SEDIMENTATION AND GAS PRODUCTION OF THE UPPER DEVONIAN BENSON SAND IN NORTH-CENTRAL WEST VIRGINIA — A MODEL FOR EXOGEOSYNCLINAL MID-FAN TURBIDITES OFF A DELTA COMPLEX.

DISSERTATION

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(Cheema, 1977)

ABSTRACT

The Benson interval, a 40 to 125-foot (12 to 38 meters) thick sequence of argillaceous siltstone and shale, caps a 600 to 950-foot (183 to 290 meters) thick silty-sandy basal tongue of the Upper Devonian Chemung Group in the 1,225 square-mile (1971 square kilometer) area in north-central West Virginia. Synthesis of data from geophysical logs of 1,000 wells, 7 cores, and gas production records indicates that the interval is a proximal turbidite system constituting a submarine fan at the toe of the Catskill delta complex, from a single source. Cruziana facies of trace fossils suggests deposition in neritic waters. Gas production is facies controlled with secondary influence by compaction-generated structural highs.

The Benson interval is subdivided into lower, middle and upper Benson. The lower and upper are further divisible into three sandstone units each, whereas the middle Benson is a single sandstone unit. The seven sandstone units are in turn, composed of several argillaceous siltstone to fine-grained sandstone turbidite beds. Extensive burrowing has reduced the porosity of the lower Benson and of the middle Benson in some areas. The upper Benson is the principal gas reservoir in north-central West Virginia and, thus, is studied in detail.

The three sandstone units of the upper Benson offlap westward. The oldest sandstone unit is the thickest and exhibits thinning of successive siltstone-sandstone turbidite beds, east-west linear trends, evidence for an erosive base, and has a gas pay-zone confined

to thicker turbidites near its base. As the fan prograded westward with time and the depositional slope decreased, thinner, younger sandstone units were deposited, imparting second order north-south trends on the predominant east-west trends. These two units, individually, show thicker successive turbidite beds and gas pay-zones restricted to their upper parts.

The interpreted shallow-water submarine fan exhibits mid-fan growth patterns with channelized deposits in the east and aggradational lobes to the west. Three facies, inner-lobe, outer-lobe and inter-lobe are identified, in the order of decreasing aggregate sandstone thickness and gas production. Thicker pay zone, lower argillaceous content, better sorting, higher porosity, presence of a highly radioactive streak, higher first-year production, and higher values of gas-production index (theoretic measure of gas production) show a close affinity with thicker aggregate sandstone.

The production appears to be independent of anticlines, fractures and structural lineaments. Initial open flow of gas is greater in the east where higher permeabilities occur in the channelized deposits.

Single source, laterally restricted flow and thinning-upward sequence near the source, fan progradation leading to radial dispersal and thickening-upward sequences away from the source, dilution of turbidite flows on the basin flank before reaching the basin axis, neritic water depth, and thin, straight and elongate facies, in response to tectonic stability and less storage capacity as exhibited by the upper Benson, constitutes a model for exogeosynclinal mid-fan turbidite.

(Cheema, 1977)

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CONCLUSIONS

1. The Benson interval and probably the entire lower part of the upper Devonian sequence (lower Chemung) of north-central West Virginia is a shallow water turbidite association, and is neither winnowed near-shore sandy muds and delta-front deposits as envisioned by Dennison (1971), nor off-shore bar sequences as interpreted by Roth (1975). Granting the turbidite origin of the 'Catskill delta complex' of central Pennsylvania (Walker, 1971) it is possible that the entire Chemung section of the study area may be turbidite to near-shore in origin. Thus, a detailed study of the Riley, Balltown and Speechley sandstones is warranted.
2. No association exists between thicker sandstones and thicker shales in the proximal turbidite milieu of the Benson interval.
3. In proximal turbidites, positive correlation exists between sandstone thickness (percent) and flow regime.
4. Reduction in the sand content of the turbidite currents precedes the change from the upper to lower flow regimes. Higher sediment content of the currents is, thus, the driving mechanism.
5. The Benson interval exhibits mid-fan facies association and dispersal pattern. Inner-lobe, outer-lobe and inter-lobe facies are defined in that order of decreasing aggregate sandstone, turbidite bed thickness and production.
6. The aggregate sandstone thickness is the most important attribute for construction of the facies map. It is also the dominant control on porosity and production, as both of these are higher in areas with thicker aggregate sandstone.

7. Mapping of the hot streak distribution in the Benson and the enclosing section indicates gross porosity and permeability trends.
8. In the absence of actual production data, Gas Production Index is an appropriate production potential indicator.
9. The Benson is primarily a facies trap with secondary contribution by compaction-generated structural highs.
10. Compaction-generated structural highs are expected in any turbidite system where belts of thick sandstones are deposited over shales. Definition of these highs through high resolution seismic surveys is worth a serious effort.
11. Structures of tectonic origin have no influence on the Benson production, a contradiction to the views of Dennison (1971, p. 1911).
12. Presence of very few fractures and their filled nature (with calcite) shows lack of relationship between fractures and production.
13. The newly defined Weston Structural Lineament and a previously known lineament have no apparent relationship to lithologic and production trends. Further study is warranted.
14. Benson exploration should be extended to the southwestern part of the study area and to the north and south of the study area. Extra care is advised for exploration to the east and west of the present activity.
15. The largely untested 500 to 800 feet (152 to 244 meters) of silty-sandy section underlying the Benson should be explored.

Deepening of the existing Benson wells may be worthwhile.

16. An understanding of the Riley sands would throw light on the western limits of the area of thick Benson sandstones.

17. Radioactive log signatures, typical of fluvial channels or river mouth-bars or offshore bars should be interpreted cautiously as similar signatures are generated by turbidite systems.

18. Gamma-ray logs of proximal turbidite systems effectively resolve sandstone percentage and average bed thickness trends for intervals as thin as one foot. It is concluded, therefore, that these logs can be used for detailed qualitative interpretation of turbidites, and that emphatic denial of this possibility by Bouma (1972, p. 205) is questionable.

19. Density of one radioactive log per square mile is more than sufficient to interpret classical turbidites. At least one core is necessary, however.