

SUBOREAL/BOREAL AMMONITE SUCCESSION AT THE OXFORDIAN/KIMMERIDGIAN BOUNDARY IN THE FLODIGARRY SECTION (STAFFIN BAY, ISLE OF SKYE, UK)

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Abstract. The Flodigarry section at Staffin Bay, Isle of Skye, has yielded numerous ammonites both of Subboreal and Boreal affinity. This has enabled close correlation of the Subboreal and Boreal ammonite zonation, and provided new palaeontological data on levels which may be considered as a potential GSSP for the Oxfordian/Kimmeridgian boundary. The traditional Oxfordian/Kimmeridgian boundary placed at the Pseudocordata/Baylei zones boundary of the Subboreal scheme corresponds precisely to the Rosenkrantzi/Bauhini zones boundary of the Boreal scheme: this level is characterized by appearance of *Pictonia* together with *Prorasenia* replacing an older assemblage of *Ringsteadia-Microbiplices* (Subboreal), as well as by first occurrence of small-sized *Amoeboceras* (*Plasmatites*) – mostly *A. praebaubini* (Boreal). A further level which may be considered as the Oxfordian/Kimmeridgian boundary is the boundary between the Bauhini Zone and Kitchini Zone of the Boreal scheme characterized by first occurrence of *Amoeboceras* (*Amoebites*) of the *A. bayi* group. This level corresponds to the Planula/Galar subzones boundary of the Submediterranean scheme, i.e. it lies close to the currently accepted Oxfordian/Kimmeridgian boundary in the Submediterranean Succession.

Riassunto. La sezione di Flodigarry a Staffin Bay, Isola di Skye, ha fornito numerosi ammoniti di affinità sia subboreale che boreale. Questo ha permesso una stretta correlazione delle zonazioni ad ammoniti subboreali e boreali, ed ha fornito nuovi dati paleontologici sui livelli che possono venir considerati come potenziali GSSP per il limite Oxfordiano/Kimmeridgiano. Il tradizionale limite Oxfordiano/Kimmeridgiano posto al limite di zona Pseudocordata/Baylei dello schema subboreale corrisponde precisamente al limite di zona Rosenkrantzi/Bauhini dello schema boreale: questo livello è caratterizzato dalla comparsa di *Pictonia* insieme con *Prorasenia*, che rimpiazzano l'associazione

più antica *Ringsteadia-Microbiplices* (subboreale), così come dalla prima comparsa di piccoli *Amoeboceras* (*Plasmatites*) – principalmente *A. praebaubini* (boreale). Un altro livello che può venir considerato come il limite Oxfordiano/Kimmeridgiano è il limite tra la Zona a Bauhini e quella a Kitchini dello schema boreale, caratterizzato dalla prima comparsa degli *Amoeboceras* (*Amoebites*) del gruppo di *A. bayi*. Questo livello corrisponde al limite di sottozona Planula/Galar dello schema submediterraneo, ossia è vicino al limite Oxfordiano/Kimmeridgiano correntemente accettato nella Successione Submediterranea.

Introduction

Due to the well known existence of two definitions of the Oxfordian-Kimmeridgian boundary – each definition resulting in the location of the boundary at a different stratigraphical level: lower in the Subboreal/Boreal Succession, and higher in the Submediterranean Succession (Matyja & Wierzbowski 1997; Schweigert & Callomon 1997), there was the need for detailed studies of the sections representative of each of these successions. The object of these studies would be to find levels which could be considered as directly (or closely) corresponding to the boundaries in question: the Pseudocordata/Baylei zones boundary (traditional Oxfordian/Kimmeridgian stages boundary in the Subboreal Succession), and the Planula/Platynota zones (or Planula/Galar subzones) boundary treated as the Oxfordian/Kimmeridgian stages boundary (or lying close to) in the Submediterranean Succession. The paper presents the preliminary results

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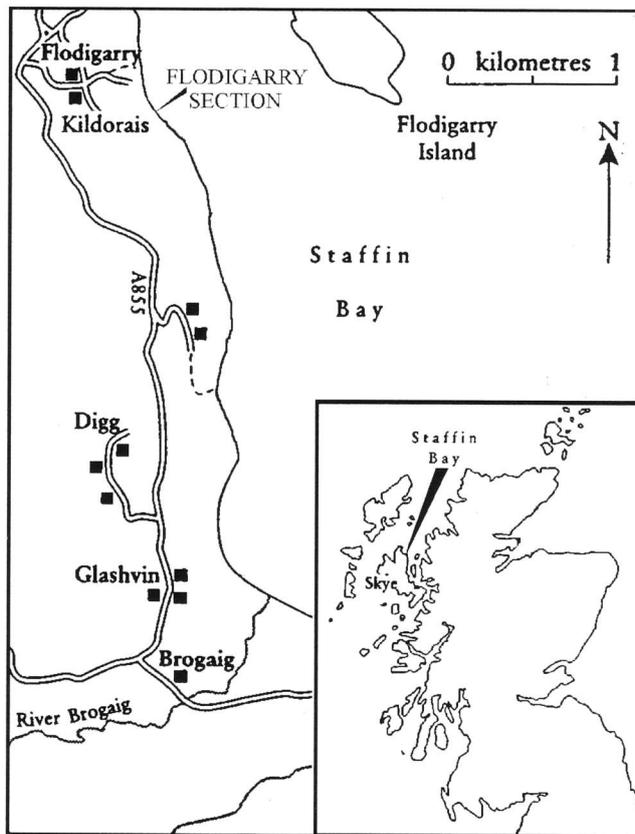


Fig. 1 - Locality maps of Staffin Bay and Flodigarry section.

of such a study in the Staffin Bay area of the Isle of Skye – typical for the Subboreal/Boreal Succession, and shows the importance of this area in the distinction of a stratotype of the Oxfordian-Kimmeridgian boundary. The paper concentrates mostly on the position of these levels in the Flodigarry section – the most representative section for the area, and it does not include the detailed description of the whole section and ammonites, or a discussion on the detailed stratigraphical correlation of the diverse palaeobiogeographical units. These will constitute a subject of a wider study published elsewhere.

The section studied

A prime candidate for designation as the Global Stratotype Section and Point (GSSP) for the base of the Kimmeridgian Stage is located at Staffin Bay, Isle of Skye, U.K. The boundary between Oxfordian and Kimmeridgian strata occurs within the Flodigarry Shale Member of the Staffin Shale Formation (Turner 1966 p. 248; Sykes 1975, p. 66), and is exposed in two rock platform exposures between the villages of Digg, Flodigarry and Kildorais (Fig. 1). That east of Digg is rather small, and covered by seaweed and boulders, and will not be considered further here, as the boundary is particularly well exposed at Flodigarry east of Kildorais.

The Staffin Shale has long been known for the richness of its ammonite fauna (Forbes 1851; MacGregor 1934; Anderson & Dunham 1966; Turner 1966; Hudson & Morton 1969; Wright 1973; Sykes 1975; Sykes & Callomon 1979; Wright 1989; Morton & Hudson 1995; Wright & Cox 2001). A comprehensive review of the ammonite faunas was given by Sykes & Callomon (1979), though the details of the ammonite succession are only at present being worked out.

The Oxfordian-Kimmeridgian boundary succession comprises a sequence of bituminous and silty shales with the frequent development of limestone lenses and beds (Fig. 2). Sykes & Callomon (1979) have shown that this section exhibits the most complete ammonite faunal succession of the Boreal Province, thus spotlighting its potential for boundary definition. The exposure at Flodigarry, being the most widespread and showing the succession to its best advantage, is the site which may be proposed for GSSP status. The section lies within the Trotternish Ridge Site of Special Scientific Interest, so that appropriate protection and preservation are assured.

The rock platform exposures at Flodigarry presented initial problems to stratigraphers in that the Oxfordian/Kimmeridgian succession is exposed in series of wave-cut platform sections cut through several steeply dipping slipped blocks (Wright 1989, figs 5, 6). Accurate correlation between slipped blocks is necessary to establish the complete succession. Currently available maps published by Morton & Hudson (1995) and Wright & Cox (2001) are largely based on the preliminary maps of Wright (1973, 1989). With the advent of possible GSSP status, the need for more detailed study of the exposures was obvious, and the necessary fieldwork was completed by the authors in summer 2001.

The detailed stratigraphy of the Flodigarry Shale Member has been set out by Sykes & Callomon (1979) and Wright (1989). The currently studied section has been measured in blocks F5 and F6 in the beach at Flodigarry and it spans Bed SS 33 (upper part) to Bed SS 45 according to standard division of the Staffin Shale Formation as summarized by Morton & Hudson (1995). The ammonite faunas were collected by the authors in the Flodigarry section at 50 successive levels. The faunas include successive members of the families Aulacostephanidae and Cardioceratidae, making possible recognition of both the Boreal and Subboreal zones and subzones of Sykes & Callomon (1979), Birkelund & Callomon (1985) and Wierzbowski & Smelror (1993), as well as necessitating some modifications to these zonal schemes.

Subboreal ammonites and zonal scheme

The uppermost Oxfordian zone, the Pseudocordata Zone, is well represented at Staffin by successive faunas of *Ringsteadia* and its microconch counterpart, mostly *Microbiplices*, and forms transitional between *Microbi-*

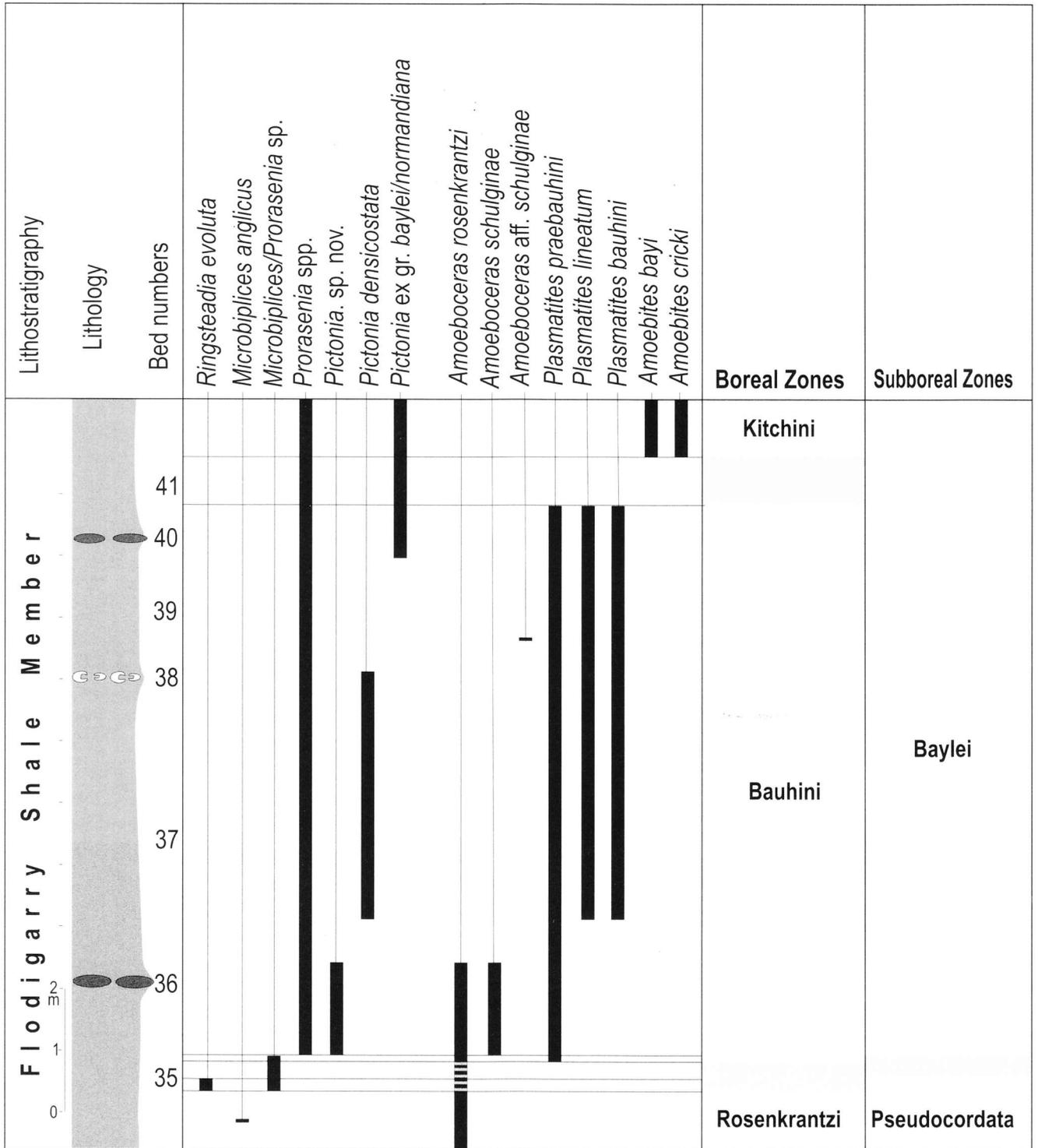


Fig. 2 - Stratigraphical distribution of ammonites and biostratigraphical interpretation of Flodigarry section; grey blocks indicate the intervals of uncertain biostratigraphical interpretation

plices and *Prorasia*. The earliest *Ringsteadia*, consisting of *Ringsteadia caledonica* Sykes & Callomon, is indicative of the Caledonica Subzone, the lowest subzone of the Pseudocordata Zone. A slightly younger fauna with *Ringsteadia brandesi* Salfeld and *Microbiplices microbiplex* (Quenstedt) and *Ringsteadia pseudoyo* Salfeld are characteristic of the Pseudoyo Subzone. Faunas with *Ring-*

steadia cf. *pseudocordata* (Blake & Hudleston), *Microbiplices anglicus* Arkell and *Microbiplices* sp. may be treated as indicative of the Pseudocordata Subzone. The uppermost subzone of the Pseudocordata Zone, the Evoluta Subzone is also present. It is marked by the occurrence of *Ringsteadia evoluta* Salfeld together with forms transitional between *Microbiplices* and *Prorasia*.

The boundary between the Pseudocordata Zone and the Baylei Zone (Fig. 2), i.e. the boundary between the Subboreal Oxfordian and Kimmeridgian, lies in the 0.5 m thick interval between the last occurrence of *Ringsteadia* - *Ringsteadia evoluta* Salfeld (1.65 m and possibly 1.47 m below Bed 36) and the first occurrence of *Pictonia* - *Pictonia* sp. nov. (1.08 m below Bed 36).

The Baylei Zone is marked by the occurrence of ammonites of the genus *Pictonia* and *Prorasenia*. Of special interest is recognition of the oldest known *Pictonia* fauna so far discovered (*Pictonia* sp. nov.) which directly precedes the appearance of *Pictonia densicostata* Buckman in the Flodigarry section (Fig. 2). The new species differs from the very close *Pictonia densicostata* Buckman in character of outer whorl which shows more regular and stronger ornamentation and is more tightly coiled. Full description of the new species will be presented elsewhere, but this finding confirms the previous suggestions that the Staffin Bay sections in Scotland are much more complete than the English sections where a hiatus must occur at the boundary of the Pseudocordata and Baylei Zones (e.g. Arkell 1956).

The boundary between the Baylei Zone and the Cymodoce Zone in the Subboreal Province lies within the continuous lineage *Pictonia-Rasenia* at the base of the *Rasenia inconstans* horizon. It thus occurs at Flodigarry above the last occurrence of *Pictonia*, of the *baylei/normandiana* group and below the first occurrence of *Rasenia inconstans* Spath.

Boreal ammonites and zonal scheme

The Upper Oxfordian part of the sequence studied contains two zones, the Regular and Rosenkrantzi Zones, and the Lower Kimmeridgian is represented again by two zones, the Bauhini and Kitchini Zones. The Regular Zone shows the occurrence of evolute, densely and regularly ribbed *Amoeboceras* of the *Amoeboceras regulare* group (Sykes & Callomon 1979). Still higher the first specimens of *Amoeboceras marstonense* Spath, indicative of the lower part of the overlying Rosenkrantzi Zone have been found.

The Rosenkrantzi Zone has had a chequered existence since it was first defined as the range zone of *Amoeboceras rosenkrantzi* Spath by Sykes & Surlyk (1976). Sykes & Callomon (1979) divided it into two subzones, a lower Marstonense Subzone characterised by the co-occurrence of *Amoeboceras marstonense* Spath and *Amoeboceras rosenkrantzi* Spath, and an upper Bauhini Subzone, marked by the incoming of members of the *Amoeboceras (Plasmatites)* group. Following Birkelund & Callomon (1985), the strata containing *Amoeboceras (Plasmatites)* spp. were removed from the Rosenkrantzi Zone and placed in the lower Kimmeridgian Bauhini Zone. The problem of the stratigraphic interval containing *Amoeboceras rosen-*

krantzi Spath but below the earliest occurrence of *Amoeboceras (Plasmatites)* spp. and above the last occurrence of *Amoeboceras marstonense* Spath, is solved here by the recognition of the Rosenkrantzi Subzone of the Rosenkrantzi Zone.

The Bauhini Zone of the lowermost Boreal Kimmeridgian is characterised by the occurrence of small-sized *Amoeboceras* spp. of the subgenus *Plasmatites* (Fig. 2). *Amoeboceras (Plasmatites) praebauhini* (Salfeld) first appears from 1.17 to 1.04 m below Bed 36. *Amoeboceras rosenkrantzi* Spath and *Amoeboceras schulginae* Mesezhnikov also occur, and continue up to 0.17 m above Bed 36. The Oxfordian/Kimmeridgian boundary in the Boreal sense thus lies between 1.65 m (last occurrence of *Amoeboceras rosenkrantzi* Spath without *Plasmatites*) and 1.17 m below Bed 36, in almost exactly the same interval of strata where the boundary in the Subboreal sense was deduced to lie (see above). The main part of the Bauhini Zone, continuing up (Fig. 2), contains *Amoeboceras bauhini* (Oppel), *Amoeboceras praebauhini* (Salfeld) and *Amoeboceras lineatum* (Quenstedt). A thin faunal horizon with numerous *Amoeboceras* aff. *schulginae* Mesezhnikov is situated in the middle of the zone.

The appearance still higher of *Amoeboceras (Amoebites) bayi* Birkelund & Callomon and *Amoeboceras (Amoebites) cricki* (Salfeld) is indicative of the Boreal Kitchini Zone as originally defined by Mesezhnikov (1968; see also Wierzbowski & Smelror 1993). The boundary between the Bauhini and Kitchini Zones runs through the 0.8 m of strata between 0.5 and 1.3 m above Bed 40 (Fig. 2). The youngest *Amoeboceras (Amoebites) subkitchini* Spath in the upper part of the Flodigarry section, found above Bed 44, is indicative of the higher part of the Kitchini Zone.

Correlation between Subboreal and Boreal zonal schemes

The section studied at Flodigarry shows a very complete ammonite succession consisting of successive members of both the Cardioceratidae and Aulacostephanidae represented by numerous specimens. This makes possible close correlation of the Boreal and Subboreal zonal schemes.

The Pseudocordata Zone (Subboreal) corresponds to a part of the Regular Zone plus the whole Rosenkrantzi Zone (Boreal). The first appearance of the ammonites of the genus *Pictonia* indicative of the base of the Baylei Zone (Subboreal) is recognized at the same level as the first appearance of *Amoeboceras (Plasmatites)* indicative of the Bauhini Zone (Boreal). The next marked faunal boundary distinguished by incoming of small *Amoeboceras (Amoebites)* of *Amoeboceras bayi* group is characteristic of the base of the Kitchini Zone (Boreal). This boundary does not correspond to any distinct faunistic

level in the Subboreal succession, being placed within upper part of the Baylei Zone. The Baylei/Cymodoce zonal boundary of the Subboreal scheme is thus considerably higher than the Bauhini/Kitchini zonal boundary of the Boreal scheme.

Summary and conclusions

The coastal exposure at Flodigarry, Isle of Skye, fulfils the principal criteria (Remane et al. 1996) for definition as GSSP for the base of the Kimmeridgian Stage. The section is well exposed, relatively thick, lacks any major hiatus, has not been subject to synsedimentary disturbance and has been subject to only minor, faulted, tectonic disturbance. It contains an abundance of well-preserved marine fossils, and does not show abrupt facies changes.

The traditional candidate level for the boundary between Oxfordian and Kimmeridgian is at the base of the Bauhini/Baylei Zones, as characterised by the association of *Amoeboceras* (*Plasmatites*) spp., *Pictonia* spp. and *Pro-rasenia* spp.. A further candidate level for the boundary

between Oxfordian and Kimmeridgian is at the base of the Kitchini Zone of the Boreal scheme where the first small-sized *Amoeboceras* (*Amoebites*) of the *A. bayi* group appear. Choosing of any of these levels as the Oxfordian/Kimmeridgian boundary requires further detailed studies of the Submediterranean Succession to recognize their correlation potentials. It should be remembered that the base of the Boreal Kitchini Zone corresponds to the Planula/Galar Subzone boundary (Schweigert & Callomon 1997; Matyja & Wierzbowski 2002) treated until the early sixties as the Oxfordian/Kimmeridgian boundary in the Submediterranean Succession, and lying fairly close to the currently accepted Oxfordian/Kimmeridgian boundary in the Submediterranean sense.

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