STRUCTURE AND SEDIMENTATION OF UPPER DEVONIAN BRADFORD GROUP "KANE" SANDSTONE OF CUSH CUSHION FIELD, WEST-CENTRAL PENNSYLVANIA

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by

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ABSTRACT

The Cush Cushion field is a prolific natural gas field and is located in west-central Pennsylvania and is productive primarily from the upper Devonian driller's "Kane sandstone". High initial natural and after fracture stimulation open flows to atmosphere, ranging from less than 1,000 mcfg/d to 29,000 mcfg/d, are common. The field lies in close proximity to a portion of the Allegheny Plateau province identified with increased structural activity, including first order folding and faulting associated with the Alleghanian orogeny, possible early growth of Alleghanian age structures, and cross-strike structural lineaments associated with recurrent movement of basement faults. The Home-Gallitzen lineament lies subparallel with the axis of the Cush Cushion field. The Kane and other sandstones of the Bradford group are marine and part of the Indiana fluvial-deltaic complex of Boswell and Donaldson (1988) associated with the prograding Catskill shoreline during early Famennian Stage. On a regional basis, three east-west elongate dip-trending Kane sandstone deposits have been identified with similar depositional characteristics and positions coinciding with documented lineaments or cross-strike structural discontinuities. The Kane sandstone of the Cush Cushion field is interpreted as a prograding distributary channel mouth bar whose deposition was controlled by paleotopography associated with the pre-Alleghanian growth folds and recurrent basement faulting of the Home-Gallitzen lineament.

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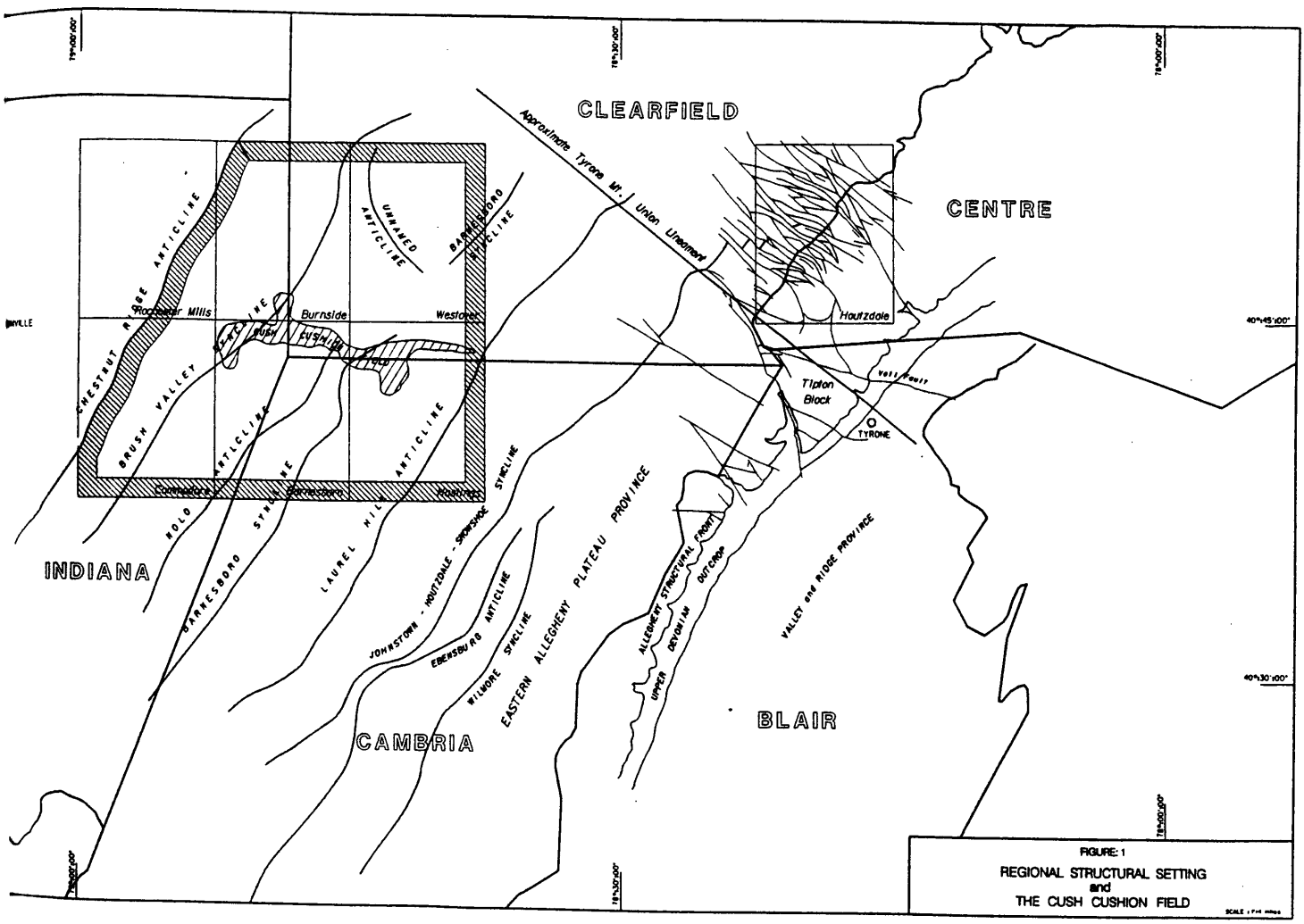

Scale 1" = 13 miles

Figure 1. Regional structural setting and the location of the Cush Cushion field study area.

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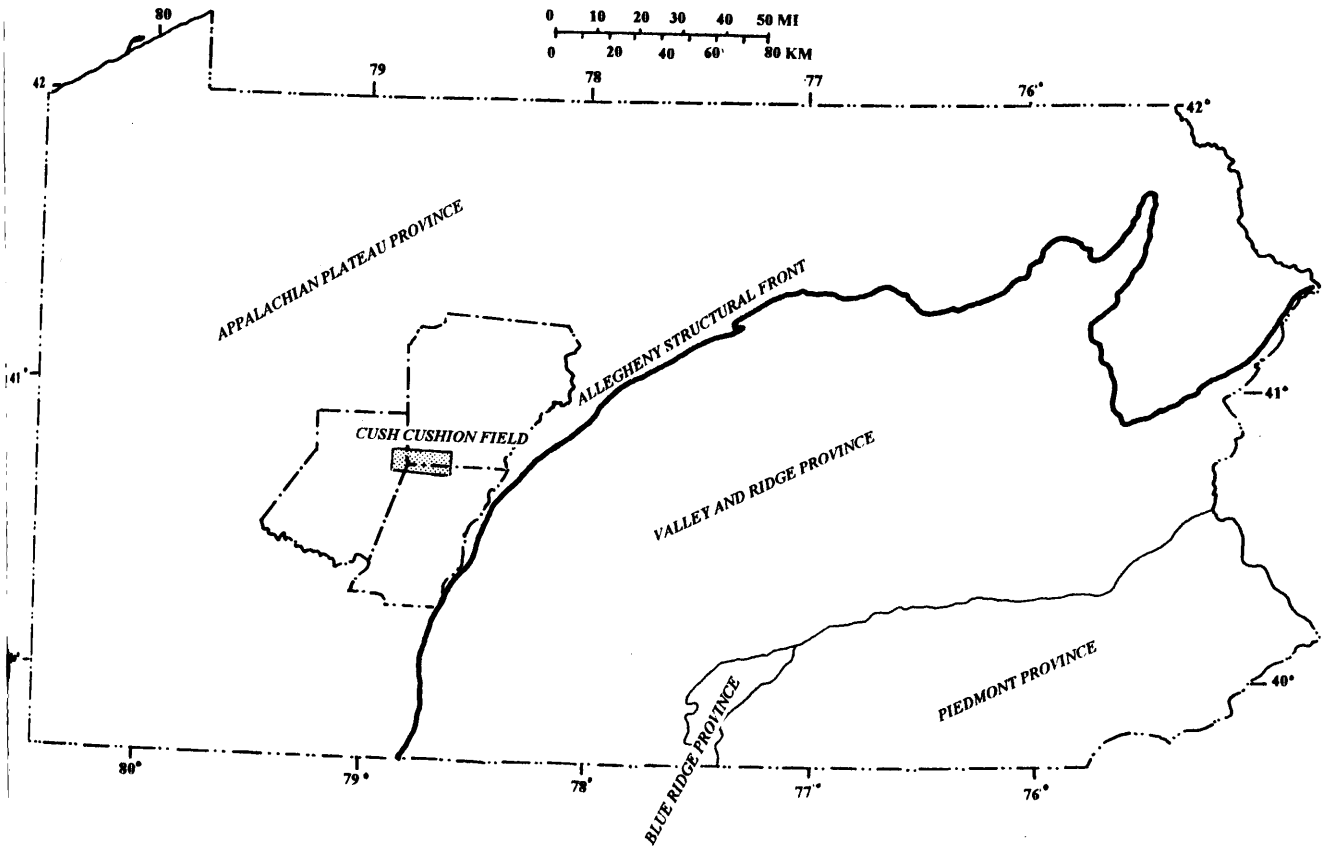

Figure 6. The Cush Cushion field and its spatial relationshipp to the physiographic provinces of Pennsylvania.

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a redirection of the main sand body of lower Kane to the south indicating positive vertical relief, which obstructed continued uninterrupted westward progradation. Some Kane sandstone, though, was deposited across this feature and it is characterized by a change in gamma ray signature from coarsening upward to fining upward. There is a pronounced thinning and decrease in the overall net thickness of the Kane sandstone trend to between 3 and 14 feet across this area. The extent of the influence of this feature is summarized on Plate X. This same area also coincides with the plunge of the Nolo Anticline (Plate VI). 4) The thickest Kane deposited in the field is located in sections 1 & 2 of the Barnesboro Quadrangle (Plate X). This thickness is in excess of 30 feet with its position coincident with a localized Bradford marker to Elk marker interval thickening (Plates II A&B) and a present day surface structural low identified on by Martin 1992 (Plate VIII) on his mapping of the Pennsylvanian Conemaugh Group. The position of these low relief areas and coincident Kane sandstone deposition indicate continued sturctural influence over time.

CONCLUSION

The Cush Cushion field, located in west-central Pennsylvania, is a prolific natural gas field producing primarily from the Upper Devonian Kane sandstone. The field is estimated to have produced between 25 and 40 billion cubic feet of natural gas from approximately 200 wells from a depth averaging 3700 feet. The field's dimensions are twelve miles in length and one and a half to two miles in width. The mechanical log characteristics and the high rate of production decline suggests a fractured reservoir.

The field is located in a part of the Appalachian Plateau province identified as part of the high plateau fold belt. The folds and faults of the region were formed by decollement tectonics of the Pennsylvanian/Permian Alleghany orogeny recognized by: 1) first order folding, with the amplitude of the folding decreasing to the west, 2) an extensive zone of transverse vertical tear faults and strike slip faults in southeastern Clearfield County, 3) the down-dropped Tipton fault block in northwestern Blair County, associated with divergent northwestward movement of the rocks in the Valley and Ridge province. In addition, cross-strike structural discontinuities also are identified within this part of the Appalachian Plateau. The Tyrone-Mt Union lineament is a major CSD described by Canich (1976) and Rodgers and Anderson (1984) and it is located eighteen miles northeast of the field. The Home-Gallitzen lineament is a more subtle CSD and is located subparallel to the field. The Home-Gallitzen lineament has been recognized by Gwinn (1964), Fergusson and Prather (1968), Parrish (1978), and Parrish and Lavin (1982). The origin of these lineaments is uncertain but changes in rock thickness and facies along the Home-Gallitzen lineament suggest it as a basement fault separating large crustal blocks. In as much as they are visible in Pennsylvanian rocks at the surface, as well as in the subsurface, it seems likely that they have been active over time. Another interpretation by Gwinn (1964) suggested that these lineaments are tear faults developed along a boundary of partially decoupled blocks of the detached sedimentary cover. His interpretation is also supported by the present study because first-order low amplitude folds of the area that are detached in the Salina salt terminate and are influenced by the lineaments. The faults and fractures associated with both styles of deformation apparently

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affected the Upper Devonian Kane sandstone, creating extensive fracturing in the reservoir. The study was unable to determine with any degree of accuracy the vertical displacement of these faults which appear to be random throughout the field. The fault lengths are less than two thousand feet to over two miles. The fault frequency is greatest in the synclines normal to the structural axes. Associated with the faulting is fracturing, identified by a friable sand zone within the net Kane sandstone.

Growth folds and paleotopography are suggested in the study area, identified by interval isopach mapping. Isopach maps of the Bradford marker to Elk marker interval suggest early growth of the detached folds of the plateau which are in general considered to be Alleghanian structures. This stratigraphic data suggests that the folds may have formed as low relief structures prior to that deformation.

The Catskill delta complex represents a clastic wedge that was deposited during the Late Devonian as a result of the Acadian orogeny. The Upper Devonian Bradford group falls within the lower Foreknobs Formation and consists of thirteen individual drillers sandstones representing shallow shelf marine deposits. The Kane sandstone is the oldest member of the Bradford group (Early Famennian) and is positioned immediately above the Late Frasnian Brallier turbidites. The Early Famennian is characterized by a prograding strandline caused by a persistent clastic influx from river-dominated deltas responding to a eustatic sealevel drop. Boswell and Donaldson (1988) recognized four fluvial-deltaic complexes associated with this prograding strandline, of which two in Pennsylvania are

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named the Elk and the Indiana deltas. The Kane sandstone of the Cush Cushion field is digitate and normal to the regional northeast (strike trend) shoreline of the ancient Indiana fluvial-deltaic complex. Two similar trending Kane sandstone deposits associated with the Indiana fluvial-deltaic complex have also been recognized both north and south of Cush Cushion field. All three Kane dip trending accumulations are interpreted to be widely spaced distributary channels and their associated mouth bars. At the Cush Cushion field, the Kane is interpreted to be a distributary mouth bar that prograded and deposited a bar finger sand where the fresh water of the ancient river left the confines of the channel, spread and mixed with the ambient sea water of the receiving basin. The rate of sedimentation in this environment was high. The geometry of the bar was dependent on the flow conditions of the river, density contrasts between the discharge waters and the receiving basin, water depth, slope of the basin, tides, and waves. In modern deltas, three physical forces or mechanisms are operative at the discharge point: inertia, friction, and buoyancy. These individual forces, or a combination of them, create distinctive depositional patterns within the river mouth bar. In all cases the coarsest sediments are deposited near the river mouth while the finer grained sediments are dispersed and deposited farther offshore. The buoyancy mechanism is interpreted for the type of mouth bar of the Kane sandstone. This buoyancy type has straight digitate distributaries with high depth to width ratios and few bifurcations (Wright 1977). A comparison of cross-section A-A' (Plate IX), which is oriented along trend strike with an example of Wright's (1977) buoyancy mechanism model, shows a good correlation. Figure 28 (B) identifies the prograding or climbing nature of the bar within the Elk and Kane time stratigraphic

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markers, along with the thickening and thinning of shales above and below the Kane sandstone.

Paleotopography on both a regional and local scale is recognized as a control on the deposition of the Kane sandstone. On a regional scale the three dip trending Kane sandstones of interpreted bar finger origin are located along documented cross-strike structural lineaments. These lineaments are speculated to have been reactivated transform faults or fracture trends that separate large crustal blocks and probably influenced the rivers of the ancient Indiana delta. Local paleotopography associated with the Cush Cushion field includes: 1) the Sylvis High which is an east-west feature associated with the Home-Gallitzen lineament that truncated the north boundary of the lower Kane sandstone, 2) a general flattening of the interval thickness between the Bradford and Elk markers subparallel to the Kane sandstone depositional strike in the Cush Cushion field, 3) a redirection to the south of the east-west trending lower Kane sand by an area of alternating north-south striking thicks and thins on the Bradford to Elk markers interval isopach (Plate II B). Also associated with this latter area is a prominent thinning of the interval as well as a change in gamma-ray signatures from a coarsening upward to a fining upward sequence in the Kane sandstone. These thick and thin areas are interpreted as paleotopographic highs where syntectonism created low amplitude undulations or escarpments. In the extreme western part of the field, the thickest Kane sandstone occurs where an identified paleotopographic low is located by the Bradford to Elk markers interval isopach. This area also is a surface structural low expression identified on the top of the Pennsylvanian

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Conemaugh Group, indicating structural influence over time.

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