**Lunar and Planetary Science XXXI**

**45 GPA IN ALL MARTIAN METEORITES;** D. Stöffler, Institute of Mineralogy, Museum für Naturkunde, Humboldt University of Berlin, Invalidenstrasse 43, 10099 Berlin, Germany, e-mail: dieter.stoeffler@rz.hu-berlin.de

**Plagioclase in shergottites and in some other Martian meteorites forms an amorphous phase called maskelynite which displays all the textural and physical characteristics of diaplectic glass as defined by [1, 2]. The maskelynite-bearing meteorites were affected by peak shock pressures (final equilibration shock pressures) ranging from 29 to 45 GPa.**

Peak pressures of up to 90 GPa as proposed recently [3-7] are grossly wrong and lead to extreme inconsistencies regarding the p-T-history of Martian meteorites.

**Introduction.** Recently it has been suggested [3-7] that (1) maskelynite is no diaplectic glass and (2) the host meteorites were affected by peak shock pressure in excess of at least 45 GPa, most probably by pressures between 80 and 90 GPa. The arguments for this interpretation was based (1) on the observation of plagioclase „melt injections“ into adjacent minerals and the lack of cleavage, contraction cracks and chemical zoning in maskelynite of Shergotty and Zagami, and (2) on the discovery of a high pressure phase in silica grains of Shergotty which would require static equilibrium pressures > 45 GPa or >70 - 80 GPa [6, 7]. The authors [4-7] drew the conclusion that the previous estimates of the peak shock pressure in Shergotty and in other Martian meteorites (29-45 GPa, [8]) are wrong although these estimates had been based on calibrations derived from a comprehensive set of shock recovery experiments [8-10]. In this abstract, it will be shown that the arguments of [3-7] are not valid because the fundamentals of shock wave compression of polyphase solids as well as existing data for the Martian meteorites were neglected or insufficiently considered by [3-7].

**Definition and diagnostics of diaplectic glass.** For the definition of diaplectic glass, its identification in shocked rocks and its correct interpretation as a shock barometer the following facts are important: The definition of diaplectic glass [1] is non-genetic and it is based on measurable physical properties and on textural characteristics as observed on the microscopic scale. Therefore, the definition is valid independently of the detailed „atomistic“ understanding of the formation process during shock compression which had been a matter of dispute until Grady [13] proposed the model of „heterogeneous yielding“ which has been improved later by [14] and [15] (see details in [16-18]).

Two types of mineral glasses are observed in shocked rocks: Diaplectic glass and normal glass. The following short definitions of both types of glasses as given in [9] are pertinent: (1) „Diaplectic glasses are optically isotropic and X-ray amorphous „minerals“ which display the shape of their parental crystals and lack any morphological evidence of flow and vesiculation. Rocks with diaplectic glasses typically preserve the texture of their unshocked counterpart“, (2) „Normal mineral glasses are characterized by flow structures, vesiculation, and sometimes schlieren. Rocks in which certain minerals, e.g. feldspars, are capable of becoming selectively shock-fused loose their pre-shock texture...“. From these definitions and additional criteria (Table 1) it must be concluded that maskelynite observed in all Martian meteorites except for the nakhlites (Table 2) is beyond any doubt diaplectic plagioclase glass. The observed marginal „melt injections“ at the grain boundaries of maskelynite grains to adjacent minerals (pyroxene, silica etc.) described by [4, 5, 7] are not in conflict with this diagnosis because they are (1) subordinate in abundance and (2) restricted to the grain boundaries. Shock-induced grain boundary melting is a characteristic and common feature observable at the contact of minerals of different shock impedance. Hence, localized formation of genuine melts (mostly on the submicroscopic scale in Shergotty) quenched to „normal glass“ of plagioclase composition is to be expected.

**Formation process and p-T-conditions for diaplectic and normal glasses.** According to [2] the following facts are essential for the formation of these glasses: Diaplectic glass is a reversion product of the high pressure „phase“ of quartz or feldspar which appears to be in an extremely dense liquid state [13-18] during shock compression. Minerals are transformed to diaplectic glass during compression to shock states (p, V-states) located on the high-pressure-phase regime of the Hugoniot curve. As demonstrated by release adiabat measurements [e.g., 19] the dense high pressure phase suddenly transforms during pressure decay to a phase with low density below about 5 GPa. This density is higher than the density of normal glass, i.e. intermediate between the density of the unshocked crystal and the corresponding synthetic glass quenched form a liquid. Diaplectic glass may be understood as a „short-range-order phase“ which keeps a memory of the previous crystalline state as indicated by its annealing behavior (Table 1).

„Diaplectic glass“ is formed from quartz and feldspars within a certain pressure range (ca. 30-45 GPa), the upper limit of which is determined by the magnitude of the post-shock temperature. The precursor crystal being in the state of a dense liquid is quenched to glass before the shock pressure is completely released. At higher shock pressure the post-shock temperature is high enough to keep the shocked material in a liquid state after pressure release so that „normal glass“ quenched from a low pressure liquid is formed. Since diaplectic glass retains the morphology and some internal texture of the parent crystal, this glass has previously been sometimes termed „solid state glass“. This is no longer a suitable term because the recent, generally favored formation models [14-18] call for a dense „liquid“ state during shock compression. These models have been completely neglected by the proponents of the non-existence of diaplectic glass in shergottites [3-5, 7] who erroneously assumed that the existence of a dense liquid state during compression would violate the definition of diaplectic glass.

**Shock history of Martian meteorites.**

The shock pressure and temperature history of shergottites has been assessed in some detail by [8, 12, 19, 20]. The findings of [3-7] do not require any revision of the p-T-history of shergottites and other maskelynite-bearing meteorites as outlined by [8]. In contrast to statements of [3-7] the previous shock pressure estimates [8, 19, 20] were not based on the refractive index of maskelynite alone (which still is the most accurate shock barometer) but on the following three independent observations or data sets: (1) Refractive index of maskelynite calibrated by shock recovery experiments on single crystal and polycrystalline plagioclase and on basalts and...
gabbro, (2) threshold pressures for the transitions of birefringent to partially isotropic and to totally isotropic plagioclase from the same set of shock recovery experiments, and (3) textural observations obtained from several series of shock recovery experiments on basalts and on chondrites [21-23]. They provide a very strong argument against the extreme peak shock pressure of 80 - 90 GPa postulated for Shergotty [3-6] which even contains minor relics of birefringent plagioclase [8] as also described by [3, 4]. According to [21] 90% of the plagioclase is diaplectic glass in basalt shocked to a peak shock pressure of 27 GPa. This is perfectly compatible with the 29±1 GPa proposed for Shergotty [8]. At > 80 GPa basalt would be pervasively shock molten due to the very high post-shock temperature which definitely exceeds 1600 °C if not 2000 °C at 80 GPa [7-10]. It would have lost its primary texture completely as demonstrated by [21, 22] and by all other known shock experiments on plagioclase [10]. None of the Martian meteorites containing plagioclase glass can have experienced peak shock pressures in excess of 45 GPa (Table 2) because all plagioclase would have been completely shock-fused above this pressure.

The p-T-history of Martian meteorites outlined above does not exclude that local pressure and temperature excursions from the final equilibration pressure (which is by definition the peak shock pressure) resulting from shock wave reverberations occurred in all meteorites (see detailed discussion in [11]). The observation of local melt pockets in Shergotty lead [8] to argue in favor of local pressure excursions of 60 to 80 GPa in Shergotty and other Martian meteorites containing melt pockets and veins. This has been overlooked by [3-7] who obviously also confused the terms „peak shock pressure“ with „local pressure peaks“. The latter are to be expected in any polycrystalline rock containing minerals of distinctly different shock impedance.

In principle, the post-stishovite phase found in Shergotty [5-7] may be the result of such local pressure and temperature peaks although it is not located within the melt pockets of Shergotty [8] as required. There it could have crystallized in a p-T-regime between some 80 and 45 GPa along the pressure release adiabat. However, the silica grains and its surroundings do not show any sign of pervasive melting and any „mixed“ melt is lacking. In addition, an 80 GPa peak in silica would cause an initial shock temperature of ~4500°C and a final post-shock temperature of ~3500°C [8-11]. It is not clear how the post-stishovite phase(s) could have formed and metastably quenched under such conditions.