EQUATION OF STATE OF ILMENITE AT LUNAR PRESSURES AND TEMPERATURES. E. J. Tronche[1], B. Chen[2], L. Gao[2], M. van Kan[1], K. Leinenweber[4], J. Li[2], T. Sanehira[3], Y. Wang[3] and W. van Westrenen[1], [1]Faculty of Earth and Life Sciences, VU University Amsterdam, The Netherlands, e-mail elodie.tronche@falw.vu.nl, [2]Department of Geology, University of Illinois at Urbana-Champaign, USA, [3] Center for Advanced Radiation Sources, University of Chicago, IL, USA, [4]Department of Chemistry, Arizona state University, AZ, USA

Introduction: Ilmenite (nominally $FeTiO_3$) is a crucial phase in the thermal and magmatic evolution of the Moon. The gravitational instability induced by the formation of ilmenite-rich cumulates towards the end of the crystallization sequence of a global lunar magma ocean [1], is thought to be the main driving force for a large-scale mantle overturn that formed the prelude to mare basalt generation [2]. In addition, the Ti-rich nature of many of these basalts is thought to be related to the dissolution of pre-existing ilmenites during ascent towards the surface [3].

To better constrain thermo-chemical convection models of these processes, physical properties of the phases involved (both minerals and melts) need to be known with sufficient accuracy.

In parallel to our study of the density of lunar magma presented elsewhere [4], we have started an experimental program to constrain the equation of state of key lunar minerals. Here, we present the results of an *in situ* X-ray diffraction study of the equation of state of a natural terrestrial ilmenite, performed at the Advanced Photon Source (APS, Illinois, USA) in November 2007. To date, the unit cell volume of ilmenite has only been determined at either high pressure or high temperature [5]. The absence of data at simultaneous high pressure and temperature prevents the construction of an accurate equation of state. In addition, effects of chemical composition (e.g., Al, Cr, MgO, and trivalent iron content) on unit cell volumes are unknown.

Sample Material and Experimental Methods: The starting material was a large (6mm diameter) homogeneous ilmenite clast from the Jagersfontein Mine, South Africa. The major element composition of the sample, obtained by electron microprobe analyses done at VU University Amsterdam, is given in Table 1. Compared to the full range of ilmenite compositions found in kimberlites this sample is relatively rich in Al and poor in Cr. The clast contains very few small (~1 micron in diameter) Ti-rich inclusions along grain boundaries, which do not affect subsequent high-pressure experimental results. The high pressure experiments were performed at the GSE-CARS beamline 13-ID-D of the APS, in a 1000 ton multi-anvil press, using the COMPRES 10/5 assembly. The rhenium furnace in this assembly is fitted with a window to allow incident and diffracted x-rays to pass the assembly without significant attenuation. [http://multianvil.asu.edu/COMPRES_cell/ COMPRES_cell_Main.htm].

	Before experiment	After experiment
SiO_2	0.06±0.07	0.17 ±0.26
TiO_2	48.41 ±0.1	48.93±0.5
Nb_2O_5	0.15 ±0.01	N/A
Al_2O_3	0.67 ±0.07	0.59 ±0.07
Cr_2O_3	0.02 ±0.01	0.00 ±0.00
FeO	41.83 ±0.32	41.89 ±1.09
MnO	0.19 ±0.01	0.18 ±0.02
MgO	7.90 ±0.08	7.72 ±0.46
NiO	0.03 ±0.01	N/A
CaO	0.02 ±0.01	0.03 ±0.02
Total	99.28	99.5

Table 1: Chemical composition of the ilmenite sample before, and after the high-pressure experiment, obtained using an electron microprobe.

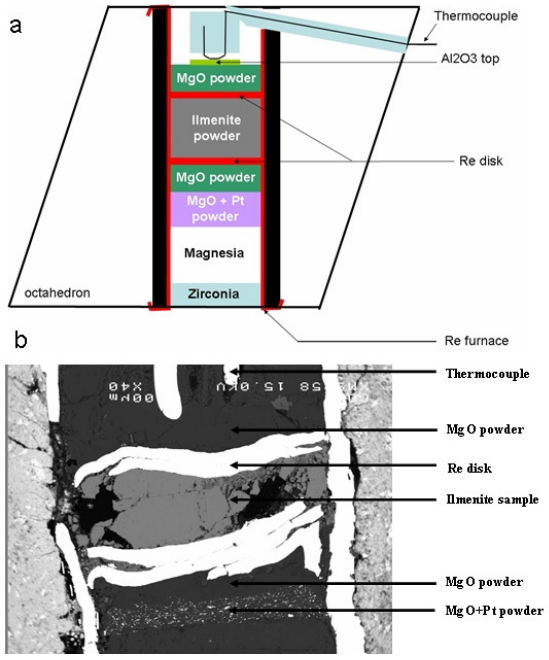

Figure 1a: COMPRES 10/5 multi-anvil assembly used for those experiments. Figure 1b: SEM picture of a polished section of the assembly after the experiments. Sample thickness after the experiment is approximately 0.6 mm.

Details of the cell assembly are shown in Figure 1a. Finely ground ilmenite powder was packed between rhenium disks to minimize sample oxidation during the experiment [6]. Two pressure calibration materials were used: MgO (packed below the Al2O3 disk and also against the 'bottom' side of the lower Re disks) and Pt (mixed with MgO at a distance of approximately 0.3 micron of the lower Re disk).

After increasing pressure to ~ 1.3GPa, temperature was slowly increased up to 1273 K. Sample diffraction patterns were collected at 1273 K, and at 200 K intervals during subsequent cooling. After reaching room temperature, pressure was further increased to ~3.1GPa, temperature was increased to 1273 K, and again, diffraction patterns were obtained during the cooling, every 200K, until room temperature. A final diffraction pattern was taken after decompression at room conditions.

Results: Microprobe analyses were repeated on the recovered run product (Fig. 1b). Results, shown in Table 1, show that the chemical composition of the sample stayed the same within error. No significant chemical reaction with parts in the assembly appears to have occurred, and the trivalent iron content of the sample has not changed. Some small areas on the edge of the experimental charge have larger MgO content than the bulk of the sample (up to 8.6 wt% MgO), probably because the Re disks did not cover the entire surface, so that MgO was transported from the calibration layer to the sample area. All in-situ diffraction patterns were taken in the center of the charge, avoiding contaminated areas.

Raw diffraction patterns of ilmenite show consistent variations with pressure and temperature (figure 2a, b): peaks shift to lower energy (i.e. toward bigger unit cell volume) at increasing temperature and constant pressure, and when pressure is decreased at constant temperature. Precise unit cell refinements are in progress. During this conference we will present these new measurements and the resulting equation of state for ilmenite suitable for application to lunar pressure and temperature conditions.

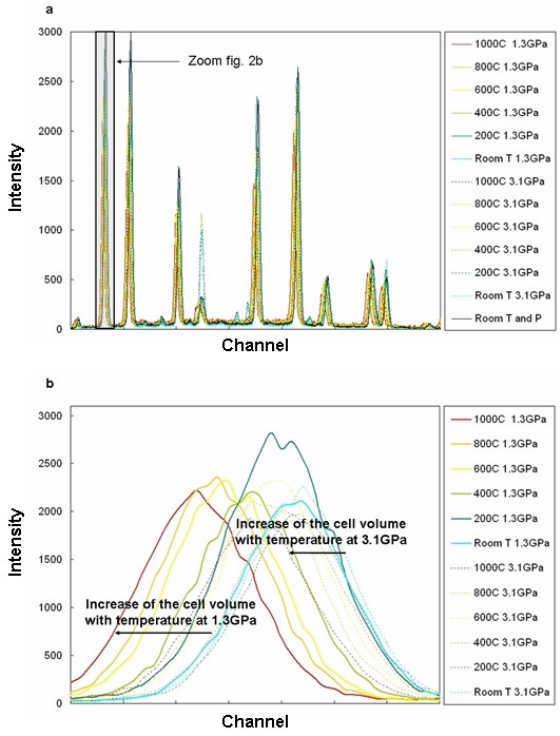

Figure 2a: X-ray diffraction patterns for ilmenite at different pressures and temperatures; horizontal axis is channel numbers in the multichannel analyzer (MCA; the channel numbers are directly proportional to photon energy of the x-rays), vertical axis is intensity (in arb. Unit). Figure 2b shows a detailed view of one of the ilmenite peaks. The different colors represent different conditions.

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