

EXTENT OF ORONTO GROUP

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ABSTRACT

The Nonesuch Formation of the Proterozoic Oronto Group of northern Wisconsin and Upper Michigan contains known hydrocarbon source strata. Other Oronto Group sedimentary rocks contain potential reservoir beds. Deposition of the Oronto Group was controlled by development of the Midcontinent Rift System. Within the central horst of the rift, formations are confined to the limits of the Ashland Syncline. Several areas of Precambrian sedimentation equivalent in age to the Oronto Group are known in adjacent rift-horst sections of Minnesota.

INTRODUCTION

Outcrop is rare in the sedimentary basins that flank the central horst. Significant Oronto exposures along the Middle River in Douglas County, Wisconsin, several wells drilled into Proterozoic clastic rock in Sawyer County, Wisconsin, and seismic and other geophysical information suggest that Oronto Group rock is distributed throughout the subsurface of these flanking basins. Geophysical data collected in Lake Superior also suggest the presence of source and reservoir rock of Oronto age.

Thwaites (1912) named and subdivided the predominantly red clastic rock of the Oronto Group into five formations: the Outer Conglomerate, Nonesuch Formation, Freda Sandstone, Eileen Sandstone, and the Amnicon Formation from oldest to youngest. On the basis of the heavy-mineral assemblage of the Oronto Group and the younger Bayfield Group, Tyler and others (1940) proposed assigning the Eileen Sandstone to the basal Orienta Sandstone of the Bayfield Group and equating the Amnicon Formation with the upper Freda Sandstone. White and others (1953) combined the Outer Conglomerate of Thwaites (1912) with the older Lake Shore Traps and the Great Conglomerate, and termed this series the Copper Harbor Conglomerate. Recent use of the name Oronto Group includes the Copper Harbor Conglomerate, Nonesuch Formation, and Freda Sandstone (Craddock, 1972a; Davidson, 1982).

All of the known Oronto Group strata of northwest Wisconsin were derived from and distributed by the processes of intracontinental rifting (Fowler and Kuenzi, 1978; Daniels, 1982; Morey and Ojakangas, 1982; Van Schmus and Hinze, 1985). Because of this relationship, this discussion of the presence, distribution, thickness, and lithology of the Oronto Group formations will be divided into three structural areas of the Midcontinent Rift System: central or St. Croix Horst, southerly or River Falls Syncline Basin; and northerly or Bayfield Basin; and the distribution of the Oronto Group in Lake Superior (fig. 1).

ST. CROIX HORST

The St. Croix Horst was identified from gravity studies by Thiel (1956) and named by Craddock and others (1963). The northerly and northwesterly flank is defined by the Pine (Minnesota)-Douglas (Minnesota and Wisconsin)-Isle Royale (Michigan) Fault System. The southerly and southeasterly border is defined by the Hastings (Minnesota)-Lake Owen (Wisconsin)-Keweenaw (Michigan) Fault System. The structural configuration of the St. Croix Horst is established by the Ashland Syncline. Within the fault boundaries of the St. Croix Horst within the Ashland Syncline the distribution of Oronto Group sedimentary strata can be controlled by ten outcrop sites and a number of mineral exploration bore holes. The location, formational status, and approximate stratigraphic thickness of these outcrop sites are:

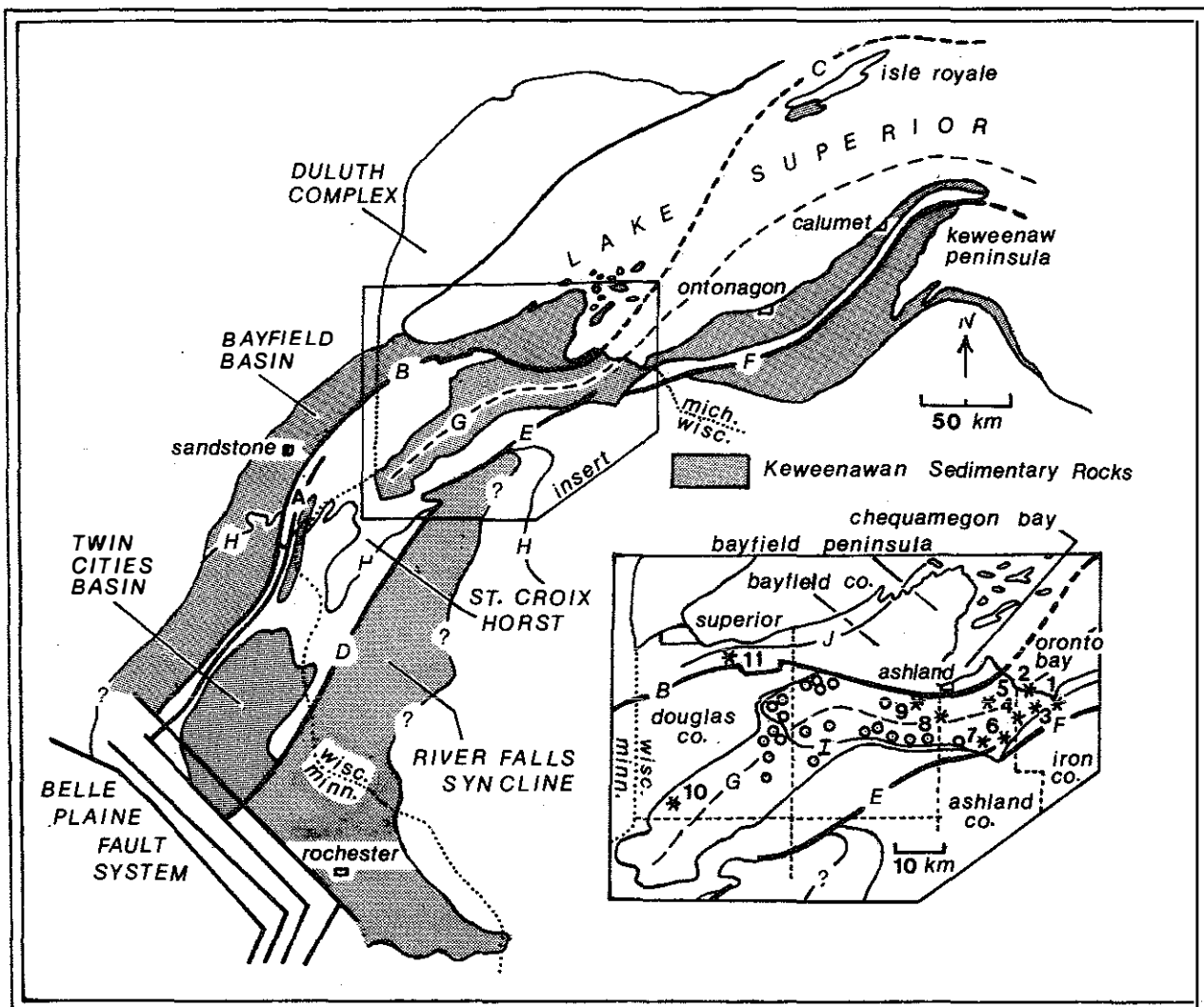


Figure 1. Generalized geologic map of the Midcontinent Rift System in the Lake Superior region. Faults forming boundaries of the St. Croix horst are A. Pine, B. Douglas, C. Isle Royale, D. Hasting, E. Lake Owen, and F. Keweenaw. Secondary faults not shown. Principal outcrop areas are 1. Montreal River and Oronto Bay, 2. Marble Point, 3. Potato River, 4. Copper Falls, 5. Bad River, 6. Silver Creek, 7. Brunsweiler River, 8. White River, 9. South Rish River, 10. St. Croix River, and 11. Middle River. Circles represent Bear Creek core sites. Other identifiers are G. Axis of the Ashland Syncline, H. Paleozoic sedimentation limit, I. Nonesuch Formation limit, and J. Oronto Group sedimentation limit north of the St. Croix Horst, after White (1966a).

1. Montreal River-Oronto Bay: T. 47 N., R. 1 E. and R. 1 W.
 Freda Sandstone: 3,650 m (Hite, 1968)
 Nonesuch Formation: 110 m (Hite, 1968)
 Copper Harbor Conglomerate: 365 m (Hite, 1968)
2. Marble Point: T. 47 N. and T. 48 N., R. 1 W.
 Freda Sandstone: underwater outcrop (Myers, 1971)
3. Potato River: T. 46 N., R. 1 W. and R. 2 W.
 Freda Sandstone: 2,750 m (Hite, 1968)
 Nonesuch Formation: 110 m (Myers, 1971)
 Copper Harbor Conglomerate: 250 m (Hite, 1968)
4. Copper Falls: T. 45 N. and T. 46 N., R. 2 W.
 Freda Sandstone: 1,850 m (Hite, 1968)
 Nonesuch Formation: 110 m (Hubbard, 1975)
 Copper Harbor Conglomerate: 140 m (Hite, 1968)
5. Bad River: T. 47 N., R. 3 W.
 Freda Sandstone: not measured (Myers, 1971)
6. Silver Creek: T. 45 N., R. 3 W.
 Freda Sandstone: 1,350 m (Myers, 1971)
7. Brunsweiler River: T. 45 N., R. 4 W.
 Freda Sandstone: not measured (Myers, 1971)
8. White River: T. 46 N., R. 4 W. and R. 5 W.
 Freda Sandstone: 1,150 m (Myers, 1971)
9. South Fish Creek: T. 47 N., R. 5 W.
 Freda Sandstone: 1,300 m (Myers, 1971)
10. St. Croix River: T. 43 N. and T. 44 N., R. 13 W. and R. 14 W.
 Copper Harbor Conglomerate: not measured (Myers, 1971)

Thwaites (1912) believed that the northern-most exposures at the South Fish Creek outcrop correlate with the Orienta Sandstone of the Bayfield Group. In their regional study of the heavy-mineral assemblages of both Oronto and Bayfield Group strata, Tyler and others (1940) determined that the epidote abundance of the total Oronto Group heavy-mineral suite ranged from 12 to 35 percent. In contrast equivalent epidote percentages within Bayfield Group formations ranged from zero to a trace. Myers (1971), in describing the South Fish Creek section, stated that "The abundance of epidote in [these] beds ... is much greater than any other exposure of Oronto." Myers considered all outcrops in these three sections to belong to the Freda Formation. In this same general area, but several kilometers to the southwest, a 550 m section of fine-grained, arkosic sandstone crops out. Thwaites (1912) established this exposure as the type section of his Eileen Formation. Tyler and others (1940) found absolutely no epidote associated with these same strata and consequently suggested that the Eileen Formation is "probably basal Orienta," a position compatible with the paleomagnetic data of DuBois (1962). By redefining the age of these outcrops, Tyler and others (1940) recognized that they were advocating the placement of Bayfield Group strata southwesterly of Oronto Group strata, a mapping anomaly considering the regional distribution of outcrops belonging to

both groups. Tyler and others (1940) offered two solutions, both involving faulting.

In 1959 and 1960 the Bear Creek Mining Company conducted a mineral exploration program in Bayfield and Douglas Counties, Wisconsin. Nonesuch Formation strata were cored as far west as Lake Nebagamon, Douglas County (T. 46 N., R. 11 W.), and as far south as T. 45 N. (open-file information, U.S. Bureau of Mines core repository, Minneapolis, Minnesota). As recently as 1982, Daniels reported that the Nonesuch Formation thinned southwesterly from 215 m in the Calumet area of Michigan to 76 m at Copper Falls, Wisconsin. Bear Creek Mining Company core data indicate this thinning trend is reversed west of Copper Falls with as much as 140 m of Nonesuch Formation cored in western Bayfield County (T. 45 N., R. 9 W.). This same Bayfield County core contained six occurrences of a "hydrocarbon filled veinlet."

Interpretation of profiles 16, 17, and 30 of the refraction seismic data of Mooney and others (1970) suggested this column is composed of units associated with their "middle" and "lower seismic unit." They loosely correlated these seismic units in northwest Wisconsin with strata of the Oronto Group. Thus, geologic and geophysical data indicate that the basaltic basement of the St. Croix Horst in northwest Wisconsin is partially covered by sedimentary units of the Oronto Group. The Copper Harbor Conglomerate defines the limits of the Ashland Syncline. Core data indicate that the Nonesuch Formation and the Freda Formation are restricted to that part of the syncline between central T. 45 N. and southern T. 48 N. and east of R. 11 W. To the southwest an Oronto Group equivalent, the Solor Church Formation, is found underlying Paleozoic rock within the Twin Cities Basin lying on top of the St. Croix Horst in east-central Minnesota. The hydrocarbon source rock evaluation of this formation is discussed by Hatch and Morey (1985).

To the north of the Twin Cities Basin, an elongate basin covering approximately 300 square km contains Oronto Group-equivalent sedimentary rock. Farnham (1967) identified this structure as a graben and, on the basis of seismic refraction velocities, correlated the rock as principally Oronto Group in age. Farnham (1967) determined this Oronto equivalent sequence ranged from 1,200 m in the north to 6,000 m at the southern border of this structure. Craddock (1972b) differed in interpretation only in showing this area of rock to be a half-graben, bounded only on the east by faults. A small part of this outlier of sedimentation to the Ashland Syncline and the Twin Cities Basin extends from Minnesota into Burnett and Polk Counties, Wisconsin.

RIVER FALLS SYNCLINE

Thwaites (1931) mentioned the presence of pre-Paleozoic red clastic rock in the subsurface of a "considerable part of northwest Wisconsin." Thwaites (1935) depicted Oronto Group sedimentary rock associated with the River Falls Syncline on his Lake Superior Basin structural map. Stauffer (1927), presented a log of a deep well located 2 km east of Rochester, Minnesota, that includes 620 m of a pre-Hinckley Sandstone "red clastic series" and makes reference to a 56 m interval "showing of oil." After model analysis of the eastern segment of their gravity traverse (Craddock and others, 1963) indicate that "Precambrian strata [here] could reach a thickness of almost 3,350 meters" in the River Falls Syncline. Refraction data of Mooney and others (1970) confirm the existence of "an important sedimentary basin ... considered Cambrian and Upper Keweenawan" in age and located east of the St. Croix Horst in west-central Wis-

consin in the River Falls Syncline and on the basis of seismic velocity values, concluded that "rocks considered probably equivalent to the Upper Keweenaw Oronto Group occur ... widely distributed in the eastern basin." The rocks are depicted to be as thick as 1,250 m. These studies thus support the suggestion of Thiel (1956) that the regional gravity low located east and south-east of the St. Croix Horst in Wisconsin "reflects a thick accumulation of Upper Keweenaw sediments."

THE BAYFIELD BASIN

Any evaluation of the extent of Oronto Group sedimentation to the north of the St. Croix Horst in Wisconsin must include outcrop along the Middle River, Douglas County (sec. 24 and 25, T. 48 N., R. 12 W.). The outcrop is not unanimously accepted as belonging to the Bayfield Group. Because Bayfield Group exposures are rather common along the southwest shore of Lake Superior from Superior, Wisconsin, northeasterly around the Bayfield Peninsula, there is no dispute regarding the existence of the Bayfield Basin. In fact, this is the specific region to which Thiel (1956) correlated gravity with geology in his classic determination of a geologic tectonic model of the Midcontinent Gravity High. The dispute concerns the age of basin sedimentary rock fill. Is the basin fill entirely of Bayfield Group strata or is a deeper Oronto Group sequence present?

A review of recent literature indicates an Oronto Group correlation for at least a part of the Middle River section is accepted by Halls (1966), White (1966a), Farnham (1967), Hite (1968), Myers (1971), and Watts (1981). White (1966a) emphasized the significance of this outcrop by stating that "this exposure is important because it shows that rocks of the Oronto Group do occur beneath the Bayfield Group north of the Douglas fault."

Because the geologic distribution of the Oronto Group north of the St. Croix Horst and into the region of Lake Superior proper is dependent upon the age of this outcrop, a review of its stratigraphic and petrographic interpretation is in order. Thwaites (1912) described in detail the Middle River sequence. Upper Keweenaw, structurally overturned, red clastic rock is found in fault contact with Middle Keweenaw basalt. Downstream, to the north, these beds become younger in age and the dip gradually declines with horizontal beds being found approximately 450 m from the fault contact. On the basis of field lithologic comparison, Thwaites (1912) assigned the oldest 111 m of this sequence to the Freda Sandstone and considered the remaining beds to be Orienta Sandstone (Bayfield Group) in conformable contact with the Oronto-age sedimentary rock. Thwaites (1912) felt so confident in this correlation that he wrote, "In the field the lithologic likeness of the lower beds of this section to the upper part of the known Annicon formation of the Oronto Group is more striking than any description can make it, so that the writer has no reasonable doubt of the correlation as given." In their regional heavy-mineral study, Tyler and others (1940) accepted the basic premise of Thwaites (1912) and added to this evaluation by determining that Oronto and Bayfield sedimentary rock could be distinguished by the presence (Oronto) or absence (Bayfield) of the mineral epidote. In their analysis of Middle River outcrop beds termed Orienta Sandstone by Thwaites (1912), Tyler and others (1940) reported no epidote; those classified as Oronto Group by Thwaites (1912) contained epidote ranging from 6 to 38 percent of the total heavy mineral suite. Hamblin (1961) substantiates this heavy-mineral group differentiation by identifying the Freda Formation as containing epidote ranging from 6 to 35 percent; his equivalent anal-

ysis of Bayfield Group clastic rock ranged from zero to 4 percent. Hite (1968) reported the Middle River Oronto Group (Freda Sandstone) units contain 9.71 percent epidote, and Bayfield Group (Orienta Sandstone) units from the same area possess 0.1 percent epidote.

Myers (1971) reported high epidote, relatively high illite and low kaolinite content, plus a relative abundance of feldspar, shale beds, and sparry calcite cement to the Middle River outcrop. He concluded that "the steeply dipping Middle River beds belong to the Oronto Group," although Myers (1971) correlated the horizontal beds at this site with the basal Bayfield Group and thus argued for the presence here of an angular unconformity.

Mooney and others (1970) conducted six east-west seismic refraction profiles north of the Douglas fault from north-central Douglas County to east-central Bayfield County. They recognized six distinct velocity groups. Three of these "layer identifications" they named the Upper, Middle, and Lower Oronto Group, and correlated these respectively with the Freda Formation, Nonesuch Formation, and Copper Harbor Conglomerate. Their portrayal of a section across the Bayfield Basin suggests that the Nonesuch Formation and the Copper Harbor Conglomerate maintain a uniform thickness in Douglas and Bayfield Counties and the Freda Formation thins to the west. These conclusions support the interpretation reached by White (1966a).

The presence and geologic extent of these Oronto Group correlatives west of the St. Croix Horst in Minnesota, as determined by drill hole and seismic analysis, is discussed by Austin (1970), Mooney and others (1970), Morey (1974), and Hatch and Morey (1985). Farnham (1967) mentioned a Bayfield Basin well-log sample that is described as a "volcanic pebble conglomerate" and speculated that this might be evidence for the presence of the Copper Harbor Conglomerate in the subsurface of Minnesota. Morey and Ojakangas (1982) supported the conclusions of these Oronto Group equivalent distribution studies but pointed out that seismic evidence suggests an absence of strata of this age in the Bayfield Basin from the region of Superior, Wisconsin, southwest to the vicinity of Sandstone, Minnesota. Morey and Ojakangas (1982) suggested that this distribution is controlled by the presence of vertical displacement, northwest-trending faults that offset the strike continuity of the Douglas Fault.

EXTENSION UNDER LAKE SUPERIOR

Watts (1981) pointed out that the presence of Middle Keweenaw basalt in the Lake Superior Basin records an initial tensional phase in the development of the Midcontinent Rift. The earlier work of Butler and Burbank (1929) and Halls (1966) observed that the basalt increases in thickness toward the center of Lake Superior.

Daniels (1982) indicated that both the Copper Harbor Conglomerate and the Nonesuch Formation increase in thickness to the north under Lake Superior from the Keweenaw Peninsula of Michigan. In the vicinity of Ontonagan, Michigan, this thickening takes place at the rate of 25 m per km for the Copper Harbor Conglomerate and 5 m per km for the Nonesuch Formation. This trend and the distribution pattern of the Nonesuch Formation suggested by White (1966a) might indicate that although the Nonesuch Formation is present and of maximum thickness under central Lake Superior, it might thin to the point of becoming absent in the western Lake Superior region.

Hamblin (1961, 1965) studied the sediment dispersal patterns in Upper Keweenawan sedimentary rocks. He believed that the Oronto basin was "the topographic basin which received Keweenawan sediments and basalts ... in approximately the present site of Lake Superior The northern boundary of the basin was probably very near the northern shore of the Lake [Superior]."

In developing a tectonic history for the Midcontinent Rift System, Hamblin (1958), White (1966a and b), Farnham (1967), Morey and Ojakangas (1982), Kalliokoski, (1982), and Green (1983) have shown that the boundary faults of the St. Croix Horst were involved in major, if not principal, movements after the cessation of Oronto time. Thus, this structure may not have been developed to the point of influencing the depositional extent of Oronto Group sedimentation.

It appears the extent of Oronto Group sedimentation in northwestern Wisconsin is much greater than indicated by the geologic and geographic extent of outcrop of the sedimentary rock. This extent is greater than the conventional portrayal of confinement to the central part of the St. Croix Horst.

CONCLUSIONS

The distribution of Oronto Group rock within the Lake Superior region is central in importance to the search for hydrocarbon because the middle unit of the Oronto Group, the Nonesuch Formation, is a known oil source. The extent and history of the Oronto Group was directly influenced by Midcontinent Rift tectonic activity.

Within the central horst of the Midcontinent Rift System, Oronto Group rock in Wisconsin is well known from outcrop and drill-core data. The limit of the rock is determined by the limits of the Ashland Syncline. To the southeast in Minnesota, Oronto-age equivalents have been identified in the Twin Cities Basin by drill core and within an unnamed graben by seismic analysis.

To the south of the horst, Oronto rock within the River Falls Syncline is suggested by several shallow wells that penetrated Precambrian clastics and by refraction analysis. To the north of the horst, the presence of Oronto strata within the Bayfield Basin is supported by seismic data and heavy-mineral data of the well studied Middle River site.

Oronto Group under Lake Superior is suggested by numerous studies of the lithology, thickness, and focus changes of Oronto sedimentary rock exposed along the south shore of Lake Superior. There appears to be sufficient evidence to suggest that Oronto Group sedimentary rock, including the organic-rich Nonesuch Formation, can be found at depth throughout the extent of the Midcontinent Rift.

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