

$$\langle \Phi | F(H) | \Psi \rangle = \int_{-\infty}^{+\infty} F(\lambda) d(\langle \Phi | E(\lambda) | \Psi \rangle)$$

for all $|\Phi\rangle$ in \mathfrak{H} and all $|\Psi\rangle$ in the set \mathfrak{D}_F of all vectors in \mathfrak{H} such that $\int_{-\infty}^{+\infty} |F(\lambda)|^2 d(\|E(\lambda)|\Psi\rangle\|^2)$ exists. Hence, if $F(\lambda) \equiv e^{iHt/\hbar}$, then \mathfrak{D}_F is the set of all vectors $|\Psi\rangle$ in \mathfrak{H} such that $\int_{-\infty}^{+\infty} d(\|E(\lambda)|\Psi\rangle\|^2)$ exists. And since $\lim_{\lambda \rightarrow -\infty} E(\lambda)|\Psi\rangle = |0\rangle$ and $\lim_{\lambda \rightarrow +\infty} E(\lambda)|\Psi\rangle = |\Psi\rangle$ for all $|\Psi\rangle$ in \mathfrak{H} , it is clear that $\mathfrak{D}_F = \mathfrak{H} \supset \mathfrak{D}_H$, so that $e^{iHt/\hbar}$ certainly exists. Also, using²

$$\langle \Phi | G^\dagger(H) F(H) | \Psi \rangle = \int_{-\infty}^{+\infty} G^*(\lambda) F(\lambda) d(\langle \Phi | E(\lambda) | \Psi \rangle)$$

it is evident that $e^{iHt/\hbar}$ is unitary and that H is identical in both pictures.

Thus the Schrodinger and Heisenberg pictures are equivalent, provided merely that H is self-adjoint.

H. S. PERLMAN

Department of Physics,
Monash University,
Victoria, Australia.

¹ Dirac, P. A. M., *Nature*, **203**, 115 (1964).

² Stone, M. H., *Linear Transformations in Hilbert Space* (A.M.S., New York, 1932).

H. S. PERLMAN assumes that H is a self-adjoint operator, operating in Hilbert space. This assumption is not valid in quantum electrodynamics. H , like the other dynamical variables, then operates on vectors in some kind of space, larger than a Hilbert space, the nature of which is unknown.

P. A. M. DIRAC*

St. John's College,
Cambridge.

* Present address: Belfer Graduate School of Science, Yeshiva University, New York.

GEOLOGY

Kink-bands and Related Geological Structures

DR T. B. ANDERSON¹ considers that kink-bands are symmetrically distributed about a planar anisotropy caused by cleavage, and that this is indicative of the major principal pressure acting within the cleavage. This is not justified since in rocks with strong planar anisotropy there is no basis for interpreting "a component parallel to the strike of the s -surface"^{1,2} as the maximum principal pressure. Indeed, according to Hoepfner³, the view that the maximum principal stress bisects the obtuse dihedral angle may be fallacious.

However, permitting Anderson's assumption, it is apparent from his values that the kink-bands are not symmetrically arrayed about the modal cleavage. This asymmetry may be explained in terms of a small discrepancy in the modal cleavage value; but it probably reflects true variations in the orientation of the kink-bands since, although the dextral kink-bands are very consistent in their orientation, it would appear from Anderson's statement that the sinistral ones are less so. Further, the two kink-bands in Anderson's Fig. 2, because they do not intersect, are not truly conjugate and may be explained in terms of a first-order shear on which a second-order shear has developed. One must, therefore,

question that Anderson's kink-band system is the product of irrotational strain as would be the case where P_{\max} is contained within the cleavage. This is critical, for should P_{\max} not be contained within the cleavage of strongly planar-anisotropic rocks the strain will be rotational, P_{\max} will not bisect the obtuse dihedral angle and the kink-bands will not be symmetrically disposed about the s -surface.

It is important to Anderson's theory that, as stated by him, "The orientation of the kink-band itself does not change". However, in a summary of work from the Rhenish Schiefergebirge, Hoepfner⁴ concluded that relative rotation between the rock and the shear-planes must occur. Similarly, in the Start Point area⁵, South Devon, where steeply dipping kink-bands cross a sub-vertical cleavage, I observed in plan view and on the cleavage face kink-bands of the same movement-sense crossing each other, bifurcating and converging.

For the orientation of the kink-bands to be consequential on the rotational movements on the foliation surfaces between the kink-planes, as suggested by Anderson, it is implicit that the direction of shear paralleling the kink-bands is also consequential. In south Devon, however, I have traced a kink-band along its strike into a single kink-plane with associated pinnate tension joints⁶, in turn passing into a strip of tension gashes *en echelon* (Fig. 1). Similar associations are figured by Engels⁷, and in all cases the movement-sense is consistent throughout the association. Thus, the direction of shear paralleling the kink-band must be the primary displacement, while rotational movement on the foliation surfaces between the kink-planes is secondary.

Although greater variation in the angle of internal friction (ϕ) might occur, it is generally thought to lie between 25° and 35° (ref. 8). According to Anderson's theory this would place limiting values of 115° and 125° on the dihedral angle between conjugate kink-bands containing P_{\max} . However, Hoepfner³ recorded values ranging between 105° and 140°, Ramsay⁹ reported values of less than 90°, and I have noted values of less than 90°

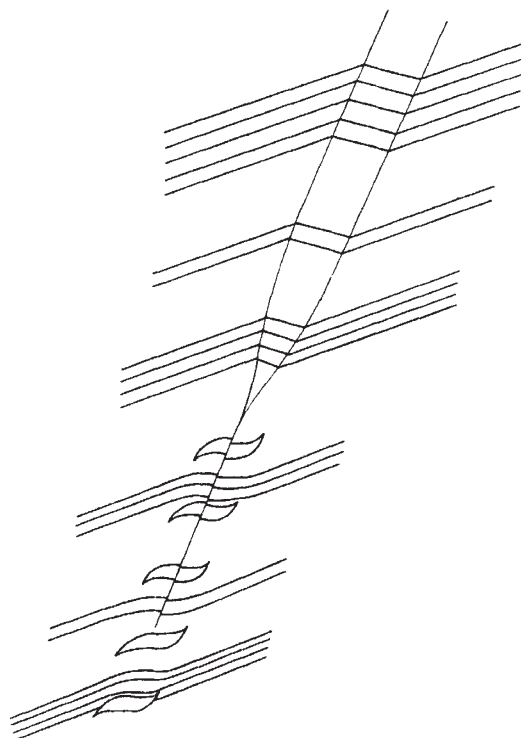


Fig. 1. Diagrammatic association of kink-band, pinnate tension joints, and tension gashes