**Petrology and Geochemistry of 3.3 Ga Komatiites– Weltevreden Formation, Barberton Greenstone Belt.**
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**Introduction:** Komatiites provide several ways of assessing the chemical and thermal evolution of the mantle. Komatiitic liquids are produced from very high degrees of partial melting of the deep mantle, and erupted as extremely fluid lavas. Komatiites are important in the study of the early Earth because they are a significant constituent of the Archean crust. It has been proposed that komatiitic liquids are also an important component of volcanism on Io. On Earth they are found almost entirely within the first two billion years of the geologic record -- the Archean. In this study we present petrographic and geochemical data on an unusually fresh sequence of these rocks, as well as a predicted fractional crystallization model which accounts for several critical observed traits of these flows.

**Background:** The Barberton Greenstone Belt (BGB) was formed during the period ~3.6 – 3.2 Ga. It consists of three stratigraphic groups, the 3.6-3.3 Ga Onverwacht Group which contains a number of komatiitic sequences, the 3.3-3.2 Ga Fig Tree Group of arc-related volcanics and sediments, and the 3.2 Ga Moodies Group [1].

The 3.3 Ga Weltevreden Formation is located in the northern facies of the BGB (north of the Inyoka Fault), is about 180 Ma younger than the Komati Formation, and correlative with the Mendon Formation, both in the southern facies. The Weltevreden and Mendon Formations lie conformably beneath basal rocks of the Fig Tree Group. The thickness of the Weltevreden is unknown because the base is not exposed, but many hundreds and possibly a few thousand meters of section are present, with individual flow units being 10-500m [1].

**Petrography:** Thinner komatiitic flows of the Weltevreden Formation, the subject of this report, are compositionally layered into random spinifex, oriented spinifex, and peridotite lithologies. The spinifex layers consist of acicular olivine, with chromite, orthopyroxene, pigeonite, and augite (Figure 1a). Pyroxene consists of fine acicular orthopyroxene cores with pigeonite and augite rims. Pyroxene also displays dendritic-barred textures. Augite also occurs as fine discrete crystals. Chromite occurs as equant and cruciform morphologies. The peridotite layers consist of fresh equant olivine phenocrysts with serpentinized rims and veins, discrete augite, fine acicular orthopyroxene crystals rimmed with clinopyroxene and equant and cruciform chromite (Figure 1b).

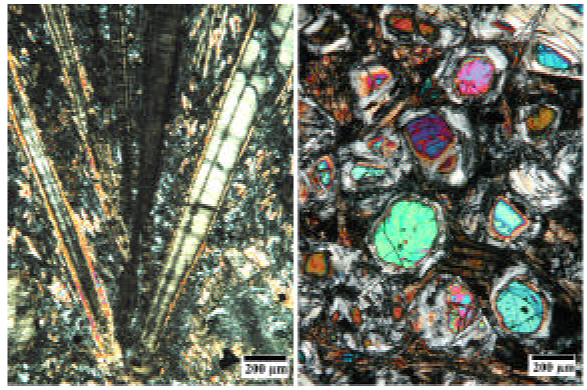

Figure 1. (a) Random spinifex composed of olivine, now serpentine, and fresh orthopyroxene rimmed by augite. (b). Peridotite composed of olivine phenocrysts and intersertal orthopyroxene. Both photomicrographs taken in crossed-polarized light.

**Mineral and Rock Chemistry:** These komatiites preserve fresh igneous minerals and glasses (melt inclusions). Microprobe analyses of olivine cores yield Mg # of 94.0 - 95.6 $\pm$ 0.1 [2]. Olivine has $Cr_2O_3$ and NiO up to 0.32 and 0.56 (wt.%), respectively. Chromite has maximum Mg # of 72.3 for cores and decreases to 35.9 for rims. These chromites have Cr # of 80-82.3 for cores that decrease to about 72.0. Orthopyroxene cores have Mg # 91.3 and Wo 0.02 and are zoned to pigeonite compositions with Mg # 87.0 and Wo 0.13. Augite has compositions of Mg # 87.0 and Wo 0.30 to Mg # 75.0 and Wo 0.43.

| | OL | CHR | OPX | PIG | AUG | RAND | ORIENT | PERID |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 41.61 | 0.13 | 55.43 | 54.29 | 53.25 | 46.14 | 48.85 | 46.34 |
| $Al_2O_3$ | 0.05 | 7.41 | 1.26 | 1.63 | 2.91 | 4.61 | 5.52 | 2.81 |
| FeO | 4.44 | 15.40 | 5.96 | 7.84 | 5.71 | 8.58 | 9.22 | 6.17 |
| MgO | 53.72 | 13.68 | 33.92 | 27.66 | 21.24 | 34.89 | 30.42 | 42.25 |
| CaO | 0.13 | 0.00 | 1.51 | 7.06 | 16.94 | 4.75 | 4.81 | 1.52 |
| $Na_2O$ | 0.00 | 0.00 | 0.02 | 0.02 | 0.07 | 0.04 | 0.05 | 0.02 |
| $K_2O$ | 0.01 | 0.02 | 0.01 | 0.00 | 0.02 | 0.04 | 0.13 | 0.06 |
| $TiO_2$ | 0.00 | 0.11 | 0.03 | 0.10 | 0.18 | 0.14 | 0.17 | 0.09 |
| MnO | 0.08 | 0.09 | 0.18 | 0.24 | 0.19 | 0.14 | 0.15 | 0.08 |
| NiO | 0.47 | 0.13 | 0.12 | 0.05 | 0.08 | 0.23 | 0.18 | 0.34 |
| $Cr_2O_3$ | 0.16 | 63.03 | 1.04 | 0.85 | 0.09 | 0.45 | 0.52 | 0.33 |
| Total | 100.66 | 99.99 | 99.48 | 99.74 | 100.69 | 100.00 | 100.00 | 100.00 |

Table 1. Representative mineral and bulk rock compositions for Weltevreden komatiites. OL: olivine, CHR: chromite, OPX: orthopyroxene, PIG: pigeonite, AUG: augite, RAND: random spinifex, ORIENT: oriented spinifex, PERID: peridotite

Bulk analyses show that these rocks are very magnesian, with MgO 30.99-45.85 wt.%. When plotted against MgO wt.%, the majority of analytical data fall on an olivine control line that intersects the MgO axis at 54 wt% - suggesting equilibrium with olivine of Mg # 96 (Figure 2). This compares well with the observed olivine of Mg # 95.6.

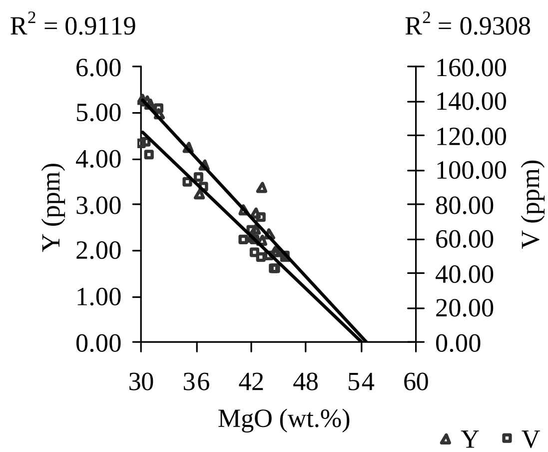


Figure 2. Graph of MgO vs. Y and V for bulk rock compositions of the Weltevreden komatiites.

**Predicted Crystallization Sequence:** MELTS predicts the 1 atm onset of olivine crystallization at 1660°C with Mg # 96.5 and ending at 1360°C with Mg# 90.1 (Figure 3) [2]. Chromite crystallization begins at 1580°C with a Cr # of 69.6. Orthopyroxene crystallization begins at 1360°C with Mg # 89.6, when it replaces olivine on the liquidus, and ends at 1240°C when it is relaced on the liquidus by pigeonite and augite, with Mg # 78.5 and 79.9, respectively. Plagioclase begins crystallization at 1200C.

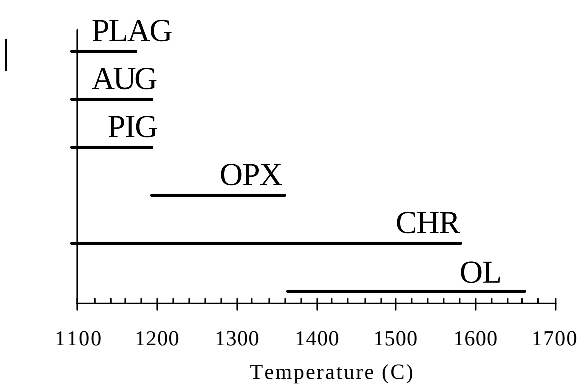


Figure 3. Phase crystallization ranges calculated by MELTS. Fractional crystallization is modeled at 1 atm and $fO_2$ of Ni-NiO.

**Discussion**: The komatiites of the Weltevreden are extremely fresh, preserving original igneous textures, and bulk rock and mineral chemistry. The spinifex, dendritic and skeletal morphologies that the constituent minerals display are consistent with formation during the quench of high temperature liquids.

These olivines are the most magnesian reported for komatiites. Although all komatiites are altered to some degree, the MgO variation plot shows that the bulk rock composition are in equilibrium with the observed microprobe data. The high MgO and $Cr_2O_3$ content of these olivines suggest that they were erupted at extremely high temperature, from a very Mg-rich parent.

Previous studies have demonstrated that the MgO content of an erupting liquid is related to its MgO content. Using the empirical relationship $T_{liquidus}$ = 1400 + [MgO% - 20) x 20] $^{o}$C [3] and the MgO content of the random spinifex layer, an eruption temperature of 1700°C is calculated. The random spinifex layer composition is used because previous studies have shown that the random spinifex and chill zone are similar to the composition of the parental melt. MELTS predicts a liquidus temperature of 1660°C. These comparable calculated eruption temperatures are higher than those reported from previous work on komatiites.

Overall, there is a good correlation between observed mineral and rock compositions and predicted values from MELTS. However, the observed chromite compositions are more Cr-rich and less Mg-rich than the chromite compositions that MELTS calculates. This variation in Cr # and Mg # in chromites may be due to subsolidus re-equilibration. The observed Mg numbers for orthopyroxene, pigeonite, and augite are slightly higher than the compositions from MELTS. In addition, the plagioclase crystallization MELTS predicts is not observed in the Weltevreden komatiites.

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**References**:[1] Lowe, D. R. and Byerly, G. R., (1999). GSA Special Paper 329, 319p. [2] Kareem, K. M. and Byerly G. R. (2002) *GSA Abstracts with Programs* Abstract # 162-9. [3] Nisbet, E. G. (1982) in Komatiites, 501-520.