Global variability in the platinum-group element contents of komatiites.

Marco L. Fiorentini¹, Stephen J. Barnes², Wolfgang D. Maier¹ and Geoffrey J. Heggie¹
¹Centre for Exploration Targeting, School of Earth and Geographical Sciences, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia. Email
²CSIRO Exploration and Mining, Bentley, WA 6102, Australia. email steve.barnes@csiro.au

Abstract. We report a large volume of high-precision platinum-group element (PGE) data generated from Archaean and some Early Proterozoic komatiites and komatiitic basalts spanning a wide range of ages (from ca. 3.5 Ga to ca. 2.0 Ga), petrological affinities (Munro-type, Barberton-type and Karasjok-type) and locations (i.e. Pilbara, Yilgarn, Superior, Kaapvaal and Fennoscandian Cratons). The main purposes of this study are to establish baselines for PGE contents of komatiites and, by inference, to investigate the variability in PGE contents of komatiite source regions in space and time.

On the basis of the analysis of our high-precision PGE dataset integrated with the entire existing body of published high-quality analytical data on komatiites and komatiitic basalts world-wide, we conclude that PGE baseline concentrations in komatiites of different petrological affinity, lithofacies type and emplacement style are generally similar worldwide. All komatiites have relative PGE patterns showing a slight enrichment of PPGEs over IPGEs attributable to limited retention of IPGEs in mantle sources, coupled with saturation in Ir-Os alloys. However, significant differences and trends exist, in particular a systematic linear increase in PGE contents of komatiites with age from the oldest at >3.5 Ga to the late Archaean group at 2.7 Ga.

Keywords: Komatiite, PGE, Late Veneer, Archaean

1 Introduction

Early Proterozoic and Archaean komatiites are widely considered to have formed by high degrees of partial melting, between 30 and 50% (Arndt, 2008), of deep mantle sources, and hence are irreplaceable sources of information on the chemical composition, and specifically the platinum group element (PGE) concentrations, of the mantle of the ancient Earth. The platinum group element budget of the mantle has been studied widely over many years, primarily as a test of hypotheses for the timing and nature of core segregation and accretion of a meteoritic veneer (Brandon et al., 2003, Lorand & Alard, 2001, Lorand et al., 2000). Platinum group element concentrations in komatiites are therefore an important line of evidence in mantle and core evolution studies, as well as being potentially important indicators of genetic processes in komatiite-hosted magmatic sulphide nickel deposits (Barnes et al., 2004a, Fiorentini et al., 2008, Keays et al., 1981, Lesher et al., 2001b).

In this study, we present a large number of high-precision platinum-group element data generated from Archaean and some Early Proterozoic komatiites, komatiitic basalts and ferropicrites ranging in age (from ca. 3.5 Ga to ca. 2.0 Ga), petrological affinity (Munro-type, Barberton-type and Karasjok-type), lithofacies (channelised lava flows, high-level sills, lava lakes, etc.), texture (e.g. spinifex-textured vs cumulate lithologies) and location (i.e. Pilbara, Yilgarn, Superior, Kaapvaal and Fennoscandian Cratons). We refer to Arndt (2008) for a comprehensive review of the main geological, petrological and geochemical features of the different komatiite types. To avoid the additional complexities of PGE fractionation during magmatic sulphide formation, this contribution focuses on komatiite units which are devoid of any significant known nickel-sulphide mineralisation.

We have integrated our PGE data with the entire existing body of published high-quality analytical data on komatiites and komatiitic basalts world-wide. The result is a global compilation of over 1500 analyses of S-poor samples, about half of which are derived from stratigraphic units not associated with sulphide mineralisation, representing a wide spectrum of komatiite types, settings and ages. The main purposes of this study are to establish baselines for PGE contents of komatiites not associated with sulphide nickel ore deposits and, by inference, to investigate the variability (or lack of it) in PGE contents of most komatiite source regions. The main conclusion of our study is that komatiite source regions were broadly similar in their total PGE concentrations, although some significant variations exist with komatiite type and particularly with time. The secular variation in source compositions dominates...
all other sources of variations, and records a history of progressive mixing of the chondritic Late Veneer over the period from 4.5 to 2.7 Ga into a lower mantle depleted in PGEs by core formation.

2 Summary of observations
1. Within the major groupings of Munro-type and Barberton-type komatiites PGE baseline concentrations in komatiites of different lithofacies type, and emplacement style are surprisingly similar, when the effects of olivine and sulphide liquid fractionation are set aside, with the exception of some subtle provincial variability. Karasjok-type (Ti-enriched) komatiites have low PPGE/Ti ratios, which are a function of unusually high Ti, but have very similar PGE patterns for similar MgO as Munro-type komatiites.

2. A small but systematic difference is observed in average PGE baseline concentrations between Barberton-type and most Munro-type komatiites of the same age, such that Barberton-type komatiites are systematically slightly depleted in PGEs for a given MgO and relative to lithophile incompatible elements represented by Ti. This is true of all the PGEs with the partial exception of Ir.

3. A number of suites of >3000 Ma old Munro-type samples, from three different localities in the east Pilbara and one in the Barberton greenstone belt, are distinctly anomalous in having distinctly depleted PGEs, more like typical Barberton-type komatiites of similar age.

4. There is a systematic linear trend across both Barberton-type and Munro-type komatiites, including the east Pilbara and Barberton suites, of decreasing mantle-normalised PPGE/Ti with age from 2700 to 3500 Ma. This trend is not explicable by any process of low pressure fractionation or contamination, and is interpreted as reflecting the composition of the mantle source.

5. Most komatiites show similar patterns of variation in IPGEs (specifically Ir) which can be explained in terms of saturation with magmatic PGM phases, most likely to be Ir-Os alloy, at source (Barnes & Fiorentini, 2008). One anomalous grouping, the Barberton-type komatiites of the Barberton Greenstone Belt itself, shows a distinctly different Ir-undersaturated trend not seen in any other suite.

3 Conclusions
On the basis of the analysis of our high-precision PGE dataset, we conclude that PGE baseline concentrations in komatiites of the same age but different petrological affinity, lithofacies type and emplacement style are generally similar worldwide. All komatiites have relative PGE patterns showing a slight enrichment of PPGEs over IPGEs attributable to limited retention of IPGEs in mantle sources, coupled with saturation in Ir-(Os) alloys. Specifically, we observe that the variable nature of emplacement style, country rock association and metamorphic grade do not seem to greatly influence the PGE baseline concentrations of the various komatiite units that we analysed. However, significant differences and trends exist, which may be attributable to other factors.

Barberton-type komatiites are variably depleted in all the PGEs relative to Munro-type komatiites of the same age in greenstone belts younger than 3000 Ma, a feature which is consistent with minor depletion due to traces of sulphide in the source. However, Barberton-type komatiites have similar abundances to Munro-type komatiites in older greenstone belts. In the data set as a whole, there is a striking linear secular trend of increasing Pt/Ti from 3500 Ma to 2700 Ma in all komatiites regardless of type.

This leads us to two alternative hypotheses: either Barberton-type komatiites are slightly PGE depleted due to S-saturation at source, the age trend is a function of a preponderance of Barberton-type komatiites in older greenstones, and the east Pilbara Munro-type komatiites are an unexplained anomaly; or else the age trend is related to a secular variation in the PGE content of komatiite source regions (Maier et al., in review). If the latter hypothesis is true, we envisage that Early Archaean komatiites are derived from plumes sourced in the deep mantle which had been stripped of its highly siderophile element budget during core segregation, and not yet refertilised by the late veneer. Late Archaean komatiites contain higher PGE contents as a result of
progressive mixing-in of late veneer over the period between the Late Heavy Bombardment (4.3 to 3.9 Ga) and 2700 Ga, at which time the mantle had become effectively homogenous with respect to PGEs.

Komatiite sources are characteristically depleted in PPGEs relative to lithophile incompatible elements such as Ti, compared with estimates for primitive upper mantle. We argue that PGE estimates for the primitive mantle may either be partially wrong or at least not universally applicable. Griffin et al. (2008) indicated that the SCLM beneath large cratonic areas is much more strongly depleted than the garnet lherzolites that have been previously accepted as representative of the Archaean SCLM. Therefore, if a metasomatised mantle has been used as a reference for primitive mantle, it is likely that PGE values have been over-estimated. This is consistent with the conclusions of Lorand and co-workers (Lorand et al., 2008) for introduction of a metasomatic PPGE-enriched sulphide component into the lithospheric mantle.

Acknowledgements

This work was carried out as part of AMIRA Project P710A, generously funded by BHP-Billiton, Norilsk Nickel (formerly Lion Ore), Independence Group NL, all of whom also provided access to drill core samples, and by the Minerals and Energy Research Institute of WA (MERIWA). We thank Marcus Burnham and staff of Geoscience Laboratories in Sudbury, and Alex Christ and staff of UltraTrace Laboratories in Perth, for their painstaking work in producing high-quality PGE analyses. The manuscript benefited from detailed discussions with John Mavrogenes, Hugh O’Neill and Ian Campbell.

References