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Contents

Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to responsible land-use and resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the 2018 field season, research scientists from the GEM program successfully carried out 18 research activities, 16 of which will produce an activity report and 14 of which included fieldwork. Activities applied a variety of geological, geochemical, and geophysical methods. These activities have been undertaken in collaboration with provincial and territorial governments, Northerners and their institutions, academia and the private sector. GEM will continue to work with these key partners as the program advances.

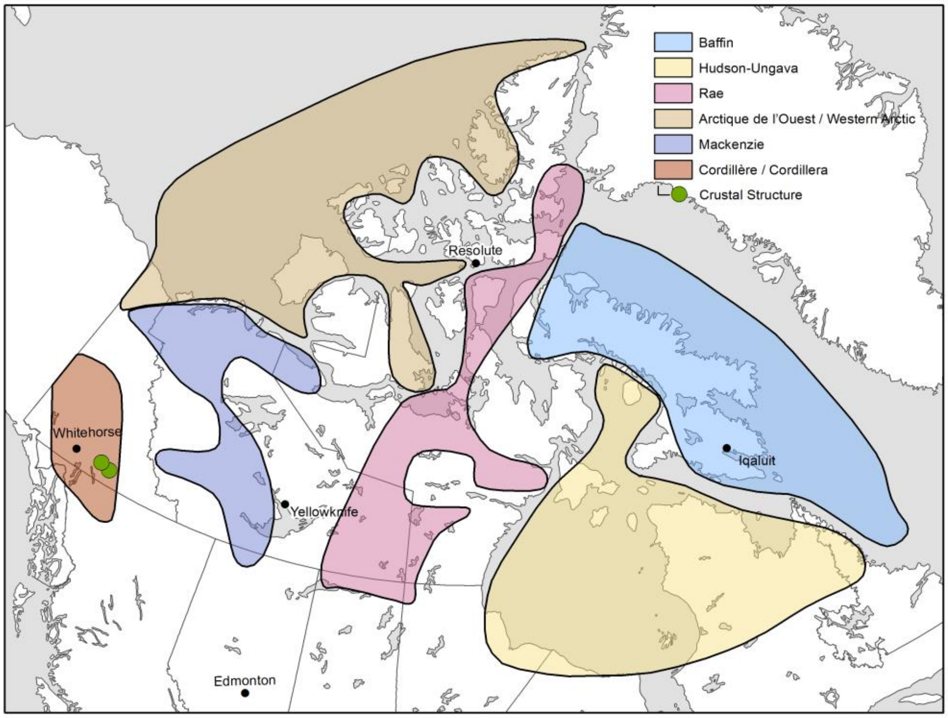

Figure 1. Overview map illustrating the footprint of the Cordillera project in northwest Canada. The locations of activities outlined in this report are indicated in green.

Introduction

The nature of individual terranes, relationships between terranes, and the timing of major accretion and orogenic collision events (Coney et al., 1980; Monger and Price, 2002; Nelson et al., 2006) is still poorly understood in the northern Cordillera in Yukon, British Columbia and Alaska. The study area of this report (Figs. 1 and 2) is situated to encompass units that may span a suture zone, considering that the accretion of the Yukon Tanana terrane (YTT) to the North American (NA) margin must have involved a major collisional and orogenic event (van Staal et al., 2018). Locally, supracrustal rocks on the eastern margin of the YTT are structurally juxtaposed, presumably along a suture zone, with the Cassiar terrane, a sliver of the ancestral North American margin (Fig. 2; e.g., Colpron et al., 2016). However, the timing, extent and products of the collision and suturing process have yet to be explicitly defined in terms of what collided, and exactly when. The presence of Slide Mountain terrane (SMT) units as potential suprasubduction ophiolite slivers (Parsons et al., 2018), units of eclogitic rocks (Petrie et al., 2015), and regions with a steep metamorphic gradient are indications that the study area is suitable to examine collisional tectonic and accretionary processes and effects. This report details how petrologic and structural mapping coupled with geochronology and geochemistry will facilitate development of a regional tectonic model and shed light on seafloor, igneous, orogenic and mineralization processes.

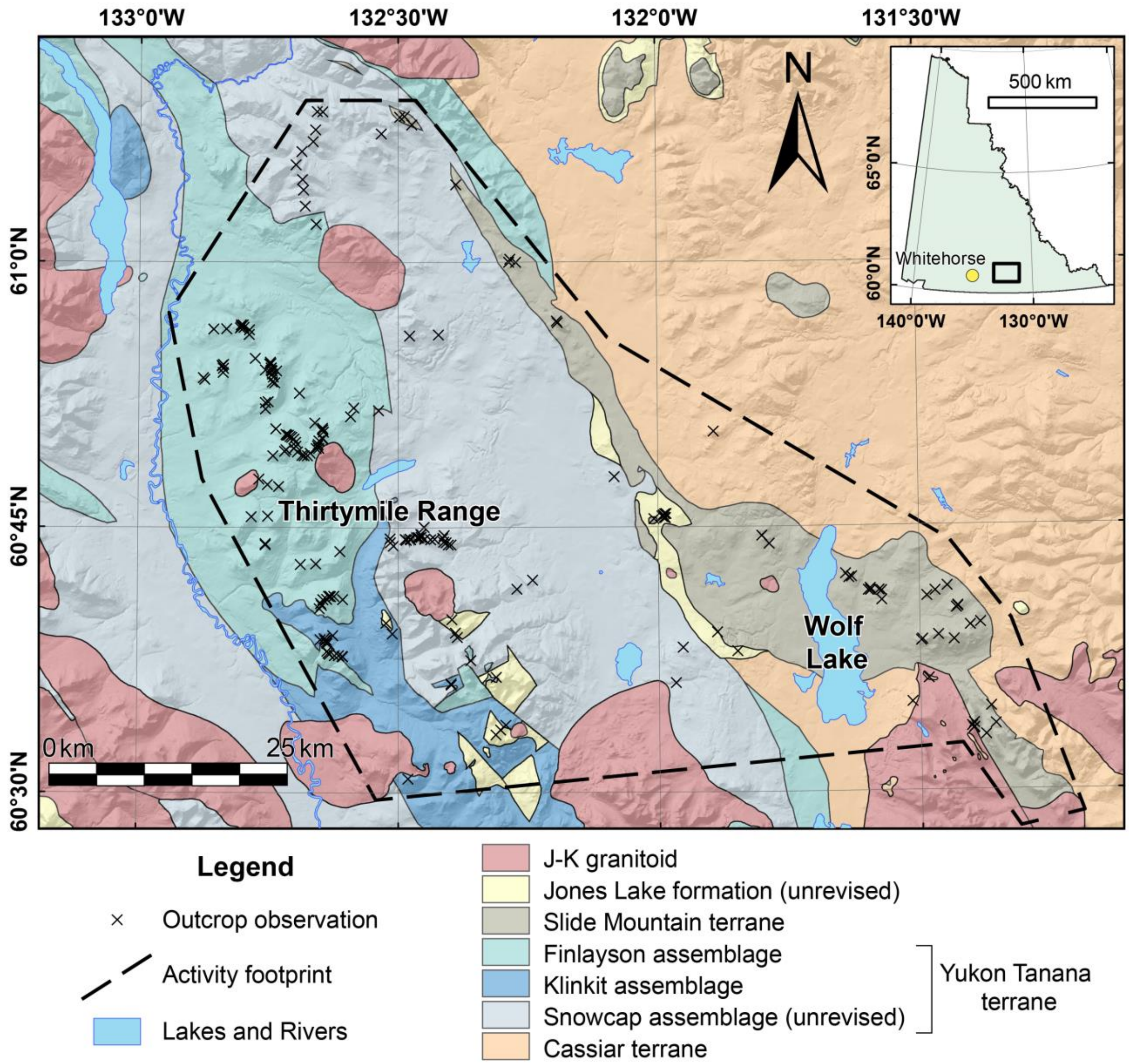

Figure 2 Tectonostratigraphic map of the Thirtymile Range and Wolf Lake study areas. The study areas are geographically separated by poorly exposed lowlands. Modified from Colpron et al. (2016). Location indicated in inset map of Yukon Territory.

Field activities

Research activity carried out under the GEM Cordillera project in the summer of 2018 was aimed at mapping the geology of the Thirtymile range, establishing the petrogenesis of Slide Mountain ophiolite fragments in the Wolf Lake region, and evaluating the nature of late conglomerate deposits. This work was completed over a five week period, through a combination of helicopter spot checks within key units, four fly-camps, and foot traverses for detailed mapping and sampling (mainly in the Thirtymile Range area). Prior to fieldwork, analysis of geophysical imagery established a prospective tectonic framework as a basis for planning objectives and specific traverses.

Objective 1: Geology of the Thirtymile Range

The previous interpretation of tectonostratigraphy in the Thirtymile Range is based on the intersection, and slight overlap, of peripheral areas of four existing published maps (Poole et al., 1960; Murphy, 1987; Gordey and Stevens, 1994; Roots et al., 2006). The region, largely comprising supracrustal rocks, was recognized to have a potential genetic relationship with the Finlayson Lake massive sulphide district (Murphy et al., 2006) that was along strike prior to Paleocene dextral motion along the Tintina fault. Geology of the region's supracrustal rocks was subdivided into Finlayson assemblage (volcanic rocks, chert, siltstones and sandstones), Klinkit assemblage (limestone with minor volcanic rocks) and Snowcap assemblage (chert, siltstones and sandstones). Locally, the designation of Snowcap assemblage may not be an accurate interpretation, as lithologies such as chert and sandstone are atypical (Piercey and Colpron, 2009). Our objective is to establish a better understanding of the regional stratigraphy and structure through mapping and sampling lithologies, and characterizing faults and folds within supracrustal rock units. Structural analysis of outcrop measurements, in conjunction with field descriptions and photos will be applied toward understanding the extent of deformation and its history. Geochemical analysis of volcanic rock samples will provide an integrated understanding of volcanic unit tectonic settings, which may be used to compare to known volcanic characteristics of the Finlayson Lake district. Igneous U-Pb zircon geochronology samples, including samples of volcanic layers and cross-cutting plutons, will be analyzed to provide absolute age constraints on both supracrustal deposition timing and the timing of deformation. Detrital zircon U-Pb geochronology samples of siliciclastic rocks will be analyzed to characterize sedimentary provenances. Such analyses provide the proportional distribution of ages representative of zircon-bearing rocks that contributed to sedimentation in the respective basins. From this series of analyses, we may be able to identify or discount multiple provenances, the presence of accreted units, and constrain the maximum age of deposition of each sampled unit (e.g., Nelson and Gehrels, 2007; Colpron et al., 2015). Fossiliferous limestone samples will be processed and analyzed for microfossil assemblages, especially for conodont fauna, to provide age constraints on carbonate units within the tectonostratigraphy.

Preliminary results

Lithologies in the western Thirtymile Range area are dominantly intermediate to mafic biotite porphyroblastic metavolcanic or metavolcaniclastic schists (Fig. 3A). They are in structural contact with extensive chert (Fig. 3B), siltstone and minor sandstone and volcanic rocks to the east. These units have previously been subdivided as Finlayson assemblage metasedimentary rocks and Snowcap assemblage, respectively. We expect that the analytical methods outlined as part of the objective will aid in the revision of these unit designations. Clast-supported conglomerates comprise angular to sub-rounded clasts that are dominantly chert (Fig. 3C), with rare sandstone and siltstone clasts. These clast types are common Finlayson assemblage lithologies locally (Colpron et al, 2006), and field relationships suggest the conglomerates mark an unconformable contact with the overlying Klinkit assemblage. Fossiliferous limestone rocks of the Klinkit assemblage (Simard et al., 2003; Fig. 3D) occupy much of the southern map area.

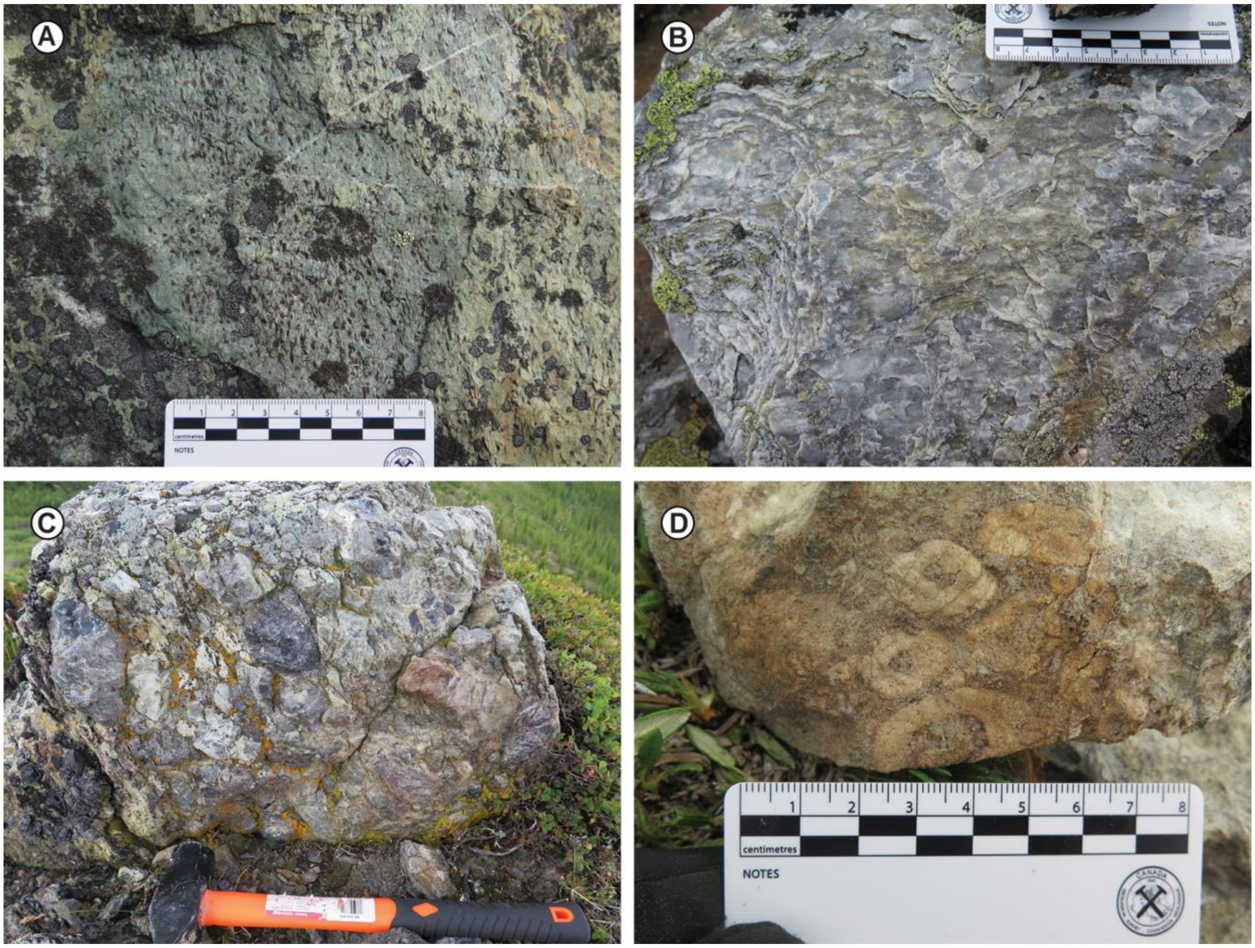

Figure 3. Lithologies of the Thirtymile Range area. A) Biotite porphyroblastic volcanic or volcaniclastic rocks of the Finlayson assemblage. B) Finlayson assemblage grey micaceous metachert. The mica contributes to a slight foliation which creates a scaley weathered surface . C) A nearly monomictic clast-supported conglomerate of dominantly black, grey, and white chert clasts. At a stratigraphic level between Finlayson and Klinkit assemblage units, this conglomerate may be basal Klinkit, composed of Finlayson chert detritus. D) Fossil crinoid stems in Klinkit assemblage carbonate rocks.

Outcrops within the Thirtymile Range exhibit outcrop-scale folds that are likely representative of large-scale structure (Figs. 4A and 4B). In the west side of the area, folds are inclined to overturned, and tight (Fig. 4A). In the central area, folds are moderately inclined and close to tight (Fig. 4B). Structural measurements indicate that the dip of axial surfaces varies between 40° and 70° eastward (Fig. 5). Concentrations of bedding-parallel foliation measurements indicate that one average limb dips eastward 30-40° and the other is subvertical, striking north-south (Fig. 5). The average interlimb angle is therefore 50-60°. Measured fold axes indicate that regional folds generally plunge shallowly to the south, with a slight spread to the southeast (Fig. 5). Rare ductile shear zones indicate that reverse dip-slip motion (east- over-west; Fig. 4C) occurred along east-dipping discrete structures at major unit boundaries. These structures follow the overall trend of steepening towards the east. Rare conglomerate outcrops illustrate the degree of flattening deformation associated with this shortening event (Fig. 4D).

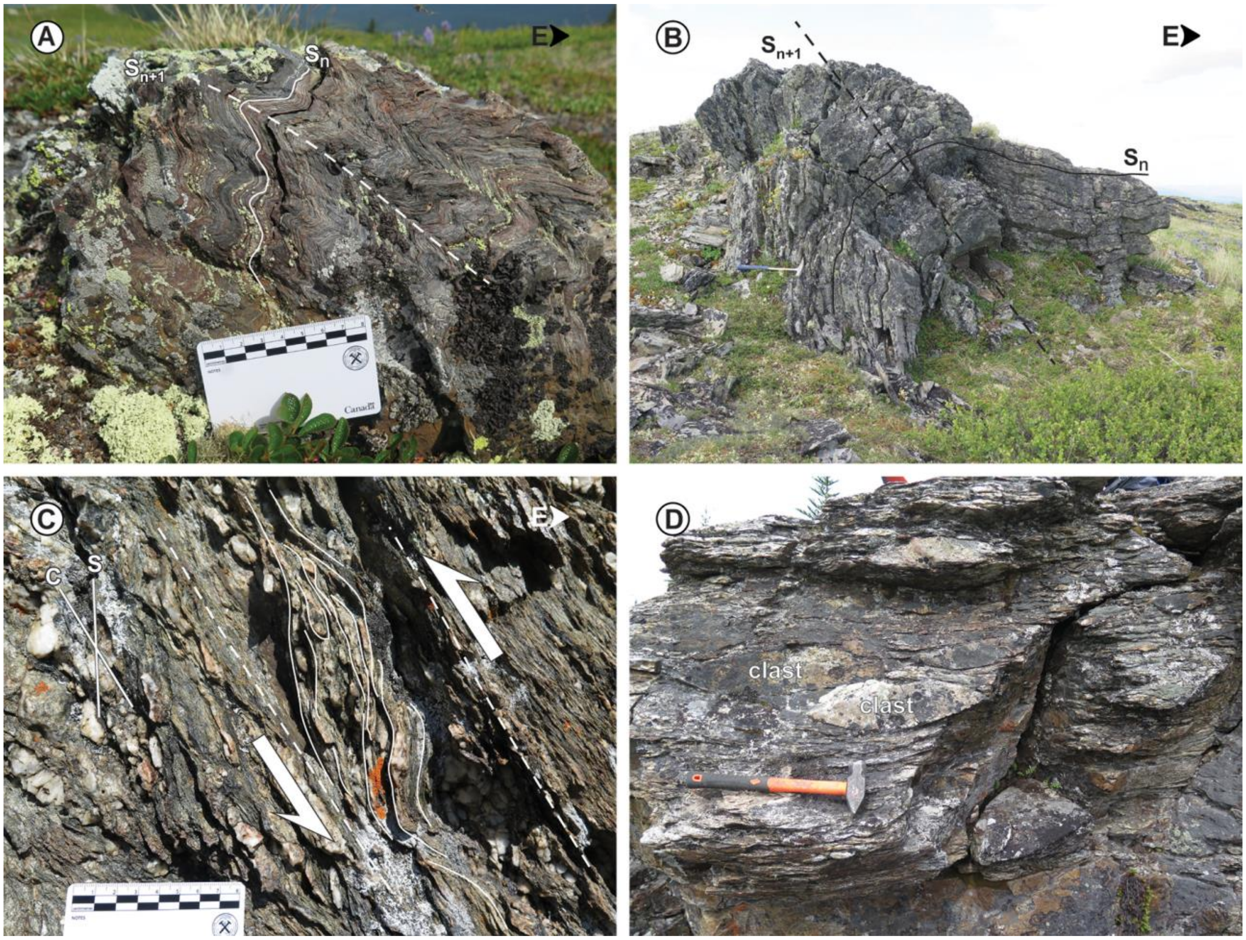

Figure 4. Structures in the Thirtymile Range area. A) Small-scale folds in finely laminated metasedimentary rocks of the western Thirtymile Range are tight and inclined to overturned. B) Outcrop-scale folds in layered metasedimentary rocks in the central Tirtymile Range are close to tight, and moderately inclined. C) Moderately inclined shear structures in layered, veined metasedimentary rocks of the eastern Thirtymile Range exhibit shear structures with consistent east-over-west sense of dip-slip motion. D). Rare conglomerate outcrops exhibit a high degree of flattening deformation, without any indication of shearing.

Objective 2: Petrogenesis of Slide Mountain ophiolite fragments in the Wolf Lake region

Within the study area potentially ophiolitic rocks, including peridotites, have previously been recognized yet their regional significance to accretionary orogenesis remains unestablished. Locally, ultramafic and volcanic units have been mapped as SMT where situated along the major structural (fault) boundary that separates the YTT from the ancestral NA Cassiar platform. A modern approach to analyzing suprasubduction zone related ophiolite petrogenesis can provide a timeline from subduction inception or rollback events through to collision and emplacement timing. This, in turn, can distinguish upper plate/lower plate relationships between collided terranes, and evaluate any potential for both oceanic plate strata-bound mineral deposits and orogenic mineralization. Our objective is to evaluate the tectonic setting of all potentially ophiolitic units within the Wolf Lake area, which includes fault-bound lozenge-shaped blocks of mafic and ultramafic rocks in the northwest of the area, isolated peridotite massifs in areas of extremely poor exposure west of Wolf Lake, and coherent mafic intrusive and volcanic packages east of Wolf Lake (Fig 2). To evaluate if the petrogenetic history involved suprasubduction processes we will

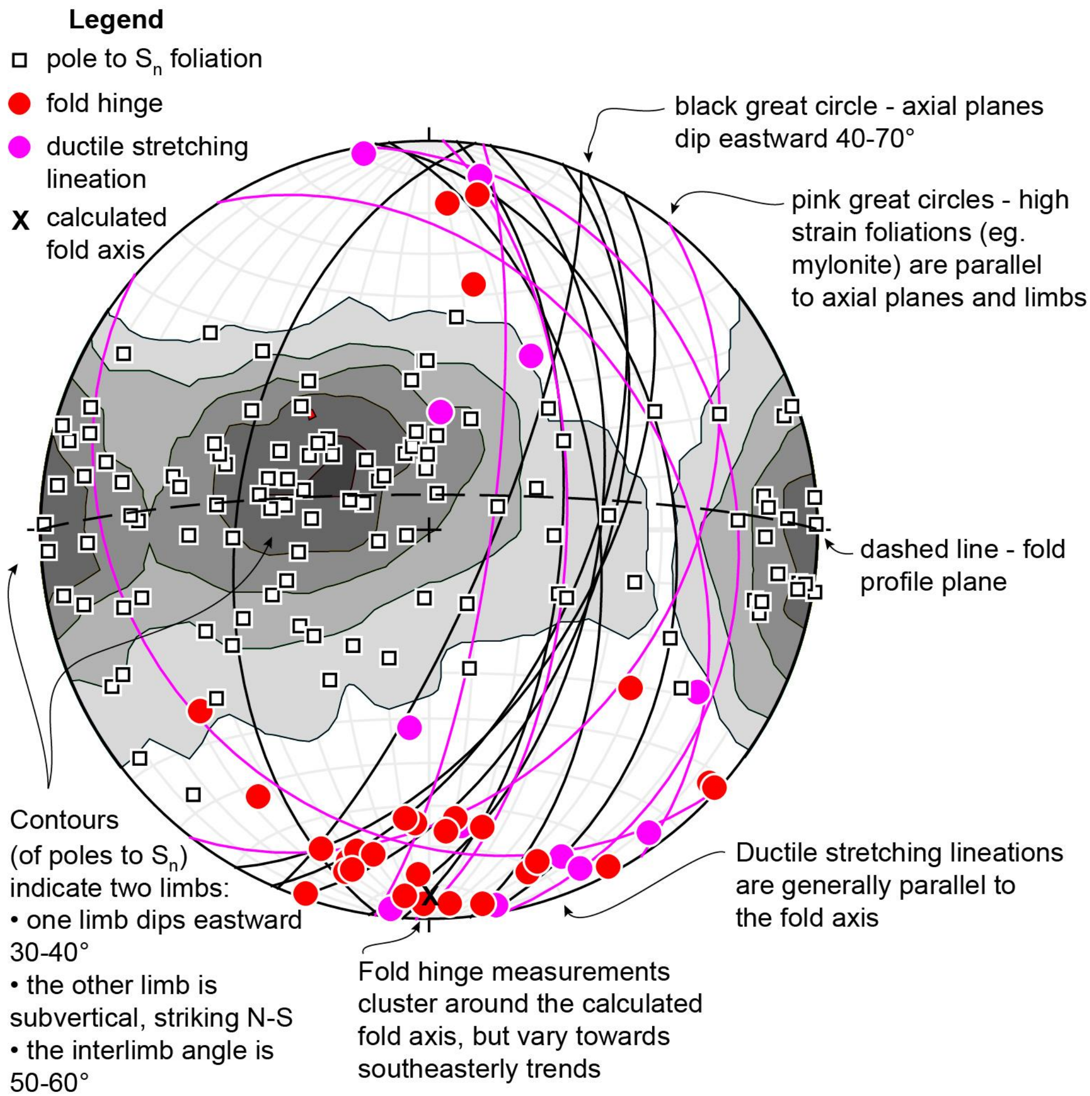

Figure 5. Equal area stereographic projection of field structural data from the western Thirtymile Range area with indicated explanations of important features.

utilize a series of analytical techniques, including petrology, whole-rock geochemical analysis, mineral chemistry analysis, and igneous geochronology.

Preliminary results

Mapping in the Wolf Lake area revealed numerous outcrops of peridotite, gabbro, diabase, basalt, and volcaniclastic rocks which form poorly exposed but distinct, cohesive units. These units exhibit evidence of low-grade to retrograde metamorphism and are generally little deformed. Peridotite outcrops exhibit pyroxene aligned into a foliation (Fig. 6A) and local mylonitic textures with rounded porphyroclastic olivine (Fig. 6B) consistent with high temperature deformation of mantle rocks. Supracrustal units structurally overlie mafic and ultramafic units and include volcaniclastic rocks, basaltic breccia with incorporated chert and plagiogranite fragments, and

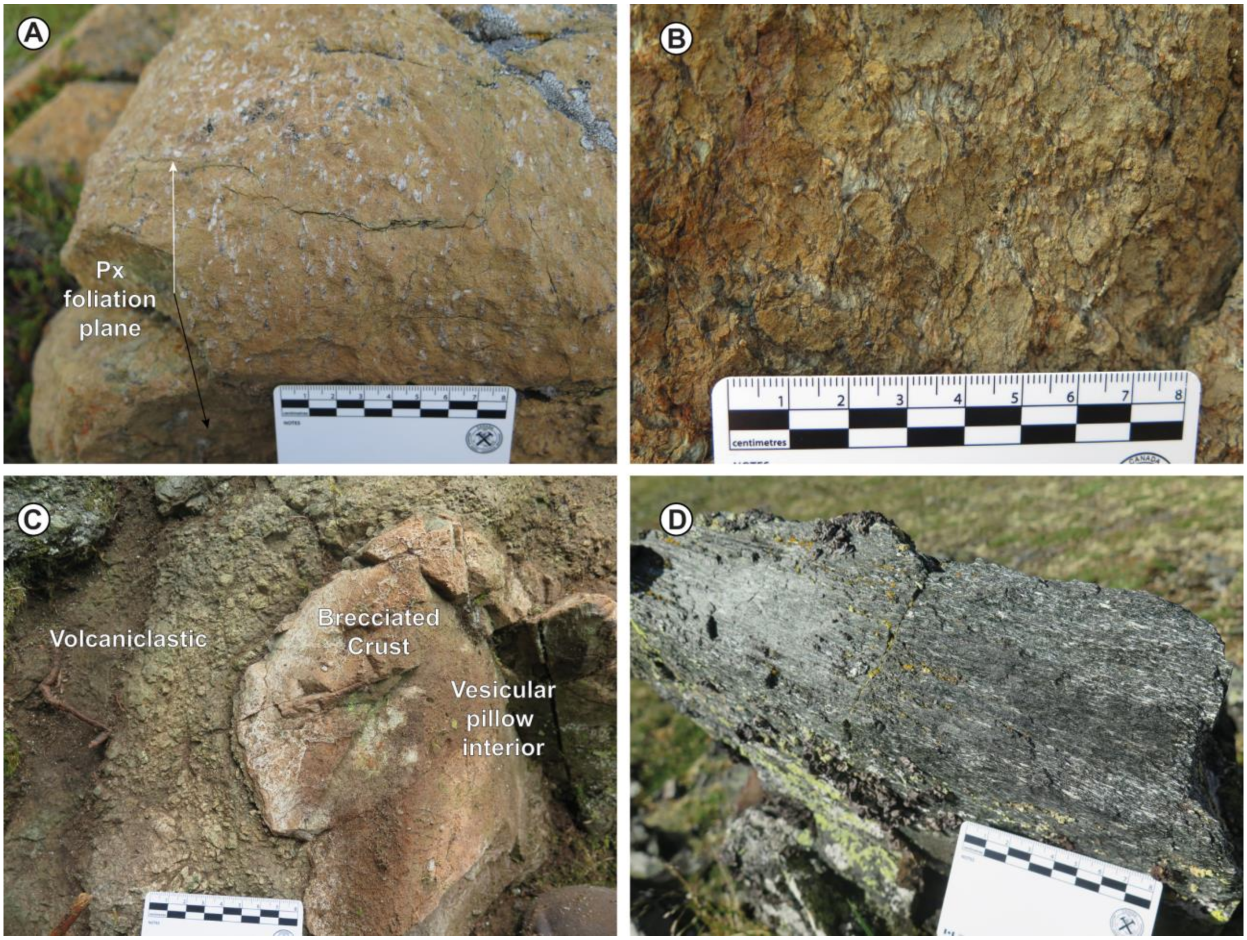

Figure 6. Potential ophiolite lithologies in SMT units, Wolf Lake area. A) Pyroxene phenocrysts aligned within a grain shape fabric in peridotite rocks imply that the foliation is a primary igneous mantle foliation. The rock has no apparent secondary tectonic recrystallization foliation. B) Mylonitic textures in some peridotite outcrops suggest high-temperature deformation, consistent with a tectonically active mantle setting. C) Volcaniclastic debris in irregular contact with vesicular basaltic rocks. The morphology of the basalt, including a vesicular interior and highly brecciated and altered rim where in contact with volcaniclastic sediments, implies that the basalt formed pillow structures during eruption onto a sea floor. D) Gabbro mylonite; fault-bound lozenges of SMT units in the northwest of the field area exhibit mylonitization of various units along their boundaries.

pillow basalt (Fig. 6C). These units exhibit evidence of phreatomagmatic processes and submarine volcanism, thus an ophiolite sequence from mantle to seafloor may be present. However, establishing the ophiolitic nature of many small lozenge-shaped fault-bound blocks of mafic and ultramafic rocks in the north of the area may be difficult, considering that they are highly dismembered and are commonly deformed along their boundaries (Fig. 6D).

Objective 3: Evaluating the nature of conglomerate in the Wolf Lake area

Middle to Late Triassic sedimentary rocks overlap both YTT and North America, post-dating their amalgamation. The Jones Lake formation (Colpron et al., 2016) is a Late Triassic part of the overlap sequence that typically comprises fine, calcareous siliciclastic rocks (Beranek and Mortensen, 2011). Rare outcrops of late siliciclastic deposits in the Wolf Lake region largely comprise coarse, polymictic conglomerate, a characteristic that is not congruent with their current unit designation as Jones Lake formation. Differentiating this conglomerate unit from other late siliciclastic rocks is important because it may not be overlap assemblage, but may be slightly older syn-orogenic sediment associated with the amalgamation of YTT and North America. Syn-orogenic conglomerates, through their stratigraphic sequence, provide a progressively changing view of the composition of the sedimentary provenance, typically the rapidly rising and eroding upper plate in a collision. They thus provide a unique view into the history of tectonism of a region. Our objective is to evaluate the provenance of the conglomerate through examining its characteristics and the nature of its clasts, which preserve petrologic and textural evidence of the unroofed terrane (potentially the eroded overriding plate). Analytical work will include detrital zircon geochronology of conglomerate matrix to establish the lag time (age of youngest detrital zircon – age of deposition), an important characteristic for establishing the tectonic setting of deposition (Cawood et al., 2012). Additionally, bulk samples of conglomerate clasts will be used for textural based analysis (e.g., Cleven et al., 2016).

Next steps

The goal of this research activity is to improve the understanding of the tectonostratigraphy of the Thirtymile Range area, and to establish the nature of ophiolitic rocks in the Wolf Lake area. With the completion of a successful field season in the summer of 2018, and with analytical work planned, we are on track to achieving these research aims.

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