A Statistical and Geophysical Investigation of Effects of Lineaments on Gas Well Yield from the Benson Sand Interval in North-Central West Virginia

THESIS

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

by

David P. Silbaugh, B.S.

Morgantown
West Virginia

1985

(Silbaugh, 1985)

ABSTRACT

Gas production from the Upper Devonian Benson interval in north-central West Virginia is affected by the occurrence of fracture zones represented by lineaments and other structural features within the area investigated. This observation was supported by using geophysical and statistical evaluation techniques. The tri-potential method of resistivity surveying was used to detect lateral resistivity anomalies associated with fracture zones. Statistical analyses, by means of graphical plots and nonparametric statistical tests, were successful in identifying and determining the significance of specific lineament trends related to gas well yield.

The tri-potential method of resistivity surveying involves comparing the apparent resistivities of three different electrode arrays. These electrode arrays are CPPC, CPCP, and CCPP where C refers to a current electrode and P a potential electrode. Fracture zones identified by this method are usually associated with high well yields, as observed by projecting well locations onto resistivity profiles.

Based on statistical results, gas wells with the highest final open flow values are located within 0.1 km (328 ft) of certain lineaments. Wells within 0.1 km of a short straight topographic lineament trending 270-299 or

(Silbaugh, 1985)

330-359 degrees have significantly higher yields than other wells, at the 0.05 and 0.1 alpha levels respectively. Also, wells within 0.1 km (328 ft) of a curvilineament trending 330-359 degrees are higher yielding than wells located further away from such a curvilineament, and this trend is significant at the 0.05 alpha level. The zone of influence for long topographic lineaments is not as restricted as those above, and appears to extend out to at least 1.0 km (0.6 mi), as shown by a chi-square statistical test which was significant at the 0.02 alpha level.

When all lineament types were combined and statistically tested, results showed that wells within 0.1 km (328 ft) of lineaments trending 270-299 degrees and 330-359 degrees have significantly higher yields than other wells at the 0.05 and 0.01 alpha levels respectively. The 270-299 degree lineament trend present in this study overlaps with the dominant trend of surface joints in the study area, while productive lineament trends within the Weston cross-srike structural discontinuity may be related to shear stresses associated with the formation of the Burning Springs anticline. Because wells near lineaments of certain orientations are significantly higher yielding than more distant wells, these lineaments probably represent narrow zones of fracturing that may be utilized to locate new wells having enhanced well yields.

Other features determined to have positive effects on well yield from the Benson are anticlines and the Weston cross-strike structural discontinuity. Also, statistical results from comparing final open flow and natural open flow well yield values to net sand thickness indicate that although naturally productive wells are often located in areas of high net sand, stimulated well yield is usually higher in areas with low net sand, especially near prime lineaments. By following the procedures and definitions used in this project, a reproducible method of lineament evaluation should be possible for gas exploration elsewhere on the Appalachian Plateau.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PLATES (see pocket in back)

PRIMARY CONCLUSIONS

Based on results of tri-potential resistivity surveys, other field work, and statistical analyses of trends between lineaments and well yield; some useful conclusions can be made about geologic factors affecting gas production from the Benson interval in north-central West Virginia. Below is a list of these primary conclusions:

1) Tri-potential resistivity surveys (TRS) can accurately locate fracture zones and aid in determining if a mapped lineament represents the surface expression of a fracture zone.

2) Fracture zone anomalies, as identified by TRS, are reproducible and vary as expected under different soil saturation and water table conditions.

3) Cultural features, terrain characteristics, and bogus resistance readings can significantly affect TRS profiles.

4) Caution should be used in locating gas well sites based only on TRS results. Not all surveyed lineaments with high yielding gas wells nearby have a distinct

fracture signature (FS); lineaments of other than prime orientations commonly exhibit distinct FSs; and not all FSs extend to depth. Ideally productive new gas well sites should be located along lineaments with prime orientations and associated with a distinct FS. However, lineaments with other than prime orientations, and having distinct FSs, may also be productive.

5) Existing wells completed within 0.1 km of a short straight topographic lineament (SST) trending between 270-299 degrees or 330-359 degrees have significantly higher yields than other wells. Therefore, where appropriate, future gas wells should be located within 0.1 km of a SST trending between 270-299 degrees or 330-359 degrees. The 270-299 degree trend is the strongest statistically, and overlaps with the regional orientation of surface joints (Perry et al., 1978) and coal face cleats (Kulander and Dean, 1980) within the study area.

6) The only statistically significant curvilineament (CVL) yield trend is for wells within 0.1 km (328 ft) of a CVL trending 330-359 degrees. Thus only CVLs of this orientation should be considered in future Benson well site selection. An explanation for this trend is not available at this time.

7) Long topographic lineaments (LTLs) appear to represent the highest gas yielding lineaments investigated in this study. Wells within 1.0 km of a LTL have significantly higher yields than other Benson gas wells. LTLs appear to be distinctly different from SSTs in the study area and may represent pre-Alleghenian fracture zones that became detached and more highly fractured in response to the formation of the Burning Springs anticline.

8) When data for all lineament types above were combined and statistically tested, results show that wells within 0.1 km (328 ft) of lineaments trending 270-299 degrees and 330-359 degrees have significantly higher yields than other wells.

9) As expected, wells within 610 m (2000 ft) of an anticlinal axis are significantly higher yielding than wells within 610 m (2000 ft) of a synclinal axis. This is a very strong trend, and has possible applications beyond the boundaries of this area.

10) The Weston Structural Lineament (Cheema, 1977) is characterized by significantly high gas well yield, and represents a cross-strike structural discontinuity [as defined by Wheeler (1980)]. Several lines of evidence support this conclusion: 1) similarities between the

Weston Structural Lineament (WSL) and other known cross-strike structural discontinuities; 2) disruption of major fold trends; 3) the statistical and geophysical results of this study; and 4) the presence of fracture zones at the surface within the WSL that may have formed due to shear (rather than tensional) stresses.

11) Wells with greater than 5 m (15 ft) of net sand have significantly higher natural open flow well yield values than wells with less than 5 m of net sand, while wells with less than 5 m of net sand have significantly higher final open flow well yield values than wells with greater than 5 m of net sand. This comparison suggests that future Benson development will be productive near prime lineaments, even in areas of low net sand.