The formation of maskelynite in moonstone ((K,Ca,Na)Al $(Si,Al)_3O_8$)

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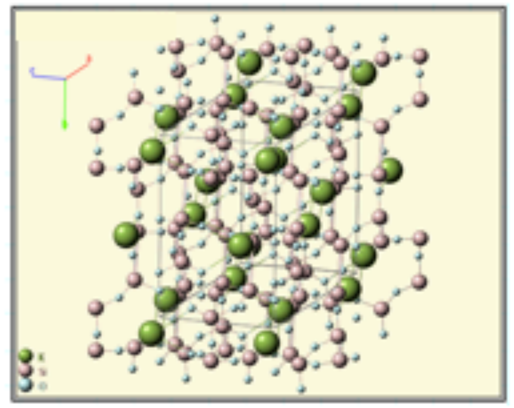
Abstract

Feldspars are aluminosilicate framework structures of low density. Upon static and dynamic compression they transform into denser structures. Lingunite is a crystalline phase of feldspar composition, which is isotypic to hollandite $Ba(Mn^{4+},Mn^{2+})_8O_{16}$ and has a higher density than feldspars. Maskelynite is an amorphous solid (meaning it lacks a crystal structure) that forms in (K,Na,Ca)-aluminosilicates upon shock compression. There is some debate as to how maskelynite is formed. It may be a true glass formed from a quenched melt, or it may be a diaplectic glass formed from a solid-state transformation of $KAlSi_3O_8$-hollandite (a high pressure form of moonstone). To investigate this, discs of moonstone were loaded into a shock gun and shocked to peak pressure of about 18 GPa to form the glass or lingunite. The shocked sample was examined by Synchrotron micro diffraction at beamline 12.2.2, ALS. We found that most of the sample was still feldspar. However, the cell parameters of the shocked feldspar deviate noticeably from those of unshocked feldspar. The cell parameters of shock-recovered sample correspond to static compression of feldspar to between 2 and 3 GPa. This probably reflects residual stresses in the sample, however it may reflect irreversible compression.

Introduction

Feldspars make up about 60% of the Earth's continental crust, and are therefore of great interest to geoscientists. The aim of this project is to study the behavior of feldspar (specifically moonstone) at high pressure, mimicking conditions of terrestrial impacts of larger asteroids such as during the Sudbury- or the Vreedefort impact events. At sufficiently high dynamic pressures, the crystal structure of feldspar collapses and becomes amorphous. This glass is called maskelynite.

The plan is to subject moonstone to high enough dynamic pressures to form maskelynite, and then to re-pressurize the glass in a diamond anvil cell and analyze the pressurized glass by x-ray diffraction. If the glass forms by a solid-state transformation instead of from melt, the glass may loosely retain some of it's former ordered structure, and static pressure may at least partially reestablish lattice periodicity. If the glass forms from a melt, there will be a more complete lack of order and the sample will remain amorphous after static compression.

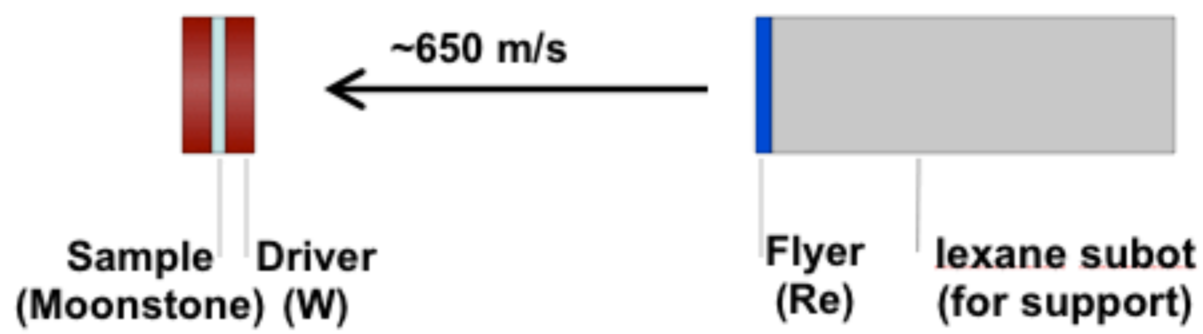


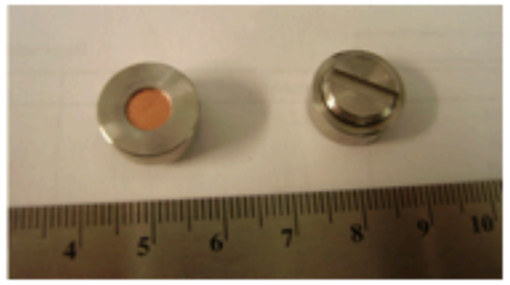
Crystal structure of orthoclase (one of the main constituents of moonstone) at ambient pressure

http://webmineral.com/data/Orthoclase.shtml

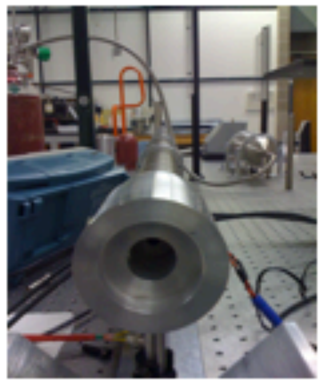
Methods

Moonstone ((K,Ca,Na) Al $(Si,Al)_3O_8$) was used as a representative feldspar. Discs of moonstone were cut from a drilled core, ground down to a thickness of 27-28 μm, then sanded to a diameter of approximately 4 mm. They were then loaded into a shock gun using a tungsten driver and rhenium flyer. The flyer was launched by compressed helium gas to velocities between 500 and 700 m/s.

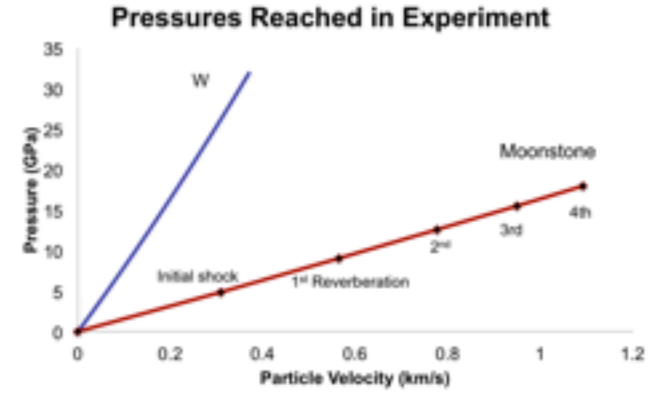




Actual chamber into which sample and driver are loaded into

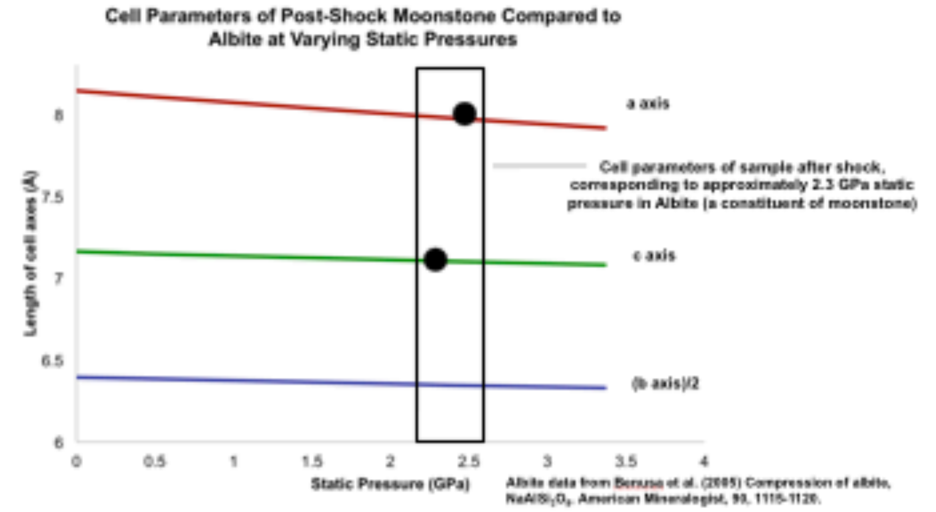


The shock gun: the target (driver and sample) is loaded into one end, and the flyer is launched by gas pressure from the other.



From the thicknesses of flyer, driver and sample and the flyer velocity, the number of shock reverberations within the sample could be found. This information, along with the Hugoniots of both the driver and sample, was used to estimate the peak pressure reached in the sample. Peak pressures were about 18 GPa.

Results



Albite data from Benusa et al. (2005) Compression of albite, $NaAlSi_3O_8$. American Mineralogist, 90, 1115-1120.

From X-ray diffraction data, the crystal structure of moonstone was still present after shock, although some noticeable deformation had occurred.

Conclusion

The moonstone was not shocked to high enough pressures for form maskelynite, probably because of a too low orthoclase component. In the future, thinner discs will be used to induce more shock reverberations (and therefore higher peak pressure). Using samples of powdered moonstone will assume higher temperatures during shock due to the rapid increase in density. This may also aid in maskelynite formation.

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