A TEST OF GENERAL SHEAR VERSUS FOLDING FOR THE ORIGIN OF A CRYPTIC STRUCTURAL FEATURE, NASON TERRANE, WASHINGTON

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Background & Purpose

• Rock Mountain is situated along Nason Ridge of the allochthonous Nason Terrane within the Cascades Crystalline Core of Washington (Fig. 1).

• The Chiwaukum Schist of the Nason Terrane has undergone at least 4 major deformational events. The most recent of these occurred at upper amphibolite facies has created a foliation striking roughly NW in a steeply dipping orientation, and NW-SE trending subhorizontal lineations (Magloughlin, 1990).

• Cutting across Nason Ridge at Rock Mountain along foliation is a cryptic structural feature which has reoriented the lineations from subhorizontal NW trending to subvertical NNE trending.

• Magloughlin (1990) hypothesized that the reorientation of lineations was the result of high angle north-side-up simple shear. A later study by Miller et al. (2006) hypothesized that reorientation was instead caused by type-II superposed folding.

• The purpose of this study is to better understand the processes of folding and ductile shearing in the formation and/or reorientation of lineations in relatively "soft" metapelitic rocks, as well as to better constrain the deformational processes expressed at Rock Mountain.

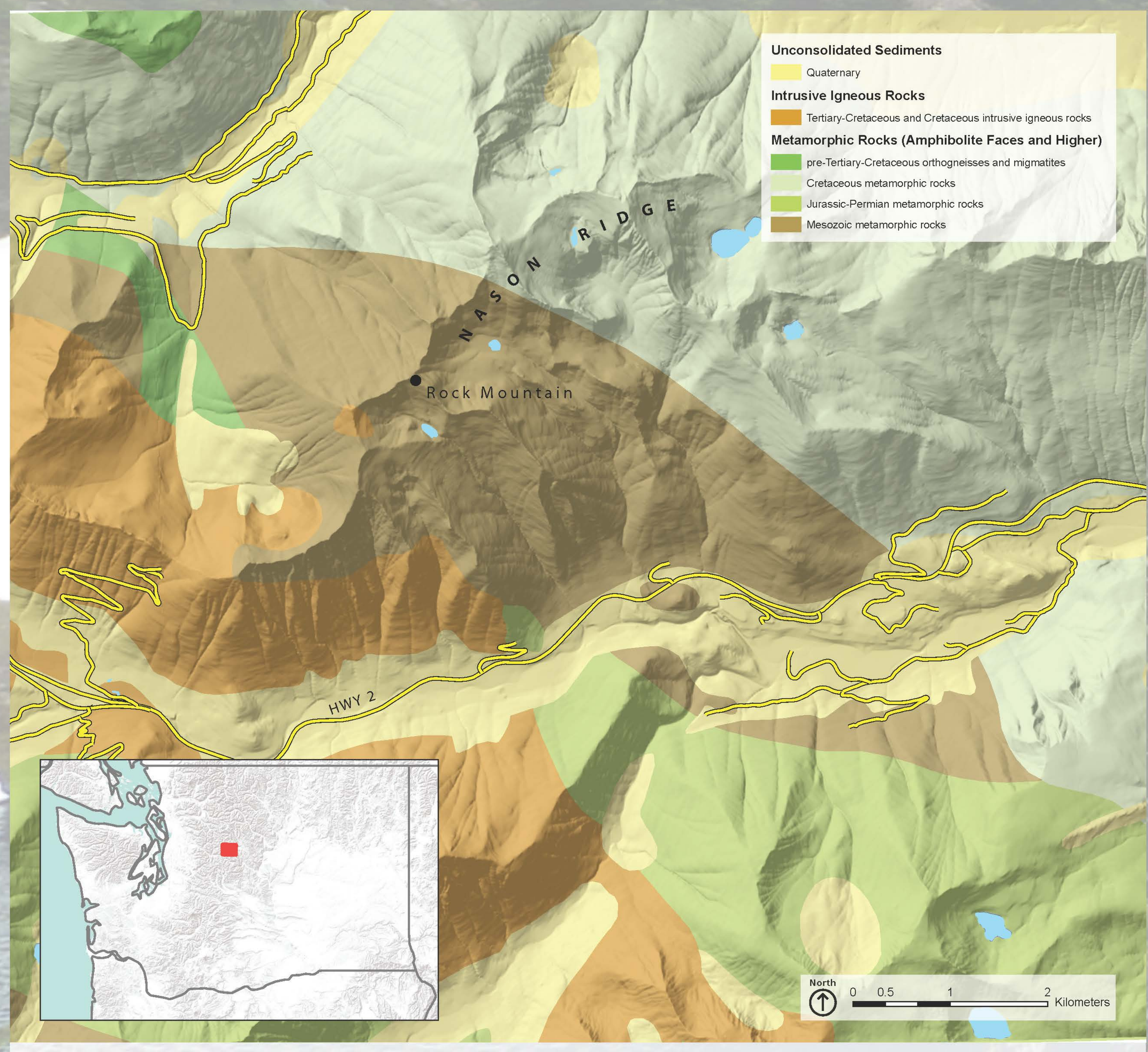

Figure 1: Location map showing location of Rock Mountain along Nason Ridge with inset map showing Washington.

Methods

• Field mapping took place during the summer of 2011. Structural measurements were taken throughout the cirque at Rock Mountain, as well as outside the zone to the NE and SW. Hand samples and drill cores were collected throughout the area for later analysis.

• Anisotropy of magnetic susceptibility (AMS) was performed on drill cores at the Institute for Rock Magnetism (IRM) and the University of Minnesota to analyze the magnetic fabric of the samples.

• Microstructural analysis and vorticity analysis was performed to better understand strain conditions at Rock Mountain as well as shear direction.

• Electron backscatter diffraction (EBSD) was performed on quartz, biotite, and hornblende to analyze the crystallographic fabric of the samples, aiding in understanding strain and sense of shear.

ABSTRACT

The Nason terrane of the Cascades Crystalline Core is a complex tectonostratigraphic terrane which has been the topic of much study due to its deformational history and importance in the debate surrounding the Baja B.C. hypothesis. Structural patterns along Nason Ridge in the central part of the terrane have been interpreted as the result of either the presence of a major shear zone (Magloughlin, 1990) or the development of fold interference patterns (Miller et al., 2006). Distinguishing fold-controlled lineations from shear zone produced lineations can be a structurally complex, but important problem. This study aims to provide a better understanding of high-temperature deformation which may be obscured due to extensive recrystallization.

Previous observations revealed a structural zone ~1 km wide striking roughly NW-SE. Fold hinges and mineral lineations approach subhorizontal orientations with increased distance from the center of the zone, indicating that this zone has a fundamentally different structural fabric than the surrounding terrane. In the zone, mineral lineations cluster tightly, plunging steeply NE. Fold hinge lines are more dispersed along the trend of the zone, possibly reflecting incomplete rotation of pre-existing fold hinges.

AMS analysis done at the Institute for Rock Magnetism at the University of Minnesota indicate the magnetic fabric correlates well with lineations and foliations measured in the field, and likewise shallows to near-horizontal away from the center of the zone. Quantification of the strength of the AMS fabric reveals an oblate spheroid which is interpreted as a proxy to an oblate strain ellipsoid, indicating a component of pure shear. Asymmetrical microstructural features include tailed porphyroclasts, mineral fish, and domino clasts. Sense-of-shear indicators also agree with the hypothesized NW side up.

It is clear from the agreement between outcrop scale structures, magnetic fabric, and microstructures that a significant structural perturbation is tightly centered on the zone. The highly focused nature of the zone and the lack of structures created by fold interference indicates that superposed folding is unlikely. These data, coupled with geothermobarometric constraints, point to a zone of displacement best characterized by general shear.

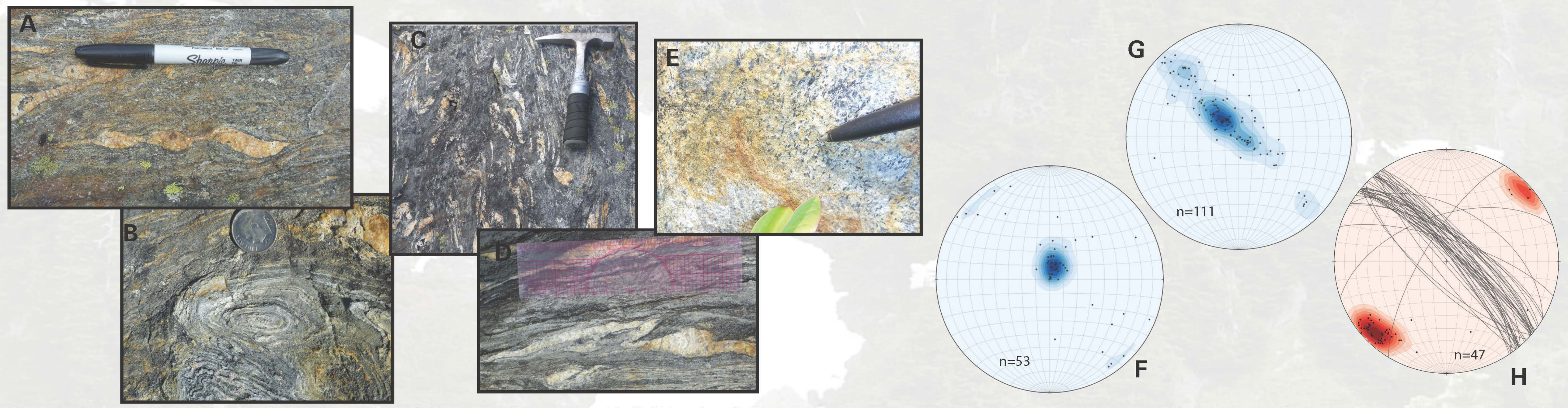

Figure 2: A) Asymmetric boudinage indicating simple shear. B) Sheath fold, indicating $\gamma > 10$. C) Chiwaukum Schist with floating and asymmetric fold hinges. D) Asymmetric fold. E) Example of steeply plunging mineral lineations. F-H) Stereonets of mineral lineations, fold hinge lines, and foliation.

Figure 3: A) An AMS analog to a Flinn diagram. B) Magnetic ellipsoid with principle susceptibility axes. C) Kappa bridge at IRM used for AMS analysis. D) Stereonet of magnetic lineation. E) Stereonet of poles to magnetic foliation.

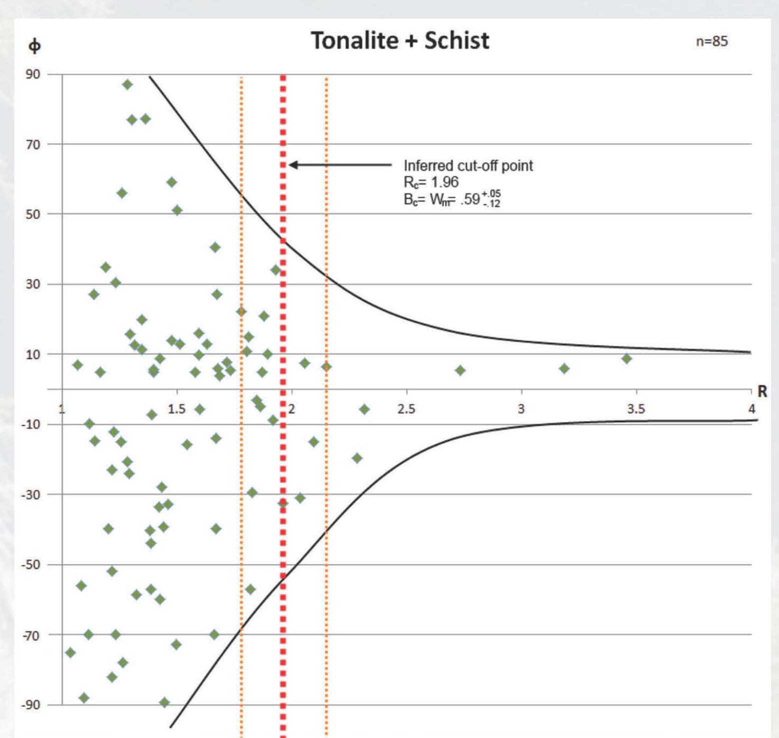

Figure 4: Vorticity analysis using the PAR method giving a vorticity of approximately $W_m = 0.59$

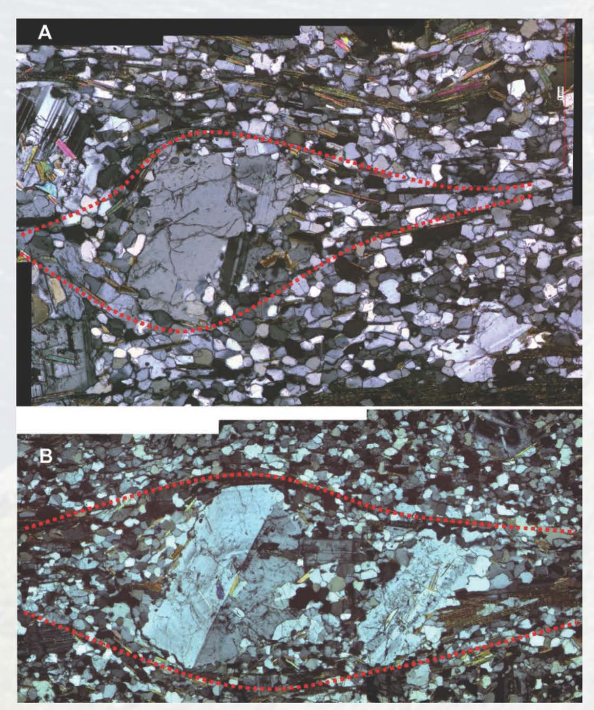

Figure 5: A) Dotted outline shows a recrystallized sigma-clast. B) Outline shows recrystallized phi-clast.

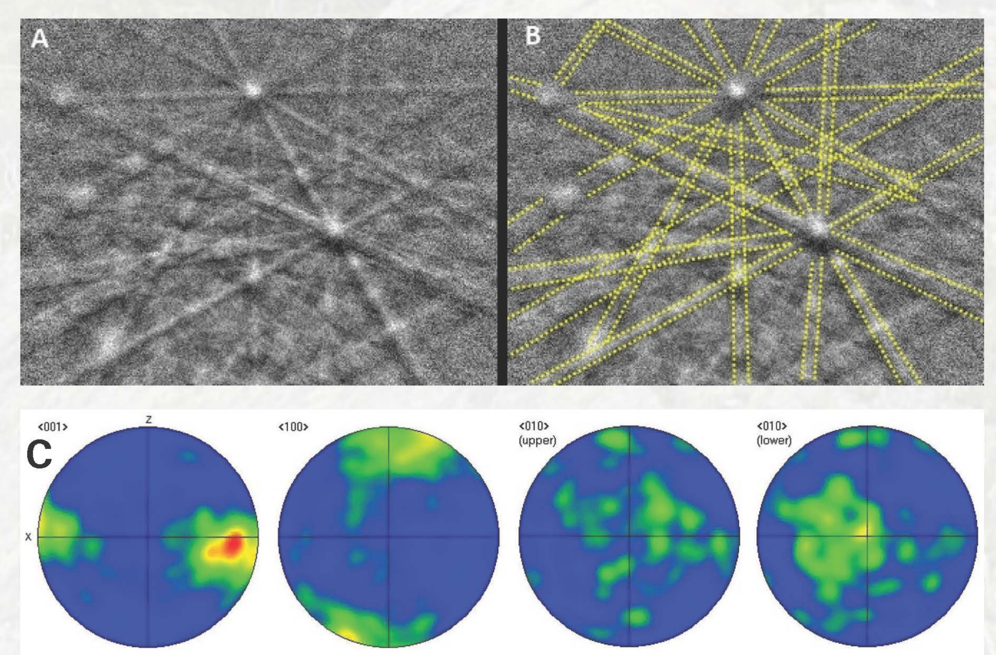

Figure 6: A) Kikuchi patterns obtained from EBSD. B) Indexed pattern used to determine phase and crystallographic orientation.
C) Stereonets of indicated crystallographic axes in Hornblende.

Results

• Field work revealed the presence of asymmetric features, as well as sheath folds (Fig. 2 A-D). There was also a lack of features indicating superposed folding such as fold interference patterns. Mineral lineations cluster tightly in a north trending subvertical orientation (Fig. 2 E & C). Fold hinges form a girdle along foliation, with the highest concentration in a north trending subvertical orientation (Fig. 2G).

• AMS data indicates an oblate magnetic ellipsoid, indicating flattening strain (Fig. 3A). Magnetic lineations (Fig. 3D) and poles to magnetic foliation (Fig. 3E) correspond well with structural data. Biotite, which controls the magnetic fabric, is shown to be oriented with its c-axis perpendicular to the foliation.

• Vorticity analysis of prophyroclasts within the schist and tonalite give a mean vorticity number Wm = .59, representing general shear strain (Fig 4). Microstructural analysis uncovered several indicators of simple shear, such as recrystallized tailed porphyroclasts (Fig. 5) as well as mineral fish, pull-apart clasts, domino clasts, and micro-boudinage.

• EBSD analysis on quartz indicated a nearly random crystallographic preferred orientation. Analysis on biotite and hornblende (Fig. 6) shows an asymmetry consistent with simple shear.

Conclusions

• Throughout the study, no notable evidence was found which would support the hypothesis of superposed folding as the primary structural cause of the features seen in the Rock Lake area. Fold hinge lineations which form a NW-SE girdle remain the only feasible indicator of lineation reorientation by fold interference. It has been shown, however, that simple shear is equally able to explain this phenomenon.

• Field mapping shows that macroscopic structural features consistently display monoclinic symmetry, and do not fit the expected geometries generally associated with superposed folding.

• Microtectonic analysis clearly indicates the presence of an annealed mylonitic fabric. This can be seen primarily by recrystallized mantled porphyroclasts as well as asymmetric features such as mineral fish, micro-boudins, pull-apart structures, and dominoed clasts. Subsequent vorticity analysis using mantled clasts, as well as sense of shear analysis, indicates NE side up general shear.

• Anisotropy of magnetic susceptibility indicates that biotite, which carries the magnetic signature, is aligned with its c-axis perpendicular to the shear direction which is further supported by electron backscatter diffraction which indicates asymmetries consistent with NE side up shear motion. EBSD performed on quartz, however, shows enigmatically random axis orientations.

• The Rock Lake Cryptic Zone of this study was accurately denoted the Rock Lake Shear Zone by Magloughlin, 1990.

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