

*It's Written in the Rocks*

# THE BWCA HISTORY

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The history of our earth is written in the rocks of Minnesota's Boundary Waters Canoe Area.

The rocks of the BWCA are part of the earliest record of earth history on the North American Continent. They provide evidence of the earliest weathering and erosion of rocks. They also record the first period of uplift which enlarged what is believed to be the primeval core of the continent, the vast Canadian Shield area (see figure on page 23).

The oldest exposed rocks in the BWCA are volcanic flows called Ely Greenstone, which formed on an ocean floor. These masses of volcanic rock are flattened on one side resem-

bling piles of dough or pillows. Such features indicate reaction with sea water during chilling of the lava and are found on lavas formed on the sea floor today.

The pillow texture makes it possible to recognize the original tops and bottoms of the submarine flows. These early rocks participated in some type of large scale movements, for the pillowed textures are deformed and the original horizontal surfaces are steeply inclined or overturned. Exposures of Ely Greenstone are found at the southwest end of Moose Lake, the north shore of Knife Lake and the east shore of Gabimichigami Lake.

At the eastern end of the BWCA,



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large masses of coarse-grained granitic rocks are found, and they cut the greenstone flows. Thus the granites are younger than the greenstone. The contact between the two rock types can be seen in exposures between Sea Gull Lake and the Kekekabic Trail. There are excellent exposures of granitic rocks along the shore lines of Saganaga and Sea Gull Lakes.

Overlying the Ely greenstone is the Knife Lake Group, a group of metamorphosed sedimentary rocks formed by the erosion of the uplifted greenstones and granitic rocks.

There is evidence that erosion of the Ely Greenstone provided a source of sediment to the early ocean and thus began the process of continental growth. Outcrops of the Knife Lake Group are beautifully exposed in Cache Bay on Saganaga Lake just across the International Boundary. Other examples are found along the shore of Moose Lake, Ensign Lake, the south and northeast shore of Knife Lake, the north and south shore of Kekekabic Lake, the shore of Ogishkemuncie Lake and the northeast shore of Gabimichigami Lake.

The complexity of the Knife Lake rocks was recognized by Professor J. W. Gruner, who completed a classic study of the stratigraphy and structure of the complex geology on the BWCA in 1941. He found that volcanic rocks (Ely Greenstone) and sediments from the erosion of the Greenstone (Knife Lake Group) were interlayered. This can only mean that the early periods of volcanism and deposition of sediments were complex. However, eventually the evidence of volcanism disappears in the geologic record.

As in the case of the greenstones, the Knife Lake sediments were deformed and metamorphosed. The deformation of the Knife Lake sediments indicates the beginning of a new period of uplift. The erosion of these rocks contributed additional rock units to the growing continent.

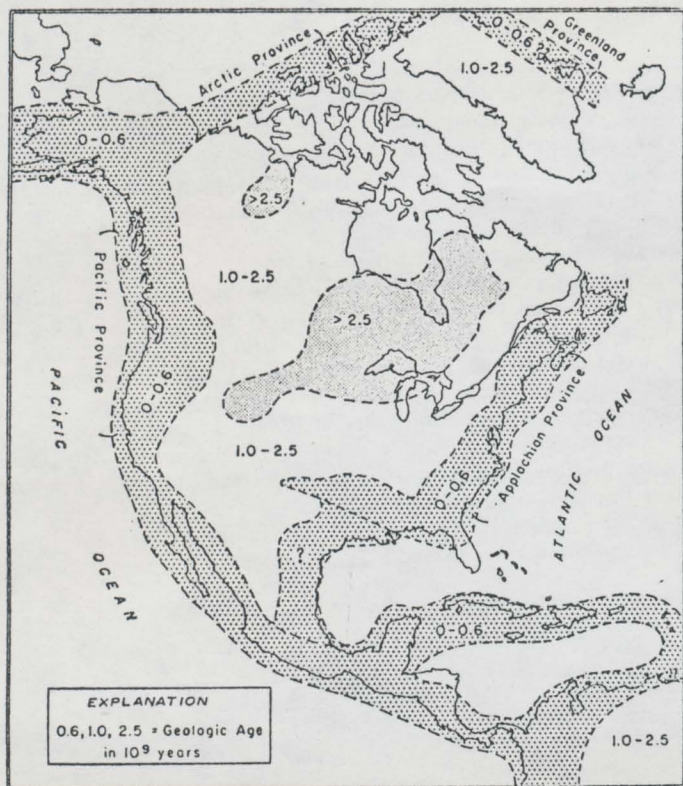
During this process, granitic rocks formed deep in the earth cut through the greenstone and sediments. These are referred to as Algoman granites and exposures are found on the islands and south shore of Snowbank Lake, east shore of Round Lake and southeast shore of Kekekabic Lake.

All of the rocks in the BWCA except for the glacial materials are older than about one billion years. This period of time is referred to as Precambrian. The rocks may be subdivided into Lower, Middle and Upper Precambrian rocks. The rocks just described belong to the Lower Precambrian.

The intensive erosion that followed the uplift of the Knife Lake sediments marks the beginning of a significantly different geological period in the BWCA. The landscape was leveled and sandy products of the intensive erosion now overlay the Knife Lake sediments as a slightly recrystallized rock called quartzite.

This type of rock formed in a near shore environment. It is overlain by several hundred feet of sediment rich in iron oxides, carbonates, silicates and sulfides. This is the economically important iron formation.

In the BWCA, exposures of this are found at the eastern end of the Kekekabic Trail and on the north shore of



*Gross patterns and ages of geologic provinces in North America, as defined by major granite-forming, mountain-building events.*

Gunflint Lake, after which this rock unit is named.

It is believed that iron formations like the Gunflint were formed in shallow seas with restricted circulation to the open ocean. The source of the iron is still a matter of conjecture. Formation of sedimentary rocks continued after the Gunflint Formation was formed but the nature of the sediment and the basins of deposition changed.

As the erosion and deposition con-

tinued, thousands of feet of mud was deposited in northeast trending basins extending into Central Minnesota. Exposures of the resulting rocks, called the Rove Formation, are found along the shore lines of the long, narrow lakes and low-lying areas of the BWCA northeast of the Gunflint Trail.

The Gunflint and Rove Formations make up the Middle Precambrian system of rocks in the BWCA. The struc-

tural relations are quite simple — gentle subsidence toward Lake Superior. The absence of intense deformation and granitic intrusions indicate that the rocks in the vicinity of the BWCA had become a part of the stable continent at the end of the Early Precambrian.

Overlying the Rove Formation outside the BWCA are isolated exposures of sandstones which formed in a near shore or delta-like environment in the vicinity of the Pigeon River along the international boundary. This indicates some uplift of the older Rove Formation and marks an unconformity which separates Middle and Upper Precambrian Rocks.

The Upper Precambrian rocks are largely igneous, but distinctly different from the older greenstones and granitic rocks. They consist of rocks which formed at depth and at the surface. Their composition is grossly similar to the greenstone but the volcanism occurred mainly on the land rather than on the sea floor.

The first recorded event of Late Precambrian igneous activity in the BWCA is the intrusion of fine to medium grained igneous rocks in the Rove Formation. The molten rock displaced existing rock layers and solidified in sill-like and dike-like masses. These rocks are referred to as the Logan Intrusives. Subsequent tilting and erosion of the resistant sills and the Rove Formation gives the BWCA northeast of the Gunflint Trail its typical "sawtooth" topography.

After and perhaps during the emplacement of the Logan Sills there was widespread volcanism in the Lake Superior region. The present north

shore of Lake Superior is developed in this sequence of volcanic flows. Minor remnants can be found in the BWCA around some small lakes. Don, Ragged and Juniper south and east of Tuscarora Lake.

Shortly after, or again perhaps during the time the North Shore volcanics were being built up, coarse-grained rocks of similar composition to the flows were being emplaced within the volcanic pile. Subsequent erosion has exposed a bow-shaped edge of these rocks, called the Duluth Complex, which extends from Duluth north to Allen, northeast to Little Sagana and east to Greenwood Lake.

Most of the lakes south of the Kekekabic Trail have exposures of Duluth Complex rocks. Professor F. F. Grout began mapping these rocks in 1918 for the Department of Geology. More recent mapping has shown that it is a complex of different periods of emplacement.

The only structural deformation after emplacement of the Duluth Complex was gentle subsidence of the older rocks toward Lake Superior. A part of the last igneous activity was the emplacement of dikes in fractures formed during this subsidence.

The entire Lake Superior region must have been an area of high relief by the end of Late Precambrian volcanism. Weathering and erosion set in and deposition began at the edges of the volcanic pile. Shorelines migrated southward.

If any deposition ever occurred in the vicinity of the BWCA after the beginning of Late Precambrian time, it has all been eroded away. Thus the

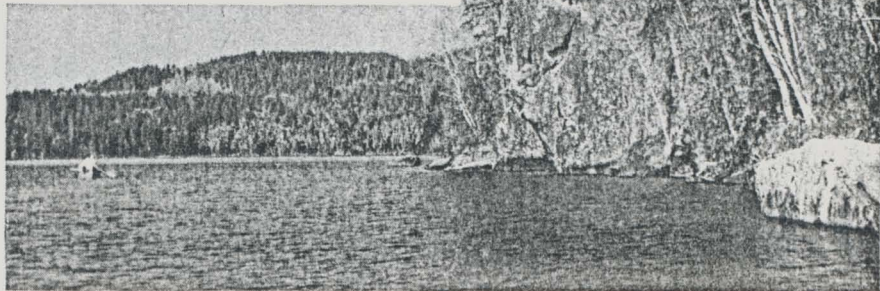
rocks of the BWCA probably were exposed to weathering and erosion from the end of the Late Precambrian until the onset of the Ice Age Pleistocene glaciation one to three million years ago.

The effects of this geologically short but dramatic period are everywhere apparent in the BWCA. Glaciation has largely shaped the present topography. The scouring action of thousands of feet of invading ice has left a large proportion of fresh rock exposures without a mantle of weathered rock. Striations on the rock surfaces indicate direction of movement of the ice lobes.

Large locally derived boulders, some up to 20-30 feet across, demonstrate the great erosional effect of the ice. The wide variety of glacial deposits attest to the complexity of deposition of glacial material during successive advances and wasting away of the ice.

In understanding the complex geo-

*SHEER granite walls form a natural fortress along the south shore of Kekebabic Lake, one of many beautiful waters in the BWCA.*



logic history of the Boundary Waters Canoe Area, it is important to understand how this "window to the Precambrian" relates to the large-scale geologic process of continental growth. Several concepts basic to current ideas on the growth of continents can be recognized in the geology of the area:

1) The total extent of the continental areas has increased throughout geologic time;

# Geologic History of the BWCA

| ERA                 | RADIOMETRIC AGE DETERMINATION                                   | FORMATION  | SIGNIFICANCE   | OUTCROP LOCATION IN THE BWCA  |
|---------------------|---|--|--|---|
| Late Pre-cambrian   |   | <b>Duluth Complex</b>  |  | Lakes South of Kekekabic Trail.   |
|                     | 1.1 Billion Years Before Present                                | North Shore Volcanics  | Volcanism on land not sea-flowed onto a stable land mass.  | Don, Ragged and Juniper Lakes and south and east of Tuscarora.  |
|                     |   | Logan Intrusives   | Intruded Rove Formation.   | Northeast of Gunflint Trail.  |
| Middle Pre-cambrian | 1.7 Billion Years Before Present                                | Rove Formation   | Thousands of feet of muds derived from sediment sources similar in location to iron formation sources.<br><br>No deformation indicates that the area had become a part of a stable continental area.   | Along shorelines of lakes northeast of Gunflint Lakes.  |
|                     | 2.0 Billion Years Before Present                                | Gunflint Iron Formation  | Lower portions are mainly a hardened sandstone but grade upward into several hundred feet of sediments rich in iron.<br><br>Source of the sediments appears to be the uplifted Knife Lake group.   | East end of Kekekabic Trail, north shore of Gunflint Lake.  |
|                     | <b>LONG PERIOD OF EROSION</b>                                   |  |  |   |
| Early Pre-cambrian  | 2.5 Billion Years Before Present                                | Algonman Granites  | Intrusion of these granites marks the deformation period of the Knife Lake Group and the second period of deformation for the Greenstone granites.   | The islands and south shore of Snowbank Lake, east shore of Round Lake, southeast shore of Kekekabic Lake.  |
|                     | Deformation Period and Renewed Uplift of Knife Lake Group ..... |  |  |   |
|                     |   | <b>Knife Lake Group</b>  | Sedimentary rocks derived from erosion of greenstone and granites first evidence of continental growth by the buildup of sedimentary rocks (Knife Lake) around a core of igneous rock (Greenstones and granites).<br><br>Transition from volcanism, to more stable period recorded in Knife Lake outcrops. | Cache Bay of Saganaga Lake, south and northeast shore of Knife Lake, Kekekabic Lake,<br><br>Ogishkemuncie Lake, Northeast shore of Gabimichigami Lake, Moose Lake, Ensign Lake. |
|                     | 2.7 Billion Years Before Present                                | Saganaga Granites  | Intrusion of granites indicates the deformation phase of greenstone — intrusions associated with periods of crustal activity.  |   |
|                     | Deformation Period .....  |  |  |   |
|                     | <b>Ely Greenstone</b>   | Oldest rocks.<br>Deposited in a marine environment.<br><br>Earliest deformation phase recorded in the deformed pillow basalts.<br><br>Provides sediment source for Knife Lake. | Southwest end of Moose Lake.<br><br>North Shore of Knife Lake.<br><br>East Shore of Gabimichigami Lake.  |   |

2) There is a relationship between elevation of mountains and their age;

3) Sediments eroded from the mountain ranges accumulate in great thickness in basins parallel to the edge of continents;

4) Localized melting occurs within the earth at the edge of continents to produce volcanoes at the surface and coarse-grained, light colored, igneous rocks called granites deep within the earth;

5) Eventually, the coastline margins are uplifted and the sedimentary rocks are structurally deformed and mineralogically changed to metamorphic rocks.

These five general concepts have their equivalents in the stratigraphic record of the BWCA. The earliest rocks are associated with a marine environment. The pillowed basalts (Ely Greenstone) erupted under water, probably offshore of the stable Canadian Shield to the north and east. Yet the younger rocks show the marine environment moved to the south and west.

Uplift, volcanism, intrusions and erosion of the uplifted areas followed the retreating shores. Areas of early uplift, now leveled by erosion and no longer the focus of deformation became part of a stable and topographically muted continental core. A process of continental growth not unlike the ripples moving out from a pebble dropped in a quiet pool.

Minnesota has had three generations of distinguished geologists who have worked in northern Minnesota. The geological data they have gathered has played an important role in the

advancement of understanding of earth processes and history.

These geologists include Professor Gruner, Professor Grout, H. N. Winchell who published the first geological map of the area in 1872; W. H. Emmons who completed a second map in 1932; Dr. G. M. Schwartz who greatly extended the areas of detailed mapping; Professor S. S. Goldich who did pioneering work in the use of and interpretations of radiometric age determinations.

The Minnesota Geological Survey is continuing its mapping program under the direction of Professor P. K. Sims. Members of the Department of Geology and Geophysics of the University of Minnesota and the Department of Geology, University of Minnesota at Duluth, contribute to this program.

Current work includes completion of the new Geologic Map of the Minnesota Bedrock Geology. From this map and other more detailed reports and maps published by the Survey, it is possible to find at least generalized descriptions of the rock types, stratigraphy and structure of most of the exposed geology in the BWCA.

It should be added that the mapping program of the Minnesota Geological Survey contributes not only to the growing fund of basic geologic knowledge and to the development of the natural resources of Minnesota, but also provides critical information needed in the growing concern for the environment.

Sound geological data is needed not only on the actual occurrences of mineralization but also for an understanding of the processes by which

the concentration was affected in the formation of the rocks. This will aid in delineating areas that will not be mineralized and those where drilling—if it must be done to evaluate the resource—can be carried out with minimum disturbance of the area and still give maximum information.

As early as 1919 copper-nickel sulfides were reported at the base of the Duluth Complex on the northeast shore of Gabimichigami. Because of the remoteness of the area and the isolated occurrence this was ignored as a serious potential mineral resource. Later discoveries along the Kawishishi River prompted exploration by mining companies in the fifties. This work uncovered marginal concentrations of copper-nickel sulfide mineralization.

It is clear that questions of further exploration and what should be done about this mineral resource are now critical social and political problems as well as economic ones.

In addition to its natural beauty, the Boundary Waters Canoe Area presents a panorama of the earth's early history with a record written in its rocks. Within its complex rock formations lie the answers to problems of large-scale earth processes and even the origin of the earth itself. This is capped by a record of glaciation which contains information relevant to something as commonplace as the day-to-day weather.

It is small wonder that every geologist who has worked in the BWCA has treated it with respect and been truly inspired by it.

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*A 20th century voyageur gazes across the azure waters of a BWCA lake from an island formed of volcanic tuff, one of a multitude of rock types found in this country.*