RESULTS OF A PILOT STUDY OF COTTAGEVILLE FIELD, JACKSON AND MASON COUNTIES, WEST VIRGINIA

by

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ABSTRACT

Gas production data from 63 wells in the Cottageville Gas Field, producing from Devonian shales, are studied in relationship to structure above and below the producing horizons, isopach data and dip aspects including highest annual production, first five years accumulated production, total accumulated production, mean annual production, initial well pressure, and calculated loss ratio values for four (4) different time periods.

A trend correlation of these parameters is presented.

It is concluded that this approach could be useful in gas exploration and development evaluation of Appalachian Devonian shale gas fields.

INTRODUCTION

The purpose of this study is to apply various methods of gas production data analysis to gas field data in order to objectively evaluate and explore relationships in the production history of the Cottageville gas field in the Devonian shale. An understanding of such relationships may contribute to estimation of recoverable reserves and to conclusions or hypotheses in the study area which may be applied to other potential gas producing shale areas.

The scope of the study is the gas production from 63 wells from Devonian shales in the southwestern Jackson County and eastern Mason County. This paper represents a step further in analysis and conclusions from a paper by the authors in 1977 (de Wys and Shumaker, 1977).

Devonian shales underlie approximately 1000,000 square miles in Kentucky, Ohio, West Virginia, Pennsylvania, and New York. It has been estimated that this area contains about 460 trillion tons of shale readily accessible to drilling, and most of this at about 10,000 feet in depth (Columbia Gas System).

The horizon of "brown shales" from which most gas has been produced is a 400' section with finer grain size, darker colors with spores and brown algae (Protasalvinia) reported. Above this zone is 1,200 feet of gray to greenish-gray shales with sandy and silty zones and a dark gray to black interval. Grain size coarsens upward from the producing horizon. Below the producing horizon is 300-400 feet of lower black shale, calcareous in the bottom portion (Tully Is.). Gas has been produced from the Brown Shale horizon for nearly 50 years from low-volume shallow wells in the western one-third of West Virginia.

Up to 4.4% by weight organic content is found in the brown shales.

Porosity in Devonian shales is very low. In two Jackson County wells in West Virginia, porosity ranged from .1 - 4.6% with overburden of 1650 PSI and 3700 PSI (obtained by oil method). By comparison, highly productive sandstone reservoirs show 10-20% of total rock volume. Most pore space found in shales is between the mineral crystals or grains and in micro and macrofractures (Science Applications, Inc., 1977).

Permeability values for the same two Jackson County wells range from .0001 - .001 Md with overburden pressures of 1650 and 3700 PSI. This is very low permeability which limits the rate of gas production by the rate at which gas can diffuse through the matrix and reach a free surface such as a bore hole or a fracture. Compared with sandstones this results in low production rates, but extended production life. Clastic silt-size quartz and feldspar are commonly segregated into lenses parallel to bedding in the very dark, organic-rich shale specimens. Higher permeability in such lenses may permit migration through such silt zones to accumulation fracture facies areas.

Mineral lined vertical fractures were commonly noted in the pay zones of two wells in western and southwestern West Virginia. In one core from western West Virginia filled and unfilled natural fractures resemble parts of nearly vertical systematic joints (Wheeler, et. al). The fractures strike N 40° - 50° E above the pay zone, and show four dominant orientations within the pay zone. As noted earlier a higher percentage of total production appears to be the result of absorbed (matrix) and adsorbed (on fracture surfaces) than from free gas. Wheeler, et al. suggest that fracture density on a larger scale may be influenced by old or reactivated suballochthon faults, by allochthony itself, by erosional release, or by two or more of these factors interacting. They further suggest slickensides can seal fractures and thus decrease permeability.

Rogers (1971) concludes from stratigraphic evidence that after a period of extensional tectonics accompanying the main subsidence, a period of true compression ensued in late Mississippian to early Permian time during which the final group of clastic sediments were deposited and the whole section deformed.

The outline of Brown shale production in West Virginia coincides strikingly with the trend of the Rome Trough. Martin and Nuckols (1976) postulated that fractures in the Devonian shales in the gas-producing areas result from reactivated movement of the basement fault blocks comprising the Rome Trough. Weaver, 1972, noted the relationship of the structure to Devonian gas production. The basement structure and magnetic intensity values in the Cottageville area (Shumaker, 1978) show the magnetic intensity contours are closely correlated with the edge of the Rome Trough which comprises a valley rift system on the Precambrian basement level. It is reasonable to assume that fracture facies developed over fault movements associated with the Rome Trough structure.

The term fracture facies is proposed for use in certain Devonian shales with the following definition of the term: rock facies containing fractures that occur over a wide area within a distinct stratigraphic interval. As applied to Cottageville field, the image conveyed is similar to a stratigraphic trap - but one where the porosity is caused by laterally limited fracture porosity with a distinct stratigraphic interval.

Data

Production data has been used as given. No standardization or altering of the data has been attempted. The complete data analysis includes mapping of production data in various relationships and decline curve analysis by computer programs and historical relationships. The comparison of production data map trends to trends of geological factors is presented here. This includes the following maps: (See Figures 1-11).

Drilling Completion Dates,
Isocontours of Highest Annual Production (1st or 2nd year production),
Isocontours of First Five Years Accumulated Gas Production,
Isocontours of Total Accumulated Production,
Isocontours of Mean Annual Gas Production,
Loss Ratio Isocontours for First Year of Gas Production Decline,
Loss Ratio Isocontours for Second Year of Gas Production Decline,
Loss Ratio Isocontours for Third Year of Gas Production Decline,
Loss Ratio Isocontours for Gas Production Decline from 1st to 5th Year of Production,
Structure Contours on Top of the Onondaga,
Structure Contours on the Bottom of the Huron Shales,

Isopressure Contours of Initial Well Pressures,
Basement Structure and Magnetic Itensity, and Fracture Facies Orientation and Devonian Shale Dip and Strike.

Gas production data was tabulated by the year. From this tabulation the highest annual production, accumulated total production, first five years accumulated production, and mean production are computed. Most of these computations are fairly standard procedure, however, less ratios may be unfamiliar. Loss ratios (Arps, 1944; Campbell, 1973) are computed in this study as follows:

$$d = \frac{q_1 - q}{q_1}$$

where: d = fraction or percent production lost

$q_1 - q$ = The gas production for the first year considered less the gas production for the second year considered.

q_1 = The gas production for the first year considered.

The resultant value represents the slant of the gas production decline curve for the period under consideration. Loss ratio values are computed for 1-2 years, 2-3 years, 3-4 years, and 1-5 years.

Structure contour maps are shown for the top of the Onondaga below the Devonian shales and for the structure at the bottom of the Huron shales which overlie the producing Devonian shales. The trend strike of the Devonian shale isopachs (N 6° E) is also used in the map comparison.

Isopressure contours are drawn on the initial pressure data obtained following well completion. No adjustment of pressure data to standardize these data has been attempted.

DISCUSSION AND CONCLUSIONS

Erwin, et al. (1976) described the problem of the Devonian shales as the nature, cause, timing of fractures, relation to regional stress and structural patterns below, within, and above the Devonian shales. This pilot study of gas production analysis methods applied to a portion of the Cottageville Field is an attempt to look at these relationships in terms of axial trends to examine what correlations may exist. Highest annual production could be indicative of porosity, fractures (permeability), gas entrapment, migration, and possibly connection with other wells (when compared with chronology of drilling). First five years total accumulation may represent aspects of permeability, total gas reserves, and gas pressures. Total accumulation should reflect all the factors related to first five year production plus a stronger indication of permeability, and reserves. Mean of Total Accumulation may show a field porosity trend and permeability interrelationship of wells. This may be one of the better indicators of reserves. Loss Ratio maps are related to permeability, pressure, and supply.

The production data, calculated production decline, and geological data computed for each well is contoured on a series of maps. The trends of the contour axes on each map are traced onto a common overlay and these trends are tabled according to correlation of trend angle with other sections of the study area. For a comparison of major map trends of the geologic, production, and production decline, the trends are plotted on a compass rose in Figure 12. It can be observed that the angular relationship is very restricted and not a broad interval. The strike of the basement magnetic survey trends relate to the first five years cumulative production and initial pressure. The dip again relates to initial pressure as well as production decline the 1-2 years. These relationships suggest the basement affects collection and availability of free gas as compared with adsorbed or absorbed gas.

The strike of structure on the top of the Onondaga limestone relates to highest annual production, first five years cumulative production, total production and the fracture facies direction (40-50° NE) of 80% of fractures in the Baler well above the gas zone and 21% in the production zone. The dip of the Onondaga relates to total production, mean annual production, and initial gas pressure. The top of this more brittle rock, as compared with shale, may represent the lower control, which reflects the basement, on the formation of fracture facies. Differential compaction of the shales over basement structures and faults may be the causal agent in fracture facies formation.

The strike on the bottom of the Huron shales relates to production decline trends both for the 3-4 years and 1-5 years. The dip relates to total production, mean annual production and initial pressure. The production decline trends for 2-3 years is also very close. The difference is possibly due to structure anomalies. Thus, the structure on the bottom of the Huron appears to affect permeability, as reflected in the slope of production decline curves.

The fracture facies orientations taken from the CGSC #11940 well in Jackson County (Larese and Heald, 1977) show three predominant directions. The main direction is 40-50° NE and relates to five production maps: highest annual production, first five years production, total production, mean annual production, and initial pressure. This strike direction is also related to strike of the top of the Onondaga limestone and to the production decline map 1-2 years. Thus the major fracture facies direction is strongly correlated with free gas accumulation and availability, and this trend is similar in its lower limits to the top of the Onondaga. This fact as mentioned above may relate to the genesis of the fractures.

The strike of structure on the top of the Devonian is the same as that on the basement magnetic survey map and thus relates to the same production and decline trends: first five years cumulative production, initial pressure being related to strike and initial pressure and production decline 1-2 years related to dip. These relationships suggest the Devonian shale top structure is related to free gas accumulation and availability.

Initial gas pressure it may be noted is related to all the geologic maps, suggesting that these different geological parameters may each play a role in accumulation and availability.

The highest degree of production relationships is seen with the top of the Onondaga limestone. Second is the fracture facies main trend, which in turn relates to the Onondaga.

The highest degree of production decline correlation is seen with the bottom of the Huron and close to it, which suggests that the structure at the base of the producing Devonian shales is somehow influencing permeability. Differential compaction, and variations in silt and organic content could be related factors in paleoenvironment. Also the fact the permeability, as reflected in decline curves, is related to strike on the bottom of the Huron, suggests that permeability differences may occur along strike onlap of beds onto the craton during the time of deposition. These various suggested relationships point to the importance of studying paleoenvironments of these stratigraphic units in projecting gas resources.

Application of this type of analysis and suggested relationships will be tested on the Eastern Kentucky Gas Field, which is presently under study.

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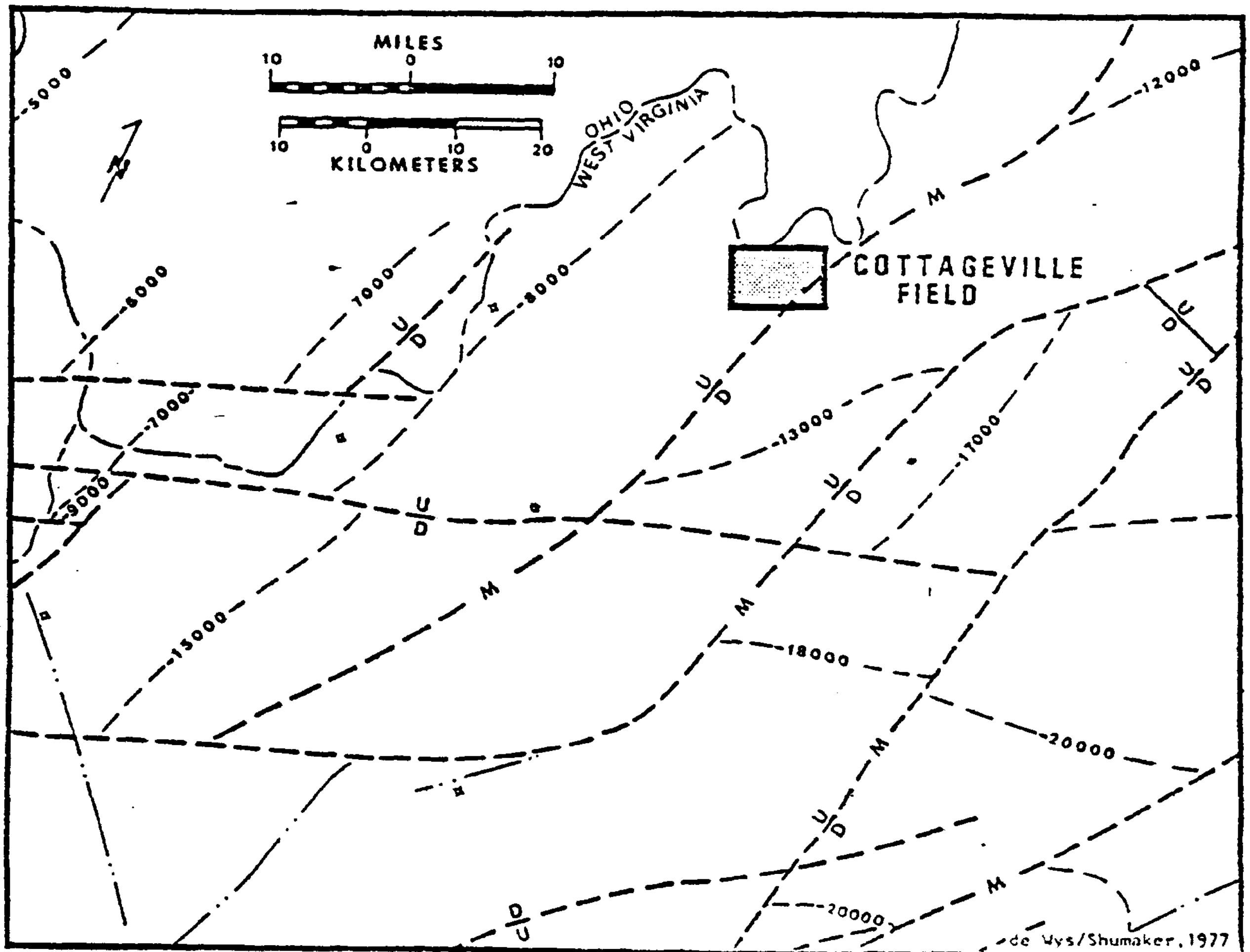

FIGURE 1 - Cottageville Field Setting in Relationship to Basement Structures and Magnetic Intensity Contours.

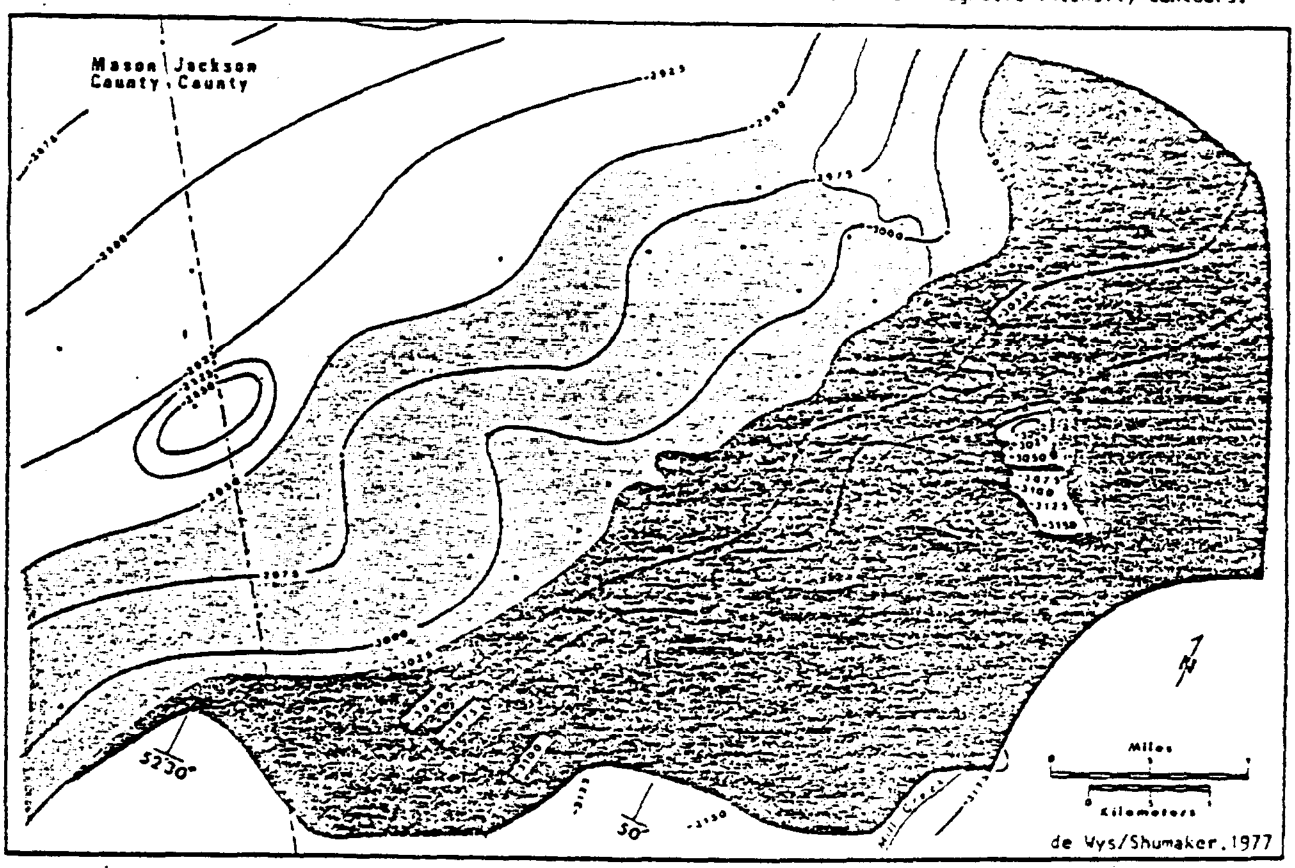

FIGURE 2 - Structure Contours on the Bottom of the Huron Shales. Contour Interval= 25 ft. After E.B. Nuckols, 1977.

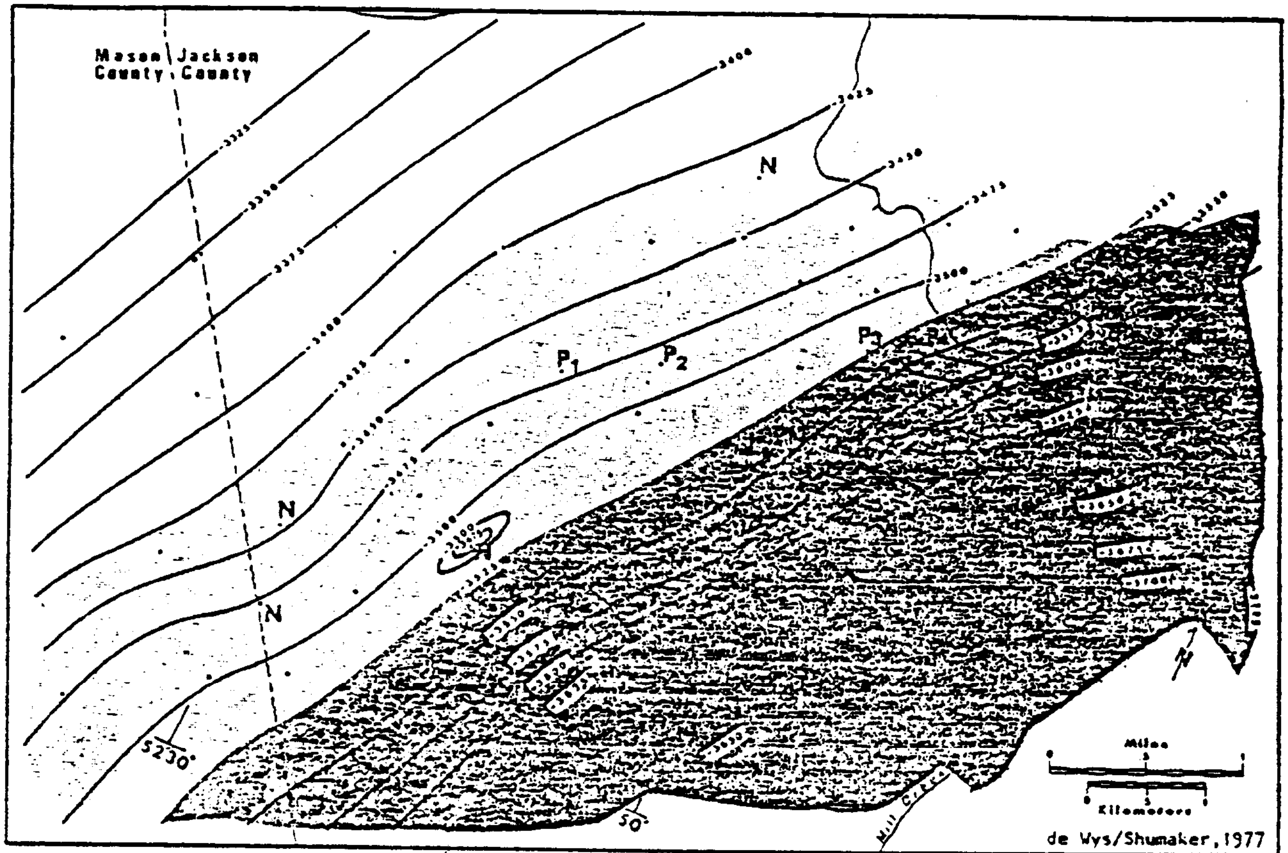

FIGURE 3 - Structure Contours on Top of the Onondaga. Contour Interval= 25 ft. New Wells=(N). Wells compared to computer curves=(P). After E.B.Nuckols,1977.

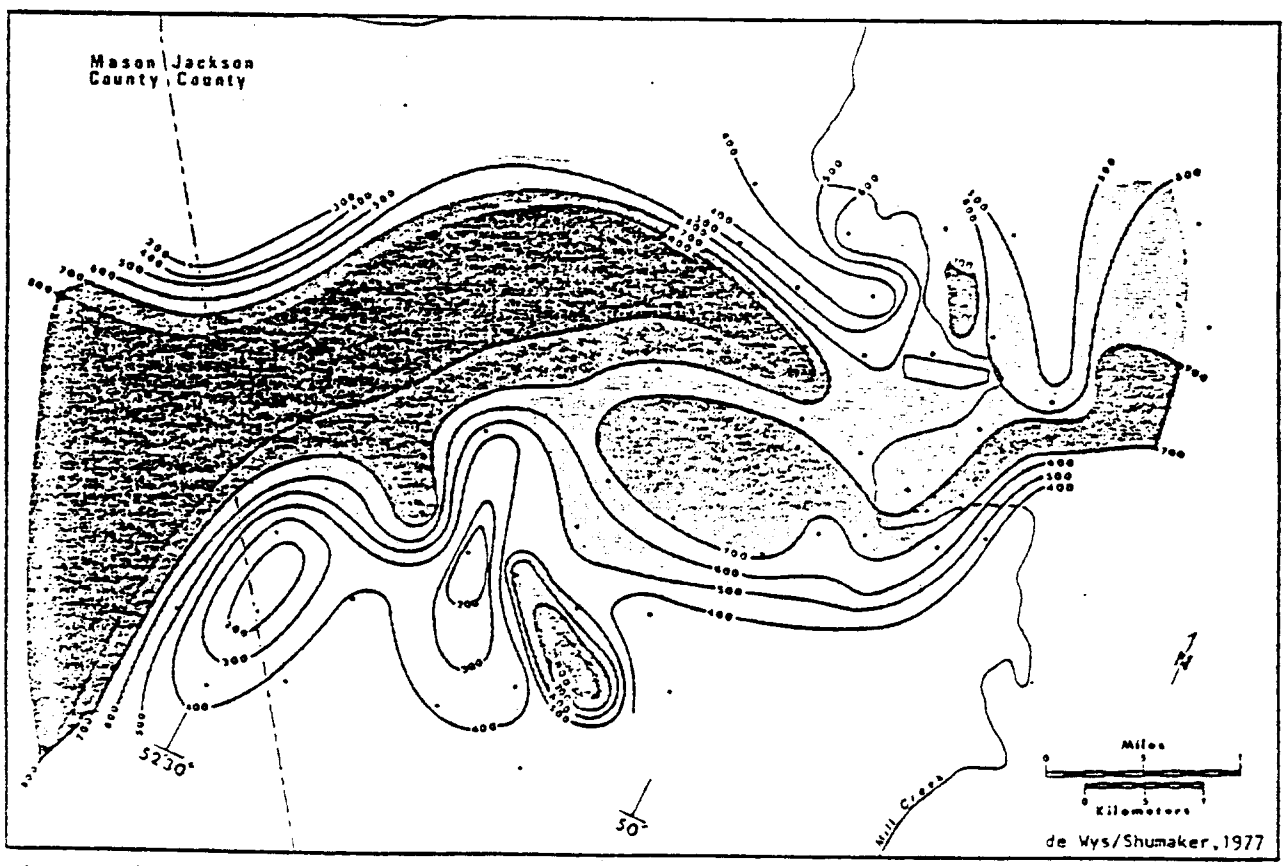

FIGURE 4 - Isopressure Contours of Initial Well Pressures. Contour Interval= 100#. t=1930-1976.

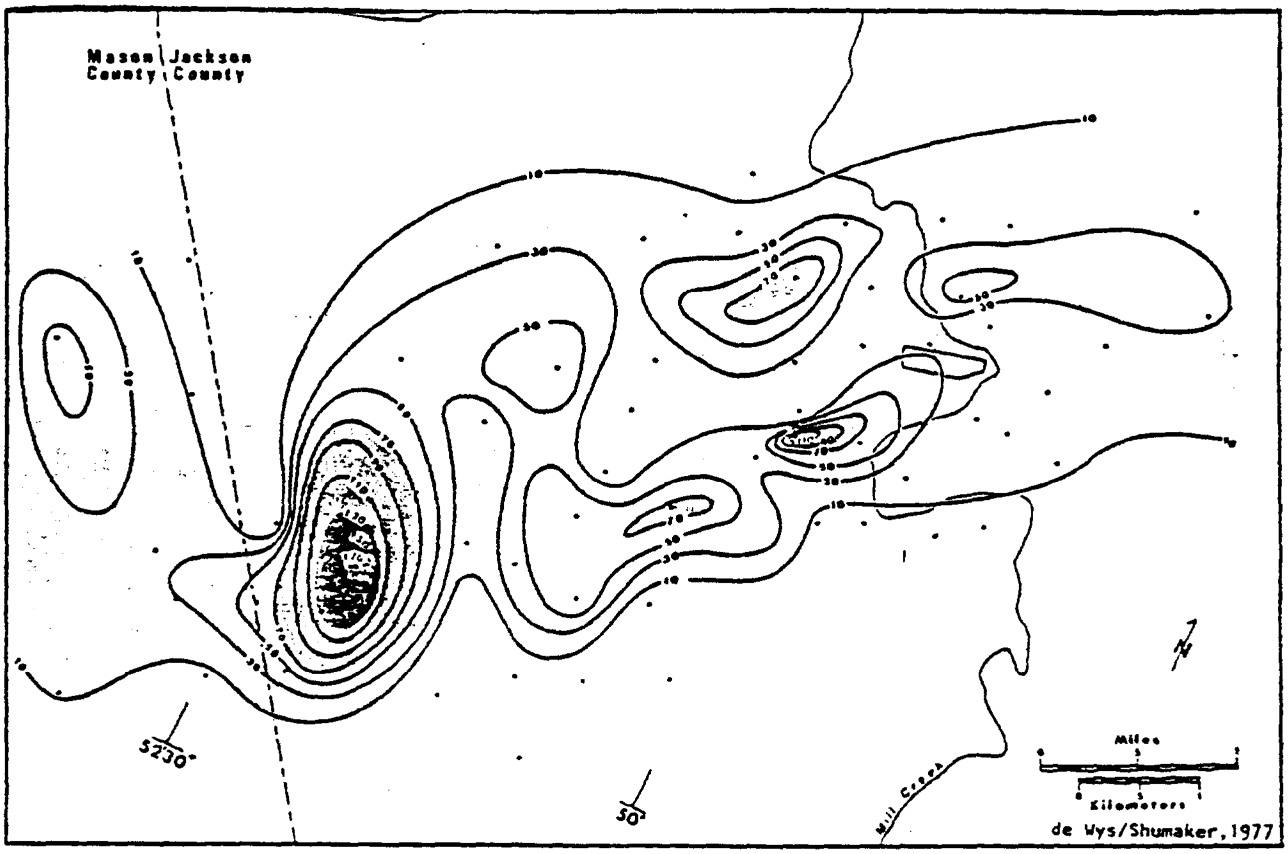

FIGURE 5 - Isocontours of Highest Annual Production (1st or 2nd year production). Contour Interval= 20MMcf/yr.

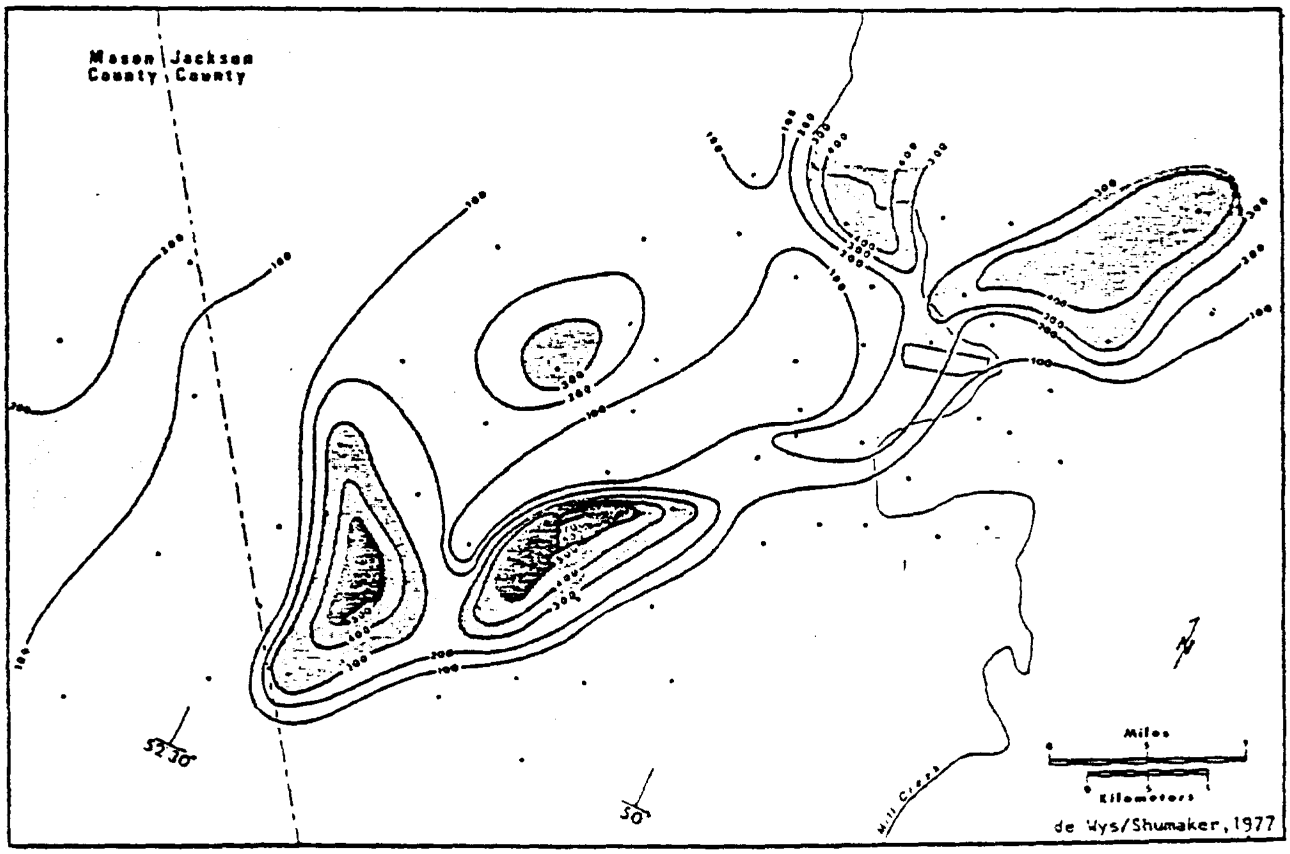

FIGURE 6 - Isocontours of Total Accumulated Production. Contour Interval= 100MMcf

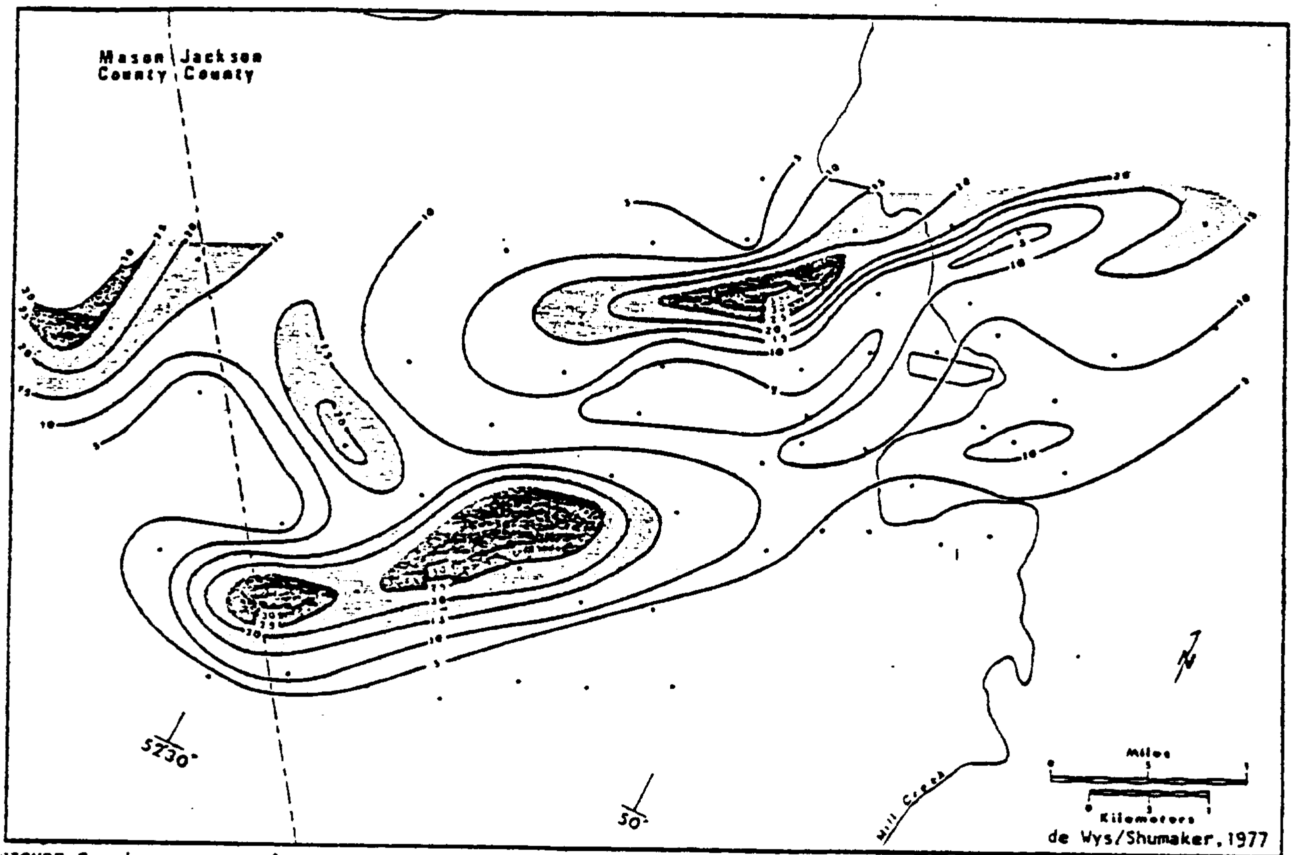

FIGURE 7 - Isocontours of Mean Annual Gas Production. Contour Interval= 5MMcf

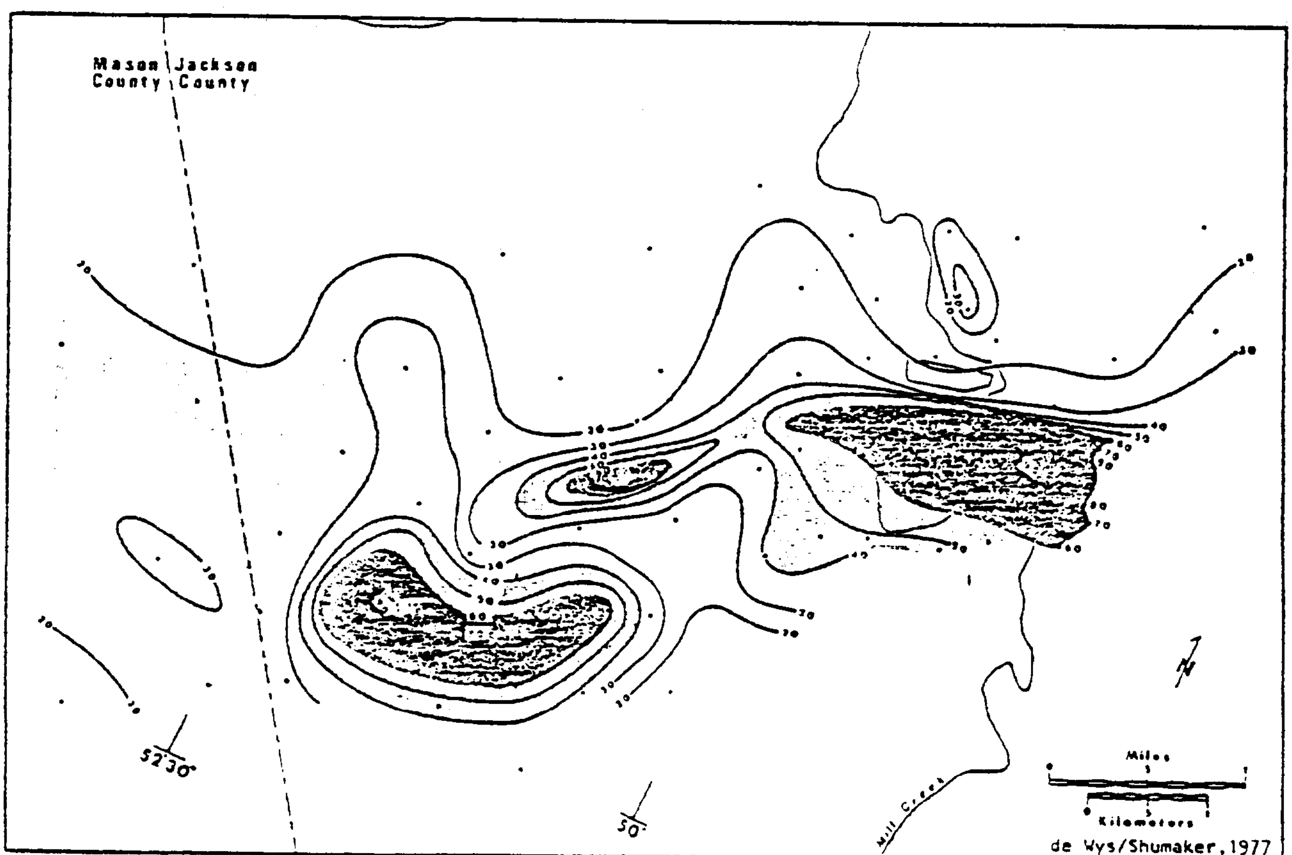

FIGURE 8 - Loss Ratio Isocontours for First Year of Gas Production. Contour Interval= 10%/yr.

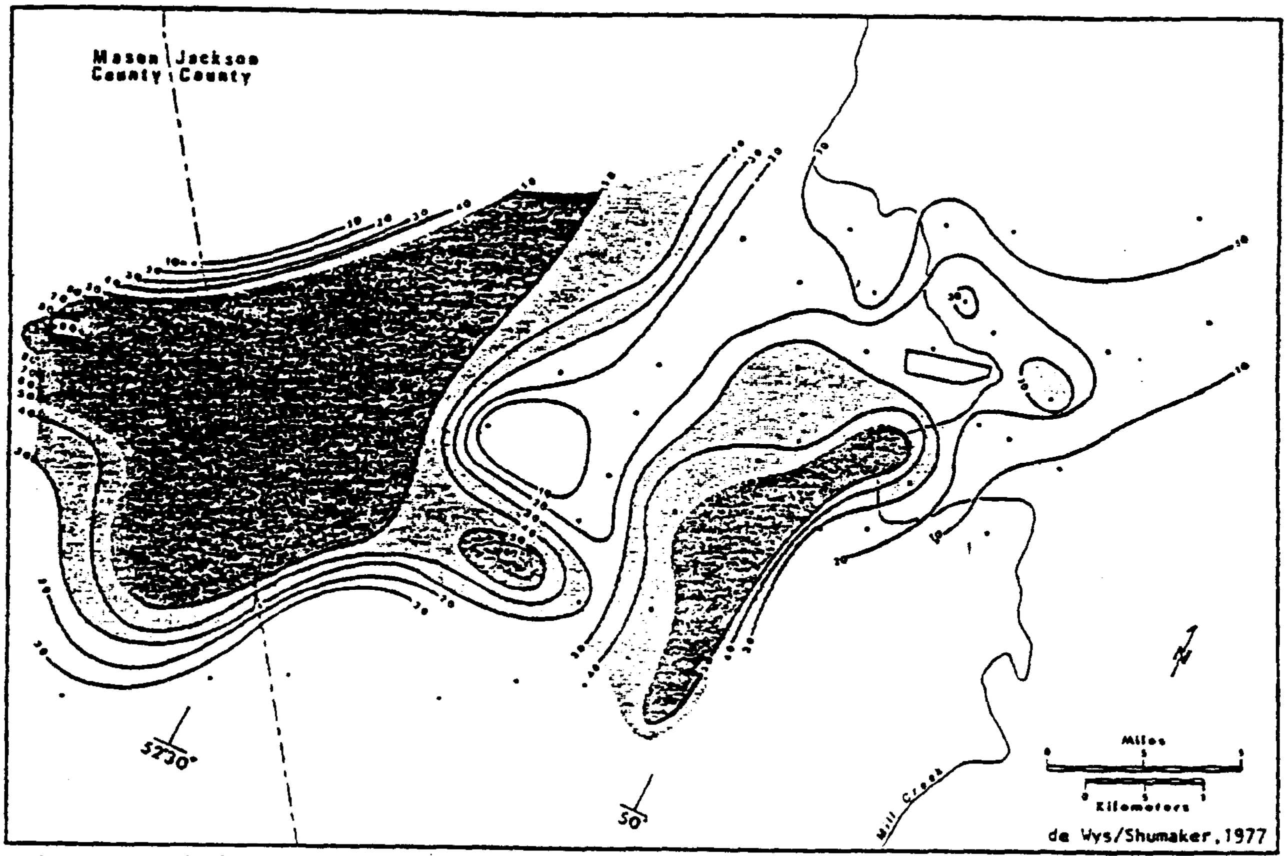

FIGURE 9 - Loss Ratio Isocontours for Second Year of Gas Production. Contour Interval= 10%/yr.

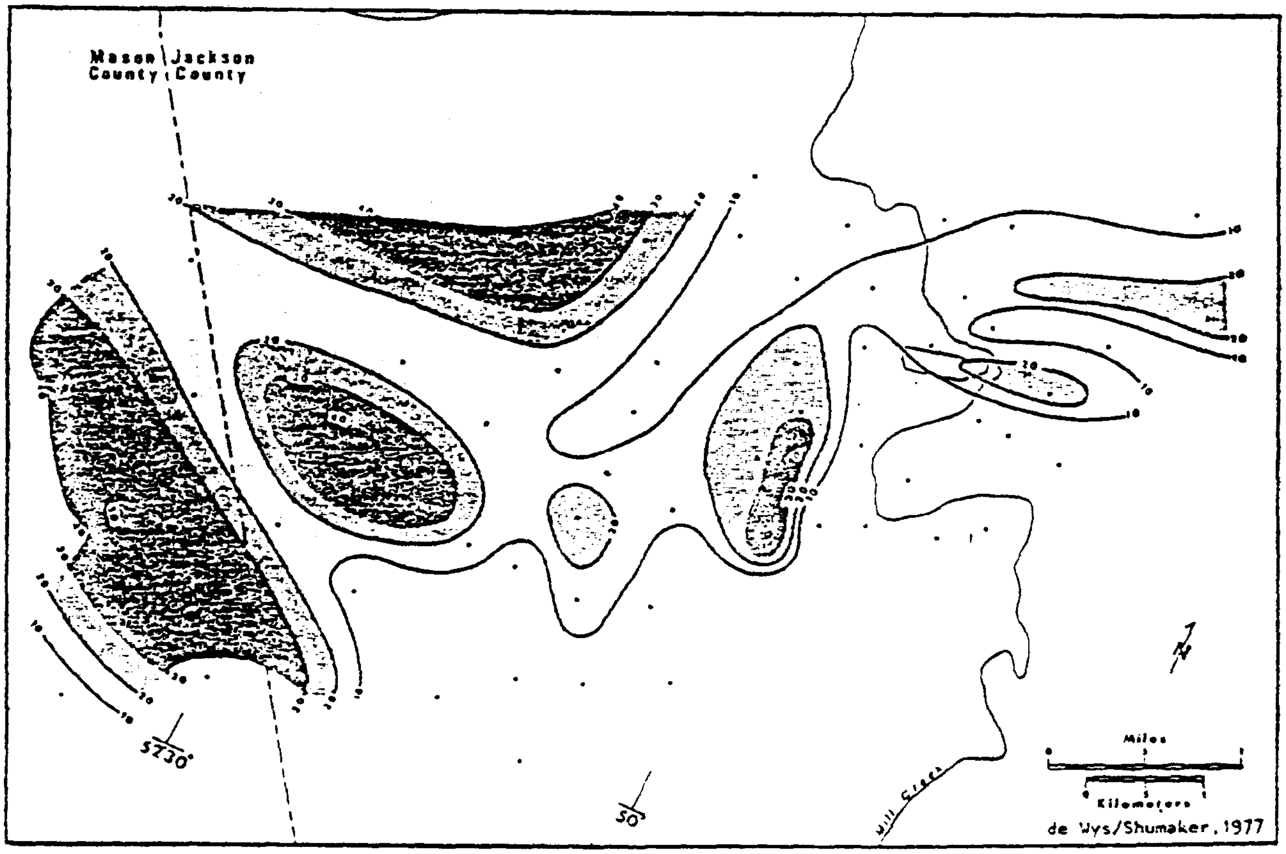

FIGURE 10 - Loss Ratio Isocontours for Third Year of Gas Production. Contour Interval=10%/yr.

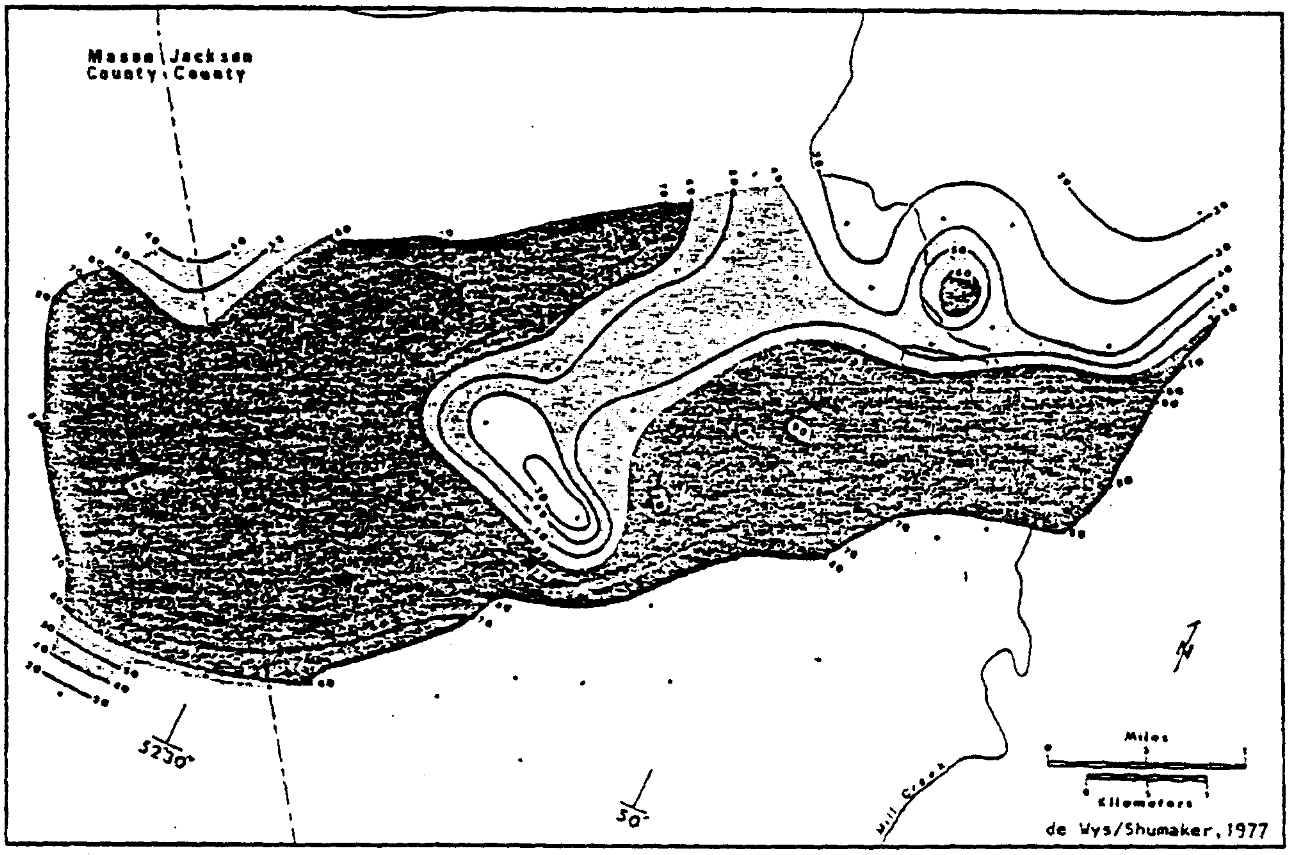

FIGURE 11- Loss Ratio Isocontours for Gas Production Decline from 1st to 5th year of Production. Contour Interval= 10%/yr.
Loss Ratio = (P 1st yr. - P 5th yr.)/P 1st yr.

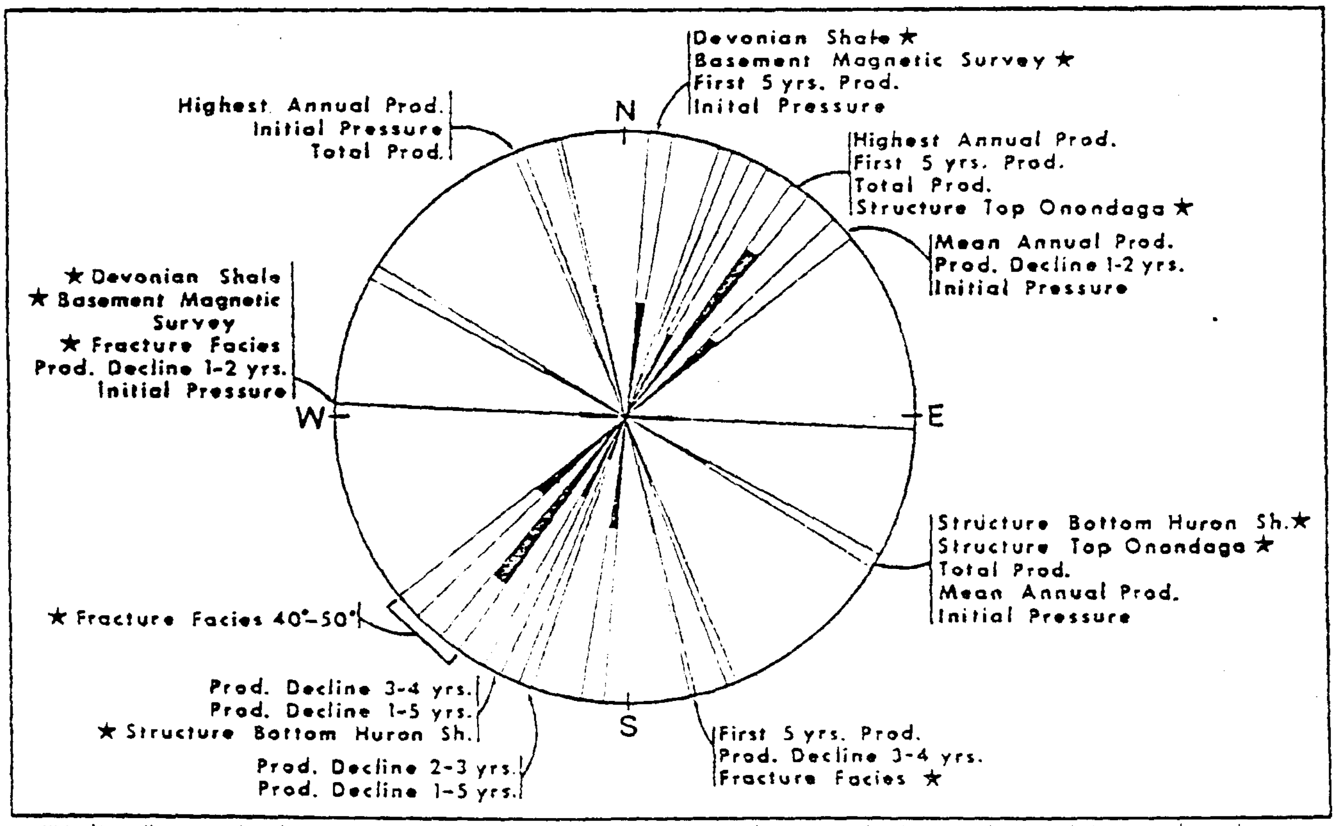

FIGURE 12 - Map trends plotted on a compass rose for comparison. The center histogram shows relat[illegible] number of [illegible] units which correlate in that direction. Note small angle of correlation in each case. Geological trends are starred.