Cambrian microfauna and palaeoecology of the
Campo Pisano Formation at
Gutturu Pala (Iglesiente, SW Sardinia, Italy)

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ABSTRACT – The microfossil content of nodular limestones of the Late Early to Middle Cambrian Campo Pisano Formation from the Gutturu Pala section of southwestern Sardinia is described and discussed with respect to palaeoecological conditions. Based on detailed facies investigations, the vertical succession of the sedimentary evolution and fossil distribution is interpreted as an environmental change from shallow-subtidal conditions at the beginning of the Campo Pisano Formation to at least deep-subtidal conditions at its end. Due to the faunal characteristics, an interval shallowing during that period is likely.

A dramatic facies replacement with the onset of the Campo Pisano Formation indicates a major reorganisation of the environment, explained by tectonic instability of the platform, accompanied by moderate relative sea-level rise and palaeoecographical and maybe climate changes. During most of the time, the persistence of only one palaeoecological assemblage indicates a more or less stable, open marine, deeper subtidal environment for most of the Campo Pisano time.

Among the taxa represented in the highly fossiliferous sediments, trilobites, echinoderms, brachiopods, and poriferids predominated. Further element are chancelloriids, hyolithids, pelagiellids, hyolithelminthids, and bradoriid arthropods. This occurrence in the Campo Pisano Formation is published here for the first time. The following bradoriid and trilobite species are newly introduced: Hipponichion ichnusn. sp., Condylaspis antiqua n. sp., and - described in open nomenclature - Clavigellus n. sp.


La drastica sostituzione di facies, che segna l’inizio della Formazione di Campo Pisano, indica una imponente riorganizzazione degli ambienti. Ciò è spiegabile innanzitutto con l’instabilità tectonica della piattaforma, alla quale si accompagnano un moderato innalzamento del livello marino e variazioni climatiche indotte dall’assetto paleogeografico. La persistenza, durante un ampio intervallo temporale, di una sola associazione paleoecologica, indica che la deposizione della maggior parte della Formazione di Campo Pisano sia avvenuta in un ambiente marino aperto, sub-tidale profondo, più o meno stabile.

Tra i gruppi di organismi rappresentati nei sedimenti riccamente fosilliferi predominano trilobiti, echinodermini, brachiopodi e poriferi; sono inoltre presenti componenti minori quali chancelloriidi, hyolithidi, pelagiellidi, hyolithelminthidi e bradoridi. La presenza di molti di essi nella Formazione di Campo Pisano è pubblicata per la prima volta in questo articolo. Sono state inoltre istituite formalmente due nuove specie, Hipponichion ichnusn. sp. e Condylaspis antiqua n. sp., appartenenti rispettivamente agli ostracodi bradoridi e ai trilobiti agnostidi, mentre una nuova specie di trilobiti corynexchidi, attribuita a Clavigellus n. sp., è stata lasciata in nomenclatura aperta.

INTRODUCTION

In southwestern Sardinia (Text-fig. 1) autochthonous Cambro-Ordovician sediments crop out in the Iglesiente and Sulcis area (summary monograph: Bechstädt & Boni, 1994). The Cambrian succession within this suite is under investigation since the 19th century. Whereas the early work was mainly focused on palaeontological topics (e.g. Bornemann, 1886, 1891; Meneghini, 1888), research changed later to sedimentological, facies and other interests.

The entire Cambrian succession has a thickness of about 2000 m and indicates an evolution from a clas-
Detailed study. Investigations on this unit were focused in rather subordinate aspects of work on the whole Cambrian succession or on special palaeontological remains. Following that work, the lower unit (Campo Pisano Formation) represents a condensed carbonate succession consisting of more or less nodular silty limestones (Loi et al., 1995). The origin of the nodularity was interpreted by Gandin (1979) and Cocoza & Gandin (1990) as due to compaction and early dissolution processes on a tectonic instable and morphological differentiated shelf. These authors compare this nodular facies to the Jurassic "Ammonitico Rosso". In contrast, Elicki (2001) presented arguments for a deposition in a morphologically rather low diversified subtidal shelf environment. After that author, the nodular texture of the Campo Pisano Formation is a result of complex late diageneric processes. Palaeontologically, the Campo Pisano Formation was never subjected to intensive investigation until recent years. Sporadic works came from Cherchi & Schroder (1984, foraminifera and problematica), from Mostler (1985, foraminifera) and from Pillola (1991, trilobites). Since the middle of the 90's, the microfauna of the Campo Pisano Formation is under investigation by the Freiberg University working group. Hitherto, some work on the so-called "small shelly fossils" is already published by Elicki (2002), Elicki et al. (2003) and Elicki & Wotte (2003). A number of further publications from there are in progress.

Regarding the higher part of the Iglesias Group (Cabitza Formation), some newer work is on the biostratigraphy and sedimentology of this siliciclastic unit. Loi et al. (1995) were able to subdivide this portion by trilobites and graptolites into six different biostratigraphic levels reaching from the early MidCambrian to the Early Ordovician (Caesaraugustian to Tremadocian). The depositional environment following the Campo Pisano carbonates is interpreted by different authors as a deeper basin setting based on sedimentological and taphonomic characters (Gandin et al., 1987; Cocoza & Gandin, 1990; Loi et al., 1995). For the late Mid-Cambrian to the Tremadocian higher Cabitza Formation, in contrast, a relatively shallow environment was interpreted by Loi et al. (1995) because of typical sedimentary features.

The aim of this paper is to present for the first time the microfauna of an entire section of the Campo Pisano Formation, which was attained by chemical preparation and by thin sections, and to discuss their palaeoecological relevance.

The palaeontological specimens described and figured herein are housed at the Geological Institute of Freiberg University (archive number 536), despite the trilobite material, which is at Dipartimento di Scienze della Terra (Cagliari University; acronym DSTCP 23).
THE SEDIMENTARY SUCCESSION OF THE CAMPO PISANO FORMATION AT GUTTURU PALA

The Gutturu Pala locality, where the here reported fauna comes from, is an abandoned sulphide-ore mine situated in the northern Iglesiente area about 4 km southeast of Fluminimaggiore (compare Text-fig. 1). The late-diagenetic to epigenetic pre-Variscan mineralization (Bonì & Balassone, 1994) has taken place within the massive carbonates of the San Giovanni Formation (Gonnesa Group), the overlying Campo Pisano Formation, interesting here, is effected only locally at its base. The whole sedimentary succession at Gutturu Pala (thickness is about 46 m) is tectonically tilted, so that the stratification is more or less vertical today. On the top of the Campo Pisano Formation, the siliciclastic sediments of the Cabitza Formation follow gradually.

The colour of the Campo Pisano limestones at Gutturu Pala is mostly red or light-red, only occasionally light-grey colours occur, while dark facies occurs at the base of the lithostratigraphic unit. Near the transition to the overlying Cabitza Formation, light-greenish/yellowish colours were observed. The colours are bound to clay minerals, but show no distinct distribution pattern over the profile. After testing 13 samples (GP 1 to GP 14) for the clay/quartz content, there is no very strong correlation between colour and clay amount or between occurrence of biota/biofacies and clay content, but it seems to exist an indefinitely trend that the redder the rock colour the higher the clay content. So, the colour may represent a proxy of the siliciclastic input, but more extensive investigation is needed to verify this indication. Generally, the clay content of the samples is less than 10% (averaged 6%). Much fewer is the quartz
content: only in some horizons an amount of less than 1% was detected. X-ray investigations carried out in this section (Lecca et al., 1983) revealed the occurrence of quartz, chlorite, illite and Fe-oxides.

Carbonate microfacies types of the Campo Pisano Formation are generally very rich in mud and include mostly wackestones, subordinate mudstones and floatstones. As the siliciclastic content, the carbonate facies types show no distinct vertical pattern of distribution.

The most conspicuous feature visible in the field is the nodular texture of large portions of the section. This diagenetic nodularity is typical for many (not for all) of the Campo Pisano sections (Pl. 1, fig. 1). The intensity of the nodular texture seems to depend on a distinct minimum content of clay. So, a distinct nodularity was observed at Gutturu Pala only in limestones showing a clay content more than about 6%; in contrast, there are also (but rare) limestones with a relatively high clay content (8.5%) which are hardly nodular (e.g. at the transition to the overlying Cabirita Formation). Most of the limestones at Gutturu Pala are more or less wavy to bulbous by originiation of diagenetic nodules (by pressure solution), which are separated from each other by accumulative seams of non-soluble material. There is no detectable correlation between the degree of nodularity and the occurrence of carbonate microfacies types or the fossil content.

Sedimentary features (e.g. erosive surfaces, cross-bedding, grading, ripples, and bioturbation) were not observed. Whereas the transition from the underlying massive limestones of the San Giovanni Formation (Gonnese Group) to the Campo Pisano Formation (Iglesias Group) is rather distinct and sharp, the transition of the Campo Pisano Formation to the overlying Cabirita Formation is gradual over a permanent increase of the clay content and a small alternation of limestone and claystone within the last few decimetres of the Campo Pisano Formation.

PALAEOONTOLGY

To obtain pristine data, for fossil biodiversity estimations solely thin-section investigations were used. Chemical extracted fossils were exclusively used for taxonomic work.

During our investigation the following groups of organisms were observed from the Gutturu Pala section:
- many: trilobites, echinoderms, brachiopods, poriferids.
- moderate: chancelloriids, hyolithids.
- rare: hyolithelminthids, bradoriids, pelagellids.

Generally, the preservation of microfossils at Gutturu Pala is not uniform. Numerous specimens were silicified during diagenesis (e.g. the trilobites and many of the brachiopods). Other taxa are preserved by original phosphate mineralogy (e.g. hyolithelminthids, bradoriids, some brachiopods). Most of the fossils are disarticulated, but they do not show signs of significant intensive or long-time transport processes (no abrasion, solution, borings). So, broken individuals are not common until the end of the Campo Pisano Formation. At the beginning of the Campo Pisano Formation, the fauna is clearly dominated by sponge spicules (= fauna 1, level GP1; Pl. 1, fig. 2). Only very seldom, some single echinoderm plates, trilobite remains or small brachiopods, bradoriids or hyolithelminthids occur. This basal part of the Campo Pisano Formation is overlain by an assemblage with a distinct higher amount on echinoderm and trilobite remains (= fauna 2, level GP2-GP4A; Pl. 1, fig. 3). Also brachiopods, chancelloriids and hyolithids occur. Fauna 3 (level GP4B-GP9) succeeds, consisting qualitatively of the same content, but showing different quantitative proportions: echinoderms and trilobites decrease significantly. The following fauna 4 (level GP10-GP14A) is characterised by a distinct increase of sponge remains. So,

EXPLANATION OF PLATE 1

Fig. 1 - Typical nodular texture of the Campo Pisano Formation. Camera lid for scale.
Fig. 2 - Spiculite facies in thin section at the base of the Campo Pisano Formation. Level GP1. Scale bar = 1 mm.
Fig. 3 - Echinoderm facies in thin section. Level GP3. Scale bar = 1 mm.
Fig. 4 - Very fissiliferous trilobite facies in thin section. Level GP14B. Scale bar = 1 mm.
Fig. 5 - Four-rayed (4+0, only three preserved) chancelloriid sclerite in thin section. Dark internal sediment is typical for the preservation of these remains. Level GP3. Scale bar = 1 mm.
Fig. 6 - Chancelloriid rosette in thin section showing horizontal and vertical rays (8+1) and trilobite remain. Level GP2. Scale bar = 1 mm.
Fig. 7 - Disarticulated echinoderm elements in thin section. Middle of photograph: polygonal thecal plate with typical marginal inlets (epispires). Level GP2. Scale bar = 1 mm.
Fig. 8 - Disarticulated echinoderm element. Same sample as for Pl. 1, fig. 7. Note the preservation of the net-like stereom. Level GP2. Scale bar = 1 mm.
this fauna is quite similar to fauna 1 with the difference that the trilobite content is higher in fauna 4. The overlying fauna 5 (level GP14B) shows a distinct decrease of poriferids and an increase of trilobites (Pl. 1, fig. 4). So, the fauna 5 is similar to fauna 2, but shows fewer echinoderms and no chancelloriids and hyolithids. The youngest faunal association of the Campo Pisano Formation at Gutturu Pala (= fauna 6, level GP14C-GP17) shows a distinct decrease of all faunal element and resembles fauna 3 in its quantitative proportions.

Summarizing, the biofacies succession within the Campo Pisano Formation at Gutturu Pala can be interpreted as two similar patterns (portions) from fauna 1 via fauna 2 to fauna 3 and, respectively, from fauna 4 via fauna 5 to fauna 6. If these successions indicate a trophic or a palaeoecological change or a changing of habitats and environments will be discussed below.

In many cases, systematic palaeontological investigation on the material attained by chemical preparation or observed in thin sections is not possible. So, the very rare hyolithids (Pl. 2, figs 3-4) are only fragmentarily preserved because of the preparation procedures. The same is for the echinoderms: as well in thin sections (Pl. 1, figs 5, 7-8) as in result of the chemical preparation (Pl. 2, fig. 11), the echinoderm (eocrinoid) remains are represented by disarticulated (but not abraded) plates and so, useless for systematics. Also, the only remain of a stone-core of a pelagellid mollusc is relictic. Nevertheless, from other sections of the Campo Pisano Formation pelagellids have recently been described (Elicki, 2002) – all observed specimens came from the same level near the base of the Campo Pisano Formation and belong to only one species: Pelagellia subangulata (Tate, 1892). The problematic pelagellid remain from Gutturu Pala comes from a stratigraphic comparable interval (GP2-level).

A special point represents the brachiopods. Many specimens were attained by chemical preparation. After first observation it seems that only very few lingulid and acrotretid species (Pl. 2, figs 5-10) represent the rather monotonous brachiopod fauna (friendly personal communication by Michal Mergl, Plzeň/Czechia).

The main microfossil content and those which allowed a systematic approach are briefly described here.

**Poriferids**

The occurrence of sponge spicules at Gutturu Pala is very patchy (Pl. 1, fig. 2; Pl. 2, figs 13-22). Those remains predominate clearly at the lowermost part of the Campo Pisano Formation (25%, level GP1), but they decrease dramatically after some decimetres (to 1-2%). A second maximum of the spicule content occurs at level GP10/GP14A interval (about 15%).

The remains are badly preserved and mostly represent siliceous hexactinellids and secondary phosphatised heteractinids. In some cases, it is not sure to decide if the remain represents a single needle or a broken part from a more complex spicule (Pl. 2, fig. 15). This is especially the case for some “monaxons” and cruciform “tetractins” (?stauractins of lyssakid porifera), which occur upwards in the section (level GP15). It cannot be excluded that some remains represent broken parts of phobactrine elements as described from the Campo Pisano Formation by Mostler (1985). Within the first 5 m of the profile (including the first poriferid maximum level), only simple monaxons, cruciform tetractins and pentactins were found (GP1-GP4). From the same interval the heteractinid *Eiffelia araniformis* (Missarzhevski, 1981) has been identified (Text-fig. 3; Pl. 2, figs 13-14). From the second poriferid maximum level, no specimens were attained by chemical preparation. After thin-section investigation, the spicules here seem to be the same than those at the base of the formation. Further chemical prepared specimens come from the GP15-level (following the second poriferid maximum).

Unfortunately, the poriferid taxa from the Cambrian of Sardinia published by Mostler (1985) are not indicated to distinct localities or sampling levels. Only for his newly introduced species *Sardospengia* (= *Dodecaactinella* *triradiata*, the locality Gutturu Pala and a sampling horizon named “layer 150” is mentioned, but lacking any explanation or graphic for the position of that layer. During the present investigation, no specimens of this affinity were observed from this section.

**Chancelloriids**

Chancelloriids represent a problematic group of Cambrian spiny skeletal elements. They were regarded as poriferids (Walcott, 1920; Butterfield &
Nicholas, 1996) or — together with halkieriids, wiwaxiids, sachitids and siphonogonuchitids — as an own class or order named Coeloscleritophora (Bengtson & Missarzhevski, 1981). Following Mehl-Janussen (1999), the latter is polyphyletic and the chancelloriids may represent a non-poriferan group of hitherto uncertain affinity.

At Gutturu Pala, chancelloriids were found only in the lower third of the succession. The sclerites are generally very rare (less than 1%), only in level GP2 they are a little enriched (up to 5%). The stone-core-preserved, phosphatised chancellorid rays are often disarticulated by chemical preparation procedures, but sometimes chancelloriid rosettes can be observed (Pl. 1, figs 5-6; Pl. 2, fig. 23).

Besides the usually disarticulated single rays, two more complex preserved taxa were observed: *Chancelloria sardinica* Mostler, 1985 (Text-fig. 4; Pl. 2, fig. 23) and *Allonia* Doré & Reid, 1965 (*Allonia* sp.). A more detailed determination of the chancellorid remains from Gutturu Pala is not reasonable because of the morphological variability of those remains associated with the rareness of the findings. Mostler (1985) described his new erected species *Chancelloria sardinica* from “layer 146” (but, again, gives no explanation for the position of that layer). For the further chancelloriids mentioned by that author, no locality is indicated.

**HYOLITHELMINTHIDS**

Hyolithelninthids are widely accepted as polychaete-worm tubes. Typically, they are small conical phosphatic tubes with a more or less irregular curved apical area. Toward the aperture, they are elongated and more straighten. The cross section may be circular (hyolithellids) or elliptical (torellellids).

At Gutturu Pala, rare and bad preserved specimens of this fossil group were found exclusively at the base (GP1-level). The specimens were identified as *Hyolithellus cf. filiformis* Bengtson, 1990. The longest fragment (Text-fig. 5; Pl. 2, figs 24-25) is nearly 3 mm long and has a circular cross-section of about 0.3 mm. The outer surface is covered by more or less regular ring-like annulations in a distance of about 50-90 µm. The relative taxonomic uncertainty results from the bigger diameter compared to the holotype (latter: 150 µm). All other characteristics fit well with the original description.

**PROBLEMATICA**

A problematic remain, represented by a more or less irregular sphere is assigned to *Aetholocapella adnata* Conway Morris, 1990 (Pl. 2, fig. 12). The only specimen has a diameter of 0.5 mm, numerous round openings (about 30 µm) and is slightly flattened at the “base”. The sphere is hollow and siliceous in composition (secondary diagenetic effect as in many associated brachiopods and trilobites). The general shape, size and diameters of the openings point to an affiliation to the taxon mentioned above. Because of the bad preservation, the original mineralogy and the internal structures are not preserved. So, this siliceous “envelope” may represent only the replaced outer wall of *Aetholocapella adnata*. The fact that (in contrast to the specimens described by Conway Morris, 1990 and by Ellicki, 1998) the present specimen is hollow can be interpreted in that way that the primary mineralogy was rather calcareous and diagenetically dissolved than phosphatic — a question which, hitherto, could not been surely inferred. A decision of the present specimen to the similar problematic structure Archaeoides is unlikely because of the lack of the flattened “base” and of differing surface structures in the latter. The biological affinity of *Aetholocapella* is still unclear. Surely, they do not represent free-living metazoa, but maybe resting bodies for storage of propagules (Conway Morris, 1990).

**ARTHROPODS**

Ostracods from the Sardinian Cambrian were reported up to now only by Mostler (1985) due to observations in thin sections of Early Cambrian archaeocyathid limestones. He described ostracods as “occasional occurring, strongly recrystallized, not nearer definable, small shells”. Also in the Campo Pisanino Formation ostracods seem to be rather rare: only in the lowest level (GP1) only few specimens of
localities of SW Sardinia, include Protolenus (Protolenus) pisidianus Dean (in Dean & Özgil, 1994). The vertical range of this latter partially overlaps the succeeding Acadoparadoxides mureroensis Zone of the basal CP2 trilobite assemblage. The specimens tentatively assigned in this paper to Clavigellus belong to the CP1 fauna (see discussion below). The CP2 fauna clearly shows a more diversified trilobite assemblage, including the above mentioned Acadoparadoxides mureroensis and Protolenus (Protolenus) pisidianus at the base, while oortocephalids have been found exclusively in the middle part of this formation, associated with Acadoparadoxides mureroensis, Calodiscus foveolatus Howell, 1935, and dorypygids. In the upper part agnostids (Peronopsis, Psychagnostus, Diplagnostus) are associated with Paradoxides sp., Pardailhania bipida (Thoral 1935), Corynexochus delagei (Miquel 1905), Agrauros sp., Dorpyge sp., Cenocephalus (Cenocephalus) sp., and Dawsonia.

The specimens obtained by chemical preparation are usually tiny and more adapted to the study of small trilobites as agnostids and eodiscids or immature developmental stages of larger individuals. Consequently, the informations about larger trilobite remains from the Campo Pisano Formation at Gutturru Pala are missing. In this paper the occurrence of Condylonyge antiqua n. sp., Skryjasagnostus aff. pompecki and representatives of Aconthinae is reported for the first time from the Sardinian Middle Cambrian; in addition, the Gutturru Pala fauna allows to identify Dawsonia as D. bohemica (Snajdr, 1950).

Due to the paucity and preservation of the arthropod taxa, description is restricted to the best represented and preserved species.

Class OSTRACODA Latreille, 1806
Order BRADORIDID Raymond, 1935
Family HIPPONICHRIONIDAE Sylvester-Bradley, 1961
Genus HIPPONICHRION Matthew, 1886

Type species – Hippionicharchion eos Matthew, 1886.

EXPLANATION OF PLATE 2

Figs 1, 2 - Hippionicharchion ichnusum n. sp.; same specimen in both pictures, stereo-photograph with weak reconstruction of broken part of margin, holotype. Level GP1. Scale bars = 0.5 mm.

Figs 3, 4 - Unassigned hyolith remains. Levels GP8 (fig. 3) and GP2 (fig. 4). Scale bars = 0.5 mm.

Figs 5-8 - Unassigned acrotretid brachiopods. Fig. 6 is detail of (5). Level GP15 (figs 5-6, 8), GP9 (fig. 7). Scale bars = 0.2 mm.

Fig. 9, 10 - Unassigned linguellid brachiopods in phosphatic preservation. Level GP1. Scale bars = 0.2 mm.

Fig. 11 - Disarticulated echinoderm remain. Level GP2. Scale bar = 0.2 mm.

Fig. 12 - Ateolobopallia adnata Conway Morris, 1990. Level GP2. Scale bar = 0.2 mm.

Fig. 13 - Small specimen of Offelia anniformis (Meech, 1881). Level GP2. Scale bar = 0.2 mm.

Fig. 14 - Bad preserved Offelia anniformis (Meech, 1881). Level GP4. Scale bar = 0.5 mm.

Figs 15-22 - Unassigned sponge spicules. Level GP15 (figs 15-19), level GP1 (figs 20-22). Scale bars = 0.2 mm (figs 16, 19-22), 0.5 mm (figs 15, 17, 18).

Fig. 23 - Chancelloria sardinica Mosterl, 1985. Level GP5. Scale bar = 0.5 mm.

Figs 24-25 - Hyolithellus cf. filiformis Bengtson, 1990. (25) is detail of (24). Note the ring-like ornamentation of the tube. Level GP1. Scale bars = 0.5 mm (fig. 24), 0.2 mm (fig. 25).
HIPPO Nichiarion ichtnusum n. sp.
Pl. 2, figs 1-2; Text-fig. 6

2003 Hippicharion sp. – ELICKI et al., p. 33, pl. 5, fig. 2.

Holotype – Right valve; FG 536/1 (Pl. 2, fig. 1).

Repository – Geological Institute, Freiberg University, archive number 536.

Derivation of name – After its occurrence in Sardinia (historical name: Ichnuma).

Type horizon and locality – Basal Campo Pisano Formation (first 0.5 m; level GP1), Gutturu Pala mine, about 4 km SE of Fluminimaggiore (SW Sardinia).

Material – Three specimens.

Occurrence – Late Early Cambrian (latest Toyonian = latest Bilbilian), Campo Pisano Formation.

Diagnosis – Carapace large (maximum length: 2.8 mm; maximum height: 2.1 mm) and sub-triangular in lateral view. Dorsal margin straight. Ventral, anterior and posterior margins only fragmentary preserved, but – if visible – without ornamentation. Lateral surface smooth. Very long anterior and posterior crest-like lobes parallel to sub-parallel to the margin and reaching near to the dorsal margin. Ventrally, the lobes approach each other very, but they do not come in touch. Anterior lobe nearly straight, posterior lobe slightly curved. Mid-dorsally a circular node is prominently developed.

Discussion – The new species differs from the other known hipparicharionids as follows: from H. eosi Matthew, 1886, H. taikalenensis Gozalo & Hinz-Schallreuter, 2002, H. geyeri Hinz-Schallreuter, 1993 and H. elikkii Gozalo & Hinz-Schallreuter, 2002 it differs clearly by the more sub-triangular shape of the carapace, by the size and shape of the lobes, and by the occurrence of a prominent mid-dorsal node. A further difference to H. geyeri Hinz-Schallreuter, 1993 is the lack of pits. From H. hispanicum Gozalo & Hinz-Schallreuter, 2002 the new species mainly differs in the shape of the carapace and in the presence of a prominent mid-dorsal node.

The biostratigraphic level of the finding horizon of Hippicharion ichnumus results from the position 0-0.5 m above the San Giovanni Formation (Gonnese Group). The top of the latter was biostratigraphically defined by Peregón et al. (2000) on the basis of archaeocyaths as Toyonian 2-3 (respectively mid to late Bilbilian, latest Early Cambrian). On the other hand, after Loi et al. (1995), based on trilobites, the Early–Mid Cambrian boundary in Sardinia is situated several metres above the base of the Campo Pisano Formation, that means that H. ichtnumus is late Toyonian (= late Bilbilian) in age.

The palaeobiogeographic distribution of the genus Hippicharion Matthew, 1886 was discussed by Gozalo & Hinz-Schallreuter (2002), coming to the result that the genus is restricted to western Gondwana, Avalonia, and Baltica and so, typical for the Acadobaltic Province sensu Sdzuy (1972).

Class TRILOBITA Walch, 1771
Order AGNOSTIDA Kobayashi, 1935
Suborder AGNOSTINA Salter, 1864
Superfamily CONDYLOPGEIDEA Raymond, 1913
Family CONDYLOPGEIDAE Raymond, 1913
Genus CONDYLOPGE Hayle & Corda, 1847

Type species – Battus rex Barrande, 1846 (by monotypy), Bohemia.

CONDYLOPGE ANTIQUA n. sp.
Pl. 3, figs 1-12

2003 Condylopyge sp. – ELICKI et al., p. 29, pl. 3, figs 3-7.

Holotype – Cephalon, DSTCP 23155, Pl. 3, fig. 5.

Repository – Dipartimento di Scienze della Terra, Cagliari University, acronym DSTCP 23.

Derivation of name – From the Latin “ancient”.

Type horizon and locality – Campo Pisano Formation, level GP9, 24.7 m above the base; Gutturu Pala section, Fluminimaggiore, SW Sardinia.

Material – Level GP9: one poorly preserved enrolled specimen, 11 cephalas and 4 pygidia, DSTCP 23001-07, 23016-17, 23029-31 and 23155; level GP14: 4 cephalas and 2 pygidia, DSTCP 23065-69 and 23154. Additional specimens from loose block GP1B: 19 cephalas and 11 pygidia, DSTCP 23082-100, 23118-121, 23135-137, 23141-144.

Occurrence – Early Middle Cambrian, Campo Pisano Formation.

Diagnosis – A Condylopyge species crescentiform shaped, relatively small anterior lobe, strong spines on the occipital ring and at the posterolateral edges, long preglabellar field and well-developed borders, in both cephalon and pygidium. Pygidial axis slightly tapering backwards, bearing the trace of trace faint furrows and a poorly marked keel, occasionally risen into a faint node; obsolete or faint impressed medial furrow posterior to the pygidial axis.
Description – Cephalon with parallel to gently rounded sides, anterior margin well rounded. Narrow border and border furrow, both broadening and shallowing in correspondence of anterolateral regions (Pl. 3, fig. 6); short and strong paired lateral spines, extending backwards from genital region. Preglabellar field long (sag.), about 1/2 of the anterior lobe, separated from a raised anterior border by a well-impressed border furrow. Axial furrows deep and sharp. Glabella convex, fungiform in shape, as long (sag.) as 70-80% of the cranial length, consisting of two lobes separated by deep, gently anteriorly arcuate transverse furrow. Anterior lobe crescentiform, sagittal length about half the width, extended posterolaterally, occupying 28-30% of the cranial length (little less in immature stages). Prominent posterior glabellar lobe, sub-elliptical to rounded sub-quadrate in outline, slightly longer (sag.) than wide (tr.) with obsolete median ridge toward posterior, and very faint median tubercle at posterior end; narrow and low occipital lobe of about equal width (tr.) as the anterior glabellar lobe, composed of a pair of swollen basal lobes and a middle portion mostly represented by the base of a well-developed posterior occipital spine. Genal region narrow around the anterior lobe, broadens adjacent to posterior lobe.

Unreleased thoracic segment (Pl. 3, fig. 7) shows a well-developed median node on the axial ring. Pygidium sub-ovate in outline, with well-developed posterolateral border. Axis convex, gently tapering backwards, occupying (sag.) 65 to 75% of whole pygidial sagittal length and transversely, about 1/2 of the maximum width of the pygidial shield, showing more or less marked trace of tree pairs, shallowing backwards furrows, impressed only at adaxial ends (Pl. 3, fig. 8) and a poorly marked keel, occasionally risen into a faint node. Faint shallow median furrow on posterior margin. Border wide, particularly developed and shallower in correspondence of the posterolateral regions; gutter-like border furrow, shallower and wider at posterolateral portions. Measurements of holotype: sagittal cranial length about 2 mm.

Discussion – Condylopype antiqua n. sp. differs significantly from most described species of Condylopype in having a medial furrow posterior to the pygidial axis and a posteriorly tapering rachis, which allow a clear distinction against Condylopype rex Barrande, 1846, C. carinata Westergård, 1936, and similar species.


The Sardinian species is very similar to C. globosa (Illing, 1916), which differs from C. antiqua in having a shorter preglabellar field and narrower border, the posterior lobe is slightly wider than long; C. globosa also differs in having weaker occipital and posterolateral spines.

A close species is represented by Condylopype amitina Rushton, 1966, from the Purley Shales, Warwickshire, which mainly differs from C. antiqua by the absence of the medial furrow, by the unfurrowed and more rounded pygidial axis, and slightly by the proportions and shape of the remaining parts of the carapace. Condylopype “etaeus” Fletcher, 1972, from SW Avalon/Newfoundland, shows close similarities in the pygidial features but the cephalon differs in having shorter preglabellar field and cephalic border and longer spines at the genal corners and on the occipital ring. Condylopype cruzensis possess shorter pygidial axis and a more marked keel, and a pair of pleural furrows in the pygidium; in addition, the border furrow and the border margin are relatively narrow and shows rather uniform width, both in the cephalon and in the pygidium (Liñán & Gozalo, 1986: pl. 1, figs 1-8). The occurrence of a pair of lateral furrows across the pygidial pleural field allows to distinguish C. regia from the Sardinian taxa.

Comparisons of C. antiqua with the only and incomplete cranidium of Condylopype sp. from southern Montagne Noire, France (Álvaro & Vizcaín, 2000, pl. 1, fig. 1) is delicate; however, the French species shows clearly narrower cheeks close to the anterior lobe and shorter (sag.) preglabellar field, which suggest more affinities with C. rex. Similar distinctive features are present in the Condylopype species figured by Geyer (1988) from Morocco. Condylopype eli from the Moroccan Anti-Atlas shows a relatively shorter preglabellar region and faint cephalic spines, longer pygidial axis and less rounded outline of the cephalic and pygidial shields.

Family uncertain
Genus SKRYJAGNOSTUS Šnajdr, 1957

Type species – Skryjagnostus pompeckii Šnajdr, 1957: Bohemia.

SKRYJAGNOSTUS aff. POMPECKII Šnajdr, 1957
Pl. 3, figs 13-20

Material – GP9, 4 cephalas and 2 pygidia, DSTCP 23010, 23018, 23035-39; GP11, 1 cephalon and 1 pygidium, DSTCP 23051-52; GPLB, 3 cephalas and 3 pygidia, DSTCP 23131-34, 23138-40; totally 8 cephalas and 6 pygidia.

Description – Semi-elliptical, strongly vaulted cranidium, slightly wider (tr.) than long (sag.), very
faintly defined or completely effaced tapering forwards glabella. Posterior end of the glabella inclined, with occasional occurrence of a extremely narrow (sag.) and long (tr.) occipital ring (Pl. 3, fig. 16). Presence of a narrow doublure.

Pygidial shape nearly identical to the cephalon, little more vaulted in all directions, with defined rachis, especially close to the tiny articulated half ring. Rachis, occupying about 85-90% of the pygidial length (sag.), usually not clearly defined at the posterior end and expanded and slightly more elevated at middle length. Traces of a faint narrow border and doublure can be observed (Pl. 3, figs 13, 17). Cephalon larger: about 1 mm long (sag).

Discussion – For many of the remains, the assignment is particularly difficult due to the absence of distinctive features and to the type of preservation - not only to the taxon but also for a certain distinction between cephalon and pygidia. Due to the peculiar morphology of this taxon, only few details can be added to the original diagnosis and description (Snajdr, 1957, p. 243, in English) and on additional illustrations given by the same author (Snajdr, 1958: pl. 6, figs 4-5, 10, 12-20). The Sardinian Skryjagnostus shows a clearly smaller articulated pygidial half-ring (transversally less than one third of the pygidium at the same level) and poorly defined anterior border. In contrast, the pygidial rachis is usually better defined. In addition, both, cephalon and pygidium are more elliptical than sub-circular in shape.

The genus Skryjagnostus is known from the Middle Cambrian Paradoxides pusillus Zone of Czech Republic and Pedinocephalus or Toxotis Zone from northwestern Siberia.

Suborder EODISCINA Kobayashi, 1935
Family EODISCIDAE Raymond, 1913
Genus Dawsonia Hartt in Dawson, 1868

Type species – Microdiscus dawsoni Hartt in Dawson, 1868.

Dawsonia bohemic a (Snajdr, 1950)  
Pl. 3, figs 21-26

1950 Aculeodiscus bohemicus bohemicus nov. gen. nov. subsp.  
Snajdr, p. 201, pl. 1, fig. 1; pl. 2, figs 1-6, pl. 3, figs 1-2.
1970 Aculeodiscus bohemicus Snajdr – Horný & Bastl, p. 81, pl. 1, fig. 10.
1990 Dawsonia bohemia (Snajd r) – Snajdr, p. 86, text-fig. 87.
1992 Dawsonia bohemia (Snajdr) – Fatka & Kordule, p. 49, fig. 2.
1995 cf. Dawsonia – Loi et al. 68, pl. 4, fig. 9.
1996 Dawsonia bohemia (Snajd r) – Kordule, p. 43, fig. 2.
2000 Dawsonia bohemia (Snajd r) – Álvaro & Vizcaíno, p. 279, pl. 1, figs 2-6.
2003 Dawsonia bohemia (Snajdr) – Elicki et al., p. 29, pl. 3, figs 1-2.

EXPLANATION OF PLATE 3

All illustrated specimens (excepted fig. 38) are housed in the Dipartimento di Scienze della Terra, Cagliari University, Pilolla Collection (DSTCP), followed by the specimen number and the acronym GP (for Gutturra Pala) flanked by the bed number. The abbreviation LB is assigned to the material originated from a loose block. Magnification x 15.8 (see scale bar).

Figs 1-12 - Condyloplexe antiqua n. sp. 1) Immature cephalon, dorsal view DSTCP. 23089, GPBL; 2) Immature cephalon DSTCP. 23003, GP9; 3) Immature cephalon DSTCP. 23085, GPBL; 4) Transversally compressed immature cephalon, DSTCP. 23083, GPBL; 5) Immature cephalon, holotype, DSTCP. 23155, GP9; 6) Large incomplete cephalon, DSTCP. 23090, GPBL; 7) Immature pygidium with unrelased thoracic segment DSTCP. 23154, GP14; 8) Incomplete pygidium, DSTCP. 23069, GP14; 9) Incomplete pygidium DSTCP. 23094, GPBL; 10) Pygidium DSTCP. 23157, GP14; 11) Incomplete pygidium DSTCP. 23097, GPBL; 12) Large fragmentary cephalon, anterolateral oblique view; DSTCP. 23001, GP9.


Figs 35-37 - Clavigellula n. sp. 35) Cranidium, larval stage, DSTCP. 23152, GP2; 36) Cranidium, larval stage, DSTCP. 23153, GP2; 37) Incomplete immature cranidium, DSTCP. 23045, GP2.

Fig. 38 - Unassigned corynexochid, DSTCP. 23063, GP11 (not described in the text).

Fig. 39 - Dorygygids, DSTCP. 23042, GP9 (not described in the text).

Fig. 40 - ?Agraulid, DSTCP. 23116, GPBL (not described in the text).

Fig. 41 - Ellipsocephalid gen. et sp. indet., DSTCP. 23122, GPBL (not described in the text).

Fig. 42 - Ellipsocephalid gen. et sp. indet., DSTCP. 23050, GP4 (not described in the text).
Material – Level GP9: 5 cephalia, DSTCP 23009, 23019-21, 23040 and 5 pygidia, DSTCP 23011-12, 23022-23, 23041; level GP11: 3 cephalia and 2 pygidia, 23053-57; level GP14: one cephalon DSTCP 23070; loose block GPLB: 11 cephalia and 3 pygidia, 23101-23109, 23110, 23145, 23147-51; totally 20 cephalia and 10 pygidia.

Discussion – Coarsely granulose semicircular cranidium, slender elevated conical glabella, occupying 65% of the cranidial length (70% and less in early growth stages) and about 30% of maximum width of the shield at the base. Glabellar segmentation effected, very faint trace of the occipital furrow, represented by a pair of narrow incisions, placed low on sides of the glabella, angling back beneath median strong and well developed cranidial spine arising from L1 (Pl. 3, figs 21-23). Narrow to absent depressed preglabellar field, flanked by the anterior tips of the strongly convex genae. Border furrow well impressed thorough, posterior border furrow shallower. Anterior border crescentiform, wide (sag.) as 20-25% of the cranidial sagittal length, narrowing towards the genal angles, typically bearing 16-20 more or less developed radial incisions defining sub-rectangular „sclerobulacea“. posterior border widens posterolaterally.

Pygidium semicircular in shape, test clearly showing coarse granulations (Pl. 3, figs 24-26); convex conical rachis delimited by deep axial furrows, reaching the posterior border furrow, occupying about 30% (tr.) of the pygidal width. Five axial rings and terminal piece, well separated by sharp furrows. Pleural region convex, with 4-5 broad pleural ribs and 5-6 deep interpleural furrows, shallow border furrow and flat to gently convex border (Pl. 3, figs 24-26).

Discussion – The concept and the historical controversy about the genus Dawsonia (Hartt in Dawson, 1868) has been recently discussed by Álvaro & Vizcaíno (2000); contemporaneously, the first occurrence of D. bohemica outside Bohemia and comparisons with congeneric species have been made by the same authors.

In SW Sardinia, in addition to the Gurturu Pala section levels GP9, GP11 and GP14, Dawsonia bohemica occurs in the GP2 assemblage of the Villaggio Norma section at Monte San Giovanni (Gonnese easternmost end of the „Cabitza syncline“) and in rare pebbles originating from the Campis Piso Formation, within the Caradocian conglomerates of the Monte Argentu Formation, north of Domusnovas. D. bohemica appears in Bohemia in the Paradoxites pusillus Zone and in southern France at the lower occurrence of Badulea tenera in the Coulouma Formation, suggesting an early Caenaraugustian age.

Order Corynexochida Kobayashi, 1935
Family Corynexochidae Angelin, 1854
Subfamily Corynexochinae Angelin, 1854
Genus Corynexochus Angelin, 1854
Type species – Corynexochus spinulosus Angelin, 1854.

Corynexochus delagei Miquel, 1905
Pl. 3, figs 27-33

1905 Corynexochus delagei n. sp. Miquel, p. 481, pl. 15, figs 4-6a, b.
1916 Corynexochus delagei Miquel – Walcott, p. 317, pl. 55, figs 3-3a.
1934 Corynexochus delagei Miquel – Lake, p. 181.
1935 Corynexochus delagei Miquel – Thoral, p. 46, pl. 3, figs 6-7.
1936 Corynexochus delagei Miquel – Resser, p. 23.
1961 Corynexochus cf. delagei Miquel – Sdzuy, 334 (616), pl. 22, fig. 6.
1968 Corynexochus aff. delagei Miquel – Sdzuy, 104, pl. 5, figs 11-12.
1972 Corynexochus sardous – Rasetti, p. 63, pl. 18, figs 1-17.
1973 Corynexochus delagei Miquel – Courtoiselle, p. 136, pl. 3, figs 8-18; pl. 25, fig. 6; pl. 27, fig. 7.
1995 Corynexochus sardous Rasetti – Loi et al., p. 68, pl. 4, fig. 7.
1995 Corynexochus latus Rasetti – Loi et al., p. 68, pl. 4, fig. 2.
2000 Corynexochus delagei Miquel – Álvaro & Vizcaíno, p. 280, pl. 1, figs 7-11.

Material – Level GP9, 6 cranidia and 2 pygidia, DSTCP 23013-14, 23024-27, 23043-44; level GP11, 5 cranidia and 1 pygidium, DSTCP 23058-62, 23064; level GP14, 3 cranidia, DSTCP 23072-74; level GPLB, 2 cranidia and 5 pygidia DSTCP 23111-14, 23130, 23159-60; totally 16 cranidia and 8 pygidia.

Description – Exhaustive description of this taxa has been made by several authors; more recently, Álvaro & Vizcaíno (2000) had the possibility to re-examine the Miquel and Courtoiselle material and add the first description of the hypostome and rostrum. The new material from Gurturu Pala is mostly represented by immature cranidia and tiny pygidia; the smallest immature cranidium (Pl. 3, figs 27-28) shows a narrow (tr.) parallel sided posterior part of the glabella, which strongly expands forwards, with deepening dorsal furrows into a pair of pits, placed just below the largest (tr.) portion of the glabella (Pl. 3, figs 27). Slightly larger cranidia clearly show the palpebral lobe and a very faint ocular ridge (Pl. 3, fig. 32, right side); at this stage the palpebral lobe is about one third of the glabellar length (exsag.), the anterior tip is close to the dorsal furrow and the posterior end far away from the glabella and from the posterior margin of the cranidium. Unfortunately, the largest cranidium is poorly preserved (Pl. 3, fig. 33) and, as for smaller specimens, nothing can be added about segmentation or peculiarities of the surface of the test.
(minute quartz crystals substituted the carapace). The available pygidia also suffer of the above-cited effacement and display more or less segmented rachis, pleural field smooth or faintly furrowed and marginal furrow usually obsolete. The figured specimen (Pl. 3, fig. 34) is about 1 mm large (tr.) and represents a transitory pygidium with incipient hints of release of its anterior segments.

**Discussion** – The high morphological variability during morphogenetic development of *Corynexochus delagei*, the diagnostic characters considered by several authors and the type of preservation, represent the main source of uncertainty for a safe assignment of specimens to this taxa.

The shape of the glabella changes considerably from sub-parallel sided up to the middle length to more or less clavate both during growth but also with distortion/compression during diagenesis (see the imprint of deformation in terrigenous material figured by Courtessole (1972, pl. 3). In tiny specimens, such as the cranidium figured by Rasetti (1972, pl. 18, fig. 3) the glabella is more expanded anteriorly than in larger specimens and resembles closely an incomplete cranidium assigned to *C. latus* (Rasetti, 1972, pl. 18, fig. 21). In other specimens, such as the cranidia figured by Loi et al. (1995, pl. 4, figs 2, 7) the glabellar shape of the specimen on his fig. 2 suggests the assignment to *latus* while the obsolence of the furrows suggest similarities with those assigned to *sardous*. The ratio between the width (tr.) of L1 and the maximum width (tr.) of the glabella has received an elevated taxonomic value in discriminating taxa of *delagei* affinities; however, as pointed out by Alvaro & Vizcaíno (2000, p. 280), this ratio ranges from 33% to 50%. The occurrence of the occipital spine and the shape of the occipital ring represented further matter of debate, but again, the variability observed on figured specimens seems mostly related to different preservation. About pygidial features, we can notice that there are strong differences in segmentation comparing internal moulds and external surfaces (see Rasetti, 1972, pl. 18, figs 6-9, 12-14, 16) and, substantially, there are no significant differences between specimens assigned by Rasetti to *C. sardous* or *C. latus* (Rasetti, 1972, pl. 18, figs 18-20, 25) and the specimens assigned to *C. delagei*. Similar considerations about flattening, internal/external mould morphology and paucity of the available material are valid for the Turkish material (Shergold & Sdzuy, 1984, p. 73-75, pl. 2, figs 9-11).

In agreement with Alvaro & Vizcaíno (2000), which discussed the position of the Sardinian taxa and prefer to maintain the species *C. latus*, we additionally propose to restrict the name *Corynexochus latus* to the type material and assign the remaining Sardinian material to *C. delagei*. For comparisons with other described *Corynexochus* species see Rasetti (1972), Courtessole (1973) and Shergold & Sdzuy (1984, with references).

**Occurrence** – *Corynexochus delagei* occurs in Montagne Noire (France) since the base of the Coulouma Formation up to the A1-A2 levels of Courtessole, in Spain (Asturias and Cantabrian Mountain Range) and Sultan Dag (Taurus Mountains, Turkey); in southwestern Sardinia, *Corynexochus delagei* ranges from the middle Campo Pisano Formation and is also known from the basal levels of the Cabitza Formation, a long range distribution which covers the upper Leonian and most of the Caesaraugustan (including the *Pardalibhania bispida* beds of the CP2 „assemblage“, the *Solenopleurotis (Manublesia) riebei* beds of the CAB1 and the *Eccaparadoxides pusillus - Eccaparadoxides mediterraneus* of the CAB2 levels.

**Subfamily ACONTHEINAE Westergård, 1950**

**Genus CLAVIGELLUS Geyer, 1994.**

**Type species –** *Clavigellus annulus* Geyer, 1994.

*Clavigellus* n. sp.
Pl. 3, figs 35-37

2003 *Clavigellus* sp. – ELICKI et al., p. 29, pl. 3, fig. 8.

**Material** – 3 immature incomplete cranidia from level GP2.

**Description** – Club-shaped unfurrowed glabella gently expanding forward from SO and constricted at the level of L1, without preglabellar field and anterior border, elevated above fixigenae; large sub-triangulare to well rounded occipital ring, slightly larger (tr.) than L1, bearing a low backward and upward directed robust occipital spine. Sub-triangular, well-rounded fixigenae, gently convex in all directions. Palpebral lobes crescentiform, abaxially inclined, occupying (exsag.) 33% to 42% of the glabellar length (excluding the occipital ring), placed about at mid-length of the glabella; faint and narrow ocular ridges, slightly obliquely directed to the largest portion of the glabella.

Anterior branches of facial suture short (exsag.) obliquely directed forwards (early meraspids) or sub-parallel for a short distance. Stout, backwards directed, genal spines, separated by a more or less impressed furrow from the posterior margin of the fixigenae. Librigenae unknown, but probably tiny and narrow.

**Discussion** – In agreement with Geyer, early corynexochids reveal a pronounced paedomorphic trend against doryyptids; these peculiar basal Mid-Cambrian stock is in addition is distinct by a propapicean suture, short palpebral lobes and a club shaped more or less expanded glabella. The Sardinian *Clavigellus* is represented by only three meraspis cranidia, so, inappropriate to erect a new species and also to compare adequately with closer taxa. However, it differs from the Moroccan *C. annulus* in
having a less vaulted cranium, slender glabella and more developed genal spines, and also immature specimens always have longer palpebral lobes; a meraspid of Clavigellus annulus (Geyer, 1994, figs 7-17) clearly shows a slender glabella, but fixigenae are much more elevated.

A closely related taxon is represented by Corynexochella: venusta Dean (in Dean & Özgü, 1994) from the basal Cal Tepe Formation (Taurus Mountains, Turkey), which occurs at the base of the Acadoparadoxides mureensiss Zone, associated with Protolenus (Protolenus) pisidianus. The Turkish species is clearly more similar to the Moroccan and to the Siberian taxa than the Sardinian one.

Clavigellus? n. sp. shows close similarities with the unassigned Corynexichid specimen (Pl. 3, fig. 38, from level GP11); this latter is in turn closely related to the specimen assigned to Corynexochus cf. delagei by Sdzuy (1961, pl. 22, fig. 7) and, as noticed by Geyer (1994), may represent a proparian corynexichid taxon close to Clavigellus, bearing „strettonia-like” palpebral lobes, present in the Iberian Chains (Spain), Montagne Noire (France) and now in Sardinia.

Occurrence — Clavigellus? n. sp. is restricted to the level GP2 of Gutturu Pala section, which strongly suggest correlation with the Protolenus (Protolenus) pisidianus beds of the CP1 assemblage (strata without Paradoxides) indicative of uppermost Early Cambrian age.

PALAEOECOLOGICAL DISCUSSION

As in younger systems, also for the Cambrian a complex of conditions can be assumed which significantly affected the biotic diversity of assemblages and their regional and ecological distribution. Although the preservation potential of organisms (and so the fossil record, respectively) is different depending on the occupied types of habitats, it is widely accepted that during the Cambrian benthic assemblages have dominated (Debrenne & Zhuravlev, 1997).

Generally, there are biotic and abiotic factors which influence the ecologic window. The main abiotic factors for an environment were represented by light, oxygenic level, available nutrients, temperature, chemistry of water and substrate, water energy and clastic input. Especially, the three first mentioned are strongly important and set absolute limits for the ecologic frame of an assemblage.

Except for one record of Givranella published by Cherchi & Schroeder (1984), primary producers (bacteria, cyanobacteria, algae) are not known from the Campo Pisano Formation until now. This is most likely a taphonomic phenomenon, already known from many other carbonate deposits of all epochs.

At Gutturu Pala, the rather monotonous fauna 1 consists nearly exclusively of filter-feeder remains. Echinoderm plates, trilobites, brachiopods, bradorids and hyolithelminths are extremely rare. So, filter feeders are the clearly prominent group of the depositional environment at the beginning of the Campo Pisano Formation. For these organisms a relatively shallow and most possibly muddy habitat with a moderate water agitation can be assumed (shallow subtidal, e.g. Mostler, 1985). The depth was maybe up to few tens of metres, what can be estimated due to the intertidal to very shallow subtidal conditions during deposition of the directly underlying strata and to the ecological requirements of fauna 1. There are no signs of allochthonous origin for the spiculate facies (as erosive base/planes, grading, clasts). A further argument for the autochthonous is suggested by investigations on other Campo Pisano sections, which show that this formation mostly starts with such a poriferid-rich portion. Based on these data, it can surely be assumed that fauna 1 is autochthonous. The mentioned biotic monotonity may reflect a certain kind of stress, most possibly restricted water exchange and/or oligotrophic conditions.

The following fauna 2 shows a distinct increase in echinoderms and trilobite remains (mostly agnostids). Besides brachiopods, also chancelloriids and hyoliths occur. The latter are rather small and include as well specimens with circular cross-section, which are interpreted as semi-infaunal mud-stickers as those with a flattened base or with quadrangular cross-section, indicating an epibenthic mode of life (compare Elicki, 1994). Chancelloriids, typical of shallow to middle-subtidal conditions, are represented by an only low amount with a little “maximum” at the base of fauna 2. Most of the above mentioned fossil groups of fauna 2 have realised a suspension-feeding behaviour on the sediment soft- to firmground surface (brachiopods: filter-feeders, agnostids are mostly represented by benthic detritus sampling suspension- and deposit-feeders [Gondylopyge, Peronopsis and most possibly also Dawsonia]; for discussion see Müller & Walossek, 1987; Debrenne & Zhuravlev, 1997; Whittington et al., 1997; Hughes, 2001; Geyer, pers. comm.). In comparison to fauna 1, this fauna 2 indicates an increase of suspension input into the open-marine shallow to middle-subtidal conditions.

The succeeding fauna 3 contains the same fossil groups as fauna 2, but with a gradual vanishing of chancellordids and hyoliths. The content on echinoderms and trilobites now decreases significantly. Nevertheless, these two epibenthic groups are the still dominating biota here. Whereas the deposit- and suspension-feeding trilobites represent autochthonous elements by taphonomic arguments, for the remains of the suspension-feeding echinoderms (distinctly less than in fauna 2) a movement from shallow and more agitated areas is possible (as in younger deposits, where transportation of skeletal remains of this organism group without markable agitation is possible over some distance). This fauna 3 persists over a
large portion of the section and represents a stable open-marine, probably deep subtidal environment.

The following succession of fauna 4 / fauna 5 / fauna 6 shows a quite similar pattern: first, passive filter-feeders predominate, followed by trilobite-echinoderm facies and finally a decrease of trilobites and echinoderms (dominance of most possible deposit-feeders). The fossils of the last decimetres of the Campo Pisano Formation are rather small and frequently broken.

So, it seems that the succession of habitats documented at Gutturu Pala were characterised twice by similar patterns: (1) firstly shallow subtidal, low-agitated and probably ecologically stressed (low diversity), followed by (2) a shallow to middle-subtidal, open-marine environment which changed finally (3) into the more distal and quiet deeper subtidal.

The dramatic facies replacement during the transition from the underlying San Giovanni Formation (Gonnese Group) to the Campo Pisano Formation (Iglesias Group) indicates a reorganisation of the sedimentary and ecological environment, which may best explained by tectonic instability of the platform (subsidence impulse, tectonic tectonics), most possibly accompanied by a moderate relative sea-level rise (e.g. Bechstädt & Boni, 1994; Loi et al., 1995; Perejón et al., 2000; Elicki, 2001). A climatic change in that time interval is under discussion. Based on sedimentological, diagenetic and isotopic investigation, Cocozza & Gandin (1990) assume a transition from arid (Santa Barbara Formation, early Gonnese Group) to tropical-humid (San Giovanni Formation, upper Gonnese Group) within a generally tidal-flat environment. In contrast, Perejón et al. (2000) agree in the arid conditions at early Gonnese time, but they doubt (but not exclude generally) a transition to tropical-humid because of the strong diagenetic overprint of the upper Gonnese Group. Consequently, the climatic situation during deposition of the Campo Pisano Formation may be concluded as still arid or tropical-humid. Regarding the higher terrigenous content of the Campo Pisano Formation an (1) increase of fluvial transported material and, consequently, of a wetter climate, or (2) a movement of the depositional area into other palaeoclimatic (= palaeogeographic) regions or (3) both, is most likely.

The interesting phenomenon at Gutturu Pala, that the ecological succession of faunas 1/2/3 more or less follows a second time (faunas 4/5/6) higher in the section, can be best interpreted as a moderate and temporary fall of the relative sea-level within a short time. After that sudden fall, the more or less same ecological succession of an again subsiding environment, respectively of a risen relative sea-level (from shallow subtidal to at least deeper subtidal) is well indicated by the faunal evolution.

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