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## II. UPPER KIMMERIDGIAN AMMONITE FAUNAS OF THE WASH AREA AND A SUBZONAL SCHEME FOR THE LOWER PART OF THE UPPER KIMMERIDGIAN

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Plates 1-3

THE AMMONITE faunas of the Wash area boreholes (Gallois and Cox 1974) provided a further test of the zonal scheme set up for the lower part of the Upper Kimmeridgian on the basis of the faunas in Dorset (Cope 1967). The validity of this scheme was confirmed by material from the Warlingham Borehole (Callomon and Cope 1971).

These new boreholes not only show that this zonal scheme holds true for East Anglia but justify the belief that subzonal division of some of these zones, for which an earlier hope was expressed (Cope 1967, p. 66), is now possible. The boreholes reproduce in remarkable detail the ammonite successions established in Dorset and Warlingham, and provide a further insight into the development of the Upper Kimmeridge Clay of East Anglia.

It also seems necessary, in the light of recent borehole evidence and of more recent collecting in Dorset, to amend slightly the position of one of the zonal boundaries.

A re-examination of these zones, their development in the boreholes, their boundaries, and any subzonal division possible, follows in ascending stratigraphical order.

### *Pectinatites (Virgatosphinctoides) elegans* Zone

Index species: *Pectinatites (Virgatosphinctoides) elegans* Cope 1967, p. 31, pl. 9.

Only the CSU 71/65 Borehole proved the *elegans* Zone in this region. The zone was not very productive of ammonites and the thickness of about 4.4 m is much less than that recorded from Dorset (22 m) or Warlingham (8 m). The ammonite succession, however, remains the same. The upper part of the zone was characterized by the zonal index species, and the lower part yielded *P. (Arkellites) primitivus* Cope. No example of the genus *Gravesia* was recorded. The base of the zone is drawn above the highest recorded *Aulacostephanus* and below the lowest *Pectinatites*. This latter genus has been recorded from the underlying *Aulacostephanus (A.) autissiodorensis* Zone in the Warlingham Borehole and from Yorkshire (Callomon in Callomon and Cope 1971). However, one character of *Pectinatites*, namely the horn on the peristome of the microconch, has not as far as the writer is aware, been found on any pectinatitids from horizons lower than the *elegans* Zone. If the origin of *Pectinatites* is to be sought in *Propectinatites* (Cope 1968), the type material of which came from the lower

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part of the *autissiodorensis* Zone, it is only to be expected that the ammonites become more *Pectinatites*-like in the upper part of the *autissiodorensis* Zone. The horn of the microconch appears to be a character developed only by *elegans* Zone times.

No subdivision of the *elegans* Zone is suggested as the range of the various species within this zone is not known over a wide area.

#### *Pectinatites (Virgatosphinctoides) scitulus* Zone

Index species: *Pectinatites (Virgatosphinctoides) scitulus* Cope 1967, p. 34, pl. 11.

The thickness of approximately 2.1 m assigned to this zone in Borehole CSU 71/65 is considerably thinner than that in Dorset (27 m) or at Warlingham (15 m). No definite evidence for the presence of this zone was established but in the absence of any evidence to the contrary, the lower boundary is placed above the highest occurrence of *P. (V.) elegans* and the upper boundary drawn, on lithological grounds only, some distance below a specimen recorded as *P. (V.)* aff. *wheatleyensis* (Neaverson). The presence of a stone band at the base of the zone (at 32.4 m) in the CSU 71/65 Borehole suggests correlation with the Yellow Ledge Stone Band in Dorset. The upper part of this zone in Dorset has hitherto failed to yield good ammonite faunas, although since the initial description of the zone (Cope 1967, p. 68) the upper part of the *scitulus* Zone has yielded some ammonite remains, albeit fragmentary and specifically unidentifiable (Cope 1971, p. 43). The upper limit of the zone is conjectural because in the absence of determinable ammonites, the thickness of the overlying *smedmorensis* Subzone is uncertain.

#### *Pectinatites (Virgatosphinctoides) wheatleyensis* Zone

Index species: *Pectinatites (Virgatosphinctoides) wheatleyensis* (Neaverson) 1925, p. 12, pl. 1, fig. 1.

Only Borehole CSU 71/65 in this area penetrated both the top and the base of this zone with a recorded thickness of approximately 15.8 m. This compares with 25.5 m in Dorset and 16.5 m at Warlingham. Comparison of the ammonite faunas with Warlingham is thus particularly interesting in that the thickness of the zone in the two boreholes is very similar. Unfortunately the lower part of the zone yielded no specifically identifiable ammonites.

In Dorset, the zone falls readily into two parts and it seems that this bipartite subdivision has wider applicability. It is proposed herein that two subzones should be recognized.

#### *Pectinatites (Virgatosphinctoides) smedmorensis* Subzone

Index species: *Pectinatites (Virgatosphinctoides) smedmorensis* Cope 1967, p. 41, pl. 15, figs. 1, 2.

In the Dorset area the base of the subzone is marked by the appearance of *P. (V.) clavelli* Cope together with *P. (V.) laticostatus* Cope and *P. (V.) smedmorensis*. These three forms range upwards through the subzone, but *P. (V.) clavelli* appears to become extinct first. The subzone was present in the Warlingham Borehole and represented by the subzonal index. The record of *P. (V.) laticostatus* from the higher part of the *wheatleyensis* Zone (Callomon and Cope 1971, p. 152) was based on a whorl fragment and the specimen might equally

have been placed in other coarse-ribbed species. None of the boreholes in the Wash area sheds any light on this subzone. The only suggestion of its presence was the unidentifiable *Virgatosphinctoides* recorded from 26·10 to 28·17 m in Borehole CSU 71/65. The other boreholes in the region to penetrate the *wheatleyensis* Zone (CSU 71/66, Hunstanton, Gayton, and Marham) were within the upper part of the *wheatleyensis* Zone, here distinguished as the *wheatleyensis* Subzone.

*Pectinatites (Virgatosphinctoides) wheatleyensis* Subzone

Index species: As *wheatleyensis* Zone.

The subzone corresponds well with the range of *P. (V.) wheatleyensis* and its described subspecies. *P. (V.) wheatleyensis minor* Cope appears first in Dorset and has hitherto not been recorded from elsewhere. *P. (V.) woodwardi* (Neaverson), *P. (V.) grandis* (Neaverson) and *P. (V.) pseudoscruposus* (Spath) are also characteristic of this subzone, though forms relating to the latter two may have persisted through to the lower part of the *hudlestoni* Zone. There appears to be a little overlap between the upper limit of *P. (V.) laticostatus* primarily characteristic of the *smedmoresis* Subzone and the lower part of this subzone.

These faunal associations are well shown in the Hunstanton Borehole, and the lowest determinable specimen from this borehole, *P. (V.) woodwardi* at 122·38 m, is clearly still within the subzone, giving a minimum thickness here of 4 m. The Gayton Borehole passed through over 7 m of the subzone without proving the base, whilst virtually 10 m can be ascribed to the subzone in the Marham Borehole again without the base being proved, this latter thickness exceeding the 7 m which the subzone occupies in Dorset. In Oxfordshire, the Wheatley Nodule Bed, the source of many of Neaverson's types clearly belongs entirely to this subzone.

The roveacrinid genus *Saccocoma* is particularly characteristic of the upper part of this subzone. In Dorset it ranges through about 6 m of bituminous shales in and below the Blackstone. The ammonite faunas confirm that the *Saccocoma* horizons in the CSU 71/65, CSU 71/66 and Hunstanton boreholes occur at approximately the same horizon as in Dorset.

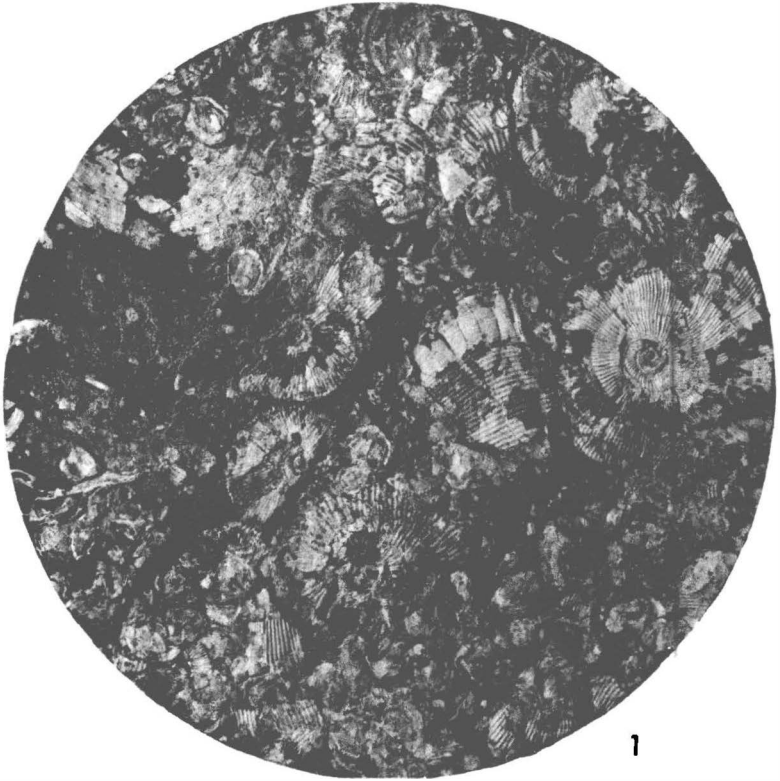
*Pectinatites (Arkellites) hudlestoni* Zone

Index species: *Pectinatites (Arkellites) hudlestoni* Cope 1967, p. 29, pl. 7.

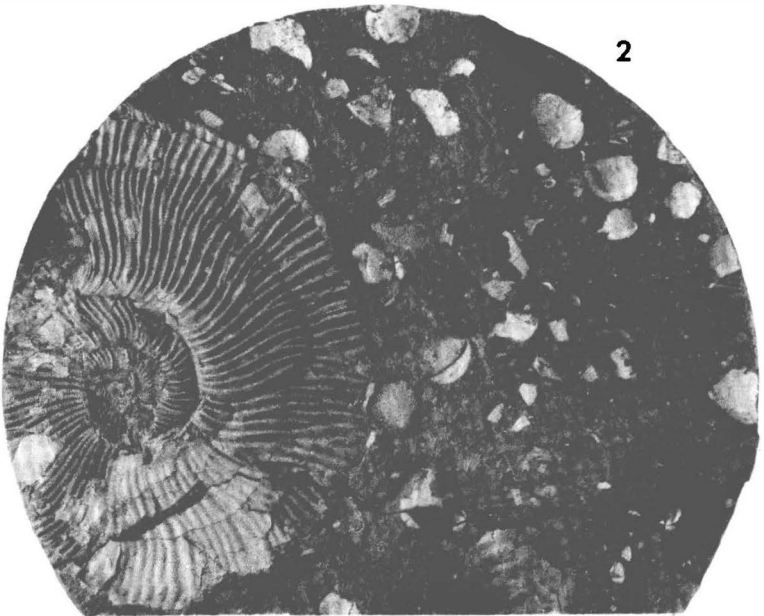
The full extent of this zone occurred in the Hunstanton Borehole (11·1 m) and Borehole CSU 71/66 (12·6 m). The base of the zone is fixed by the first appearance of *P. (V.) reisiformis* Cope. This species has now been found in Dorset in the shales above the Blackstone and below the Rope Lake Head Stone Band, thus requiring a downward adjustment in the boundary between the *wheatleyensis* and *hudlestoni* zones. When the *hudlestoni* Zone was originally erected, the shales above the Blackstone had yielded only fragmentary ammonites, which were provisionally identified as *P. (V.) wheatleyensis delicatulus* (Neaverson) (Cope 1967, p. 49). As a result of further collecting it now appears clear that these ammonites properly belong to *P. (V.) reisiformis*. With the downward adjustment of this zonal boundary, the *hudlestoni* Zone becomes by far the thickest of these Upper Kimmeridgian zones in Dorset, and under this new interpretation has a thickness at Kimmeridge of some 45 m. The zone is thinner outside of Dorset,

## EXPLANATION OF PLATE 1

- Fig. 1. *Pectinatites (Pectinatites) eastlecottensis* (Salfeld); IGS Skegness Borehole, 120·78 m, Kimmeridgian, *pectinatus* Zone, *eastlecottensis* Subzone, BDF 5533, × 1.
- Fig. 2. *Pectinatites (Pectinatites) cornutifer* (Buckman); IGS Skegness Borehole, 120·70 m, Kimmeridgian, *pectinatus* Zone, *eastlecottensis* Subzone, BDF 5531, × 1.

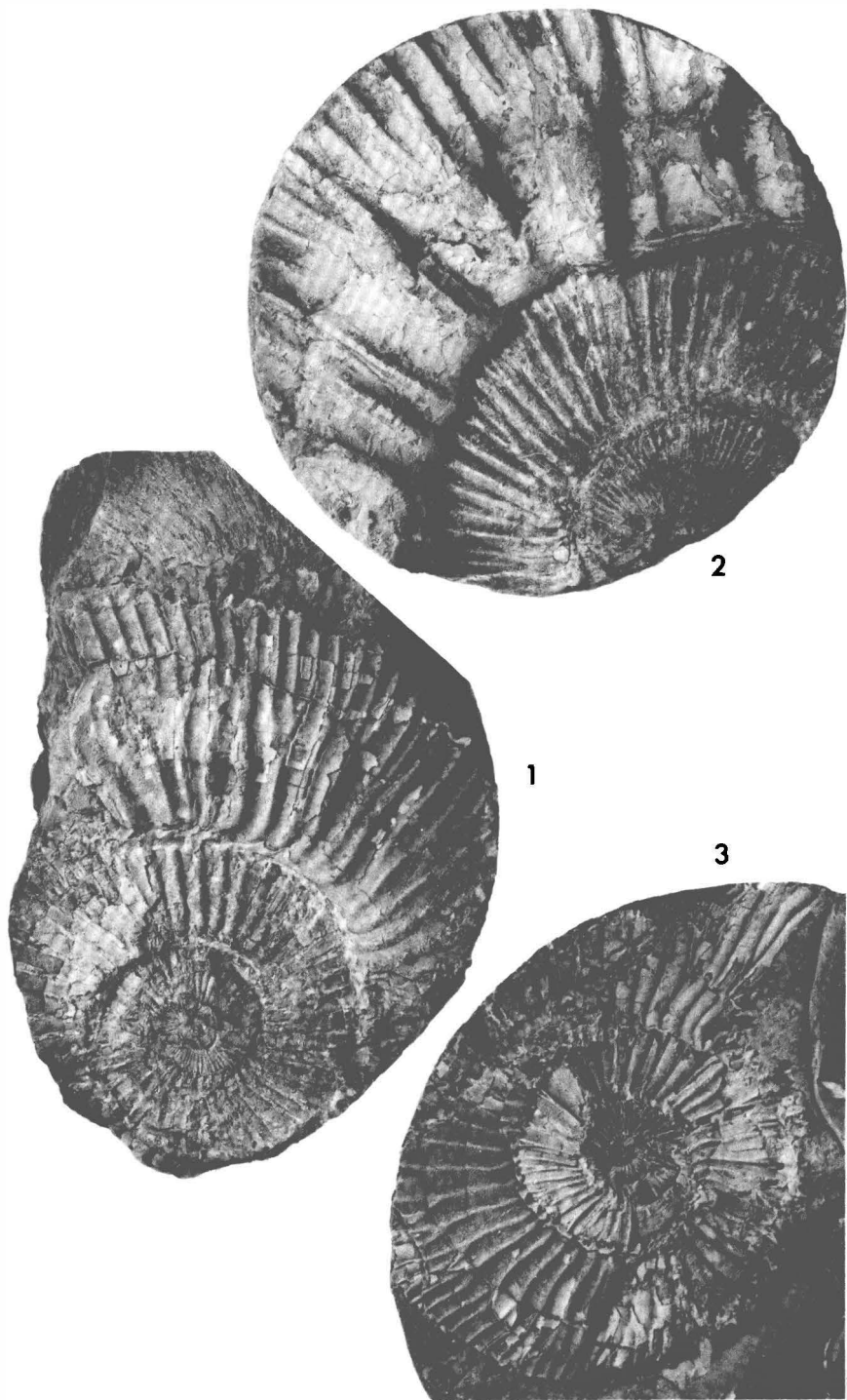


1



2

Upper Kimmeridgian ammonites



Upper Kimmeridgian ammonites

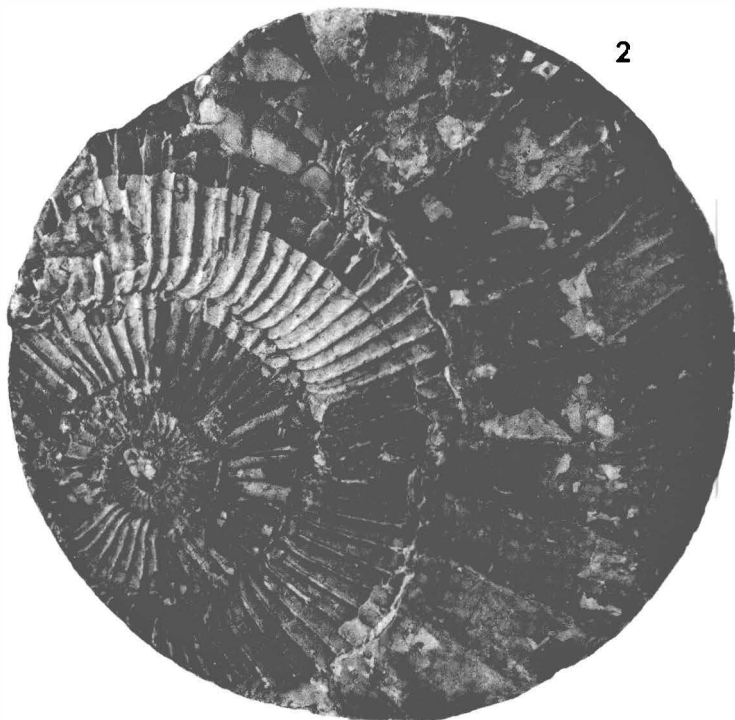
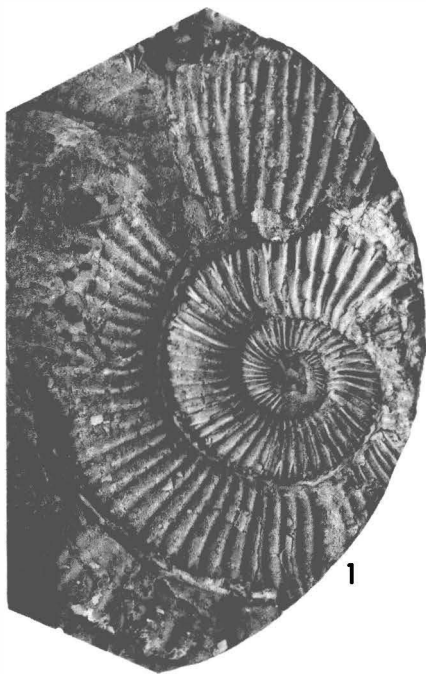
## EXPLANATION OF PLATE 2

- Fig. 1. *Pectinatites (Virgatosphinctoides) cf. encombensis* Cope; IGS Skegness Borehole, 124.59 m, Kimmeridgian, *hudlestoni* Zone, *encombensis* Subzone, BDF 5588,  $\times 1$ .
- Fig. 2. *Pectinatites (Virgatosphinctoides) reisiiformis* Cope; IGS Hunstanton Borehole, 116.31 m, Kimmeridgian, *hudlestoni* Zone, *reisiiformis* Subzone, BDD 3671,  $\times 1$ .
- Fig. 3. *Pectinatites (Virgatosphinctoides) wheatleyensis* (Neaverson); IGS Gayton Borehole, 91.39 m, Kimmeridgian, *wheatleyensis* Zone, *wheatleyensis* Subzone, BDB 9143,  $\times 1$ .



## EXPLANATION OF PLATE 3

- Fig. 1. *Pectinatites (Virgatosphinctoides) cf. pseudoscruposus* (Spath); IGS Gayton Borehole, 90·47 m, Kimmeridgian, *wheatleyensis* Zone, *wheatleyensis* Subzone, BDB 9134, × 1.
- Fig. 2. *Pectinatites (Virgatosphinctoides) pseudoscruposus* (Spath); IGS Gayton Borehole, 92·15 m, Kimmeridgian, *wheatleyensis* Zone, *wheatleyensis* Subzone, BDB 9151, × 1.
- Fig. 3. *Pectinatites (Virgatosphinctoides) woodwardi* (Neaverson); IGS Hunstanton Borehole, 122·38 m, Kimmeridgian, *wheatleyensis* Zone, *wheatleyensis* Subzone, BDD 3767, × 1.



Upper Kimmeridgian ammonites

as the figures from the Wash area boreholes (and the Warlingham Borehole) show. The zone may well be completely absent in both the Swindon and Oxford areas, as the Shotover Fine Sands, doubtfully assigned to this zone (Cope 1967, p. 71) have not yielded identifiable ammonites. In Yorkshire, evidence has now been found to show that the *hudlestoni* Zone is probably completely unrepresented.

As with the *wheatleyensis* Zone, a twofold subzonal division seems readily discernible in this zone.

#### *Pectinatites (Virgatosphinctoides) reisiformis* Subzone

Index species: *Pectinatites (Virgatosphinctoides) reisiformis* Cope 1967, p. 50, pl. 22; pl. 23, fig. 3.

The subzonal base is fixed by the first appearance of the index species. It is associated with its subspecies *P. (V.) reisiformis densicostatus* Cope, with *P. (V.) abbreviatus* Cope and the zonal index species, *P. (A.) hudlestoni*, the latter species ranging through the succeeding subzone. The upper part of the subzone is characterized by *P. (V.) donovani* Cope in Dorset, but this latter species lies within the recorded range of *P. (V.) reisiformis* in the Wash area.

The subzone was proved in the Hunstanton Borehole and Borehole CSU 71/66 which confirmed the faunal association established in Dorset and in the Warlingham Borehole.

#### *Pectinatites (Virgatosphinctoides) encombensis* Subzone

Index species: *Pectinatites (Virgatosphinctoides) encombensis* Cope 1967, p. 57, pl. 27, fig. 1; pl. 28.

This subzone is characterized by the zonal index species, the subzonal index and also by *P. (V.) magnimaculus* Cope, this latter species having not yet been recorded outside of Dorset. In Dorset, the Basalt Stone Band (Cope 1967, p. 8) is a good marker horizon which may be taken as the bottom of the subzone giving a subzonal thickness of almost 16 m (up to the White Stone Band).

The subzone is recognizable in the borehole ammonite faunas from Skegness (2 m minimum), Hunstanton (3.5 m), and CSU 71/66 (approximately 3.5 m). The Warlingham fauna again confirms the validity of this subzone.

#### *Pectinatites (Pectinatites) pectinatus* Zone

Index species: *Pectinatites (Pectinatites) pectinatus* (Phillips) 1871. (Neotype figured Arkell 1956, pl. 41, fig. 6.)

Results of collecting from the upper part of the *pectinatus* Zone are shortly to be published. The faunas of the lower part of the zone have already been described (Cope 1967) and several species from the South Midlands figured by Buckman (1922-30). It now seems clear that a twofold division of the *pectinatus* Zone is possible.

#### *Pectinatites (Pectinatites) eastlecottensis* Subzone

Index species: *Pectinatites (Pectinatites) eastlecottensis* (Salfeld) 1913, p. 429, pls. 41, 42.

The subzonal index species appears in Dorset a little above the White Stone Band, and the sudden appearance of the exceptionally densely ribbed specimens

is a feature found in most boreholes. This species occurred in the Skegness, Hunstanton and CSU 71/66 boreholes. In the latter borehole only three-quarters of a metre separated the lowest specimen of *P. (P.) eastlecottensis* from the highest *P. (V.) encombensis* of the preceding zone. The Warlingham Borehole, however, failed to yield any *pectinatus* Zone ammonites.

In Dorset, the White Stone Band is taken as a convenient boundary for the base of the subzone. This characteristic horizon of coccolith limestone has been identified readily in many of the Dorset sections, and it is believed to form a widespread marker horizon elsewhere. Nine metres above this horizon in Dorset, the Middle White Stone Band also contains significant coccoliths. The Skegness, CSU 71/66 and Hunstanton boreholes each passed through a coccolith-rich bed, up to 1.6 m, below which were specimens of *P. (P.) eastlecottensis*. The *hudlestoni/pectinatus* zonal boundary must be drawn below these latter occurrences, and it seems that this combination of facts may be interpreted in several different ways:

1. the coccolith-rich horizon may not be the same age as the White Stone Band in Dorset (it is perhaps the equivalent of the Middle White Stone Band), or
2. *P. (P.) eastlecottensis* appears earlier in the Wash area, or
3. collection failure is responsible for *P. (P.) eastlecottensis* not having been recorded from lower horizons in Dorset. There is in fact 3 m of shale below the White Stone Band and above the highest recorded *P. (V.) encombensis* of the *encombensis* Subzone, and this latter interpretation appears the most likely.

Accompanying the subzonal index ammonite are *P. (P.) cornutifer* (Buckman) (= *P. (P.) nasutus* (Buckman)), *P. (P.)* aff. *pectinatus*, and, so far only in Dorset, *P. (P.) inconsuetus* Cope. Other ammonites which may be expected include the large macroconch form of *Pectinatites*, *Wheatleyites* (Buckman 1923). Specimens of the latter are recorded from areas of Oxfordshire and Buckinghamshire and several were figured by Buckman in "Type Ammonites". The genus has also been found more recently in Dorset, just below the Freshwater Steps Stone Band.

#### *Pectinatites (Paravirgatites) paravirgatus* Subzone

Index species: *Pectinatites (Paravirgatites) paravirgatus* Buckman 1922, pl. 353.

A full description of the ammonite faunas of this subzone based largely on collections from Dorset will shortly be published. In the meantime, however, it is thought useful to record the existence of a distinctive fauna in the upper part of the *pectinatus* Zone.

Hitherto *Paravirgatites* has been placed in the subfamily Dorsoplanitinae, but there is no doubt that it belongs in the subfamily Pectinatitinae. The microconchs of *Paravirgatites* have the ventral horn so absolutely (and uniquely) characteristic of *Pectinatites*. Associated pectinatitids include *P. (Pectinatites) naso* (Buckman) in the lower part, whilst the upper part has yielded a series of hitherto undescribed pectinatitids.

None of the Wash area boreholes has yielded Kimmeridge Clay as high as this, beds above the *eastlecottensis* Subzone being overlain by the basal Sandringham Sands/Spilsby Sandstone nodule bed unconformity. The subzone was probably present in the Warlingham Borehole and a possible specimen of *Paravirgatites* occurred there (Callomon and Cope 1971, p. 151). Recorded faunal lists from

the Shotover Grit Sands include forms characteristic of this subzone in Dorset as well as those of the underlying *eastlecottensis* Subzone. It may be, therefore, that if more precise collecting had been carried out when exposures of the Shotover Grit Sands and the lower part of the Cemetery Beds at Swindon were readily available, this twofold division of the zone would have been foreseen.

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