CORRESPONDENCE

DEPOSITION OF THE OLD RED SANDSTONE

SIR,—Dr. K. W. Barr (1960, *Geol. Mag.*, xcvii, 263–264) draws attention to sedimentary features of the Old Red Sandstone of Ekmanfjorden, Vestspitsbergen (Dineley, 1960, *Geol. Mag.*, xcvii, 18–32), which are commonly regarded as typical of, if not restricted to, turbidity current deposits. Depositional features very similar to those Barr singles out are being studied by each of us, as well as by Dr. H. W. Ball, in other Old Red Sandstone formations, British and North American.

The upper Lykta Division (Emsian) of Vestspitsbergen and the Ditton Series (Gedinnian-Siegenian) of the Welsh Borders are strikingly similar lithologically. Each consists dominantly of red or sometimes green siltstones and abundantly of sandstones. Vertebrate-bearing intraformational conglomerates, subordinate to the finer beds, are important units of both successions. Their widely scoured bases mark the abrupt juxtaposition of very differently graded rocks, and appear to define local " cyclothems ". These major groupings, commonly tens of feet thick, seem to recur throughout the upper Lykta Division as well as the Ditton Series. They typically show the following vertical sequence: (1) conglomerate with basal disconformity (2) thick sandstone (3) thick siltstone. Inasmuch as grain size diminishes upwards, these " cyclothems " resemble the graded graywacke-shale pairs of geosynclinal " turbidites ". But in detail, unlike the superficially identical " turbidite " grouping, each " cyclothem " consists of well-defined sedimentation units, often separated by sharp bedding planes evincing subaerial exposure, reworking or brief non-deposition. Each major grouping in the Old Red Sandstone clearly accumulated gradually.

Cross-bedded sandstones in the middle sections of several " cyclothems " at Ekmanfjorden have been transformed into thick slumps (Dineley, p, 25, and text-fig. 3). Similarly contorted beds occur elsewhere in the Old Red Sandstone of Spitsbergen and in the Carboniferous red-beds of St. Jonsfjorden. In most instances slumping apparently ceased before the next bed was formed; in a few, as in convolute bedding, the upper parts of the sandstone flowed after deposition of the overlying bed. Thick sandstone slumps are not known in the Ditton Series, although thin convolute-bedded sandstones and siltstones are not uncommon. The larger structures from these formations are exactly analogous to thick, slumped, cross-bedded sandstones in the Trias of Cheshire (Rice, 1939, *Proc. Liver. Geol. Soc.*, xvii, 361–370). Comparable to the smaller structures are convolute-bedded sandstones and siltstones described from the red-bed Moenkopi Formation of Arizona (McKee, 1954, *Geol. Soc. Amer.*, *Mem.* 61, pp. 56, 65, and plate 8 A-D, 10B). Abundant signs of exposure in the Old Red Sandstone, Trias and Moenkopi suggest that slumping took place in shallows, or perhaps even subaerially.

The linear sole marks reported from Ekmanfjorden (Dineley, p, 26, and text-fig. 4) find parallels in the Ditton Series, the Moenkopi (McKee, p. 63, and plate 9 A-C), and the Lower Keuper around Liverpool (Cummins, 1958, *Liver. and Manch. Geol. Jour.*, ii, 37–43). Flute casts dominate the sole marks in the Ditton Series; load casts and groove casts are not common. As in Vestspitsbergen, suncracks commonly exist within the same thin beds as these bottom markings. Likewise, the Lower Keuper and Moenkopi abound in proofs of exposure—notably reptilean footprints (especially *Chirotherium*), suncracks, rainprints and pseudomorphs—as well as in sole marks. The bottom markings from all these formations are clearly very like those described from typical marine " turbidites ", but the environment where they formed was obviously quite different. " Flash floods " or sheet floods, as Barr suggests, sweeping over the Old Red Sandstone floodplains, may well have been important in the deposition of the coarser beds and in the formation of their sole features. But in our opinion there is no certain evidence that such

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floods led to the creation of turbidity currents, in the sense of dense flows beneath bodies of relatively still and clear water, shallow or deep. We believe that the Old Red Sandstone " cyclothems " accumulated more slowly and more uniformly, probably in fluviatile and shallow lacustrine regimes where " normal " currents operated. Interestingly enough, the metamorphosed red sandstone-siltstone measures present in the Dartmouth Slates of South-West England, holding many sedimentary features in common with the Ditton Series, have appeared to certain workers to be a deep-water " flysch ". There is now evidence that these beds are of continental, Old Red Sandstone facies (Dineley, in press).

Discovery of the features mentioned above demands no reversal of our beliefs concerning the deposition of the Old Red Sandstone, either of Britain or Spitsbergen. It does remind us, however, that the production of graded bedding, sole marks and deformational structures is not limited to environments where ill-sorted sediments are deposited rapidly by turbidity currents.

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WENLOCK STRATA OF SOUTH MAYO

SIR,—In his account of the stratigraphy and structure of the Wenlock strata of South Mayo (*Geol. Mag.*, 1960, xcvii, 265), Professor J. G. C. Anderson describes two phases of folding affecting the Silurian strata of the Croagh Patrick syncline and assumes that the gently plunging folds which roughly parallel the axis of the major structures are the earliest folds in the area.

I have recently completed mapping the ground immediately to the south of the Owenwee river, and have found that a complicated tectonic sequence of events affects the southern limb of the syncline. The intense stretching of boulders in the basal Wenlock conglomerate is parallel to an *a* direction lying on the axial plane of folds which plunge steeply to the west. These steep folds undoubtedly pre-date the first folds described by Professor Anderson, since the schistosity in the basal Wenlock psammites associated with the steep folds is, in places, deformed by a penetrative cleavage, dipping steeply northwards, which is axial to the first folds of Anderson. The steep cleavage which is prominent on the southern limb of the Croagh Patrick syncline can be shown to be a second structure on another line of evidence, since the folds with which it is associated face downwards, although the major structure faces upwards.

I am unable to agree with Professor Anderson's assertion that the major arcuate swings in strike of the southern limb of the syncline can be referred to a single phase of deformation associated with the north-westward plunging second folds. The major arcuate swing of strike around the northern margin of the Corvock granite is related to the intrusion of the granite stock and Stanton (1959) has shown that the swing in strike north-west of Cregganbaun is undoubtedly due to shearing parallel to the north-west to south-east dextral Maam faults.

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REFERENCE

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