

ZAGAMI: TRACE ELEMENT ZONING OF PYROXENES BY SYNCHROTRON X-RAY (SXRF) MICROPROBE, AND IMPLICATIONS FOR ROCK GENESIS. A.H. Treiman* and S.R. Sutton#. *SN-2, NASA/JSC Houston, TX 77058 and Cosmochemistry Research Associates, Inc., Southboro MA 01772. #Department of Geophysical Sciences and Consortium for Advanced Radiation Sources, University of Chicago, Chicago IL 60637, and Department of Applied Science, Brookhaven National Laboratory, Upton NY 11973.

Pyroxenes in the Zagami shergottite are chemically zoned [1,2], potentially providing a record of magmatic processes in Zagami's genesis. Zoning of Ni, Cu, Zn, and Ga contents was investigated by SXRF microprobe. Most pyroxenes have normally zoned rims and reversely zoned cores; maximum Ni contents are in an intermediate zone. This pattern is consistent with initial growth of skeletal or 'soda-straw' pyroxenes, subsequently overgrown and infilled. The highest Ni abundances in pigeonite, ~200 ppm, suggest that Zagami's parental magma contained ~30-40 ppm Ni, and that Zagami contains <25% cumulus pyroxene.

ANALYTICAL TECHNIQUES: Thin sections of coarse and fine-grained lithologies, mounted on pure silica glass, were used in these analyses. Chosen pyroxene grains had {100} cleavage traces at 90°, i.e. had their c axes and elongations perpendicular to the section plane. Analytical traverses for major and minor elements were by electron microprobe, wavelength dispersive mode. Analyses for trace elements were obtained along approximately the same traverses with the X-ray microprobe, beam line X26A, at the National Synchrotron Light Source, Brookhaven National Laboratory. The beam of synchrotron X-rays was collimated to 10 micrometers diameter. The thin sections were oriented at 45° to the incident beam, and fluoresced X-rays were collected with a Si(Li) energy dispersive detector at 90° to the incident beam. X-ray collection times were 10-30 minutes per spot. In some cases, the thin section had to be repositioned to eliminate interference from diffracted X-rays. On collected spectra, background was estimated by a polynomial fit, and areas for specific X-ray peaks calculated with a peak-stripping routine. In pigeonite, X-ray K α and β peaks for Ni, Cu, Zn, and Ga were above background. Elemental concentrations were calculated from peak areas and known relative fluorescence yields, referenced to Fe abundances from EMP [3,4]. Analytical precision (counting statistics) ranges from a few % to 20%. Accuracy is $\pm 20\%$ because of uncertainties in fluorescence yields and inexact registry between the activation volumes in EMP and SXRF.

RESULTS: Abundances of Fe and Ni across a pigeonite grain are shown in Fig. 1. Antithetical behavior of Fe and Ni is expected in a crystal growing from a silicate melt, as Ni is compatible and Fe is incompatible. A point with aberrant Ni (330 ppm, Fig. 1) and Cu likely represents a grain of Ni-rich sulfide included in the analysis volume. Abundance patterns for Cu (1-19 ppm) and Ga (1-9 ppm) generally follow that of Fe, suggesting that they are incompatible in pigeonite. Abundances of Zn in this pigeonite are essentially constant at 60-70 ppm. Patterns in other analyzed pigeonite and augite grains are similar, except that Zn concentrations are greater at rims than cores; the reason for this difference is unknown.

INTERPRETATION: The abundance patterns of the Figure are not consistent with crystal growth along plane exterior fronts at surface equilibrium: compatible/incompatible element abundance ratios decreasing linearly as the cube of distance from the core [5]. The crystal rims follow this relation, but the cores are reversely zoned. If the regions of highest Ni (and Mg) were the earliest, then the pyroxenes may have grown initially in skeletal, 'soda-straw', or 'hopper' shapes. Skeletal growth is consistent with presence of magmatic inclusions in the pyroxene [6], and Fe-enriched pyroxene around the inclusions.

The Ni content of Zagami's parental melt and the proportion of cumulus phases can be constrained by the abundances of Ni in the pyroxenes. The maximum Ni contents of augite and pigeonite are ~200 ppm, the volume-weighted core averages ~180 ppm. With

$NiD_{\text{pig/liq}} = 5-7$ calculated from [7], the highest Ni in pigeonite implies Zagami's parental melt had 28-40 ppm Ni. Zagami's bulk Ni content is ~60 ppm [1,8], consistent with the inference that Zagami is enriched in crystals over melt [1,2]. Ni mass balance suggests that Zagami contained 12.5-18% cumulus pyroxene of the highest Ni content, or 14-21% cumulus pyroxene of core average composition. If $NiD_{\text{px/liq}} = 3.3$, the melt would contain 60 ppm Ni, and Zagami would contain no cumulus pyroxene; if $NiD_{\text{px/liq}} = 15$, the melt would contain 13 ppm Ni and Zagami would contain 28% cumulus pyroxene. If our Ni analyses are 20% too high, Zagami could contain up to 29% cumulus pyroxene (of core composition). These estimates are below the 45% cumulus pyroxene inferred from melting experiments [1]; the source of discrepancy is not clear.

These chemical and textural data suggest a history in which Zagami's parental magma contained ~30-40 ppm Ni and was slightly enriched, <25% by mass, in skeletal (i.e. 'hopper' or 'soda-straw') shaped pyroxenes. These pyroxenes grew outward and inward, producing normally zoned overgrowths and reversely zoned interiors. Most of the magma in the cores of crystals was in physical communication with the bulk magma, and so could flow out of the cores as the pyroxenes grow. Pockets of melt trapped among the skeletal arms or in core became the magmatic inclusions [6] surrounded by Fe-enriched pyroxene.

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[1] Stolper & McSween (1979) G.C.A. 43, 1475. [2] Smith & Hervig (1979) Meteoritics 14, 121. [3] Hanson et al. (1987) Nucl. Instrum. Methods B24/25, 400. [4] Lu et al (1989) Chem. Geol. 75, 123. [5] Pearce (1987) Contrib. Mineral. Petrol. 97, 451. [6] Treiman (1985) Meteoritics 20, 229. [7] Colson et al. (1988) G.C.A. 52, 539-553. [8] Smith et al. (1984) Proc. L.P.S.C. 14th, B612.

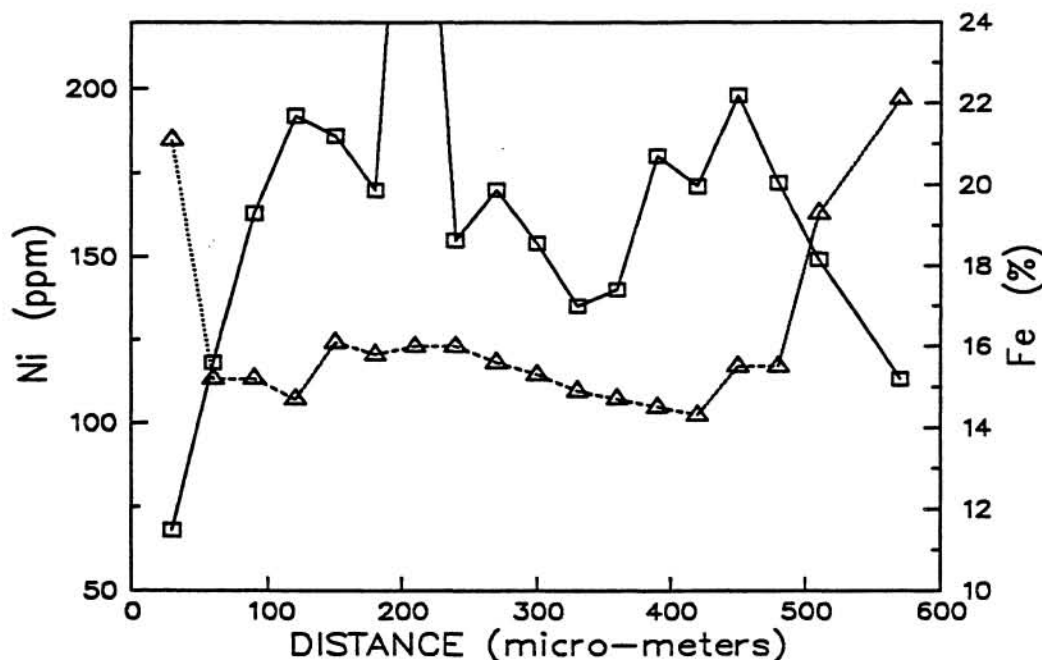


Figure 1. Analytical traverse across pigeonite 999A. Ni (ppm, squares) by SXRF; Fe (triangles, %) interpolated from EMP data. Ni datum off scale (330 ppm) is associated with excess Cu and significant Rb, and likely represents a sulfide grain in a magmatic inclusion (vis [6]).