BRITTLE AND DUCTILE DEFORMATION IN THE BURNTSIDE LAKE FAULT ZONE OF QUETICO, ONTARIO

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INTRODUCTION

Granitic specimens collected within the Burntside Lake fault zone in Ontario's Quetico Provincial Park have undergone both brittle and ductile deformation. Examination of twenty-three thin sections formed the bulk of this study in which the styles and results of physical deformation within the Burntside Lake fault zone are described.

All specimens were taken from the same unit, referred to in the field as granitic migmatite. This unit is a quartz, plagioclase, and alkali feldspar rock, with occasional rafts of biotite schist. The schist rafts were rare and no specimens of this portion of the unit were taken for this study. The specimens exhibit a considerable variety of brittle and ductile deformational features. Continuous fractures and microfaults with offset are evidence for brittle deformation, while crystals with undulose extinction, subgrain development, and kinked twins show the effects of ductile processes. Specimens were classified as breccia, microbreccia, or mylonite, following the scheme of Wise, et al. (1984).

OBSERVATIONS AND DISCUSSION

The best indications of brittle deformation are "continuous fractures cutting across grains of different compositions and orientations" (Mitra 1984, p.52). This is evident in Figure 1, which shows a set of parallel microfaults cutting across the entire thin section. Often it is difficult to tell how continuous a fracture is, but visible offsets, present in several specimens, along such a fracture can help indicate a microfault. Brittle deformation fractures crystals, and can produce a breccia of angular crystalline fragments. In most of the specimens classified as breccias, it was fairly obvious that the rock had been a mylonite prior to brittle deformation, since features caused by ductile deformation were only slightly obscured by brittle fracture. Where brittle deformation has been most intense, grain size is reduced further by multiple fractures, creating microbreccias. Usually, grains of all compositions have been completely shattered. However, the pieces sometimes remain in place and the approximate dimensions of the original grain can be seen. In Figure 2, a grain of ribbon quartz remained somewhat intact, but is surrounded by tiny angular fragments typical of the microbreccias.

Ribbon quartz is the result of ductile deformation, and is detectible in all specimens to a certain degree. Ribbon quartz means elongated quartz subgrains. Recovery responses to strain, like dislocation glide and cross-slip, which are thermally activated, can generate subgrains with high-angle boundaries (Knipe 1989), as seen in the ribbon quartz. Lobate grain boundaries, observed in several specimens, are likely the result of syntectonic migration recrystallization, and such "textures are generally relict in the low-temperature environment" (Groshong 1988, p.1331). These ductile deformation features observed in the quartz are, therefore, created in a relatively high temperature environment.

Undulose extinction caused by ductile deformation is universal in the feldspars in the specimens, but is not nearly as extreme as that seen in the quartz. Kinking of albite twins produces extinction bands in plagioclase and is also indicative of ductile deformation. Quartz experiences ductile deformation at lower temperatures than feldspar (Tullis and Yund 1977). Consequently, at temperatures producing extensive ductile deformation in quartz, feldspar will show some evidence of ductile processes, but will be far less deformed. As shown in Figure 3, feldspar has somewhat undulose extinction, but the quartz has been far more deformed into the elongate subgrains of ribbon quartz. In the photomicrograph, the quartz appears to have flowed around the feldspar, confirming the fact that feldspar is more rigid at high temperatures. The relatively fresh appearance of the feldspar, compared to the quartz, does not disprove the theory that the ductile deformation occurred at relatively high temperatures, since feldspar remains fairly rigid, even at temperatures that allow significant deformation of quartz.

It is extremely important to note that the fractures and microfaults formed by brittle deformation cross the ribbon quartz. This is shown in Figures 1 and 4. It thus appears impossible for the brittle and ductile deformation to have occurred simultaneously. Since the brittle features override, and partially or wholly destroy the ductile features, it is my analyzed on an I.C.A.P. Six leucogranite specimens and six migmatite specimens are plotted on a ternary diagram according to the potassium, sodium, and calcium percentages in each rock (Figure 3). These data also exhibit overlapping chemistry for the two rock types.

An interesting relationship exists between the pre-existing microcline and plagioclase with the later perthite. The perthite appears fresh and glassy and surrounds older or replaced microcline indicating the perthite is secondary relative to the microcline. This relationship can be explained by an introduction of potassium-rich fluids into the pre-existing rocks. Plagioclase(An37-42) plus potassium ions forms perthite according to the reaction given by Collins (1988):

$$\begin{array}{llll} CaAl_2Si_2O_8 + K = KAl\,Si_3O_8 + & NaAlSi_3O_8 & + SiO_2 + Ca + Al \\ NaAlSi_3O_8 & CaAl_2Si_2O_8 & \\ & \text{MYRMEKITE} & \end{array}$$

A volume for volume replacement of the pre-existing plagioclase with potassium ions forms perthite and myrmekite. The myrmekite grains contain plagioclase with the composition of about half of the An content of the parent plagioclase. This relationship is present in both batholithic and migmatitic rocks: parent plagioclase An_{37-42}, myrmekite plagioclase An_{18-22}.

CONCLUSIONS

Petrographic and chemical analysis shows the migmatite leucosomes are mineralogically and chemically similar to the leucogranite. Perthite, engulfing older microcline, along with the presence of myrmekite, indicates an introduction of potassium into these rocks. Also supporting this conclusion is the fact that the An composition of the myrmekite is half the An composition of the parent plagioclase (Collins, 1988).

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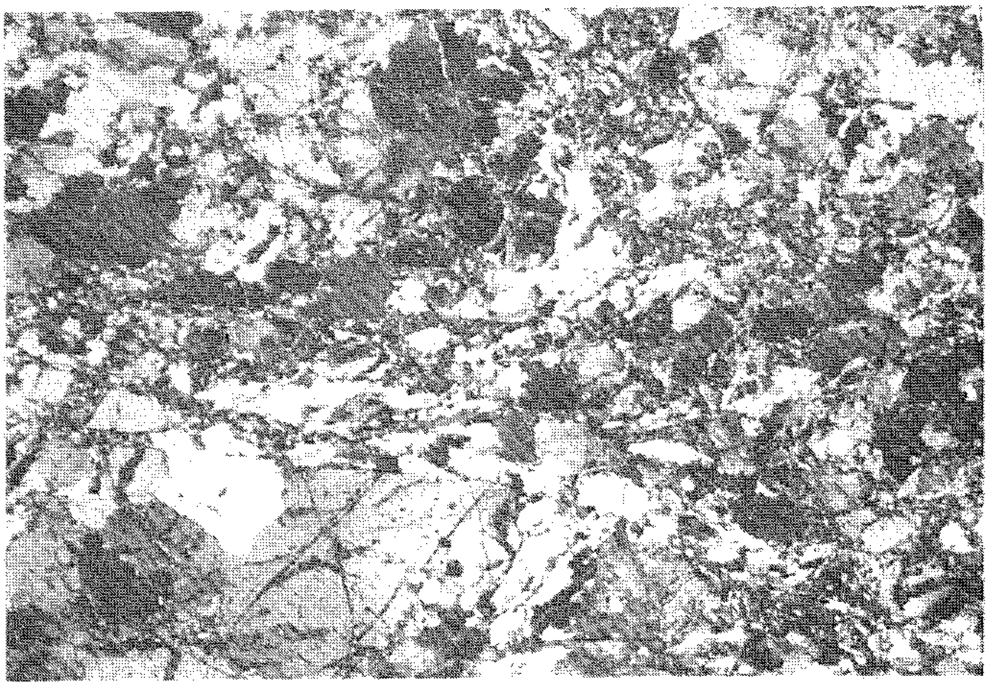
Figure 1: Parallel microfaults (roughly horizontal in photo) through quartz and feldspar. Polars crossed, magnification 13X, photo width 12.0 mm.



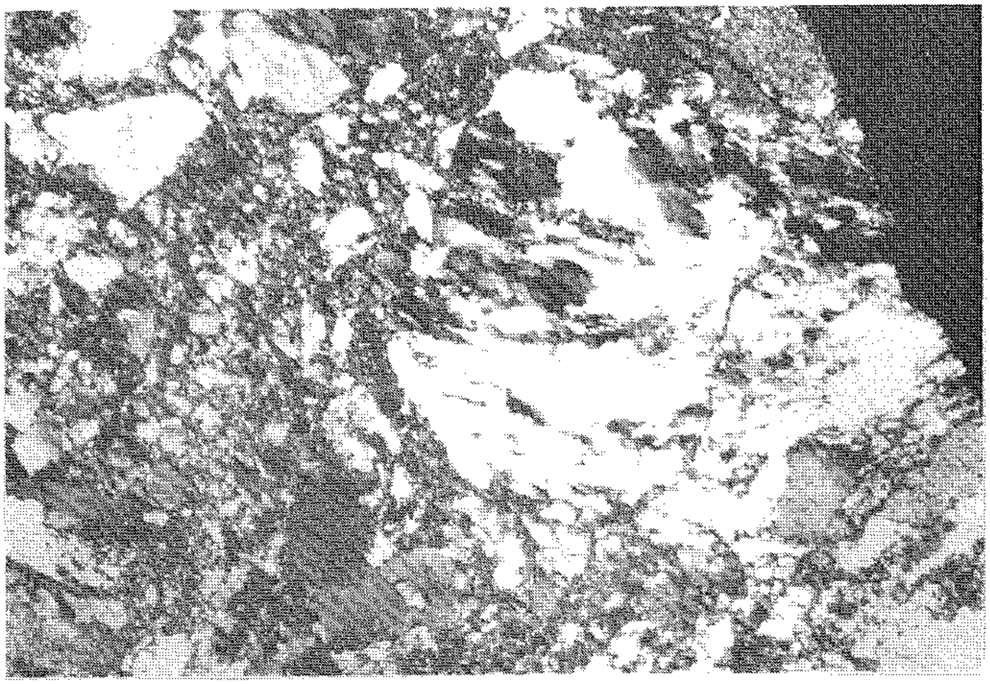
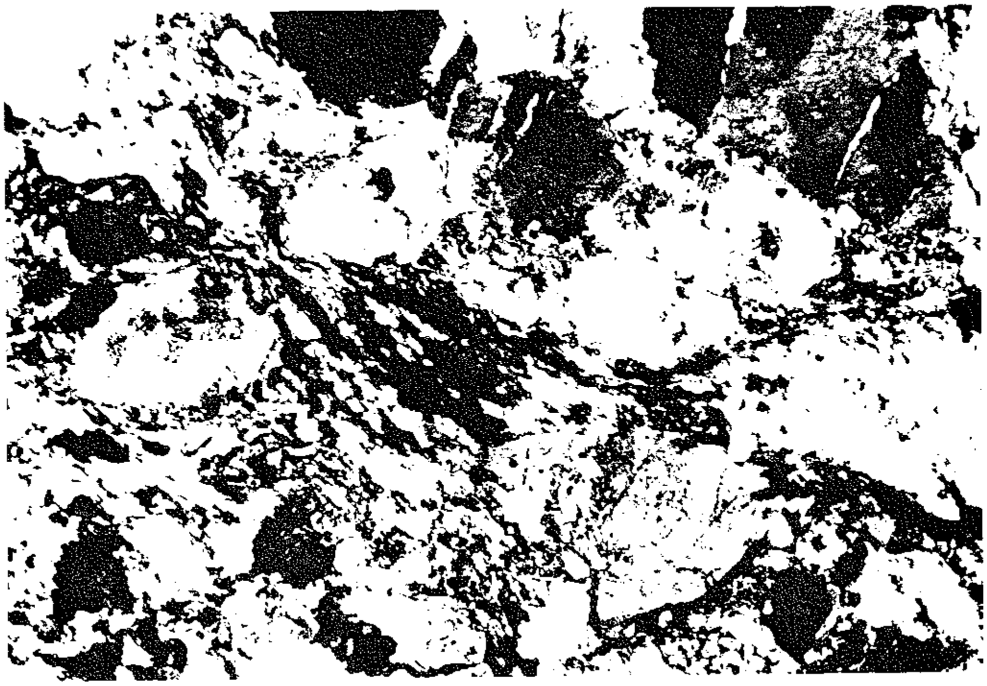


Figure 2: A partially intact grain of deformed quartz (filling most of the right half of the picture) surrounded by the fragments of a microbreccia (left and bottom). Polars crossed, magnification 40X, photo width 4.0 mm.

Figure 3: Ribbon quartz (top left, center, right) appears to have flowed around the more rigid feldspar crystals (large grains). Polars crossed, magnification 13X, photo width 12.0 mm.



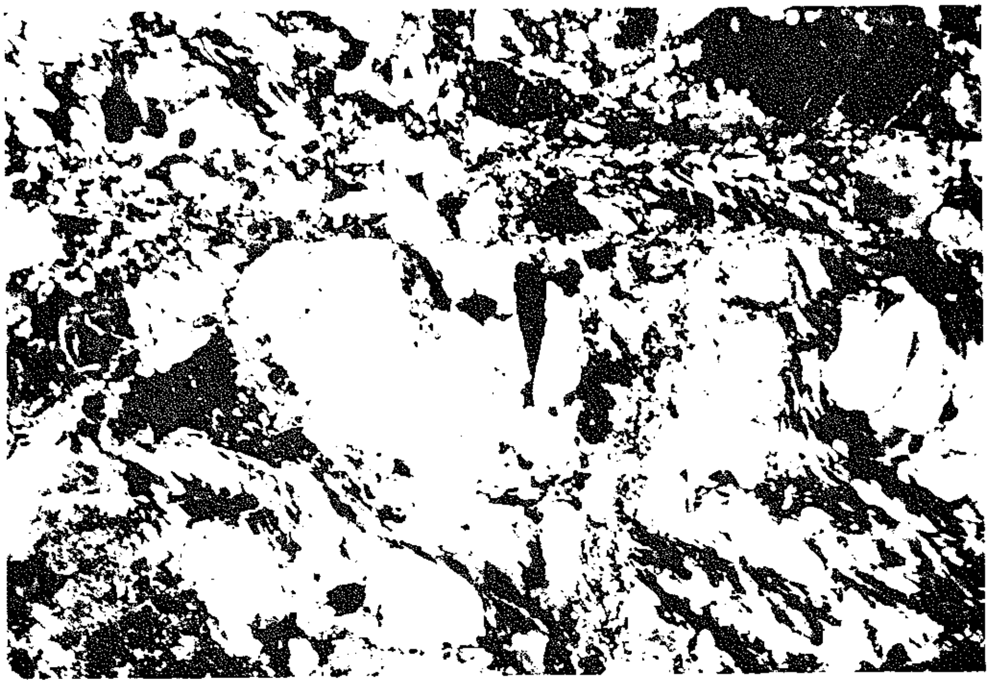


Figure 4: Microfaults through elongated quartz and large feldspar grains. Polars crossed, magnification 19X, photo width 8.0 mm.

conclusion that the brittle deformation post-dates the ductile deformation.

Additional analysis indicates that the brittle deformation followed the ductile deformation significantly later in time, after a period of non-deformation, and not as a transition or gradual change. Some ductile processes can lead to work hardening, which may build to the point of brittle failure. However, this occurs primarily with lower temperature ductile mechanisms, and it appears more likely that the ductile deformation in this area proceeded at relatively high temperatures, indeed high enough to produce flow of material (dislocation creep), which "can counterract the hardening processes" (Knipe 1989, p.133). Brittle deformation is restricted to low temperatures, especially when extensive shattering of crystals, to the point of creating a microbreccia, is the result. This difference in likely formation temperatures of the brittle and ductile features indicates that the brittle deformation occurred after cooling from the temperatures which allowed for ductile deformation. Probably this cooling was not at all immediate, and a significant amount of time passed between episodes of deformation.

Brittle deformation occurs within a very narrow fault zone, approximately 100 to 200 yards wide, while ductile deformation is universal among my specimens. The five microbreccias have experienced the most brittle deformation, and except for one, all are located directly on the main trace of the fault. The nine breccias received a moderate amount of brittle deformation, and generally are the same distance or slightly farther from the fault trace than the microbreccias. The five mylonites experienced little or no brittle deformation, and are generally farther from the fault trace than the breccias. Ductile deformation appears to be fairly uniform among the specimens, indicating that it was likely the result of regional metamorphism, while the brittle deformation was later in time and was far more localized.

CONCLUSIONS

The granitic migmatite unit along the Burntside Lake fault zone exhibits evidence for both brittle and ductile deformation. Ductile deformation was caused by high temperature regional metamorphism and faulting, which affected all specimens, and produced mylonites. Brittle deformation occurred significantly later than ductile deformation, and made breccias from the pre-existing mylonites. Brittle deformation was confined to narrow fault zones, and consequently affected only those specimens collected very close to the trace of a brittle fault.

The main fault trace within the Burntside Lake fault zone, east of Kettle Lake, may be mislocated as currently mapped, since fracturing of outcrop, evidence of nothing more than late-stage brittle deformation, was the main feature used to identify the fault in the field. If indeed the brittle deformation occurred much later than the ductile deformation, and in a far more restricted area, it may be inappropriate to assume that brittle effects produced the faults most significant in regional structural analysis. With further study, other linear features of the landscape may be found to contain a better "main trace," one which has a larger displacement and was created by the regional metamorphism.

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STRUCTURAL STUDY OF A BIOTITE SCHIST

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INTRODUCTION

In the summer of 1989, I worked within the Quetico Provincial Park in an area, due north of Neil Island and into Lost Bay (see map), that includes the contact between a hornblende gneiss unit and a biotite schist unit near an anticline that deforms both units and is orientated N55E. Splays of the Burntside Lake Fault deform these units as well. The particular area has not been included in any small or large structural study in the recent past but the general area has been studied extensively by the Beloit College faculty and students (see Burntside Lake Fault Zone Project in *Second Keck Research Symposium in Geology* and the conclusion to this abstract). To futher the knowledge of the history of the area, I studied the structural deformation of the biotite schist macroscopically and microscopically.

METHODS OF STUDY

I photographed and measured orientations the structural features and recorded their relationships to each other. Oriented specimens were collected of both the hornblende gniess and the biotite schist units and the dikes which cut them.

I compared the structural data collected in the field from the schist unit and contact between it and the gneiss unit on stereonets and maps attempting to correlate it with the the anticline, the Burntside Lake Fault and its splays, and the microscopic structural features observed in thin section.

I collected specimens of the schist around the anticline and atvariable distances away from the fault splays to compare the samples for their relative deformation, mineralogy and petrography. I also collected specimens of some intrusions from this area in order to compare their deformation and mineralogy to that of the rock into which they intruded.

MAP SHOWING WORK AREA AND BEARING OF PARASITIC FOLD AXES