The Cephalopod Bank in the Gröden/Val Gardena Sandstone of the Bletterbach

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ABSTRACT
The Cephalopod Bank, an about 2 m thick calcite-cemented sandstone bed in the Bletterbach Gorge, represents the first marine transgression of the Bellerophon Sea into the Gröden/Val Gardena Sandstone. Preliminary sedimentological and palaeontological studies allow the subdivision of the Cephalopod Bank in three units: A, B and C. Unit A is characterized by *Skolithos* burrows and was deposited during the initial marine transgression, probably in a nearshore environment. In unit B the environment was deepening and marine fossils occur. Internal molds of half preserved coiled nautiloids and molds of orthoconic nautiloids are frequent and indicate a shallow marine environment with low sedimentation. Occasional rapid sedimentation events (storms?) caused the preservation of vertically oriented coiled nautiloid molds.

KEY WORDS
orthoconic, nautiloids, *Tirolonautilus*, *Lopingoceras*, *Skolithos*, *Bellerophon*

1. INTRODUCTION

In the Bletterbach Gorge near Aldein/Aldino (Dolomites, South Tyrol/Northern Italy) a morphological step can easily be distinguished because it forms, due its hardness, the top of the waterfall which divides the Butterloch from the upper part of the Bletterbach (Figs 1, 2). Below the waterfall, an about 2 m thick set of marine strata, called "*Cephalopod Bank*", consists of calcite-cemented sandstone beds (Massari et al., 1994). The Cephalopod Bank is situated in the lower part of the Gröden/Val Gardena Sandstone, about 75 m above its base. The entire Gröden/Val Gardena Sandstone is dated as Wuchiapingian (Lopingian, late Permian; Kustatscher et al., 2014). The age, origin and formation process of this marine interval is still controversially discussed. The aim of this short paper is to summarize, through a brief review of the research history, the state of knowledge about the Cephalopod Bank and to anticipate some considerations on the taphonomy of the invertebrate fossil fauna preserved in it, and the environmental conditions in which this fauna was deposited.

2. HISTORICAL BACKGROUND

According to Klebelsberg (1946), it was Leo Perwanger who discovered the Cephalopod Bank with its rich marine fauna and got Mutschlechner (1933) involved. The latter presented it in

FIG. 1: Overview image of the Bletterbach Gorge. [Cartografia provinciale e coordinamento geodati – Ripartizione 28. Licenza CC-BY (https://creativecommons.org/licenses/by/4.0/deed.it)]

FIG. 2: Cephalopod Bank (CB) at the waterfall outcrop.

a brief note for the first time containing a list of cephalopod remains collected from this marine deposit. The list included coiled nautiloids such as *Pleuronautilus* sp., *Nautilus* sp., *Mojsvaroceras* sp.; orthoconic nautiloids as *Orthoceras* sp., *Cycloceras* sp. and one ammonoid, ?*Parapronorites* sp. Later, Leonardi (1968) reproduced the cephalopod list of Mutschlechner (1933) and figured a slab with imprints of *Orthoceras* sp. and ammonoids.

Conti et al. (1975, 1977) recovered abundant nautiloid specimens in good state of preservation from the Cephalopod Bank during campaigns in the years 1973 and 1974. They enlisted *Tainoceras* sp., *Pleuronautilus* sp., *Mojsvaroceras* sp., *Lopingoceras* sp. and other forms similar to *Metacoceras* sp. and *Thuringionautilus* sp., but could not give specific attributions due to the lack of enough taxonomic characters on the casts. The authors evidenced the affinity of this fauna with the nautiloid fauna of the Bellerophon Formation known from the Dolomites and the Julfa Beds of North West Iran, suggesting an upper middle Permian age. A cast of a pectinoid bivalve was also described and figured. The deposition of the Cephalopod Bank was attributed to a short marine ingression immediately followed by a regression or to sedimentary deposits brought inland by a rising tide.

Broglio Loriga et al. (1988) designated the fauna of the Cephalopod Bank as Orthoconic Nautiloid Assemblage and remarked that it is overlain by continental red beds in which the famous footprint beds occur. This Orthoconic Nautiloid Assemblage includes orthoconic nautiloids such as *Neocycloceras* sp. and *Lopingoceras* sp.; coiled nautiloids such as *Tainoceras* sp., *Metacoceras* sp., *Mojsvaroceras* sp., *Pleuronautilus* sp., *Thuringionautilus* sp., *Germanonautilus* sp. or *Stearoceras* sp., ?*Permonautilus* sp. and the ammonoid ?*Parapronorites* sp.

Farabegoli et al. (1986), Massari et al. (1988) and Perri & Farabegoli (2003) distinguished in the Gröden/Val Gardena Sandstone and Bellerophon Formation three transgressive-regressive cycles, whereas Massari et al. (1994), Massari & Neri (1997), Posenato (2010) and Kustatscher et al. (2017) proposed six 3rd-order transgressive-regressive sequences for the entire Lopingian. For Massari et al. (1988), the Cephalopod Bank represents the acme of the transgression of their first second-rank sedimentary cycle. In the Cephalopod Bank, they noticed a subtle coarsening upward trend from fine- to medium-grained sandstone, which is accompanied by an upward increase in the scale of sedimentary structures, from trains of small-scale symmetrical wave ripples, sometimes with mud drapes and sparse bioturbation, to plane and locally low-angle lamination, to poorly distinct and amalgamated hummocky stratification (wave length 50 cm). The sharp base may reflect erosion and reworking during the advancing transgression, whereas the upward increase in scale of sedimentary structures and grain size seems to reflect a regressive trend. A shore-face setting is suggested by the faint hummocky stratification, but a typical foreshore facies is apparently absent, perhaps due to the low preservation potential. For Posenato (2010), the Cephalopod Bank corresponds to the maximum flooding surface of sequence Lo 2 (Lo = Lopingian) and marks the first short-term marine ingression in the western Dolomites.

Kustatscher et al. (2017) suggested that the short-term marine ingression evidenced by the Cephalopod Bank shifted the pre-existing channel-floodplain system toward the West and that the area was transformed in a costal-deltaic area. The earlier reconstruction of Massari & Neri (1997) proposed a shoreface to foreshore setting, whereas recent re-evaluation reconstructed a fluvio-deltaic setting.

This review shows how in literature the fossils of the Cephalopod Bank are generally listed in open nomenclature and have neither been systematically described nor figured. No data about their taphonomy and stratigraphic distribution within the marine interval are available.

3. THE CEPHALOPOD BANK

Below the waterfall, the Cephalopod Bank is 230 cm thick and composed of 15 beds of calcite-cemented grey upward coarsening sandstone (Figs 2–4). It marks the first short-term marine transgression of the Bellerophon Sea on the fluvial plain of the Gröden/Val Gardena Sandstone and represents the maximum flooding surface of the sequence Lo 2 (Posenato, 2010), but the ingression horizon comprises also other beds around the Cephalopod Bank (Kustatscher et al., 2017).

The basal 70 cm of fine-grained calcareous sandstone was rapidly deposited and later colonized by suspension feeders which produced thin *Skolithos* burrows (Fig. 5). The *Skolithos* ichnofacies is one of the original ichnofacies introduced by Seilacher (1963, 1967) in which the most common ichnogenus is *Skolithos*. Dominance of vertical burrows of suspension feeders reveals high abundance of organic particles that are kept in suspension in the well-oxygenated water column by waves and currents. *Skolithos* burrows are typical for instable sandy substrates in high-energy environments close to the shoreline (Buatois & Mangano, 2011). No other fossils have been found in this basal part of the Cephalopod Bank up to the top of bed 6. The beds 1 to 6 are grouped into the unit A, characterized by the presence of *Skolithos* burrows.

At the base of bed 7 appear abundant small bivalves and rare microgastropods, preserved as external casts and internal molds. Some fragments of coiled and orthoconic nautiloids are present within bed 7 and at its top also complete specimens of "half" coiled nautiloids without an upper flank occur (Fig. 6A). According to Tanabe et al. (1984), this type of preservation is possible only under certain circumstances. The dead nautiloid descends to the seafloor where only the lower flank of shell immerges in the soft sediment. After the decomposition of the soft parts, the sediment fills the lower part of the shell. Under low sedimentation rate the upper half of the shell is dissolved before it can be completely covered by sediments. By means of this, only the lower flank of the nautiloid shell is preserved. Maeda (1987), Maeda & Seilacher (1996) and Wani & Grupta (2015) presented an alternative model for „half"-ammonoid preservation. In this model at low levels of turbulence, draft currents transport sediment through the septal neck into the bottom half of the ammonoid camerae, before it will be completely buried in sediment. Once the shell is enclosed by sediment, the upper parts of the camerae and septa remain exposed to pore water and were dissolved more rapidly than the parts of the shell filled with sediment. After septal dissolution, the shell collapses so that only the lower part of the shell remains preserved. This model is not applicable to "half"-nautiloids because their calcareous siphuncular tube did not favour draft filling (Seilacher & Gishlick, 2015).

The frequent occurrence in beds 7 and 10 of isolated "half" body chambers which are less than half filled with sediment without traces of the phragmocone let presume that the sedimentation rate was low. No sediment could enter through the septal neck into the phragmocone so that only a small part of the body chamber could be filled and preserved before the upper part of shell with the complete phragmocone was dissolved on the seafloor (Fig. 7). If the sedimentation rate would have been high, then at least the entire body chamber of the nautiloid would have been filled by sediment during complete burial so that it could be preserved as internal mould after shell dissolution. Therefore, the model of Tanabe et al. (1984) agrees well with the "half" nautiloid preservation observed in the Cephalopod Bank. Brett & Braid (1986) argued that only few shells will give origin to recognizable fossils if they are not buried within a few tens of years and that larger shells will be preserved only if background sedimentation rates exceed about 10 cm/100 years. A

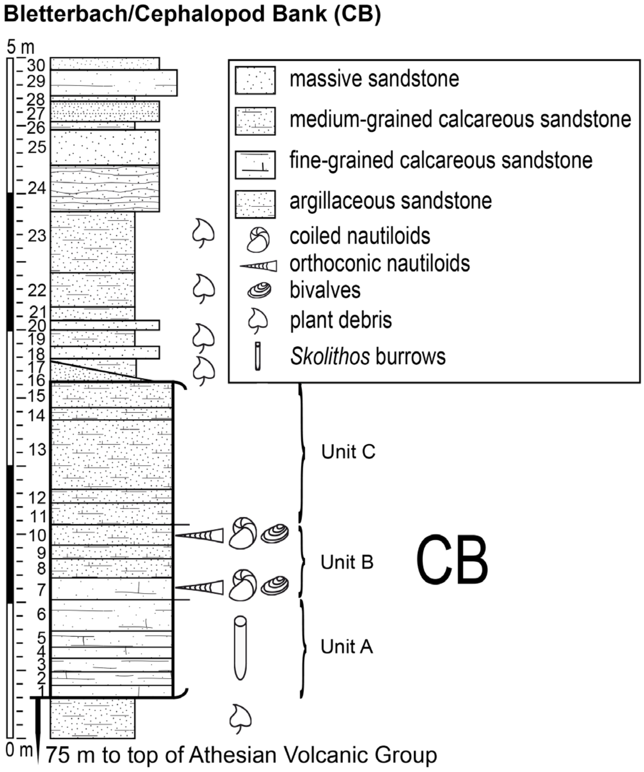

FIG. 3: Stratigraphic column of the Cephalopod Bank at the waterfall outcrop.

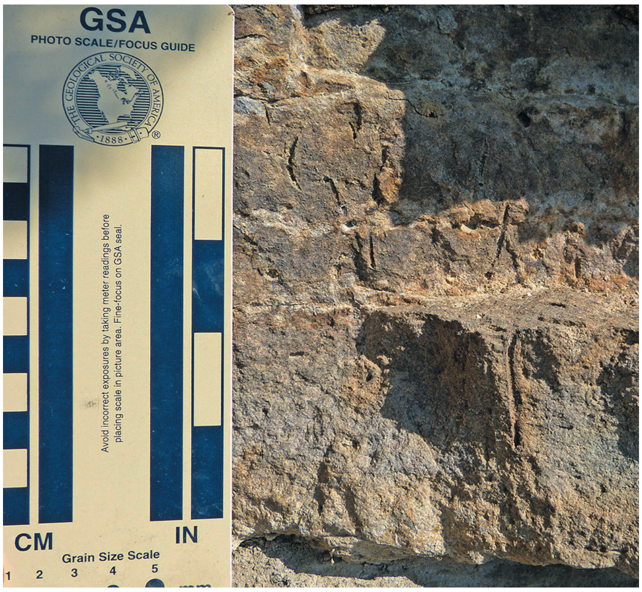

FIG. 4: Cephalopod Bank at the waterfall outcrop with numbers of beds.

low sedimentation rate of <10 cm/100 years can be assumed for the formation of such "half"-nautiloids in the Cephalopod Bank. Beds 7 to 10 form unit B which is characterised by marine fossils. Fossils are rare in beds 8 and 9, and the sediment is coarser then in bed 7. The fossils of the basal part of bed 10 are mainly preserved as molds of fragmented nautiloids, *steinkerne* of body chambers of "half" nautiloid specimens and of pectinoid bivalves (Fig. 6C). Above bed 10, no fossils occur on the waterfall outcrop and the medium-grained calcareous sandstone contin-

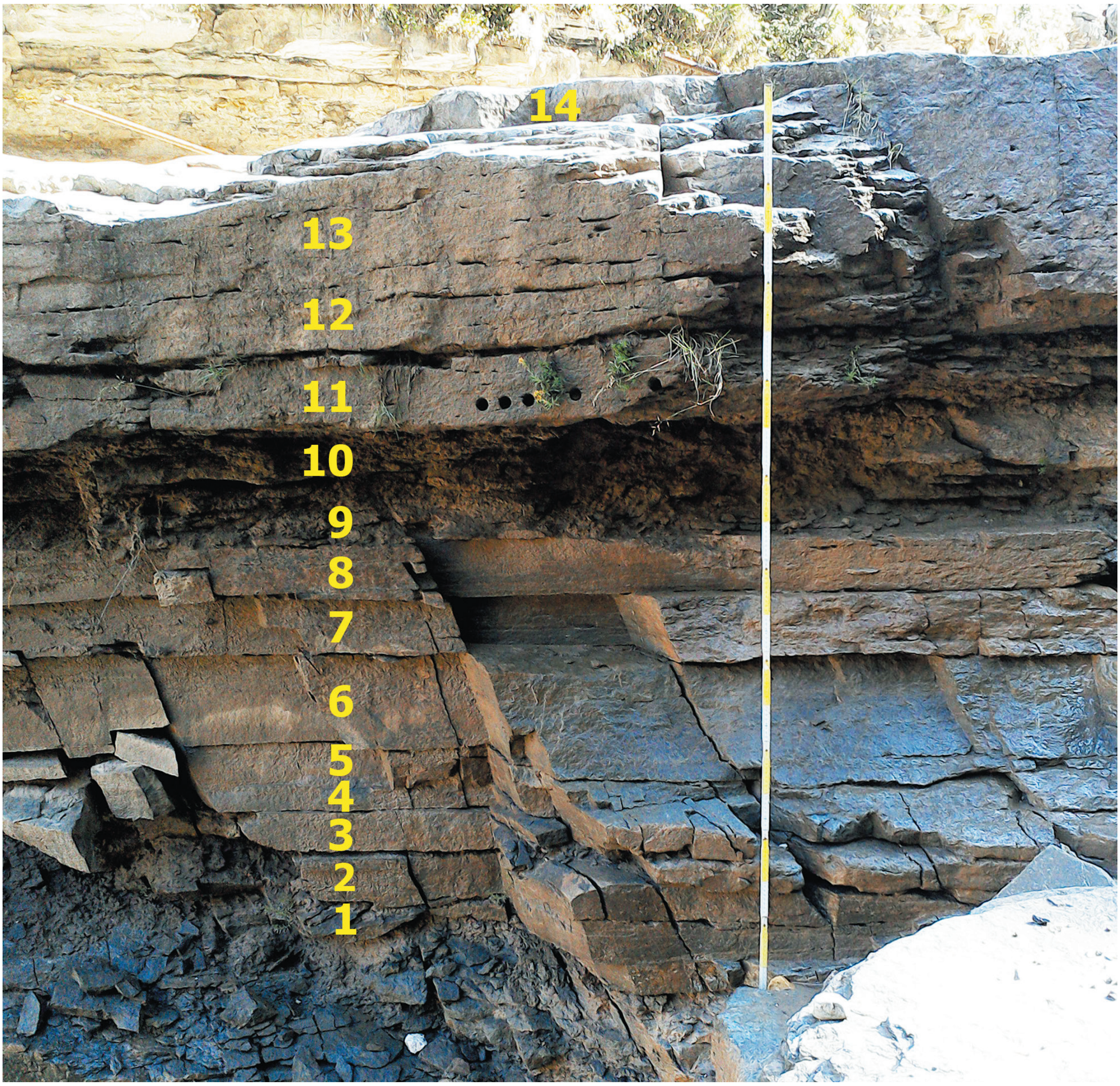

FIG. 5: *Skolithos* burrows from unit A of the Cephalopod Bank.

ues until bed 15, which is the last calcite-cemented sandstone bed of the Cephalopod Bank. The beds 11 to 15 constitute the unit C.

Fragmented shell material as it occurs in beds 7 and 10 is common either in some highly energetic nearshore environments where the fragmentation is mechanical or in quieter offshore environments where the shell material lies for a relatively long period on the sea floor and is subject to bioerosion (Brenchley & Harper, 1998). The presence of "half" nautiloids in both beds indicates a low sedimentation rate and a long resting time for shells on sea-floor and consequently the second possibility seems to be more likely. Therefore, a shallow marine either than a shoreface setting *sensu* Massari et al. (1988) can be assumed for the Cephalopod Bank. In shoreface setting the fragile nautiloid shells would have suffered abrasion, reworking and weathering without forming "half"-nautiloids, but further research is needed to clarify this point.

On dispersed slabs collected in the Bletterbach Gorge as loose blocks deriving from the upper part of bed 10 of the Cephalopod Bank, molds of coiled nautiloids are often vertically oriented and not deposited parallel to bedding as usual (Figs 6E1–E2). According to Reyment (1970), younger individuals of the coiled nautiloid *Germanonautilus bidorsatus* (Schlotheim, 1820) are also frequently found vertically oriented in the Muschelkalk of Germany. For the author, such fairly depressed, flat and concave shells should be oriented vertically, considering the air remaining in the chambers after sinking. The same will likely be true for similar shaped nautiloids of the Cephalopod Bank. Raup (1973) demonstrated experimentally that after death the shell of modern *Nautilus* cannot maintain a vertical orientation on the sea floor unless the depth is less than about 10 m. It must be considered that the shell shape of modern *Nautilus* is slightly compressed with a rounded venter so that the vertical orientation is not a stable one. Instead, for nautiloids with wide flat venters found in vertical position also greater depths may be assumed due to their stable vertical position, especially if the shell is stabilized by sinking deeply into the soft sediment preventing its overturn by bottom currents. For the vertically embedded nautiloids of the Cephalopod Bank a rapid sedimentation event has to be presumed. The vertically oriented shells were rapidly covered by sediment and frozen in place before full waterlogging caused their overturn. This rapid embedding produced the tight closure of the shells preventing the infiltration of sediment in the phragmocone so that only the body chamber could be filled forming a *steinkern* (Olivero, 2007). The successive dissolution of the aragonitic shells left only the molds of the phragmocones. Olivero (2007) documented among the vertically embedded ammonoids from the Santonian-lower Campanian Santa Marta Formation in Antarctica also shells in vertical position preserved in a parallel laminated division of a coarse grained tempestite bed.

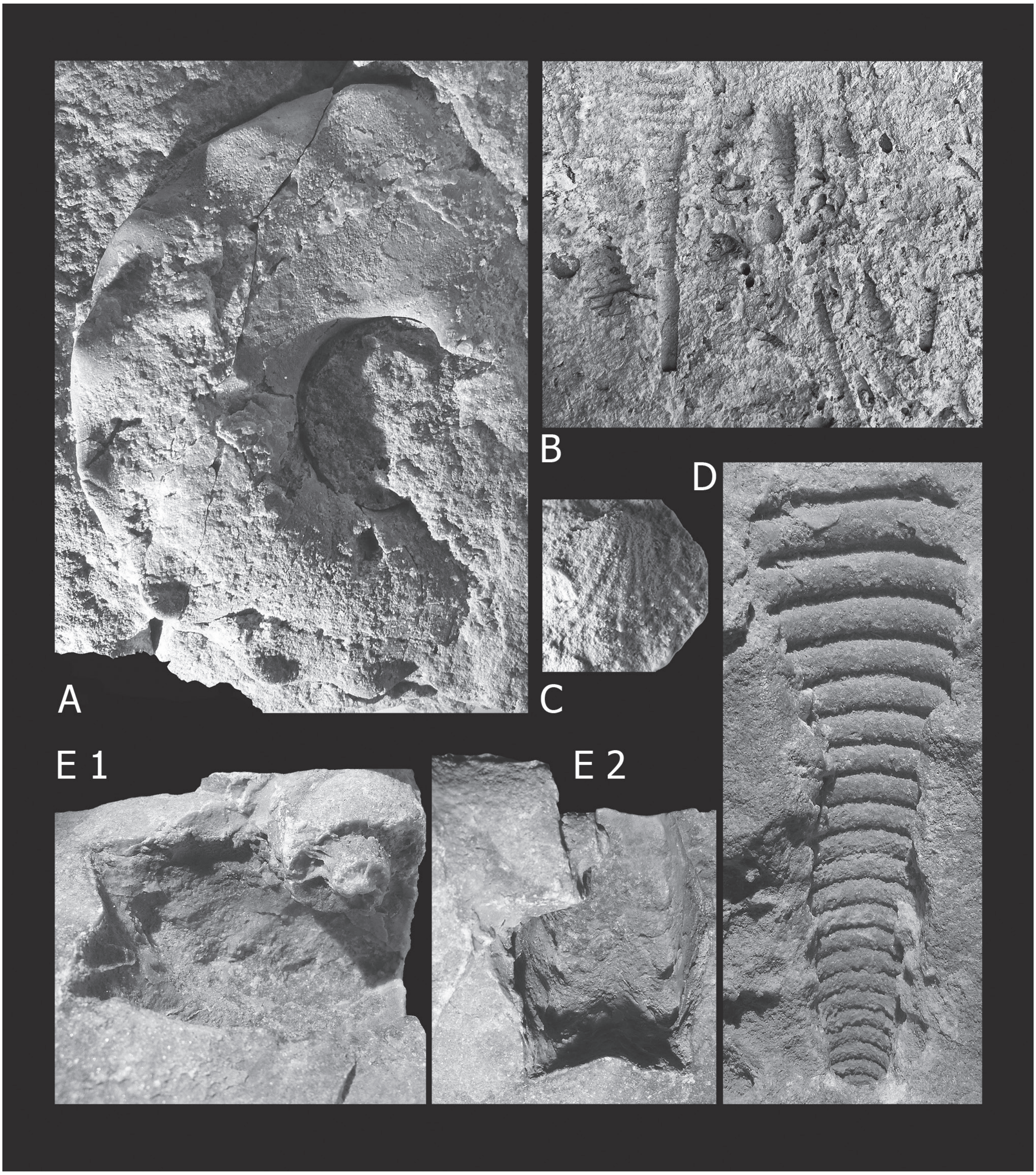

FIG. 6: Coiled and orthoconic nautiloids and pectinoid bivalve from unit B of the Cephalopod Bank. A) internal mold of coiled half-preserved nautiloid from top of bed 7 (x 1); B) parallel oriented orthoconic nautiloids, debris, (x 0.5); C) silicone cast of external mold of pectinoid bivalve, left valve, bed 10, (x 1.5); D) mold of an annulated orthoconic nautiloid, debris, (x 1.5); E1–E2) mold of a vertically embedded coiled nautiloid, E1 lateral view, E2 ventral view, debris (x 1).

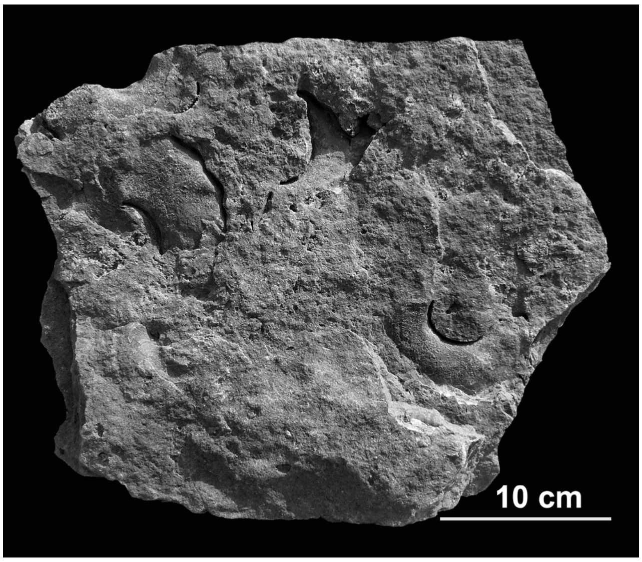

FIG. 7: Slab with "half" nautiloid body chambers, debris, bed 7.

4. THE NAUTILOID FAUNA OF THE CEPHALOPOD BANK

The nautiloid fauna is characterized by the abundance of annulated orthoconic nautiloids (Figs 6B, 6D). These fossils are often fragmented, but must have reached a length of about 20 cm. As can be seen on a slab collected from loose blocks of the Cephalopod Bank, some orthoconic shells show a parallel orientation due to current action (Fig. 6B). In the nautiloid horizon A (Posenato & Prinoth, 2004) from the Bellerophon Formation of the Bletterbach and the Balest (Gröden/Val Gardena), orthoconic nautiloids are rare and of small size, in the nautiloid horizon B of the Bellerophon Formation they are nearly absent. The coiled nautiloids are represented mainly by shells with developed ventrolateral shoulders carrying nodes and ribs but also smooth *Nautilus*-like shells occur. Posenato (2010) suggested that coiled nautiloids with transitional characters between *Stearoceras* sp. and *Germanonautilus* sp. already observed by Broglio Loriga et al. (1988) may represent, according to the emended diagnosis of the genus *Tirolonautilus* proposed by Prinoth & Posenato (2007), the oldest representatives of the genus *Tirolonautilus* in the Dolomites. The orthoconic and coiled nautiloids from the Cephalopod Bank have been attributed in literature to 11 different genera which are mainly based on incomplete specimens preserved as molds. A revision of this nautiloid fauna, which is beyond the scope and purpose of this short paper, will be carried out in a further work and must take into consideration the individual and intraspecific variability and the changes of shape during different ontogenetic growth stages.

5. CONCLUDING REMARKS

The Cephalopod Bank is composed of 15 beds which can be divided in three units: A, B and C (Fig. 3). Unit A is characterised by *Skolithos* burrows and was deposited probably in a nearshore environment, dominated by rapidly changing conditions with fast sedimentation. The marine fauna is not evenly distributed but restricted to unit B which is only 60 cm thick and located in the middle part of the Cephalopod Bank. In unit B the environment was deepening. Small bivalves could be detected at the base of bed 7, later appear also nautiloids which are representative of a shallow marine environments. The sedimentation rate was low so that only "half" nautiloids could be preserved. In bed 10 the fauna becomes richer with abundant fragments of "half" nautiloids and some pectinoid bivalves.
The presence of "half" preserved body chambers of nautiloids suggests for the Unit B of the Cephalopod Bank a shallow marine environment with low sedimentation rate and turbulence. This is in contrast to the shoreface settings *sensu* Massari et al. (1988) where fragile cephalopod shells would have been destroyed by subsequent abrasion, reworking and weathering and where no "half"- nautiloids could be preserved. During occasional rapid sedimentation events (storms?), many nautiloid shells of the upper part of bed 10 were buried in vertical position and could be preserved entirely as molds. Until now, this marine interval is known only from the Bletterbach Gorge in the Dolomites.

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