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Revision of the stratigraphy of the Longobucco Group (Liassic, southern Italy); based on new data from nannofossils and ammonites

By JEREMY R. YOUNG¹⁾, C. TARQUIN TEALE¹⁾ and PAUL R. BOWN²⁾

ABSTRACT

The Longobucco Group is an anomalous sequence of Liassic sediments up to 1500 m thick, outcropping as a set of thrust slices in northeastern Calabria, southern Italy. It has African-margin affinities and faunas, but contains anomalously large amounts of siliciclastic debris, and may represent an intermediate sub-domain during the early Tethyan rifting. We recognise and name four widely mappable formations recording rifting and subsidence on Hercynian basement. Macrofaunal evidence indicates that the three lower formations (continental to shelf facies) are of early and mid-Liassic age. The uppermost formation consists of turbidites rapidly deposited in deep water during and after the main rifting phase, which we date as near the mid-late Liassic boundary. This reinterpretation is based on new evidence from nannofossils and ammonites. Nannofossils, even though not well-preserved or diverse are widespread and of considerable biostratigraphic use. One new combination, *Mitrolithus jansae* (WIEGAND), is proposed.

ZUSAMMENFASSUNG

Die Longobucco-Gruppe ist eine unregelmässige Abfolge von Liassedimenten, die, bis zu 1500 m mächtig, als eine Reihe von Schubzonen im Nordosten Kalabriens (Süditalien) zutage treten. Sie zeigen Ähnlichkeiten zum afrikanischen Kontinentalrand mit entsprechenden Faunen, enthalten aussergewöhnlich grosse Vorkommen von siliziklastischem Gesteinsschutt und könnten eine intermediäre Periode während der frühen Öffnungsphase des Tethys-Meeres verkörpern. Wir erkennen und nennen vier grossräumig kartierbare Formationen, die das Auseinanderbrechen und Absenken des herzynischen Grundgebirges darstellen. Die Makrofauna zeigt, dass die drei unteren Formationen (Kontinental- bis Schelffazies) aus dem frühen und mittleren Lias stammen. Die oberste Formation besteht aus Turbiditen, die während und nach der Hauptsenkungsphase (am Übergang vom mittleren zum oberen Lias) schnell in tiefem Wasser abgelagert wurden. Diese Interpretation stützt sich auf neue Funde von Nannofossilien und Ammoniten. Nannofossilien, obwohl weder gut erhalten noch mannigfaltig, sind doch weit verbreitet und von bedeutendem biostratigraphischem Wert. Eine neue nomenklatorische Kombination, *Mitrolithus jansae* (WIEGAND), wird vorgeschlagen.

RIASSUNTO

Il Gruppo di Longobucco è costituito da una serie sedimentaria liassica affiorante come una serie di scaglie tettoniche sul margine nord-est della Calabria, S. Italia. Lo spessore complessivo raggiunge i 1500 m. La sequenza ha affinità con il Margine Africano della Tetide, ma contiene molto detrito siliciclastico, e forse rappresenta una

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zona intermedia nel primo periodo di «rifting» della Tetide. Riconosciamo quattro formazioni litostratigrafiche che ricordano i periodi di «rifting» e subsidenza sul basamento Ercinico. L'esame dalla macrofauna mostra che le tre formazioni più basse (facies continentali e di piattaforma) sono del Lias inferiore e Lias medio. Le formazioni più recenti consistono in torbiditi depositate rapidamente in un mare molto profondo durante e dopo le principali fasi di «rifting», che abbiamo datate al passaggio Lias medio-Lias superiore. Questa reinterpretazione è basata su nuovi rinvenimenti di nannofossili e ammoniti. I nannofossili sono mal conservati ma diffusi e molto utili per la biostratigrafia. Una nuova combinazione, *Mitrolithus jansae* (WIEGAND) è proposto.

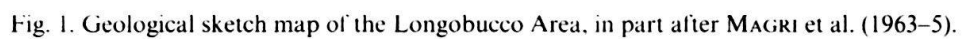
Introduction

The Longobucco Group is a sequence of early Jurassic sediments that outcrop over an area of about 170 km² in north-eastern Calabria (southern Italy, Fig. 1). The sediments of the group are preserved as a series of allochthonous and para-autochthonous thrust slices which formed during early Miocene Alpine compression and are a part of the Longobucco unit (sensu AMODIO-MORELLI et al 1979). However, despite this deformation, reasonably continuous and unmetamorphosed sections are preserved. These contain up to 1500 m of sediments ranging from continental clastics, via littoral and shelf clastic-carbonate sediments, to deep-marine turbidites. They were deposited unconformably on a Palaeozoic basement and record the early rifting of this basement in the Liassic.

Unravelling of the tectonostratigraphy of the region suggests that the Longobucco Group and its basement are part of Apenninic Italy, and so were palaeogeographically on the southern margin of Tethys (DE ROSA et al. 1980, SCANDONE 1982). This is also supported by the palaeontological provinciality of the ammonites, and arguably of the nannofossils. Whereas contemporaneous sequences in the Apennines are predominantly composed of calcareous sediments, the Longobucco Group contains siliciclastic detritus throughout the sequence. Within it are arkosic and lithic arenites which could have been locally derived (ZUFFA et al. 1980). They are subordinate, however, to quartz arenites. The origin of these is harder to explain and they possibly came from a juxtaposed (?) European massif. This suggests that the Longobucco Group may represent an intermediate palaeogeographic domain within the early Jurassic Tethys. Hence its history, and particularly the timing of sediment influx and rifting, are of interest for Tethyan geology.

Work has been done on various aspects of the Longobucco Group (particularly around the turn of the century), but no integrated study of the sedimentary sequence exists, and there have been some serious stratigraphic misinterpretations. These have been incorporated in various palinspastic reconstructions of the Calabrian Arc (e.g. BONARDI et al. 1982).

In this paper we present some early results of an integrated study being carried out by one of us (C.T.T.), and in particular a revised biostratigraphy, based on macrofossils and calcareous nannofossils. The latter group has rarely been used in Jurassic biostratigraphy. However, nannofossils are widely distributed in the Longobucco turbidites (which are otherwise virtually unfossiliferous), and hence provide invaluable extra information. Also some of the results of this study, may prove of use for Jurassic nannofossil biostratigraphy. As a result of our work on this material we found that revision of the genus *Mitrolithus* DEFLANDRE 1954 was necessary, and this is given in the systematic taxonomy.



Lithostratigraphy

Two groups of Jurassic sediments outcrop on the Ionian margin of north-eastern Calabria, the Longobucco and Caloveto Groups. The latter outcrops as isolated thrust slices and klippen northeast and east of the Longobucco Group's outcrop area. Most earlier workers (e.g. DI STEFANO 1904, QUITZOW 1935) associated the two groups closely. However, work on the Caloveto Group (SANTANTONIO & TEALE, in prep.) demonstrates

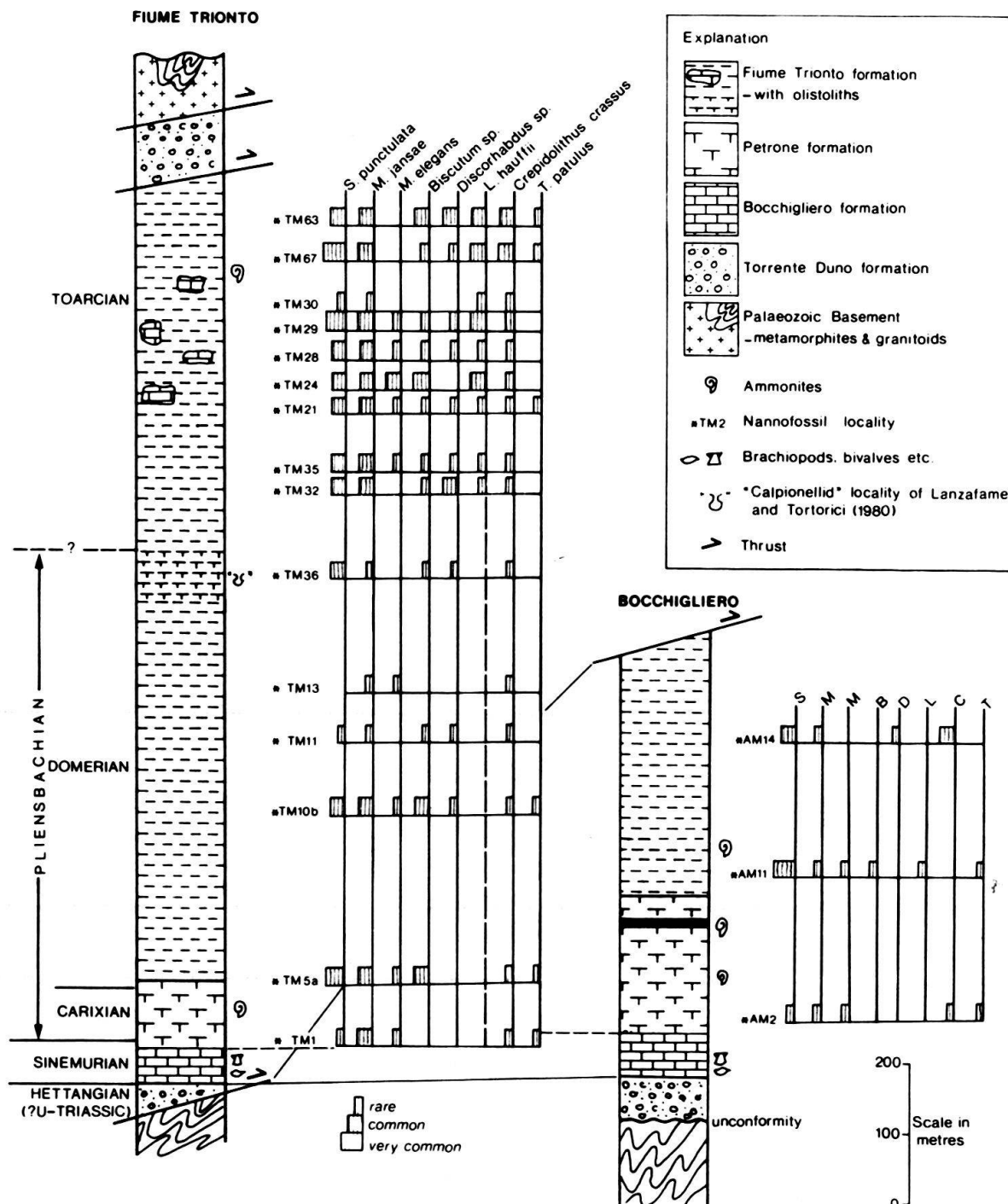


Fig. 2. Sedimentary logs, and nannofossil distribution charts for the Fiume Trionto and Bocchigliero traverses, indicating the position of fossil localities and our age interpretation.

that it is a condensed pelagic sequence, of Pliensbachian to Neocomian age. Hence it is sedimentologically and stratigraphically distinct from the, Liassic, Longobucco Group.

Within the Longobucco Group there is a clear threefold lithological subdivision. This was recognised by the early workers, who generally used the terms:

3. Formazione calcareo-marnoso-arenacea
2. Calcarei neri a brachiopodi
1. Verrucano, or anageniti ed arenarie

Some later workers (VIGHI 1953, MAGRI et al. 1963–5, BARBERA LAMAGNA 1970) in addition recognised a unit between 2 and 3, which VIGHI termed the “conglomerato e breccie transgressivi”. Our fieldwork indicates that this is a series of channel conglomerates locally occurring near the base of unit 3.

LANZAFAME & TORTORICI (1980) subdivided unit 3 into four members. The lowest of these has a distinct facies, can be traced between thrust slices, and mapped widely; we consider it a distinct unit. The other three members are not widely traceable outside their type areas. Sedimentological studies indicate that they are merely local turbidite facies variations.

Thus we recognise four major units in the Longobucco Group, which we consider to have formation status. We name these the Torrente Duno, Bocchigliero, Petrone, and Fiume Trionto Formations. This is similar to the position of ZUFFA et al. (1980) who described four broad facies associations in their pilot petrographic study. They are described in the Table and on Figure 2, but as field mapping is still in progress they are not distinguished on Figure 1.

The two stratigraphically important sections are separated by a significant thrust (see Fig. 2). This opens the possibility that these sections came from separate sub-basins and have been tectonically juxtaposed. This is probably not the case since the two sections have very similar stratigraphies, and diagenetic fabrics, and there is evidence for their correlation from macrofossils and nannofossils, as discussed in the biostratigraphic sections. The Bocchigliero section does seem, however, to have a better pelagic fauna and flora, and may have been deposited in more open marine conditions.

Biostratigraphy

Introduction: Since the first geological description of the area by LOVISATO (1879) numerous workers have studied aspects of the biostratigraphy of the Longobucco basin, notably around the turn of the century. MAGRI (1963–5) provided a good summary and bibliography of earlier work, and important subsequent studies have been made by BARBERA LAMAGNA (1970), DUBOIS (1976), and LANZAFAME & TORTORICI (1980). A number of problems were, however, left unresolved, as discussed below.

1. *Torrente Duno Formation (continental clastics):* The lithological similarity of this formation to the Alpine Verrucano tectofacies (see CASSINIS et al. 1979) suggested a Triassic age to various workers (e.g. LOVISATO 1879, LANZAFAME & TORTORICI 1980). This analogy is supported by our discovery at one horizon of a “J-shaped” feeding burrow, *Feursichnus communis* BROMLEY & ASGARD 1979. This ichnospecies has previously only been recorded from continental facies Triassic, of Germany (HÄNTZCHEL 1975) and Greenland (original description).

Table: Summary of the sedimentological and palaeontological features of the formations of the Longobucco Group.

STRATIGRAPHIC UNIT & Type section	THICKNESS & PROBABLE AGE	ENVIRONMENTS OF DEPOSITION
FIUME TRIONTO FM. (FTFM) Vallone di Fiume Trionto below Longobucco	1200+ m L.Domerian to E.Toarcian	Turbidites, seismoturbidites (sensu MUTTI ET AL 1984), megaturbidites, hemipelagites, olistostromes, debris flows and olistoliths. Local extensional normal faulting in sequence. Olistoliths are of BFM, TDFM, & occasionally basement. Trace fossil associations are dominated by deep water forms (Protopalaeodictyon, Palaeodictyon, Neonereites, and Cosmoraphe), Chondrites is present only in the lower part of the sequence.
PETRONE FM. (PFM) Lower Fosso Petrone	30 - 220 m L.Carixian to E.Domerian	Biomicroites, marls, lithic wackestones, channelised breccias and conglomerates, slumps and minor disconformities. Storm & deltaically dominated shelf, shelf break, and slope deposits. Trace fossils include: <u>Diplocraterion</u> , <u>Rhizocorallium</u> , <u>Chondrites</u> and <u>Zoophycos</u> . Plant debris, lamellibranchs and ammonites are locally present. A red ammonitiferous marl occurs about 20m from the top, and is a useful datum.
BOCCHIGLIERO FM. (BFM) Cliffs to the South, S.E., and N.E. of Bocchigliero.	0 - 60 m Sinemurian to E.Carixian	(b) 0-30m of bio- & pelmicrites. Strongly bioturbated, few original bedforms are preserved. Locally with rich faunas including: <u>Pecten</u> , <u>Pholadomya</u> , <u>Lithiotis</u> , <u>Waldheimia</u> , <u>Rhynchonella</u> , <u>Terebratula</u> , <u>Zelleria</u> , and <u>Spiriferina</u> . Sub-littoral open marine shelf facies. (a) 0-40m of siliciclastic rich bio- and oosparites, bio-, oo-, pel- and onkomicrites. Diverse shelly fauna. <u>Thalassinoides</u> , <u>Spongelliomorpha</u> and <u>Skolithos</u> are abundant. Sigmoidal cross stratification (sensu MUTTI ET AL 1984b), and current bi-directionality. Complex littoral, shore face and lagoonal facies.
TORRENTE DUNO FM. (TFM) Cliffs to the East of Bocchigliero.	0 - 70 m Hettangian	Polymict conglomerates and breccias, sand-, silt- and mudstones. Unconformable on basement. Plant debris, rafted coals, and trace fossils (<u>Ophiomorpha</u> , <u>Fuersichnus communis</u>). Facies developed indicate ephemeral braided stream and alluvial fan environments.

However, DUBOIS (1976) has recorded Jurassic spores from the top of the formation, and both the trace fossil and the facies are manifestly capable of being diachronous. We also consider it significant that the formation passes gradually and conformably into the overlying, marine, Bocchigliero Formation. As discussed below this is Sinemurian in age, thus the Torrente Duno Formation is probably mainly Hettangian, rather than Triassic.

2. *Bocchigliero Formation (littoral and shallow marine limestones)*: The faunas of this formation, well documented by the early workers, are dominated by brachiopods and bivalves (notably pectinids) with rarer gastropods, echinoderms, corals and bryozoa. As no good ammonites or foraminifera have been found, this benthic macrofauna has had to be used for biostratigraphy. A Liassic age is clearly indicated by various genera, such as *Zeilleria*, *Spiriferina*, and *Lithiotis*. Detailed work by FUCINI (1893, 1896, 1920), GRECO (1892, 1893), DI STEFANO (1900, 1904), ONETTI (1915), and MAGRI et al. (1963–5) indicates that the fauna is early Liassic, probably Sinemurian. There is less agreement as to whether it is early or late Sinemurian.

In addition some evidence has been presented for a Carixian (early Pliensbachian) age for the top of the formation; BARBERA LAMAGNA (1970) recorded an *ibex* zone (mid-Carixian) ammonite fauna from it. Also LANZAFAME & TORTORICI (1980) interpreted brachiopod assemblages from the uppermost level as Carixian. Unfortunately, in neither case is the evidence very strong, but it is quite possible that the Bocchigliero Formation is, in part, Carixian.

The faunas of the Bocchigliero and Fiume Trionto thrust slices are very similar, suggesting that they correlate closely.

3. *Petrone Formation (marls and shelf-slope clastics)*: Although not prolifically fossiliferous, this formation has yielded reasonable ammonite faunas, mainly from the Bocchigliero section. As a result it is the best dated part of the sequence. Early workers interpreted the faunas as late Liassic (Toarcian); notably GRECO (1896), FUCINI (1893b, 1896), and DI STEFANO (1904). Subsequent revision of this work has indicated a Domerian (late Pliensbachian) age: BONARELLI (1896), FUCINI (1920), MAGRI et al. (1963–5), and BARBERA LAMAGNA (1970). This is supported by our work, as discussed below.

The base of the Petrone Formation is frequently complicated by the presence of small thrusts, disconformities, channel conglomerates, prograding fan conglomerates, and debris flows. This, and the absence of good Carixian faunas, suggested to various authors that the marls were disconformable on the limestones. However, in some places (notably the Trionto section) a gradual transition is visible, and we feel it is unlikely that there is a significant hiatus. Instead the Carixian is probably represented by the lower part of the Petrone Formation (in which good ammonite faunas have not been found), or by the upper part of the Bocchigliero Formation, neither of which have suitable facies for the preservation of ammonites.

4. *Fiume Trionto Formation (turbidites)*. This forms the bulk of the succession but has been the least well dated part. As turbidites are usually deposited rapidly, and as they grade into the marls below, various authors have suggested that they are probably not much older than the marls; i.e. late Liassic (e.g. GRECO 1896, FUCINI 1920, MAGRI et al. 1963–5). On the other hand CORTESE (1895) interpreted them as part of the Eocene flysch seen further east. More importantly LANZAFAME & TORTORICI (1980) recorded a calpion-

nellid assemblage from three sites including one half way up the Fiume Trionto section. This suggested to them a Berriasian age for these samples and so a Toarcian to Cretaceous age for the formation. However, they described their specimens as badly preserved and strongly recrystallized (“mal conservato e fortemente ricristallizzato”), so this data cannot be regarded as conclusive. Unfortunately we have not been able to re-examine their material.

Our evidence, as discussed in detail below, strongly indicates that the turbidites are Liassic. This comes in part from nannofossils. Although not very well preserved or diverse, the nannoflora is distinctively upper Liassic. A similar age is indicated by a new ammonite locality near the top of the section with lowermost Toarcian ammonites. It is extremely hard to reconcile this data with the record of calpionellids. The nannofossils occur throughout the section so we can be confident that there is no tectonically introduced Berriasian, and reworking of the ammonites and all the nannofossils is not credible. So we feel it is more likely that the fossils found by LANZAFAME & TORTIRICI were foraminifera, or calcified radiolaria.

Thus it seems the Fiume Trionto Formation was deposited in a short period around the Domerian/Toarcian boundary. It is, however, likely that younger turbidites were deposited, since the uppermost preserved turbidites are the end members of a deepening sequence of facies and ichnocoenoses, and no shallowing cycle is seen.

Nannofossil evidence

Introduction: Smear slides were prepared using standard techniques from some 64 samples, mostly from the Fiume Trionto section, as this is the longest and least deformed section in the area. We also looked at some samples from the Bocchigliero section to test the correlation of these two sections. Nannofossils were present in most of the samples, but were usually poorly preserved and neither common nor diverse. However about 20 of the samples contained reasonably abundant and well-preserved nannofloras, the distribution of which is shown on Figure 2. Most of these better samples came from unusually pale and thick interturbidite beds, and probably represent genuinely hemipelagic sediments.

Results

The nannoflora obtained from the processed samples was of low diversity consisting of the following nine species:

Biscutum sp.

Crepidolithus crassus (DEFLANDRE, in DEFLANDRE & FERT 1954) NOEL 1965.

Discorhabdus sp.

Lotharingius hauffii GRÜN & ZWEILI 1974

Mitrolithus elegans DEFLANDRE, in DEFLANDRE & FERT 1954

Mitrolithus jansae (WIEGAND 1984a) n.comb.

Parhabdolithus liasicus DEFLANDRE 1952

Schizosphaerella punctulata DEFLANDRE & DANGEARD 1938

Tubirhabdus patulus ROOD HAY & BARNARD 1973 ex PRINS 1969

A brief discussion is given of those species of particular interest, or biostratigraphic significance.

A. *Biscutum* and *Discorhabdus*: The appearance of the Biscutumaceae in the Lower Jurassic is of major biostratigraphical value and evolutionary significance. They first occur in the Lower Pliensbachian, and have a radiating placolith structure.

B. *Crepidolithus crassus*: This occurs ubiquitously in the samples studied, probably because of its massive blocky structure, which is resistant to diagenetic dissolution, and actually promotes secondary overgrowth. It ranges from Upper Sinemurian to Kimmeridgian.

C. *Lotharingius hauffii*: A small ellipsagelosphaerid coccolith with a narrow, cross filled, centre. This species is the first of the highly successful ellipsagelosphaeraceae, coccoliths with imbricate placolith rims. Its first occurrence is hence of biostratigraphic and evolutionary interest, and seems to occur in the Upper Pliensbachian. As illustrated (Plate, Fig. B, C) the central structure is not preserved in our material, but identification is possible from the rim structure, and size.

D. *Mitrolithus elegans* and *Mitrolithus jansae*: Both these species have limited ranges within the Lower Jurassic, but lack of distributional data has so far prevented their effective biostratigraphical use. The approximate range of *Mitrolithus elegans* is Lower Sinemurian to Lower Toarcian. *Mitrolithus jansae* is less well known but has been recorded from the Upper Sinemurian to Lower Toarcian (see below – systematic taxonomy).

E. *Parhabdolithus liasicus*: A typical Lower Jurassic form ranging from Sinemurian to Lower Toarcian.

F. *Schizosphaerella punctulata*: A bivalved nannofossil of uncertain affinities. It is commonly found in great abundance in Lower Jurassic strata and to a lesser extent in the Middle Jurassic. It has been described in great detail by AUBRY & DEPECHE (1974), MOSHKOVITZ (1979), KÄLIN (1980) and KÄLIN & BERNOULLI (1984). KÄLIN suggested that rather than behaving solely as a sediment contributor, *S. punctulata* acts more importantly as a site for nucleation of diagenetic calcite, a phenomenon seen in many of the Longobucco samples (see Plate, Fig. J, K)

Age determination

Lower Jurassic calcareous nannofossils are relatively poorly studied, and the limited distribution data (particularly away from northwestern Europe) has so far prevented the development of a universally acceptable zonation scheme. However, there have been enough studies of well-dated sections for the ranges of most of the more important species to be reasonably well constrained. This information is summarised in Figure 3. Our age determination of the studied section is based on the following points.

1. The nannoflora is a typical, if slightly impoverished, Lower Jurassic assemblage.
2. The presence of Biscutumaceae implies an age of at least early Pliensbachian.
3. *M. elegans*, *M. jansae*, *P. liasicus* indicate an age not younger than early Toarcian.
4. *Lotharingius hauffii* indicates an age of at least late Pliensbachian.

AGE	AMMONITE ZONE		SPECIES										
			Schizosphaerella punctulata	Tubirhabdus patulus	Parahadolithus liasicus	Mitrolithus elegans	Crepidolithus crassus	Biscutum sp.	Discorhabdus sp.	Mitrolithus jansae	Lotharingius hauffii		
TOARCIAN	late	levesquei											
		thouarense											
		variabilis											
	early	bifrons											
		falciferum											
		tenuicostatum											
PLIENSCHACHIAN	late (Domerian)	spinatum											
		margaritatus											
	early (Carixian)	davoei											
		ibex											
		jamesoni											
SINEMURIAN	late	raricostatum											
		oxynotum											
		obtusum											
		turneri											

Fig. 3. Composite range chart for the nannofossil species found in the Longobucco samples. Based on data in CRUX (1984), HAMILTON (1982), MEDD (1982), PRINS (1969), WIEGAND (1984a), and unpublished data of P.R.B.

- The flora is quite unlike typical middle or late Jurassic assemblages; ellipsagelosphaerids are not dominant, and key genera such as *Stephanolithion* and *Cyclagelosphaera* are absent. Thus the age of the section is early Pliensbachian to early Toarcian, with an age of at least late Pliensbachian for those samples with *L. hauffii*.

For intrabasinal correlation the most important problem was whether the Bocchigliero and Fiume Trionto thrust slices were of the same age or merely had similar but diachronous facies. The similarity of the nannofossil assemblages observed from these sections suggests that the lithologies may be directly correlatable.

The ammonite evidence, which suggests a late Pliensbachian to early Toarcian age, is in good agreement with the nannofossil data. This is an interesting affirmation of the utility of nannofossil biostratigraphy in Lower Jurassic rocks.

Assemblage interpretation

Although the assemblages from the Longobucco sediments are sufficiently similar to other Lower Jurassic sediments to allow confident dating, they are rather unlike typical assemblages from northwestern Europe. They lack several species usually present, such as *Calculus cribrum* and *Axopodorhabdus cylindratus*. This reduced diversity might be a

preservational effect; however, the high abundances of *M. jansae* (Fig. 2) are anomalous. In this respect the floras are very similar to ones recovered from the northwestern African margin on DSDP leg 79 (site 547B). Sinemurian and early Pliensbachian nannofloras from this material are dominated by *M. jansae* (WIEGAND 1984b, and P.R.B., unpubl. data). Another assemblage with similarities to the Longobucco material was reported by NICOSIA & PALLINI (1977) from the Domerian and Toarcian Rosso Ammonitico of the central Apennines. They did not identify *Mitrolithus* but it is likely that the species they recorded as *Parhabdolithus* cfr. *robustus* was *M. jansae*.

So there are distinct indications that the differences between the Longobucco nannoflora and northwestern European nannofloras reflect latitudinal or environmental controls.

Ammonite evidence

Revision of previous work

Numerous authors have recorded ammonites from the Petrone Formation and possibly from parts of the basal Fiume Trionto Formation. However their correlations were based on a range of different zonal schemes, some of which are now obsolescent. A revision of their biostratigraphic conclusions in the framework of modern zonal schemes (DEAN et al. 1961, WIEDENMAYER 1980) indicates that the faunas are predominantly upper Domerian, *spinatum* zone. The lower Domerian *margaritatus* zone is indicated by the recording of *Fuciniceras cornacaldense* (TAUSCH). There is no significant evidence for the Toarcian other than three species which GRECO (1896) tentatively recorded; (?) *Harpoceras* (*Grammoceras*) *radians* REIN [this is a junior synonym of (?) *Hildaites striatus* GUÉX], (?) *H. serpentinum* REIN, and (?) *Harpoceras falciferum* SOWERBY. These would suggest the *falciferum* zone, but we doubt their validity.

For the most part these localities seem to be at the top of the Petrone Formation, and in the Bocchigliero thrust slice (BARBERA LAMAGNA 1970). Unfortunately, however, it is often impossible to determine the precise stratigraphic position of localities from the geographical information given.

Our Domerian fauna

We collected a reasonable ammonite fauna at a locality in the Vallone Santa Croce (Bocchigliero thrust slice) from an ammonitiferous red marl near the top of the Petrone Formation (black horizon on Fig. 2). This is composed of:

Protogrammoceras marianii (FUCINI)

P. curionii (MENEGHINI)

P. celebratum (FUCINI) (Plate, Fig. N)

P. dilectum (FUCINI) (Plate, Fig. O)

P. pectinatum (MENEGHINI)

Fuciniceras cf. *ambiguum* (FUCINI)

F. ex gr. lavinianum (MENEGHINI)

(Specimens are deposited from Rome University Geology Dept. with G. Pallini and M. Santantonio, who identified them.)

This fauna, like the others from Longobucco has, as noted by GRECO (1896), a fully Mediterranean character. This is shown in particular by the absence of amaltheids (cf. HOWARTH 1973). Nonetheless, as WIEDENMAYER (1980) has demonstrated the standard zonal scheme of DEAN et al. (1961) is still the most useful frame of reference for Mediterranean ammonite faunas in the Domerian. Within this scheme our fauna belongs to the *stokesi* subzone of the *margaritatus* zone: i.e. it is earliest Domerian in age.

Combining this with the earlier work as described above we have good evidence from ammonites for the entire Domerian, but not for the Toarcian.

Our Toarcian fauna

We discovered a new ammonite bearing locality about 100 m below the top of the Fiume Trionto section. Sixteen specimens were collected here, all fairly well preserved and without marked abrasion or other signs of reworking.

The assemblage consists of:

Dactylioceras pseudocommune FUCINI

D. perplicatum FUCINI (Plate, Fig. O)

D. triangulum FISCHER

D. simplex FUCINI, sensu PALLINI in FARINACCI et al. (1978)

Lioceratoides sp. (Plate, Fig. P)

We consider this fauna to be lowermost Toarcian (*tenuicostatum* zone of DEAN et al. 1961). In particular, the co-occurrence of *Lioceratoides* (a remnant of late Domerian faunas) with the earliest *Dactylioceras* species (*D. pseudocommune*) is significant. This indicates the *mirabile* subzone of GUÉX (1973). More generally it is widely accepted that *Dactylioceras* first appears in the basal Toarcian (see FERRETTI 1970, and GUÉX 1973 for discussion).

The preserved top of the Fiume Trionto Formation is thus early Toarcian in age.

Summary and conclusions

1. The lithostratigraphy indicates that the Longobucco Group was deposited without substantial hiatuses in a subsiding basin. Within this sequence four formations are consistently recognisable, recording progressively deepening depositional environments.
2. The biostratigraphic data show that the formations are not strongly diachronous, but represent basinwide changes in depth due to rifting.
3. The entire group is Lower Jurassic in age. In particular the Fiume Trionto Formation is Domerian–Toarcian in age, not ranging into the Cretaceous as has been suggested, and used in reconstructions of the Calabrian Arc. This interpretation is based on strong evidence from ammonites and nannofossils.
4. The ammonite evidence further suggests that the Fiume Trionto Formation, which is 1300 m thick, was deposited within the *spinatum* and *tenuicostatum* ammonite zones. This indicates a time span of 4 m.y. or less, and so a deposition rate in excess of 300 m/m.y. Also this was accompanied by marked subsidence, as indicated by ichno-coenoses and sedimentary facies. The lower three formations by contrast were all

deposited near sea level and are only some 200 m thick. As they represent most of the early Jurassic, a time period of 10–15 m.y., their average deposition rate was only around 20 m/m.y.

Hence the Fiume Trionto Formation records a period of greatly increased local subsidence, deposition, and presumably extensional tectonism. Further evidence of this, late Pliensbachian–early Toarcian, activity is provided by the presence of olistoliths, debris flows and megaturbidites in the succession (Table 1, TEALE 1985).

5. The evolution of the Longobucco basin is thus closely comparable to that of other sequences in the Tethys as elucidated by BERNOULLI & JENKINS (1974). The first indications of rifting are in the late Triassic with major rifting occurring in the Pliensbachian to Toarcian interval. The Longobucco basin is anomalous however, as rifting occurred on a crystalline basement, not platform carbonates, and was followed by deposition of siliciclastic sediments.
6. The nannofossil study is one of the first attempts to use this group to solve stratigraphic problems in the Liassic – as opposed to nannofossil studies in already well dated sections. It demonstrates that they are useful in this period even at the present limited state of study. This is particularly valuable since rather few microfossil groups are useful in the Liassic.

Systematic taxonomy

Genus *Mitrolithus* DEFLANDRE 1954 (emend)

Type species *Mitrolithus elegans* DEFLANDRE 1954

Emended diagnosis. – Coccoliths with an outer rim of thin broad calcite laths, oriented perpendicular to the base, and tangential to the ellipse. The central area is filled by a massive circular boss or spine consisting of several superimposed cycles of radial calcite elements. The spine sits in the coccolith rim on an inner cycle of rim elements and is attached via a narrow, hollow spine base.

Remarks. – DEFLANDRE first erected the genus *Mitrolithus* in 1954 defining it as “Discolithe en cuvette dont le centre porte une protubérance massive évasée, d’allure fongiforme, donnant à la vue latérale l’aspect d’une mitre” (a bowl shaped discolith the central area of which bears a massive flaring mushroom-shaped protuberance, giving the lateral view the appearance of a mitre). The emended diagnosis introduces ultrastructural details into the description, and removes unnecessarily restrictive and imprecise similes. It covers both *M. elegans* and *M. jansae*.

Mitrolithus elegans DEFLANDRE 1954

- 1954 *M. elegans* DEFLANDRE in DEFLANDRE & FERT, p. 148, Pl. Fig. 9–11, Textfig. 67.
 1965 *Alvearium dorsetense* BLACK, p. 136 and 138, Fig. 8.
 1967 *A. dorsetense* BLACK, p. 139.
 1969 *M. elegans* PRINS, p. 552, pl. 1; Fig. 11.
 1973 *A. dorsetense* ROOD, HAY & BARNARD, p. 382, Pl. 3, Fig. 9.
 1984 *M. elegans* CRUX, p. 81, Fig. 8 (5, 6), Fig. 14 (9, 10, 11).

Remarks. – An emended diagnosis of this species is not given as work is still in progress. We have included figures of it to illustrate the affinities to *M. jansae*. The SEM illustration (Plate, Fig. L) is the first published with the spine attached and clearly shows its distinctive “*A. dorsetense*” distal surface. It also exhibits rather peculiar layering, a highly variable feature.

Mitrolithus jansae WIEGAND 1984 n.comb. (BOWN & YOUNG)

1969 *Mitrolithus irregularis* n.sp. PRINS, Pl. 1, Fig. 12 invalid (ICBN art 32).

1984a *Calxivascularis jansae* n.gen. n.sp. WIEGAND, p. 1151, Pl. 1, Fig. A–G.

1984b *C. jansae* WIEGAND, p. 665–6, Pl. 3, Fig. 4.

Description. – The diagnosis and description given in WIEGAND (1984a) is very comprehensive and no addition is considered necessary. It should, however, be noted that the species shows considerable variation in the relative dimensions of the spine and rim, and in the shape of the spine.

Size. – 4–8 μm .

Remarks – *Mitrolithus* as described by DEFLANDRE remained monospecific until 1969 when PRINS figured the species “*irregularis*” and attributed it to *Mitrolithus*. Unfortunately he omitted a written diagnosis and description, thus creating a *nomen nudum*. The species remained neglected until in 1984 WIEGAND described and illustrated a new genus and species, *Calxivascularis jansae*, identical to PRINS’ *M. irregularis* (compare PRINS’ Pl. 1/12 and WIEGAND’S Fig. 1/F).

Although the specific name *jansae* stands as the first valid description of the coccolith, we suggest that the genus *Calxivascularis* is superfluous. The two species appear to be very closely related, and both genera are otherwise monospecific.

Differences. – Both *M. elegans* and *M. jansae* are usually observed in side view as illustrated by PRINS, whose sketches show the distinguishing characters well. *M. jansae* commonly possesses a higher rim than *M. elegans*, often entirely enclosing the spine, which is nearly parallel sided in contrast to the flaring spine of *M. elegans*. In plan view *M. jansae* is markedly more rounded than *M. elegans*. We suspect that, as PRINS (1969) suggested, *M. jansae* evolved from *M. elegans*; by a heightening of the rim and elongation of the elements of the spine. However, more biostratigraphical data are needed to prove this.

Distribution. – *M. jansae* has only appeared twice before in nannofossil literature, but has also been observed elsewhere by us.

1. PRINS (1969) recorded it, as *M. irregularis*, in samples from unspecified northwestern European localities, and gave it a range from the *davoei* zone to the *spinatum* zone (mid–Upper Pliensbachian).
2. WIEGAND (1984a, b) recorded the species from DSDP leg 79, site 544b (off the Moroccan coast, northwestern Africa) in cores he dated as late Sinemurian to early Pliensbachian, although without ammonite control.
3. BOWN (1983, unpublished data) observed rare *M. jansae* in samples from the Mochras borehole, northwestern Wales, ranging from the *spinatum* zone to the *tenuicostatum* zone (Upper Pliensbachian to Lower Toarcian).

This distributional information is summarized in Figure 3. It suggests that this distinctive and solution-resistant coccolith also has considerable biostratigraphical potential, at least in the Tethyan area.

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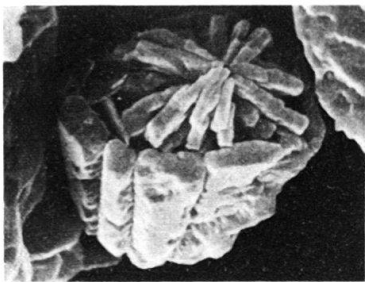
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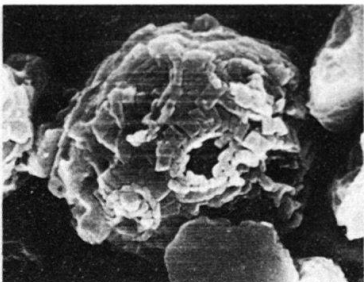
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Plate

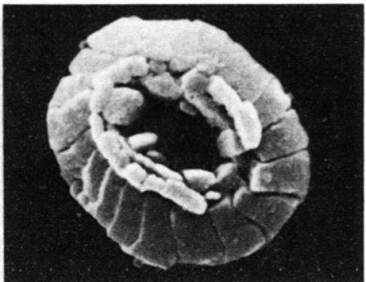
- Fig. A, D, G, H: *Mitrolithus jansae* (WIEGAND 1984) n.comb. A, D from DSDP, sample 547B-15-1. A \times 8000, D \times 6500 (same specimen). G, H from sample TM66, \times 1500, cross polars. Note variation.
- Fig. B, C: *Lotharingius hauffii* (GRUN & ZWEILI 1974), from sample AM11. B coccosphere \times 3000. C \times 7500.
- Fig. E: *Discorhabdus* sp., from sample TM28. \times 8000.
- Fig. F: *Biscutum* sp., from sample TM28. \times 7500.
- Fig. I, L: *Mitrolithus elegans* DEFLANDRE 1954. I from sample TM21, \times 1500, cross polars. L from sample J237 (I.C. colln. locality unknown), \times 4000. Spine exhibits layering and shows "*A. dorsetense*" type distal surface.
- Fig. J, K: *Schizosphaerella punctulata* DEFLANDRE & DANGEARD 1938. From sample TM29. J phase contrast, K cross polars, \times 1000. Note thick overgrowth fringe around two-thirds of the test.
- Fig. M: *Crepidolithus crassus* (DEFLANDRE 1955) NOEL 1965. From sample TM35, \times 4500.
- Fig. N: *Protogrammoceras celebratum* (FUCINI). From Vallone Santa Croce (PFM). \times 0.6.
- Fig. O: *P. dilectum* (FUCINI). From Vallone Santa Croce (PFM). \times 1.2.
- Fig. P: *Lioceratoides* sp. From locality 2 km northeast of Longobucco (FTFM). External mould, \times 1.5.
- Fig. Q: *Dactylioceras perplicatum* FUCINI. Same locality as P. \times 1.5.



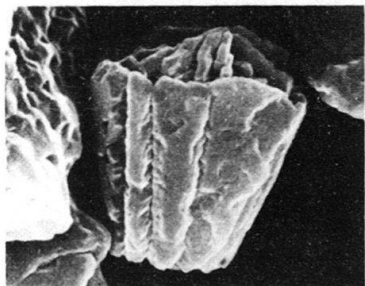
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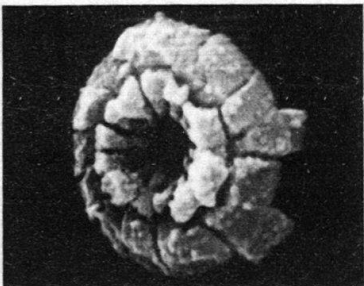
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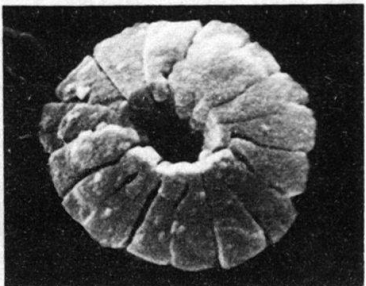
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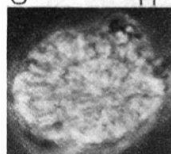
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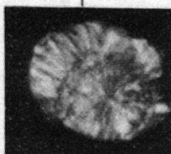
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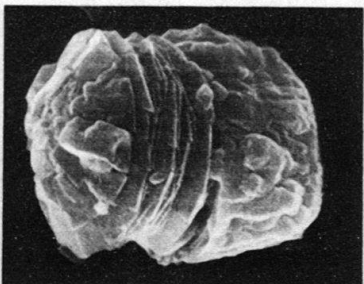
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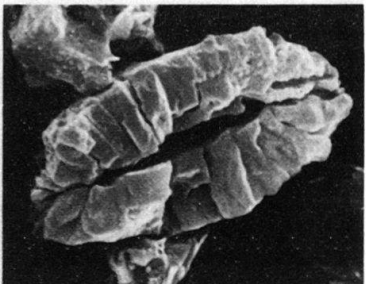
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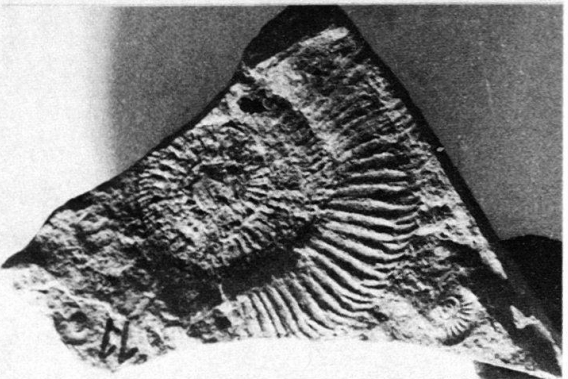
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