CLEAVAGE IN WEAKLY DEFORMED MUDSTONES
KEITH A. W. CROOK
Geology Department, Australian National University, Canberra

ABSTRACT. Cleavage is well developed in mudstone sequences in eastern Australia in which broad, open, plane cylindrical parallel folds are common. The cleavage, which is penetrative on the scale of an outcrop, consists of statistically parallel quasi-planar fractures, commonly 0.25 to 0.5 inches apart, which tend to anastomose. Cleavage surfaces are not slickensided and lack visible recrystallization. The trace of the cleavage on bedding planes is an anastomosing system of statistically parallel fractures.

The cleavage is statistically axial plane for meso- and macroscopic folds, although fanning is evident in plots from small areas. Cleavage-bedding intersections can be used to define statistically a local fold axis (B′).

The cleavage is not related to movements between competent beds and probably developed as a response of a considerable thickness of mudstone to strain attendant on folding.

It is proposed that cleavage having the morphology described be termed reticulate cleavage. Morphologically, reticulate cleavage conforms to Leith’s definition of fracture cleavage, of which it is a variety.

INTRODUCTION

The techniques of the structural analyst are not often applied to weakly deformed and apparently unmetamorphosed sedimentary sequences. The significance of the mesoscopic structural features found in such sequences is thus likely to be overlooked.

One mesoscopic feature that is prominent in the mudstones of such sequences is a distinctive type of cleavage. The purpose of this paper is to describe and to illustrate the features of this cleavage, to show its geometric relationship to folds, to point out certain field observations relating to its origin, and to propose a name by which it may be distinguished from other types of cleavage.

GEOLoGICAL SETTING

Mudstones with a cleavage incipiently to strongly developed are common in various parts of eastern Australia, particularly in the Tamworth Trough, which is part of the New England Geosyncline of northeastern New South Wales (Crook, 1963).

The mudstones, which are poorly fissile, are olive green, olive brown, or occasionally greenish gray. They are generally moderately indurated; under a hammer blow, fragments will crush to a powder, rather than splinter into smaller fragments. The mudstones contain much silt and clay, and some show an alternation, usually on a scale of one inch or less, of persistent bands rich in very fine sand to coarse silt, and bands rich in finer silt and clay. Chlorite is the dominant clay mineral in some of the mudstones, at least. Albite is prominent in the coarser fractions.

The sequences which contain the mudstones may be thick; that in the Tamworth Trough has a maximum thickness of 18,700 feet (Crook, 1961, p. 197). In such thick sequences, mudstone is commonly the dominant rock type. In some outcrops mudstone and slightly coarser material are interbedded rhythmically on a scale of a few inches (pl. 1). More usually many hundreds of feet of banded or homogeneous mudstone contain only scattered arenite beds a few feet thick. Arenite or rudite units 50 to 100 feet thick and mudstone units up to a few hundred feet thick are regularly interbedded in some places.
PLATE 1

A. Cleavage in mudstone with siltstone interbeds. Spring Creek, Montaray, south of Tamworth, New South Wales. Hammer is 12.5 inches long.

B. Close up of part of (A). Scale is 8 inches long.
and mudstone is the dominant rock type. The proportion of mudstone to coarser material in one such sequence (the Baldwin Formation of the Tamworth Trough) is about 60:40 (Voisey, 1958).

In the Bowen and Yarrol Basins, Queensland (Hill and Denmead, 1960) and the Tamworth Trough, New South Wales (Crook, 1963), where the macroscopic structural features are known, broad, open, plane cylindrical parallel folds occur. In the Tamworth Trough the regional fold axis is statistically horizontal; individual fold axes in the mudstone sequence may be horizontal, or they may plunge north or south at low angles. The outer zone of the folded belt contains homoclinal areas, structural terraces, and folds with vertical axial surfaces. Dips rarely exceed 30°. This zone is succeeded, as the strongly deformed Central Complex (Voisey, 1959) is approached, by an inner zone of folds with steeply east-dipping axial surfaces. The eastern limbs of synclines are steeper than the western limbs, locally being vertical, but the lengths of the limbs, where visible, are subequal, and the folds are thus symmetrical across their axial surfaces. Fold hinges in the inner zone are sharper than those in the outer zone.

The mesoscopic features of these two broadly defined zones also tend to differ. Mesoscopic folds, which are of similar geometry to the macroscopic folds, are most common in the inner zone. Cleavage is usually only incipiently

Fig. 1. Sixty-seven poles to bedding, Lindsay’s Creek district, New South Wales.
A. Trace of cleavage on bedding surface of mudstone—an anastomosing system of fractures. View looking down on outcrop, Marangaroo Station, Loomberah, south of Tamworth, New South Wales.

B. Polygonal fragments, a characteristic weathering product of very strongly cleaved mudstone. Gooroolba-Biggenden Road, South Coast High, Queensland. Match-box is 2 inches long.
or weakly developed in the outer zone, but typically is strongly developed throughout the inner zone. In neither zone are bedding plane slickensides commonly seen. Strictly planar joints, in several sets, cut mudstones and arenites in both zones.

**MORPHOLOGY**

The cleavage consists of quasi-planar fractures that are penetrative on the scale of an outcrop (pl. 1-A) but commonly not penetrative on the scale of a hand specimen (pl. 1-B). The fractures, which are commonly 0.25 to 0.5 inches apart, are statistically planar and tend to anastomose in profile view. The cleavage planes are not slickensided, and to the naked eye neither recrystallization nor the growth of new minerals is visible. The bedding is not distorted or disrupted by the cleavage. The cleavage-bedding intersection, as seen on the bedding planes, consists of an anastomosing system of statistically parallel fractures (pl. 2-A).

Regionally the degree of development of the cleavage varies, but normally it is uniform for any particular small area. The cleavage, when incipient, is barely distinguishable from the irregular fracture that results from weathering. Stronger development of the cleavage makes the quasi-planar fractures more
easily visible, and they may be at least as prominent as the bedding fissility. Weathering of very strongly cleaved mudstone produces a characteristic mass of acutely terminated elongate, polygonal fragments.

GEOMETRIC RELATIONSHIPS

The statistically constant relationship between cleavage attitudes and the local fold axis ($B'$), for a small area in the Tamworth Trough, is shown by comparison of a $\pi$-diagram of bedding planes (fig. 1) and cleavage-bedding intersections (fig. 2), which give similar orientations for $B'$. The cleavage fans about the axial surfaces of mesoscopic folds, which here are vertical or dip eastward at angles exceeding $70^\circ$ (fig. 3). A $\beta$-plot of the cleavage (fig. 3) shows a concentration of points along a plane containing $B'$, perhaps indicating some plunge variation.

The regional axial surface is defined by a plot of poles to cleavage (fig. 4). Fanning is again apparent. The strike of the axial surface is almost identical to that of the regional fold axis ($B_1$) obtained from macroscopic features (Crook, 1963).

The cleavage may be considered as statistically axial plane for meso- and macroscopic folds although showing a tendency to fan about the fold axis.

Fig. 3. $\beta$-plot from 33 cleavage planes, with poles also shown (x). Lindsay’s Creek district, New South Wales.
Fig. 4. Two hundred poles to cleavage planes, Contours 1/2-5-6-10-15%. Tamworth Trough sequence, New South Wales.

GENESIS

In the Tamworth Trough sequence, cleavage is developed in mudstone blocks, which vary from a few inches to many feet in length, that are incorporated in conglomerate units (pl. 3). The mudstone of the blocks is lithologically identical to that forming the bulk of the sequence. The cleavage in the blocks is morphologically identical to that in adjacent mudstone beds and is of similar orientation. This observation, the common absence of competent beds, and the almost complete absence of slickensided bedding planes ("movement horizons"), suggest that relative movement between competent beds is unlikely to have produced the cleavage. Both in the Tamworth Trough and elsewhere. More probably, in view of its widespread development in thick mudstone sequences, the cleavage developed in response to strain in the whole sequence, attendant on folding.

The absence of the cleavage from competent beds, when these are present (pl. 1-A), should also be noted. These beds apparently have responded to strain by developing joints which are commonly widely spaced.

NOMENCLATURE

Leith (1905, p. 12) defined fracture cleavage as "independent of a parallel arrangement of the mineral constituents". Wilson (1946) describes fracture
Cleavage in mudstone block in conglomerate. Boiling Down Creek, Goonoo Goonoo, south of Tamworth, New South Wales.

cleavage as fanning about the axial surfaces of folds and as “formed by parallel closely spaced fracture-planes cutting the rock, and between the individual pairs of planes there is no special tendency for the rock matter to split parallel to them” (1946, p. 264). All these features are typical of the cleavage of weakly deformed mudstones, and there can be no doubt that this cleavage is fracture cleavage in Leith’s sense.

Several morphologically distinct cleavage types are encompassed by Leith’s definition, as is apparent from discussions of cleavage by De Sitter (1956), Knill (1960), Rickard (1961), and others. To avoid confusion it is proposed that the cleavage of weakly deformed mudstones be termed reticulate cleavage. The name is derived from the reticulate pattern of fractures visible on surfaces normal to the cleavage. The term ‘reticulate cleavage’ should be applied to all cleavage having the morphology described, regardless of its apparent origin or the rock types in which it occurs.

CONCLUSIONS

Reticulate cleavage is a morphologically distinctive type of fracture cleavage, characteristic of weakly deformed mudstones, and probably of certain other rock types. Reticulate cleavage may be used in structural analysis since it has a statistically constant geometric relationship to meso- and macroscopic folds, for which it is statistically axial plane, with a tendency to fan. It can therefore be used to determine the attitude of local and regional fold axes,
References


