Ammonite Zonal Stratigraphy in the Albian of North Germany and its Setting in the Hoplitinid Faunal Province

Zonale Ammoniten-Stratigraphie im Alb N-Deutschlands und ihre Bedeutung für die Hopliten-Faunenprovinz

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with 5 text-figures and 1 table

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Abstract: Ammonites although common in the Lower Albian, *Leymeriella tardefurcata* Zone clays of north Germany, are of very scattered occurrence throughout the remaining Lower, Middle and Upper Albian sediments. A review of the ammonite occurrences known to the author is given and it is apparent that all the Zones and many of the Subzones of the Albian of the European, or hoplitinid, faunal province are represented in northern Germany. The ammonites indicate that the more marginal Flammenmergel facies, previously thought to be almost entirely of Upper Albian age, has a diachronous base which extends well back into the Middle Albian southward in the region of the Harz and Rhenish massifs. In the central and northern parts of the depositional basin, now the north German plain, clays and marls were deposited throughout much of the Upper Albian.

A brief comparison is made between the north German Albian sequence and those of the Anglo-Paris basin and East Anglia. Germany is unique in western Europe in possessing a well developed, little condensed sequence in the basal part of the *Leymeriella tardefurcata* Zone, Subzone of *„Proleymeriella" schrammeni* and *Leymeriella acuticostata*. In England and northern France, *Leymeriella* does not appear in the sequence until the top of the *tardefurcata* Zone; in sediments of the Subzone of *Leymeriella regularis*. Earlier sediments in England contain *Hypacanthohoplites* similar to those found in the lower part of the *tardefurcata* Zone in Germany, but these are accompanied by the hoplitid genus *Farnhamia*, not known in Germany. *Leymeriella* of *acuticostata* Subzone age are known as far north as Spitzbergen and a possible palaeogeographic explanation of this minor provincialism is suggested.

The Middle and Upper Albian ammonites of Europe were much more cosmopolitan. Although the hoplitinid genera predominated in the Middle Albian, incursions from the Tethyan and southern provinces occurred from time to time. These southerly derived elements increase in number southward in the seaways linking the european shelf seas with the Tethys. In Germany, as elsewhere in Europe, the predominantly hoplitinid fauna of the Middle Albian gave way in the Upper Albian to a mixed ammonite fauna in which the endemic hoplitinids co-existed with such southerly derived elements as the keeled mortoniceratinids and the capricorn brancoceratids. A palaeogeographic explanation of these changes and the separation of the European shelf seas from those of the Canadian Arctic is attempted.

Kurzfassung: Obwohl Ammoniten im Unter-Alb – in den Tonen der *Leymeriella tardefurcata*-Zone N-Deutschlands – allgemein verbreitet sind, sind sie in den restlichen Unter-, Mittel- und Ober-Alb-Sedimenten nur vereinzelt zu finden. Ein Überblick über die dem Autor bekannten Ammoniten-Vorkommen wird gegeben. Es ist offensichtlich, daß alle Zonen und viele der Subzonen des europäischen Alb oder der Hopliten-Faunenprovinz in N-Deutschland vertreten sind. Die Ammoniten lassen erkennen, daß die marginale Flammenmergel-Fazies, von der man früher annahm, daß sie fast das gesamte Ober-Alb vertrete, eine diachrone Basis besitzt, die nach Süden (Harz und Rheinisches Massiv) bis ins Mittel-Alb hinabreicht. Im zentralen und nördlichen Teil des Sedimentationsbeckens, jetzt die Norddeutsche Tiefebene, wurden fast das ganze Ober-Alb hindurch Tone und Mergel abgelagert.

Ein kurzer Vergleich wird angestellt zwischen dem norddeutschen Alb, dem des Anglo-Pariser Beckens und dem von E-Anglia. Deutschland besitzt einmalig für W-Europa eine gut entwickelte, leicht kondensierte Folge im basalen Teil der *Leymeriella tardefurcata*-Zone, den *„Proleymeriella" schrammeni*- und *Leymeriella acuticostata*-Subzonen. In England und N-Frankreich erscheint *Leymeriella* erst am Top der *tardefurcata*-Zone, in Sedimenten der *Leymeriella regularis*-Subzone. In England enthalten jüngere Sedimente *Hypacanthohoplites*-Arten, die denen ähnlich sind, die in Deutschland im unteren Teil der *tardefurcata*-Zone gefunden werden; doch die englische Fauna enthält außerdem noch die Hoplitiden-Gattung *Farnhamia*, die in Deutschland nicht gefunden wird. Leymeriellen der *acuticostata*-Subzone sind nach Norden bis Spitzbergen bekannt. Eine paläogeographische Erklärung für diesen kleinen Provinzialismus wird gegeben.
Die Mittel- und Ober-Alb Ammoniten Europas waren stärker kosmopolitisch. Obwohl die Hopliten-Gattungen im Mittel-Alb vorherrschend waren, fanden von Zeit zu Zeit Vorstöße aus der Tethys und aus südlichen Faunenprovinzen statt und in entsprechenden Änderungen der Faunenvergesellschaftungen ihren Niederschlag. Diese südlichen Faunenelemente nehmen in den Verbindungswegen zwischen den N-europäischen Schelfmeeren und der Tethys nach Süden hin zahlenmäßig zu. In Deutschland, wie überall in Europa, ging die vorherrschende Hopliten-Fauna des Mittel-Alb im Ober-Alb zurück zugunsten einer gemischten Ammonitenfauna, in der die endemischen Hopliten zusammen mit südlichen Elementen (Mortoniceraten und capricorne Brancoceraten) vorkommen. Es wird versucht, eine paläogeographische Erklärung für diese Faunenverschiebung und die Trennung der europäischen Schelfmeere von denen der kanadischen Arktik zu finden.

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Preface

In 1972, the writer examined all the available ammonites from Albian sediments in north west Germany then known while a guest of Dr. E. Kemper of the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover. The material examined is contained in the collections of the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover-Buchholz, the Niedersächsisches Landesamt für Bodenforschung, Hannover, the Geologisch-Paläontologisches Institut der Universität Hamburg, the private collection of Herr Hans Jürgen Dirks, Hannover, and the British Museum (Natural History), London. This was supplemented by a brief examination of certain sections under the guidance of Dr. Kemper and Dr. G. Ernst then of the Technische Hochschule der Universität, Braunschweig. Subsequently, Dr. Kemper and Dr. K.-H. Georgi of the Deutsche Texaco A. G., Dr. K. Oekentorp and Dr. C. Frieg of the Geologisch-Paläontologischen Instituts und Museums, Universität Münster, have kindly sent on loan additional material for study. The review of the ammonite zonal stratigraphy given here stems from this work. I would like to thank my colleagues already mentioned above together with Dr. Fr. Schmid of the Niedersächsisches Landesamt für Bodenforschung and Dr. Chr. Spaeth of the Geologisch-Paläontologisches Institut der Universität Hamburg.

1. Introduction

Much of our more detailed knowledge of the stratigraphy of the Albian sediments of north Germany stems from the early work of geologists such as Ernst (1922, 1927), Althoff & Seitz (1934), Stolley (1937), Brinkmann (1937) and Seitz (1956). In the last ten years in particular much progress has been made with the detailed lithological descriptions of quarry, clay-pit and

borehole sequences together with their microfaunal, ammonite and belemnite faunas (e. g. Schott *et al.* 1967, 1969, Jordan 1968, Jordan & Schmid 1968, Kemper 1973, 1975, 1976, Spaeth 1971, 1973, Bertram & Kemper 1971, Kemper, Rawson, Schmid & Spaeth 1974, Speetzen, El Arnauti & Kaever 1974, Georgi 1976 and Price 1977a, b, among others). Although ammonites are common in the lower part of the Lower Albian sediments in north Germany, they are of scattered occurrence throughout the remaining Lower, Middle and Upper Albian sediments. However, at certain levels good collections have been made and the ammonites are there to be found.

Unfortunately, many of the ammonites collected before the second world war were destroyed, but others thought to have been lost have now been rediscovered and to these specimens can be added the product of post-war collecting. There is not sufficient space in this paper to give a comprehensive description of the material or stratigraphy in the detail it deserves and by so doing provide a revision of Stolley's (1937) account. Such a task is best attempted by workers in Germany who have easy access to the sections concerned. A locality map is given in Fig. 1 and the ammonite zonal scheme determined in the Albian European, or hoplitinid, faunal province is given in Table 1.

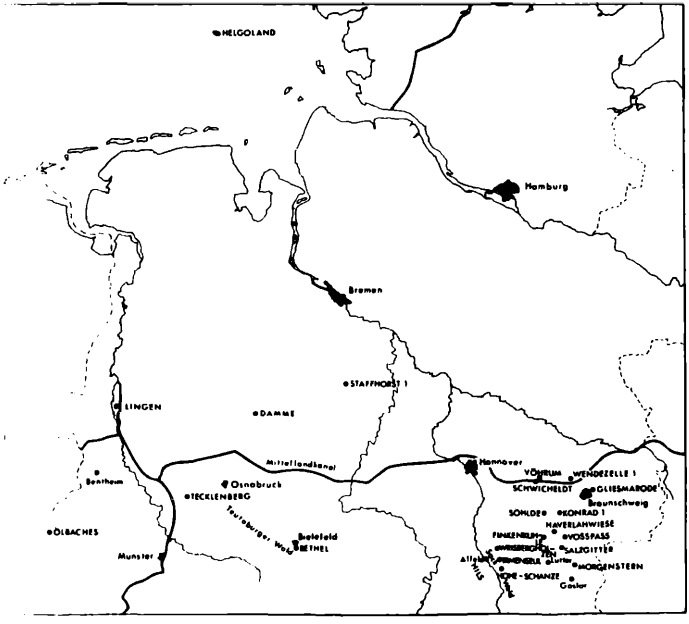


Fig. 1. Locality map of sections in northern Germany mentioned in the text.

2. Review of the ammonite Zonal stratigraphy in north Germany

2.1 *Lower Albian*

The uppermost Aptian and Lower Albian in the central part of the depositional basin, the Harz foreland region of the north German plain around Hannover and Braunschweig, are represented by thick grey clays with layers of septarian iron-stone nodules. These clays are well seen at outcrop and in borings in the Hannover-Salzgitter area and pass quickly southward into sandstones flanking the Harz and Rhenish positive areas such as the Hils, Osning, Dörenther and Rothenberg sandstones. Outside the central basin area, Lower Albian sediments are strongly condensed or are absent reflecting the presence of positive areas such as the Pompeckj Schwelle towards the Baltic (Fig. 2A).

Knowledge of the detailed ammonite sequence stems from the work of Stolley (1937) and in particular, Brinkmann (1937). The latter author demonstrated that in the area of the Mittellandkanal south-east of Hannover (Figs. 1 and 3), there is a continuous sequence from clays containing the ‚Clansayes 'auna' now classified with the *jacobi* Zone of the Upper Aptian up to an horizon near, but perhaps not at the top of the *tardefurcata* Zone. This early work has been well extended by Kemper (1975). The highest part of the *tardefurcata* Zone (Subzone of *Leymeriella regularis*) and the succeeding *mammillatum* Zone, although present, are imperfectly known (Table 1).

2.1.1 Zone of *Leymeriella tardefurcata*. The region to the east and south of Hannover is unique in providing a relatively complete sequence from clays characterised by species of *Hypacanthoplites* and the immediate ancestor of *Leymeriella-Callizoniceras (Wollemaniceras) keilhacki* (Wolleman) subspecies *anterior* Brinkmann, classified with the topmost part of the *jacobi* Zone (Upper Aptian), up into clays representing the *tardefurcata* Zone. Spath (e. g. 1941: 668) drew the base of the *tardefurcata* Zone at the appearance of *Leymeriella schrammeni*. This level is shown in the Mittellandkanal section near Schwicheldt (Brinkmann 1937) and in the neighbouring claypit section at Vörhum (Fig. 3), where Bed 6 (ii) contains *L. schrammeni anterior* Brinkmann and can be taken to mark the approximate base of the *tardefurcata* Zone sediments.

The sequence of species in the overlying clays and the development of the genus *Leymeriella* was demonstrated by Brinkmann (1937) and Casey (1957). Recently, Kemper (1975) has described part of the ammonite fauna including species of the associated genus *Hypacanthoplites* and has revized the Zonal scheme. In the writer's opinion, however, it seems unnecessary to introduce a distinct Zone of *Leymeriella schrammeni* at the base of the Albian (Kemper 1973, 1975) nor a distinct Zone of *L. regularis* at the top (Kemper 1973). The writer would agree with Kemper (1975) that there is little justification for the introduction of a Subgenus *Proleymeriella* (Breistroffer 1947). Although *Leymeriella* („*Proleymeriella*") *schrammeni* and *L. (L.) tardefurcata* might look distinct when in isolation, no logical subgeneric distinction could be made between the ancestral *L. schrammeni* and its descendant *L. tardefurcata* in the Hannover sequence.

The uppermost Subzone of the *tardefurcata* Zone characterized by *L. regularis* is not well known in north Germany and a diverse ammonite fauna comparable to that described by Casey (1957, 1960–) from largely condensed *regularis* Subzone sediments in England has not yet been recorded. However, in Schacht Konrad 1, north of Salzgitter (Fig. 1), there is an interval between clays of *mammillatum* Zone age at 428 m depth and clays of mid-*tardefurcata* Zone (*acuticostata* Subzone) age at 475 m depth from which no samples have been preserved. Part of

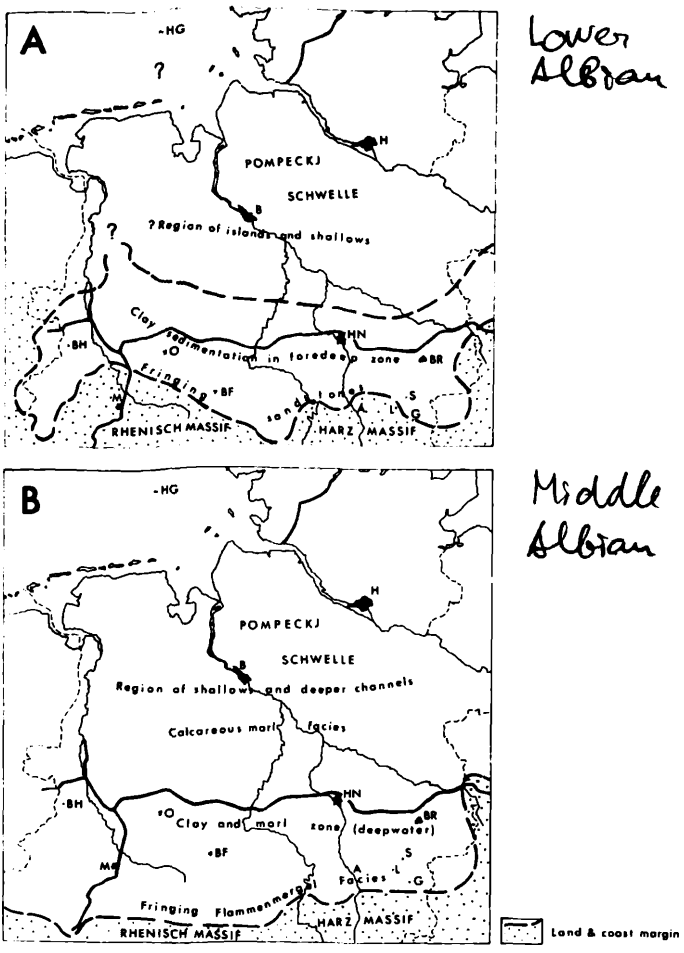


Fig. 2. Palaeogeographic maps of northern Germany: A. Lower Albian, B. Middle and Upper Albian. Abbreviations: HG–Helgoland, B–Bremen, BH–Bentheim, O–Osnabrück, M–Münster, BF–Bielefeld, HN–Hannover, A–Alfeld, L–Lutter, S–Salzgitter, G–Goslar, BR–Braunschweig.

Table 1. Zonal and Subzonal scheme for the lower, middle and upper Albian in the hoplitinid ammonite faunal province.

Substages	Zones	Subzones	
Upper Albian	*Stoliczkaia dispar*	*Mortoniceras (Durnovarites) perinflatum*	
		Mortoniceras (Mortoniceras) rostratum	
	Mortoniceras (Mortoniceras) inflatum	*Callihoplites auritus*	
		Hysteroceras varicosum	
		Hysteroceras orbignyi	
		Dipoloceras cristatum	
Middle Albian	*Euhoplites lautus*	*Anahoplites daviesi*	
		Euhoplites nitidus	
	Euhoplites loricatus	*Euhoplites meandrinus*	
		Mojsisovicsia subdelaruei	
		Dimorphoplites niobe	
		Anahoplites intermedius	
	Hoplites (Hoplites) dentatus	*Hoplites (Hoplites) spathi*	
		Lyelliceras lyelli	
		Hoplites (Isohoplites) eodentatus	
Lower Albian	*Douvilleiceras mammillatum*	*Protohoplites puzosianus**	
		Otohoplites raulinianus	
		Cleoniceras (Cleoniceras) floridum	
		Sonneratia kitchini	
	Leymeriella tardefurcata	Northern Germany	Anglo-Paris basin
		Leymeriella regularis	*Leymeriella regularis*
		Leymeriella acuticostata	*Hypacanthoplites milletioides*
		‚Proleymeriella' schrammeni	*Farnhamia farnhamensis*

* There is possibly a non-sequence above this Subzone in England.

this interval could be of *regularis* Subzone age. Sediments of *tardefurcata* Zone age have been proved to a depth of 495 m at Schacht Konrad 1.

Despite the account by Brinkmann (1937) detailed lithostratigraphic description and bed by bed collecting still needs to be done in this central basin region in order to produce a comprehensive stratigraphic and faunal account of this very important *tardefurcata* Zone sequence. At present, very little faunal material in the various collections can be tied to an exact level in the sequences exposed in individual sections.

Georgi (1976) has described in detail the lithological sequences in the marginal sandstone facies around Lutter, Salzgitter Bad and Goslar together with its foraminiferal fauna.

2.1.2 Zone of *Douvilleiceras mammillatum*. Although *Douvilleiceras* has been recorded from north Germany (e. g. Seitz 1956), there has been, hitherto, no certain evidence for the presence of the *mammillatum* Zone. The genus *Douvilleiceras* has a range extending from the *mammillatum* Zone into the Middle Albian (*eodentatus* and *lyelli* Subzones). In the Schacht Konrad 1 sequence, sited in the central depositional area, at depths between 423 m and 428 m two

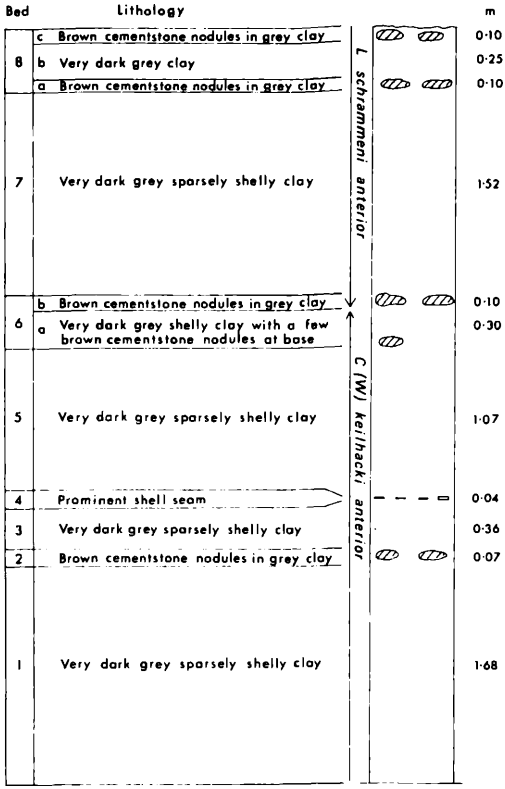


Fig. 3. Section in uppermost *jacobi* Zone and lowest *tardefurcata* Zone clays in the claypit 1 km S. of Vöhrum and about 1 km NE. of the Mittellandkanal section at Schwicheldt described by Brinkmann (1937: 1–2). The base of the *tardefurcata* Zone is taken at the appearance of *Leymeriella schrammeni anterior* in Bed 6b and is thus in accord with Brinkmann and Spath's interpretation of the base of the Albian.

specimens of *Otohoplites* have been found associated with the bivalve *Inoceramus salomoni*. This interval of clay sediment lies below a good development of the *Hoplites (Isohoplites) eodentatus* Subzone and, with little doubt, is of *mammillatum* Zone age but the Subzonal age is uncertain. It is quite likely that part of the interval between 428 m and 475 m mentioned above, is also of *mammillatum* Zone age. Away from the central basin area, *mammillatum* sediments are either absent or greatly condensed (Seitz 1956).

2.2 *Middle Albian*

In northern Germany, sediments of Middle Albian age are more variable both in lithology and thickness than those of the *tardefurcata* Zone. They are found over a much greater area reflecting the widespread transgression which occurred during the early part of the *Hoplites dentatus* Zone as a consequence of tectonic activity. The palaeogeography of the Middle Albian (Fig. 2B) has been demonstrated by Schott *et al.* (1967, 1969). It was thought, at one time, that the Middle Albian was restricted to the concentricus shales, minimus clays and greensand and the splendens clay. However, ammonite occurrences indicate that in the depositional area bordering the Harz massif in the south, the *Euhoplites loricatus* Zone in part and the *Euhoplites lautus* Zone are represented within the lower part of the Flammenmergel facies. In the northern area, extending from the Schwaförden area northward to Helgoland, Middle Albian sediments are more calcareous and develop reddish intercalations (e. g. Spaeth 1971).

2.2.1 Zone of *Hoplites dentatus.* Subzone of *Hoplites (‚Isohoplites') eodentatus:* A good development of this Subzone is present at Schacht Konrad 1, in the deep basinal area north of Salzgitter, and it is the only locality in northern Germany where this Subzone is known to be present. It is represented by fossiliferous grey silty clay from below a phosphatic nodule bed at 410 m depth down to a depth of 418 m. *H. (‚I.') sp.* occurs at 413 m depth and *H. (‚I.') eodentatus* is present between 414 m and 418 m depth, all accompanied by numerous specimens of *Inoceramus (Birostrina) concentricus* (Parkinson).

Subzone of *Lyelliceras lyelli:* No sediments of this Subzone have yet been proved in northern Germany. Immediately above the nodule bed at 410 m depth in Schacht Konrad 1, the clays contain a *spathi* Subzone fauna. Whether the nodule bed is of *lyelli* Subzone age or lowest *spathi* Subzone age, cannot be determined in the absence of fossils.

Subzone of *Hoplites spathi:* Clays and glauconitic loams representing the *spathi* Subzone are of widespread occurence in northern Germany, although ammonites are scarce. Stolley (1937) records *spathi* Subzone ammonites from the lower minimus clays at various localities in the Hannover and Braunschweig areas, but none of the specimens formerly in Berlin and Braunschweig have survived the war. In Schacht Konrad 1, at about 405 – 410 m depth, the *spathi* Subzone is represented by grey clays with many fossils. Unfortunately, the material was not collected with precision and some typical *spathi* Subzone species, such as *Hoplites dentatus* (J. Sowerby) and *H. maritimus* Owen, are recorded from the depth range 415 – 418 m which is of *eodentatus* Subzone age. However, these specimens are preserved in an identical manner to specimens collected from below depths of 405 – 410 m and had presumably fallen down from this interval.

The other localities in the Salzgitter region which have yielded *spathi* Subzone ammonites seen by the writer, are, the disused Ziegeleigrube Vosspass and the disused Tagebau Haverlahwiese. From Vosspass, Dr. Spaeth has collected phosphatic fragments of *Hoplites dorsetensis* Spath, *H.* cf. *similis* Spath and *Hoplites* sp. (all in the Hamburg University collection), which indicate the upper part of the *spathi* Subzone. They come from Bed 39 of Spaeth (1971: 77, 117), but their position within that bed is unknown.

In the Dirks collection (Hannover), there are phosphatic fragments of *Hoplites canavarii* Parona & Bonarelli and *H. canavariformis* Spath from Haverlahwiese, which indicate the upper part of the *spathi* Subzone. No stratigraphic details were recorded, but their presence would indicate that the section has been extended downward since its description by Spaeth (1971: 123 – 124).

There are some specimens transitional between *Hoplites* and *Euhoplites* from the Hannover Troye, Salzgitter, which indicate the extreme top of the *spathi* Subzone (Hannover Coll.). This material is referred to again below.

The other specimens of *spathi* Subzone age examined by the writer from northern Germany were found near the border with Holland in Nordrhein-Westfalen at Ölbach, Frankenmühle near Wüllen, Damme north of Osnabrück and at Helgoland. The specimens from Ölbach were found by Dr. Chr. Spaeth and Dr. W. F. Anderson in a stream bed, washed out from a grey glauconitic silty clay sequence and consist of small phosphatic fragments of *Hoplites* indicating a *spathi* Subzone age. The exact horizon in the sequence is unknown. The specimens collected by Dr. Anderson have been figured by Kemper (1976, pl. 6, figs 5–8) and include *Hoplites (H.)* cf. *persulcatus* Spath and *Hoplites (H.)* sp. *dentatus* group. A similar suite of specimens were collected by Dr. Kemper from clays at Winterreise, Holland.

Ammonites preserved in ironstone found in the old Eisengrube at Damme include *Hoplites (H.)* transitional between *H. (H.) dentatus* evolute variety and *H. (H.) escragnollensis* (Geol. Pal. Inst. Univ. Münster B6.711 GIM, B6.712 GIM) which indicates the presence of sediments of the upper part of the *spathi* Subzone. Three ammonites are known from the ‚minimus Kreide' of Helgoland which indicate that the upper part of the *spathi* Subzone is represented there (Kemper, Rawson, Schmid & Spaeth 1974: 132). They are, *Hoplites (H.)* aff. *escragnollensis* Spath (Stühmer Coll.), *H. (H.)* aff. *paronai* Spath and *H. (H.)* sp. transitional to *Dimorphoplites* (Kustermann Coll.).

2.2.2 Zone of *Euhoplites loricatus*. *Loricatus* Zone sediments are present in the Teutoburger Wald and are well developed in the Braunschweig–Salzgitter area but, with the exception of the Alteld area in the Sack syncline, they have not yet been detected elsewhere with certainty. The term ‚Splendens tone', which might suggest a *loricatus* Zone connotation, covers sediments ranging throughout the Middle Albian and is not a precise term. Only the *intermedius* Subzone is recognizable definitely at the moment, but there are higher horizons represented at or about the *subdelaruei* and *meandrinus* Subzones.

Subzone of *Anahoplites intermedius:* Stolley (1937) recorded the presence of the *intermedius* Subzone in the Wendezelle 1 boring and at Gliesmarode. In Schacht Konrad 1, between 381 m and 405 m depth there are shelly mid-grey clays with numerous *Inoceramus (Birostrina) concentricus*, together with a more silty clay band within the sequence. The ammonites, which are crushed, indicate the *intermedius* Subzone and include: *Anahoplites intermedius* Spath, *A. praecox* Spath, *Euhoplites* of the *loricatus-microceras* group, *Dimorphoplites niobe* Spath (early form) and *Hamites tenuicostatus* Spath.

At Vosspass, *Euhoplites subtabulatus* Spath and *E. loricatus* occur as phosphatic fragments and probably indicate the *intermedius* Subzone. These specimens in the Hamburg University collection probably come from the upper part of Bed 39 (Spaeth 1971: 117). A very good fauna of *intermedius* Subzone age preserved in phosphate has been collected from Haverlahwiese, mainly by Herr Dirks, and it should be possible to determine its stratigraphic position within the section. The ammonites include *Anahoplites praecox* Spath, *A.* sp., *Euhoplites microceras* Spath, *E.* cf. *loricatus* Spath, *Dimorphoplites hilli* Spath and *D.* aff. *pinax* Spath (early form).

In the Tagebau Finkenkuhle, Salzgitter-Bad, the shaley glauconitic sandy clay sediments of Bed 18 (Spaeth 1971: 77, 119) contains the following ammonites; *A.* cf. *praecox* by preservation, but with no stratigraphic position recorded, *Euhoplites microceras* Spath 3 m above base, *E.* sp. (forerunner of *E. proboscideus*) 3.10 m above base, *E.* sp. 5 m above base (Spaeth Coll.,

Hamburg University). The material, which is preserved as partly crushed moulds, indicates that the lower 3.10 m of Bed 18 is probably of *intermedius* Subzone age.

Further west, Dr. Georgi has collected a specimen of *E. loricatus* probably of *intermedius* Subzone age preserved in a Flammenmergel-like matrix from the outcrop Katzenbau, at Hils bei Delligsen, Alfeld. The specimens of *Hoplites (H.)* from the Hannover Troye, mentioned above, lie on the boundary of the *spathi* and *intermedius* Subzones, but there are no late *spathi* Subzone *Hoplites (H.)* or early species of *Anahoplites* of the *intermedius* group which would fix their exact position.

A large specimen of *Euhoplites pricei* Spath preserved in reddish silty sandstone has been collected from the Gault-Sandstein of the MTB Altenbeken, oberhalb Rauher Grund (Geol. Pal. Inst. Univ. Münster B.6710 GIM).

Subzone of *Dimorphoplites niobe:* There is at present no evidence of sediments of this Subzone age in northern Germany.

Subzones of *Mojsisovicsia subdelaruei* and *Euhoplites meandrinus:* In Dr. Spaeth's collection (Hamburg) there are some specimens collected from the more Flammenmergel-like facies of Beds 17 and 15 in the Tagebau Finkenkuhle (Spaeth 1971). These are *loricatus* Zone species of *Euhoplites*, one from the basal Flammenmergel-like layer of Bed 17, the other from a similar layer in the lower part of Bed 15, both of them preserved partly crushed in the matrix of the beds concerned and, therefore, indigenous to them. There are also four phosphatised specimens in the same collection, probably from Beds 16 and the lower part of 14, identifiable as *E. subtuberculatus* Spath (late form indicating the *meandrinus* Subzone), *E.* sp., and *Dimorphoplites* sp. of either *subdelaruei* or *meandrinus* Subzone age. An indigenous specimen of *Euhoplites* from Bed 14, apparently not the one recorded as *E. nitidus* by Spaeth (1971: 119), has a rib pattern which suggests a late *loricatus* Zone age, but whether the venter is sulcate (*loricatus* Zone) or channeled (*lautus* Zone) cannot be determined from the specimen.

The only other localities from which a late *loricatus* Zone fauna is known is at Bethel in the Teutoburger Wald and in the Salem road section near Bielefeld. A specimen of *Dimorphoplites* cf. *doris* Spath preserved in greenish glauconitic clayey sandstone, was collected by Althoff from the ‚Grünsand in Mtl. Alb' at Bethel and is now preserved in the Hannover collections. Althoff & Seitz (1934: 7) record a specimen of *Euhoplites lautus* ‚var'. *biloba* Spath from the Salem road section. This is a distinct species which occurs at the top of the *meandrinus* Subzone sediments in England.

2.2.3 Zone of *Euhoplites lautus.* Ammonites of *lautus* Zone age as now restricted (Table 1) were recorded by Stolley (1937) from a few localities in northern Germany. Collecting during the last twenty-five years has provided much new information. In all but two of the localities from which specimens are now available, the *lautus* Zone sediments are within the Flammenmergel facies. The idea in English minds that the Flammenmergel is of Upper Albian age and the equivalent of the Upper Greensand sequence, which stems from Stolley (1937, table opposite p. 63), has to be abandoned. It appears likely that the base of the Flammenmergel facies is diachronous, being earlier in age close to the Harz and Rhenish massifs and later as it fingers out into marls in the more central trough areas. It was noted above that in the Tagebau Finkenkuhle, Salzgitter-Bad and to the west near Alfeld, the *loricatus* Zone is represented by sediments with distinct Flammenmergel-like bands. The *nitidus* Subzone has been proved in all the sections mentioned below, but the *daviesi* Subzone has not yet been proved with any certainty in northern Germany.

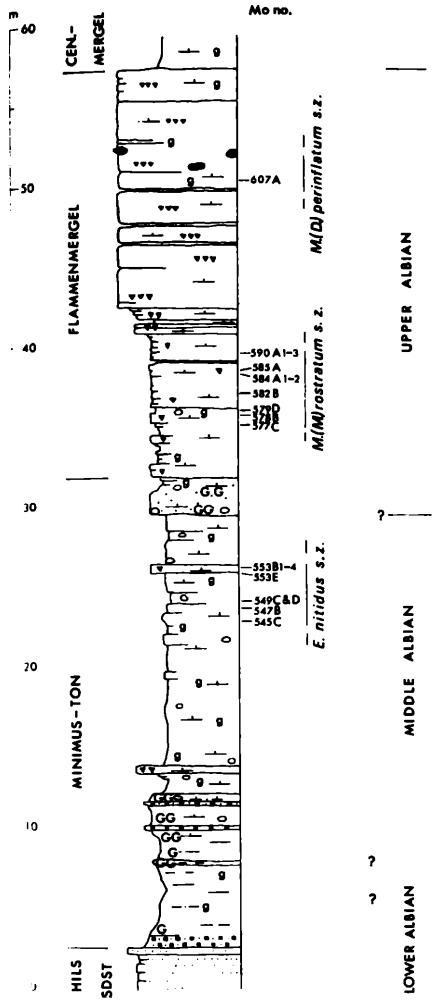


Fig. 4. Section in Albian sediments in the north east part of the Grube Morgenstern, 2 km NE. of Hahndorf, Goslar. Section provided by Dr. K.-H. Georgi.

Subzone of *Euhoplites nitidus:* In the Hamburg collection, there are two fragmentary specimens of *Euhoplites* from Söhlde near Braunschweig, preserved in phosphate with the original shell. These specimens are *Euhoplites lautus* (J. Sowerby) and *E. lautus duntonensis* Spath and are the specimens collected by Ernst from the upper minimus clays which were recorded by Spath (1928: 264, 1943: 726) and Stolley (1937: 26). In this area, therefore, the *nitidus* Subzone is in a clay facies. To the west at Bielefeld, in the Salem road section, Althoff & Seitz (1934) record *E. lautus duntonensis* with indicates that the *nitidus* Subzone is in a marly facies here also.

To the south in the Goslar, Salzgitter and Sack syncline areas, the *nitidus* Subzone and possibly the *daviesi* Subzone are present within the lower part of the Flammenmergel facies. In the section at the Grube Morgenstern, north of Goslar, the whole of the Albian sequence is exposed (Fig. 4). The Lower Albian sediments have been described by Georgi (1976) and I am indebted to him for the details of the lithological sequence and for sending the ammonite material collected from it for identification. The following ammonites indicate the presence of the *nitidus* Subzone; *Euhoplites* cf. *opalinus* Spath sample no. Mo 545C, *E. lautus* (J. Sowerby) Mo 547B, *E. opalinus* Mo 549C1, *E. truncatus-opalinus* group Mo 549C3, *E.* cf. *lautus* Mo 549C4, *Hamites* spp. Mo 549D1–3, *Dimorphoplites tethydis* (Bayle) Mo 553B1, *E. truncatus-opalinus* group Mo 553B2, *E. opalinus* Mo 553B4.

Spaeth (1971: 115) records *Euhoplites truncatus* Spath from Bed 20 at Vosspass. It is preserved as a steinkern in Flammenmergel-like matrix with the shell replaced by a thin pyrite coating as are all the specimens from the Flammenmergel facies. Apart from this specimen, there are others from Vosspass in both the Hamburg and Hannover collections, including *E.* cf. *lautus* and *E. opalinus*, which are preserved in exactly the same manner as the specimen from Bed 2 referred to above, but no stratigraphic horizons have been recorded. The ammonites are associated with *Inoceramus (Birostrina) concentricus* Parkinson. A specimen of *Euhoplites opalinus* preserved as a crushed cast in the Flammenmergel matrix of Bed 6 at Finkenkuhle was recorded as *E.* cf. *alphalautus* Spath (an Upper Albian, *varicosum* Subzone species) by Spaeth (1971). It could be either of *nitidus* or *daviesi* Subzone age.

To the west of the Salzgitter district in the Sackwald, the Flammenmergel sequence has been described by Jordan (1968) and Jordan & Schmid (1968). The lower part of the Flammenmergel in the Hohe Schanze area (Jordan & Schmid 1968: 59, 62–63) up to Flammenmergel 3 is of Middle Albian age and not basal Upper Albian as recorded. Fundort 2 and 4 include *E.* cf. *truncatus*, *E.* cf. *opalinus* and *E. lautus*, together with *Inoceramus (Birostrina) concentricus* (Niedersächsisches Landesamt Coll.). In the Sackwald, therefore, the lower part of the *lautus* Zone is also well within the Flammenmergel.

Between Hannover and Bremen, in the Schwaförden area, lies the mine shaft Staffhorst described by Spaeth (1971: 124–126). This section is in the depositional area adjacent to the Pompeckj-Schwelle. Spaeth indicates *lautus* Zone sediments between 834 m and 852.5 m depth but a re-examination of the ammonites and bivalves shows that this interval is of basal Upper Albian age.

2.3 *Upper Albian*

The ammonite Zonal and Subzonal scheme for the Upper Albian recognized by Spath (e.g. 1941: 668) has been the subject of substantial revision (Owen 1976a). It is shown in Table 1. The *Dipoloceras cristatum* Subzone has been included in the Upper Albian Zone of *Mortoniceras (M.) inflatum* for some years. More recently, it has become clear that the *‚aequatorialis'* Subzone

in Spath's original sense was synonymous with the *Callihoplites auritus* Subzone. Spath (1932: 409) realized that his original interpretation of the English forms referred to *Mortoniceras (M.) inflatum aequatorialis* (Kossmat) was incorrect and that his var. *aequatorialis* was closer to specimens that he considered to be conspecific with *M. (M.) kiliani* (Lasswitz). However, this latter form, the *M. (M.) alstonensis* of Breistroffer (1940), is a species of the lower part of the *dispar* Zone and this fact has added much international confusion to an already incorrect reading of the higher part of the Upper Albian sequence. Major problems also affected Spath's original classification of the *dispar* Zone.

The ammonite sequence in the higher part of the Upper Albian sediments recognized in France (Breistroffer 1940, 1947), Germany (Stolley 1937) and now England (Owen 1976a) and elsewhere, shows that the *Callihoplites auritus* Subzone is followed directly by a time interval in which the genus *Stoliczkaia* existed (i.e. the Zone of *Stoliczkaia dispar*). This interval can be divided into two parts. An earlier part in which species of the subgenus *Mortoniceras*, typified by *M. (M.) rostratum* (J. Sowerby) are very characteristic and are associated with *Stoliczkaia* (*Faraudiella*), and a later part in which the subgenus *Mortoniceras* is replaced by the subgenus *Durnovarites*, typified by *M. (D.) perinflatum* Spath. Neither *Durnovarites* nor the associated genus *Arrhaphoceras* are present in the *rostratum* Subzone below, and they are accompanied by species of *Stoliczkaia* in the strict sense. The Subzone of *Arrhaphoceras substuderi* proposed by Spath actually included, therefore, sediments in which the subzonal index fossil did not occur, it being a species of the *perinflatum* Subzone. The scheme given in Table 1 more accurately reflects the ammonite sequence in the hoplitinid province.

2.3.1 Zone of *Mortoniceras (M.) inflatum*. Sediments of the *cristatum*, *orbignyi* and *auricosum* Subzones have been found in north Germany, but the presence of sediments of *auritus* Subzone age has not yet been proved without doubt and might reflect a substantial non-sequence or strong condensation of sediments recognisable over a wide area of western Europe.

Subzone of *Dipoloceras cristatum*: The only locality from which *cristatum* Subzone fossils have been seen by the writer is at Schacht Staffhorst 1 in the Schwalförden area between Hannover and Bremen. Stolley (1937: 17, 30), however, records the presence of *Dipoloceras cornuelianum* (d'Orbigny) and *Euhoplites subtilis* Spath, which indicate the *cristatum* Subzone, in the section of upper minimus clay exposed in the Mastbruch railway cutting situated in the deeper area of the depositional basin. At the Schacht Stafforst 1, between 854.5 m and 858.5 m depth (the lower part of Bed 12 of Spaeth 1971: 125) there is a specimen of *Inoceramus (Birostrina) sulcatus subsulcata* Wiltshire preserved in marl which in this case marks the lowest part of the *cristatum* Subzone, but the exact stratigraphic position within this interval of marl is unknown. Two specimens of *Euhoplites*, one specifically indeterminate, the other *E.* cf. *lautus thetonotus* (Seeley), were found between 847.5 m and 854.5 m depth (upper part of Bed 12 and Bed 11 of Spaeth) and suggest a *cristatum* Subzone age. Above this occur *orbignyi* Subzone fossils. To the south, Althoff & Seitz (1934: 9) record *Inoceramus (Birostrina) concentricus* and *I. (B.) sulcatus* from near the bottom of Bed 2 in the Salem trench section near Bielefeld. This probably indicates the Middle – Upper Albian boundary, which, here also, is in a marl facies.

Further to the south east within the area of the Flammenmergel facies, Bed 5 at the Tagebau Finkenkuhle (Spaeth 1971: 118) and Bed 9 of the Ziegelei Vosspass (Spaeth 1971: 115) both contain *I. (B.) sulcatus* indicating the lower part of the Upper Albian. However, *I. (B.) sulcatus* has a range from the base of the *cristatum* Subzone to the top of the *orbignyi* Subzone when it

reverts back into a *concentricus* form, and no ammonites have yet been found associated with it in the Salzgitter area.

Subzone of *Hysteroceras orbignyi:* This Subzone is known to be present at two localities both within the clay-marl facies region. The first in the Schacht Stafforst 1 at depths between 843 m and 847.5 m (within Bed 10 of Spaeth 1971: 125) where the following were found, but no exact depths were recorded; *Hysteroceras orbignyi* (Spath), *Euhoplites* cf. *solenotus* (Seeley), *I (B.) sulcatus* and *Inoceramus anglicus* Woods.

In an oil boring at Lingen, north of Bentheim (Lingen 35), at a depth of 719 m a specimen of *Hysteroceras* of the *orbignyi* Subzone was recovered from the core, and at 716.5 m depth *I. (B sulcatus* is present. This material is preserved in pale-grey clay.

It is possible that the specimens of *‚Mortoniceras (Pervinquieria) inflatum'* recorded by Althoff & Seitz (1934:8) from 9 m above the base of Bed 2 in the Salem trench near Bielefeld could also be of *orbignyi* Subzone age. Equally, they could be of *varicosum* Subzone age, but unfortunately, the specimens have not been traced. Even less certain are the records of *orbignyi* Subzone fossils given by Stolley (1937).

Subzone of *Hysteroceras varicosum:* Sediments of this Subzone are known to be present at two localities. At Mergelkuhle bei Stahl Johann in the Teutoburger Wald near Tecklenburg phosphatised ammonites have been collected and are now preserved in the Hamburg collection. They include *Hysteroceras binum* (J. Sowerby), *H. subbinum* Spath, *H. carinatum* Spath, *H. varicosum* (J. de C. Sowerby) and *Mortoniceras* sp. The other locality is the Schacht Staffhorst 1 where, between 841.5 m and 843 m depth (in the upper part of Bed 10 of Spaeth 1971:125) *Euhoplites alphalautus* Spath and *E.* cf. *vulgaris* Spath are present in the marls. Stolley (1937: 32) records *varicosum* Subzone ammonites, but these records cannot be checked at present. As yet the *varicosum* Subzone has not been proved in the Flammenmergel.

Subzone of *Callihoplites auritus:* No ammonites of *auritus* Subzone age have as yet been discovered in northern Germany (cf. Stolley 1937). There is certainly room for the presence of sediments of this age in the Flammenmergel sequences in the Goslar-Salzgitter, Hils and Sackwald areas which, while containing the bivalve *Aucellina gryphaeoides*, occur below proven sediments of *dispar* Zone age, but no ammonites have been found as yet. In the Sackwald, this interval could include the lower part of Flammenmergel 4 below Fundort 10 and 11 which indicate the *dispar* Zone (Jordan & Schmid 1968: 59, 63 – 64).

2.3.2 Zone of *Stoliczkaia dispar.* Careful collecting by Dr. Georgi in the section in Flammenmergel at the Grube Morgenstern in the Goslar area, has provided important information on the sequence of the highest Albian sediments in northern Germany (Fig. 4). It is apparent that sediments representing both Subzones of the *dispar* Zone are well developed in this quarry and this can be used as the basis for an analysis of the important collections of *dispar* Zone ammonites made elsewhere, some of which have no precise stratigraphic information recorded with them. All *dispar* Zone ammonites seen by the writer are preserved as partly crushed steinkerns in a hard splintery Flammenmergel matrix.

Subzone of *Mortoniceras (M.) rostratum:* In the Grube Morgenstern Dr. Georgi has collected the following ammonites from sediments classified with the *rostratum* Subzone (Fig. 4); *Puzosia* sp. sample no. Mo 578B, *Anisoceras armatum* (J. Sowerby) Mo 585A, *Callihoplites* cf. *acanthonotus* Spath (?non Seeley) Mo 584A2, *C.* sp. ind. Mo 585A, *C. vraconensis* (Pictet & Campiche) Mo 590A1, *C.* sp. ind. Mo 590A2 – 3.

Ammonites have also been collected from known stratigraphic horizons in the higher part of the Flammenmergel sequence in the Sackwald (Jordan & Schmid 1968: 63 – 64) which sug-

the *rostratum* Subzone rather than the *perinflatum* Subzone. The material, which is preserved in the collection of the Niedersächsisches Landesamt für Bodenforschung, Hannover, includes *Callihoplites* sp. from a little above the middle part of Flammenmergel 4 at Mullenberg (Fundort 11 of Jordan & Schmid 1968: 63 – 64); the specimen identified as *Anisoceras perarmatum* Pictet & Campiche recorded by Jordan & Schmid (1968: 63) from Fundort 10 of Flammenmergel 4 in the Wrisbergholzen section (which is transitional to *A. armatum*) and a *Mortoniceras (M.)* sp. that could be *M. (M.) rostratum* (J. Sowerby) from Fundort 13 in Flammenmergel 5 at Irmenseul, in the Hohe Schanze area.

The ammonite specimens in the Hopke collection preserved in the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, indicate that at Hillenberg near Salzgitter, both the *rostratum* and *perinflatum* Subzone are present in the upper part of the Flammenmergel sequence, but no precise horizons have been recorded. Ammonites indicating the *rostratum* Subzone include *M. (M.)* aff. *rostratum* (J. Sowerby) with a *stoliczkai*-like outer whorl No. AB 5, and *M. (M.)* cf. *alstonensis* (Breistroffer) AB 6. A specimen of *M. (M.)* cf. *rostratum* (labelled ‚Flammenmergel, Salzgitter' is preserved in the collections of the British Museum Natural History), London (BMNH., C 12850).

Subzone of *Mortoniceras (Durnovarites) perinflatum:* Sediments of this Subzone are well developed in the uppermost part of the Flammenmergel in the Goslar, Salzgitter Hils and Sackwald areas. At the Grube Morgenstern (Fig. 4), Dr. Georgi has found *Mortoniceras (Durnovarites)* cf. *quadratum* (Spath) Mo 607A from the top part of the sequence. At the outcrop ‚Wrisbergholzen', Sackwald, he has obtained *Pleurohoplites* cf. *subvarians* Spath Wri 775A and at the outcrop ‚Kalkdorn', Hils, he has collected *Stoliczkaia* sp., a *perinflatum* Subzone form in England Kl 748A9, *Callihoplites tetragonus dorsetensis* Spath Kl 748A8, *C. vraconensis* (Pictet) Kl 748A5 & A7, *C.* sp. *tetragonus – vraconensis* group Kl 748A3, *C. tetragonus compressa* Spath Kl 748A2, *C.* cf. *atavus* Spath Kl 748A4, *C.* sp. Kl 748A1, *Anisoceras perarmatum* Pictet & Campiche Kl 748A9. In the Niedersächsisches Landesamt collection there is a specimen of *Callihoplites advena* Spath from Flammenmergel 5 of the Sackwald, not recorded by Jordan & Schmid (1968), which is a *perinflatum* Subzone species.

The ammonites in the Hopke Collection (Hannover) include the following *perinflatum* subzone species from Hillenberg, Salzgitter; *Stoliczkaia* cf. *notha* (Seeley) AB 9, *S.* cf. *dispar* (d'Orbigny) unnumbered, *Mortoniceras (Durnovarites)* cf. *quadratum* (Spath) AB 7, *M. (D.)* cf. *subquadratum* (Spath) AB 8, *Arrhaphoceras substuderi* Spath AB 16, *A. precoupei* Spath AB 10, *Pleurohoplites* aff. *renauxianus* (d'Orbigny) AB 20, AB 21, *P.* cf. *subvarians* Spath AB 17, AB 18. In the same collection are the following ammonites which could be of either *rostratum* or *perinflatum* Subzone age: *Hamites (Stomohamites) venetzianus* Pictet AB 23, *Idiohamites* sp. AB 24, *Anisoceras picteti* Spath AB 26, *A.* aff. *picteti* AB 25, AB 27, *Lechites gaudini* (Pictet & Campiche) AB 28 – 30, AB 32 – 33, cf. *Lechites moreti* Breistroffer AB 31, *Puzosia* cf. *mayoriana* (d'Orbigny) AB 1 – 2, AB 4, *P.* cf. *sharpei* Spath AB 3, *Callihoplites* cf. *vraconensis* (Pictet & Campiche) AB 12, AB 14, *C.* cf. *tetragonus compressa* Spath AB 13, *C.* cf. *senilis* Spath AB 15, *C. seeleyi* Spath AB 22. Similarly, there is a specimen of *Callihoplites* in the Wiedenroth collection (Hannover) from the upper part of the Flammenmergel in the Vosspass quarry, although the exact position is not recorded. This specimen also could be of either *rostratum* or *perinflatum* Subzone age.

In the collection of the British Museum (Natural History), London, there are three specimens labelled ‚Flammenmergel, Salzgitter' which are probably all of *perinflatum* Subzone age. *Anisoceras* cf. *campichei* Spath (BMNH., C 12852), *Puzosia* cf. *spathi* Breistroffer

(BMNH., C 12851) and *Stoliczkaia notha* (Seeley) (BMNH., C 12853). In the same collection are four specimens from the Flammenmergel of Warunsberg, Salzgitter; *Anisoceras* cf. *picteti* Spath (BMNH., C 14357), *Idiohamites* cf. *dorsetensis* Spath (BMNH., C 14358), *Puzosia* cf. *spathi* Breistroffer (BMNH., C 14356) and *Mortoniceras* (*Durnovarites*) sp. ind. (BMNH., C 14355).

Through the courtesy of Dr. C. Frieg, the writer has identified ammonites indicating the *rostratum* Subzone of the *dispar* Zone from a boring at Hamm (Dummberg 1) on the southern side of the Münster Basin. No ammonites of *dispar* Zone age have been seen in the highest marls of the Albian dated by microfaunas in the northern area between Hannover and Bremen.

3. Comparison with Albian sediments in England and northern France

Although sparse in occurence, the ammonite fauna of north-west Germany listed above, shows a sequence closely comparable to that seen in England and France except in the lower part of the Lower Albian where there is an important difference. The fauna as a whole is typical of the hoplitinid faunal province (Owen 1971a: 130–133).

3.1 *England*

Lower Albian: The sequence in the Lower Albian sediments of England has been described by Casey (1961). The sediments consist essentially of sands, sandstone and phosphatic nodule beds in loam or sand, deposited in comparatively high energy shallow water conditions, together with subordinate sandy limestones and rare clays. Non-sequences and condensation are common and even polyphase condensation is known (e. g. Owen 1972). Where sediments of *tardefurcata* Zone age are fossiliferous, Casey has demonstrated (1957, 1961) that the approximate English equivalent of the *schrammeni* and *acuticostata* Subzones of the north German clay facies do not contain *Leymeriella*, although species of *Hypacanthoplites* which occur in Germany during this period, are present (Kemper 1975). In England, these species of *Hypacanthoplites* are associated with the earliest Albian hoplitinid ammonite genus *Farnhamia* in what appears to be the equivalent of the *schrammeni* Subzone clays of north Germany. Casey (1957) has suggested that the hoplitids and the lyelliceratids were ecologically mutually exclusive and this is possibly the reason why *Leymeriella* is absent from the English area until the *regularis* Subzone. Another possibility is that *Leymeriella*, with its comparatively small size and thin shell, preferred quieter open-sea conditions away from the shallow current-swept sea covering south-eastern and eastern England. Drifted *post-mortem* shells should have penetrated into the English sea area because the species of *Hypacanthoplites* show that there was a connection with the Lower Albian North Sea, but perhaps these shells could not survive the very high energy region of the shallow waters of the archipelago of the London platform region (Fig. 5A). However, *Farnhamia* is unknown outside the area of the Weald and this lends support to Casey's suggestion.

In England, the *regularis* Subzone sediments are of very scattered occurrence (Casey 1957, 1961, Owen 1972), but have yielded a good ammonite fauna which has been described by Casey (1957, 1960–). *Leymeriella* is a common element and is associated with species of *Anadesmoceras*, *Cleoniceras* and very rare *Pictetia*, *Eogaudryceras* and aconeceratids. It is likely that this fauna was present in the north German sea area also, but the *regularis* Subzone sediments appear to have been largely removed, as to a slightly lesser extent they have been

England, by late Lower Albian tectonic movements. That some *regularis* Subzone and *mammillatum* Zone sediments in England were deposited in deeper quieter water is indicated by the occurrence of clays of *regularis* Subzone age in the narrow trough in the Brighton – Steyning area, Sussex (the Horton Wood Clay) and clays of *Cleoniceras floridum* Subzone age in the Sevenoaks area, Kent (Casey 1961).

A rich *mammillatum* Zone fauna has been described from England by Casey (1961, 1960 –) in which cosmopolitan ammonite genera such as *Douvilleiceras*, *Beudanticeras* and even *Cleoniceras* are associated with early members of the Hoplitinae such as *Sonneratia*, *Pseudosonneratia*, *Otohoplites*, *Protohoplites*, *Tetrahoplites* all of which are endemic to the hoplitinid faunal province of the *mammillatum* Zone. The sediments representing this Zone are for the most part strongly condensed into loams or sandy clays with layers of current-sorted phosphatic nodules during periods of tectonic instability.

Middle Albian: Sediments of Middle Albian age in England indicate a substantial change in the nature and extent of the seas in which they were deposited (Owen 1971a, 1976a). In the *dentatus* Zone, sediments of *eodentatus* Subzone age are of very limited occurrence and only in the beds of the Carstone Member of the Lower Greensand in the Isle of Wight is an indigenous fauna of this Subzone known for certain. The *lyelli* Subzone sediments also show a very patchy development with much condensation outside the areas of structural troughs in the Weald or the basin area of Oxfordshire, Wiltshire and north Dorset. Where preserved, the sediments consist of typical Gault clay with an ammonite fauna showing an incursion of elements such as *Hysteroceras*, *Oxytropidoceras*, *Brancoceras* and *Eubrancoceras*, typical of the Tethyan and southern provinces, which had penetrated through France to co-exist with the endemic *Hoplites*. This incursion was short lived and in the *spathi* Subzone the ammonites of southern provincial origin, such as *Oxytropidoceras*, *Mojsisovicsia*, *Eubrancoceras*, are very rare in comparison with the population of *Hoplites*. *Spathi* Subzone sediments, consisting for the most part of clays which become more silty close to the margins of the depositional basin, are much more extensive than those of the *lyelli* Subzone, but strong condensation of the sequence close to the area of the London Platform, marked by phosphatic nodule beds, points to periods of strong current scour probably due to tectonic instability.

In the lower part of the *loricatus* Zone (*intermedius* Subzone), clay sedimentation reached its known maximum extent (Owen 1971a, fig. 51). Unfortunately, early Upper Albian erosion has removed much of the later *loricatus* Zone sediments and in particular, those of the *lautus* Zone. In consequence, sediments of these two Zones are only well developed in parts of southern and south eastern England and in parts of East Anglia. Sediments of the *daviesi* Subzone are very restricted, having been proved only in Kent and East Sussex. Incursions of ammonites of southern provincial derivation occur rarely at intervals (e. g. the *subdelaruei* Subzone).

Upper Albian: In the early Upper Albian, there occurred a marked period of tectonic activity within the *cristatum* Subzone which affected much of the World's epicontinental seas. In England these movements produced a slight upward tilt towards the west and renewed movements of faults which had originated at the Jurassic – Cretaceous boundary (Owen 1971b). The resulting strong submarine current scour planed-off the upper layers of the Lower Gault removing this Member altogether in the region of London north of the Thames and south Essex. Minor tectonic activity continued throughout the remainder of the *cristatum* Subzone and the

orbignyi Subzone, producing condensed sequences (Owen 1976a). Associated with this tectonic activity, there occurred a major invasion of southerly derived ammonites such as *Dipoloceras*, early *Mortoniceras*, *Hysteroceras* and *Beudanticeras*, and on this occasion these southerly derived elements stayed to co-exist with the endemic hoplitinid fauna throughout the whole area of the hoplitinid faunal province during the Upper Albian.

More settled conditions in the *varicosum* Subzone and deepening of the central areas of the sedimentary basin, led to the deposition of thick clays in eastern and south eastern England and loamy or sandy deposits in the west near to the sediment source areas. Following similar sedimentation in the *auritis* Subzone, there occurred a marked period of broad, low amplitude folding with west – east trending axes. The accompanying erosion removed, or strongly condensed, much of the sediment deposited during this Subzone in south eastern England. This tectonic activity heralded a rapid extension of the Upper Greensand facies eastward into the Weald and Berkshire during the early part of the *rostratum* Subzone. Clays continued to be deposited, however, in the *dispar* Zone in the area of East Anglia and East Kent, although the highest sediments preserved are distinctly silty and micaceous.

Within the Lower Cenomanian, a further period of tectonic activity produced in southern England a similar folding pattern to that seen in the earlier *auritus* Subzone, with, in this case, the highest Albian sediments preserved in the troughs of the broad, low-amplitude folds. The area of East Anglia flanking the North Sea region appears to have been strongly tilted or even block faulted producing erosion of the Upper Albian clays. The Cambridge Greensand is the product of this erosion and consists of well worn phosphatic debris derived from clays of the *auritus*, *rostratum* and *perinflatum* Subzones which has been swept westward and re-deposited in a matrix of Lower Cenomanian Chalk Marl. The bed rests on an eroded surface of Upper Gault of lower *dispar* Zone age at the outcrop from Barrington (Cambridgeshire) south west into Hertfordshire.

It is pertinent to mention here briefly that Spath (1923–1943) and the writer have recognized ammonites of the following Middle and Upper Albian Subzones in the thin Hunstanton Red Rock sequence. Division C of Wiltshire (1869: 185–188), the lowest unit contains ammonites which indicate the presence of the uppermost part of the *spathi* Subzone (e.g. *Hoplites (H.) canavariformis* Spath, *H. (H.) pretethydis* Spath), the *intermedius* Subzone (*Anahoplites praecox* Spath, *A. evolutus* Spath), the *meandrinus* and basal *nitidus* Subzone (*Dimorphoplites* aff., *niobe* late transitional form, *D. perelegans* Spath, *D. hilli* Spath, *D. tethydis* Spath non Bayle). Division B contains a late *cristatum* Subzone and earliest *orbigny* Subzone fauna of *Euhoplites* spp., such as *E. ochetonotus* (Seeley), *E. solenotus* (Seeley), *E. trapezoidalis* Spath, *E. inornatus* Spath associated with *Beudanticeras* spp. and *Inoceramus (Birostrina) sulcatus* Parkinson. Ammonites are rare in division A, the topmost unit, but *Mortoniceras (M.) inflatum* (J. Sowerby), preserved in the matrix of division A, suggests the presence of the *auritus* Subzone.

3.2 *Normandy and the Paris Basin*

Lower Albian: Sediments of *tardefurcata* Zone age in France are similar to those found in England. In northern France, they have been subjected to the same amount of condensation, but in south eastern France, where the area is strongly affected by early Alpine tectonic movement, condensation is very marked with polyphase condensation of Lower and Middle Albian sediments occurring in some places. It is not certain that any sediments equivalent to those of the *Farnhamia farnhamensis* Subzone in England are present in France. Highly condensed

sediments of *Hypacanthoplites milletioides* Subzone age are known only in the Boulonnais, Ardennes and southern part of the Paris Basin (e. g. Casey 1961, Amedro & Destombes 1975, Larcher, Rat & Malapris 1965, Destombes & Destombes 1965). As in England, it is only in the *regularis* Subzone that *Leymeriella* is found in the French sequence (e. g. Breistroffer 1947, Casey 1957, Larcher, Rat & Malapris 1965, Destombes, Juignet & Rioult 1973) and its occurrence is then widespread.

Sediments of *mammillatum* Zone age, rarely uncondensed in England, are well represented by thick clays and loams in the Aube (Destombes & Destombes 1965, Destombes 1970, 1973) and in the northern part of the Pays de Bray (Destombes 1973, 1977). Elsewhere, the sequences are condensed and in south east France are mixed by polyphase erosion with later and earlier Albian and late Aptian ammonites. In the clay sequence of the Bois de Perchois, Aube, the early evolution of the genus *Otohoplites* can be determined in sediments of *floridum* Subzone age (Destombes 1970 and in preparation). This is the only known area where this can be seen at present. In the Aube and in the northern Pays de Bray, Destombes (1977) has determined a subzonal sequence for the upper part of the *mammillatum* Zone which differs from that recognized by Casey (1961). The Subzone of *Protohoplites puzosianus*, which is relegated to an horizon within the *raulinianus* Subzone by Destombes (1977), is recognizable at Wissant and in the condensed fauna in the Ardennes, but is not present in the sequence at Bully, in the northern Pays de Bray, nor in the Aube. A non-sequence is possible in the two latter areas which would account for the absence of the *puzosianus* Subzone fauna, but the resolution of this problem must await the discovery of a sequence in which the *bulliensis, normanniae* and *puzosianus* faunas are all present. An interesting feature of the lower *mammillatum* Zone clays in the Bois de Perchois sections in the interfingering of clays containing a distinct Tethyan fauna (Owen 1971a; footnote p. 118). This bears witness to occasional invasions from the south of an ammonite fauna distinct from that known over the area of the *mammillatum* Zone european shelf seas – the hoplitinid faunal province – which can be recognized already in the Lower Albian.

Middle Albian: Clay sediment of *eodentatus* Subzone age is developed in the northern Pays de Bray and at the outcrop in the southern and eastern margins of the Paris Basin from the area of Clermont-en-Argonne to the western Aube. Condensation by current winnow is evident in these regions and more particularly in other areas where remnants of sediments of the *eodentatus* Subzone are known. The *lyelli* Subzone is well represented by thick very fossiliferous clays at the outcrop from north of Clermont-en-Argonne around the south east margin of the Paris Basin to the eastern Yonne, and in the Pays de Bray (e. g. Destombes & Destombes 1965, Owen 1971a). During the *lyelli* Subzone there occurs the first principal invasion of an ammonite fauna from the Tethyan province to the south via the Paris Basin region, including genera such as *Hypophylloceras, Desmoceras, Lyelliceras, Brancoceras, Eubrancoceras* and *Oxytropidoceras*. These exotic elements are more common in this region than further north in France and England, a feature seen in the more restricted incursions in the earlier *eodentatus* Subzone and in the later *spathi* and *intermedius* Subzones (Owen 1971a, 1973).

From the Lower Gault sequence in England and in the Boulonnais, it is apparent that incursions of ammonites of Tethyan derivation occurred at intervals, particularly during the *tabdelaruei* Subzone when *Mojsisovicsia* became a common element of the ammonite fauna. Unfortunately, in the southern part of the Paris Basin, sediments of post-*intermedius* Subzone middle Albian age have been eroded away as a result of tectonic movements within the *cristatum*

Subzone. Even in the Boulonnais, the highest part of the *loricatus* Zone sequence is condensed and only the *nitidus* Subzone of the *lautus* Zone is represented (Owen 1971a). In the Pays de Caux, sediments of *dentatus* and *loricatus* Zones age are condensed and incomplete and consist of pebbly loam marking the proximity of this area to the margin of the depositional basin (Owen 1971a: 102–107, Destombes, Juignet & Owen 1977). Near to the positive areas of Armorica, Morvan and the Ardennes, Middle Albian sediments are generally sandier, particularly in the *intermedius* Subzone and, when preserved, in the later part of the *loricatus* Zone.

Upper Albian: In France, sediments of Upper Albian age rest non-sequentially upon a planed-off surface of Middle Albian sediments as in England. However, at Wissant (Boulonnais) the lower part of the *cristatum* Subzone is represented by clays instead of, as elsewhere, in a phosphatic nodule bed containing a pebble fauna of this age or within a non-sequence. This is the only known locality in western Europe at present at which the sediments of the earliest part of the *cristatum* Subzone are preserved in a relatively uncondensed state (Owen 1971a). Knowledge of the Upper Albian ammonite zonal sequence in France stems from the work of Breistroffer (e. g. 1940, 1947), who brought up to date much of the work of Jacob (1908) on the classic sections in south-east France and adjacent Switzerland. Much work still requires to be done, however, to determine the detailed zonal stratigraphy of the Upper Albian sediments in the outcrops around the Paris Basin, Pays de Bray and Normandy. Largely through the work of Destombes & Destombes (1938, 1965), Destombes (1958), Larcher, Rat & Malapris (1965) and unpublished information collected by the writer, it is apparent that the central basin areas were the site of clay sedimentation and that more sandy deposits and, eventually, Gaize were accumulated near the margins of the depositional basin flanked by the variscide massifs as in Germany and England.

Above the basal *cristatum* Subzone clays at Wissant referred to above, the remainder of the *cristatum* and the *orbignyi* Subzones are severely condensed, but were originally clays. The bulk of the Upper Gault clays at Wissant is apparently of *variosum* Subzone age. In the south-eastern part of the Paris Basin (Haute Marne and Aube), the Upper Albian is represented by clays and marls. Upper Albian sediments close to the Armorican and Morvan massifs and in the Ardennes are for the most part in a sandy or hard ‚Gaize' facies comparable to the English Upper Greensand and the German Flammenmergel. There is some evidence that the base of the Gaize is diachronous, being earlier nearer the massifs. In the coastal sections of the Pays de Caux, the *varicosum* Subzone is still represented by sandy clay and loam. The overlying Gaize is of *auritus* Subzone and *dispar* Zone age (e. g. Destombes, Juignet & Owen 1977). Elsewhere, in the marginal areas, the *varicosum* Subzone may also be included within the sandy facies as well as the *auritus*, *rostratum* and *perinflatum* Subzones. The writer has pointed out recently that the so-called ‚Vraconnian' substage is the equivalent of one Subzone, that of *Mortoniceras (Durnovarites) perinflatum*, and the term should be abandoned (Owen 1976a: 492).

4. Palaeogeography

The similarity of Albian and Cenomanian sediment sequences in northern Germany and eastern England, suggests that they formed part of a common mid-Cretaceous North Sea basin, one that had been in existence since the late Jurassic early Cretaceous tectonic movements which have affected much of Europe (Fig. 5). The faulting and folding which occurred during this phase altered profoundly the previous pattern of depositional areas seen in the Jurassic sediments

(Owen 1971a: 143, 1971b). During the early and middle parts of the *tardefurcata* Zone (*schrammeni* and *acuticostata* Subzones) and the upper part of the *mammillatum* Zone of the Lower Albian, and the *dentatus* and *lautus* Zones of the Middle Albian, there is evidence that a narrow strait was open extending from the Albian North Sea northeastward along the graben between the Caledonide belts of Greenland and Norway as far north as Spitzbergen. Lower and Middle Albian sediments within this region contain a typical hoplitinid provincial ammonite fauna. This North Sea area appears to have been totally separated from the growing Atlantic (Owen 1976b) until well within the Upper Cretaceous. Johnson (1975) indicates a sea-way between Scotland and Greenland linking the Atlantic with the North Sea during the Albian, but there is no published bore-hole information to support this contention. Unfortunately, no detailed information is available concerning the Albian sequence within the area of the North Sea traversed by recent gas and oil exploration work.

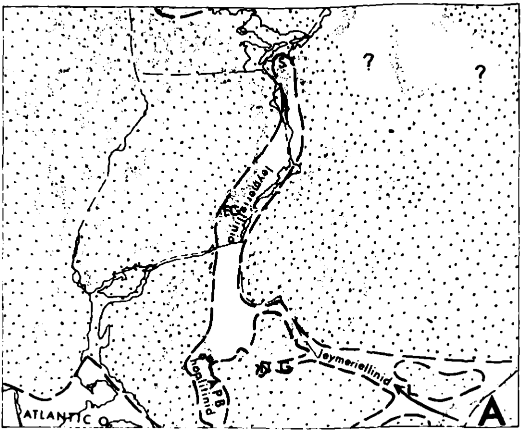
During the Lower Albian (Fig. 5A), in the *tardefurcata* Zone, the London – Ardennes platform appears to have been partly land (towards the Ardennes) and a Region of very shallow seas and islands which provided a tenuous link between the North Sea and the shallow seas of England and France. It was only in the *regularis* Subzone that *Leymeriella* spread from the North Sea into the region of the Anglo – Paris basin and further south in France. During the *mammillatum* Zone, the Anglo – Paris basin, although subjected to folding movements, slowly subsided and in the southern area of France and the Paris Basin connections with the Tethys occurred at intervals.

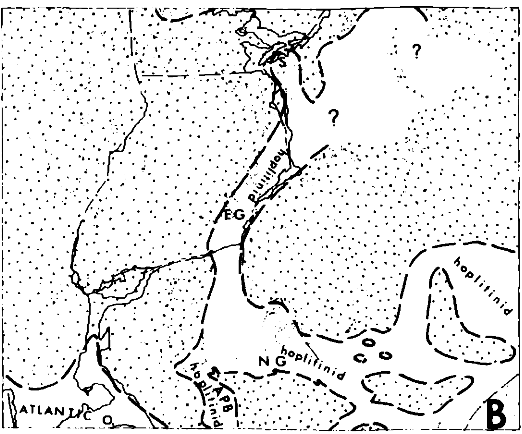
During the Middle Albian (Fig. 5B), in the *dentatus* Zone, the area of the London Platform was a site of clay sedimentation overall certainly by the *spathi* Subzone. No physical barriers to ammonite migration would have then existed between the North Sea and Anglo Paris basins. Firm, but perhaps ephemeral, links existed between the Paris basin and the Tethys which permitted intermittent invasions of a southern ammonite fauna into the hoplitinid province.

The early Upper Albian, mid-*cristatum* Subzone, phase of tectonic disturbance which produced faulting, tilting and submarine erosion of sediments in the region of the Anglo-Paris basin and complete removal of the Lower Gault in the north London-south Essex region, had a profound effect also on the narrow strait extending northward to Spitzbergen (Fig. 5C). In Spitzbergen (Nagy 1970) and Greenland (Spath 1943, 1946), the hoplitinid fauna of the *cristatum* Subzone is mixed with the *Gastroplites* fauna of the Arctic-North American Boreal as indicating that a marine connection had opened between Spitzbergen and the Canadian Arctic. Whatever the precise systematic position of *Gastroplites cantianus* Spath, found in the *cristatum* Subzone sediments at Folkestone, Kent, might be (Jeletzky 1977: 113), it is a gastroplitinid ammonite closely related to the *Gastroplites* fauna of the Arctic-North American Boreal province (or gastroplitinid province of Owen 1973: 149) and totally different from the members of the hoplitinid fauna of the european seas. *G. cantianus* marks the southernmost known penetration of this Arctic provincial fauna during the short period in the Upper Albian when the link between the Greenland – Spitzbergen strait and the Arctic seas remained open. This connection and the Greenland – Spitzbergen strait itself were closed shortly after the *cristatum* Subzone, and there is no evidence of any post-*orbignyi* Subzone Albian ammonite faunas of the hoplitinid province penetrating northward into these areas.

The tectonic disturbances outlined above coincided with a major invasion of the european shelf seas by ammonites of the Tethyan and southern province called here the brancoceratid faunal province (Figs 5C, D). This fauna, which had made minor incursions into the hoplitinid

L. Albian, mid-tardefurc zone





LEGEND

Modern 1000m isobath and pecked coastline

presumed land areas and coastline

Ammonite migration routes
G=gastroplitind B=brancoceratid

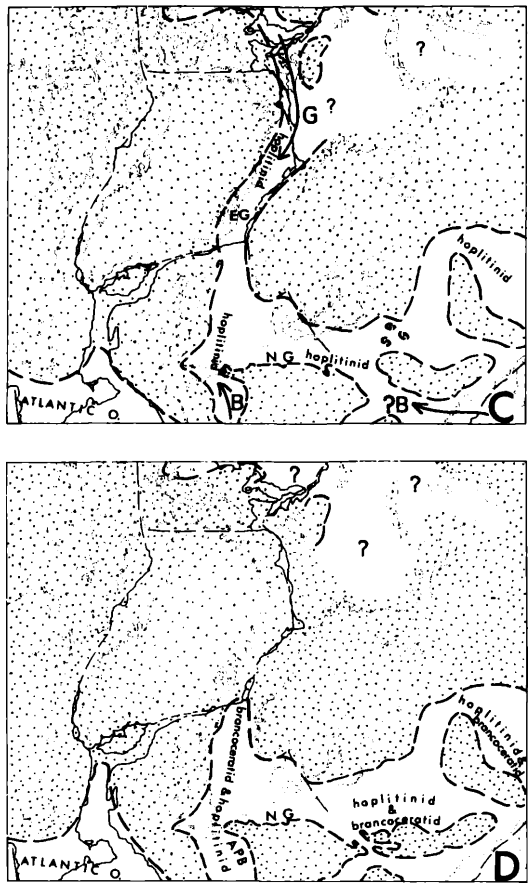


Fig. 5. Palaeogeographic maps of north-west Europe during the Albian: A. Lower Albian, mid-*tardefurcata* Zone (*acuticostata* Subzone); B. Middle Albian, *loricatus* Zone (*intermedius* Subzone); C. Early Upper Albian *cristatum* Subzone; D. Upper Albian, *dispar* Zone. Abbreviations: S–Spitzbergen, EG–East Greenland, APB–Anglo-Paris Basin, NG–North Germany. Reconstructions are plotted on a zenithal equidistant projection centred upon the approximate position of the lower Cretaceous North Pole. The fit of the continental regions together and the ocean floor spreading in the Atlantic are in accordance with the available field data. The reconstructions assume, therefore, an expanding Earth (Owen 1976b).

province during the Middle Albian only to retreat, now stayed to colonize the whole province and to co-exist with the endemic hoplitinids throughout the Upper Albian.

It is also apparent that a migration route into the north German area existed to the east through Poland south eastward into southern Russia and thence to the Tethys, up to and including the Lower Albian. It is likely that this route was also important during the Middle and Upper Albian. However, the determination of its nature must await completion of detailed and comprehensive studies of the sequences in eastern Europe now being carried out by our Polish and Russian colleagues.

References

Althoff, W. & Seitz, O. (1934): Die Gliederung des Albium bei Bielefeld. *Abh. westf. Prov. Mus. Naturk.*, 5 5–26, Münster.

Amédro, F. & Destombes, P. (1975): Observations nouvelles sur l'Albien inférieur des Ardennes. *Bull. Int Géol. Bass. Paris, 12:* 57–58, Paris.

Bertram, H. & Kemper, E. (1971): Das Alb von Hannover. *Beih. Ber. nathist. Ges. Hannover, 7:* 27–74, 3 Taf., Hannover.

Breistroffer, M. (1940): Révisions des Ammonites du Vraconian de Salazac (Gard) et considérations générales sur ce sous-étage Albien. *Trav. Lab. Géol. Univ. Grenoble, 22:* 73–171, Grenoble.

– (1947): Sur les Zones d'Ammonites dans l'Albien de France et d'Angleterre. *Trav. Lab. Géol. Univ Grenoble, 26:* 17–104, Grenoble.

Brinkmann, R. (1937): Biostratigraphie des Leymeriellenstammes nebst Bemerkungen zur Paläogeographie des nordwestdeutschen Alb. *Mitt. Geol. Staatsinst. Hamb., 16:* 1–18, Hamburg.

Casey, R. (1957): The Cretaceous Ammonite genus *Leymeriella*, with a systematic account of its British occurrences. *Palaeontology, 1:* 28–59, London.

– (1960–): A Monograph of the Ammonoidea of the Lower Greensand. Palaeontogr. Soc. (Monogr. not yet completed, London.

– (1961): the Stratigraphical Palaeontology of the Lower Greensand. *Palaeontology, 3:* 487–621, 8 Taf. London.

Destombes, J.-P. & Destombes, P. (1938): Remarques sur l'Albien du Pays de Bray. *Ann. Soc. géol., N.* 63 119–125, Lille.

Destombes, P. (1958): Révision de l'Albien de la Région du Havre. Deductions paléogéographiques sur NW du Bassin Parisien au Crétacé moyen. *Bull. Soc. géol. Fr., (6) 8:* 305–313, Paris.

– (1970): Biostratigraphie des Ammonites dans l'Albien inférieur et moyen, argileux, du Bassin de Paris *C. R. Acad. Sci. Paris, D 270:* 2061–2064, Paris.

– (1973): Hoplitidae et zonation nouvelle de l'Albien inférieur de Bully – St. Martin (Bray occidental). *C. R. Acad. Sci. Paris, D 277:* 2145–2148, Paris.

– (1977): 3. The Gault at Bully, Pays de Bray. *In* Destombes, P., Gamble, H. J., Juignet, P. & Owen, H. G.: Cretaceous and lower Tertiary of Seine-Maritime, France: a guide to key localities. *Proc. Geologists' Assoc., 88:* 25–27, London.

Destombes, P. & Destombes, J.-P. (1965): Distribution Zonale des Ammonites dans l'Albien du Bassin de Paris. *Mém. Bur. Rech. géol. min., 34:* 255–270, Paris.

Destombes, P.; Juignet, P. & Owen, H. G. (1977): 2. The Cretaceous in the Cliffs of the Bec du Caux. *In* Destombes, P., Gamble, H. J., Juignet, P. & Owen, H. G.: Cretaceous and lower Tertiary of Seine-Maritime, France: a guide to key localities. *Proc. Geologists' Assoc., 88:* 18–25, 1 Taf., London.

Destombes, P.; Juignet, P. & Rioult, M. (1973): Ammonites de l'Aptien-Albien du Bec du Caux, Normandie (N. W. France). *Bull. Soc. géol. Normandie, 61:* 49–106, 5 Taf., Le Havre.

Ernst, W. (1922): Über den Oberen Gault von Lüneburg. *Z. dt. geol. Ges., 73,* M 12: 191–322, Berlin.

– (1927): Ueber den Gault von Helgoland. *In* Pompeckj-Festband. *N. Jb. Mineral. Geol. Paläont. Beil.-Bd., 58B:* 113–156, Stuttgart.

Georgi, K.-H. (1976): Mikrofaunistisch-lithologische Untersuchungen der Hilssandstein-Region (Apt/Alb) im Raum Salzgitter-Goslar. *Mitt. Geol. Inst. Techn. Univ. Hannover, 13:* 5–112, 7 Taf. Hannover.

Jacob, C. (1908): Études Paléontologiques et Stratigraphiques sur la partie moyenne des terrains Crétaces dans Les Alpes Françaises et Les Régions voisines. *Trav. Lab. Géol. Univ. Grenoble, 8:* 280–590, 6 Taf., Grenoble.

Jeletzky, J. A. (1977): Mid-Cretaceous (Aptian to Coniacian) history of Pacific Slope of Canada. *Spec. Pap. palaeont. Soc. Japan, 21:* 97–126, 1 Taf., Fukuoka.

Johnson, R. J. (1975): The base of the Cretaceous: A Discussion. *In* Woodland, A. W. (Ed.): Petroleum and the Continental Shelf. *1:* 389–398, Institute of Petroleum, London.

Jordan, H. (1968): Gliederung und Genese des Flammenmergels (Alb) in Hils- und Sackmulde (Süd-Hannover). *Z. dt. geol. Ges., 117:* 391–424, Hannover.

Jordan, H. & Schmid, F. (1968): Zur Altersstellung und Gliederung des Flammenmergels (Oberalb) im Sackwald. *Geol. Jb., 85:* 55–66, Hannover.

Kemper, E. (1973): The Aptian and Albian stages in northwest Germany. *In* Casey, R. & Rawson, P. F. (Ed.): The Boreal Lower Cretaceous. *Geol. J. Spec. Issue, 5:* 345–360, Liverpool.

– (1975): Die Cephalopoden aus dem Unter-Alb (Zone der *Leymeriella tardefurcata*) von Altwarmbüchen. *Ber. nathist. Ges., 119:* 87–111, Hannover.

– (1976): Geologischer Führer durch die Grafschaft Bentheim und die angrenzenden Gebiete. (5. Auflage): 1–206, 34 Taf., Nordhorn, Bentheim.

Kemper, E.; Rawson, P. F.; Schmid, Fr. & Spaeth, Chr. (1974): Die Megafauna der Kreide von Helgoland und ihre biostratigraphische Deutung. *Newsl. Stratigr., 3:* 121–137, 2 Tab., Leiden.

Larcher, C.; Rat, P. & Malapris, M. (1965): Documents paléontologiques et stratigraphiques sur l'Albien de l'Aube. *Mém. Bur. Rech. géol. min., 34:* 237–253, Paris.

Nagy, J. (1970): Ammonite faunas and stratigraphy of Lower Cretaceous (Albian) rocks in southern Spitzbergen. *Skr. norsk Polarinst., 152:* 1–58, 12 Taf., Oslo.

Owen, H. G. (1971a): Middle Albian Stratigraphy in the Anglo-Paris Basin. *Bull. Brit. Mus. nat. Hist. (Geology) Suppl., 8:* 1–164, 3 Taf., London.

– (1971b): The Stratigraphy of the Gault in the Thames Estuary and its bearing on the Mesozoic Tectonic History of the Area. *Proc. Geologists' Assoc., 82:* 187–207, London.

– (1972): The Gault and its junction with the Woburn Sands in the Leighton Buzzard area, Bedfordshire and Buckinghamshire. *Proc. Geologists' Assoc., 83:* 287–312, London.

– (1973): Ammonite faunal provinces in the Middle and Upper Albian and their palaeogeographical significance. *In* Casey, R. & Rawson, P. F. (Ed.): The Boreal Lower Cretaceous. *Geol. J. Spec. Issue, 5:* 145–154, Liverpool.

– (1976a): The stratigraphy of the Gault and Upper Greensand of the Weald. *Proc. Geologists' Assoc., 86:* 475–498, London.

– (1976b): Continental Displacement and expansion of the Earth during the Mesozoic and Cenozoic. *Phil. Trans. R. Soc., 281:* 223–291, London.

Price, R. J. (1977a): The stratigraphical zonation of the Albian sediments of north-west Europe, as based on Foraminifera. *Proc. Geologists' Assoc., 88:* 65–91, London.

– (1977b): The evolutionary interpretation of the Foraminiferida *Arenobulimina, Gavelinella,* and *Hedbergella* in the Albian of north-west Europe. *Palaeontology, 20:* 503–527, 3 Taf., London.

Schott, W. *et al.* (1967, 1969): Paläogeographischer Atlas der Unterkreide von Nordwestdeutschland mit einer Übersichtsdarstellung des nördlichen Mitteleuropa. *I & II,* 306 Kart. (1967). Erläuterungen, 315 S. (1967, 1969). Bundesanst. f. Bodenforsch., Hannover.

Spitz, O. (1956): Über das Vorkommen der Gattung *Douvilleiceras* im unteren Mittelalb von Nordwestdeutschland. *Geol. Jb., 71:* 643–644, Hannover.

Spaeth, Chr. (1971): Untersuchungen an Belemniten des Formenkreises um *Neohibolites minimus* (Miller 1826) aus dem Mittel- und Ober-Alb Nordwestdeutschlands. *Beih. geol. Jb., 100:* 1–127, 9 Taf., Hannover.

– (1973): *Neohoplites ernsti* and its occurrence in the Upper Albian of northwest Germany and England. *In* Casey, R. & Rawson, P. F. (Ed.): The Boreal Lower Cretaceous. *Geol. J. Spec. Issue, 5:* 361–368, Liverpool.

Spath, L. F. (1923–1943): A Monograph of the Ammonoidea of the Gault. Palaeontogr. Soc. (Monogr.), *1 & 2:* 1–787, 72 Taf., London.

– (1946): Preliminary notes on the Cretaceous ammonite faunas of East Greenland. *Medd. Grønland, 132:* 1–12, København.

Speetzen, E.; El-Arnauti, A. & Kaever, M. (1974): Beitrag zur Stratigraphie und Paläogeographie de Kreide-Basisschichten am SE-Rand der Westfälischen Kreidemulde (NW-Deutschland). *N. Jb Mineral. Geol. Paläont. Abh., 145*: 207–241, Stuttgart.

Stolley, E. (1937): Die Stratigraphie des norddeutschen Obergaults, Minimus-Tons und Flammenmergel im Vergleich mit dem englischen Lower and Upper Gault. *N. Jb. Mineral. Geol. Paläont., Beil. Bd 78(A)*: 1–65, Stuttgart.

Wiltshire, T. (1869): On the Red Chalk of Hunstanton. *Quart. J. geol. Soc. London, 25*: 185–192, London