SUBSURFACE GEOMETRY AND GROWTH HISTORY OF THE WARFIELD STRUCTURE IN SOUTH-CENTRAL WEST VIRGINIA, CENTRAL APPALACHIAN BASIN

THESIS

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ABSTRACT

The subsurface geometry and growth history of the Warfield structure were studied based on seismic and well data in south-central West Virginia. Using computer software packages of the MCS (Mapping-Contouring System), the SURFACEIII (Surface Contouring System) and the DEAM (Data Editing and Management System), structure and isopach maps of the Upper Paleozoic System were completed by retrieving, editing and contouring over six thousand shallow wells from the database of the DEAM system. Seismic data were quantitatively processed and analyzed in order to provide constraints on the deeply-buried structures in the Lower Paleozoic System.

The shallow Warfield structure above the Devonian Onondaga Limestone largely consists of the Warfield anticline and the Lovely monocline: the crestal trace of the anticline is horizontal at this level with a generally northeast-trending closure and a northwest-dipping axial plane; the Lovely monocline is on the southeastern limb of the Warfield anticline forming a steeper-dipping segment of that limb. At the intermediate level between the Devonian Onondaga Limestone and the Ordovician Trenton Limestone, the closure of the anticline is lost as the fold plunges northeastward. At the deep level below the Ordovician Trenton horizon, however, the Warfield anticline no longer exists, and it is replaced by an asymmetric half-graben which is bounded by a basement fault along the eastern margin of the Rome Trough called the Trough-

Margin fault; the Trough-Margin fault is a deeply-buried basement fault with a steep dip; the Warfield fault, which is adjacent to the Trough-Margin fault and is associated with the Lovely monocline, dips steeply to the north but extends to the surface and had a small amount of post-Pennsylvanian, normal displacement.

The Warfield structure had a complex growth history and significantly influenced the sedimentation in south-central West Virginia throughout the Paleozoic. From the Early Cambrian to the Late Ordovician, the tectonic regime of the Warfield structure area was characterized by extension and differential sedimentation which were responsible for the formation of the half-graben and the deposition of the thick sequence of the Lower and Middle Cambrian System. From the Late Ordovician to the Middle Devonian, the Warfield anticline formed as a northeast-plunging fold at the intermediate level. From the Middle Devonian to the Pennsylvanian, the crustal stress caused a structural inversion and southeastward shifting in thickening trend of sediments across the horizontal Warfield anticline and the Lovely monocline at the shallow level. Finally, during the post-Pennsylvanian period, minor extension and normal dip-slip displacement occurred on pre-existing faults.

The trend of the Warfield structure changes from east-west at its southern bend, to northeast in the middle segment and north-south at its northern bend. The southern bend is linked to a east-west-trending regional fault system called

the 38th Parallel lineament and the northern bend to a north-south-trending fault system called the Burning-Mann lineament, whereas the middle segment is parallel to a northeast-trending magnetic gradient called the New York-Alabama lineament. The geometry and growth history of the Warfield structure is speculated to be influenced by the 38th Parallel and the Burning-Mann lineaments, which define a Wedge-shaped Fault System in the west-central Appalachian basin.

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The following conclusions are drawn from subsurface studies of the Warfield structure:

1. The Warfield structure consists of several genetically related structural elements including the Warfield anticline, the Lovely monocline, the Warfield fault, the Trough-Margin fault and several other folds, monoclines and faults at the eastern margin of the Rome Trough. The Trough-Margin fault is a deeply-buried basement structure with a high-angle dip toward the northwest under the southeastern limb of the Warfield anticline (Figs 7.3, 7.28 and 7.33). It formed and was most active during the Early and Middle Cambrian. The Warfield anticline, which is situated on the down-thrown side of the Trough-Margin fault, is a basement-controlled shallow structure above the Ordovician Trenton Limestone (APPENDIX I-1 through APPENDIX I-10). There developed several smaller anticlines over the basement horst blocks at the southern and northern ends of the Warfield anticline (Figs 7.8, 7.33, and 7.58). The configuration of the Warfield anticline changes with depth (compare Figs 4.1 through 4.6 with Figs 5.1 through 5.4): the northeast-trending crestal trace of the fold is horizontal at the Mississippian horizons (the Mississippian Little Lime, Pencil Cave, Greenbrier Limestone, Big Injun Sand, Coffee Shale and Berea Sandstone, etc.) with a northeast-trending closure of about 300 feet and a northwest-dipping axial plane; at the intermediate horizons (the Devonian Onondaga Limestone and Oriskany Sandstone, the

Silurian Newburg Sandstone and Tuscarora Sandstone), the closure is lost as the fold plunges toward the northeast. The Warfield fault is a steep north-dipping dip-slip fault adjacent to the Trough-Margin fault, which shows the post-Pennsylvanian normal displacement (Shumaker and Coolen, 1993). The Lovely monocline, a shallow structure on the southeastern limb of the Warfield anticline that is close and sub-parallel to the Warfield fault and the Trough-Margin fault, is related to the post-Onondaga reactivation of the Trough-Margin fault with a small amount of reverse movement (Shumaker and Coolen, 1993), and part of the movement is post-Pennsylvanian as the monocline is also mapped on the surface coals (Shumaker, personal communication).

2. The trend of the Warfield structure changes from east-west in the southern bend area to northeast in the middle segment and north-south in the northern bend area. The southern and northern bends are linked to the 38th Parallel and the Burning-Mann lineaments, respectively, and the middle segment is parallel to the New York-Alabama lineament. The geometry and growth history of the Warfield structure during the Paleozoic were influenced by these three lineaments to define a wedge-shaped structure in the central part of the Appalachian basin.

3. On the basis of subsurface mapping and seismic analysis, the Warfield structure is divided vertically into the shallow, intermediate and deep structural levels according to their changes in geometry and structural style. The shallow

Warfield structure largely consists of the horizontal Warfield anticline and the Lovely monocline above the Devonian Onondaga Limestone (Figs 4.1 through 4.6). The intermediate Warfield structure is characterized by a gently northeast-plunging Warfield anticline between the Devonian Onondaga Limestone and the Ordovician Trenton Limestone (Figs 5.1 through 5.4). The deep Warfield structure, below the Trenton Limestone, is an asymmetric half-graben bounded by the Trough-Margin fault (Figs 6.1 through 6.5).

4. The growth history of the Warfield structure can be generalized in terms of 5 tectonic regimes: the Precambrian regime was probably responsible for the formation of the 38th Parallel, the Burning-Mann and the New York-Alabama lineaments related to the Grenville orogeny; the Early Cambrian-Late Ordovician regime, which was characterized by a regional extension and differential subsidence probably in association with the Iapetus rifting, was responsible for the formation of the Warfield structure at the deep level; the Late Ordovician-Middle Devonian regime, which might have resulted from the Taconic orogeny, was responsible for the formation of the northeast-plunging Warfield anticline at the intermediate level; the Middle Devonian Onondaga-Pennsylvanian regime, which might have been initiated by the Acadian orogeny and probably terminated by the Alleghanian orogeny, was responsible for the structural inversion and southeastward shifting in the trend of increased rock thickness; finally, the post-Pennsylvanian regime was characterized by extension

and normal dip-slip displacement along preexisting faults (for example the Warfield fault). The complex history and changes in stress regime of the Warfield structure might be related to alternating FORWARD and BACKWARD movement of a basement WEDGE-BLOCK bounded by the 38th Parallel, the Burning-Mann and the New York-Alabama lineaments in response to regional changes in stress regime within the North America Plate.

5. The Warfield structure influenced the sedimentation in south-central West Virginia throughout the Paleozoic. The large offset of basement along the Trough-Margin fault during the Cambrian was responsible for the deposition of a thick sequence of rift sediments that abruptly changes thickness across the Trough-Margin fault (Figs 6.7 through 6.10, Figs 7.4, 7.29 and 7.34). This study also found a shift in the trend of rock thickness from northwest to southeast after deposition of the Onondaga Limestone (Figs 4.7 through 4.18, Figs 4.25 through 4.27, Figs 7.4, 7.29 and 7.34) which is attributable to the structural inversion and reactivation of the Wedge-shaped Fault System.

6. The vertical change in structural style of the Warfield structure should affect the entrapment of hydrocarbons in south-central West Virginia. Shallow structure, from the surface to the Onondaga Limestone, is a horizontal anticline with a closure of 300 feet and several monoclines, and hydrocarbons are presently being produced from both structural and stratigraphic traps; the northeast-plunging Warfield anticline at the intermediate level might be

favorable for the up-dip migration and entrapment of hydrocarbons toward the southwest in reservoirs of the Devonian and Silurian Systems; the small drape anticlines developed over the uplifted basement blocks southeast of the Trough-Margin fault and in the southern and northern bend areas could trap hydrocarbons either at shallow or at deep levels given suitable reservoirs. Generally, the deep structures beneath the Warfield anticline northwest of the Trough-Margin fault lack the closure traps, but fault traps and sedimentary traps such as the pinch-out and unconformities might exist according to the abrupt thickness changes across the Trough-Margin fault. More detailed seismic data and an analysis of deeply-buried reservoir potential including thermal maturation studies are required to further assess the deep potential of the Warfield structure.