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SEQUENCE STRATIGRAPHY AND SEA-LEVEL CHANGES IN THE MID-CRETACEOUS (ALBIAN TO TURONIAN) OF SOUTHERN ENGLAND; A PRELIMINARY INVESTIGATION

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The detailed analysis of a sedimentary succession requires an accurate, viable, chronostratigraphic framework. This is especially true if sequence stratigraphy is to be attempted, as inaccuracies in dating will tend to invalidate any model and make relative sea-level changes impossible to assess. Within the Albian to Turonian interval there are available detailed and well-tested biostratigraphic zonal schemes based on both micro- and macro-palaeontology; across southern England two 'mega-sequences' are identified as well as many other regionally significant sequence boundaries. Maximum flooding surfaces are identified at a number of horizons, including a level within the *Euhoplites lautus* Zone, a level within the *Hysteroceras orbignayi* Subzone, a level low in the *Stoliczkaia dispar* Zone, a level in the *mid-Mantelliceras mantelli* Zone, a level within the *M. dixoni* Zone and in the *mid-Acanthoceras jukes-brownei* Zone. There may be other less well-defined maximum flooding surfaces and there are still some problems with the events in the Late Cenomanian.

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INTRODUCTION

The mid-Cretaceous (Albian to Turonian) sediments of southern England are interesting from a sequence stratigraphic point of view because of firstly, their marked lateral facies changes and problematic depositional setting; and, secondly, because they are relatively precisely chronostratigraphically controlled, both from biostratigraphy (Kennedy, 1969, 1970; Owen, 1976; Carter and Hart, 1977; Hart, 1973, 1982; Hart *et al.,* 1989) and from other methods such as Milankovitch cyclicity (Hart, 1987a,b; Gale, 1989). Semi-quantitative biostratigraphic techniques such as graphic correlation can also be applied which further enhance chronostratigraphic resolution.

By placing the sediments within a high resolution chronostratigraphic framework, and by recognising maximum onlap, dramatic facies variations, hardground surfaces, hiati and significant biostratigraphic events (e.g. plankton abundance peaks), a detailed sequence stratigraphy can be constructed. Of particular interest is the use of systems tract analysis to define and predict depositional setting.

A local sea-level curve can also be constructed (Simmons *et al.,* 1991) and compared to the global curve of Haq *et al.* (1987) and other more localised curves (Hancock, 1989). Whilst some differences with the Haq *et al.* (1987) curve exist, these can be ascribed to local tectonic controls and problems in chronostratigraphic resolution. Much of the mid-Cretaceous of southern England was deposited in a shelf setting, although this was probably deeper water than that of the present day continental shelf. South-west England is a particularly suitable area in which to study sea-level changes (Simmons *et al.,* 1991), since even small changes in relative sea-level are likely to cause major facies shifts. It should be stressed that it is only relative sea-level change which is being measured-a combination of the effects of subsidence, sediment supply and eustacy. In the mid-Cretaceous of southern England it is difficult to assess how much subsidence is masking the eustatic signal (Hart, 1990).

CHRONOSTRATIGRAPHY

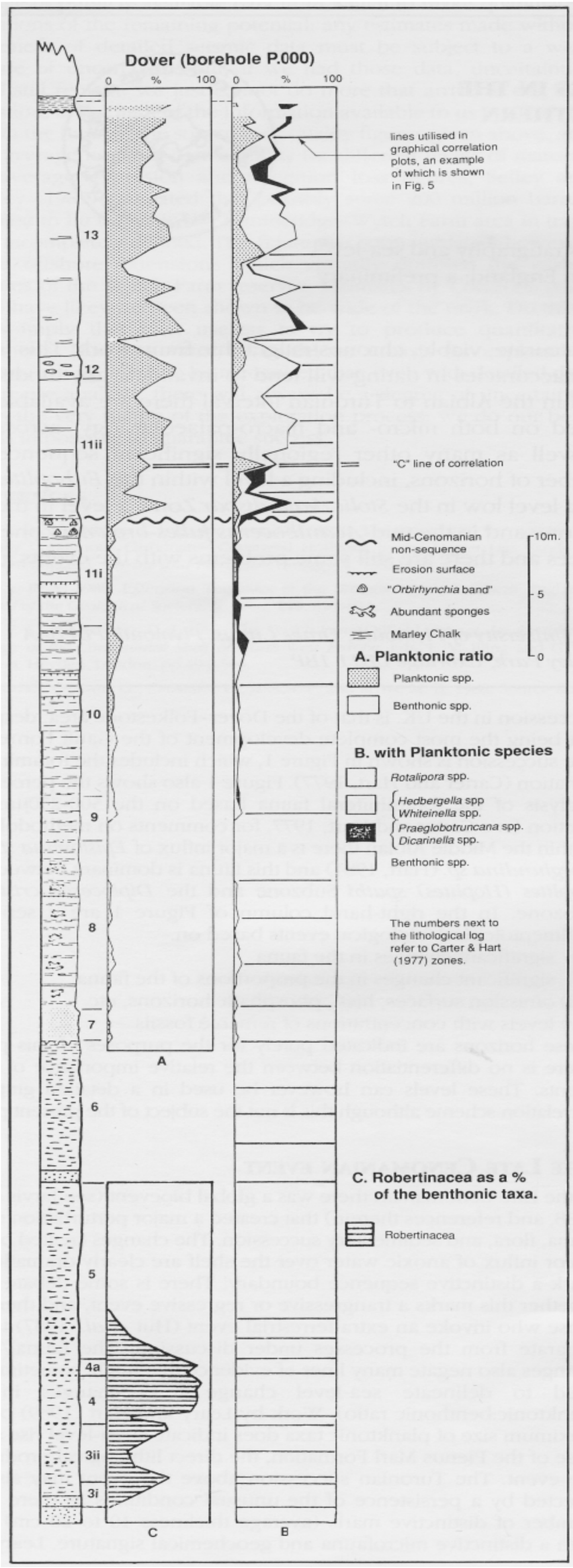
For the purpose of this paper the succession under consideration is that which includes the Middle and Upper Albian, the Cenomanian and part of the Turonian. The (unofficial) standard reference succession in the UK. is that of the Dover-Folkestone area, despite it not being the most complete development of the Gault Formation. The succession is shown in Figure 1, which includes the foraminiferal zonation (Carter and Hart, 1977). Figure 1 also shows the percentage analysis of the foraminiferal fauna based on the 500-250µm size fraction (see Carter and Hart, 1977, for comments on methodology). Within the Middle Albian there is a major influx of *Epistomina sp.* and *Hoeglundina sp.* (Hart, 1984) and this fauna is dominant between the *Hoplites (Hoplites) spathi* Subzone and the *Diploceras cristatum* Subzone. In the right-hand column of Figure 1 are a series of sedimentological/biological events based on:

(i) significant changes in the fauna
(ii) significant changes in the proportions of the fauna
(iii) omission surfaces, hiati, phosphatic horizons, etc.
(iv) levels with concentrations of remanié fossils

These horizons are indicated purely for the purposes of this paper. There is no differentiation between the relative importance of these events. These levels can however be used in a detailed graphical correlation scheme although this is not the subject of the present paper.

THE LATE CENOMANIAN EVENT

In the Late Cenomanian there was a global bioevent (see Jarvis *et al.,* 1988, and references therein) that created a major perturbation of the fauna, flora, and sedimentary succession. The changes created by this major influx of anoxic water over the shelf are clearly dramatic and mark a distinctive sequence boundary. There is some debate as to whether this marks a trangressive or regressive event, and there are those who invoke an extra-terrestrial event (Hut *et al.,* 1987) totally separate from the processes under discussion. The faunal/floral changes also negate many lines of evidence that might sometimes be used to delineate sea-level change (e.g. changes in the planktonic:benthonic ratio). Work by Leary and Hart (1989) on the maximum size of planktonic taxa does indicate a sea-level rise at the base of the Plenus Marl Formation, the direct lithological product of the event. The Turonian succession above the event may also be affected by a persistence of the unusual conditions as there are a number of distinctive marls (average thickness 10 to 20 cm) each with a distinctive microfauna and geochemical signature. Leary and



Wray (1989) interpreted these as the direct product of ash falls, although it is possible to argue that they are the result of an intermittent, continual effect of the presence of anoxic water over the shelf. This may have continued up to the level of the Late Turonian times when a generally accepted relative fall in sea-level (Haq *et al.,* 1987; Hancock, 1975, 1989: Hancock and Kauffman, 1979) caused a withdrawal of this water from the area of southern England.

SEQUENCE STRATIGRAPHY

Using the highly developed chronostratigraphy for the interval under discussion it is possible to produce a plot of the succession across southern England (Figure 2). The Albian/Cenomanian boundary interval in south-west England is basically that presented by Simmons *et al.* (1991). The remainder of the correlation is based on successions in Dover, Folkestone, Glyndebourne (Lake *et al.,* 1987), Eastbourne, Southerham (Sussex), the Isle of Wight, Dorset and Devon. Some of the events indicated in Figure 1 are also apparent on Figure 2 and can thereby be assessed as to their relative importance. Several of these events are quite clearly basinwide and separate important sequences. Others are more local in extent and cannot be traced outside the more central parts of the Wessex Basin. In the area of Purbeck and north Dorset there is a major problem in this correlation. In this area there is a clear break in the regional pattern as one crosses the Mid-Dorset Swell (Kennedy, 1970; Drummond, 1970; Carter and Hart, 1977). This feature appears to affect the Late Albian to Middle Cenomanian interval and, possibly, reflects deposition over a re-activated Variscan (or older) structure. Intra-Cretaceous faulting is well known on the Dorset coast and in the area of the Wytch Farm oilfield (Drummond, 1970; House, 1989 and references therein), although it is not suggested that the whole of the swell is just a simple fault. The tracing of individual sequence boundaries across the feature is difficult, although Carter and Hart (1977) have shown how the succession thins, zone-by-zone, towards the feature.

SEA-LEVEL CHANGES

When this correlation scheme is converted into a time framework (Figure 3) it can be seen that five important sequences are identified. Each of these is divisible into a number of smaller components but all follow the same style. The initial phase (Middle Albian and Early-Middle Cenomanian) is then extended further towards the basin margins in the Late Albian and Late Cenomanian respectively Maximum flooding surfaces (MFS) - following the sequence stratigraphy nomenclature - can be seen at a number of levels and these, together with the postulated sequence boundaries, are shown in Figure 3. The sea level changes within the Albian are very close to the general curve provided by Hancock (1989), although this is to be expected as the evidence on which we are working is similar to that of Hancock. The only difference is that in this case we are taking cognisance of the microfaunal changes and the detailed correlation within the Gault Clay Formation that is possible using the Foraminifera. Within the Chalk succession there are some differences from the model proposed by Hancock (1989) but these were discussed, in part, by Simmons *et al.* (1991). It is interesting to note that few authors recognise the importance of the mid-Cenomanian non-sequence (Carter and Hart, 1977), yet this must be a major sequence boundary as it coincides with a major change in sedimentation and fauna/flora.

As indicated by Hart (1990) these relative changes in sea-level must be considered in the light of the overall basin subsidence of the Wessex Basin. If the calculations of Hart (1990) are even broadly correct then the axis of this sea-level curve must be tilted considerably.

Figure 1: The Gault Clay Formation and the 'Lower Chalk' in the Dover-Folkestone area. The zones (3i-13) are the foraminiferal zones of Carter and Hart (1977). Graph A shows the planktonic/benthonic ratio (based on the 250-500µm grain-size fraction). Graph B shows the same curve separates into planktonic genera (see legend). Graph C shows the percentage of Robertinacea in the benthonic fauna. The lines across column B are the 'events' used in graphical plots. The mid-Cenomanian non-sequence and the 'C' line are also indicated. The 'C' line is based on a flood of Rotalipora spp and can be traced over large areas of southern England.

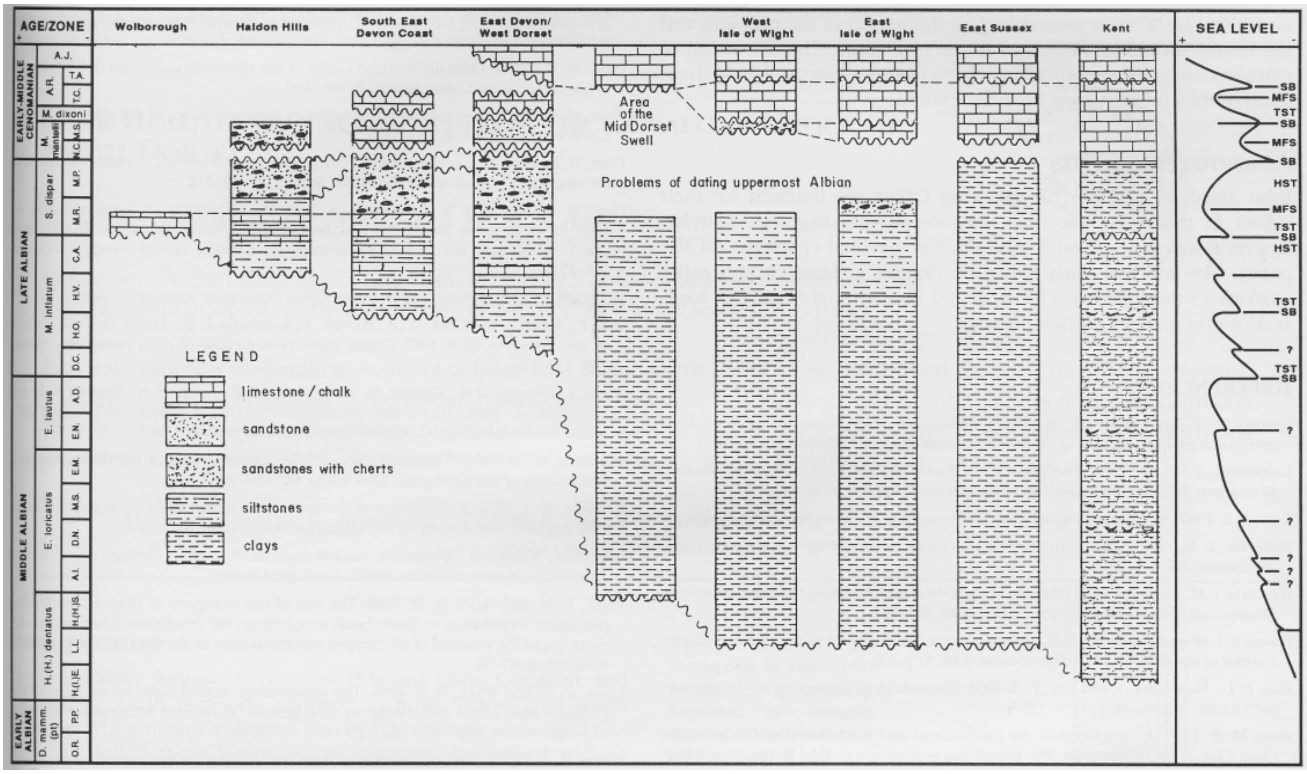


Figure 2. Correlation of the various lithological units across southern England. The detailed data for south-west England are taken from Simmons et al. (1991). The data are plotted against an arbitrary vertical scale which simply represents each of the zones and sub-zones of the Cretaceous succession. The right-hand column shows the relative changes of sea-level and the location of the more important Sequence Boundaries (SB), Maximum Flooding Surfaces (MFS), Highstand Systems Tracts (HST) and Transgressive Systems Tracts (TST).

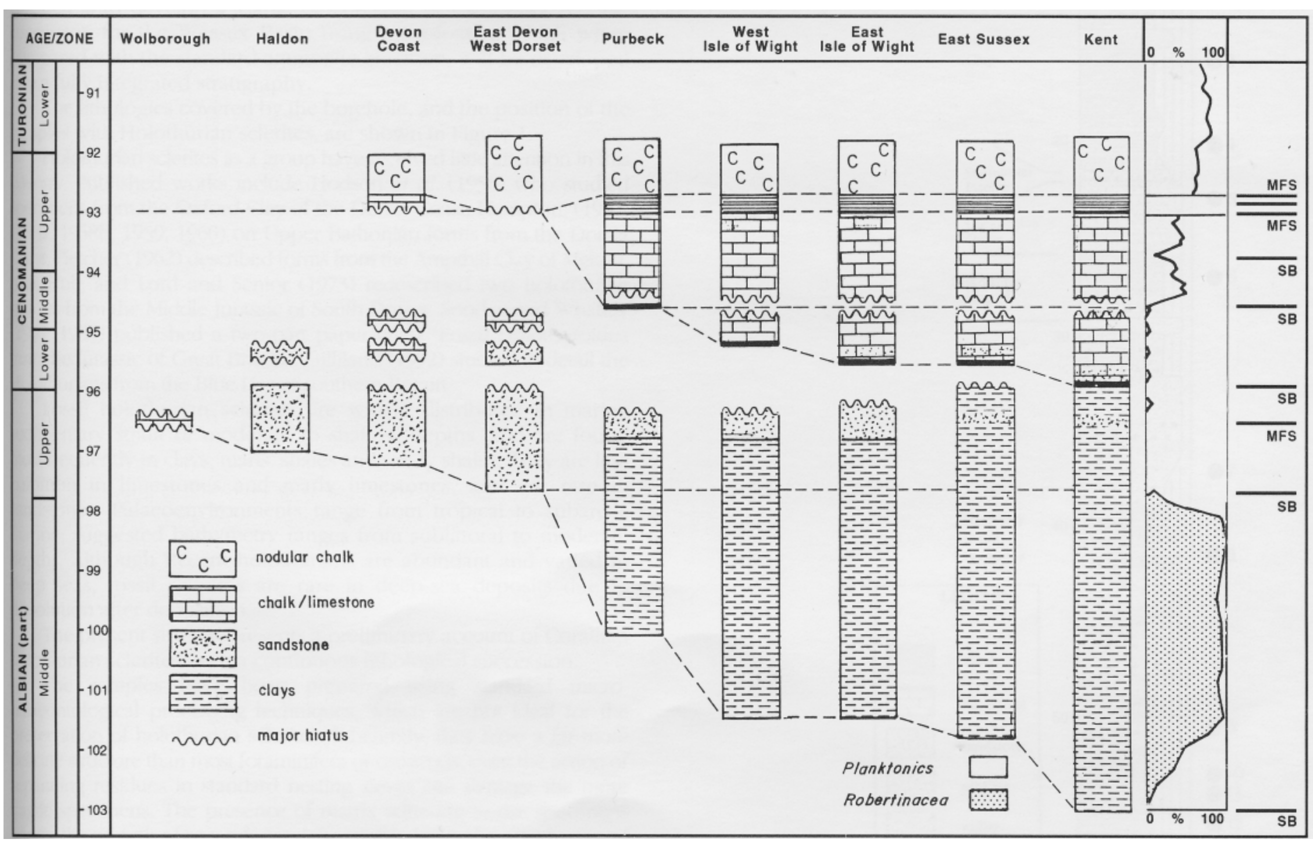


Figure 3. The same information as Figure 2, but plotted against the time scale of Haq et al. (1987). The larger sequences for the Albian, Cenomanian and Turonian are discussed in the text.

Work is proceeding on this aspect of the problem and the results should be presented in the near future. The inclusion of calculations based on Milankovitch cyclicity will mean that such an analysis may be genuinely time-dependent.

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REFERENCES

CARTER, D. J. and HART, M. B. 1977. Aspects of Mid-Cretaceous stratigraphical micropalaeontology. B*ulletin of the British Museum (Natural History), Geology,* **29,** 1-135.

DRUMMOND, P. V. O. 1970. The Mid-Dorset Swell. Evidence of Albian-Cenomanian movements in Wessex. *Proceedings of the Geologists' Association,* **81**, 679-714.

GALE, A. S. 1989. A Milankovitch scale for Cenomanian time. *Terra Nova*, **l**, 420-425.

HANCOCK, J. M. 1975. The Petrology of the Chalk. *Proceedings of the Geologists' Association,* **86,** 4)9-535.

HANCOCK, J. M. 1989. Sea-level changes in the British region during the late Cretaceous. *Proceedings o/ the Geologists' Association,* **100**. 565-594.

HANCOCK, J. M, and KAUFFMAN, E. G. 1979. The great transgressions of the Late Cretaceous. Jo*urnal of the Geological Society, London,* **136,** 175-186.

HAQ, B. U., HARDENBOL, J. and VAIL, P. R. 1987. Chronology of fluctuating sea-levels since the Triassic. *Science,* **235,** 1156-1167.

HART, M. B. 1973. A correlation of the macrofaunal and microfaunal zonations of the Gault Clay in SE England. In: *The Boreal Lower Cretaceous,* Eds: R. Casey and P. F. Rawson, Geological Journal Special Publication **5**, 267-288.

HART, M, B. 1982. Turonian foraminiferal biostratigraphy of Southern England. *Memoires du Museum National d'Histoire Naturelle, nov. ser.. Ser. 3,* **49,** 203-207.

HART, M. B. 1984. The Superfamily Robertinacea in the Lower Cretaceous of the UK and adjacent areas of NW Europe. In: *Proceedings of the 2nd International Conference on Benthonic Foraminifera,* Ed: H. Oertli. Benthos, **83,** 289-298.

HART, M. B. 1987a. Orbitally induced cycles in the Mesozoic sediments of SW England. *Proceedings of the Ussher Society,* **6**, 483-490.

HART, M. B. 1987b. Orbitally induced cycles in the chalk facies of the United Kingdom. *Cretaceous Research,* **8**, 335-348.

HART, M. B. 1990. Cretaceous sea-level changes and global eustatic curves; evidence from SW England. *Proceedings of the Ussher Society,* **7**, 268-272.

HART, M. B., BAILEY, H. W., CRITTENDEN, S., FLETCHER, B. N., PRICE, R. J, and SWIECICKI, A., 1989. Cretaceous. In: *Stratigraphical Atlas of Fossil Foraminifera,* Eds: D. G. Jenkins and J. W. Murray, British Micropalaeontological Series, Ellis Horwood, Chichester, 273-371.

House, M. R. 1989. *Geology of the Dorset Coast.* Geologists' Association Guide.

HUT, P., ALVAREZ, W., ELDER, W. P., HANSEN, T., KAUFFMAN, E. G., KELLER, G., SHOEMAKER, E. M. and WEISSMAN, P. R. 1987. Comet showers as a cause of mass extinctions. *Nature,* **329**,718-126.

JARVIS, I., CARSON, G. A., COOPER, M. K. E., HART, M. B., LEARY, P. N., TOCHER, B. A. and ROSENFELD, A. 1988. Microfossil assemblages and the Cenomanian-Turonian (Late Cretaceous) oceanic anoxic event. *Cretaceous Research,* **9**, 3-103.

KENNEDY, W. J. 1969. The correlation of the Lower Chalk of south-east England *Proceedings of the Geologists' Association,* **80,** 459-560.

KENNEDY, W. J. 1970. A correlation of the uppermost Albian and Cenomanian of south-west England. *Proceedings of the Geologists' Association,* **81,** 613-677.

LAKE, R.D., YOUNG, B., WOOD, C.J. and MORTIMORE, R.N. 1987. *Geology of the Country around Lewes.* Memoir of the British Geological Survey.

LEARY, P. N. and HART. M. B. 1989. The use of the ontogeny of deep water dwelling planktonic foraminifera to assess basin morphology, the development of water masses, eustacy and the position of the oxygen minimum zone in the water column. *Mesozoic Research,* **2**, 67-74.

LEARY, P. N. and WRAY, D. S. 1989. The foraminiferal assemblages across three Middle Turonian marl bands and a note on their genesis. *Journal of Micropalaeontology,* **8**, 143-148.

OWEN, H. G. 1976. The stratigraphy of the Gault and Upper Greensand of the Weald. *Proceedings of the Geologists Association,* **86,** 475-498, for 1975.

SIMMONS, M D., WILLIAMS, C. L. and HART, M. B. 1991. Sea-level changes across the Albian Cenomanian boundary in south-west England. *Proceedings of the Ussher Society,* **7**, 408-412.