IV. UPPER KEWEENAWAN STRATIGRAPHY

SUMMARY STRATIGRAPHY

M.G. Mudrey, Jr. and M.E. Ostrom

The boundary between the uppermost volcanic rock of the Middle Keweenawan and the Upper Keweenawan is not resolved. The volcanic rock grades upward with increasing abundance of interbedded immature volcanic sediments, until no more flows are found. The classical boundary is drawn at the top of the uppermost lava flow; many modern studies suggest that the boundary should be drawn at a lower level (Hubbard, 1975). In Wisconsin the Upper Keweenawan sedimentary rock is divided into two groups with an apparent unconformity between them. This division, with changes in formational names, is generally accepted for Minnesota. In Michigan, however, correlation of the upper group is more difficult. (See figure 2 on page 17.)

ORONTO GROUP

Daniels (1982) considered the three formations of the Oronto Group to be a transgressive-regressive alluvial fan/lacustrine system that filled the (Midcontinent) rift basin during the last stages and following cessation of volcanic activity. The basal unit of the Oronto Group within Wisconsin is the Copper Harbor Conglomerate, which is gradational and interbedded with the upper part of the Portage Lake Lavas. The Copper Harbor Conglomerate is 150 to 2,000 m thick, and is a reddish brown, lithic conglomerate and sandstone (Hite, 1968). The conglomerate varies considerably, but consists dominantly of subangular to rounded fragments of Middle Keweenawan volcanics and intrusives, and a lesser amount of Lower Proterozoic rock. The Nonesuch Formation overlies the conglomerate and appears in places to interfinger with it. Barghoorn and others (1965) described the Nonesuch Formation as thinly laminated gray siltstone and black shale, visually distinguishable from enveloping red-brown coarser grained units; conglomeritic horizons occur locally. Both solid and liquid hydrocarbon is found sporadically in the copper-bearing ore zone in the lower 9 m of this formation. Subsurface oil seeps are quite common at the Copper Range Mine in White Pine, and a fresh exposure of fractured shale can yield about 1 liter of oil even after several months. In Wisconsin the maximum thickness on the east is 120 m, but it thins rapidly westward to 40 m near Mellen (Aldrich, 1929, p. 111). The Freda Formation is the major unit of the Oronto Group. It has an estimated thickness of 4,000 m. It is noted for its red color, which is present throughout except for local leaching or bleaching along fractures or within the more porous and permeable coarse units in the upper part of the section. The Freda Formation is both compositionally and texturally immature. The sedimentary structures of the Freda have long been interpreted as evidence of a fluvial depositional environment. Hite (1968, p. 60) provided details on the stratigraphy and sedimentology.

BAYFIELD GROUP

The basal unit of the Bayfield Group is the Orienta Formation, a feldspathic sandstone up to 900 m thick (Myers, 1971). It thins rapidly to the west and pinches out west of Washburn, Wisconsin. The critical lower contact with the underlying Freda Formation is not exposed. The best interpretation is that the Orienta lies with slight angular discordance upon the underlying Freda, and elsewhere it is known to be in fault contact with Middle Keweenawan volcanics. The Devils Island Formation overlies the Orienta Sandstone, is a fine- to

medium-grained quartz sandstone, and is thin bedded and laminated. Although not exposed, the lower contact of the Devils Island with the Orienta appears to be conformable. This formation is estimated to be 100 m thick. The Chequamegon Formation is the youngest formation of the Bayfield Group. The Chequamegon is predominantly a medium-grained grayish red to pale red feldspathic sandstone. The lower contact of the Chequamegon appears to be gradation with the Devils Island Formation. This sandstone appears to be about 330 m thick. Some data suggest that the Chequamegon may be Cambrian in age (Ostrom and Slaughter, 1967). An alternate interpretation of Upper Keweenawan sedimentary rock is possible. Ostrom recognizes some stratigraphic relationships in the Lake Superior region that suggest to him that the Chequamegon and the Orienta might be correlative, and that the overlying Devils Island might be equivalent to the Galesville Formation of Late Cambrian age. This would necessitate an unconformity at the base of the Devils Island.

JACOBSVILLE FORMATION

A large area of Jacobsville Formation occurs immediately south of the Keweenaw Peninsula and along the Lake Superior shoreline near Marquette, Michigan. It is a thick red bed sequence about 3,500 m thick and consists of sandstone with some conglomerate and siltstone. The Jacobsville is generally assigned to the Upper Keweenawan, although others, such as Dorr and Eschmann (1973), assign the sandstone to the Cambrian. The sandstone is known to overlie Middle Keweenawan volcanics, and to the east the sandstone can be shown to rest on a paleosol (Kalliokoski, 1975). The paleosol formation is significant in that it represents a period of subareal erosion and intense chemical weathering in the source area.

CORRELATION

The Bayfield Group has been correlated with the Jacobsville Formation of the northern Peninsula of Michigan (Thwaites, 1935; Raasch, 1950; Hamblin, 1961; Hite, 1968) and with the Hinckley of Minnesota (Tyler and others, 1940; Raasch, 1950). There is a possibility that it also correlates with all or part of the Cambrian Mt. Simon Sandstone.

The Bayfield Sandstone was named by Lane and Seaman (1907) for exposures of red and brown and white-striped quartz sandstone with streaks of red clay shale located near Jacobsville, Michigan, and which Irving (1883) called the "Eastern Sandstones." This sandstone is conglomeratic in its base where it overlaps older formations.

The Jacobsville Formation differs from the Bayfield in its heavy mineral composition. According to Denning (1949), who sampled 14 outcrops of Jacobsville, 12 outcrops contain epidote and apatite, one contains only apatite, and one contains neither apatite nor epidote. These minerals occur in the Oronto Group and in the Orienta Formation. They are not found in the overlying Devils Island Formation.

Hamblin believes that a signficant break in sedimentation occurred between deposition of the Freda red feldspathic sandstone and the Jacobsville quartz sandstone in the Northern Peninsula. Hamblin (1961) stated that "suggestions of an angular conformity between the Freda and Jacobsville are ... found in several outcrops in Whitefish Bay." In 1958 he reported the existence of a pre-Jacobsville erosion surface. Van Hise and Leith (1911, p. 614) described this as a "profound unconformity ..." and went on to say that "the manner in which the Cambrian sandstone cuts unconformably across the several series of

the Precambrian is well illustrated on the east side of the Precambrian area of the Upper Peninsula of Michigan and northern Wisconsin." In the absence of the Freda Formation, the Jacobsville overlies basement rock.

The feldspar content of the Jacobsville is similar to the whole of the Freda and the Orienta. Analyses of outcrop samples collected from the Jacobsville Formation between Marquette and Munising in the Upper Peninsula of Michigan indicate feldspar contents of from 20 to 40 percent, although some beds may contain less than 5 percent.

The lithologic, mineralogic, and textural character of the Jacobsville, plus paleomagnetism and other characteristics, is interpreted to indicate that the Jacobsville may be equivalent to either or both the Freda and the Orienta.

Rock units in southern Wisconsin and southeastern Minnesota that are tentatively correlated with the Devils Island Formation include the Hinckley Formation of northeastern Minnesota, the "Hinckley-Mt. Simon" of southeastern Minnesota, and the Mt. Simon Sandstone of Wisconsin. The bases for correlation are (1) similar stratigraphic position, namely above either Precambrian crystalline rock or rock of the Oronto Group and below the Eau Claire Formation; (2) lithologic and mineralogic similarity; (3) contact relationships that show conformity and unconformity at the base and conformity and transition at the top; and (4) occurrence within the same geological and structural province, namely the structural feature manifest as the Midcontinent Gravity High.

RESERVOIR CHARACTERISTICS OF THE KEWEENAWAN SUPERGROUP, LAKE SUPERIOR REGION

Richard W. Ojakangas

INTRODUCTION

This is a brief review of the stratigraphic, sedimentologic, and petrographic characteristics of the several thousand meter thick, post-volcanic, siliciclastic Keweenawan Supergroup in the Lake Superior region with an emphasis on petroleum reservoir potential. It has been known for several decades that the black Nonesuch Shale, low in the post-volcanic rock column, is rich in organic material and even exudes petroleum in the Copper Range Mine, White Pine, Michigan. During late Precambrian time, many sedimentary and volcanic rock units were deposited in the Lake Superior region. The upper Precambrian rock column can be thought of as consisting of three sequences: pre-volcanic quartz sandstone (Ojakangas and Morey, 1982a), Keweenawan volcanic rock (Green, 1982b), and the post-volcanic sedimentary rock units that are the subject of this paper.

Keweenawan Supergroup rock, a red bed sequence that includes the Oronto Group and the overlying Bayfield Group, and their correlative rock units, are dominated by coarse clastic units that have potential as reservoir rock for petroleum that may have been generated within the Nonesuch Shale during deep burial. Few published data are available on porosity and permeability of these units. Petrography has focused on the framework composition of the sandstone and conglomerate, rather than on diagenesis.

STRATIGRAPHY AND SEDIMENTOLOGY

The post-volcanic sedimentary rock units were deposited in and adjacent to the Midcontinent Rift all along its 1,400 km length, but are exposed only in the

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