Economic Geology
Vol. 98, 2003, pp. 495–515

Geochemistry and Origin of the Intrusive Hosts of the Noril'sk-Talnakh Cu-Ni-PGE Sulfide Deposits

N. T. Arndt,

Géosciences, LCGA, Université de Grenoble 1, 1381 rue de la Piscine, 38400 St. Martin d'Heres, France

G. K. Czamanske,†

750 West Greenwich Place, Palo Alto, California 94303

R. J. Walker,

Department of Geology, University of Maryland, College Park, Maryland 20742

C. Chauvel,

Géosciences, LCGA, Université de Grenoble 1, 1381 rue de la Piscine, 38400 St. Martin d'Heres, France

and V. A. Fedorenko

Central Research Institute of Geological Prospecting for Base and Precious Metals (TsNIGRI), Varshovskoye Shosse 129B, Moscow 113545, Russia

Abstract

The world-class deposits of Cu, Ni, and platinum-group elements (PGE) of the Noril'sk-Talnakh district in Russia are hosted by relatively small, complex mafic-ultramafic bodies that intrude Permian sedimentary rocks and the lowermost suites of the Siberian continental flood-volcanic sequence. The Noril'sk-type, ore-bearing intrusions immediately overlie, and are probably penecontemporaneous with, weakly mineralized intrusions of the Lower Talnakh type, which have similar petrological features but contrasting and much more variable Nd, Os, and Sr isotopic compositions. Several types of spatially associated intrusions were emplaced after the ore-bearing intrusions and the flood-volcanic sequence.

To clarify relations between the various types of igneous bodies (flood-volcanic rocks, Noril'sk-type intrusions, Lower Talnakh-type intrusions, and later intrusions) and to help understand the formation of the ore deposits, we undertook a detailed geochemical and Nd, Os, and Sr isotopic study of eight of the more important intrusions. The data indicate that these intrusions formed by the input of a series of magma pulses, each of which produced rocks with distinctive petrology and chemical compositions. These compositions are interpreted to have formed from mixtures of mantle-derived magmas and different types of crustal rock, which were encountered and assimilated during passage to the surface. Some of these variations may be superimposed on heterogeneities inherited from the mantle source.

The magmas that formed the Lower Talnakh-type intrusions became contaminated with large amounts of crustal rock in a deep staging chamber. The chemical and isotopic characteristics of the resultant hybrid magmas are broadly similar to those of basalts of the lower and middle Nadezhdinsky lava subsuites ($Nd_{1\text{-}2}$), which are located about one-third of the way through the overlying lava sequence. These magmas became saturated in sulfur during contamination, and segregation of sulfides resulted in the depletion of chalcophile elements recorded in the $Nd_{1\text{-}2}$ lavas.

Magmas feeding the ore-bearing intrusions had trace element and isotopic compositions similar to those of the basalts in the upper two-thirds of the volcanic sequence. These magmas underwent lower degrees of contamination in a deep staging chamber and sulfur saturation was not reached. These magmas therefore contained a full compliment of chalcophile elements when they encountered anhydrite-rich sediments during passage toward the surface. Assimilation of these sediments led to the segregation of sulfides to form the ores.

Two aspects of our data impose important constraints on the ore-forming process. The first is the Os isotopic composition of the ore sulfides (avg γ_{Os} ~7), which is similar to that of mantle rocks and very different from those of sulfides that segregate from highly contaminated magma. The second is the absence of Ni depletion in olivine in rocks from the ore-bearing intrusions, most notably in the ore-rich, picritic gabbrodolerites. The simplest explanation is that the sulfides segregated from magmas that were not highly contaminated and were transported into the intrusions by magmas different from those that yielded the sulfide. If this explanation is correct, it imposes some modifications to earlier models of sulfide ore deposition in the conduits of flood basalts.

† Corresponding author: e-mail, czamrandg@earthlink.net

0361-0128/01/3337/495-21 $6.00