PETROLOGY AND STRUCTURE ALONG THE BASSWOOD TRACE OF THE BURNTSIDE LAKE FAULT, NORTH-EAST MINNESOTA

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Introduction:

Basswood Lake is located in the Boundary Waters Canoe Area Wilderness, north-east of Ely, Minnesota. The area is covered by lakes and forests with dense undergrowth. Topographic relief is low and rounded from glaciation. Rocks in the area are Archean in age (≈2.7 by). The Vermilion Fault, which crosses northern Minnesota, splays northward at Burntside Lake and the main trace of the fault continues north-east through Basswood Lake into Canada. Movement along the fault is thought to have occurred in late Archean time. The sense of motion, as well as the amount of displacement, is unknown, but displacement is thought to be on the order of a few miles. Mapping was conducted in the Basswood Lake portion of the fault zone, during the summer of 1988. Petrologic and structural data were collected in order to determine the lithologies in the fault zone and its sense of motion.

Faults:

The weak rock within the fault zone occupy topographic lows because of Pleistocene glacial scour. The main faults, along Pipestone Bay and Jackfish Bay, are almost completely under water and trend N30E to N40E. Minor splay faults occupy valleys, forming linear swamps, and trend N58E to N65E. The faults were recognized by: linear topographic lows, change in lithology from one outcrop to the next, trends in mylonite zones, and cataclastized rock. In some areas cataclasis is so extreme that the rocks are unrecognizable, stained bright pink or red from hydrothermal activity, highly fractured, and often obliterating any pre-fault fabric in the rock. Some areas underwent more ductile deformation, and formed mylonite zones. Not all cataclasis is easily visible in outcrop, but is observable in thin section, and is characterized by strained quartz grains, and hornblende altered to biotite and chlorite along recognizable shear planes.

Foliation:

Structural data was measured from lenses, rafts, or compositional layers within the various mapped lithologic units when possible. Previous work in the area has shown that the attitude of the rafts can be used to define large scale fold structures. Over the whole map, foliated structural elements strike between N60E and N80E; on the whole this is about 20°E of the strike of the main fault traces. Dips of foliations are usually steep and range from NW through vertical to SE, indicating slight overturning or isoclinal folding. Primary foliations are defined by hornblende and biotite alignment and have strikes parallel to splay faults. Secondary foliations, defined by sheared quartz bands and secondary biotite, have strikes parallel to the main fault traces.

Lithologic Units:

Most of the rocks in the map area are pink granite. This consists of massive pink rock with minor amounts of mafic minerals, pink pegmatite veins, white to red stained quartz veins, light yellowish-pink veins, and bands of light pinkish-gray rock. Within this background are lenses, rafts and layers of other lithologies. Rafts are large (.5 m to entire outcrop size), oriented xenoliths. Definition of units is based on the color, mineralogy, texture, and frequency of inclusions.

Meta-sediments (As)

Outcrops are very well layered with alternating bands of a few cm of coarse and fine grained quartz-rich gneiss and minor biotite schist. Outcrops form steep cliffs. Based on coarse to fine grain size, and the presence of biotite, this may represent a turbidite sequence, or a sandstone-shale sequence.The texture in thin section shows the coarse to fine layering seen in hand specimen. Most the rock is quartz (50-60%) and feldspars (35%), with thin layers of chlorite (originally biotite), and traces of calcite.

Biotite schist migmatite (Amb)

Exposures of Amb are evenly layered or banded with alternating layers of pink granite and biotite ± hornblende schist. The layers are continuous over the outcrop; width varies from very fine (a few mm) to wide bands (up to 1 m). The schist layers have a well-defined biotite schistosity, often with pink or white leucocratic layers. The mafic minerals, which comprise 50% of the rock are biotite and hornblende. Both show some alteration to chlorite. The remainder of the schist is mostly quartz (20-60%), feldspars (30-60%), and trace minerals. Leucocratic layers are mainly quartz and feldspars. In some outcrops the layers are folded in open or chevron folds; ptygmatically folded quartz veins are contained within some of the wider mafic bands.

Amphibolite rafts are associated with biotite schist bands; comprising 5-10% of the Amb unit. They tend to be equidimensional, on an outcrop scale, and coarse grained.Texture and composition of the amphibolite rafts suggest that the protolith is dioritic or gabbroic. Mafic minerals (clinopyroxene, hornblende, biotite) comprise 55-90% or the rock. The remainder is subequal amounts of quartz, plagioclase, orthoclase, minor amounts of secondary chlorite, and trace minerals. Relict igneous textures are preserved in hornblende and the feldspars.

Diorite gneiss (Ad)

Diorite gneiss occurs as rafts or lenses within the outcrop of pink granite. The size and distribution of the rafts varies from small, 0.5 m rafts (20% of the outcrop) within a huge outcrop of pink granite, to outcrops of predominantly diorite gneiss (90%), up to 10 m, cross-cut by granitic veins. The presence of a diorite gneiss raft of any size delineates the unit as diorite gneiss. Weathered surfaces appear predominantly white with large (2-3 mm), distinct, aligned hornblende crystals. Fresh surfaces show the hornblende to be in contact with each other, and in greater proportion than appears on the weathered surface. Hornblende (30-35%) is the dominant mafic mineral, and is slightly altered to biotite and chlorite. Plagioclase (50-60%) and orthoclase (0-10%) make up the rest of the rock; both are sericitized. Quartz is absent. Locally, diorite gneiss lenses are intruded into biotite hornblende schist. Amphibolite rafts occur in outcrop with diorite gneiss rafts (10% of the outcrop).

Hornblende granite gneiss (Ahg)

Generally lighter, whiter in color than Ag. Distinguished form Amb by its lack of even banding and from Ad by lack of diorite gneiss lenses. Amphibolite rafts are present as narrow (10-40 cm) and long (up to 3 m) and ribbony-shaped lensoidal rafts.

Granite migmatite (Ag)

This is typical leucocratic pink granite. It lacks any layers of biotite schist or rafts of diorite gneiss or amphibolite. The massive pink rock is cross cut by small (1-4 cm) quartz veins, larger (5-15 cm) pegmatite veins, and wide bands (20-60 cm) of slightly darker grayish-pink rock. Compositionally, quartz is 40-60% of the rock, potassium feldspar is 25-35%, and plagioclase is 15-20%. Small amounts of trace minerals, hornblende and biotite (1-5%) are present and show alteration to chlorite.

Basalt dike (not on map)

A small dike of unaltered basalt was located on the north-west side of United States Point. The dike is 5-8 cm wide and has columnar joints. It follows a joint in the pink granite, which it intrudes. The dike extends about 20 m before it is covered by moss and lichen. In that interval, no displacement by fault motion, crosscutting by pegmatite veins, or fault related joints was observed. The freshness of the rock indicates that it was intruded after the tectonic activity, including faulting, in the area had ceased. Most likely this dike is corresponds to Keweenawan age (1.2 by) igneous activity. Such dikes have been found in the Boundary Waters area, but none this far north (Woodard, personal comm., 1988).

Conclusion:

If the numerous splay faults are interpreted as additive shears, which point in the direction of slip, the sense of motion on the fault was right lateral. Geometrically this works well on the eastern trace, where there are 2 or 3 well mapped small splay faults (see Fig. 1). The western trace does not fit as well geometrically, but as it joins the main trace in the north-east, it must have the same sense of motion. Small schist lenses observed within the fault zone showed displacement along a plane parallel to the main fault trace, but the displacement is left lateral, providing conflicting evidence to the dextral shear hypothesis (Fig.2). The age of the fault is bracketed by deformation and migmatization of the wall rocks, since the fault displaces migmatized units, and by intrusion of the Keweenawan basalt. Faulting probably occurred between 2.6 and 1.2 by.

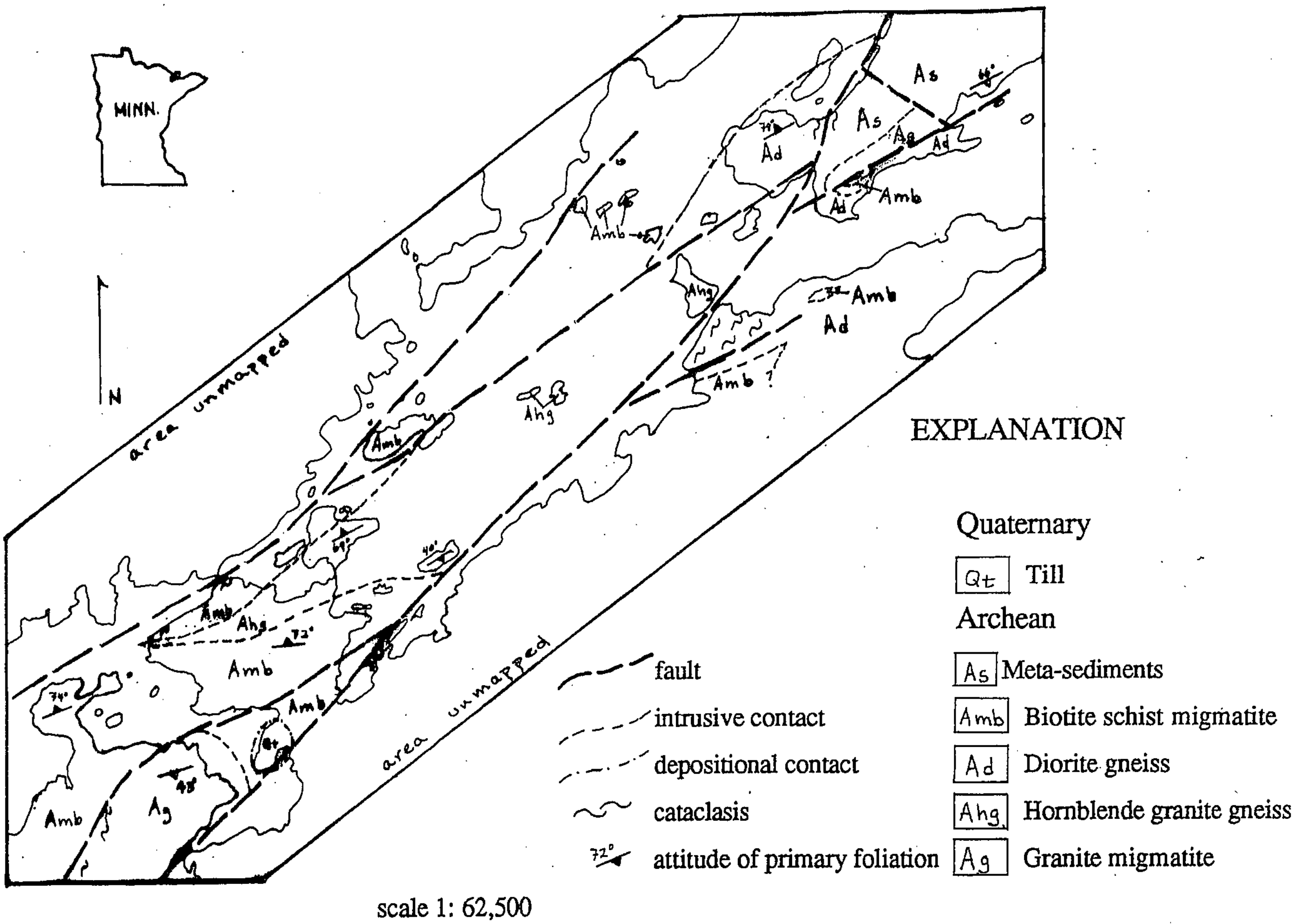

Figure 1. Geologic map of Basswood Lake, Lake Co., MN

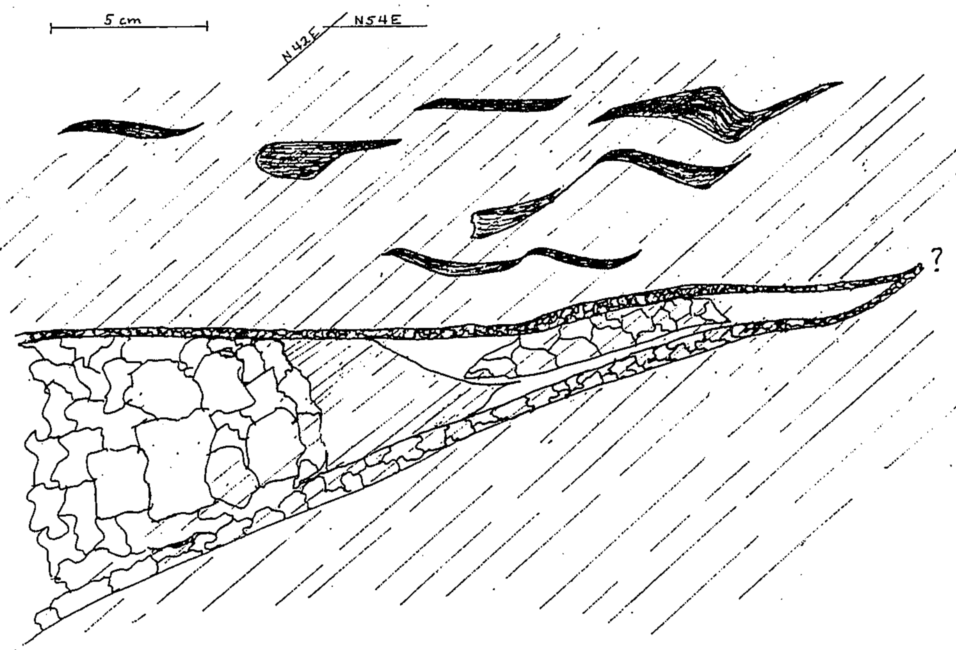

Figure 2. Sheared schist lenses in migmatite with subparallel foliation in pegmatite vein.