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Laue Asterism and Deformation Bands*

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From X-ray and optical observations on aluminium single crystals in tensile deformation it is shown that the asterism in the usual type of Laue patterns is associated with macroscopic misorientations of the crystal. The changes of orientation may be ascribed to two distinct types of deformation bands, the kink bands previously reported by Cahn and others, and lamellar regions where the primary slip system is less marked and additional systems operate. The nature of these latter bands is discussed in relation to current ideas on inhomogeneous deformation.

Introduction

During the past thirty years there has been considerable controversy over the interpretation of the asterism observed in Laue patterns from deformed metal crystals. It was originally believed that the asterism observed in regions of a crystal well removed from end constraints, such as at the centre of a long parallel-sided single crystal, was due to local distortion of the lattice in the neighbourhood of the active slip planes, the distortion being the same as if small parts of the crystal had rotated as 'rollers' on the slip plane. Evidence of this local curvature effect was first found in the classic experiment of Taylor (1928) on compressed aluminium single crystals, although the amount of rotation, $\sim 10^\circ$, was much less than that which would have occurred if the 'roller' action were literally true. This result was confirmed by Yamaguchi (1929) examining aluminium single crystals after tensile deformation.

Barrett (1940), however, concluded, from experiments also on compressed aluminium single crystals, that there was no basis for this idea, and that the asterism was due to the formation of comparatively coarse 'deformation bands'. These latter were described as regions bounded by $\{100\}$ planes which adopted differing orientations due to the operation of different slip systems. An additional complication was introduced by Heidenreich & Shockley (1948), who deduced from electron-diffraction evidence that rotation about the operative slip-plane normal took place. Rotational slip, of which this is a special case, has been the subject of detailed discussion by Wilman (1951) and his co-workers, who suggest that the deformation bands observed by Barrett are indeed rotational slip bands. Yen & Hibbard (1949) also concluded that the asterism from bent aluminium single crystals shows evidence of this type of slip.

Some confirmation of Barrett's views that the asterism corresponds to macroscopic misorientations was observed by Röhm & Kochendörfer (1950). They found no asterism at all in crystals deformed very carefully by pure shear. Interest has recently been stimulated in the nature of deformation bands in aluminium after tensile deformation.

Honeycombe (1950) and Cahn (1951) have shown that these form on the $\{110\}$ plane perpendicular to the operative slip direction. Cahn concludes that the asterism associated with these 'kink' bands corresponds again to rotation about the $\langle 211 \rangle$ 'roller' axis, to be referred to herein as the 'T' axis, and explains this on the basis of the collection of edge dislocations.

At about the time the present work was completed two other papers on the same subject appeared. Chen & Mathewson (1951) have confirmed Cahn's observations on kink bands, in particular making the X-ray investigation in greater detail. Honeycombe (1951), using principally the technique of X-ray micrography, has made an important contribution by demonstrating the existence within a single crystal of two distinct types of deformation bands, namely kink bands, as just discussed, and regions of secondary slip. The latter are more strictly the deformation bands observed by the earlier workers, as summarised by Barrett (1940).

The present position may thus be summarised: for tensile deformation the asterism earlier attributed to local curvature is explained by kink bands although the other type of deformation band must apparently be responsible for some asterism and there is the possibility that rotational slip also enters into the deformation; for compression Barrett's observations must presumably be preferred to Taylor's by virtue of their greater detail, but the geometry of deformation bands under compression is not fully understood. Bearing in mind the two latest contributions to the subject, the work now to be described gives additional confirmation of Chen & Mathewson's observations on kink bands and throws further light on the regions of secondary slip reported by Honeycombe.

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* Communication from the National Physical Laboratory.

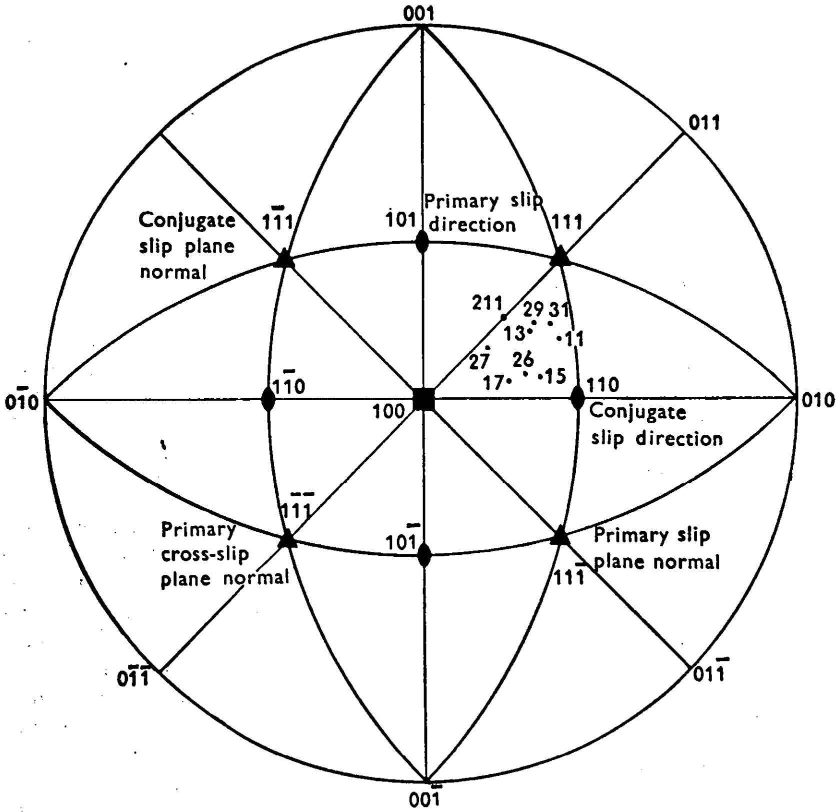

Fig. 1. Stress-axis orientations of the specimen and definition of slip nomenclature.

Experimental

Specimen blanks in the shape of flat tensile test-pieces of gauge length 40 mm., width 5 mm. and thickness 1·5 mm., were cut from cold-rolled aluminium sheet of 99·99% purity.

Single crystals were grown by the strain–anneal method, the treatment consisting of an initial annealing for 6 hours at 500° C., extension of 1·5% at room temperature, and a final anneal for 48 hr. with the temperature rising steadily from 470° C. to 550° C. This produced single crystals extending over all or nearly all of the parallel-sided gauge length. The specimens selected were electrolytically polished in a perchloric acid–ethyl alcohol bath.

The extension, which ranged from 1 to 40%, was carried out in a small hydraulic tensile machine. To this latter had been attached a back-reflexion film holder and collimator system giving a specimen–film distance of 1 cm. The whole apparatus was mounted on a rotating stand at the side of the X-ray tube so that preliminary optical observations and setting up could be made by viewing the specimen through the collimator with a travelling microscope of ×20 magnification. To obtain a record of the position of the stress axis on each Laue pattern the apparatus was rotated through 180° after exposure so that the film was in the transmission-pattern position. All the film except for strips near the edges was then masked by a metal sheet. A half-second 'flash' of X-rays from the tube was sufficient to leave a shadow of the specimen on the exposed strips of the film. The crystal orientations were deduced from these Laue patterns using a Greninger chart (Greninger, 1935). The stress-axis orientations of the specimens examined are shown in Fig. 1.

Measurement of the extension was made between fine fiducial marks inscribed on the specimen near the ends of the gauge length. Other marks defined the areas selected for the successive X-ray and optical observations made at several extensions during the deformation. Phase-contrast optical micrographs were obtained on a Vickers projection microscope after removal of the specimen from the apparatus.

Back-reflexion Laue patterns, using molybdenum radiation at 50 kV., were taken with two sizes of circular collimators: small-beam patterns of diameter 0·58 mm. and large-beam patterns of 1·10 mm. diameter. To determine the accuracy with which a selected area could be irradiated, patterns were taken with a polycrystalline specimen, setting the beam to overlap a grain boundary by equal amounts on either side. The resulting patterns showed the two single-crystal patterns superimposed, the intensity of the spots in each being approximately equal. With the small beam used, a misalignment of 0·1 mm. would

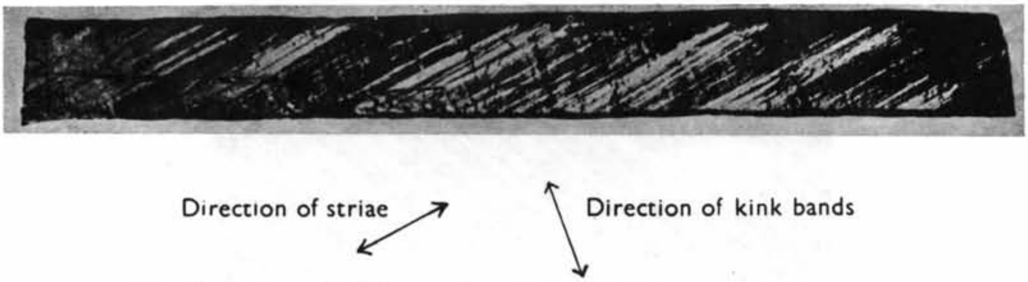

Fig. 2. Specimen 13, 4 % extension, showing kink bands and striae. × 3.

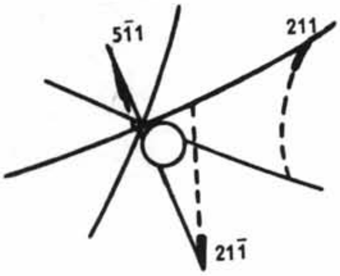

Fig. 4. Predicted asterism for rotation about T axis, specimen 17.

Fig. 3. Specimen 17, 5 % extension. Circles show areas irradiated by large and small X-ray beams. No striae in irradiated areas. × 50.

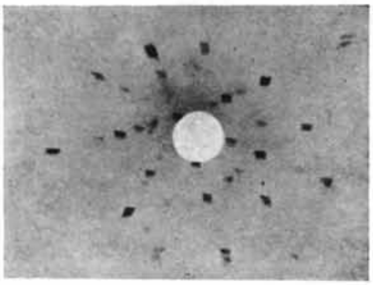

Fig. 5. Specimen 17, observed asterism. Direct comparison with Fig. 4 shows splitting of spots to be about T axis.

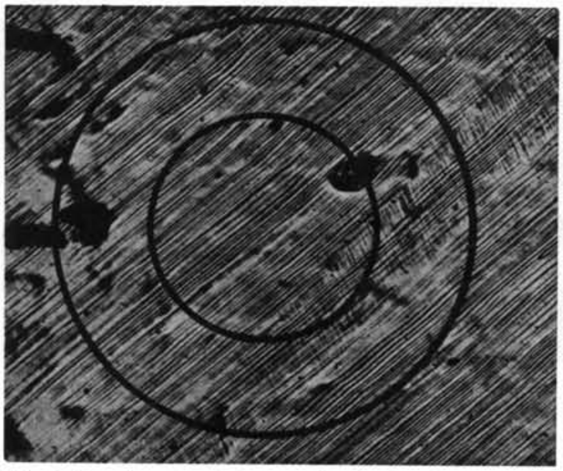

Fig. 6. Specimen 26, 6 % extension. Stria of second slip across irradiated areas. × 50.

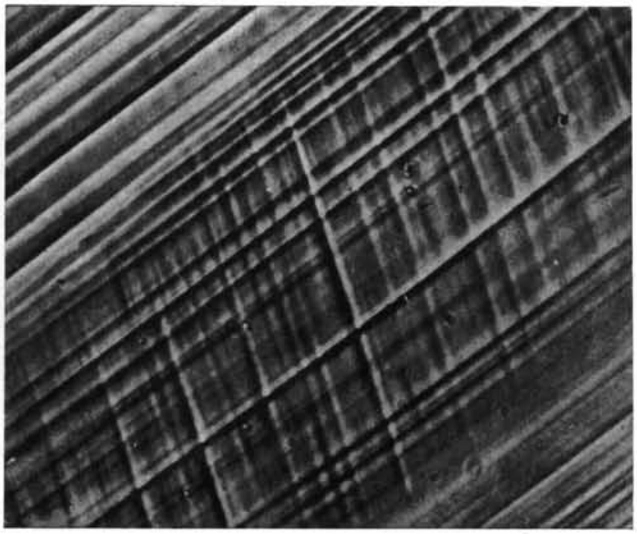

Fig. 7. Specimen 26, 9 % extension. Second slip system in stria. × 500.

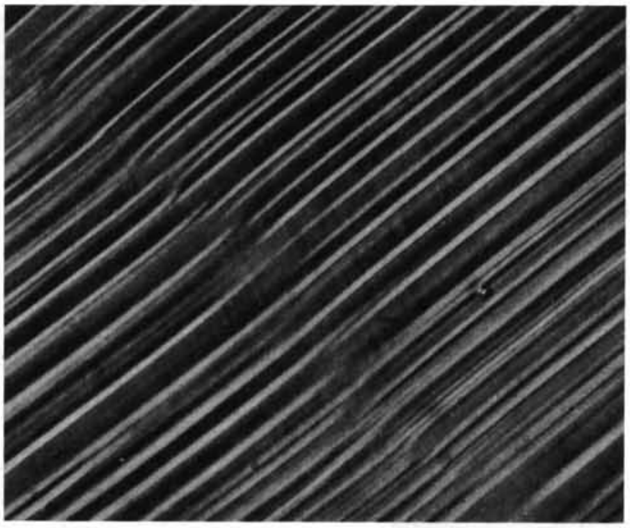

Fig. 8. Specimen 26, 9% extension. Kink band with second slip faintly visible in the vicinity. ×500.

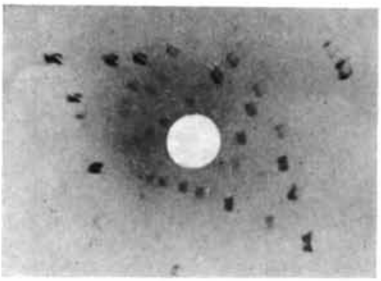

Fig. 9. Specimen 26, 9% extension, large X-ray beam.

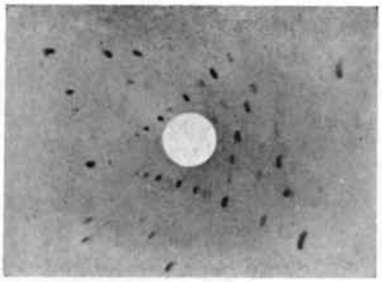

Fig. 10. Specimen 26, 9% extension, small X-ray beam.

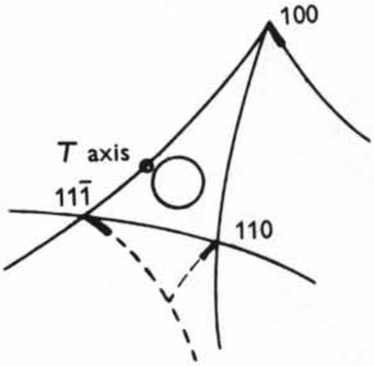

Fig. 11. Predicted asterism for rotation about the *T* axis, specimen 26.

Fig. 12. Specimen 29, 10% extension. Well marked striae of rumpled appearance. Kink bands approximately perpendicular to slip lines. ×50.

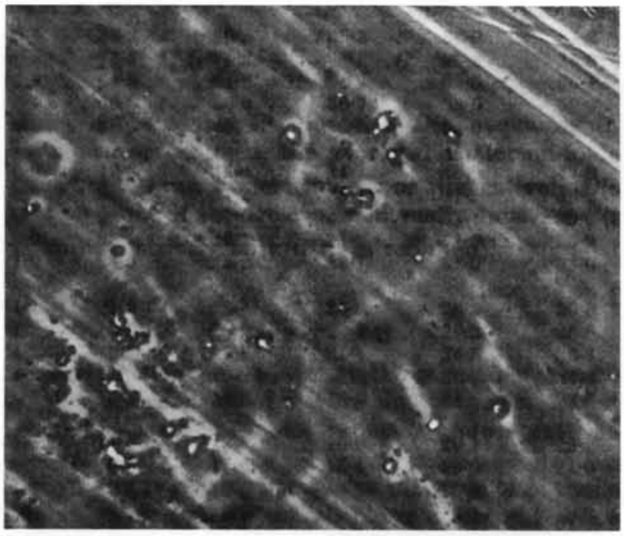

Fig. 13. Specimen 29, 10% extension, showing two sets of markings in addition to primary slip within the stria. × 1000.

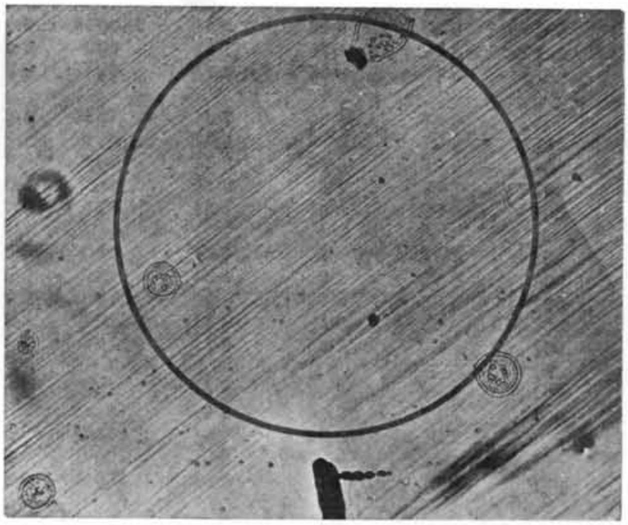

Fig. 14. Specimen 13, 1% extension. Faint slip lines throughout irradiated area. × 50.

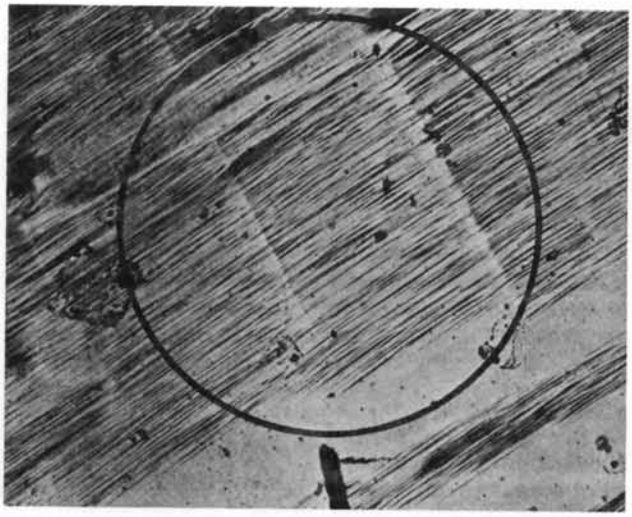

Fig. 15. Specimen 13, 4% extension, same area as Fig. 14. Kink bands and striae well developed. × 50.

have given irradiated areas of the two crystals in the ratio of 5:2. Intensity ratios of this amount should be clearly apparent and it may thus be concluded that the setting is accurate to better than 0·1 mm.

The asterism in each pattern was interpreted by plotting the spreads of three or more reflections on a stereographic projection and deriving the unique rotation axis to which this corresponded. This is a more positive method of determining the rotation axis than that of comparing the observed asterism with the asterism predicted for various axes. The latter method, however, is simpler to demonstrate and will be used for the illustrations herein although detailed analysis of the type described above was made first in every case.

Results

There are four main observations common to all the eight specimens examined:

(*a*) In every case the principal slip system was that of the highest resolved shear stress, as calculated from the known orientation of the specimen. The mean spacing of the slip lines at magnifications of ×500 was 1·5±0·3 microns. This measurement is the perpendicular distance between slip planes. There seemed little evidence that the spacing was appreciably less as the extension increased from 1% to 20%, the main difference being that at the lower extensions most of the slip lines corresponded to small displacements.

(*b*) Deformation bands of the type described by previous workers as kink bands were observed in all the specimens, Fig. 8. The ease with which they can be detected depends largely on their orientation with respect to the surface examined, but under favourable conditions they are clearly visible after 2% extension. The spacing of the kink bands, the perpendicular distance between them, was between 0·2 mm. and 0·8 mm., decreasing with extension.

(*c*) The third feature observed in the micrographs appeared as striae in which the main slip system was much less prominent, Figs. 2, 13 and 15, and in which, in some cases, a second slip system could be seen, Figs. 6 and 7. The direction of the striae was always slightly inclined to the primary slip lines. The striae varied considerably in size, the largest extending right across the crystal, having a length of nearly 1 cm. and a width of up to 0·5 mm.

(*d*) X-ray patterns taken with the large X-ray beam invariably showed more marked asterism than those taken at the same point with the small beam, Figs. 9 and 10. This demonstrates that the bulk of the asterism is due to macroscopic misorientations on the same scale as the dimensions of the X-ray beam.

The major difference between specimens lay in the interpretation of the asterism. In four of the specimens, 11, 17, 27 and 31, the spread of the reflexions could be interpreted as rotation about the appropriate *T* axis. This is illustrated by Figs. 4 and 5. In the remaining specimens no such agreement could be found, Figs. 9–11. In view of observation (*d*) above, it was reasonable to correlate this difference with features in the micrographs of magnification ×50, and it was indeed found that where the irradiated area contained striae the asterism did not correspond to rotation about the *T* axis. For example, in Fig. 6, the irradiated area for the X-ray patterns Figs. 9 and 10, the stria is clearly visible, while on the other hand the area corresponding to Figs. 4 and 5, shown in Fig. 3, reveals no striae. This observation simplified the problem into two parts, one of the kink bands and their associated rotation about the *T* axis, and the second of the striae and their complex rotations. Since other investigators have recently discussed the nature of kink bands in some detail the results on this subject will be dealt with but briefly here.

Kink bands

In specimen 17 small-beam patterns were taken from areas overlapping a kink band and in an adjacent region. The asterism which agreed with rotation about the *T* axis was very marked in the former case. For the area shown in Fig. 3 the asterism after 3% extension also corresponded to rotation about the *T* axis. Since no kink bands were visible, however, it was not certain whether the asterism was due (*a*) to misorientation of bands bounded by the positions where the kink bands should be, or (*b*) to irregular misorientations throughout the area but about the same axis. To distinguish between these possibilities slit beam patterns (the irradiated area being a narrow rectangle 2 mm.×0·5 mm.) were taken parallel and perpendicular to the calculated positions of the bands. If (*a*) is true the pattern with the slit perpendicular to the bands should show greater asterism but if (*b*) is true then the patterns should show similar asterism. The former was indeed the case. From this it may be deduced that although the fold bands were not yet visible the long band-like type of misorientation had already developed within the crystal.

Detailed consideration of the striae

It will be seen from the optical micrographs that the striae do not display a uniform appearance, and in fact they may be divided into two classes: (*A*) those showing clearly defined slip lines corresponding to a second system, Figs. 6 and 7, and (*B*) those showing little or no slip lines either of the primary or secondary systems but having a rumpled appearance, Figs. 12 and 15. It is not immediately evident that these are the same feature, and consequently this point was investigated.

An obvious characteristic common to all the striae is their habit of lying slightly inclined to the main slip lines. Observations on the side surfaces of the

Table 1. *Appearance of striae and orientation relationships*

Specimen	Angle of second slip plane		Appearance of striae		Geometrical possibility that markings in striae are kink bands	
	With main surface	With side surface	Main surface	Side surface	Main surface	Side surface
13	28°	73°	*B*	*A*	Yes	No
17	62	70	Possibly *A*	*A*	—	No
26	70	68	*A*	—	No	—
28	26	78	*B*	—	Yes	No
29	24	79	*B*	*A*	Yes	No

crystals also revealed striae slightly inclined to the slip lines, but in general of different appearance from those on the main surface. This suggested that the appearance was connected with the orientation of the surface. The angles between the second operative slip plane and the surfaces were then calculated for each specimen and compared with the type of striae, Table 1. It is clear that when the angle is small, ~ 20°, the appearance is type (*B*), while at large angles, ~ 70°, type (*A*) results.

The rumpled markings still remain to be explained. Honeycombe (1951) considers them to be due to complicated cross-slip, since they resemble some of Brown's electron micrographs attributed to this effect (Brown, 1950, p. 103). It may also be remarked that they also resemble closely the strain markings reported by Banerjee (1950). Specimen 29 shows an excellent example of this type (*B*) appearance, and accordingly was investigated in detail. It was found that within the stria in addition to the primary slip lines there are two sets of roughly parallel markings, Fig. 13. The directions of these are shown on the standard projection, Fig. 16, as the points M_2 and M_3. The traces on the surface of the three other possible slip planes are represented by the points P_2, P_3 and P_4. There is no agreement between these two sets of points so that it may be concluded that the individual markings are not unresolved slip bands, i.e. the markings as a whole do not correspond to cross slip. Very good agreement is obtained, however, on the assumption that the markings are kink bands, as shown by the proximity of the observed points M_2 and M_3 to the points K_2 and K_3, which are the traces of kink bands perpendicular to the slip directions D_2 and D_3. It seems that this is a reasonable explanation since the type (*B*) appearance is associated with the second slip plane being at a small angle to the surface, with the result that the kink band makes

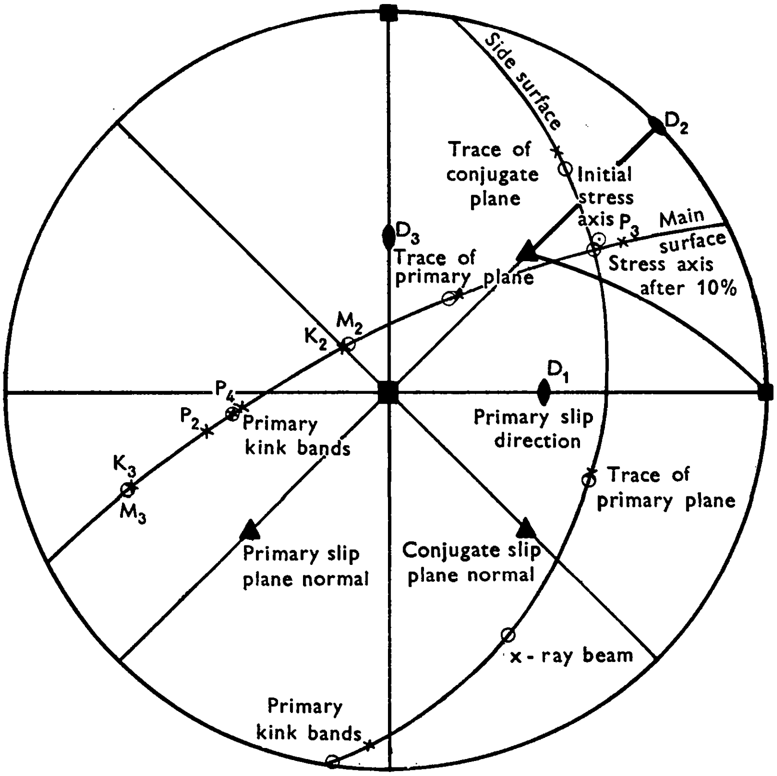

Fig. 16. Stereographic projection of specimen 29. Circles: observed points; crosses: calculated points.

a large angle with the surface and produces more marked rumpling. To test this hypothesis an additional specimen, 28, of orientation very similar to 29 in all respects, was extended 10%. The appearance of the striae was almost identical.

These conclusions are also confirmed by specimen 13 where the type (*B*) appearance is observed on the main surface. The second slip plane makes an angle of 28° with the surface and the markings in the striae correspond to kink bands for one of the slip directions on the conjugate plane.

Conversely, where the type (*A*) appearance is observed the additional markings agree with the slip lines and not with kink bands.

Turning now to the connection between the asterism and the striae, it is clear from the observations where only kink bands lie within the irradiated area that the splitting of the X-ray spots corresponding to rotation about the *T* axis must imply different orientations on either side of the band. A different set of kink bands within the striae will produce another splitting, so that a beam overlapping the region of primary kink bands and a stria may display fourfold splitting corresponding to rotation about the *T* axes of the two operative systems. This appears to be the explanation of the fourfold splitting observed in Fig. 9.

From the detailed optical observations on specimen 29, however, it was concluded that there were two additional sets of kink bands within the striae. This might be expected to produce a complex asterism in a pattern where the beam lay within the stria, and an even more complex effect when the beam overlapped the edge of the stria. Small-beam patterns taken in these positions did not agree with this entirely, the former showing little asterism and the latter, showing splitting probably corresponding to one of the additional *T* axes, the conjugate *T* axis. It is possible that the complicated array of kink bands in this stria causes no simple 'rumpling' as is the case when a single set of kink bands is present.

There are two other possible explanations of the misorientation of the material in the striae with respect to the surrounding regions. In specimen 13 neither kink bands nor striae were visible after 1% extension, the micrographs revealing only faint slip lines over the whole area examined, Fig. 14. Both features were evident, however, after 2% extension and became more marked without altering appreciably in size after 4%, Fig. 15. Consequently, once a stria is formed it is probably deforming as a single crystal under very close constraints. This may well produce misorientation similar to that found near the shoulders of a tensile test-piece, although in the present case, because of the complexity of the surrounding constraints, it may defy analysis.

Finally there is the explanation that the distortion due to adjacent material affects only a small boundary region and the stria and the neighbouring part of the crystal deform as individual single crystals. The operation of different slip systems then gives different bulk rotations of the two parts, the rotation being about the axis perpendicular to the stress axis and the appropriate slip direction. Combination of different amounts of rotation about these two axes could, of course, give almost any relative spread of the fragments of the Laue spots, but it may be remarked that in specimen 29, where the stria shows less slip than the neighbouring area, the expected rotation around the primary bulk rotation axis is consistent with the splitting observed.

In conclusion, then, although it is certain that the striae produce asterism it cannot be stated whether one or all of the causes above are responsible.

Discussion

In view of the recent papers of Chen & Mathewson (1951) and Honeycombe (1951) the points where there is general agreement will not be discussed in great detail. These, in particular, are the observations that the kink bands lie in the $\{110\}$ planes normal to the operative slip direction, and that the asterism associated with the kink bands takes the form of splitting about the $\langle 211 \rangle$ axis in the slip plane perpendicular to the slip direction. The second point is probably more clearly demonstrated by the present work than by Chen & Mathewson since the latter authors were not aware of the second type of deformation band, which gives a very different asterism.

The main contribution which the present paper has to make concerns the striae. These have certainly been observed by Honeycombe as regions of secondary slip, while Chen & Mathewson report a feature which they describe as the 'bunching' of the slip lines. They state, however, that this effect occurs when kink bands are not formed, and, in particular, for stress-axis orientations near the [111]. Since, however, kink bands and striae occur within the same crystal it is possible that Chen & Mathewson's observation is of a different phenomenon. The deformation bands observed in aluminium by Barrett & Levenson (1940) appear to be mainly of the kink-band type. On the other hand, the bands described by earlier workers and investigated in iron by Barrett & Levenson (1939), which are characterized by the operation of additional slip systems, are of the striae type. That the striae are a frequent cause of asterism in Laue patterns of the usual type is amply demonstrated herein but the detailed interpretation of the resulting asterism presents some difficulty. In every case where the X-ray beam overlapped striae the asterism could not be explained on the basis of rotation about the *T* axis as was possible where only kink bands lay within the irradiated area.

It remains to discuss the origin of the striae. There is evidence from the micrographs that the positions of the kink bands are undisturbed by the striae, that is to say, that the bands continue in the

Table 2. *Predicted and observed slip systems*

	Slip systems predicted on classical	Slip systems on new treatment			Slip systems
Specimen	theory	Single	Duplex	Multiple	observed
27	1*a*, 3*d*	1*a*	1*a*, 3*d*	1*a*, 1e, 3*d*, 3*e*, 4*a*, 4*d*	1*a*, 3
17	1*a*	1*a*	1*a*, 2*c*	1*a*, 1e, 2*c*, 2*h*	1*a*, 2
31	1*a*	1*a*	1*a*, 1e	1*a*, 1e, 3*d*, 3*e*, 4*a*, 4*d*	1*a*
11	1*a*	1*a*	1*a*, 1e	1*a*, 1e, 3*d*, 3*e*, 4*a*, 4*d*	1*a*, 4*a*
26	1*a*	1*a*	1*a*, 1e or 2*c*	1*a*, 1e, 2*c*, 2*h*	1*a*, 2
29	1*a*	1*a*	1*a*, 3*d*	1*a*, 1e, 3*d*, 3*e*, 4*a*, 4*d*	1*a*, 3, *d*, *e*
13	1*a*	1*a*	1*a*, 3*d*	1*a*, 1e, 3*d*, 3*e*, 4*a*, 4*d*	1*a*, 3
15	1*a*	1*a*	1*a*, 2*c*	1*a*, 1e, 2*c*, 2*h*	1*a*

Nomenclature of slip elements, referring to Fig. 1:

Slip planes: 1,$(11\bar{1})$; 2,(111); 3,$(1\bar{1}1)$; 4,$(1\bar{1}\bar{1})$

Slip directions: *a*, $[101]$; *c*, $[10\bar{1}]$; *d*, $[110]$; *e*, $[011]$; *h*, $[01\bar{1}]$.

When both slip plane and slip direction could be found, the observed slip is described by a number, indicating the plane, and a letter indicating the direction. When the plane only can be stated, the number only is used; and when the direction only can be stated, the letter is used.

same positions on the other side of the striae. This suggests that the arrays of dislocations must be sufficiently stable after about 1% deformation to establish the sites at which the kink bands develop in subsequent deformation and that only after this initial stage do the striae develop. If this were not so, and both types of band developed as soon as deformation began, it is difficult to see why the kink band should continue undisturbed by the striae. On this basis it appears that the striae are regions of complex deformation enforced by the inherently inhomogeneous deformation associated with the kink bands.

An alternative suggestion by Wilman (1951) is that deformation bands are due to rotational slip. It is not specified which type of band he is discussing but the present work and previous investigations have demonstrated beyond dispute that the rotation associated with kink bands is about the $\langle 211\rangle$ axis in the plane of the band. This could hardly be mistaken for rotational slip about the normal to the band so the possibility that kink bands in tension are due to rotational slip may be dismissed. Since the second type of deformation band, however, appears to form lamellae roughly parallel to the primary slip plane, there is a possibility that they are associated with rotation about the slip-plane normal. The present observations do not support this, for in only one of the seven areas examined where striae cross the irradiated area could the asterism correspond to this axis, and in the pattern overlapping the edge of a stria in specimen 29 the splitting is definitely not about this axis. There are, nevertheless, additional axes, $\langle 100\rangle$ and $\langle 110\rangle$, about which Wilman finds evidence of rotational slip. The condition deduced from his abrasion experiments that the axis should lie in or near the surface is probably not relevant in the present case of tension, so that by considering all the axes of these types it should be possible to find one which will explain the asterism. The difficulty still remains that the striae form on planes near (111) and rotational slip on this plane does not explain the asterism. Consequently an explanation on the basis of rotational slip demands bands, approximately parallel to (111), of rotational slip on a very different plane. There seems little point in pursuing these speculations further in the present state of knowledge.

A more fruitful correlation of the features of the striae is with the ideas proposed by Calnan & Clews (1950, 1951*a*, *b*, *c*) for the deformation of polycrystalline aggregates. The essential problem in this work is to explain the inhomogeneous deformation necessary for the maintenance of cohesion at the grain boundaries. It is postulated that for a part of a grain under applied tensile stress the effective stress system can be represented by a simple tensile stress, T_e, initially coincident with the applied stress direction but which under increasing applied stress moves to a point of lower resolved shear stress. This movement continues until slip occurs. The slip takes place on a single system if T_e lies within the unit triangle, on two systems if T_e lies at a triangle edge, or on multiple systems if T_e has reached the minima of resolved shear stress at the corners of the unit triangle. The element of slip relieves the stresses between the grains or parts of grains, T_e returns to the position of the applied stress and the cycle of events is repeated, leading again to single, duplex or multiple slip. In regions where the constraints are greatest, for example near grain boundaries, multiple slip is to be expected more frequently.

The inhomogeneities of deformation in a single crystal indicated by the formation of both types of deformation band suggest that the polycrystalline concepts may be applicable here. It was found in every case where additional slip systems were detected that these were indeed consistent with the systems predicted by the polycrystalline treatment. This is shown by Table 2, where the slip systems predicted on classical theory, on the new treatment, and those observed are compared. Only in the case of specimen 27 is a second system, the conjugate, expected to be brought into operation by rotation of the stress axis to the boundary of the unit triangle. For all the other specimens the orientation of the stress axis after deformation is within the original unit triangle. The systems listed on the basis of the new treatment are those expected to be operative in a grain of the appropriate orientation in a polycrystalline aggregate in order to accommodate inhomogeneous tensile deformation. With the greatest constraints to the grain there is the highest probability for multiple slip; with lesser constraints duplex slip is more probable. It is reasonable to suppose that the latter case corresponds more closely to the deformation of a single crystal, and consequently the duplex systems are expected to be operative. The general agreement of the observed systems with the duplex systems in Table 2 gives confirmation of this hypothesis. Even more convincing is the detail in specimen 29 where, however, the evidence is of multiple slip. The stress-axis orientation of this crystal is 17° from the [111] direction, and T_e may be expected to move to the [100] [111] edge, where the duplex slip occurs, and thence to the [111] direction. At this latter point the resolved shear stresses are equal on six systems, two planes for each of the three $\langle 110 \rangle$ directions (*a*, *d* and *e* of Table 2) symmetrically arranged around the [111] at a distance of 35°. In the micrographs of this specimen evidence of the conjugate system was certainly found and the interpretation of the markings in the striae led to the conclusion that the markings were kink bands corresponding to precisely the expected slip directions.

It thus appears that the concepts introduced in Calnan & Clews's treatment, although a simplification of complex stress systems, do give a realistic description of the deformation of not only the grains in a polycrystalline aggregate but also of single crystals. That is to say, the view that the deformation proceeds by the operation of the predicted single, duplex, or multiple slip systems in varying degrees in different parts of a grain seems essentially correct.

Since the local constraints will not be the same for all the striae the amounts of slip on the operative systems, and consequently the rotations of the striae with respect to the remainder of the crystal, may be expected to vary. For this reason it is hardly surprising that the asterism at the edges of the striae was not capable of systematic analysis.

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