POTASSIUM BENTONITES IN THE WENLOCK LIMESTONE OF SHROPSHIRE

by

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Summary

K-bentonite beds consisting of mixed-layer mica-montmorillonite with some kaolinite and interpreted as being of volcanic origin are described from the Wenlock Limestone of Wenlock Edge, Shropshire. The mineralogy of the K-bentonites contrasts markedly with the detrital muscovite, chlorite, quartz and carbonate of the associated limestones. Correlation of K-bentonites and also of persistent shale beds has been made over a distance of 1.5 km. The time planes provided by the K-bentonites and also apparently by the persistent shale beds are useful in tracing details of thickness and facies changes within the Wenlock Limestone.

Introduction

In Murchison's 'Silurian System' there are several references to bands of unctuous or saponacous clay within the Silurian strata of the Wenlock Edge, Ludlow and Woolhope areas. The clay beds were known to consist of 'Walkers soap' or 'Walkers earth' which is a local name for 'fullers earth'. Murchison (1839, pp. 204, 205, 249) refers to beds of this clay situated at the base of the Aymestry Limestone and also within the Wenlock Shale. Barrow *et al.* (1919) mention a similar bed that was once mined from the lower part of the Wenlock Limestone and sold as fullers earth. Similar clays have been described by Davidson and Maw (1881) and by Pocock *et al.* (1938, p. 112) from the Wenlock Shales near the base of the Coalbrookdale Beds.

Butler (1937) described the physical properties of clay beds he recognised in the Wenlockian of the Walsall borehole and concluded that the beds were bentonites formed from the alteration of airborne volcanic dust. Later Butler (1939, p. 43) recognised a similar bed within the Wenlock Limestone of the Wrens Nest, Dudley, and also mentioned the fact that several of the thin shale beds within the limestone were laterally persistent.

At many localities within the Silurian of Wenlock Edge, prominent bedding planes can be seen within the Wenlock Limestone. Some of these planes are associated with K-bentonites conforming both to the original description by Weaver and Bates (1952), and to current usage of the term, in consisting mainly of mixed-layer mica-montmorillonite formed by *in-situ* alteration of volcanic material.

Other prominent bedding planes within the Wenlock Limestone are overlain by green calcareous shale, a few centimetres thick, largely of detrital origin. In this paper individual prominent bedding planes and K-bentonites are correlated between three quarries on Wenlock Edge over a distance of 1.5 km. (Fig. 1). These horizons could prove very useful in accurately tracing changes of facies and thickness within the Wenlock Limestone between individual time planes. Shergold and Bassett (1970) have recently described the different limestone facies of the area, including the quarries mentioned, and the reader is referred to their paper and bibliography for further information.

Localities

The three quarries examined lie on the north-west side of the B4371 between 2 and 3.5 km south-west of Much Wenlock, Shropshire. The successions given in Figs. 1 and 2 were measured at the following places.

Coates Quarry	(SO 604994)
Hayes Quarry	(SO 60159920)
Lea Quarry	(SO 593984 to 595986)

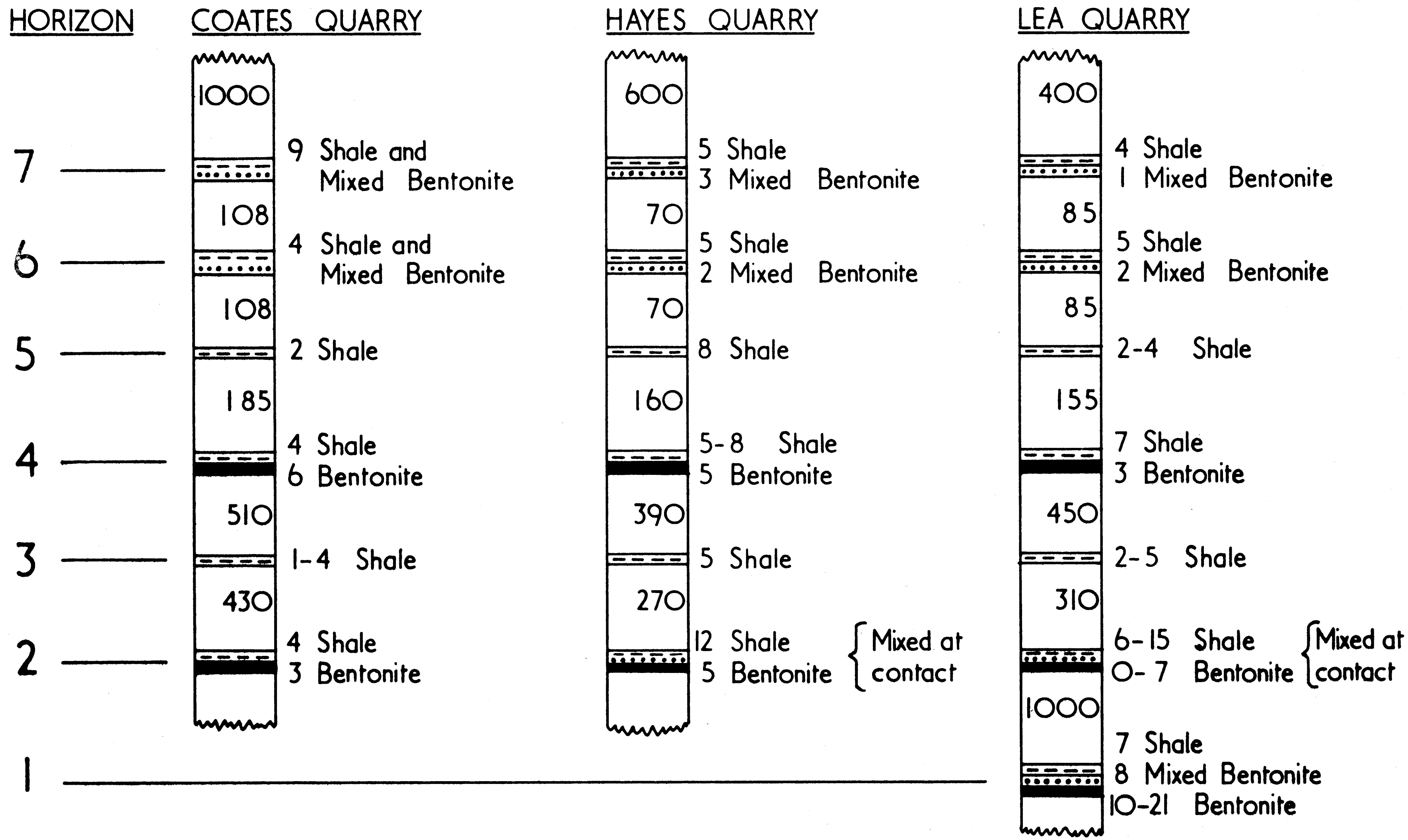

Fig.1. Diagrammatic stratigraphic sections to show relative positions and thicknesses of K-bentonite, mixed K-bentonite/shale and persistent shale horizons 1-7 in Coates, Hayes and Lea Quarries, Wenlock Edge, Shropshire. Measured limestone thicknesses between horizons 1-7 and thicknesses of the persistent horizons are given in centimetres.

Field Appearance

The bentonite beds, where fresh, consist of a pale green to white clay, which has a soapy feel, and expands and disintegrates rapidly when placed in water. On exposed surfaces the beds turn yellow or orange, due to the oxidation of pyrite to iron hydroxide, and in near-surface exposures the whole bed is usually orange-brown in colour. Within the beds pyrite usually occurs as framboidal masses up to 1 mm. across and occasional rosettes of gypsum crystals a few millimetres across occur in the weathered beds. The bentonites are not cemented with calcite but the thickest bentonite seen was traversed by many distorted calcite veins.

The lower contacts of the bentonites are usually sharp, the bed resting on a few millimetres of shale overlying limestone. The upper contacts may be sharp against green shale or calcareous shale, or there may be a zone of mixed shale and bentonite grading upwards into green shale. Details of individual bed thicknesses and character are given in Figure 1.

In Hayes Quarry the bentonite of horizon 4 was observed to pass onto the top of a reef mass composed mainly of stromatoporoids and tabulate corals. Over the area of the reef the detrital sediment and bentonite were mixed whereas laterally to the reef the bentonite had sharply defined upper and lower contacts with green shale. It seems probable that the activities of the organisms of the reef were responsible for the mixing of the volcanic material with the normal detrital sediment of the area.

The bentonites do not contain fossils: although corals may project into bentonite beds, they are not rooted within the bed. The calcareous shale bands are not richly fossiliferous but crushed corals and brachiopods are frequently seen in them. The bentonite beds generally stop on reaching the margin of a reef and within the reef there is no visible evidence of the bentonite. Presumably the organisms living on the reef were able to disperse the volcanic material. In one instance at Hayes Quarry a bentonite was seen to pass faintly over a reef indicating that at the time of deposition the reef, of width 9m., had an elevation of only one metre over the surrounding sea floor.

Outside reef areas, in normal bedded limestone, the thickness of the bentonites is often variable and in extreme cases bentonites can be observed to die out laterally, as at Lea Quarry where the bentonite of horizon 2 reduces from 7 cm. to nothing over a horizontal distance of 100 m. along the quarry face. Such changes in thickness could be due to irregular deposition of volcanic material, but are more likely due to currents reworking the deposited material. Irregular deposition would imply a fairly close source of volcanic activity for which there is no other evidence in the area.

Correlation

Fig. 2 shows the marked similarity of the grouping of the bentonites and shales within the three quarries. The successions given are based on direct measurements and also on measurements made from photographs. Detailed correlation reveals thickness changes between the quarries which represent real differences in depositional rates, since measurements can be taken between time-lines marked by the bentonites and also apparently by the shale bands. The variation in thickness between the quarries is due to gradual expansion of the whole section rather than a large increase in one part of the section. There is little difference in limestone lithology between the quarries and it is assumed that any post-depositional thickness changes have affected the three sections equally.

Where bentonites die out laterally they are replaced by prominent shale beds, (*e.g.* horizon 2, Lea Quarry) thus it is possible that the prominent shale beds found in the quarries (horizons 3 and 5) are represented by bentonites nearby. It is certain that the presence of the original material of the bentonite inhibited limestone formation immediately above the bentonite since there are invariably a few centimetres of shale present above the bentonites before limestone reappears. Thus it is not unreasonable to assume that the presence of the bentonitic material also had an affect over a considerable area of the sea floor.

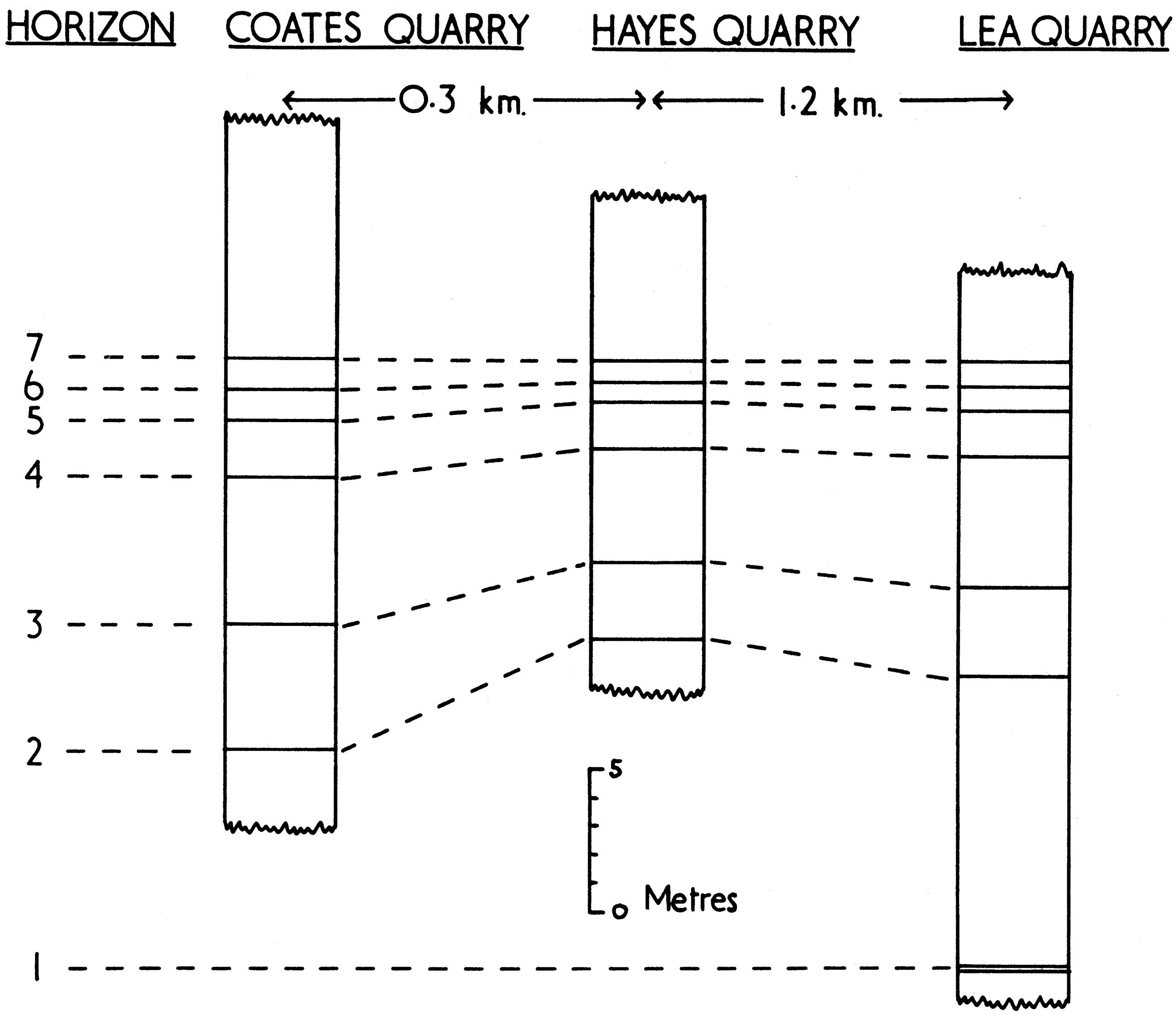

Fig. 2 Stratigraphic sections of the Wenlock Limestone in Coates, Hayes and Lea quarries to show relative positions of persistent horizons 1-7 and thickness changes between the quarries.

Table 1

Rock type and horizon	Locality	K_2O	Na_2O	CaO
K-bentonite 4	Coates Quarry	4.36	0.08	1.63
K-bentonite 4	Lea Quarry	4.61	0.33	1.45
K-bentonite 2	Coates Quarry	4.82	0.04	2.50
K-bentonite 2	Lea Quarry	4.48	0.04	0.85
K-bentonite 1	Lea Quarry	3.43	trace	3.33
K-bentonite -	Woodbury (MacEwan, 1956)	5.00	0.51	3.08
Shale 4 cm. above 7	Lea Quarry	3.91	0.80	4.58
Clay-Lst. below 2	Coates Quarry	3.51	0.92	9.39
Shale 5 cm. above 1	Lea Quarry	3.95	0.80	6.95
Clay-Lst. 15 cm. below 1	Lea Quarry	3.25	1.01	7.75

Table 1 Partial analyses of K-bentonites and closely associated sediments from the Silurian of Wenlock Edge, Shropshire, and of a K-bentonite from Woodbury, Worcestershire.

It is not proposed to give the bentonites described here specific labels since there are many other bentonites present within the Wenlock Limestone and other Silurian strata of Shropshire, and a complete study of a formation should be made before individual beds are labelled within the formation.

Chemistry

Samples of bentonites, and the associated sediments were analysed by XRF methods for K, Na and Ca. The analyses presented in Table 1 confirm the potassic nature of the bentonites with a range from 3.43 to 4.82 per cent K_2O. CaO varies from 0.85 to 3.33 per cent with most of the calcium in the clay mineral, though a little must be in the small amounts of calcite and gypsum which do occur within the bentonite horizons. The sodium content of the bentonites is low, with only one analysis giving more than 0.1 per cent Na_2O. Basically the clay is a mixture of a mica structure and a Ca-montmorillonite. The lower K_2O and higher CaO content of horizon 1 relative to the others is due to a higher proportion of Ca-montmorillonite in the mixed-layer clay.

Analyses of the associated green shales and clay-limestones (Table 1) show that the bentonites are deficient in sodium relative to the associated sediments and slightly enriched in potassium. In the shales the K_2O probably lies mainly in detrital mica and the CaO in calcite. An analysis of a similar clay band from the base of the Aymestry Limestone at Woodbury, Worcestershire, given by MacEwan (1956) is included in Table 1 for comparison.

Mineralogy

Bentonites

The clay mineralogy of the beds was studied using whole rock diffractometer traces.

All the bentonies studied consist of mixed-layer mica-montmorillonite together with variable, but generally small amounts of kaolinite. The proportion of mixed-layer clay to kaolinite and also the proportions of mica to montmorillonite within the mixed-layer clay are highly variable.

Table 2 shows the variation in basal spacing of the clay under different treatments. The greatest variation within a bed occurs in horizon 1 where the basal spacing of the clay increases from the bottom to the top of the bed, the variation not being perfectly regular. The larger basal spacings of the untreated clay of horizon 1 and its greater expansion on treatment with Ethylene glycol relative to the other horizons, indicate that a greater proportion of expandable layers of Ca-montmorillonite relative to non-expandable mica layers is present in the mixed-layer clay. This is confirmed by the chemical analyses already given.

Clay treatment	Horizon 1 base — top	Horizons 2, 4, 6, 7. range of variation
Untreated	12.1 — 13.6	11.5 - 12.1
Ethylene glycol 1 hr. at 70^oC	15.4 — 16.6	12.7 - 13.5
1N KOH soaking for 24 hrs.	11.0	10.5 - 11.0
Heating 500^oC for 2 hrs.	9.8	9.8

TABLE 2 Variation in basal spacing in A of mixed-layer mica-montmorillonite in K-bentonites of horizons 1, 2, 4, 6 and 7 under various treatments.

Bentonite horizons 2, 4, 6 and 7 have similar properties and are grouped together in Table 2 since the range of variation within each bed at different localities was found to be similar to the range of variation between individual beds. Horizons 2 and 4 are pure bentonites but in 6 and 7 the bentonitic material is mixed with detrital shale.

The mica present in the mixed layer structure is dioctahedral with 060 at 1.50A and is the 1Md polymorph of Yoder and Eugster (1955, p. 245), a randomly oriented specimen showing the characteristic 112 and 112 reflections. The 1Md polymorph is generally thought to form at low temperatures and is consistent with an origin by alteration of volcanic material in the marine environment. The incomplete collapse of the clay to between 10.5 and 11.0A rather than to 10A also indicates derivation of the clay from non-micaceous parent material (Weaver 1958, p.853).

All the reactions observed are typical of the behaviour of mica-montmorillonite derived from the alteration of non-micaceous material and correspond well with previously described K-bentonites thought to be formed by the *in situ* alteration of volcanic ash or glass (Hower and Mowatt, 1966; Mossler and Hayes, 1966; Trewin, 1968). The structure of the clay is also described by MacEwan (1956) from the horizon originally mentioned by Murchison at the base of the Aymestry Limestone.

Shales

All samples of the limestones and of the green shales occurring above the bentonite beds and separating the bedded limestones, contain a similar mineral assemblage. The minerals present were determined from diffractometer traces using whole rock samples. All specimens contained chlorite (non-swelling), muscovite and quartz, and lacked the mixed-layer mica-montmorillonite and kaolinite present in the bentonites. Calcite was present in most samples but immediately above the bentonites, and after weathering, the shales may be non-calcareous. Small amounts of dolomite and feldspar are present. The feldspar type could not be identified with certainty on the whole rock traces. Examination of thin sections shows the quartz to be mainly detrital, in grains up to 0.1 mm. across, and the muscovite to be present in highly birefingent flakes up to 0.15 mm. long, showing little sign of alteration. Chlorite was seen in a few patches, where it may have formed from the alteration of biotite. Feldspar could not be detected with certainty in thin section.

Bioclasts were present in all samples of green shales and limestones, usually in the form of broken shell, coral and algal fragments.

Conclusions

The beds of mixed-layer mica-montmorillonite which occur in the Wenlock Limestone are K-bentonites and have properties consistent with formation from fine volcanic ash or glass in a marine environment. Within the Wenlock Limestone they could provide an accurate set of time planes for tracing in detail changes in thickness and facies of the sediments. Some of the beds are discontinuous over the area studied, due to non-deposition of volcanic material or erosion by currents, but even if bentonitic material is locally absent at a particular horizon a prominent shale bed is present in its place. Thus it appears that the presence of bentonite inhibited the formation of cemented limestone. This is also borne out by the fact that the shales immediately above the bentonites are never cemented to limestone. K-bentonites are not generally seen in reefs due to the activities of organisms in dispersing the volcanic material and mixing it with the normal detrital sediment.

Acknowledgements

My thanks are due to Dr. T.P. Scoffin for reading the manuscript and also for helpful discussion on the bentonites in the light of his own observations. A.J. Mucklow Ltd. and Ridge Limestone Ltd. kindly allowed access to their quarries and the latter provided a useful plan of their quarrying operations.

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Manuscript received 25th September 1970.