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Permian Tectonics, Eustasy, and Climates in Wyoming

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Some of the basement structural features associated with the Ancestral Rockies Orogeny in Wyoming affected late Paleozoic deposition. Important trends of faults are revealed by: 1.) analysis of regional aeromagnetic data showing offsets in Precambrian basement, 2.) new regional data on the stratigraphy of the Permian Phosphoria-Park City-Goose Egg deposystem, and 3.) new mapping of the configuration of the Leonardian/Wolfcampian (Tensleep/Weber) unconformity.

Tectonics and eustasy both significantly influenced Permian systems tracts. Tectonics controlled the location and thickness of facies tracts. Fluctuations in sea level and climatic changes controlled lithofacies types and early diagenesis.

Eustasy and climate appear to have been linked. Rising sea levels were accompanied by cooler, more humid tropical conditions, similar to the Bahamas of today. These conditions coincided with extensive upwelling of silica- and phosphate-rich waters rising out of the Antler foredeep, with implications about wind patterns. Falling sea levels were associated with warmer arid conditions, like those of the modern Persian Gulf. This linkage suggests that the driving force behind Permian eustasy was high-latitude continental glaciation.

The large-scale tectonics that created the Ancestral Rocky Mountains were accompanied by smaller-scale movements along regional and local fault trends that are only now being recognized. In particular, stratigraphy and sedimentology of the Ervay Member of the Park City Formation reflect the development of structures (horsts-and-graben, and folds) along major lineaments, leading to at least three significant embayments that affected the character of the Ervay shoreline.

The Phosphoria/Park City sequence was laid down on the ramp that characterized western North American during the Paleozoic. Regional depositional slope was generally to the west. The Phosphoria/Park City is thickest in a large embayment that curved broadly eastward from central Utah to southern Montana.

Within this embayment, maximal Permian transgression laid down the petroliferous carbonates of the Ervay member of the Park City formation in an eastward thinning set of about four parasequences. On a smaller scale, a number of east-west trending faults and lineaments shaped the Ervay shoreline in important ways.

Measured sections and detailed subsurface evaluations along the east flank of the Big Horn Basin document the pervasive influence of paleostructural features. Valleys incised into the Tensleep, and the positions of overlying Permian facies tracts, follow lineaments defined on aeromagnetic data. Outcrops of the upper Tensleep, lower Franson, and Ervay intervals frequently display water-escape features and disrupted or contorted bedding interpreted to have formed as a result of syndepositional earthquakes. Numerous measured sections also document that Sheep Mountain and Zeismann Dome are paleostructures that originated in large part during this time. An incised valley-fill formed on the Tensleep unconformity is exposed on the flank of Zeismann Dome and follows an old tear fault. The same fault trend also partly controls entrapment of oil in the Tensleep Formation at Enigma Field. Additionally, the crest of the present-day Zeismann structure is offset from its paleostructural position. Facies variations along the length of Sheep Mountain indicate that the Ervay strandline straddled the west flank of the present structure, whereas lagoonal deposits dominate the east flank.

The Tongue River lineament (northern Bighorn Basin) formed an embayment that pushed the Ervay shoreline dramatically eastward. This once was the site of a huge stratigraphic trap, and a presumably very large oil accumulation that (sadly) was breached by Laramide uplift of the Bighorn Mountains. This paleo-low trend also appears to have created a passageway that may have fed marine waters eastward into the Ervay saltpans of the paleo-Powder River Basin.

The Tensleep lineament (southern Bighorn Basin) caused tectonic movement and erosion in a persistent E-W trending depositional low. In this low area: 1.) incisement was almost 100 ft (33 m) deeper than in surrounding areas, 2.) Lower Franson streams flowed, and 3.) the Ervay shoreline facies tracts markedly aggrade. This aggradation created a thick stack of tidal-flat deposits that contain unusually well developed parasequences and well-preserved fenestral porosity. These shoreline carbonates change facies updip (eastward) into interbedded lagoonal redbeds, anhydrites, and tight dolomites, giving rise to the stratigraphic trap for Cottonwood Creek and related oil fields.

This large stratigraphic trap created a catchment for about 1 billion barrels of oil generated by Phosphoria source rocks during Jurassic through late Cretaceous time. Oddly, oil in the Cottonwood Creek area displays inverse density gradation, the highest structural positions containing oil of low gravity (19-20^{o}) and low GOR's (<100 CF/B), and positions near the oil/water contact having higher gravity (35-45^{o}+) oil with much higher GOR's (up to 20,000 CF/B). These different oils may reflect a gradual change in Phosphoria-sourced oils during progressive burial and maturation.

Farther south, in the Wind River and Green River basins, changes in the trend of the Ervay shoreline appear to relate to movements on several lineaments. A dramatic shift occurs along the northern flank of the Cherokee Ridge, where the Ervay shoreline changes strike from NE-SW to E-W. This change coincides with a normal fault with 2000 ft (660 m) of late Paleozoic throw. This fault appears to be a westward extension of the Nash Creek-Mullen Fork shear zone, a major Precambrian suture.

In summary, late Paleozoic tectonics played a major role in the Phosphoria petroleum system. Faulting along lineaments was instrumental in creating at least two large stratigraphic traps for oil, and may have created others yet to be discovered. Fracturing associated with E-W oriented lineaments also could have provided a pathway for long-distance eastward migration of Phosphoria oil from the early "cooking pot" in the Wyoming-Idaho Overthrust Belt.