

The Ammonite Zones of the Toarcian (Ammonitico Rosso Facies) of Southern Switzerland and Italy

Autor(en): **Donovan, Desmond T.**

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The Ammonite Zones of the Toarcian (Ammonitico Rosso Facies) of Southern Switzerland and Italy

By Desmond T. Donovan (Bristol, England)

With 4 figures in the text

RIASSUNTO

Una nuova descrizione vien data del profilo toarciano di Valdorbica presso Gubbio (Umbria). Questo lavoro contiene pure descrizioni dettagliate di parecchi ammoniti raccolti sul posto (fig. 1-3).

Il profilo della Valle della Breggia (Canton Ticino) è stato riveduto e nuove informazioni sono state aggiunte. Sono accluse notizie su parecchie altre località visitate dall'autore.

La suddivisione in zone del Toarciano in Svizzera meridionale ed in Italia centrale e settentrionale viene riveduta in base ai lavori di campagna dell'autore e a recenti pubblicazioni, specialmente a quelle del VENZO (1952). Vien presentato un nuovo schema di zone e subzone basato su quello del MERLA (1932) ma modificato coi dati di recenti lavori. L'autore conclude che i termini di «zona a *falcifer*» e «zona a *Serpentinum*» non possono venire adoperati per la zona inferiore del Toarciano nei territori in questione, e un indice zonale soddisfacente non può ancora essere trovato, dato la scarsità dei fossili a quel livello. La «zona a *bifrons*» (auctt.) viene sostituita dalla «zona a *mercati*», la quale corrisponde pressa poco alla durata del genere *Mercaticeras*. Questa «zona a *mercati*» vien definita più precisamente dividendola in due subzone con gli indici subzonali rispettivi *Hildoceras sublevisoni* (sotto) e *H. semipolitum* (sopra). E' stato constatato che queste due specie sono presenti nello stesso ordine in tutti i profili esaminati. I generi piuttosto rari *Frechiella* e *Leukadiella* sono probabilmente caratteristici per la zona a *mercati*.

Il termine «zona a iurense» adoperato da numerosi autori per il rimanente del Toarciano, viene pure scartato per la quasi assoluta mancanza di *Lytoceras iurense*. L'indice *Phymatoceras erbaense* viene scelto per la zona al disopra della zona a *mercati*, nella quale le Hildocerataceae con costole composte dominano: *Phymatoceras* ed il suo subgenere *Chartronia* si mantiene durante tutta questa zona. Si propongono due subzone cogli indici *Pseudomercaticeras latum* (sotto), *Brodieia bayani* (sopra). La subzona a *latum* vien definita dalla durata del genere *Pseudomercaticeras*, sino all'inizio di *Brodieia*. A Valdorbica il Dactylioceratida *Collina* è ridotto alla subzona, ma in altri posti la sua durata non è sufficientemente evidente. La subzona *Bayani* corrisponde alla durata del genere *Brodieia*, al quale s'accompagnano *Paroniceras* e *Pseudogrammoceras*.

La zona più alta del Toarciano, come vien definito in questo lavoro, è chiamata la zona *Meneghinii* secondo la specie *Dumortieria meneghinii*. Essa è divisa in subzona inferiore, con la sola *Dumortieria*, e in subzona superiore, provvisoriamente chiamata subzona di *Pleydellia* spp., nella quale quest'ultimo genere è pure rappresentato.

Vengono tirate conclusioni circa l'estensione temporale e circa l'utilità stratigrafica di certi generi d'ammoniti. Si costata che *Harpoceras* e *Polyplectus* sono generi di lunga estensione, presenti dai più bassi stati del Toarciano fino alla subzona a *bayani* (nel caso di *Harpoceras*) e fino alla subzona *Meneghinii* (nel caso di *Polyplectus*). Per adesso questi generi non possono essere usati per la stratigrafia zonale. *Erycites* e *Hammatoceras* appaiono nella subzona *Bayani* e persistono sino nel Bajociano inferiore («Aaleniano»). I generi *Catacoeloceras* e *Peronoceras* sembra si riducano alle zone *Mercati* e *Erbaense*. Le specie dei *Dactylioceratidi* hanno probabilmente più lunga estensione di parecchie specie di *Hildocerataceae* e sono meno utili stratigraficamente. I generi abbondanti *Phylloceras* e *Lytoceras* non vengono considerati, dato che la loro utilità stratigrafica è molto ridotta.

Nella parte paleontologica alcuni generi e specie vengono esaminati, e vengono forniti dati bibliografici delle figure di tutte le specie menzionate in questo lavoro. Considerando le numerose illustrazioni già esistenti di ammoniti del Toarciano svizzero ed italiano, non è stato ritenuto necessario includere figure in questo lavoro.

INTRODUCTION AND ACKNOWLEDGEMENTS

The scheme of zonal subdivision here presented is founded primarily on collecting by the writer. Although the ammonite fauna of the Toarcian ammonitico rosso has received lavish monographic treatment, this has been carried out principally on museum collections for which exact horizons were not recorded. The lack of detailed stratigraphy was recently pointed out by ARKELL (1956, p. 217).

A recent survey¹⁾ has shown that a single zonal scheme for the Lower Jurassic can be applied throughout Britain, Germany, parts of France, and intervening areas; that is, for Europe north of the Alpine belt. The writer's enquiries have shown that, south of the Alpine geosyncline, the Toarcian zones used to the north (SPATH, 1942; now under revision) cannot be applied, and an independent scheme has been worked out. The sections on which this scheme is founded are in the facies of alternating red marls and grey limestones known to Italian geologists as ammonitico rosso. Travelling southwards, this facies is first met with in the autochthonous zone of the Lombardian Alps, the well-known outcrops of the Alta Brianza, near Como, and in Canton Ticino. Further east, it is found in certain nappes of the Northern Calcareous Alps in Austria. The facies has a wide distribution in the Mediterranean region, but the writer has seen sections only in the Ticino and the Central Apennines. The writer hopes that investigators with suitable opportunities will test the scheme in other parts of the Mediterranean region.

I owe my thanks to my companions during the field work, Miss U. KAUFMANN (now Mrs. WOLFE) and Dr. C. E. PERIAM. At the Geological Institute of Florence University Dr. AZZAROLI kindly gave me facilities, in Professor MERLA's absence, to examine maps and collections. Dr. W. T. DEAN helped me with the preliminary sorting out of the ammonites collected, and we have had a number of useful discussions on nomenclature. Professor R. TRÜMPY has very kindly read the typescript and assisted with publication.

I wish to acknowledge, with thanks, the receipt of a sum from the Government Grant for Scientific Investigations, administered by the Royal Society, which made the field work possible.

DESCRIPTIONS OF SECTIONS

During a visit to Switzerland and Italy in 1953, selected sections through the ammonitico rosso facies of the Toarcian were examined in order to determine the succession of ammonite genera and species in greater detail than was available in published works. In all cases a detailed lithological section was measured, and the horizons of ammonites recorded to the nearest 5 cm above the base of the formation or some other convenient datum level. The most instructive

¹⁾ By M. K. HOWARTH, W. T. DEAN and the present writer; now being prepared for publication.

section was at Valdorbria, and the zonal scheme now proposed is largely founded on it.

Valdorbria (Umbria)

Domerian and Toarcian rocks are exposed in an inlier along the valley of the Sentino, south-west of Valdorbria and about 3.5 km east-north-east of Scheggia. The section was described, and many ammonites listed, by BONARELLI (1893). The inlier is shown on the recent geological map on a scale of 1:100.000 (sheet 116, Gubbio, 1952).

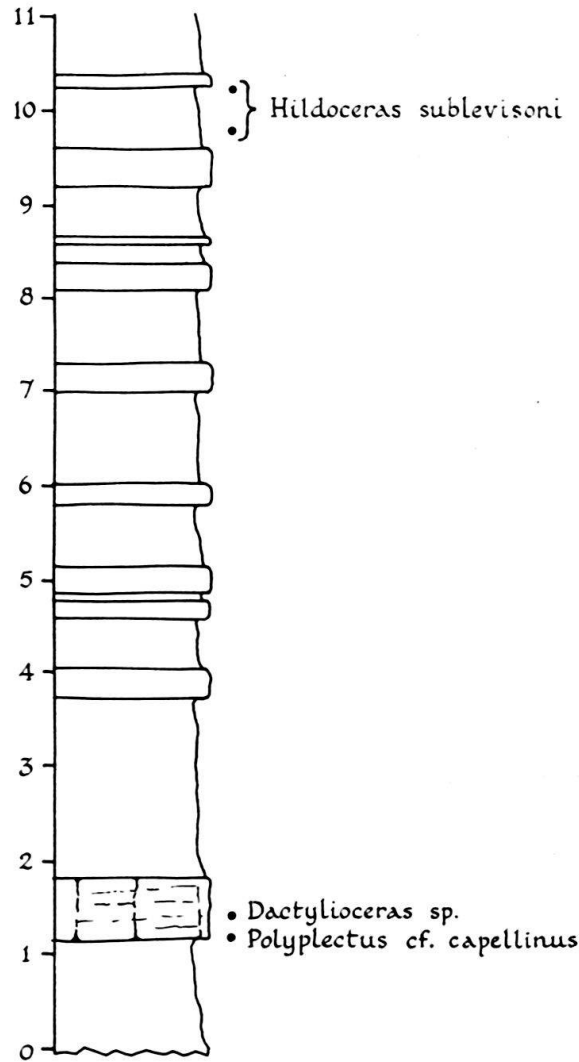


Fig. 1. The lowest part of the Toarcian section at Valdorbria.

Explanation of conventions used. The figures are reproduced to a uniform scale of 1 cm = 1 metre. The scale of metres is marked on each figure, those for figures 1-3 being consecutive. Grey, green-grey and pink-grey beds are shown uncoloured, red marls are shown black. The black discs mark the actual levels at which the ammonites were found; the brackets are merely for convenience in labelling. Records of *Phylloceras* and *Lytoceras* are omitted.

The core of the inlier is formed by compact, often massive, cream and grey limestones, with marl partings, whose thickness cannot be measured on account of tectonic disturbance. The uppermost part of these limestones yields Domerian

ammonites. From about 19 m to about 16 m below the top of the series there is a fauna with several species of *Protogrammoceras* in an intercalation of thin-bedded, red, nodular limestones, while about 10.5 m below the top *Arietoceras algovianum* (OPPEL) and *A. cf. ruthense* (REYNÈS) were found. *Reynesoceras* was also collected, but the exact horizon is uncertain.

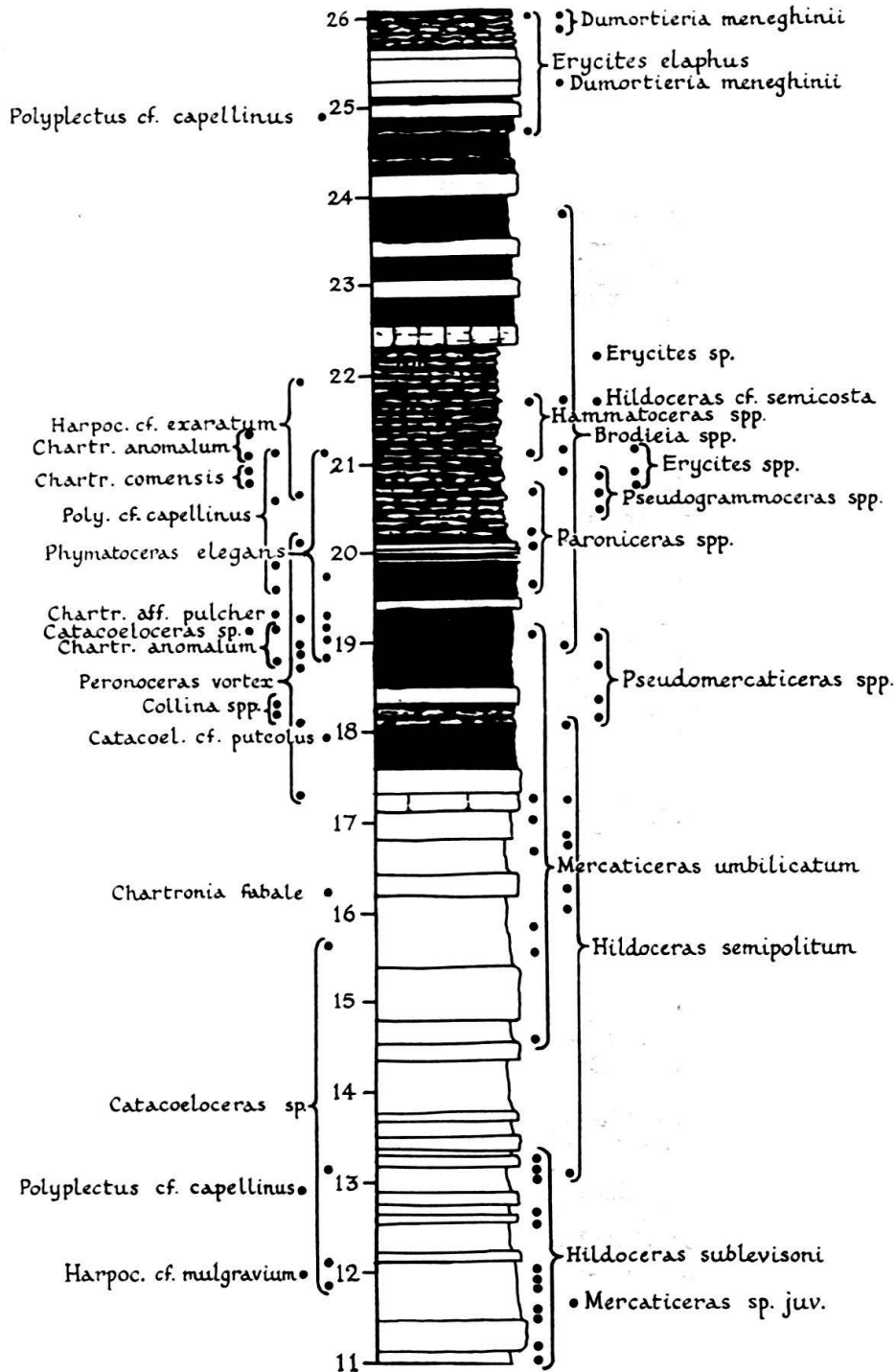


Fig. 2. The middle part of the Toarcian section at Valdorbia.

Above these limestones is a thickness of about 32 m of light greenish-grey marls and marly limestones, in thick beds. The lowest Toarcian ammonites (*Dactylio-*

ceras sp. and *Polyplectus* cf. *capellinus* (QUEN.) were found about 16 m below the top, and at about 8 m below the top ammonites become common. The upper (ammonite-bearing) part of these marls are shown in figures 1 and 2.

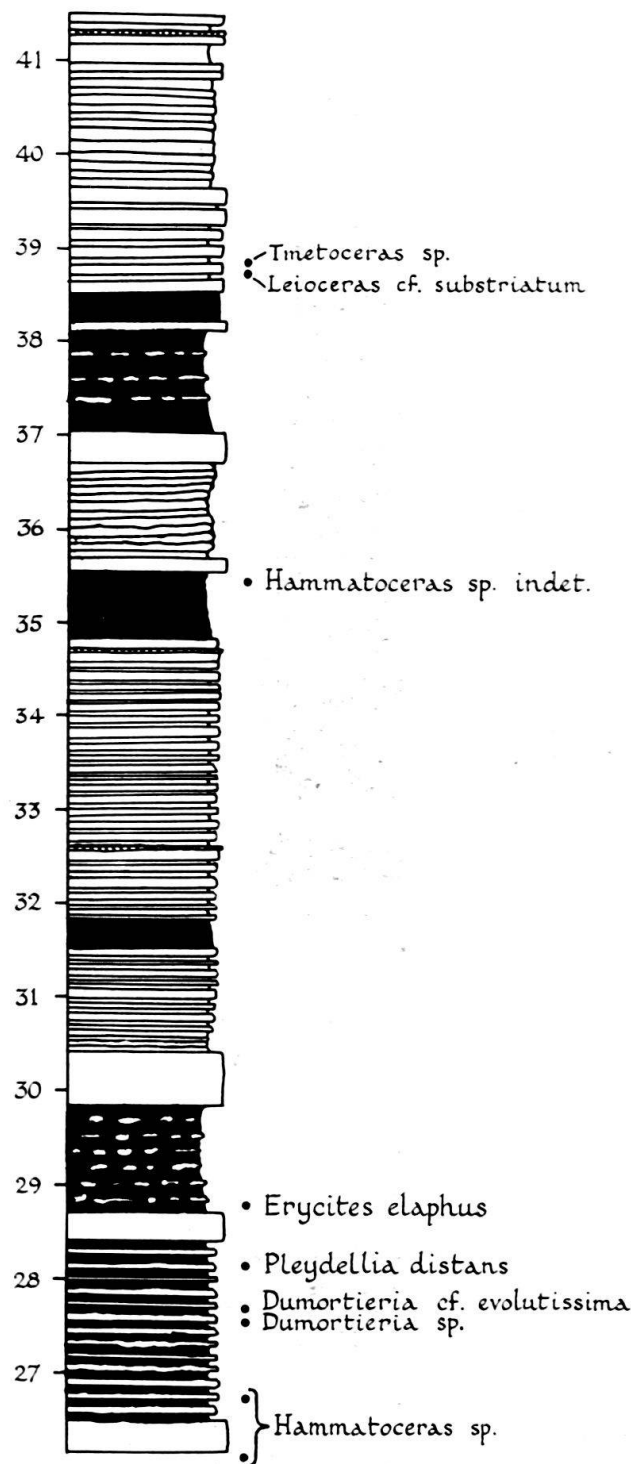


Fig. 3. The upper part of the Toarcian section at Valdorbja.

The greenish-grey marls pass fairly abruptly into beds of the ammonitico rosso facies, consisting of red marls, sometimes with calcareous nodules, alternating with hard, fine-grained, grey limestone. The main part of the ammonitico

rosso is about 12 m thick and carries abundant ammonites at many levels (figures 2 and 3). It is succeeded by thin-bedded limestones and marls with occasional inter-

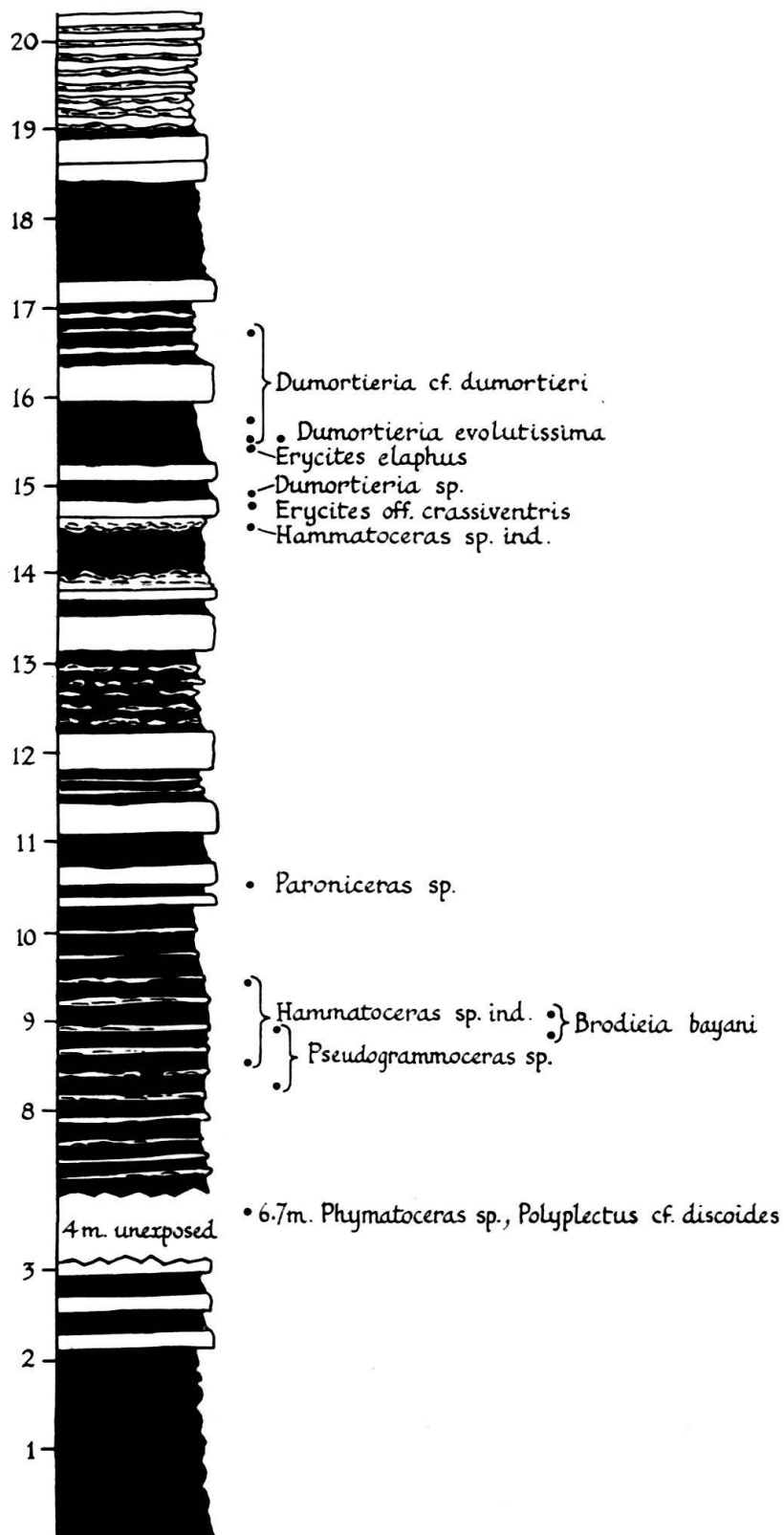


Fig. 4. The upper part of the Toarcian section at Fonte S. Giglio.

calations of red marl. Above the ammonitico rosso ammonites were found at occasional horizons only.

Sections were measured and collected from at the western end of the inlier, on both sides of the stream, and the results correlated (figures 1 to 3). The section on the hillside north of the road is affected by a small fault, parallel with the contours, which throws down to the north and therefore cuts out part of the succession. Levels marked on the sections here reproduced are given above an arbitrary datum corresponding to the lowest level exposed in the section north of the road. The lowest 6 m are not exposed on the south side of the valley.

The whole of the Toarcian is shown in this section, although the base and the top cannot be exactly defined. The base must lie at or below the lowest fossiliferous horizon shown in figure 1. The top must lie in the unfossiliferous interval between the horizon of *Pleydellia* (22.2 m above datum) and that of *Leioceras* and *Tmetoceras* (32.7 m above datum). All the proposed zones can be recognised in the Toarcian.

Monte Cucco (Umbria)

A section through the Toarcian Ammonitico rosso was examined at Fonte S. Giglio, at the northern end of the Liassic outcrop of this mountain (1:100,000 geological map, sheet 116, Gubbio, 1952). The lowest beds exposed are pale green-grey marls, similar to the strata with *Hildoceras* at Valdorbia, but at the present locality barren. These beds are succeeded by ammonitico rosso exposed to a total thickness of 17 m followed by grey limestones and marls. No fossils were collected in place from the bottom 6 m of ammonitico rosso, but the upper part yielded the ammonites shown in figure 4.

Monte Subasio (Umbria)

The geology of this mountain, which lies south-east of Assisi, has been described by PRINCIPI (1909), who later (1923, p. 112) published lists of fossils from the Toarcian of the Fosso delle Carceri, in which he recognised three zones (see page 41). A description has also been given by FIORENTIN (1912). RENZ (1923, p. 274) collected from a locality near Gabbiano, at the south-eastern end of the massif, and noted Domerian Limestones overlain by ammonitico rosso, which he found to range from 'Bifrons' to early Aalenian date.

Dr. C. E. PERIAM in 1953 collected ammonites from the ammonitico rosso in the Fosso delle Carceri, which is the first valley to the south-east of Assisi. The following species were obtained in place, the figures indicating the horizon, or range of horizons, from which each species was collected, measured above the base of the ammonitico rosso:

Mercaticeras spp. 1.7–4.1 m.

Hildoceras cf. *sublevisoni* FUCINI 1.9–4.0 m.

H. semipolitum S. S. BUCKMAN 5.3 m.

Polyplectus cf. *capellinus* (QUEN.) 3.2, 4.5 m.

Harpoceras cf. *falcifer* (J. SOW.) 4.8, 5.1 m.

Catacoeloceras sp. 2.4 m.

Dactyloceras aff. *subarmatum* (YOUNG & BIRD) as figured by MONESTIER, 1931, pl. 3, fig. 3. 2.4 m.

Nodicoeloceras (?) sp. 3.0 m.

Breggia gorge (Canton Ticino)

The section lies on the Breggia a short distance downstream from the old post bridge on the track between Castello S. Pietro and Morbio Superiore, south of east from Mendrisio. The beds dip steeply to the south. The succession was described in detail by RENZ (1920), and there are later references by WEBER & QUERVAIN (1934, p. 858) and VONDERSCHMITT (1940, p. 212, pl. 12, section 2). RENZ listed the ammonite faunas, and further detailed collecting in the ammonitico rosso was carried out by the writer in 1953. The faunal succession may be summarised as follows, RENZ's generic attributions being modernised²):

RENZ horizon:

5 o. *Graphoceras concavum* (J. Sow.), *Ludwigia lucyi* (S. S. BUCK.).

5 u. *Pleydellia* spp. ('*Cotteswoldia*', '*Grammoceras subcomptum*' etc.), *Ludwigia* spp. ('*Lioceras ambiguum*' etc.), *Brasilia bradfordensis* (S. S. BUCK.), *Graphoceras concavum* (J. Sow.), *Dumortieria* spp., *Erycites* spp., *Hammatoceras* spp.

4 o. *Pleydellia aalense* (ZIET.) & other spp. (including '*Cotteswoldia*').

Dumortieria spp.

Tmetoceras scissum (BEN.).

Erycites spp.

Hammatoceras spp.

4 u. *Dumortieria* spp.

3 o. *Erycites* spp.

Hammatoceras spp.

Paroniceras spp.

Phymatoceras erbaense (v. H.) & other spp.

Grammoceras striatulum (J. DE C. SOW.) & other spp.

Pseudogrammoceras fallaciosum (BAYLE) & other spp.

Haugia spp.

3 u. *Hildoceras* spp.

Mercaticeras spp.

Phymatoceras tirolense (v. H.).

Harpoceras spp.

Frechiella spp.

Brodieia bayani (DUM.).

Dactyloceras commune (J. Sow.) etc.

Collina meneghini (BON.) etc.

(2 o. Domerian.)

Beds 3 u. and 3 o. comprise the ammonitico rosso, altogether about 14 m thick. Detailed collecting by the writer showed that in 3 u. the ranges of certain ammonites were restricted: *Hildoceras sublevisoni* (FUCINI) was found from 1.4

²) *Lytoceras* and *Phylloceras* omitted, being unimportant for stratigraphical purposes. The generic grouping of the Graphoceratinae requires revision; I have mainly followed SPATH (1936).

to 3.2 m above datum³), *H. semipolatum* (S. S. BUCK.) from 3.7 to 4.65 m above datum. *Mercaticeras* was restricted to the lower part, the highest specimen being found at a level of 3.95 m. Fragments of *Harpoceras* were found throughout, from *H. sp. indet.* at 2.0 m to *H. cf. exaratum* (Y. & B.) at 10.0 m. *Brodieia sp. cf. alticarinata* (MERLA) was found at 8.2 m. Dactylioceratids were only found in the lowest 4 m.

Bed 4 o. is a brecciated, grey limestone, 25 cm. thick, with abundant ammonites; it is likely that the fauna is condensed, and perhaps partly derived.

ZONES OF THE TOARCIAN OF ITALY AND ADJACENT REGIONS

Early workers on the Toarcian of Italy and neighbouring regions were usually content to adopt the zonal system founded by OPPEL (1856), and added to by various later workers. OPPEL's zones were set up for England, France and Germany, and many of his successors also worked in these countries. The conception that zonal systems might be geographically restricted in their usefulness was hardly appreciated, and as a result of the broad interpretation of ammonite species many zones were used in areas where their index species, as strictly defined, do not exist. In some cases, zones became arbitrary units, whose recognition had little or nothing to do with the contained fauna. In due course, detailed researches in many areas showed that the old zones could not be universally applied, and different schemes were proposed for different areas.

BONARELLI, discussing the section at Valdorbis which is redescribed in the present paper (p. 35), divided the Toarcian into two zones: the '*falciferum-Zona*' below and the '*jurense-Zona*' above (1893, p. 208). The first had been used by BUCKMAN (1889, p. 447), the second by OPPEL (1856, p. 228). The '*falciferum-Zona*' included all the strata up to, and including, the Mercati Zone of the present paper. The '*jurense-Zona*' was the approximate equivalent of my Erbaense and Meneghinii Zones.

BELLINI (1900) substituted zones of *serpentinum* and *bifrons* for BONARELLI's comprehensive '*falciferum-Zona*'; his scheme was:

Toarcian Stage	{	Opalinum (from REYNÈS, 1868, p. 63).
		Jurense
		Bifrons (from REYNÈS, 1868, p. 35).
		Serpentinum (from OPPEL, 1856, p. 197).

In 1923 PRINCIPI returned to a restricted *falcifer* zone in place of *serpentinum*, and substituted *Dactylioceras commune* for *Hildoceras bifrons*. In north-western Europe *Harpoceras falcifer* has been used by many authors in preference to *Amm. serpentinus* on account of the doubt as to the correct identity of the latter species (see ARKELL, 1956, p. 35, note). The zone of *Dactylioceras commune* was first used by WRIGHT (1858, p. 25) as a substitute of OPPEL's Posidonomyen-bett or Bronni Zone, that is, for all the Toarcian below the Jurense Zone.

The first attempt to find indices specially suited to the Italian succession was made by MERLA (1932, p. 4), who retained the Falcifer and Jurense Zones in

³ The datum level used for measurements was the lowest point in the ammonitico rosso visible on the right bank in 1953; believed to be about 0.5 m above the actual base of the formation.

BONARELLI's sense, and followed BELLINI in his subdivision of the Falcifer Zone. The Jurensis Zone was newly subdivided. MERLA's indices are:

Upper Toarcian (Zone of <i>Lytoceras jurensis</i>)	{	Zone of <i>Denckmannia rudis</i>
		Zone of <i>Lilliae</i> sp.
Lower Toarcian (Zone of <i>Harpoceras falcifer</i>)	{	Zone of <i>Hildoceras bifrons</i> (and <i>Mercaticeras mercati</i>)
		Zone of <i>Harpoceras serpentinum</i> .

It will be noted that *M. mercati* is introduced as an additional index for the Bifrons Zone. The index 'Lilliae' was derived from the hemera of that name used by BUCKMAN (1898, table facing p. 450), while *D. rudis* was a new introduction.

The most recent version of MERLA's scheme is by VENZO (1952, p. 114), who added extra index species:

Upper Toarcian	{	Zone of <i>Denckmannia rudis</i> , <i>Brodiceras</i> , <i>Phymatoceras</i> (pars).
		Zone of <i>Lilliae</i> and <i>Denckmannia erbaensis</i> .
Lower Toarcian	{	Zone of <i>Hildoceras bifrons-semipolatum</i> , <i>Mercaticeras</i> <i>mercati</i> , <i>Coeloceras</i> , <i>Dactylioceras</i> .
		Zone of <i>Harpoceras falciferum</i> – <i>Hildaites serpentinum</i> .

This table forms the basis of the proposals now put forward.

The old broad zones of *Harpoceras falcifer* and *Lytoceras jurensis*, as used by authors from BONARELLI onwards, are now discarded. The range of *H. falcifer* is uncertain, it is not very common and in any case this zone is synonymous with 'Lower Toarcian' as generally used. *Lytoceras jurensis* does not occur in the Ticino and Italy, and it is undesirable to perpetuate the use of this zonal name in a sense different from that familiar in north-western Europe, where it includes the horizons of *Dumortieria* and *Pleydellia* (v. SPATH, 1942).

Reasons for other changes will be given below. One or two general observations may be made on the ranges of various species and genera. Both *Harpoceras* and *Polyplectus* are long-ranging genera, and the species identified as *P. cf. capellinus* ranges from near the base of the Toarcian up to the base of the Meneghinii Zone. The range of other species is insufficiently known, but it is clearly undesirable to use them as zonal fossils, as has been done in some other areas. *Harpoceras* is rare at many Italian sections and the sequence, if any, of species is unknown.

Erycites and *Hammatoceras* are another pair of long-ranging genera. At Valdorbia they are first found in the Bayani Subzone of the Erbaense Zone, and persist into the Bajocian. According to FOSSA-MANCINI (1915) they persist into the Middle Bajocian with *Stephanoceras* and *Emileia*.

The Dactylioceratid species seem to be less useful for zonal purposes than those belonging to the Superfamily Hildocerataceae. They have a more sporadic vertical distribution and species are less easily distinguished.

Phylloceratidae and Lytoceratidae have been omitted from consideration. They are abundant throughout the ammonitico rosso facies of the Toarcian, but, although a number of species have been recognised, they are long-ranging and the differences between them are often small, so that they are inferior to the other ammonites for stratigraphical purposes.

The following scheme of zones and subzones is now proposed:

Bajocian Stage

Toarcian Stage ⁴⁾	{	Zone of <i>Dumortieria</i>	{	Subzone of <i>Pleydellia</i> spp.
		<i>meneghinii</i>	{	Subzone of <i>D. meneghinii</i> s. s.
	{	Zone of <i>Phymatoceras</i>	{	Subzone of <i>Brodieia bayani</i>
		<i>erbaense</i>	{	Subzone of <i>Pseudo-mercaticeras</i> (<i>Crassiceras</i>) <i>latum</i>
{	Zone of <i>Mercaticeras</i>	{	Subzone of <i>Hildoceras</i>	
	<i>mercati</i>	{	Subzone of <i>Hildoceras</i> <i>semipolitum</i>	
		Unnamed zone.		Subzone of <i>Hildoceras</i> <i>sublevisoni</i>

Domerian Stage

In the present state of knowledge a satisfactory index cannot be found for the lowest part of the Toarcian. MONESTIER, working in southern France, adopted the Falcifer zone, which had been originally introduced by BUCKMAN (1889, p. 447) for part of the English succession (MONESTIER, 1922, p. 324). This was used in Italy by MERLA (1932, p. 4) for the whole Lower Toarcian, including the *Hildoceras* fauna, MONESTIER's more restricted Falcifer Zone being replaced by the Serpentinum Zone, which dates from OPPEL (1856, p. 157) and was also proposed for use in northern Europe. VENZO gave the zone of *Harpoceras falciferum* – *Hildaites serpentinus* as the lowest Toarcian zone, below the *Hildoceras* fauna.

In the area Britain–France–Germany, the Falcifer and Serpentinum Zones are usually regarded as synonymous, and are used for the zone above the *Tenuicostatum*, and below the *Bifrons* Zone (SPATH, 1942; ARKELL, 1956, p. 35).

The Serpentinum Zone must be rejected, as ARKELL points out (*loc. cit.*), because the index species has never been satisfactorily defined, apart from any other considerations. In fact, the records do not suggest that any species to which the name *serpentinum* has been applied occurs in the lowest part of the Italian Toarcian. It was not recorded by VENZO (1952) in his comprehensive fossil lists for the Alta Brianza.

Harpoceras falcifer (J. SOWERBY), whether or not it is a suitable zonal index in southern France (the writer is not qualified to express an opinion), cannot be used in Italy. The detailed studies of the sections at Valdorbis and Breggiagorge have shown that, at the former locality, *H. cf. falcifer* occurs associated with *Hildoceras* in the Mercati Zone⁵⁾ and related species of *Harpoceras* are found as high as the Erbaense Zone; while at Breggiagorge *H. cf. falcifer* occurs in the Erbaense Zone, above the highest *Hildoceras*. The evidence which is available shows that the genus, and probably also individual species, have long ranges.

⁴⁾ The upper boundary of the Toarcian has been subjected to a variety of interpretations. It is here used in the original sense of D'ORBIGNY, who introduced the term, to include beds with ammonite species which are now referred to *Dumortieria* and *Pleydellia* (*Amm. Levesquei*, *Amm. aalensis*: D'ORBIGNY, 1850, p. 615).

⁵⁾ The exact level is not known, so the record is not shown in figure 2.

In the sections studied by the writer, there is a series of beds with very few fossils between the highest Domerian ammonites and the *Hildoceras* fauna which is taken to mark the base of the Mercati Zone. At Valdorbis *Polyplectus* cf. *capellinus* and a poorly preserved *Dactylioceras* were found in these beds (figure 1), but the first species named is unsuited to be zonal index, being both rare and long-ranging (p. 42); the *Dactylioceras* is not considered to be specifically identifiable. In the most complete section studied by VENZO, near the Albergo La Salute (Alpe Turati), this part of the section is obscured (VENZO, 1952, p. 98, fig. on p. 99), and none of his sections provides evidence for a separate, distinctive fauna below that with *Hildoceras* and *Mercaticeras*.

The foregoing considerations make it clear that, while it is undesirable to perpetuate inappropriate usage of the terms 'Falcifer Zone' or 'Serpentinum Zone' no satisfactory substitute has been found. A suitable index must be sought in sections which display fossiliferous beds between the Domerian and the Mercati Zone.

The term Bifrons Zone has been commonly used for that part of the Toarcian characterised by abundance of the genus *Hildoceras*, but is unsuitable, for the index species *H. bifrons* is rare or absent at southern Swiss and Italian localities. The zone was first employed by REYNÈS in the Aveyronnais region of southern France, where it may or may not be suitable. *Hildoceras bifrons* (BRUGUIÈRE), of which typical examples have been figured by BUCKMAN (1918, pl. 114A), is an easily recognisable species with a well-marked groove on the whorlside and the area on the dorsal side of the groove strongly inflated. It has not been found by the writer at Breggiagorge or at Valdorbis, while in the Alta Brianza it is rare (VENZO, 1952, p. 117, 120). Records of the species by old authors cannot be relied upon, for earlier workers figured many ammonites as '*Hildoceras bifrons*' which bear no resemblance to the species. MERLA refers some of these to other species, and points out that the '*H. bifrons*' of MENEGHINI and of BONARELLI are to be excluded from the species. MERLA illustrated '*Hildoceras bifrons* var.', but this specimen is quite different from the typical *H. bifrons* (MERLA, 1932, p. 52, pl. 7, fig. 9).

Merla spoke of a '*bifrons* (Mercati) zone', and since *bifrons* is unacceptable, the name Mercati Zone is now adopted, with index species *Mercaticeras mercati* (VON HAUER). The zone embraces the range of the genus *Mercaticeras* except that where it overlaps with that of *Pseudomercaticeras* the upper limit of the zone is taken at the incoming of the last-named genus⁶). More accurately, where sufficient fossils are present, the zone is defined in terms of its two subzones, based upon species of *Hildoceras*.

The lower subzone is named after the species *Hildoceras sublevisoni* FUCINI (see p. 50), the upper from *H. semipolitum* S. S. BUCKMAN (p. 50). Detailed collecting at Breggiagorge, at Valdorbis, and at M. Subasio (see p. 39) has shown that the ranges of these two species are almost mutually exclusive. At Valdorbis, where more specimens were collected than at the other localities, there is a very slight overlap between the two species (fig. 2). The Sublevisoni Subzone is therefore

⁶) At Valdorbis one example of *M. umbilicatum* was found in the Erbaense Zone; fig. 2.

defined as the range of *H. sublevisoni* up to the first appearance of *H. semipolitum*, the Semipolitum Subzone by the range of its index species.

The genera *Harpoceras* and *Polyplectus* range through the zone, but are not common at the localities examined by the writer. According to VENZO, *Polyplectus* is common in the Alpe Turati (1952, p. 120). Both genera are found also in the succeeding zone. In the case of *Polyplectus*, the same species (*P. cf. capellinus*) is found throughout the Toarcian at Valdorbìa.

Frechiella occurs throughout the Mercati Zone. At Breggiagorge the writer found it at the base of the Sublevisoni Subzone. In the neighbourhood of Lake Como, MITZOPOULOS and RENZ found a horizon with *Frechiella* in the upper part of the 'Bifrons Zone' (1929, p. 5). It is generally believed to be diagnostic of the zone, although it was recorded from 'Toarciano superiore' by VENZO (1952, p. 118). The genus is rare compared with *Mercaticeras* and *Hildoceras*. A still more uncommon genus is *Leukadiella*, recorded from 'Bifrons Zone' by RENZ (1927, p. 424; 1947, p. 175). It has been found at a number of localities in the Eastern Alps, the Ticino and the Apennines (RE NZ, 1925c, p. 216), but appears to be exceedingly rare.

Chartronia is occasionally found in the Semipolitum Subzone, but is more common in the Erbaense Zone.

Catacoeloceras first appears in the zone, and also ranges higher. Material available is not adequate to determine the succession, if any, of species in this genus. *Peronoceras vortex* is first found in the Semipolitum Subzone.

MERLA's two subdivisions of the 'Jurense Zone', namely *Lilliae* sp. below and *Denckmannia rudis* above, are not now adopted. The first is replaced by a zone based upon an index species; as regards the second, the writer has not been able to confirm its stratigraphical value, and the index species does not appear to be common in Italy (cf. VENZO, 1952, p. 116).

VENZO (*op. cit.*, p. 114) added '*Denckmannia erbaensis*' to MERLA's '*Lilliae*', and the term Erbaense Zone is now proposed for the next major division of the Toarcian. The zone corresponds to the time of existence of the Hildoceratid derivatives with evolute shell and compound ribs: *Chartronia* (= *Denckmannia*), *Phymatoceras*, *Pseudomercaticeras*. It is divided into two new subzones, the lower of *Pseudomercaticeras latum*, the upper of *Brodieia bayani*. Evidence of these subzones is principally provided by the Valdorbìa section. From other localities inadequate material is available, but none contradicts the arrangement here suggested.

The base of the Latum Subzone is taken at the appearance of the genus *Pseudomercaticeras*. *Chartronia* appears in force at about the same level, but is rarely found below (see above). At Valdorbìa, *Collina* is restricted to this subzone, but evidence as to its range elsewhere is inadequate. In the Alpe Turati, Venzo recorded it from the lower Toarcian (1952, p. 118). *Mercaticeras* ranges up into the subzone.

The Bayani Subzone is defined by the range of the genus *Brodieia*. *Pseudogrammoceras* and *Paroniceras* are also characteristic of the subzone, as shown by the sections at Monte Cucco and Valdorbìa. *Pseudogrammoceras fallaciosum* (Bayle) is a common species. The long-ranging genera *Hammatoceras* and *Erycites* make their first appearance in the Bayani Subzone.

The subgenera *Chartronia* and *Phymatoceras* are found in both subzones; at Valdorbja, the well-known species *C. comensis* is restricted to the Bayani Subzone, but this may not be the case elsewhere. *Polyplectus* also occurs in both subzones, as well as in the zones above and below. At Valdorbja, the highest record of *Harpoceras* lies in the Bayani Subzone, and a single, poorly preserved *Hildoceras* cf. *semicosta* was found in the same subzone.

Catacoeloceras is found in the Latum Subzone, but probably does not range very much higher. The characteristic Dactylioceratid of the zone is *Peroniceras*, which is found in both subzones. *Peroniceras vortex*, a species first described from Yorkshire, England, is common, and various others have been described.

The index species *Dumortieria meneghinii* is now used for the highest zone of the Toarcian. VENZO (1952, p. 114) adopted the zone of *D. levesquei* from HAUG (1910, p. 954), but this species is not common in Italy. The long-ranging genera *Polyplectus*, *Hammatocheras* and *Erycites* occur throughout the zone, but the ranges of individual species in these genera are not sufficiently well known to be used stratigraphically. The Meneghinii Zone can therefore be recognised by the presence of the genus *Dumortieria* itself, or, in the upper part of the zone, *Pleydellia*.

The zone is divided into two subzones, a lower characterised by *Dumortieria* without *Pleydellia*, and an upper in which both genera are present. It is not easy to find names for these subzones, for there is little evidence on the distribution of species within the zone. The lower is regarded, provisionally at least, as the subzone of *D. meneghinii* s. s.; a different index species may be substituted if a suitable one can be found. At Breggiagorge, indeed, RENZ records *D. meneghinii* from the lower subzone only (1920, bed 4 o., p. 544; & cf. p. 546-47), but I have no confirmation of this from other sections.

The upper subzone is defined by the presence of the genus *Pleydellia*, but I have insufficient information as to the species of this genus, and their relative abundance, to propose an index species. The subdivision is therefore left as the subzone of *Pleydellia* spp. in the hope that an index species will be proposed by someone familiar with suitable sections.

It is uncertain whether the genus *Tmetoceras* occurs already in the Meneghinii Zone⁷). It is possible that it does, as it appears to be an evolutionary offshoot from *Dumortieria*. At Valdorbja, however, *Tmetoceras* was found at a single horizon well above the highest *Dumortieria*, and the record by RENZ of *Tmetoceras*, *Pleydellia* and *Dumortieria* all together in beds 4 o. and 5 u. at Breggiagorge may be due to the fact that the former bed is condensed (see p. 41) and the latter highly disturbed. *Tmetoceras* certainly occurs in the basal part of the Bajocian, and is associated with *Leioceras* at Valdorbja. FOSSA-MANCINI (1915), describing the Montagna della Rossa, in Umbria, records *Tmetoceras scissum* as having a long range, from the Meneghinii Subzone (bed 5) into beds with *Emileia* and *Stephanoceras* which must lie well up in the Bajocian. Certain of FOSSA-MANCINI's records are puzzling and probably due to misidentifications, but this seems improbable with so distinctive a genus as *Tmetoceras*.

⁷) The ranges of *Dumortieria* (recorded as *Catullocheras*) and *Tmetoceras* overlap at Rabacal, in Portugal (PERROT, 1955, p. 9).

PALAEOONTOLOGICAL NOTES

The purpose of this section is to define the species cited in the stratigraphical part of the paper, and provide references to authors and to reliable illustrations. A full palaeontological treatment has not been attempted.

The classification followed, with minor emendations, is that of the section Cephalopoda: Ammonoidea of the Treatise on Invertebrate Paleontology (Mollusca 4, 1957).

Superfamily **Eoderoceataceae** SPATH, 1929Family **Dactylioceratidae** HYATT, 1867Genus *Peronoceras* HYATT, 1867

The type species is *Amm. fibulatus* J. DE C. SOWERBY, designated by BUCKMAN (1911, p. v). The genus *Porpoceras* BUCKMAN (*loc. cit.*) (type species: *Amm. vortex* SIMPSON, by original designation) is regarded by the present writer as a synonym of *Peronoceras*. Both have fibulate ornament, with some of the primary ribs joining in pairs at the tubercles on the shoulder of the whorl. *Peronoceras* was said by BUCKMAN to comprise compressed species, while *Porpoceras* was said to include 'strongly ornamented, massive' forms. These differences of ornament and whorl-section are not regarded as of generic importance.

Peronoceras vortex (BUCKMAN *ex* SIMPSON)

1855. *Ammonites vortex* SIMPSON, p. 60.

1911. *Porpoceras vortex* SIMPSON sp. BUCKMAN, p. 29b, pls. 29A, B (Supposed types figured).

A number of specimens attributed to this species were collected from the upper part of the Mercati Zone, and the lower part of the Erbaense Zone at Valdorbia.

Genus *Collina* BONARELLI, 1893

The type species is *C. gemma* BONARELLI, designated by BUCKMAN (1927, p. 44). The genus comprises Dactylioceratids with a blunt keel which is crossed by the ribs. In the poor specimens found at Valdorbia, the keel appears at a diameter of about 2.0 cm. The material is not adequate for discussion of the species represented.

Genus *Catacoeloceras* BUCKMAN, 1923

The type species is *C. confectum* S. S. BUCKMAN, by original designation. The genus is characterised by rapidly-expanding, sphaeroconic septate whorls, followed by a body-chamber in which the whorl-height and thickness cease to increase, so that the umbilicus opens out excentrically. The adult size is smaller than in many Dactylioceratidae.

Catacoeloceras* sp. cf. *puteolum (S. S. BUCKMAN *ex* SIMPSON)

1855. *Ammonites puteolus* SIMPSON, p. 58.

1912. *Coeloceras puteolus* SIMPSON sp. BUCKMAN p. 61b, pl. 61 (supposed holotype figured).

The figured specimen, which is complete with body-chamber, is 6.1 cm. in diameter. The penultimate whorl is strongly depressed, the greatest thickness lying at the tubercles where the primary ribs bifurcate, about halfway between the umbilical suture and the periphery. On the body-chamber the tubercles are gradually lost. There are about 38 primaries on the last whorl.

The Italian specimens are less than half the size of the figured specimen of *C. puteolum*, the diameters of complete specimens ranging from 2.4 to 3.2 cm. The shell-form and ornament are very similar.

Superfamily **Hildocerataceae** HYATT, 1867

Family **Hildoceratidae** HYATT, 1867

Subfamily **Harpoceratinae** NEUMAYR, 1875

Genus *Harpoceras* WAAGEN, 1869

Ammonites falcifer J. SOWERBY, 1820, was designated the type species of the genus by ARKELL (1951), and validated by the International Commission on Zoological Nomenclature, under its plenary powers, in Opinion 303 (1954).

Harpoceras cf. falcifer (J. SOWERBY)

1820. *Ammonites falcifer* J. SOWERBY, p. 99, pl. 254, fig. 2.

1956. *Harpoceras falcifer* (SOWERBY). ARKELL, pl. 33, figs. 5a, b (type refigured).

The inner whorls of the species bear blunt tubercles near, but not on, the umbilical margin, each giving rise to a pair of ribs which curve forward towards the venter. At a diameter of about 4.0 cm. (in the holotype) this style of ornament is abruptly replaced by the falciform ribbing characteristic of *Harpoceras*. The ornament continues, apparently, to the adult stage. The venter is flattened and there is a narrow smooth band on either side of the keel.

The Swiss and Italian material which is compared with the species is probably not identical with the English form. The ornament on the innermost whorls is not so coarse, and the transition to falciform ribbing takes place earlier and more gradually. The flattened venter is more sharply demarcated from the whorl-sides and there is a tendency for faint grooves to appear on either side of the keel, at least on the internal mould.

Harpoceras cf. exaratum (YOUNG & BIRD)

1828. *Ammonites exaratus* YOUNG and BIRD, p. 266.

1909. *Harpoceras exaratum* YOUNG and BIRD sp. S. S. BUCKMAN, p. 5b, pl. 5 (supposed type figured).

A few fragments show considerable resemblance to this well-known Yorkshire species in the general aspect and the broad ribs. They may be found to belong to a distinct species, however, if better material is examined.

Genus *Polyplectus* S. S. BUCKMAN, 1890

The type species is *Amm. discoides* ZIETEN, by monotypy. The genus is here interpreted as including, in addition to the oxycones for which it was proposed,

species of the group exemplified by *Amm. elegans* J. SOWERBY, in which the keel is flanked by narrow grooves, and intermediate forms such as *Amm. complanatus* D'ORBIGNY, *non* BRUGUIÈRE (= *Amm. subplanatus* OPPEL, *pars*).

***Polyplectus* cf. *capellinus* (QUEN.)**

1846. *Ammonites capellinus* QUENSTEDT, p. 106.

1849. *Ammonites capellinus* QUENSTEDT, pl. 7, fig. 2.

The interpretation of the species is not very satisfactory. The type figure is of a crushed ammonite on a slab of shale, and a later figure (QUENSTEDT, 1885, pl. 44, fig. 14) apparently reproduces the same specimen. The whorl-section of the type is, therefore, unknown. The species is distinguished from *P. discoides* (ZIETEN) by the much closer ribbing. An ammonite from Gloucestershire, England, figured by WRIGHT (1884, pl. 82, fig. 12) may be intermediate between the two species.

The Italian specimens tentatively identified with the species have sharp venters, with no shoulders to the whorl as are present in *P. subplanatus* (OPPEL). Most are entirely septate, but one shows the beginning of the body-chamber at a diameter of about 7.5 cm. Some examples closely match the figure of *P. capellinus* in the density of the ribbing. Others have fewer ribs, and resemble Wright's figure mentioned above, but although there is some evidence for the existence of two species on the basis of the ribbing, the material available is inadequate for the study of the variation in this character, which, in any case, appears to have no stratigraphical significance.

***Polyplectus* cf. *subplanatus* (OPPEL)**

1845. *Ammonites complanatus* BRUGUIÈRE. D'ORBIGNY, p. 353, *pars*, pl. 114, figs. 1, 2, 4 only (*non* BRUGUIÈRE).

1856. *Ammonites subplanatus* OPPEL, p. 244.

OPPEL did not refer to particular figures on D'ORBIGNY's plate 114 when he set up the species, but figure 3, which appears to be a peripheral view of *P. bicarinatus*, was excluded by DUMORTIER (1874, pp. 51-52).

The Italian forms collected by the writer are fragmentary and indifferently preserved, and, being internal moulds, they lack the keel and present a bluntly rounded venter. They resemble the ammonite figured by REYNÈS (1879, Lias sup. pl. 5, figs. 28, 29; as *Amm. bicarinatus*), which should probably be referred to *P. subplanatus*.

***Polyplectus* cf. *bicarinatus* (MÜNSTER in ZIETEN)**

1831. *Ammonites bicarinatus* MÜNSTER. ZIETEN, p. 22, pl. 15, figs. 9a-c.

A single specimen found at Valdorbis at the base of the Mercati Zone is close to this species.

Subfamily Hildoceratinae HYATT, 1867

Genus *Hildoceras* HYATT, 1867

HYATT, when he proposed the genus, included in it *H. bifrons* (BRUG.), *H. walcotti* (J. SOW.) and *H. Hildense* (YOUNG & BIRD), the last two being considered

synonymous. BUCKMAN designated *H. bifrons* as type species of the genus (1889, p. 111).

Hildoceras bifrons (BRUGUIÈRE) has been frequently recorded from Italy and adjacent areas, but it is not a common species there. In the past this name was applied to a wide variety of Hildoceratids. The type figure (reproduced, with an illustration of a topotype, by BUCKMAN, 1918, pl. 114A) is quite clear and shows an ammonite in which the inner, smooth part of the whorl-side is inflated, and marked off from the ribbed area by a groove. It is clear from an examination of specimens and of figures that the majority of Italian records of this species were based on misidentifications.

Hildoceras sublevisoni FUCINI

1874. *Ammonites Levisoni* (SIMPSON). DUMORTIER, p. 49, pl. 9, figs. 3, 4 (*non* SIMPSON).
 1905. *Hildoceras bifrons* BRUG. FUCINI, pl. 113, pl. 5, figs. 13a, b, 14, 15, pl. 6, figs. 3a, b (*non* BRUGUIÈRE).
 1122. *Hildoceras sublevisoni* FUCINI, p. 182.
 1925. *Hildoceras bifrons* BRUG. RENZ, pl. 3, fig. 3, (*non* BRUGUIÈRE).
 1932. *Hildoceras sublevisoni* FUCINI. MERLA, p. 51, pl. 7, figs. 1a, b, 10.
 9932. *Hildoceras sublevisoni* FUC. var. *raricostata* MITZOP. MERLA, p. 51, pl. 7, fig. 4.

MERLA (1932, p. 51) accepted DUMORTIER's figures as type of the species. He figured as var. *raricostata* an ammonite which corresponds exactly with the type, and as typical forms of the species two specimens which are more closely-ribbed.

In the present writer's experience this is the commonest species of *Hildoceras* in the Toarcian of southern Switzerland and Italy. It is the index of the Sublevisoni Subzone (see p. 44). RENZ figured an example from Corfu, Greece.

The assemblage collected at Valdorbis is interesting for the variation in size of individuals preserved complete with their body-chambers. The diameter of complete specimens ranged from about 1.8 to 7.8 cm. There is no correlation between size and stratigraphical position. There is fairly wide variation in the proportions of the shell and in the ornament. The ribs vary from being numerous and weak, occasionally almost reduced to striae, to few and well-marked; the number of ribs on the body-chamber is between 35 and 50. The body-chamber occupied from one-half to five eighths of a whorl, and shows hardly any modification of ornament or coiling. In some individuals the coiling of last part of the body-chamber is slightly excentric, and in others there is a slight weakening of the ribs near the aperture. The lateral groove, which is diagnostic of the genus *Hildoceras*, shows some variation, being well-marked in some examples while in others it is hardly apparent. All clearly belong to a single variable assemblage.

Hildoceras semipolitum S. S. BUCKMAN

1889. *Hildoceras bifrons* (BRUGUIÈRE) variety. BUCKMAN, pl. 22, figs. 30, 31; pl. A, fig. 28.
 1902. *Hildoceras semipolitum* BUCKMAN, p. 4 (new name for above).
 1932. *Hildoceras semipolitum* BUCKMAN. MERLA, p. 52, pl. 7, figs. 3, 6, 7.
 1952. *Hildoceras semipolitum* BUCKMAN. VENZO, p. 120, pl. B, fig. 13.

The type is the specimen figured by BUCKMAN in 1889, and named in 1902. It has not been traced. Paratypes are in the Manchester Museum.

The species has a spiral groove on the whorl-side, a little nearer to the umbilical margin than to the periphery, and is closely ribbed. It is easily distinguished from *H. bifrons* by the strongly compressed whorl-section, less well-marked groove, and closer, fainter ribbing. It is closer to *H. hildense* (YOUNG & BIRD), but has still more compressed whorls and narrower venter, smaller umbilicus, and closer ribbing.

Hildoceras semipolatum characterises the subzone above that of *H. sublevisoni* (see p. 44).

Hildoceras cf. semicosta S. S. BUCKMAN

1926. *Hildoceras semicosta* BUCKMAN, pl. 685.

Part of a body-chamber collected at Valdorbja, much higher in the succession than all the other *Hildoceras* (fig. 2), bears some resemblance to this species. The whorl-section and ornament are similar, but there is no sign of a groove on the whorl-side.

Genus *Mercaticeras* BUCKMAN, 1913

The type species is *Amm. mercati* VON HAUER, restricted by BUCKMAN (see below). The genus *Murleyceras*, (BUCKMAN, 1921, pl. ccxvi), with type species *Amm. Murleyi* J. BUCKMAN, is a synonym of *Mercaticeras*.

Mercaticeras mercati (VON HAUER)

1856. *Ammonites mercati* VON HAUER, *pars*, p. 43, pl. 23, figs. 6, 7 only (*non* figs. 4, 5, 8-10).

1913. *Mercaticeras mercati* VON HAUER. BUCKMAN, p. vii (species restricted).

The figured specimen, which is 3.1 cm. in diameter, has part of the body-chamber preserved. BUCKMAN referred the three specimens figured by VON HAUER to three different species (see below), but the distinctions, which depend on the size of the umbilicus, are fine. The type specimen came from Erba, near Como. At Valdorbja the evolute species (*M. umbilicatum*) predominates, but specimens approaching *M. mercati* s. s. also occur.

Mercaticeras tyrrhenicum (FUCINI, 1905, p. 111, pl. 6, fig. 1) is similar to the species, but closer ribbed. It may be a synonym.

Mercaticeras umbilicatum S. S. BUCKMAN

1856. *Ammonites mercati* VON HAUER, *pars*, p. 43, pl. 23, figs. 4, 5 only.

1913. *Mercaticeras umbilicatum* BUCKMAN, p. vii (new name for above).

1932. *Mercaticeras mercati* (HAUER). MERLA, p. 45, pl. 6, figs. 4, 5a, b, 6, 7.

1932. *Mercaticeras humeralis* MERLA, p. 45, pl. 6, figs. 1a, b, 2, 3.

The name was proposed by BUCKMAN when he restricted VON HAUER's *Amm. mercati* (see above). MERLA, in restricting *M. mercati* to VON HAUER's figures 4, 5, omitted to notice that these figures had already been renamed by BUCKMAN. *M. humeralis* is believed by the present writer to be a synonym of *M. umbilicatum*.

This is the commonest species of *Mercaticeras* collected at Valdorbja, and it occurs also at Breggiagorge.

Mercaticeras dilatatum (MENEHINI)

1883. *Hildoceras (Lillia) dilatatum* MENEHINI, p. 368, pl. 21, figs. 1 a, c.

1932. *Mercaticeras dilatatum* (MENEHINI). MERLA, p. 49, pl. 6, figs. 17, 19-23.

The species differs little, except by closer ribbing, from one of VON HAUER's (1856) figures of *M. mercati*, namely his plate 23, figures 8, 9, which was renamed *M. involutum* by BUCKMAN (1913, p. vii).

Subfamily Bouleiceratinae ARKELL, 1950

Genus *Paroniceras* BONARELLI, 1893

The type species by original designation is *Amm. sternalis* VON BUCH.

No study of species has been made, for in the sections examined by the writer the material collected was not well-preserved. RENZ has described and figured many species (1922, 1925a, 1925b, 1925c, 1927, 1933). In Italy the genus appears to be diagnostic of the Bayani Subzone.

Genus *Frechiella* PRINZ, 1904

The type species is *Amm. subcarinatus* YOUNG & BIRD by original designation.

Fragmentary material only has been found by the writer. Many species have been described and figured by RENZ (1922, 1925b, 1925c, 1927, 1933). The genus usually occurs in, and may be restricted to, the Mercati Zone.

Subfamily Grammocerotinae BUCKMAN, 1904

Genus *Pseudogrammoceras* S. S. BUCKMAN, 1901

The type species is *Amm. struckmanni* DENCKMANN, by monotypy. In 1904 (p. cxliii) BUCKMAN erroneously stated it to be *Pseudogrammoceras regale* BUCKMAN. In the *Treatise* (p. 260) *Pseudogrammoceras* was placed as a synonym of *Grammoceras*, but the forms exemplified by the respective type species are distinct; *Grammoceras* typically has sharp ribs, with concave interspaces, while *Pseudogrammoceras* has flat, rounded ribs with angular interspaces. While admitting that the two groups grade into one another and that the distinction may not be really of generic significance, it is convenient to retain *Pseudogrammoceras* for stratigraphical purposes.

One body-chamber from Valdorbja shows good agreement with *P. fallaciosum* BAYLE. Another specimen from the same place, complete with body-chamber at a diameter of 6.0 cm, resembles the inner whorls of *P. regale* S. S. BUCKMAN (1904, p. cxlv, figs. 134, 138). An individual retaining most of the body-chamber at a diameter of only 4.1 cm. belongs to a closely-ribbed species which is probably unnamed.

Genus *Pleydellia* S. S. BUCKMAN, 1899

The type species is *P. comata* S. S. BUCKMAN, as was recognised by that author in 1923 (p. 55). *Cotteswoldia* (type species: *Amm. costulatus* ZIETEN, designated by BUCKMAN, *op. cit.* p. 56) is a synonym. The type species are extreme

forms, *C. costulata* having strong ribs, while *P. comata* is striate on the outer whorls; but there is a series of intermediate species, and the striate stage succeeds the costate at different sizes in different species. None of the distinctions listed by BUCKMAN (1904, p. cxxxvii) are regarded as of generic significance, and separation of the two genera is not practicable.

Pleydellia distans (S. S. BUCKMAN)

1890. *Grammoceras distans* BUCKMAN, p. 196, pl. 33, figs. 1, 2.

1902. *Cotteswoidia distans* BUCKMAN, p. 2.

A typical example was found at Monte Cucco. Specimens from Valdorbica represent a variant with closer ribbing, and with a few ribs joined in pairs.

Genus *Dumortieria* HAUG, 1885

The type species is *Ammonites levesquei* D'ORBIGNY, designated by BUCKMAN (1890, p. 231). The genus *Catullocceras* GEMMELLARO (1886) (type species: *Amm. Dumortieri* THIOLLIÈRE in DUMORTIER) is regarded as a synonym by the present writer. It was upheld in the *Treatise*, but shows no essential differences from *Dumortieria*. For other synonyms, see the *Treatise* (p. 262).

Dumortieria meneghinii (ZITTEL MS.) HAUG

1870. *Ammonites Levesquei* D'ORBIGNY. MENEGHINI, p. 48, pl. 10, figs. 4, 5 (*non* D'ORBIGNY).

1887. *Dumortieria Meneghinii* (ZITT. in coll.). HAUG, p. 128.

1952. *Dumortieria meneghinii* ZITTEL in HAUG. VENZO, p. 122, fig. 4.

The species differs from *D. levesquei* by having a wider umbilicus and more compressed whorls.

Dumortieria cf. dumortieri (THIOLLIÈRE MS.) DUMORTIER

1874. *Ammonites Dumortieri* (THIOLLIÈRE). DUMORTIER, p. 269, pl. 57, figs. 3, 4.

A closely ribbed species found at Valdorbica is near to this species in side view, but has more compressed whorls, with the thickness only about 21% of the diameter.

Dumortieria evolutissima mut. **multicostata** PRINZ

1904. *Dumortieria evolutissima* mut. *multicostata* PRINZ, p. 67, pl. 30, fig. 2.

Specimens from Valdorbica agree with this species, but are not good enough for positive identification.

Subfamily *Tmetoceratinae* SPATH, 1936

Genus *Tmetoceras* BUCKMAN, 1892

The type species is *Am. scissus* BENECKE, by original designation. The species is an evolutionary development from *Dumortieria* in which the keel has been replaced by a ventral sulcus. Periodic constrictions are usually conspicuous. Material collected by the writer was too fragmentary for a discussion of species.

Family **Graphoceratidae** BUCKMAN, 1905Subfamily **Leioceratinae** SPATH, 1936Genus *Leioceras* HYATT, 1867

The type species is *Nautilus opalinus* REINECKE, designated by BUCKMAN (1887, p. 21). A single example of *L. cf. substriatum* BUCKMAN was found at Valdorbja, immediately below the horizon with *Tmetoceras*.

Family **Hammatoceratidae** BUCKMAN, 1887Subfamily **Phymatoceratinae** HYATT, 1900

The family includes Hildoceratacean genera distinguished by joining of some of the ribs, in pairs or larger groups, at the umbilical margin of the whorl. The junction is often, but not always, marked by a tubercle. This character first appears in *Pseudomercaticeras*, which in all other respects is similar to *Mercaticeras* from which it was clearly derived, and in *Phymatoceras* (*Chartronia*), a single example of which was found in the Semipolitum Subzone at Valdorbja. Whether the subfamily is polyphyletic, as suggested in the *Treatise* (p. 265), is a question that awaits investigation.

Genus *Phymatoceras* HYATT, 1867Subgenus *Phymatoceras* S. S.

A variety of species have been included in the genus by different authors probably because no figures were given or cited by HYATT in 1867, the two syntype species, *P. enervatum* HYATT and *P. robustum* HYATT, being described but not illustrated. In 1897, however, in reply to an inquiry from S. S. BUCKMAN, HYATT wrote 'the *Phymatoceras robustum* is the young of *Am. tirolensis*, DUM., Pt. iv, Pl. xxiv' (quoted by BUCKMAN, 1898, p. xxx), and in 1900 HYATT repeated this information, stating that 'type of *Phymatoceras* is *Amm. tirolensis*, DUMORTIER...' (HYATT, 1900, p. 577). The type species of *Phymatoceras* is therefore *P. robustum*⁸, and this species is exemplified by the ammonite figured by DUMORTIER (1874, pl. 24) as *Amm. tirolensis* VON HAUER.

In the *Treatise* (p. 265) *Chartronia* S. S. BUCKMAN, 1898 (including *Lillia* BAYLE, 1878, a homonym, and *Denckmannia* S. S. BUCKMAN, 1898) is considered as a synonym of *Phymatoceras*, but the two genera were upheld recently by the present writer (DONOVAN, 1954, p. 18). It is useful to restrict *Phymatoceras* S. S. to species in which the inner whorls, at least, have periodic constrictions which are preceded by paired ribs meeting in an umbilical tubercle, these ribs being often more prominent than the others. In the type species and in the well-known *P. erbaensis* (VON HAUER) the other ribs are simple and not paired. There are forms which, by increase in the number of paired ribs and weakening of the constrictions, are transitional to *Chartronia*, although the typical forms of each subgenus are distinct. Both subgenera have a septate keel.

⁸) According to the Rules of Nomenclature the nominal type species must be one of the original nominal syntypes.

Phymatoceras erbaense (VON HAUER)

1856. *Ammonites erbaensis* VON HAUER, p. 42, pl. 11, figs. 10–14.

1932. *Denckmannia erbaensis* HAUER, MERLA, p. 19, pl. 1, figs. 10a, b, 11.

The original of VON HAUER's figures 10, 11 is here designated the lectotype of the species.

Examples found at Valdorbja have slightly more slender whorls than the lectotype.

Phymatoceras elegans MERLA

1932. *Phymatoceras elegans* MERLA, p. 17, pl. 1, figs. 3, 5, 12.

The original of figure 3 is here designated lectotype of the species.

The species is closely similar to the inner whorls of the type species, *P. robustum* (see above), but on available information it is not possible to decide whether the two species are synonyms. The species differs from *P. erbaensis* (VON HAUER) in having more compressed whorls, narrower grooves on the venter, and closer ribbing.

Subgenus *Chartronia* BUCKMAN, 1898

The distinction between *Chartronia* and *Phymatoceras* has been noted above. *Chartronia* is here adopted as the earliest valid name⁹⁾ for the ammonites with a continuous row of umbilical tubercles, and without constrictions. It includes the synonyms *Lillia* (BAYLE, 1878, preoccupied by *Lillia*, BOIE, 1844), *Denckmannia* (BUCKMAN, 1898) and *Loryella* (BREISTROFFER, 1947). The type species is *Chartronia binodata* BUCKMAN, by original designation.

The innermost whorls of the species of this group have prominent umbilical tubercles, each giving rise to two or three sigmoidal ribs. At this stage the ornament is usually rather coarse. With increase in size, the tubercles become proportionately reduced, and the ribs closer and less strongly curved. In some species, at least, the tubercles disappear altogether and the outer whorls bear simple ribs only. The venter is bisulcate with a septate keel, but the grooves may be lost on the outer whorls.

Phymatoceras (Chartronia) comense (VON BUCH)

1831. *Ammonites comensis* VON BUCH, pl. 2, figs. 1–3.

Several examples from Valdorbja are attributed to the species.

Phymatoceras (Chartronia) aff. pulcher MERLA

1932. *Phymatoceras pulcher* MERLA, p. 30, pl. 3, figs. 1, 2, 6.

The original of MERLA's plate 3, figure 1 is here designated lectotype of the species. Two specimens from Valdorbja resemble the species in ornament, but have thicker whorls, and a smaller umbilicus, about 35% of the diameter instead of 40% in the typical form of the species.

⁹⁾ It has page precedence over *Denckmannia*.

Phymatoceras (Chartronia) fabale (BUCKMAN *ex* SIMPSON)

1855. *Ammonites fabalis* SIMPSON, p. 77.

1921. *Phymatoceras fabale* BUCKMAN, pl. 244 (supposed holotype figured).

1932. *Denckmannia cornucopia* MERLA, p. 22, pl. 2, figs. 4, 6a, b, 7, 8.

This species was described, but not illustrated, by SIMPSON, and figured in 1921. The Italian material which is here referred to the species is similar in proportions to *P. (C.) comense* (VON BUCH), but has coarser and more widely-spaced ribs. The form is also exemplified by the specimen figured by VON HAUER (1856, pl. 11, figs. 1–3) as the typical form of *P. (C.) comense*, which differs, however, from VON BUCH's type in the particulars already mentioned. '*Denckmannia cornucopia*' represents the inner whorls of *P. (C.) fabale*. *P. (C.) chelussi* (PARISCH & VIALE) is an allied form with closer ribbing.

The species was found at one level only at Valdorbis, at level 16.3 m (fig. 2). It is the earliest species of *Phymatoceras* and the only one found in the Mercati Zone.

Phymatoceras (Chartronia) chelussi (PARISCH & VIALE)

1906. *Hildoceras (Lillia) Chelussii* PARISCH & VIALE, p. 156, pl. 11, figs. 10, 11.

1932. *Lillia Chelussii* PARISCH & VIALE. MERLA, p. 15, pl. 1, fig. 2.

Typical examples were found at Valdorbis.

Phymatoceras (Chartronia) anomalum MERLA

1932. *Phymatoceras anomalum* MERLA, p. 31, pl. 3, figs. 5, 10a, b.

The original of MERLA's plate 3, figures 10a, b is here designated the lectotype of the species.

Genus *Pseudomercaticeras* MERLA, 1932

The type species is *P. parvilobum* MERLA designated by ARKELL (1957, p. 266). The genus has page precedence over *Crassiceras* (*op. cit.*, p. 42) (type species: *C. latum* designated by ARKELL, *loc. cit.*) which is here considered to be a synonym.

The genus resembles *Mercaticeras* in shell form, but is distinguished by the presence of umbilical tubercles on the inner whorls, two or more ribs springing from each tubercle. In the adult shell the inner part of the whorl-side may become smooth, as in *Brodieia* which succeeded *Pseudomercaticeras* stratigraphically and presumably evolved from it.

Pseudomercaticeras latum (MERLA)

1932. *Crassiceras latum* MERLA, p. 43, pl. 5, figs. 10a, b.

The species is adopted as the index for the lower subzone of the Erbaense Zone.

Pseudomercaticeras canavarii (FRANCESCHI)

1921. *Lillia Canavarii* FRANCESCHI, p. 50, figs. 1, 2.

1932. *Crassiceras Canavarii* (FRANCESCHI). MERLA, p. 42, pl. 5, figs. 7, 8a, b, 9.

The specimen illustrated by FRANCESCHI was refigured by MERLA (pl. 5, figs. 8a, b; not fig. 7 as stated). The species is distinguished from *P. latum* by the wider umbilicus and narrower whorls.

Genus *Brodieia* S. S. BUCKMAN, 1898

The genus was set up by BUCKMAN (1898, p. xxxi) with the type species *Brodieia curva* BUCKMAN. A year later BUCKMAN (1899, p. xxxiii) substituted the name *Brodiceras*, on the assumption that *Brodieia* was invalidated by *Brodia* SCUDDER 1881, a genus of fossil insects. The assumption was incorrect as the two names are spelt differently, and *Brodieia* therefore stands according to the Rules of Nomenclature.

The genus possesses sigmoidal ribs joined in groups of two or more to umbilical tubercles, but is differentiated from *Chartronia* and *Haugia* by the fact that the keel is not septate.

A number of examples of *Brodieia* were obtained at Valdorbja, too poorly preserved for full study and identification. Some resemble *B. bayani* (DUMORTIER), while others show weakening of ornament on the inner part of the whorl-side as in *B. alticarinatum* (MERLA). Another specimen shows good agreement with one of the syntypes of *B. gradatum* (MERLA, 1932, pl. 4, fig. 8).

Subfamily Hammatoceratinae BUCKMAN, 1887

Genera *Erycites* GEMMELLARO, 1886 and *Hammatoceras* HYATT, 1867

These two genera, which have been regarded by all workers as closely related (if not, indeed, synonymous), appear to form a pair of which *Hammatoceras* is the 'macroconch' and *Erycites* the corresponding 'microconch', in the terminology proposed by CALLOMON (1955, p. 238). The macroconch is a comparatively large ammonite, with loss of ornament on the body-chamber; this feature is common in *Hammatoceras* (many figured examples consist of septate whorls only, and thus appear entirely ribbed; QUENSTEDT'S 1885, pl. 49, fig. 1, 31 cm. in diameter, is probably nearly complete). Microconchs are often about half the size of the macroconchs and show no weakening of the ornament. This is true of *Erycites* in which the body-chamber is often preserved; many figured specimens are complete with the aperture. In general, species of *Hammatoceras* have compressed whorls, and are more involute, while *Erycites* tends to a circular whorl-section and an open umbilicus, but it is impossible to make a rigid division between the two genera on these characters. It is better to adopt the body-chamber characters as diagnostic, as explained above. Both genera have approximately the same stratigraphical range, beginning in the Erbaense Zone and crossing the boundary from the Toarcian into the Bajocian.

The type species of *Hammatoceras* is *Amm. insignis* (SCHÜBLER MS) ZIETEN. When HYATT set up the genus he included the species *Amm. insignis* and *Amm. variabilis* D'ORBIGNY; *Amm. insignis* was stated to be the type by BUCKMAN (1887, p. 13). BUCKMAN later (1888, p. 45) made *Amm. variabilis* the type species of his genus *Haugia*.

The examples of *Hammatoceras* found consisted of imperfect inner whorls only, inadequate for proper identification. The material from Valdorbja includes forms similar to *H. sieboldi* (OPPEL, 1862, p. 144, pl. 46, figs. 1a, b), and to *H. tenuinsigne* VACEK (1886, p. 88, pl. 12, figs. 6, 7, 7a).

The type species of *Erycites* is *Amm. fallax* BENECKE, designated by LÓCZY (1915, p. 381), but this species was a homonym of *Amm. fallax* GUÉRANGER. The name *Erycites fallifax* was proposed by ARKELL (1957, p. 267) to replace it.

Three groups of *Erycites* are represented among the Italian material examined:

***Erycites perplanum* (PRINZ)**

1881. *Ammonites insignis* SCHÜBLER. MENEGHINI, 1881, pl. 12, fig. 3 (*non* SCHÜBLER).
 1904. *Hammatoceras insigne* SCHÜBLER, mut. nov. *perplana* PRINZ, 1904, p. 72.
 1933. *Hammatoceras perplanum* PRINZ. MERLA, p. 19, pl. 3, fig. 2 (Meneghini's example refigured).

This is a species with slender whorls for which PRINZ's name, under which he cited MENEGHINI's figure, has priority. MERLA has pointed out that *Hammatoceras clavatum* FOSSA-MANCINI (1915, p. 11) is a synonym, as it has the same figure of MENEGHINI as its type.

PRINZ and MERLA referred the species to *Hammatoceras*, but according to the criteria outlined above it is an *Erycites*, for the type is complete with evolute, ornamented body-chamber at a diameter of 7.0 cm. It is possible that the type is immature, for the material from Valdorbis includes a complete body-chamber about 11.0 cm. in diameter.

***Erycites elaphus* MERLA**

1933. *Erycites elaphus* MERLA, p. 25, pl. 4, fig. 5.

Erycites intermedius PRINZ (1904, p. 94, pl. 16, figs. 1a, b) seems to be close to *E. elaphus*, but PRINZ's illustration was apparently drawn from an indifferently preserved example, and for the present it seems better to use MERLA's name, for which a good figure is available. A re-examination of PRINZ's material from the Bakony Mountains might demonstrate his name to be the valid one for the species.

***Erycites* aff. *crassiventris* MERLA**

1933. *Erycites crassiventris* MERLA, p. 26, pl. 4, fig. 1.

This name is provisionally adopted for a series of specimens with more slender whorls, and a wider umbilicus, than *E. elaphus*. Some of the examples have more widely-spaced primary ribs than the type, but this may be an individual variation.

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