CORRESPONDENCE

CONJUGATE FOLDS, KINKS AND DRAG

SIR,—John G. Ramsay's account of the geometry of conjugate fold systems (1962) has just come to my notice. The topic is one of wide geological significance, as Ramsay recognizes in referring to concertina or zig-zag folds as having certain similarities with the types he describes, although box-folds are in fact even more closely comparable (Hills, 1953). However, zig-zag folds are of several types, some having single rather than paired kink-planes which may be conjugate but which also include median (vertical or near vertical) surfaces, others predominantly median (near vertical) kinks, which are often complicated by shear-folding (Hills, 1953, briefly treats these types).

Ramsay appears to refer categorically to yielding by kinking, conjugate folding and the like as occurring in brittle materials. A more comprehensive discussion of this point would have been appreciated, as his justification seems to lie in the statements that these structures are " often related both in space and time with the development of faults, thrusts, and joints ", and that the conjugate structure " usually (but not invariably) made an angle of less than 45 degrees to the principal stress axis ". In fact, yielding of the type under discussion is best known and was first recognized in the plastic deformation of metals and mineral crystals. Kinking in single crystals produces angular " folds " in the glide or slip planes, but median and single conjugate kink planes may also combine to give curvilinear as well as kinked deformation in " bend-gliding " (Orowan, 1942). Deformed mica crystals illustrate these structures admirably. The mechanism of twin-gliding is, of course, similar, but more intimate in relation to the fine structure of the crystals. Although the notion of brittleness is perhaps not precisely definable, Ramsay will, I think, be hard pressed to sustain his claim that the specimens illustrated in his paper, and especially his Text-fig. 1, represent brittle failure. Nadai (1931) was among the first to recognize kinking and folding connected with paired (and ideally conjugate-paired) kink planes, as an element of the plastic deformation of geological materials.

As to previous statements by me and by others relating to drag-folding and the precise direction of fault displacements, I have been at some pains to avoid using " drag-fold " in connection with fault-drag, and in fact point out that a flexure normally develops before the fault. I do this, however, for a single fault, not for kinking between a pair of parallel surfaces. I have certainly never mentioned " the line at right angles to the axes of drag folds produced by movements on the fault ". I merely state that the flexing (not kinking) " affords a ready means of determining the direction of relative displacement of the blocks ", which, in context, is a purely qualitative statement. Similar reservations apply *a fortiori* to Nevin's remarks, made with his usual delightful skill in lucid expression. He refers to " drag " on faults and distinguishes this from " drag-folding ". He states that the " drag " is largely developed before faulting, and says simply that it indicates the " relative movement " of the blocks—a statement that could not be made more qualitative, as the word " direction " does not appear. Nevin's and my comments on drag-folds in folded terrains are, of course, limited to their context and are not transferable to a discussion on faulting, especially since neither of us uses drag-fold in that connection.

In my experience I have not known of any geologist attempting to determine the precise direction of translation on a fault by taking a line at right angles to the axes of associated minor folds. On the other hand, the use of " drag " to indicate the up- or down-thrown block is universal.

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https://doi.org/10.1017/S0016756800057836 Published online by Cambridge University Press

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18th March, 1963

AGE OF THE ALPINE FOLDS OF SOUTHERN ENGLAND

SIR,—It is well known that quite large folds of Alpine age occur in east–west lines across the southern part of England. Where well developed, as in the Isle of Wight for example, they show a pronounced monoclinal form which, at outcrop, involves Mesozoic and Tertiary strata. Very steep beds, "younging" to the north, form a middle limb connecting nearly horizontal strata to the north and south. Although these structures therefore have an overall simple fold form, in detail they are quite complex. For instance, Arkell (1938 ; 1947A) has very fully described and illustrated the cleavage and fault pattern associated with the Isle of Purbeck monocline. These monoclinal Alpine folds are the most recent orogenic structures to be seen in Britain and clearly merit a detailed structural study. Meanwhile, it seems worth attempting to fit their development into the Tertiary time scale of events as precisely as the evidence will allow.

The age of these folds is generally assigned to the Miocene period (for example, see Wells and Kirkaldy, 1948, pp. 290–1), but attempts have been made to define the date of the fold movements more closely. Wooldridge and Linton (1939, p. 15) and Arkell (1947B, p. 182 and p. 189) agree in placing the folding in late Oligocene or early Miocene times, following the deposition of the youngest strata, the Middle Oligocene Hamstead Beds (Curry, 1958, pp. 41–2), seen to be involved in the folds in the Isle of Wight. They argue that most of the Miocene period would have been occupied by denudation of the structures with the production of the surface bearing the Pliocene deposits of south-east England. There is, however, another aspect to this problem.

It is clear, as Webster (in Englefield, 1816, p. 201 and pl. 47, fig. 1) recognized, that the steeply dipping Chalk in the eastern Isle of Wight monocline was formerly connected to the flat lying Chalk seen in outcrop in the southern part of the island. Thus it may be estimated that about 2,000 feet of near horizontal Cretaceous rocks have been removed by erosion from the area immediately south of the steep limb of the fold (see, for example, Section No. 2, the relevant portion of which here forms the basis of Text-fig. 1, on Sheet 47 of the Horizontal Sections of the Geological Survey). Further, there seems to be no reason why this thickness should not have been overlain by the southward continuation of the Tertiary sequence now seen in the steep limb. Indeed, the recognition of Tertiary strata on the floor of the English Channel south of the Isle of Wight (Curry, 1962) supports the view that the Eocene and presumably also the Oligocene were formerly present above the Chalk in the southern part of the island. Altogether, then, there may have been some 4,000 feet of Cretaceous and Tertiary rocks above the present level of erosion immediately south of the steep limb.

If such a thickness has been removed then it seems reasonable to assume that a considerable thickness is likely to have also been eroded from the area only a mile or so to the north. Thus, on fitting the monoclinal fold form to the available data and completing the structure *above* the present level of erosion, it seems likely that *much younger* flat lying strata were originally present above