SHOCK PRESSURE CALIBRATION FOR LUNAR PLAGIOCLASE. J. Fritz[1]*, K. Wünnemann[1], A. Greshake[1], V.A.S.M. Fernandes[2], U. Boettger[3] and U. Hornemann[4] , [1]Museum für Naturkunde, Leibniz-Institut an der Humboldt Universität zu Berlin, Invalidenstr. 43, 10115 Berlin, Germany (*joerg.fritz@mfn-berlin.de), [2]Physics Institute, University of Berne, 3012 Berne, Sidlerstr. 5, 3012 Bern, Switzerland, [3]German Aerospace Center DLR e.V., Institute of Planetary Research, Rutherfordstr. 2, 12489 Berlin Germany, [4]Ernst-Mach-Institut für Kurzzeitdynamik, Fraunhofer Institut, Am Klingenberg 1, 79588 Efringen-Kirchen, Germany.

Introduction: Shock recovery experiments using a Ca-rich plagioclase (An_{94}) were performed in order to extend the shock experimental data set on plagioclase [1] towards the Ca-rich endmember. This aims at: **1)** investigating the mechanisms of shock deformation in silicates; **2)** providing quantitative shock pressure calibration for lunar rocks and Ca-rich plagioclase bearing meteorites; **3)** documenting the Raman spectroscopic changes during shock metamorphism, i.e., for applications in future space missions equipped with Raman instruments.

Material and Methods: A gabbro from Grass Valley, California, USA was experimentally shocked (Table 1) at the Ernst-Mach-Institute, Freiburg (Germany) using the reverberation technique [2,3]. After recovery, the samples were analysed by optical microscopy and Raman spectroscopy using a notch filter-based Dilor LabRam system equipped with a red (632 nm) HeNe laser, and an edge filter based Witec alpha300 R system with a green (532 nm) Nd-YAG laser.

Table 1: Details of shock experiments using TNT (20 GPa) and C4 (24, 28 and 36 GPa) explosives. Shock pressure (P), thickness of driver (D) and cover (C) plate, and time of maximum shock compression (t).

P [GPa]	D [mm]	C [mm]	t [µs]
20	4	5	0.83
24	4	11	0.43
28	4	6.2	0.47
36	3	6.5	0.18

Results: Macroscopically the plagioclase shocked to 20 GPa appears fragmented, white, and lacks any lustre (Fig. 1). In contrast, the samples shocked to 24, 28 and 36 GPa (not shown) were recovered as coherent and lustrous material. This indicates a transition from brittle (20 GPa) to ductile (>20 GPa) behaviour during dynamic shock compression and decompression.

Transmitted light microscopy with crossed polarisers revealed that the plagioclase shocked to 20 GPa displays strong undulatory extinction. At shock pressures of 24 GPa plagioclase was almost completely transformed into an isotropic phase (maskelynite). Applying higher shock pressures of 28 and 36 GPa results in complete isotropisation.

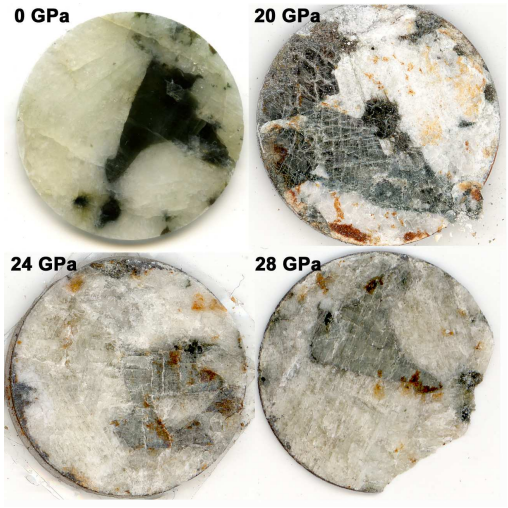

Figure 1: Macroscopic images of unshocked (0 GPa) and shocked (20, 24, 28 GPa) gabbro discs (15 mm ∅) mainly composed of plagioclase (white) and pyroxene (green).

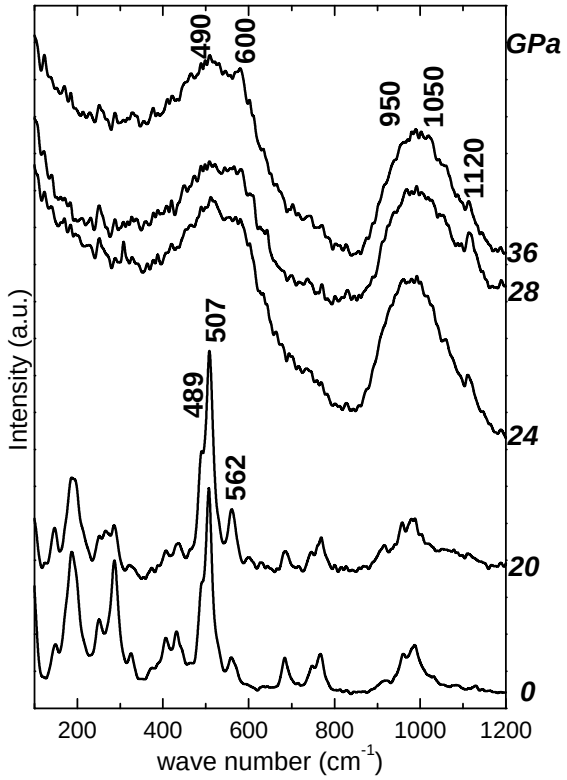

Figure 2: Raman spectra of birefingent plagioclase (0 and 20 GPa) and isotropic maskelynite (24, 28 and 36 GPa).

Raman spectroscopic investigations revealed no substantial differences between unshocked plagioclase and plagioclase shocked to 20 GPa (Fig. 2). The transformation of plagioclase into maskelynite which ocurrs at higher pressures (~24 GPa) is clearly recogniscable in the Raman spectra. The Raman spectra show identical variations as those collected from naturally shocked martian meteorites [4] indicating a common transformation mechanism. The characteristic Raman bands of plagioclase [5] are absent in the amorphous maskelynite: the dominant Raman bands at ~490 and ~510 cm^{-1} together with the band at ~560 cm^{-1} merge into a broad hump ranging from 490 to 600 cm^{-1}. A broad hump between 950 and 1050 cm^{-1} and a weak band at 1120 cm^{-1} are recorded during the Nd-YAG laser measurements. This feature drowns into the luminescence background during measurements performed with a 632 nm HeNe laser.

Discussion: The behaviour of plagioclase during shock metamorphism can be discussed by comparing the shock pressures required to form maskelynite from plagioclase of different chemical composition (Fig. 3).

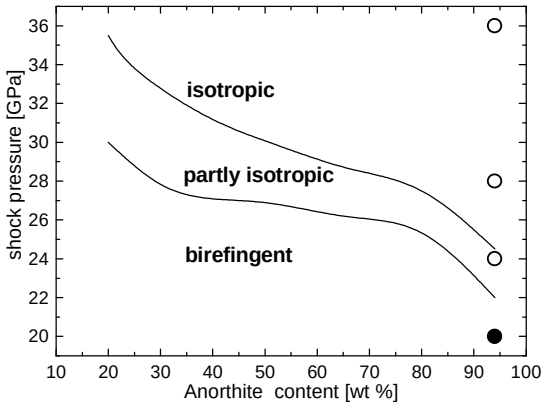

Figure 3: Crystallographic properties of experimentally shocked plagioclase. Data for $An_{<80}$ from [1], and for An_{94} from this work. ● = birefringent; ○ = isotropic.

The shock pressures required to form maskelynite decrease with increasing An-content. This dependence is contrary to the thermal behaviour of plagioclase where melting temperatures increase with increasing An-content. The diametrically opposed behaviour strongly argues that maskelynite is not a "hot" silicate melt quenched at high confining pressures during adiabatic release from shock compression. In contrast, the dependence of shock pressure and chemical composition advocates that the stability of the crystal lattice fails due to pressure overload. Along the albite-anorthite joint, Na^{+} is substituted by Ca^{2+}, and in order to preserve the electrical neutrality of the crystal Si^{4+} is substituted by Al^{3+}. The Al-O bonds are weaker as the Si-O bonds. The crystal lattice of anorthite endures less confining pressure compared to albite, and hence lower shock pressures are required for the shock-induced coversion into maskelynite.

A "cold" and ductile formation of maskelynite is in agreement with the mineralogic [4], petrographic [6], geochemic [7], and geophysic [8] properties of martian meteorites. A "cold" transformation is corroborated by maskelynite bearing lunar meteorites retaining Ar-ages identical to crystallisation ages determined by thermally more resistand radiogenic chronometers [9]. Contrary to "hot" melting of silicates and quenching during pressure release, a "cold" and ductile transformation rationalizes that bacteria, algae and lichen survive shock experiments while the crystal lattice of enclosing plagioclase completely fails [10].

Conclusion: 1) The shock transformation of plagioclase into maskelynite results from a pressure induced collapse of the plagioclase crystal lattice during shock loading followed by an increase of disorder and volume during decompression. The same mechanism was identified for the transformation of quartz into a diaplectic glass [3]. **2)** Ca-rich plagioclase (An_{94}) starts transforming into maskelynite at shock pressures >20 GPa. The experimental data allows to apply quantitative shock pressure barometry on plagioclase from lunar rocks and high-Ca plagioclase bearing meteorites. **3)** Raman spectroscopy represents a quick and non-destructive method to discriminate plagioclase and maskelynite. The work contributes to Raman spectroscopic measurements on materials relevant for investigations during future space missions.

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