Petroleum Source Rocks and Stratigraphy of the Bakken Formation in North Dakota

RICK L. WEBSTER

The Bakken Formation (Devonian-Mississippian) of North Dakota is a relatively thin unit consisting of upper and lower black organic-rich shales separated by a calcareous siltstone middle member. The shales are hard, siliceous, pyritic, fissile, and noncalcareous. They contain abundant conodonts and tassianites and have planar laminations accented by pyrite. The upper and lower shales were apparently deposited in an offshore marine anoxic environment where anoxic conditions may have been caused by a stratified water column resulting from restricted circulation. Organic matter in the black shales was derived mostly from planktonic algae.

Organic geochemical analyses revealed the Bakken shales to be very organic rich (average 11.33 wt. % of organic carbon), and visual kerogen typing revealed this organic matter to be predominantly an amorphous type inferred to be sapropelic. The onset of hydrocarbon generation was determined to occur at an average depth of 9000 ft (2745 m) by interpretation of plots of geochemical parameters with depth. Hydrocarbon content and thermal kerogen breakdown increase greatly in the shales where they are buried greater than 9000 ft. The effective source area of the Bakken lies mostly in McKenzie, Williams, Dunn, and Billings counties. Oil generation was probably initiated in the Bakken about 75 m.y. ago (Late Cretaceous time) at a temperature of about 100°C, with initial expulsion of oil from the Bakken probably occurring 70 m.y. ago.

Vertical fracture systems located primarily along the Nesson anticline, Antelope oil field, and the Billings anticline seem to be the most reasonable way for migration of oil to have occurred from the Bakken into adjacent rock units. The amount of oil generated by the Bakken in North Dakota is 92.3 billion bbl. If only 10% of this was actually expelled from the shales, it could easily account for the 3 billion bbl of known type II oil reserves in the Williston basin.

INTRODUCTION

This study is a stratigraphic and geochemical investigation of the black shales of the Bakken Formation in the North Dakota portion of the Williston basin. These shales have been cited as possible source rocks of petroleum (Murray, 1968; Dow, 1974). The Bakken Formation provides a good opportunity to study geochemical changes in source rock maturation with depth in a single stratigraphic unit, as numerous samples of the formation in North Dakota are available from the North Dakota Geological Survey. The study area is confined to the extent of the Bakken within North Dakota where it is known only from the subsurface (Figure 1); thus, it was studied by the use of cores, cuttings, and geophysical logs.

The Bakken is easily divided into three members (Figure 2) and these are used informally here: an upper shale member, a middle siltstone member, and a lower shale member. Conodonts have been used to date the lower Bakken Shale as Famennian (upper Polygnathus styriacus Zone) and the upper Bakken Shale as Kinderhookian (lower Siphonodella crenulata Zone) by Hayes and Holland (1983).

GENERAL GEOLOGY

Well Log Characteristics

The Bakken displays characteristic log responses that are unique in the Paleozoic rock section of the Williston basin (Figure 2), and it is thus widely used as a “marker” unit in the basin. The shales of the formation always display very high gamma-ray readings (greater than 200 API units) which are almost always off the log scale and not quantifiable. They also display high interval transit times (80–120 μsec/ft) on the sonic log. High resistivity readings (greater than 100 Ω•m) are seen...