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Formation of nanoscopic Lingunite and alternating augite-plagioclase wedges at Lockne impact crater, Sweden

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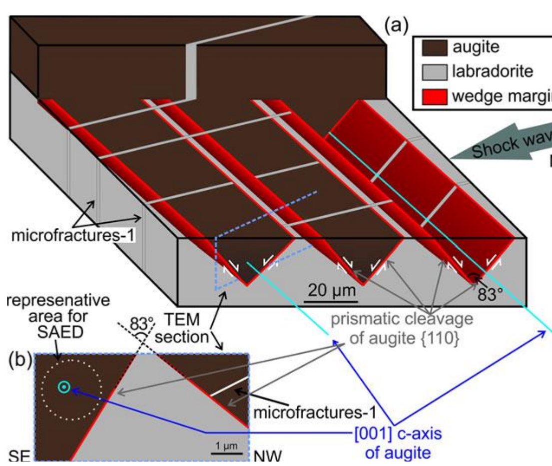
Abstract

The study reports peculiar alternating augite-plagioclase wedges, Lingunite nanocrystals and amorphous plagioclase (maskelynite) in basement dolerites of Lockne impact structure, Sweden. Classical optical microscopy is coupled with spectroscopy and high resolution electron microscopy. The results reveal that the wedges develop from the {110} prismatic cleavage of augite, as they are filled with molten labradorite pushed from the neighboring bulk labradorite grain. The occurrence of lingunite suggests that the local pressure was above 19 GPa and the local temperature overwhelmed 1000 °C. These values are up to 10 times higher than previous values estimated numerically for bulk pressure and temperature.

1. Introduction

This study investigates wedges developed at the augite-plagioclase grain boundary in the doleritic in situ basement rocks of the Lockne impact structure, Sweden. The combined microscopic and spectroscopic studies of the micro/nanoscale wedges reveal that these are deformation-induced features. Further investigations lead to identification of Lingunite nanocrystals and amorphous plagioclase (maskelynite) at the wedge boundaries. The samples showing wedges, 12 out of 18 studied, are distributed in the impact structure within a radius of up to 10 km from the crater center. The margins between the augite and labradorite wedges are sharp and the {110} prismatic cleavage of augite develops into fractures and thereafter into wedges. The fractures are filled with molten labradorite pushed from the neighboring bulk labradorite grain. Compared to the bulk labradorite, the dislocation density and the residual strain in the labradorite wedges are significantly higher. Furthermore, the occurrence of lingunite suggests that the local pressure was above 19 GPa and the local temperature overwhelmed 1000 °C. High shock-induced temperatures are manifested by maskelynite injections into microfractures in augite located next to the wedges. We discuss a possible model of shock heterogeneity at mineral interfaces, which formed the wedges and may lead to longer duration of the same shock pressure and a concentration of high temperature thus triggering the kinetics of labradorite transformation into lingunite and maskelynite.

2. Figures



Schematics of the wedges and crystallographic features of augite. The microfractures-1, the {110} prismatic cleavage developing into planar fractures, and the c-axis [001] of augite are shown. The blue dashed line represents orientation and position of the TEM section. Note that the figure reconstructs the geometry of the wedges at the augite-labradorite grain boundary. In nature, augite covers the entire wedges. However, if the figure shows a complete augite grain, it would be impossible to visualize the microstructure of the wedges. Therefore, for proper visualization of the wedges, augite is shown only as a thin layer and is not covering the wedges [1].

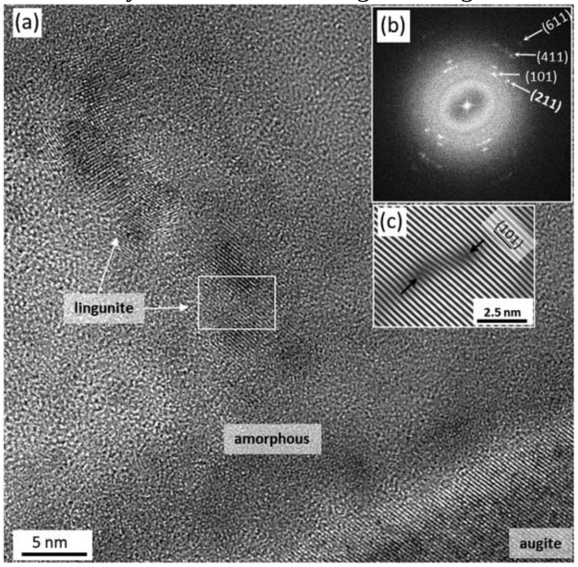


Figure 2: HRTEM analysis of the augite-labradorite wedge interface. (a) Well-crystallized augite (rightdown)and amorphous matrix containing lingunite nanocrystals. (b) FFT pattern from a lingunite area. Numbers indicate indices of Bragg reflection planes. (c) IFFT pattern of the area in the white frame displaying two edge dislocations (s. black arrows) in {101} planes[2].

3. Summary and Conclusions

The shock waves caused fracturing of the augite grain along its prismatic cleavage planes and motored injection of the melt labradorite into the fractures. We infer that the shock waves may induce deformation structures with complex geometries, such as alternating wedges. Transformation of plagioclase into lingunite is accompanied by amorphization of the plagioclase. It is noteworthy that, even though there are 188 confirmed impact structures on Earth[3], many with feldspar bearing target rocks, there is only one short report on silicate-hollandite in a target rock of the Manicougan impact structure[4]. To our knowledge, transformation of plagioclase into high pressure polymorphs, due to reverberations of shock-wave at heterogeneous mineral interfaces has not been reported so far.

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