Chapter 4

Isolated Olistoliths from the Longobucco Basin, Calabria, Southern Italy

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ABSTRACT

The Longobucco Group is a cover sequence of Liassic sediments recording rifting of Hercynian crystalline basement. Within turbidites of the upper part of this sequence are numerous olistoliths, up to 250 m long. These are not parts of olistostromes, or other mass movement deposits, but appear to have travelled into the basin independently; hence the term 'isolated olistolith' seems appropriate for them. Soft-sediment deformation structures around the margins of one well-exposed olistolith suggest an analogy with 'outrunner-blocks' recently described from a modern submarine slope-failure complex by Prior *et al.* (1982, 1984). In both cases the blocks appear to have travelled considerable distances across very low slopes without disturbing the underlying sediments to any great extent. Transport probably occurred relatively rapidly with the aid of overpressuring of the underlying sediments.

INTRODUCTION

Isolated olistoliths may be defined as massive blocks of rock occurring out of place, but with sedimentary contact relationships, within unrelated sediments. These relationships, which suggest that the blocks were emplaced as single masses into the basins in which they occur, are conceptually improbable, and only rarely observed. In this paper we describe examples found while mapping the Longobucco Group in Calabria, S. Italy.

The Longobucco Group is a 1500-m thick sequence of sediments which records the formation of a deep extensional basin on Hercynian crystalline basement in the Early Jurassic (Young *et al.*, 1986; Santantonio and Teale, this volume). The olistoliths are colossal blocks, up to 250 m long, of shallow marine limestones and other lithologies from the base of the succession. They occur, however, in the upper part of the sequence, within basin–plain turbidites. Recognition of the blocks as isolated olistoliths helped considerably in the development of our understanding of the history of the basin. Additionally, finely preserved soft-sediment deformation features found around some of the olistoliths provide new evidence for the mechanism of emplacement of such blocks.

After describing the Longobucco olistoliths and their setting, we briefly review analogous cases described from other areas. In particular, comparisons are made between the Longobucco olistoliths and some blocks emplaced during a recent submarine slope failure, described from British Columbia by Prior *et al.* (1982, 1984). This comparison leads us to propose a possible mechanism of emplacement for isolated olistoliths.

Terminology

Some comment on terminology is needed, since virtually every author has used different nomenclature when describing isolated olistoliths (see Table 1). The most common terms are: olistolith; slide block; and

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glide block. Others include: exotic block; allochthonous block; allochthonous exotic block; sedimentary klippe; olisthothrymma; olisthoplaka; and local names such as Cipit block. The use of the terms 'exotic' and 'allochthonous' seems inappropriate, and potentially confusing, since they have strongly tectonic overtones, whereas the relations are clearly sedimentary. The combination 'allochthonous exotic' is pointless since the two words have essentially the same meaning in this context. 'Sedimentary klippe' evocatively describes a common outcrop mode but is completely misleading in terms of geological relationships. The neologisms 'olisthothrymma' and 'olisthoplaka' were proposed by Richter and Mariolakis (1973) and Richter (1973) for, respectively, slide masses occurring independently, and ones occurring as isolated fragments of gravity nappes. These seem unnecessary and unwieldy names, and they have not been widely used.

'Slide block' and 'glide block' are more attractive terms, and have been increasingly used of late. In current usage (Nardin *et al.*, 1979) slides are mass movements with limited internal deformation. They include both slumps, in which rotation is important, and glides, in which only linear motion occurs. Thus, 'slide block' and 'glide block' have nearly the same meaning and can both legitimately be used. Of them 'slide block' seems preferable as its meaning is clearer, and since some blocks are rotated.

The term is, however, explicitly genetic and so an alternative is needed for cases where the mechanism of emplacement is uncertain, and for field use. Although olistolith (Greek—slide stone) does have genetic roots they are not explicit, so it has been used much more in a descriptive sense. The main problem with its use is that as originally defined, by Flores (1955), it only covered matrix-supported clasts. However, this definition, and that of olistostromes, was clearly emended by Jacobacci (1965) and Abbate *et al.* (1970), so that blocks occurring independently of olistostromes were included. We favour this usage with the addition of the qualifier 'isolated' where appropriate.

THE LONGOBUCCO OLISTOLITHS

Background—The Longobucco Group

The olistoliths discussed in this paper occur within the Liassic sedimentary rocks of the Longobucco Group. These outcrop over some 170 km^2 as a tectonically shortened, but well preserved, sequence on the north-east margin of Calabria, S. Italy (Fig. 1). They probably extend farther beneath the late Tertiary deposits of Calabria, and may occur offshore. Associated with the group are condensed pelagic sediments of Liassic to Early Cretaceous age, the Caloveto Group (Santantonio and Teale, 1985; and in preparation). Together these two groups constitute the Mesozoic cover sequence to Hercynian granitoids and metamorphites of the Longobucco Unit. This unit forms a part of the Calabro-Peloritani Arc, which is generally interpreted as an isolated fragment of the Eo-Alpine chain thrust over the Apenninic carbonate sequences (Scandone 1979, 1982). Palinspastic reconstructions suggest that the Longobucco Unit occupied a position between the Apenninic units to the west and the main Calabrian Alpine units to the east, on the African margin of the Tethys (De Rosa *et al.*, 1980).

The main subsidence and basin formation event recorded by the Longobucco Group occurred during the Late Pleinsbachian–Early Toarcian and so was synchronous with the well-documented late Liassic break-up of Triassic carbonate platforms throughout the Tethyan area (Bernoulli and Jenkyns, 1974). This suggests that it too developed by rifting, although in this case of a crystalline basement. The facies developed in the Longobucco Basin were, however, quite different from the typical Tethyan carbonates, due to the influx of siliciclastic detritus. Santantonio and Teale (this volume) discuss further aspects of the setting of the group. Important studies of its sedimentology and stratigraphy include those of Magri (1963–65), Zuffa *et al.* (1980), and Young *et al.* (1986).

The succession commences with up to 70 m of 'red beds', mixed continental clastics, the Torrente Duno Formation (Fig. 2). These lack age-diagnostic fossils but are probably Hettangian. The base is commonly faulted, but in places the formation can be seen to rest directly on crystalline basement rocks. Upwards, it passes gradationally into variable shallow marine carbonates, commonly sandy up to 60 m thick. These have Sinemurian shelly faunas and constitute the Bocchigliero Formation. The succeeding Petrone Formation is up to 200 m thick and records passage into deeper water with bioturbated marls the dominant lithology; it has yielded quite good Pliensbachian ammonite faunas.

The bulk of the succession is formed of turbidites of the Fiume Trionto Formation, in which the olistoliths occur. Up to 1200 m of the turbidites are preserved, and presumably they were originally thicker, as the top of the formation is everywhere either truncated by erosion, or cut-out by thrust faults. Near the preserved top of the sequence ammonites of the *tenuicostatum* Zone, earliest Toarcian, have been found

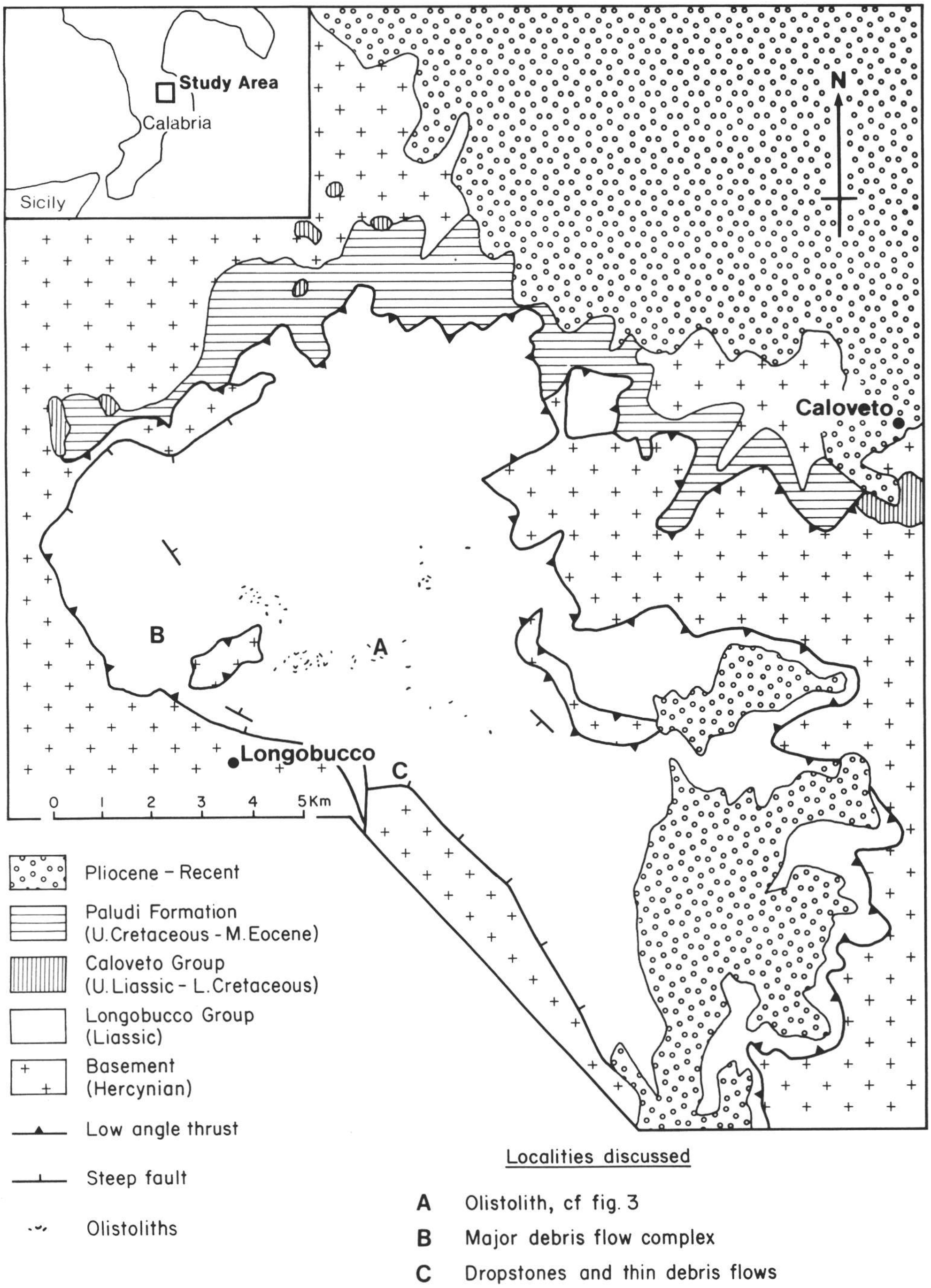

Fig. 1. Sketch map of Longobucco Basin showing extent of the Longobucco and Caloveto Groups and distribution of the olistoliths. Inset, location map.

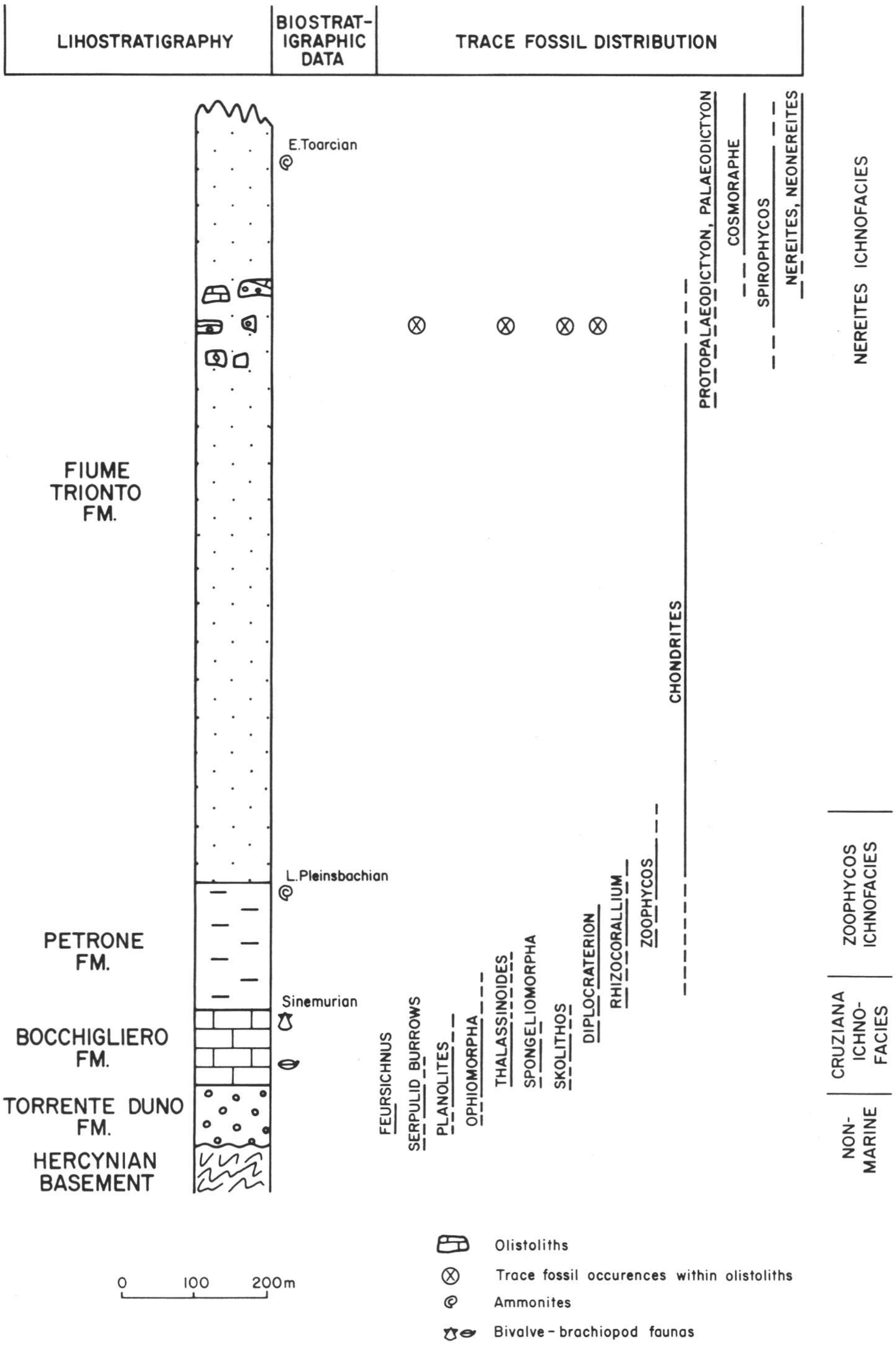

Fig. 2. Composite stratigraphic column of the Longobucco Group indicating the various formations and the main biostratigraphic control points. Nannofossils from throughout the Fiume Trionto Fm. confirm the Pliensbachian–Toarcian age. Also shown is the vertical distribution of trace fossils, illustrating the progressive deepening of the basin.

(Young *et al.*, 1986). Deposition was thus virtually confined to the upper Pliensbachian, and must have been very rapid, *c.* 300 m/Ma. Furthermore, the trace fossil associations in the turbidites indicate progressive deepening (Fig. 2), to the *Nereites* ichnofacies—generally taken to suggest lower bathyal to abyssal sedimentation. So overall subsidence, and presumably rifting, was considerable.

The bulk of the turbidites are quartz-arenites of rather problematic provenance, with palaeocurrents derived from the north-west (CTT unpublished data; Zuffa *et al.*, 1980). They appear to be unchannelized and show the characteristics of the basin plain or outer fan turbidite associations of Mutti and Ricci Lucchi (1972). Subsidiary lithologies include: carbonate turbidites in the lower part; a few very thick beds, up to 17 m, similar to the seismoturbidites of Mutti *et al.* (1984); rare lithic arenite turbidites and debris flows; the olistoliths; and interturbidite hemipelagic marls with common calcareous nannofossils.

The olistoliths

The olistoliths are most common toward the top of the turbidites—about a thousand metres from the base of the succession. They are not, however, grouped at any one horizon, but seem to be randomly distributed through the interval in which they occur. About fifty olistoliths have been identified and mapped. They are typically 50–100 m long and 15–25 m thick, ranging up to 250 m long and 35 m thick. Significantly smaller blocks have only rarely been found, despite intensive mapping and logging of the sequence. The blocks are usually tabular with markedly flat bases and steep sides. With the exception of a few small ones their internal bedding is always sub-parallel to that of the enclosing turbidites—and they are invariably the right way up as indicated by cross-bedding, geopetal fills, etc.

The most common block lithologies are limestones similar to those of the Bocchigliero Formation. This similarity includes: general lithology—siliclastic-rich oolitic and bioclastic limestones; sedimentological features such as trough, sigmoidal, and herring-bone cross-stratification; similar shelly faunas and ichnocoenoses. Perhaps most strikingly, an unusual and distinctive diagenetic fabric seen in the Bocchigliero Fm. also occurs in the olistoliths. This is a mesoscopic banding (up to 5 cm) which occurs in some oolitic limestones due to concentration of quartz into discrete zones, sometimes approximately parallel to bedding, elsewhere forming a reticulate network. The combination of all these features clearly indicates that these olistoliths are composed of the Bocchigliero Formation, and so are indubitably allochthonous.

Other lithologies are also sometimes seen, including the Torrente Duno red beds, rare basement granites, and carbonates, of possibly Pliensbachian age, from the Lower Caloveto Formation. The occurrence of Torrente Duno and Bocchigliero Formation sediments as olistoliths indicates that these formations were originally present over a wider area than the subsequent turbidite basin. Very similar sediments also occur in the Taormina area of Sicily, so they may have been widespread shelf sediments. By contrast, the absence of Petrone Formation marls, and presence of Lower Caloveto Formation limestones, suggests that basin-high differentiation was established by the Pliensbachian.

Olistolith–sediment relations

The Longobucco olistoliths mainly outcrop on valley sides and so their general relations with the enclosing sediments are quite clear, unlike those of olistoliths outcropping in areas of low relief. The details of the block margins are, however, rarely well exposed. The most readily observed feature is turbidite onlap. In almost all cases normal turbidite beds can clearly be seen to be laterally equivalent to the blocks, to butt against them, and lap over them. So, the blocks are not occurring within mass-movement deposits, and must have been introduced to the basin independently.

Details of the block–sediment relationships are particularly well shown around the sides and base of one large, easily accessible block (Fig. 3a). This is located on the north side of the Trionto valley, by the Sila–Rossano road (S.S. 177), 5 km from the village of Longobucco (Fig. 1, locality A). This block is 900 m from the base of the sequence, is composed of Bocchigliero Fm. carbonates, and is about 20 m thick.

As shown schematically in Fig. 4 it lies concordantly on the underlying turbidites, which show no sign of block-related deformation. At various places along the block margins small accumulations of cobble- to boulder-sized limestone clasts occur. These have similar lithologies to the block and are probably talus derived from it. The surrounding turbidites lap onto and around the sides of the block and eventually over its top (Fig. 4).

On the east side of the block is a zone of considerable soft sediment deformation, characterized by recumbent folds, with associated boudinage, accommodation, and injection structures. The folds have an eastward-verging asymmetry—away from the block.

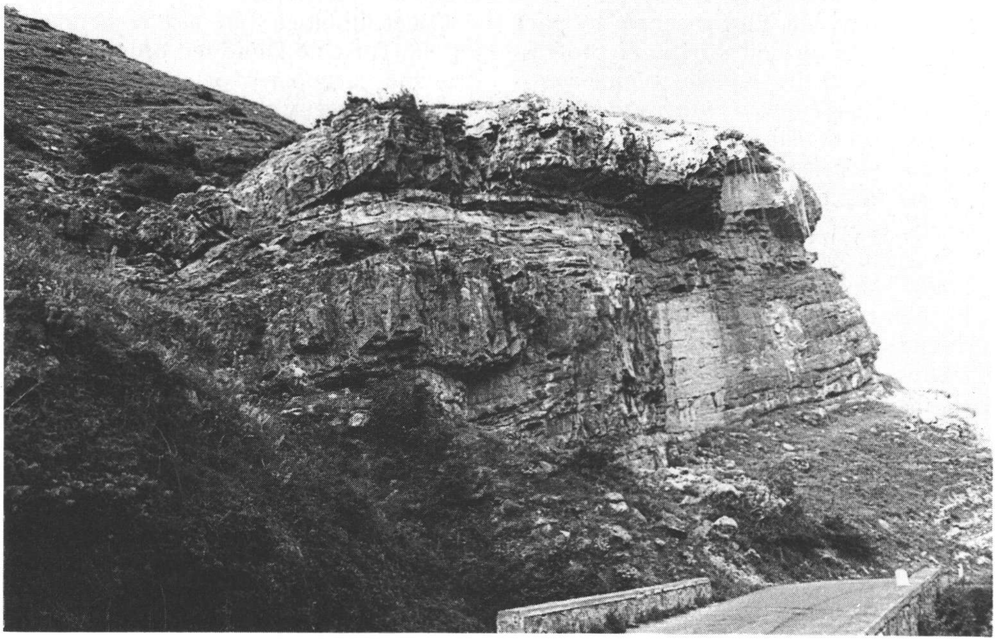

Fig. 3a.

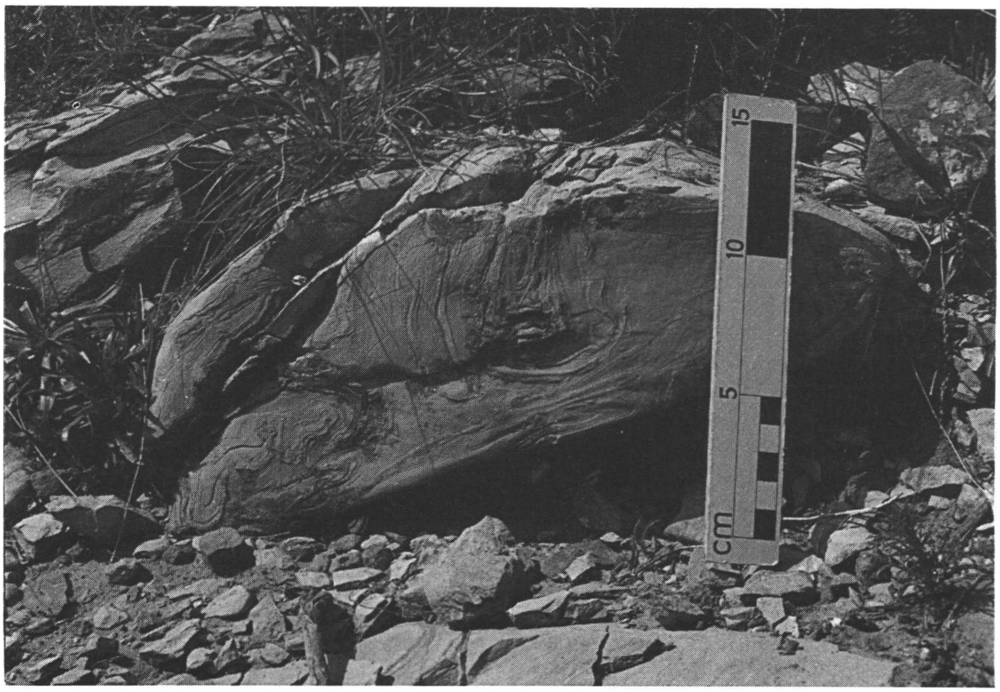

Fig. 3b.

This suggests that they were produced by shortening in front of the block as it slid in, and so that this side was the front of the block.

On the west side of the block, the probable rear, there is another zone of strong soft sediment deformation. Here the structures within the turbidites are chaotic and display no obvious common sense of asymmetry (Fig. 3b). Mixed into them are occasional clasts (from a few millimetres to 3 m long) of comparable lithologies to those of the large block. This

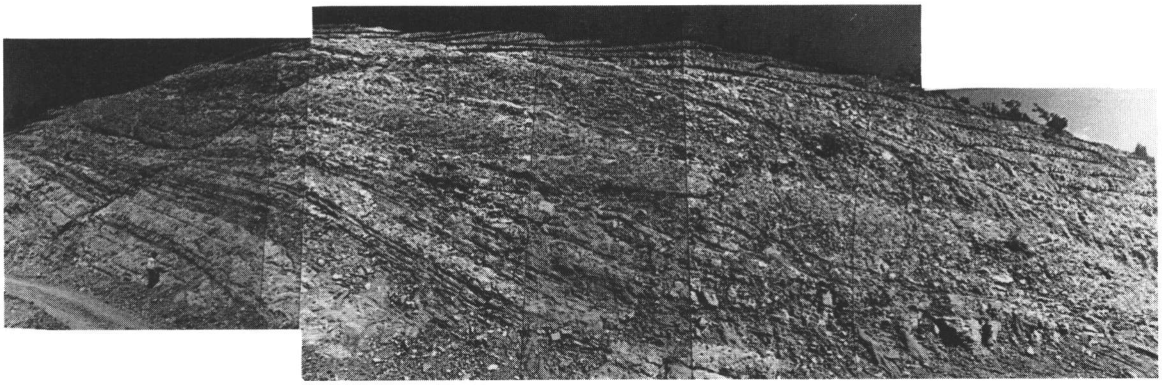

Fig. 3c.

Fig. 3d.

Fig. 3. a. View of the olistolith discussed in the text. b. Block of chaotically deformed sediments from the zone to the west of the olistolith. c. Photomosaic of major debris flow outcrop near the basin margin (at point B, Fig. 1). d. View of a second olistolith.

zone approximately follows bedding, and can be traced some way from the block. Farther west, along the road to Longobucco, a major debris flow is exposed with clasts up to 1.5 m long. The flow is 3.3 m thick at its eastern-most outcrop and can be traced west for 2 km, thickening to 5 m, before exposure is lost. Unfortunately, there is a hundred-metre gap in the outcrop between the block and the debris flow, which means they cannot be directly correlated. However, detailed logging and mapping of the turbi-

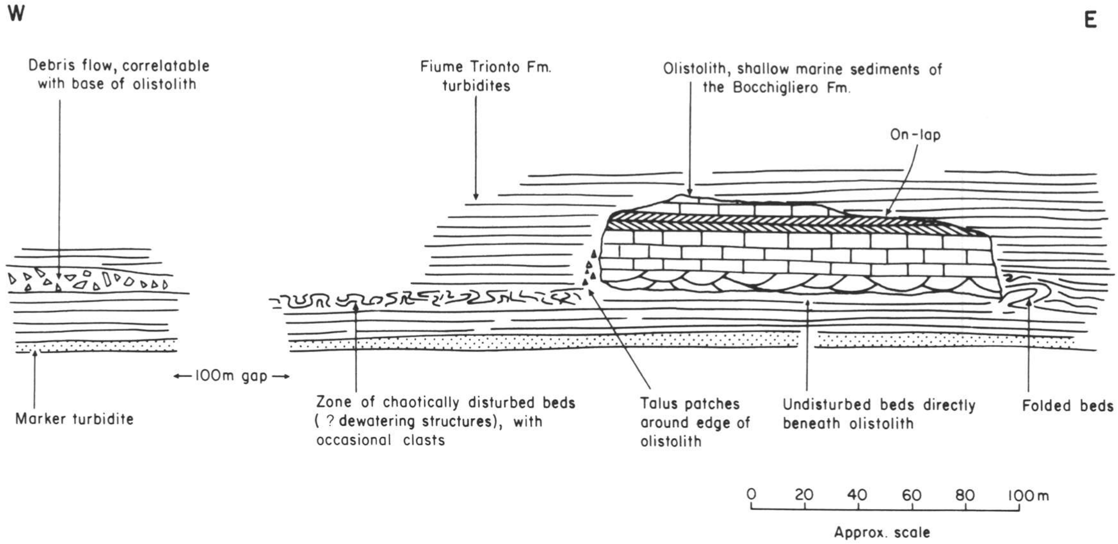

Fig. 4. Schematic diagram of the relationships of the surrounding sediments to the olistolith described in the text.

dite beds above and, most usefully, below the debris flow indicates that it is at the same stratigraphic level as the base of the block. So it seems that the olistolith, chaotic zone and debris flow were all products of the same sedimentation event.

Olistolith setting

The sequence of deposits, the soft sediment structures and the thickening trend of the debris flow all indicate derivation from the west. In this direction the turbidites can be traced continuously for some 4 km until the boundary of the Longobucco Group outcrop is reached. This boundary is a steeply dipping thrust, with basement in the hanging wall, and Longobucco Group sediments in the footwall. The thrusting is probably a result of Alpine compression during emplacement of the Longobucco Unit. However, such thrusting could well have occurred along reactivated normal faults of the original, extensional, margin of the Longobucco turbidite basin. That this is so is suggested by the fact that debris flows and lithic arenite turbidites become more common towards the fault: near it are some spectacular sections almost entirely composed of debris flows (Fig. 3c). Elsewhere along the margin, pebble-sized dropstones of basement schists occur in the turbidites; these must have fallen from a nearby fault scarp.

So it seems reasonable to presume that there was an active fault scarp along this margin, and that the olistoliths were derived from it. This implies transport of 2–5 km for most of the blocks, and probably slightly more if the effects of deformation within the sequence are taken into account.

The bulk of the turbidites, however, are quartz-arenites with NW–SW-directed palaeocurrents, as indicated by widespread sole marks. Neither the composition nor the palaeocurrents suggest derivation from the basin margin to the south-west, which was the source of the lithic arenite turbidites, debris flows, and olistoliths. Instead, the quartz-arenites were probably derived by recycling of sandstones from a source to the north-west, now lost. Hence the main axis of the turbidite basin, and so the regional palaeoslope, must have been oriented NW–SE, parallel to the south-west margin. Furthermore, the unchannelized basin–plain type facies of the turbidites, and the rarity of slumping in the sequence, suggest that this slope was gentle. So the olistoliths must have been emplaced obliquely across a very shallow slope, as shown in Fig. 5. This poses intriguing problems for their mechanism of emplacement, problems which we address in the final section.

OTHER CASES

Isolated olistoliths do not seem to be common and there are only a few well-described examples. The main features of a number of these olistoliths—from a variety of areas, geological periods, and settings—are summarized in Table 1. They are listed in order

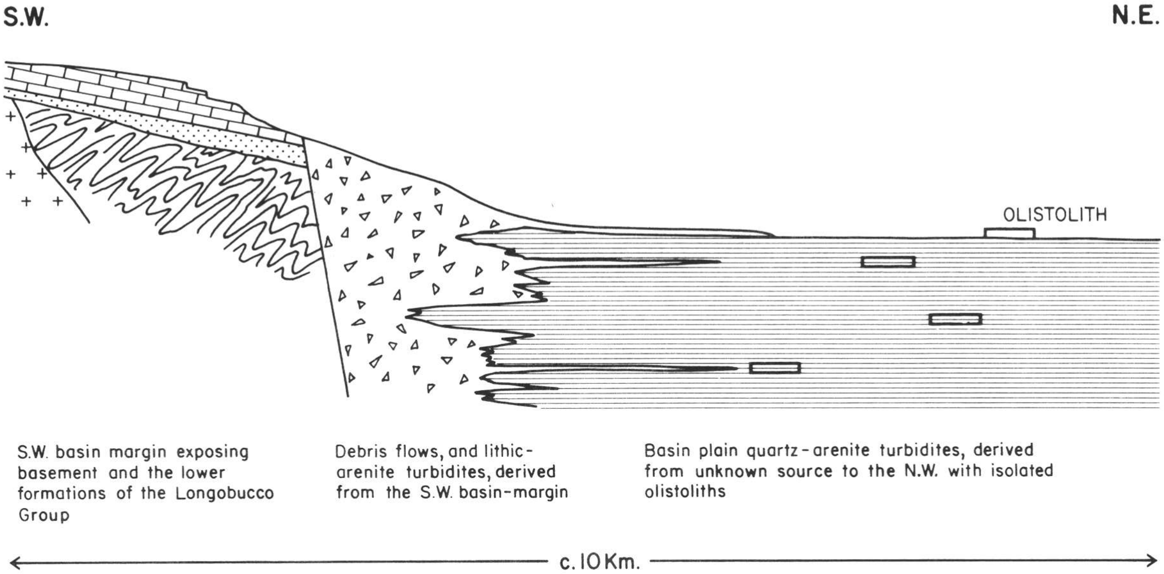

Fig. 5. Cartoon illustrating the inferred facies relationships across a section of the south-west margin of the Longobucco Basin, during the early Toarcian.

of block size and include, for comparison, examples probably best considered as fallen boulders (the Cipit Blocks), and as small gravity nappes (the Oman Exotics). Some other possibly analogous cases were excluded from the table since the blocks have debris flow deposits around their bases. These include the 'fallen stack' and other massive blocks in the Helmsdale boulder beds of north-east Scotland (Bailey and Weir, 1932; Pickering, 1984), and the celebrated Cretaceous blocks occurring in Oligocene lake sediments near Alès, S. France (Heim, 1923; Koop, 1952; Arène *et al.*, 1978).

It is clear from the table that the nature of the enclosing sediments is highly variable—and so it is presumably not a critical factor. Block lithology is also variable, but with carbonates dominating.

The predominance of extensional tectonic settings is interesting. This is doubtless in part an indication that extensional tectonics are likely to produce suitable conditions for block formation and transport, but may also in part reflect the greater potential of extensional settings for eventual preservation of decipherable relationships. In thrust settings subsequent deformation is liable to destroy block–sediment relations producing melanges of similar appearance whatever the genetic relations of the blocks to the matrix.

The olistoliths range in size from tens of metres to a couple of kilometres. They thus grade down into boulders, and up into sedimentary nappes—such as the Oman exotics described by Glennie *et al.* (1973) and Wilson (1969). Robertson (1977) and Richter (1973) have described blocks of similar size apparently formed by the detachment of fragments from the leading edge of larger sedimentary nappes, or slides. Distances travelled are rarely unambiguously constrainable, but in all the cases in the table it is clear that a suitable fault-scarp or other source occurred within a few kilometres of the blocks. Ten kilometres is about the maximum indicated distance of transport.

The cases most closely analogous to the Longobucco olistoliths seem to be those described from Antarctica by Ineson (1985), and from the Northern Apennines by Naylor (1981, 1982) and by Abbate *et al.* (1970). Both Naylor (1982) and Ineson (1985) discuss block–sediment relations. As with the Longobucco olistoliths they found that the blocks typically had planar bases which rested concordantly on the sediments below. Above the base the sediments onlapped or draped over the block. Naylor also recorded block-derived debris and breccias around the sides of the blocks, analogous to the talus accumulations seen around the Longobucco olistoliths. In addition, he listed a range of deformation features occurring in the sediments at the bases of the blocks which he ascribed to settling of the blocks after emplacement—including de-watering and liquefaction structures, small slump structures, and crumpling and contortion of bedding. Ineson did not find

TABLE 1. Listing of the salient features of various olistoliths comparable with the Longobucco olistoliths, organized in approximate order of size. The Oman Exotics are probably better considered as gravity nappes, but are included for comparison.

Author	*Location*	*Setting*	*Enclosing sediments*	*Olistoliths*	*Size*	*Distance*	*Terms used*
Fursich and Wendt (1977), Cros (1967)	Cassinian Fm. Dolomites, Northern Italy	Depositional carbonate margin	Triassic slope carbonates	Triassic reef carbonates	1–20 m	0.5–5 km*	Cipit blocks
Prior *et al.* (1982, 1984)	Kitimat Arm Fjord, B.C., Canada	Head of fjord	Modern fjord bottom clays and silts	Slabs, probably of delta front sands and silts	to 75 m	to 6 km*	Slide blocks Outrunner blocks
Cronan *et al.* (1974), Fisher and Bunce (1974)	DSDP site 232. Gulf of Aden	Newly formed oceanic rift	Upper Miocene nannofossil ooze	Upper Miocene lithified shallow marine sandstone	25 m T	—	Slide blocks
Teale (1985), Young *et al.* (1986)	Longobucco Basin, Calabria, S. Italy	Small extensional basin	Upper Liassic basin–plain turbidites	Lower Liassic shelf carbonates and clastics	10–250 m	2–6 km*	Olistoliths
Ineson (1985), Farquharson *et al.* (1984)	James Ross Island, Antarctic Peninsula	Back-arc basin	Lower Cretaceous lower slope clastics	Upper Jurassic laminated radiolarian mudstones	200–800 m	5–10 km	Glide blocks Slide blocks
Conaghan *et al.* (1976)	Nubrigyn Field, New South Wales, Australia	Depositional carbonate margin	Lower Devonian slope carbonates	Lower Devonian reef and platform carbonates	4–1400 m	to 10 km	Allochthonous blocks
Carrasco-V. (1973, 1977)	Valles-San Luis Potosi platform, Mexico	Bypass carbonate margin	Albian slope micrites and debris flows	Lower Cretaceous platform carbonates	to 95 m T	to 3.5 km	Allochthonous exotic blocks
Naylor (1981/2, 1984), Abbate *et al.* (1970)	Casanova Complex, N. Apennines, Italy	Passive continental margin	Upper Cretaceous–P'gene turbidites and debris flows	Ophiolitic igneous rocks and pelagic sediments	to 2 km	? a few km	Slide blocks Olistoliths
Stoneley (1981)	Kuh-e-Dalneshin area, S. Iran	Extensional basin	Upper Cretaceous siliceous pelagics	Cenomanian neritic limestones	to 1 km	? a few km	Exotic blocks
Richter and Mariolakis (1973)	Gavrovo Massif, Epiros, Greece	Intra-basinal ridge	Oligocene turbidites	Upper Cretaceous reef limestones	1+ km	?12 km*	Olisthothrymma
Wood (1981)	Lagonegro Basin, S. Apennines, Italy	Extensional basin	Middle Triassic (Ladinian) shales	Middle Triassic (Anisian) neritic lsts	to 20 km	—	Olistoliths
Glennie *et al.* (1973), Wilson, (1969)	Oman Mountains	Newly formed oceanic rift	Upper Cretaceous radiolarites	Permo-Triassic platform carbonates	to 20 km	?10 s of km	Exotic blocks Oman exotics

Author: where two references are given the main source of information is listed first.
Size: in most cases this is range of lengths of olistoliths. Where size of smallest olistoliths is not stated in references only size of largest is quoted. T denotes thickness, as opposed to length.
Distance: this is the distance from present position of block to probable source. *—our estimate, from maps etc. in the reference.
Abbreviations: P'gene—Palaeogene; lsts—limestones.

talus deposits or soft sediment deformation in the enclosing rocks but did describe 'glide-induced shear brecciation and folding' in the base of one block. Overall, then, there does seem to be a characteristic suite of emplacement-related structures. Which of these are seen in any one case will depend on such factors as the lithology of the block and of the enclosing sediment, and their subsequent deformation and diagenesis.

The best description of a modern analogue for these deposits seems to be that given by Prior *et al.* (1982, 1984) from the Kitimat Arm Fjord in British Columbia, Canada. They used a variety of oceanographic techniques to study a major slope-failure complex affecting a delta at the head of the fjord.

Side-scan sonar mapping of the fjord/bottom revealed isolated blocks occurring in front of the main landslide/debris flow. These so-called 'outrunner' blocks were found to occur up to one kilometre down-fjord from the front of the debris flow. The blocks appear to have continued to move downslope after the underlying debris flow, on which the blocks had been moving, had lost momentum and stopped. The blocks, lying on the fjord-bottom muds, are up to 50 m × 75 m in surface area, and 4 m high and are lying on a slope of less than 0.5°. Prior and his co-workers were also able to identify glide tracks left by the blocks on the fjord bottom mud as they moved over it. Surrounding these glide tracks, detritus was found which had been carried and shed by the blocks during their passage.

MODE OF OCCURRENCE

There are two basic problems in explaining isolated olistoliths: the mechanisms of formation of the blocks, and mechanisms of transport. These are discussed separately below.

Mechanisms of formation

This is the lesser of the two problems, and the clear association of olistoliths with active extensional regimes suggests that one common process is likely to be detachment of blocks from submarine fault scarps during earthquakes. This should occur most readily where strata in the fault scarp dip towards the basin. Detachment can then occur by sliding along bedding planes. Assuming rotation does not occur during emplacement, this would produce olistoliths with internal bedding subparallel to that of the surrounding sediments—as is the case with the Longobucco olistoliths, and those from the Antarctic Peninsula (Ineson, 1985). However, normal faulting is usually accompanied by back-rotation of the footwall block. This means that dips in the fault scarp are much more likely to be away from the basin than towards it. Under these circumstances slope-failure would be most likely to occur by rotational collapse. Blocks produced in this way would have internal bedding at high angles to the enclosing sediments—as described by Wood (1981) from the Lagonegro Basin, and by Naylor (1982).

Lithology is also obviously important: only massive rocks are liable to produce large blocks. This is reflected in the predominance of carbonates among the block lithologies in Table 1. It is also clear in the particular case of Longobucco, where the olistoliths are formed predominantly of the shallow marine limestones of the Bocchigliero Formation. The associated debris flows and lithic turbidites, by contrast, are dominated by material derived from the basement granites and schists, even though like the olistoliths they appear to have been derived from the south-west margin of the basin. Evidently these rocks were more common in the source area of the olistoliths but were less liable to form massive blocks.

Mechanisms of emplacement

The basic method of emplacement which has been suggested for most of the examples in the table is slow downslope sliding, similar to that of subaerial block slides, with motion occurring when the downslope component of gravity is sufficient to overcome the frictional forces. The principal problem with this model is that a large block resting on soft sediments should sink into them, or at least compact them. So, downslope motion would involve ploughing through a layer of sediment. This should in turn considerably impede movement, making forward motion unlikely on gentle slopes, and should create a wake of severely deformed sediments.

The blocks in Kitimat Fjord described by Prior *et al.* (1982, 1984) occur on a slope of less than 0.5 degrees and appear to have sunk somewhat into the surrounding sediment. In consequence, Prior *et al.* suggested a rather different mechanism of emplacement: relatively rapid 'skidding' of slabs over the sediment, with support in part from high pore-fluid pressures generated by the weight of the slabs. This overpressuring effect would also produce a low-strength layer able to reduce the resistance to motion—an effect analogous to the lubrication generated by the water layer produced beneath an ice-skate. This mechanism might enable a block to travel considerable distances over negligible, or even reversed, slopes, until it slowed to a speed where it began to sink into the underlying sediments. The additional resistance to motion caused by the deformation of these sediments would then abruptly brake the block.

This mechanism seems to be applicable to the Longobucco olistoliths. It provides an explanation for their occurrence several kilometres from the basin margin on what would otherwise be expected to be a negligible slope. The field relations, discussed above, fit well with this model: the folding in front of the block could have been caused by it nosing into the sediments as it came to rest; similarly, the disruption of the sediments behind the block may have been produced by the rapid escape of overpressured pore waters after the passage of the block. Prior *et al.* also suggested this as a cause for the glide tracks they observed, the sediments of which appeared to have lower pore-water contents than the surrounding fjord-bottom muds.

A major difference between the two cases is that in Kitimat the blocks are associated with a massive slope-failure complex which seems to have transported the blocks a considerable distance before they outran it under their own momentum, as the main flow came to a halt. In the Longobucco case, by contrast, there is only a relatively thin debris flow deposit in direct association with the block. Thus the independent motion of the block is liable to have been much more important in this case.

CONCLUSIONS

Isolated olistoliths are phenomena intermediate between fallen boulders and gravity nappes in scale and in emplacement process, in that important effects arise from the overpressuring of sediments beneath them. The Longobucco olistoliths provide unusually clear evidence for this and for the ability of such blocks to move long distances down gentle slopes independently of other mass-movement processes. This evidence may be worth considering when the origin of blocks with more ambiguous relations are considered—for instance olistoliths associated with debris flows, or blocks in melanges.

Whatever their mode of origin, olistoliths can be useful in elucidating basin histories, and deserve special attention wherever their occur. In the particular case of the Longobucco Basin they have given information on the basin geometry, on the original extent of the various lithofacies, on the diagenetic history of the rocks, and on synsedimentary tectonics.

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