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CORRESPONDENCE AND NOTES

New fold terminology – equal and unequal folds

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Abstract – The new terms 'equal fold' and 'unequal fold' are defined by whether the ratio of dips of limbs, measured in degrees, is less or greater than $1\frac{1}{2}$.

For a long period until about 20 years ago the terms 'symmetrical fold' and 'asymmetrical fold' were generally used to indicate whether the outward dips in an antiform or inward dips in a synform were approximately the same or markedly different. Since then these terms have become increasingly used with different meanings, relating to either (a) whether the axial plane bisects the interlimb angle, or (b) relative limb lengths and the closely related property of whether axial planes are perpendicular to enveloping surfaces. The current widely accepted use of the terms in these senses is exemplified by the second edition of the American Geological Institute's *Glossary of Geology* (Bates & Jackson, 1980), and could be supported by quotation from numerous modern textbooks of structural geology.

It might at first appear that the previous usage of the terms relating to the symmetry of folds would now be covered by 'upright' and 'inclined' (for definitions of these and other aspects of fold terminology see Fleuty, 1964). This is, however, frequently not the case for two main reasons. Firstly these adjectives relate to the dip of the axial plane rather than dips of the fold limbs: if the axial plane does not bisect the interlimb angle, an upright fold can have marked differences in the dips of the two limbs or an inclined fold can have limbs with similar dip values. Secondly, if folds are gentle or open, it is possible to find axial planes bisecting interlimb angles and upright (dipping more steeply than 80°), yet fold limbs with widely different dip values (and very different outcrop widths on approximately horizontal land surfaces). This applies to many folds in the southeastern half of England.

The last point can be considered in relation to a graph of the dip values of the limbs of a horizontal (non-plunging) fold, in which the axial plane bisects the interlimb angle (Fig. 1). It is best to start with limbs dipping in opposite directions, that is the left half of Figure 1. Line OA is the lower limit of the left half of the graph and represents folds which are completely upright or recumbent (vertical or horizontal axial planes respectively); every point within the operative part of this diagram (area AOL) can, of course, represent two different fold geometries with axial planes normal to each other. The limiting case for inclined folds (axial plane dipping at 80°) can also be plotted – line BF. The area of the graph between these lines (area OABF) would include folds which are upright (axial plane dipping < 80°) but some with large differences in the dips of the two limbs (e.g. 20° and −1°) and very large differences

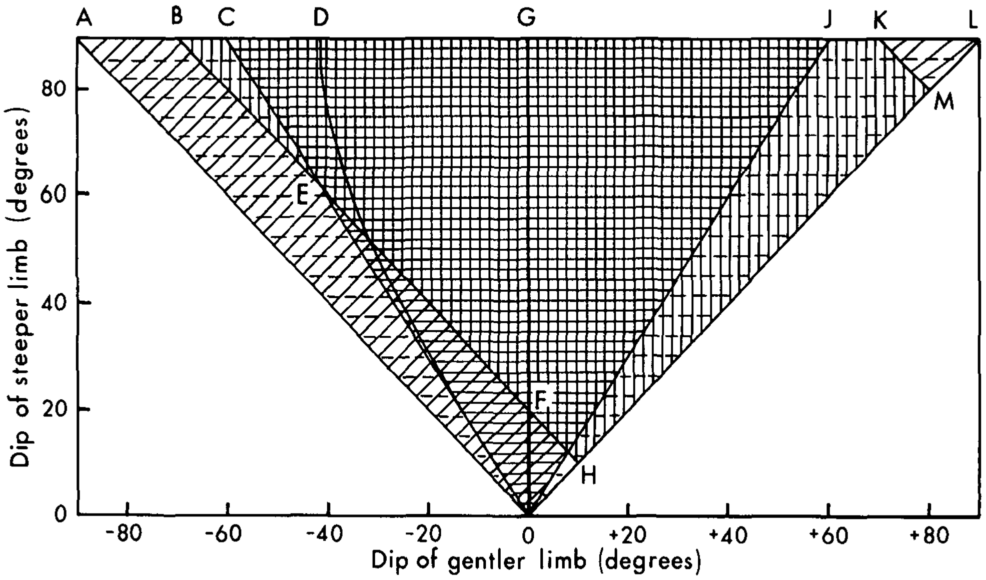

Figure 1. Graph of dips of limbs of horizontal (non-plunging) folds; for explanation see text. On the horizontal axis negative values represent dips of the gentler limb in an opposite direction to that of the steep limb, while positive values represent dips in the same direction. Diagonal ornament represents upright and recumbent folds while vertical lines show the area of inclined folds. Continuous horizontal lines indicate unequal folds while broken horizontal ornament shows areas of equal folds.

in outcrop widths on horizontal surfaces (approximately 1:19.6 for this example). Geology at present lacks any simple term to describe such a situation. It is therefore proposed that a new term should be introduced to deal with this – unequal folds.

There are two obvious ways in which the terms 'equal fold' and 'unequal fold' can be defined – by the ratio of outcrop widths of the fold limbs on horizontal surfaces or by the ratio of dip values. Whichever is chosen can easily be related to the other by trigonometric tables, but to the author the ratio of dip values appears preferable, since they can often be measured directly in the field and are frequently recorded on geological maps. On the other hand outcrop widths are affected by topography, and calculation of the equivalent width on a horizontal surface is somewhat complex. It is proposed that an unequal fold be defined as one in which the dip of the steeper limb is at least 50% greater than the dip of the gentler limb (measurements in degrees). In Figure 1 the line for dip values in the ratio 3:2 is shown (line OC) and also that which would give outcrop widths on horizontal surfaces in this ratio (curved line OD). It is apparent that for low angles of dip the two are almost coincident.

As an example of the main value of the term 'unequal fold' one can take the syncline which is centred on Southwick, immediately north of the Portsdown anticline in the Hampshire Basin of southern England. The unequal nature of this fold is shown well by the outcrop of the Reading Beds in the two limbs of the syncline (Fig. 2). An estimate of the dips of the limbs can be obtained from the thickness of these beds and their widths of outcrop in places where there is no topographic interference, in the western parts of the area shown in Figure 2. The regional memoir gives the Reading Beds as having a fairly uniform thickness of 32 m over most of this area (Melville & Freshney, 1982), while well borings gave thicknesses of 109 ft 6 ins (33.5 m) at New Brighton, 125 ft (38 m) at Hermitage and 102 ft (31 m) at Wickham, respectively 13 km E, 13 km ESE and 5 km WNW from Southwick (White, 1913). Taking the last figure (31 m) from the nearest borehole gives a dip of about 9° in the southern limb and approximately $1\frac{3}{4}°$ in the northern limb. Although there is some uncertainty in these dip values, from both the thickness of beds and the exact positions of outcrops, they are not likely to differ much from the figures given, and this fold is clearly unequal in terms of the definition given above. There is no information on the attitude of its axial plane, and its definition within the wide flat hinge zone would present some problems. If, however, it is taken as bisecting the interlimb angle, it would dip at approximately $86\frac{1}{2}°$ and this fold would be defined as upright despite the very unequal nature apparent from Figure 2.

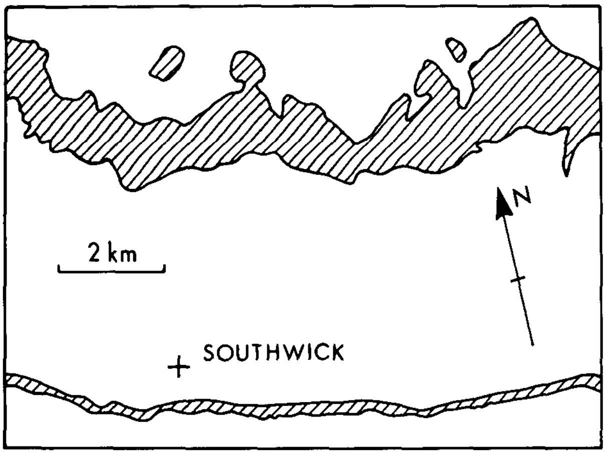

Figure 2. The outcrop of the Reading Beds (diagonal stripes) in a part of the syncline around Southwick, based on the 1:63360 sheet 316 of the British Geological Survey.

The greatest advantage of the term 'unequal fold' will clearly be its use for folds which have markedly different dips of their limbs but their axial plane upright. It could, however, also be useful to describe a fold as equal if, despite having an inclined axial plane, the dips of its two limbs were approximately the same (ratio $< 1\frac{1}{2}:1$) due to differences of limb thickness, and therefore having an axial plane not bisecting the interlimb angle. With the definitions given above there will be a few inclined equal folds, even when the axial plane bisects the interlimb angle (falling in the small area BEC in Fig. 1). In the opinion of the author this is not a drawback, since the availability of another adjective to describe such folds adds to the information which can be easily and rapidly conveyed. If, however, the reader considers this situation to be diadvantageous, it is hoped and believed he will consider it much preferable to having more complex rules governing the use of the new terms.

Having defined equal and unequal folds in relation to horizontal hinges, and limbs dipping in opposite directions, it is necessary to consider other, more complex situations. First this treatment can be extended to horizontal folds with limbs dipping in the same direction, represented by the right half of Figure 1. Here there is again a lower limit to the graph – line OL, where interlimb angles become 180° or zero and folding fades out or becomes isoclinal. The limiting case for inclined folds (line BF) can be extended to H. The area OABH then relates to the majority of upright and recumbent folds, although there is another small area of such folds represented by the triangle KML. Inclined folds fall in the area BHMK. There is generally less need for the terms 'equal' and 'unequal' in folds with limbs dipping in the same direction, since there are already several adjectives to describe the variations of fold geometry. On the other hand to exclude their use from such folds would lead to more complex rules than permitting such use. There appears to be no good reason for excluding the use of these terms from folds with limbs dipping in the same direction, and indeed their use could give additional useful, easily obtainable information on the geometry of such folds. In Figure 1, therefore, another line can be drawn to separate equal and unequal folds – line OJ. Unequal folds would fall in the area OCJ and equal folds occupy the remaining parts of triangle OAL.

Until now the consideration of fold geometry has been restricted to horizontal (non-plunging) examples. The terms 'equal fold' and 'unequal fold' must, however, also be available to describe plunging folds (axes inclined 10°–80°). Vertical folds could not be unequal, since an axis with a plunge of 80° requires both limbs to have dips of 80° or more.

To summarize briefly, it is proposed that a fold be termed 'unequal' if the ratio of dip of the steep limb to dip of the gentler limb (measured in degrees) is greater than $1\frac{1}{2}$, but 'equal' if the ratio is less than this figure. Although these new terms may have other uses, their greatest advantage will be in areas of only slight deformation, where it will be possible to describe simply and briefly folds which have markedly different dips in their two limbs although having upright axial planes.

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