be due to the passage of multiple shock waves (see Rinehart, *this vol.*, p. 31).

In shock stage II *biotite* and *amphibole* show only effects of mechanical deformation; kink bands develop in biotite and lamellar features are observed in amphibole.

Typical phenomena in shock stages I and II are transitions of tectosilicates from undisturbed crystals to the disordered or amorphous phases described above. It can be concluded, from the preservation within the glassy grains of cleavage, grain boundaries, and twin boundaries, and from the absence of all flow structures, that these transformations took place as subsolidus reactions. Since there are, in the suevite, also glasses which have been clearly produced by true melting of quartz, feldspar, and other minerals (Stages III and IV), it seems useful to have proper terms designating these two types of amorphous phases which have apparently been produced under different conditions, and which differ from each other in physical properties, as, for instance, in the degree of short-range order.

It is therefore proposed to apply the term *diaplectic*[1] to all products produced by shock waves in such a way that morphological characteristics of the liquid state are lacking. The term *diaplectic minerals* thus applies to all disordered and deformed mineral crystals modified by shock waves without melting. *Diaplectic quartz* and *diaplectic feldspar* thus designate quartz and feldspar exhibiting planar elements, slip lamellae, lowered indices of refraction, and lowered birefringence (Stage I). *Diaplectic glasses* (of quartz, feldspar, or other minerals) are amorphous phases produced by shock waves without melting, and are distinguishable from ordinary molten glasses by the criteria presented in Table 3 (Engelhardt *et al.*, 1967).

Diaplectic glasses represent intermediate stages of structural order between the crystalline and normal glassy phases. This conclusion is supported by measurements of their physical properties; e.g., refractive index, density, and the calculated molar refractivity and ionic refractivity of oxygen.

[1] From the Greek word *diaplesso* = to destroy by striking or beating.

TABLE 3

| Diaplectic glasses | Normal glasses |
|---|---|
| Morphological features of the previous crystalline state are preserved (e.g., grain boundaries, twin boundaries, cleavage). | Morphology is determined by surface tension; no sharp corners, edges, or uniform boundary planes occur. |
| No flow structures.<br>Vesicles absent. | Flow structures are present.<br>Vesicles of circular or nearly circular shape are common. |
| Refractive index and density are higher than those of normal glass of the same chemical composition. | No transitional stages occur between the crystalline phases and normal glass. |
| Diaplectic quartz glasses often contain high-pressure phases (i.e., coesite and stishovite). | |

These studies were made on diaplectic quartz and plagioclase glasses. Diaplectic quartz glasses separated from a biotite gneiss from Aufhausen have densities between 2.219 and 2.261, and corresponding refractive indices between 1.460 and 1.4635. These values are higher than those for synthetic, normal $SiO_2$-glass; i.e., $n = 1.4585$, and $d = 2.200$ (see Fig. 9 in Engelhardt *et al.*, *this vol.*, p. 475). The density of diaplectic plagioclase glass ($An_{39}$) separated from a plagioclase amphibolite from Bollstadt varies between 2.449 and 2.557; the corresponding refractive indices range between 1.523 and 1.532 (Fig. 4). Normal plagioclase glass of this composition has much lower values: 2.432 and 1.521, respectively (see Fig. 4).

Molar refractivity, calculated from density and refractive index using the Lorentz-Lorenz equation, decreases with increasing density for both quartz and plagioclase glasses (Fig. 3 in Engelhardt *et al.*, 1967 and Fig. 4, this paper). The same relation is true for the ionic refractivity of oxygen, calculated on the assumption that contributions from the cations remain constant with increasing density. This result indicates a smaller polarizability of oxygen in diaplectic glasses than in

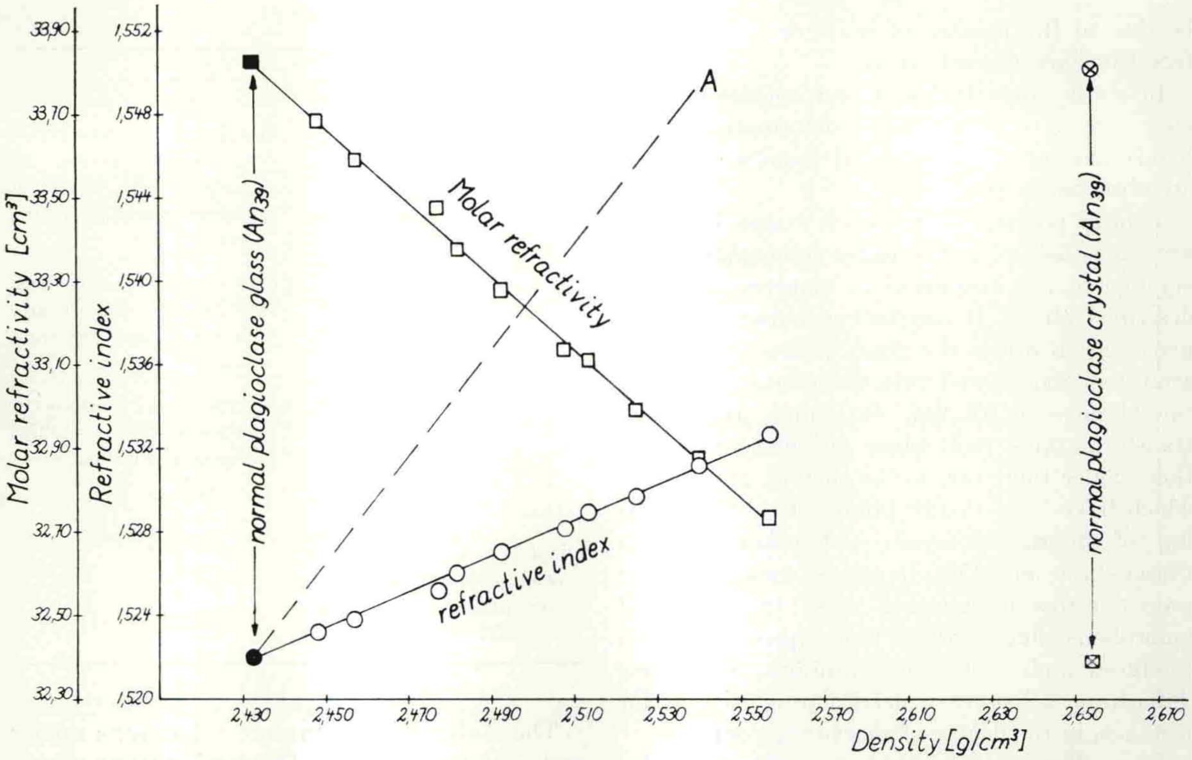


Fig. 4. Refractive index (circles) and molar refractivity (squares) as a function of density for different plagioclase ($An_{39}$) phases. Open circles and squares: Diaplectic andesine glass from Bollstadt. A: indicates the curve for calculated refractive index as a function of density for a constant molar refractivity of 33.83 cm³ (normal andesine glass, $An_{39}$) (after Fig. 5, Engelhardt *et al.*, 1967).

normal glasses. Hence, the structural state of diaplectic glasses approaches that of the crystalline phases from which they were formed. Infra-red absorption spectra of diaplectic glasses from other craters (Bunch, Cohen, and Dence, *this vol.*, p. 509) seem to confirm this conclusion. A detailed description of diaplectic quartz and plagioclase glasses is given by Engelhardt *et al.* 1967).

Both the normal and diaplectic phases of any plagioclase composition can be characterized simply by the difference ($n_1$–$n_2$) between the refractive index of the normal crystal or diaplectic phase ($n_1$) and that of normal plagioclase glass ($n_2$) of the same composition. This relation is illustrated in Figure 5 for normal plagioclase crystals, for one diaplectic andesine ($An_{31}$), and for three diaplectic plagioclase glasses ($An_{23}$, $An_{31}$, and $An_{36}$) taken from crystalline fragments collected at different suevite outcrops. The difference ($n_1$–$n_2$) for shock-produced phases of a definite composition gives a rough scale for measuring shock intensities, assuming that shock intensity is inversely proportional to the difference ($n_1$–$n_2$) (Stöffler, 1967).

## STAGE III

This stage of shock metamorphism is characterized by the selective melting of tectosilicates as a result of the very high residual temperatures produced by shock pressures in the range of about 500 to 650 kilobars. Normal glasses, containing vesicles, streaks (schlieren), and well-developed flow structures are formed by this process.

*Plagioclase* and *alkali feldspar* transform into normal glass (Fig. 6), showing typical morpholog-