BASIN ANALYSIS OF THE LATE DEVONIAN
(UPPER BRALLIER--CHEMUNG) INTERVAL
OF NORTHERN WEST VIRGINIA

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ABSTRACT

Upper Devonian Chemung interval sediments in northern West Virginia prograded westward with time and were confined by basin closure to the south. Sedimentation patterns were influenced by displacement of underlying basement features along the Rome Trough, the inferred Eastern Cross-Over Rift, Pocono Dome, and the Weston Cross-Strike Structural Discontinuity. These observations are supported by the construction of a regional cross-section network and isopach maps based on 1662 well logs in a 90 quadrangle (4528 square mile) area.

Thick intervals of stata defined between regionally correlatable transgressive shale markers can be traced westward to their basin plain shale equivalents and eastward to their correlative outcrops. Between the Alexander and the younger Warren Sands, isopach mapping identified depoaxes for three intervals and showed eastward thickening of five others within the study area. Commonly, depoaxes and isopach strike trends are parallel to the Rome Trough and depositional patterns indicate that its axis coincided with a basinal setting throughout much of the Upper Devonian. Isopach mapping also shows that sedimentation within the Rome Trough was restricted south of the northwestward projection of the Weston CSD (Lewis County) during this time, while certain units (such as the Lower and Upper Benson) are anomalously prograded to the north of this

feature. A lower basement block within the Rome Trough north of the CSD is proposed to have controlled this sedimentation.

Synthesis of core observations, regional map patterns, and environmental indicators displayed in the relatively more proximal surface exposures near Elkins (Randolph County) resulted in facies interpretations ranging from anoxic basin plain to delta front environments for units from the top of the Alexander Sand to the lower portion of Riley interval. Two end-member storm deposit models inferred from outcrop observations include "amalgamated proximal" and "non-amalgamated distal" varieties. The interval from the top of the Alexander to base of the Lower Benson represents the construction of a shaly shelf bulge early in the history of Catskill clastic wedge and forms a foundation for subsequent Benson deposition.

The Benson interval, an important gas reservoir in the region, was chosen for detailed analysis. Its evaluation illustrates the contribution of just a few discrete depositional facies to Upper Devonian sedimentation. In addition to mapping and outcrop observations, analysis included examination of 5 Benson cores from the western half of the subsurface study area. Individual core samples were sorted by their well log facies which corresponded to 3 distinct lithological types. These included the bioturbated silty Lower Benson, the channelized sandy Upper Benson, and

the shales of the overlying transgressive lower portion of the Riley interval. Petrographic characteristics and macroscopic features exhibited by these samples and cores provided a "finger print" characterizing each facies, showing not only the differences between them, but also the degree of variation within any one particular log facies.

A shelf depositional model is proposed for the bioturbated siltstones of the Lower Benson with a position below storm wave base, and having distant deltaic sources to the northeast and east. A more comprehensive model for the Upper Benson is possible as a result of this study. Its components include: (1) transitional to strike-oriented trends in the proximal (eastern) setting where wave influence and geostrophic currents are important, (2) parallel dip-oriented shelf slope trends (controlled by downstepping of the eastern edge of the Rome Trough), and (3) distal (western) strike-oriented trends that are non-dip oriented and in places parallel to the basin axis.

Storm wave contact with the seabottom in the proximal prodelta to delta front setting is proposed as the mechanism responsible for entrainment of sediments into the water column and subsequent wave-base influenced deposition in the proximal shelf, dip-oriented density current deposits on the shelf slope, and channel/channel-fringe progradation onto the basin plain. This deposition was probably associated with a relative low-stand of sea level.

Lithologies indicate that the lowermost portion of the Riley interval represents channel abandonment and basin plain deposition associated with a transgressive rise in sea level following the deposition of the Benson units.

Future exploration and development of the important Upper Benson "Sand" should be aided by using these interpretations and understanding the nature of its enclosing rocks.

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SUMMARY AND CONCLUSIONS

The sedimentation and stratigraphy of Upper Devonian rocks of northern West Virginia were based on geophysical logs from 1662 wells, cores of the Benson interval from five wells, and outcrops near Elkins, West Virginia. The main emphasis of this study was the Benson "Sand" and its immediately enclosing strata, although this basin analysis examined the stratigraphic interval from the Onondaga to the Warren. Stratigraphic cross sections established regional correlations and nine different isopach maps were constructed for various intervals. These cross sections and maps were supplemented with core studies by company consultants. My analysis of all these data resulted in the conclusions summarized below, beginning with conclusions based on <u>mapping and map interpretation</u>.

1. Depoaxes are inferred east of the study area from thickness maps of the Onondaga to Warren (Plate 6), Alexander to base of Lower Benson (Plate 11), Alexander to top of Upper Benson (Plate 12), Gross (Total) Benson (Plate 13), and Lower Benson (Plate 14) intervals.

2. Depoaxes within the study area lie parallel to the eastern edge of the Rome Trough for the Alexander to Warren (Plate 7), Benson to Bradford (Plate 8), and Bradford to Warren (Plate 9) intervals. These depoaxes are summarized on Plate 10.

3. Basinward (westward) progradation of progressively younger intervals can be observed on the isopach maps and the regional dip cross sections (Pocket Exhibit 3).

4. Based on most intervals mapped, the basin exhibits closure to the south and opens northward within the study area, in agreement with regional basin-wide patterns for the Silurian and Devonian as illustrated in Figures 8 through 12.

5. Thick stratigraphic intervals consist of numerous discrete facies and therefore the individual trends, character, and depoaxes of these individual facies (other than the Benson) are sacrificed in order to show generalized attributes. Individual facies maps of the Benson, on the other hand, illustrate the trends and thickness of a relatively thin interval.

6. A lobate prograding slope apron is indicated by the thickness map of the Alexander to base of Lower Benson Interval (Plate 11). These deposits constructed a "shelf bulge", upon which the Benson "Sands" accumulated.

7. A new relatively deep-water distal shelf interpretation (including aerobic conditions and deposition below storm wave base) is proposed for the massive and bioturbated siltstones of the Lower Benson (Figure 15). Deltaic sources are evidenced by map trends of this unit (Plate 14) to the east and northeast of the study area.

8. A more comprehensive regional picture for Upper Benson deposition is indicated from isopach maps which include proximal (eastern) transitional/strike-oriented trends, parallel dip-oriented shelf slope trends, and basinal (western) non-oriented or strike-oriented trends as illustrated by Plates 15a, b, and c. A depositonal model is proposed for the Upper Benson (Figure 17).

9. The Rome Trough, shown in Plate 2 along with other basement features, formed a sag that defines the basinal position for several Upper Devonian sedimentary intervals. Structural block faulting, downward along the eastern edge of this feature, controlled the position of shelf slope sedimentation. Sedimentation patterns also indicate differential block faulting within the Rome Trough north and south of the Weston CSD (Cross Strike Discontinuity).

10. Some sedimentation patterns indicate that sediments preferentially funneled through the Eastern Cross-Over Rift in their dispersal toward the Rome Trough. Other patterns show thin to absent deposition over the West Virginia (Pocono) Dome (which probably was activated by tilting of a basement block), and thickness trends superimposed over the Weston CSD (Plate 2). The evidence for syn-tectonic sedimentation (growing structures) is significant.

11. The abundance of small displacement thrust and reverse faults (Plate 5) trending parallel to Alleghanian folds (Plates 3 and 4) causes anomalous local thickness

values and their recognition is necessary for accurate stratigraphic analysis and interpretations.

As illustrated by Cross Section "X" (Pocket Exhibit 4), the subsurface intervals analyzed can be correlated eastward to the Elkins, West Virginia outcrop. Outcrop analysis provides important insights about depositional environments for these rocks.

1. Correlation confidence was increased in this study by the availability of logs of a new well located east (four miles proximal) of the Elkins outcrop.

2. Rocks show more proximal environments of deposition in the outcrop compared with the subsurface sections starting 9 miles to the west in the study area.

3. Progradational sequences such as the Pound Member, and upper part of the Red Lick Member have been distinguished from retrogradational sequences such as the Blizzard Member and the lower portion of the Red Lick Member.

4. Storm deposits recognized in the outcrop were grouped into two types including 1) amalgamated proximal storm deposits (Figure 6) and 2) non-amalgamated distal storm deposits (Figure 7). Type 2 (distal facies) is interpreted to form in deeper and more offshore seas than type 1 (proximal facies).

5. Transgressive shale markers at the top of the Briery Gap Member (Alexander) and Pound Member (Benson) can be traced westward across the state and allow the

correlation of equivalent basin shales, driller sands, and eastern outcrop units (Figure 3).

Core anlaysis permitted a detailed study of a select interval of deposition (the Benson interval) within the lower part of the Catskill clastic wedge. The following conclusions were drawn.

1. Based on petrographic and macroscopic properties, "finger print" characteristics of the shaly lowermost part of the Riley Interval (facies "a"), the sandy Upper Benson (facies "b"), and the silty Lower Benson (facies "c") were identified that augmented the interpreted depositional environments of these intervals established from their mapped thickness and lithological patterns.

2. Comparison of rock properties from core analysis showed both the differences between facies, and within facies, observable from well to well.

Based on the data analyzed, a depositional model for the Lower and Upper Benson intervals is proposed (Figures 15 and 17). Elongate marine belts of sandstone/siltstone change orientation east to west from interpreted shoreline to basin axis in the following manner: 1) strike trends dominate shelf sedimentation between fair-weather and storm wave base; 2) dip trends dominate slope sedimentation coinciding with the eastern edge of the Rome Trough and sedimentation caused by turbidity flows; 3) strike trends for axial flow of waning turbidity flows occur along the basin axis within the area of the Rome Trough.

An understanding of the Benson using these interpretations explains the mapped patterns and depositional character of the Benson "Sands", and should aid future exploration and development of the important Upper Benson gas reservoir rock.