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The Origin of Platinum Group Minerals from the Freetown Intrusion, Sierra Leone, Inferred from Osmium Isotope Systematics

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Abstract

The origin of certain alluvial platinum-group mineral (PGM) grains is controversial, with two major proposed models. One involves primary formation within ultramafic intrusions, followed by weathering into laterites with no further alteration prior to alluvial concentration. The other involves in addition, solution of the platinum-group elements (PGE) during weathering of the ultramafic source rocks, probably by organic reactions, followed by the supergene growth of the macroscopic grains within laterites.

In order to provide further evidence concerning the formation of macroscopic (~ mm in size) platinum-group mineral grains, the authors have studied the osmium isotope ratios in PGM grains from the Freetown peninsula in Sierra Leone using an ion microprobe.

Indirect isotopic evidence and modeling are required to infer their origin as no PGM grains larger than ~10 μm have ever been discovered in situ within the source rocks. Unlike virtually all other alluvial PGM grains that have been studied, the Freetown ones are distinguished by ^{187}Os/^{188}Os ratios that are much higher than canonical mantle values and vary considerably between different grains (0.12 = ^{187}Os/^{188}Os = 0.28). The ^{187}Os/^{188}Os ratios are, with one exception, the same for individual osmium-rich inclusions within the platinum-iron alloy host of each grain, although different grains have significantly different 187Os/188Os ratios. In the one significant exception, there are two Os-Ru-Ir alloy inclusions within a single platinum-iron alloy host which have ^{187}Os/^{188}Os ratios that are different from each other.

Various models are considered to explain these observations: (1) the elevated osmium isotope ratios could be primary and derived from a mantle inhomogeneity such as a mantle plume; (2) the intruded material with a canonical mantle signature may have reacted with the host rocks at the time of the intrusion or at a later stage during postulated metamorphic or hydrothermal activity, or (3) the supergene remobilization could have modified the osmium isotope signature of the PGM. Interpretation of the osmium isotopes is by no means unambiguous. The range of ^{187}Os/^{188}Os ratios is far higher than known mantle sources which, combined with the grain to grain variation, seems to rule out the primary formation model. Sr, Nd, and O isotope evidence indicates no reaction with the host rocks during intrusion or by metamorphic or hydrothermal activity and mixing calculations show that enhancement of the radiogenic Os during intrusion could only have been small.

The evidence points to some extremely localized process which could, however, have acted in two ways: either a preexisting high concentration of rhenium and PGE (a xenolith) was incorporated into the magma chamber, remained essentially unmixed with the majority of the material in the chamber, and after extrusion of the gabbro, PGE nuggets were weathered out into laterites, or alternatively, concentration processes within the magma chamber produced a localized concentration of rhenium—possibly in copper sulfides or late magmatic iron oxides in acid intrusions—which, when chemically dissolved in the supergene environment, precipitated PGE nuggets with extremely radiogenic ^{187}Os/^{188}Os signatures.

The data presented in this paper in conjunction with work elsewhere have been used to demonstrate that the processes producing highly radiogenic ^{187}Os/^{188}Os signatures cannot have resulted from large-scale processes and have been used to dismiss a number of previously proposed models. However, a resolution between the two alternative models proposed is not possible using the present data.