Within one thin section, the occurrence of plagioclase grains containing lamellae of different thicknesses (ranging from less than 1 μ up to about 8 μ), together with irregular isotropic areas, seems to indicate that lamellae in plagioclase are formed within a smaller range of shock pressures than the planar elements produced in quartz (see also Robertson *et al.*, *this vol.*, p. 433).

Isotropic or nearly isotropic lamellae in plagioclase have been investigated in a specimen of dioritic gneiss (from Zipplingen) containing quartz, plagioclase (An_{31}), amphibole, and biotite. As many as three different sets of lamellae are to be found in one single plagioclase crystal. They are oriented parallel to crystallographic planes of low Miller indices. The measured planes are given in Table 2.

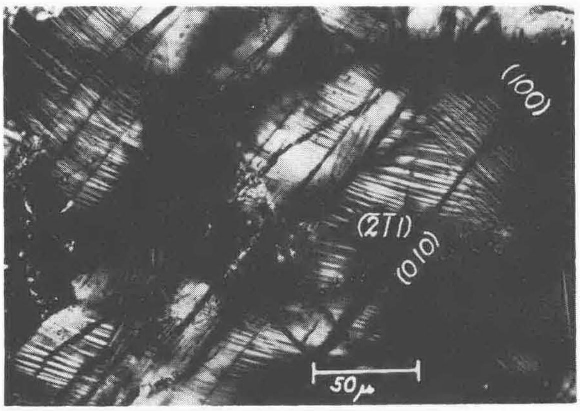

Fig. 1. Andesine in dioritic gneiss, Zipplingen. Isotropic slip bands (black) are parallel to (100) and $(\bar{2}\bar{1}1)$; isotropic twin lamellae (black) are parallel to (010). Irregular isotropic areas (black) are present. Crossed nicols.

Frequency is here defined as the number of measured sets of a particular crystallographic orientation as a fraction of all measured lamellae (it is identical with frequency, F_{II}, in the paper of Engelhardt *et al.*, *this vol.*, p. 475).

Most lamellae are parallel to the shortest vectors of the Bravais lattice and to the greatest number of Si–O bonds. It is therefore assumed that they are produced by a peculiar form of shock-induced crystal gliding. This process produces a sequence of periodically repeated layers of disordered material which remain isotropic after pressure release. Similar deformation patterns in metals are known as slip bands (see, e.g. Seeger, 1958). Slip bands in plagioclase are unknown from rocks formed by normal processes within the earth's crust, and they must be therefore considered as a typical criterion for shock damage. In some plagioclase grains, unusual cleavages have been found, distinct from those

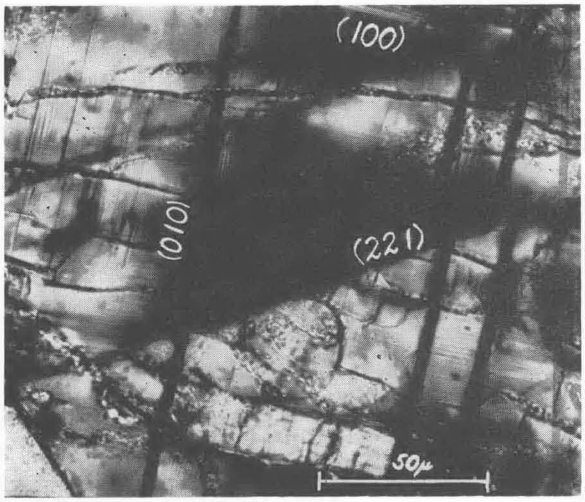

Fig. 2. Andesine in dioritic gneiss, Zipplingen. Isotropic slip bands (black) are parallel to (010) and (100). Irregular isotropic areas (black) are sharply separated from unaffected areas (light) by shear planes parallel to (221). Narrow albite twin lamellae (black) are at extinction. Crossed nicols.

TABLE 2

Orientation of planar lamellae in plagioclase crystals in a dioritic gneiss from Zipplingen.

(hkl)	Frequency %	(hkl)	Frequency %	(hkl)	Frequency %
(001)	25	$(1\bar{1}0)$	2	$(\bar{1}02)$	1
(010)	11	(102)	2	$(0\bar{2}1)$	1
(100)	10	$(0\bar{1}2)$	2	$(2\bar{1}0)$	1
$(1\bar{2}0)$	10	(150)	2	$(\bar{2}01)$	1
(012)	7	$(1\bar{3}0)$	2	$(\bar{1}11)$	1
(130)	6	(101)	1	(211)	1
(201)	2	(011)	1	$(1\bar{1}2)$	1
$(\bar{1}01)$	2	(210)	1	$(\bar{2}21)$	1
			and others		

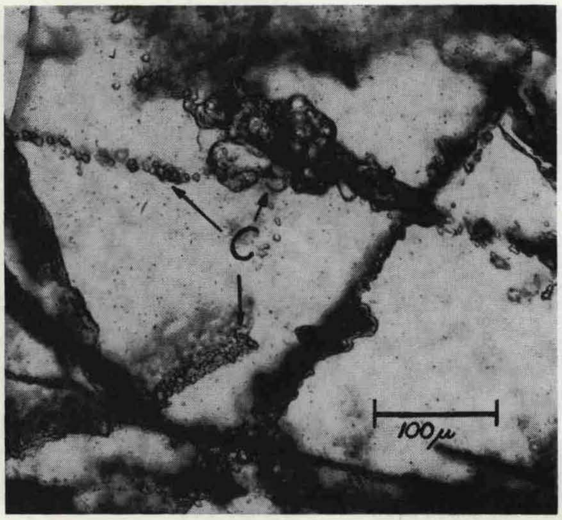

Fig. 3. Diaplectic quartz glass (light areas) with aggregates of fine-grained coesite (C) within a fragment of biotite granite from Aufhausen.

observed in normal feldspar, but parallel to definite crystallographic planes.

Plagioclase which shows these deformation phenomena also shows an unusually strong decrease of both refractive index and birefringence. Refractive indices between 1.550 and 1.533 (most grains having 1.537) have been measured in andesine (An_{31}) from Zipplingen, which normally should have an index of 1.550 (n_z). These andesine crystals have the optical properties of a highly disordered plagioclase, according to the optical orientation and optic axis angles. The average optic axis angle of 69 crystals was found to be 80.5 degrees instead of 88.5 degrees for ordered An_{31} (Burri *et al.*, 1967).

A strong decrease of optic axis angle has also been found in the orthoclase feldspar in these granitic inclusions. A detailed description of shocked plagioclase is given in another paper (Stöffler, 1967).

Biotite in rocks of this stage of shock metamorphism shows well-developed kink bands; these features are also produced in biotite during natural and experimental static deformation of rocks (Griggs *et al.*, 1960) and by dynamic deformation experiments on rocks (Cummings, 1965; Short, 1966).

STAGE II

Quartz is gradually transformed into an amorphous phase exhibiting a lower index of refraction and lacking birefringence. This phase does not produce X-ray diffraction lines. It still preserves original grain boundaries and sometimes preserves the shock-produced planar elements described above (Stage I).

Coesite and stishovite occur in these glasses. Coesite, which can be seen by the microscope (Fig. 3), forms very fine-grained aggregates often arranged in planes (shear planes?).

Feldspar is also gradually transformed into an amorphous phase. Isotropization begins either in irregular patches or as a lamellar pattern. In the first case, larger isotropic (or nearly isotropic) areas within one crystal are sometimes sharply separated from unaltered areas by uniform planes, commonly of definite crystallographic orientations (such as (101) (102) (221) etc.) which have apparently acted as shear planes (Fig. 2). In the latter case, the affected lamellae are either pre-existing twin lamellae or shock-produced multiple sets of lamellae (or planar elements) as described above (Stage I). Very often, in plagioclase twins following the albite law, one set of lamellae has lowered refractive index and birefringence, or is completely isotropic; while the other set of lamellae seems not to be affected. This asymmetrical behavior of such twins is not the result of chemical differences between the sets of lamellae, as was proved by electron microprobe analyses. It is rather the result of a favored orientation of the twin system relative to the direction of the deforming forces, by which slipping on (010) and isotropization is favored. Slipping may also be favored in one set of lamellae by a higher content of pre-existing lattice defects.

By means of fabric analysis of the dioritic gneiss specimen, it was shown that grains with asymmetrically isotropized twin lamellae have no preferred orientation in the rock (Stöffler, 1967). This randomness may reflect disorganization of the shock front due to interactions at free surfaces and grain boundaries, or may perhaps