

WITH THE AUTHOR'S COMPLIMENTS.

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in the Upper Chalk.*

BY

A. J. JUKES-BROWNE, F.R.S., F.G.S.

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TWO STAGES IN UPPER CHALK.

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ON THE RECOGNITION OF TWO STAGES IN THE UPPER CHALK.

By A. J. JUKES-BROWNE, F.R.S., F.G.S.

WHEN writing a general account of the Upper Chalk of England for vol. iii of the *Cretaceous Rocks of Britain* (Mem. Geol. Survey, 1904), I stated the belief of Mr. W. Hill and myself that the British Upper Chalk comprised more than one division of the value of a stage. We grouped the zones then recognized into two divisions, pointing out that the lower zones were essentially the Chalk with *Micrasters* and the upper zones the Chalk with *Belemnites*; but we did not systematically adopt these divisions as stages with definite names.

It was remarked (op. cit., p. 5) that "Our knowledge of the several faunas is not yet sufficiently complete to enable us to say precisely where a line could best be drawn between the two divisions or stages, and it is possible that some modifications of the zones will have to be made before two such stages can be established. Moreover, if such a division be found natural and desirable the existing

nomenclature of the Chalk will have to be abandoned, for the formation will then be divided into four parts instead of three, so that the names Lower, Middle, and Upper could no longer be retained. The time has hardly yet arrived for this change to be made, but Mr. Hill and I wish to express our belief that it will come, and that some scheme of nomenclature more resembling that of the French geologists will have to be adopted for the Upper Cretaceous Series of England”.

Nearly ten years have passed since the above was written, and the further researches which have been made since that time have only tended to strengthen our belief, but have at the same time shown the wisdom of waiting for more evidence before deciding where the line between the two divisions of the Upper Chalk should be drawn.

A more careful consideration of the question has convinced me that the distinction between these two portions of the Upper Chalk is less marked in England than it is in France or Germany. In England there is little variation in the lithological character of the deposit, which consists of nearly pure chalk throughout a thickness of some 1,100 feet. As a consequence the fauna has a similar facies throughout, and there is a complete passage from each zone to the next one, so that many species range from one into another. Moreover, all kinds of Cephalopoda except Belemnites are rare, so that it is impossible to use Ammonoids as zonal indices, and we are obliged to have recourse to Belemnites and Echinoderms.

On the other hand, in parts of France and Germany the pure chalk passes into other kinds of calcareous deposits, such as argillaceous marl, marly limestone, Bryozoa and siliceous limestones. Moreover, Ammonites are much less rare, and M. de Grossouvre has shown that a reliable zonal classification can be established on the recorded occurrences of the different species. There is also a greater number and greater variety of Echinoderms on the Continent than in England, so that the faunal difference between the one set of zones and the other is more apparent. Probably when the Brachiopoda have been more fully studied they also will show a more restricted range of species and varieties.

The cause of this more marked difference of fauna on the Continent is doubtless the fact that parts of the European region were land during most of the Cretaceous period, and that there was a greater variety of life in the shallower waters near the land-tracts than in the deeper water which lay over the British area and the greater part of the Paris Basin.

Before proceeding any farther it is necessary to make some remarks on the zonal division of the Upper Chalk. Until recently only six zones were recognized as its components in the South of England, but so long ago as 1899 and 1900 Mr. A. W. Rowe remarked that the true *Actinocamax quadratus* is so rare a fossil in England that *Offaster pilula* would be a better index fossil for the zone which has hitherto gone by the name of the former. At the same time he pointed out that *A. quadratus* only occurs in the higher part of the zone, the form found in the lower part being *A. granulatus*.

More recently Messrs. Griffith & Brydone have proposed to divide

this zone, as developed in Hampshire,¹ into three sub-zones, viz.: (1) a sub-zone of *Echinocorys scutatus*, var. *depressa*, (2) a sub-zone of *O. pilula*, and (3) a sub-zone of *A. quadratus*. Mr. Brydone informs me, however, that he has since come to the conclusion that it will be better to make two distinct zones out of this great thickness of chalk, a lower zone of *O. pilula* and an upper one of *A. quadratus*. This proposal has the advantage of agreeing with the zonal divisions adopted in Germany, where this portion of the Chalk has been divided by Schlüter into a lower zone of *Scaphites binodosus* and a higher one of *A. quadratus*.²

In France also two zones have been recognized in this part of the Chalk; by J. Lambert in the Department of the Yonne, by A. Peron in the vicinity of Reims and Epernay, and in Aquitaine by Arnaud.

In the Yonne a series of zones was established by Lambert³ and indicated by letters, his zone M being about 100 feet thick and corresponding with the *O. pilula* zone of Mr. Brydone, for it is characterized by the abundance of *O. pilula* with what is now known as *A. granulatus*. His zone N, about 130 feet thick, corresponds roughly with that of *A. quadratus*, its special fossils being *A. quadratus*, *Offaster corculum*, and *Micraster Schroderi* (= *M. glyphus* in Lambert's papers).

The same two zones can be recognized in the Marne near Reims where A. Peron⁴ has shown that the 'craie à *A. quadratus*' is divisible into two zones, a lower one characterized by *Micraster gibbus*, var. *fastigatus*, Gauthier, and an upper one with *M. glyphus* (= *Schroderi*) and *Salenia Heberti*. *Offaster pilula* is also common in the lower zone and rare in the upper. In Aquitaine a similar succession of zones has been established by H. Arnaud,⁵ and lettered in a similar manner from A to S. Of these the zone P¹ (= that of *O. pilula*) is characterized by the occurrence of *Micraster regularis*, *Echinocorys orbis*, and *Pyrina petrocoriensis*, and M. de Grossouvre has shown that its special Ammonite is *Placenticerus bidorsatum*. The zone P² (= that of *A. quadratus*) is a sandy chalk with few fossils except bands of *Ostrea vesicularis*, but examples of *A. quadratus* and *Mortoniceras delawarensis* have been found in it.

From these observations it is clear that both in the South of England, the North of France, and in Aquitaine, the mass of chalk which lies between the zone of *Marsupites* and the Chalk containing *B. mucronata* is divisible into two distinct zones which are recognizable by the occurrence of certain species of Echinoderms and Belemnites, apart from the rarer occurrence of Ammonoids. Thus, if the zone of

¹ *The Zones of the Chalk in Hants*, by C. Griffith & R. M. Brydone (Dulau & Co., 1911), pp. 3, 10.

² See Schlüter in *Zeitsch. der Deutsch. Geol. Gesellschaft*, Bd. xxviii, p. 457, 1876, and *Imp. Geol. Inst., Vienna, Sitz. for 1877*.

³ Lambert, "Terrain Crétacé du départ. de l'Yonne": *Bull. Soc. Sci. hist. et nat. de l'Yonne for 1876*.

⁴ Peron, "Terrain de craie dans le Sud-est du bassin angloparisien": *op. cit. supra* (1887).

⁵ "Le Terr. Crét. du Sud-ouest," *Mém. Soc. géol. France* (1877); and "Report of Excursion to the Charente", *Bull. Soc. géol. France* (1877).

Holaster planus be included in the Upper Chalk or Senonian there will be seven zones without reckoning that of *Ostrea lunata*.

In the following pages I shall endeavour to show that the Upper Chalk or Senonian of England, France, and Germany really contains two distinct faunas, and is consequently divisible into two stages as distinct as the Cenomanian and Turonian. I shall also consider the range of some of the component members of these faunas with the special object of determining the most natural line of division between these two stages.

French geologists long ago recognized the difference between the assemblages found in the lower and upper parts of d'Orbigny's Senonian stage, but they have never tabulated the fossils with the view of demonstrating the precise amount of this difference. They have divided the ancient 'Senonian' into two parts, and have given these parts definite names, but regard them as sub-stages and not as primary divisions of the series. German geologists have also recognized a division into Unter- and Ober-Senon, but they do not adopt the French names and they do not agree as to the horizon at which the plane of separation should be drawn.

To tabulate the whole Senonian fauna would be both a laborious and unnecessary task. If it really comprises two different assemblages, their diversity should be made apparent by a separate tabulation of two or three classes of organisms and especially by the Cephalopoda. This we shall find to be the case, but as Cephalopoda are not everywhere abundant I shall supplement their evidence by that of the Echinoids and the species of the genus *Inoceramus*.

Further, in order that the tabulated lists may be readily compared with one another the zones of the Senonian in England, France, and Germany must be correlated with one another, and as the zonal nomenclature has not yet been unified and perhaps cannot ever be made the same for all three countries, I have prepared a table of equivalent zones for reference.

The French and English zones are easily correlated because we have practically adopted the French zones, but in Germany the case is different. In the latter country the beds which contain typical *Micraster cortestudinarium* are known as the 'Cuvieri-planer' from the abundance of *Inoceramus Cuvieri*, and are placed at the top of the Turonian stage. This zone is overlain by a great thickness of grey marl and marly clay in which there are few Echinoderms, but a large number of *Inocerami* and Cephalopoda, the species indicating that these beds represent our zone of *Micraster coranguinum* with perhaps some of the underlying zone of *M. cortestudinarium*. These marls have been called the 'Emschermergel' from their development near Ems, and Dr. Schlüter regarded them as forming a separate stage between the Turonian and Senonian, but others more correctly consider the special character of the fauna as due to special local conditions of deposition.

The 'Emscher' Beds are succeeded by a set of sandy marls which Schlüter classed as Unter-Senon and divided into three zones, with the indices of (1) *Marsupites ornatus*, (2) *Pecten muricatus*, and (3) *Scaphites binodosus*. The two higher zones correspond with that

of *O. pilula* in the Anglo-Parisian region, but in Germany this Echinid is only found in the overlying zone of *A. quadratus*, so that it cannot be used as an index, and *Scaphites binodosus* may be adopted instead. *A. granulatus* ranges throughout these marls, which are often called the 'granulaten-kalk'.

The Ober-Senon of Schlüter, i.e. the zones of *A. quadratus* and *B. mucronata*, corresponds with the rest of the English Upper Chalk. The equivalence of these zones is shown in the following table, in which I have also inserted the Ammonite zones established by de Grossouvre as an international basis of comparison:—

ENGLAND.	FRANCE.	GERMANY.	AMMONITE ZONES.
<i>B. mucronata</i> .	<i>B. mucronata</i> .	<i>B. mucronata</i> .	{ <i>Pachydiscus neubergicus</i> .
<i>A. quadratus</i> .	<i>A. quadratus</i> .	<i>A. quadratus</i> .	{ <i>Hoplites Vari</i> .
<i>Offaster pilula</i> .	<i>Offaster pilula</i> .	<i>S. binodosus</i> .	{ <i>Mortoniceras delawarensis</i> .
<i>Marsupites</i> .	<i>Marsupites</i> .	<i>Marsupites</i> .	{ <i>Placenticerases bidorsatum</i> .
<i>M. coranguinum</i> .	<i>M. coranguinum</i> .	<i>Emscher marls</i> .	{ <i>P. syrtale</i> .
<i>M. cortestudinarium</i> .	<i>M. decipiens</i> .	<i>I. Cuvieri</i> .	{ <i>Mortoniceras texanum</i> .
			{ <i>M. emscheris</i> .
			{ <i>Barroisicerases Haberfellneri</i> .

The reader will now be able to understand the zonal arrangements employed in the following tables and to appreciate the evidence thus presented. It will be convenient to begin with that of the Cephalopoda, and the first table shows the distribution of these fossils in the North of Germany, where they are more abundant than in England or France. This table has been compiled from that given by M. de Grossouvre in 1902¹ with the correction of a few misprints and mistakes:—

TABLE I.
CEPHALOPODA OF THE UPPER CHALK IN NORTH GERMANY.

SPECIES.	<i>Cuvieri</i> zone.	The <i>Emscher</i> .	Zone of <i>Marsupites</i> .	Zone of <i>S. binodosus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Mortoniceras Emscheris</i> , Schlüter	-	x	-	-	-	-
<i>M. pseudotexanum</i> , de Gross.	-	x	-	-	-	-
<i>Gauthiericerases Margæ</i> , Schlüter	-	x	-	-	-	-
<i>Peroniceras subtricarinarium</i> , d'Orb.	x	x	-	-	-	-
<i>P. Moureti</i> , de Gross.	-	x	-	-	-	-
<i>P. westphalicum</i> , Stromb.	-	x	-	-	-	-
<i>P. tridorsatum</i> , Schlüter	-	x	-	-	-	-
<i>Barroisicerases Haberfellneri</i> , v. Hauer	-	x	-	-	-	-
<i>Mumiericerases clypeale</i> , Schlüter	-	-	x	-	-	-
<i>Placenticerases syrtale</i> , Morton	-	-	x	-	-	-
<i>P. bidorsatum</i> , Römer	-	-	-	x	-	-
<i>Puzosia Mulleri</i> , de Gross.	x	-	-	-	-	-
<i>Desmoceras patagiosum</i> , Schlüter	-	-	-	-	-	x
<i>D. obscurum</i> , Schlüter	-	-	-	x	x	-

¹ "Recherches sur la Craie Supérieure": Mém. Carte Dét. de la France, fasc. ii, p. 700.

SPECIES.	Cuvieri zone.	The Emscher.	Zone of Marsupites.	Zone of S. binodosus.	Zone of A. quadratus.	Zone of B. macronata.
<i>Sonneratia Daubreei</i> , de Gross.	-	x	-	-	-	-
<i>Hoplites falcatus</i> (?), Mant.	-	-	-	-	-	x
<i>H. caesfeldensis</i> , Schlüter	-	-	-	-	-	x
<i>H. Vari</i> , Schlüter	-	-	-	-	-	x
<i>H. costulosus</i> , Schlüter	-	-	-	-	-	x
<i>H. lemfordensis</i> , Schlüter	-	-	-	-	-	x
<i>H. dolbergensis</i> , Schlüter	-	-	-	-	-	x
<i>Hauericeras pseudo-Gardeni</i> , Schlüter	-	-	-	x	-	-
<i>Pachydiscus peramplus</i> , Mant.	x	-	-	-	-	-
<i>P. dulmenensis</i> , Schlüter	-	-	-	x	-	-
<i>P. lettensis</i> , Schlüter	-	-	-	-	x	-
<i>P. Stobai</i> , Nilsson	-	-	-	-	x	x
<i>P. gallicianus</i> , Schlüter	-	-	-	-	-	x
<i>P. icenicus</i> (?), Sharpe	-	-	-	-	-	x
<i>P. Portlocki</i> , Sharpe	-	-	-	-	-	x
<i>P. Koeneni</i> , de Gross.	-	-	-	-	-	x
<i>P. auritocostatus</i> , Schlüter	-	-	-	-	-	x
<i>P. haldemensis</i> , Schlüter	-	-	-	-	-	x
<i>P. neubergicus</i> , Schlüter	-	-	-	-	-	x
<i>P. Wittkindi</i> , Schlüter	-	-	-	-	-	x
<i>Gaudryiceras lunebergense</i> , Schlüter	-	-	-	-	-	x
<i>Phylloceras velledæformis</i> , Schlüter	-	-	-	-	-	x
<i>Scaphites Geinitzi</i> , d'Orb.	x	-	-	-	-	-
<i>S. aquisgranensis</i> , Schlüter	-	-	-	x	-	-
<i>S. binodosus</i> , Römer	-	-	-	x	-	-
<i>S. inflatus</i> , Römer	-	-	-	x	-	-
<i>S. hippocrepis</i> , Dekay	-	-	-	x	x	-
<i>S. gibbus</i> , Schlüter	-	-	-	-	-	x
<i>S. spiniger</i> , Schlüter	-	-	-	-	-	x
<i>S. constrictus</i> , Sow.	-	-	-	-	-	x
<i>S. ornatus</i> , Römer	-	-	-	-	-	x
<i>S. Reussi</i> , d'Orb.	-	-	-	-	-	x
<i>S. Roemeri</i> , d'Orb.	-	-	-	-	-	x
<i>S. pulcherrimus</i> , Römer	-	-	-	-	-	x
<i>S. tridens</i> , Kner	-	-	-	-	-	x
<i>S. nodifer</i> (?), Hagenow	-	-	-	-	-	x
<i>Ancyloceras Cuvieri</i> , Schlüter	x	x	-	-	-	-
<i>A. padebornensis</i> , Schlüter	x	x	-	-	-	-
<i>A. retrorsum</i> , Schlüter	-	-	-	-	x	x
<i>A. pseudo-armatum</i> , Schlüter	-	-	-	-	-	x
<i>Crioceras cingulatum</i> , Schlüter	-	-	-	x	-	-
<i>Toxoceras turonense</i> , Schlüter	x	-	-	-	-	-
<i>Hamites Berkelis</i> , Schlüter	-	-	-	-	-	x
<i>H. reticostatus</i> , Schlüter	-	-	-	-	-	x
<i>H. cylindræus</i> , Defr.	-	-	-	-	-	x
<i>Turrilites tridens</i> , Schlüter	-	x	-	-	-	-
<i>T. plicatus</i> , d'Orb.	-	x	-	-	-	-
<i>T. varians</i> , Schlüter	-	x	-	-	-	-
<i>T. undosus</i> , Schlüter	-	x	-	-	-	-
<i>Heteroceras polyplacum</i> , Schloth.	-	-	-	-	-	x
<i>Helicoceras reflexum</i> , Quendst.	x	-	-	-	-	-
<i>H. flexuosum</i> , Schloth.	x	-	-	-	-	-

SPECIES.	<i>Cuvieri</i> zone.	The <i>Emscher</i> .	Zone of <i>Marsupites</i> .	Zone of <i>S. binodosus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Baculites brevicosta</i> , Schlüter	-	x	-	-	-	-
<i>B. bohemicus</i> , Fritsch	x	-	-	-	-	-
<i>B. incurvatus</i> , Dujard	-	x	x	x	-	-
<i>B. anceps</i> , Lam.	-	-	-	-	-	x
<i>B. Knorri</i> , Desor	-	-	-	-	-	x
<i>Nautilus liotropis</i> , Schlüter	-	x	-	-	-	-
<i>N. neubergicus</i> , Redtenb.	-	x	-	-	-	-
<i>N. westphalicus</i> , Schlüter	-	-	-	x	-	-
<i>N. patens</i> , Kner	-	-	-	-	-	x
<i>N. altenensis</i> , Schlüter	-	-	-	-	-	x
<i>N. darupensis</i> , Schlüter	-	-	-	-	-	x
<i>N. loricatus</i> , Schlüter	-	-	-	-	-	x
<i>N. vaalsiensis</i> , Binkh.	-	-	-	-	-	x
<i>Actinocamax pederbornensis</i> , Schlüter	x	-	-	-	-	-
<i>A. westfalicus</i> , Schlüter	-	x	-	-	-	-
<i>A. verus</i> , Müller	-	x	x	x	-	-
<i>A. granulatus</i> , Blainv.	-	-	x	x	-	-
<i>A. Grossouvrei</i> , Janet	-	-	x	x	-	-
<i>A. Toucasi</i> , Janet	-	-	x	x	-	-
<i>A. mammillatus</i> , Nilsson	-	-	-	-	x	-
<i>A. quadratus</i> , Blainv.	-	-	-	-	x	-
<i>Belemnitella mucronata</i> , Schloth.	-	-	-	-	x	x

From this table it will be seen that in Germany there are two very distinct assemblages of Cephalopoda; the one set being almost entirely restricted to the four lower zones, and the other set to the *quadratus* and *mucronata* zones. The one fauna comprises forty-seven species and the other forty-six species, of which only two are common to both, these two being *Desmoceras obscurum* and *Scaphites hippocrepis*. All the commoner and characteristic species of each fauna are absolutely restricted to it.

The passage zone of *S. binodosus* has yielded fifteen species, of which eight are peculiar to it, two range up into the *quadratus* zone, and five range down into lower zones. It will be seen in the sequel that the evidence of the *Inocerami* confirms the inference that this zone is more closely allied to the zone below than to the one above. Hence Dr. Schlüter seems to have been fully justified in drawing the line between his Unter- and Ober-Senon at the base of the *quadratus* chalk.

We will now pass to Belgium and the North of France, where a fair number of Cephalopoda have been obtained, though far fewer than in Germany. The following table shows the range of those which have been recorded from Belgium, the Cotentin, and Touraine, as well as from the Paris Basin proper; but it will be seen that few species are yet known to occur in the zones of *A. granulatus* and *A. quadratus*. In the Paris Basin these zones have not yet been specially examined and searched, except in the neighbourhood of Sens and of Reims; a few remains of Ammonoids have been found

near Sens, but they are so imperfect that de Grossouvre was not able to identify them. No doubt better specimens will be obtained in course of time, and then the evidence will probably tend to coincide more closely with that of the German distribution of species.

In this table the letter F stands for France and B for Belgium.

TABLE II.
CEPHALOPODA IN BELGIUM AND THE NORTH OF FRANCE.

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M. coronatum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. pilula</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Tissotia Ewaldi</i> , de Buch.	F.	-	-	-	-	-
<i>T. haplophylla</i> , Redtenb.	F.	-	-	-	-	-
<i>Barroisiceras Haberfellneri</i> , v. Hauer	F.	-	-	-	-	-
<i>Mortoniceras Bontanti</i> , de Gross.	-	F.	-	-	-	-
<i>M. Bourgeoisii</i> , d'Orb.	-	F.	-	-	-	-
<i>M. Emscheris</i> , Schlüter	-	F.	-	-	-	-
<i>M. Zeilleri</i> , de Gross.	F.	-	-	-	-	-
<i>Gautiericeras Marga</i> , Schlüter	F.	-	-	-	-	-
<i>G. bijuvaricum</i> , Redtenb.	F.	-	-	-	-	-
<i>Peroniceras Moureti</i> , de Gross.	F.	-	-	-	-	-
<i>P. subtricarimatum</i> , d'Orb.	F.	-	-	-	-	-
<i>P. tridorsatum</i> , Schlüter	F.	-	-	-	-	-
<i>P. westfalicum</i> , Schlüter	F.	-	-	-	-	-
<i>Hoplites Lafresnayi</i> , d'Orb.	-	-	-	-	-	F.
<i>Desmoceras ponsianum</i> , de Gross.	F.	-	-	-	-	-
<i>D. Stobæi</i> , Nilsson	-	-	-	-	-	B.
<i>Sphenodiscus Ubaghsi</i> , de Gross.	-	-	-	-	-	B.
<i>Placenticeras Fritschi</i> , de Gross.	F.	-	-	-	-	-
<i>P. syrtale</i> , Morton	-	-	F.	-	-	-
<i>Sonneratia Janeti</i> , de Gross.	F.	-	-	-	-	-
<i>Pachydiscus peramplus</i> , Mant.	F.	-	-	-	-	-
<i>P. telinga</i> , Stoliczka	F.	-	-	-	-	-
<i>P. leptophyllus</i> , Sharpe	-	-	F.	-	-	-
<i>P. colligatus</i> , Binkh.	-	-	-	-	-	F., B.
<i>P. gollevillensis</i> , d'Orb.	-	-	-	-	-	F.
<i>P. neubergicus</i> , Schlüter	-	-	-	-	-	F., B.
<i>P. inopinus</i> , Hébert	-	-	-	-	-	F.
<i>P. parisiensis</i> , Hébert	-	-	-	-	-	F.
<i>Scaphites Lamberti</i> , de Gross.	F.	-	-	-	-	-
<i>S. Meslei</i> , de Gross.	F.	-	-	-	-	-
<i>S. Potieri</i> , de Gross.	F.	-	-	-	-	-
<i>S. constrictus</i> , Sow.	-	-	-	-	F.	F., B.
<i>S. spiniger</i> , Schlüter	-	-	-	-	-	F.
<i>S. Verneuilli</i> , d'Orb.	-	-	-	-	-	F.
<i>S. tridens</i> , Kner	-	-	-	-	-	B.
<i>S. aquisgranensis</i> , Schlüter	-	-	-	F., B.	-	-
<i>S. hippocrepis</i> , Morton	-	-	-	B.	-	-
<i>Ancyloceras Douvillei</i> , de Gross.	-	F.	-	-	-	-
<i>Hamites cylindraceus</i> , Defr.	-	-	-	-	-	F., B.
<i>H. carolinus</i> , d'Orb.	-	-	-	-	F.	-
<i>Baculites anceps</i> , Lam.	-	-	-	-	-	F., B.
<i>B. incurvatus</i> , Dujard.	-	-	F.	B.	-	-
<i>B. Faujasi</i> , Sow.	-	-	-	-	-	B.

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M.</i> <i>coranginum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. pilula</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Nautilus Dekayi</i> , Morton	-	-	F.	-	-	-
<i>N. Heberti</i> , Binkh.	-	-	-	-	-	F., B.
<i>N. Le Hardyi</i> , Binkh.	-	-	-	-	-	B.
<i>N. vaalsiensis</i> , Binkh.	-	-	-	-	-	B.
<i>Actinocamax verus</i> , Müller	-	-	F.	-	-	-
<i>A. Grossouvrei</i> , Janet	-	-	F.	-	-	-
<i>A. westfalicus</i> , Schlüter	F.	F.	F.	B.	-	-
<i>A. granulatus</i> , Blainv.	-	-	-	F., B.	-	-
<i>A. quadratus</i> , Blainv.	-	-	-	-	F., B.	-
<i>A. Alfridi</i> , Janet	-	-	-	-	F.	-
<i>Belemnitella mucronata</i> , Schloth.	-	-	-	-	F., B.	F., B.

No definite conclusions can be based on the above list, because so few species of Cephalopoda have yet been found in the zones of *O. pilula* and *A. quadratus*; but so far as the evidence goes it confirms that of the German Cephalopoda, for not one of the species occurring in the four lower zones ranges up into the higher. The zone of *B. mucronata* comprises nineteen species, and this fauna is completely different from that of the beds below the *quadratus* zone.

I have also tabulated the distribution of the Cephalopoda which occur in the corresponding zones of the South of France, Ammonoids being fairly numerous in some areas, especially in the Charentes, the Bordelais, and the Pyrenees. The deposits of Southern France differ so much from those of the northern area that the same zonal terminology is not applicable. Coquand, however, established a number of sub-stages which have again been subdivided by Arnaud, the result being a series of 'assises' which are practically zones. From the tabular view of these divisions and their principal fossils which has been given by de Grossouvre (op. cit., p. 383, table xiv) it is easy to correlate Arnaud's lettered zones with those of the Paris Basin, and from this source I have compiled a separate table of the Senonian Cephalopoda.

To print this table would unduly increase the length of this essay, but I may state some of the facts which are thus brought out. The most important fact is the obvious existence of two different faunas, the four lower zones having yielded no fewer than fifty-three species of Cephalopoda, and not a single one of them ranges into the two higher zones (i.e. of *A. quadratus* and *B. mucronata*), although these have jointly produced twenty-eight species. From the zone of *Placenticerus bidorsatum*, the equivalent of our *O. pilula* zone, eleven species have been obtained of which three are restricted to it, while all the rest range down into the zone below (that of *Placenticerus syrtale*), and none of them range upwards. Here, therefore, the plane of division between the two stages is clearly marked.

England is considered last because so few species of Cephalopoda

have yet been found in our 'Upper Chalk', but so far as their evidence goes it confirms that of France and Germany. In the following table the separate records for the zones of *O. pilula* and *A. quadratus* are based on those given by Messrs. Griffith & Brydone, and on the fact that the highest beds in the Yorkshire cliffs belong to the former zone, though true *A. quadratus* has recently been found by Mr. Stather near Bridlington.

TABLE III.
CEPHALOPODA OF THE UPPER CHALK IN ENGLAND.

SPECIES.	Zone of <i>M. cortestudinarium</i> .	Zone of <i>M. coronatum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. pilula</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Pachydiscus leptophyllus</i> , Sharpe	-	x	x	x	x	-
<i>P. Portlocki</i> , Sharpe	-	-	-	-	-	x
<i>P. icenicus</i> , Sharpe	-	-	-	-	-	x
<i>P. Oldhami</i> , Sharpe	-	-	-	-	-	x
<i>Hauericeras pseudo-Gardeni</i> , Schlüter	-	-	-	x	-	-
<i>Haploceras</i> sp. (aff. <i>catinus</i>)	-	-	-	-	-	x
<i>H. obscurum</i> , Schlüter	-	-	x	-	-	-
<i>Lytoceras Jukesi</i> , Sharpe	-	-	-	-	x	x
<i>Phylloceras velledaeformis</i> , Schlüter	-	-	-	-	-	x
<i>Hamites cylindraceus</i> , Defr.	-	-	-	-	-	x
<i>Heteroceras polyplacum</i> , Schloth.	-	-	-	-	-	x
<i>Scaphites binodosus</i> , Römer	-	-	-	x	-	-
<i>S. inflatus</i> , Römer	-	-	-	x	-	-
<i>Baculites Faujasi</i> , Sow.	-	-	-	-	-	x
<i>Nautilus Bayfieldi</i> , F. & C.	-	-	-	-	-	x
<i>N. cf. atlas</i> , Whit.	x	-	-	-	-	-
<i>N. darupensis</i> , Schlüter	-	-	-	x	-	-
<i>Actinocamax granulatus</i> , Blainv.	-	x	x	x	-	-
<i>A. verus</i> , Müller	-	x	x	x	-	-
<i>A. westfalicus</i> , Schlüter	-	x	-	-	-	-
<i>A. Toucasi</i> , Janet	-	-	-	x	-	-
<i>A. quadratus</i> , Blainv.	-	-	-	x	x	-
<i>Belemnitella mucronata</i> , Schloth.	-	-	-	-	-	x
<i>B. lanceolata</i> , Schloth.	-	-	-	-	-	x

The total number of species enumerated above is twenty-four, of which twelve occur in the four lower zones and thirteen in the higher, the only Ammonoid which is ostensibly common to the two faunas being *Pachydiscus leptophyllus*; but there is no doubt that several species have been included under this name, and that when they have been differentiated one form will prove to be restricted to the lower zones. The only locality yet known where *A. quadratus* occurs in the zone of *O. pilula* is the Salisbury district, where it prevails, as Dr. Blackmore informs me, to the exclusion of *A. granulatus*.

THE next step is to see if the evidence of the Echinodermata coincides with and confirms that of the Cephalopoda. The Echinoderms will be tabulated in the same way as the Cephalopoda, beginning with those of Germany. The following table has been compiled from several sources, and may not be quite complete as regards the irregular forms, though it is practically so for the Regulares, this part being taken from Schlüter's monograph on that order:—

TABLE IV.
ECHINODERMATA IN NORTH GERMANY.

SPECIES.	Cuvieri zone.	The Emscher.	Zone of Marsupites.	Zone of S. benodosus.	Zone of A. quadratus.	Zone of B. mucronata.
<i>Cidaris Merceyi</i> , Cott.	x	-	-	-	-	-
<i>C. sceptrifera</i> , Mant.	x	x	-	-	-	-
<i>C. hirudo</i> , Sorig	-	-	-	x	-	-
<i>C. ? pistillum</i> , Quendst.	-	-	-	-	-	x
<i>C. pseudopistillum</i> , Cott.	-	-	-	x	-	-
<i>C. Hertha</i> , Schlüter	-	-	-	-	-	x
<i>C. mammillata</i> , Cott.	-	-	-	-	-	x
<i>C. gigas</i> , Schlüter	-	-	-	-	-	x
<i>C. darupensis</i> , Schlüter	-	-	-	-	-	x
<i>C. cometes</i> , Boll	-	-	-	-	-	x
<i>C. striatula</i> , v. d. Marck.	-	-	-	-	-	x
<i>C. alata</i> , Boll	-	-	-	-	-	x
<i>C. spinosa</i> , Boll	-	-	-	-	-	x
<i>C. baltica</i> , Schlüter	-	-	-	-	-	x
<i>C. Faujasi</i> , Desor	-	-	-	-	-	x
<i>C. cf. Hardouini</i> , Desor	-	-	-	-	-	x
<i>C. Gosæ</i> , Schlüter (= <i>clavigera</i> , part).	-	-	-	x	-	-
<i>C. vexillifera</i> , Schlüter	-	-	-	-	-	x
<i>Temnocidaris Baylei</i> , Cott.	-	-	-	-	-	x
<i>T. danica</i> , Cott.	-	-	-	-	-	x
<i>Porocidaris lingualis</i> , Desor	-	-	-	-	-	x
<i>Pleurocidaris regalis</i> , Goldf.	-	-	-	-	-	x
<i>Salenia gehrdensis</i> , Schlüter	-	-	-	x	-	-
<i>S. Quendstedti</i> , Schlüter	-	-	-	x	-	-
<i>S. Heberti</i> , Cott.	-	-	-	-	x	-
<i>S. obnupta</i> , Schlüter	-	-	-	-	-	x
<i>S. anthophora</i> , Müll. (= <i>Bonissenti</i> , Cott.)	-	-	-	-	-	x
<i>S. stelfifera</i> , Hagen.	-	-	-	-	-	x
<i>S. pygmaea</i> , Hagen.	-	-	-	-	-	x
<i>S. maestrichtensis</i> , Schlüter	-	-	-	-	-	x
<i>Peltastes heliophorus</i> , Ag.	-	-	-	-	-	x
<i>Cyphosoma radiatum</i> , Sorig	x	x	x	-	-	-
<i>C. spathuliferum</i> , Forbes	-	x	-	-	-	-
<i>C. gehrdense</i> , Schlüter	-	-	-	x	-	-
<i>C. cf. magnificum</i> , Ag.	-	-	-	x	-	-
<i>C. ornatissimum</i> , Ag.	-	-	-	-	-	x

SPECIES.	Cuvieri zone.	The Emscher.	Zone of Marsupites.	Zone of S. binodosus.	Zone of A. quadratus.	Zone of B. macronata.
<i>Cyphosoma princeps</i> , Hagen.	-	-	-	-	-	x
<i>C. tenuatum</i> , Hagen.	-	-	-	-	-	x
<i>C. pseudoradiatum</i> , Schlüter	-	-	-	-	-	x
<i>C. polygophorum</i> , Schlüter	-	-	-	-	-	x
<i>Echinocyphus tenuistriatus</i> , Desor	-	-	-	x	-	-
<i>Zeuglopleurus pusilla</i> , Röm.	-	-	-	x	-	-
<i>Goniopygus Heberti</i> , Cott.	-	-	-	-	-	x
<i>Phymechinus cretaceus</i> , Schlüter	-	-	-	-	-	x
<i>Diplotagma altum</i> , Schlüter	-	-	-	-	-	x
<i>Catopygus obtusus</i> , Desor	-	-	x	x	-	-
<i>Caratomus truncatus</i> , d'Orb.	-	-	-	-	x	-
<i>Micraster coranguinum</i> , Leske	-	x	x	-	-	-
<i>M. cortestudinarium</i> , Goldf.	x	-	-	-	-	-
<i>M. gibbus</i> , Lam. (<i>Epiaster</i>)	-	-	-	x	x	x
<i>M. glyphus</i> , Cott.	-	-	-	-	x	x
<i>M. Haasi</i> , Stolley	-	-	-	-	x	-
<i>M. Gotschei</i> , Stolley	-	-	-	-	x	-
<i>M. Schroderi</i> , Stolley	-	-	-	-	x	-
<i>Epiaster brevis</i> , Desor	x	-	-	-	-	-
<i>Ananchytes vulgaris</i> , var. <i>conica</i>	-	-	-	-	x	x
<i>A. vulgaris</i> , var. <i>gibba</i>	-	x	-	-	x	-
<i>A. vulgaris</i> , var. <i>ovata</i>	-	-	x	x	x	x
<i>A. vulgaris</i> , var. <i>conoidea</i>	-	-	-	-	x	x
<i>Galerites albogalerus</i> , Leske	-	x	-	x	-	x
<i>G. Roemeri</i> (= <i>abbreviatus</i> , Desor)	-	-	-	-	-	x
<i>Offaster pilula</i> , Lam.	-	-	-	-	x	-
<i>O. corculum</i> , Goldf.	-	-	-	-	-	x
<i>Cardiaster granulosis</i> , Goldf.	-	-	-	x	x	x
<i>C. jugatus</i> , Schlüter	-	-	x	-	-	-
<i>C. Heberti</i> , Cott. (= <i>maximus</i> , Schlüter)	-	-	-	-	x	x
<i>Hemiaster ligeriensis</i> , d'Orb.	-	-	-	x	-	-
<i>H. rechlinghausensis</i> , Schlüter	-	-	x	-	-	-
<i>Pygurus rostratus</i> , Röm.	-	-	x	-	-	-
<i>Marsupites testudinaris</i> , Schloth.	-	-	x	-	-	-
<i>Uintacrinus westfalicus</i> , Schlüter	-	-	x	-	-	-
<i>Bourgetiacrinus ellipticus</i> , Müll.	-	-	x	x	x	-

From this table it will be seen that there are two different Echinoderm faunas in Germany, just as there are two different Cephalopodan faunas, only two species passing from the lower three to the two highest zones. There is not, however, such a clearly marked line of separation; the fauna of the *S. binodosus* zone seems from the tabulated species to be linked as closely with the higher as with the lower zones, for it contains sixteen species, of which number ten appear to be restricted to the zone and three range both up and down, while one passes downward only and two range upward. This result, however, is deceptive, because the Emscher is so poor in Echinoderms that only six species have been recorded from it, and only eight have been found in the *Marsupites* zone. If these zones were as productive in Germany as they are in England and France it

is probable that the number of species ranging from them to the equivalent of the *Offaster pilula* zone would be very much larger.

In the Franco-Belgian region a much greater number of Echinoderms has been obtained from the corresponding series of beds. The following table has been compiled chiefly from the separate lists given by M. de Grossouvre in the work already mentioned, but the Belgian species have been corrected in accordance with Mr. Lambert's recent revision of them, as published in the Mém. Mus. Roy. Belg. for 1911. I have not, however, included all his new species. The Belgian occurrences are indicated by the letter B., and those in France by the letter F.; these latter include the records from Touraine and the Cotentin as well as the Paris Basin:—

TABLE V.

ECHINODERMATA OF THE UPPER CHALK IN THE NORTH OF FRANCE AND BELGIUM.

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M.</i> <i>coranginum</i> .	Zone of <i>Marsipites</i> .	Zone of <i>O. pilula</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Cidaris hirudo</i> , Sorig	x	x	x	x	x	x
<i>C. subhirudo</i> , Cott.	-	-	-	-	x	x
<i>C. pseudohirudo</i> , Cott.	-	-	-	-	-	x B.
<i>C. sceptrafera</i> , Mant.	x	x	x	x	x	x
<i>C. clavigera</i> , Koenig	x	x	x	-	x	x
<i>C. Merceyi</i> , Cott.	x	-	-	-	-	-
<i>C. perlata</i> , Sorig	x	-	-	-	-	-
<i>C. perornata</i> , Forbes	x	x	-	-	-	-
<i>C. subvesiculosa</i> , d'Orb.	x	x	-	-	-	-
<i>C. serrifera</i> , Forbes	x	-	-	-	-	-
<i>C. serrata</i> , Desor	-	-	-	x	x	x B.
<i>C. turonensis</i> , Gauthier	-	x	x	-	-	-
<i>C. Faujasi</i> , Desor	-	-	-	-	-	x B.
<i>C. Hardouini</i> , Desor	-	-	-	-	-	B.
<i>C. lingualis</i> , Desor (<i>Porocidaris</i>)	-	-	-	-	-	B.
<i>Cyphosoma radiatum</i> , Sorig	x	x	-	x	x	x B.
<i>C. granulatum</i> , Goldf.	-	x	-	-	-	x
<i>C. corollare</i> , Agas.	-	x	-	-	-	B.
<i>C. magnificum</i> , Cott.	-	x	x	-	-	-
<i>C. Koenigi</i> , Mant.	-	x	x	x	B.	-
<i>C. Delaunayi</i> , Cott.	-	-	x	-	-	-
<i>C. Corneti</i> , Cott.	-	-	-	-	-	B.
<i>C. elongatum</i> , Cott.	-	-	-	x	x	x
<i>C. remus</i> , Cott.	-	x	-	-	-	-
<i>C. spathuliferum</i> , Forbes	-	-	-	-	-	B.
<i>Salenia incrustata</i> , Cott.	-	x	-	x	x	-
<i>S. Bourgeoisii</i> , Cott.	-	x	x	-	-	-
<i>S. geometrica</i> , Ag.	-	x	x	-	-	-
<i>S. anthophora</i> , Müller	-	-	-	B.	B.	-
<i>S. Janeti</i> , Cott.	-	-	-	-	-	x
<i>S. Bonissentii</i> , Cott.	-	-	-	-	-	x
<i>S. Heberti</i> , Cott.	-	-	-	-	x	-
<i>S. maestrichtensis</i> , Schlüter	-	-	-	-	-	x B.
<i>Peltastes heliophorus</i> , Cott.	-	-	-	-	-	x B.

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M. coranguinum</i> .	Zone of <i>Macrugites</i> .	Zone of <i>O. pilula</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. maucronata</i> .
<i>Pyrina Bourgeoisii</i> , Cott.	-	-	x	-	-	-
<i>P. ovulum</i> , Lam.	-	-	x	-	-	-
<i>Nucleolites analis</i> , Ag.	-	-	-	-	-	F., B.
<i>N. minimus</i> , Ag.	-	-	x	-	-	-
<i>N. coravium</i> , Ag.	-	-	-	-	-	F., B.
<i>Echinobrissus Guillièri</i> , Cott.	x	-	-	-	-	B.
<i>Catopygus elongatus</i> , Desor.	-	-	x	-	-	B.
<i>C. fenestratus</i> , Ag.	-	-	-	-	B.	B.
<i>Oolopygus Orbignyï</i> , Cott.	-	-	-	-	-	x
<i>O. pyriformis</i> , Ag.	-	-	-	-	B.	B.
<i>Trematopygus oblongus</i> , Desor.	-	-	x	-	-	-
<i>Hemiaster nasutulus</i> , Sorig.	x	-	-	-	-	-
<i>H. nucleus</i> , Desor.	x	-	-	-	-	-
<i>H. ligeriensis</i> , d'Orb.	-	-	x	-	-	-
<i>H. angustipneustes</i> , Desor.	-	x	x	-	-	-
<i>H. prunella</i> , Lam.	-	-	-	-	-	F., B.
<i>H. Neustria</i> , Desor.	-	-	-	-	-	F.
<i>Linthia spiennesensis</i> , Schlüter	-	-	-	-	-	B.
<i>Cassidulus lapiscaneri</i> , Lam.	-	-	-	-	-	F., B.
<i>C. elongatus</i> , d'Orb.	-	-	-	-	-	B.
<i>C. Peroni</i> , Gautier.	x	-	-	-	-	-
<i>Chlypeolampas ovum</i> , Ag.	-	-	-	-	-	B.
<i>Heteropneustes tenuiporus</i> , Cott.	-	-	x	-	-	-
<i>Caratomus avellana</i> , Dubois	-	-	-	-	-	F., B.
<i>C. ocellatus</i> , Cott.	-	-	-	-	-	B.
<i>C. hemisphericus</i>	-	-	-	-	-	B.
<i>C. peltiformis</i> , Wahl.	-	-	-	-	-	B.
<i>C. sulcatoradiatus</i> , Desor.	-	-	-	-	B.	B.
<i>Hemipneustes ocellatus</i> , Cott.	-	-	-	-	-	B.
<i>H. striatoradiatus</i> , d'Orb.	-	-	-	-	-	B.
<i>Rhynchopygus Marmini</i> , d'Orb.	-	-	-	-	-	F., B.
<i>Faujasia Faujasi</i> , d'Orb.	-	-	-	-	-	B.
<i>F. Delaunayi</i> , d'Orb.	-	x	-	-	-	-
<i>Peroniaster Cotteaui</i> , Gauthier	-	-	-	-	x	-
<i>Cardiaster granulatus</i> , Goldf.	x	x	-	x	B.	F., B.
<i>C. Heberti</i> , Cott. (= <i>maximus</i> , Schl.)	-	-	-	-	-	F., B.
<i>Plesiaster bucardium</i> , Goldf.	-	-	-	-	-	B.
<i>Galerites albogalerus</i> , Klein.	-	x	x	x	x	-
<i>G. circularis</i> , Buc.	-	x	x	-	-	-
<i>G. sulcatoradiatus</i> , Goldf.	-	-	-	-	-	B.
<i>Echinocorys scutatus</i> , var. <i>gibba</i>	x	x	-	-	-	B.
<i>E. scutatus</i> , var. <i>striata</i>	-	x	x	x	x	x B.
<i>E. scutatus</i> , var. <i>conica</i>	-	x	x	x	x	x B.
<i>E. scutatus</i> , var. <i>meudonensis</i>	-	-	-	-	-	x B.
<i>E. orbis</i> , Arnaud	-	-	-	-	-	x B.
<i>Holaster placenta</i> , Ag.	x	-	-	-	-	-
<i>Offaster pilula</i> , Lam.	-	-	x	x	x	x B.
<i>O. Gauthieri</i> , Lamb.	-	-	-	-	-	x
<i>Orthopsis miliaris</i> , d'Arch.	-	-	x	-	-	-
<i>Holactypus turonensis</i> , Desor	-	-	x	-	-	-
<i>Epiaster brevis</i> , Schlüter	x	-	-	-	-	-
<i>E. gibbus</i> , Schlüter	-	x	x	-	-	-
<i>Micraster decipiens</i> , Bayle	x	-	-	-	-	-

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M.</i> <i>coranguinum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. pitata</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Micraster turonensis</i> , Bayle	-	x	-	-	-	-
<i>M. senonensis</i> , Lamb.	x	x	-	-	-	-
<i>M. senonensis</i> , var. <i>belgica</i> , Lamb.	-	-	-	B.	-	-
<i>M. icauensis</i> , Lamb.	x	-	-	-	-	-
<i>M. Cayeuxi</i> , Parent	x	x	-	-	-	-
<i>M. coranguinum</i> , Leske	-	x	x	B.	B.	-
<i>M. gibbus</i> , Lam., var. <i>fastigatus</i>	-	-	-	x	-	-
<i>M. gibbus</i> , Lam., var. <i>Stolleyi</i>	-	-	-	-	B.	B.
<i>M. Brongniarti</i> , Hébert	-	-	-	-	-	F., B.
<i>M. Schroderi</i> , Stolley	-	-	-	-	x B.	F., B.
<i>M. regularis</i> , Arnaud	-	-	-	-	x	F.
<i>M. cipliensis</i> , Schlüter	-	-	-	-	-	B.
<i>Leucaster remensis</i> , Gauthier	-	-	-	-	x	-
<i>Marsupites testudinarius</i> , Schloth.	-	-	x	-	-	-
<i>Uintacrinus westfalicus</i> , Schlüter	-	-	x	-	-	-
<i>Bourgetocrinus ellipticus</i> ; Müll.	x	x	x	x	x	-

In considering this table, if in the first place we leave the *Offaster* zone out of account we find that the three lower zones have yielded forty-eight species and that the two higher zones contain no fewer than fifty-six species. Of this large number only ten species and varieties are common to the two assemblages, which are thus very different, though, as might be expected, they are not so entirely distinct as those of the more highly organized Cephalopoda.

The line of division between the two stages is not, however, so clearly indicated by the Echinoderms, for the fauna of the *Offaster* zone seems to form a complete passage from the one to the other. This zone has yielded fifteen species, of which ten range both up and down, one ranges downward only, three range up but not down, and one is restricted to the zone. The fact is that the tabulated number of occurrences is hardly sufficient to give a reliable result, and we can only infer that the zone might be placed in either stage.

In passing to the South of France we come to a different area of deposition, inhabited by an assemblage of Echinoderms which differed considerably from that of the Anglo-Parisian basin. Some of the northern species do occur in it, but there are a large number of others. From the lists given by M. de Grossouvre, in the work already mentioned, I have compiled a table of the distribution of species in the Aquitanian and Pyrenean areas, in order to ascertain what evidence they afford. This list includes no fewer than one hundred species, and yet is probably not quite complete; the greater number (sixty-three species) occur in the two higher zones and only ten of these range down into the three lower zones. The equivalent of the *Offaster* zone has yielded twenty-four species, and of these ten range both upward and downward, three range down only, and six pass up, while five are restricted. Here again, therefore, the existence of two different faunas and consequently of two distinct

stages is very apparent, but there is a transition from one Echinoderm fauna to the other, and the zone might be placed in either stage.

Lastly, Table VI shows the distribution of the Echinoids and Crinoids through the same zones in England, and in compiling this I have received special assistance from Mr. A. W. Rowe, who has kindly sent me notes regarding the identification and range of all the species, so that this list is more correct than any that has previously been published.

In comparing this with the preceding lists it will be noticed that the number of species is less and that the proportion of them which ranges from the lower to the higher zones is greater. Both these peculiarities are doubtless owing to the fact that in England there is little variation in the lithological character of the Upper Chalk, the whole of it being a deep-water facies of the formation deposited under conditions which did not change greatly from beginning to end. There was, therefore, no sudden or rapid extinction of species, only the increasing rarity of some and the occasional introduction of new forms.

In spite of these conditions there are many species which do not range from the lower to the higher zones. The total number of species and varieties enumerated is fifty-one, and of these forty-four occur in the lower four zones and twenty-five in the two higher zones, nineteen species being common to the two assemblages. This is less than half of the larger fauna, so that there is still a considerable difference between them. The zone of *O. pilula* has yielded twenty-seven species, of which seventeen range both up and down, only two have an exclusively upward range, while eight do not range higher; it is therefore more closely connected with the lower than the higher zones.

TABLE VI.
ECHINODERMS IN ENGLAND.

SPECIES.	Zone of <i>M. coriostellaterrami.</i>	Zone of <i>M. coranquinum.</i>	Zone of <i>Marsupites.</i>	Zone of <i>O. pilula</i> and <i>A. granulatus.</i>	Zone of <i>A. quadratus.</i>	Zone of <i>B. mucronata.</i>
<i>Cidaris hirudo</i> , Sorig	x	x	x	x	x	x
<i>C. sceptrifera</i> , Mant.	x	x	x	x	-	-
<i>C. clavigera</i> , Koenig	x	x	x	-	-	-
<i>C. perornata</i> , Forbes	x	x	x	x	-	-
<i>C. subvesiculosa</i> , d'Orb.	x	x	x	x	x	x
<i>C. Merceyi</i> , Cotteau	x	x	-	-	-	-
<i>C. serrifera</i> , Forbes	x	x	-	-	-	-
<i>C. serrata</i> , Desor	-	-	-	-	-	x
<i>C. pleracantha</i> , Ag.	-	x	-	x	x	x
<i>Cyphosoma Koenigi</i> , Mant.	x	x	x	x	-	x
<i>C. corollare</i> , Ag.	-	x	x	x	x	x
<i>C. granulolum</i> , Goldf.	x	-	-	-	-	-
<i>C. magnificum</i> , Cott.	-	-	-	x	x	x
<i>C. elongatum</i> , Cott.	-	-	x	-	-	-
<i>C. radiatum</i> , Sorig	x	x	x ?	-	-	-
<i>C. spatuliferum</i> , Forbes	x	x	x	x	-	-

SPECIES.	Zone of <i>M. cortestudinarium</i> .	Zone of <i>M. coranguinum</i>	Zone of <i>Marsupites</i> .	Zone of <i>O. pilula</i> and <i>A. granulosus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Salenia granulosa</i> , Forbes	x	x	x	x	x	x
<i>S. geometrica</i> , Ag.	-	-	x	x	x	x
<i>S. magnifica</i> , Wright	-	-	-	-	x	x
<i>Zeuglopleurus Rowei</i> , Gregory	-	-	x	-	-	-
<i>Helicodiadema fragile</i> , Wilt.	-	x	x	x	x	x
<i>Echinocorys scutatus</i> , Leske (<i>ovata</i>)	-	x	x	x	x	x
<i>E. scutatus</i> , a gibbous form	-	-	x	x	-	-
<i>E. scutatus</i> , var. <i>gibba</i> , Lam.	x	-	-	-	x	-
<i>E. scutatus</i> , var. <i>depressa</i> , Bryd.	-	x	x	x	-	-
<i>E. scutatus</i> , var. <i>pyramidata</i> , Bryd.	-	-	x	x	-	-
<i>E. scutatus</i> , var. <i>subconica</i> , Bryd.	-	-	-	-	-	x
<i>Galerites albogalerus</i> , Leske	x	x	x	x	-	x
<i>G. albogalerus</i> , var. <i>globulus</i> , Desor	-	x	x	-	-	-
<i>Cardiaster ananchytis</i> , Goldf.	-	x	x	x	-	x
<i>C. Cotteanus</i> , Schlüter	x	-	-	-	-	-
<i>Offaster pilula</i> , Lam. (type)	-	-	x	x	x	x
<i>O. pilula</i> (dwarf var.)	-	-	-	-	x	x
<i>Holaster planus</i> , Mant.	x	-	-	-	-	-
<i>H. placenta</i> , Ag.	x	x	x	x	-	-
<i>Micraster cortestudinarium</i> , Goldf.	x	-	-	-	-	-
<i>M. præcursor</i> , Rowe	x	x	-	-	-	-
<i>M. coranguinum</i> , Leske	-	x	x	x	x	-
<i>M. glyphus</i> , Cott.	-	-	-	-	x	x
<i>Epiaster gibbus</i> , Lam.	x	x	x	-	-	x
<i>Infulaster excentricus</i> , Bosc.	x	x	x	-	-	-
<i>I. rostratus</i> , Forbes	-	x	x	x	x	-
<i>Hemiaster minimus</i> , Ag.	x	x	x	x	x	x
<i>Marsupites testudinarium</i> , Schloth.	-	-	x	-	-	-
<i>Untacrinus westfalicus</i> , Schlüter	-	-	x	-	-	-
<i>Pentacrinus Bronni</i> , Hagenow	-	-	-	-	-	x
<i>P. Agassizi</i> , Hagenow	x	-	-	-	-	-
<i>Isocrinus Kloedeni</i> , Hagenow	-	x	x	x	-	-
<i>Bourgetocrinus ellipticus</i> , Müller	x	x	x	x	x	-
<i>Ophiura serrata</i> , Römer	-	x	x	x	-	-
<i>Roveacrinus communis</i> , Douglas	x	x	x	x	-	x

Another group of fossils which furnishes useful evidence of the distinctness of the two faunas is the genus *Inoceramus*. This was studied by Schlüter in Germany in 1876,¹ and a tabular view of this zonal distribution in that country is given at the end of his monograph. Recently the genus has been more thoroughly investigated, so far as the British species are concerned, by Mr. H. Woods, whose excellent monograph will henceforward be the chief book of reference for the European species generally.

The species which occur in France, Germany, and other countries now require re-examination in the light of Mr. Woods' researches and studies of the various type-specimens, but by the aid of some notes on foreign forms in Mr. Woods' monograph, I have been able to compile a list of those which occur in the Paris Basin.

¹ *Palæontographica*, Bd. xxiv, 1876-7.

The following tables, showing the zonal distribution of the species of *Inocerami*, have thus been prepared from the sources above mentioned, that for North Germany being taken from Schlüter, with some corrections and modifications:—

TABLE VII.
INOCERAMI IN THE UPPER CHALK OF ENGLAND.

SPECIES.	Zone of <i>M. corstianum</i> .	Zone of <i>M. coranginum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. plicata</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. micronata</i> .
<i>Inoceramus Lamarcki</i> , Park. (type) (= <i>I. Brongniarti</i> , Mant.)	x	x	-	-	-	-
<i>I. Lamarcki</i> , var. <i>Cuvieri</i> , Sow.	x	x	-	-	-	-
<i>I. Lamarcki</i> , var. <i>Websteri</i> , Mant.	x	-	-	-	-	-
<i>I. Lamarcki</i> , var. <i>undulatus</i> , Mant.	x	-	-	-	-	-
<i>I. cordiformis</i> , Sow.	x	x	x	-	-	-
<i>I. involutus</i> , Sow.	x	x	-	-	-	-
<i>I. inconstans</i> , Woods	x	x	x	x	x	x
<i>I. inconstans</i> , var. <i>striatus</i> , Mant.	?	x	-	-	-	-
<i>I. inconstans</i> , var. <i>sarumensis</i> , Woods	-	-	-	-	-	-
<i>I. digitatus</i> , Sow.	-	x	-	-	-	-
<i>I. undulato-plicatus</i> , Römer	-	x	-	-	-	-
<i>I. undulato-plicatus</i> , var. <i>digitatus</i> , Sch.	-	x	-	x	-	-
<i>I. cardissoides</i> , Goldf.	-	-	?	x	-	-
<i>I. subcardissoides</i> , Schlüter	-	?	-	-	-	-
<i>I. pinniformis</i> , Will.	-	-	-	x	-	-
<i>I. balticus</i> , Bohm	-	-	x	x	x	x
<i>I. lingua</i> , Goldf.	-	-	x	x	?	x
<i>I. lobatus</i> , Goldf.	-	-	x	x	-	-
<i>I. tuberculatus</i> , Woods	-	-	-	x	-	-

TABLE VIII.
INOCERAMI IN THE UPPER CHALK OF NORTH GERMANY.

SPECIES.	<i>Cuvieri</i> zone.	The <i>Enschel.</i>	Zone of <i>Marsupites</i> .	Zone of <i>S. benodosus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. micronata</i> .
<i>Inoceramus Lamarcki</i> , Park. (= <i>Brongniarti</i> , Schlüter, etc.)	x	-	-	-	-	-
<i>I. Lamarcki</i> , var. <i>Cuvieri</i> , Sow.	x	x	-	-	-	-
<i>I. involutus</i> , Sow.	-	x	-	-	-	-
<i>I. involutus</i> , var. <i>exogyroides</i> , Meek	-	x	-	-	-	-
<i>I. involutus</i> , var. <i>umbonatus</i> , Meek	-	x	-	-	-	-
<i>I. digitatus</i> , Sow.	-	x	-	-	-	-
<i>I. subcardissoides</i> , Schlüter	-	x	-	-	-	-
<i>I. unduloplicatus</i> , Schlüter	-	x	-	-	-	-
<i>I. radians</i> , Schlüter	-	x	-	-	-	-
<i>I. subquadratus</i> , Schlüter	-	x	-	-	-	-
<i>I. gibbosus</i> , Schlüter	-	x	-	-	-	-
<i>I. cardissoides</i> , Goldf.	-	?	x	-	-	-
<i>I. cancellatus</i> , Goldf.	-	-	x	x	-	-
<i>I. balticus</i> , Bohm (= <i>Crippsi</i> , auct.)	-	-	x	x	x	x
<i>I. lingua</i> , Goldf.	-	-	x	x	-	-
<i>I. lobatus</i> , Goldf.	-	-	x	x	-	-

TABLE IX.
INOCERAMI IN THE UPPER CHALK OF THE PARIS BASIN.

SPECIES.	Zone of <i>M. decipiens</i> .	Zone of <i>M.</i> <i>coranginum</i> .	Zone of <i>Marsupites</i> .	Zone of <i>O. pilula</i> and <i>A. granulatus</i> .	Zone of <i>A. quadratus</i> .	Zone of <i>B. mucronata</i> .
<i>Inoceramus Lamarcki</i> , Park. (type)	x	x	-	-	-	-
<i>I. Lamarcki</i> , var. <i>Cuvieri</i> , Sow.	x	x	-	-	-	-
<i>I. Lamarcki</i> , var. <i>Mantelli</i> , de Mercey	x	x	-	-	-	-
<i>I. Lamarcki</i> , var. <i>undulatus</i> , Sow.	x	-	-	-	-	-
<i>I. inconstans</i> , Woods (= <i>Brongniartii</i>).	x	-	-	-	-	-
<i>I. involutus</i> , Sow.	x	x	-	-	-	-
<i>I. digitatus</i> , Sow.	-	x	-	-	-	-
<i>I. lezennensis</i> , Decocq	-	x	-	-	-	-
<i>I. inaequalis</i> , Schlüter	x	-	-	-	-	-
<i>I. unduloplicatus</i> , Röm.	-	x	-	-	-	-
<i>I. subcardissoides</i> , Schlüter	-	x	-	-	-	-
<i>I. balticus</i> (= <i>Crippsi</i> , auct.)	-	-	-	-	x	x
<i>I. lingua</i> , Goldf.	-	-	?	-	-	-

From these lists it will be seen that the English list is the most complete, and that the evidence of the *Inocerami* accords entirely with that of the Cephalopoda. The zone of *Offaster pilula* in England has yielded nine species, of which five, and probably six, range downward, while only three of them range upward. In Germany the same zone has yielded four species, all of which range down into the *Marsupites* zone and only one (*balticus*) passes up into the higher zones.

INFERENCES.

Reviewing the results which have been obtained from the tabulated distribution of Cephalopoda, Echinoderms, and *Inocerami* in the Upper Chalk, we arrive at the following conclusions:—

1. That the Upper Chalk, with its equivalent in France and Germany, contains two distinct assemblages or faunas, and consequently that it comprises two stages as distinct from one another as are the Albian, Cenomanian, and Turonian.

2. That the evidence of the Cephalopoda fixes the line of division between the zones of *Offaster pilula* and *Actinocamax quadratus*.

3. That the distribution of *Inocerami* in all three countries leads to the same conclusion as that of the Cephalopoda.

4. That the evidence of the Echinoderms is less definite, because the assemblage found in the *O. pilula* zone is everywhere a passage fauna with many species that range both up and down.

The exact position of the boundary-plane between the two stages is of course a mere matter of detail. The important point, which is so obvious from an inspection of the preceding tables, is the recognition of the fact that our Upper Chalk is not a single stage comparable with the Middle Chalk or Turonian, but comprises two such stages for which names must be adopted.

With regard to the plane of division between them, the weight of evidence indicates that it should be drawn at the top of the zone of *Offaster pilula* and *Scaphites binodosus*. This line seems to be clear enough in Germany, but has not yet been accurately determined in England or France.

NOMENCLATURE.

Having demonstrated the existence of two different faunas, and consequently of two different stages, in what we have hitherto been accustomed to call the Upper Chalk, it becomes necessary to consider by what names they should be called. The old-fashioned names Lower Middle and Upper Chalk may still be used for divisions which can be shown on geological maps, because they have usually well-marked lithological boundaries, but we cannot continue to employ them as stage-names, since the Chalk is really divisible into four stages, not three as was formerly supposed.

There can be little doubt that we must adopt the French method of nomenclature, and it will also be convenient to employ the actual French names for these stages as far as possible, because these names are in general use on the Continent. Unfortunately, however, the French geologists are not yet agreed on the question of simplifying their nomenclature and making it accord with the stratigraphical value of their divisions.

The French terminology originated with d'Orbigny in 1843, and at first he only recognized two divisions or stages in the Chalk, giving these the names of *Turonien* and *Sénonien*. Subsequently he became aware that his *Turonien* included two distinct faunas and also that there was another fauna above his *Sénonien* in Denmark. Consequently in 1852 he established four stages under the names of *Cénomancien*, *Turonien*, *Sénonien*, and *Danien*. These names have been in use ever since that date, and the definitions of them given by d'Orbigny in his *Géologie Stratigraphique* of 1852 show that the first three correspond very closely with our Lower, Middle, and Upper Chalk.

As time went on, however, French geologists found that the *Senonian* was divisible into two or more parts, which they regarded as stages or sub-stages. Thus the *Senonian* of the Paris Basin was divided by Lambert in 1876 into Lower and Upper divisions, while that of Aquitaine was divided by Coquand into four parts, to which he gave the names of *Coniacien*, *Santonien*, *Campanien*, and *Dordorien*.¹

In 1879 de Mercey pointed out that there were really only two separate stages in the *Senonian* of d'Orbigny, but that these ought to be recognized and that one of them should receive a new name while *Senonian* was retained for the other; just as d'Orbigny himself had given a new name to part of his original *Turonien*, but retained that name for a restricted *Turonian*. De Mercey advocated the retention of the name *Senonian* for the upper part and the adoption of Coquand's name *Santonian* for the lower part.²

The correlation of the successive zones was not, however, fully established in 1879. Coquand's stages were really sub-stages, but they

¹ Coquand, Bull. Soc. géol. France, ser. II, t. xiv, p. 746, 1857.

² Bull. Soc. géol. France, ser. III, t. vii, p. 355, 1879.

were definite stratigraphical units, and de Mercey was wrong in supposing that the *Coniacien* had no separate existence. The *Santonien* was not therefore the equivalent of the whole "Sénonien Inférieur" as he supposed. Moreover, French geologists were so accustomed to the use of the name Senonian in its wider and more comprehensive application that the idea of its restriction to a portion of the original stage did not commend itself to them. Hence a complicated system of stages and sub-stages was adopted, which included an unnecessary number of names and could not possibly be used with advantage in any other country. The following table shows the divisions recognized by de Grossouvre in 1901:—¹

STAGES.	SUB-STAGES.	ASSISES.
DANIEN		
SÉNONIEN	{ Campanien	{ Supérieur.
	{ Corbiérien	{ Inférieur.
		{ Santonien.
		{ Coniacien.
TURONIEN	{ Angoumien	
	{ Saumurien	
CÉNOMANIAN . .	(not divided).	

It is obvious that this scheme is illogical; the Corbiérien and Campanien have the same palæontological and stratigraphical value as the Turonian, and consequently the retention of a comprehensive Senonian can only produce confusion and misapprehension. This seems to have been perceived by de Lapparent, for in the latest edition of his *Traité de Géologie* he remarks (p. 1883) that "The old Sénonien of d'Orbigny really includes two very distinct faunas of Cephalopoda, *Mortoniceras* and *Placenticeras* prevailing in the one which is the fauna of the Emscher marls of Westphalia. The other fauna, in which *Pachydiscus* and *Baculites* are conspicuous, is that of the Chalk of Haldem and Lemberg and of the beds near Tercis. The beds which contain it form the Aturien stage, from the Adour on the banks of which this division is well developed".

De Lapparent therefore divides his Upper Cretaceous Series into six stages, for which he adopts the names Cénomanién, Turonien, Emschérien, Aturien, Danién, and Montien, thus excluding the Albién and including the Montien, which others regard as the base of the Eocene Series. The stages with which we are concerned he subdivides in the following manner:—

STAGES.	SUB-STAGES.	ZONES.
ATURIEN	{ Maestrichtien	Calcaire à <i>Baculites</i> .
	{ Campanien	{ Craie de Meudon.
		{ Craie de Reims.
EMSCHÉRIEN	{ Santonien	{ Craie à <i>Marsupites</i> .
	{ Coniacien	{ Craie à <i>M. coranguinum</i> .
		Craie à <i>N. cortestudinarium</i> .

From this it is evident that de Lapparent wished to abandon the term Senonian altogether instead of adopting the view advocated by

¹ "Recherches sur la Craie Supérieur": Mém. Carte Dét. de la France, fasc. ii, table after p. 700.

de Mercey; further, that he proposed two new stage-names when he might have adopted those used by de Grossouvre. On the other hand, it seems to me that de Mercey was right in principle and that he was quite justified in saying—"L'équité scientifique exige que les dénominations des étages de d'Orbigny subsistent dans la nomenclature, quels que soient les changements apportés dans la délimitation des étages, ou bien les démembrements opérés à leur dépens."

I am therefore strongly of opinion that the name Senonian should be used for one of these stages, and the only question is to which of them should it be applied. The name is taken from the tribe of the Senones who inhabited the country round Sens, and so far as this typical area is concerned it might be used equally well for either division, since the beds of the Lower Senonian crop out to the south-east of Sens and those of the Upper Senonian to the north-west.

We need therefore only consider to which stage the name can be most usefully and conveniently applied. Now de Grossouvre has shown that the 'Maestrichtien' is not a sub-stage, but only a part of the zone of *Pachydiscus neubergicus*, which is elsewhere included in the Campanian; in the same way its equivalent in Aquitaine (the Dordonien) is shown to be merely part of the Campanian.¹ Consequently he adopts the name *Campanian* (derived from the 'champagne' of the Charentes) to denominate the stage for which de Lapparent introduces the new name of *Aturian*. Campanian has the priority, and is now generally recognized by French geologists as a good name for this division of the Upper Chalk. There is, therefore, no need for *Aturian*, which should be dropped as a synonym.

On the other hand, all the names proposed for the 'Sénonien Inférieur' are open to objection. The application of Santonian to the whole stage is untenable, because the real and original Santonian was only a part of it, and Coquand was right in so regarding it. The name *Corbiérien* has not found favour in France because it is taken from a locality, Corbières in the Pyrenees, where the beds differ from those of the Anglo-Parisian Basin, both in their fauna and their lithological characters. '*Emschérien*' is open to the same objection, the Emscher marls being a local facies and their fauna a poor one, especially in Echinoderms, so that they do not form a suitable exemplar or type for reference.

These considerations make it clear that if the name Senonian is to be used at all it should be applied to the lower part of d'Orbigny's division, that of Campanian being adopted for the higher one. Further, there is not the slightest occasion for the use of sub-stages; a primary division of the series into stages and a subdivision of these stages into zones is all that is necessary, any kind of intermediate term is both cumbersome and useless.

In its complete development the Chalk of Northern Europe appears to be divisible into five stages, though the Danian is of smaller

¹ In both districts, however, it forms the highest portion of his zone of *P. neubergicus*, and is characterized by the presence of *Sphenodiscus Ubaghsi* and a special set of Echinoderms, so that it seems to be separable as a distinct zone.

thickness and altogether of smaller importance than the rest. The following table sets forth the names which I would adopt for these stages, and the zones which they comprise :—

STAGES.	ZONES.
DANIAN	<i>Nautilus danicus.</i>
CAMPANIAN	{ <i>Belemnitella mucronata.</i> <i>Actinocamax quadratus.</i> <i>Offaster pihula.</i> <i>Marsupites.</i>
SENONIAN	{ <i>Micraster coranguinum.</i> <i>M. decipiens.</i> <i>Holaster planus.</i>
TURONIAN	{ <i>Terebratulina lata.</i> <i>Rhynchonella Cuvieri.</i>
CENOMANIAN	{ <i>Holaster subglobosus.</i> <i>Schloenbachia varians.</i>