STRATIGRAPHY

Previous page: Lower Jurassic ammonites (*Platypleuroceras caprarium*) from Bornholm, Denmark – see Donovan & Surlyk (2003, this volume). Photo: Kristian Kloth-Jørgensen.

The Lower Jurassic of Europe: its subdivision and correlation

Kevin N. Page

The Lower Jurassic Sub-system comprises four stages, in chronological order, the Hettangian, Sinemurian, Pliensbachian and Toarcian. Each stage is subdivided into a sequence of 'standard zones' (= chronozones) and subzones – each correlated primarily on the basis of its ammonite fauna. A further increase in stratigraphical resolution is available by the use of intra-subzonal units known collectively as 'horizons'. The close link between ammonites and chronostratigraphy means that faunal provincialism may determine which zonal framework, and therefore which subdivision of the Lower Jurassic, applies in different regions of Europe. Such provincialism is of minor importance in the early Jurassic (Hettangian – Lower Pliensbachian) but increases significantly in the Upper Pliensbachian and into the Toarcian where at least three ammonoid faunal provinces are distinguishable. The standard zonal schemes for each relevant faunal area are discussed here, with greatest emphasis being placed on the Northwest European Province, which is characteristic of much of northern Europe throughout most of the Early Jurassic. Intra-subzonal units have only been described in certain regions for parts of the Lower Jurassic but where recognisable these are introduced.

Keywords: Europe, Lower Jurassic, ammonite zonal biostratigraphy

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The Jurassic System takes its name from the Jura Mountains of eastern France and Switzerland, first recognised as having rocks of a distinctive geological division by Alexander von Humbolt in 1795. It was not until 1829, however, that the term 'Jurassique' was introduced by Brongniart (1829), although in a restricted sense essentially for what is now known as the Middle Jurassic (Torrens & Getty 1980). Inclusion of what is now Lower and Upper Jurassic was soon made and by 1842, with the publication of Alcide d'Orbigny's 'Palaeontologie Française, terrains Jurassique' (1842–1849), a system of subdivision of a modern-looking Jurassic system into stages was well under way (Arkell 1933; Rioult 1974).

D'Orbigny's stages, Oppel zones and the Lower Jurassic

The stages introduced by d'Orbigny (1842–1849) were designed to be of worldwide use and were based on the assumption that periodic mass extinctions followed by rapid re-establishments of new faunas characterised stage boundaries (Arkell 1933, p. 9). The duration of the existence of a particular 'fauna' therefore correlated rocks belonging to a specific stage. For what is now considered to be Lower Jurassic, he recognised three successive stages: Sinémurien (after Semur-en-Auxois in Burgundy, eastern France), Liasien (derived from the old lithological or lithostratigraphical term 'Lias') and Toarcien (after Thouars in western France). D'Orbigny (1842–1849) included in each of his stages a series of fossil 'zones', using the term in a purely palaeontological sense to indicate the general stratigraphic range of particular taxa.

The term 'zone' was refined by Albert Oppel (1856–1858), who developed a sequence of such divisions for the entire Jurassic System. Oppel also apparently firmly established the use of Lower Jurassic ('Unterer Jura') in a modern sense, as being equivalent to the earlier essentially lithostratigraphical division known as 'Lias'. Although not specifically using d'Orbigny's stages, Oppel referred to Zonengruppen or Etagen. For the Lower Jurassic he recognised three successive divisions of this type: Semur-Gruppe (equivalent to d'Orbigny's Sinémurian), Pliensbach-Gruppe (equivalent to Liasien, named after Pliensbach in Württemberg, Germany) and Thouars-Gruppe (equivalent to Toarcian). Very importantly, Oppel established the 'Zone des *Ammonites planorbis*' as marking the base of the Jurassic. This convention still stands, as does Oppel's general framework of zones, the only significant subsequent change being the creation of the Hettangian Stage by Renevier (1864) for the first two zones of Oppel's original scheme.

Many other stage names have been proposed for parts of the Lower Jurassic in Europe, some have continued to be used for divisions at the level of substage, but most are now redundant. A full list of such terms was provided by Arkell (1933), together with extensive discussion of the origins of the various schemes for subdividing the Jurassic System. Conventionally the Sinemurian, Pliensbachian and Toarcian stages are divided into an upper and a lower substage (Dean *et al.* 1961), generally used without a specific identifying name. Nevertheless, substage names are occasionally used and these are introduced in the relevant sections below.

Chronostratigraphy: stages, standard zones, subzones, chronozones and ammonites

Chronostratigraphy is the establishment of a series of subdivisions of geological time, using actual rock units as standards for reference. There is much discussion of this method and it is not necessary to develop it further here (see, for example, Hedberg 1976; Callomon 1984; Harland *et al.* 1990; Salvador 1994; Remane *et al.* 1996). Chronostratigraphic divisions are defined only at their base in a suitable stratotype section, the top of the unit being identified by the actual or correlated base of the next equivalent ranked division of the scale. Chronostratigraphical divisions form a hierarchy with *systems*, *series* and *stages* being three divisions of decreasing rank (although the term series is almost never used in Jurassic stratigraphy).

The definitions of stages and systems is now regulated by the International Commission on Stratigraphy (ICS), a project of IUGS/UNESCO, through subcommissions focused on single systems. The aim is to formally recognise an internationally agreed *Global Stratotype Section and Point* (GSSP) for the base of every system and for every stage of every system (Cowie *et al.* 1986; Salvador 1994). Several such proposals have now been ratified by IUGS, including the Sinemurian Stage of the Lower Jurassic, and several others are likely to be agreed within the next few years.

Below the level of stage, subdivisions at the level of *chronozone* and ultimately *zonule* can be used, but are not formally regulated through the International Subcommission on Jurassic Stratigraphy (ISJS) or the ICS. In the Jurassic, the often great abundance of ammonites and their wide geographical distribution has led to their use for correlating sequences of *standard zones*. As discussed at great length elsewhere (Callomon 1965, 1984; Callomon & Donovan 1974; Cox 1990), these standard zones are chronozones and should therefore be treated as such – a fact ignored by some authors (e.g. Whittaker *et al*. 1991) who confuse Jurassic ammonite zones with biozones, where the use of fossils in correlation is not explicitly linked to geological time. As discussed by the former authors, although the names of the zonal units are derived from species names, they are by convention quoted non-italicised (e.g. Jamesoni Chronozone or Jamesoni [Standard] Zone and not *Uptonia jamesoni* Zone or Biozone). This is the convention followed by working groups of the International Subcommission on Jurassic Stratigraphy.

Other fossil groups, especially microfossil, have been used to construct true biozonal schemes for the marine Jurassic but the resolution of these schemes is usually inferior to the ammonite scale. Indeed, the latter scale is typically used as a 'standard' against which biozonal schemes are correlated. For this reason, only the ammonite-based standard zonations for Europe will be considered further here; microfossil schemes for the Jurassic of Northwest Europe were reviewed by Cox (1990) and Dommergues (1997), based on dinocysts (Woollam & Riding 1983; Falconnier 1997), calcareous nannofossils (Bown *et al*. 1988; Gardin 1997), foraminifera (Copestake & Johnson 1989; Bassoullet 1997; Ruget & Nicollin 1997) and ostracods (Bate & Coleman 1975; Lord 1978; Park 1984; Bodergat 1997; Colin 1997). Tables 71 and 72 in Dommergues (1997) provide a recent cross-correlation between these various schemes, and others based on macrofossil groups – the latter including belemnites (based on Doyle 1990; Combémorel 1997), brachipods (based on Alméras *et al*. 1997) and echinoderms (based on Thierry *et al*. 1997).

Intra-subzonal units: biohorizons and zonules

Most Jurassic chronozones are divided into subchronozones, largely for historical reasons, as the creation of new subchronozones within existing chronozones achieves a degree of nomenclatural stability at a chronozonal level. Smaller divisions than subchronozones, however, are also used in Jurassic ammonite stratigraphy and their use to further refine correlations again avoids 'tampering' with an established standard zonation. Such divisions are generally known collectively (and sometimes confusingly) as 'horizons' although including two conceptually different types of unit (Page 1995a).

The first type of horizon, known as a *zonule* (as adopted by Phelps (1985) following Hedberg (1976), is the smallest subdivision of a chronostratigraphical scale. It should therefore be defined, as with higher divisions, by a basal boundary stratotype.

The second type of unit is a *biohorizon* and is defined as "a bed or series of beds, characterised by a fossil assemblage, within which no further stratigraphical differentiation of the fauna or flora can be distinguished" (Callomon 1984, p. 624). The earlier term *hemera*, proposed by Buckman (1893), is considered to be the chronological equivalent of *biohorizon* (cf. Callomon 1984), i.e. as period is the time equivalent of system. Biohorizons are the smallest palaeontologically correlatable segments of geological time using 'guide fossils' and unlike 'normal' chronozones are effectively defined at both their bases and tops. Their duration is typically geologically very short but a significant time gap may exist between each successive unit and is shown as an interval on any correlation diagram (Page 1992, 1995a; Dommergues *et al*. 1994a). The use of biohorizons is rather like events in event stratigraphy, as they enable the correlation of virtually isochronous time lines between successions at different localities (Callomon 1984, 1985). By convention, zonules are quoted in a similar fashion to zones and subzones with a non-italicised specific name (e.g. Planorbis Zonule) but biohorizons typically retain an italicised specific epithet (e.g. *planorbis* Biohorizon).

Biohorizonal and zonule schemes have been derived in different regions for different parts of the Jurassic and relevant Lower Jurassic schemes are introduced below. They represent the ultimate in resolvable chronology for the Jurassic, and the average zonule or biohorizon plus interval duration is potentially less than 200 000 years in the Lower Jurassic of Northwest Europe (Page 1995a).

Ammonoid provincialism in the Lower Jurassic of Europe: consequences for correlation

Ammonoids, like any group of organisms, frequently show distinctive geographical distribution patterns, reflecting ecological and physical controls on individuals and populations. Such patterns are characterised as biogeographical provinces and the inevitable consequence of using ammonites for correlation purposes is that every province, almost by definition, will have a different scheme of standard zones. These differences can inevitably make interprovincial correlations at zonal, and especially subzonal and horizon level, difficult. Up to four contemporaneous faunal provinces can be recognised in the Lower Jurassic of Europe. Most are geographically adjacent and inter-provincial correlations are thus usually fairly good, although the southernmost faunas of the Mediterranean Province are sometimes sufficiently distinct as to present significant correlation problems when compared to better known successions further north.

As discussed by Page (1996), the main faunal provinces recognised in the Lower Jurassic of Europe are:

1. *Northwest European Province.* The province was characteristic of much of Europe from the Hettangian to the Early Pliensbachian and again in the Late Toarcian, when great faunal uniformity characterised most of the region. Faunal affinities are virtually entirely from southern or Tethyan areas (i.e. the Mediterranean Province) and direct connection to the Arctic or Boreal Sea was lacking (except perhaps in the earlier Late Toarcian). Zonal schemes of the Northwest European Province are well-developed reflecting the long history of research on the area.

   At times in the Pliensbachian, and also earlier, faunas in the Lusitanian basin (Portugal) developed a separate character from those of the rest of the Northwest European Province (Dommergues & Mouterde 1987), thereby creating some correlation problems. A separate sequence of 'horizons' has consequently been recognised for this area for the Lower Pliensbachian, but whether full province or simply sub-province status is warranted is unclear.

2. *Mediterranean Province.* This was characteristic of deeper water areas of southern and south-eastern Europe (Italy, Austria, southern Spain, etc.) throughout the Jurassic. Faunal sequences of the province are often less well-known in detail than those of more northerly areas, and zonations therefore tend to be relatively crude in comparison, but with considerable potential for refinement.

3. *Subboreal Province.* The establishment of direct marine connections with the Boreal Sea in the Late Pliensbachian and Toarcian enabled some mixing of Arctic Province faunas and the previously separated faunas of Northwest Europe (see Fig. 2). The abundance of Boreal taxa alongside more southerly forms distinguishes the province in the more northerly areas of Europe (such as northern Britain). The zonation is well-established and correlates fairly well with more southerly areas as a result of faunal overlap.

4. *Submediterranean Province.* The province developed in parallel with the Subboreal Province in the late Pliensbachian in regions between the former and the Mediterranean Province (e.g. in mid to southern France). Boreal taxa are usually infrequent and an independent zonation is used in the Lower Toarcian, but with significant similarities to that of Subboreal areas.

The following sections summarise and correlate available zonal schemes for each of the faunal provinces or sub-provinces recognised in Europe. The emphasis is on the Northwest European and Subboreal schemes as these are most appropriate for northern European areas (including Britain, northern France, northern Germany and Denmark). Stratotypes are only identified when clearly described in the literature. It would be premature to propose such definitions for other units, pending a reassessment of taxal ranges and surviving localities. Only the taxa which are useful for correlating each subzone are cited; other forms will be present but these are not always chronologically diagnostic.

Hettangian Stage

The Hettangian Stage as originally proposed by Renevier (1864) corresponded to the first two zones of the schemes proposed by Oppel (1856–1858) for the Jurassic, namely those of *Ammonites* [*Psiloceras*] *planorbis* and *Ammonites* [*Schlotheimia*] *angulatus*. This interpretation remains essentially unchanged, the only difference being the later creation of a Liasicus 'Zone' for the lower part of the original *angulatus* Zone.

The base of the Hettangian Stage and the Jurassic System

The Jurassic colloquium in Luxembourg in 1962 recommended that the Planorbis 'Zone' should form the lowest part of the Hettangian Stage (Mauberge 1964); this zone, as conventionally interpreted, marks the first occurrence of ammonites in Northwest Europe, after the re-establishment of fully marine conditions towards the end of the Triassic Period.

The type locality of the index fossil of the first subchronozone and the first chronozone of the Jurassic of the Northwest European Province (i.e. *Psiloceras planorbis* (J. de C. Sowerby 1824)) is on the coast of west Somerset near Watchet in south-west England. A proposal in 1967 to the 2nd Luxembourg colloquium on the Jurassic System recommended that a type section for the zone should actually be selected in this region (D.T. Donovan, P.E. Kent and H.C. Ivimey-Cook in: Morton 1971). There has been much subsequent discussion as to where exactly the boundary should be drawn (e.g. Torrens & Getty 1980; Warrington & Ivimey-Cook 1990), culminating in the proposal of Warrington *et al.* (1994) to establish a section at St Audries Bay, east of Watchet as a GSSP. The issue as to whether the region is in fact suitable for such a definition has not, however, been thoroughly addressed (Page 1994; Page *et al.* 1994).

The latter proposal placed the base of the subchronozone and chronozone at the then first recorded occurrence of ammonites in Bed A21 of Palmer (1972; equivalent to Beds 13–15 of Whittaker & Green 1984). Ammonites had not previously been recorded any lower in the immediate area and, indeed, characteristically Triassic ammonoids are entirely lacking in Britain (although there is a problematic record of an indeterminate, and therefore completely undiagnostic psiloceratid, from presumed latest Triassic deposits elsewhere in the region; Donovan *et al.* 1989). This definition, therefore, relies to a certain extent on negative evidence, as emphasised by the subsequent discovery of earlier ammonites at the same locality by Hodges (1994) in Beds A18 and A19 (Beds 8 and 9 of Whittaker & Green 1984) and the author, westwards along the coast in Doniford Bay nearer Watchet. Further work on the sections has revealed a succession of ammonite faunas, previously unrecognised, which correlates well with faunas recovered from the Wilkesley Borehole in Cheshire in north-west England (Bloos & Page 1997, 2000a; Page & Bloos 1998). The lowest fauna in the borehole is characterised by the ribbed psiloceratid, *Psiloceras erugatum* (Phillips), as already noted by D.T. Donovan (in: Poole & Whiteman 1966, pp. 50, 140). Re-examination of the higher faunas reveals the presence of *Neophyllites* and the subchronozonal index *P. planorbis* itself.

The same sequence is present in Somerset with Bed 8 now known to yield *P. erugatum* (Bloos & Page 1997, 2000a; Page & Bloos 1998). No ammonites are presently known from demonstrably lower levels in Britain. In response to the new discoveries in Somerset, Warrington & Ivimey-Cook (1995) modified their original proposal and placed the base of the Jurassic System at the base of Bed A18 (Bed 8 of Whittaker & Green 1984). As discussed by Bloos & Page (1997, 2000a), however, elsewhere in Europe the *erugatum* fauna has not yet been positively identified, the earliest ammonites typically belonging to *Neophyllites* (Bloos 1999) or *P.* ex grp *sampsoni* (Portlock)/*psilonotum* (Quenstedt), indicating a degree of diachroneity in the first occurrence of ammonites. Even where late Triassic *Choristoceras* ammonite faunas are present below psiloceratids, such as in Mediterranean regions, there remains an 'ammonite gap', and the earliest 'Jurassic' ammonites also appear to represent later species close to the *P. sampsoni*/*psilonotum* group (Bloos 1985; Hallam 1990).

More complete sequences of ammonoid faunas from the uppermost Triassic (Rhaetian Stage) to the lowermost Jurassic are known, however, elsewhere in the world and two have been proposed as candidate GSSPs in New York Canyon, Nevada, USA (Guex 1980, 1982; Guex *et al.* 1997) and northern Peru (von Hillebrandt 1994, 1997). Whether a 'New World' definition for the base of the Jurassic System is acceptable on historical grounds remains to be determined, but it is clear that at the present state of knowledge, it is not possible to accurately correlate these sections with any in Europe (Bloos & Page 2000a).

The St Audries Bay section remains the best exposed Triassic–Jurassic boundary section in Britain, although the ammonite faunas are better preserved in Doniford Bay along the Somerset coast to the west. The *erugatum* fauna itself, however, is very rare and poorly preserved in Somerset, but much better developed, both in terms of abundance and preservation, in Cheshire and North Yorkshire in northern England, although only known *in situ* in boreholes (Bloos & Page 2000a). None of these localities is, therefore, ideal as a GSSP, not least due to the absence of Triassic ammonoids below in a continuous open marine sequence, but also due to the present lack of clear records of *P. erugatum* outside Britain. If the latter could be identified elsewhere, however, for instance amongst some of the early and poorly characterised psiloceratids in New York Canyon, a final agreement on the selection of a suitable GSSP for the base of the Jurassic System would be much closer.

Hettangian correlative schemes and ammonoid provincialism

Hettangian faunas are remarkably similar globally, reflecting the relatively small number of available ammonoid taxa, so soon after the Late Triassic mass extinctions. No direct Boreal links existed in Europe, so a simple pattern of a northern Northwest European Province and a southern and deeper water Mediterranean Province is recognisable (Fig. 1).

Northwest European Province (Britain, Ireland, France, Germany, etc.)

The origins of the standard zonation for the Hettangian of the region go back to the original scheme presented by Oppel (1856–1858) with the later addition of a Liassicus Zone by Collenot (1869). The zonation as presently employed is that established by D.T. Donovan (in: Dean *et al.* 1961) with later additions by Elmi & Mouterde (1965) and Bloos (1979, 1983), summarised diagrammatically by Mouterde & Corna (1991) and reviewed by Mouterde & Corna (1997).

Mouterde & Corna (1991, 1997) presented a scheme of zonules which are here integrated with a sequence of biohorizons established as a result of recent studies in south-west England by Page (1994, 1995b, 2002a), Page & Bloos (1998) and Bloos & Page (2000a, b). Few of the units summarised below have established or proposed stratotypes, with the notable exception of the Planorbis Subchronozone (and therefore the Planorbis Chronozone) at the base of the stage and hence the Jurassic System. Cox (1990) has suggested reference sections for each zone, although these are not equivalent to basal boundary stratotypes; some of these proposals would require revision, however, based on new information on the succession of ammonite faunas both at the proposed localities and elsewhere.

Planorbis Chronozone
Index. Psiloceras planorbis (J. de C. Sowerby 1824).
Author. Oppel (1856).

Planorbis Subchronozone
Index. As Planorbis Chronozone (see above).
Author. Trueman (1922).
Stratotype. Proposed by Warrington *et al.* (1994), modified by Warrington & Ivimey-Cook (1995); base of Bed 8 (= A18), St Audries Bay, west Somerset, England (see discussion above).
Correlating fauna. Dominated by smooth whorled species of *'Psiloceras'* and *Neophyllites* (*sensu* Lange

Northwest European Province				Mediterranean Province	
Chronozone	Subchronozone	Zonule	Biohorizon	Faunas	Chronozone
Angulata	Depressa	Depressa	*pseudomoreana*	*marmorea/depressa*	*Marmorea*
			depressa		
	Complanata	Complanata	*striatissima*	?	
			complanata		
			similis		
	Extranodosa	Extranodosa	*extranodosa*	*extranodosa*	*Megastoma*
			amblygonia	?	
Liassicus	Laqueus	Hadroptychus	*hadroptychus*	*Storthoceras/ Alsatites*, etc.	
		Liassicus	*laqueolus*		
		Laqueus	*laqueus*		
	Portlocki	Portlocki	*schroederi*		
			portlocki		
			hagenowi		
			prometheus	*tenerum*	
Planorbis	Johnstoni	Belcheri	*intermedium*	*calliphyllum*	*Calliphyllum*
		Johnstoni	*johnstoni*		
			Caloceras sp.2		
			Caloceras sp.1		
	Planorbis	Plicatulum	*plicatulum*		
		Sampsoni	*sampsoni* α	*'psilonotum'*	
		Planorbis	*planorbis*		
			antecedens		
			imitans		
			erugatum		

Fig. 1. Hettangian subdivisions and correlations: Northwest European and Mediterranean Provinces. For explanation, see text. The double lines separating the biohorizons on this and later figures indicate the stratigraphic interval conceptually present between each successive division of this kind (see discussion in text).

1941) but with ribbed *Psiloceras erugatum* at the base of the subchronozone.

Included subdivisions. Planorbis Zonule (including *Psiloceras erugatum, Neophyllites imitans, N. antecedens* and *Psiloceras planorbis* Biohorizons), Sampsoni [= Psilonotum] Zonule (including *Psiloceras sampsoni* α Biohorizon), Plicatulum Zonule (including *plicatulum* Biohorizon) (Mouterde & Corna 1991, 1997; Page 1994; Page & Bloos 1998; Bloos & Page 2000a, b).

Comment. Buckman (1930 in: Buckman 1909–1930) first proposed a *plicatus* Hemera, subsequent raised to the status of 'horizon' (= zonule) by Elmi & Mouterde (1965) and ultimately a subzone by von Hillebrandt (1990). Status as a zonule is provisionally retained here, however, pending an assessment of ammonite faunas in south-west England, where circumstantial evidence suggests that at least three, maybe four, correlatable biohorizons could ultimately be recognisable, potentially lending support to raising the status of the unit to subchronozone.

Johnstoni Subchronozone

Index. Caloceras johnstoni (J. de C. Sowerby 1824).

Author. Von Schloenbach (1863) as a zone, Trueman (1922) as a subzone (but see discussion by D.T. Donovan in: Dean *et al.* 1961, p. 444).

Correlating fauna. Early species of *Caloceras*.

Included subdivisions. Johnstoni Zonule (including *Caloceras* sp. 1, *Caloceras* sp. 2 and *C. johnstoni* Biohorizons), Belcheri Zonule (including *C. intermedium* Biohorizon) (Mouterde & Corna 1991, 1997; Page 1994).

Liassicus Chronozone

Index. Alsatites liassicus (d'Orbigny 1844).

Author. Collenot (1869).

Portlocki Subchronozone

Index. Waehneroceras portlocki (Wright 1881).

Author. Lang (1924).

Correlating fauna. Early species of *Waehneroceras* including *W.* (*Curviceras*), also *Psilophyllites*.

Included subdivisions. Portlocki Zonule (including *W.* (*Curviceras*) *prometheus*, *Psilophyllites hagenowi*, *Waehneroceras portlocki* and *W. schroederi* Biohorizons) (Mouterde & Corna 1991, 1997; Page 2002a).

Laqueus Subchronozone

Index. Laqueoceras laqueus (Quenstedt 1856).

Author. Reynès (1879).

Correlating fauna. Laqueoceras is typical, with *Alsatites* above, in association with common late *Waehneroceras* spp. (= *'Saxoceras'*) and late *Caloceras* at higher levels.

Included subdivisions. Laqueus Zonule (including *Laqueoceras laqueus* Biohorizon), Liassicus Zonule (including *Alsatites laqueolus* Biohorizon), Hadroptychus Zonule (including *W. hadroptychus* Biohorizon) (Mouterde & Corna 1991, 1997).

Angulata Chronozone

Index. Schlotheimia angulata (Schlotheim 1820).

Author. Oppel (1856).

Extranodosa Subchronozone

Index. Schlotheimia extranodosa (Waehner 1886).

Author. Lange (1922) as Germanica Zone (name changed due to apparent synonymy by Donovan 1952).

Correlating fauna. Early species of *Schlotheimia*.

Included subdivisions. Extranodosa Zonule (including *Schlotheimia amblygonia* and *S. extranodosa* Biohorizons) (Bloos 1984; Mouterde & Corna 1991, 1997).

Complanata Subchronozone

Index. Schlotheimia complanata von Koenen 1902.

Author. Spath (1942) replacing the Stenorhyncha Zone of Lange (1922).

Correlating fauna. Schlotheimia spp. including relatively compressed and smooth whorled macroconchs, with giant forms at higher levels. The rare early arietitid *Schreinbachites* is locally recorded.

Included subdivisions. Complanata Zonule (including *S. similis*, *S. complanata* and *S. striatissima* Biohorizons) (Bloos 1984; Mouterde & Corna 1991, 1997; Page 1995b; Bloos & Page 2000b).

Depressa Subchronozone

Index. Schlotheimia depressa (Waehner 1886).

Author. Bloos (1983).

Correlating fauna. The index species and its allies, especially *S.* ex grp *pseudomoreana* (Spath). ?*Paracaloceras* is also known, but is very rare.

Included subdivisions. Depressa Zonule (including *S. depressa* and *S. pseudomoreana* Biohorizons) (Bloos & Page 2000b; Page 2002a).

Comment. The Depressa Subchronozone was established by Bloos (1983, 1984) but was reduced in status to a zonule by Mouterde & Corna (1991, 1997). In Britain, the subchronozone is well-developed, although has only recently been recognised; it includes the *pseudomoreana* and '*Schlotheimia* sp. 2' Biohorizons of Page (1995b) (Page & Bloos 1998; Bloos & Page 2000b).

Mediterranean Province (Austria)

The subdivision of the Hettangian Mediterranean Province is not well-developed despite the presence of considerably richer ammonoid faunas than in Northwest European areas. A sequence of three zones, Calliphyllum, Megastoma and Marmorea, was recognised by Waehner (1886) and used again by Lange (1952). Blind (1963) subdivided the Calliphyllum 'Zone' and attempted to subdivide the higher zones, although Bloos (1984) considered that these schemes were not entirely satisfactory.

The Marmorea Chronozone has been the subject of some discussion as to its meaning and indeed whether it ranges into the Sinemurian (Taylor 1986), but in a European sense at least, a wholly Hettangian age is most likely (Bloos 1983, 1984).

Calliphyllum Chronozone

Index. Psiloceras calliphyllum Neumayr 1879.

Author. Waehner (1886).

Correlating fauna. Species of *Psiloceras,* especially the index, and early *Waehneroceras* (= *Curviceras*) at higher levels.

Included subdivisions. The *psilonotum* and *calliphyllum* faunas (= Zones I–II of Blind 1963; Bloos 1984).

Megastoma Chronozone

Index. ?*Kammerkarites megastoma* (Waehner 1886).

Author. Waehner (1886).

Correlating fauna. Species of *Kammerkarites, Waehneroceras* (*sensu lato*), *Alsatites* and *Caloceras*.

Included subdivisions. The *tenerum, Storthoceras/Alsatites* and *extranodosa* faunas (Blind 1963; Bloos 1984).

Marmorea Chronozone

Index. Schlotheimia marmorea (Oppel 1856).

Author. Waehner (1886).

Correlating fauna. Species of *Schlotheimia* with common early Arietitidae (*Paracaloceras*, etc.).

Included subdivisions. Includes an *S. marmorea/S. depressa* fauna at the top of the chronozone (as indicated by Bloos 1984).

Sinemurian Stage

The Sinemurian Stage corresponds to the zonal range suggested by Oppel (1856) minus the Hettangian of Renevier (1864), i.e. with a Bucklandi Chronozone at the base and a Raricostatum Chronozone at the top. Additional zones have been added subsequently, but the modern interpretation remains essentially unchanged. Although the Lower Sinemurian Substage has no common alternative name, the term Lotharingian (from 'Lorraine, France') is often used in France for the Upper Sinemurian (after Haug 1910 in: Haug 1908–1911 but *sensu* Spath 1942 as Haug's stage included the Turneri Zone, now considered to be Lower Sinemurian; Dean *et al.* 1961).

The base of the Sinemurian Stage

The base of the stage is drawn at the base of the Conybeari Subchronozone, the lowest division of the Bucklandi Chronozone. D.T. Donovan (in: Morton 1971) proposed that the stratotype for the stage should be established on the Dorset–Devon coast, near Lyme Regis. In this area, the relatively well-preserved and first obvious Sinemurian fauna (i.e. dominated by arietitid ammonites, including *Metophioceras*) occurs in nodules on the base of Bed 19 of Lang (1924) although traces of *Vermiceras* have now been found about 0.25 m lower, in Bed 18 (author's unpublished data), and 0.25 m above the last *Schlotheimia* seen on the surface of Bed 17 (Page 1992); this is *c.* 0.75 m lower than Donovan's original designation of the base of Bed 21 for the base of the stage.

Recent study of other sections on the coast of the neighbouring county of Somerset has revealed a considerably expanded Hettangian–Sinemurian succession, more than four times thicker than that at Lyme Regis (Palmer 1972; Whittaker & Green 1984; Page 1992, 1995b). In particular, it has been possible to demonstrate that near Lyme Regis the faunal record is incomplete (Page 1992, 1995b; Bloos & Page 2000b). The Dorset section is not therefore a suitable stratotype let alone a candidate GSSP, whereas the Somerset section has great potential and was proposed as such by Page *et al.* (2000) and ratified by IUGS at the Rio de Janeiro symposium in August 2000 – the first Lower Jurassic GSSP to be formally approved (Bloos & Page 2002). It is the faunal completeness and expanded succession (*c.* 14 m for the earliest Sinemurian Conybeari Subzone alone) which makes the locality unusual in Europe. Elsewhere, for instance in Germany and south-east France, successions are usually much thinner and much less complete.

The base of the Sinemurian at East Quantoxhead is taken at the first occurrence of abundant arietitid ammonites 70 cm above the base of Bed C100/145 (Palmer 1972; Whittaker & Green 1984) and only 20 cm above the last common Hettangian *Schlotheimia*. This fauna, with *Vermiceras quantoxense* (Bloos & Page) and *V. palmeri* (Bloos & Page), underlies an assemblage including *Metophioceras* ex grp *brevidorsale* (Quenstedt) and *M. conybearoides* (Reynes) which is normally the earliest recorded in the Sinemurian elsewhere in Europe (Bloos 1997; Bloos & Page 2000a; Page *et al.* 2000).

Sinemurian correlative schemes and ammonoid provincialism

Sinemurian provincialism is essentially the same as in the Hettangian, with a broad Northwest European Province over much of Europe, and a Mediterranean Province in south-easternmost areas. Some endemism or geographic restriction of genera and species in Portugal at times in the Late Sinemurian probably indicates some links with North Africa (i.e. the Ethiopian Province *sensu* Page 1996; Figs 2, 3).

Northwest European Province (Britain, Ireland, France, Germany, Switzerland, etc.)

The subdivision of the stage into chronozones and subchronozones, as started by Oppel (1856–1858) and developed through the work of W.D. Lang and L.F. Spath (Lang *et al.* 1923; Lang 1924; Spath 1924, 1942; Lang & Spath 1925b), was eventually stabilised by D.T. Donovan (in: Dean *et al.* 1961). The only subsequent changes have been in the name of zonal indices as a result of the identification of senior synonyms. Ivimey-Cook & Donovan (1984) proposed the removal of the Bucklandi Subchronozone and lowering of the base of the Semicostatum Zone to include most of the former subzone. Page (1992), however, retained a Bucklandi Subchronozone as the unit forms a significant and important stratigraphical unit that is readily recognisable internationally. Corna *et al.* (1997) provided a recent review of the zonation of the stage and the zonules therein, essentially reproducing the scheme presented diagrammatically by Corna *et al.* (1991).

Bloos (1985) proposed a sequence of 'horizons' for the basal part of the stage, the divisions identified being very similar to those of the earliest part of a zonule scheme described by Corna (1987). Page (1992) introduced a sequence of biohorizons for the entire Sinemurian, the Upper Sinemurian part of which was correlated with French successions in Burgundy (Dommergues 1993) to produce the revised biohorizonal scheme of Dommergues *et al.* (1994a). Additional biohorizons in the Lower Sinemurian, especially the Conybeari Subchronozone were recognised by Page (1995a, b), Bloos & Page (2000b) and Page *et al.* (2000). Reference sections for each zone were suggested by Cox (1990), but now require some modification based on new faunal information from various regions.

Lower Sinemurian Substage

Bucklandi Chronozone
Index. Arietites bucklandi (J. Sowerby 1818).
Author. Oppel (1858).

Conybeari Subchronozone
Index. Metophioceras conybeari (J. Sowerby 1816).
Author. Tutcher (1918) as a zone, Trueman (1922) as a subzone.
Stratotype. Level 0.7 m above the base of Bed C100/145, East Quantoxhead, Somerset, UK (see discussion above).
Correlating fauna. Species of *Metophioceras*, with early *Vermiceras* and *Epammonites*. Giant *Charmasseiceras* typical.
Included subdivisions. Latisulcatum Zonule (including *Vermiceras quantoxense*, *Metophioceras* sp. 2, and *M. conybearoides* Biohorizons), Rotarium Zonule (including *Epammonites rotarius*, *M. rouvillei, Coroniceras rotator* and *V. elegans* Biohorizons), Conybeari Zonule (including *Metophioceras conybeari* Biohorizon) (Corna 1987; Corna *et al.* 1991; Page 1992, 1995a, b; Bloos & Page 2000b, 2002; Page *et al.* 2000).

Rotiforme Subchronozone
Index. Coroniceras rotiforme (J. de C. Sowerby 1824).
Author. Collenot (1879) as a zone, Trueman (1922) as a subzone.
Correlating fauna. Evolute and strongly ribbed species of *Coroniceras*, with occasional *Charmasseiceras* at certain levels.
Included subdivisions. Hyatti Zonule (including *Epammonites silvestrei*, *Coroniceras* cf. *defneri*, *C. rotiforme*, *C.* aff. *rotiforme* and *C. caprotinum* Biohorizons),

Fig. 2. Lower Sinemurian subdivisions and Northwest European horizons. For explanation, see text.

<table>
<tr><th rowspan="2">Chronozone</th><th rowspan="2">Sub-chronozone</th><th colspan="2">Northwest European Province</th><th>Mediterranean Province</th></tr>
<tr><th>Zonule</th><th>Biohorizon</th><th>Fauna</th></tr>
<tr><td rowspan="8">Turneri</td><td rowspan="5">Birchi</td><td>Bordoti</td><td>31: cf. bordoti</td><td rowspan="12">ceratoides
? part</td></tr>
<tr><td rowspan="4">Turneri</td><td>30: subturneri</td></tr>
<tr><td>29: birchi</td></tr>
<tr><td>28: pseudobonnardi</td></tr>
<tr><td>27: obtusiformis</td></tr>
<tr><td rowspan="3">Brooki</td><td rowspan="3">Brooki</td><td>26: hartmanni</td></tr>
<tr><td>25: brooki</td></tr>
<tr><td>24: sulcifer</td></tr>
<tr><td rowspan="11">Semicostatum</td><td rowspan="4">Sauzeanum</td><td rowspan="4">Sauzeanum</td><td>23: cf. semicostatum</td></tr>
<tr><td>22: alcinoeiforme</td></tr>
<tr><td>21: Euagassiceras</td></tr>
<tr><td>20: cf. resupinatim</td></tr>
<tr><td rowspan="2">Scipionanum</td><td>Nodulatum</td><td>19: pseudokridion</td><td rowspan="11">?</td></tr>
<tr><td>Scipionanum</td><td>18: acuticarinatum</td></tr>
<tr><td rowspan="5">Lyra</td><td>Alcinoe</td><td>17b: alcinoe</td></tr>
<tr><td rowspan="2">Crossi</td><td>17a: Paracoroniceras sp</td></tr>
<tr><td>16: bodleyi</td></tr>
<tr><td>Charlesi</td><td>15b: cf. charlesi</td></tr>
<tr><td>Lyra</td><td>15a: lyra</td></tr>
<tr><td rowspan="19">Bucklandi</td><td rowspan="5">Bucklandi</td><td>Bisulcatus</td><td>14: multicostatum</td></tr>
<tr><td rowspan="3">Isis</td><td>13: cf. scunthorpense</td></tr>
<tr><td>12: isis</td></tr>
<tr><td>11: aff. isis</td></tr>
<tr><td>Coronaries</td><td>10: scylla</td></tr>
<tr><td rowspan="6">Rotiforme</td><td>Schloenbachi</td><td>9: kridion</td></tr>
<tr><td rowspan="5">Hyatti</td><td>8: caprotinum</td><td rowspan="5">rotiforme</td></tr>
<tr><td>7b: aff. rotiforme</td></tr>
<tr><td>7a: rotiforme</td></tr>
<tr><td>6: cf. defneri</td></tr>
<tr><td>5c: silvestrei</td></tr>
<tr><td rowspan="8">Conybeari</td><td>Conybeari</td><td>5b: conybeari</td><td rowspan="8"></td></tr>
<tr><td rowspan="4">Rotarium</td><td>5a: elegans</td></tr>
<tr><td>4: rotator</td></tr>
<tr><td>3b: rouvillei</td></tr>
<tr><td>3a: rotarius</td></tr>
<tr><td rowspan="3">'Latisulcatum'</td><td>2b: conybearoides</td></tr>
<tr><td>2a: Metophioceras sp.B</td></tr>
<tr><td>1: quantoxense</td></tr>
</table>

'Schloenbachi' Zonule (including *C.* aff. *kridion* Biohorizon) (Corna 1987; Corna *et al.* 1991, 1997; Page 1992, 1995b).

Bucklandi Subchronozone
Index. As Bucklandi Chronozone (see above).
Author. Spath (1942) as a subzone.
Correlating fauna. Large and massive whorled Arietitidae (*Arietites*) typical with *Coroniceras* at certain levels. Early *Arnioceras* and *Charmasseiceras* present, the former in the upper part of the subchronozone.

Included subdivisions. Coronaries Zonule (including *Vermiceras scylla* Biohorizon, previously included in the Rotiforme Subzone by Page 1992 but placed at the base of the Bucklandi Subchronozone by Corna *et al.* 1997), Isis Zonule (including *Arietites* aff. *isis*, *A. isis* and *A.* aff. *scunthorpense* Biohorizons), Bisulcatus Zonule (including *Coroniceras multicostatum* Biohorizon) (Corna 1985; Corna *et al*. 1991, 1997; Page 1992, 1995b).

Semicostatum Chronozone

Index. Arnioceras semicostatum (Young & Bird 1829).
Author. Judd (1875).

Lyra Subchronozone

Index. Paracoroniceras lyra (Hyatt 1867).
Author. Buckman (1918) as Gmuendense Zone, changed to Reynesi Subzone by D.T. Donovan (in: Dean *et al*. 1961, after a junior synonym of *P. lyra*, subchronozone renamed accordingly by Guérin-Franiatte 1966). Equivalent to the Charlesi Subzone of Mouterde & Tintant (1980).
Correlating fauna. Species of *Paracoroniceras* and *'Pararnioceras'*, with common *Arnioceras* at certain levels.
Included subdivisions. Lyra Zonule (including *Coroniceras lyra* (*sensu stricto*) Biohorizon), Charlesi Zonule (including *P.* cf. *charlesi* [= *C. lyra* in Page 1992] and *Arnioceras bodleyi* Biohorizons), Crossi Zonule (probably includes the *Paracoroniceras* sp. Biohorizon of Page 1992), Alcinoe Zonule (including the *'Pararnioceras' alcinoe* Biohorizon; included in the Scipionanum Subzone by Corna 1987 and Corna *et al*. 1991, 1997) (Corna 1987; Corna *et al*. 1991; Page 1992).

Scipionanum Subchronozone

Index. Agassiceras scipionanum (d'Orbigny 1844).
Author. Tutcher (1918).
Correlating fauna. Species of *Agassiceras* and *Arnioceras*. May include early *Euagassiceras* (*E. striaries* (Quenstedt)) in the higher part of the subchronozone (*teste* Corna *et al*. 1997).
Included subdivisions. Scipionanum Zonule (including *Arnioceras acuticarinatum* Biohorizon), Nodulatum Zonule (including *Arnioceras pseudokridion* Biohorizon) (Corna 1987; Corna *et al*. 1991, 1997; Page 1992).

Resupinatum Subchronozone

Index. Euagassiceras resupinatum (Simpson 1843).
Author. Tutcher (1918) as a zone, Trueman (1922) as a subzone.
Correlating fauna. *Euagassiceras* and *Arnioceras*.
Included subdivisions. Sauzeanum Zonule (including *E.* cf. *resupinatum*, *'Euagassiceras'* sp., *'Pararnioceras' alcinoeiforme* and *Arnioceras* cf. *semicostatum* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992).

Turneri Chronozone

Index. Caenisites turneri (J. de C. Sowerby 1824).
Author. Wright (1860).

Brooki Subchronozone

Index. Caenisites brooki (J. Sowerby 1818).
Author. Lang (1914, W.D. Lang in: Lang *et al*. 1923).
Correlating fauna. Early species of *Caenisites* and some *Arnioceras* and *'Sulciferites'* (i.e. late *Charmasseiceras*).
Included subdivisions. Brooki Zonule (including *Sulciferites sulcifer*, *C. brooki* and *Arnioceras hartmanni* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992).

Birchi Subchronozone

Index. Microderoceras birchi (J. Sowerby 1820).
Author. Collenot (1869) as a zone, Spath (1942) as a subzone.
Correlating fauna. Species of *Microderoceras*, *Caenisites* ex grp *turneri*, early *Epophioceras* locally and common early *Promicroceras* at higher levels.
Included subdivisions. Turneri Zonule (including *Caenisites obtusiformis*, *Epophioceras pseudobonnardi*, *Microderoceras birchi* and *Caenisites subturneri* Biohorizons), Bordoti Zonule (including *Caenisites* cf. *bordoti* Biohorizon) (Corna *et al*. 1991, 1997; Page 1992).

Upper Sinemurian Substage

Obtusum Chronozone

Index. Asteroceras obtusum (J. Sowerby 1817).
Author. Oppel (1856).

Obtusum Subchronozone

Index. As Obtusum Chronozone (see above).
Author. Spath (1942) as a subzone of *'Promicroceras planicosta* or *obtusum* (*sensu stricto*)*'* (= Planicosta Zone of Lang 1914).
Correlating fauna. Early species of *Asteroceras*, with *Promicroceras* (but not *P. planicosta*), *Xipheroceras* and occasionally late *Arnioceras*.

Chronozone	Subchronozone	Northwest European Province: Zonule	Northwest European Province: Biohorizon		Mediterranean Province: Biohorizon	
Raricostatum	Aplanatum	Tardecrescens	XL:	*aplanatum/tardecrescens*	*tardecrescens/romanicum*	
			XXXIX:	*recticostatum*	*oosteri/gruenae*	
			XXXVIII:	*aureolum*		
	Macdonelli	Meigeni	XXXVII:	*macdonnelli*	*meigeni/macdonnelli*	
			XXXVI:	*meigeni*	*meigeni*	
					meigeni/charpentieri	
			XXXV:	*subplicatum*	*liciense*	
					favrei	
	Raricostatum	Boehmi	XXXIV:	*boehmi*	*boehmi*	
			XXXIII:	cf. *intermedium*		
		Crassicostatum	XXXII:	*crassicostatum*		
		Raricostatum	XXXI:	*raricostatum*	*raricostatoides*	
		Rhodanicum	XXX:	*rhodanicum*	*quenstedti*	
	Densinodulum	Edmundi	XXIX:	*'Echioceras'* sp.3		
			XXVIII:	*radiatum*		
			XXVII:	grp *armatum*		
			XXVI:	*bispinigerum*		
			XXV:	*lymense*		
			XXIV:	*subplanicosta*	*rigidum*	
		Delicatum	XXIII:	*delicatum*		
Oxynotum	Oxynotum	Oxynotum	XXII:	*doris*	*salisburgense*	
			XXI:	*bifer*		grp *oxynotum*
			XX:	grp *oxynotum*		
	Simpsoni	Gagateum	XIX:	*driani*		
			XVIII:	*gagateum*		
			XVII:	*exortum*		
Obtusum	Denotatus	aff. Glaber	XVI:	aff. *glaber*	*glaber*	
		Fowleri	XV:	*denotatus*	*Eparietites*	
			XIV:	*fowleri*		
			XIII:	cf. *undaries*		
	Stellare	Blakei	XII:	*sagittarium*		
			XI:	aff. *arnouldi*	*suevicum*	aff. *saltriense*
			X:	*blakei* s.s.		
		Stellare	IX:	*stellare*		
			VIII:	cf. *landrioti*		*retusum*
			VII:	*margaritoides*		
			VI:	aff. *margaritoides*		
			V:	*'Galaticeras'*		
					?	
	Obtusum	Confusum	IV:	*obtusum*	*ceratoides* (part)	
			III:	*semicostatoides*		
			II:	cf. *confusum*		
			I:	aff. *confusum*		

Fig. 3. Upper Sinemurian ('Lotharingian') subdivisions and Northwest European horizons. For explanation, see text.

Included subdivisions. Confusum Zonule (including *Asteroceras* aff. *confusum*, *As.* cf. *confusum*, *Arnioceras semicostatoides* and *As. obtusum* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a). *As. confusum* is here preferred to *As. obtusum* as an index for a zonule, as the latter is relatively rarely recorded and the former is more typical of this level in Northwest Europe.

Stellare Subchronozone

Index. *Asteroceras stellare* (J. Sowerby 1815).

Author. Buckman (1910) as a zone, Lang (1914) as a subzone.

Correlating fauna. Late species of *Asteroceras*, also *Promicroceras*, *Xipheroceras*, some *Epophioceras* with early *Aegasteroceras* at the top of the subchronozone.

Included subdivisions. Stellare Zonule (including *'Galaticeras'* [=? *Bouhamidoceras*], *Asteroceras* aff. *margaritoides*, *As. margaritoides*, *Epophioceras* cf. *landrioti* and *As. stellare* Biohorizons), Blakei Zonule (including *Aegasteroceras blakei*, *Arnioceras* aff. *arnouldi* and *Aegasteroceras sagittarium* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Denotatus Subchronozone

Index. *Eparietites denotatus* (Simpson 1855).

Author. Buckman (1918) as a hemera; Buckman (1919 in: Buckman 1909–1930) in a zonal context.

Correlating fauna. Species of *Eparietites*, with *Aegasteroceras* (grp *simile*) at lower levels.

Included subdivisions. Fowleri Zonule (including *Eparietites* cf. *undaries*, *Ep. fowleri* and *Ep. denotatus* Biohorizons), Glaber Zonule (including *Ep.* aff. *glaber* Biohorizon) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Oxynotum Chronozone

Index. *Oxynoticeras oxynotum* (Quenstedt 1843).

Author. Oppel (1856).

Simpsoni Subchronozone

Index. *Oxynoticeras simpsoni* (Simpson 1843).

Author. Buckman (1918) as a hemera, Spath (1942) as a subzone.

Correlating fauna. *O.* ex grp *simpsoni* and *Gagaticeras*.

Included subdivisions. Gagateum Zonule (including *Gagaticeras exortum*, *G. gagateum* and *Paroxynoticeras driani* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Oxynotum Subchronozone

Index. As Oxynotum Chronozone (see above).

Author. Buckman (1918) as a hemera, Spath (1942) as an alternative name for his Bifer Subzone.

Correlating fauna. *Oxynoticeras* grp *oxynotum*, *Bifericeras* and some *Palaeoechioceras*.

Included subdivisions. Oxynotum Zonule (including *O.* ex grp *oxynotum*, *Bifericeras* ex grp *bifer* and *Gleviceras doris* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Raricostatum Chronozone

Index. *Echioceras raricostatum* (Zieten 1831).

Author. Oppel (1856).

Densinodulum Subchronozone

Index. *Crucilobiceras densinodulum* Buckman 1923.

Author. Buckman (1923 in: Buckman 1909–1930) as a hemera. W.D. Lang (1926 in: Lang & Spath 1926) as a subzone.

Correlating fauna. *Crucilobiceras*, *Eoderoceras*, *Gleviceras* and at restricted levels, early echioceratids (including *'Plesechioceras'* [= *'Paltechioceras' sensu lato*] etc.).

Included subdivisions. Delicatum Zonule (including *'Plesechioceras' delicatum* Biohorizon), Edmundi Zonule (including *Crucilobiceras subplanicosta*, *Oxynoticeras lymense*, *Eoderoceras bispinigerum* and *Eoderoceras* ex grp *armatum* Biohorizons), Radiatum Zonule nov. (including *Echioceras radiatum* and *Echioceras* [= *Paltechioceras sensu lato*] sp. 3 Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Raricostatum Subchronozone

Index. As Raricostatum Chronozone (see above).

Author. Buckman (1918) as a *raricostatoides* hemera, Spath (1942) as a subzone (*E. raricostatoides* is generally considered to be a junior synonym of *E. raricostatum*).

Correlating fauna. Raricostate *Echioceras* spp., with some *Crucilobiceras*, *Eoderoceras* and *Gleviceras*.

Included subdivisions. Rhodanicum Zonule (including *Echioceras rhodanicum* Biohorizon), Raricostatum Zonule (including *E. raricostatum* Biohorizon), Crassicostatum Zonule (including *E. crassicostatum* Biohorizon), Boehmi Zonule (including *'Paltechioceras'* cf. *intermedium* and *'P.' boehmi* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Macdonnelli Subchronozone

Index. Leptechioceras macdonnelli (Portlock 1943).

Author. Buckman (1918) as a hemera, W.D. Lang (1926 in: Lang & Spath 1926) as a zone, Spath (1942) as a subzone.

Correlating fauna. *Leptechioceras* spp., with some eoderoceratids (including *Epideroceras* in more southerly areas) and early *Radstockiceras*.

Included subdivisions. Meigeni Zonule (including *Leptechioceras subplicatum*, *L. meigeni* and *L. macdonnelli* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Aplanatum Subchronozone

Index. Paltechioceras aplanatum (Hyatt 1889).

Author. Buckman (1918) as a hemera, Lang (1926) as a zone, Spath (1942) as a subzone.

Correlating fauna. Late species of *Paltechioceras*, with *Eoderoceras* and *Epideroceras,* the latter typically in more southerly areas.

Included subdivisions. Tardecrescens Zonule (including *Paltechioceras aureolum*, *P. rectiradiatum* and *P. aplanatum/tardecrescens* Biohorizons) (Corna *et al*. 1991, 1997; Page 1992; Dommergues *et al*. 1994a).

Comment. The *Eoderoceras donovani* and *Vicininodiceras simplicicosta* Biohorizons were provisionally included in the Sinemurian by Page (1992) and Dommergues *et al*. (1994a). New information from North Yorkshire, however, suggests that at least the former is best considered to be of basal Pliensbachian age. The latter remains stratigraphically problematic, however, and is consequently no longer used as a biohorizonal index, pending clarification of the precise position of the specimens recorded by Donovan (1990) on Raasay, Scotland.

Mediterranean Province (Austria, Italy)

The basic Northwest European chronozonal and subchronozonal framework is generally used in Mediterranean areas, for example by Donovan (1990), Dommergues *et al*. (1995), Blau (1998) and especially Blau & Meister (1999). At zonule/biohorizonal level, however, correlation is typically less precise as many species appear to be different and the relative generic composition is also often distinct in Mediterranean areas. In the Lower Sinemurian, only generalised correlations seem to be possible (Corna *et al*. 1991, 1997), but in the Upper Sinemurian, there are considerably more links, and in the Raricostatum Chronozone in particular, some biohorizons are even correlatable between provinces, as demonstrated by Blau & Meister (1999; Fig. 3).

Summarising from figures 2–4 of Blau & Meister (1999), the following is a generalised and provisional composite sequence of biohorizons or faunas for the Mediterranean Province in the Upper Sinemurian:

1. Obtusum Chronozone, Obtusum Subchronozone (Confusum Zonule, may include elements of the *Arnioceras ceratoides* fauna of the Apennines, Italy); Stellare Subchronozone (Stellare Zonule, including *Asteroceras retusum* and *As.* aff. *saltriense* (part?) faunas/Biohorizons (Adnet, Austria); Blakei Zonule, including *As.* aff. *saltriense* (?part) (Adnet) and *As. suevicum* (Lienz, Austria) faunas/Biohorizons); Denotatus Subchronozone (Fowleri Zonule, including *Eparietites* fauna/Biohorizon (Lienz, Austria); Glaber Zonule (including *E. glaber* fauna/Biohorizon (Lienz and Adnet, Austria)).

2. Oxynotum Chronozone, Simpsoni Subchronozone (Gagateum Zonule, no recorded faunas in Blau & Meister 1999), Oxynotum Subchronozone (Oxynotum Zonule, including *Oxynoticeras* ex grp *oxynotum* (Adnet, Austria) and *Paroxynoticeras salisburgense* (Lienz, Austria) faunas/Biohorizons).

3. Raricostatum Chronozone, Densinodulum Subchronozone (Delicatum–Edmundi Zonules, part?, including *G. rigidum* fauna/Biohorizon, part?); Raricostatum Subchronozone (Rhodanicum Zonule, including *Echioceras quenstedti* Biohorizon; Raricostatum Zonule, including *E. raricostatoides* Biohorizon; Crassicostatum Zonule, no confirmed records in Blau & Meister 1999; Boehmi Zonule, including *Paltechioceras boehmi* Biohorizon (Apennines, Italy)); Macdonelli Subchronozone (Meigeni Zonule, including *'Paltechioceras' favrei, 'P.' liciense, Leptechioceras meigeni/P. charpentieri, L. meigeni* and *L. meigeni/L. macdonnelli* Biohorizons (Lienz, Austria)); Aplanatum Subchronozone (Tardecrescens Zonule, including *Paltechioceras oosteri/Miltoceras gruenae* (Lienz, Austria) and *P. tardecrescens/P. romanicum* Biohorizons (Apennines, Italy and Lienz, Austria)).

Localities and faunas are described by Dommergues *et al*. (1994b; Apennines, Italy), Dommergues *et al*. (1995; Adnet, Austria) and Blau (1998; Lienz, Austria).

Pliensbachian Stage

The stage name was first used by Oppel (1856) as 'Pliensbach-Gruppe', with a zonal composition identical to that still used throughout Europe. Pliensbach is near Boll in Württemberg, southern Germany. Oppel's stage is essentially the same as d'Orbigny's earlier non-geographically named (and hence rejected) 'Liasien' (d'Orbigny 1842). 'Charmouthian' is another early synonym attributed to Mayer-Eymar (1864) but considered by Dean *et al.* (1961) as having been first published by Renevier (1874).

Unlike other Lower Jurassic stages, the Pliensbachian is often subdivided into named substages, the Lower Pliensbachian corresponding to the Carixian Substage (after 'Carixa' = Charmouth, Dorset, England; Lang 1913) and the Upper Pliensbachian corresponding to the Domerian Substage (after Monte Domaro in the Lombardy Alps, Italy; Bonarelli 1894).

The base of the Pliensbachian Stage

The first zone of Oppel's original 'Pliensbach-Gruppe' is still used as the first of the stage, namely the Jamesoni 'Zone' (Oppel 1856), now with a Taylori Subchronozone forming its lowest unit. D.T. Donovan (in: Morton 1971) discussed the base of the stage and indicated that the Taylori Subzone was first recognised on the coast of southern England in Dorset near Charmouth. The base of the stage at that locality (= base of Bed 105 of Lang 1928) lies immediately above a non-sequence which omits the highest two subzones of the Sinemurian. The locality is not suitable, therefore, for defining the base of the stage, according to ICS guidelines. A non-sequence at the base of the stage is also widespread throughout much of northern Europe, including at Pliensbach itself (Geyer 1964; Morton 1971).

Where more complete Sinemurian–Pliensbachian successions are exposed, however, for instance in Robin Hood's Bay (North Yorkshire, England; Tate & Blake 1876; Dommergues & Meister 1992; Page 1992; Hesselbo & Jenkins 1995) and the Isle of Raasay (western Scotland; Oates 1978; Donovan 1990; Page 1992), drawing a suitable base can be somewhat problematic. In Robin Hood's Bay, above the last typical Sinemurian-type ammonites (*Paltechioceras*) is a fauna with a small eoderoceratid described by Dommergues & Meister (1992) as *'Bifericeras' donovani*. At this level occur the first, rare *Apoderoceras*, a genus more characteristic of the Taylori Subzone than the index *Phricodoceras taylori* itself, but it is not until slightly higher in the Yorkshire succession that the latter genus is recorded.

On Raasay, however, above the last *Paltechioceras* and below common *Apoderoceras*, Donovan (1990) reported a fauna with a rare liparoceratid, *Vicininodiceras*. This fauna was included in the Sinemurian by Donovan and also by Page (1992), but its assignment to the stage is somewhat problematic, especially as its stratigraphical relationship to *'Bifericeras' donovani* is presently unknown.

Recent work on the Robin Hood's Bay sections by the Pliensbachian Working Group of the ISJS (in 1999) has confirmed the presence of small (?juvenile) *Apoderoceras* in association with *'Bifericeras' donovani* (= *donovani* Biohorizon or Zonule), that this level is therefore suitable for marking the base of the Pliensbachian Stage and that the fauna is typical of a conventional Pliensbachian and not the terminal Sinemurian as implied by Dommergues *et al.* (1994a, 1997). The section has now yielded results from other stratigraphical techniques, including microfossil assemblages and chemostratigraphy, leading to a formal proposal as a GSSP in late 2002 (Meister *et al.* 2002), the base of the stage being drawn at the base of Bed 73 (or 1011) of Dommergues & Meister (1992).

Pliensbachian correlative schemes and ammonoid provincialism

Early Pliensbachian faunas show a great deal of uniformity throughout northern Europe and most of the region is included in a Northwest European Province. Mediterranean Province faunas, although differing in taxonomic detail, are sufficiently well-correlated with those further north and west that the same standard zonation is used for both provinces, but faunal successions are nevertheless distinguishable at horizonal level (Figs 4, 5).

In the upper part of the Lower Pliensbachian and throughout the Upper Pliensbachian, however, the establishment of direct connections with Boreal regions resulted in a faunal spectrum developing across Europe from assemblages dominated by Boreal taxa in the northern areas (characterising a Subboreal Province) through faunas dominated by Mediterranean faunas in central and western areas (Submediterranean Province) to true Mediterranean Province faunas in the south. No true Arctic Province faunas (*sensu* Page 1996) are recognisable in Europe, however. Inter-provincial faunal links facilitate good correlations and it is possible to use the same standard zonation throughout Europe, but faunal sequences may be very different at horizon level.

The development of endemism in the early Pliensbachian of Portugal has necessitated the establishment of a different sequence of horizons from adjacent Submediterranean areas and sub-provincial or full provincial status may therefore be justifiable.

Northwest European Province (Britain, France, Germany, northern Spain, etc.)

The zonal and subzonal framework of the province is used throughout Europe and is based on Oppel's original scheme (Oppel 1856). For convenience, the province is here equated temporally with the Lower Pliensbachian Substage (equivalent to the first three zones of Oppel's scheme) and a description of the Upper Pliensbachian zonation of northern areas is included under the heading of Subboreal Province. The subzonal framework follows D.T. Donovan (in: Dean *et al.* 1961) as reviewed by Dommergues *et al.* (1997). Reference sections for each chronozone were proposed by Cox (1990) but some need modification in the light of new information on faunal successions elsewhere.

A number of systems of horizons, primarily in the sense of zonules, have been proposed for the early part of the stage in the province and include the schemes of Dommergues (1979) and Phelps (1985), with later revisions by Dommergues & Meister (1987), Dommergues (1987, 1997) and Dommergues *et al.* (1991).

Lower Pliensbachian Substage

Jamesoni Chronozone
Index. *Uptonia jamesoni* (J. de C. Sowerby 1827).
Author. Oppel (1856).

Taylori Subchronozone
Index. *Phricodoceras taylori* (J. de C. Sowerby 1826).
Author. Spath (1923).
Stratotype. Proposed by Meister *et al.* (2002): base of Bed 73/1011, Robin Hood's Bay, North Yorkshire, UK (see discussion above).
Correlating fauna. Species of *Apoderoceras*, with rarer *Phricodoceras* and *Radstockiceras*. *Tetraspidoceras* is common in southern areas (Dommergues *et al.* 1997).
Included subdivisions. Donovani Zonule, Nodogigas/grp Aculeatum Zonule, Taylori Zonule (Dommergues *et al.* 1991, 1997; Meister *et al.* 2002).
Comment. The basal unit of the stage characterised by *Bifericeras donovani* is here quoted as a 'Zonule' for consistency with higher subdivisions of the Pliensbachian. In Meister *et al.* (2002), however, the unit is treated as a 'Biohorizon'.

Polymorphus Subchronozone
Index. *Polymorphites polymorphus* (Quenstedt 1845).
Author. Buckman (1918) as a hemera, Spath (1923) as a subzone.
Correlating fauna. Species of *Polymorphites*, with early *Platypleuroceras* in the upper part of the subchronozone. *Radstockiceras* and *Epideroceras* also locally present.
Included subdivisions. Polymorphus Zonule (Dommergues *et al.* 1991, 1997).

Brevispina Subchronozone
Index. *Platypleuroceras brevispina* (J. de C. Sowerby 1827).
Author. Von Seebach (1864) as part of a larger zone, Buckman (1918) as a hemera, Spath (1923) as a subzone.
Correlating fauna. *Platypleuroceras* ex grp *brevispina* and spp. *Radstockiceras* and *Tragophylloceras* also present, with *Metaderoceras* in more southerly areas.
Included subdivisions. Brevispina Zonule, Submuticum Zonule (Dommergues *et al.* 1991, 1997).

Jamesoni Subchronozone
Index. As Jamesoni Chronozone (see above).
Author. Buckman (1918) as a hemera, D.T. Donovan (in: Dean *et al.* 1961) as a subzone.
Correlating fauna. *Uptonia* ex grp *jamesoni* and spp. *Tragophylloceras* and *Coeloceras* also typical locally.
Included subdivisions. Jamesoni Zonule, Pettos Zonule (Dommergues *et al.* 1991, 1997).

Ibex Chronozone
Index. *Tragophylloceras ibex* (Quenstedt 1843).
Author. Oppel (1856).

Masseanum Subchronozone
Index. *Tropidoceras masseanum* (d'Orbigny 1844).
Author. Buckman (1918) as a hemera, Spath (1923) as a subzone.
Correlating fauna. *Tropidoceras* spp., *Tragophylloceras* frequent, especially in more southerly areas.
Included subdivisions. Masseanum Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al.* 1991, 1997).

<table>
<tr><th rowspan="2">Chronozone</th><th rowspan="2">Subchronozone</th><th colspan="3">Northwest European Province</th><th colspan="2">Mediterranean Province</th></tr>
<tr><th>Zonule (NW European s.s.)</th><th colspan="2">Zonule (Lusitanian)</th><th>Zonule</th><th>Chronozone (Spain)</th></tr>
<tr><td rowspan="7">Davoei</td><td rowspan="2">Figulinum</td><td>Figulinum</td><td colspan="2" rowspan="11"></td><td rowspan="5">Costicillatum</td><td rowspan="7">Dilectum</td></tr>
<tr><td>Angulatum</td></tr>
<tr><td rowspan="3">Capricornus</td><td>Crescens</td></tr>
<tr><td>Capricornus</td></tr>
<tr><td>Lataecosta</td></tr>
<tr><td rowspan="2">Maculatum</td><td>Maculatum</td><td rowspan="2">Volubile–Pantanellii</td></tr>
<tr><td>Sparsicosta</td></tr>
<tr><td rowspan="14">Ibex</td><td rowspan="3">Luridum</td><td>Luridum</td><td>Dilectum</td><td rowspan="3">?</td></tr>
<tr><td>Crassum</td><td rowspan="2">aff. Dilectum</td></tr>
<tr><td>Rotundum</td></tr>
<tr><td rowspan="10">Valdani</td><td>Alisiense</td><td rowspan="3">Catriense</td><td rowspan="14">Demonense</td></tr>
<tr><td rowspan="5">Actaeon</td><td colspan="2">Beirense</td></tr>
<tr><td colspan="2">Amaltheiforme</td></tr>
<tr><td colspan="2">Splendens</td><td rowspan="8">?</td></tr>
<tr><td colspan="2">Polymorphoides</td></tr>
<tr><td colspan="2">Renzi</td></tr>
<tr><td>Valdani</td><td></td><td rowspan="4">Dayiceroides</td></tr>
<tr><td>Maugenesti</td><td>Maugenesti</td></tr>
<tr><td rowspan="2">Arietiforme</td><td></td></tr>
<tr><td>Carinatum</td></tr>
<tr><td>Masseanum</td><td>Masseanum</td><td colspan="2" rowspan="2">Uptonia sp.</td></tr>
<tr><td rowspan="12">Jamesoni</td><td rowspan="3">Jamesoni</td><td rowspan="2">Pettos</td><td>Mediterraneum</td></tr>
<tr><td colspan="2">Bronni–Lata</td><td>Flandrini</td></tr>
<tr><td>Jamesoni</td><td colspan="2">Bronni–Jamesoni</td><td>Erythreum</td></tr>
<tr><td rowspan="2">Brevispina</td><td>Submuticum</td><td colspan="2">Acanthobronnii</td><td>?</td><td rowspan="9">Aenigmaticum</td></tr>
<tr><td>Brevispina</td><td colspan="2">Muellensis</td><td>Sellae</td></tr>
<tr><td rowspan="2">Polymorphus</td><td rowspan="2">Polymorphus</td><td colspan="2">Costatus</td><td rowspan="7">?</td></tr>
<tr><td colspan="2">Biruga</td></tr>
<tr><td rowspan="5">Taylori</td><td rowspan="3">Taylori</td><td colspan="2">Dayiforme</td></tr>
<tr><td colspan="2">Caprariforme</td></tr>
<tr><td colspan="2" rowspan="3"></td></tr>
<tr><td>Nodogigas/grp Aculeatum</td></tr>
<tr><td>Donovani</td></tr>
</table>

Fig. 4. Lower Pliensbachian ('Carixian') subdivisions and correlations: Northwest European and Mediterranean Provinces. For explanation, see text.

Valdani Subchronozone

Index. Acanthopleuroceras valdani (d'Orbigny 1844).

Author. Collenot (1869) as a zone, Buckman (1918) as a hemera, Spath (1942) as a subzone.

Correlating fauna. *Acanthopleuroceras* spp., with *Tragophylloceras*, *Liparoceras*, and *Beaniceras* at higher levels.

Included subdivisions. Arietiforme Zonule, Maugenesti Zonule, Valdani Zonule, Actaeon Zonule, Alisiense Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Luridum Subchronozone

Index. *Beaniceras luridum* (Simpson 1855).

Author. D.T. Donovan (in: Dean *et al*. 1961).
Correlating fauna. *Beaniceras* grp *luridum* with *Liparoceras* spp. and *Tragophylloceras*.
Included subdivisions. Rotundum Zonule, Crassum Zonule, Luridum Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Davoei Chronozone
Index. *Prodactylioceras davoei* (J. Sowerby 1822).
Author. Oppel (1856).

Maculatum Subchronozone
Index. *Androgynoceras maculatum* (Young & Bird 1822).
Author. Lang (1936) as a zone, Spath (1938) as a subzone.
Correlating fauna. *A*. ex grp *maculatum* and *Liparoceras*.
Included subdivisions. Sparsicosta Zonule, Maculatum Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Capricornus Subchronozone
Index. *Androgynoceras capricornus* (Schlotheim 1820).
Author. Wright (1863) used the index for a zone equivalent to the Davoei Zone of Oppel; retained as a subzone by D.T. Donovan (in: Dean *et al*. 1961).
Correlating fauna. *A. lataecosta, A*. grp *capricornus,* etc. with *Liparoceras* (including *L*. (*Becheiceras*)) and, at certain levels, *Prodactylioceras*.
Included subdivisions. Lataecosta Zonule, Capricornus Zonule, Crescens Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Figulinum Subchronozone
Index. *Oistoceras figulinum* (Simpson 1855).
Author. Lang (1936).
Correlating fauna. *Oistoceras* spp. with *Liparoceras (Becheiceras), Tragophylloceras* and *Prodactylioceras* at certain levels.
Included subdivisions. Angulatum Zonule, Figulinum Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Northwest European Province: Lusitanian ?Sub-Province (Portugal)

Faunal differentiation in the early Pliensbachian has resulted in some correlation difficulties at intra-subzonal level between Portuguese faunas and those elsewhere in Europe. General affinities are however Northwest European. Local subdivisions as tabulated by Dommergues *et al*. (1991, 1997, based on Dommergues 1987) are shown in Figure 4, and include:

1. Jamesoni Chronozone, Taylori Subchronozone (unnamed interval, Caprariforme Zonule, Dayiforme Zonule); Polymorphus Subchronozone (Biruga Zonule, Costatus Zonule); Brevispina Subchronozone (Muellensis Zonule, Acanthobronni Zonule); Jamesoni Subchronozone (Bronni–Jamesoni Zonule, Bronni–Lata Zonule, Uptonia sp. Zonule – ?part).

2. Ibex Chronozone, Masseanum Subchronozone (Uptonia sp. Zonule – ?part); Valdani Subchronozone (Dayiceroides Zonule, including *Acanthopleuroceras carinatum* and *A. maugenesti* ?Biohorizons, Renzi Zonule, Polymorphoides Zonule, Splendens Zonule, Amaltheiforme Zonule, Beirense Zonule and unnamed interval); Luirdum Subchronozone and Davoei Chronozone as Northwest European Province.

Subboreal Province (Britain, northern Germany, etc.)

Increased faunal polarisation between southern and northern Pliensbachian faunas in the Upper Pliensbachian (= Domerian Substage) makes intra-subzonal correlations difficult or impossible. Subboreal faunas in particular, are dominated by Amaltheidae with only very rare representation of Mediterranean Hildocerataceae. The former dominate in the south, however, and correlate detailed horizonal sequences. The basic zonal/subzonal framework employed is nevertheless identical to that used elsewhere in Europe and follows M.K. Howarth (in: Dean *et al*. 1961). Significantly, Howarth (1991–1992) has proposed definitions for the bases of the subzones of the substage using northern English sites, all falling within the scope of the Subboreal Province as interpreted here. No complete system of biohorizons has been specifically proposed for the province, but the sequence of zonules used by Dommergues *et al*. (1997) can be applied. Full descriptions of faunas and successions can be found in Howarth (1955, 1956, 1957, 1991–1992).

Upper Pliensbachian Substage

Margaritatus Chronozone
Index. *Amaltheus margaritatus* (de Montfort 1808).
Author. Oppel (1856).

Chronozone	Subchronozone	Subboreal Province Zonule	Submediterranean Province Zonule	Mediterranean Province Zonule (Austria–Italy–Spain)		Mediterranean Province Subchronozone (Spain)	Mediterranean Province Chronozone (Spain)
Spinatum	Hawskerense	Hawskerense	Hawskerense	Elisa		Elisa	Emaciatum
				Emaciatum			
		Elaboratum	Lotti	Imitator			
	Apyrenum	Solare	Solare	Solare		Solare	
		Transiens	Transiens	Levidorsatum		Levidorsatum	Algovianum
		Salebrosum	Salebrosum	Meneghinii		Meneghenii	
Margaritatus	Gibbosus	(unnamed interval)	?	?		Accuratum	
			Ruthense				
		Algovianum	Algovianum	Accuratum			
		(unnamed interval)	Bertrandi (II)				
			Kurrianus	Canavarii			
			Ugdulenai	Ugdulenai			
			Macrum	Bertrandi (I)		Bertrandi	
			Ragazzonii	Ragazzonii		Ragazzonii	
	Subnodosus		Boscense	Cornacaldense		Cornacaldense	Lavinianum
		Normanianum	Depressum	Celebratum	Isseli		
	Stokesi	Celebratum	Celebratum				
		Nitescens	Nitescens	Marianii			
				Isseli/ Brevispiratum			
		Monestieri	Monestieri		Brevispiratum		
		Occidentale	Occidentale	Lavinianum/ Portisi	Lavinianum		
					Portisi		

Fig. 5. Upper Pliensbachian ('Domerian') subdivisions and correlations: Subboreal, Submediterranean and Mediterranean Provinces. For explanation, see text.

Stokesi Subchronozone

Index. *Amaltheus stokesi* (J. Sowerby 1818).

Author. Lang (1936).

Defined base. Base of Bed 1, Hawsker Bottoms or Bed 12, Staithes, Staithes Sandstone Formation, North Yorkshire, England (Howarth 1955, 1991–1992; Cox 1990).

Correlating fauna. *Amaltheus* ex grp *stokesi* with rare *Protogrammoceras*. *Tragophylloceras* and *Liparoceras* (*Becheiceras*) present, especially in more southerly areas.

Included subdivisions. Occidentale Zonule, Monestieri Zonule, Nitescens Zonule, Celebratum Zonule (Dommergues 1979; Phelps 1985; Dommergues *et al*. 1991, 1997).

Comment: The zonules of Dommergues *et al*. (1997) are recognised largely on the basis of *Protogrammoceras* which is typically very rare or absent in more northerly areas, thereby making the recognition of such units increasingly difficult from south to north.

Subnodosus Subchronozone

Index. *Amaltheus subnodosus* (Young & Bird 1828).

Author. Spath (1942) as a Nodifer Subzone; name changed to Subnodosus by Howarth (1955) for reasons of synonym.

Defined base. Base of Bed 18, Hawsker Bottoms or Bed 26, Staithes, Cleveland Ironstone Formation, North Yorkshire, England (Howarth 1955, 1991–1992).

Correlating fauna. *Amaltheus* ex grp *subnodosus* with rare *Protogrammoceras*.

Included subdivisions. Normanianum Zonule, unnamed interval (Dommergues *et al*. 1991, 1997).

Comment: The Normanianum Zonule of Dommergues *et al*. (1997) is recognised on the basis of *Protogrammoceras* which is typically very rare or absent in more northerly areas, thereby making recognition of the unit increasingly difficult from south to north.

Gibbosus Subchronozone
Index. Amaltheus gibbosus (Schlotheim 1820).
Author. Buckman (1918) as a hemera, Kuhn (1935) as a zone, Spath (1942) as a subzone.
Defined base. Base of Bed 21, Hawsker Bottoms or Bed 32, Staithes, Cleveland Ironstone Formation, North Yorkshire, England (Howarth 1955, 1991–1992).
Correlating fauna. Amaltheus ex grp *gibbosus,* and rare *Protogrammoceras.*
Included horizons. Unnamed interval, Algovianum Zonule, unnamed interval.
Comment. The Algovianum Zonule of Dommergues *et al.* (1997) is recognised on the basis of *Protogrammoceras* which is typically very rare or absent in more northerly areas, thereby making the recognition of the unit increasingly difficult from south to north.

Spinatum Chronozone
Index. Pleuroceras spinatum (Bruguière 1789).
Author. Oppel (1856).

Apyrenum Subchronozone
Index. Pleuroceras apyrenum (Buckman 1911).
Author. Spath (1942).
Defined base. Base of Bed 25, Hawsker Bottoms, Cleveland Ironstone Formation, North Yorkshire (Howarth 1955, 1991–1992; non Cox 1990).
Correlating fauna. Pleuroceras ex grp *solare (Phillips), P. apyrenum,* etc. and occasional *Amaltheus* ex grp *margaritatus.*
Included subdivisions. Salebrosum Zonule, Transiens Zonule, Solare Zonule (Dommergues *et al.* 1991, 1997).

Hawskerense Subchronozone
Index. Pleuroceras hawskerense (Young & Bird 1928).
Author. Buckman (1922) as a hemera, Spath (1942) as a subzone.
Defined base. Base of Bed 38, Hawsker Bottoms, or Bed 32, Staithes, Cleveland Ironstone Formation, North Yorkshire (Howarth 1955, 1991–1992).
Correlating fauna. Pleuroceras ex grp *hawskerense* and occasional *Pseudamaltheus engelhardti* (d'Orbigny).
Included subdivisions. Elaboratum Zonule, Hawskerense Zonule (Dommergues *et al.* 1991, 1997).

Submediterranean Province (southern France, northern Spain, etc.)

The Submediterranean Province developed in parallel with the Subboreal and is also therefore primarily a phenomenon of the Upper Pliensbachian (= Domerian). Faunas are dominated by Hildocerataceae, with some Dactylioceratidae but Amaltheidae are usually much less common than in Subboreal areas. In consequence, a separate sequence of zonules is recognised for the Upper Pliensbachian of the Submediterranean Province (Meister 1989; Dommergues *et al.* 1991, 1997) as follows:

1. Margaritatus Chronozone, Stokesi Subchronozone (as Subboreal Province); Subnodosus Subchronozone (Depressum Zonule, Boscense Zonule); Gibbosus Subchronozone (Ragazzonii Zonule, Macrum Zonule, Ugdulenai Zonule, Kurrianus Zonule, Bertrandi Zonule (II), Algovianum Zonule, Ruthense Zonule, unnamed interval).

2. Spinatum Chronozone, Apyrenum Subchronozone (as Subboreal Province); Hawskerense Subchronozone (Lotti Zonule, Hawskerense Zonule).

Mediterranean Province (Austria, Italy, southern Spain)

Faunas in the province are commonly so different from those of northern Europe that it is remarkable that the same standard zonation can often be used. The presence of interprovincial correlative tie-lines is very important in linking northern and southern areas, but many problems still remain, leading to the introduction by Braga *et al.* (1982) and Braga (1983) of a new zonal scheme for the Mediterranean Province, as correlated by Dommergues *et al.* (1997) with Submediterranean and Northwest European schemes and reproduced here on Figures 4 and 5.

Several sequences of 'horizons' are also recognised within the Mediterranean Province for the Pliensbachian Stage and schemes for Austria/Italy and Spain are also tabulated on Figures 4 and 5 (after Braga 1983; Meister 1987; Ferreti 1990; Dommergues *et al.* 1991, 1997; Meister *et al.* 1994).

Toarcian Stage

The stage name was derived by d'Orbigny (1842–1849) from the town of Thouars in central western France (Poitou) where the division is well-developed and rich in ammonites. Unlike those of the earlier Lower Jurassic stages, all the zones of the modern Toarcian Stage postdate Oppel's simple scheme of 1856 (with a 'Zone der

Posidonia bronni', followed by a 'Zone des *Ammonites jurensis*').

As for the Pliensbachian, the Toarcian is divided into two substages. Both these substages have names, the Lower Toarcian corresponding to the Whitbian (after Whitby in North Yorkshire, north-east England; Buckman 1910) and the Upper Toarcian to the Yeovilian (after Yeovil in Somerset, south-west England; Buckman 1910). The original definition of Whitbian included the Variabilis Zone but was redefined by M.K. Howarth (in: Dean *et al*. 1961) to exclude that zone which was reassigned as the lowest of the Yeovilian. Unlike for the Pliensbachian, however, these geographical names for substages have fallen into disuse.

The base of the Toarcian Stage

The base of the lower zone of Oppel's Toarcian, (with the bivalve *'Posidonia' bronni* as index) corresponds to the changeover in Northwest Europe from typical Pliensbachian ammonite faunas with *Pleuroceras* to typical Toarcian faunas with abundant *Dactylioceras*.

The base of the stage in the type region (Submediterranean Province as used here) corresponds to the base of the Tenuicostatum Chronozone. This zone, however, has its type locality on the coast of northern England (North Yorkshire; Buckman 1910, Subboreal Province), and this has led to various proposals or assumptions that this latter area should include the basal boundary stratotype of the stage (e.g. M.K. Howarth in: Morton 1971; Cox 1990; Howarth 1991–1992).

The lower part of the Tenuicostatum Chronozone as used in both provinces is a Paltum Subchronozone, the base of which was defined by Howarth (1991–1992) as the base of Bed 26, Kettleness, **or** the base of Bed 58, Staithes (basal Grey Shales Member, Whitby Mudstone Formation), both in North Yorkshire (sections as described by Howarth 1955, 1973). The use of this stratigraphic division dates back to Buckman (1922) with reference to a fauna in the highly condensed Middle–Upper Lias 'Junction Bed' of Dorset, southern England (Buckman 1910; Jackson 1926). The characteristic *Protogrammoceras* fauna of Buckman's *paltus* Hemera is abundant in Dorset, but does not occur as part of a clear faunal succession due to the highly condensed and lenticular nature of the uppermost Pliensbachian – Lower Toarcian 'Junction Bed'. In Yorkshire, however, the fauna is much rarer, although the rock succession itself is considerably expanded. Nevertheless, as noted by Howarth (1992, p. 5 in: Howarth 1991–1992), *P. paltum* is probably not a good index, but was selected as it is restricted to this level in Britain.

Further south in Europe, similar *Protogrammoceras* (or *'Paltarpites'*) occur at higher and lower levels (Howarth 1992, p. 7 in: Howarth 1991–1992). In addition, the earliest Toarcian *Dactylioceras*, in association with *P. paltum*, are abundant and characteristic in southern areas but virtually absent in Britain. The association of the former, including *Dactylioceras* (*Eodactylites*) *mirabilis* Fucini and *D.* (*E.*) *simplex* Fucini, with *P. paltum* in Spain (e.g. Goy & Martinez 1990) and even in southern Germany (Schlatter 1985) presents a better scenario, however, for defining the base of the stage (cf. Elmi 1997; Elmi *et al*. 1997). Detailed correlations between the northern European Tenuicostatum Chronozone and the unit of the same name in southern areas is not yet established in detail, due to apparent differences in the dactylioceratid faunas (cf. Elmi *et al*. 1997). Nevertheless, it is very unlikely that sections in Britain will be suitable candidate GSSPs as they are faunally impoverished when compared to southern Europe and hence have a more limited international correlation potential.

Toarcian correlative schemes and ammonoid provincialism

Early Toarcian faunas show similar distribution patterns to those of the Late Pliensbachian, as Boreal connections appear to have persisted throughout the substage. As in the Pliensbachian, a Subboreal to Submediterranean to Mediterranean Province transition is recognisable. Unlike the Pliensbachian, however, separate zonal schemes exist for all three provinces (Fig. 6). There are very close links, however, between Submediterranean and Subboreal faunas, so whether a distinct zonal/subzonal scheme is needed is debatable. Even at intra-subzonal level, similarities are sufficient that many cross-correlations are possible.

In the Late Toarcian, these similarities are so great that only one zonal scheme is justifiable in Northwest Europe and only one scheme is therefore reviewed here for a Northwest European Province (Fig. 7). Rare Boreal links include occasional *Pseudolioceras*, mainly in northern Britain. This unified scheme combines elements of the British standard of W.T. Dean (in: Dean *et al*. 1961) and Howarth (1980) with the French schemes of Gabilly *et al*. (1971, 1974), Gabilly (1976) and Elmi *et al*. (1991, 1994, 1997).

Subboreal Province (northern Britain)

A restricted Subboreal Province is most characteristic of northern England and Scotland in the Lower Toarcian (from late Tenuicostatum to Bifrons Chronozones) when faunas are dominated by dactylioceratids with less common Hildocerataceae, especially in Scotland. The presence at certain levels of Boreal hildocerataceans, such as *Tiltoniceras*, *Elegantuliceras*, *Ovaticeras* and *Pseudolioceras*, is typical. Further south in Britain, faunas become more Submediterranean in character and late dactylioceratids of the Bifrons Chronozone are rare in Dorset and Somerset.

The following scheme for the Lower Toarcian is that of M.K. Howarth (in: Dean *et al*. (1961) as modified by Howarth (1973) and defined by Howarth (1991–1992). The included biohorizons are described more fully elsewhere (Page 2002b) and are based on observations by the author and records by Howarth (1962, 1973, 1978, 1991–1992). The system of zonules for the 'North West European' Province of Elmi *et al*. (1997; essentially the Submediterranean Province as used here) is applicable, at least in part, to the Subboreal Province and is utilised below.

Lower Toarcian Substage

Tenuicostatum Chronozone

Index. Dactylioceras tenuicostatum (Young & Bird 1822).

Author. Buckman (1910) replacing the Annulatus Zone of Tate & Blake (1876) (the latter with a stratigraphically incorrectly placed index; see M.K. Howarth in: Dean *et al*. 1961).

Paltum Subchronozone

Index. Protogrammoceras paltum (Buckman 1922).

Author. Buckman (1922) as a hemera, Howarth (1973) as a subzone.

Defined base. Provisionally defined (see comment) as base of Bed 55, Staithes, Ketteness Member, Cleveland Ironstone Formation, North Yorkshire, England (Howarth 1955, 1973, 1991–1992; Cox 1990).

Correlating fauna. *Protogrammoceras paltum*, and very rare early *Dactylioceras* (including *D. pseudocommune* Fucini).

Included subdivisions. Paltum Zonule (including *Protogrammoceras paltum* Biohorizon).

Comment. Although useful for correlating the base of the Toarcian in a Subboreal/UK sense, Howarth's North Yorkshire reference section is not a ratified GSSP (see discussion above).

<table>
<tr><th colspan="3">Subboreal Province</th><th colspan="3">Submediterranean Province</th><th colspan="3">Mediterranean Province</th></tr>
<tr><th>Chronozone</th><th>Subchronozone</th><th>Biohorizon</th><th>Zonule</th><th>Subchronozone</th><th>Chronozone</th><th>Chronozone</th><th>Subchronozone</th><th>Zonule</th></tr>
<tr><td rowspan="8">Bifrons</td><td rowspan="2">Crassum</td><td>crassum–semipolitum</td><td>Semipolitum</td><td rowspan="5">Bifrons</td><td rowspan="8">Bifrons</td><td rowspan="8">Bifrons</td><td rowspan="5">Bifrons</td><td>Semipolitum</td></tr>
<tr><td>crassum–bifrons</td><td rowspan="2">Bifrons</td><td rowspan="2">Bifrons</td></tr>
<tr><td rowspan="3">Fibulatum</td><td>vortex</td></tr>
<tr><td>braunianus</td><td rowspan="2">Apertum</td><td rowspan="2">Apertum</td></tr>
<tr><td>turriculatum</td></tr>
<tr><td rowspan="3">Commune</td><td>athleticum</td><td>Lusitanicum</td><td rowspan="3">Sublevisoni</td><td rowspan="3">Sublevisoni</td><td>Lusitanicum</td></tr>
<tr><td>commune</td><td>Tethysi</td><td>Tethysi</td></tr>
<tr><td>ovatum</td><td>Sublevisoni</td><td>Sublevisoni</td></tr>
<tr><td rowspan="5">Serpentinum</td><td rowspan="2">Falciferum</td><td>falciferum</td><td>Douvillei</td><td rowspan="2">Falciferum</td><td rowspan="5">Serpentinum</td><td rowspan="5">Levisoni</td><td rowspan="2">Falciferum?</td><td rowspan="4"></td></tr>
<tr><td>pseudoserpentinum</td><td>Pseudoserpentinum</td></tr>
<tr><td rowspan="3">Exaratum</td><td>elegans</td><td rowspan="2">Strangewaysi</td><td rowspan="3">Elegantulum</td><td rowspan="3">Levisoni</td></tr>
<tr><td>exaratum</td></tr>
<tr><td>elegantulum</td><td>Elegantulum</td><td rowspan="3">Striatus</td></tr>
<tr><td rowspan="6">Tenuicostatum</td><td rowspan="2">Semicelatum (I)</td><td>antiquum</td><td rowspan="2">'Semicelatum'</td><td rowspan="5">'Semicelatum' (II)</td><td rowspan="6">Tenuicostatum</td><td rowspan="6">Polymorphum</td><td rowspan="5">'Semicelatum' (II)</td></tr>
<tr><td>semicelatum</td></tr>
<tr><td>Tenuicostatum</td><td>tenuicostatum</td><td>Tenuicostatum</td><td rowspan="4">Paltarpites</td></tr>
<tr><td rowspan="2">Clevelandicum</td><td>clevelandicum</td><td rowspan="2">Crosbeyi</td></tr>
<tr><td>crosbeyi</td></tr>
<tr><td>Paltum</td><td>paltum</td><td>Paltum</td><td>Paltum</td><td>Mirabile</td></tr>
</table>

Fig. 6. Lower Toarcian subdivisions and correlations: Subboreal, Submediterranean and Mediterranean Provinces. For explanation, see text.

Clevelandicum Subchronozone
Index. Dactylioceras clevelandicum Howarth 1973.
Author. Howarth (1973) = *Dactylioceras* sp. nov. horizon of M.K. Howarth (in: Dean *et al*. 1961).
Defined base. Base of Bed 18, Grey Shales Member, Whitby Mudstone Formation, North Yorkshire coast (e.g. Kettleness/Port Mulgrave), England (Howarth 1973, 1991–1992).
Correlating fauna. D. grp *clevelandicum.*
Included subdivision. Crosbeyi Zonule (including *Dactylioceras crosbeyi* and *D. clevelandicum* Biohorizons).

Tenuicostatum Subchronozone
Index. As Tenuicostatum Chronozone (see above).
Author. Buckman (1930 in: Buckman 1909–1930) as a hemera, M.K. Howarth (in: Dean *et al*. 1961) as a 'horizon', Howarth (1973) as a subzone.
Defined base. Base of Bed 20, Grey Shales Member, Whitby Mudstone Formation, North Yorkshire coast (Kettleness/Port Mulgrave), England (Howarth 1973, 1991–1992).
Correlating fauna. D. tenuicostatum.
Included subdivisions. Tenuicostatum Zonule (including *Dactylioceras tenuicostatum* Biohorizon).

Semicelatum (I) Subchronozone
Index. Dactylioceras semicelatum (Simpson 1843).
Author. M.K. Howarth (in: Dean *et al*. 1961) as '*D. semicelatum* horizon', Howarth (1973) as a subzone. The index has been used by Mauberge (1948, 1952) for a Tenuicostatum–Semicelatum Zone and a Semicelatum Zone, effectively as a synonym of the Tenuicostatum Chronozone as a whole.
Defined base. Base of Bed 28, Grey Shales Member, Whitby Mudstone Formation, North Yorkshire coast (e.g. Kettleness/Port Mulgrave area), England (Howarth 1973, 1991–1992).
Correlating fauna. D. semicelatum and *Tiltoniceras antiquum* (Wright).
Included subdivisions. Semicelatum Zonule (including *Dactylioceras semicelatum* and *Tiltoniceras antiquum* Biohorizons).
Comments. The Semicelatum Subchronozone of the Subboreal Province is as restricted by Howarth (1973). In the Submediterranean and Mediterranean provinces, however, a 'Semicelatum Subzone' is also used but broadly equates to the Clevelandicum, Tenuicostatum and Semicelatum Subchronozones combined. Clearly, different names are needed to distinguish the two units, but pending a full revision the two subchronozones are here distinguished as Semicelatum (I) and Semicelatum (II), respectively.

Serpentinum Chronozone
Index. Harpoceras serpentinum (Schlotheim 1813).
Author. Oppel (1856) suggested the use of *Ammonites serpentinum* as an alternative index to *Posidonia bronni*. Reynès (1868) restricted a Serpentinus Zone to the lower part of the Lower Toarcian (below a Bifrons Zone) and its use was restricted further by the recognition of a basal Tenuicostatum Zone. The use of *H. serpentinum* as an index has priority over *H. falciferum* (J. Sowerby 1820) first used as a zonal index by Haug (1885) and subsequently by most British authors (e.g. M.K. Howarth in: Dean *et al*. 1961; Howarth 1991–1992).

Exaratum Subchronozone
Index. Cleviceras exaratum (Young & Bird 1828).
Author. Buckman (1910) as a zone, Arkell (1956) as a subzone.
Defined base. Base of Bed 33, Mulgrave Shale Member, Whitby Mudstone Formation, North Yorkshire coast (e.g. Rosedale Wyke to Lingrow Knock or Saltwick Bay area, Whitby), England (Howarth 1962, 1991–1992; Cox 1990).
Correlating fauna. Elegantuliceras, Cleviceras and early *Harpoceras* in succession. *Dactylioceras* (*Nodicoeloceras*) and *Hildaites* ex grp *levisoni* present.
Included subdivisions. Elegantulum Zonule (including *Elegantuliceras elegantulum* Biohorizon), Strangewaysi Zonule (including *Cleviceras exaratum* and *C. elegans* Biohorizons).

Falciferum Subchronozone
Index. Harpoceras falciferum (J. Sowerby 1820).
Author. Haug (1885) as a broader zone (including the Exaratum Subzone), Buckman (1930 in: Buckman 1909–1930) as a hemera, Arkell (1933) as a subzone.
Defined base. Base of Bed 41, Mulgrave Shale Member, Whitby Mudstone Formation, North Yorkshire coast (e.g. Saltwick Bay area, Rosedale Wyke to Lingrow Knock, etc.) England (Howarth 1962, 1991–1992).
Correlating fauna. Harpoceras ex grp *falciferum.*
Included subdivisions. Pseudoserpentinum Zonule (including *Harpoceras* pseudoserpentinum Biohorizon), Douvillei Zonule (including *H. falciferum* Biohorizon).

Bifrons Chronozone
Index. Hildoceras bifrons (Bruguière 1789).
Author. Reynès (1868) as a zonal index.

Commune Subchronozone

Index. Dactylioceras commune (J. Sowerby 1815).

Author. Wright (1863) as a zone in a broad sense, and equivalent to Lower Toarcian, M.K. Howarth (in: Dean *et al*. 1961) as a restricted subzone. Equivalent to the 'Communis Beds' or Subcarinata Zone of Thompson (1910).

Suggested re-defined base. Base of Bed 47, Whitby, Alum Shale Member, Whitby Mudstone Formation, North Yorkshire, England (sections described by Howarth 1962, 1991–1992). This definition is modified from that of Howarth (1991–1992) and Cox (1990) to include the *ovatum* Biohorizon. It is suggested that 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 grp *sublevisoni* are taken to indicate the lower part of the chronozone (abundant *H.* ex grp *sublevisoni* occurs with rare *Ovaticeras ovatum* near Ilminster in southern England; unpublished observations by the author).

Correlating fauna. Dactylioceras, including *D. commune* and *D. athleticum* (Simpson), also *Ovaticeras. Hildoceras* spp., including *H. lusitanicum* Meister are usually uncommon.

Included subdivisions. Sublevisoni Zonule (including *Ovaticeras ovatum* Biohorizon), Tethysi Zonule (including *Dactylioceras commune* Biohorizon), Lusitanicum Zonule (including *D. athleticum* Biohorizon).

Fibulatum Subchronozone

Index. Peronoceras fibulatum (J. de C. Sowerby 1823).

Author. Thompson (1910).

Defined base. Base of Bed 60, Alum Shale Member, Whitby Mudstone Formation, Whitby, North Yorkshire, England.

Correlating fauna. Peronoceras, Zugodactylites and *Porpoceras* spp. with some *Hildoceras* (including *H. bifrons*).

Included subdivisions. Apertum Zonule (including *Peronoceras turriculatum* and *Zugodactylites braunianus* Biohorizons), Bifrons Zonule (part, including *Porpoceras vortex* Biohorizon).

Crassum Subchronozone

Index. Catacoeloceras crassum (Young & Bird 1828).

Author. Corroy & Gérard (1933).

Defined base. 1.5 m above the base of Bed 72, Whitby **or** the base of Bed XIIV, Alum Shale Member, Whitby Mudstone Formation, Ravenscar, North Yorkshire, England (Howarth 1962, 1978, 1991–1992).

Correlating fauna. Abundant *Catacoeloceras* with less frequent *Hildoceras* including *H. semipolitum* Buckman.

Included subdivisions. Bifrons Zonule (part, including *Catacoeloceras crassum – H. bifrons* Biohorizon), Semipolitum Zonule (including *C. crassum – H. semipolitum* Biohorizon).

Submediterranean Province (southern England, France, Germany, northern Spain, etc.)

Although strong links exist between northern and southern regions, faunas of Submediterranean areas in the Lower Toarcian are usually richer in Hildocerataceae, sometimes to the virtual exclusion of Dactylioceratidae. The separate chronozonal schemes historically used in Britain and France are not entirely necessary as the greatest faunal changes actually occur within Britain, between southern England (Dorset and Somerset) and northern England (North Yorkshire) and Scotland (Isle of Raasay).

The chronozonal framework employed in France is identical in zonal composition to that in Britain, but differs at the level of subzones and horizons due to faunal differentiation. The scheme summarised here follows Elmi *et al*. (1991, 1994, 1997) and is largely based on Gabilly *et al*. (1971) and Gabilly (1976).

Lower Toarcian Substage

Tenuicostatum Chronozone

Index and author. As Subboreal Province (see above).

Paltum (or Paltus) Subchronozone

Index, author and defined base. As Subboreal Province (see above).

Correlating fauna. Protogrammoceras paltum and, in certain areas*, Dactylioceras (Eodactylites)* spp., *Neolioceratoides* and *Lioceratoides.*

Included subdivisions. Paltum [Paltus] Zonule (Gabilly *et al*. 1974; Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Semicelatum (II) Subchronozone

Index and author. As Subboreal Province, but used here in a less restricted sense (*sensu* Gabilly *et al*. 1971; see comments below).

Correlating fauna. Dactylioceras spp. including *D. semicelatum,* and rarer hildoceratids, including *Protogrammoceras* and *Neolioceratoides*.

Included subdivisions. Crosbeyi Zonule, Tenuicostatum Zonule, Semicelatum Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Comments. The exact relationship of the Submediterranean Semicelatum Subchronozone to the Subboreal subchronozone of the same name is problematic as both the Crosbeyi and Tenuicostatum Subchronozones are difficult to recognise outside their type area. The conventional usage continued here is to draw the base of the Submediterranean division at the first occurrence of abundant *Dactylioceras* (*Orthodactylites*) – this would therefore equate with the base of the Clevelandicum Subchronozone of Subboreal areas. As the definition of the subchronozone in that region has been stabilised by formal definition (Howarth 1991–1992, see above), it is necessary to rename the Submediterranean division. As suggested above in discussion of the subchronozone in the Subboreal Province, pending full revision the two units are here distinguished as 'Semicelatum' (I) (Subboreal) and 'Semicelatum' (II) (Submediterranean and Mediterranean).

Serpentinum Chronozone

Index and author. As Subboreal Province (see above).

Elegantulum Subchronozone

Index. Elegantuliceras elegantulum (Young & Bird 1828)

Author. Gabilly (1976) as a subzone, equivalent to his earlier Strangewaysi Zone.

Correlating fauna. *Elengantuliceras, Harpoceras* ex grp *serpentinum, Cleviceras, Hildaites* and dactylioceratids including *'Nodicoeloceras'*.

Included subdivisions. Elegantulum Zonule, Strangewaysi Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Comment. The subchronozone is probably exactly equivalent to the Subboreal Exaratum Subchronozone as it appears to have a coincident base (the definition of Howarth 1991–1992 cited above could also therefore apply to this subchronozone; indeed, this is necessary if the Serpentinus Chronozone is to be used in both provinces).

Falciferum Subchronozone

Index and author. As Subboreal Province (see above).

Correlating fauna. Harpoceras ex grp *falciferum, Hildaites* and dactylioceratids including *Nodicoeloceras.*

Included subdivisions. Pseudoserpentinum Zonule, Douvillei Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Comments. The subchronozone as used in Submediterranean areas is probably equivalent to that of Subboreal regions. A common defined base is therefore necessary if the same name is to be used in both provinces and that of Howarth (1991–1992) may be appropriate.

Bifrons Chronozone

Index and author. As Subboreal Province (see above).

Sublevisoni Subchronozone

Index. Hildoceras sublevisoni Fucini 1922.

Author. Donovan (1958).

Correlating fauna. Abundant *Hildoceras* spp. including *Hi.* ex grp *sublevisoni, Harpoceras* ex grp *falciferum, Dactylioceras* ex grp *commune*, etc.

Included subdivisions. Sublevisoni Zonule, Tethysi Zonule, Lusitanicum Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Comments. See discussion on Subboreal Province Commune Subchronozone regarding equilibration with the Submediterranean Scheme. Howarth (1992, p. 177 in: Howarth 1991–1992) includes faunas with *Hi. sublevisoni* within a Falciferum Subchronozone *sensu anglico*. As *Harpoceras* ex grp *falciferum* persists into the Sublevisoni Subchronozone, however, this interpretation would conflict with the established interpretation of French authors in the type region of the Bifrons Chronozone (e.g. Gabilly *et al*. 1971) where the first appearance of primitive *Hildoceras* (i.e. *Hi.* ex grp *sublevisoni)* is regarded as marking the base of the zone. This latter convention is followed here.

Bifrons Subchronozone

Index and author. As Bifrons Chronozone (see above).

Correlating fauna. Hildoceras bifrons and allied species abundant, with rarer *Harpoceras subplanatum* (Oppel), *Phymatoceras* and dactylioceratids, including *Zugodactylites* and *Catacoeloceras*.

Included subdivisions. Apertum Zonule, Bifrons Zonule, Semipolitum Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Comments. A Semipolitum Subchronozone has been used in Submediterranean Province areas (e.g. in Elmi *et al*. 1991, 1994), after Donovan (1958), but was reduced to the status of 'Horizon' (= zonule) by Elmi *et al*. (1997).

Northwest European Province (Britain, France, Germany, northern Spain, etc.)

In the Upper Toarcian, good faunal links throughout most of more northerly areas of Europe suggest that only one zonal scheme for the region is justifiable (Fig. 7). Faunas are richer in more southerly areas, especially in Phymatoceratidae, but the bulk of the correlatively important Grammoceratinae (Hildoceratidae) are very widespread. The following scheme is based on the French systems of Gabilly *et al.* (1971, 1974) and Elmi *et al.* (1991, 1994, 1997), taking into account the earlier British zonation of W.T. Dean (in: Dean *et al.* 1961) as modified by Howarth (1980). All intrasubzonal units are here used as zonules, no complete schemes of biohorizons presently being available for the province.

Upper Toarcian Substage

Variabilis Chronozone

Index. Haugia variabilis (d'Orbigny 1845).

Author. Buckman (1888 in: Buckman 1887–1907) as a subzone of larger Jurensis Zone. First used as a zone by Welsch (1903).

Variabilis Subchronozone

Index. As Variabilis Chronozone (see above).

Author. Buckman (1925 in: Buckman 1909–1930) as a hemera, used as a horizon by Gabilly *et al.* (1971) and a subzone by Gabilly (1976).

Correlating fauna. Haugia ex grp *variabilis, Denckmannia* and *Catacoeloceras dumortieri* (de Brun).

Included subdivisions. Navis Zonule, Jugosa Zonule (Gabilly 1976; Elmi *et al.* 1991, 1994, 1997).

Comment. Interpretation of the base of the Variabilis Chronozone differs between Britain and France depending on whether the last occurrence of *Hildoceras semipolitum/Catacoeloceras* spp. or the first occurrence of *Haugia* is taken as a guide (the former would indicate Bifrons Chronozone, Crassum Subchronozone in Britain and the latter Variabilis Chronozone, Variabilis Subchronozone in France). The base of the conventional Variabilis Chronozone is therefore drawn at a lower level in France than in Britain as all three taxa are recorded together. This latter convention is followed here.

Illustris Subchronozone

Index. Haugia illustris (Denckman 1887).

Northwest European Province			Mediterranean Province		
Chronozone	Subchronozone	Zonule	Zonule	Subchronozone	Chronozone
Aalensis	Fluitans	Buckmani	?	Fluitans	Aalensis
		Lugdunensis	Fluitans		
	Mactra	Celtica	Flamandi	Mactra	
		Mactra	Mactra		
		Tectiforme			
Pseudoradiosa	Pseudoradiosa	Pseudoradiosa		?	Meneghinii
	Levesquei	Munieri	Meneghinii		
		Insignisimilis			
Dispansum	Gruneri	Gruneri		Reynesi	Speciosum
	Insigne	Pachu			
		Cappucinum		Speciosum	
Thouarsense	Fallaciosum (I)	Fallaciosum		Fallaciosum (II)	Bonarellii
	Fascigerum	Fascigerum			
	Striatulum	Thouarsense		Mediterraneum	
		Doerntense			
	Bingmanni	Bingmanni			
Variabilis	Vitiosa	Vitiosa	Subregale	Alticarinatus	Gradata
	Illustris	Phillipsi	Aratum		
		Illustris		?	
	Variabilis	Jugosa		Gemma	
		Navis			

Fig. 7. Upper Toarcian subdivisions and correlations: Northwest European and Mediterranean Provinces. For explanation, see text.

Author. Stolley (1909) as a zone, Gabilly *et al*. (1971) as a horizon, Gabilly (1976) as a subzone.
Correlating fauna. *Haugia* grp *illustris*, *H. phillipsi* (Simpson), etc. (including *Haugiella*), *Hammatoceras* spp., *Denckmannia*.
Included subdivisions. Illustris Zonule, Phillipsi Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Vitiosa Subchronozone
Index. *Haugia vitiosa* (Buckman 1909).
Author. Gabilly (1976) as a subzone.
Correlating fauna. *Haugia* grp *vitiosa, Denckmannia, Hammatoceras, Pseudogrammoceras*.
Included subdivisions. Vitiosa Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Thouarsense Chronozone
Index. *Grammoceras thouarsense* (d'Orbigny 1844).
Author. Brasil (1896) as a zone.
Comment. In Britain, only two subchronozones are conventionally recognised in the Thouarsense Chronozone (e.g. Dean *et al*. 1961; Howarth 1980). The lower or Striatulum Subchronozone corresponds broadly to the combined Bingmanni, Striatulum and Fascigerum Subchronozones of the scheme used here. The upper or Fallaciosum Subchronozone is probably more or less equivalent to the division of the same name used here.

Bingmanni Subchronozone
Index. *Pseudogrammoceras bingmanni* (Denckman 1887).
Author. Gabilly *et al*. (1971) as a zone, Gabilly (1976) as a subzone.
Correlating fauna. *P. bingmanni* and *P. struckmanni* with rarer *Podagrosites,* etc.
Included subdivisions. Bingmanni Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Striatulum Subchronozone
Index. *Grammoceras striatulum* (J. de C. Sowerby 1823).
Author. Buckman (1888 in: Buckman 1887–1907).
Correlating fauna. *Grammoceras* spp. including the index and *G. thouarsense* with some *Pseudogrammoceras,* etc.
Included subdivisions. Doerntense Zonule, Thouarsense Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).
Comment. Use of *G. striatulum* as an index by Buckman (1888 in: Buckman 1887–1907) has priority over the use of *G. thouarsense* (used first as a zone by Brasil 1896) and also by Elmi *et al*. (1997).

Fascigerum Subchronozone
Index. *Esericeras fascigerum* (Buckman 1888 in: Buckman 1887–1907).
Author. Gabilly *et al*. (1971) as Esericeras Subzone, Guex (1975) as Fascigerum Subzone.
Correlating fauna. *E. fascigerum* and *E.* spp., *Pseudogrammoceras differens* (Ernst) and *Grammoceras penestriatulum* (Buckman), etc.
Included subdivisions. Fascigerum Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Fallaciosum (I) Subchronozone
Index. *Pseudogrammoceras fallaciosum* (Bayle 1878).
Author. Nicklès (1907), probably as a broader division; replaces the Struckmanni Subzone of W.T. Dean (in: Dean *et al*. 1961) due to the latter's stratigraphically incorrectly placed index (Howarth 1980).
Correlating fauna. *P.* grp *fallaciosum, Osperlioceras*, etc.
Included subdivisions. Fallaciosum Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).
Comment. As a Fallaciosum Subchronozone is also used in Mediterranean Province areas, but may not be exactly time equivalent, the Northwest European unit is here designated 'Fallaciosum (I)'.

Dispansum Chronozone
Index. *Phlyseogrammoceras dispansum* (Lycett 1860).
Author. Buckman (1889) as Dispansum Beds, Buckman (1910) as Dispansum Zone.
Comment. The Dispansum Chronozone as used here corresponds to the Dispansum Subzone of the Levesquei Zone of British authors (e.g. W.T. Dean in: Dean *et al*. 1961; Howarth 1980).

Insigne Subchronozone
Index. *Hammatoceras insigne* (Zieten 1830).
Author. Welsch (1897) as a zone, Theobald & Mauberge (1949) as a subzone.
Correlating fauna. *H.* ex grp *insigne, Phlyseogrammoceras dispansum*, etc.
Included subdivisions. Cappucinum Zonule, Pachu Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Gruneri Subchronozone
Index. *Gruneria gruneri* (Dumortier 1874).
Author. Gabilly *et al*. (1971) as a 'Horizon' (= Zonule), used as a subzone by Elmi *et al*. (1991, 1994).
Correlating fauna. *Gruneria* ex grp *gruneri, Hammatoceras perplanum* Prinz, etc.
Included subdivisions. Gruneri Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Pseudoradiosa Chronozone
Index. Dumortieria pseudoradiosa (Branco 1879).
Author. Haug (1892).

Levesquei Subchronozone
Index. Dumortieria levesquei (d'Orbigny 1844).
Author. Benecke (1901) as a broader *'levesquei-*Schichten', Buckman (1925 in: Buckman 1909–1930) as a hemera, later as a subzone (Spath 1942).
Correlating fauna. *D.* ex grp *levesquei, Catulloceras*.
Included subdivisions. Insignisimilis Zonule, Munieri Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).
Comment. Broadly equivalent to the Levesquei Subzone of the Levesquei Zone of British authors (e.g. W.T. Dean in: Dean *et al.* 1961; Howarth 1980).

Pseudoradiosa Subchronozone
Index. As Pseudoradiosa Chronozone (see above).
Author. Used as a subzone by Gabilly *et al*. (1971).
Correlating fauna. *D.* ex grp *pseudoradiosa* including *D. explanata* Buckman, *Huddlestonia*, etc.
Included subdivisions. Pseudoradiosa Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).
Comments. Broadly equivalent to the Moorei Subzone of W.T. Dean (in: Dean *et al*. 1961) although *D. moorei* was later found to co-occur with the first *Pleydellia* and therefore placed in the Aalensis Zone, Mactra Subzone by Gabilly (1976).

Aalensis Chronozone
Index. Pleydellia aalensis (Zieten 1832).
Author. Reynès (1868).
Comment. Broadly equivalent to the Aalensis Subzone of W.T. Dean (in: Dean *et al*. 1961).

Mactra Subchronozone
Index. Pleydellia mactra (Dumortier 1874).
Author. Mouterde (1952) informally as a 'horizon', Elmi (1967) as a Horizon, as a subzone by Gabilly *et al*. (1971).
Correlating fauna. *P.* ex grp *mactra* and the last *Dumortieria* ex grp *moorei* (Lycett) with rarer *Pseudammatoceras*, etc.
Included subdivisions. Tectiforme Zonule, Mactra Zonule, Celtica Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).

Fluitans Subchronozone
Index. Pleydellia fluitans (Dumortier 1874).
Author. Elmi *et al*. (1991, 1994).
Correlating fauna. P. fluitan, P. lugdunensis (Dumortier)*, P. buckmani* Mauberge, rarer *Pseudammatoceras*, etc.
Included subdivisions. Lugdenensis Zonule, Buckmani Zonule (Gabilly 1976; Elmi *et al*. 1991, 1994, 1997).
Comments. The subzone was created by Elmi *et al*. (1991) as a replacement for the Aalensis Subzone as *P. aalensis* itself was considered to be a primitive form of the Mactra Subzone. The Buckmani Subzone of Gabilly (1976) was also reduced to the status of a 'Horizon' (= Zonule).

Mediterranean Province (Italy, Austria, southern Spain, North Africa, etc.)

The closest correlations between Mediterranean and Submediterranean areas are in the Bifrons and Aalensis Chronozones. At other levels, the degree of faunal differentiation has necessitated the creation of the zonal schemes of Donovan (1958), Elmi *et al*. (1974), Guex (1973) and other authors. A number of horizons (probably mainly with the status of zonules) are tabulated by Elmi *et al*. (1991, 1994) and summarised again by Elmi *et al*. (1997), as reproduced here on Figures 6 and 7.

Lower Toarcian Substage

Polymorphum Chronozone
Index. Dactylioceras polymorphum Fucini 1919.
Author. Jimenez & Rivas (1979). Equivalent to the Mirabile Zone of Guex (1973; index: *D. mirabile* Fucini).

Mirabile Subchronozone
Index. Dactylioceras mirabile Fucini 1919.
Author. Colo (1961) as a 'horizon' or 'niveau', used as a subzone by Guex (1973).
Correlating fauna. Dactylioceras (*Eodactylites*) spp., *Protogrammoceras* (= *Paltarpites*)*, Lioceratoides,* etc.
Included subdivisions. 'Paltarpites' fauna (?part; Elmi *et al.* 1991, 1994, 1997).

Semicelatum (II) Subchronozone
Index and *Author.* As Subboreal Province (see above), but used in the sense of the Submediterranean Province. Broadly equivalent to the 'Niveau à *Protogrammoceras madagascariense*' of Colo (1961) and the Madagascariense Subzone of Guex (1973; index: *Protogrammoceras madagascariense* (Thevenin 1908)).

Correlating fauna. Dactylioceras spp. including *D. semicelatum*, also *Protogrammoceras madagascariense* Thevenin, etc.
Included subdivisions. 'Paltarpites' fauna (?part), *'striatus'* fauna (?part; Elmi *et al*. 1991, 1994, 1997).

Levisoni Chronozone
Index. Hildaites levisoni (Simpson 1843).
Author. Guex (1973).

Levisoni Subchronozone
Index. As Levisoni Chronozone (see above).
Author. Guex (1973).
Correlating fauna. Hildaites spp. including *H. levisoni*, also *Dactylioceras* spp., etc.
Included subdivisions. The *'striatus'* fauna (?part; Elmi *et al*. 1991, 1994, 1997).

Falciferum Subchronozone
Index and author. As Subboreal Province (see above).
Correlating fauna. Harpoceras grp *falciferum, Mercaticeras,* etc.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Bifrons Chronozone
Index and author. As Subboreal Province (see above).

Sublevisoni Subchronozone
Index and author. As Submediterranean Province (see above).
Correlating fauna. Hildoceras grp *sublevisoni,* etc.
Included subdivisions. Sublevisoni Zonule, Tethysi Zonule (Elmi *et al*. 1991, 1994, 1997).

Bifrons Subchronozone
Index and author. As Submediterranean Province (see above).
Correlating fauna. Hildoceras grp *bifrons.*
Included subdivisions. Lusitanicum Zonule, Apertum Zonule, Bifrons Zonule, Semipolitum Zonule (Elmi *et al*. 1991, 1994, 1997).
Comment. The Semipolitum Zonule has been previously used as a full subchronozone (see note under Submediterranean Province above).

Upper Toarcian Substage

Gradata Chronozone
Index. Brodieia gradata (Merla 1932).
Author. Atrops & Elmi (1971) as a subzone.

Gemma Subchronozone
Index. Gabyllites [*Collina*] *gemma* (Bonarelli 1893).
Author. Gallitelli-Wendt (1970).
Correlating fauna. Peronoceras, Podagrosites, Pseudopolyplectus, etc.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Alticarinatus Subchronozone
Index. Merlaites alticarinatus (Merla 1932).
Author. Mouterde (1967) as a 'niveau', Atrops & Elmi (1971) as a subzone.
Correlating fauna. Crassiceras spp.*, Phymatoceras, Pseudogrammoceras, Polyplectus*, etc.
Included subdivisions. Aratum ?Zonule, Subregale ?Zonule (Elmi *et al*. 1991, 1994, 1997).

Bonarellii Chronozone
Index. Hammatoceras bonarellii Parisch & Viale 1906.
Author. Elmi *et al*. (1991, 1994) as a replacement, in part, for the Rivierense Zone of Elmi (1986; index *Osperlioceras rivierense* (Monestieri)).

Mediterraneum Subchronozone
Index. Pseudogrammoceras mediterraneum Rivas 1975.
Author. Used as a subzone by Elmi *et al*. (1991, 1994).
Correlating fauna. Pseudogrammoceras sp. including *P.* cf. *bingmanni,* also *Polyplectus, Oxyparoniceras*, etc.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Fallaciosum Subchronozone
Index and author. As Northwest European Province (see above).
Correlating fauna. Pseudogrammoceras fallaciosum, Polyplectus, Oxyparoniceras, Erycites, etc.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Speciosum Chronozone
Index. Hammatoceras speciosum Jamensch 1902.
Author. Used as a zone by Elmi *et al*. (1991, 1994).

Speciosum Subchronozone
Index. As Speciosum Zone (see above).
Author. Used as a subzone by Elmi *et al*. (1991, 1994).
Correlating fauna. Hammatoceras insigne, Osperlioceras, Pseudogrammoceras pachu.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Reynesi Subchronozone
Index. Osperlioceras reynesi (Monestier 1921).

Author. J. Mattei (in: Gabilly *et al*. 1971) as 'Assises à *Pseudogrammoceras reynesi*'.
Correlating fauna. *O. reynesi* and spp., *Hammatoceras perplanum*, etc.
Included subdivisions. None (Elmi *et al*. 1991, 1994, 1997).

Meneghini Chronozone
Index. *Dumortieria meneghinii* Haug 1887.
Author. Donovan (1958).
Correlating fauna. *D. meneghinii* with *Catulloceras* grp *perroudi, Osperlioceras, Hammatoceras, Erycites* etc.
Included subdivisions. Meneghinii ?Zonule, unnamed interval (Elmi *et al*. 1991, 1994, 1997).

Aalensis Chronozone
Index and author. As Northwest European Province (see above).

Mactra Subchronozone
Index and author. As Northwest European Province (see above).
Correlating fauna. *Pleydellia* grp *mactra* etc.
Included subdivisions. Mactra Zonule, Flamandi Zonule (Elmi *et al*. 1991, 1994, 1997).

Fluitans Subchronozone
Index and author. As Northwest European Province (see above).
Correlating fauna. *Pleydellia* spp. including *P. fluitans*.
Included subdivisions. Fluitans Zonule, unnamed interval (Elmi *et al*. 1974, 1991, 1994, 1997).

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