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# A SEQUENCE OF BIOHORIZONS FOR THE SUBBOREAL PROVINCE LOWER TOARCIAN IN NORTHERN BRITAIN AND THEIR CORRELATION WITH A SUBMEDITERRANEAN STANDARD

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*Abstract.* A sequence of sub-subzonal correlative units at the level of biohorizon is described for the Subboreal Province, Lower Toarcian of North Yorkshire, north west England. Nineteen such units are recognised, as follows: Tenuicostatum Chronozone, Paltum Subchronozone (*paltum*), Clevelandicum Subchronozone (*crosbeyi, clevelandicum*), Tenuicostatum Subchronozone (*tenuicostatum*), Semicelatum Subchronozone (*semicelatum, antiquum*), Serpentinum Chronozone, Exaratum Subchronozone (*elegantulum, exaratum, elegans*), Falciferum Subchronozone (*pseudoserpentinum, falciferum*), Bifrons Chronozone, Commune Subchronozone (*ovatum, commune, athleticum*), Fibulatum Subchronozone (*turriculum, braunianus, vortex*), Crassum Subchronozone (*crassum-bifrons, crassum-semipolitum*). The presence of shared taxa permits detailed correlations to be established with submediterranean zonal schemes in more southerly areas of Europe and an equilibration of zonal boundaries across the region is therefore proposed, providing a uniformity of interpretation for the European Lower Toarcian.

*Riassunto.* Viene descritta una sequenza di unità correlative sottozonali a livello di bioorizzonte per la Provincia Subboreale, Toarciano inferiore del North Yorkshire, Inghilterra nord-ocidentale. Sono state riconosciute diciannove di tali unità, come segue: Cronozona a Tenuicostatum, Subcronozona a Paltum (*paltum*), Subcronozona a Clevelandicum (*crosbeyi*, *clevelandicum*), Subcronozona a Tenuicostatum (*tenuicostatum*), Subcronozona a Semicelatum (*semicelatum*, *antiquum*), Cronozona a Serpentinum, Subcronozona ad Exaratum (*elegantulum*, *exaratum*, *elegans*), Subcronozona a Falciferum (*pseudoserpentinum*, *falciferum*), Cronozona a Bifrons, Subcronozona a Commune (*ovatum*, *commune*, *athleticum*), Subcronozona a Fibulatum (*turriculum*, *braunianus*, *vortex*), Subcronozona a Crassum (*crassum-bifrons*, *crassum-semipolitum*). La presenza di taxa in comune permette di stabilire correlazioni dettagliate con gli schemi zonali submediterranei in aree più meridionali dell'Europa, e pertanto viene proposta una equilibrazione dei limiti zonali attraverso la regione, fornendo un'interpretazione uniforme per il Toarciano inferiore europeo.

## Introduction

A detailed analysis of the sequence of ammonite faunas in the Lower Toarcian in North Yorkshire readily facilitates the refinement of the existing Standard Zonation of the Substage, through the recognition of a sequence of intra-subzonal units at the level of biohorizon (or "faunal horizon" sensu Callomon 1985; Page 1995). Although tabulated by Page (2003), this sequence is here formally defined for the first time in order to establish full stratigraphical meaning. As most of the characteristic elements of the northern English faunas have been described by Howarth (1962, 1973, 1978, 1992), immediate use of this biohorizonal scheme is facilitated.

As discussed by Page (1996, 2003) the Yorkshire faunas characterise a Subboreal Province being dominated, virtually throughout, by dactylioceratidae with some hildoceratidae, mainly early harpoceratids and late *Hildoceras*. In addition, the presence and local abundance of certain characteristically Boreal Hildoceratidae, such as *Elegantuliceras*, *Ovaticeras* and *Pseudolioceras* is typical. In contrast, more southerly areas are characterised by ammonite faunas rich in hildoceratid genera throughout, with dactylioceratids being dominant only at lower levels (Gabilly 1976; Elmi et al. 1994, 1997). These latter faunas are typical of a Submediterranean Province (sensu Page 1996, 2003) and remarkably assemblages are also present in the condensed limestone-marl sequences of the "Junction Bed" of south-west England (Dorset-Somerset; as briefly reviewed by Howarth 1992, pp. 19-26); a transect across Britain consequently revealing a remarkable transition from typical submediterranean faunas in the south to the classic subboreal faunas of North Yorkshire in the north (Fig.1).

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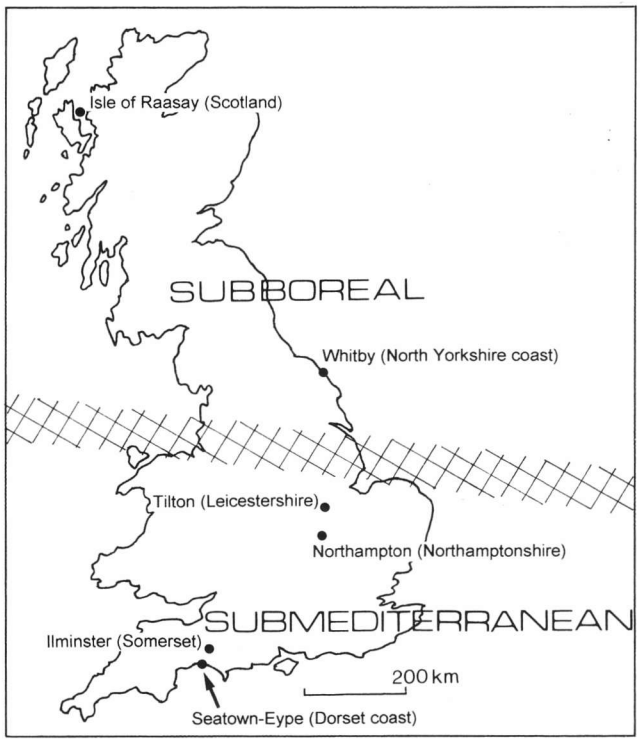


Fig. 1 - Key UK Lower Toarcian localities and districts. Generalised Subboreal-Submediterranean bio-provincial boundary indicated by cross-hatching.

Very close faunal links between the two provinces, even at sub-subzonal level, facilitate detailed correlations between the Subboreal biohorizons described here and the sequence of Submediterranean Province "Horizons" (= zonules sensu Phelps 1985; Page 1995) to be established. Unlike biohorizons, which are discrete beds yielding a diagnostic fauna, the latter units are true sub-subzones and completely fill the stratigraphical column.

## The sequence of Biohorizons in the Subboreal Lower Toarcian of northern Britain

The following sequence is based primarily on reference sections on the North Yorkshire coast. Full locality details and descriptions of sections can be found in Howarth (1955, 1962, 1973, 1978, 1992) and further discussion of zonal and subzonal nomenclature is provided by Howarth (in Dean et al. 1961), Elmi et al. (1997) and Page (2003). Abbreviations as follows: WMFm= Whitby Mudstone Formation, Mb=Member, Fm=Formation, NHM= Natural History Museum, London. An asterix (*) indicates the source of the type specimen of the listed species.

### Tenuicostatum Chronozone

Index: *Dactylioceras tenuicostatum* (Young & Bird). Author: Buckman (1910). Comment: the base of the Toarcian Stage in Europe corresponds to the base of the Tenuicostatum Chronozone, the type locality of which is on the coast of northern England. Faunas at this level are, however, very rare in North Yorkshire and elsewhere in Britain only known form very condensed and incomplete sequences. Further south in Europe, in submediterranean province regions, similar *Protogrammoceras* and early *Dactylioceras* (*Eodactylites* spp.) are much better known (as reviewed by Elmi et al. 1997), although detailed correlations with the historical type-area have yet to be established and a Global Stratotype Section and Point formally established.

**1. Paltum Subchronozone.** Index: *Protogrammoceras paltum* (Buckman, 1922). Author: Howarth (1973) as a subzone. Defined base (provisional): base of Bed 26, Kettleness, or Staithes-Port Mulgrave area, Cleveland Ironstone Fm (Cox 1990, p.173; Howarth, 1992, p.5). Comment: Toarcian ammonites are not recorded below Bed 3 on the North Yorkshire coast, although inland and around 10 km to the north-west near Saltburn, a single specimen of *Dactylioceras* (see below) may suggest that the base of the stage lies at a lower level, within the top of the Cleveland Ironstone Formation (equivalent to Beds 26 to 28 of the coastal sequence) – Howarth's definition is therefore provisionally followed here.

I. *Protogrammoceras paltum* Biohorizon. Author: Buckman (1922) as a hemera. Reference section: Beds 26-28, Cleveland Ironstone Fm to Bed 3, Grey Shales Mb, WMFm, Kettleness, North Yorkshire coast. Fauna: rare *Protogrammoceras paltum* (Buckman) (including Howarth 1992, text. fig. 11, pl.1, fig.1) and very rare *Dactylioceras* (*Eodactylites*) *pseudocommune* Fucini (including Howarth 1973, pl.1, fig. 1). Comment: the characteristic *Protogrammoceras* fauna is rare in North Yorkshire, but more abundant on the Dorset coast of southern England, in the highly condensed "Junction Bed" (Howarth 1992, pp. 24-26, pls.1, 2). Despite being the source of the holotype of the index species (pl. 2, fig. 2), the sequence in this latter area is too thin and incomplete to provided a suitable reference section.

Dactylioceratids are very rare at this level and Howarth (1973, pp. 246, 253-254) discusses the stratigraphical origin of the lowest recorded specimen in Britain from near Saltburn in Cleveland, and concludes that it represents *D. pseudocommune* and is most likely to have come from a level equivalent to Bed 26 on the coast. Crucially, the only specimen recorded from the latter area, in the same level as *Protogrammoceras* (Bed 3), is a similar sharp and radial ribbed form (NHM C77295), unlike typical *D.* (*Orthodactylites*) *crosbeyi*, from higher in the sequence (see below). The latter is therefore considered here to represent the same species group as the Saltburn specimen; beds 26-3 are therefore provisionally united within the same biohorizon.

**2. Clevelandicum Subchronozone.** Index: *Dactylioceras* (*Orthodactylites*) *clevelandicum* Howarth. Author: Howarth (1973). Defined base: base of Bed 18, Grey Shales Mb, WMFm., North Yorkshire coast (e.g. Hawsker Bottoms/Kettleness/Port Mulgrave) (Howarth, 1992, p. 5).

II. *Dactylioceras crosbeyi* Biohorizon. Author: Page (2002), equivalent to the lower part of the *Dactylioceras* sp. nov. horizon of Sylvester-Bradley in Howarth (1961). Reference section: Bed 18, Grey Shales Mb, WMFm, Port Mulgrave, (Brackenbury Wyke to Rosedale Wyke area), North Yorkshire coast. Fauna: common **D.* (*O.*) *crosbeyi* (Simpson) (including Howarth 1973, pl.1, figs 2-4, pl.2, figs 1-4).

III. *Dactylioceras clevelandicum* Biohorizon. Author: Page (2002), equivalent to the upper part of the *Dactylioceras* sp. nov. horizon of Sylvester-Bradley and Howarth (in Dean et al. 1961). Reference section: Bed 19b, Grey Shales Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: common **D.* (*O.*) *clevelandicum* Howarth (including Howarth 1973, pl. 3, figs 1*, 2, 3, pl. 4, figs 1, 2, pl. 5, fig. 3).

**3. Tenuicostatum Subchronozone.** Index: as Tenuicostatum Chronozone (see above). Author: Howarth (1973). Defined base: base of Bed 20, Grey Shales Mb, WMFm, North Yorkshire coast (e.g. Kettleness/Port Mulgrave), England (Howarth 1992, p. 5).

IV. *Dactylioceras tenuicostatum* Biohorizon. Author: Buckman (1930) as a hemera, Sylvester-Bradley in Howarth (in Dean et al. 1961)

as a "horizon". Reference section: Beds 20-27, Grey Shales Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: common **D. (O.) tenuicostatum* (Young & Bird) (including Howarth 1973, pl. 5, figs. 1*, 2, pl. 6, figs. 2, 3).

**4. Semicelatum (I) Subchronozone.** Index: *Dactylioceras semicelatum* (Simpson). Author: Howarth (1973) as a restricted subzone. Defined base: base of Bed 28, Grey Shales Mb., WMFm., North Yorkshire coast (e.g. Kettleness/Port Mulgrave) (Howarth 1992, p. 5). Comments: the Semicelatum Subchronozone of the Subboreal Province as restricted by Howarth (1973) is not the same as that of the Submediterranean and Mediterranean provinces in Elmi et al. (1997), which broadly equates to the Clevelandicum, Tenuicostatum and Semicelatum subchronozones combined. Following Page (2002) these two units are distinguished as Semicelatum (I) and Semicelatum (II), respectively.

V. *Dactylioceras semicelatum* Biohorizon. Author: Sylvester-Bradley and Howarth (in Dean et al. 1961) as a "horizon". Reference section: Beds 28-31,Grey Shales Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: common **D. (O.) semicelatum* (including Howarth 1973, pl. 6, fig. 1, pl.7 , figs 1, 2, pl. 8, figs 1-4, pl. 9, figs 1, 2) and very rare *Meneghiniceras lariense* (Meneghini) (Howarth 1976, p. 773, figs 1, 2).

VI. *Tiltoniceras antiquum* Biohorizon. Author: Buckman (1898) as an *acutum* Hemera (*T. acutum* (Tate), a junior synonym of *T. antiquum* (Wright)). Reference section: Beds 32, Grey Shales Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: common **Tiltoniceras antiquum* (Wright) (including Howarth 1992, text fig.*13, pl. 6, fig. 7, pl. 7, figs 2, 3) and *Dactylioceras (Orthodactylites) semicelatum* (including Howarth 1973, pl. 9, fig. 3).

### Serpentinum Chronozone

Index: *Harpoceras serpentinum* (Schlotheim). Author: Oppel (1856), as an alternative name for his *Posidonia bronni* Zone. The use of *H. serpentinum* as an index has priority over *H. falcifer* (J. Sowerby), as first used by Haug (1885) and subsequently by most British authors (e.g. Howarth in Dean et al. 1961, also 1992).

**5. Exaratum Subchronozone.** Index: *Cleviceras exaratum* (Young & Bird). Author: Buckman (1910) as a zone. Defined base: Base of Bed 33, Mulgrave Shale Mb, WMFm, North Yorkshire coast (e.g. Hawsker Bottoms/Port Mulgrave) (Cox 1990, p. 173; Howarth 1992, p. 6).

VII. *Elegantuliceras elegantulum* Biohorizon. Author: Buckman (1930) as a hemera. Reference section: Beds 33-34, Jet Rock Beds, Jet Rock Mb, WMFm, Hawsker Bottoms, North Yorkshire coast. Fauna: common **Elegantuliceras elegantulum* (Young & Bird) (including pl. 7, figs 4,8, pl. 8, figs 2-21, pl. 9, fig. 1).

VIII. *Cleviceras exaratum* Biohorizon. Author: Buckman (1930) as a hemera. Reference section: Beds 35-36, Jet Rock Beds, Jet Rock Mb, WMFm, Hawsker Bottoms, North Yorkshire coast. Fauna: common **Cleviceras exaratum* (including Howarth 1992, text fig. 10, pl. 9, figs 2-6, pl. 10, figs 3, 4, pl. 11, figs 9-17, pl. 12, figs 1-5, pl. 13, figs 1, 2) with less frequent *Harpoceras serpentinum*, *Hildaites forte* (Buckman) (including Howarth 1992, pl. 32, fig. 2), *Hildaites murleyi* (Moxon) (including Howarth 1992, pl. 31, figs 1-4, 6, 7), *Phylloceras heterophyllum* (J. Sowerby), *Lytoceras crenatum* (Buckman), *L. nitidum* (Young and Bird) and probably also *Dactylioceras* sp..

IX. *Cleviceras elegans* Biohorizon. Author: Page (2002). Reference section: Beds 37-40, Jet Rock Beds, Mulgrave Shale Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: *Cleviceras elegans* (J. Sowerby) (including Howarth 1992, pl. 12, figs 6-8, pl. 14, fig. 2, pl. 15, fig. 1) frequent, with *Harpoceras serpentinum* (including Howarth 1992, pl. 16, fig. 2), *Hildaites murleyi*, *Dactylioceras (Orthodactylites) semiannulatum* Howarth (including Howarth 1978, pl. 1, figs 4, 5, 7), *Nodicoeloceras crassoides* (Simpson) and *Phylloceras heterophyllum*. Comment: the tripartite sequence of ammonite faunas of the Exaratum Subchronozone is commented on by Howarth (1992, p.6) but no formal subdivisions were created. Comment: the neotype of *C. elegans* belongs to the same assemblage in the Ilminster district of Somerset, south-west England (Howarth 1992, pp. 100-101).

**6. Falciferum Subchronozone.** Index: *Harpoceras falciferum* (J. Sowerby). Author: Arkell (1933) as a restricted subzone. Defined base: Base of Bed 41, Mulgrave Shale Mb, WMFm, North Yorkshire coast (e.g. Saltwick Bay/Port Mulgrave) (Howarth 1992, p. 6).

X. *Harpoceras pseudoserpentinum* Biohorizon. Author: Page (2002) as *mulgravium* Biohorizon. Reference section (provisional): Beds 17-18, "Junction Bed", Barrington-Shepton Beauchamp area, Somerset (probably equivalent to Bed 41 (?part), Mulgrave Shale Mb, WMFm, Port Mulgrave, North Yorkshire coast. Fauna: evolute, fine ribbed *H.* ex gr. *falciferum* (=*H. pseudoserpentinum* Gabilly), with *Dactylioceras* (including *D.* cf. *anguiforme* (Buckman) and *D. verme* (Simpson)), probable *Nodicoeloceras crassoides* (Simpson) and early *Hildoceras* sp. (Somerset); *H.* ex gr. *falciferum*, *Hildaites murleyi*, *Dactylioceras* sp. (North Yorkshire). Comment: the harpoceratid fauna of the Falciferum Subchronozone on the North Yorkshire coast is incompletely characterised as much of the material is crushed. Nevertheless, evidence from Somerset (per. obs.) indicates that typical *H. pseudoserpentinum* Gabilly) occurs below true *H. falciferum* (specimens of the former include NHM C77481-2 from Bed 5 at Barrington, previously identified as *H. falciferum* by Howarth (e.g. 1992, pp. 22-23).

XI. *Harpoceras falciferum* Biohorizon. Author: Buckman (1930) as a hemera. Reference section (provisional): Beds 42-45, Mulgrave Shale Mb, WMFm, Saltwick Bay, Whitby, North Yorkshire coast. Fauna: *H. falciferum* sensu stricto (including Howarth 1992, pl. 20, figs 1,7 and possibly pl. 18, fig. 3, pl. 20, fig. 5 and text fig. 33), *Dactylioceras consimile* (Buckman), *D. gracile* (Simpson), *Nodicoeloceras incrassatum* (Simpson) and *Phylloceras heterophyllum*. Comment: the reference horizon is provisional, pending further analysis of available specimens from North Yorkshire.

### Bifrons Chronozone

Index: *Hildoceras bifrons* (Bruguière). Author: Reynès (1868).

**7. Commune Subchronozone.** Index: *Dactylioceras commune* (J. Sowerby). Author: Howarth (in Dean et al. 1961) as a restricted subzone, equivalent to the Subcarinata Zone of Thompson (1910). Defined base: 0.75 m below the top of Bed 47, Bituminous Shales Beds, Mulgrave Shale Mb, WMFm, Saltwick Bay, Whitby, North Yorkshire coast. This definition is modified from that of Howarth (1992, p. 6) and Cox (1990, p. 173) to include the *ovatum* Biohorizon, following Page (2002). This modification is necessary to equate the base of the Bifrons Chronozone in the Subboreal Province with that in the Submediterranean and Mediterranean Provinces where faunas with *Hildoceras* ex gr. *sublevisoni* Fucini are taken to indicate the lower part of the chronozone (Elmi et al. 1997, p. 28); the association of *H.* ex gr. *sublevisoni* (= *H. laticosta* Bellini, part, in Howarth 1992) and *Ovaticeras ovatum* (Howarth 1992, pp. 22, 141, 143, pl. 23, fig. 4.) has been proven near Ilminster in southern England (pers. obs., as recorded by Howarth 1992, p. 22). Relatively involute *H.* ex gr. *falciferum* persists at this level.

XII. *Ovaticeras ovatum* Biohorizon. Author: Buckman (1910) as a hemera. Reference section: topmost 0.75 m of Bed 46 and Bed 47, Bituminous Shales Beds, Mulgrave Shale Mb, WMFm, Saltwick Bay, Whitby, North Yorkshire coast . Fauna: *Ovaticeras ovatum* (Young & Bird) (Howarth 1992, pl. 24, figs 3-5, pl. 25, fig. 1), *Dactylioceras* cf. *toxophorum* (Buckman), *D.* cf. *consimile*, *Phylloceras heterophyllum*.

XIII. *Dactylioceras commune* Biohorizon. Author: Page (2002), includes the *subcarinata* Hemera of Buckman (1930). Reference section: Beds 49 (Hard Shales Beds)-Bed 54 (Main Alum Shales Beds), Alum Shale Mb, WMFm, Whitby, North Yorkshire coast. Fauna: common *D. commune* (J. Sowerby) with *D. praepositum* Buckman, *D. temperatum* (Buckman), *D. crassiusculum* (Simpson) and uncommon *H.* sp. cf. *tethysi* Geczy (in Bed 51), *H. lusitanicum* Meister (in beds 52-54, including Howarth 1992, pl. 35, fig. 1 from Bed 54), *Phylloceras heterophyllum* and rare *Frechiella subcarinata* (Young and Bird) (probably including Howarth 1992, pl. 29, figs 6, 7).

XIV. *Dactylioceras athleticum* Biohorizon. Author: Buckman (1930) as a hemera. Reference section: Beds 55-59 Main Alum Shales Beds, Alum Shale Mb, WMFm, Whitby, North Yorkshire coast. Fauna: common *D. athleticum* (Simpson), *D. praepositum*, *D. temperatum*, *D. crassescens* (Simpson), with rarer *H. lusitanicum* Meister (including in beds 55 and xxviii), *Pseudolioceras lythense* (Young & Bird), *Phylloceras heterophyllum* and *Lytoceras cornucopia* (Young & Bird) (Howarth 1992, pp. 9-11). Comment: equivalent to Beds xxvii-xxviii at Ravenscar (Howarth 1962b), which although having yielded a less diverse fauna, are readily recognisable and suitable for use as a parastratotype. Significantly these levels have also yielded a single *?Zugodactylites* sp. (pers. obs.).

**8. Fibulatum Subchronozone.** Index: *Peronoceras fibulatum* (J. de C. Sowerby). Author: Thompson (1910). Defined base: base of Bed 60, Alum Shale Member, Whitby Mudstone Formation,Whitby, North Yorkshire coast (Howarth 1992, p. 6).

XV. *Peronoceras turriculatum* Biohorizon. Author: Page (2002). Reference section: Bed xxix, Main Alum Shales Beds, Alum Shale Mb, WMFm, Ravenscar, North Yorkshire coast. Fauna: common *Peronoceras fibulatum* (J. de C. Sowerby) (may include Howarth 1978, pl. 4, fig. 1), *P. turriculatum* (Simpson), *P. perarmatum* (Young & Bird) (may include Howarth 1978, pl. 5, fig. 1 from "Beds 60-63" at Whitby), *P. subarmatum* (Young and Bird) and rarer *Pseudolioceras lythense* (Young and Bird) (pl. 27, fig. 2), early *Hildoceras* ex gr. *bifrons* (probably *H. apertum* Gabilly) and *Phylloceras heterophyllum*. Comment: equivalent, at least in part, to Beds 60-63 ("lower half") of Howarth (1992) at Whitby, which may also yield *Zugodactylites* (in Bed 62). The *P. turriculatum* figured by Howarth (1978, p. 2, fig. 3, pl. 3, fig. 3) from an specified level in Bed 63 in Whitby may have come from either the *turriculatum* or the succeeding *braunianus* biohorizon.

XVI. *Zugodactylites braunianus* Biohorizon. Author: Buckman (1930) as a hemera. Reference section: Bed xxxi, Main Alum Shales Beds, Alum Shale Mb, WMFm, Ravenscar, North Yorkshire. Fauna: common *Peronoceras* spp. including *P. fibulatum*, *P. subarmatum* (Young & Bird) and *P. turriculatum* with *Zugodactylites braunianus* (d'Orbigny) (including Howarth 1978, pl. 7, figs 2-4, pl. 8, fig. 5), *Z. thompsoni* Howarth, *Hildoceras apertum* Gabilly (including NHM C68505, C78203, 20, etc.) and rarer *Ps. lythense* (including Howarth 1992, pl.27, fig.3), *Harpoceras subplanatum* (Oppel), *Phylloceras heterophyllum* and *Lytoceras cornucopia*. Comment: probably equivalent to Beds 63 ("top 0.3 m)-64 (lowest 0.1 m) at Whitby.

XVII. *Porpoceras vortex* Biohorizon. *Author*: Buckman (1930) as a hemera. Reference section: Beds xlii-xliv, Cement Shales Beds, Alum Shale Mb, WMFm, Ravenscar, North Yorkshire coast. Fauna: *Porpoceras* ex gr. *vortex* (Simpson) (including *P. verticosum* Buckman and *P.vorticellum* Buckman), *H. bifrons* sensu stricto (including NHM C68243-51, C68519) and occasional *Pseudolioceras lythense* and *Harpoceras subplanatum* (Oppel). Comment: broadly equivalent to lower 1.5 m of Bed 72 at Whitby.

**9. Crassum Subchronozone.** Index: *Catacoeloceras crassum* (Young & Bird). Author: Corroy & Gérard (1933). Defined base: base of Bed XIIV, Alum Shale Member, Whitby Mudstone Formation, Ravenscar, North Yorkshire (cf. Howarth 1992, p. 6).

XVIII. *Catacoeloceras crassum-Hildoceras bifrons* Biohorizon. Author: Page (2002). Reference section: Beds xlv-xlvii, Cement Shales Beds, Alum Shale Mb, WMFm, Ravenscar, North Yorkshire coast. Fauna: common *C. crassum* (including "*Collina*" *mucronata* (d'Orbigny)) in association with *Hildoceras bifrons* sensu stricto. Comment: the same fauna is apparently present from around 1.5 m above the base of Bed 72 at Whitby below the first *H. semipolitum*, although exact levels are not recorded by Howarth (1992, pp. 9,10).

XIX. *Catacoeloceras crassum-Hildoceras semipolitum* Biohorizon. Author: Page (2002). Reference section: Beds xlviii-liii, Cement Shales Beds, Alum Shale Mb, WMFm, Ravenscar, North Yorkshire coast. Fauna: *C. crassum* (including "*Collina*" [= "*Mucrodactylites*"] *mucronata* (d'Orbigny)), *Hildoceras semipolitum* (Buckman) (including Howarth 1992, pl. 38, fig. 2 from bed xlix). Comment: probably includes the upper part of Bed 72 at Whitby, with *H. semipolitum* (Howarth (1992, pp. 9,10). The base of the Variabilis Chronozone and hence the Upper Toarcian is drawn at the first occurrence of *Catacoeloceras dumortieri* (Mauberge) following the interpretation of Elmi et al. (1997, p. 30). At Whitby this level is missing in a non-sequence below the Aalenian, but at Ravenscar, *C. dumortieri* first occurs in Bed liv. *H. semipolitum* persists and in southern England (Somerset) can be abundant in association with *Haugia variabilis* (d'Orbigny) in the lower part of the Variabilis Chronozone (including Variabilis Subchronozone; per. obs.). At Ravenscar, *Haugia* sp. is first recorded by Howarth in Bed lviii, also in association with *Catacoeloceras dumortieri* (Mauberge), around 2 m above the latter's first occurrence. Intermediate levels (Bed lv) also yield *Phylloceras heterophyllum*, "*C. crassum*" and *Pseudolioceras boulbiense* (Young & Bird) (Howarth 1992, pl. 27, fig. 6) (pp. 9, 13).

## Correlation with Submediterranean Province areas

As Submediterranean faunas are frequently richer in Hildoceratacеae, sometimes to the virtual exclusion of Dactylioceratidae, separate zonal schemes have historically evolved. Significantly, however, the transition between submediterranean style faunas and subboreal occurs between southern England (Dorset and Somerset) and northern England (North Yorkshire), thereby enabling detailed inter-provincial correlations to be established within a relatively small geographical area. The correlation of the Submediterranean scheme reviewed by Elmi et al. (1997) with the Subboreal sequence here described is discussed below and illustrated by Fig. 2:

**Tenuicostatum Chronozone, Paltum Subchronozone:** Paltum Horizon - the presence of *Eodactylites* and *Protogrammoceras* ex gr. *paltum* indicates a general correlation with the subboreal *Protogrammoceras paltum* Biohorizon.

**Semicelatum (II) Subchronozone:** Crosbeyi Horizon - explicitly includes the *Dactylioceras crosbeyi* and *Dactylioceras clevelandicum* biohorizons as is stated to be equivalent to the subboreal Clevelandicum Subchronozone by Elmi et al. (1997, p. 26). Tenuicostatum Horizon – equivalent to the Tenuicostatum Subchronozone as stated by Elmi (1997, p. 26) and hence including the *Dactylioceras tenuicostatum* Biohorizon. Semicelatum Horizon - equivalent to the Tenuicostatum Subchronozone (as stated by Elmi 1997, p. 26) and hence includes the subboreal *Dactylioceras semicelatum* and *Tiltoniceras antiquum* biohorizons.

**Serpentinum Chronozone, Exaratum [Elegantulum] Subchronozone:** as the Elegantulum "Subzone" of Elmi et al. (1997) is identical in stratigraphical range to the earlier named Exaratum Subchronozone as used here, the former name is considered to have priority. Elegantulum Horizon - explicitly includes the subboreal *Elegantuliceras elegantulum* Biohorizon. Strangewaysi Horizon – the presence of *Cleviceras exaratum* and *C. elegans* (Elmi et al. 1997, p. 26) indicates a correlation with the Subboreal *Cleviceras exaratum* and *Cleviceras elegans* biohorizons.

**Falciferum Subchronozone:** Pseudoserpentinum Horizon – explicitly includes the subboreal. *Harpoceras pseudosepentinum* Biohorizon. Douvillei Horizon - *Orthildaites douvillei* (Haug) is recorded in southern Britain in association with typical *Harpoceras* ex gr. *falciferum* (e.g. in Howarth 1992), thereby confirming a correlation with the *Harpoceras falciferum* Biohorizon.

**Bifrons Chronozone, Sublevisoni Subchronozone:** the submediterranean subchronozonal index is abundant and characteristic, but relatively rare in subboreal areas - it is therefore appropriate to retain a differentiated subchronozonal nomenclature. Sublevisoni Horizon - The presence of *Hildoceras* ex gr. *sublevisoni* (= *H. laticosta* Bellini, part, in

| Subboreal Province | | | Submediterranean Province | | |
|---|---|---|---|---|---|
| Zone | Subzone | Biohorizon | Zonule | Subzone | Zone |
| Bifrons | Crassum | *crassum–semipolitum* | Semipolitum | Bifrons | Bifrons |
| | | *crassum–bifrons* | Bifrons | | |
| | Fibulatum | *vortex* | | | |
| | | *braunianus* | Apertum | | |
| | | *turriculatum* | | | |
| | Commune | *athleticum* | Lusitanicum | Sublevisoni | |
| | | *commune* | Tethysi | | |
| | | *ovatum* | Sublevisoni | | |
| Serpentinum | Falciferum | *falciferum* | Douvillei | Falciferum | Serpentinum |
| | | *pseudoserpentinum* | Pseudoserpentinum | | |
| | Exaratum | *elegans* | Strangewaysi | Elegantulum | |
| | | *exaratum* | | | |
| | | *elegantulum* | Elegantulum | | |
| Tenuicostatum | Semicelatum (I) | *antiquum* | Semicelatum | 'Semicelatum' (II) | Tenuicostatum |
| | | *semicelatum* | | | |
| | Tenuicostatum | *tenuicostatum* | Tenuicostatum | | |
| | Clevelandicum | *clevelandicum* | Crosbeyi | | |
| | | *crosbeyi* | | | |
| | Paltum | *paltum* | Paltum | Paltum | |

Fig. 2 - Correlation of Subboreal Province biohorizons (as described here) and Submediterranean Province horizons (after Elmi et al. 1997).

Howarth 1992) in association with *Ovaticeras ovatum* in southern Britain indicates a correlation with the subboreal *Ovaticeras ovatum* Biohorizon. Tethysi Horizon – the presence of *H.* cf. *tethysi* Geczy in the lower part of the subboreal *Dactylioceras commune* Biohorizon indicates a correlation. Lusitanicum Horizon – as *H. lusitanicum* sensu Elmi et al. (1997) non Howarth (1992) is now known to range from the upper part of the subboreal *Dactylioceras commune* Biohorizon to near the top of the *Dactylioceras athleticum* Biohorizon, a correlation is established.

**Bifrons Subchronozone:** Apertum Horizon – the presence of *Hildoceras apertum* in the *Zugodactylites braunianus* Biohorizon and its probable occurrence in the *Peronoceras turriculatum* Biohorizon below, establishes a correlation. Bifrons Horizon – *H. bifrons* sensu stricto first occurs in levels intermediate between the *Zugodactylite braunianus* and *Porpoceras vortex* biohorizons, as defined here (including Bed xxxii at Ravenscar (NHM C78248) and Bed 65 near Whitby (NHM C78221). The boundary between the Apertum and Bifrons horizons is therefore placed at this level in the subboreal sequence. The Bifrons Horizon would therefore include both the *Porpoceras vortex* and *Catacoeloceras crassum-Hildoceras bifrons* biohorizons. Semipolitum Horizon – explicitly includes the subboreal *Catacoeloceras crassum-Hildocera semipolitum* Biohorizon.

## Concluding remarks

Although the base of the stage is poorly characterised in North Yorkshire due to the rarity of the ammonite faunas of the *Protogrammoceras paltum* Biohorizon, at higher levels the presence of a considerable number of shared taxa permits detailed links to be established between subboreal and submediterranean correlations schemes for Europe. The equilibration of zonal boundaries, as discussed above, can provide a uniformity of interpretation of the Lower Toarcian in this region, although faunal differentiation indicates that the maintenance of different subzonal and sub-subzonal nomenclature is appropriate to facilitate the application of each scheme in local stratigraphical studies.

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