STRUCTURAL PRINCIPLES AND TRAP GEOMETRIES IN THE NORTHERN APPALACHIANS

June 10, 2008; Morgantown, WV

BOTTOM LINE

The classical structural inversions observed in the Appalachians follows this sequence: Grenville compression; Iapetan rifting (Rome trough); Taconic (Queenston delta), Acadian (Catskill delta) and Alleghenian compression, and Pangea rifting.

Reversal on older basement-deep Cambrian normal faults created inversion structures with thrust faults in younger Ordovician carbonates, such as the Trenton-Black River section. These inversion structures in turn created flexures in the younger Devonian shales, which should be taken into account when developing an exploration model for the shale interval.

From this workshop we can conclude the following: 1) many previously undocumented trap styles must exist in the Appalachians; 2) deep extension-related gas traps exist; 3) inversion structures have both deep (Trenton-Black River) and shallow (Devonian shale) potential; 4) subtle-strike parallel thrusts are present; and 5) an understanding of the interaction of various structural events with different styles offers great exploration potential in the Appalachians.

PROBLEMS ADDRESSED

The complex structural history of the Appalachian basin, which includes two major extensional events and four major compressional events, must be fully understood before one can interpret potential structural prospects and their appropriate geometries. These major structural events did not occur simultaneously throughout the basin. Instead, events get younger to the south, resulting in overprinting of each successive event on rocks to the north, further complicating a correct structural interpretation.

The detailed geometry of Appalachian rift basins is more complex than previously thought, and many potential trap types may exist in the rift and immediate post-rift packages.

TECHNOLOGY OVERVIEW

The course was designed to present structural principles and general structural trap geometries in the northern Appalachian basin, not individual trap locations. Presentations were focused on the three major structural phases that have been recognized: rifting during extension events; thrusting during compression events; and inversion.

Normal fault patterns associated with rifting are much more complicated than shown in older structural models. Instead, rift basins are made up of multiple normal and offset rift segments of alternating depth and dip direction along the trend. The normal faults commonly "zig-zag" along trend, resulting in alternating, localized compression (inside corner) and extension (outside corner) and fracture changes from corner to corner. Higher permeability is associated with extension zone fractures, lower permeability with the compression zone fractures. The conclusion is that you need to understand the details in fault plain geometry to make accurate interpretations and predictions.

The overlap area between faults is called a displacement transfer zone (DTZ). Localized fractures and faults form structural traps in this zone, as well as migration pathways for fluids, and sediment entry points into these small, localized basins. DTZ are classified as conjugate (convergent or divergent) or synthetic, and further separated as approaching, overlapping, collateral or collinear.

The Gulf of Suez was presented as an example of the newer rift geometry/sedimentary model. The model includes structural features, such as rift border faults, rift shoulder uplifts, flexural margins and intra-rift horst blocks, and sedimentation features, such accommodation zones, sediment entry points, submarine and alluvial fans, fault controlled channels with channel fill, areas of turbidity flow and distal turbidites, deltas, submarine talus deposits, and nearshore sand deposits.

One needs to fully understand the fault geometry in the model in order to make predictions, and where you are dealing with full grabens, and where you have half grabens. You also need to understand porosity development in the accumulation zone, displacement transfer zones, and the interaction of faults in order to develop better models that can be applied to other basins.

Dr. Nelson noted that thrusting in the northern Appalachians displays structural geometries and traps that are quite similar to those observed in other thrust belts in the world. He also stated that thin-skinned thrusting in the Valley and Ridge often has developed above pre-existing rift structures in deeper Cambrian units and then was cut by late-stage extension features. He described the general geometry and the arcuate nature of major thrust structures due to a loss of shortening toward the tip ends of "bow" structures.

Other slides illustrated the types of folds common in thrust-faulted terrains, including buckle folds, fault propagation folds, fault bend folds and disharmonic folds. However, successful exploration requires an understanding of the full range of thrust-related fold types, including mixed folds. Examples were presented from the western Wyoming thrust belt.

Lateral and oblique ramps were described, using examples from large outcrops in Wyoming. He then reviewed interpretations of lateral ramps in the Appalachians, saying that the concept evolved from the recognition of cross strike discontinuities (CSD's), but added that he does not happen to believe that they are lateral ramps. His reason: lateral ramps occur in single thrust sheets, not in multiple sheets that are present in the Appalachians.

Thrust duplexes can create multiple pay intervals because reservoirs are repeated within the large structural picture. Broad anticlines form above these multiple faults, which can form, in his words, "a whole herd of horsts."

Triangle zones occur at the frontal end of a thrust belt, wedged into the forelandward section, creating, in our basin, the Allegheny Front, where passive roof thrusts dipping to the west are overridden by eastward dipping thrusts above the upper decollement.

There are several examples of structural inversion in the Appalachians. Cambrian rifting served to localize thrust structures during later Paleozoic compression events. In many cases, the older rift faults were reactivated as high angle reverse faults, creating antiforms over older extensional features. Then, during later Triassic/Jurassic time, rifting-related extensional faults cross cut these older thrust features. So, the classical structural inversion observed in the Appalachians follows this sequence: Grenville compression; Iapetan rifting (Rome trough); Taconic (Queenston delta), Acadian (Catskill delta) and Alleghenian compression, and Pangea rifting.

Maps and cross sections illustrating this sequence of structural inversion events were shown, including a seismic section of the structure that created the Trenton-Black River Cottontree field in West Virginia. Reversal on older basement-deep Cambrian normal faults created an inversion structure with several thrust faults in the Black River. This inversion structure created a flexure in the younger Devonian shales, which should be taken into account when developing an exploration model for the shale interval.

Dr. Nelson concluded with this summary: 1) many previously undocumented trap styles must exist in the Appalachians; 2) deep extension-related gas traps exist; 3) inversion structures have both deep (Trenton-Black River) and shallow (Devonian shale) potential; 4) subtle-strike parallel thrusts are present; and 5) an understanding of the interaction of various structural events with different styles offers great exploration potential in the Appalachians.

CONNECTIONS

The above observations were based on a workshop sponsored by PTTC's Appalachian Region in Morgantown, WV on June 10, 2008.

<u>Speaker</u>:

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