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Montmorillonite and zeolites in Mesozoic and Tertiary beds of southern England

IN a recent article in this magazine Brown *et al.* (1969) described zeolites of the clinoptilolite–heulandite type occurring in association with montmorillonite and other minerals in certain late Mesozoic and early Tertiary deposits of south-east England. We are interested in their conclusion that these minerals formed diagenetically in conditions chemically and physically equivalent to those provided by water-deposited volcanic ash but nevertheless are unrelated to volcanoes. This is based on the lack of direct evidence of volcanic activity such as glass shards, tuffaceous textures, and minerals specifically of volcanic origin.

We have, however, pointed out in a recent article on English fuller's earths (Hallam and Sellwood, 1968) that such direct evidence will rarely be forthcoming; this is true for the vast majority of bentonites. For instance, the very thorough analysis of the classic Cretaceous bentonites of Wyoming by Slaughter and Earley (1965) failed to reveal any trace of volcanic glass or tuffaceous textures but they gave good reasons why the preservation of these features is not normally to be expected except in geologically very young deposits. A good case for a volcanic origin can be made, however, on circumstantial evidence.

Montmorillonite may form in soils in a variety of ways, still poorly understood, but a terrestrial derivation for the English Jurassic and Cretaceous fuller's earths and other purely montmorillonitic beds is ruled out by lack of illite, kaolinite, and detrital quartz and feldspar, which are otherwise ubiquitous in the Mesozoic and Tertiary clays of this country. Hence the montmorillonite must have formed authigenically, either from volcanic ash, as is well documented in the literature, or by the sort of changes sketched out by Brown *et al.*

Applied specifically to the deposits we have studied, there are several objections to their non-volcanic interpretation, which involves dissolution of silica from opaline sponge spicules or flint, removal of alkalis and alkaline earths from glauconite, micas, or feldspars, and the dissolution of calcium carbonate. We have found no trace of either flint or sponge spicules in the Bathonian fuller's earth, and glauconite is far from abundant in this or the associated beds. In both the Bathonian and Aptian fuller's earths detrital feldspar and mica are absent, except for rare biotite. The only feldspars present (albite and sanidine) are clearly authigenic and hence cannot plausibly be invoked as source minerals. These feldspars, together with the glauconite, comprise only a minute volume of the rock. It is inconceivable that such limited quantities of material could have supplied all the ions required for the formation of the montmorillonite, which forms almost all of the rock, and is even questionable for the genesis of the quite abundant zeolites. No evidence is known to us of any leaching of the glauconite, which seems indistinguishable petrographically from any other Mesozoic glauconite. Brown *et al.* also invoke the simultaneous dissolution of both silica and calcium carbonate, which does not seem likely on grounds of pH. We have so far confined our attention to the fuller's earths but we see no reason for postulating a different origin for beds of similar composition, or indeed for those Cretaceous and Tertiary clays in which the montmorillonite has been diluted by detrital illite, kaolinite, quartz, and feldspar. Viewed in a broader perspective the hypothesis of Brown *et al.* fails to account for the simultaneous appearance in the late Mesozoic stratigraphic record of montmorillonite in large quantities together with authigenic feldspars, zeolites, and cristobalite–tridymite.

In the absence of a satisfactory alternative we believe it necessary to invoke volcanic ash falls since their alteration can clearly account for all these minerals. The pronounced increase in glauconite in the late Mesozoic might in part be a further consequence of this, as we have argued previously. A further point in support is that the fuller's earths contain rare non-authigenic biotite, hence strengthening the close comparison with the Wyoming bentonites.

As for the source of the volcanic ash, it is well appreciated that this can be carried in large quantities for hundreds of miles and that therefore the likelihood of locating the volcano is very slight. Contrary to what Brown *et al.* maintain, there is in fact direct evidence of late Mesozoic vulcanicity at no great distance from southern England. Since we wrote our paper we have learned of a major series of basaltic and andesitic lavas and tuffs in the Cenomanian of northern Spain (Rat, 1959), and sediments have been found in Northern Ireland with basaltic tuff fragments associated with Maestrichtian foraminifera (J. M. Hancock, personal communication). There is also a possibility that some of the Mull basalts may be late Cretaceous in age (Martin, 1968). More evidence may come from the further exploration of Mesozoic deposits of the continental shelf around the British Isles.

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Fortran II and Fortran IV programs for petrochemical calculations

TWO FORTRAN II and four FORTRAN IV programs for the calculation of many common petrochemical parameters of igneous rocks have been developed from an extended version of D. B. McIntyre's modified norm programme (Seaver Laboratory, Pomona College, California, Tech. Rep. no. 14, 1963). Output is unselective with the same parameters being produced for both dunite and rhyolite, but modifications to the logic to suit the individual petrologist or metamorphic rocks are easily accomplished. A memory storage capacity of at least 40K decimal (1620) or 8K hexadecimal (1130) is required. Where greater capacity is available combinations of programs may be made. Copies of listings suitable for use with IBM 1620 and 1130 computers may be obtained from the department.