FRESH MELT INCLUSIONS IN 3.3 GA KOMATIITIC OLIVINES FROM THE BARBERTON GREENSTONE BELT, SOUTH AFRICA. M. E. Thompson[1] and K. M. Kareem[1], X. Xie[1], and G. R. Byerly[1]
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Introduction: Studies of komatiitic lavas continue to play a significant role in refining our understanding of early planetary tectonism, and thermal and compositional structure of the crust-mantle. Komatiites further represent a major lithologic component of the primitive landscapes which fostered early life on Earth, and may have played a significant part in modification of early atmospheric and hydrospheric compositions. The antiquity of nearly all komatiitic sequences typically result in diagenetic, metamorphic and tectonic modification which often include severe hydration and other chemical and mineralogical changes, and make petrologic interpretations of original igneous processes difficult. In this report we present data on several unusually fresh komatiitic flows, including compositions of fresh olivines and melt inclusions, as well as preliminary modeling of fractionation processes.

Background: The Barberton Greenstone Belt (BGB) consists of a complex suite of metavolcanic and metasedimentary rocks ranging in age from about 3.6 to 3.2 Ga [1,2]. Komatiitic lavas are found throughout the first 300 Ma of the sequence, including the 3.3 Ga Weltevreden Formation -- a 1-2 km thick stratigraphic unit of flows, each 10-500m thick, as well as significant accumulations of komatiitic tuffs. The contact between the Weltevreden and overlying Fig Tree felsic metasediments contains the S3 impact layer and represents a major tectonic break between plume and arc tectonic regimes.

Komatiites of the Weltevreden Formation differ significantly from others in the Barberton Greenstone Belt in several respects. They often occur as unusually thick layered ultramafic complexes that are internally fractionated to lithologies ranging from dunites to pyroxenites and gabbros [3]. Chemically they belong to the group of komatiites characterized as alumina-undepleted, and have near chondritic elemental ratios and abundances. They are also the freshest komatiites found in the Barberton Greenstone Belt [4].

Petrography of Inclusions. Fresh melt inclusions are recognized based on their isotropic behavior in polarized light, and transparent, pale-colored and homogeneous appearance in plain light (Fig. 1). They occur only within the interior of fresh olivine phenocrysts in the cumulate portions of komatiitic lava flows. Many more inclusions occur within these olivines, and within serpentinized olivines in both spinifex and cumulate portions of the flows, but these inclusions are now represented by fine chloritic material. The inclusions range in diameter from 5-50 microns, but are commonly about 10-15 microns. Many, but not all, inclusions contain a small, fluid-filled contraction bubble, usually about 25% of the diameter of the melt inclusion, and a small proportion of the inclusions contain daughter crystals of chromite and/or augite (Fig. 2). The chromite occurs as micron-sized, honey-brown skeletal octahedra within the inclusions. The augite typically occurs as saw-toothed crystals epitaxially growing from the olivine wall of the inclusion, usually as a single optically coherent crystal. Rarely, the augite occurs as a feathery dendritic within the inclusion.

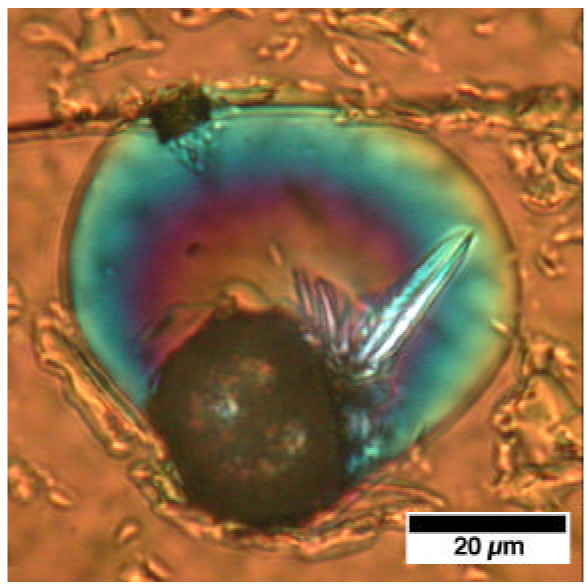

Figure 1a. Photomicrograph of fresh melt inclusion within host olivine taken in polarized light at 400x.

Microchemistry. We have analyzed melt inclusion glasses, adjacent olivine, and included chromite and augite by electron microprobe using natural and synthetic glasses, olivine, pyroxene, and chromite standards, mostly from the Smithsonian Institute collection of standard materials. Glass analyses were done with a beam defocused to just under the diameter of the melt inclusion, and avoiding daughter crystals and contraction bubbles. Table 1 provides examples of compositions of olivine, augite, and glass. A preliminary examination of the glass compositions suggests that these are simply trapped melts that have been little modified by processes other than fractional crystallization of the host olivine from the original komatiitic liquid. Some inclusions have been further modified by crystallization of augite. Zoning within the host olivine crystal is typically a steep, 10-15 micron wide, zone of Fe-enrichment from cores of Mg#95 to Mg#90.

Table 1. Components of Weltevreden Komatiite

	Olivine	Augite	Spinifex	Glass	Orig. Liquid
SiO2	41.60	48.20	46.15	67.10	47.20
Al2O3	0.07	9.24	4.62	16.07	4.61
FeO	4.55	3.21	8.58	1.17	8.30
MgO	53.80	13.83	34.90	1.68	34.81
CaO	0.15	23.34	4.75	12.69	3.73
Na2O	0.00	0.12	0.04	1.33	0.41
K2O	0.00	0.00	0.04	0.07	0.02
TiO2	0.00	0.65	0.14	0.44	0.14
Cr2O3	0.23	0.30	0.41	0.09	0.41
NiO	0.48	0.16	0.24	0.05	0.24
MnO	0.07	0.05	0.14	0.03	0.14
Total	100.95	99.10	100.00	100.72	100.00

Modeling: We have used MELTS to model the fractional crystallization of trapped komatiitic liquids represented by these inclusions. Mass balance calculations suggest that the iron enrichment found in the adjacent olivine host crystal is sufficient to account for the fractionation found in the melt inclusion. About 70% Rayleigh fractionation is needed to modify trapped komatiitic liquid to the felsic liquid represented by the melt inclusions. The best results are obtained by forcing only olivine to crystal, bypassing spinel, orthopyroxene, augite, and feldspar crystallization down to 850C from the komatiitic liquidus at 1660C. This process is apparently permissible because of the rapid quenching of the komatiitic flow, and the difficulty in nucleating additional phases within the trapped liquid. Inclusions which have augite daughter crystals do display further compositional variation consistent with augite fractionation.

Discussion: The inclusions we report here are very similar to those reported from another remarkably fresh sequence of komatiitic flows in the 2.7 Ga Belingwe Greenstone Belt of Zimbabwa [5]. Both sets of melt inclusions are characterized by glasses of felsic composition: silica (to 67% ox.wt.), alumina (to 16% ox.wt.); and augites within extremely high alumina (to 10% ox.wt.) and lime (to 23% ox.wt.) contents. Extreme fractionation of olivine accounts for these observations. These inclusions also have oxide totals close to 100%, and though we have not yet directly measured H2O, it is likely that it is an very minor oxide in these komatiitic melts (discussion of H2O in komatiites in [6]).

The results from using MELTS also allow use to back-model the starting composition of highly mobile elements in the komatiite liquid. The komatiitic liquid in equilibrium with olivine Fo96 has 0.41% Na2O, 0.02% K2O, and 3.73% CaO. Because of the mobility of these elements during even minor flow-seawater alteration, we believe these are much better estimates of the original composition of the Weltevreden komatiites. We are currently obtaining trace element compositions on these inclusions.

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References:

[1] Byerly G. R. et al. (1996) Precamb. Res. 78, 125-138. [2] Lowe D. R. and Byerly G. R. (1999) GSA Spec. Paper 329, 319p. [3] Anhaeusser C. R. (1985) GAC Spec. Paper 28, 281-303. [4] Kareem K. M. and Byerly G. R. (2001) GSA Annual Mtg. [5] McDonough W. F. and Ireland T. R. (1993) Nature, 365, 432-434. [6] Arndt N. et al. (1998) Geology 26, 739-742.