

PLATE XVIII

- FIGS. 1, 2.—*Cranocephalites indistinctus* sp. nov. Teebjaerg, *Indistinctus* Zone (bed 28).
 Fig. 1a, b: holotype; complete adult with peristome (no. 1435).
 Fig. 2a, b: complete adult; somewhat evolute variety (no. 1437).
 FIG. 3.—*Cranocephalites borealis* (Spath). Teebjaerg, *Borealis* Zone (bed 18).
 Another complete, adult phragmacone (no. 1156).

CORRESPONDENCE

FACIES IN METAMORPHISM AND TECTONICS

SIR,—A difference in usage exists between Turner's recent publication (Fyfe, Turner, and Verhoogen, 1958, ch. 1) and an earlier one (Turner and Verhoogen, 1951). The recent recommendation is more compatible with custom in fields other than that of metamorphism. However, the earlier is a widely known text. It is therefore opportune to clarify the difference and perhaps, in so doing, to emphasize a parallelism between metamorphic, structural, and sedimentary terms.

"Facies" can be used to refer to present-day observable properties—

"This sample is a sandy facies of a horizon which is commonly silty."

"This sample is a folded facies of a bed which is elsewhere found fractured."

"This sample is a diopside-quartz-calcite facies of a rock occurring nearby as limestone."

On the other hand, there is a tendency to use the same term in referring to conditions which existed some time ago "... a littoral facies ..."

"... a more deeply buried facies ..."

"... a high-temperature facies ..."

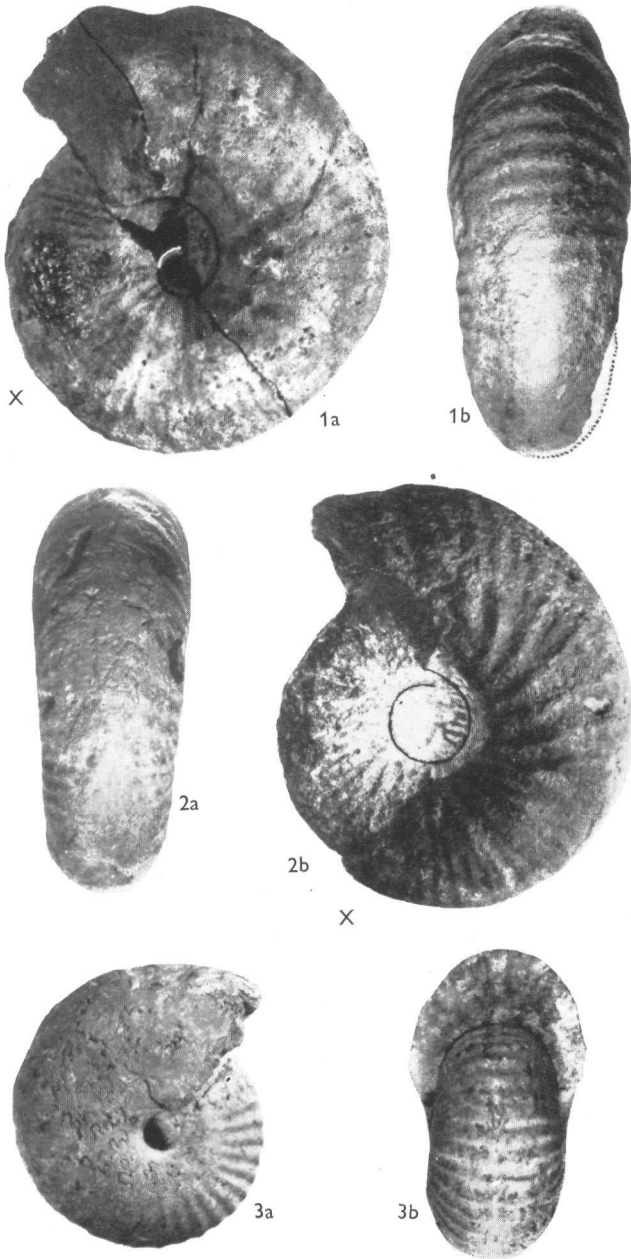
Consequently, two series of definitions are possible—

(a) "The 'sandy facies' is the facies of rocks whose grain-size range is such and such."

and (b) "The 'littoral facies' is the facies of rocks which were deposited between the low and high tide lines."

Using a series of definitions such as (a), the assignment of a rock to a facies is a matter of observation; using definitions such as (b), the assignment is a matter of conjecture. Permissible sentences are then "This rock of sandy facies is thought to be of littoral facies", etc. The two uses are convenient as long as they are clearly distinguished; but if "a facies classification" is set up (in the singular) it must be quite clear whether genetic or observational pigeonholes are intended.

Turner's recent classification is unambiguously observational. In spite of the retention of some facies-names, this is something of a change from the earlier work quoted. In the earlier work (p. 446), the Amphibolite Facies as defined embraced that range of temperature and pressure for which the assemblage hornblende-plagioclase is stable. Although minerals were used as criteria, the entity recognized was a range of conditions, and it was a matter for conjecture whether or not the pair, for example, andalusite-muscovite was stable in the same range. In the recent recommendations, the form of definition is a list of assemblages; andalusite-muscovite is associated with hornblende-plagioclase by arbitration. The conjecture just mentioned should now be rephrased—"to what extent do the assemblages grouped together by definition actually overlap in stability fields?" To



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those whose business is description, the change is beneficial, for the processes of conjecture and of assigning rocks to facies have been divorced. The only loss is that petrologists no longer have a handy phrase to express "that range of physical conditions, whatever it may be, within which the pair hornblende-plagioclase is stable". The nearest approach may be "the hornblende-plagioclase stability field". Some such phrase seems necessary to express concisely those conjectures, so crucial, at which petrography and experiment both aim, e.g.—

"the stability field of hornblende-plagioclase encloses entirely that of andalusite-muscovite"

or "... overlaps only partially ..."

A parallel may now be noted thus :

observation	conjecture
sandy facies hornblende-plagioclase facies (1958)	littoral facies hornblende-plagioclase stability field

In the case where the past conditions can be described from present knowledge, "facies" may be used for both observation and conjecture; but in the case where the past conditions can be referred to only obliquely ("Those conditions, whatever they may be, in which hornblende-plagioclase is stable"), the mineral names occur twice and so "facies" should only be used once; otherwise conjecture and observation would be indistinguishable.

Turn now to tectonic terms. Harland proposes (1956) that form, scale and composition should be included in a description of a tectonic facies. An example is "isoclinal fold, amplitude 1,000 feet, of a shale unit 100 feet thick". Abbreviating, we may use this form to express conjectures such as—

"The isoclinal 1,000' \times 100' shale folds and the nearby 500' \times 500' \times 40' limestone folds were formed under similar conditions."

(It is not the present concern to discuss fold description; a concise quantitative scheme is obviously possible. See for example the proposal of Matthews (1958).)

Generalizations will arise such as—

"This association is so common that 500' \times 500' \times 40' limestone folds are put in the isoclinal 1,000' \times 100' shale fold facies."
and "It is thought that all the structures so grouped in the isoclinal 1,000' \times 100' shale fold facies were formed under similar conditions."
The conformity with Turner's recently recommended usage is exact; but again a need arises for a term for a set of conditions, as yet unknown, which can be referred to by a specific example ("Those conditions, whatever they were, in which such and such a fold was formed"). Perhaps simply "field" will serve, e.g. "stability field" in the metamorphic discussion above.

With the foregoing remarks in mind, the relation of a tectonic facies to a regime may be re-examined (Harland and Bayly, 1958). Harland (1956) used "facies" to refer both to things observable now and to conditions in the past—to both "facies" and "fields" as here used; but the two terms are retained in the following section as a convenience at least temporarily.

Suppose a field acts upon part of a rock mass, and deformation results. The facies of that part can then be observed and described in terms of form, scale and composition. Since the field conjectured will involve among other things three principal stresses, it can at this stage if desired be put in one of the four classes described by Harland and Bayly (1958, p. 91). If the orientation of the structure is determined, the statement of its facies and its orientation will describe its style; at the same time, the field can be suggested as belonging to a particular regime.

In a more complex case, the style observed may point to a sequence of events and so to a sequence of fields. Each field will belong to a particular regime, so that a sequence of regimes is also implied. With regard to facies, it is held that only one facies can now be observed; it may be "isoclinal 1,000' × 100' refolded open 200' × 1,000' × 100' on perpendicular axes, schist" and it might be inferred that the facies of the rock at some earlier time was simply "isoclinal 1,000' × 100' shale"; but it is held that in tectonics a rock *is* of only one facies at the present time.

Turner's review of the facies classification makes an opportunity to distinguish observation from conjecture. It has been the purpose of these remarks to seize upon the opportunity and to note how a close correspondence in meaning can be preserved between metamorphic and tectonic terms.

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CULM STRATIGRAPHY

SIR,—Professor Scott Simpson has recently presented (*Geol. Mag.*, xciv, 201-8) a review of Culm stratigraphy which I can in general accept without reservation. An aspect which needs clarification, however, is the stratigraphic succession in the Greywacke Group and the Central Devon Group. Greywackes undoubtedly succeed the Limestone and Chert group both in North-West and in North-East Devon, but with the intervention of a thin shaly and silty series of Namurian age. Greywacke deposition begins, however, at different times; in the north-west later than R_2 (my own observation) in the north-east before R_2 (J. M. Thomas, unpubl.), in the south-west before H (Owen, D. E., 1950). Provided that the Greywacke Group is taken to include all beds above the top of the Cherts, which seems a reasonably homochronous line, there seems no objection to the use of the classification here.

I have, however, grave doubts as to the value of the Central Devon Group as a stratigraphic term. It is an indication of our lack of knowledge of these beds that Scott Simpson can describe them as consisting of "facies similar to the Millstone Grit" whilst Ashwin (unpubl. thesis, Univ. of London) refers to the same rocks as exclusively greywackes. In the north-west I can demonstrate that the strata of Coal Measure type in which the early Westphalian flora and fauna are found (i.e. the Morchard type of Ussher) pass upwards into more greywackes, these higher greywackes being Ussher's Eggesford Grits. There is no doubt that these two facies recur in various parts of Central Devon, but whether the repetition is structural or stratigraphical is a problem which only careful mapping can solve. In the north-east the Coal Measure type is apparently absent, and greywacke deposition is continuous. Thus until further evidence is available, I feel it would be unwise to suggest that the succession is simply greywacke followed by non-greywacke deposition.

I find it particularly pleasing that Scott Simpson finds much to approve in