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# Ammonites and stratigraphy of Lower Jurassic black shales and pelagic limestones from the Belluno Trough, Southern Alps, Italy

By HUGH C. JENKYNS[1]), MASSIMO SARTI[2]), DANIELE MASETTI[2]) and MICHAEL K. HOWARTH[3])

«È una facies particolare che ha il suo massimo sviluppo nella regione extraalpina, ma della quale, per quanto sporadici e limitati, non mancano esempi anche nel bacino mediterraneo.» – DAL PIAZ (1907) on Toarcian organic-rich shales of the Alpi Feltrine.

## ABSTRACT

In the pelagic succession of the Igne Formation of the Belluno Trough, Southern Alps, Italy, there is a widespread unit of millimetre-laminated black-to-brown organic-rich shales typically interbedded with manganese-rich limestones. Toarcian ammonites collected in situ within the Igne Formation above these shales date a widespread nodular level, locally in *Ammonitico Rosso* facies, as *bifrons* Zone (*sublevisoni* Subzone), and furthermore suggest that the age of the organic-rich level is early *falciferum* Zone. Organic-rich shales from the Lombardian Basin and the Trento Plateau, elsewhere in the Southern Alps, are also demonstrated to be of *falciferum*-Zone age. The Alpine black shales are of identical age to the German *Posidonienschiefer*, French *Schistes Cartons* and English *Jet Rock* of epicontinental northern Europe. This organic-rich horizon thus possesses remarkable stratigraphic value. The concept of an Early Toarcian regional anoxic event, similar to those documented from the Cretaceous, seems a viable working hypothesis.

## RIASSUNTO

Argilliti laminate nere o brune, ricche in sostanza organica e tipicamente intercalate a calcari manganesiferi formano un esteso orizzonte all'interno dei sedimenti pelagici della Formazione di Igne (Bacino di Belluno, Alpi Meridionali, Italia).

Ammoniti toarciane appartenenti alla Zona a *bifrons* (Sottozona a *sublevisoni*) e alla Zona a *falciferum* superiore sono state raccolte in posto in orizzonti fossiliferi sovrastanti gli «scisti organici» e suggeriscono per questi ultimi un'età corrispondente alla Zona a *falciferum* inferiore. Della stessa età sono, sempre nell'ambito delle Alpi Meridionali, gli «scisti organici» del Bacino Lombardo e del Plateau di Trento.

È anche verificata l'isocronia tra gli «scisti organici» delle Alpi Meridionali e le analoghe formazioni epicontinentali dell'Europa settentrionale (*Posidonienschiefer* della Germania, *Schistes Cartons* francesi e *Jet Rock* dell'Inghilterra), a conferma del notevole valore stratigrafico di questo orizzonte.

Un «evento anossico» regionale del Toarciano Inferiore, del tutto simile a quelli già documentati nel Cretacico rappresenta ora un'ipotesi di lavoro estremamente interessante.

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## Introduction

We here report on the stratigraphical significance of newly collected ammonite faunas from the pelagic Lower Jurassic of the Belluno Basin, Southern Alps. The ammonites derive from several horizons within the Igne Formation and were all collected in situ. The lithologies and faunas sampled and admirably described by BOYER (1913) from near Longarone were not accurately located within measured sections; those described by CAVALLIN & MASSIOTTA (1976) from near Claut were derived from talus.

The Igne Formation, established by CASATI & TOMAI (1969), is developed as a series of deep-marine pelagic limestones, typically grey in colour, and darker shales. It is underlain by the dark cherty dolomitic limestones of the Soverzene Formation and capped by the redeposited oolites of the Vajont Formation. Stratigraphic and sedimentary schemes and the palaeogeographic and palaeotectonic framework are outlined in BOSELLINI et al. (1981a) and WINTERER & BOSELLINI (1981).

These ammonites were collected during a study of a geographically widespread sequence of deep-marine organic-rich typically millimetre-laminated black-to-brown shales (the "marnes noires" of BOYER 1913) and intercalated manganese-rich carbonates which occur not only in the Igne Formation of the Belluno Basin but also in Lombardy, in the Trento Zone (Fig. 1) and elsewhere in the Tethyan region. In this account we generally refer to the organic-rich levels as "black shales". They commonly contain fish scales and plant debris, with micritic calcite and clay minerals such as illite and smectite dominating the fine fraction; organic-carbon contents typically range between 1 and 3%. Where possible the ammonite faunas have been collected and located with reference to this black-shale marker horizon, and thus placed in a sound stratigraphic context. Most of the localities described are close to the village of Longarone (Fig. 2). Some stratigraphic data from other localities in the Southern Alps (Lombardian and Trento Zones) are also discussed.

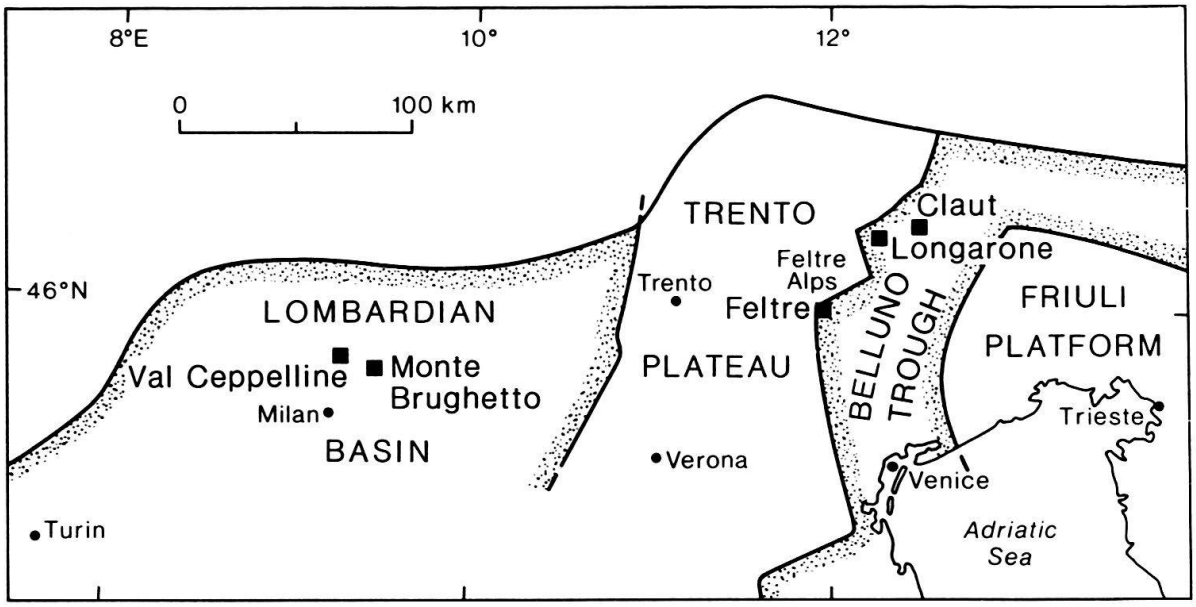


Fig. 1. Map of the palaeotectonic elements of the Southern Alps, showing principal localities mentioned in the text. After BOSELLINI et al. (1981b), and WINTERER & BOSELLINI (1981).

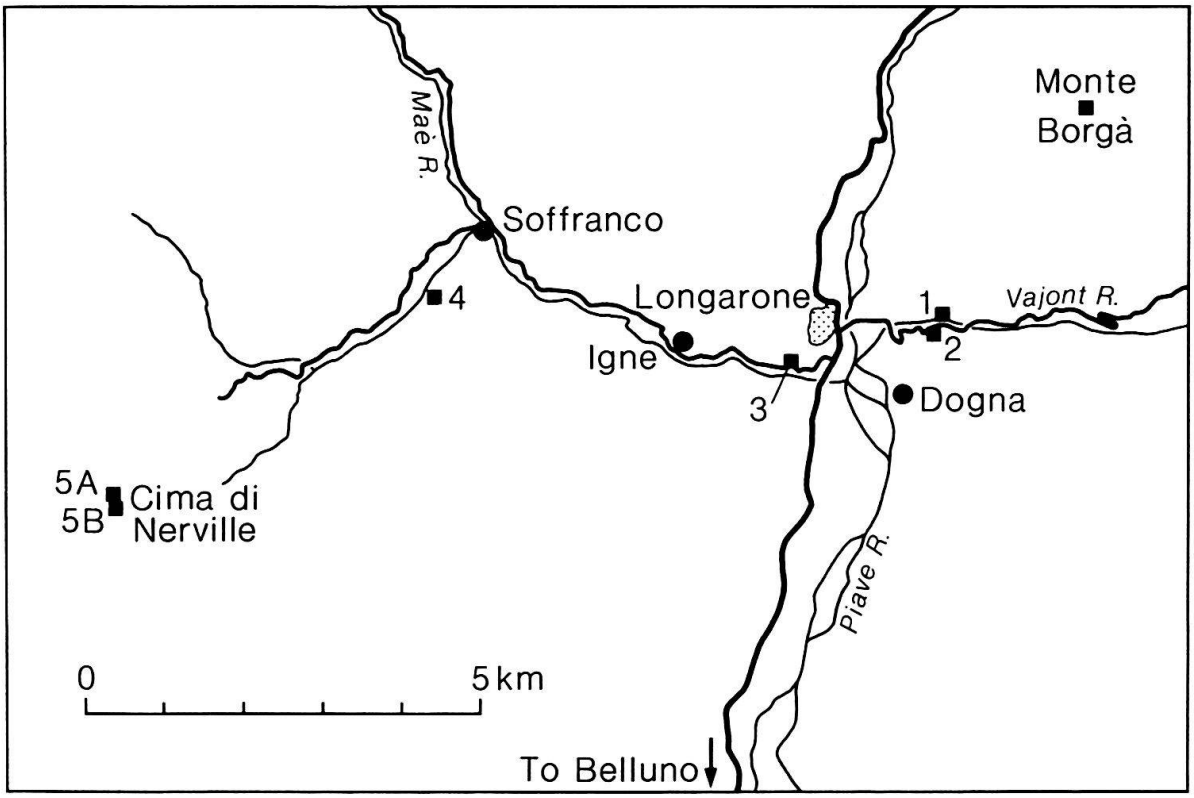


Fig. 2. Detail of the area around Longarone, showing location of sections described in the text and other relevant localities.

## Localities and fauna

*Locality 1:* By far the best exposure of the black shales and associated ammonite-bearing strata is found below the Vajont Dam on the northern bank of the Torrente Vajont in a cliff section (Fig. 3). Here some 9 m of black-to-brown laminated shales and interbedded brown-weathering manganoan limestones are developed; they are underlain by a massive belemnite-bearing pink limestone that attains a maximum thickness of 90 cm but thins laterally (Fig. 4). We have only found one indeterminate ammonite impression in this massive limestone, whose microfacies is dominated by micrite containing rare microfossils: Foraminifera, carbonate-replaced radiolarians and sponge spicules plus occasional quartz shards. Above the top of the black shales and manganoan limestones there is a gradual transition to 4.2 m of regularly bedded limestones and marls, on top of which are 7 m and 3.6 m of grey and red nodular limestones respectively (*Ammonitico Rosso* facies). At a level 30 cm above the top of the highest brown-weathering manganoan limestone, which we take as the upper limit of the "black-shale" sequence, we have found the following ammonites:

*Dactylioceras* sp. indet. (two specimens)

At a level 60 cm above the top of the highest manganoan limestone we have found the following ammonites:

*Dactylioceras* cf. *anguiforme* (BUCKMAN)
*Harpoceras* sp. indet.
*Dactylioceras* sp. indet. (numerous specimens)

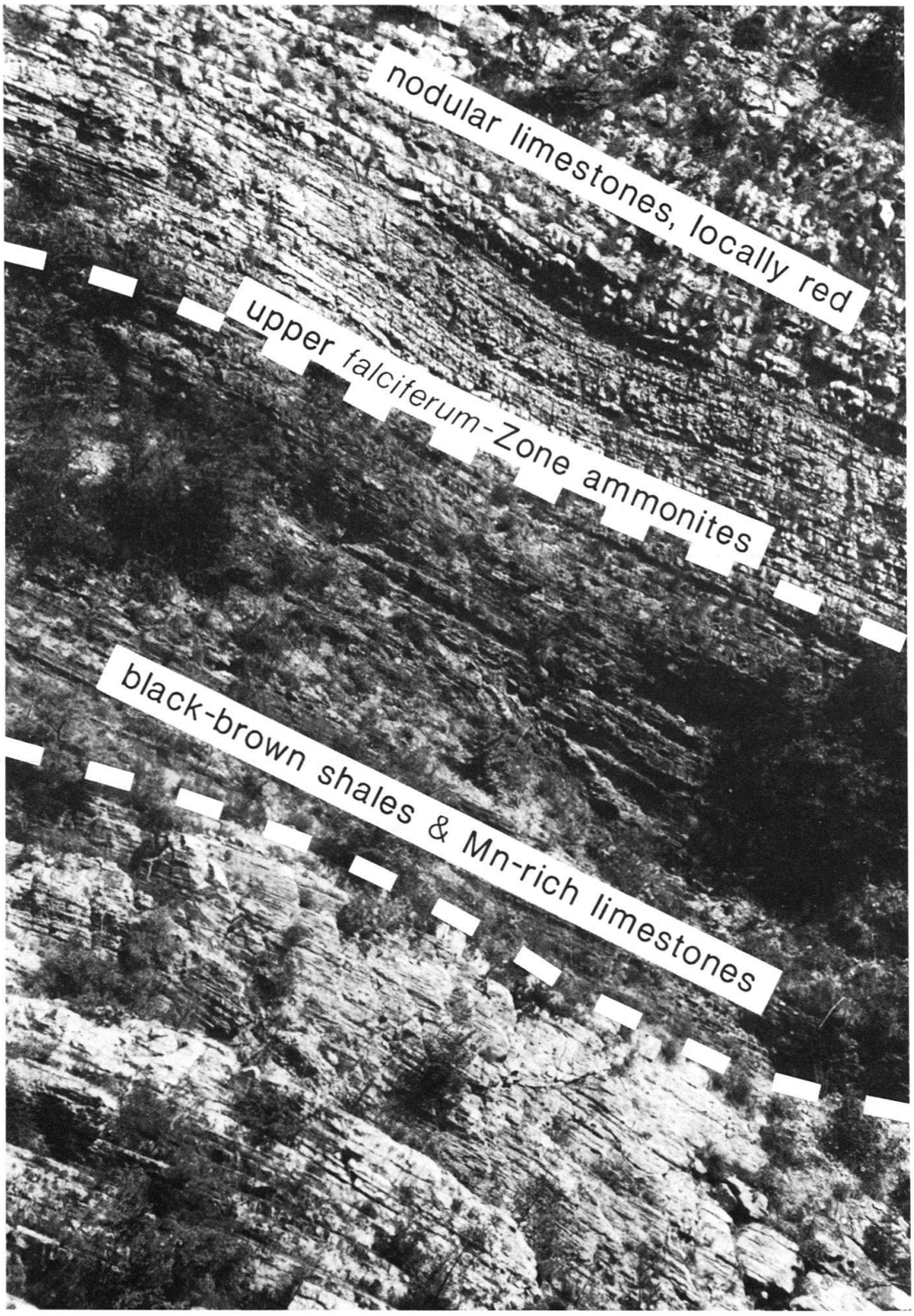


Fig. 3. Part of the section exposed in the Vajont Gorge (Locality 1) showing the field aspect of the organic-rich shales and manganoan limestones (contained within the discontinuous white bands) together with their stratigraphical relationship to the beds containing ammonites.

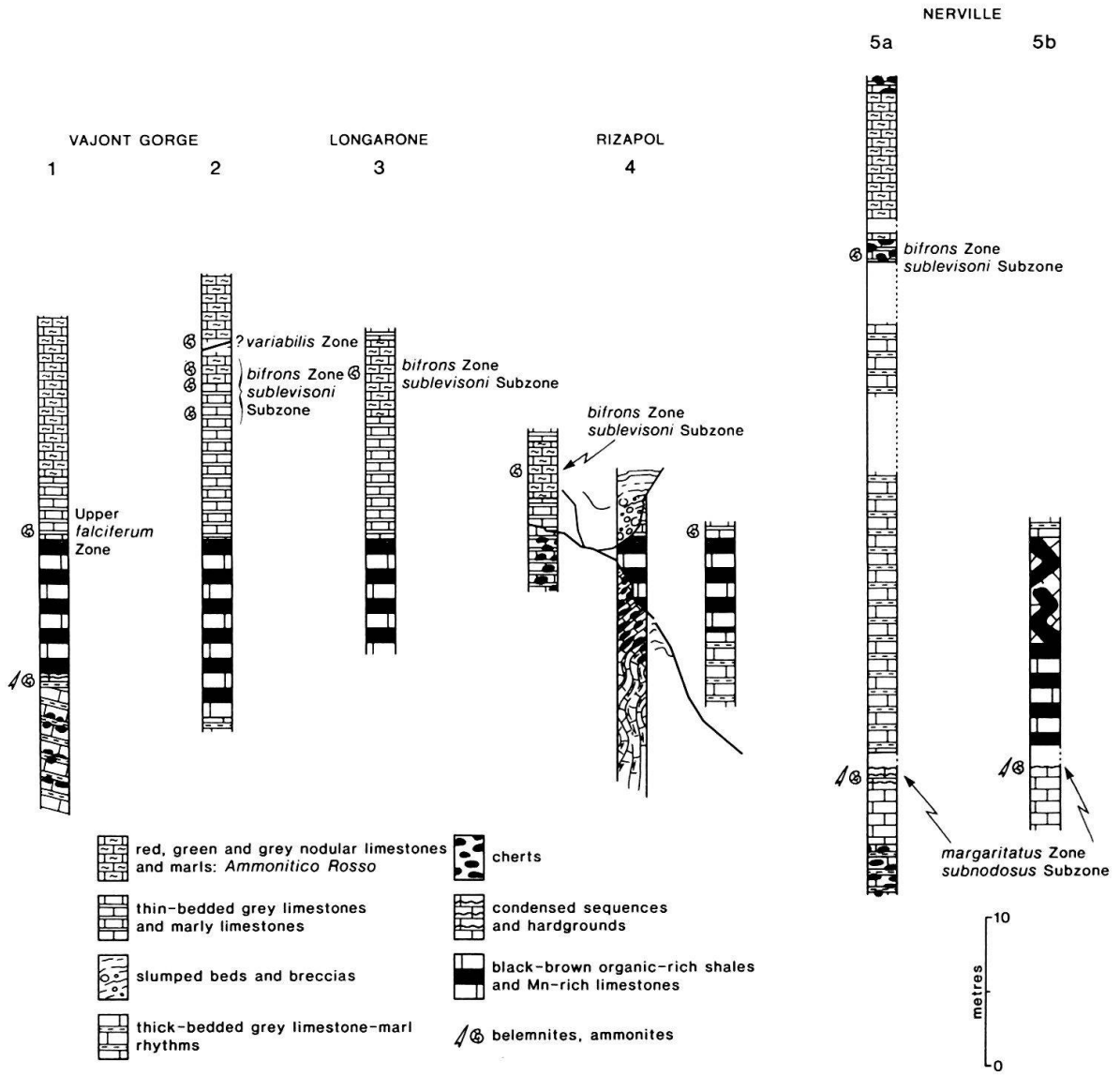


Fig. 4. Vertical sections through the Igne Formation of the Belluno Basin illustrating stratigraphy and suggested inter-relationships of organic-rich shales and manganoan limestones.

These ammonites, specifically the *Dactylioceras* cf. *anguiforme* (BUCKMAN), indicate the higher part of the *falciferum* Zone.

*Locality 2:* The second locality is located on a hill-side dirt road on the south side of the gorge a little below the entrance of the tunnel west of the Vajont Dam (Fig. 2); it is approached from the village of Dogna. Although there is some faulting, the base of the grey nodular ammonite-bearing horizon apparently lies some 10 m above the top of the black shales and manganoan carbonates which here are some 12 m thick. This nodular level is characterized by a pelletal microfacies rich in small ammonites, shells of *Bositra buchi,* echinoderm debris, carbonate-replaced sponge spicules and radiolarians, plus sparse dolomite rhombs and occasional tiny quartz shards. According to JEFFERIES & MINTON (1965) the stratigraphic range of *Bositra buchi* ( = *Posidonia alpina* auctt.) is Toarcian to Oxfordian inclusive.

The stratigraphical relationships of Locality 1 can be seen from Locality 2 by gazing north at the opposite wall of the Vajont Gorge. The black shales and interbedded carbonates are clearly visible and the nodular horizon above them is picked out as it changes colour from red *(Ammonitico Rosso)* to grey along the strike. Ammonites have been collected from four separate levels in Locality 2 (Fig. 4). The lowest level, 8.7 m above the top of the black shales, has yielded:

*Mercaticeras umbilicatum* BUCKMAN
*Hildoceras sublevisoni* FUCINI
*Noedicoeloceras* sp. indet.
Dactylioceratid indet.

The next fossiliferous unit, some 30 cm to 180 cm higher in the section, has yielded:

*Hildoceras sublevisoni* FUCINI
*Hildoceras* sp. indet.
?*Mercaticeras* sp. indet.

The level 80 cm above this has yielded:

*Hildoceras sublevisoni* FUCINI

All these levels pertain to the *sublevisoni* Subzone of the *bifrons* Zone. Another ammonite level, 2 m higher in the section, is separated by a fault from the beds below; it has yielded a specimen of ?*Brodieia* sp., suggesting the presence of the *variabilis* Zone (cf. GÉCZY 1984).

*Locality 3:* The third locality is located outside Longarone on the road to Igne and Zoldo (Fig. 2). Here, the base of the red nodular carbonate crops out 10.5 m above the top of the sequence of white-weathering black shales (12.5 m exposed; base not seen) with intervening regularly bedded grey limestones and marls; the thickness of the red limestone is 3.1 m and it is underlain by 2.2 m of similar grey nodular facies. This exposure is netted and it is difficult to extract fauna. We have, however, collected one large ammonite 80 cm above the base of the red nodular carbonate: this is a *Hildoceras orthum* (BUCKMAN), indicative of the *sublevisoni* Subzone of the *bifrons* Zone. The microfacies of this red nodular carbonate or *Ammonitico Rosso* is very similar to that of the grey nodular lithology exposed at the same level at Locality 2 except that the filament-like profiles of *Bositra buchi* are uncommon in thin section. We believe that this level is equivalent to that described as "Igne" by BOYER (1913) which can be dated, from his faunal list, as *bifrons* Zone, *sublevisoni* Subzone and *semipolitum* Subzone.

*Locality 4:* The fourth locality lies along the forestry road at Rizapol, in the Valle dei Grisol, close to the village of Soffranco (Fig. 2). The facies is developed as 4 m of a grey nodular limestone resembling *Ammonitico Rosso* in all but colour; synsedimentary disturbances, chiefly slump folds, locally affect this facies. In thin section it is a dense micrite containing occasional ammonite fragments and rare shells of *Bositra buchi.*

The exact stratigraphical relationship of the ammonite-bearing horizon with the black-to-brown shales is here unclear, although both are locally exposed along the road; complications also arise as the organic-rich shales and associated brown-weathering limestones thin, from an exposed maximum of approximately 6.3 m, and finger out laterally, apparently being banked up against a small slump-induced high (Fig. 4); chertified slump rubble also cuts them out locally. Faulting and failure of exposure do not permit accurate measurements, although it is apparent that the ammonite-rich level

occurs stratigraphically above the black shales. The following ammonites have been identified from this locality:

*Hildoceras sublevisoni* FUCINI (many specimens)
*Mercaticeras* sp. indet.
*Harpoceras falciferum* (J. SOWERBY)
*Lytoceras* sp. indet.
*Calliphylloceras* sp. indet.
*Mercaticeras* cf. *dilatum* (MENEGHINI)
This fauna is characteristic of the *bifrons* Zone, *sublevisoni* Subzone.

*Comment.* – We believe that all these nodular horizons (in Localities 1–4) represent the same stratigraphic level, namely Lower Toarcian, *bifrons* Zone, *sublevisoni* Subzone. This subzone is represented by a nodular limestone level whose base occurs between 4 and 10 m above the top of the prominent black-shale/manganoan carbonate sequence.

*Locality 5:* Locality 5a is located on a steeply dipping slope close to the Forcella Nerville, about 2 km east of Rifugio Bianchet, Pian dei Gat, Sedico (Fig. 2). Here a grey limestone, dipping northwards at 38°, and containing numerous examples of the orthocone *Aulacoceras,* plus a substantial fauna of ammonites, is exposed in a gulley; the thickness of the fossil-rich bed is at least 5.2 m and the ammonite fauna dominantly derives from the upper metre of this unit. Exposure fails for about 1 m above the ammonite-bearing limestones before a sequence of marly limestones is visible, but no

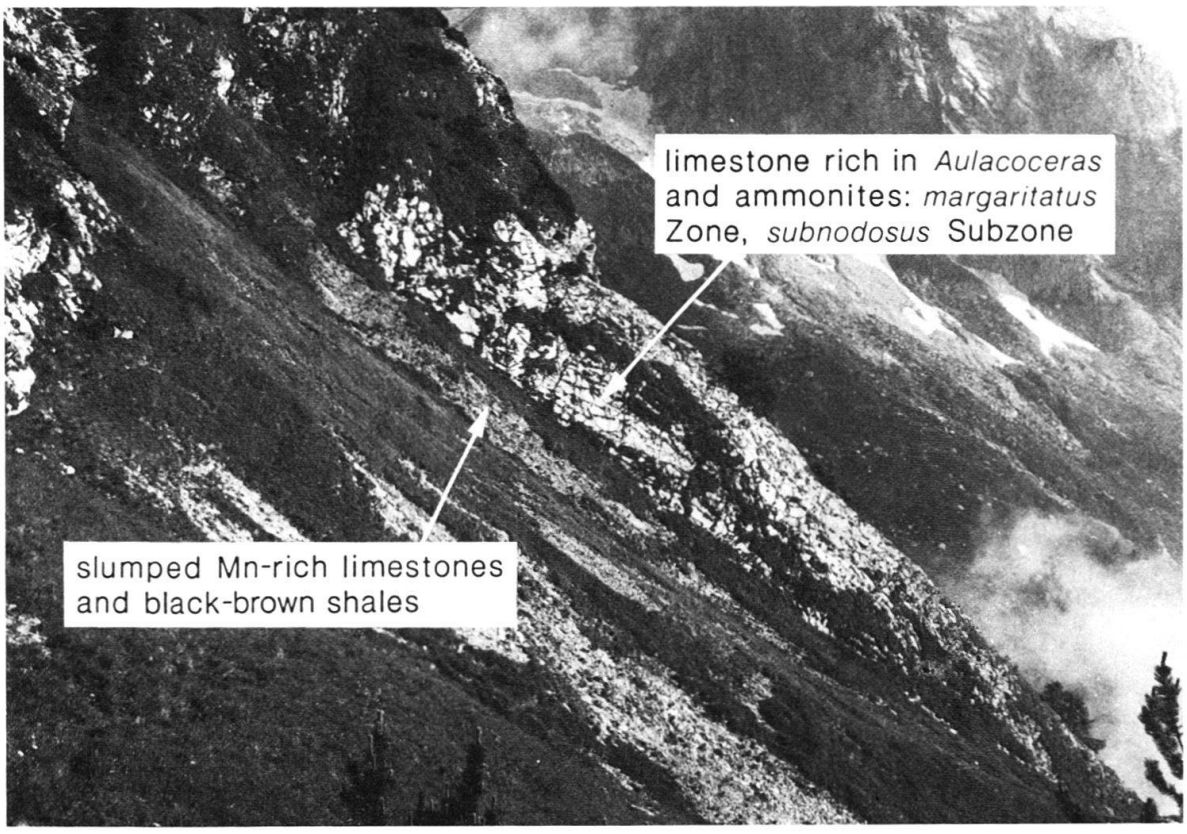


Fig. 5. Field aspect of Locality 5b, Forcella Nerville. The photo shows a steeply dipping bedding surface (hardground) of fossiliferous limestone, on which the slumped Mn-rich carbonates and organic-rich shales rest.

black shales and manganoan limestones are seen. However, where the sequence is repeated by faulting in the next valley to the south (Locality 5b), some 16 m of slumped manganoan limestones and interbedded black-brown shales are exposed, albeit incompletely, and rest, with an exposure gap of 1.5 m, upon the *Aulacoceras*/ammonite-rich limestone (Fig. 5). Perhaps between these two localities, only a few hundred metres apart, the black shales finger out, as they do at Rizapol (Fig. 4).

The microfacies of the faunally-rich horizon is dominantly micritic and contains sparite- and micrite-filled radiolarian moulds, calcite-replaced sponge spicules, occasional Foraminifera, rare echinoderm debris and tiny ammonite segments. Of note is the absence of the shells of *Bositra buchi*, implying a pre-Toarcian age.

The following fauna has been identified from this locality:

5a: *Aulacoceras* (many specimens)
*Aveyroniceras acanthoides* (REYNES)
*Aveyroniceras mortilleti* (MENEGHINI)
*Reynesoceras* cf. *morosum* (BETTONI)
*Fuciniceras cornacaldense* (TAUSCH)
*Fuciniceras* sp. indet.
?*Fuciniceras* sp. indet.
*Arieticeras* sp. indet.
?*Calliphylloceras* sp. indet.
Belemnites
Crinoid ossicles

5b: *Aulacoceras* (many specimens)
*Aveyroniceras* sp. indet.
*Dactylioceratid* indet.
*Phylloceras* or *Calliphylloceras* sp. indet.
*Caliphylloceras* sp. indet.
*Lytoceras* sp. indet.
*Fuciniceras* sp. indet.
Nautiloids
Belemnites

If these ammonites represent a coeval association, the occurrence of *Aveyroniceras*, *Reynesoceras*, *Fuciniceras*, and *Arieticeras* together in one bed at Locality 5a fixes its age as *margaritatus* Zone, *subnodosus* Subzone. This is equivalent to the *gloriosus* Subzone of FANTINI SESTINI (1975, 1977). That these four genera only overlap in the *subnodosus* subzone is demonstrated by the work of FANTINI SESTINI and that of WIEDENMAYER (1980) in Lombardy.

Locality 5b also contains associated specimens of *Aveyroniceras* and *Fuciniceras* and is hence of the same age.

At Locality 5a, approximately 37 m above the top of the *Aulacoceras*- and ammonite-bearing level, a grey nodular facies has been found. Thin sections show a microfacies similar to that encountered at Localities 2 and 3, in which *Bositra* shells are present. The following ammonites have been identified at this level:

*Dactylioceras commune* (J. SOWERBY)
*Phymatoceras* sp. indet.

These ammonites indicate the *sublevisoni* Subzone of the *bifrons* Zone.

## Stratigraphic interpretation

The zones and subzones identified by us only partly correspond to those found by CAVALLIN & MASSIOTTA (1976) in talus from the Igne Formation exposed by the Torrente Cellina, near Claut (Fig. 1). They distinguished a grey limestone containing a Pliensbachian *spinatum*-Zone fauna and a nodular *Ammonitico Rosso* containing ammonites of the *tenuicostatum, falciferum, bifrons* and *erbaense* Zones. We have examined this locality but not found any organic-rich shales in the section. BOYER (1913) cited fossils from the Igne Formation pertaining to the *bifrons, variabilis* and *thouarsense* Zones of the Toarcian. He further noted that at Monte Borgà (Fig. 2) the black shales are directly overlain by fossiliferous Toarcian which apparently pertains to the *thouarsense* Zone (presence of *Grammoceras fallaciosum*).

Our dating of faunas above (upper *falciferum* Zone) and below (*margaritatus* Zone, *subnodosus* Subzone) the unfossiliferous black shales allows us to set constraints on the duration of organic-rich sedimentation in the Belluno Basin. The time involved could embrace the upper part of the *margaritatus, spinatum, tenuicostatum* and lower part of the *falciferum* Zones. The thickness of strata representing the *tenuicostatum* Zone in the Tethyan Zone is always very thin: in the Lombardian sections examined by WIEDENMAYER (1980), it is invariably less than 0.5 m, although in Umbria it may be a little thicker (GALLITELLI-WENDT 1969). Where identified in the Austrian Alps it is never thicker than 0.25 m and is commonly represented by a stratigraphic gap (FISCHER 1966); a similar circumstance exists in Hungary (GÉCZY 1984), and KOTTEK (1966) does not record it from the Ionian Zone of western Greece. Thus it is virtually certain that the black shales and limestones must chiefly represent the lower part of the *falciferum* Zone and/or the *spinatum* Zone and the *gibbosus* Subzone of the *margaritatus* Zone.

Our studies have demonstrated clearly (Fig. 4) that the black shales and associated strata are laterally discontinuous, something remarked upon by BOYER (1913). Thus the stratigraphic proximity of a datable horizon to the black shales does not necessarily give an accurate guide to their age: there are many nonsequences and synsedimentary disturbances. However, the fact that in Locality 1 the transition from the black shales and manganoan limestone to the overlying ammonite-bearing horizons is gradual, with no abrupt lithological change, suggests that the organic-rich unit is wholly or partly of early *falciferum*-Zone age. In contrast, the compact limestone bed rich in *Aulacoceras* and ammonites of *subnodosus*-Subzone age that occurs at Locality 5b contains hardgrounds and is very different to the overlying black shales and manganoan limestones: we suspect that there is a stratigraphic gap between the two lithologies.

In Localities 2 and 3 the base of the nodular ammonite-bearing horizon (*bifrons* Zone, *sublevisoni* Subzone) is between 8 and 10.5 m above the top of the black shales and manganoan limestones, whereas the whole of the section at Locality 1 is more condensed (Fig. 4). We assume that this thickness of section represents typical undisturbed sediments. The facies that overlie the black shales are a series of regularly bedded pelagic grey limestones and marls strictly comparable to the Domaro or Medolo of Lombardy. Sedimentary rates for these facies are estimated as 15–25 mm/$10^3$ years (BERNOULLI 1972). Taking 20 mm/$10^3$ years as average, half a million years would have elapsed during the deposition of 10 m of section. Allowing one million years for the duration of a Toarcian

ammonite zone (cf. VAN HINTE 1976; HARLAND et al. 1982; KENNEDY & ODIN 1982), it is probable that deposition of the black shales took place during the *falciferum* Zone.

To summarize: based particularly on the ammonites from Locality 1 and the general stratigraphy of Localities 2 and 3, we suggest that the organic-rich black shales and associated manganoan limestones from the Belluno Trough are of early *falciferum*-Zone age.

## Black shales from the Lombardy Basin and Trento Plateau

Organic-carbon rich shales have been recorded from a number of pelagic sections in the Lombardian Basin (Fig. 2) where they have been recognized as Toarcian in age (e.g. Val Varea: BERNOULLI 1964; Monte Brughetto: GAETANI & POLIANI 1978). In an attempt to arrive at a more refined level of dating we have interpreted the palaeontological data of CANTALUPPI & MONTANARI (1969) from a section adjacent to the Val Varea, known as the Val Ceppelline, both located north of the hamlet of Suello between Lecco and Como. In the Val Ceppelline, where the organic-rich level is very poorly exposed, we recognize the *tenuicostatum* Zone (whose base is taken to coincide with the appearance of the first *Dactylioceras*) below the shales and the *bifrons* Zone above them (Fig. 6). Thus the black shales certainly pertain to the *falciferum* Zone and conceivably part of the *tenuicostatum* Zone as well. Our interpretation of the stratigraphy differs slightly from that of MONTANARI (1974).

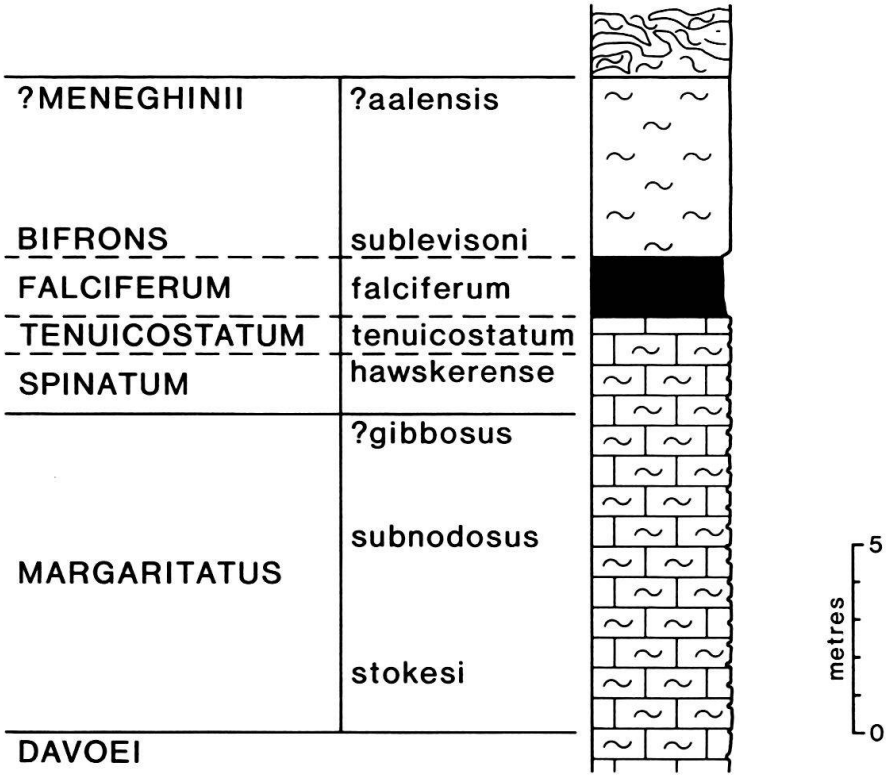


Fig. 6. Interpreted stratigraphy of the Val Ceppelline section, Lombardian Basin based on the faunal list of CANTALUPPI & MONTANARI (1969). The organic-rich shales (represented by the black ornament) overlie pelagic grey limestones; they are capped by pelagic red nodular limestones *(Ammonitico Rosso)* which are involved in a slump of probable post-Toarcian age. Ammonite zones shown in capitals; subzones in lower case. The Pliensbachian–Toarcian boundary lies at the junction between the *spinatum* and *tenuicostatum* Zones.

On Monte Brughetto, some 15 km east of the Val Varea and Val Ceppelline, a good roadside section of the organic-rich shales is exposed. The records of *Dactylioceras polymorphum* and *Hildaites* 1 m above the top of the shales are in conflict, as the former ammonite indicates the *tenuicostatum* Zone whereas the latter is typical of the *falciferum* Zone (cf. GAETANI & POLIANI 1978). This section contains a number of slumps, suggesting that the *Dactylioceras* may have been derived, a conclusion furthermore suggested by Otto Kälin's find (pers. comm. 1982) of the identical species some 12 m below the base of the black shales, immediately beneath where the section becomes argillaceous. Thus it seems that the organic-rich shales represent the *falciferum* Zone and conceivably part of the *tenuicostatum* Zone as well.

The Trento Plateau (Fig. 2) constitutes a structurally elevated palaeogeographic element of the Southern Alps, whose eastern edge is exposed in the Feltre Alps north of Venice (cf. WINTERER & BOSELLINI 1981). The detailed description of the pelagic Jurassic of this area by DAL PIAZ (1907) includes mention, in the Val di Vesa, of a black bituminous shale containing fish teeth and scales, a description which matches our own observations. According to DAL PIAZ, these shales pass laterally into grey-green limestones containing ammonites of basal Toarcian age. Since no *tenuicostatum*-Zone ammonites have been recognized from these limestones and the oldest forms (*Hildaites serpentinus, Hildaites levisoni*) pertain to the *falciferum* Zone, we take this as the age of the organic-rich shales (cf. CLARI & PAVIA 1980).

## Stratigraphic significance of organic-rich shales in the Southern Alps

The observations recorded above from the Belluno and Lombardian Basins and the Trento Plateau suggest that the organic-rich shales and associated manganoan limestones are of identical age, namely the *falciferum* Zone of the Toarcian. The data from the Belluno Basin indicate that these black shales chiefly represent the lower part of this zone and an extension down into the *tenuicostatum* Zone is not excluded. However, we lack sufficient stratigraphical resolution to say whether the black shales are everywhere early *falciferum* Zone in age or whether they were formed at slightly different times within, say, a *tenuicostatum-falciferum*-Zone window, their exact duration of deposition being perhaps governed by local environmental factors. Nevertheless, we believe that this organic carbon-rich level represents a marker unit of remarkable stratigraphic value. The idea that these beds are the product of some kind of regional "black-shale event" is given further credence by the fact that a level of lower *falciferum*-Zone organic-rich shales occurs across France, Switzerland, Germany, North Sea and northeastern England (*Schistes Cartons, Posidonienschiefer, Jet Rock:* WEITSCHAT 1973; MORRIS 1979; HOWARTH in COPE et al. 1980; RIEGRAF 1982; RIEGRAF et al. 1984) as well as elsewhere in the Tethyan region (e.g. GERMANN & WALDVOGEL 1971; WALZEBUCK 1982). Such widespread organic-rich horizons, present in both epicontinental and pelagic domains, recall those documented from the Cretaceous where they have been referred to the influence of Oceanic Anoxic Events (SCHLANGER & JENKYNS 1976; JENKYNS 1980; SCHLANGER et al. 1985).

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