Brora (Callovian), Sutherland

[NC 904 031]-[NC 909 031], [NC 887 038]-[NC 899 040]

K.N. Page

Introduction

The exposures of Callovian rocks at Brora show an unusually thick succession dominated by shales and sandstones. The GCR site includes coastal foreshore exposures south of the River Brora estuary [NC 904 031]–[NC 909 031] and river-cliff exposures west of Brora town bridge [NC 887 038]–[NC 899 040] (Figure 6.6). The foreshore exposures continue eastwards towards those of the Bathonian GCR site also known as Brora (see Brora (Bathonian) GCR site report, this volume). The geology of the district was first described by Murchison (1829a,b), and later by Judd (1873). Lee and Pringle (1932) synthesized the stratigraphy in their review of the Mesozoic rocks of Scotland, and Arkell (1933) reviewed the ammonite-based dating. Sykes (1975) formally defined the current lithostratigraphical units, as reviewed by Duff (1980), and Page (1988) briefly commented on the correlation of the Lower Callovian succession. Most recently, the sections have been described by Hurst (in Trewin and Hurst, 1993).

The GCR site includes the type sections of the following lithostratigraphical units (Sykes, 1975 with amendments):

- Clynelish Quarry Sandstone Member: south bank of River Brora; Locality 5 [NC 899 040] of Hurst (in Trewin and Hurst, 1993)
- Fascally Sandstone Member: north bank of River Brora; opposite Locality 5 [NC 899 040] of Hurst (in Trewin and Hurst, 1993)
- Fascally Siltstone Member: foreshore [NC 909 031] south of River Brora estuary; complete section not always visible, depending on level of sand
- Brora Brick Clay Member: for base, north bank of River Brora, see Locality 7 [NC 888 040] of Hurst (in Trewin and Hurst, 1993); for remainder, foreshore [NC 905 032] south of River Brora estuary
- Glauconitic Sandstone Member: cliffs in north bank of River Brora [NC 888 040] (see Locality 7 of Hurst (in Trewin and Hurst, 1993))
- Brora Shale Member: foreshore [NC 904 031] south of the River Brora estuary; only the lowest 15.6 m can be seen on the beach, and
- The type areas of the Brora Argillaceous and Brora Arenaceous formations.

The exposures also provide valuable reference sections for a number of Callovian chronostratigraphical units that make them of international interest, although they may be superseded by other European sites at which the subzonal boundaries may be formally defined in the future.

Description

The following composite section of the Callovian succession (comprising the Brora Argillaceous Formation and lower part of the Brora Arenaceous Formation) is based mainly on Sykes (1975) and Hurst (in Trewin and Hurst, 1993).

Thickness (m)

Brora Arenaceous Formation
Clynelisb Quarry Sandstone Member

Friable, pale-yellowish, fine-grained, well-sorted, highly quartzose sand with clay-rich laminae often with disseminated plant remains; variably bioturbated; elsewhere locally, several horizons of nodular, silicified sandstone; sedimentary structures apparently lacking except for some cross-bedding; fauna including abundant lucinoid bivalves, large *Chlamys,* and ammonites (*Euaspidoceras, Hecticoceras* and *Quenstedtoceras*)	*c.* 20
Fascally Sandstone Member	
Thickly bedded, grey-green, intensely bioturbated, muddy, fine- to very fine-grained, sandstone with sandy silts at top; fauna including bivalves (lucinoids with less abundant *Barbatia, Chlamys* and *Meleagrinella*)*;* belemnites; common ammonites (*Kosmoceras* and *Quenstedtoceras*)*; Thalassinoides* and traces of wave-ripple lamination	6.5
Brora Argillaceous Formation	
Fascally Siltstone Member	
Predominantly coarse siltstone passing up into fine sandstone; calcareous nodules at some levels; poorly fossiliferous with bivalve fauna showing gradual change from lucinoid- and/or *Cucullaea* (*Idonearca*) –dominated assemblages in lower finer-grained beds, to *Chlamys*-dominated assemblages in sandier beds near top; ammonites including *Kosmoceras, Longaeviceras* and *Peltomorphites*	33.5
Brora Brick Clay Member	
Bituminous, sandy silts and laminated muddy siltstones grading up into pale greenish-grey clay, in five rhythms; single row of limestone doggers near middle; fauna increasing in numbers and diversity upwards with bivalve assemblages dominated firstly by lucinoids and/or *Cucullaea* (*Idonearca*)*,* then *Palaeonucula* and finally *Entolium; Bositra buchii* (Roemer) crowded in some clay horizons; *Solemya woodwardiana* Leckenby also present; belemnites and ammonites including *Kosmoceras* and *Binatisphinctes;* base marked by abrupt upward reduction in grain size	15
Glauconitic Sandstone Member	
Muddy, glauconitic, bioturbated silty sandstone (4.15 m) with thin, shale interbeds and horizons of phosphatic nodules associated with belemnite (*Cylindroteuthis*) accumulations, overlain by grey siltstone (2 m) and then slightly glauconitic, silty sandstone (3.9 m) showing five coarsening-upwards cycles and with a prominent bed of limestone doggers near base and horizons of phosphatic nodules (some containing *Rhaxella* sponge spicules); restricted fauna dominated by *Cylindroteuthis* and *Meleagrinella braamburiensis* (Phillips); *Lingula craniae* Davidson locally abundant; plant fragments and sporadic ammonites (*Kosmoceras*)*;* trace fossils including *Thalassinoides, Diplocraterion* and *Chondrites* identifiable at sand-shale boundaries	10.1
Brora Shale Member	

Silty sands (2.3 m) grading rapidly upwards to very dark, organic-rich shales (*c.* 25 m) with some thin (0.05 m) seams of glauconitic sand and shell beds with bivalves (*Protocardia?* and *Trautscholdia* in lower part, *Meleagrinella* above); and sporadic ammonites including *Kepplerites* and *Sigaloceras*	*c.* 27.5
Brora Roof Bed: Intensely bioturbated, medium-grained sandstone with a few quartzite pebbles; top marked by thin, glauconitic sand with *Cylindroteuthis,* and top surface with preferentially orientated gastropods (*Pietteia*)*;* relatively well-preserved ammonite fauna including *Kepplerites* and *Proplanulites;* otherwise fauna dominated by the bivalve *Corbula obscura* (J. Sowerby); *Myophorella, Gervillella, Pleuromya* (*in* vertical burrowing position) and reworked fragments of coal from underlying beds also present	up to 2.3

Brora Coal Formation

The most easily identified point in the succession is the Brora Roof Bed, at the base of the Brora Shale Member, which forms a prominent reef marking the seaward limit of exposure along almost 1 km of the foreshore [NC 905 032]–[NC 902 029]. About 100 m east of the sewage pipe that crosses the beach [NC 905 032], the first outcrops of the Glauconitic Sandstone Member are seen low on the beach. Parts of the Brora Brick Clay and Fascally Siltstone members are seen farther east where they form a broad low intertidal platform (Hurst in Trewin and Hurst, 1993). The Brora Shale Member is again exposed in the core of an anticlinal structure about 80 m downstream from the western end of the cliff [NC 888 040] in the north bank of the River Brora. The eastern limb of this structure then takes exposures of the overlying Glauconitic Sandstone and Brora Brick Clay members down to river level farther downstream; only the lowest third of the latter member crops out along the river bank. The Fascally Sandstone and Clynelish Quarry Sandstone members are well exposed in the river cliffs [NC 899 039]–[NC 899 040] nearer to Brora town centre. The sharp boundary between the two members is well exposed in the south bank at the southern end of the section but, normally, the best exposures of the Fascally Sandstone Member are seen in the north bank at the northern end of the section where the top of the Fascally Siltstone Member may also be seen.

Interpretation

The Brora Roof Bed yields a Lower Callovian ammonite fauna including the type specimen of the subzonal index taxon *Kepplerites* (*Gowericeras*)*gowerianus* (J. de C. Sowerby, 1827) (refigured by Tintant, 1963). The type specimen of the similar *K. childanum* S.S. Buckman (1923a) although recorded from the 'Brora Roof Bed' is in a shaly matrix and may be from a higher horizon (Page, 1988). The Brora Roof Bed has also yielded the genera *Proplanulites* (Read and Phemister, 1925) and *Cadoceras* (Natural History Museum, London collections). As a whole, the fauna is consistent with the *gowerianus* Biohorizon of the Gowerianus Subzone (Koenigi Zone).

Ammonites occur sporadically in the overlying Brora Shale Member and include *Kepplerites* (*Gowericeras*) cf. *galilaeii* (Oppel) (Natural History Museum, London collections) indicative of the Galilaeii Subzone, Koenigi Zone, *Sigaloceras* ex gr. *calloviense* (J. Sowerby) (at *c.* 10.7 m above the base of the shale and indicative of the Calloviense Subzone, Calloviense Zone) and *Sigaloceras* ex gr. *enodatum* (Nikitin) (from borehole sections, and indicative of the Enodatum Subzone, Calloviense Zone) (Sykes, 1975; Page, 1988). Sykes' (1975) records of *Homeoplanulites* cf. *difficilis* S.S. Buckman and *Kosmoceras* sp. are problematic and do not, as originally suggested, necessarily prove, respectively, the Enodatum and Medea subzones, although a level in this interval is still likely.

Ammonites also occur sporadically in the Glauconitic Sandstone Member. *Kosmoceras* (*Gulielmiceras*)*jason* aucct. is recorded in the lowest part (Middle Callovian Jason Subzone and Zone), *K.* (*Zugokosmokeras*) *obductum* (S.S. Buckman) (macroconch and microconch) in the succeeding silts (Obductum Subzone, Coronatum Zone) and unspecified

indications of the Grossouvrei Subzone (Coronatum Zone) are noted above (Sykes, 1975; Sykes in Duff, 1980).

The succession of age-diagnostic ammonites in the Brora Brick Clay Member includes, at the base, *Kosmoceras* (*Zugokosmokeras*) ex gr. *grossouvrei* R. Douvillé (including the microconch forms recorded under the names *gulielmi* (J. Sowerby), *castor* (Reinecke) and *pollux* (Reinecke)). These suggest the middle part of the Grossouvrei Subzone. Associated abundant macroconch and microconch *Binatisphinctes comptoni* (Pratt) at higher levels indicate the *comptoni* Biohorizon of the upper Grossouvrei Subzone. The lower part of the Upper Callovian Athleta Zone is indicated by *K.* (*Lobokosmokeras*) ex gr. *phaeinum* S.S. Buckman at *c.* 10.6 m above the base. Callomon and Sykes (in Duff, 1980) proposed the foreshore exposures south of Brora as an international reference section for the base of the Phaeinum Subzone, retaining the now lost Calvert Brickpit in Buckinghamshire (Callomon, 1968) as its 'type locality'.

Although ammonite faunas are poor in the Fascally Siltstone Member, the Phaeinum Subzone (Athleta Zone) is indicated near the base by *K.* (*L.*) ex gr. *pbaeinum* and *Longaeviceras* cf. *placenta* (Leckenby). Higher levels include *K.* (*L.*) *proniae* (Teisseyre) at 10 m above the base (Proniae Subzone, Athleta Zone), *K.* (*K.*) ex gr. *kuklikum* (= *K. spinosum* aucct., part) at 29 m above the base (Spinosum Subzone, Athleta Zone) and *Quenstedtoceras benrici* R. Douvillé and *Peltomorphites* in the top 5 m (Henrici Subzone, Lamberti Zone) (Sykes, 1975). Callomon and Sykes (in Duff, 1980) proposed reference sections for the Proniae and Spinosum subzones on the foreshore south of Brora, and for the Henrici Subzone in river sections west of Brora. As with the Phaeinum Subzone, the 'type localities' of these three subzones (Calvert, Buckinghamshire for the Proniae Subzone and Woodham, Buckinghamshire for the Spinosum and Henrici subzones; Arkell, 1939b; Callomon, 1968) are now lost.

Ammonites are common in the Fascally Sandstone Member and include *Quenstedtoceras* ex gr. *lamberti* (J.Sowerby) and *Kosmoceras* ex gr. *compressum* (Quenstedt) and ex gr. *spinosum* (J. de C. Sowerby) indicating the Upper Callovian Lamberti Zone and Subzone. Callomon and Sykes (in Duff, 1980) proposed the river sections in the upper part of the member as reference sections for this subzone, the original type locality of which, at Woodham Brickpit, Buckinghamshire, is now lost, as already stated. Ammonites in the Clynelish Quarry Sandstone Member also indicate the Lamberti Zone and Subzone. They include common *Euaspidoceras hirsutum* (Bayle) (including the type specimen of *E. clynelishense* Arkell) with *Quenstedtoceras* ex gr. *lamberti* (including *Q. sutberlandiae* (J. de C. Sowerby)) and *Hecticoceras* sp.. No ammonites were recorded by Sykes (1975) from the Brora Sandstone Member, which is assumed to be all, or mainly, of Late Jurassic (Early Oxfordian) age.

The Callovian succession at Brora has particular significance for sedimentological and palaeogeographical studies of the region. Callovian sedimentation began with a significant marine transgression represented by the sandstone of the Brora Roof Bed; this overlies non-marine coal and was deposited in a shallow-marine setting. The abundance of both land-derived material (plant fragments and spores) and marine microplankton (dinoflagellate cysts) in the overlying Brora Shale Member indicates a nearshore open marine depositional environment (MacLennan and Trewin, 1989). According to Hurst (in Trewin and Hurst, 1993), the Glauconitic Sandstone Member represents a period of slow deposition. The remainder of the Brora Argillaceous Formation and all of the Brora Arenaceous Formation forms a marine, coarsening-upwards sequence commencing with offshore marine clays of the Brora Brick Clay Member and culminating, in the Oxfordian Stage, in cross-bedded, porous, pebbly sandstones representing a coastal marine bar system. The rhythms in the Brora Brick Clay Member are interpreted as the result of deposition from small gravity flows (Hurst in Trewin and Hurst, 1993).

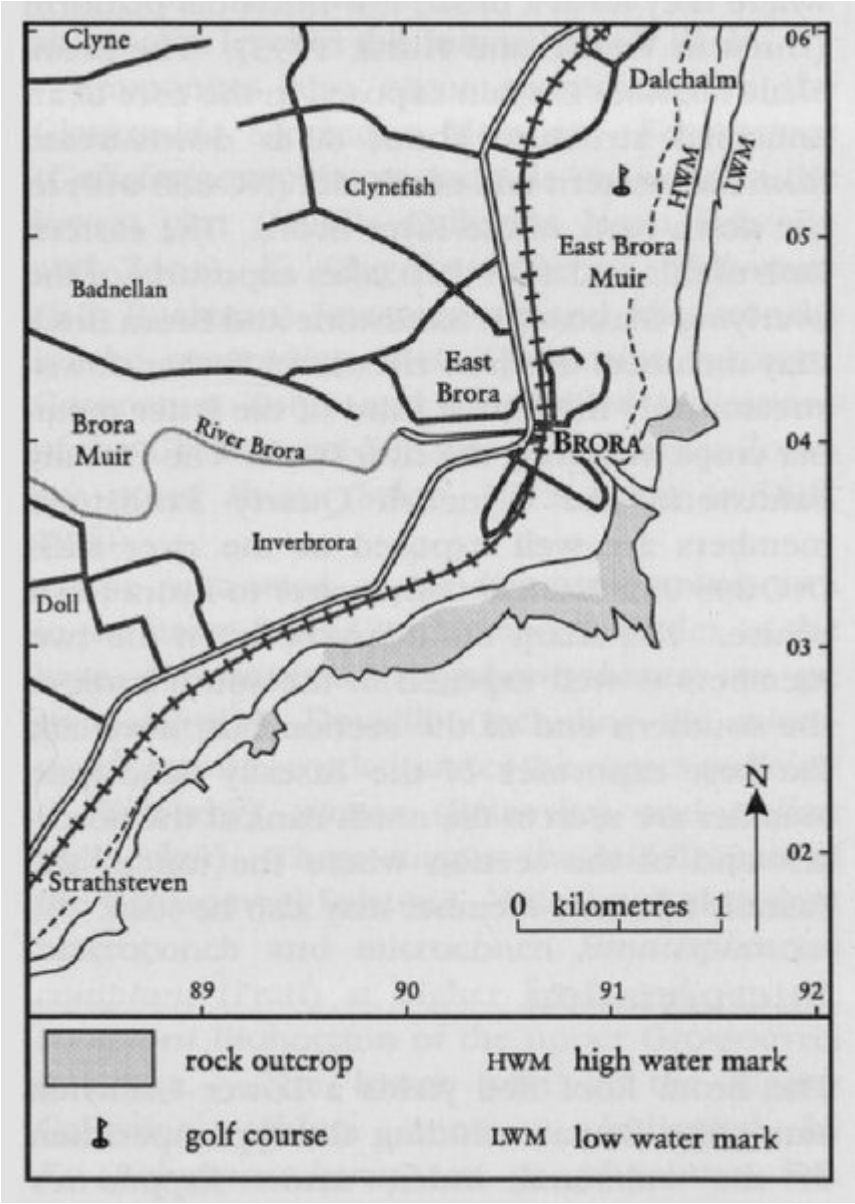
The Callovian succession is one of the thickest (*c.* 115 m) in Britain and, although lithostratigraphically distinct, includes a bituminous-shale episode in upper Middle Callovian, and lower Upper Callovian times (Brora Brick Clay Member), just as in the upper part of the Peterborough Member (Oxford Clay Formation) in southern and central England (see Peterborough Brickpits GCR site report, this volume). For discussion of the relationship of the Brora sections with those of the Balintore area, farther south, see Cadh'-an-Righ GCR site report (this volume).

Conclusions

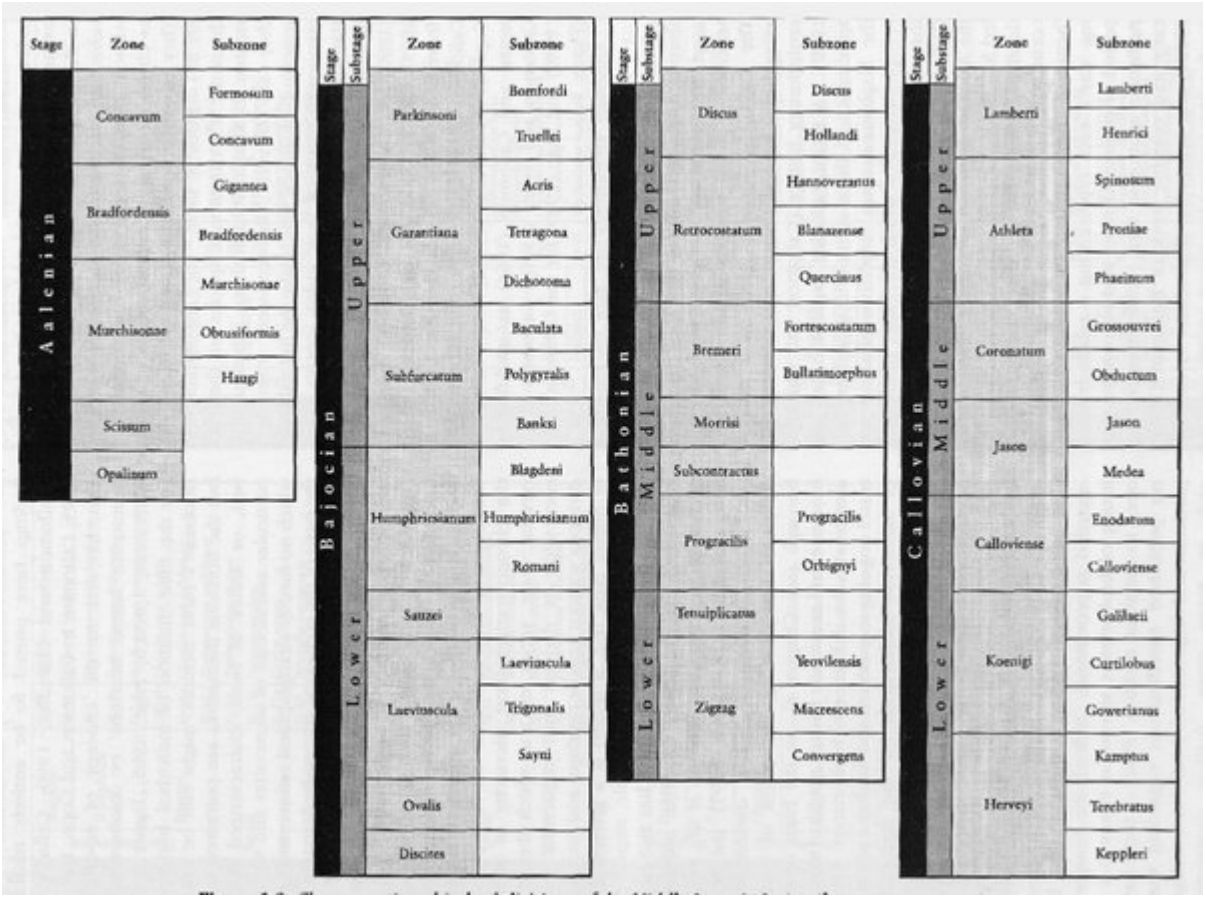
The primary national significance of the Brora Callovian GCR site is that the exposures combine both lithostratigraphical type sections and chronostratigraphical reference sections. The coastal and river sections reveal the most complete and

accessible sections in the Callovian rocks of the Moray Firth Basin. They represent the type areas of the Brora Argillaceous and the Brora Arenaceous formations and include the type sections of their component members. The fossils of these formations include many species of ammonite and bivalve, the type localities for some of which are here. It also includes reference sections for all of the Upper Callovian subzones (see (Figure 1.3), Chapter 1). The diagnostic ammonite faunas, which have not been studied systematically, show a considerably lower diversity than those in southern England owing to a much-reduced Tethyan influence in these extremely northern Subboreal regions (cf. Page, 1996b). A corresponding relative increase in numbers of Arctic genera such as *Longaeviceras* may be expected but remains to be demonstrated. The site is an important one for palaeogeographical as well as stratigraphical studies (see Cadh'-an-Righ GCR site report, this volume).

References



(Figure 6.6) Locality map for the Brora (Callovian) GCR site.)



(Figure 1.3) Chronostratigraphical subdivisions of the Middle Jurassic Series (for sources, see text).)