Geology and jade prospects of the northern St. Cyr klippe (NTS 105F/6), Yukon

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ABSTRACT

Nephritic jade deposits have been found along faulted contacts between serpentinite and siliceous units at the King Arctic mine in southeastern Yukon. In the St. Cyr klippe near Quiet Lake south-central Yukon, serpentinite units of the Slide Mountain oceanic assemblage are thrust above phyllite units of the Cassiar terrane. This contact has the potential to contain jade deposits similar to the ones found at the King Arctic mine. However, bedrock mapping during the summer of 2013 failed to identify large jade deposits within the field area, but smaller jade deposits may have been overlooked. The absence of jade mineralization could be due to the lack of fluid migration through faults, but is more likely due to the low silica content of the phyllite.

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INTRODUCTION

Jade deposits associated with suture zones have been found extending northward from the United States-Canada border, through British Columbia and into Yukon (Harlow and Sorensen, 2005). Jade refers to two different monomineralic rocks: nephrite and jadeitite. Jadeitite consists of pure jadeite, *i.e.*, the Na-pyroxene end member ($NaAlSi_2O_6$), while nephrite is the microcrystalline, amphibole (tremolite-actinolite) variety ($Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$). Jade is most often used as gemstone for jewelry, sculpture, and ornamental stones. British Columbia accounts for three quarters the world's jade production. The world market for jade is estimated at 300 tonnes per year (Scott, 1996).

Nephritic jade throughout the Canadian Cordillera is associated with serpentinite in fault contact with metasedimentary or felsic igneous rocks (Simandl *et al.*, 2001). Nephrite deposits are uncommon in Yukon, but when present they are associated with Slide Mountain and Cache Creek ultramafic rocks. In southeast Yukon at the King Arctic mine (Fig. 1), nephrite occurs in layers up to 3 m thick along northwest-striking reverse faults that imbricate a serpentinite mélange of the Slide Mountain assemblage with basal chert conglomerate and sandstone of the Money Creek formation (Devine *et al.*, 2004). The serpentinite units have thicknesses ranging from <1 m to 150 m and are associated with talc-schist zones along the fault boundaries, which result from shearing and fluid flow. The faulted contacts are sealed by the jade mineralization indicating syn-faulting jade formation (Devine *et al.*, 2004). The suggested age of the D_4 faulting, based on regional tectonics, is Jurassic to Cretaceous, and is thought to be related to shortening of the Yukon–Tanana terrane (Murphy *et al.*, 2003).

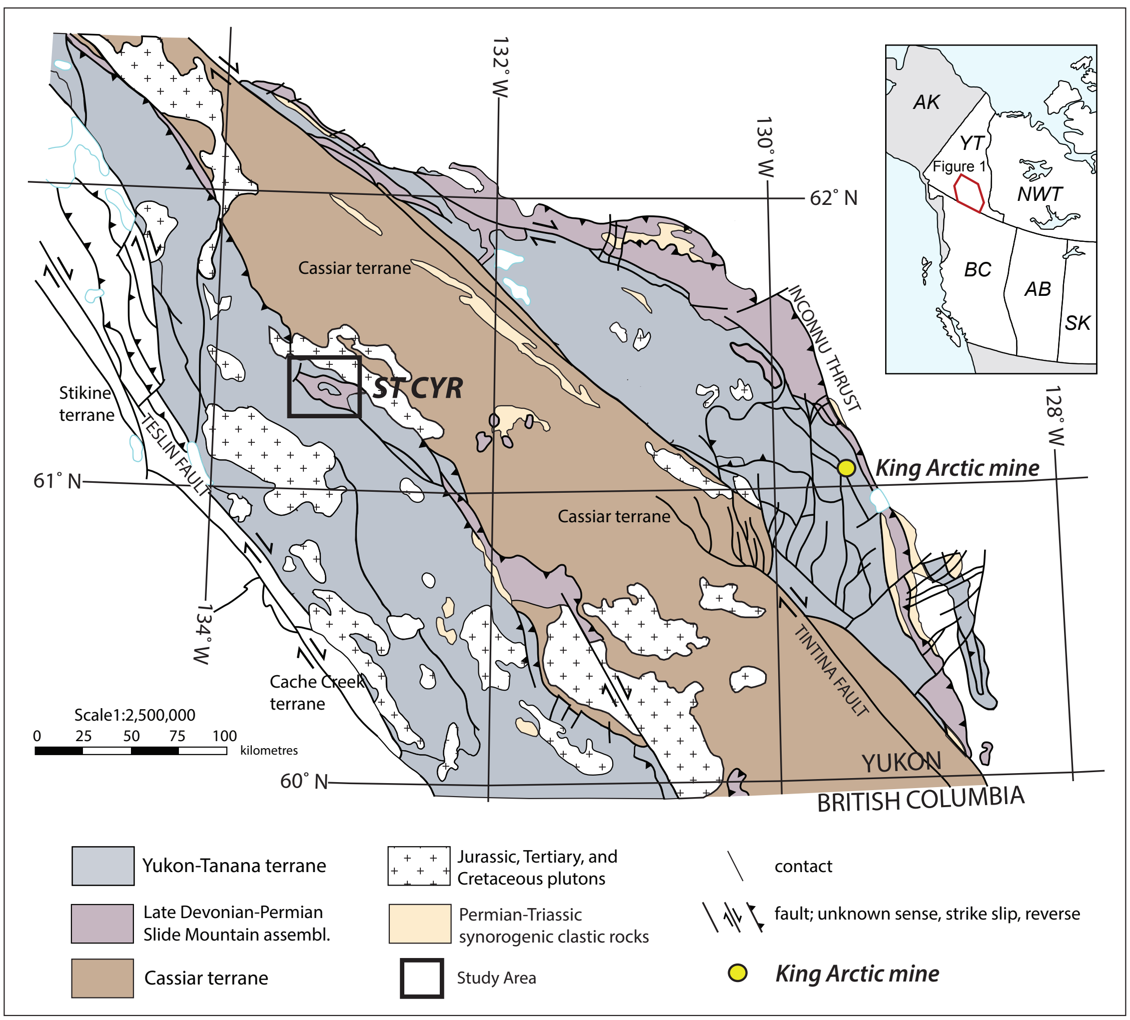

Figure 1*. Simplified regional map of southeastern Yukon modified from Colpron et al., 2006. Study area is marked by a black box. King Arctic mine is marked by a yellow circle.*

In the northwest section of the St. Cyr klippe (Fig. 1), serpentinite units of the Slide Mountain assemblage are thrust above phyllite of the Cassiar terrane. These thrust contacts have the potential to host jade deposits similar to those found at the King Arctic mine. This contribution describes the lithology and structures of the northern part of the St. Cyr klippe, and the jade prospects of the area. Geological mapping at 1:20 000 and 1:50 000, conducted during the summer of 2013 in the southwest corner of NTS 105F/6, serves as the basis for this research.

REGIONAL SETTING

The Yukon-Tanana terrane (YTT), located in the northern Cordillera, is interpreted as a composite arc built on the rifted margin of North America that is associated with the opening of the Slide Mountain Ocean (SMO) during a Devonian, east-dipping subduction event (Murphy *et al.*, 2006; Nelson *et al.*, 2006). The YTT is composed of four main tectonic assemblages (Colpron *et al.*, 2006): Snowcap, Finlayson, Klinkit, and Klondike. The basal Snowcap assemblage contains Neoproterozoic to earliest Devonian sedimentary rocks derived from the Laurentian continental margin and forms the substrate of the Yukon-Tanana arc. The Finlayson assemblage is late Devonian-early Mississippian and represents a paired continental arc and extending back arc. The Klinkit units are attributed to a middle Mississippian to early Permian island arc assemblage. Lastly, the Klondike assemblage is middle to late Permian and represents continental arc material (Colpron *et al.*, 2006). Typically, the SMO assemblage occurs as a mixture of serpentinite, ultramafic rocks, gabbro, chert, and marble throughout the Canadian Cordillera (Mortensen, 1992b). Starting in the mid-Permian, the SMO was closed by west-dipping subduction beneath the YTT and by the early Triassic (Beranek *et al.*, 2011) the closure was complete. Shortening of the continental margin continued into the Jurassic resulting in the YTT and SMO occurring as thrust panels or klippen obducted onto North American strata, in this case the Cassiar terrane (Murphy *et al.*, 2006; Nelson *et al.*, 2006; Mortensen, 1992a&b). Re-accretion occurred in the Permo-Triassic as evidenced by the presence of YTT and SMO detrital zircons in Triassic units deposited on the continental margin (Beranek *et al.*, 2010). The Cassiar terrane represents a slice of the North American continental margin assemblage that is presently located southwest of the right-lateral, strike-slip Tintina fault (Fritz *et al.*, 1991). The Cassiar terrane generally contains siltstone, sandstone, shale, and limestone, and metamorphic equivalents of quartzite and muscovite-graphitic-quartz schist (Tempelman-Kluit, 2012).

ST. CYR KLIPPE

GEOLOGIC SETTING

The St. Cyr klippe is a 70-km long by 15-km wide, northwest-striking metamorphic unit that contains imbricated slices of YTT and SMO rocks. It lies in the region between the Tintina and Teslin faults (Fig. 1; Tempelman-Kluit, 2012). Previously all units in the St. Cyr klippe were mapped as the Slide Mountain oceanic terrane (Tempelman-Kluit, 1979; Erdmer, 1992; Fallas, 1999); however, to the southeast of the study area is an eclogite-bearing, quartzofeldspathic, high-pressure metamorphic unit. The eclogite occurs as lenses within coherent slices of quartzofeldpathic rocks with igneous and sedimentary protoliths that are part of the YTT arc (Gilotti *et al.*, 2013; Petrie *et al.*, 2012). To the northeast, rocks of the St. Cyr klippe are cut by the Cretaceous Nisutlin batholith.

Our study area (Fig. 2) is located in the northwest part of the St. Cyr klippe and contains units of the Cassiar terrane, Tower Peak assemblage, and Slide Mountain assemblage. The Tower Peak assemblage, described by Fallas (1999) as a greenschist-facies metavolcanic unit, has no age or provenance constraints. Results from sampling in the spring of 2014, including U/Pb geochronology, bulk rock, and trace element geochemistry will provide these constraints as part of Isard's MS thesis. The Slide Mountain assemblage occurs as a mafic-ultramafic unit with a MORB-like protolith that is related to the late Devonian to early Triassic SMO (Fallas, 1999; Gabrielse *et al.*, 1993; Mortensen, 1992a,b).

The Tower Peak assemblage is emplaced over the Slide Mountain assemblage, which in turn overlies the phyllite units of the Cassiar terrane forming a composite klippe. Both thrust faults are dipping shallowly to the south. A post-thrusting syncline is present that folds phyllite units of the Cassiar terrane, the Tower Peak assemblage, and Slide Mountain terrane.

LITHOLOGIC DESCRIPTIONS

The best prospect for jade mineralization is at the base of the klippe, provided the right rock types (*i.e.*, serpentinite and silica-rich rocks) are in contact. Therefore, units of the Cassiar terrane in the footwall of the St. Cyr klippe, and the Tower Peak and Slide Mountain Ocean slices in the klippe itself are described below.

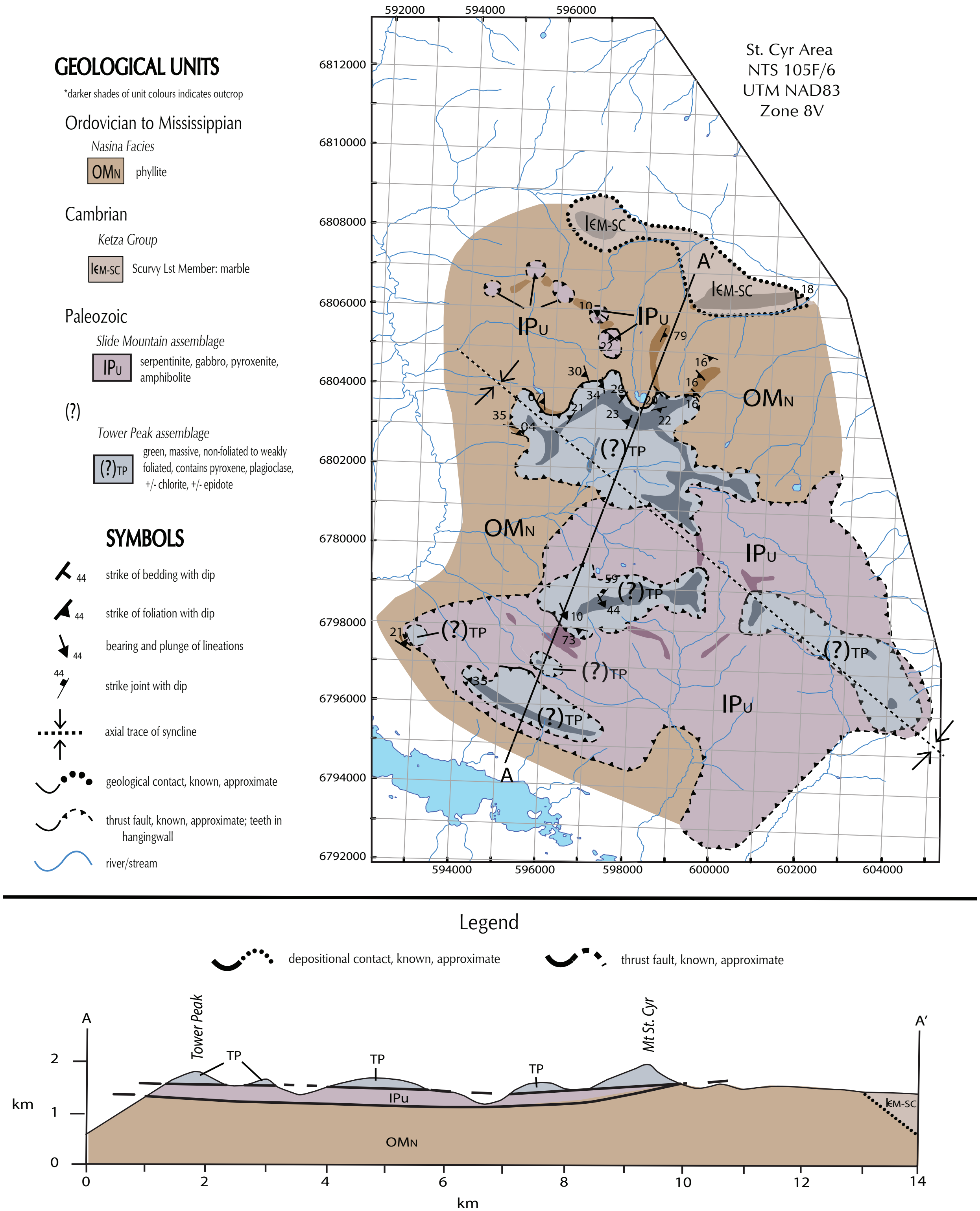

Figure 2. *Geological map of the NW St. Cyr klippe with cross section A-A′.*

Cassiar terrane

The Cassiar units in the St. Cyr area (Fig. 2) include phyllite and a panel of marble. The Cassiar terrane here is dominated by black to dark green, fine-grained phyllite consisting of quartz + biotite + muscovite ± chlorite (Fig. 3a). A >300 m-thick marble unit (Fig. 3b), correlating with the Scurvy limestone member of the Ketza group (Tempelman-Kluit, 2012), is exposed in the northern section of the map area. The marble is coarse-grained with ~0.5 to 5.0 cm thick alternating dark and light grey layers dipping 18° east. This unit is structurally higher than the phyllite, and the contact between the units dips approximately 45° to the east.

Tower Peak unit

The Tower Peak assemblage is grey to green, very fine to medium grained, and weakly foliated to massive (Fig. 3c). Cataclasite-ultracataclasite rocks containing secondary quartz and calcite veins occur adjacent to the fault zones (Fig. 3e). Many of these rocks have angular clasts within a very fine-grained groundmass; there is no evidence of rotation to determine fault movement. There are local occurrences of incohesive fault gouge at contacts with the Cassiar terrane. The Tower Peak rocks are mainly composed of feldspar and pyroxene (Fig. 3d). Epidote and chlorite are present as secondary metamorphic minerals while quartz and calcite are most likely derived from secondary fluids associated with brittle deformation. The occurrence of epidote and chlorite suggest greenschist facies or lower P-T conditions. Many of the feldspar grains are interlocking suggesting an igneous protolith, most likely a diabase or gabbro. The mafic mineralogy and igneous protolith suggests the Tower Peak assemblage may be part of the oceanic Slide Mountain assemblage. Prominent joints dip steeply to moderately northwest, while a weak, local foliation dips gently southwest.

Slide Mountain terrane

The Slide Mountain rocks are serpentinite, pyroxenite, and gabbro with rare amphibolite. Generally, the serpentinite is black to green, fine grained, massive, fibrous, and glassy (Fig. 4a,b). Powder XRD analysis using a D8 Advance Bruker instrument at the Department of Chemistry, University of Iowa indicates that lizardite is the serpentinite mineral. A unit of brecciated serpentinite, 2 to 3 m thick, weathering tan, and containing large, angular clasts approximately 1to 40 cm with a fine grained, fibrous serpentinite matrix (Fig. 4c), lies in the eastern part of the map area. In the same area, massive, tan-weathering ultramafic lenses occur within serpentinite that is approximately 3-5 m thick (Fig. 4d). The gabbro is black with undeformed plagioclase crystals, fine to coarse grained, and foliated to massive. Calcite veins commonly cut the serpentinite and gabbro. The veins are typically 1to 4 cm thick (Fig. 4e,f). A rare metagabbro (amphibolite) outcrops in one location. The amphibolite is black, coarse grained, massive, and approximately 1 to 2 m thick. Orange-weathering, serpentinized pyroxenite, with pseudomorphs after chromite, is massive to foliated. These ultramafic rocks are intercalated with the serpentinite and gabbro on a one meter to tens of meters scale.

JADE POTENTIAL

Jadeitite typically occurs in high pressure–low temperature metamorphic terranes, while nephrite occurs at greenschist-facies or lower conditions. The rock units in the northwest part of the St. Cyr klippe reached greenschist facies, and therefore, only have the potential to host nephrite. Since lizardite is the main serpentine mineral, metamorphic temperatures were probably <300°C (Evans *et al.*, 2013). Nephritic jade is produced by either Ca-metasomatism in serpentinite at contacts with silica-rich rocks, or replacement of dolomite by silicic fluids (Harlow and Sorensen, 2005). Replacement of dolomite by silicic fluids is an unlikely mechanism at St. Cyr because it requires post-magmatic fluids to be channeled by fissures and faults through dolomite (Sekerina, 1992).

At the King Arctic mine, jade mineralization was controlled by reverse faults that imbricated serpentinite with the basal conglomerate and sandstone of the Money Creek formation and limestone of the White Lake formation, together with fluid migration synchronous with D_4 faulting (Devine *et al.*, 2004). In the northwest section of the St. Cyr klippe, nephrite could have formed along thrust contacts between phyllite in the footwall and serpentinite in the hanging wall. However, no large nephrite deposits were found during our mapping along the basal thrust of the St. Cyr klippe.

The apparent absence of jade in the St. Cyr klippe could be explained if no fluid migration occurred during emplacement of the serpentinite. The presence of numerous calcite veins within the serpentinite suggests fluid migration did occur; however, the secondary calcite veins may have formed at a later time. The more likely explanation for the lack of jade is that the phyllite does not have a high enough silica content to facilitate metasomatic exchange—unlike the silica-rich chert conglomerate at the King Arctic mine. Similarly, nephrite is unlikely to form at fault contacts between the serpentinite and the Tower Peak units because the Tower Peak has a brecciated mafic protolith, probably consisting of basalt, diabase, and gabbro. Although large jade deposits were not found in this study, the possibility exists for smaller occurrences of nephritic jade in the St. Cyr area. Elsewhere in southern Yukon, nephrite deposits may exist where serpentinite units of the Slide Mountain assemblage are in fault contact with silica-rich units.

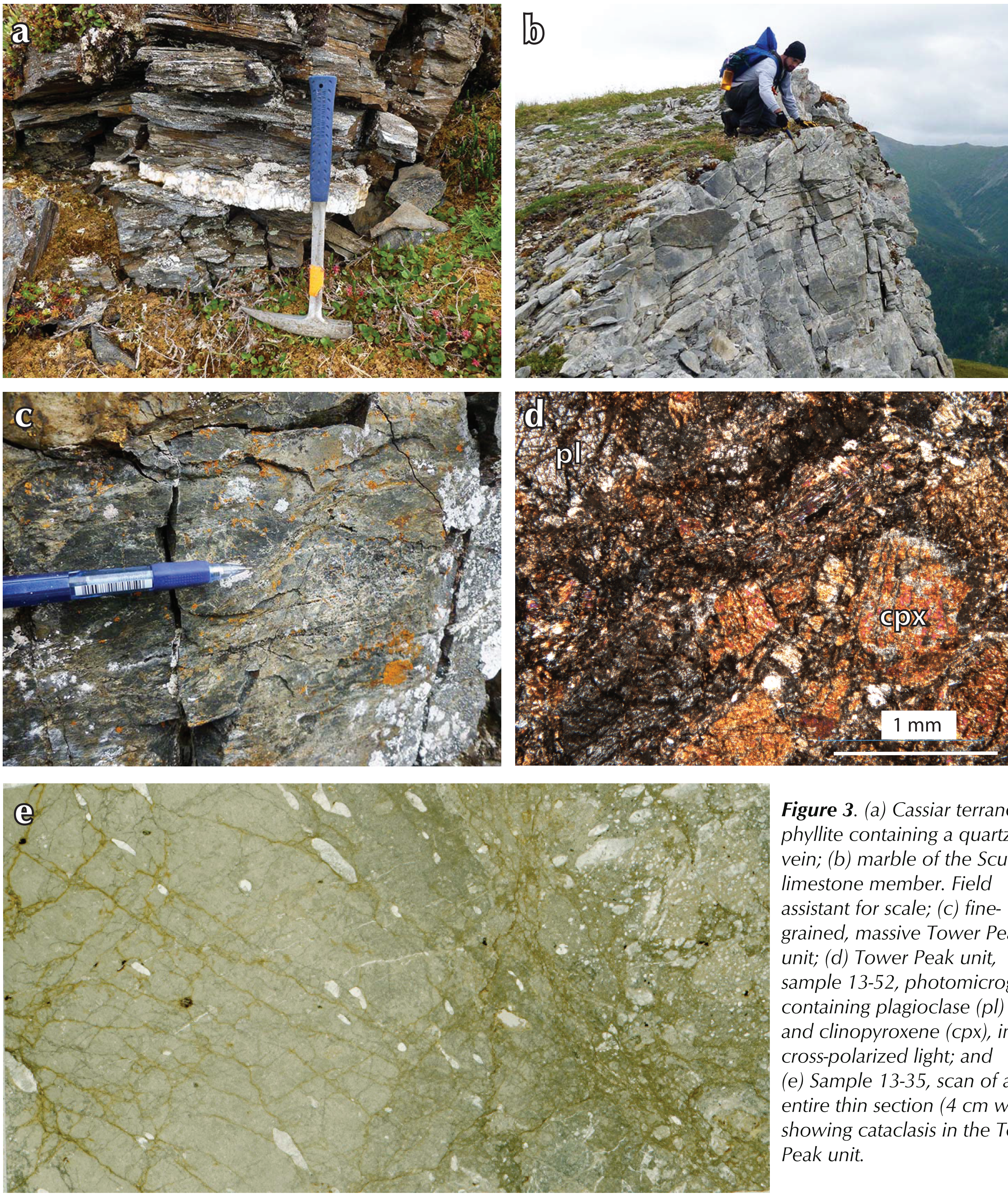

***Figure 3**. (a) Cassiar terrane phyllite containing a quartz vein; (b) marble of the Scurvy limestone member. Field assistant for scale; (c) fine-grained, massive Tower Peak unit; (d) Tower Peak unit, sample 13-52, photomicrograph containing plagioclase (pl) and clinopyroxene (cpx), in cross-polarized light; and (e) Sample 13-35, scan of an entire thin section (4 cm wide) showing cataclasis in the Tower Peak unit.*

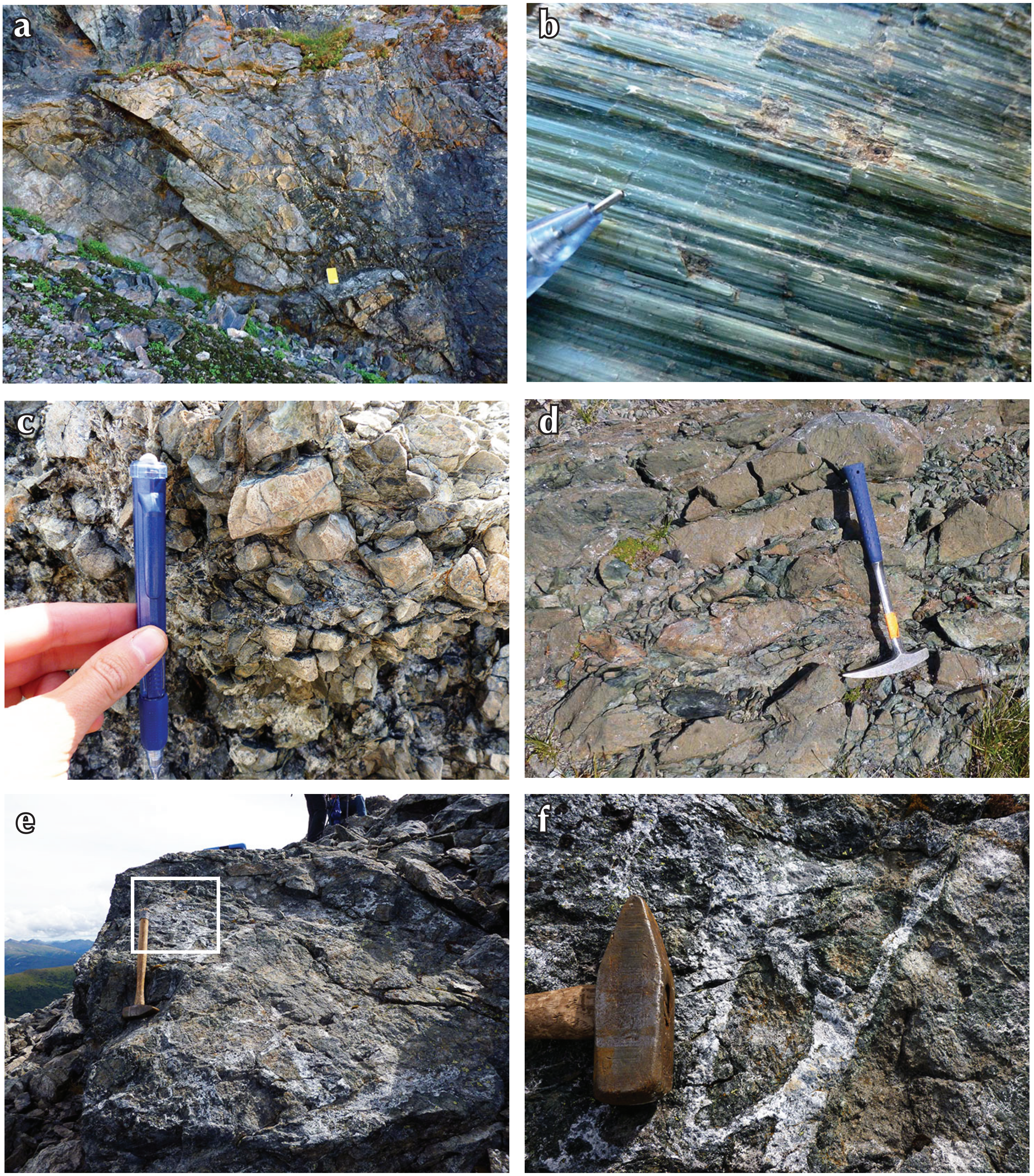

***Figure 4**. Slide Mountain Assemblage: (a) massive serpentinite; (b) fibrous serpentinite; (c) brecciated serpentinite clasts with a fine-grain serpentinite matrix; (d) massive, orange weathering ultramafic rock; (e) calcite veins in a massive gabbro, white box indicates photograph f; and (f) close-up of area in (e).*

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