SEISMIC IMAGING AND HYDROGEOLOGIC CHARACTERIZATION OF THE POTOMAC FORMATION IN NORTHERN NEW CASTLE COUNTY, DELAWARE

by

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ABSTRACT

The Potomac Formation consists of Cretaceous non-marine deposits and includes the most important confined aquifers in the Coastal Plain of northern Delaware. Water supply demands of a growing population in the area make detailed understanding of aquifers increasingly important. Therefore, this study aimed to delineate the stratigraphic architecture of the Potomac Formation with a focus on the sand bodies that provide significant volumes of groundwater. Previous studies based on borehole correlations indicate that the stratigraphy of the Potomac Formation is complex and lithologically heterogeneous, making aquifer sands difficult to correlate.

This project utilized an unconventional seismic system for collecting near-surface, high-resolution seismic reflection data to better define the stratigraphy of the Potomac Formation and its aquifers. A 20-km land-streamer seismic survey (LSS) was conducted on seven public roadways in an area with significant suburban development where long, continuous conventional seismic lines cannot be obtained. The seismic survey was conducted on paved and unpaved roadway surfaces at a variety of orientations relative to the regional stratigraphic dip, yielding a dataset with moderate-to-low S/N ratio. To calibrate the seismic data to lithologies, a 500-ft-deep (152-m-deep) borehole was drilled adjacent to one of the seismic lines using a continuous coring system. Wireline geophysical logs, including gamma, resistivity, and sonic, were obtained after the completion of drilling. The processed seismic sections, core lithologies, and geophysical log data were integrated to develop the stratigraphic interpretations. To evaluate the efficiency of the data collection process

and the data quality obtained with this survey, a conventional land survey was conducted on farm fields adjacent to one of the LSS lines. The land streamer survey data collection process proved more efficient than that for the conventional survey and provided superior data quality despite minor disadvantages such as traffic control, traffic noise, and a need for larger crews.

Eleven stratigraphic horizons were identified on the processed seismic sections and seven well-log cross sections and subsequently were correlated. These correlations follow previous interpretations in most parts of the study area; however locally, these horizons are not parallel and show erosional relief. Six lithofacies were identified in the cores: paleosols, lake, frequently flooded lake/abandoned channel, splay/levee, fluvial channel, and splay channel. Geophysical log patterns for these lithofacies were identified in the continuously cored borehole and one more borehole located near another seismic line and then correlated with the seismic data. A seismic facies classification was established using instantaneous amplitude and reflection length and related to these interpreted environments. Using this classification, seismic facies were defined that correspond to four of the lithofacies: fluvial channel seismic facies (very low to low continuity and variable amplitude), paleosol seismic facies (moderate to high continuity and moderate to high amplitude), splay/levee seismic facies (low continuity and low amplitude), and a frequently flooded lake/abandoned channel and splay/levee combined seismic facies (low to moderate continuity and low to moderate-high amplitude).

The analysis of seismic facies sections provides, for the first time, a two-dimensional basis for detailed understanding of the dimensions and distribution of lithofacies in the Potomac Formation. These results indicate that the sand bodies have

average width, thickness, and width/thickness ratio of 173.4 m, 10.7 m, and 17.3, respectively. They are poorly connected, with only 27% of the sand bodies identified on the seismic lines exhibiting contact with other sand bodies. These sand-body dimensions suggest that the depositional system was characterized by an anastomosing fluvial style with winding channel sands encased in a section dominated by fine-grained overbank sediments. This system produced a complex, labyrinth-style heterogeneity of lithologies.

Based on the vertical trends in proportion of coarse-grained fluvial deposits interpreted from the seismic facies sections, the Potomac Formation is subdivided into three intervals, bounded by discontinuities, that may have sequence stratigraphic significance: in the lower part of the formation, a lowermost lowstand systems tract characterized by a 1:2 ratio of fluvial channel to paleosol; in the middle, a transgressive systems tract where this proportion decreases to 1:3; and an upper interval of early highstand systems tract deposits where the proportion of sand increases slightly to 1:2.5.

These results provide a refined geologic framework for the Potomac Formation and target areas for future evaluation of aquifer properties useful for groundwater models. The results also indicate that the two-dimensional lateral connectivity of the sand bodies of the Potomac Formation is limited to short distances, contrary to correlations in previous studies that have indicated connection of sands between wells at distances of at least 3 km. The results of this study highlight the importance of integrating multiple sources of geologic information for the interpretation of the stratigraphic architecture of non-marine sediments, and the value of roadway-based

high-resolution land-streamer seismic data for the interpretation of near-surface (less than 300-m-depth) aquifer sand characteristics in developed areas.