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Authors' addresses

J.J. Ryan *(jryan@nrcan.gc.ca)*
S.P. Gordey *(sgordey@nrcan.gc.ca)*
Geological Survey of Canada
605 Robson Street, Suite 101
GSC Pacific, Vancouver
Vancouver, British Columbia
V6B 5J3

P. Glombick *(glombick@ualberta.ca)*
Department of Earth and Atmospheric Sciences
University of Alberta
1-26 Earth Sciences Building
Edmonton, Alberta T6G 2E3

S.J. Piercey *(spiercey@nickel.laurentian.ca)*
Department of Earth Sciences
Laurentian University
Ramsey Lake Road
Sudbury, Ontario P3E 2C6

M.E. Villeneuve *(mvillene@nrcan.gc.ca)*
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

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Update on bedrock geological mapping of the Yukon–Tanana terrane, southern Stewart River map area, Yukon Territory[1]

J.J. Ryan, S.P. Gordey, P. Glombick, S.J. Piercey, and M.E. Villeneuve

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Abstract: The Yukon–Tanana terrane in the Stewart River area consists of twice-transposed, amphibolite-facies gneiss and schist of mostly of (?)Paleozoic age. Quartz-rich metaclastic rocks (quartzite, quartz-mica schist, psammite, conglomerate) appear to have been deposited during the mid-Paleozoic, rather than the Proterozoic as previously suspected. Broadly contemporaneous amphibolite of intermediate to mafic composition interdigitates with, and lies structurally (and possibly stratigraphically) above, the metaclastic rocks. Extensive orthogneiss (including augen granite) intrudes both. The orthogneiss and amphibolite formed the subvolcanic root and volcanic cover, respectively, of a Devono-Mississippian island arc. These rocks served in turn as basement to a Permian magmatic arc, manifested as the Klondike schist and related plutons. A co-magmatic Permian orogeny resulted in extensive transposition and metamorphism of the mid- and late Paleozoic rocks. The Lucky Joe Cu-Au occurrence, of recent interest in the area, occurs generally within the complex, possibly structurally modified interface between metaclastic and amphibolite successions.

Résumé : Dans la région cartographique de Stewart River, le terrane de Yukon-Tanana se compose surtout de gneiss et de schistes du faciès des amphibolites qui ont subi deux épisodes de transposition et remontent principalement au Paléozoïque(?). Des roches métasédimentaires clastiques riches en quartz (quartzites, schistes à quartz-micas, psammites, conglomérats) semblent s'être déposées au Paléozoïque moyen plutôt qu'au Protérozoïque comme on le soupçonnait précédemment. En gros contemporaines des roches métasédimentaires clastiques, des amphibolites de composition intermédiaire ou mafique forment avec celles-ci des interdigitations et les surmontent structuralement (et peut-être stratigraphiquement). Des orthogneiss (comprenant du granite oeillé) sont répandus et recoupent les deux types de roche précédents. Les orthogneiss et les amphibolites constituaient respectivement la racine subvolcanique et la couverture volcanique d'un arc insulaire dévono-mississippien. Ces roches ont ensuite servi de socle à un arc magmatique du Permien dont les manifestations correspondent au schiste de Klondike et aux plutons associés. Une orogenèse contemporaine de l'activité magmatique au Permien a engendré une transposition et un métamorphisme généralisés des roches du Paléozoïque moyen et tardif. Le gîte de Cu-Au de Lucky Joe, qui a récemment suscité l'intérêt dans la région, est associé en grande partie à l'interface complexe et fortement déformée qui sépare les successions de roches métasédimentaires clastiques et d'amphibolites.

[1] Contribution to the Ancient Pacific Margin NATMAP Project

INTRODUCTION

Geological mapping in the Stewart River area is a component of the Ancient Pacific Margin NATMAP Project (Fig. 1), initiated by the Geological Survey of Canada, Yukon Geology Program, and the British Columbia Geological Survey Branch. The NATMAP Project seeks to understand the composition, relationships, and metallogeny of poorly understood pericratonic terranes lying between the ancestral North American margin and those known with more certainty to be tectonically accreted (Thompson et al., 2000; Colpron et al., 2001). The Stewart River component focuses on the Yukon–Tanana terrane, comprising complexly deformed, mostly (?)Paleozoic meta-igneous and metasedimentary rocks. This report presents highlights of the 2002 field season. The reader is directed to Ryan and Gordey (2001a, b; 2002a, b) for more comprehensive descriptions of the geology mapped in the 2000 and 2001 field seasons.

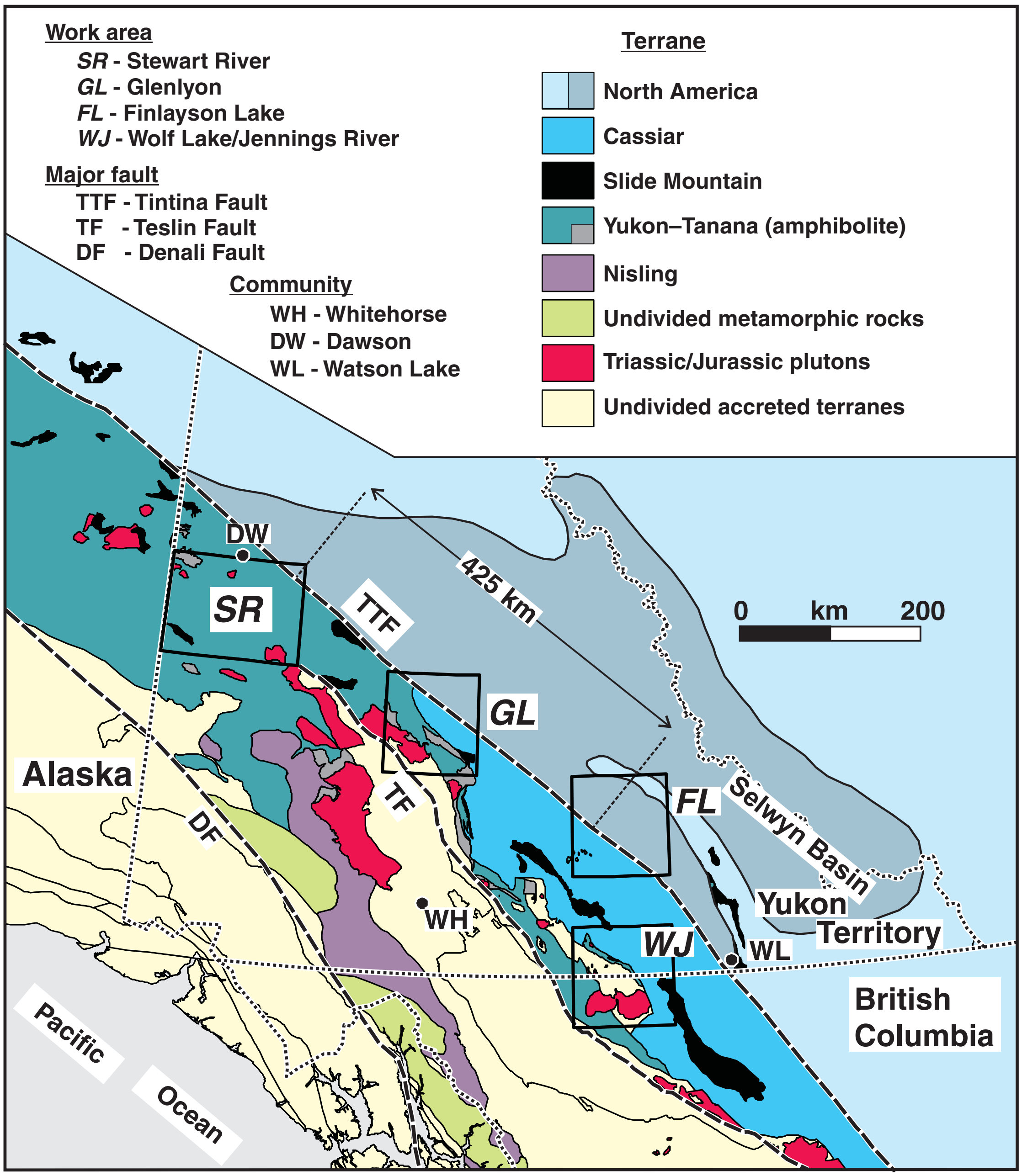

Figure 1. Location of NATMAP project areas in the Yukon Territory and northern British Columbia. Restoration of Cretaceous–Tertiary dextral offset of about 425 km (Dover, 1994) along the Tintina Fault places the Stewart River area in close proximity to the Finlayson Lake area. A project in southern British Columbia (not figured) comprises the southern component of the NATMAP project (Thompson et al., 2000, and references therein).

The objective of the Stewart River project is to investigate the stratigraphic, structural, and tectonic history and the economic framework of this large tract of Yukon–Tanana terrane by mapping about two-thirds of the area over a four-year period (Fig. 2). The geology will be interpreted in light of new geophysical data collected in this area under the Targeted Geoscience Initiative (Shives et al., 2002). Concurrent surficial geological studies are aimed at understanding the Quaternary history and setting of the numerous placer gold deposits in the region (e.g. Jackson et al., 2001, 2002; Rotheisler et al., 2003).

Access into the heart of the Stewart River area (Fig. 2) is by boat along the Yukon and Stewart rivers. Helicopter access is restricted by extensive tree cover except in local areas of high elevation. Mapping was undertaken mainly by foot traverses from boat on the Yukon and Stewart rivers, by truck in the Henderson Dome area, and from short camps mobilized by helicopter. All-terrain vehicles were used on placer mining access roads along Henderson and Maisy Mae creeks and the Sixty Mile River. Helicopter spot checks were completed in widely separated areas in the southwest part of the map area where foot traverses or fly camps were impractical.

The progress of bedrock mapping, and the area of proposed work for summer 2003, is shown in Figure 2. In 2002, 1:50 000 scale mapping was concentrated in map areas NTS 115 N/1, 2, 7, 8 and portions of NTS 115-O/2, 5, 6, 7, 9, 10, 12. Ease of access and logistical opportunity have controlled areas mapped to date and have led to an irregular distribution of ground covered. In 2003, gaps in the mapping will be filled and the mapping extended to cover about twelve 1:50 000 scale map areas. These new data and previous work in surrounding areas (e.g. Bostock, 1942; Tempelman-Kluit, 1974) will be synthesized into a new geological map of the Stewart River area.

As was the case in 2000 and 2001, bedrock mapping during 2002 was hampered by a thick (~1 m) soil veneer, thick gravel, and loess deposits in valley bottoms, and by thick cover of forest, moss, and lichen. The detailed aeromagnetic and gamma-ray surveys (Shives et al., 2002) have proved highly effective as an aid to bedrock mapping in this poorly exposed, unglaciated terrain.

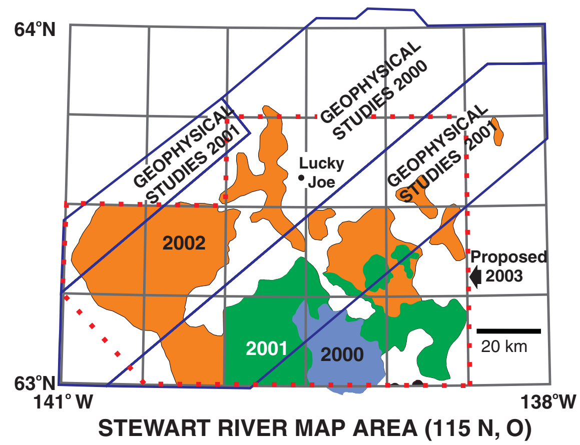

Figure 2. *Progress of bedrock mapping in the Stewart River map area. The grid outlines 1:50 000 NTS areas. Helicopter-borne detailed aeromagnetic and gamma-ray surveys were flown in 2000 and 2001. Mapping planned for 2003 would complete areas to the extent indicated by the dotted line.*

GEOLOGICAL FRAMEWORK

The Stewart River area is underlain by twice-transposed, amphibolite-facies gneiss and schist of mostly (?)Paleozoic age. These are intruded by younger plutonic rocks (Jurassic, Cretaceous, and Eocene) and overlain by upper Cretaceous volcanic rocks. Metasiliciclastic rocks are widespread and dominated by psammite and quartzite, with lesser pelite and rare conglomerate. The siliciclastic rocks were previously thought to be as old as late Proterozoic (e.g. Tempelman-Kluit, 1974); however, preliminary detrital zircon geochronology and geochronology for plutonic rocks constrain them to the middle Paleozoic (Villeneuve, work in progress, 2002). Amphibolite of intermediate to mafic composition interdigitates with, and lies stratigraphically above, the siliciclastic rocks. Although intensely tectonized, heterogeneous compositional layering and local vestiges of primary textures in the amphibolite such as breccia clasts and pillow selvages indicate derivation from volcanic and volcaniclastic rocks. Marble horizons ((?)reefs) occur within the amphibolite and the siliciclastic rocks. A complex of orthogneissic rocks with diorite, tonalite, granodiorite, and monzogranite protoliths intrudes both the siliciclastic and the amphibolitic assemblages; it is interpreted as a subvolcanic intrusive complex.

The Paleozoic rocks in the field area exhibit a regional foliation (S_T) characterized by high-strain transposition of layering in the gneiss and schist, with abundant intrafolial isoclinal folds that are commonly rootless. Strain intensity within the regional foliation locally grades to mylonite. Primary compositional layering (S_0) in metasedimentary rocks, unit contacts, and a pre-existing foliation (S_1) can be traced around closures of the transposition folds, indicating that these folds are at least F_2 structures. F_2 deformation appears to accompany the regional metamorphism; preliminary geochronological results indicate that the deformation happened during the mid-Permian (Villeneuve, work in progress, 2002). The F_2 folds are generally recumbent to shallowly inclined, close to isoclinal, long-wavelength structures. They commonly lack an axial-planar foliation, and their axes parallel a regional extension lineation (L_2). This relationship helps distinguish F_2 and F_3 folds, which can have very similar styles. The latter are open, moderately inclined (but varying from shallow to steep), shallowly plunging structures with weak axial-planar fabric where developed in schistose layers and no associated extension lineation. The map area is also affected by faults of varied significance. Most could not be observed directly, but are interpreted to exist from changes in rock type and/or structural grain; some are also well delineated by prominent physiographic and aeromagnetic lineaments. Locally, fault breccia and slickensides provide direct evidence of fault contacts.

HIGHLIGHTS OF THE 2002 MAPPING SEASON

Applications of the recent multisensor geophysical data

A strong correlation was found between rock composition and the aeromagnetic and gamma ray data acquired during the TGI project (Shives et al., 2002). The geophysical anomaly maps correlate well with the structural grain of the bedrock and help define unit contacts. Of particular note is a strong correlation between certain members of the Carmacks Group mafic lava and high-magnitude aeromagnetic anomalies. Other conspicuously high magnetic anomalies are explained by the presence of amphibolite and orthogneiss that have magnetite porphyroblasts.

Rock units that show exceptional correlation with the gamma ray data include (?)Eocene porphyritic rhyolite dykes and flows, as well as syeno- to monogranitic plutons of varied ages and states of strain.

Metasiliciclastic and amphibolitic rocks

Mapping in 2002 demonstrated that quartz-rich metasiliciclastic rocks of the Stewart River area are far more widespread than amphibolitic rocks mapped during the 2000 and 2001 field seasons. The most extensive amphibolite (possibly metavolcanic) centres around the Thistle Creek area (Ryan and Gordey, 2001a). Away from Thistle Creek, at deeper structural levels, quartz-rich siliciclastic rocks are volumetrically more significant than amphibolite. The siliciclastic rocks and amphibolite are, however, clearly interstratified and the amphibolite appears to occur structurally (and possibly stratigraphically) higher in the sequence. This probably indicates that much of the Stewart River area exposes the siliciclastic foundation upon which a metavolcanic pile was built. It has been generally suggested by previous workers (e.g. Tempelman-Kluit, 1974) that some quartzite in the Yukon–Tanana terrane is late Proterozoic. However, detrital zircons from a quartzite sample collected along the Stewart River yielded SHRIMP (Sensitive High Resolution Ion Microprobe) ages ranging from Archean to Devono-Mississippian (Villeneuve, work in progress, 2002).

Rare occurrences of quartz-rich conglomerate were mapped in the southwestern part of the map area. White quartzite represents the most abundant clast type in the conglomerate. A similar-looking occurrence of conglomerate mapped along the Yukon River in 2000 also included clasts of tonalite. A detrital zircon sample from this conglomerate yielded SHRIMP ages ranging from Archean to Devonian (Villeneuve, work in progress, 2002). Thus far, we have no reason to suspect that any Proterozoic rocks occur in the Yukon–Tanana terrane in the Stewart River area.

Marble

Although some marble horizons locally form fault slivers, partially detached from the original stratigraphic position, others are demonstrably interleaved with both quartzite and amphibolite. Local thick marble bodies near amphibolite may represent reefs fringing island-arc volcanoes. Other carbonate horizons were built during low sediment discharge in a siliciclastic setting.

Ultramafic rocks

Scattered lozenges and boudins of ultramafic rocks occur across the map area. They are composed of amphibolite-facies metagabbro, with lesser associated metapyroxenite (now actinolite) and rare serpentinite. Some bodies appear to be scattered along major high-strain zones and may represent fragments of larger bodies (e.g. possibly ophiolites). Others are more likely boudins of mafic-ultramafic intrusive sheets (dykes or sills). Determining the original setting of the ultramafic lozenges will be crucial to unravelling the tectonic evolution of the Yukon–Tanana terrane rocks; however, this task is made very difficult by the high degree of strain and metamorphism.

Orthogneiss

Mapping during the 2002 season revealed that a much higher proportion of the Stewart River area is underlain by orthogneissic rocks than was ascertained during 2000 and 2001. The orthogneiss is derived from metaplutonic rocks and in places is merely strongly foliated, rather that truly gneissic. Protolith compositions include diorite, tonalite, granodiorite, and some granite. Augen granite is discussed separately below. The gneiss varies from thin transposed sheets (dykes and sills) to larger plutonic bodies with several tens of square kilometres of map extent. The orthogneiss crosscuts the amphibolite and metasiliciclastic rocks, and locally completely obliterates the stratigraphic contacts between the two. A preliminary U-Pb zircon analysis for a tonalitic orthogneiss body from along the Stewart River yields an earliest Mississippian age (Villeneuve, work in progress, 2002), similar to the age of some detrital grains in the quartzite (*see* above). Preliminary geochemical analyses indicate that the orthogneiss has a calc-alkaline arc affinity (Piercey, work in progress, 2002).

Augen granite

Augen granite (monzogranite and syenogranite) is regionally widespread. It is characterized by augen-shaped porphyroclasts of potassic feldspar and/or quartz in a strongly foliated to gneissic groundmass of granitic composition. The augen are derived from original 5 to 50 mm diameter phenocrysts in porphyritic intrusions. Although many augen granite bodies appear similar in the field, preliminary geochronology demonstrates that at least two distinct suites occur, one latest Devonian and one middle Permian (Mortensen, 1990; Villeneuve, work in progress, 2002). These rocks are part of two separate arc-related magmatic events that are being characterized throughout the Yukon–Tanana terrane. The augen granite also constitutes some of the rocks included by Tempelman-Kluit (1974) in the Klondike schist in the west side of the map area (*see* below).

Possible Klondike schist

An extensive area of schist in the western reaches of the Stewart River area was correlated by Tempelman-Kluit (1974) with the Klondike schist of the Klondike gold fields (McConnell, 1905; Mortensen, 1990). In the type location, Klondike schist includes chlorite schist, felsic schist, quartz-feldspar augen schist, and orthogneiss, derived from both volcanic and plutonic meta-igneous rocks that have yielded middle Permian ages (Mortensen, 1990). The basis for Tempelman-Kluit's correlation is readily apparent in the western part of the area because the rocks there share similar characteristics with rocks in the type locale; however, the extent and protolith of the schist is more difficult to discern in the west than in the Klondike region. Much of the area mapped by Tempelman-Kluit (1974) appears to be derived from intensely muscovite-altered and cleaved tonalite-granodiorite and some augen granite, and not necessarily from volcanic rocks characteristic of the Klondike River area; it could be dominated by Devono-Mississippian, rather than Permian, protoliths.

Chlorite schist and lapilli tuff breccia

An anomalously low-grade and relatively low-strain assemblage occurs near the confluence of the Ladue and White rivers in map area NTS 115 N/1. Tempelman-Kluit (1974) mapped this as sheared greenstone (his unit Pv), noting that it includes chloritic greenstone, lithic tuff, and chert. High-strain zones within the unit comprise chloritic to sericitic phyllonite, probably derived from mafic to felsic volcanic and volcaniclastic rocks. Platy metamorphic minerals are barely visible with a hand lens, indicating that these rocks have not undergone the prolonged middle-amphibolite facies metamorphism that characterizes most of the Yukon–Tanana terrane rocks throughout the area. An entire hillside on the shore of the White River opposite the confluence with the Ladue River is underlain almost entirely by a unit of intermediate-composition lithic tuff, wherein lithic fragments vary in composition between rhyolite and andesite. Plagioclase and hornblende (chlorite-altered) phenocrysts are abundant and well preserved. The rocks are cleaved, but not schistose. This unit cannot be correlated with any other rocks mapped in the Stewart River area. From the dip of the regional structural grain, we interpret that this lower grade unit was fault juxtaposed possible beneath the more highly metamorphosed siliciclastic rocks after peak thermal metamorphism (after the middle Permian).

(?)Eocene porphyritic rhyolite

Quartz- and/or potassic feldspar-phyric rhyolite intrusions occur across much of the map area and are most abundant in the western portion. They are commonly exposed in small, blocky felsenmeer rather than in intact bedrock. Quartz phenocrysts vary from 1 to 12 mm in diameter and from clear to smoky grey and smoky blue-grey. Most occurrences appear to be dykes, ranging in thickness from 2 m to more than 100 m and trending broadly north-south. Other occurrences have very low aspect ratios and may represent plugs or stocks. Some bodies exhibit miarolitic cavities, indicative of emplacement at shallow crustal depth. Volcanic tuff associated with dykes has been observed in one locality in the southwestern part of the area.

The rhyolite porphyry dykes in the Stewart River area strongly resemble a widespread, north-trending, feldspar-porphyry dyke swarm mapped by Tempelman-Kluit (1974) in the Stevenson Ridge, Kluane Lake, and Aishihik Lake areas to the south. There, Tempelman-Kluit (1974) noted that the dykes are truncated and overlain by the Carmacks Group, which he interpreted as Eocene or younger. The Carmacks Group is now known to be late Cretaceous (e.g. Lowey et al., 1986). In the Stewart River area, at least one locality shows the porphyry dykes to crosscut basalt at the base of the Carmacks Group, indicating that the dykes are younger. The dykes resemble a felsic porphyry mapped in the northernmost part of the Stewart River map area that has been described as early Tertiary by Mortensen (1996). We interpret the porphyry bodies in the southern Stewart River area to be early Tertiary as well. It is also possible that the dykes described farther south are an older suite or that the overlying volcanic rocks there were misidentified by Tempelman-Kluit (1974) as Carmacks Group.

Carmacks Group

Carmacks Group volcanic rocks show significant compositional variation across the Stewart River area. In the Henderson Dome area, for example, they include brown to black basalt and basaltic andesite, grey dacite and rhyodacite, brick-red trachyandesite, and rare beige- to white-weathering rhyolite. Some layers are tuffaceous and locally brecciated. The thickness of individual volcanic horizons is difficult to ascertain, but apparently varies from a few metres to hundreds of metres.

The sub-Carmacks unconformity appears to have moderate relief, as is evidenced by its slightly irregular trace across the present topography. Broadly, the base of the Carmacks Group has an elevation similar to that of the Eocene and present erosional surfaces, possibly indicating that the Yukon Plateau is largely a Late Cretaceous (or older) feature that was maintained through the Eocene and to modern times.

Lucky Joe mineral prospect

The Lucky Joe copper-gold mineral prospect, near Lucky Joe Creek, generated significant exploration interest in 2002. The prospect was targeted by a local prospector on the basis of coincidence between magnetic anomalies in the new aeromagnetic coverage (Shives et al., 2002) and the existing regional geochemical data. The property was originally explored and drilled in the 1970s by Silver Standard and Rio Tinto Canadian Exploration Limited. Copper Ridge Explorations Inc. has optioned 100 per cent interest in the property and is currently undertaking an aggressive soil-geochemistry survey. The Lucky Joe prospect has an apparent stratabound association between magnetite-bearing amphibolite and chalcopyrite-bearing metasiliciclastic schist. It appears to have very large areal extent and is a flat-lying, near-surface target (Copper Ridge Explorations Inc., available at http://www.copper-ridge.com/copgold-fr.html, accessed November 2002). Some malachite staining and chalcopyrite mineralization were observed in orthogneissic intrusive sheets within the schist and amphibolite, indicating that some mineralization must be synchronous with or postdate the intrusions. An overarching model has not yet been developed for the occurrence. Geological mapping around the prospect is planned for 2003 (Fig. 2), to place it in a regional stratigraphic, magmatic, metallogenic, and structural context.

DISCUSSION

Lithologically, the metavolcanic and metaplutonic rocks studied during 2002 represent a typical arc sequence, a setting consistent with preliminary geochemical analyses. In particular, amphibolitic rocks have island-arc tholeiite geochemical signatures, and metaplutonic rocks have calc-alkaline affinities (Piercey, work in progress, 2002). Preliminary U-Pb zircon geochronology of the orthogneissic rocks indicates that they are part of a regionally widespread Devono-Mississippian magmatic event and likely represent the arc infrastructure to the coeval metalliferous back-arc basin within the Yukon–Tanana terrane rocks in the Finlayson Lake region (Murphy, 1998; Piercey, 2001). If the 425 km of dextral offset along the Tintina Fault is restored (Fig. 1), the Finlayson Lake region lies immediately northeast of the Stewart River area. The Lucky Joe copper-gold mineral prospect is dissimilar to the volcanic-hosted massive sulphide deposits of the Finlayson Lake district and may represent a new and exciting mineral target in the Yukon–Tanana terrane.

Plutons of mid-Permian age may belong to another arc succession built upon this mid-Paleozoic substrate. Like the Devono-Mississippian rocks, the mineral potential of the Permian rocks remains largely untested.

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