

Nd-Pb-Sr Isotope Systematics of Crustal Assimilation in the Voisey's Bay and Mushuau Intrusions, Labrador, Canada

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Abstract

Assimilation of crustal rocks by mafic magmas is considered important for the formation of sulfide ores. Radiogenic isotope systems may allow one to quantify the amount of contamination and to distinguish between possible contaminants. We have studied Sm-Nd, Rb-Sr, and U-Pb isotope systems in two mafic intrusions of the Nain Plutonic Suite: the 1333 Ma Voisey's Bay intrusion that hosts the major Ni-Cu-Co sulfide deposit of the same name, and the 1317 to 1313 Ma Mushuau intrusion, which contains only minor sulfide mineralization. In addition, we have analyzed potential contaminants: Archean Nain gneisses of various composition, and Paleoproterozoic enderbitic gneisses and Tasiuyak paragneisses. The analyses were performed on carefully handpicked plagioclase and apatite fractions in order to obtain more reliable isotopic data and check for closed system behavior.

The Voisey's Bay intrusion has the most mantlelike, least-contaminated initial isotopic compositions among the basic intrusions of the Nain Plutonic Suite: $\epsilon_{\text{Nd}} = -1$ to -2 , $^{87}\text{Sr}/^{86}\text{Sr} = 0.7034$ to 0.7038 , $^{206}\text{Pb}/^{204}\text{Pb} = 15.34$ to 15.54 , $^{207}\text{Pb}/^{204}\text{Pb} = 15.10$ to 15.18 , and $^{208}\text{Pb}/^{204}\text{Pb} = 35.24$ to 35.56 . These isotopic ratios are uniform in various troctolite and gabbro phases from all parts of the intrusion (Eastern Deeps, Discovery Hill zone, and Reid Brook zone). Isotopic signatures of the Mushuau intrusion are quite distinct from the Voisey's Bay intrusion and typical for the rest of the Nain Plutonic Suite: $\epsilon_{\text{Nd}} = -3$ to -10 , $^{87}\text{Sr}/^{86}\text{Sr} = 0.7034$ to 0.7052 , $^{206}\text{Pb}/^{204}\text{Pb} = 14.21$ to 14.55 , $^{207}\text{Pb}/^{204}\text{Pb} = 14.63$ to 14.77 , and $^{208}\text{Pb}/^{204}\text{Pb} = 34.36$ to 34.65 . The Voisey's Bay and Mushuau intrusions were, therefore, not only separated by 16 to 20 m.y. in time but also have different magma sources and/or styles of contamination.

The isotopic data imply that the primary magmas of the Voisey's Bay intrusion were either derived from an enriched continental mantle or contaminated by a small amount of crustal material during ascent through lower-middle crust. Subsequent contamination with Tasiuyak gneisses in the upper crust was volumetrically minor, probably about 8 to 13 percent. No late-stage contamination with Archean crustal material is detected. The amount of assimilated enderbitic gneisses is difficult to evaluate because their difference in isotopic composition from the Voisey's Bay intrusion is small. Observed isotopic variations in the Mushuau intrusion can be explained by assimilation of 15 to 35 percent of a U-depleted Archean crust similar to Nain gneisses. Some rocks from both the Voisey's Bay and Mushuau intrusions were either modified by contact metamorphism caused by emplacement of the Voisey's Bay syenite or gained excessive local contamination.

The Voisey's Bay intrusion occupies a unique position in the Nain Plutonic Suite, being the oldest and the least-contaminated mafic intrusion. We suggest that these may be essential conditions for the origin of the Voisey's Bay deposit. The Voisey's Bay parental magmas were only moderately affected by contamination during ascent through the crust and probably did not undergo early sulfide separation. In contrast, the parental magmas of the Mushuau intrusion, as well as most other basic magmas in the Nain Plutonic Suite coeval with voluminous granitoids, were probably extensively contaminated with hot restites from intracrustal melting and/or granitoid melts, reached early sulfide saturation, and lost much of their Ni and Cu content.