LINGUNITE DISCOVERY IN DOLERITIC ROCK OF THE LOCKNE IMPACT CRATER, SWEDEN: EVIDENCE OF IMPACT ENERGY LOCALIZATION AT HETEROGENEOUS MINERAL INTERFACES.

B. Reznik[1], A. Kontny[1] and A. Agarwal[2], [1]Division of Structural Geology and Tectonophysics, Institute of Applied Geosciences, Karlsruhe Institute of Technology, Germany (boris.reznik@kit.edu), [2]Department of Earth Sciences, Indian Institute of Technology, Roorkee, Uttarakhand, India.

Introduction: Plagioclase is a major constituent mineral of the earth's crust and stony meteorites. Shock-induced high-pressure transformations of plagioclase have been documented in meteorites [1,2] or reproduced experimentally in static experiments [3,4]. Lingunite is a high P-T plagioclase polymorph but with tetragonal crystal symmetry similar to that of hollandite [3,4]. Even though more than 200 impact structures are known on earth, many with feldspar bearing target rocks and frequently showing shock pressures over 20 GPa, there is only one report on hollandite in a target rock of the Manicougan impact crater [5].

In this study, shock induced transformation of plagioclase into lingunite nanocrystals and amorphous plagioclase (labradorite) is identified along interfaces between augite and labradorite in doleritic target rock of the 455 Ma old Lockne impact crater, Sweden.

Materials and petrological observations: Samples were collected from moderately shocked rocks at distances between 4 to 10 km from the crater centre, where shock pressure and temperature (P-T) ranges between 0.1 to 3 GPa and 0 to 127° C, respectively, have been calculated [6].

Optical observations of dolerites revealed a peculiar microstructures appearing as alternating augite-labradorite lamellae (Fig.1). The closely spaced interfaces in the lamellae provide an interesting opportunity to verify if the propagation of shock waves across interfaces results in local stress concentration and phase transformations.

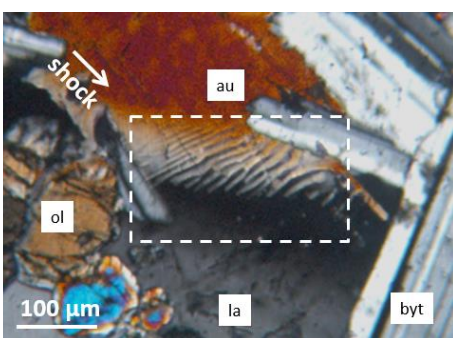

Fig. 1 Polarized light micrograph of dolerite containg augite (au), labradorite (la) olivine (ol) and bytownite (byt) minerals as well as peculiar alternating au-la lamellae (dashed area).

Interfacial analysis: First, the interfaces were probed by Raman spectroscopy using a Bruker SENTERRA spectrometer. The spectra from bulk labradorite and augite minerals (Fig.2) are comparable to the labradorite and augite spectra in literature [7,8] and are in good agreement with our petrological results (Fig. 1).

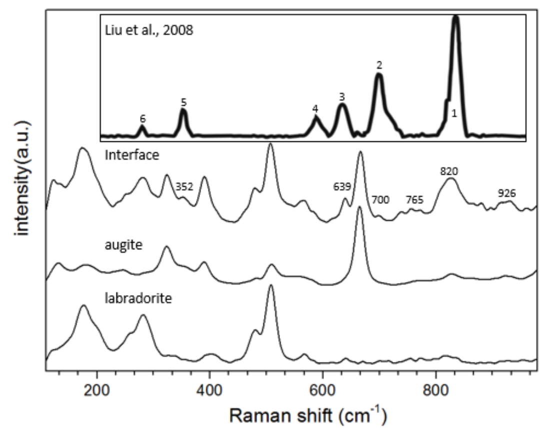

Fig. 2 Raman spectra from augite-labradorite lamellae interface, augite and labradorite bulk minerals. Inset: Raman spectrum of lingunite at in- situ pressure of 19 GPa from Liu et al. [4].

The spectrum from the augite-labradorite lamellae interface shows active bands corresponding to labradorite and augite as well as additional bands at 926, 820, 765, 700, 639 and 352 cm^{-1}. The intense 820 cm^{-1} and weak 700, 639 and 352 cm^{-1} bands are unique and neither characteristic of augite nor labradorite. However, these bands compare well with the lingunite spectra reported by Liu et al. [4].

Further interfacial investigations were done at the nm-scale using a Philips CM 200 FEG/ST transmission electron microscope. At the labradorite - augite lamella interface, well-ordered augite crystal boarded with randomly oriented, nanocrystals embedded in an amorphous matrix are observed (Fig.3). The inset in this figure is a fast fourier diffractogram showing round-shaped Debye-Scherrer rings superimposed with a diffuse halo.

The diffuse halo corresponds to the formation of amorphous plagioclase while the diffraction positions of the rings can be assigned to lingunite [1,3,4,5].

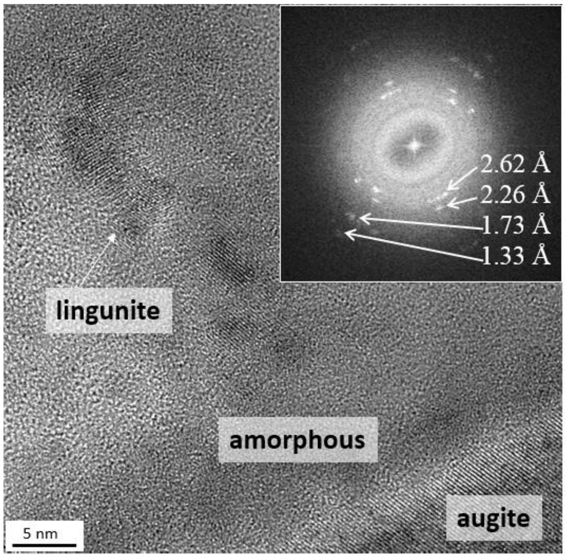

Fig. 3 Augite-labradorite interface analyzed by high-resolution transmission electron microscopy. Lingunite nanocrystals are embedded in amorphous matrix contacting with well-crystallized augite. Inset: diffractogram showing characteristic interplanar distances of lingunite.

Conclusions: The presence of lingunite nanocrystals embedded into amorphous matrix at labradorite-augite interfaces suggest a shock-induced melt. From experimental studies it is known that lingunite forms at P-T over 19 GPa and 1000°C [6], therefore its occurrence (Figs.2,3) implies the formation of nano-scale regions where the local shock P-T spikes were up to 10 times higher than expected [9]. This is the first report on high P-T phase transitions of plagioclase into lingunite at heterogeneous mineral interfaces in a terrestrial rock.

Acknowledgements: Deutscher Akademischer Austauschdienst, Germany (DAAD) is thanked for the financial support of AA. TEM investigations were funded from DFG project KO1514-8-54.

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