STAFFIN

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Introduction

Staffin Bay contains some of the most important exposures of Oxfordian strata in Britain. The sections lie on the east coast of the Trotternish Peninsula near the northern extremity of Skye and comprise low cliff and foreshore exposures that extend northward for 2.8 km from the coast east of Digg to Flodigarry (Figure 5.14). Sedimentation was apparently continuous at Staffin from the Callovian Age through the Oxfordian and into the Kimmeridgian Age. There is thus a largely unbroken Oxfordian succession including all eight ammonite zones within the stage and with 12 of the 13 subzones represented by ammonitiferous strata. The sequence here is the international stratotype for much of the Boreal Oxfordian.

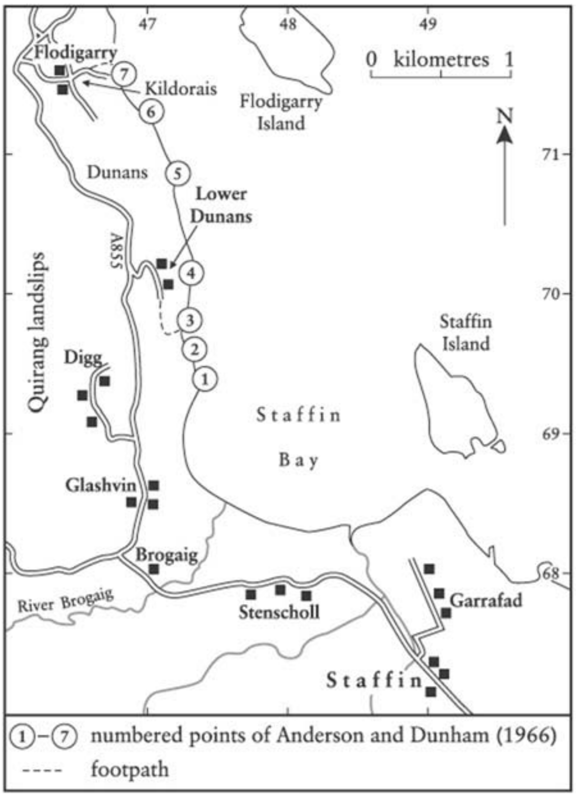

Figure 5.14: Locality map of the Staffin and Kildorais GCR sites (after Cox and Sumbler, in press).

Although the beds exposed in Staffin Bay were first described by Pennant (1774) and later by MacCulloch (1819), and considered by the latter to be the youngest Mesozoic strata in the area, it was not until the work of Forbes (1851) that it was realized that beds equivalent in age and facies to the Oxford Clay of England are present at Staffin. The presence of Upper Oxfordian strata at Staffin was first demonstrated by MacGregor (1934). The area was later studied by Anderson and Dunham for the Geological Survey (field work undertaken and written up in 1936–1937, memoir published in 1966). Turner (1966, 1970) studied the general stratigraphy and the ammonites of the Cordatum Zone, and Morris (1968) studied the Upper Oxfordian ammonites. Hudson and Morton (1969) wrote a field guide to the area, and Wright (1973) published revised maps for some of the exposure. Sykes (1975) thoroughly revised the stratigraphy of the Callovian and Oxfordian beds. Both Wright and Sykes had attempted to use the Sub-Boreal zonal scheme for the Middle and Upper Oxfordian at Staffin. Sykes and Callomon (1979) introduced a new zonal scheme for the Boreal Middle and Upper Oxfordian, for which the Staffin area became the stratotype for many of the zones and subzones. Birkelund and Callomon (1985) slightly amended the Boreal zonal scheme, re-drawing the Oxfordian– Kimmeridgian boundary at Staffin. Wright (1989) published detailed maps of the Upper Oxfordian and Kimmeridgian outcrops at Staffin, and Morton and Hudson (1995) produced a detailed field guide to the outcrops, with revised maps.

Description

The Staffin site exposes 104.5 m of Oxfordian strata comprising richly fossiliferous shales, silts and subordinate sandstones. These make up part of the Callovian to Kimmeridgian Staffin Shale Formation (Turner, 1966), and cover the complete Oxfordian zonal range from the Mariae Zone at the base to the Rosenkrantzi Zone at the top with the omission solely of the Maltonense Subzone, which is not exposed. A detailed measured section of the Staffin Shale has been published by Sykes and Callomon (1979), and this was amended slightly by Wright (1989) and Morton and Hudson (1995), while retaining Sykes and Callomon's bed numbers. The main features of the Oxfordian succession are illustrated by the section below and Figure 5.16, summarized from Sykes and Callomon (1979). A complete ammonite faunal list is given below.

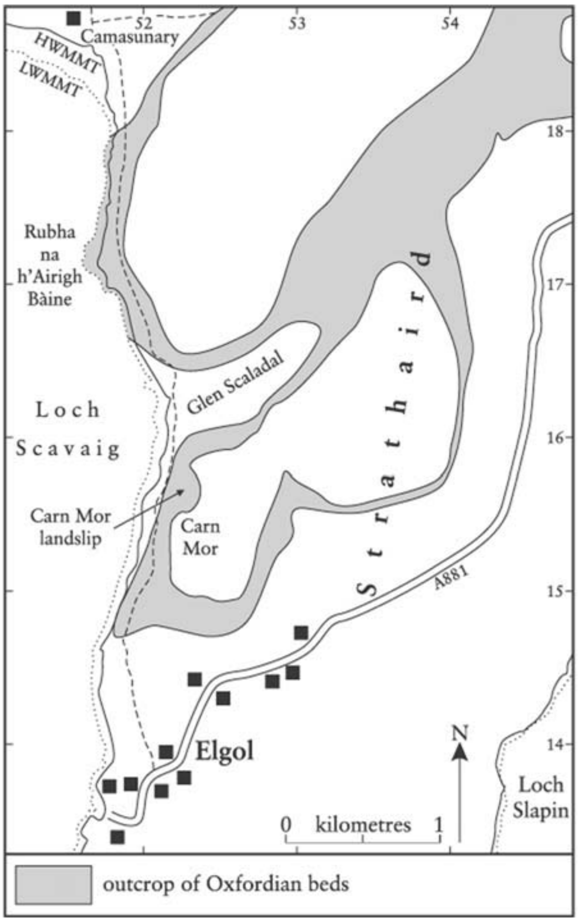

Figure 5.16: Map of the foreshore at Digg, with detailed logs (after Morton and Hudson, 1995, figs 39, 40).

		Thickness (m)
Staffin Shale Formation		
Flodigarry Shale Member (pars), Blakei (pars), Ilovaiskii, Glosense, Koldeweyense and Serratum subzones, Regulare and Rosenkrantzi zones		
36–30	Dark-grey, bituminous, shaley clays alternating with silty clays. Very occasional calcareous concretions. Limestone band, or band of limestone concretions (Bed 36) at top. *Nuculoma* common near base; occasional pectinid bivalves. Prolific *Amoeboceras* spp. throughout, including *A. rosenkrantzi*, with *Ringsteadia* spp. and *Microbiplices* sp. near top and occasional *Decipia* sp. and *Cardioceras* spp. near to and at base respectively.	about 40
Digg Siltstone Member, Tenuiserratum (pars) and Blakei (pars) subzones		
29–26	Pale-grey, sandy silt with thin beds of fine-grained sandstone and dark-grey silt. *Perisphinctes* spp. and *Cardioceras* spp. abundant; bivalves dominated by *Cucullaea* sp.	25+
Glashvin Silt Member, Cordatum (pars), Vertebrale, ?Maltonense and Tenuiserratum (pars) subzones		
25–21	Dark-grey, carbonaceous silts, with beds of green clay, and woody bands associated with thin, sharp-based sandy beds up to 5 cm thick. *Cardioceras* spp. and *Perisphinctes* spp. abundant; in silts, rich faunas of bivalves (*Pinna, Cucullaea, Pleuromya* and *Pholadomya*) often preserved in life position	20.5
Dunans Clay Member, Scarburgense, Praecordatum, Bukowskii, Costicardia and Cordatum (pars) subzones		
6–21	Pale, grey-green clays with several horizons of red-weathering, nodular sideritic limestone. Repeated occurrences of thin bands of dark-grey silt full of woody debris. *Cardioceras* spp., *Goliathiceras* spp., *Peltoceras* spp. common, with rare *Longaeviceras. Oxytoma, Nuculoma* and *Dentalium* common throughout, with *Thracia* and *Camptonectes* near top	31.5
(Continuation down of Dunans Clay Member into Upper Callovian)		

A stratigraphical log of the section is given in Figure 5.15. There is no one continuous section through the Staffin Shale Formation. The area of the Trotternish Peninsula north of Staffin has been affected by a substantial series of landslips during the Holocene (Anderson and Dunham, 1966). Numerous blocks containing the complete succession from the Upper Bathonian to the Lower Kimmeridgian, with a thick cover of Tertiary basalt, have rotated and slipped down to a level slightly lower than present-day sea level. The sea has now cut a rock platform through this mass of slipped blocks, the degree of slipping of each block resulting in different levels of exposure of the strata from one block to the next. In the extreme, the red and green mottled mudstones of the Skudiburgh Formation (Bathonian) are faulted against the Flodigarry Shale (Upper Oxfordian). Westerly dips vary from only a few degrees to almost vertical (Wright, 1989, fig. 6). In most blocks, dips are steep. Baking of the shales has taken place close to Tertiary dykes and sills. The sections of Sykes and Callomon (1979) and Morton and Hudson (1995) were compiled by correlation of the disjointed successions in the various slipped blocks. Some parts of the succession are not exposed; other parts are exposed at several localities. In general, Lower and Middle Oxfordian strata are exposed in the centre of the coastal strip, and Upper Oxfordian at the north and south ends where pressure from the Quirang landslip has brought slices of sheared, sometimes rotated, Flodigarry Shale down to sea level.

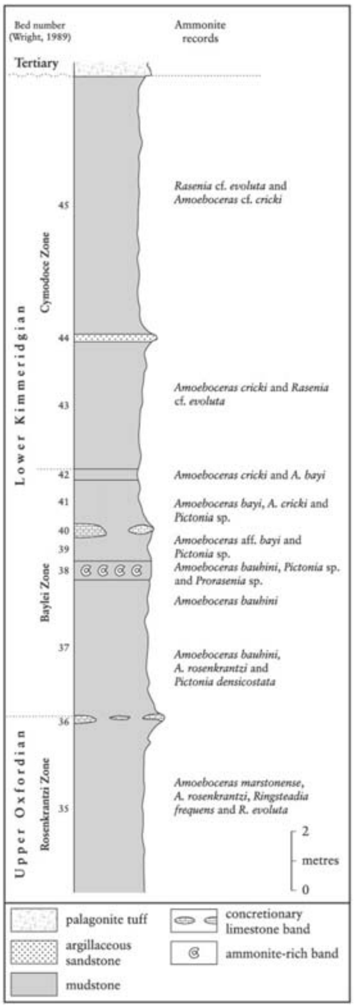

Figure 5.15: General log of the Staffin Shale succession (after Morton and Hudson, 1995, table 4).

A lack of local names for the various minor headlands between Staffin and Flodigarry led Anderson and Dunham (1966) to number the headlands Point 1 to Point 7, and this has been followed by subsequent authors. Wright (1973, 1989) gave the more important slipped blocks identification letters, D1 to D5 for those in the south near Digg, and F1 to F8 for those in the north near Flodigarry. A general map of the coastline is given in Figure5.14, and more detailed maps and logs in Figures 5.16 and 5.17. The description is given from south to north, although the principal southern access route given by Morton and Hudson (1995) leads to the shore north of Point 3.

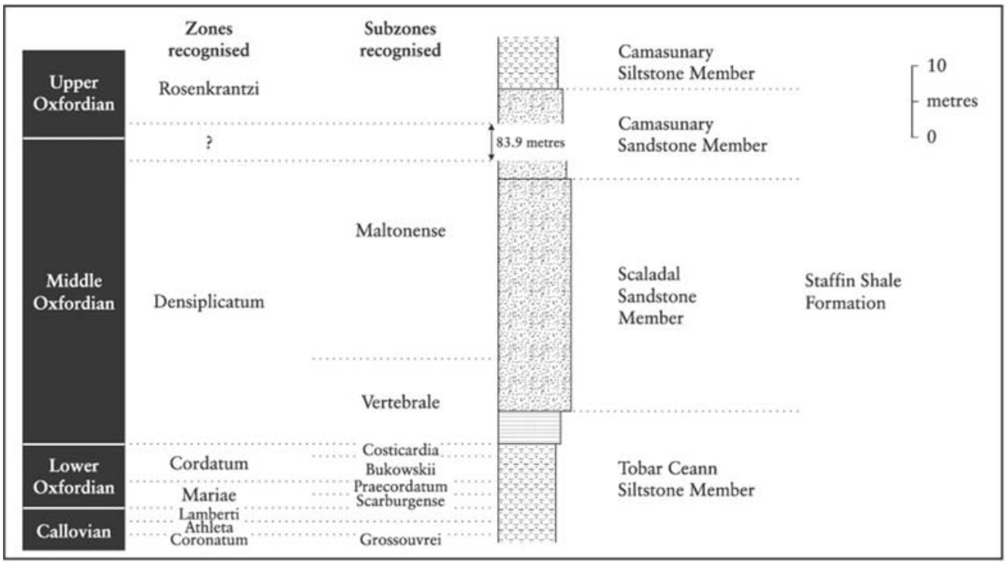

Figure 5.17: Map of the foreshore at Flodigarry, with detailed log (after Morton and Hudson, 1995, fig. 42).

A large boulder on the shore 275 m south of Point 1 is a convenient marker for the southern limit of the Oxfordian beds. Just to the south-east of it, red and green mottled mudstones of the Skudiburgh Formation are exposed. There are poor exposures of the Digg Siltstone dipping at 60° to the north-west, 50 m north of the boulder (Exposure D2, Figure5.16). Northwards across a small fault, vertically dipping exposures of the Flodigarry Shale yield good *Amoeboceras glosense* (Bigot and Brasil) and *Perisphinctes* (cf. *Dichotomoceras*) sp..

In the small bay between Point 1 and Point 2 (Figure5.16), a prominent 0.35 m thick limestone (Bed 40 of Wright, 1989) can be located in the mid beach at exposure D5A. It is not persistent and can be traced only 20 m north-westwards before dying out. Below it are 5 m of shale containing the early Kimmeridgian *Amoeboceras bauhini* (Oppel), resting on a persistent, 0.2 m thick, limestone (Bed 36 of Sykes and Callomon, 1979). This limestone and the shales below it yield *Ringsteadia* spp. and *Amoeboceras rosenkrantzi* Spath of the uppermost Oxfordian. Beneath are good exposures of Flodigarry Shale yielding *Amoeboceras regulare* Spath (Regulare Zone), and then to the north in exposure D5B, good exposures of shale yielding *Amoeboceras serratum* (J. Sowerby) and *A. koldeweyense* Sykes and Callomon (Serratum Zone). On the north side of the bay between Points 2 and 3, there is a steeply dipping exposure of Glashvin Silt yielding *Cardioceras (Plasmatoceras)* sp. and *C. (Vertebriceras)* spp. (Vertebrale Subzone). In the base of the cliff, the Glashvin Silt contains many perisphinctids, *Cardioceras (Subvertebriceras) densiplicatum* Boden and *C. (Miticardioceras) tenuiserratum* (Oppel) (Tenuiserratum Subzone). The silts in the rock platform are baked by a thick dyke. On the north side of the dyke, just north of Point 3, the Dunans Clay containing an excellent Cordatum Zone fauna with *Cardioceras (C.)* spp. is seen particularly well in a gently dipping succession that extends down to the Callovian Belemnite Sand at low tide.

Exposures of the Lower Oxfordian rocks continue northwards round Point 4 into the bay between Points 4 and 5, where the Lower Oxfordian is well exposed in the rock platform. The Dunans Clay contains distinctive, reddish-weathering, iron-rich bands. Numerous cardioceratids are present representing the Bukowskii, Costicardia and Cordatum subzones. The dip is south-westwards and, down the section, prominent cementstone horizons in the Upper Callovian appear close to Point 5.

North of Point 5, faulting brings the Dunans Clay–Glashvin Silt succession back into the rock platform. There are two fault blocks, with slightly different orientations. The more northerly, with beds dipping vertically and striking almost due north, shows a succession from the Dunans Clay, with *Cardioceras bukowskii* Maire and *Rursiceras* sp. (Bukowskii Subzone), well into the Glashvin Silt of the Vertebrale Subzone. The dark, silty shales of the latter, with their numerous paler, silty bands, contain exceptionally well-preserved ammonites seen in crosssection in the rock platform. The beds are crowded with *Cardioceras, Vertebriceras* and *Perisphinctes,* both macroconchs and microconchs, all complete, with the body chambers partly filled with micrite, and the inner whorls crushed.

Between Points 5 and 6, the red and green mottled silts of the Skudiburgh Formation are prominently seen in the rock platform, with, at mid-tide level, a faulted slice of Flodigarry Shale containing *Amoeboceras* sp.. North of Point 6, the extensive exposures of Flodigarry Shale in Flodigarry Bay are encountered. The succession is best examined in Block F6 (Figure 5.17), where there is almost continuous exposure for 50–100 m south of the large boulder in the centre of the bay. Immediately seawards of the beach boulders, a prominent 0.35 m limestone bed is reached, trending in an arc northwards from the beach boulders to the centre of the large boulder (Figure 5.18). This is Bed 40, which, being more persistent than its equivalent at Digg (Figure 5.16), is more extensively exposed. Down section, a layer of impersistent concretions is reached 6.5 m below Bed 40. These are spaced 5–10 m apart along the beach, and have generally been assumed to be equivalent to the Bed 36 limestone at Digg, whose top there marked the Oxfordian–Kimmeridgian boundary. The Oxfordian taxa *Amoeboceras rosenkrantzi* and *Ringsteadia* spp. are indeed abundant below these concretions at Flodigarry; however, *A. rosenkrantzi* also occurs in the overlying 2 m of shale, and this has given problems in defining the Oxfordian–Kimmeridgian boundary at Flodigarry (see below). Older beds are seen to the north of the large boulder, particularly in blocks F4 and F2, where *Amoeboceras koldeweyense, A. serratum* and *A. regulare* can be found in the usual ascending sequence.

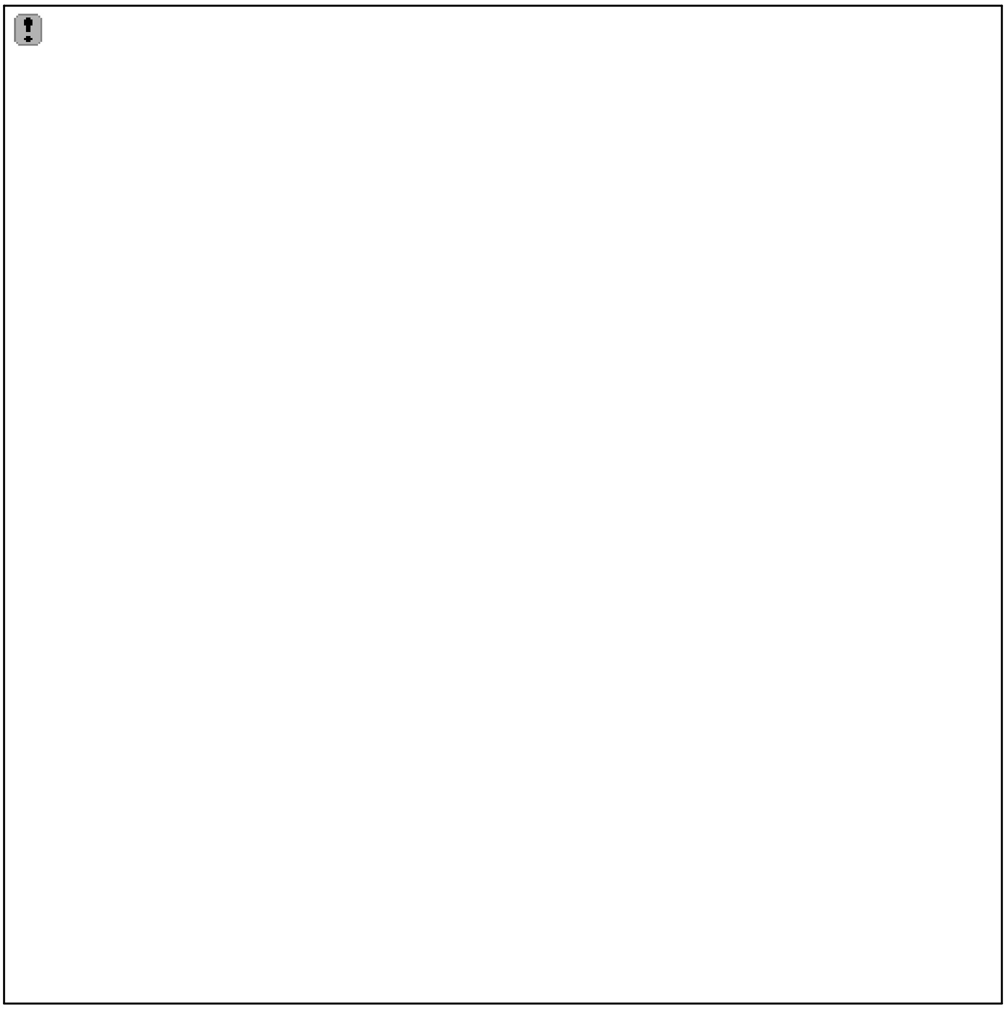

Figure 5.18: View looking north along the beach at Flodigarry, showing the 0.3–0.4 m limestone of Bed 40 dipping steeply west, and curving round under the large boulder in the middle distance. The large boulder is the one in the middle of Figure 5.17. (Photo: J.K. Wright.)

The following list of Oxfordian ammonites recorded from Staffin has been compiled from Turner

(1966, 1970), Sykes (1975), Sykes and Callomon (1979) and Birkelund and Callomon (1985).

Mariae Zone

Scarburgense Subzone (Bed 6 (pars), Bed 7 and Bed 8 (pars)):

Cardioceras (Scarburgiceras) scarburgense (Young and Bird) (rare), *Goliathiceras* sp., *Quenstedtoceras* sp. and *Longaeviceras staffinense* Sykes Praecordatum Subzone (Bed 8 (pars) to Bed 12 (pars)):

Cardioceras (Scarburgiceras) praecordatum Douvillé, *C. (S.) alphacordatum* Spath, *Euaspidoceras* sp. and *Peltoceras* sp.

Cordatum Zone

Bukowskii Subzone (Bed 12 (pars) to Bed 18):

Cardioceras (Scarburgiceras) bukowskii, *C. (S.) alphacordatum*, *C. (S.)* cf. *excavatoides* Maire, *C. (S.) reesidei* Maire, *Goliathiceras (Korythoceras) korys* (S. Buckman), *Euaspidoceras* sp., *Peltoceras (Parawedekindia) arduennense* (d'Orbigny), *P. gerberi* (Prieser) and *P. (Peltomorphites) hoplophorous* (Buckman)

Costicardia Subzone (Bed 19 and Bed 20 (pars)):

Cardioceras (Cardioceras) costicardia Buckman, *C. (Subvertebriceras) costellatum* Buckman, *Peltoceras (Parawedekindia) arduennense*, *P. (Peltoceratoides) williamsoni* (Phillips) and *Mirosphinctes* sp.

Cordatum Subzone Bed 20 (pars) and Bed 21 (pars):

Cardioceras (Cardioceras) cf. *cordatum* (J. Sowerby), *C.* spp. and *Goliathiceras (Pachycardioceras) repletum* (Maire)

Densiplicatum Zone

Vertebrale Subzone (type locality) (Bed 21 (pars)):

three horizons are present,:

(a) with *Cardioceras (Plasmatoceras) popilaniense* Boden,

(b) with *C. (Scoticardioceras) excavatum* (J. Sowerby), *C. (Subvertebriceras) densiplicatum*, *C. (S.) zenaidae* Ilovaisky and *C. (S.) sowerbyi* Arkell,

(c) with *C. (P.) tenuistriatum* Borissjak and *C. (P.) tenuicostatum* Nikitin. *Perisphinctes (Dichotomosphinctes) rotoides* Ronchadzé and *P. (Arisphinctes)* sp. also occur

Maltonense Subzone: not exposed

Tenuiserratum Zone

Tenuiserratum Subzone (type locality) (Bed 26 and Bed 27 (pars)):

Cardioceras (Miticardioceras) tenuiserratum, *C. (M.) mite* Buckman, *C. (Maltoniceras) schellwieni* Boden, *C. (Cawtoniceras) cawtonense* Blake and Hudleston, *Perisphinctes (Dichotomosphinctes)* cf. *antecedens* Salfeld

Blakei Subzone (type locality) (Bed 27 (pars) to Bed 31 (pars)):

Cardioceras (Cawtoniceras) blakei, *C. (C.) ogivale* (S. Buckman), *C. (Maltoniceras) vagum* Ilovaisky, *C. (Miticardioceras) tenuiserratum*, *Perisphinctes* spp.

Glosense Zone

Ilovaiskii Subzone (type locality) (Bed 31 (pars)):

Amoeboceras ilovaiskii (M. Sokolov), *A. transitorium* Spath, *A. newbridgense* Sykes and Callomon, *A. shuravskii* (D. Sokolov), *A. nunningtonense* Wright, *Decipia* sp. and *Perisphinctes* sp.

Glosense Subzone (type locality) (Bed 31 (pars)):

Amoeboceras glosense Bigot and Brasil, *A. damoni* Spath and *A. nunningtonense*

Serratum Zone

Koldeweyense Subzone (type locality) (Bed 31 (pars) to Bed 33 (pars)):

Amoeboceras koldeweyense, A. serratum, A. mansoni Pringle and *Perisphinctes (Dichotomoceras)* cf. *bifurcatus* Quenstedt. Serratum Subzone (type locality) (Bed 33 (pars)):

Amoeboceras serratum, A. mansoni, A. shulginae Mesezhnikov, *A.* cf. *freboldi* Spath, *A. regulare, A. leucum* Spath, *Perisphinctes* sp. and *Euaspidoceras* sp.

Regulare Zone (type locality) (Bed 33 (pars) and Bed 34):

Amoeboceras regulare, A. freboldi, A. leucum, A. schulginae and *Ringsteadia caledonica* Sykes and Callomon

Rosenkranktzi Zone (type locality) (Bed 35 and Bed 36):

Amoeboceras marstonense Spath, *A. rosenkrantzi, Ringsteadia caledonica* and *R. pseudocordata* Blake and Hudleston

Interpretation

The Oxfordian sequence at Staffin is remarkable for its completeness (Figure5.15) and for the often exceptional preservation of its ammonites. Within the Dunans Clay, the initial Mariae Zone is to some extent thinly developed. Though there is no evidence of condensed sedimentation, the Scarburgense Subzone in particular is only 3 m thick. The Cordatum Zone shows a much more expanded sequence within the Dunans Clay, with a series of exceptionally well-preserved faunas representing all three subzones. This is the most complete, continuously fossiliferous sequence through the Cordatum Zone in Britain.

The Glashvin Silt succession is unfortunately not complete, and the Maltonense Subzone of the Densiplicatum Zone is not exposed. However, the underlying Vertebrale Subzone is very well exposed, with abundant ammonites, at several localities. The Digg Siltstone sequence is again not complete, but numerous well-preserved *Miticardioceras* from both the Tenuiserratum and Blakei subzones of the Tenuiserratum Zone are very common. This is the only naturally occurring exposure of the Blakei Subzone anywhere in Britain.

The Flodigarry Shale succession is complete and well exposed. Though the Glosense Zone appears thin (Figure 5.15), it is thinly developed wherever it is seen in clay facies (Gallois and Cox, 1977, fig. 2; Gaunt *et al* ., 1992, fig. 26) and appears to have occupied only a comparatively short period of time. The Serratum Zone is excellently developed with a beautifully preserved sequence of ammonite faunas, many microconchs showing perfectly preserved apertures. The Regulare Zone is similarly well exposed and fossiliferous, this being the only permanent section in Britain where Regulare Zone sediments are visible.

Amoeboceras rosenkrantzi (Rosenkrantzi Zone) occurs up to and within the marker bed 36 at Digg, the top of this being taken as the Oxfordian–Kimmeridgian boundary (Morton and Hudson, 1995). However, as was pointed out by Wierzbowski and Matyja (pers. comm., 1998), at Flodigarry, it is not so easy to distinguish the Oxfordian–Kimmeridgian boundary. *Amoeboceras rosenkrantzi* occurs in the 2 m of shale above a concretion band, which had been regarded as being the equivalent at Flodigarry of the marker Bed 36 of Digg. One view would be that the Oxfordian–Kimmeridgian boundary at Flodigarry is not marked by this concretion band but instead lies within shale some 2 m higher than the Flodigarry concretion band, which would not be the equivalent of Bed 36.

However, as well as *A. rosenkrantzi*, this 2 m of shale also contains *A. bauhini*. This association was regarded by Sykes and Callomon (1979) as forming a Bauhini Subzone of the Rosenkrantzi Zone. Later, it was realized that *A. bauhini* is an indicator of the Early Kimmeridgian Baylei Zone, occurring along with the Kimmeridgian species *Pictonia densicostata* S. Buckman at South Ferriby Pit (Birkelund and Callomon, 1985; see site report for South Ferriby, this volume). It was then realized that the perisphinctid that occurs along with *A. rosenkrantzi* and *A. bauhini* in this 2 m of shale at Flodigarry was not *Ringsteadia* cf. *pseudocordata* Blake and Hudleston as recorded by Sykes and Callomon (1979), but *Pictonia densicostata* (Morton and Hudson, 1995). The result of this reasoning would be to say that concretion marker Bed 36 is recognizable at Flodigarry, that the 2 m of shale above it that contains *A. rosenkrantzi* is Kimmeridgian, and that *A. rosenkrantzi* carries on across the Oxfordian– Kimmeridgian boundary.

The succession at Staffin is comparable with that of the East Midlands of England in showing an almost entirely argillaceous succession from the Middle Callovian into the Lower Kimmeridgian strata, there being no marked changes in lithology at either the lower or the upper boundaries of the Oxfordian Stage. This argillaceous succession is considered to have been laid down during a major inundation of the Hebridean shelf area commencing with the transgression that occurred during the preceding Callovian. Subsequent to the deposition of the Dunans Clay during the Early Oxfordian, a regressive episode continued through the Mid Oxfordian with the deposition of sandy silts and thin sandstones (Glashvin Silt and Digg Siltstone). These correspond to the Tobar Ceann Siltstone and Scaladal Sandstone of Strathaird on south Skye. At the beginning of the Late Oxfordian, a second phase of deepening occurred in this basin marked by the deposition of the bituminous Flodigarry Shale. Only in latest Oxfordian times did argillaceous facies reach Strathaird (Camasunary Siltstone).

The abundance of well-preserved ammonites in the Staffin succession indicates the prevalence of an undisturbed, low-energy depositional regime. Though ammonites are sometimes preserved in three dimensions, particularly in the Cordatum Zone, they are normally found as flattened impressions. Despite this, the original nacreous aragonite shell is often present, and the preservation can be excellent, particularly in the Flodigarry Shale, with the finest details of the ribbing and aperture preserved. Nowhere else does such a rich, complete and significant sequence of Oxfordian faunas occur. The closest approach to such completeness outside this part of Scotland occurs in north Cambridgeshire and Humberside where ten index assemblages occur, but where the exposures are not as good, and are not permanent.

Bivalves are associated with the ammonites and are usually confined to discrete horizons. They indicate quiet-water depositional conditions, the associations being dominated by infaunal species such as *Nuculana, Grammatodon, Trautscholdia, Pinna* and *Pleuromya.* Conditions must frequently have been anoxic, particularly during deposition of the bituminous Flodigarry Shale, with a lack of benthic fossils. The absence of scavengers in these conditions resulted in the most perfect preservation of ammonites occurring in this member.

Conclusions

Staffin is one of Britain's most important Jurassic sites, being a primary reference standard of global significance for the Oxfordian Stage. The Oxfordian faunal sequence here has produced 14 zonal or subzonal ammonite faunas. There are rich assemblages of both Boreal and Tethyan affinities, of which the Boreal cardioceratid faunas are the most significant. The Tenuiserratum Zone with its prolific faunas of diminutive cardioceratids was first recognized at Staffin by Sykes and Callomon (1979). This zone is now recognized in Greenland, Russia and Poland. The *Amoeboceras* faunas of the Flodigarry Shale are of great importance, the detailed revision of the *Amoeboceras* zonation of the Boreal Upper Oxfordian succession by Sykes and Callomon (1979) having been based in large part on evidence obtained from Staffin. The site provides the best available section through the Upper Oxfordian strata anywhere in the Boreal Province and is of essential international significance for the study of the Upper Jurassic Series.

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