SYMPOSIUM ON GEOCHEMISTRY AND CHEMISTRY OF OIL SHALE
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# GEOLOGICAL SETTING OF OIL SHALES IN THE PERMIAN PHOSPHORIA FORMATION AND SOME OF THE GEOCHEMISTRY OF THESE ROCKS

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## SUMMARY

Recent studies of the Meade Peak and the Retort Phosphatic Shale Members of the Phosphoria Formation have investigated the organic carbon content and some aspects of hydrocarbon generation from these rocks. Phosphorite has been mined from the Retort and Meade Peak members in southeastern Idaho, northern Utah, western Wyoming and southwestern Montana. Organic carbon-rich mudstone beds associated with the phosphorite in these two members also were natural sources of petroleum. These mudstone beds were differentially buried throughout the region so that heating of these rocks has been different from place to place. Most of the Phosphoria source beds have been deeply buried and naturally heated to catagenetically form hydrocarbons. Deepest burial was in eastern Idaho and throughout most of the northeastern Great Basin where high ambient temperatures have driven the catagenesis to its limit and beyond to degrade or to destroy the hydrocarbons. In southwest Montana, however, burial in some areas has been less than 2 km, ambient temperatures remained low and the kerogen has not produced hydrocarbons (2). In these areas in Montana, the kerogen in the carbonaceous mudstone has retained the potential for hydrocarbon generation and the carbon-rich Retort Member is an oil shale from which hydrocarbons can be synthetically extracted.

The Phosphoria Formation was deposited in a foreland basin between the Cordilleran geosyncline and the North American craton. This foreland basin, which coincides with the area of deposition of the two organic carbon-rich mudstone members of the Phosphoria, has been named the Sublett basin (Maughan, 1979). The basin has a northwest-southeast trending axis and seems to have been deepest in central Idaho where deep-water sedimentary rocks equivalent to the Phosphoria Formation are exceptionally thick. The depth of the basin was increasingly shallower away from central Idaho toward the Milk River uplift -- a land area in Montana, the ancestral Rocky Mountains. The basin is composed of land areas in Colorado, the Humboldt highland in northeastern Nevada and intervening carbonate shelves in Utah and Wyoming. The phosphorites and the carbonaceous mudstones were deposited on the foreslope between the carbonate and littoral sand deposits on the shelf and the dominantly cherty mudstone sediments in the axial part of the basin.

Paleomagnetic evidence indicates that in the Permian the region would have been within the northern hemispheric trade wind belt; and wind-direction studies determined from studies of sand dunes, indicate that the prevailing winds from the Milk River uplift would have blown offshore across the Phosphoria sea. Offshore winds would have carried surface water away from the shore and generated upwelling in the sea in eastern Idaho and adjacent areas in Montana, Wyoming and Utah.

Prior to deposition of the Phosphoria, the region was the site of extensive deposition of shallow-water carbonate sediments. Equivalent rocks in the northern part of the basin are dominantly sandstone derived from the adjacent Milk River uplift and similar sandstone strata in the southeastern sector were derived from the ancestral Rocky Mountains uplift. Tectonic subsidence of the Sublett basin in part of the region seems to have provided a sea-floor profile favorable for upwelling circulation and the shift in deposition from regional carbonates and local sandstone into a more complex depositional pattern that included the accumulation of the mudstone-chert-phosphorite facies that comprises the Phosphoria Formation. High biological productivity and the accumulation of sapropel on the sea floor is associated with contemporary coastal upwelling (1) and similar environmental and depositional conditions are attributed to the rich accumulations of organic matter in the Phosphoria Formation.

Sapropelic mudstone and phosphorite composing the Meade Peak Member are approximately 60 m thick near the center of the Sublett basin. The Meade Peak thins to the north, east and south away from the area of maximum sapropel accumulation and towards areas of shoaling, which were unfavorable environments for depositional preservation of organic matter near the margin of

the Phosphoria sea. The Retort Member is thickest in southwestern Montana where it is approximately 30 m thick. The Retort closely resembles the Meade Peak except that its thickness is about half that of the Meade Peak and its shorelines and apparent depocenter are displaced northward from those of the Meade Peak.

Organic carbon content in the Meade Peak is greatest, averaging about 9 wt %, near the Wyoming border east of Pocatello, Idaho (3) and is offset northeastward from the central axis of the basin onto the flank of the area of thickest accumulation of organic carbon-rich mudstone. This offset position of the maximum organic carbon concentration is believed to approximately coincide with an area of upwelling marine currents from out of the deeper parts of the Sublett basin onto the submarine slope of fringing barrier island and carbonate bank deposits. Organic carbon content of the Retort is greatest, averaging about 10 wt %, near Dillon, Montana. The center of maximum organic carbon deposition in both the Meade Peak and the Retort approximately coincides with that of maximum Phosphorus concentration.

Traces of many metals, some of unusually high concentration (4), occur in the carbonaceous shale and phosphorite beds of the Phosphoria. The loci of the average concentration of several metals in the carbonaceous shale members also approximate the loci of organic carbon and phosphorus. It seems likely that the trace metals were concentrated from the sea water by the organisms living in the Phosphoria sea, as were the carbon and the phosphorus, but some metals have been diagenetically adsorbed onto the residual organic matter or are incorporated in the clay or other minerals in these rocks. The coincidence of the metallic concentrations, the phosphorus and the organic carbon in the Retort and the Meade Peak are believed to confirm the indicated location of centers of upwelling in southwest Montana and in the vicinity of the Idaho-Wyoming border.

Petroleum generation from the Phosphoria Formation has been investigated and a total yield of 30.7 tons is estimated by Claypool and others (2). Oil expelled from these rocks has been discovered and produced from the Pennsylvanian Tensleep Sandstone and the middle Permian Park City Formation in central Wyoming. Oil in the Lower Permian upper member of the Minnelusa Formation in northeastern Wyoming and adjacent areas as well as the probable Lower Permian part of the Weber Sandstone in northwestern Colorado has probably been derived from the Phosphoria Formation. Hydrocarbon generation has taken place in most of the region where burial has been in excess of about 2 km. In eastern Idaho, the critical depth of burial occured as early as Late Triassic and regionally the maximum depth of burial of the Permian rocks is inferred to have been at the end of the Cretaceous Period, although sediments continued to accumulate in local, intermontane basins through the Paleocene and into early Eocene time (2). In southwest Montana, however, depth of burial has been less than 2 km, hydrocarbons have not been generated and the carbonaceous mudstones remain effective oil shales.

## LITERATURE CITED


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