original texture of the rock is preserved (Fig. 13). Many pyroxene grains contain deformation lamellae. This zone corresponds to stage 2. A very narrow transition zone (maximum thickness about 0·2 mm) separates the stage 2 zone from the interior of the fragment where the plagioclase is birefringent but some pyroxene crystals still show deformation lamellae. The transition zone and the latter region belong to stage 1. The plagioclase in the transition zone shows no deformation lamellae.

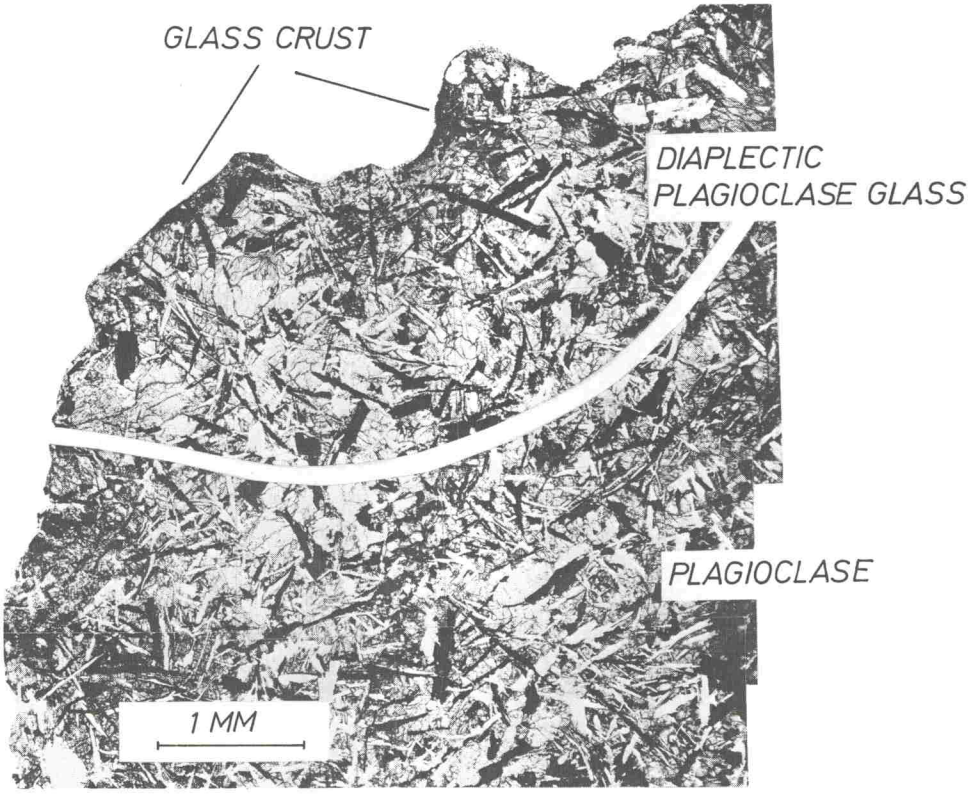

Fig. 12. Shocked basaltic rock coated with vesicular glass. Zones of progressive shock metamorphism. Plane light. (10085-25—M61).

Stages of progressive shock metamorphism have been extablished for shocked rocks from breccias of several terrestrial meteorite craters (STÖFFLER, 1966, 1967; CHAO, 1967, 1968; DENCE, 1968; ENGELHARDT and STÖFFLER, 1968).

The stages found in the fall-out breccia (suevite) of the Ries Basin are essentially conformable with those of lunar shock metamorphism as described above.

Hence, the lunar regolith can be compared with terrestrial suevite-like impact breccias. There are similarities and differences between both. The lunar regolith as well as suevite is a mixture of rock and mineral fragments in all stages of shock metamorphism together with unshocked fractured rocks and minerals. Characteristic of the regolith are indications of multiple impacts, whereas each terrestrial suevite is the

product of one single event. On the lunar surface impacts into the unconsolidated soil ejected from older impact craters produced breccias consolidated by a glassy matrix. The multiple repetition of such processes is evident from fragments of old breccias included in younger breccias (Fig. 2). Another pecularity of the regolith, due to the lack of an atmosphere on the moon, is the occurrence of regularly shaped glass bodies which have not been found in terrestrial suevites.

In conclusion, no process other than multiple meteoritic impacts can have produced, transported and deposited a clastic sediment with the composition and texture of that of the lunar regolith.

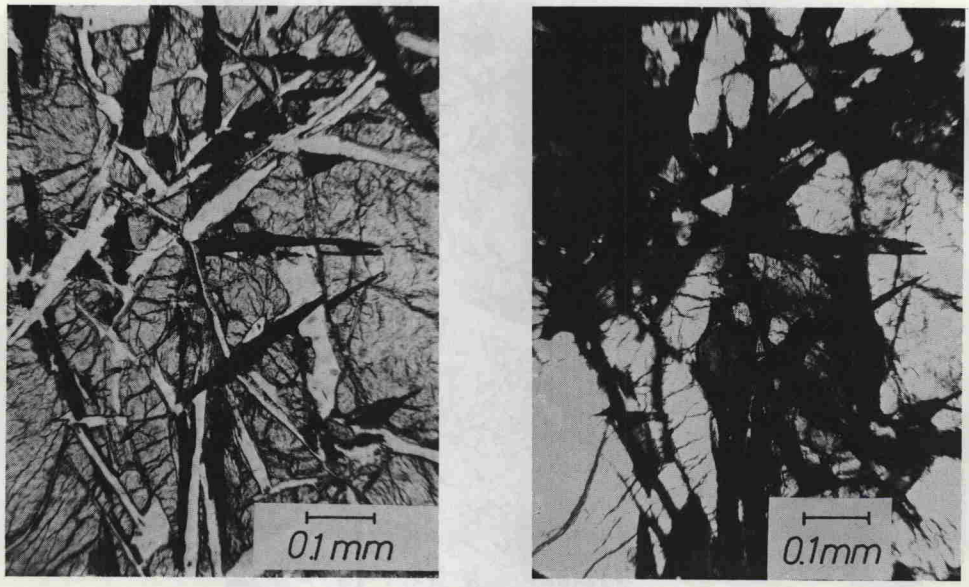

Fig. 13. Detail from Fig. 12.
(a)—(left) Laths of diaplectic plagioclase glass (white), ilmenite (black), pyroxene (gray). Plane light. (b)—(right) Crossed nicols.

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REFERENCES

AGRELL S. O., SCOON J. H., MUIR I. D., LONG J. V. P., MCCONNELL J. D. C. and PECKETT A. (1970) Mineralogy and petrology of some lunar samples. *Science* **167**, 583–586.

AHRENS T. J. and ROSENBERG J. T. (1968) Shock metamorphism: experiments on quartz and plagioclase. In *Shock Metamorphism of Natural Materials*, (editors B. M. French and N. M. Short), pp. 59–81. Mono.

AHRENS T. J., PETERSEN C. F. and ROSENBERG J. T. (1969) Shock compression of feldspars. *J. Geophys. Res.* **74**, 2727–2746.