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Contrasting Petrological and Geochemical Relationships in the Voisey's Bay and Mushuau Intrusions, Labrador, Canada: Implications for Ore Genesis

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Abstract

New data on the Voisey's Bay and Mushuau intrusions indicate that the two bodies, which were formerly grouped as the Reid Brook Complex, differ markedly in age, petrology, geochemistry, and the scale of known mineralization. U-Pb dating of baddeleyite and zircon has revealed that the Mushuau intrusion has an age of 1.313 Ga, which is ~20 m.y. younger than the 1.333 Ga Voisey's Bay intrusion. The Voisey's Bay intrusion is host to the 124 million tons Ni-Cu-Co sulfide deposit (reserves + resources). Mineralization occurs at the base of an upper subchamber (the Eastern Deeps subchamber) and in a conduit that connects the Eastern Deeps to a lower subchamber (the Reid Brook subchamber). The mineralization is associated with a basal breccia that contains abundant reacted inclusions of paragneiss. Within the Eastern Deeps, the basal mineralization is overlain by a varied-textured troctolite that contains variable amounts of disseminated sulfide and gneiss inclusions. By comparison, only minor amounts of sulfide mineralization have been observed within the Mushuau intrusion. The Mushuau intrusion comprises a layered unit that has been intruded by a stellate-textured troctolite along its contact with footwall orthogneiss. The layered unit consists dominantly of melatroctolite at the margin with leucotroctolite toward the center and olivine gabbro at the core. The cumulates of the Mushuau intrusion are richer in olivine and thus have higher MgO contents than those of the Voisey's Bay intrusion. Notwithstanding this, olivines in the melatroctolite inclusions of the Voisey's Bay intrusion (which are thought to represent disrupted cumulus layers) contain up to 81 mole percent forsterite, whereas those in the melatroctolite of the Mushuau intrusion contain no more than 70 mole percent forsterite. Nickel depletion in olivine is more pronounced in the Voisey's Bay intrusion than in the Mushuau intrusion. Our data indicate that the parental magmas of both intrusions were broadly basaltic (MgO < 8.1 wt %) and that the magma of the Mushuau intrusion was more evolved than that of the Voisey's Bay intrusion, yet still capable of forming olivine-rich cumulates. The troctolites of the Voisey's Bay intrusion have Ce/Yb = 22 to 27, whereas most troctolites of the Mushuau intrusion have Ce/Yb = 12 to 17. The rocks of the Mushuau intrusion are simple mixtures of mantle-derived magma and local orthogneiss, whereas the rocks of the Voisey's Bay intrusion are formed by multiple stages of crustal contamination including an early stage of contamination at lower midcrustal level and a late stage of contamination by Tasiuyak paragneiss at upper crustal level. The assimilation of the sulfide-bearing Tasiuyak paragneiss by magma at Voisey's Bay may have promoted initial sulfide saturation and/or increased sulfide oversaturation, thus contributing to the segregation of large amounts of sulfide liquid from magma. Continuing flow of magma through a dynamic conduit system at Voisey's Bay has caused the local accumulation of sulfide of sufficient size and grade to constitute mineable reserves.