Strain Progression Analysis of the Calef Member of the Eliot Formation, Epping Quadrangle, Southeast New Hampshire

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Introduction, History, and Problem:

The bedrock of the Seacoast region of New Hampshire is characterized by folded metamorphosed sedimentary rocks that have been intruded by igneous bodies. Other features present in the area include younger igneous dikes and faults. A distinctive rock unit, present in the Epping 7.5-minute quadrangle, is the Calef Member of the Eliot Formation. Features present within this rock suggest that it has been deformed by four tectonic events. Field observations of the Member show that the presence and nature of these features changes from east to west, implying differing amounts of strain through the unit.

Analysis of strain progression in the Calef Member of the Eliot Formation, present in the Epping 7.5-minute quadrangle, is a potentially important contribution to New Hampshire and New England geology. The western margin of the Member is thought to be fault-bounded and therefore the location of the highest strain in the Member. Response to this strain is shown by kinematic indicators in the rocks, including deformational surfaces called *foliation* or *cleavag* and folds. Examination of samples of the Calef Member will allow for characterization of these features and interpretation of the strain conditions under which they formed. Samples spanning the east-west extent of the Member will show the difference in strain conditions across the rock unit (see Figure 1 for planned sampling lines).

(graphic)

Figure 1. Reference map of the Epping Quadrangle with line segments 1. -3. showing planned cast-west sampling locations. SOb =Berwick Formation, SOec=Calef Member. SOem= Micaccous Eliot Formation. SOe= Eliot Formation. FromSchulz and Loveless (2001).

No previous study has focused exclusively on the Calef Member. Freedman (1950), Sundeen (1971), and Schulz and Loveless (2001) have recognized the Member and its aerial extent in regional mapping, but a detailed structural analysis of the rock unit has not been carried out. Schulz and Loveless (2001) suggest a fault as the western boundary of the Calef (shown by large-scale kinematic observations), and this proposed work will help to confirm this hypothesis. Characterization of deformational features of the Calef Member will be used to interpret the tectonic history of the rock unit.

Approach/Methodology

Analyses carried out in this study can be compared to results from experimental studies of rocks similar to those of the Calef Member. Publications of Paterson and Weiss (1966), Waldron and Sandiford (1988), and Srivastava et al. (1998) summarize how rocks respond to different stress conditions based on several variables. The features present in the Calef Member can be compared to those generated in the experiments, and then the deformational history can be interpreted. Analysis of small-scale features in rocks requires examining oriented samples through an optical microscope. In order to transmit light and therefore, the rock samples must be prepared as *thin sections.* Thin sections are professionally prepared, 30 micron-thick slices of rock mounted (by epoxy) onto a glass microscope slide. In addition to optical microscopy, scanning electron microscopy (SEM) can be used for further analysis. The high magnification, high resolution SEM not only shows very small features of the rock samples, but also uses an Energy Dispersive System (EDS) for chemical analysis. SEM/EDS work requires use of polished thin sections, whose production is similar to that of normal thin sections with an additional process of surface textural polishing.

The optical microscopy will serve as the primary method of sample analysis, while the SEM/EDS will provide complimentary chemical data. Preliminary optical observations have shown that four deformational surfaces are present in the Calef Member of the Eliot Formation. A deformational surface or foliation is a planar feature formed by distortion of a rock. The spatial orientation of a. deformational surface suggests the direction of the stress that created it; surfaces are often oriented perpendicular to the direction of maximum compression. The four surfaces in the Calef, called S1, S2, S3, and S4 (ordered chronologically), represent four separate deformational events (Figure 2). The character of these surfaces describes the strain conditions and type of deformation that occurred in each of these events. S1 and S2 are thought to represent deformation at rather high temperatures and pressures, likely during metamorphism of the rock. S3 surfaces represent axial planes of folds in the rock. An axial plane of a fold can be thought of as a sheet of paper that cuts directly through the hinge of a fold. S4 surfaces are similar, except they represent axial planes of tighter folds than those defined by S3. These tighter folds give the rock a “crinkled” appearance and are thought to have been produced by faulting of the Calef Member. The presence, tightness, and concentration of

(graphic)

these fault-related folds are essential in determining the strain progression in an east to west direction across the Member. The S4 surfaces are evident in outcrops of the Calef Member near its western margin and seem to become less obvious and describe gentler folding towards the east. Detailed optical observation of many samples of the Calef Member is needed to accurately characterize all deformational surfaces. This characterization can then be compared to the experimental models of deformation, leading to an interpretation of the strain history and its variance within the Calef Member.

Figure 2. Deformational surfaces S1I - S4 shown in a photograph of a thin section sample of the Calef Member. Photo is ~10 mm wide.

Variance in the chemical composition of the ubiquitous mineral chlorite with increased strain and metamorphism can be indicated by the SEM/EDS method. The chemical analysis of several samples performed by SEM could indicate chemical change from east to west and therefore suggest a possible correlation with the suspected strain variation.

Geological Significance and Implications

The study of the strain progression in the Calef Member of the Eliot Formation has regional geologic implications. The Calef Fault, as it has been dubbed by Bothner and Hussey (1998), is proposed as a branch of the Norumbega Fault, a large fault system extending from Massachusetts northeast through Maine. Confirmation of the presence of the Calef Fault as the western boundary of the Member would support the hypothesis proposed by these authors. In addition, the entire deformational history of the Calef Member can be extended to other rock types in southeast New Hampshire and southern Maine. Field observations show that the adjacent Eliot Formation has been affected by the same deformational events as the Calef Member, but its response to these events is shown differently due to dissimilarity in rock composition. Thin section analysis of several samples of the Eliot Formation will also be performed in order to compare its structural character with the Calef Member.

Outcome

The proposal for structural analysis of the Calef Member has spawned from a United States Geological Survey- sponsored mapping project of the Epping 7.5-minute quadrangle. The goal of this mapping project is to produce a geologic map of the area, illustrating the aerial distribution of different rock units as well as other geologic features, such as faults and folds. This proposed research will focus on one component of the Epping Quadrangle, but the results will be applied to the entire area and beyond. In the last two years, I have become increasingly interested in structural geology and interpretation of deformational events. Carrying out this research will not only allow me to apply the techniques I have learned in the classroom and in the field, but also prepare me for further education and independent research. The results of this research will be reported in a senior thesis and also submitted to the Geological Society of America for presentation at the annual meeting of the Society's Northeast section in March of 2002. Preparation of a thesis and presentation will serve as valuable practice for summary of research in graduate school, which I plan to attend beginning in the fall of 2002.

Location

Work on the project will primarily take place in two locations: on campus and in the Epping 7.5 minute quadrangle. Oriented whole rock samples will be collected from outcrops in Lee and Epping (both within the quadrangle), sent for thin section preparation, and analyzed at facilities on campus. The Earth Sciences Department houses research-grade petrographic microscopes that can be used for examination of samples, while scanning electron microscopy will take place in UNH's Instrument Center in Kendall Hall. Analysis, interpretation, and evaluation of samples will take place exclusively on campus.

My Role

I will be the primary researcher in this project. I have spent the summers of 2000 and 2001 making observations of the Calef Member in the field while generating hypotheses concerning its structural history. I have taken two courses in structural geology (one Advanced Structure and Regional Geology), one course in optical mineralogy (where optical microscope skills were gained), and have independently researched literature on the subject of rock deformation. I feel that my coursework and field experience qualifies me to carry out this project and make an accurate assessment of the results.

Jeff Schulz, my field partner during the Epping Quadrangle mapping, has already contributed to preliminary research by preparing some thin sections and discussing the mineral characteristics of the rock. Dr. Wallace Bothner and Dr. Jo Laird have served as Jeff and my mapping advisors for the duration of the project. Dr. Bothner will act as my sponsor for this project, serving as a structural geology resource. He and Dr. Laird will likely accompany me during the SEM/EDS work, as their personal research has previously employed the instrument. Dr. Laird, a metamorphic petrologist, will also serve as a resource during microscopic analysis of the samples.

Timetable

I am currently enrolled in ESCI 795, Special Topics in the Earth Sciences. Throughout this semester, I have sought geological journal articles containing information pertinent to the study of the deformation of the Calef Member. In late October to early November, I will collect new samples from the Epping Quadrangle. The detailed analysis will begin immediately should I be granted funds. Previously collected samples will be sent for thin section production during the first weeks of the spring semester (production from late January to mid-February). Optical and scanning electron microscopy will take place once the thin sections are received (late February to early March). I will finish the analysis and interpretation over the remainder of the semester, summarizing the results in a senior thesis to be completed in early May 2002.

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