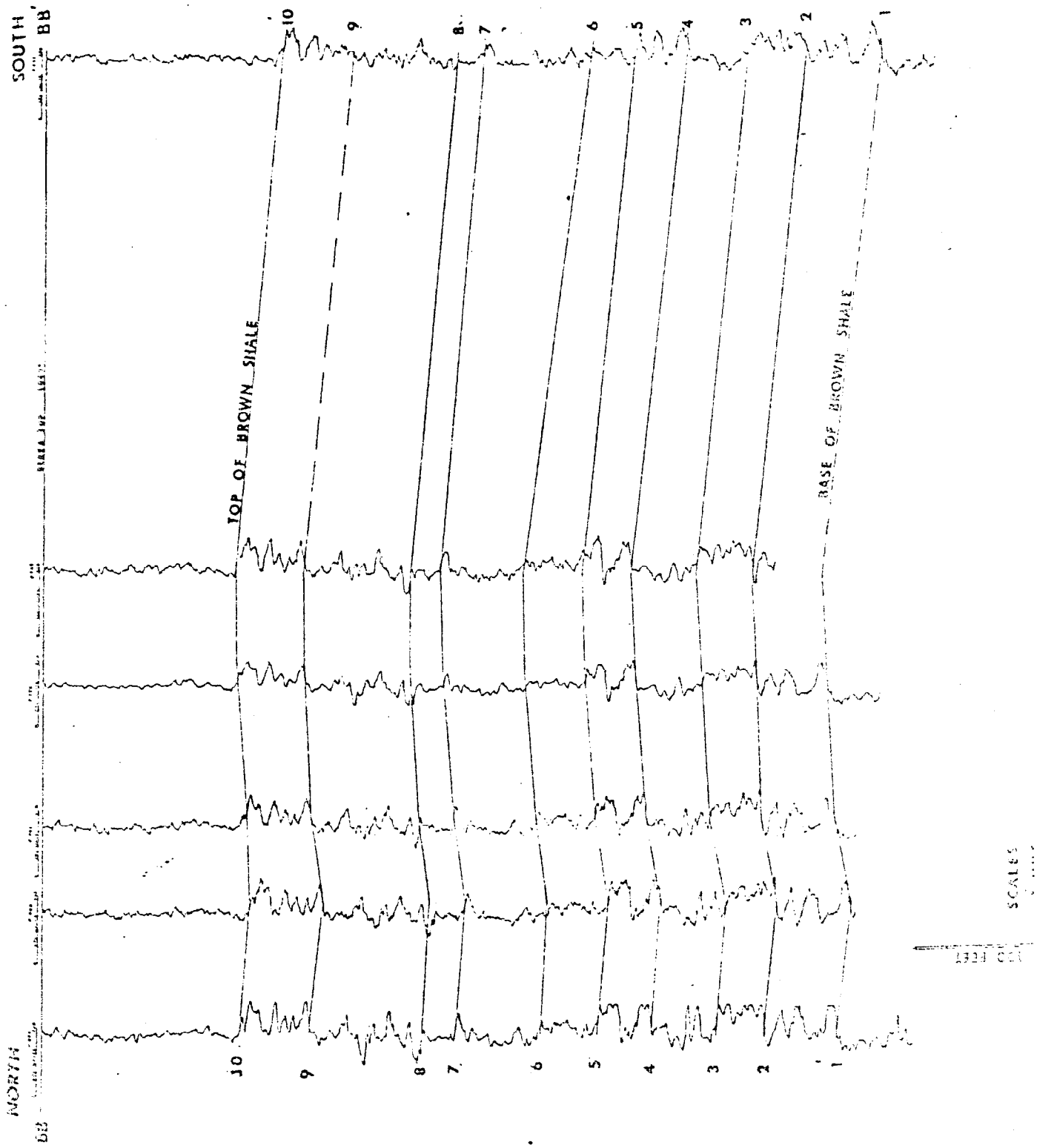
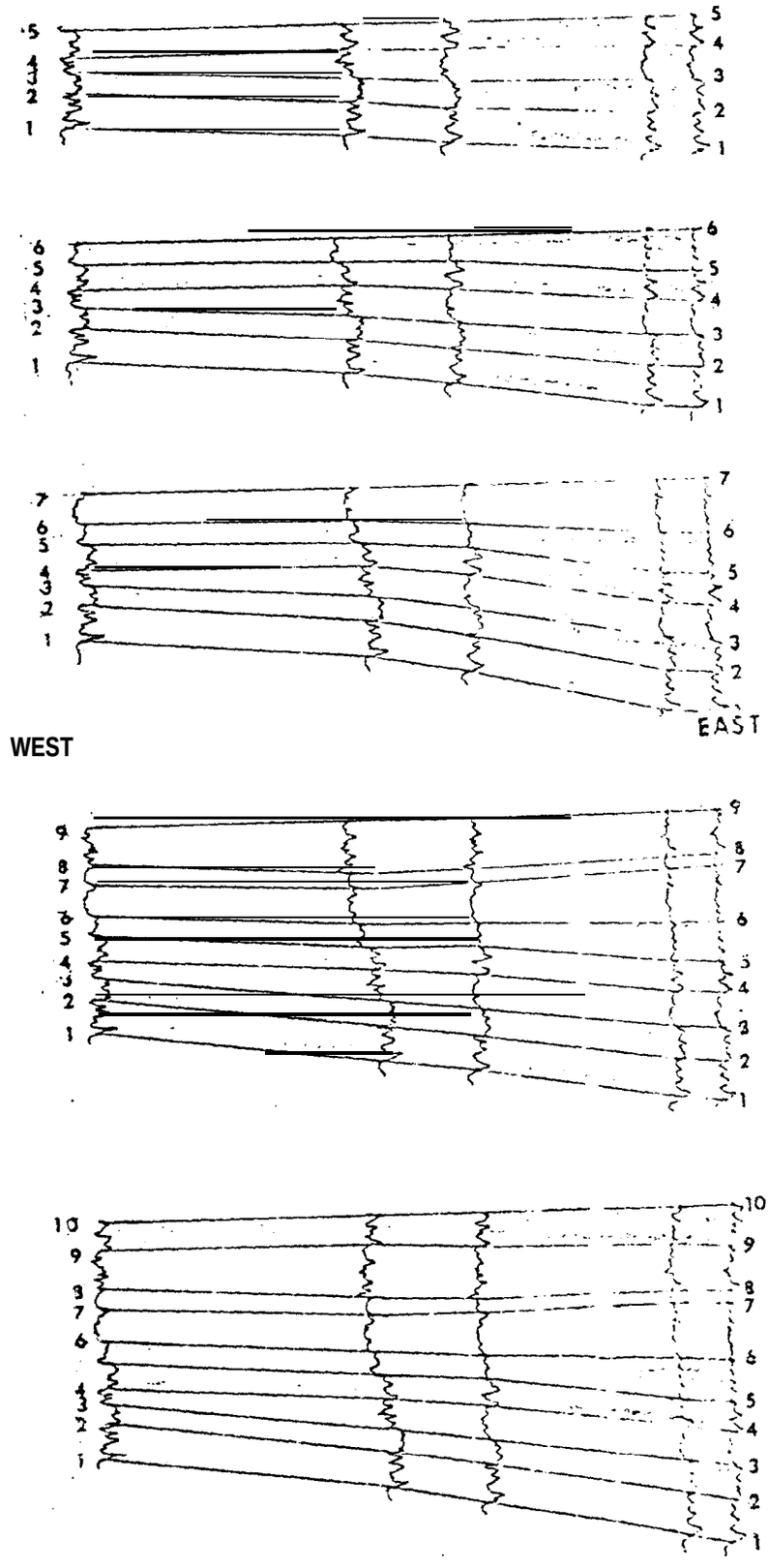

SOUTH
BB'
NORTH
BB
TOP OF BROWN SHALE
BASE OF BROWN SHALE
10
9
8
7
6
5
4
3
2
1
SCALES

FIGURE 14

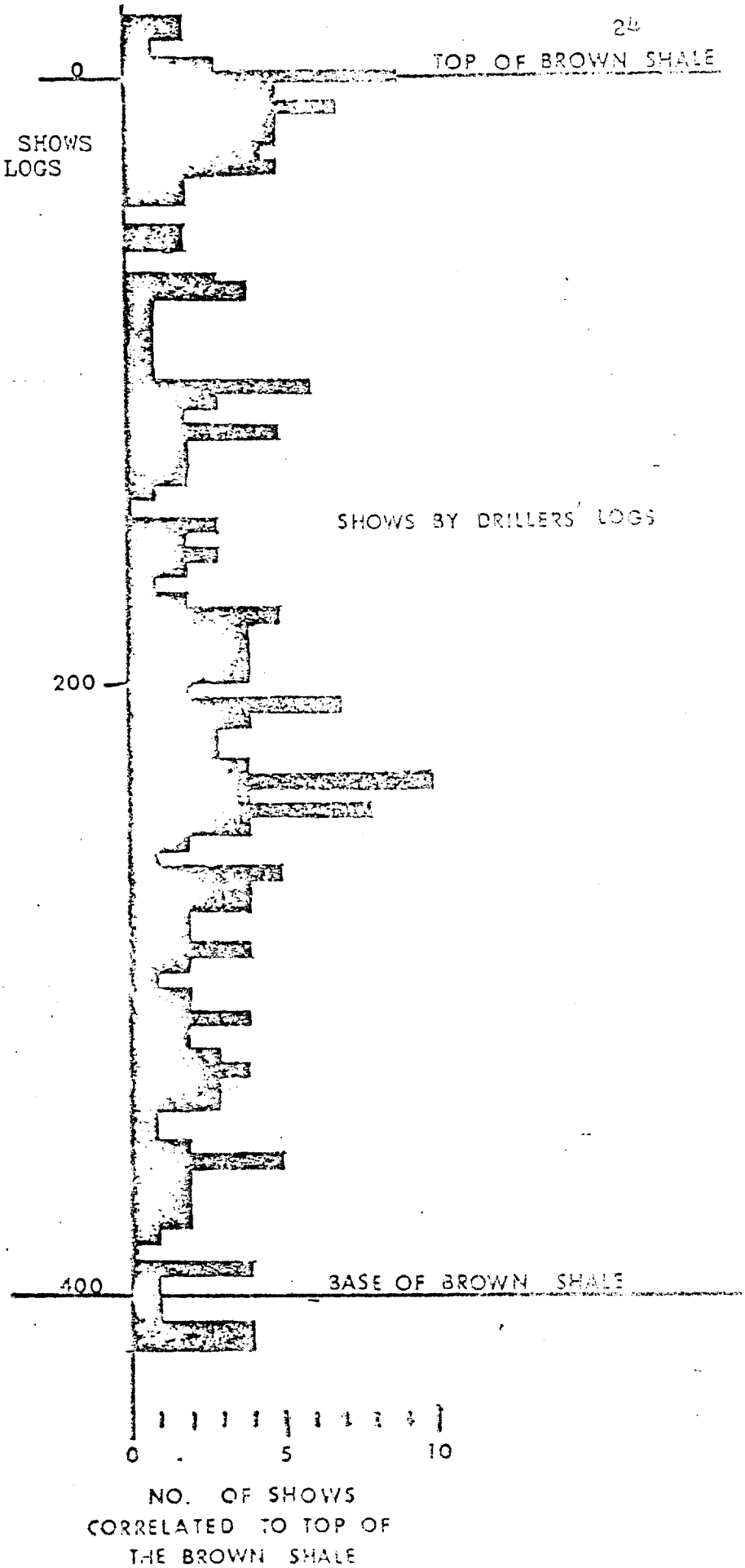


STRATIGRAPHIC SEQUENCE OF CROSS-SECTION AA – AA'

BROWN SHALE

FIGURE 15

CORRELATION OF GAS SHOWS WITH DRILLERS' LOGS

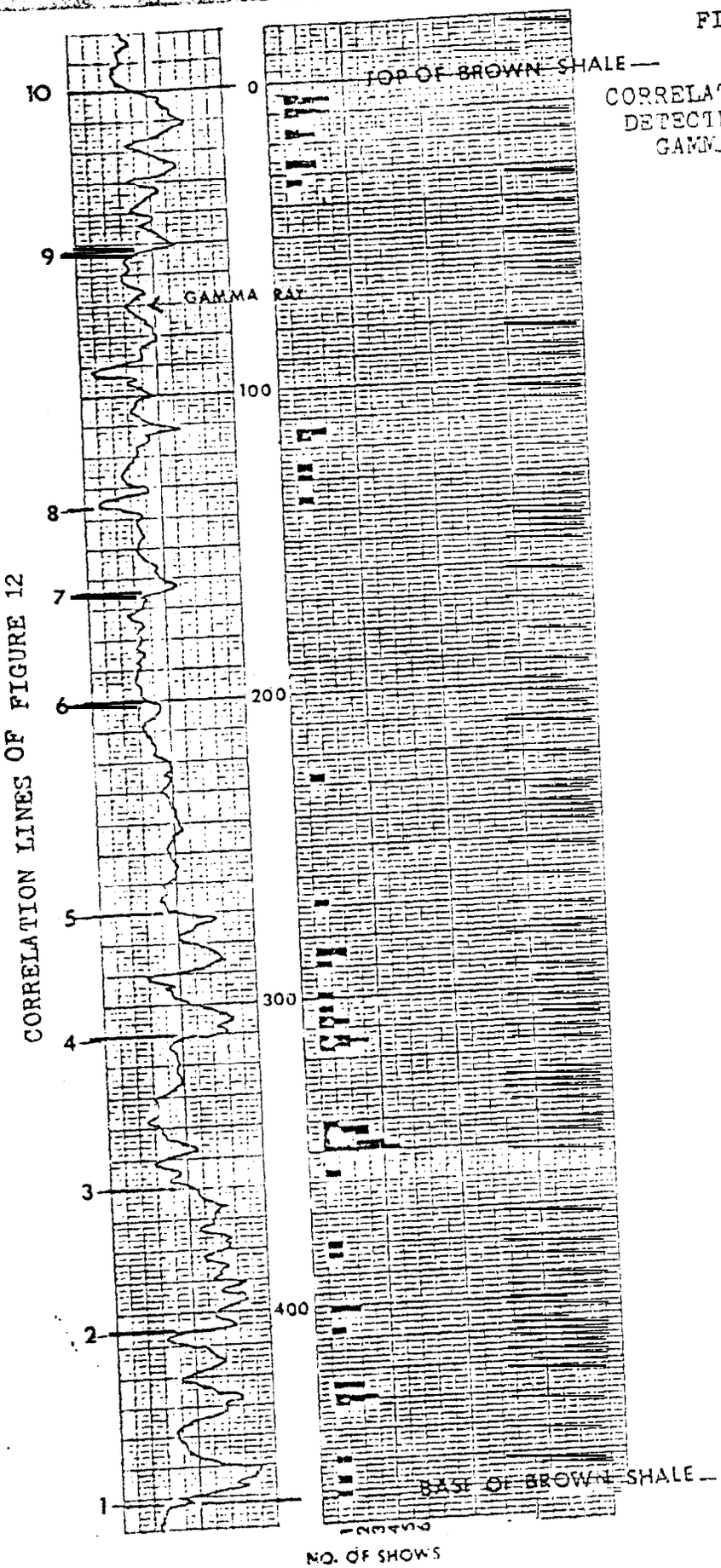


indicates that the greatest frequency of gas shows occurs in the top and middle portions of the Brown shale. Gas entry logs (temperature logs and sibilation logs) show that gas entry generally comes from zones of low density and high gamma-ray count which occur predominately in the top and in the lower sections of the Brown shales. Well-to-well correlation is difficult in older wells that have such logs because of the varying degrees of skin damage and because of the lover sensitivity of the older logging tools. Recent logging in the eastern sections of the field, using improved techniques, indicates that shows may be correlated by stratigraphic interval from well to well. Figure 16 shows gas entry points based on 11 sonic gas-detection logs. These are shown as a gamma-ray log which represents the 11 wells Shows are most numerous between correlation lines 3 and 4. Closer examination reveals that the entry points are spread across a "hot" shale and a shale streak just beneath. Possible correlation errors between entry point and gamma-ray count make it difficult to pinpoint the gas-bearing zone. It is possible that gas entry nay occur at the sharp contact between the two shales, or from a more porous zone directly above the contact.

There is a definite correlation between production and the stratigraphy within the Devonian shale. Not only are the Brown shales (Huron shales) the most productive, but specific low-density, high-organic zones within these

FIGURE 16

CORRELATION OF SONIC DETECTED SHOWS TO GAMMA-RAY LOG



shales are the most productive, While there is not a precise one-to-cne correlation between stratigraphy and shows from well to well, there is clearly a tendency for shows to correlate by stratigraphic position.

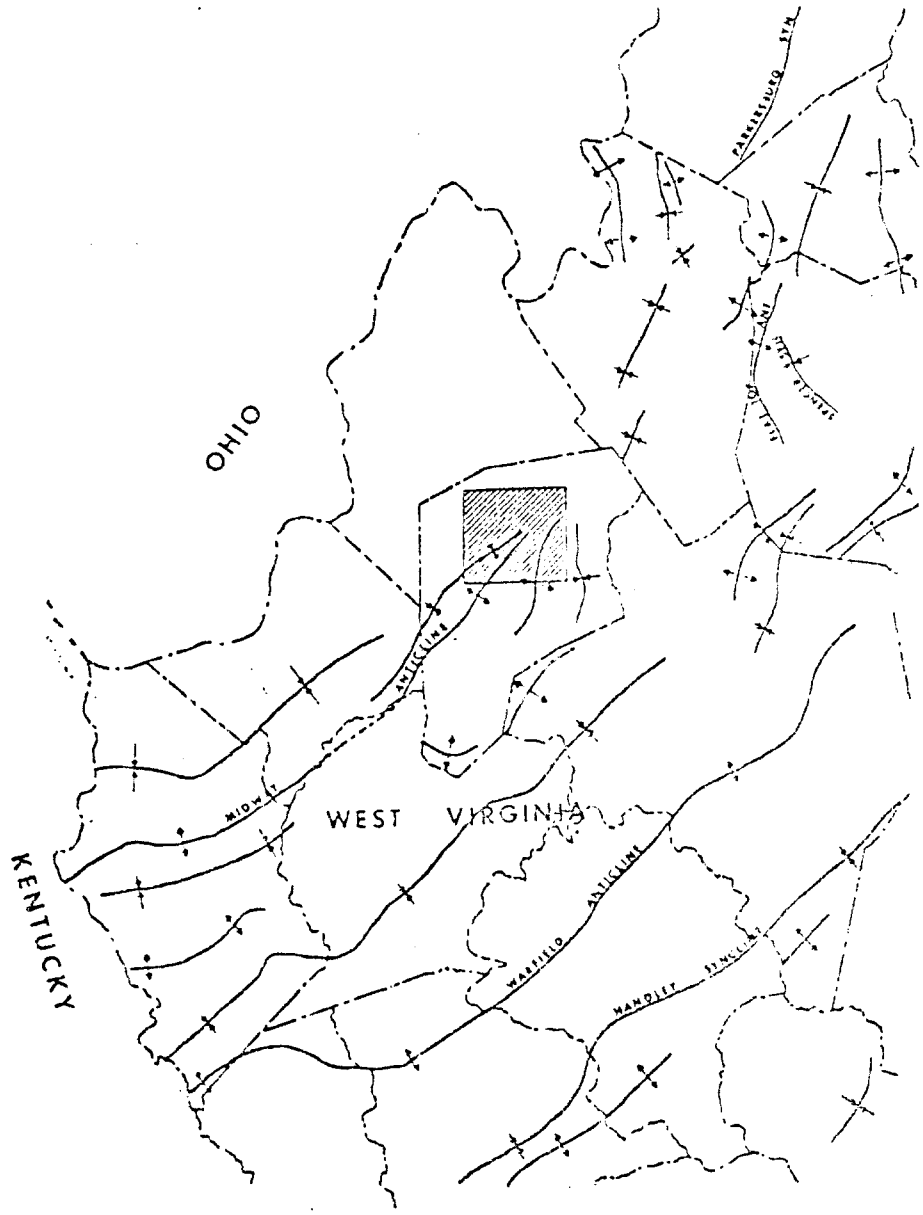
STRUCTURE

Figure 17 is a map showing the fold axes of southern West Virginia modified from the West Virginia Geologic and Economic Survey map (Cardwell, et al, 1976). The dominant structural feature in the study area is the Midway anticline. The anticline can be traced in the subsurface from Kentucky into the study area, striking approximately N60°E, and plunging northeastward into the Appalachian basin. The northeastward extent is unknown, but it is not shown to continue on any published map.

Separating the Midway and Extra sections of the field is a low relief anticline which strikes N10-15°E. This structure intersects the Midway anticline in the center of the study area (figure 18). Structural relief of the Midway Anticline is greatest in the southwest portion of the study area, particularly on the south flank. This relief is sharply reduced where the two structures merge. The structural features observed are probably due to deeply buried basement faults associated with the Cambrian Age Rome Trough (Shumaker, 1978a).

Where well control is abundant, the structure as mapped on the base of the Brown shale correlates well with that on the Berea Sandstone. The Berea structure (figure 18) is more subdued than the Brown shale structure (figure 19). The predominate structural features persist upward into

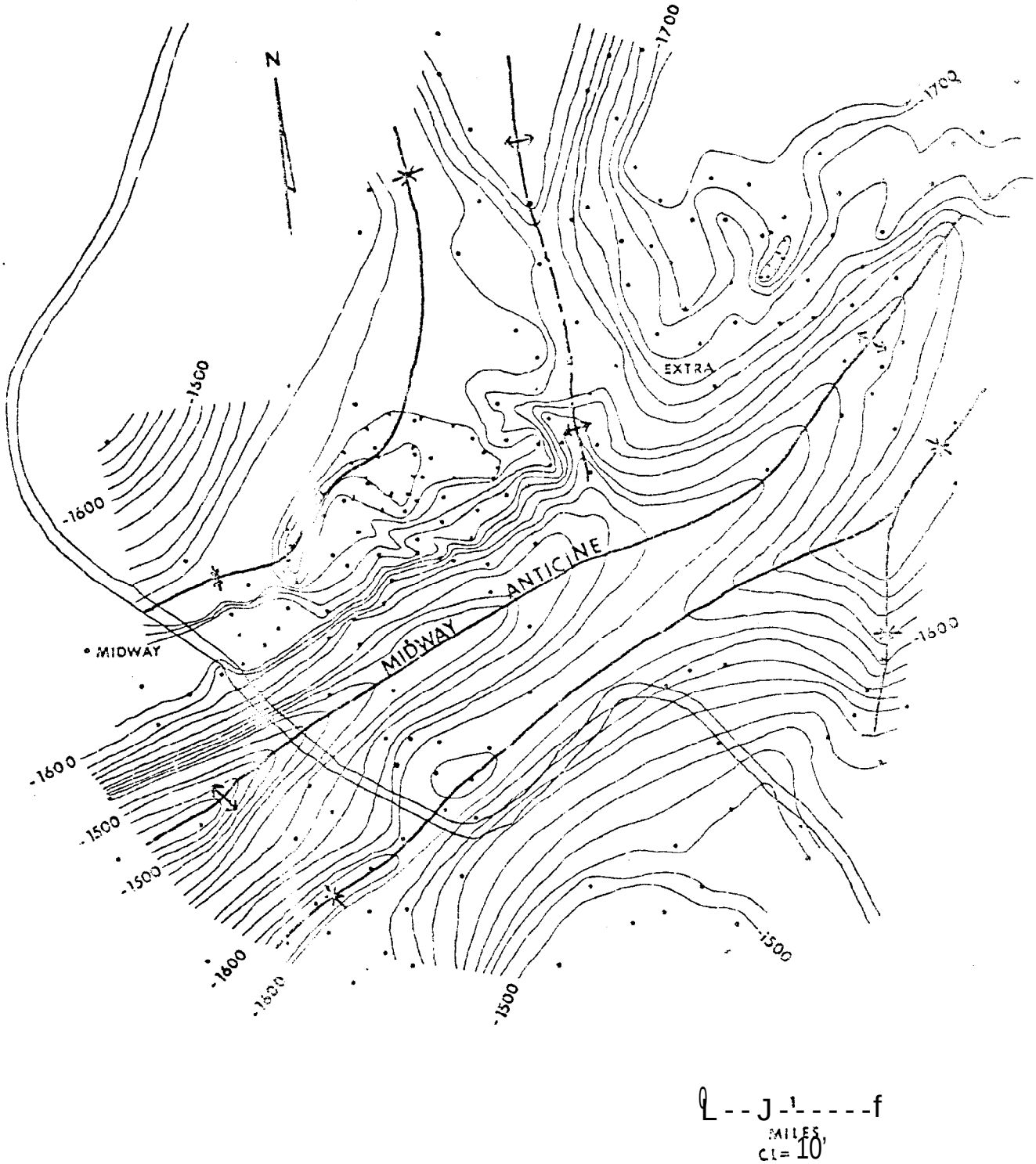
FIGURE 17



TECTONIC MAP OF SOUTHWESTERN WEST VIRGINIA

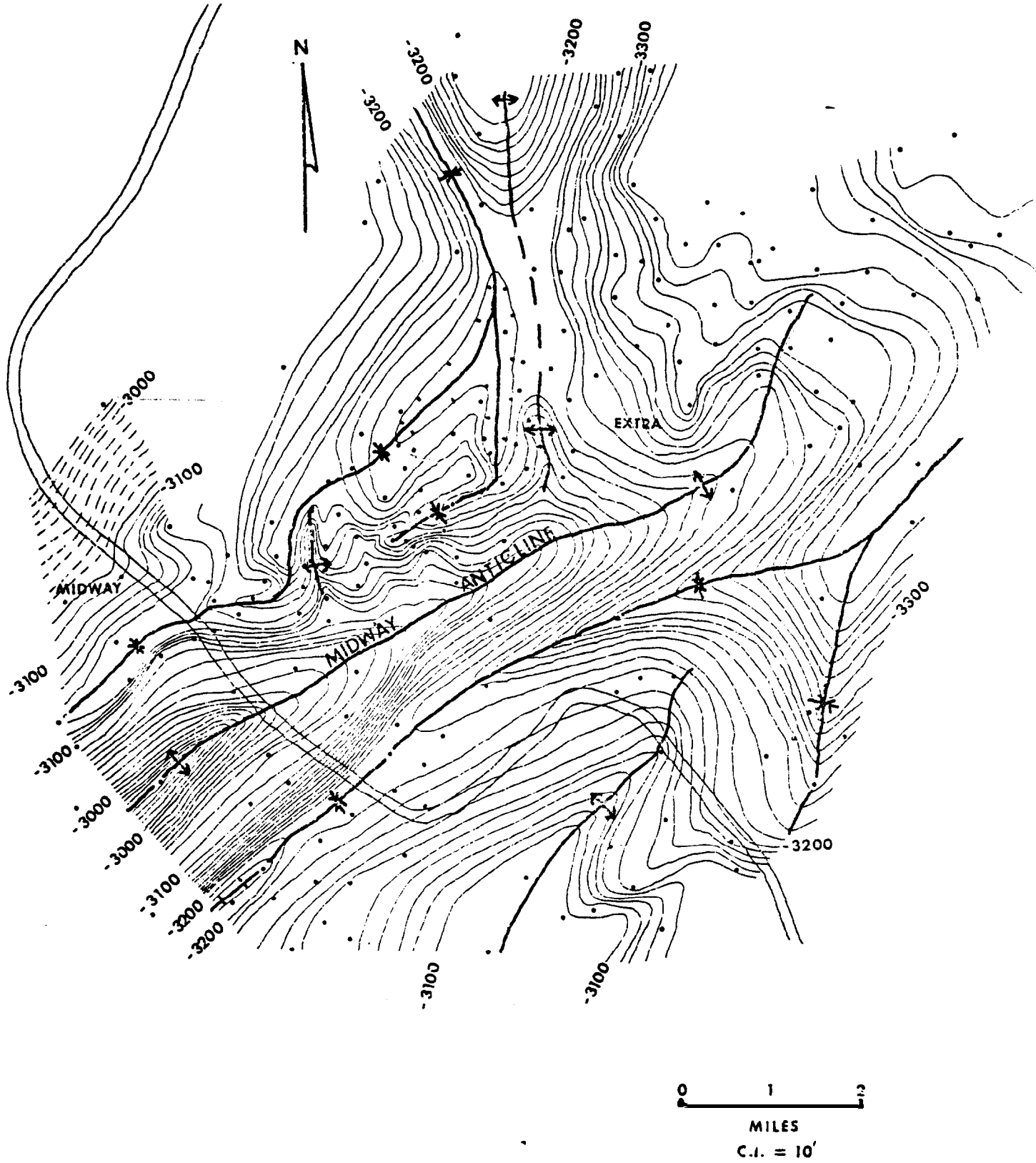
AFTER W.V.G.S
OIL & GAS FIELDS OF
W. VA.,
CARDWELL, ET. AL
1976

FIGURE 13



AREA STRUCTURAL MAP
(See figure 2 for well number and Appendix A for data)

FIGURE 19



B A S E OF BROWN SHALE (L. HURON) STRUCTURE

(See figure 2 for well number and Appendix A for data)

the Mississippian where the Midway Anticline can be mapped on top of the Greenbrier Limestone.

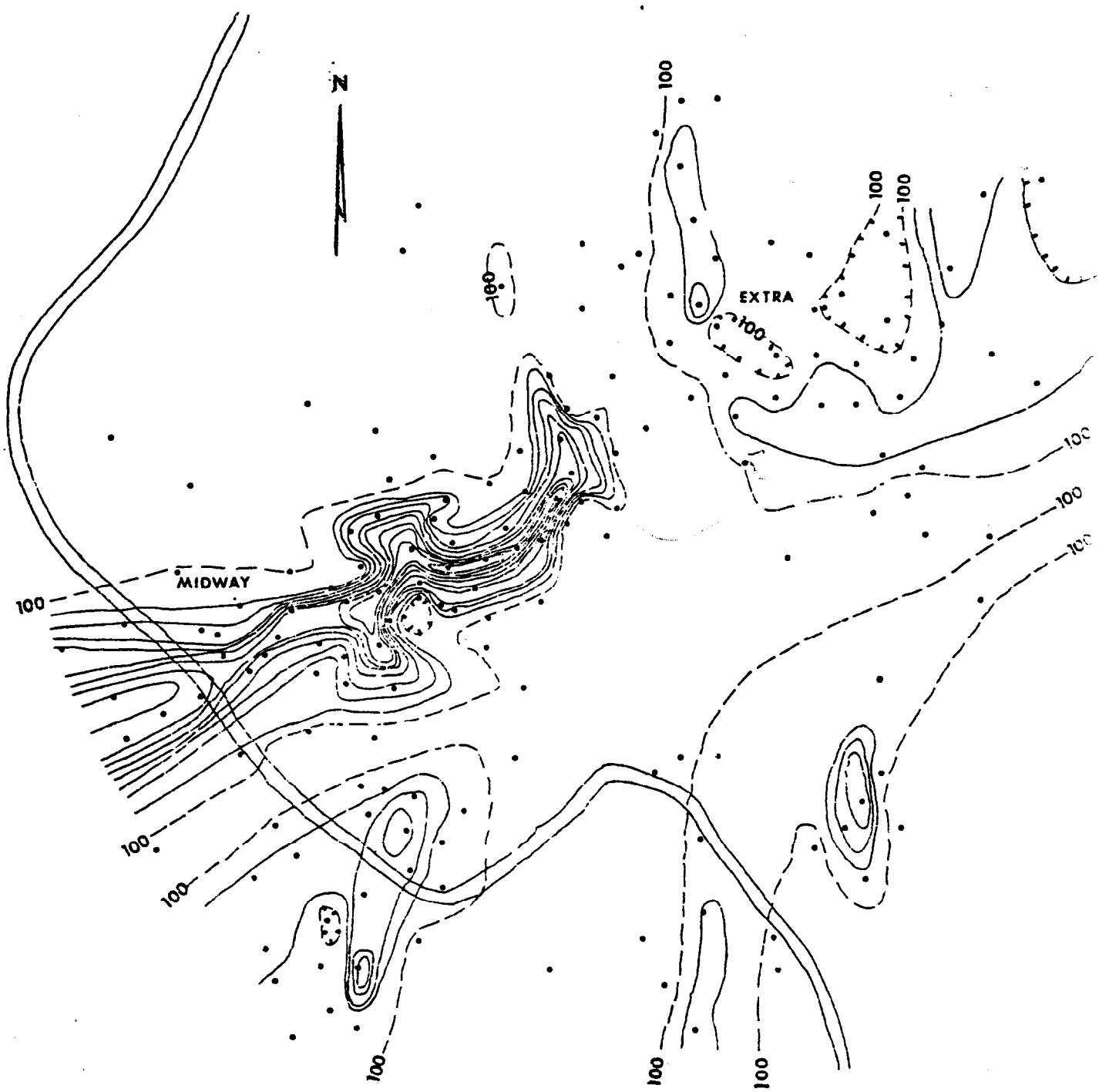
The study area lies above the deeply buried Rome Trough, and the Midway-Extra structure is considered to be related to basement faulting. Even though the major basement deformation forming the Rome Trough occurred during the Cambrian, it is now realized that these faults were intermittently active during the Paleozoic, and that they were active growth faults that affected sedimentation. Structural offsets of the basement occurred throughout the time of Brown shale sedimentation causing the observed thickening and facies changes of the shale to the east.

PRODUCTON

Commercial production from the Devonian shale is generally considered to be a function of the quantity of open fractures which intersect the well bore. Production from the Brown shales in the study area should be related to fractures. Therefore, the more intense or open these intersecting fractures are, the greater the production potential, providing there is no well-bore damage. As indicated in the discussion of stratigraphy, certain high organic zones within the Brown shale zones are more productive. If the production is strictly related to stratigraphy , it should be similar to stratigraphic traps, or production should be on the crest of structures if the porosity is a blanket type.

To study the three-dimensional aspect of the production, an isopotential map (figure 20) was prepared based on the initial open flows reported after stimulation. The commercial production in the Midway portion of the field follows the trend of the northwest flank of the structure extending six miles long and less than two miles wide. The production in the Extra portion of the field is not as sharply defined. Seemingly, the production of the field is separated by the north-south trending structural high (compare figures 19 and 20). A series of exaggerated cross-sections (figure 21) was prepared with a cross-section

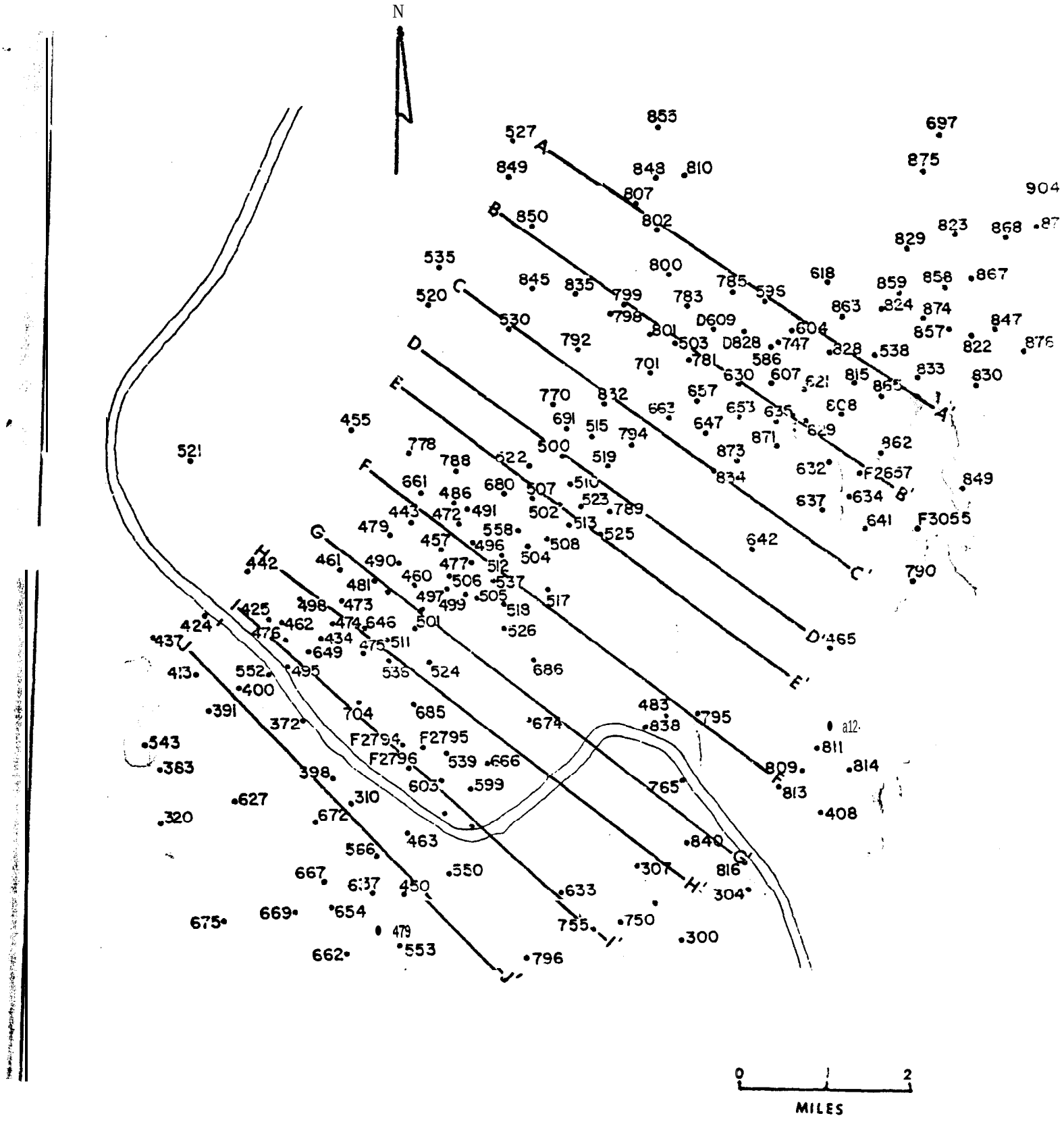
FIGURE 20



BROWN S H A L E ISOPOTENTIAL
OPEN FLOW AFTER STIMULATION

MILES
C.I. = 100
MCF/D

FIGURE 21



INDEX OF CROSS SECTIONS-FIG. 22

of the isopotential map superimposed (figure 22). The production is structurally related, as it sharply increases in the same structural position on each cross-section. There are no noticeable stratigraphic changes in the region of higher production, so it is assumed that the porosity is a fracture porosity. The highest production potential, and thus, the most intense fracturing, is located on the west flank of the Midway anticline, just east of the axis of the syncline (see J-J', figure 22). The production also increases slightly along the east flank of the structure (see H-H', figure 22), but there is no appreciable production associated with the crest of the Midway anticline. As indicated, the relationship is best seen in the Midway section of the study area where production follows the west flank of the Midway anticline. However, note that the isopotential lines turn to the north at the intersection of the north-trending structure and they follow the west flank and, to some degree, the crest of the high. The Extra section of the field does not show this relationship as clearly as the Midway section, This may relate to less well control in the Extra section,, Current drilling in the Extra area may prove that shale production is highest on the lower flank of the Midway anticline.

The origin of the porosity at this position CA the structure is not certain, However, production is probably a function of local porosity caused either by the develop-

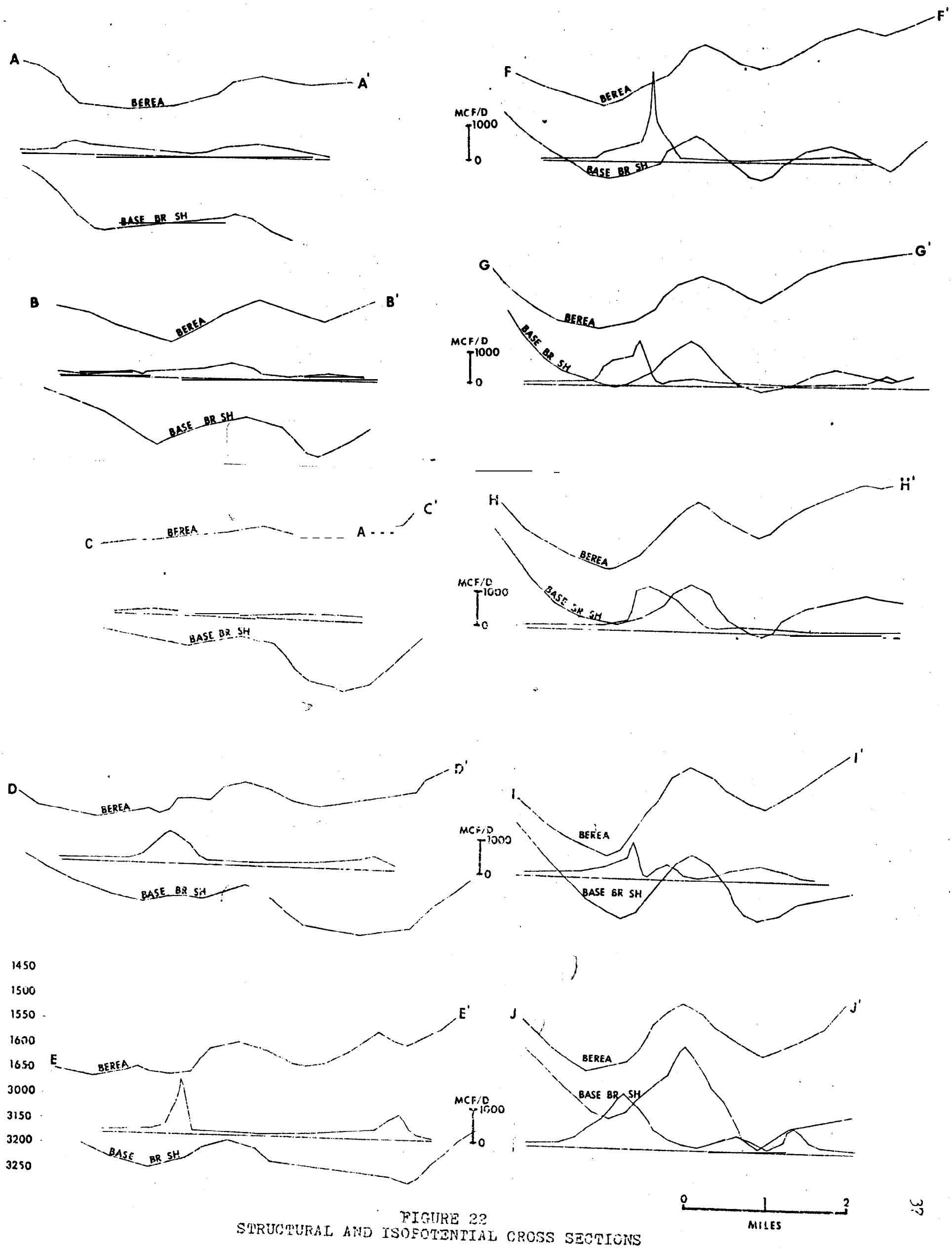


FIGURE 22
STRUCTURAL AND ISOPOTENTIAL CROSS SECTIONS

ment of a unique local fracture system or by the opening or intensification of the regional fracture pattern in the Brown shale. Whatever the origin of these fractures, the production fits well with the concept of the development of a porous fracture facies within the shale (Shumaker, 1978b).

The thinning of the Brown shale (figure 11) over the Midway-Extra field suggests growth of the structure during Late Devonian time. Structural trends are similar to the basement structures mapped by Shumaker (1978b). These facts indicate that structure in the Lower Huron in the study area is probably related to basement structure. The regional fracture system has been noted to change across the Rome Trough (Kulander and Dean, 1978). The porosity may relate to a regional fracture system or to more intense local fracturing. Furthur work is required to define which is correct.

The combination of structural and isopotential maps is a valuable exploration method to predict trends and future well locations in the Brown shale for this study area. The highest production potential is adjacent to the synclinal trough where dip is high. Areas fitting these criteria would include both flanks of the Midway anticline in the western portion of the Extra section and an extension of the present production trend along the western flank of the Midway anticline in the Midway section of the field.

WELL COMPLETION

All producing Brown shale wells in the field drilled before 1977 were shot, after drilling to total depth, generally with 6300 pounds of explosives (ten pounds of explosives per foot). The type of explosive varied from 80% gelatinated nitroglycerin to a mixture of ammonium nitrate and fuel oil. After cleaning out the shot to total depth, a slotted liner covering the section was usually run in the well to keen the well bore open. Tubing was then run to facilitate fluid removal.

The initial open flow after shooting 81 wells within the field (Table I) indicates that wells with initial open flows greater than 100,000 cubic feet per day were not as significantly affected, Indeed, expiosivs stimulation can damage the formation, which nay result in a loss of production,

A new method of shooting called "gaseous frac" has been devaloped to achieve greater induced fracture penetration than the conventional 80% gel shots, In this process, a shaped charge, similar tc a perforation jet, is detonated to initiate fracture. Several microseconds later, a high-velocity charge is detonated which causes high pressure gases to propoqate the fracture, A test shot was conducted on a shale outcrop by Basin Surveys in 1978 resulting in penetration of 12 to 14 feet by the shaped charge. Preliminary results indicate that the gaseous frac is equivalent

TABLE I

AFTER SHOOTING OPEN FLOWS/% INCREASE/NUMBER OF WELLS

NATURAL OPEN FLOW (MCF/D)	60	61-100	101-200	201-300	300	AVERAGE
SHOW	32MCF/D 220% (5 wells)	79MC F/D 690% (6 wells}	146MCF/D 46% (8 wells)	220MCF/D 2100% (3 wells)	675MCF/D 6650% (14 wells)	123MCF/D 1273% (36 wells)
10-20	47MCF/D 176% (7 wells)	73MCF/D 406% (12 wells)	170MCF/D 1038% (6 wells)	--- --- ---	355MCF/D 2264% (4 wells)	180MCF/D 992% (29 wells)
21-30	--- --- ---	73MCF/D 204% (1 well)	197MCF/D 697% (3 wells)	209MCF/D 679% (2 wells)	526MCF/D 2156% (6 wells)	293MCF/D 1128% (12 wells)
31-40	--- --- ---	--- --- ---	132MCF/D 301% (4 wells)	202MCF/D 445% (1 well)	--- -I- ---	156MCF/D 349% (5 wells)
41-60	--- --- ---	--- --- ---	137MCF/D 159% (4 wells)	246MCF/D 392% (1 well)	316MCF/D 602% (1 weli)	195MCF/D 292% (6 wells)
61-100	--- --- I--	... ... ---	141MCF/D 1 0 5 % (2 wells)	273MCF/D 207% (1 well)	495MCF/D 427% (1 well)	262MCF/D 292% (4 wells)
101-200	--- --- ---	79MC F/D -37% (1 well)	em- --- ---	260MCF/D 116% (3 wells)	622MCF/D 297% (3 wells)	389MCF/D 167% (7 wells)
200	--- --- ---	--- --- ---	--- --- ---	260MCF/D -17% (1 well)	805MCF/D 189% (3 wells)	669MCF/D 141% (4 wells)

to convential gel shots in stimulating the Brown shale. If so, then no advantage would be realized in using the more expensive gaseous frac.

Hydraulic fracturing is proving to be an efficient means to stimulate Brown shale production. Devon Corporation successfully water-fractured the Brown shale in the Midway-Extra field (PUT-847, C. Higginbotham #862). The initial open flow was 15,000 cubic feet per day at total depth, and after frac, the well gauged332,000 cubic feet per day, Wells driiled in the Extra section of the field in 1978 have shown that those wells which were fractured had open flows significantly greater than those wells which were shot, The wells completed by fracturing have not been "on line" long enough to compare with wells completed by shooting. The increase in cumulative production of fractured wells may surpass the 17-46% increase over shot wells as reported by Ray (1976). This increase probably reflects improvement in fracture technology since the tine cf Ray's original analysis.

RESERVES

Calculating ultimate recoverable reserves for the Brown shale has generally been based on empirical extrapolation Of the rate of production to the economic life of the well or to the economic production rate limit. The economic life of the well is that point in time where cost of work-over program is not justified by the expected increased production after workover. For the purpose of this paper, a well. life of 40 years will be used for calculating reserves. The economic iimit of the production rate is the production rate which will pay for the operation of the well, This limit is governed by the market price of the gas and the cost of the services to produce the well. Such services include well maintainance, chart reading, overhead expenses, current liability for the well, salvage value, etc. The economic limit has dropped because the field market price has risen. For the purpose of this study, the economic limit will be set at a conservative figure of 7,030 cubic feet per day,

A hyberbolic decline curve, was used to calculate reserves using the Simplex method of optimization (Deming and Morgan, 1973). The hyperbolic decline rate is proportional to a fractional power of the production rate as given by the equation:

$$qt = qi \times (1 + n \times di \times t)^{(-1/n)} \qquad (1)$$

where: qt = production rate at time t; qi = initial production rate; n = fractional exponent; and di = initial decline

rate. Simplex was set to minimize the sum of the deviations from the actual production rate minus the calculated production rate, Cumulative production (Qt) for a given time was calculated by the equation!

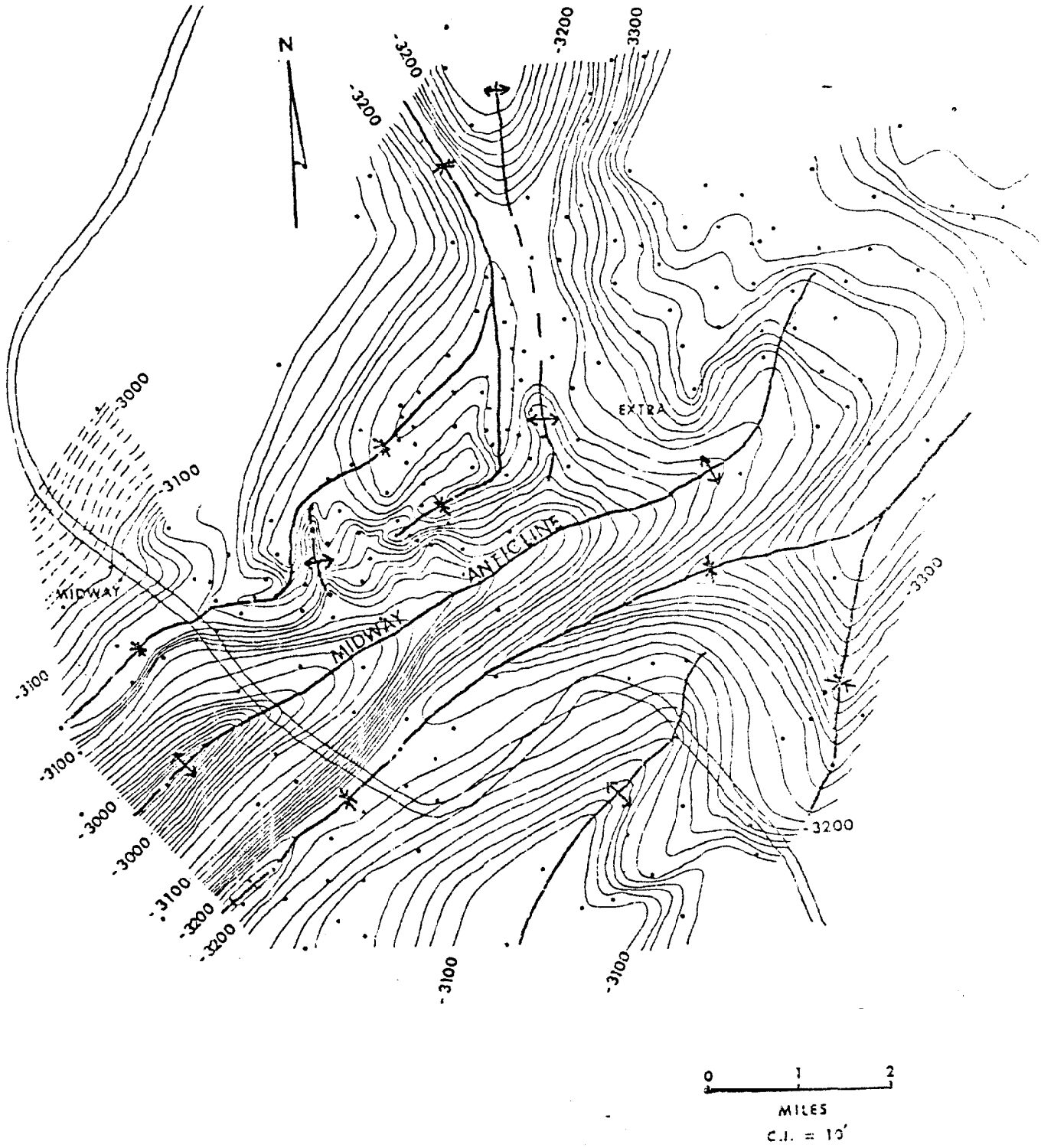
$$Qt = (qi^{n}/(1-n)di) \times (qi^{(1-n)} - qt^{(1-n)}) \qquad (2)$$

where qt was determined by equation (1).

Figure 23 shows the production decline curve for an average of 39 wells within the field, Cummulative production for 40 years (350 days per year) is 434,000,000cubic feet with the rate at the 40th year, 20,000 cubic feet per day. Using this decline, at the end of 150 years, the average well in the field will be producing over 12,000 cubic feet per day with a cumulative production of over 1,000,000,000 cubic feet, It is doubtful if this would ever be reached because (1) the nature of the hyperbolic decline tends to over estimate towards the end of production, (2) the well bore would not physically last 150 years, and (3) fluid encroachment would drown out production,

The average well spacing for the field is 160 acres per well which is based on the area within the iOO,OCO cubic feet per day contour on the isopotential map (figure 20). Reserves per acre per well are calculated at 2,721,000 cubic feet per acre-foot (Table II).

FIGURE 19



BASE OF BROWN SHALE (L.HURON) STRUCTURE

(See figure 2 for well number and Appendix A for data)

the Mississippian where the Midway Anticline can be mapped on top of the Greenbrier Limestone,

The study area lies above the deeply buried Rome Trough, and the Midway-Extra structure is considered to be related to basement faulting. Even though the major basement deformation forming the Rome Trough occurred during the Cambrian, it is now realized that these faults were intermittently active during the Paleozoic, and that they were active growth faults that affected sedimentation. Structural offsets of the basement occurred throughout the time of Brown shale sedimentation causing the observed thickening and facies change; of the shale to the east,

Commercial production from the Devonian shale is generally considered to be a function of the quantity of open fractures which intersect the well bore. Production from the Brown shales in the study area should be related to fractures. Therefore, the more intense or open these intersecting fractures are, the greater the production potential, providing there is no well-bore damage. As indicated in the discussion of stratigraphy, certain high organic zones within the Brown shale zones are more productive. if the production is strictly related to stratigraphy, it should be similar to stratigraphic traps, or production should be on the crest of structures if the porosity is a blanket type.

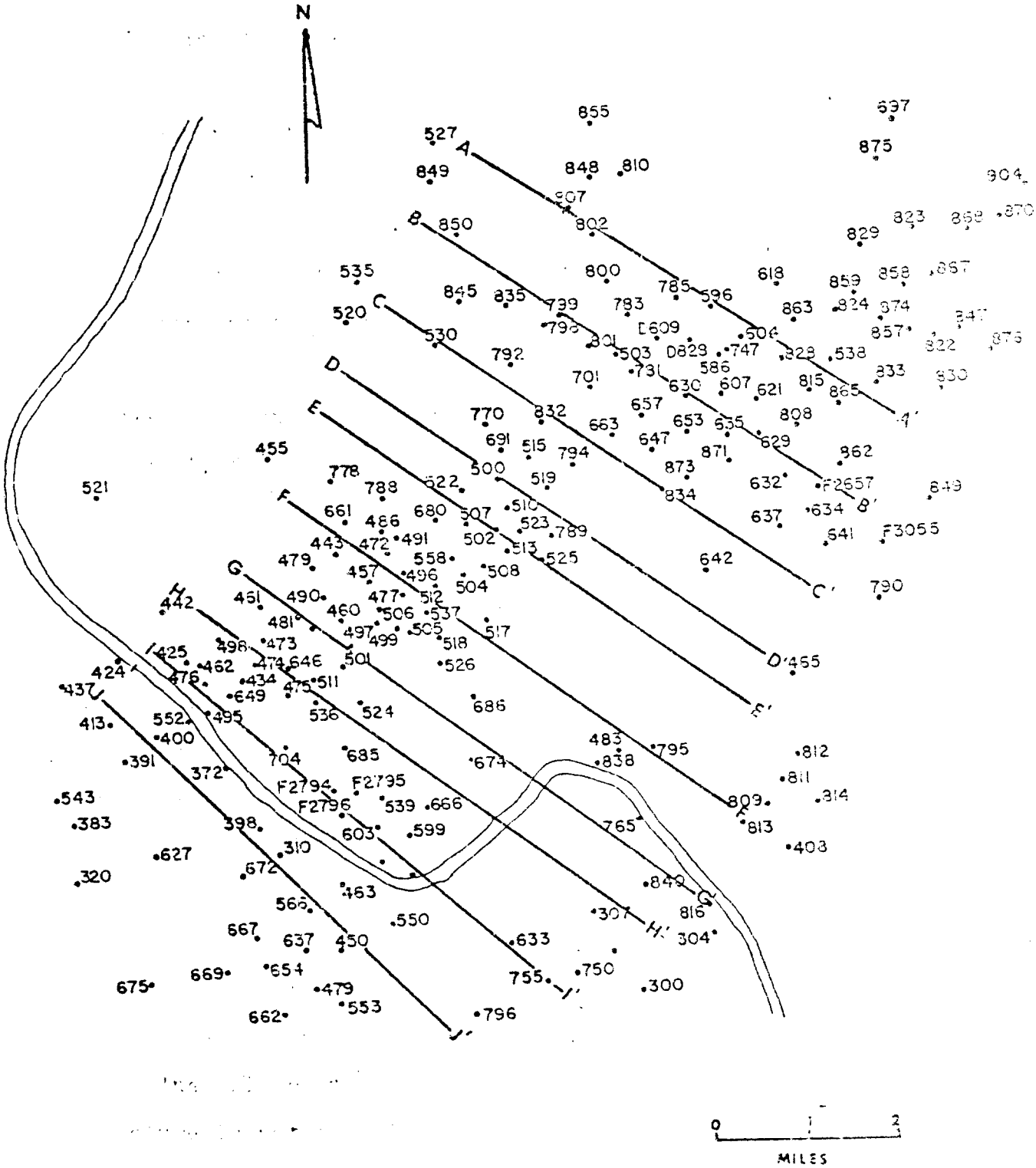
To study the three-dimensional aspect of the production, an isopotential map (figure 20) was prepared based on the initial open flows reported after stimulation. The commercial production in the Midway portion of the field follows the trend of the northwest flank of the structure extending six miles long and less than two miles wide. The production in the Extra portion of the field is not as sharply defined. Seemingly, the production of the field is separated by the north-south trending structural high (compare figures 19 and 20). A series of exaggerated cross-sections (figure 21) was prepared with a cross-section

FIGURE 20

0 1 2
MILES
C.I. = 100
MCF/D

BROWN SHALE ISOPOTENTIAL
OPEN FLOW AFTER STIMULATION

FIGURE 21



INDEX OF CROSS SECTIONS - FIG. 22

PRODUCTION DECLINE CURVE AVERAGE BROWN SHALE WELL N MIDWAY - EXTRA

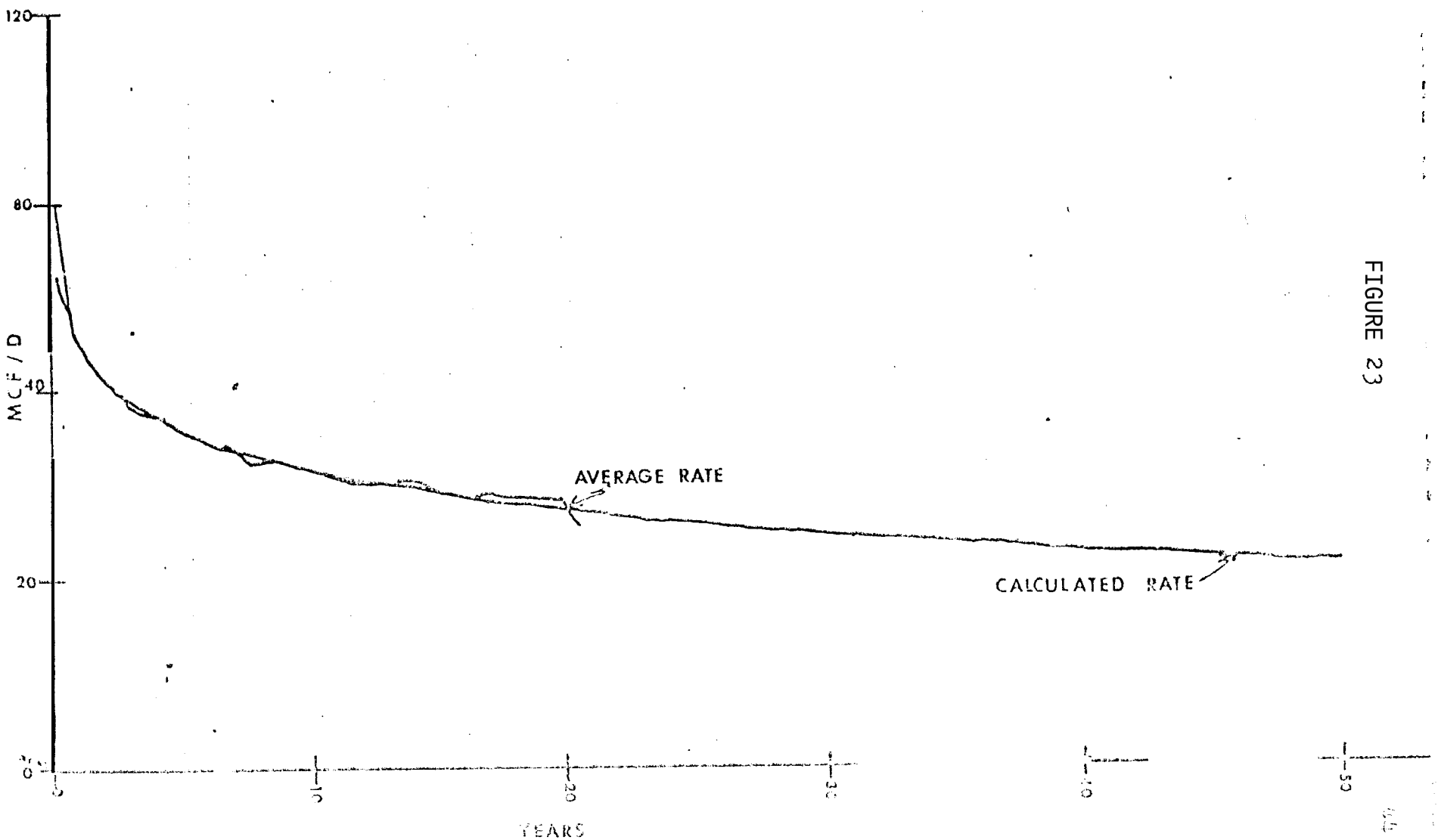


FIGURE 23

TABLE II

FIELD RESERVES

TOTAL NUMBER OF ACRES IN FIELD	14,356
AVERAGE ACRES PER WELL	160
AVERAGE RESERVES RECOVERABLE PER WELL	434 MMCF
RESERVES PER ACRE	2,721 MCF
AVERAGE BROWN SHALE INTERVAL	400 F
AVERAGE TOTAL THICKNESS OF "BROWN" SHALES	250 F
RESERVES PER NET FOOT	0.25 CF

ECONOMIC POTENTIAL

Economic considerations are of paramount importance in the evaluation of geologic prospects presented to the individual or company financing a. well. The cost values of any study are most often related to the present economic conditions or to predicted economic conditions. These values are different from the viewpoint of the independent producer as compared to the consumer. The independent producer evaluates a prospect by using an economic yard-stick (payout time, present worth, rate of return, etc.!. The consumer evaluates the well in terms of recoverable reserves over a given amount of time,

For the producer, economic evaluations are based on the cash flow generated by the production schedule (expected production for a well per unit length of time). For the purposes of this discussion, the production schedule used in the following example is calculated from the decline curve for the average Devonian shale well In the Midway-Extra Field, Private companies and investor.5 do not like to disclose facts such as the price received for the gas, their tax bracket, the anticipated rate of return on their investment, or their investment costs, Therefore, while these data were generally available to the author, specifics of the data could not be published. For the purposes of this writing, general but realistic figures will be used

which do no% reflect any one company's or investor's standards and goals.

The assumptions made are that a Brownshalewell is drilled and completed to a depth of 4000 feet in 1978, and that the field market price of the gas is $1.75/MCF. The initial investment for the well is $116,625 (Table III). Depending upon the drilling and completion methods to be used, costs may vary from $70,000 to $150,000 or more. A production schedule for the average well is given in Table IV. Column (2) is the average rate (in thousand cubic feet per day) that the well is expected to produce each year and Column (3) is the annual production based on 350 days per year. Actual operation of the field has been an average of 114 days on-line production for the first year and an average of 240 days on-line production per year thereafter. Until recently, most of the wells in the field were shut-in during the summer months when demand for production is low. Column (3) of Table V is the cash flow generated per year based on a $1.75/MCF field-market price minus 1/8 paid for royalty and 8.63% paid for the West Virginia Business and Occupation Tax, The cost of producing the well is estimated at $1,800 per year which includes: meter reading, normal field maintainance, overhead, etc. Net operating income, before Federal Income Tax, of $535,112 is given at the bottom of Column (5) of Table V (Column (3) minus operating expense of $1,800 per year).

TABLE III

INITIAL INVESTMENT COSTS

INTANGIBLES

LABOR	$ -2,000
LOCATION (CONSTRUCTION, PERMITS, ETC)	3,150
CONTRACT DRILLING: 4000 ft. @ $9.25/ft.	37,000
DAY WORK: 1 DAY @ $3,000/DAY	3,000
SERVICE RIG: 7 DAYS @ $700/DAY	4,900
SERVICES:	
CEMENTING AND FLOAT EQUIPMENT	1,800
ELECTRIC LOGGING (OPEN HOLE)	3,000
TREATMENT COSTS (FRACTURE)	9,000
PERFORATING AND CASED HOLE LOGGING	2,000
TRUCKING AND DOZER WORK	3,000
OVERHEAD	1,500
CONTINGENCY (5%)	3,500
SUBTOTAL	$ 73,850

TANGIBLES

CASING AND TUBING:	
9 5/8 " 200 ft. @ $10.24/ft.	$ 2,050
7 " 2500 ft. @ $6.53/ft.	16,325
4 1/2 " 4000 ft. @ $3.74/ft.	14,960
2 3/8 " 4000 ft. @ $1.86/ft.	7,440
WELLHEAD ASSEMBLY, METER, ETC.,	1,000
SUBTOTAL	$ 42,775
TOTAL	$116,625

BASIS OF ECONOMIC ANALYSIS

GAS SALES VALUE = $1.75
WORKING INTEREST - ROYALTY(12.5%) = 87.5%
OVERHEAD COST3 = $1,800
MISC. TAXES = 0
B & 0 TAXES = 8.63%
INVESTMENT COSTS = -$116,625
TANGIBLE COSTS = $42,775
INTANGIBLE COSTS = $73,850
SALVAGE VALUE = 0
FEDERAL INCOME TAX BRACKET = 48%
LIFE OF INVESTMENT = 40 YEARS

TABLE IV

PRODUCTION SCHEDULE FOR AVERAGE BROWN SHALE WELL

(1) Year	(2) MCF/DAY	(3) Yearly Production (MCF)	(4) Cumulative (MCF)
1	83.4	29190	29190
2	64.3	22512	51702
3	55.1	19292	70994
4	49.4	17283	88277
5	45.3	15866	104143
6	42.3	14791	118934
7	39.8	13940	132874
8	37.8	13241	146115
9	36.2	12652	158767
10	34.7		
11	33.5	12748	182626
12	32.4	11326	193952
13	31.4	10980	204932
14	30.5	10672	215604
15	29.7	10388	225992
16	29.0	10312	236124
17	28.3	9898	246022
18	27.7	9634	255706
19	27.1	9431	265187
20	26.6	9296	274433
21	26.1	9124	283507
22	25.6	8960	292567
23	24.8	a306	301373
24	14.8	8662	310135
25	24.4	a529	318564
26	24.0	8400	326964
27	23.6	8278	335242
28	23.3	8162	343404
29	23.0	8054	351458
30	22.7	7948	359406
31	22.4	7847	367253
32	22.2	7752	37 5005
33	21.9	7662	382667
34	21.6	7570	393237
35	21.4	7486	397723
36	21.2	7406	405129
37	20.9	7329	412458
38	20.7	7252	419710
39	20.5	7182	426892
40	20.3	7112	434004

TABLE V

NET WORKING INCOME BEFORE FEDERAL INCOME TAX

(1)	(2)	(3)	(4)	(5)
YEAR	MC F/YR	GROSS WORKING INTEREST REVENUE	OVERHEAD	NET WORKING INTEREST BFIT
1978	29190	43697.10	1800.00	39039.70
1979	22512	34471.50	1800.00	29696.60
1980	19292	29540.80	1800.00	25191.40
1981	17283	26464.50	1800.~0	22380.60
1982	15866	24291.80	1800.00	20398.10
1383	14791	22648.70	1800. JO	18394.10
1984	13940	21345.60	1800.00	17703.40
1985	13241	20275.20	1800.00	16725.40
1936	12652	19373.30	1800.00	15331.30
1987	12148	18601.60	1800.00	15196.20
1988	11711	17932.40	1800.00	14584.80
1989	11326	17342.90	1800.00	14046.20
1390	10980	16813.10	1800.00	13562.10
1991	10672	16341.53	1800.00	13131.20
1992	10338	15906.60	1800.00	12733.50
1993	10132	15514.60	1800.00	12375.60
1994	9898	15156.30	1855.30	12048.30
1995	9684	14828.60	1800.00	11743.80
1994	9431	14517.70	1800.00	11461.80
1937	9296	14234.50	1800.00	11206.00
1998	9124	13971.10	1800.00	10365.30
1999	8960	13720.00	1800.00	10735.31::
2000	8806	13484.10	1800.00	10520.40
2001	8662	13263.60	1803.00	10313.90
2032	8529	13060.00	1800.00	10132.90
2303	8400	12562.50	1800.00	9952.40
2004	8'78	12675.60	1800 . GO	9781.60
2305	8162	12498.00	1800.00	9619.40
2006	8054	12332.60	1800.00	9468.20
2007	7348	12170.30	1800.00	9320.00
2008	7847	12015.70	1800.00	9178.70
2009	7752	11870.23	1800.00	9045.80
2010	7662	11732.40	1800.00	8919.80
2011	7510	11499.50	1800.00	8707.10
2012	7486	11462.90	1800.00	8573.60
2013	7406	11340.40	1800.00	8561.70
2014	7329	11222.50	1800.00	8453.90
2015	7252	11104.60	1800.00	3346.20
2016	7182	10997.40	1800.00	6248.30
2017	7112	10890.20	18013.00	8150.37
40	433944	664'458.00	72000.00	535112.00

Taxable income (Column (6) of Table VI) is computed by substracting the net operating cash flow before Federal Income Tax from the sum of the intangible well costs ($73,850), the depreciation of the tangible income ($1,069.37 per year), and the depreciation allowance. The depreciation allowance was computed by multiplying the net income in Column (4) of Table VI by the appropriate depreciation percentage,

The net cash flow after Federal Income Taxes is given in Column (5) of Table VII. A cumulative cash flow (Column (7) of Table VII) of $248,523 is expected with all of the initial investment returned in the seventh year of production,

In order to account for the length of time an investment has, cash flows are discounted. Discounting equates money-on-hand to money received during some point in time, A dollar to be received in 40 years is not worth a dollar today, So, by discounting the dollar to be received, the two are comparable.. The net income of the well after Federal Taxes is discounted at a 16.5% rate and yields the discounted cash flow in Column (5) of Table VIII, The cumulative present worth (Column (6) of Table VIII) at the end of 40 years is $-182,54. The last ten years of production represent 17.1% of the total recoverable reserves, but only contribute 1% of the cumulative net cash flow.

Various criteria are used to rank investments in terms

TABLE VI

INCOME TAX SCHEDULE

(1) YEAR	(2) INTANGIBLE WELL COSTS	(3) DEPRECI-ATION	(4) NET INCOME	(5) DEPRECIATION ALLOWANCE	(6) TAXABLE INCOME	(7) FIT
1978	73850.00	1069.37	-35879.60	0.00	0.00	0.00
1979	0.00	1069.37	28627.20	7583.73	21043.40	10100.80
1980	0.00	1069.37	24122.00	6498.97	17623.00	8459.04
1981	0.00	1069.37	21311.20	5822.19	15489.00	7434.72
1982	0.00	1069.37	19328.70	4373.06	14955.60	7178.68
1983	0.00	1069.37	17824.70	3623.79	14200.90	6816.43
1984	0.00	1069.37	16634.00	3201.84	13432.10	6447.40
1985	0.00	1069.37	15656.00	3041.28	12614.70	6055.05
1986	0.00	1069.37	14831.90	2905.99	11925.90	5724.43
1987	0.00	1069.37	14126.80	2790.24	11336.50	5441.52
1988	0.00	1069.37	13515.40	2689.86	10825.50	5196.24
1989	0.00	1069.37	12976.80	2601.43	10375.30	4980.14
1990	0.00	1069.37	12492.70	2521.96	9970.74	4785.95
1991	0.00	1069.37	12061.80	2451.22	9610.58	4613.07
1992	0.00	1069.37	11664.40	2385.99	9278.41	4453.63
1993	0.00	1069.37	11306.20	2327.19	8979.01	4309.32
1994	0.00	1069.37	10978.90	2273.44	8705.46	4178.62
1995	0.00	1069.37	10679.40	2224.29	8455.11	4058.45
1996	0.00	1069.37	10395.40	2177.65	8217.75	3944.52
1997	0.00	1069.37	10136.60	2135.17	8001.43	3840.68
1998	0.00	1069.37	9895.93	2095.66	7800.27	3744.12
1999	0.00	1069.37	9666.53	2058.00	7608.53	3652.09
2000	0.00	1069.37	9451.03	2022.61	7428.42	3565.64
2001	0.00	1069.37	9249.53	1989.54	7259.99	3484.79
2002	0.00	1069.37	9063.53	1959.00	7104.53	3410.17
2003	0.00	1069.37	8883.03	1929.37	6953.66	3337.75
2004	0.00	1069.37	8712.23	1901.34	6810.89	3269.22
2005	0.00	1069.37	8550.03	1874.70	6675.33	3204.15
2006	0.00	1069.37	8398.83	1849.89	6548.94	3143.49
2007	0.00	1069.37	8250.63	1825.54	6425.09	3084.04
2008	0.00	1069.37	8109.33	1802.35	6306.98	3027.35
2009	0.00	1069.37	7976.43	1780.53	6195.90	2974.03
2010	0.00	1069.37	7850.43	1759.86	6090.57	2923.47
2011	0.00	1069.37	7637.73	1724.94	5912.79	2838.13
2012	0.00	1069.37	7604.23	1719.43	5884.80	2824.70
2013	0.00	1069.37	7492.33	1701.06	5791.27	2779.80
2014	0.00	1069.37	7384.53	1683.37	5701.16	2736.55
2015	0.00	1069.37	7276.83	1665.69	5611.14	2693.34
2016	0.00	1069.37	7178.93	1649.61	5529.32	2654.07
2017	0.00	1069.37	7081.00	1633.53	5447.47	2614.78
40	73850.00	42772.70	418487.00	100253.00	354110.00	169971.00

TABLE VII

NET WORKING INCOME AFTER FEDERAL INCOME TAX

(1) YEAR	(2) NET WORKING INTEREST BEFORE FIT	(3) FEDERAL INCOME TAX	(4) NET WORKING INTEREST AFTER FIT	(5) SALVAGE INVESTMENT	(6) NET CASH FLOW	(7) CUMULATIV CASH FLOW
1978	39039.70	0.00	39039.70	-116625.00	-77585.30	-77585.30
1979	29696.60	l'JlC0.83	19595.80	0.03	19595.80	-57989.50
1980	25191.40	3459.04	16732.30	0.03	16732.30	-41257.20
1931	22380.60	7434.72	14945.80	0.00	14945.80	-26311.40
i982	20398.10	7178.68	13219.40	0.00	13219.40	-13092.00
1983	18894.10	6816.43	12077.60	0.00	12077.60	-1014.40
1984	17703.40	6447.40	11256.00	0.00	11256.00	10241.60
1985	16725.40	6055.05	10670.30	0.00	10670.30	20911.90
1936	15901.30	5724.43	10176.80	0.00	10176.80	31088.70
'1937	15196.20	51111.52	9754.63	0.00	9754.68	40843.38
1988	14584.80	51'36.24	9383.56	0.00	9388.56	50231.94
1989	14046.20	4380.14	9056.06	0.00	9066.06	59298.00
1990	13562.10	4725.95	8776.15	0.00	8776.15	68074.15
1991	13131.20	4613.07	8518.13	0.00	8518.13	76592.28
1992	12733.80	4453.63	6280.17	0.00	8280.17	84872.45
1993	12375.60	43C9.92	8065.68	11.00	8065.68	92938.13
1994	12048.30	4178.62	7369.68	0.00	7869.68	100807.81
1995	11748.80	4058.45	7690.35	0.00	7690.35	108498.16
1996	11464.80	3944.52	7520.26	0.00	7520.28	116018.44
1997	11206.00	3840.68	7365.32	0.00	7365.32	123383.76
1398	10965.30	3742.12	7221.18	0.00	7221.18	130604.94
1939	10735.90	3652.09	7053.81	0.00	7083.81	137688.75
2000	10520.40	3565.64	6954.76	0.00	6954.76	144643.51
2001	10318.90	i484.79	6834.11	0.00	6834.11	151477.62
2002	10132.90	3410.17	6722.73	0.00	6722.73	158200.35
2003	9952.40	3337.75	6614.65	0.00	6614.65	164815.00
2004	9781.60	5269.22	6512.38	0.00	6512.38	171327.38
2005	9619.40	3204.15	6415.25	0.00	6415.25	177742.63
2006	9r68.20	3143.49	6324.71	0.00	6324.71	184067.34
2007	9320.00	3084.04	6235.96	0.00	6235.96	190303.30
2338	9178.70	3027.35	5151.35	0.00	6151.35	196454.65
2009	9045.30	2974.03	6071.77	0.00	6071.77	202526.42
2010	8913.80	2923.47	5995.33	0.00	5996.33	208522.75
2011	8707.10	2638.13	5868.97	0.00	5868.97	214391.72
2312	8673.60	2824.70	5848.90	0.00	5848.90	220240.62
2013	8561.70	2779.80	5731.90	0.00	5781.90	226022.52
2014	8~53.90	2736.55	5717.35	0.00	5717.35	231739.87
2015	8346.20	2633.34	5652.86	0.00	5652.86	237392.73
2015	8248.30	2654.07	5594.23	0.00	5594.23	242986.96
2017	3153.37	2614.78	5535.59	0.00	5535.59	248522.55
40	535112.00	169971.00	355130.00	-116625.00	248509.00	

TABLE VIII

NET INCOME AFTER FEDERAL INCOME TAX DISCOUNTED AT 16.5%

(1) YEAR	(2) NET AFIT	(3) DISCOUNT FACTOR	(4) DISCOUNT AFIT	(5) DISCOUNT CASH FLOW	(6) CUMULATIVE CASH FLOW
1978	39039.70	0.92648	36169.58	-71881.39	-71831.39
1979	19595.80	0.79526	12583.83	15583.83	-56297.57
1980	16732.30	0.68263	11421.97	11421.97	-44875.60
1981	14945.80	0.58595	8757.47	8757.47	-36118.14
1982	13219.40	0.50296	6648.83	6648.83	-29469.31
1983	12077.50	0.43173	5214.20	52.14. 20	-24255.10
1984	11256.50	0.37058	4171.24	41.71.24	-20083.86
1985	10670.30	0.31809	3394. 16	3394.16	-16685.75
1986	10176.80	0.27304	2778.6':	2778 .69	-13911.01
1987	9754.68	0.23437	2236.21	2286.21	-11624.79
1988	9388.56	0.20118	1888.76	1888.76	-9736. 03
1989	9066.06	0.17268	1565.56	1555.56	-8170.47
1990	8776.15	0.14823	1300.86	1300.86	-6869.61
1991	8518.13	0.12723	1083.79	1083.79	-5785.82
1992	8280.17	0.10921	904.30	904.30	-4381.52
1993	8065.68	0.09375	756.12	756.12	-412 5.40
1994	7869.68	0.08047	633.26	633.26	-3492. 15
1995	7690.35	0.06907	531.13	531.18	-2960.97
1996	7520.28	0. c5929	445.87	445.87	-2515.10
1997	7365.22	0.05089	374.33	374.33	-2140.27
1998	7221.18	0.04368	315.45	315.45	-1824.82
1999	7083.31	0.03750	265.62	265.62	-1559.20
2000	6954.76	0.03219	223.85	223.85	-1335.36
2001	6834.11	0.02763	188.81	188.81	-11~6.55
2002	6722.73	0.02371	159.43	159.43	-987.12
2003	6614.65	0.02036	134.65	134.65	-852.48
2004	6512.18	0.01747	113.79	113.75	-733.59
2005	6415.25	0.31500	96.22	96.22	-642.47
2006	6324.71	0.01287	81.42	81.42	-561.05
2007	6235.96	0.01105	68.91	58.91	-492.13
2008	6151.35	0.00949	58.35	58.35	-433.79
2009	6071.77	0.30814	49.44	49.44	-384.35
2010	5996.33	0.00699	41.91	41.91.	-342.44
2011	5868.97	0.00600	35.21	35.21	-337.23
2012	5948.90	0.00515	30.12	30.12	-277.12
2313	5781.90	0.00442	25.56	25.56	-251.56
2014	3717.35	0.00379	21.69	21.69	-229.87
2015	5652.86	0.00326	18.41	18.41	-211.46
2016	5594.23	0.00230	15.64	15.64	-195.32
2017	5535.59	0.00240	13.28	13.28	-18 2.54
40	365130.00	0.00000	107868.44	-182.54	

of their profitability. The most common yardsticks used in the Appalachians are the profits-to-investment ratio (P/I ratio), payout, and the rate of return. The ?/I ratio for the well *has* a yield of 2.13 which means for every dollar invested, 2.13 dollars will be returned. The P/I ratio,. when multiplied by 100%, yields the total percent profit generated by the investment, or 213%. Payout is an index which states when the initial investment will be returned. The payout for the initial investment of $116,625 will occur in the seventh. year which is a relatively high index. The rate of return is an index which takes time into account by discounting the Cash flows, It is the percentage which discounts the net working income after Federal Taxes to zero. The rate of return for the example well is 16.5% which is good when compared to an excellent rate of 20%.

From an investor's viewpoint, a Brown shale well is a good investment,. particularly because of the relatively low drilling Costs (low initial investment) and the low risk. (Under5% of the wells drilled in the field were plugged after reaching total depth.) Because all the wells in the field were shot, the decline curve of the production schedule for the example well. would be lower than a modern-day fractured well. The hydro-fractured well should result in accelerated production, increasing the profi tability indices.

Consumers of natural gas are of two types; the resi-

dential and the commercial users. The residential consumer is dependent upon the gas producer and the gas utility to supply their product at rates comparable to other forms of energy. Under a free market, the gas price will undoubtedly rise to a price comparable to the cost of other forms of energy. The producer can then achieve more effective gas recovery and will achieve profits comparable to other investments, While the effect on the consumer will be higher cost, it will be to the consumer's advantage because he will have a relatively long term supply cf gas, The commercial user of natural gas has the option of either passing the Increased cost on to his customers, or if he is capable, he can develop his own reserves. The last option is occurring more often today in Brown shale producing areas because of the relatively inexpensive, long-term reserves and the low well maintainance and initial investment costs, If a company were to borrow capital for the development of a well for its *own* use, the average cost over a 40 year period would be approximately $.51/MCF using the same assumptions previously stated, The free market price is now $1.75/MCF (1978). With deregulation of prices, it will probably climb higher.

The recent curtailments of natural gas to the larger industrial consumers during the winter of 1977-78 have made us aware of the fact that the price of gas Is perhaps not as important as the supply of natural gas, From the stand-

point of future planning and growth, the commercialconsumer dependent upon natural gas should obtain Long-range (30 to 40 years) rather than accelerate3 supplies.

CONCLUSIONS

The Midway-Extra Devonian shale field began production in the late 1940's, and it is still a viable expanding field, Initial drilling was projected to the Oriskany Sandstone interval with upper pays as secondary targets. The shale producing trend was soon established, and most of the drilling had been completed by the late 1950's. From 1974 to the present, drilling development and step-out wells have been tied to increased well-head price and the need for long range reserves,

The stratigraphy of the Brown shale portion of the Devonian shale is characterized by a zone of kerogen-rich shales alternating with gray shales. 'Total average thickness of the Brown shale (Lower Huron) is 400 feet with 50 to 70% brown to black (colored) shales. The zone thickens to the east, but as it thickens, it becomes less rich in kerogen-rich shales. The zones of Brown shales probably represent times of decreased clastic deposition. The thickness of the Brown shales is greater in synclines adjacent to structures, suggesting that these were growing during Late Devonian time,

Structurally, the field includes several synclines and anticlines. The dominate feature is the Midway anticline, a growth structure, striking N60°E, which can be traced 'from the study area into Kentucky. Intersecting

the Midway Anticline is a low relief north-south structura high which extends northward out of the study area,

Brown shale production is from the top and middle portions of the Brown shales with an indication that the less dense and more kerogen-rich portions of the shale are more productive. The relationship between production and structure suggest that the gas production is from a fracture system developed by stresses during or after folding. For reasons not readily apparent, the main fracture porosity is situated on the flank of the northwestern structure near the adjacent syncline. Wells drilled on the crest of the Midway Anticlins have resulted in dry holes or wells with low production. Structure and isopotential maps are useful tools in delineating production trends. The combined use of these maps allows one to predict the relationship of production to structure and foliow an exploration rationala rather than resorting to a random drilling program.

The reserves for the average shale well in the field is limited by the number of years the well is capable of producing, not by the rate of production, The average well. to date has produced less than half of the estimated 434 million cubic feet of recoverable reserves, The time to recover investment costs within the present economic framework is 7 years,

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APPENDIX A

Sub-sea Elevations and Initial Open Flows

Used in the Preparation of Scb-surface Mapping

SUB-SE.5 ELEVATION

PERMIT NUMBER	ELEV.	TOP BEREA	TOP BR. SH.	BASE BR. SH	IOF	FOF/HR	PRESS/HR
300	882	-1495	-2683	-3137	58	246/13	820/18
304	566	-1532	-2725	-3169	24	60/16	NA
307	926	-1524	-2734	-3135	HA	NA	NA
310	589	---	m-	---	---	---	---
320	572	-1474	---	---	---	---	---
372	534	-1539	-2696	-3066	NA	150/NA	NA
333	634	-1527	---	---	---	---	---
389	534	-1608	-2801	-3186	26	327/27	880/24
391	593	-1615	-2735	-3134	150	251/NA	850/96
398	658	-1550	-2738	-3122	84	111/NA	NA
400	573	-1620	-2728	-3099	NA	313/NA	NA
408	602	-1533	-2768	-3245	54	133/1	885/72
413	594	-1629	-2739	-3137	NA	1007/3	NA
424	579	-1645	-2771	-2955	Show	329/3	NA
425	618	-1637	-2782	-3132	Show	329/8	900/48
434	613	-1659	-2767	-3162	NA	553/6	NA
437	604	-1632	-2771	-3086	NA	520/1	NA
442	592	-1641	-2773	-3148	Show	103/NA	NA
443	952	-1679	-2798	-3218	94	495/NA	900/24
444	857	-1659	-2823	-3188	NA	800/1	NA
445	798	-1648	-2767	-3156	15	24/19	NA
450	601	-1582	---	-3149	Nh	500/4	NA
455	889	-1695	-2331	-3431	12	NA	NA
457	883	-1630	-2504	-3231	184	987/NA	900/72
460	839	-1641	-2301	-3168	Show	939/NA	950/24
461	622	-1688	-2758	-3193	18	1265/1	NA
462	729	-1526	-2761	-3126	15	325/NA	650/NA
463	627	-1599	-2797	-3193	18	377/2	NA
465	939	-1610	-2888	-3336	7	152/1	780/96
472	750	-1675	-2805	-3234	103	298/30	900/46
473	706	-1679	-2807	-3209	30	750/2	NA
474	707	-1703	-2852	-3249	21	750/NA	NA
475	661	-1599	-2759	-3147	231	1164/NA	180/1
476	591	-1691	-2784	-3227	show	603/NA	NA
477	928	-1647	-2837	-3212	377	2499/NA	NA
479	755	-1592	-2753	-3125	NA	152/NA	NA
481	898	-1662	-2809	-3167	45	140/NA	200/2
482	655	-1600	-2760	-3157	238	848/2	175/1
483	591	-1534	-2769	-3189	NA	NA	NA
486	835	-1717	-2725	-3065	21	1175/1	NA
490	700	-1563	-2831	-3195	30	193/11	200/3
491	893	-1670	-2837	-3237	Show	315/NA	300/2
495	572	-1630	-2743	-3124	50	NA	NA
496	901	-1657	-2829	-3209	NA	367/NA	738/21
497	662	-1642	-2773	-3199	30	60/NA	NA
498	603	-1657	-2767	-3077	21	200/NA	NA
499	787	-1624	-2797	-3165	NA	377/NA	200/1
500	876	-1657	-2819	-3239	15	620/NA	120/2
501	835	-1597	-2770	-3151	327	827/NA	125/1
502	870	-1662	-2820	-3230	NA	1009/NA	800/24
503	621	-1691	-2399	-3311	15	412/NA	130/2
504	920	-1641	-2815	-3221	NA	852/NA	750/24
505	811	-1599	-2729	-3139	260	NA	NA
506	678	-1628	-2776	-3181	NA	499/NA	245/1

SUB-SEA ELEVATION

PERMIT NUMBER	ELEV.	TO? BEREA	TO? BR. SK.	BASE BR. SH	IOF	FOF/HR	PRESS/HR
507	886	-1654	-2538	-3252	37	202/18	787/92
508	864	-1658	-2836	-3224	73	511/NA	NA
510	811	-1618	-2779	-3209	21	660/NA	95/1
511	838	-1592	-2746	-3117	103	379/NA	NA
512	914	-1636	-2815	-3222	158	1961/NA	NA
513	923	-1652	-2882	-3218	326	781/NA	800/NA
515	865	-1647	-2822	-3235	73	169/10	405/13
517	654	-1578	-2746	-3158	NA	48/51	865/240
518	437	-1596	-2729	-3153	NA	84/NA	NA
519	880	-1641	-2830	-3248	20	78/30	850/168
520	820	-1645	-2820	-3180	NA	2 1/NA	NA
521	712	-1547	-2613	-2 78	NA	N A	NA
522	873	-1645	-2762	-3232	15	14 5/NA	810/72
523	901	-1619	-2796	-3109	NA	1 00/NA	710/24
524	834	-1549	-a-	-3076	5	35 8/NA	NA
525	932	-1594	-2891	-3208	Show	NA	NA
526	910	-1564	-2735	-3121:	Show	NA	NA
527	925	-1622	-2740	-3185	Show	23/15	NA
530	623	-1655	-2825	-3203	21	336/1	960/26
535	715	-1649	-2803	-3209	Show	14/23	NA
536	897	-1577	-2695	-3112	21	381/NA	70/1
537	920	-1623	-2794	-3196	174	j 0 0/NA	NA
538	955	-1671	-2853	-3339	24	211/1	930/96
539	621	-1604	-2724	-3199	15	327/NA	420/16
543	540	-1644	-2740	-3130	24	250/1	NA
550	823	-1566	-2752	-3147	39	79/15	NA
552	581	-1614	-2740	-3109	NA	876/1	NA
553	542	-1543	-2728	-3144	NA	152/NA	700/NA
558	a97	-1661	-2828	-3209	33	14 6/NA	41/1
566	916	-1.597	-2778	-3185	NA	70/24	NA
586	854	-1716	-2926	-3334	60	103/NA	825/48
596	684	-1704	-2941	-3346	33	119/NA	850/62
599	601	-1612	-2766	-3194	7	158/25	800/96
603	598	-1610	-2782	-3188	28	424/8	NA
604	596	-1715	-2927	-3335	18	60/NA	855/72
607	813	-1702	-2909	-3347	15	198/29	880/72
613	608	-1508	-2742	-3237	S how	158/NA	710/NA
618	634	-1694	-2920	-3344	24	73/29	870/72
621	628	-1677	-2893	-3305	47	189/24	890/48
624	933	-1557	-2769	-3247	Show	NA	NA
627	638	-1475	-2622	-2959	Show	15/48	NA
629	840	-1663	-2865	-3308	56	246/NA	920/42
630	848	-1694	-2892	-3304	Show	84/NA	790/72
632	668	-1627	-2849	-3295	29	207/NA	840/24
633	604	-1507	-2708	-3126	NA	43/NA	400/44
634	913	-1622	-2345	-3272	11	61/NA	760/72
635	830	-1685	-2873	-3295	158	231/NA	875/48
637	923	-1620	-2826	-3282	21	60/28	820/72
638	575	-1583	-2719	-3171	a	158/30	790/96
639	647	-1604	-2788	-3172	s how	i 0 3/NA	NA
641	907	-1638	-2856	-3323	Show	57/29	680/72
642	992	-1604	-2806	-3247	NA	43/21	NA
646	660	-1635	- 2784	-3170	Show	3 5/NA	480/168
647	905	-1685	-2879	-3315	89	273/NA	800/96
649	777	-1626	-2748	-3159	14	94/32	NA

SUB-SEA ELEVATION

PERMIT NUMBER	ELEV.	TOP BEREA	TOP BR. SH.	BASE BR. SH.	IOF	FOF/HR	PRESS/HR
653	918	-1678	-2877	-3320	56	169/NA	765/96
654	921	-1536	-2736	-3119	Show	163/NA	NA
657	909	-1710	-2901	-3336	Show	103/32	750/96
661	915	-1679	-2790	-3225	10	60/NA	780/144
662	841	-1504	-2691	-3069	NA	110/NA	NA
663	833	-1688	-2887	-3292	Show	84/23	640/72
666	646	-1609	-2749	-3198	Show	146/24	745/Max
667	956	-1609	-2814	-3214	24	NA	NA
669	737	-1673	-2813	-3208	Show	55/NA	NA
672	924	-1557	-2724	-3096	133	231/NA	NA
674	917	-1600	-2993	-3208	NA	56/NA	NA
675	656	-1589	---	---	NA	NA	NA
680	672	-1675	-2845	-3228	39	112/29	540/120
685	864	-1544	-2706	-3077	Show	39/3	NA
686	584	-1565	-2758	-3164	NA	NA	NA
691	862	-1661	-2818	-3238	Show	66/NA	585/192
697	970	-1705	-2915	NA	NA	NA	NA
701	601	-1686	-2874	-3305	Show	119/NA	740/264
704	604	-1544	-2696	-3066	Show	25/19	NA
747	896	-1706	---	---	NA	NA	NA
750	828	-1490	---	---	NA	NA	NA
755	592	-1478	-2680	-3098	Show	NA	NA
765	584	-1548	-2716	-3141	NA	NA	NA
770	844	-1665	---	---	Show	NA	NA
778	849	-1662	---	---	NA	NA	NA
781	608	-1698	-2892	-3327	Show	60/24	660/168
783	809	-1713	-2907	-3339	Show	202/24	855/168
785	629	-1706	-2905	-3347	Show	119/19	775/168
788	914	-1672	-2836	-3232	Show	84/24	675/168
789	911	-1625	-2804	-3226	Show	127/24	595/168
790	912	-1645	-2866	-3344	Show	119/24	715/72
792	842	-1650	---	---	17	47/NA	NA
794	838	-1646	-2828	-3258	Show	73/11	565/192
795	609	-1589	---	---	NA	NA	NA
796	629	-1486	---	---	NA	NA	NA
797	799	-1510	-2718	-3153	NA	26/NA	NA
798	595	-1658	-2836	-3257	NA	94/18	950/Max
799	782	-1677	-2849	-3276	NA	94/13	900/168
800	879	-1719	-2911	-3344	NA	239/NA	950/168
801	612	-1680	-2876	-3294	NA	119/17	785/168
802	628	-1676	-2862	-3292	NA	283/16	950/NA
807	634	-1644	-2822	-3244	NA	84/NA	925/NA
808	644	-1644	-2846	-3306	NA	179/NA	760/NA
809	635	-1566	-2782	-3237	NA	315/NA	785/NA
810	696	-1690	-2886	-3304	Show	36/24	NA
811	666	-1590	-2804	-3268	Show	492/NA	650/NA
812	739	-1611	-2829	-3293	Show	103/NA	750/NA
813	732	-1546	-2764	-3220	NA	73/NA	700/NA
814	928	-1572	-2782	-3250	Show	73/NA	720/NA
815	958	-1662	-2862	-3322	NA	163/NA	710/NA
816	583	-1536	-2743	-3192	NA	60/18	560/NA
822	975	-1695	-2899	-3335	NA	386/4	890/NA
823	660	-1680	-2887	-3366	NA	160/4	770/NA
824	852	-1693	-2898	-3368	NA	329/5	830/NA

SUB-SEA ELEVATION

PERMIT NUMBER	ELEV.	TO? BEREA	TOP BR. SH.	BASS BR. sii.	IOF	FOF/HR	PRESS/HR
828	942	-1684	-2888	-3346	NA	82/NA	725/NA
829	625	-1720	-2935	-3405	NA	350/4	865/NA
830	711	-1661	---	---	NA	280/4	860/NA
832	852	-1648	-2816	-3235	40	NA	530/NA
833	910	-1695	-2905	-3380	NA	270/5	840/NA
834	897	-1669	-2871	-3313	103	NA	649/NA
835	---	a--	---	---	NA	NA	NA
838	se-	w--	---	---	NA	NA	NA
840	---	a--	---	---	NA	NA	NA
845	---	w--	a--	---	NA	NA	NA
847	650	-1688	-2906	-3395	Show	332/24	925/NA
848	927	-1665	-2851	-3282	NA	NA	NA
849	---	---	---	---	NA	NA	NA
850	---	---	e_m-	---	NA	NA	NA
855	980	-1638	-2820	-3250	NA	NA	NA
857	949	-1695	-2906	-3388	42	322/5½	850/NA
858	662	-1695	-2904	-3383	25	385/4½	800/NA
859	833	-1695	-2906	-3378	27	582/3½	850/NA
862	920	-1655	-2850	-3328	NA	200/4	895/NA
863	800	-1688	-2890	-3350	NA	NA	NA
865	850	-1663	-2870	-3333	NA	120/4	705/NA
867	926	-1708	-2918	---	NA	NA	NA
868	990	-1694	-2910	---	18	120/4	810/NA
870	925	-1707	-2927	---	13	395/4	860/NA
871	863	-1615	-2815	-3.262	NA	NA	NA
873	918	-1660	-2844	-3282	NA	NA	NA
874	666	-1684	-2896	-3372	8	170/4	780/NA
875	480	-1709	-2918	-3392	16	280/4	920/NA
876	673	-1685	-2905	-3403	15	280/4	920/NA
904	---	---	---	---	NA	NA	NA
D609	612	-1708	-2794	-3293	NA	146/24	900/Max
D828	518	-1700	-289S	-3343	Show	103/24	525/15
F2657	---	-1626	---	---	NA	NA	NA
F2794	590	-1572	---	---	NA	NA	NA
F2795	573	-1591	w_e-	e_m-	NA	NA	NA
F2796	590	-1599	---	---	NA	NA	NA
F3055	---	---	---	---	NA	NA	NA