Bulk Chemical Compositions of Meteorites Analyzed by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

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Introduction

Many new meteorites representing rare achondrite (extraterrestrial igneous rocks) groups are being recovered from both hot and cold deserts. A significant fraction of these meteorites are both coarse-grained (grain size > 1 cm) in texture and small in size (mass < 100 g), making accurate determinations of their bulk rock chemical composition rather challenging. Bulk rock chemical compositions of igneous rocks are required for classifying new meteorites, determining genetic relationships to other members of their class, and understanding the processes of planetary origin. We successfully obtained elemental analyses of several angrites using a ~1 mm^2 raster of polished sections by laser ablation ICP-MS [1]. This technique yielded inconsistent answers for two coarse-grained angrites, NWA 4590 and NWA 4801, leading us to try an alternative method by means of analysis of their fusion crusts. The melting of the meteorite's surface during passage through the Earth's atmosphere forms the fusion crust (thickness ~100 µm) covering the meteorite (Fig. 1). The mass contained in the fusion crust may represent ~1 g of fused meteorite, which is larger than most samples taken for bulk compositional analysis (<0.1 g). Laser ablation ICP-MS is a powerful microanalytical technique employed here to analyze the thin fusion crust by performing raster scans covering a few mm^2 on multiple fragments of the fusion crust.

Experimental

Determination of elemental abundances were performed on a New Wave UP193FX excimer laser coupled to a Thermo Element XR™ ICP-MS at the Plasma Analytical Facility, NHMFL. A portion of the fusion crust was rastered using a100 µm beam spot, scanned at 20 µm/s, 20 Hz, 2-4 mJ laser energy. The estimated crater depths are ~10-20 µm. The peaks ^{7}Li, ^{9}Be, ^{23}Na, ^{25}Mg, ^{27}Al, ^{29}Si, ^{31}P, ^{34}S, ^{43}Ca, ^{45}Sc, ^{47}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{57}Fe, ^{59}Co, ^{60}Ni, ^{71}Ga, ^{74}Ge, ^{82}Se, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{95}Mo, ^{97}Mo, ^{121}Sb, ^{123}Sb, ^{133}Cs, ^{138}Ba, ^{139}La, ^{140}Ce, ^{141}Pr, ^{144}Nd, ^{147}Sm, ^{151}Eu, ^{154}Gd, ^{158}Gd, ^{159}Tb, ^{164}Dy, ^{165}Ho, ^{166}Er, ^{169}Tm, ^{174}Yb, ^{175}Lu, ^{180}Hf, ^{181}Ta, ^{182}W, ^{193}Ir, ^{232}Th, and ^{238}U, were monitored in low resolution (R = 300). Elemental abundances were obtained by using relative sensitivity factors obtained from reference values for MPI-DING glasses, ML3B-G, StHs6/80-G and ATHO-G, and from NIST SRM 612.

Results and Discussion

We obtained new multi-element bulk compositions for two hot desert achondrites, NWA 4590 (angrite) and NWA 4468 (shergottite, linked to Mars), tabulated in [2]. Particularly of interest were the elements Ni, Co, Ga, Ge, Mo, Sb, and W, that partition between the silicate mantle and metallic core of an asteroid or protoplanet. We obtained elemental abundances for these elements that are of precision comparable to the best bulk compositional analytical techniques that use significantly larger samples. The results are encouraging, and a more detailed series of tests will be performed on large meteorites with well-known bulk compositions, before extensive application to new meteorites. This technique has the potential to become the method of choice for all bulk compositional elemental analysis of new meteorites, particularly those recovered from Antarctica.

Fig. 1: NWA 4590 with black fusion crust.

Acknowledgements

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References

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[2] Shirai, N., *et al.*, Lunar & Planetary Sci. Conf. XL, #2170 (2009).