Petrography and Geochemistry of Metamorphic Rocks along the Southeast Block, Pipestone Trace, Burntside Lake Fault Zone
Boundary Waters Canoe Area, Northern Minnesota

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INTRODUCTION

The Pipestone fault trace is a splay fault of the Burntside Lake Fault Zone found in the Basswood Lake area of the Boundary Waters Canoe Area in Northern Minnesota (Fig. 1). The Pipestone fault trace cuts through felsic igneous intrusive bodies and schistose units of probable Archaean age, although accurate ages are not yet available. The faults are poorly described and the age is poorly constrained.

This study attempts to define the individual units along this fault trace, through the use of field, petrographic, and geochemical methods. We are particularly concerned with the determination of protoliths for the highly metamorphosed rocks, especially the metasediments and metavolcanics. The nature of the fault activity in the area, which is another major subject of concern, can be analysed by observing microscopic deformational patterns and variations in geochemical alteration.

FIELD ANALYSIS AND PETROGRAPHY

Samples of each rock unit were collected, oriented, and labeled. All units were followed along strike to determine field relationships, and a general field description was recorded. Geologic mapping, including a detailed record of structural features of the southeast fault block, was completed. This data was compiled, along with data from maps of the northwest fault block completed by other individuals, onto a master copy of the Basswood Lake West Quadrangle.

Petrographic analyses were conducted on rocks of each unit. Samples were grouped together by unit and analysed for alteration and mineralogy in relation to fault proximity. Point counts were done on some of the intrusive samples. Deformational trends and degree of metamorphism were noted both within and between units. Once the petrographic information was gathered, it was compared to data obtained through field analyses.

The units present in this block of the fault zone can be broken down into six major compositional groups:

1) A series of metatonalites is composed mainly of plagioclase and quartz, with biotite being the major mafic component. It appears that the biotite, because of its shredded character and association with accessory sphene, is a product of the breakdown of amphiboles, the major mafic constituent in these rocks before they were metamorphosed. Quartz grains in one section of this unit were found to have extinction patterns varying from simple undulatory extinction in samples distant from the fault to increasing degrees of polygonization as the fault was approached. This is the most graphic visual evidence of deformational change observed within a single unit as the fault was approaced, but all units show this same deformational trend to some degree. Rafts of these intrusives are found in the gneisses to the north, indicating that the metatonalites must be older than the gneisses.

2) North of the metatonalites, there is a gneissic unit which appears to be related to the metatonalite intrusives (Fig. 2), but is younger. It is distinguished from them by the presense of amphibolite rafts and by gneissic banding observed in certain outcrops. The most abundant minerals in this unit are plagioclase and quartz, but there is also chlorite, amphibole, opaques (probably hematite), potassium feldspar, and minor amounts of garnet. The presense of garnet porphyroblasts in this and other units indicates at least amphibolite facies metamorphism.

3) A minor amphibolite breccia unit (dike?) is only found in isolated parts of the study area. It is composed almost entirely of chlorite which formed as an alteration product of amphibole or pyroxene.

4) A metavolcanic group, comprising thin layers of green slate along with quartz and carbonate rich layers, has a volcanically-derived protolith and could possibly be related to the Ensign Lake green slates studied by Gruner (Gruner, 1941). It is composed mainly of chlorite and quartz with all minerals showing a strong linear orientation. The quartz grains in this unit are all highly strained and are aligned with their optic axes parallel to the direction of elongation.

5) A biotite schist unit is very widespread in the southern part of the study area and gives the most obvious deformational picture observed in any of the units. Some of these specimens have pervasive mylonitic textures. Most specimens found near the fault exhibit a high degree of ductile deformation, including rotated quartz grains which show polygonization, and a strong mineral alignment. This unit is older than the metatonalites, as is evidenced by crosscutting relationships observed on an island in Pipestone Bay.

6) A chlorite schist unit is thought to be the oldest unit in the study area (Woodard, personal communication). It is probably related to the Ely greenstone. It is very fine grained, metabasaltic in character, and is composed mainly of chlorite, formed as an alteration product of amphibole or pyroxene. Pillow textures are common in outcrop exposures.

GEOCHEMISTRY

Geochemical analyses were performed at the Colorado College using x-ray fluorescence techniques. Samples were fused into glass disks after being powdered, dried, and combined with a lithium tetraborate flux. Samples were analysed for both major and trace elements, and results were plotted up on a variety of diagrams to determine protoliths. INAA on these samples is currently being run at Oak Ridge Laboratories.

Some problems arose when plots were made of the data for the felsic igneous intrusive rocks. Samples thought to be tonalites, based upon petrographic analyses, plotted on the CaO-Na2O-K2O diagram as tonalites (Fig. 3), but when the same data were plotted on the Rb-Ba-Sr diagram (Fig. 4), the rocks appeared to be diorites. Another sample of felsic intrusive from the southern part of the study area, which looked like a tonalite in thin section, is actually a granodiorite when it is plotted on the CaO-Na2O-K2O diagram (Fig. 3). This problem could be due in part to the fact that the Cao-Na2O-K2O diagram has no field for diorites, but there still is a problem in relating the petrographic data to the geochemical data. It is possible that the additional quartz, which makes the samples appear to be tonalites when seen in thin section, is a hydrothermal product related to the fault activity, which would mean that the units are actually diorites as the geochemistry suggests.

The metavolcanic sample apparently follows the igneous trend on the MgO-CaO-Al2O3 discriminant diagram, but more samples are needed to identify sources more specifically. The source may have been derived from the same source as the basalts of the Ely greenstone, but it also may have originated as a silicic tuff or a volcaniclastic deposit. The biotite schist definitely has a sedimentary origin as either a subgraywacke or an arkose, as is shown by the plots on the Al2O3-SiO2-Fe2O3; Fe2O3+TiO2+CaO-0.73 SiO2-Al2O3, and the MgO-K2O-Na2O diagrams. There is an amphibolite group within a section of the biotite schist which exhibits the same igneous properties as the amphibolite breccia unit. The chlorite schist unit appears to have had a volcanic protolith, probably a basalt and possibly from the same source as the Ely greenstone.

CONCLUSIONS

1) The protolith for the biotite schist was a subgraywacke or an arkose.
2) The protolith for the chlorite schist was a basalt.
3) The amphibolite breccia and metavolcanics units had igneous protoliths.
4) The leucocratic quartz monzonite is actually a granodiorite.
5) The degree of deformation increases as the fault is approached.
6) More analysis should be done on the felsic intrusive bodies to see if the quartz, which makes them look like tonalites, is a hydrothermal alteration product or is actually a part of the original rock.
7) Research should be undertaken to see if the metavolcanics are related to the Ensign Lake green slates described by Gruner.
8) A comparison of batholithic rocks from the Vermillion batholith and the felsic intrusives in the study area should be performed.

REFERENCES

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Gruner, J.W., 1941, Structural geology of the Knife Lake area of northeastern Minnesota: Geologic Society of America Bulletin, 52, pp. 1577-1642.

Fig. 1 Geologic Map of the Pipestone Trace
BurntsideLake Fault Zone

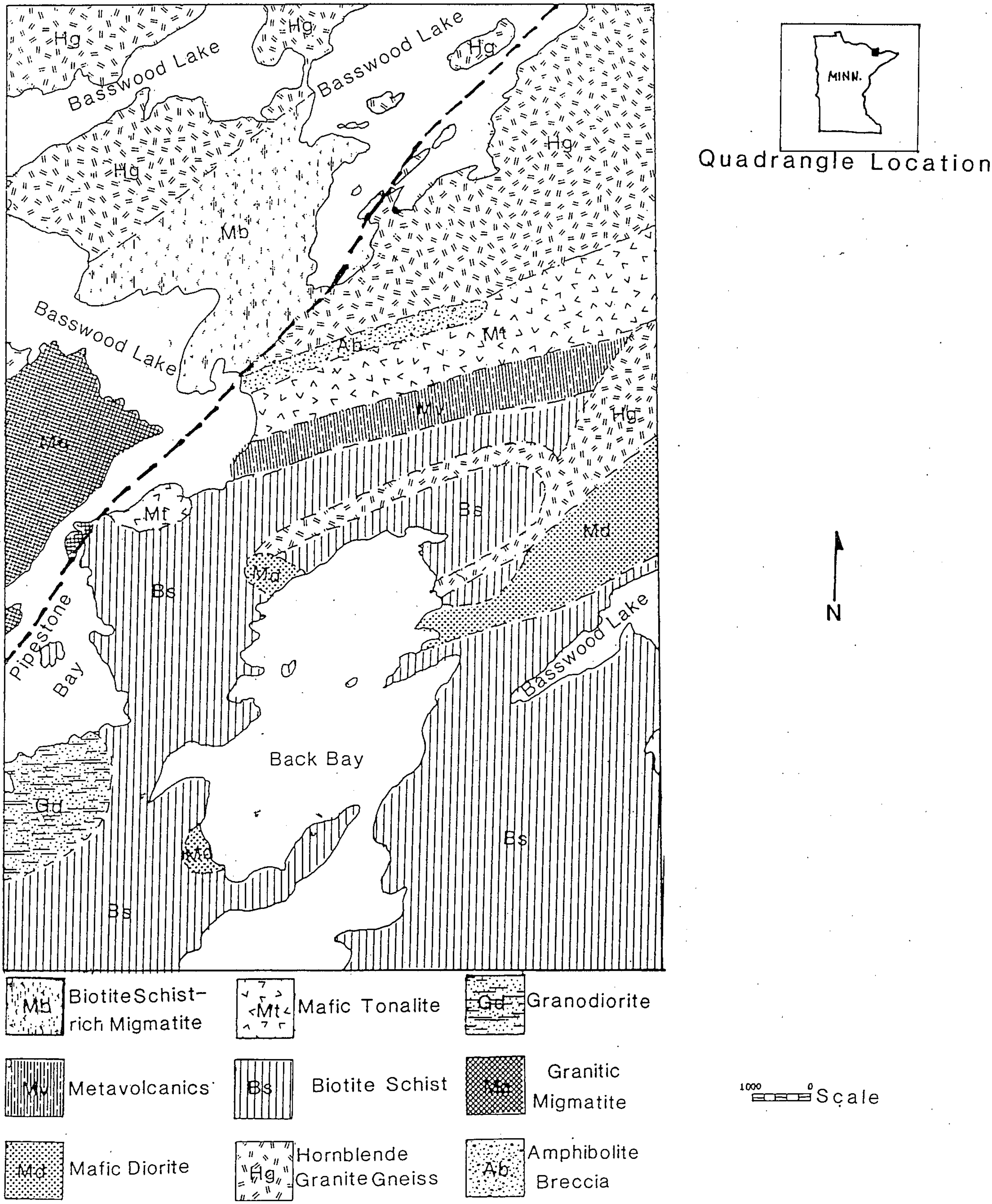


Fig. 2

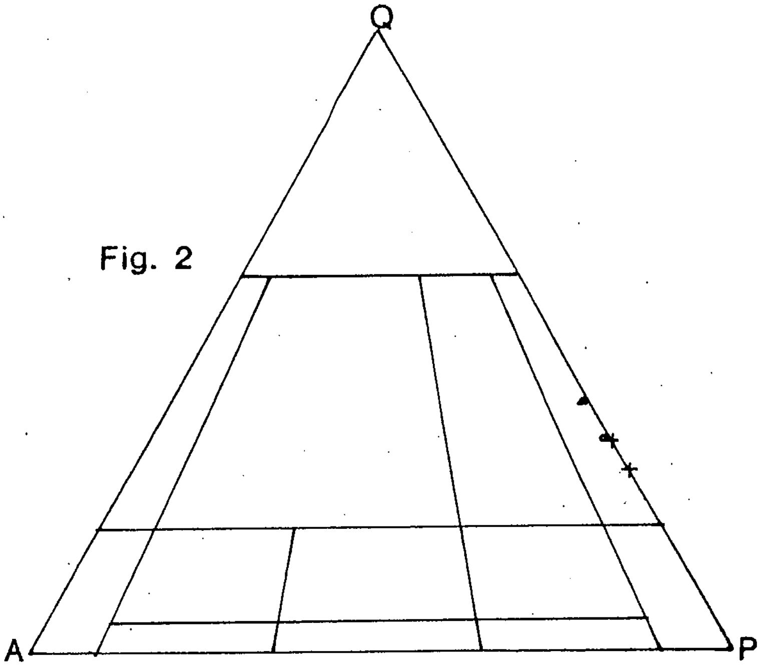


Fig. 3

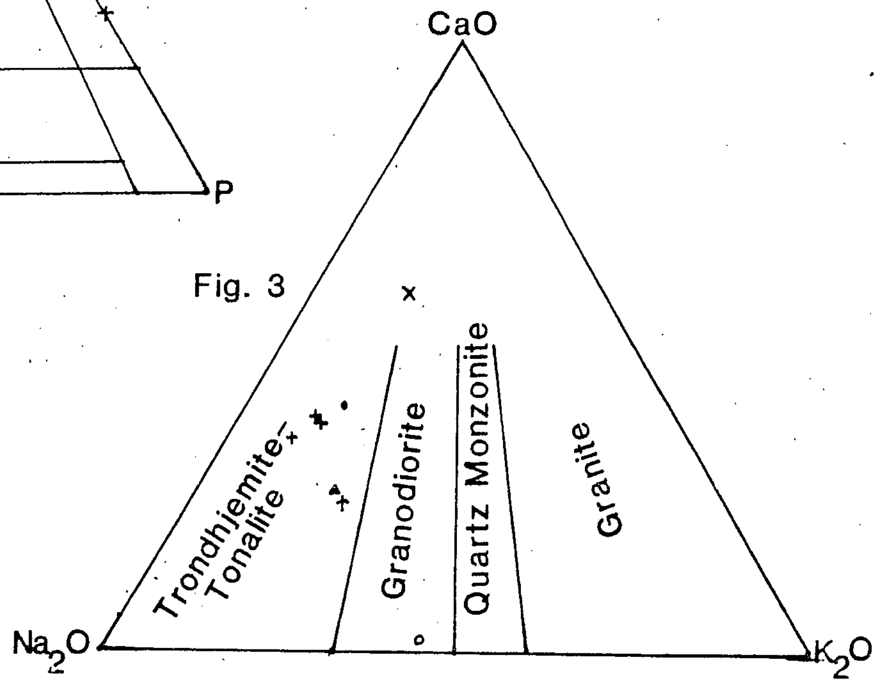
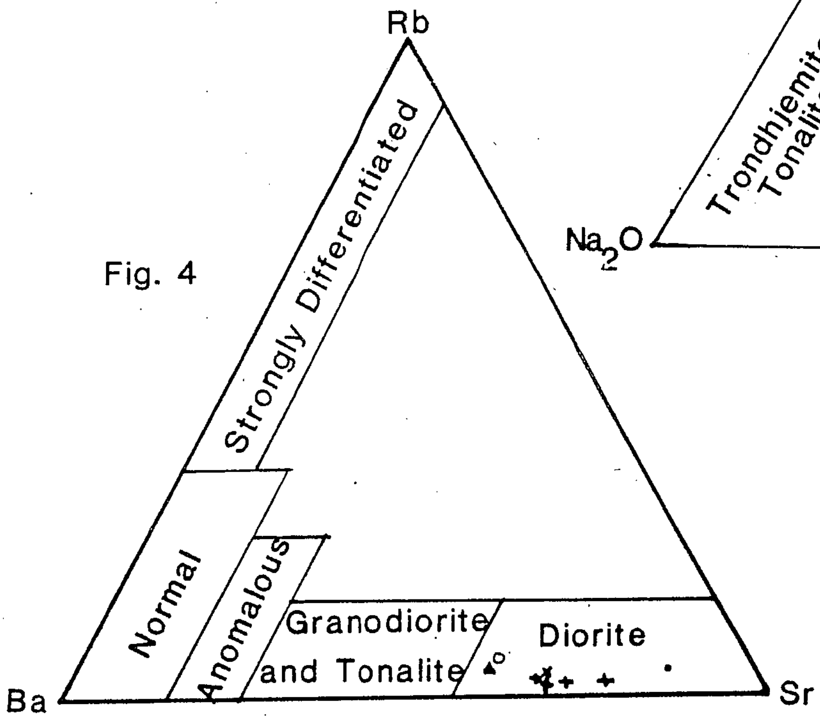


Fig. 4



+ Mafic Tonalite
o Granodiorite
▲ Hornblende Granite Gneiss
x Mafic Diorite
▲ Biotite Schist
■ Metavolcanics
□ Chlorite Schist
✱ Amphibolite Breccia
• Hornblende Granite Gneiss(?)