RESERVOIR ROCKS OF THE CATSKILL DELTA IN NORTHERN WEST VIRGINIA: STRATIGRAPHIC BASIN ANALYSIS EMPHASIZING DEPOSYSTEMS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

(J.S. Lewis, 1983)

LIST OF PLATES

LIST OF PHOTOGRAPHS

ABSTRACT

The genesis and stratigraphy of reservoir sandstones of the "Catskill Delta" (Upper Devonian--Lower Mississippian) are poorly understood. These sandstones were studied in northern West Virginia to better determine their position, geometry, trend, and distribution, utilizing both subsurface and surface data and emphasizing stratigraphic basin and deposystem analyses. The stratigraphic interval studied ranges in thickness from 2000 feet (610 m) to 3100 feet (945 m) and includes the Upper Devonian Chemung and Hampshire (Catskill) Formations, and the Lower Mississippian Pocono Formation.

Base-lined (relative method) gamma-ray logs facilitated the recognition of five regionally mappable lithostratigraphic units, which formed the foundation for a stratigraphic basin analysis of this sequence, including the construction of seven detailed stratigraphic cross sections, six interval isopach maps, and an assessment of basement tectonic controls on sedimentation.

The Elkins outcrop section (Randolph County) provided surface stratigraphic control in the southern part of the study area and provided sedimentologic, petrographic, and paleontologic evidence needed to suggest environments of deposition. Correlation of this section to gamma-ray logs of the subsurface allows for the recognition and description of various subsurface reservoir sandstones in outcrop.

The stratigraphic cross sections constructed illustrate the positition, trend, distribution, and to some extent geometry of subsurface reservoir sandstones, which are interpreted within the

context of the major lithostratigraphic units. Comparison of structure contour and interval isopach maps to the inferred geographical locations of the Rome Trough, a possible Cambrian cross-over rift zone, and the Pocono Dome, indicates that these basement structures may have influenced sedimentation during the Upper Devonian and Lower Mississippian.

As part of a deposystem analysis, four major facies were recognized in the Elkins section and in the subsurface. The vertical succession of facies and their respective environments of deposition for the Upper Devonian are: 1) Facies A--gray shales with thin-bedded siltstones (thin-bedded turbidites and hemipelagic shales); 2) Facies B--thick-bedded and amalgamated siltstones and sandstones (storm deposits); 3) Facies C--thick-bedded to massive sandstones with interbedded red and gray shales (barrier-beach and associated back-barrier deposits); and 4) Facies D--dominant redbeds with minor interbedded sandstone (lower delta plain marsh--interfluvial mudflats). Additionally, much of the Pocono Formation is identified as a transgressive or destructional facies, which somewhat resemble Facies C deposits.

The integration and analysis of the subsurface and surface data generated indicates that these strata, particularly the nearshore and offshore deposits, were deposited in a wave and storm dominant deltaic complex, which received an ample sediment (sand) supply to the littoral zone. This interpretation represents a modification of previous models suggested by Allen and Friend (1968) and Walker (1971, 1972) for the "Catskill clastic wedge" in other portions of the Appalachian basin.

SUMMARY AND CONCLUSIONS

1) Subsurface stratigraphic analysis utilizing base-lined gamma-ray logs (relative method) allows for a qualitative comparison between individual logs and the determination of "true" thickness changes of reservoir rocks or facies of the Catskill deltaic sequence.

2) The stratigraphic sequence studied can be subdivided into five regionally recognizable and mappable lithostratigraphic units (intervals) in northern West Virginia, three of which are informally named the Riley, Bradford, and Speechley shales intervals and two others which correspond to the formally named Hampshire and Pocono Formations, from stratigraphic bottom to top.

3) These mappable lithostratigraphic units provide the framework necessary for a stratigraphic basin analysis of this sequence, which included: the construction of seven detailed stratigraphic cross sections, including an outcrop to subsurface correlation; the completion of six interval isopach maps; the determination of regional depositional strike; the assessment of basement tectonic controls on sedimentation; and the general determination of sand-body position, geometry, trend, and distribution.

4) The stratigraphic cross sections constructed (Plates 4 to 10) emphasize the correlation of the aforementioned lithostratigraphic units and especially the 50 percent clean sandstones of this sequence.

The construction of cross sections using base-lined gamma-ray logs and relatively closely spaced data points is an excellent means of displaying facies relationships in this sequence and of graphically illustrating the position, trend, distribution, and to some extent geometry of the subsurface reservoir sandstones.

5) The Elkins outcrop section (Randolph County) provided surface stratigraphic control in the southern portion of the study area and was correlated to wire-line logs of the subsurface section. As such, various informally named drillers' sands of the subsurface are tentatively recognized and described in outcrop. For instance, the Benson sandstone which was interpreted in the subsurface as mid-fan turbidites by Cheema (1977) and Cheema et al. (1977), is recognized in outcrop as thick-bedded and amalgamated storm deposits exhibiting hummocky cross-stratification, and was probably deposited in relatively shallow water (between storm- and fair-weather wave base) of the delta front--prodelta during a lowstand of sea level.

6) Comparison of the structure contour maps constructed in this study to the inferred geographical locations of basement tectonic elements, and to the interval isopach maps constructed, permits the assessment of possible basement tectonic controls on sedimentation during the Upper Devonian and Lower Mississippian. The following general observations and conclusions can be made: a) the structure contour maps constructed on the top of the Upper Benson sandstone and on the base of the Mississippian Greenbrier Group both exhibit struc-

tural maxima in the area of the Pocono Dome (southern Randolph County) and structural minima overlying the eastern margin of the Rome Trough in the northwestern corner of the study area. Additionally, a northeast trending "synclinal zone" is present in an area of speculative Cambrian cross-over rifting, which is present between the plunge-out points of the Chestnut Ridge and Hiram anticlines in the central portion of the study area; b) the eastern margin of the Rome Trough generally coincides with trends of higher than normal or maximum isopach values on the Total interval, Bradford interval, Speechley shales interval, Hampshire Formation, and Pocono Formation isopach maps and therefore may have influenced sedimentation in this area; c) interval isopach maps indicate anomalously high thickness values within the proposed cross-over rift zone on the Total interval, Bradford interval, Speechley shales interval, and the Hampshire Formation isopach maps. Furthermore, the Pocono Formation may be seen to thicken more rapidly to the northwest practically coincident with this speculative basement fault zone. Circumstantial evidence therefore indicates the probable presence of a basement rift zone, which apparently has influenced sedimentation of younger than Cambrian-aged rocks, in much the same way as the Rome Trough has; d) Flower's (1955, 1956) and Dally's (1956) area of thinned or absent Pocono Formation (Pocono Dome) is substantiated in this study of the Pocono Formation. Additionally, thinning is observed also on the Total interval, Bradford interval, Speechley shales interval, and the Hampshire Formation isopach maps in the same general geographical area (southern Randolph County)--presumably indicating some influence on sedimentation during the Upper

Devonian and Lower Mississippian. Additionally, cross sections indicate relatively high net sandstone and sandstone percentage in the Hampshire Formation in this area, as opposed to the northern part of the study area, which might indicate the development of shelf-like conditions earlier here as the result of uplift. If this is the case, then the lowermost sandstones of the Hampshire Formation in this area should be younger than the lowermost sandstones of the Hampshire Formation of the central and northern parts of the study area (see Plates 7 to 10).

7) The stratigraphic cross sections of this study (Plates 4 to 10) do not support the interpretation of Dally (1956) that the lower (older) beds of the Pocono Formation are absent in the area of the Pocono Dome--which would have been expected had this feature formed by the gradual transgression of a positive element. Rather, the evidence indicates that this stratigraphic enigma formed either as the result of non-deposition attending an expanding erosional surface, or as the result of uplift with the resultant erosional beveling of the Pocono Formation. Considering the latter case, the erosional removal of the Pocono would be expected to be greatest in uplifted or stable areas (Pocono Dome), whereas areas which may have expierienced basement-related downwarping (proposed area of cross-over rifting and the Rome Trough) would be characterized by the preservation of anomalously young Pocono Formation, which could be recognized by a relatively rapid thickness increase in the Pocono Formation. In either case, the stratigraphic cross sections constructed document well the presence of

an angular unconformity between the Mississippian Greenbrier Group and the Pocono Formation, such that the upper (younger) beds of the Pocono Formation are missing in the area of the Pocono Dome (see Plates 7 to 10).

8) The Elkins outcrop section provided the sedimentologic, petrographic, and paleontologic evidence needed to suggest environments of deposition for this sequence, as part of a deposystem analysis. The vertical succession of facies and their respective depositional environments for the Upper Devonian and Lower Mississippian sequence are: a) Facies A--gray shales with thin-bedded siltstones (thin-bedded turbidites and hemipelagic shales); b) Facies B--thick-bedded and amalgamated siltstone and sandstone (storm deposits); c) Facies C--thick-bedded to massive sandstones with interbedded red and gray shales (high energy barrier-beach complex and associated back-barrier deposits); d) Facies D--dominant redbeds with minor interbedded sandstone (lower delta plain mudflats--interfluvial marsh); and e) Pocono Formation--not adequately describable in outcrop but consisting of non-red strata, including gray and tan sandstones with marine fossils (marine and marginal marine sandstones developed during Pocono transgressions), which are similar to sandstones of Facies C, although of an overall transgressive rather than regressive nature.

9) The integration and comparison of subsurface and outcrop data resulted in the recognition of these facies in the lithostratigraphic units of the subsurface section. Facies A deposits are most abundant

in the Riley and Speechley shales intervals. Thick-bedded and amalgamated storm deposits of Facies B are represented in the subsurface by thickening and "cleaning-upward" cycles in the Riley interval, by the Bradford interval, and by 25 percent clean sandstone "build-ups" in the Speechley shales interval. Facies C is recognized in the subsurface as the lower Hampshire Formation and as the driller's Balltown--Speechley interval in the eastern and northern parts of the study area. Based largely on the comparison of wire-line log and lithologic data, Facies D is recognized in the subsurface as the upper Hampshire Formation. The Pocono Formation represents the destructional facies of the Catskill deltaic sequence, present between the diagnostic redbeds of the upper Hampshire Formation and the base of the Mississippian Greenbrier Group, consisting of deposits which are very similar to Facies C rocks, particularly in terms of the geometry, trend, and distribution of sandstones. Redbeds, however, are only present in the basal portions of the Pocono Formation.

10) Comparison of outcrop and subsurface data generated in this study to deposystem or facies models for the "Catskill" by previous workers has resulted in the generation of new evidence--indicating that the sequence studied is best interpreted within the context of a deltaic complex and more specifically a wave and storm dominant delta, of which the present study area was but a small part. This interpretation represents a modification of the models suggested by Allen and Friend (1968) and Walker (1971, 1972) for the "Catskill" in other portions of the Appalachian basin.