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POTENTIAL HOSTS TO PLATINUM GROUP ELEMENT CONCENTRATIONS IN THE CANADIAN CORDILLERA

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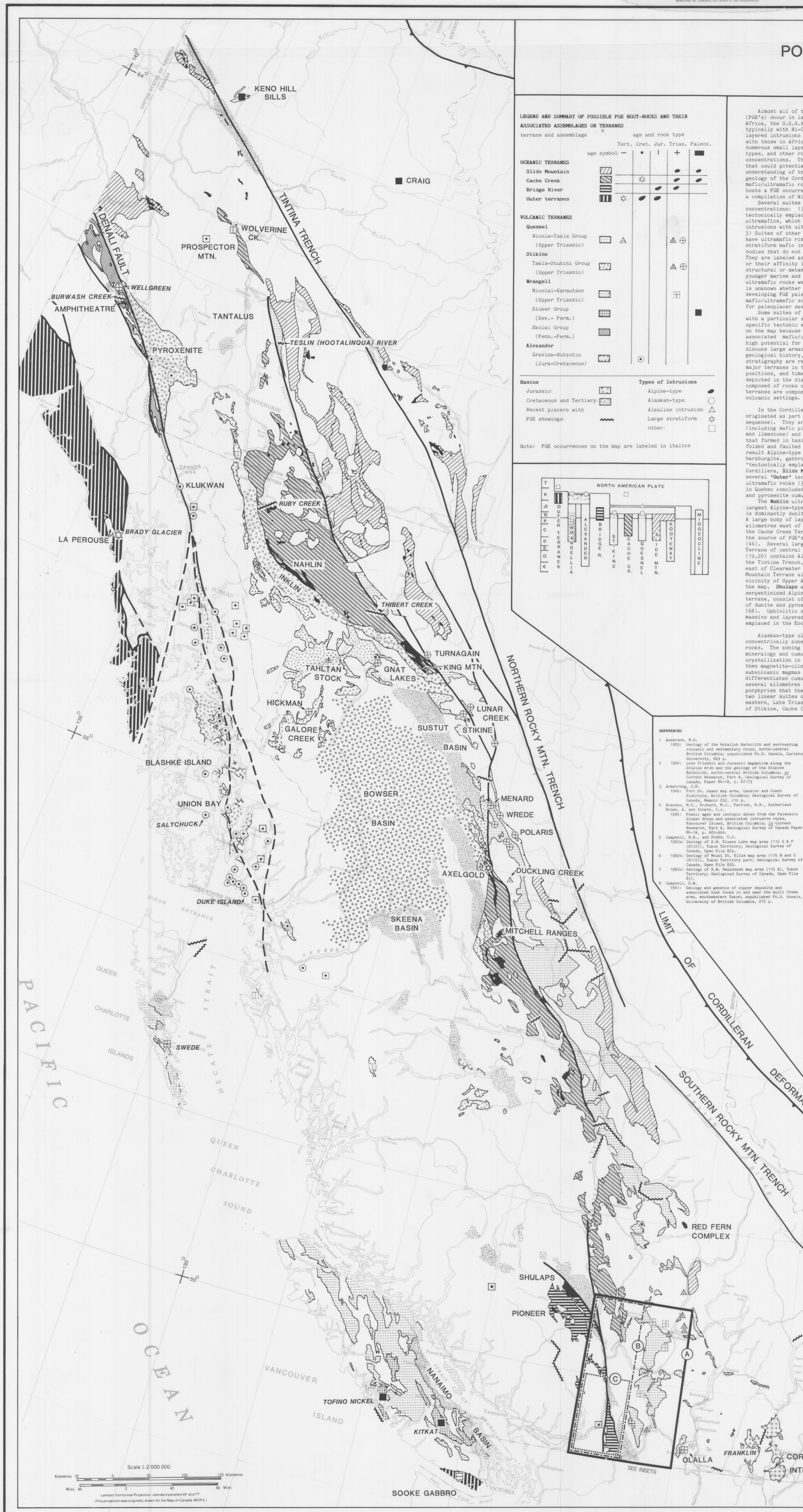

LEGEND AND SUMMARY OF POSSIBLE PGE HOST-ROCKS AND THEIR ASSOCIATED ASSEMBLAGES OR TERRANES

Terrane and assemblage — age and rock type (Tert. Cret. Jur. Trias. Paleoz.)

OCEANIC TERRANES: Slide Mountain; Cache Creek; Bridge River; Outer terranes

VOLCANIC TERRANES
- Quesnel: Nicola-Takla Group (Upper Triassic)
- Stikine: Takla-Stuhini Group (Upper Triassic)
- Wrangell: Nicolai-Karmutsen (Upper Triassic); Sicker Group (Dev.-Perm.); Skolai Group (Penn.-Perm.)
- Alexander: Gravina-Nutzotin (Jura-Cretaceous)

Basins: Jurassic; Cretaceous and Tertiary; Recent placers with PGE showings

Types of intrusion: Alpine-type; Alaskan-type; Alkaline intrusion; Large stratiform; other

Note: PGE occurrences on the map are labeled in italics

INTRODUCTION

Almost all of the worlds reserves of platinum-group elements (PGE's) occur in layered mafic and ultramafic complexes in Africa, the U.S.S.R., and the U.S.A., where PGE's are associated typically with Ni-Cu sulphides, and/or chromite. There are no layered intrusions in the Canadian Cordillera comparable in size with those in Africa, the U.S.S.R., or the U.S.A, but there are numerous small layered mafic/ultramafic bodies of different types, and other rocks that could potentially contain PGE concentrations. This open file is a compilation of all rocks that could potentially host PGE minerals, given the present understanding of the environments of PGE mineralization and the geology of the Cordillera. At least one member of each group of mafic/ultramafic rocks displayed on the map (or nearby placers) hosts a PGE occurrence. The reader is referred to (44, 52) for a compilation of Ni, chromite, and PGE occurrences.

Several suites of rocks in the Cordillera could host PGE concentrations: 1) Alpine-type ultramafics, which are probably tectonically emplaced slivers of ocean floor. 2) Alaskan-type ultramafics, which are relatively small zoned alkaline intrusions with ultramafic cores and mafic to ultramafic rims. 3) Suites of other types of alkaline intrusions, two of which have ultramafic rims or phases with associated PGE's. 4) Large stratiform mafic intrusions. 5) Layered mafic or ultramafic bodies that do not fit into the general groups listed above. They are labeled as 'other', and are either unique occurrences, or their affinity is unknown as a result of complicated structural or metamorphic relationships. 6) Jurassic and younger marine and nonmarine basins in which mafic and ultramafic rocks were a major source of detritus. Although it is unknown whether the physiochemical conditions necessary for developing PGE paleoplacers prevailed, there is evidence for a mafic/ultramafic source in each of the basins, and the potential for paleoplacer development is recognized.

Some suites of mafic/ultramafic complexes are associated with a particular stratigraphic assemblage as a result of their specific tectonic environment (64). The assemblages are shown on the map because they are more widespread than their associated mafic/ultramafic complexes and delineate regions of high potential for undiscovered complexes. In order to easily discuss large areas of the Cordillera that have a common geological history, fault-bounded blocks with unique stratigraphy are referred to as terranes. The names of the major terranes in the Cordillera, their spans of age, relative positions, and time of amalgamation to form bigger terranes are depicted in the diagram to the left. Oceanic terranes are composed of rocks characteristic of ocean basins, and volcanic terranes are composed in part of rocks formed in a variety of volcanic settings.

ALPINE-TYPE ULTRAMAFICS

In the Cordillera, Alpine-type ultramafics appear to have originated as part of newly formed ocean floor (ophiolitic sequence). They are associated with other oceanic lithologies (including mafic pillowed volcanics, ribbon chert, argillite, and limestone) and occur in oceanic terranes. Oceanic rocks that formed in basins between other terranes were intensely folded and faulted during amalgamation of the terranes, and as a result Alpine-type ultramafics (dunite, pyroxenite, peridotite, harzburgite, gabbro, serpentinite) are referred to as 'tectonically emplaced'. The oceanic terranes in the Cordillera, **Slide Mountain, Cache Creek, Bridge River** and several **'Outer'** terranes, all contain numerous bodies of ultramafic rocks (32). A study of the Thetford Mines ophiolites in Quebec concluded that PGE's are concentrated in the dunite and pyroxenite cumulates (45).

The **Nahlin** ultramafic body in the Cache Creek Terrane is the largest Alpine-type ultramafic in the Canadian Cordillera. It is dominantly dunitic peridotite, but cumulates are rare (62). A large body of layered gabbro occurs at **King Mountain**, 68 kilometres east of Dease Lake (14,30). The ultramafic rocks of the Cache Creek Terrane (14,15,33) in northern B.C. are probably the source of PGE's in the placers in **Ruby** and **Thibert** creeks (44). Several large ultramafic bodies occur in the Cache Creek Terrane of central B.C. (53,65,66). Slide Mountain Terrane (19,20) contains Alpine-type ultramafic rocks east and west of the Tintina Trench, and as far south as the **Red Fern Complex** east of Clearwater Lake (38). Small ultramafic bodies in Slide Mountain Terrane also occur west of Kootenay Lake and in the vicinity of Upper Arrow Lake, but they are too small to show on the map. **Shulaps** and **Pioneer**, two large, intensely serpentinized Alpine-type ultramafic bodies in the Bridge River terrane, consist of harzburgite that encloses conformable layers of dunite and pyroxenite, with chromite as a common accessory (68). Ophiolitic sequences on southern Vancouver Island contain massive and layered gabbro, for example **Sooke Gabbro** that was emplaced in the Eocene.

ALASKAN-TYPE ULTRAMAFICS

Alaskan-type ultramafics (23-26,60) are generally concentrically zoned alkalic intrusions of mafic and ultramafic rocks. The zoning is not always well defined, but the mineralogy and cumulates are distinctive, with fractional crystallization in the order dunite, olivine-clinopyroxenite, then magnetite-clinopyroxenite. The complexes represent subvolcanic magmas in which mafic minerals precipitated to form differentiated cumulates. They are relatively small intrusions, several kilometres or less in diameter, coeval with the augite porphyries that they intrude. In the Cordillera, they occur in two linear suites of distinct age and tectonic position. The eastern, Late Triassic suite formed just prior to amalgamation of Stikine, Cache Creek, Quesnel, and Slide Mountain terranes.

The western, mid-Cretaceous suite was emplaced at the time of amalgamation of Wrangell and Alexander terranes and their subsequent accretion to the North American continental margin.

The eastern suite (24-26,50,51) is intimately associated with Upper Triassic porphyritic augite basalts of the Takla Group in northern B.C. and the Nicola Group in the southern B.C. (34-36,40,47,48). Most of the members of the suite occur as a cluster in northern B.C. (eg. **Polaris, Wrede, Menard**); whereas **Turnagain, Lunar** and an unnamed body were probably offset from the cluster by dextral strike slip faults (16). Geochemical studies of **Tulameen Complex** (13), the one member of the suite in southern B.C., indicate that PGE's are concentrated where chromite occurs in the layered dunitic core of the complex (55). **Polaris, Wrede, and Turnagain** are the only complexes in the north with a large proportion of dunite. The **Turnagain** ultramafic complex (9,10) contains occurrences of Ni-Cu sulphides. PGE-bearing placers are associated with Takla and Nicola volcanics, and the Tulameen Complex (44,52).

The Upper Triassic ultramafic bodies in Stikine Terrane are associated with large granitoid plutons and Upper Triassic porphyritic augite basalt of the Stuhini Group (1,2,15,54,56). The **Gnat Lakes** ultramafite is part of the Hotailuh Batholith, and ultramafic phases occur in the **Hickman** and **Stikine** plutons. The three ultramafic bodies have mineralogy similar to that of Alaskan-type complexes, but lack the olivine phases.

The western, mid-Cretaceous suite of Alaskan-type ultramafics (23,60) is both coeval with and intrudes Early to mid- Cretaceous porphyritic augite basalt of the Gravina-Nutzotin Assemblage. The suite extends from the **Pyroxenite Creek** intrusion near Haines Junction, Yukon Territory, to southeast of Prince Rupert (22). The **Pyroxenite Creek** intrusion (28,57,58) displays crudely concentric zones of olivine pyroxenite, magnetite pyroxenite, and hornblende pyroxenite. A small body to the east may also be an Alaskan-type intrusion but is poorly exposed and has not been studied in detail. Most of the members of the western suite occur in southeast Alaska, and many are less than a few square kilometres in area. The greatest concentration of ultramafics is around **Duke Island** (23), and the largest single complex is near **Union Bay**. These complexes (60), and one at **Blashke Islands**, are among several complexes that have a dunitic core surrounded by most of the successive outer zones of peridotite, olivine pyroxenite, magnetite pyroxenite, and hornblende pyroxenite. **Klukwan** is a large intrusion of hornblende pyroxenite. Magnetite is common in the pyroxenites, ilmenite is an accessory throughout, and chromite occurs in the dunitic cores. The ultramafic rocks intrude early-formed gabbro, and have contact metamorphic aureoles up to 300 m wide.

OTHER ALKALINE INTRUSIONS

Two alkaline intrusions, Coryell and Copper Mountain in southern B.C., contain PGE occurrences. The **Coryell Intrusions** are dominantly Tertiary syenite with pyroxenite phases. The PGE showings of the Franklin Camp are confined to the pyroxenite phases (52). A Cretaceous syenitic lacolith similar to Coryell occurs at **Prospector Mountain**, in Yukon Territory.

Copper Mountain pluton, which has PGE's concentrated in pegmatites (44), is one member of a suite of Upper Triassic to Lower Jurassic alkalic intrusions called the Copper Mountain Suite (67). **Copper Mountain** (37, 46) and **Iron Mask** (43) are two of several members of the suite in southern B.C., and the diagram below (inset A) of the Hope-Ashcroft area shows their tectonostratigraphic relationships to surrounding rocks. In north-central B.C., the **Duckling Creek Syenite Complex** (3,18), a part of Hogem Batholith, has ultramafic phases that resemble cumulates. Members of the Copper Mountain Suite in northern B.C. are spatially associated with the Upper Triassic Stuhini Group, and include the **Tahltan** and **Galore Creek** stocks. The **Tahltan stock** (15,39), also known as 10-Mile Creek stock, consists of syenite with a pyroxenite (diopsidic augite) rim. Calcite veins in the stock contain minor amounts of galena, pyrite, and chalcopyrite. **Galore Creek** is mainly syenite and monzonite with nepheline and pseudoleucite (67).

LARGE STRATIFORM INTRUSIONS

Axelgold is the only large intrusion in the Canadian Cordillera that may be vaguely similar to large stratiform intrusions that host the majority of the worlds reserves of PGE's. **Axelgold** layered gabbro (24-26,50,67) is a 12 km-long elliptical intrusion that was emplaced into the Cache Creek Terrane in the Early Cretaceous. It consists of layers of olivine gabbro cumulates (plagioclase, augite, and olivine) with minor layers of picrite, peridotite, and anorthosite. Cumulates are at least 1500 m thick, but the original thickness is unknown because the base is not exposed and the top has been eroded. The bowl-like layering is discordant to the vertical contacts with country rocks. Sulphides are weakly disseminated throughout the intrusion, and slightly enriched in the middle of the 1000 m-thick contact aureole. Chromite is concentrated in the peridotite layers, and ilmenite occurs as two massive segregations.

A group of large layered Oligocene intrusions in Alaska is called the **La Perouse** suite. The **La Perouse** layered gabbro (21), the largest of the four members of the suite, is about 6000 m thick, and has the same shape, structure, lithologies, and style of layering as **Axelgold** (25). At its southeast corner, basal ultramafic cumulates host the Brady Glacier Ni-Cu deposit which has high concentrations of PGE's (21). If similar relationships exist at **Axelgold**, then ultramafic cumulates and PGE's could be expected to occur at the (unexposed) base of the **Axelgold** intrusion.

OTHER

Several unrelated occurrences of mafic/ultramafic rocks have potential for PGE concentration. Near the **Craig** property, Yukon Territory, serpentinized ultramafics are associated with Ordovician and Silurian slates in a fault zone. The ultramafics are interpreted to have formed in an extensional strike-slip fault zone. Zoned mafic sills northeast of the Tintina Trench are up to 200 m thick (61). They intrude the **Keno Hill** quartzite and are thought to be mid-Mississippian. Several layered intrusions (dominantly diorite) of unknown affinity occur in the Coast Mountains (67). At the southern end of the Coast Plutonic Complex, the **Giant Mascot** mine is in a roughly zoned dioritic part of the Spuzzum Pluton associated with ultramafic phases (31,63,67). An interpretation of its relationships to other rocks in the region is shown below in the diagrams of the Hope-Ashcroft area (inset C). An alkaline complex at **Olalla** with precious metal occurrences intrudes the Nicola volcanics and is interpreted to be part of the Triassic root of the Nicola volcanic arc.

Several occurrences of PGE's are known in rocks of Wrangell Terrane (27), either in Upper Triassic basalt, or in rocks underlying the basalt. At the **Kitkat** Property, PGE's are associated with lenses of Ni-Cu sulphides in basalt of the Sicker Group (52), a Devonian to Permian complex of volcanics and subvolcanic intrusions (4,41,42). The **Tofino Nickel** property, hosted by rocks of the Sicker Group, contains PGE's (52). **Wellgreen** is a zoned peridotite, dunite and olivine gabbro body in southwest Yukon Territory with Ni-Cu sulphides and PGE showings (8). It is a sill or dyke, and is one of many mafic/ultramafic bodies (including Canalask) that intrudes the Pennsylvanian to Permian **Skolai** Group (5-7,50). Late Triassic K-Ar dates on phlogopite, if representative of the time of emplacement, indicate that **Wellgreen** could be genetically related to the Upper Triassic **Nicolai** greenstone, a tholeiitic rift-type basalt. The association may be significant because Triassic tholeiitic rift basalts in the U.S.S.R. have PGE concentrations. The Upper Triassic **Karmutsen** tholeiitic basalt on Vancouver Island is correlative with the **Nicolai** greenstone, and overlies the **Sicker** Group (41,42). At the **Swede** Property on Queen Charlotte Isand, PGE's are concentrated in diabase dykes in the **Karmutsen** (52).

JURASSIC AND YOUNGER BASINS

The oldest sediments known to be derived from a Cordilleran mafic/ultramafic source are shale, greywacke, and conglomerate of the lower Jurassic **Inklin** Assemblage (14,15). The **Inklin** is interpreted to be derived from Quesnel Terrane following uplift associated with amalgamation of Stikine, Cache Creek, and Quesnel terranes. The Cache Creek Terrane, thrust southerly onto the Inklin Assemblage in the Middle Jurassic, was the major source of siltstone and chert-pebble conglomerate in the northern part of the **Bowser Basin** (12,17). Sediments in the **Bowser Basin** were deposited in environments ranging from deep marine to deltaic to alluvial fan. A small area north of the Sustut Basin represents the most proximal part of the **Bowser Basin** (14). In the mid-Cretaceous (Albian) the lower part of the nonmarine **Sustut Group** was derived from uplifted metamorphic rocks of the Omineca Belt (11). The metamorphic detritus was carried by rivers that flowed westerly over rocks of the Quesnel Terrane and probably over Alaskan-type ultramafics. The **Bowser Basin** was deformed into northeasterly-verging folds and thrust faults in the Late Cretaceous (11,12), and became a source of detritus for the upper part of the **Sustut Group.** If any PGE's accumulated in the **Bowser Basin** in the Jurassic, they may have been reconcentrated in the **Sustut Basin** in the Late Cretaceous. Paleocurrents from the Late Cretaceous sediments indicate that rivers flowed easterly and westerly into the **Sustut Basin**, and longitudinally down the basin to the southeast (11). South of the Bowser Basin, the Skeena Group has lithologies similar to those of the Sustut Group, but its base is older (Hauterivian).

The Amphitheatre Formation was deposited by rivers flowing southwesterly over a pediment of Gravina-Nutzotin Assemblage, Skolai Group, and Nicolai Group (5-7) in the Oligocene. In southern B.C., between Bridge River and Quesnel terranes, a formerly continuous basin (29) was offset by the Fraser Fault. The basin had an eastern source of Cache Creek and Nicola volcanics from Late Jurassic to mid-Cretaceous, when the Relay Mtn. and Jackass Mtn. groups were deposited. In mid to Late Cretaceous time, chert pebbles in the overlying Pasayten Group and Virginian Ridge Formation were derived from the west (the Bridge River Terrane). In the Queen Charlotte Islands (59), Lower Jurassic to Upper Cretaceous clastic sediments were derived from uplifted regions to the east. The Nanaimo Group on Vancouver Island consists of Late Cretaceous coarse and fine marine clastics with a western and southwestern source. Sediments in fault-controlled Late Cretaceous to Tertiary nonmarine basins that had a mafic/ultramafic source include those in the Tintina Trench, the Tantalus Formation, and Eocene sediments in the Princeton area.

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REFERENCES

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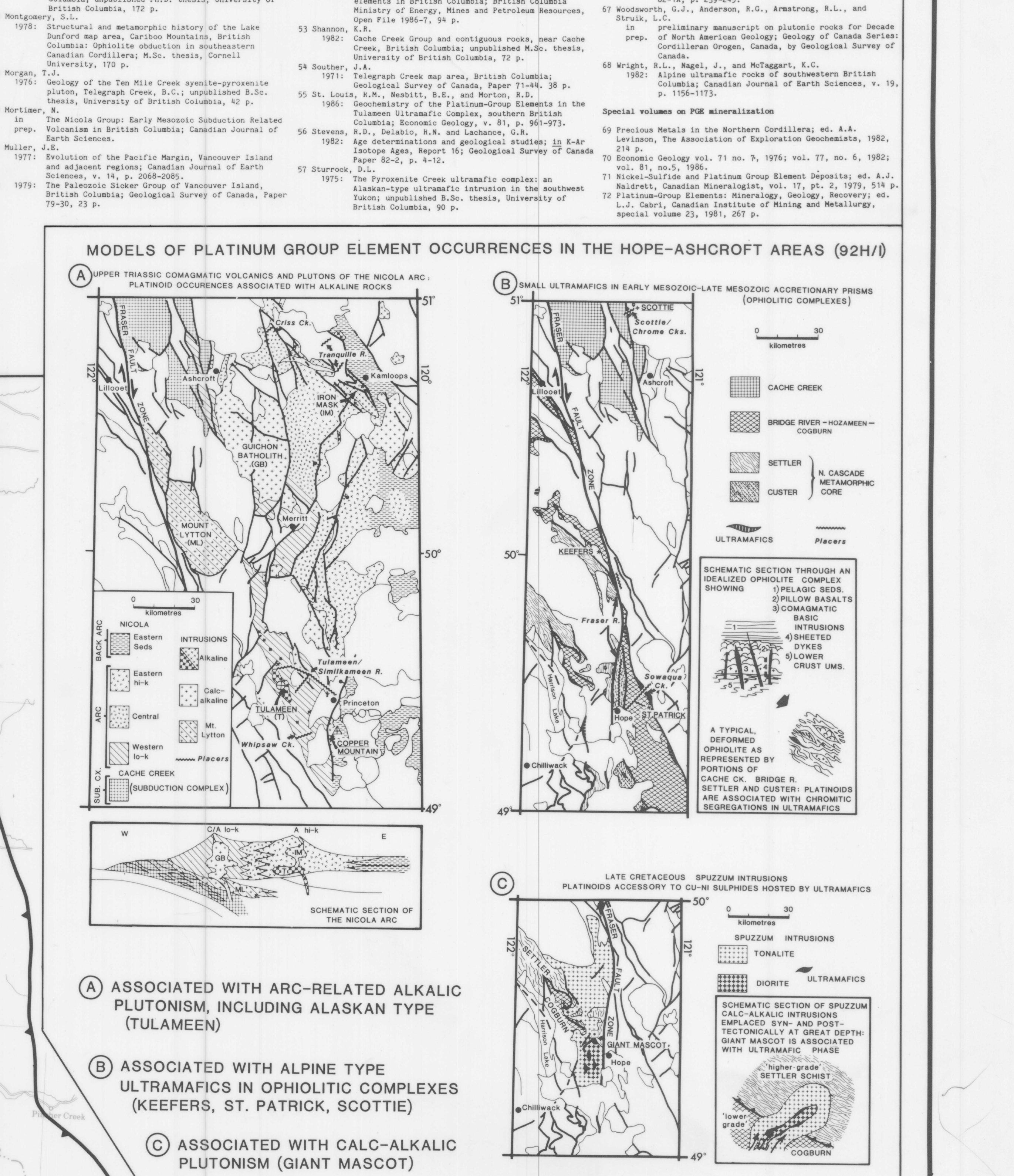
MODELS OF PLATINUM GROUP ELEMENT OCCURRENCES IN THE HOPE-ASHCROFT AREAS (92H/I)



Ⓐ ASSOCIATED WITH ARC-RELATED ALKALIC PLUTONISM, INCLUDING ALASKAN TYPE (TULAMEEN)

Ⓑ ASSOCIATED WITH ALPINE TYPE ULTRAMAFICS IN OPHIOLITIC COMPLEXES (KEEFERS, ST. PATRICK, SCOTTIE)

Ⓒ ASSOCIATED WITH CALC-ALKALIC PLUTONISM (GIANT MASCOT)

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