Albian Stage and Substage boundaries

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The base of the Albian Stage has been defined in the European province at the earliest appearance of the ammonite *Leymeriella ('Proleymeriella') schrammeni anterior* Brinkmann, the earliest member of the important 'mid-Cretaceous' ammonite superfamily Acanthocerataceae. A type section in the Harz fore-deep region of northern Germany has been proposed. A certain amount of intra-provincial variation in the ammonite fauna around this boundary is known in the European province. This does not provide insuperable difficulties, however, in the recognition of late Aptian and early Albian ages in the various lithological sequences within this province. *Leymeriella* is generally unknown in the Canadian-Russian Arctic province, but the association of a *Leymeriella* of *schrammeni* Subzone age with a *Freboldiceras* in north Greenland, provides a useful correlation of these largely disparate provincial ammonite faunas. Correlation with the Gondwanan province is less certain at present. The length of Albian time (14–15.5 Ma) has led to the recommendation that Substage boundaries should be defined for the Middle and Upper Albian. The Subzone of *Lyelliceras lyelli* provides a good base for the Middle Albian, one that can be recognized in both the European and Gondwanan provinces. The base of the Upper Albian is marked by *Dipoloceras cristatum* an ammonite which is also of widespread occurrence in both of these provinces. The occurrence of the Arctic province ammonite *Pseudogastroplites* in the *cristatum* Subzone provides a good marker for correlation of this province with the European and Gondwanan provinces.

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The Albian Stage is characterised by three distinct ammonite faunal provinces; the European, Arctic and Gondwanan. The stratigraphy and ammonite sequence of the European province has been studied in detail (eg. Spath 1923–43, Breistroffer 1947, Casey 1961 & 1960–, Destombes 1979, Owen 1971, 1976, 1984, Saveliev 1974, 1976, 1981) and the so-called 'standard' ammonite zonal and subzonal scheme for the Albian applies, essentially, to that region alone. The Arctic province had an ammonite fauna endemic to it which is largely disparate to both the European province and the North Pacific subprovince of the Gondwanan province. A separate zonation has been developed for this Arctic province (eg. Imlay 1959, 1960, Jones & Grantz 1967, Jeletzky 1980), and the few points of correlation with the European province have been discussed by Birkelund & Håkansson (1983), Jeletzky (eg. 1980) and Owen (1973).

The Gondwanan province includes all the geographic regions of the Earth not included in the European and Arctic provinces. Invasions of ammonites characteristic of the Gondwanan province into the European province occurred throughout the Albian. In the Upper Albian, the more cosmopolitan elements co-existed with the endemic hoplitinids in the European province. Points of correlation are relatively frequent, therefore, within the late Lower, Middle and Upper Albian between these two provinces. Unfortunately, there appears to be a widespread sedimentary hiatus in the epicontinental seas of the Gondwanan province involving the late Aptian (*Hypacanthoplites jacobi* Zone) and the early Albian (the equivalent of the *Leymeriella tardefurcata* Zone). There are problems, therefore, in the recognition of the base of the Stage on a global scale; problems which not only affect the ammonite faunas, but the ostracod and foraminferal faunas and the nannoplankton as well.

The length of the Albian in terms of 'absolute' isotope dating (14–15.5 Ma. eg. Odin 1982, Harland et al. 1982), makes it advisable to recognize and define Substage boundaries for the Middle and Upper Albian. The definition of these two additional boundaries provides index ammonites (*Lyelliceras lyelli* and *Dipoloceras cristatum* respectively) which are geographically widespread in the epicontinental sea deposits of both the Gondwanan and European provinces. It is possible to correlate these short intervals with the

Zone	Subzones			
	N. Germany	Anglo-Paris Basin	Soviet Union	
Leymeriella tardefurcata	*Leymeriella regularis*	*Leymeriella regularis*	*Leymeriella regularis*	lower Albian (part)
	Leymeriella acuticostata	*Hypacanthoplites milletioides*	*Leymeriella tardefurcata*	
	Leymeriella schrammeni	*Farnhamia farnhamensis*	?	
Hypacanthoplites jacobi		*Hypacanthoplites anglicus*		
		Hypacanthoplites rubricosus		
		Nolaniceras nolani		upper Aptian (part)

Table 1. Lower boundary of the Albian in the European province according to the ammonite zonation.

Arctic faunal province. Apart from the distribution of ammonites, micropalaeontological markers are also available at these Substage boundaries which are of use in the classification of oceanic borehole core sequences in which ammonites are absent or very uncommon.

The base of the Albian Stage

Breistroffer (1947) recommended that the base of the Albian Stage should be placed at the beginning of the *Leymeriella tardefurcata* Zone. Hitherto, Spath (eg. 1943, 668) had included in the Albian his Zone of *Diadochoceras nodosocostatum* which occurred immediately before the Zone of *Leymeriella tardefurcata*. According to Spath, the *nodosocostatum* Zone is characterized by species of what are now called *Nolaniceras* in the early part of the Zone (*nolani* Subzone) and *Hypacanthoplites* (*jacobi* Subzone) in the later part; ammonites of strong Aptian affinities. Casey (eg. 1957, 1961) followed Breistroffer in placing the base of the Albian Stage at the beginning of the *tardefurcata* Zone (base of the *Leymeriella schrammeni* Subzone), and this practice has been generally followed. The base of the *schrammeni* Subzone, and of the Albian Stage in the European faunal province, is marked by the appearance of *Leymeriella schrammeni anterior* Brinkmann, the first member of the genus *Leymeriella* which proliferated within the *tardefurcata* Zone and gave rise to the important superfamily Acanthocerataceae (eg. Brinkmann 1937, Casey 1957, Kemper 1975, Saveliev 1973).

The author has recommended that a horizon, the junction of Beds 6a and 6b in a measured section of clays spanning the uppermost Aptian and lowest Albian exposed near Vörhum in the Hannover-Braunschweig area of north Germany, be taken as a formal boundary stratotype (Owen 1979, 569). This lithological boundary and its palaeontology in north Germany has been described in some detail (Kemper et al. 1982a).

Within many areas of the European faunal province, the earliest Lower Albian is either not represented by sediment sequences, or is subject to minor but important ammonite provincialism (table 1). *Leymeriella* appears to have been en-

demic initially to the Albian North Sea basin, the margins of which included North Germany and eastern Greenland, with a narrow strait linking the Arctic epicontinental seas marked by Spitzbergen and north Greenland (Nagy 1970, Owen 1973, Birkelund & Håkansson 1983). Although *Leymeriella* extended to areas of eastern and southern Europe by the early *Leymeriella acuticostata* Subzone (Owen 1984), it did not become ubiquitous in the European province until the *Leymeriella regularis* Subzone. In southern England and northern France, pre-*regularis* Subzone *tardefurcata* Zone sediments contain species of *Hypacanthoplites* which also occur in the *schrammeni* and *acuticostata* Subzones in north Germany, but *Leymeriella* is absent. Using this occurrence of species of *Hypacanthoplites* common to north Germany and southern England, Casey (1961) has correlated his Subzone of *Farnhamia farnhamensis* with that of *Leymeriella schrammeni*. Unfortunately, the hoplitid genus *Farnhamia* has not yet been found outside southern England.

Interprovincial correlation of the equivalent of the *schrammeni* Subzone is also difficult. Among ammonite alternatives which might be considered to be suitable to mark the base of the Albian, and which are geographically more widespread in distribution, none provide as precise a boundary for the Stage as does *Leymeriella* in the European province. *Hypacanthoplites* occurs in the Gondwanan province as a rarity, but its species are too long ranging and imprecise to be suitable for use as boundary markers. It does not occur in the Arctic province. To extend the base of the Albian back to the base of the *Hypacanthoplites jacobi* Zone would not solve the problem of interprovincial correlation. It would involve, also, the placing of the Albian boundary at a non-sequence in most areas outside north Germany, the present boundary stratotype area. *Douvilleiceras* is a cosmopolitan ammonite genus in the European and Gondwanan provinces. It appears first in the *regularis* Subzone of the *tardefurcata* Zone and has a long time range into the early Middle Albian (*Lyelliceras lyelli* Subzone). Unfortunately, the morpho-species of *Douvilleiceras* are not sufficiently distinctive to provide a precise base for the Stage which can be recognized easily over a wide area. Because of the presence of *Douvilleiceras*, it has been assumed that sediment containing this genus in a number of areas in the Gondwanan province are of Lower Albian, *Douvilleiceras mammillatum* Zone age. In fact, they can be shown in a number of instances to be of early Middle Albian age.

It would appear to be sensible at present to retain the base of the Albian at the base of the *schrammeni* Subzone in the well documented European province, and to investigate the occurrence of extra-European province visitors for the purposes of correlation. Much of this investigation still requires to be done, but it is becoming clear that a major sedimentary hiatus affects the late Aptian and at least the early Lower Albian throughout much of the Gondwanan province. The recent discovery of early Albian ammonites in Peary Land, north Greenland (Birkelund & Håkansson 1983) has largely solved the problem of correlation of the earliest Albian of the European province with that of the Arctic province. *Leymeriella trollei* Birkelund & Håkansson indicates a *schrammeni* Subzone age, although not the earliest part of the Subzone. It is associated with the Arctic genus *Freboldiceras*. *Freboldiceras praesingulare* Birkelund & Håkansson is considered to be slightly earlier in age than *F. singulare* Imlay of the *Brewericeras hulenense* Zone of Alaska (Imlay 1960). A critical examination of the occurrence of *Arcthoplites* indicates that it is confined to the *Leymeriella acuticostata* Subzone (the *L. tardefurcata* Subzone of eastern European workers). In Peary Land, Birkelund & Håkansson (1983) report the occurrence of *Arcthoplites jachromensis* (Nikitin) a few metres above the late *schrammeni* Subzone fauna. Nagy (1970) records the association of the *acuticostata* Subzone species *Leymeriella germanica* Casey with a *Freboldiceras* – *Arcthoplites* fauna in southern Spitzbergen.

In terms of the micro-palaeontology of the late Aptian and early Albian, there are no suitable appearances of foraminiferal or nannoplankton species known at present (eg. Hart et al. 1981, Taylor 1982). However, the recent revision of the ostracods of the *Protocythere nodigera* group by Kemper (1982b) provides a number of species, including *P. nodigera* sensu stricto, which appear close to the base of the Albian as defined by the ammonite fauna.

The base of the Middle Albian Substage

The earliest Zone of the Middle Albian in the European (hoplitinid) faunal province, that of *Hoplites dentatus,* has included since its definition by Casey (1961), the Subzone of *Hoplites ('Isohoplites') eodentatus.* This Subzone is characterized by ammonites which are morphologically transitional between *Pseudosonneratia* of the *typica* group and *Hoplites* of the *dentatus* group. It replaced the poorly defined Subzone of *Douvilleiceras inaequinodum* of Spath (eg. 1941, 668), included by him in the *D. mammillatum* Zone. Subsequent investigation of the ammonite fauna of this Subzone, and the need to be able to define a Substage boundary for the Middle Albian capable of widespread geographical recognition, has suggested the *eodentatus* Subzone be regarded as latest Lower Albian. Its ammonite fauna is essentially of *mammillatum* Zone aspect and it is included here in that Zone (and see Owen 1984).

It is fortunate that the *eodentatus* Subzone, which can be recognized only in the European (hoplitinid) faunal province, has seen invasions of the more cosmopolitan douvilleiceratid and lyelliceratinid ammonites characteristic of the Gondwanan (brancoceratid) faunal province. Among the endemic hoplitinids such as *Hoplites ('Isohoplites') eodentatus* and its allies, which are closer to *Pseudosonneratia* and should be included in that genus (Saveliev 1976), species of *Otohoplites* are common. At the end of the Subzone, the *eodentatus* group exhibited a relatively sudden change in the arrangement of the rib-endings on the ventral-lateral shoulders from the isometric arrangement characteristic of *Pseudosonneratia* to the en-echelon pattern characteristic of *Hoplites* sensu stricto. In the hoplitinid faunal province, the base of the overlying Subzone of *Lyelliceras lyelli,* here regarded as the base of the Middle Albian Substage, can be placed at this relatively sudden and general adoption of the ventral aspect of *Hoplites.*

Among the more cosmopolitan elements, *Douvilleiceras* is common in the *eodentatus* Subzone; it is rare in deposits of *Lyelliceras lyelli* Subzone age, although it occurs up to the end of that Subzone. The lyelliceratinid genus *Tegoceras,* which occurs in the *mammillatum* Zone in the European province albeit that it is rare, also undergoes a relatively sudden morphological change at the end of the *eodentatus* Subzone to produce *Lyelliceras lyelli* and its relatives of the *lyelli* Subzone. The base of the *lyelli* Subzone is marked by the occurrence of *Lyelliceras pseudolyelli* (Parona & Bonarelli), *L. hirsutum* (Parona & Bonarelli) and *L. huberianum* (Pictet) among other species in both the European and Gondwanan provinces (eg. Owen 1971, Destombes, Juignet & Rioult 1973, Destombes 1979).

The Subzone of *Lyelliceras lyelli* is capable of wide geographic recognition in both the hoplitinid and brancoceratid faunal provinces (Owen 1971, 1984) and its base, defined above, is an ideal boundary for the base of the Middle Albian Substage. The best sedimentary and faunal sequence across the boundary is situated in the classic region of the Aube, France, where, a number of sections can provide a regional stratotype (eg. Owen 1971, Destombes 1979). Problems do arise, however, in correlating the Arctic province with the rest of the World at this boundary (Owen 1973). However, in Spitzbergen *Pseudosonneratia ('Isohoplites')* and early *Hoplites* sensu stricto are both associated with species of the Arctic genus *Grycia* including *G. sablei* (Imlay) (Nagy 1970).

In terms of micropalaeontological markers, the base of the *lyelli* Subzone corresponds to the base of Zone 3(i) of Price (1977 and see Hart et al. 1981). Among nannoplankton species which appear at about this boundary, *Prediscosphaera cretacea, Dictyococcites parvidentatus, Gaarderella granulifera* and *Braarudosphaera regularis* might prove useful in the classification of oceanic borehole core sequences (Taylor 1982). In this context, it is worth noting that a *Lyelliceras lyelli* Subzone ammonite fauna has been described from the Deep Sea Drilling Project boring, Hole 398D, on the Biscay margin (Renz 1979).

The base of the Upper Albian Substage

A strong case for drawing the lower boundary of the Upper Albian at the appearance of the ammonite *Dipoloceras cristatum* (Brongniart), and contemporary species of *Dipoloceras,* was made

by Breistroffer (1947). With few exceptions, this practice has been followed by subsequent workers. *Dipoloceras cristatum* and its close relatives are of widespread geographical distribution in both the European and Gondwanan provinces and provide, therefore, an easily recognized marker for the purposes of correlation. In the European (hoplitinid) province, the appearance of this group coincides with the start of a general colonisation by the brancoceratinid, mojsisovicsiinid and mortoniceratinid ammonites of the Gondwanan province, which co-existed with the endemic hoplitinids throughout the remainder of the Albian. In a few areas of the European province (eg. Transcaspia in the Soviet Union) *Dipoloceras* has not yet been found, but species of *Semenovites* which occur also in the *cristatum* Subzone of western Europe are well represented and permit a direct correlation to be made (Owen 1984).

A marine link between the European (hoplitinid) and Arctic (gastroplitid) faunal provinces existed for a short interval of time in the early Upper Albian (Owen 1973, Jeletzky 1980). *Pseudogastroplites,* an Arctic province ammonite genus, is represented by a unique specimen of *P. cantianus* (Spath) in Bed VIII of the Gault at Folkestone, Kent, south east England. The correlation of the Arctic province ammonite sequence with that of Europe given by Jeletzky (1980, 20) is not based on firm evidence. The possibility of a sequence of *Pseudogastroplites* faunas, as advocated by Jeletzky, of which *P. arcticus* Jeletzky is the last and might be the equivalent of the *cristatum* Subzone of Europe, needs further investigation.

The ammonite occurrences can be supplemented by the relatively rapid change in morphology shown in the bivalve genus *Birostrina.* At the base of the *cristatum* Subzone in the little-condensed clay sequences at Wissant, north east France, and Folkestone, south east England, *Birostrina concentrica* (Parkinson), the abundant concentrically-ribbed form of Middle Albian deposits, changes into the radially-ribbed form *B. sulcata* (Parkinson) by means of a short-lived intermediate stage called *B. 'subsulcata'* (Wiltshire). *B. sulcata* reverts back into the *concentrica* form, again by means of a *subsulcata* stage, by the beginning of the *Hysteroceras varicosum* Subzone. Comparisons with the ammonite faunas show that these changes are synchronous events wherever *Birostrina* is found.

The section at Folkestone, Kent, is selected here as the stratotype of the Middle Albian – Upper Albian boundary within the hoplitinid province. It can be argued that the basal part of Bed VIII of the Gault of Folkestone is a condensed phosphatic pebble horizon produced by a period of current scour associated with tectonic disturbance in the early part of the *cristatum* Subzone. However, this condensation is not extensive and both at Folkestone and in borings nearby, the lower part of Bed VIII is represented by a thin clay sequence in which the vertical change from *B. concentrica* to *B. sulcata,* mentioned above, is seen to occur. At Folkestone, these earliest *cristatum* Subzone sediments are preceded by sediments of *Anahoplites daviesi* Subzone age which yield ammonites of the *Anahoplites rossicus* Subzone (sensu Saveliev 1981) of the Soviet Union (Owen 1984). Although a more complete sequence of clays of earliest *cristatum* Subzone age is present at Wissant, on the opposite side of the Channel from Folkestone, *daviesi* Subzone sediments are absent (Owen 1971). Within the broad Gondwanan faunal province, the best known sequence across the Middle Albian – Upper Albian boundary is situated in Tarrant County, Texas, in the United States (eg. Young 1966) where the *cristatum* Subzone is represented within the Goodland Limestone.

No precise foraminiferal or nannofossil Zone boundaries coincide with the base of the *cristatum* Subzone (eg. Price 1977, Taylor 1982). However, *Tranolithus salillum* appears at, or near, the base of the *cristatum* Subzone and might prove a useful marker fossil.

Summary

At the Symposium on Cretaceous Stage Boundaries held in Copenhagen in October 1983, the following recommendations were made concerning the Albian.

1. The lower boundary of the Albian Stage be placed at the base of the Subzone of *Leymeriella schrammeni* with a stratotype section at Vöhrum in the Hannover-Braun-

schweig region of north Germany (Owen 1979).

2. The lower boundary of the Middle Albian Substage be placed at the base of the *Lyelliceras lyelli* Subzone which also corresponds with the base of the foraminiferal Zone 3(i) of Price, the stratotype section being in the Aube, France.

3. The lower boundary of the Upper Albian Substage be placed at the base of the *Dipoloceras cristatum* Subzone with a stratotype section at Folkestone, Kent, England. This boundary coincides with the morphological change in the bivalves from *Birostrina concentrica* (Parkinson) to *Birostrina sulcata* (Parkinson). It is possible that the nannoplankton species *Tranolithus salillum* appears at this level.

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Dansk sammendrag

Etagen albiens nedre grænse defineres på grundlag af første optræden af *Leymeriella schrammeni* og en grænse stratotype foreslås i Nordtyskland. Denne grænse kan korreleres med den arktiske provins, men endnu ikke med Gondwana provinsen. På grund af etagens lange varighed (14–15,5 mill. år) anbefales det at definere nedre, mellem og øvre albien formelt. Mellem og øvre albien foreslås defineret på grundlag af henholdsvis første optræden af *Lyelliceras lyelli* og *Dipoloceras cristatum*.

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