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doi:10.4095/297300

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Recommended citation
Chapman, J.B., 2015. Syn-magmatic deformation and structural relationships within Jurassic granitoid rocks of the Aishihik batholith, Yukon: 2015 report of activities for GEM-2 Cordillera Project; Geological Survey of Canada, Open File 7961, 12 p. doi:10.4095/297300

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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 investment in responsible 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 summer 2015, GEM program has successfully carried out 14 research activities that include geological, geochemical and geophysical surveying. 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 collaborators as the program advances.

Activity Summary

Granitoid igneous rocks formed 205-180 million years ago (late Triassic to early Jurassic) host Yukon's only operating copper mine and other significant copper and gold deposits. However, exploration for additional deposits is hampered by many factors, including a lack of knowledge of the controls that determine the location of any individual deposit. Copper minerals at Minto mine and the Carmack Copper exploration property, two of the largest deposits in Yukon, are hosted within narrow corridors of highly-deformed rocks, within much larger bodies of similar but undeformed rock. Similar deformation has previously been seen within granitoid rocks in the western Aishihik batholith, interpreted to have been caused during their initial formation. This study aims to examine northern and eastern portions of

the Aishihik batholith, to determine the regional extent of this deformation, and to assess the relative roles of initial formation and later tectonic processes.

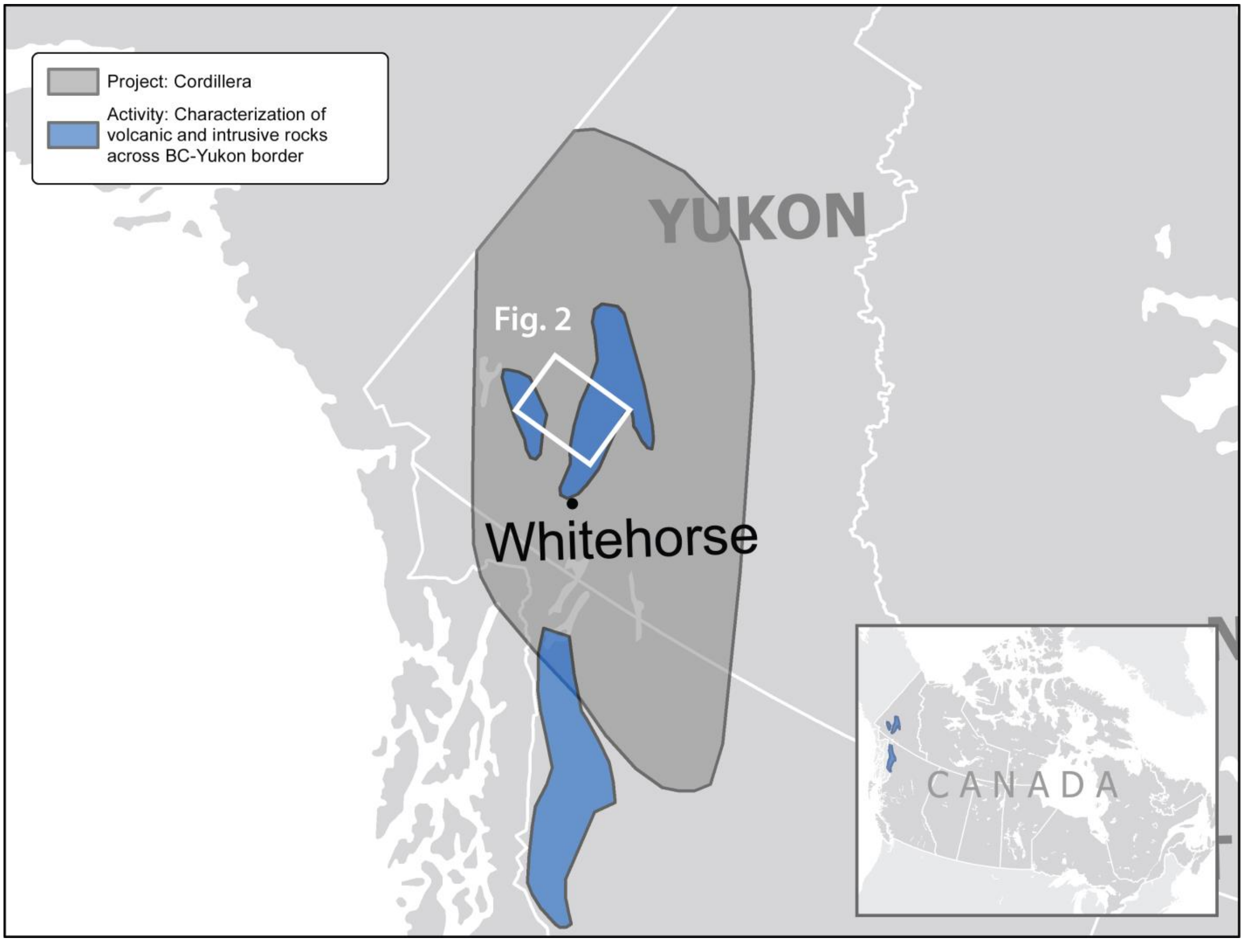


Figure 1. Spatial extent of the GEM-2 Cordillera Project area within Canada. Location of Figure 2 indicated by inset.

Introduction

The Minto Cu-Au mine in central Yukon is the only copper mine currently in production in northern Canada. Minto mine contributes a significant portion of Yukon's economic productivity and skilled labour employment and will continue to do so for the near future. Despite its regional economic importance, surprisingly little is understood about the processes and environment that led to the formation of this cluster of high-grade metal deposits, and no close global analogues are known. Along strike in British Columbia, similar late Triassic to early Jurassic arc plutonic rocks host numerous, typical copper, molybdenum and gold porphyry deposits. However, despite extensive outcropping of this suite in Yukon only one other sizeable deposit has been defined: the Carmacks Copper deposit at Williams Creek. Recent exploration activity in search of further Minto-style mineralisation has been unsuccessful.

Recent work at Minto and Carmacks Copper has identified the genetic importance of gneissic deformation corridors within the host mid-crustal granitoid bodies, and has highlighted geochemical and mineralogical similarities to alkali suite porphyry deposits in British Columbia (Tafti, 2005; Hood, 2012). Identification of these tectonic and geochemical fingerprints in other Triassic-Jurassic bodies in the district may help to provide more effective exploration for additional mineralization of similar style. Regional studies conducted by Johnston and Erdmer (1995) identified margin-parallel gneissic deformation of inferred Jurassic mid-crustal granodiorite of the Aishihik batholith. That study was confined to the western edge of the batholith, and deformation was interpreted to represent a solid-state shear fabric developed due to inflation of the batholith during emplacement into its host terrane (Johnston and Erdmer, 1995). Gneissic fabrics at the Minto deposit were interpreted by Hood (2012) to represent deformation localized along internal, igneous contacts between sequentially-emplaced granitoid intrusions, again during inflation of the plutonic body. In turn, Hood (2012) interpreted these corridors as the focus for magmatic-hydrothermal fluids exsolved from the cooling and ascending igneous bodies, which introduced copper and gold.

Solid-state and syn-magmatic deformation within mid-crustal plutons, and between those plutons and their host country rocks, may play an important role in localizing fluid flow during later, gold-rich alkaline magmatism. The gradual evolution of Triassic-Jurassic plutonic magmatism toward more alkaline compositions has been noted in many well-endowed porphyry districts in British Columbia, and may also occur within the mid-crustal Long Lake suite exposed in Yukon. If so, the coincidence of alkalic magmatism and structural preparation may provide a powerful vector to mineralization. Sites visited during the summer of 2015, detailed below, were chosen to investigate the regional occurrence of margin-parallel gneissic deformation of Aishihik batholith rocks, and to examine the textural and mineralogical expression of this deformation in comparison to gneissic fabric previously observed at the Minto and Carmack Copper deposits.

Field observations

In order to test genetic interpretations outlined in Johnston and Erdmer (1995), confirm whether or not syn-magmatic deformation textures occur in locations other than those observed on the western margin of the Aishihik batholith, and test the nature of contacts between the Long Lake suite and its host rocks, field spot checks were made in two zones along the eastern margin of the batholith and a number of zones along its northern margin (Fig. 1; Fig. 2).

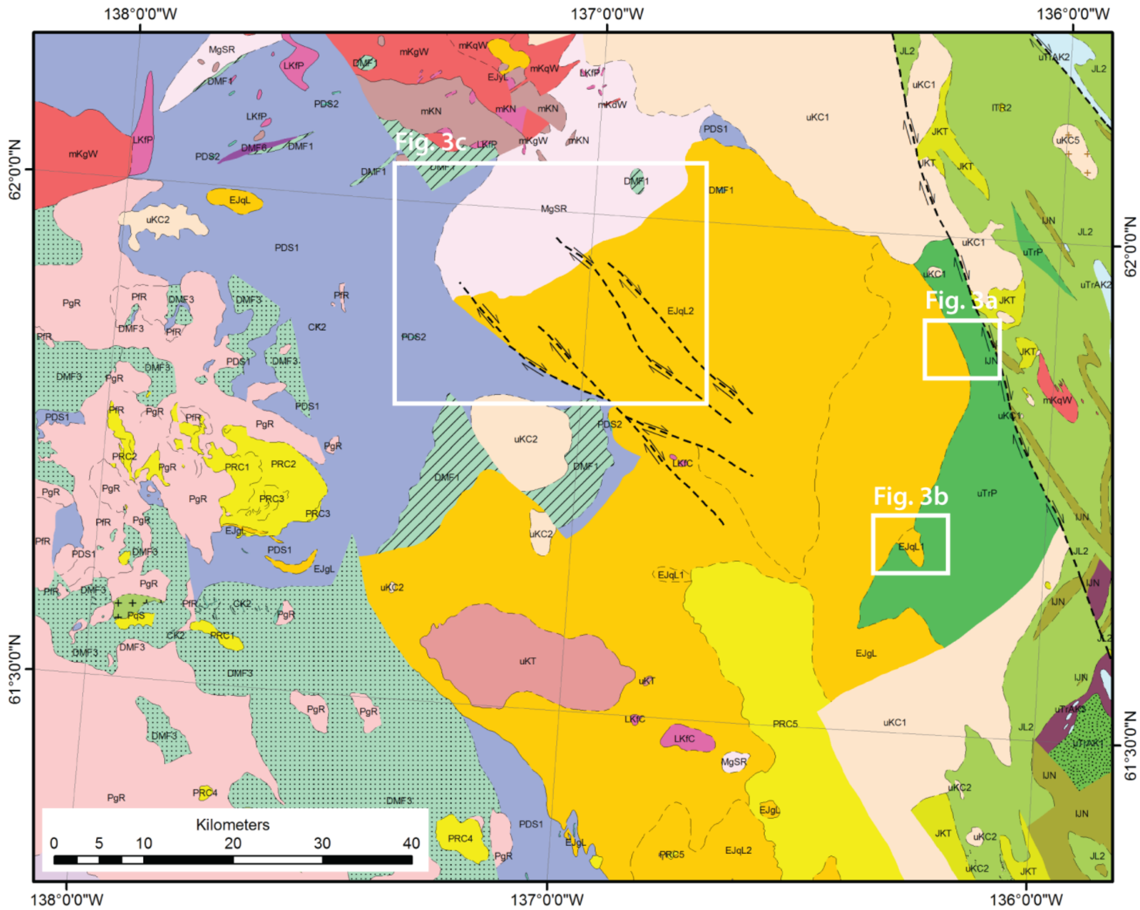


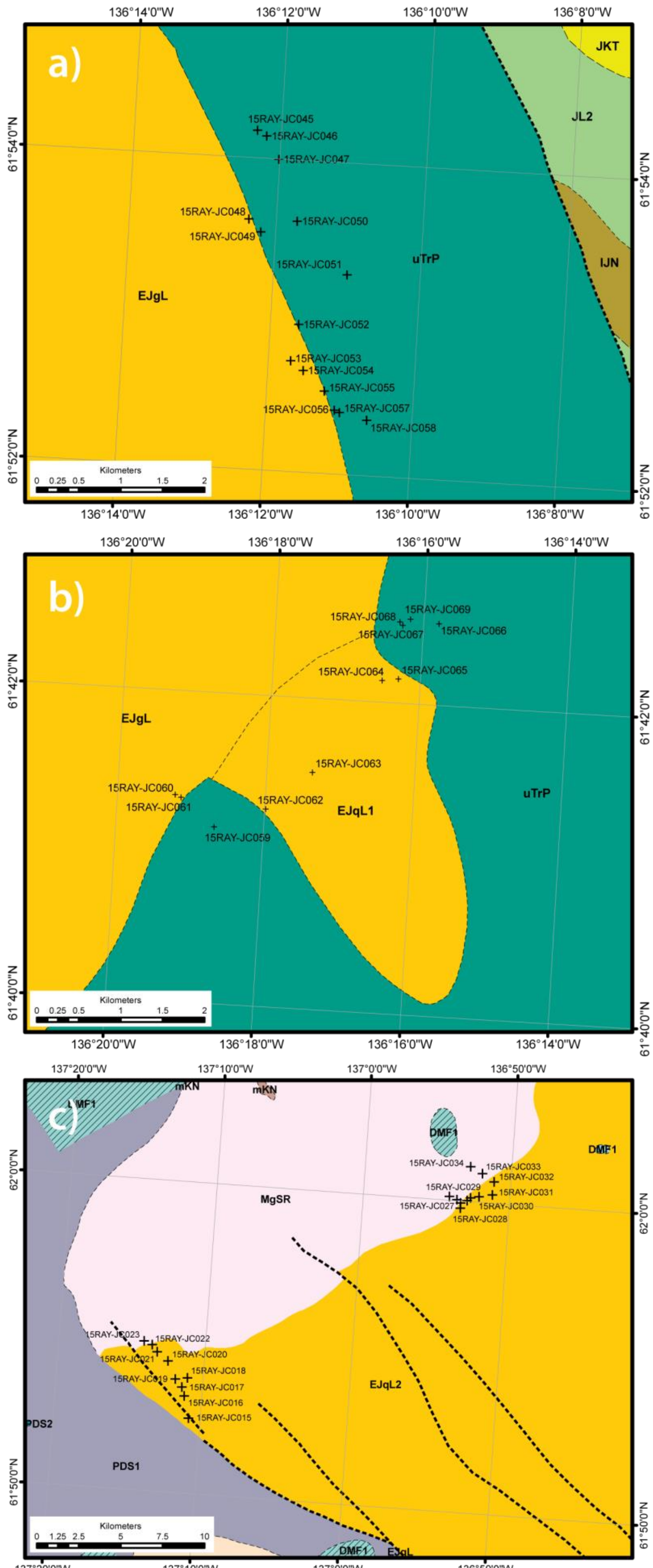
Figure 2. Geological bedrock map of the northern extent of the early Jurassic Aishihik batholith (EJqL). Contacts to its host country rocks at the north and eastern margins were investigated at locations shown in insets. Geology modified from Colpron (2015).

Razor Mountain

Locations 15RAY-JC045 to -JC058 (Fig. 3a) are located on and around Razor Mountain, at the western margin of the Nordenskiold River valley south of Carmacks. This zone was chosen as the only portion of the eastern contact of the Aishihik batholith that had been located with confidence on previously published maps (Gordey and Makepeace, 2003).

To the east of the contact, country rocks to the batholith are dominated by variably aphanitic, olivine- and augite-phyric basalts of the Upper Triassic Povoas Formation of the Lewes River Group. These rocks are pervasively and intensely cataclastically fractured and commonly cut by quartz veins. Deformation and vein orientations are locally highly variable, but appear to broadly parallel the orientation of the contact between the Aishihik batholith and the Povoas formation.

Figure 3. Detailed geological bedrock maps of the principal locations discussed within this report:
a) Razor Mountain;
b) Kirkland Creek;
c) Nisling River.
Geology modified from Colpron (2015).



At locations west of the contact, the Aishihik batholith comprises medium to coarse-grained equigranular and coarse-grained potassium feldspar-phyric granodiorite, attributed to the Early Jurassic Long Lake suite. By examination of cross-cutting relationships, the earliest Long Lake phase present at most locations is a coarse to very coarse, mafic-rich and k-spar phenocryst-bearing granodiorite (Fig. 4a). This phase has a ubiquitous, moderately- to well-developed foliation, defined by alignment of hornblende and lesser biotite mafic phases and feldspar phenocrysts. The foliation is sub-vertical, and its strike is approximately north-south. Angular, brecciated, jigsaw-fit mafic xenoliths are sparsely-distributed within the granodiorite.

This early foliated phase is commonly intruded by a moderately porphyritic to equigranular, unfoliated granodiorite, with lesser mafic content. The unfoliated phase appears to be compositionally similar to the earlier, foliated phase. Foliation in the earlier phase is cut at moderate to high angles by the unfoliated phase. Directly adjacent to the contact between the two, the unfoliated phase displays a weak to well developed, fine- to medium-grained, mafic-poor chill margin (Fig. 4b). Where the intrusive phase forms narrow dykes, its texture is fine-grained to aplitic. It may be that some of these dyke phases are similar to the widespread and common Jurassic aplite dykes that are observed throughout the district, but without observed cross-cutting relationships and a lot more geochronology, this cannot be confirmed.

Kirkland Creek

Further investigation of deformation within and relationships between internal phases of the Aishihik batholith and their contact to host country rock was conducted at a second location along the eastern contact (Fig. 3b). This locality is approximately 25 km south-southwest of Razor Mountain, on the northern slopes of the Kirkland Creek valley. Recent regional reconnaissance and updated mapping have identified a 2 by 5 km pluton containing quartz monzonite phases at the periphery of the batholith (Colpron, 2015). This zone was chosen to investigate the contact between the pluton and monzonite-poor phases that comprise the bulk of the batholith.

In common with the Razor Mountain location, the country rock in the Kirkland Creek zone is dominated by variably porphyritic augite- and plagioclase-phyric to aphanitic basalt of the Povoas Formation. Deformation appears lesser here, although vegetation obscures much of the outcrop, and no tightly constrained contact between this and the felsic batholith could be determined.

Within the peripheral phases, felsic granitoid rocks are dominated by a medium-grained, k-spar phyric monzonite to granodiorite – containing distinctive and abundant, pale blue, anhedral, quartz phenocrysts – and medium to coarse-grained granodiorite. In the northeast, strongly foliated granodiorite contains pods and dykes of undeformed syenogranite. Foliation, as proximal to Razor Mountain, is near-vertical, but oriented northwest-southeast, sub-parallel to the approximate contact between the Long Lake suite and Povoas formation.

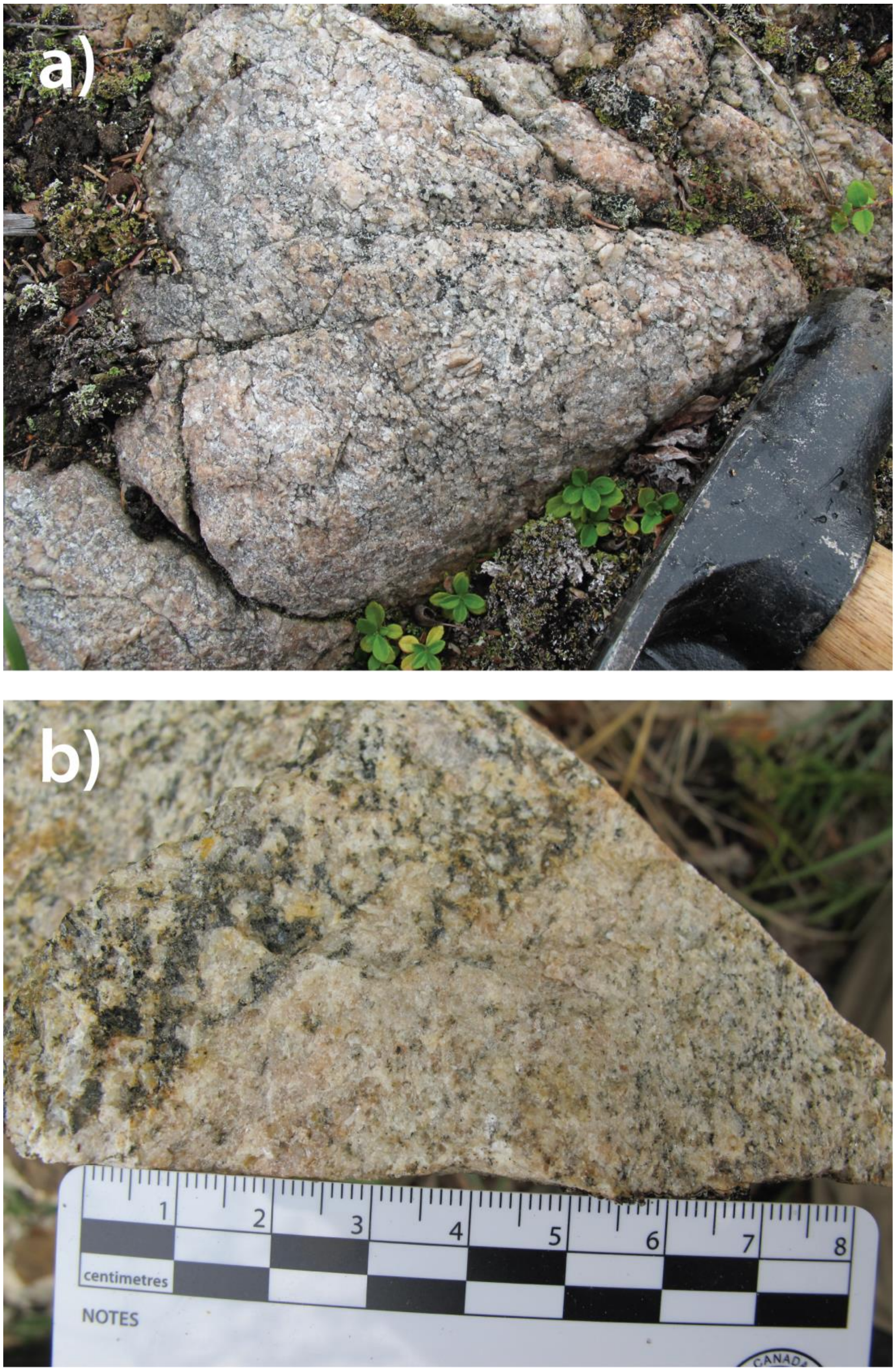


Figure 4. Granodiorite outcrop and lithology at 15RAY-JC048: a) moderately foliated, k-spar phyric, hornblende-bearing, potassium feldspar phenocrysts range in size between 1 and 3 cm; b) equigranular, mafic-poor, unfoliated granodiorite (lower) cross cutting foliation in earlier granodiorite.

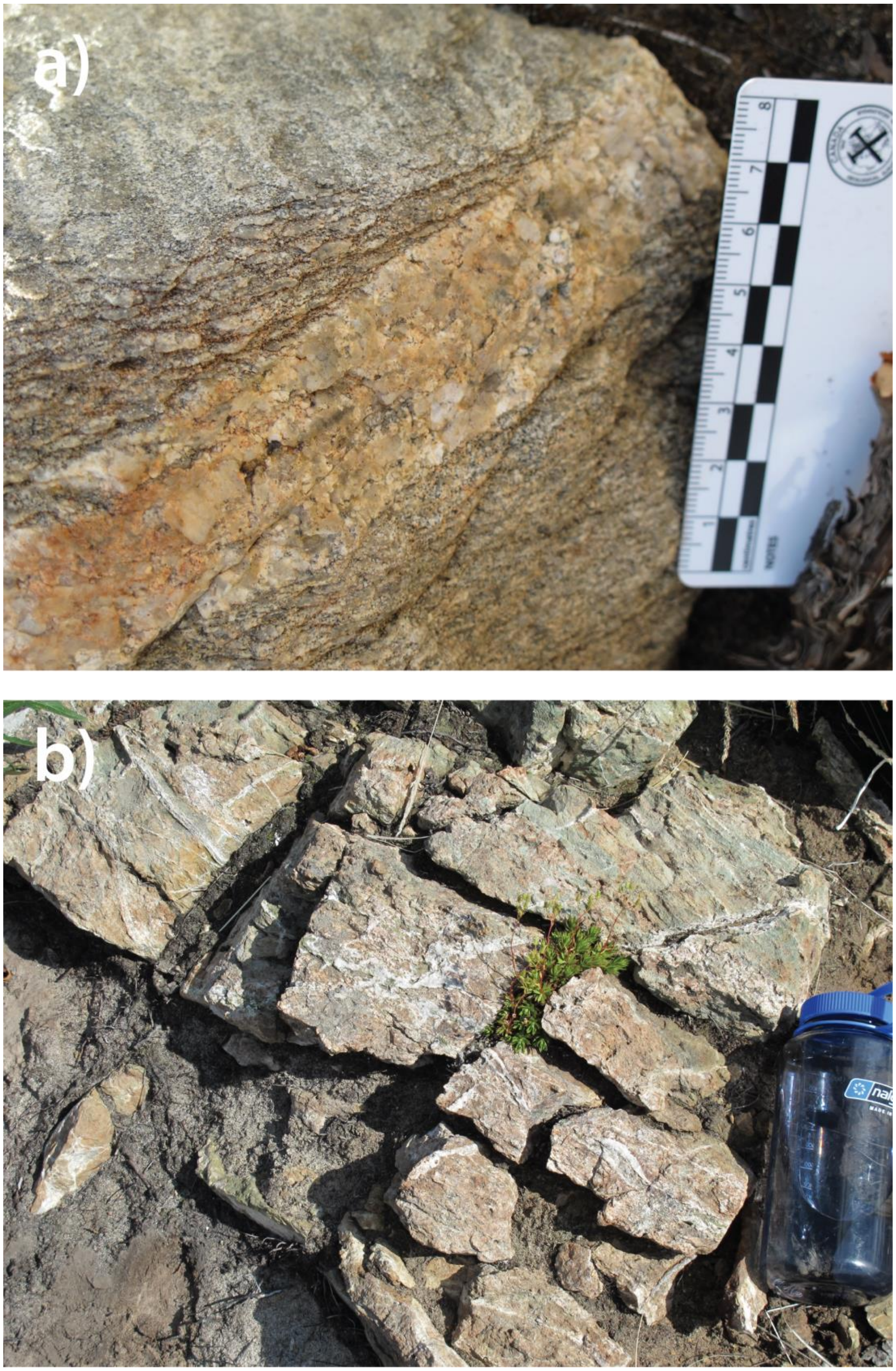


Figure 5. Intrusion and alteration of Mississippian rocks at location 15RAY-JC023: a) highly foliated, Mississippian, Simpson Range granodiorite cut by presumed Jurassic, fine grained, unfoliated granodiorite; b) metasomatic alteration of host Mississippian metavolcanic rocks to epidote-garnet skarn, cut by multiple generations of carbonate veining.

Nisling River

In addition to the analysis conducted along the eastern edge of the batholith, summarized above, additional observations were made along the northern margin of the batholith while conducting regional-scale mapping under the GEM-2 Crustal Blocks activity (Ryan et al., 2015). This margin was transected a number of times (Fig. 3c), in order to determine whether a thrust emplacement relationship between the batholith and its host rocks (Colpron, 2015) could be verified in the ground. No evidence for a large displacement thrust fault was discovered at any location in this vicinity, but rather, an intact intrusive contact that has local structural modification (Ryan et al., 2015). Two such localities are discussed below in comparison to the observations made at the eastern margin.

Location 15RAY-JC023 lies just to the north of a concealed contact between k-spar megacrystic granodiorite of the Jurassic Long Lake suite to the south and strongly foliated Mississippian Simpson Range granitoid gneiss to the north. At 15RAY-JC023, the Mississippian granitoid is intruded by numerous granite pegmatite dykes, compositionally similar to the Jurassic granodiorite to the south (Fig. 5a). Portions of volcanic Mississippian country rock have been metasomatized to epidote-garnet skarn (Fig. 5b), likely by interaction with aqueous, magmatic-hydrothermal fluids related to the pegmatite magmatism.

Location 15RAY-JC027 is a low, elongated peak. At its northern end, it is composed of granitoid gneiss with pegmatite dykes, similar to that seen at -JC023. At its southern end, the rocks are undeformed, k-spar phyric, hornblende-bearing granodiorite of possible Jurassic age. Between the two, the provenance of the rocks is less easily assigned. Although in appearance, they are strongly tectonized and deformed in a similar manner to the Mississippian suite, and contain stretched k-spar phenocrysts as seen elsewhere in Mississippian granitoids (J. Ryan, *pers. comm.*), their relationship with the putative Jurassic rocks to the south appears to be somewhat gradational. More detailed petrography will need to be conducted to determine their relationship more clearly.

Conclusions

At most locations studied, gneissic deformation of Early Jurassic granitoid phases appears to have occurred at an early stage during batholith emplacement. Margin-parallel deformation of granodiorite is common, intruded by later, undeformed generations of the same magmatic sequence. Skarnification of deformed marginal host phases may have resulted from magmatic fluid flow related to batholith emplacement, and does not appear to be linked to copper and gold mineralizing fluids. Deformation observed in the course of these field visits differs markedly from that seen at known mineralized locations. This style of margin-parallel deformation lacks much of the partial melt and very high temperature solid state chemical and mineralogical features seen at both Minto and Carmacks Copper. Both the Minto and Carmacks Copper deposits occur well within the margins of their host plutons, and simple emplacement deformation may be expected to be lesser. Future work within this study will therefore seek to define characteristics that fingerprint those areas of deformation and coincident mineralization, with possible influence by evolved alkalic magmatism within Yukon Jurassic plutonic bodies, which may form high-prospectivity exploration targets.

Next Steps

Detailed mineralogical and geochemical characterization will be performed on samples returned from visited field locations.

Acknowledgements

This activity was wholly funded by the Government of Canada's Geomapping for Energy and Minerals Program. Many thanks are extended to Patrick Sack of the Yukon Geological Survey for stimulating discussion and guidance, and to Meghan Moher and Yannick Morneau for assistance in the field. Many thanks to my GSC colleague Jim Ryan for accommodation while in the field and access to helicopter transport, and Stephen Williams is thanked for patient and efficient GIS assistance. Thanks also to Trans North Helicopters and pilot Bob Skinner for skillfully and professionally enabling access to demanding and highly vegetated terrain.

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