with lamellae is lower than in Apollo 11 soils and breccias. In Apollo 12 soils 12070 and 12001 less than 1% of all pyroxene fragments contain lamellae.

Olivine

No shock effects have been observed by optical microscopy and by X-ray analysis in the Apollo 12 samples available for our studies. Transmission electron micrographs were obtained from shocked olivine grains from Apollo 11 described in ENGELHARDT *et al.* (1970). Dislocations in (010) with the Burgers vector parallel to [001], characterized by long screw components have been observed (Fig. 2). Wavy dislocations predominantly parallel to [010] have been found in particles with (001) approximately perpendicular to the electron beam. The dislocation density has been estimated to 10^{10}–10^{11} per cm^2.

Transmission electron micrographs of some olivine particles from soil 12070,139 revealed screw dislocations with the Burgers vector parallel to [001]. They may be of shock origin.

Ilmenite

Deformational twin lamellae occur in shocked basalt fragments containing pyroxene with shock lamellae. They obviously form at similar or lower shock pressures than those required for the formation of pyroxene lamellae.

Tridymite

Planar features parallel to a hexagonal prism have been observed in tridymite adjacent to diaplectic plagioclase glass in the basalt fragment 12057,14 (see below). It may be that they were produced by shock.

SHOCK METAMORPHISM OF CRYSTALLINE ROCKS

From the observed shock effects in Apollo 12 samples the previously established classification of progressive shock metamorphism of Apollo 11 rocks (ENGELHARDT

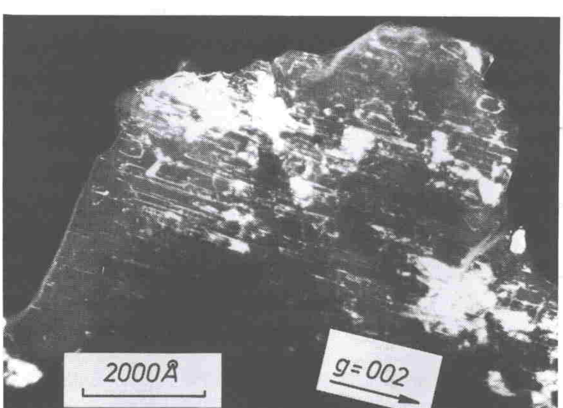

Fig. 2. Dislocations in shocked olivine from Apollo 11 (10085,26). Transmission electron micrograph. Dark field image produced by a reflection $\vec{g} = 002$. Particle normal near [010]. Acceleration voltage 100 kV. (Siemens Elmiscope 101.)

et al., 1970, p. 380) could be confirmed. According to this classification which is in general agreement with our classification proposed for terrestrial shocked rocks (STÖFFLER, 1966; ENGELHARDT and STÖFFLER, 1968; STÖFFLER, 1971), 5 stages of increasing shock metamorphism can be recognized in the fragments of lunar crystalline rocks based on well-defined shock effects in plagioclase and pyroxene and on the selective or complete shock fusion of rocks. The characteristics of stages 1 to 5 are described in some detail in a previous paper (ENGELHARDT *et al.*, 1970).

Shock pressures lower than those of stage 1 produce strong irregular fracturing of all rock constituents and mosaicism of plagioclase and pyroxene. Small fragments of basaltic rocks belonging to this stage of deformation are rather frequent in soil and breccias of Apollo 11 and Apollo 12.

Basaltic fragments of stages 1 and 2 are very rare, both in soil and breccias. Out of 79 basalt fragments > 0.25 mm of Apollo 11 soil (10085,25; 10085,26) only three fragments were found of stage 1 and three of stage 2. One small basalt fragment of stage 1 and one of stage 2 were found as inclusions in breccia fragments of Apollo 11 soil. No basalts of stages 1 and 2 were found among 58 basalt fragments > 0.25 mm from Apollo 12 soil (12033,74; 12070,139; 12001,89). Thin section 12057,14 of a basalt fragment provides interesting information about shock effects in lunar polycrystalline rocks. The modal composition (point counting) is 53 vol. % pyroxene, 38 vol. % plagioclase, 9 vol. % opaques, and a minor amount of tridymite. All pyroxene grains contain sets of equidistant shock lamellae, mostly within limited areas, which are often slightly bent. Most of the ilmenite grains show fine twin lamellae.

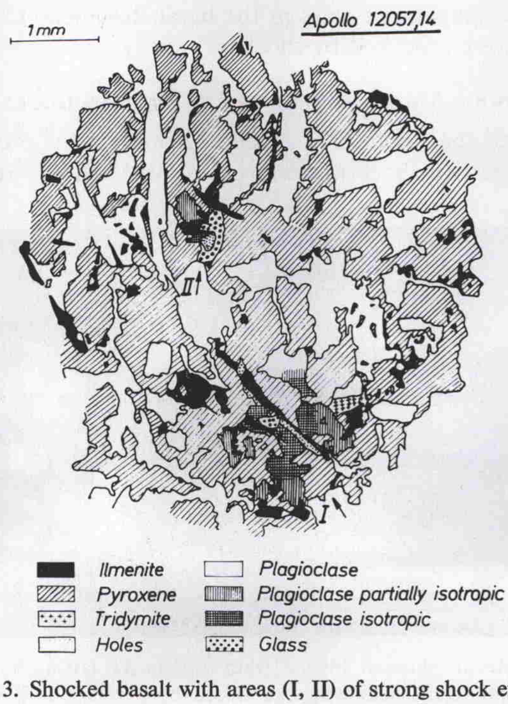

Fig. 3. Shocked basalt with areas (I, II) of strong shock effects.