Geology, geochemistry, and new isotopic ages of selected PGE-Ni-Cu bearing, mafic/ultramafic complexes in Alaska-Yukon and Russian Far East regions

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The discovery, development, and production of platinum group elements (PGE) in the Alaska-Yukon and the Russian Far East have taken place in widely different periods, but in similar geologic settings. From 1926-2002, approximately 92 tonnes of PGE has taken place in both areas; about 75 percent of the total has been sourced from mines in the Russian Far East. A comparison of historical precious metal output from the Alaska-Yukon (AK-YK) and Russian Far East (RFE) regions is provided in Table 1.

Estimated production of precious metals from the Russian Far East, Alaska (USA) and Yukon (Canada) regions, 1885-2002 (1)

Commodity	*Russian Far East*	*Alaska*	*Yukon*	*Total*
Gold (tonnes)	4,970.0	1,130.0	422.4	6,522.4 (202.81 million oz)
Silver (tonnes)	700.9	4,644.1	5,458.0	10,803.0 (335.97 million oz)
Platinum Group Elements (tonnes) (2)	70.1	21.8	NA	91.9 (2.85 million oz)

(1) From Alaska State, US Federal, and Russian Federation sources and this study.
(2) >95 percent is iso-ferroplatinum.

The most significant PGE-geological settings in both diverse regions include the following: 1) mid-Proterozoic and Tertiary, synorogenic layered mafic intrusions (Lanatrsky and Kuveralog, RFE; Crillion-La Perouse AK); 2) Triassic and Tertiary-Cretaceous, sill form tholeiitic intrusions (Nikolai-Kluane and Farewell, AK-YK; Kviinum-Shanuch RFE); 3) Ural-Alaskan zoned mafic-ultramafic complexes of variable age (Goodnews Bay and SE Panhandle, AK; Konduer and Koryak-Kamchatka Platinum Belt, RFE); 4) composite plutons (Salt Chuck, Flat, Granite Mountain, AK); 5) dismembered arc and oceanic rift ophiolite belts (Chugach, W. Brooks Range, 70-Mile, Mt Hurst, AK-YK; Kuhul, RFE); and 6) placers mainly derived from 3 above.

In this presentation, we briefly outline the geologic framework, present new isotopic ages, and propose tectonic environments for four PGE provinces: 1) Goodnews Bay, SW AK; 2) Galmeononsky-Seinavsky, Northern Kamchatka, RFE; 3) Farewell, Western AK; and 4) Sredinny, Southern Kamchatka, RFE.

The Goodnews Bay district is the site of Alaska's premier PGE district, and is responsible for >95 percent of the historic Alaskan PGE output. Two elongate Ural-Alaskan intrusions at Red and Susie Mountains are composed of dunite-wehrlite cores and hornblende clinopyroxenite and clinopyroxenite rims, with host rocks that underwent high temperature contact metamorphism. Coarse hornblende fractions collected during this study from hornblende clinopyroxenite yielded 40Ar/39Ar ages ranging from 188-193 Ma, or Middle Jurassic in age.

Paired Ural-Alaskan intrusions in the Galmeononsky-Seinavsky district are found in the geographic center of the Koryak-Kamchatka Platinum Belt (KKPB), which extends from Koryakia to northern Kamchatka for a distance of approximately 1,000 km. The KKPG contains at least six Ural-Alaskan zoned ultramafic complexes, all of which contain dunite cores and successive rims of clinopyroxenite, peridotite, gabbro and uncommonly diorite. Significant lode chromite-isoferroplatinum mineralization occurs mainly in dunite phases and more than 31 tonnes of platinum has been produced from streams dissecting the Galmeononsky massif. Earlier Russian workers recognized the similarities of the Goodnews Bay district in SW Alaska and the Galmeononsky-Seinavsky district on the Kamchatka Peninsula and believed that they were part of the same metallogenic belt that extended across the Bering Straits. However, samples from the Galmeononsky-Seinavsky intrusions analyzed during this study yielded 40Ar/39Ar hornblende and biotite ages ranging from 71.5 to 73.9 Ma. Basaltic flows thought to be coeval with the Ural-Alaskan intrusions in the KKPG have yielded whole rock 40Ar/39Ar ages ranging from 60.6-64.6 Ma.

The Ural-Alaskan zoned intrusions in SW Alaska and the KKPG are thought to be emplaced as extension-related calc-alkaline magmas associated with two distinct subduction events—one in Middle Jurassic and the other during the Late Cretaceous. Both areas have paired belts of slightly older dismembered ophiolites inboard from the intrusions; namely the Goodnew Bay ophiolite in SW Alaska and the Kuhul arc ophiolite in northern Kamchatka. In both Goodnews Bay and Koryak-Kamchatka regions, compression and obduction of oceanic crust preceded extensional tectonics that led to the formation of the Ural-Alaskan complexes.

In the Farewell and Sredinny terranes of Central Alaska, USA and Kamchatka, Russia, tholeiitic, differentiated, peridotite, clinopyroxenite, and gabbro sills, norite-dominant, layered intrusions, and cogenetic, alkali olivine basalt flows intrude and overlie Paleozoic and Mesozoic, continental margin deposits of accretionary origin. Significant PGE, nickel, cobalt and copper sulfide deposits are associated with mafic-ultramafic intrusions in both areas. In the Farewell area, the mafic and ultramafic sills and pillow basalts intrude and overlie: 1) silty limestone and shale of the Late Cambrian-Lower Ordovician Lyman Hills Formation and 2) calcareous sandstone and shale of the Permian-Pennsylvanian Sheep Creek Formation. The Farewell terrane mafic-ultramafic sills are enstatite rich, orthopyroxene poor, and contain Ti-enriched chromitites. REE and other trace element data from the Farewell suite suggests a magma-mixing model

with local crustal contamination. Samples of the Sheep Creek sills yield plateau 40Ar/39Ar ages ranging from 225.6 to 233.7 Ma.

Overall geological and geochemical framework indicates that the PGE-Ni-Cu bearing mafic-ultramafic intrusions in the Farewell area formed during a Late Triassic continental margin rifting event. Mineralized mafic/ultramafic intrusions in the Farewell terrane can be compared to Late Triassic, tholeiitic sills and cogenetic basalts that intrude and overly the Wrangellia terrane of western North America, or the mafic intrusions and volcanic rocks hosted in Paleozoic terrigenous deposits on the Taimyr Peninsula of eastern Siberia. The strong evidence for a Siberian affinity for the host rocks in the Farewell area are mainly derived from recent, and voluminous paleontological studies.

In the Sredinny terrane of southern Kamchatka, more than 40 peridotite, pyroxenite, and noritic intrusions cut metamorphosed sandstone and siltstone of the Kamchatka and Kolpakova Groups. Previous Russian workers believed that the mafic intrusions were Triassic-Jurassic in age. REE and trace element data and the widespread appearance of garnet in the gabbro-norites suggest that chrondritic magmas of the Sredinny terrane have been contaminated by crustal sources. 40Ar/39Ar plateau ages from six mafic sills and layered intrusions in the Sredinny terrane range from 49.8 to 53.0 Ma; a seventh sill yielded a 40Ar/39Ar age of 84.3 Ma.

The early Tertiary, mineralized layered and sill-form intrusions in the Sredinny terrane are similar to rift related, mineralized, layered peridoitie-gabbro complexes of Tertiary age in the Crillion La Perouse and related gabbroic complexes that cut metamorphosed island arc and flysch deposits of southern Alaska.