BC Geological Survey

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Geology of the Tulameen Alaskan-type ultramafic-mafic intrusion, British Columbia

parts of NTS 92H/07 and 10

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Geology of the Tulameen intrusion modified from Findlay (1963)

0 0.5 1

kilometres

Scale 1:20 000

LAYERED ROCKS

MIOCENE

Mb — Olivine basalt flows, massive to columnar-jointed (equivalent to Chilcotin Group)

unconformity

EOCENE

Princeton Group

EPa — Allenby Formation: sandstone with minor siltstone, conglomerate, grey shale, carbonaceous shale and coal; minor vitric crystal tuff

EPc — Cedar Formation: aphyric to porphyritic, mafic to felsic volcanic and volcaniclastic rocks, mostly subaerial, with minor siliciclastic sedimentary strata

unconformity

UPPER TRIASSIC

uTrN — Nicola Group undivided: pyroxene±plagioclase-phyric volcanic and volcaniclastic rocks with interbedded volcanic wacke, siltstone, mudstone and limestone/marble; uTrN', schistose rocks with actinolite, chlorite, epidote and minor garnet (upper greenschist to lower amphibolite facies)

INTRUSIVE ROCKS

EOCENE

Egd — Britton stock: granodiorite

MIDDLE TO LATE CRETACEOUS

KgO — Otter Lake pluton: granite to granodiorite

MIDDLE TO LATE JURASSIC

Eagle Plutonic complex

JEt — Eagle tonalite: tonalite to granodiorite

LATE TRIASSIC TO JURASSIC

TrJgd — Boulder stock: granodiorite

TrJgb — Boulder stock: gabbro

LATE TRIASSIC(?)

Trgb — Gabbro (Lawless and Arrastra creeks area)

Trhb — Hornblendite (peripheral to Tulameen ultramafic-mafic intrusion)

Trhpx — Hornblende clinopyroxenite (Lawless Creek area and peripheral to Tulameen ultramafic-mafic intrusion)

LATE TRIASSIC

TULAMEEN ULTRAMAFIC-MAFIC INTRUSION

sd — Medium to pale grey, medium-grained clinopyroxene-biotite-hornblende syenodiorite, variably saussuritized

gb — Dark to medium grey-green, medium grained syenogabbro-gabbro, biotite-bearing; locally strong igneous mineral lamination and modal layering; commonly saussuritized

hb — Black to dark greenish grey, coarse-grained to pegmatitic hornblendite; magnetite and biotite bearing; locally feldspathic

hpx — Black to dark greenish grey, coarse-grained hornblende clinopyroxenite with minor hornblendite, clinopyroxenite and magnetitite; locally biotite rich and rarely feldspathic

hopx — Dark greenish grey, medium- to coarse-grained, olivine-hornblende clinopyroxenite and minor clinopyroxenite

opx — Dark grey-green, medium-grained to pegmatitic olivine clinopyroxenite and olivine-bearing clinopyroxenite; locally contains remobilized and intermixed blocks of plastically deformed dunite

wepx — Dark greenish grey, medium-grained wehrlite, olivine clinopyroxenite and clinopyroxenite

we — Dark greenish grey medium-grained wehrlite

dupx — Dark greenish grey medium-grained dunite, wehrlite and clinopyroxenite

du — Dark grey to greenish grey, medium-grained dunite with minor wehrlite and chromititite schlieren; variably serpentinized,

MAP SYMBOLS

- Geological contact, defined or approximate
- Geological contact, inferred
- Unconformity, defined or approximate
- Unconformity, inferred
- Steeply dipping fault, defined or approximate
- Steeply dipping fault, inferred

Structure

- Bedding, tops known, inclined
- Bedding, tops unknown, inclined, vertical
- Foliation, inclined, vertical
- Igneous mineral lamination/modal layering, inclined, vertical
- Trend of igneous mineral lamination/modal layering
- Minor fold showing plunge and axial-plane dip
- Minor fold showing plunge
- Modal layering, inclined, vertical
- Chromitite schlieren, inclined, vertical
- Minor fold of chromitite schlieren showing axial-plane dip

Mineralization

- Chromitite locality in cunite
- Cr-Pt (MINFILE)
- Alkalic porphyry Cu±Au±Ag±Pt±Pd (MINFILE)
- Cu±Pt±Pd±Ag±Au (MINFILE)
- Cu-Pd-Pt±Ag±Au (Champion Zone)
- Magnetitite (MINFILE)

Topography

- Lake
- Flooded land (swamp)
- Stream or river
- Contour (100m)
- Spot height (m)
- Road (dirt)
- Gravel bar
- Building

Approximate mean magnetic declination August 2017 for centre of map area: 15 degrees 56 minutes east, decreasing annually 9.1 minutes per year

N — 1° 36' — Grid North — Magnetic North — Magnetic Declination

Base Map Information

Base map produced from digital TRIM (Terrain Resource Inventory Management) 1:20 000-scale topographic database, British Columbia Ministry of Natural Resource Operations.

North American Datum 1983 (NAD83). Universal Transverse Mercator Projection (Zone 9). Elevation in metres above mean sea level. Contour interval 100m.

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Tulameen Alaskan-type Intrusion

The Tulameen Alaskan-type ultramafic-mafic intrusion (Late Triassic; 62 km^2) lies ~20 km due east of Princeton in southern British Columbia near the western margin of the accreted arc terrane of Quesnellia. The intrusion belongs to a global class of ultramafic-mafic intrusions emplaced in convergent margin or supra-subduction zone tectonic settings that are gaining prominence as an exploration target for magmatic Ni-Cu-platinum group element (PGE) mineralization (Nixon et al., 2015). For example, the Turnagain Alaskan-type intrusion in northern British Columbia is unusually enriched in Ni(-Co-Cu-PGE) sulphides and contains a low-grade Ni-sulphide resource that ranks ninth among the world's largest deposits in terms of contained Ni metal (1842 Mt @ 0.21 wt % Ni and 0.013 wt % Co; Mudd and Jowitt, 2014; Nixon et al., 2017). The Giant Mascot ultramafic-mafic intrusion in southern British Columbia is the only significant past-producer of nickel in the province (1958-74; 4.2 Mt sulphide ore @ 0.77 wt % Ni and 0.34 wt % Cu with minor Co, Ag and Au and unreported PGE; Manor et al., 2015, 2016). The ultramafic-mafic intrusions that host these mineral deposits form two distinct mineralogical subtypes: Giant Mascot carries abundant orthopyroxene, which is typically lacking in Alaskan-type intrusions sensu stricto (Nixon et al., 2015).

The Tulameen ultramafic-mafic intrusion is a classic Alaskan-type body zoned from a dunite core (with minor chromitite) through olivine clinopyroxenite to hornblende clinopyroxenite (with minor hornblendite and magnetitite) at the margin. The geology of the intrusion is modified slightly from the original work of Findlay (1963) and subsequent mapping (Nixon et al., 1997). The principal modifications include inferred northeasterly trending faults cross-cutting the intrusion along major topographic lineaments; northwesterly trending faults oriented subparallel to lithological contacts in an area of complex geology at the southern end on the intrusion; and a reinterpretation of contacts with Late Triassic host rocks of the Nicola Group as ductile faults (mylonitic shear zones; Nixon and Rublee, 1988; Rublee, 1994). Geology outside the Tulameen intrusion has been compiled from regional mapping by Massey et al. (2010), work in the Lawless Creek area by Eastwood (1960), and a study of the Eagle tonalite-granodiorite pluton at the western margin of the map area by Greig (1989). Despite faulted contacts, rafts of hornfelsed Nicola rocks within the Tulameen complex confirm its intrusive nature. Minor satellite bodies of hornblende clinopyroxenite and hornblendite intrude Nicola rocks peripheral to the Tulameen complex.

Ongoing high-precision CA-ID-TIMS U-Pb geochronology of zircon in ultramafic and mafic rocks of the Tulameen intrusion has yielded preliminary dates of ca. 204-206 Ma (latest Triassic). The dates are consistent with emplacement of the ultramafic-mafic rocks contemporaneous with Late Triassic volcanism in the Nicola Group. The metasedimentary and metavolcanic rocks of the Nicola Group that envelop the Tulameen intrusion form a westward-dipping homoclinal succession. The main period of deformation (folding, ductile faulting) and regional metamorphism (upper greenschist to lower amphibolite facies) of the Nicola Group post-dated emplacement of the Tulameen intrusion. The timing of this deformation and metamorphism is considered to be broadly synchronous with emplacement of the Middle Jurassic to mid-Cretaceous Eagle Plutonic suite (Greig, 1992). Nicola rocks near the contact with the Eagle pluton are notably schistose and share the same penetrative fabric as the pluton. North of the Tulameen intrusion, schistosity in the Nicola Group passes into a well-defined cleavage a couple of kilometres east of the Eagle contact; however, lower amphibolite facies metamorphism persists for at least 3 kilometres from the contact in the Lawless Creek area. Penetrative fabrics are typically absent within the Tulameen rocks except for localized thin mylonitic shear zones and a pervasive foliation in gabbroic rocks at the southern end of the complex. Petrographic studies reveal the presence of metamorphic assemblages (actinolite/actinolitic hornblende, epidote and chlorite) in ultramafic rocks near the margin of the intrusion.

The mineralogy and textures of the Tulameen rocks are well preserved although feldspathic lithologies (gabbro-syenogabbro-syenodiorite) are commonly saussuritized. Cumulate textures predominate in the ultramafic rocks and modal layering is rare. Gabbroic rocks commonly display an igneous lamination and/or preferred orientation of ferromagnesian minerals (hornblende/clinopyroxene) and modal layering is relatively common though localized. Sparse chromitite schlieren in the dunite core are typically less than 20 cm long and 3 cm wide. Their attitude varies radically over short distances and some chromitites are folded or contorted into irregular shapes. Serpentinization of the dunite is highly variable and local occurrences of dunite breccia cemented by serpentine minerals appear related to late brittle faults.

Pt-Fe alloy mineralization associated with chromitite schlieren in the dunite core and derivative placers is well documented (e.g., Nixon et al., 1990). Outside the dunite core, occurrences of Cu mineralization are widespread and preferentially hosted by hornblende clinopyroxenite and feldspathic rocks. A 700 metre-long zone of intermittent copper sulphide mineralization, the Champion Zone, hosted in magnetite-bearing biotite-hornblende clinopyroxenite and hornblendite was examined in detail near the western margin of the intrusion (Nixon et al., 2018). The principal sulphides are chalcopyrite and lesser bornite accompanied by minor pyrite and rare pyrrhotite. The sulphides occur in various textural settings: as inclusions in primary silicate and oxide minerals; interstitially in unaltered rocks; as interstitial recrystallized sulphides intergrown with actinolite/epidote; and as pyritic replacements of interstitial Cu-Fe sulphides in areas affected by hydrothermal fluids. Precious metal minerals include sperrylite ($PtAs_2$), mertieite [$Pd_8(Sb,As)_2$] and a silver mineral. The occurrence of Cu-Fe sulphides enclosed by primary igneous minerals and interstitially in the least altered rocks indicates an orthomagmatic origin for the mineralization. Despite the low modal abundance (typically <1%) of sulphides in the rock, grab samples from the Champion Zone contain up to 0.5 wt % Cu, 1.9 g/t Pt+Pd (Pd/Pt~1.5) and 0.4 g/t Au. This style of mineralization is known from layered intrusions in extensional tectonic environments (e.g., Platinova Reef, Skaergaard intrusion, Greenland; Holwell and Keays, 2014) but apparently has not been documented in Alaskan-type complexes. Future research is focusec on developing a new mineral deposit model for orthomagmatic Cu-PGE sulphides in ultramafic-mafic intrusions in convergent margin settings.

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