Highly siderophile element abundances and ^{187}Re-^{187}Os isotope systematics of Gorgona Island komatiites and Costa Rican picrites

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I. Introduction

• Highly siderophile element (HSE) and Re-Os isotope data are examined for rocks of the Caribbean Large Igneous Province (CLIP)[1],[2]. This suite includes a komatiitic lava flow on the east coast Gorgona Island, two komatiites from the western side of the island, and for three picrites from the Tortugal Suite of Costa Rica. The anomalously young nature of these komatiites (~89 Ma) make them of particular interest. Komatiites are usually Archean in age, and therefore the circumstances in which these rocks fored is of particular interest to the continued study of the Earth's mantle.

• The aim of this study is to examine different localities that are part of the CLIP to assess large-scale heterogenaity of the plume that formed the CLIP, as well as the potential for open system behavior to explain any deveations from the expected initial Os values. Variations in γOs (Fig. 4) between these rock suites offers insight into the heterogeneity of the mantle plume that formed the CLIP. γOs is the percent deveation of initial Os of a sample from chondritic values of Os.

II. Geology

• Gorgona is a small island off the coast of Columbia and hosts the youngest suite of komatiites in the world. The GOR 152 – 160 flow is from the eastern side of the island (Fig. 1), and is a weakly differentiated komatiite flow (no cumulate zone) [3]. Previous studies have reported near chondritic γOs values for this side of the island (-0.5 to +3.0). The western half of the island (represented in this study by GOR 23B and 47) has had significantly higher γOs values (+11.1 to +12.4).

• The Tortugal suite of Costa Rica represents the hottest of the secularly cooling lavas from the Galapagos plume, which is part of the CLIP [2]. This suite is thought to have formed via melting of the hottest plume axis, as compared to Gorgona (and other CLIP lavas) which formed from lower pressure due to plume capture at by a mid ocean ridge [2]. The Tortugal suite has γOs values that range from -2.8 to -1.6

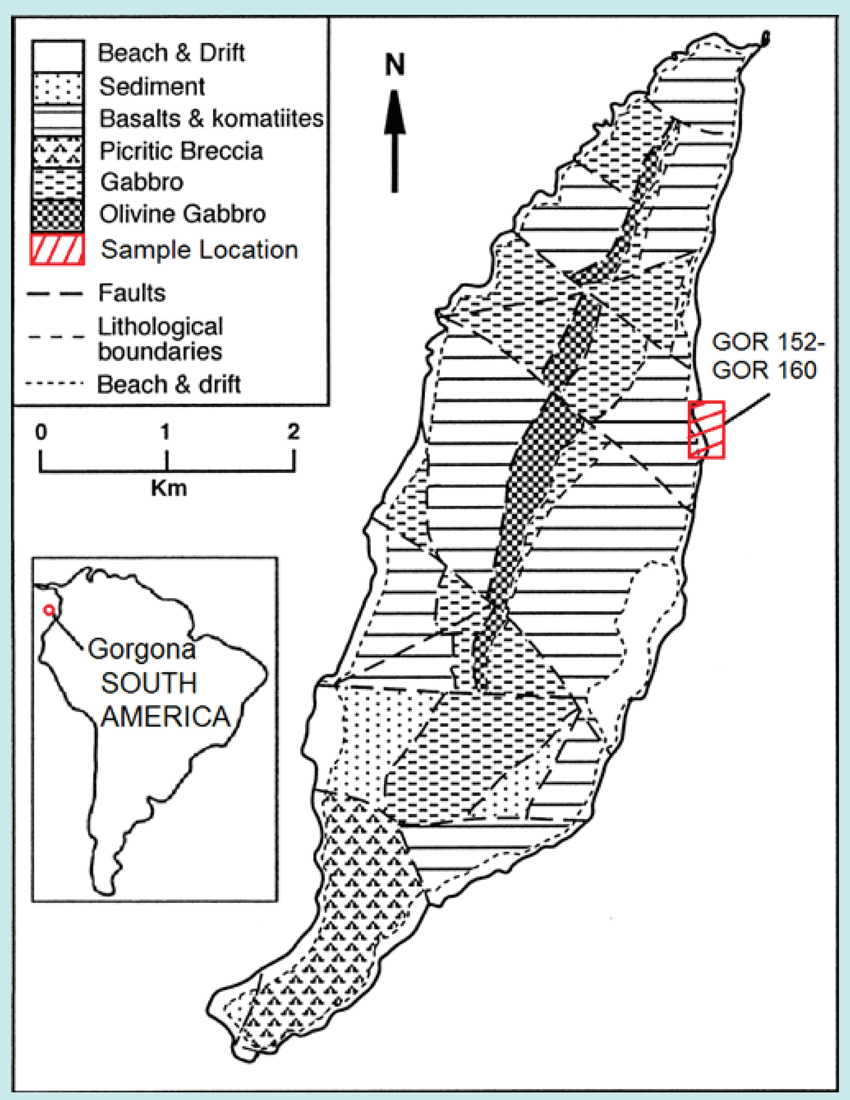


Figure 1: (above) Map of Gorgona Island. Note the location on the east coast where the 152 – 160 flow was sampled from. The island is a sequence of uplifted and tilted mafic and ultramafic rocks, which are a part of the Serrania de Baudo igneous and sedimentary belt, which is part of the CLIP.

III. Methods

• Whole-rock major element concentrations are obtained via X-Ray Fluorescence (XRF) at Franklin and Marshall College.

• ~1g aliquots of finely powdered whole rock sample are digested with *aqua regia* in carious tubes with appropriate amounts of ^{190}Os, ^{185}Re, ^{99}Ru, ^{105}Pd, ^{191}Ir, and ^{194}Pt spikes.

• Osmium is separated using solvent and back extractions, and then purified by micro-distillation. Os ratios are analyzed using Thermo-Fisher Triton Thermal Ionization Mass Spectrometry (TIMS).

• Rhenium, Ru, Pd, Ir, and Pt are separated using anion exchange chromatography. These ratios were analyzed via a Nu Plasma multi-collector Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

IV. HSE Data

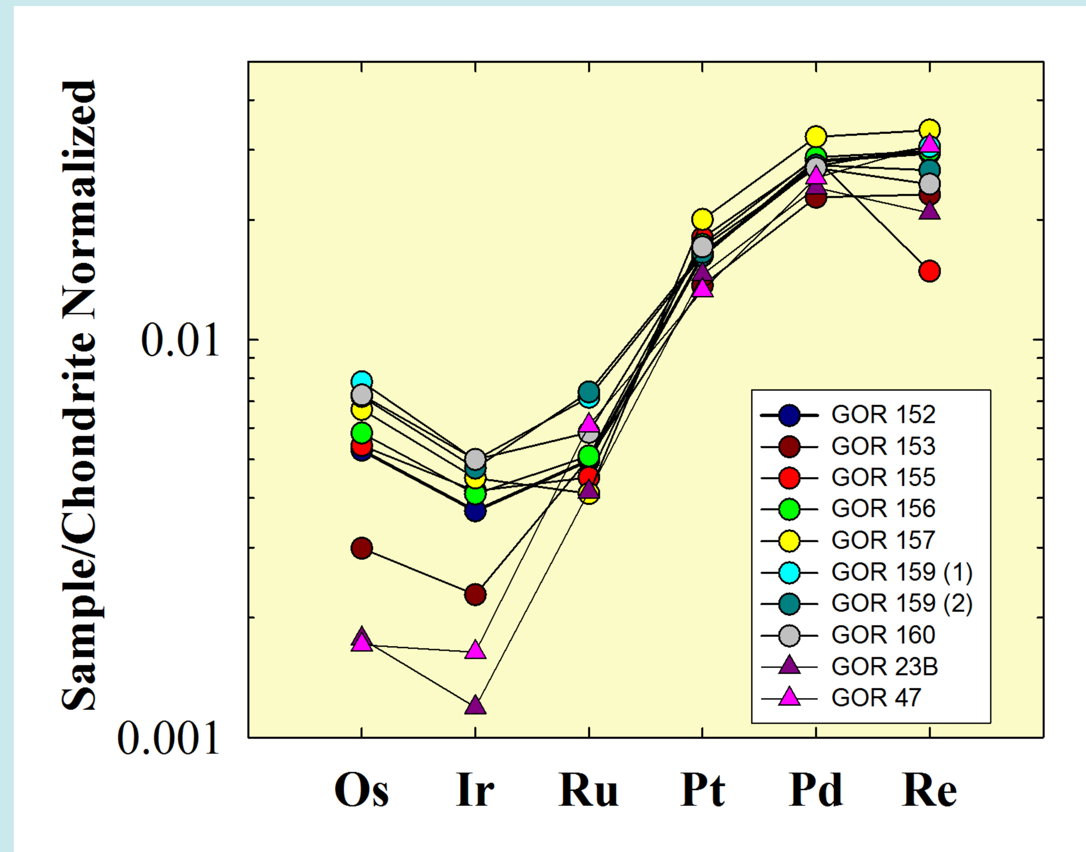
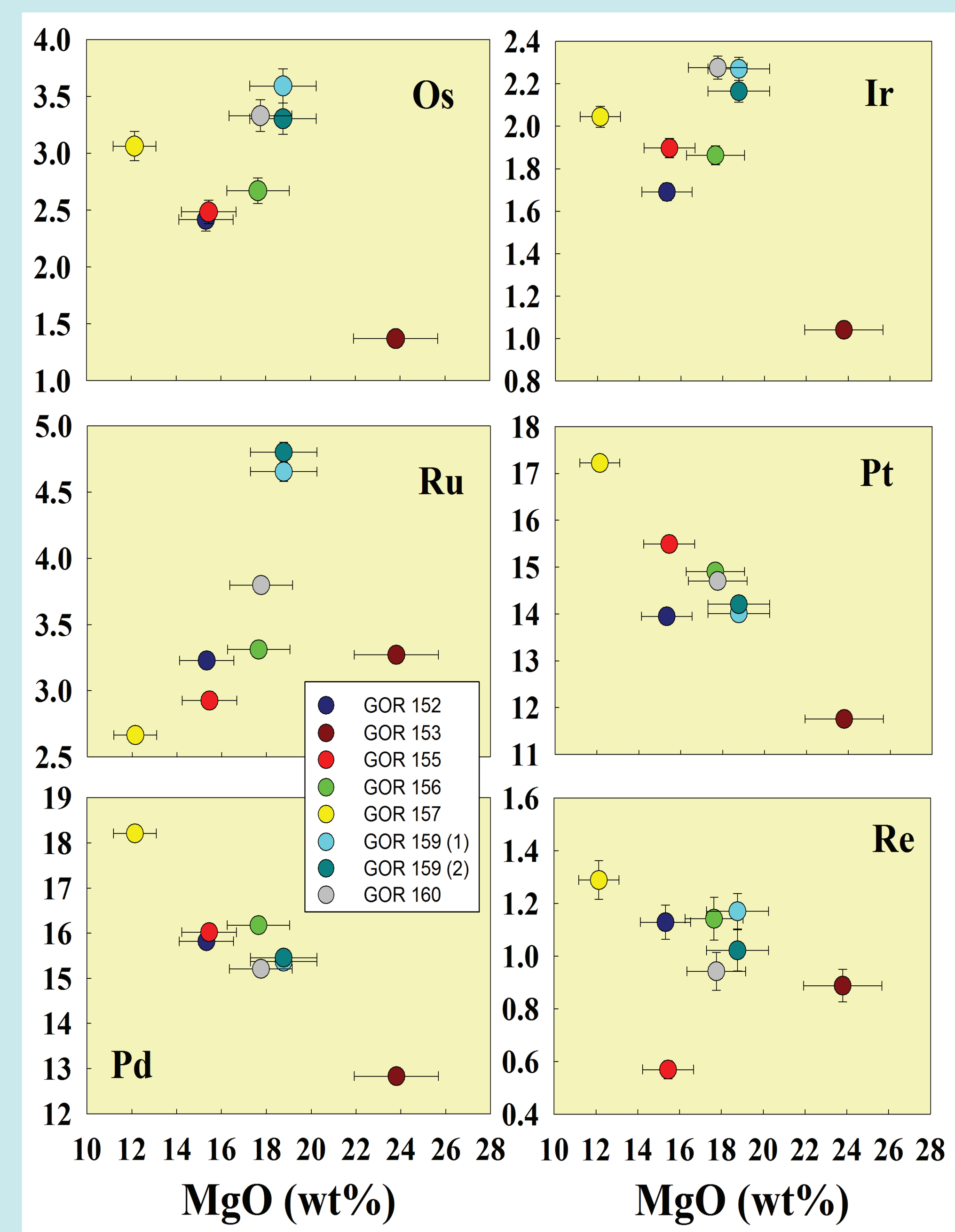


Figure 2: (left) C1 chondrite normalized HSE patterns of the Gorgona Island GOR 152 – 160 komatiite flow are shown in circles. GOR 23B and 47 (West Coast) are shown in triangles. Repeat analysis for GOR 159 shown in two different colors

Normalized values of the incompatible HSE (Pt, Pd, and Re) are slightly less depleted across all samples compared to normalized compatible HSE (Os, Ir, and Ru) values. There is a general trend of enrichment through the upper chilled margin and through the spinifex zone of the flow, but the HSE patterns are generally similar (within uncertainty) across all samples.

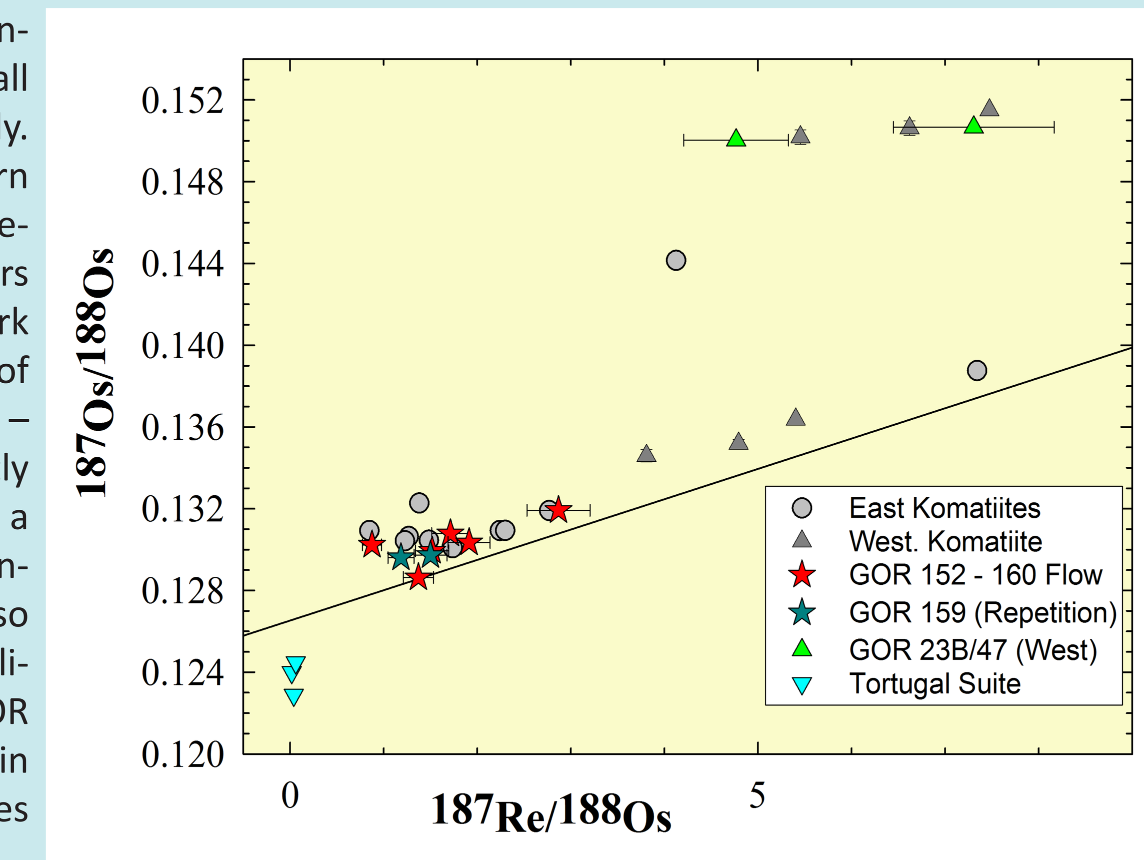
Figure 3: (right) HSE concentrations vs. MgO of the GOR 152 – 160 flow. All y axis (differing HSE) values are in ppb, and x axis (MgO) values are in wt%. Note the negative trends in the incompatible HSE (Pt, Pd, and Re), which create negative olivine control lines. These negative olivine control lines show a decline in incompatible HSE as MgO increases. Olivine being the dominant MgO phase in these rocks, this negative trend indicates that these komatiites are olivine controlled.

Compatible HSE do not have a strong trend, but Ru and Os show a weak positive control line. The positive compatible control line indicate that these komatiites could be classified as a Munro-type lava [4].



V. Re-Os Systematics

Figure 4: (right) $^{187}Os/^{188}Os$ vs $^{187}Re/^{188}Os$ with an 89 Ma chondritic reference isochron for all samples repesented in this study. "Eastern komatiites" and "western komatiites" (both in grey) represent data from [1]. Red stars denote the 152 – 160 flow. Dark red stars indicate the replication of GOR 159. Note that the GOR 152 – 160 flow falls near or slightly above the isochron indicating a slight enrichment in Re and potential open system behavior. Also note the western komatiite outliers above isochron with the GOR 23B/47 repetition falling within uncertainty to the same samples analyzed from a prior study [1].



VI. Discussion

• The GOR 152 – 160 exhibits slightly open system behavior. The flow (if it were a closed system) would plot directly on the 89 Ma reference isochron (within uncertainty). Figure 4 shows clearly that there are outlying points within the flow, and although they are close to the isochron, they are not directly touching, and thus the flow is classified as an open system.

• The western komatiites (GOR 23B and GOR 47) are significantly more enriched in Re (Fig. 4). It has been previously suggested that open system behavior is not a sufficient enough to explain the large γOs variations from between the east coast and west coast [1] (+0.9 and +2.7 and +10.6 to +13.1, respectively). This study is consistent with those prior in the conclusion that the cause of this large deviation from chondritic Os values is a result of the lava being sourced from a different region within the CLIP plume.

• HSE patterns of the GOR 152 – 160 flow are consistent with olivine fractionation. The incompatible HSE vs MgO patterns show a clear negative olivine control trend (Fig. 3) which indicates an olivine controlled system.

• The Costa Rican Torugal picrite suite exhibits distinctly different Re/Os systematic compared to the both the western and eastern Gorgona komatiites. It was expected that these locals would produce similar γOs because of their connection to the CLIP, but the Tortugal suite must have been sourced from a different region of the plume that formed the CLIP because of the vastly different Re/Os isotope ratios (Fig. 4).

VII. References

[1] Walker R. J., Storey M., Kerr A. C., Tarney J., Arndt N. T. (1999) Implications of 187Os isotopic heterogeneities in a mantle plume: evidence from Gorgona Island and Curacao. Geochim. Cosmochim. Acta 63, 713–728.

[2] Trela J., Gazel, E., Sobolev A. V., Moore L., Bizimis M., Jicha B., Batanova V. G. (2017). The hottest lavas of the Phanerozoic and the survival of deep Archean reservoirs. Nature Geoscience. In press.

[3] Echeverria L. M. (1980) Tertiary or Mesozoic Komatiites from Gorgona Island, Colombia: Field Relations and Geochemistry. Contrib. Mineral., Petrol. 73, 253-266.

[4] Puchtel I. S., Brandon A. D., Humayun M., Walker, R.J. (2005) Evidence for the early differentiation of the core from Pt–Re–Os isotope systematics of 2.8-Ga komatiites. Earth and Planetary Science Letters 237, 118-134.