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The historical section of Goni (Lower Graptolitic Shales, SE Sardinia)

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LOCALITY	northern periphery of Goni village, at geographical coordinates: 39°34'46.7" N, 9°17'08.8" E).
LITHOSTRATIGRAPHIC UNIT	Lower Graptolitic Shales (informal unit).
AGE	middle and late Wenlock (late Sheinwoodian and Homerian stages).
WHAT TO SEE	At least several metres thick succession of black alum shales, tectonically sandwiched between two competent banks of Ockerkalk limestone.

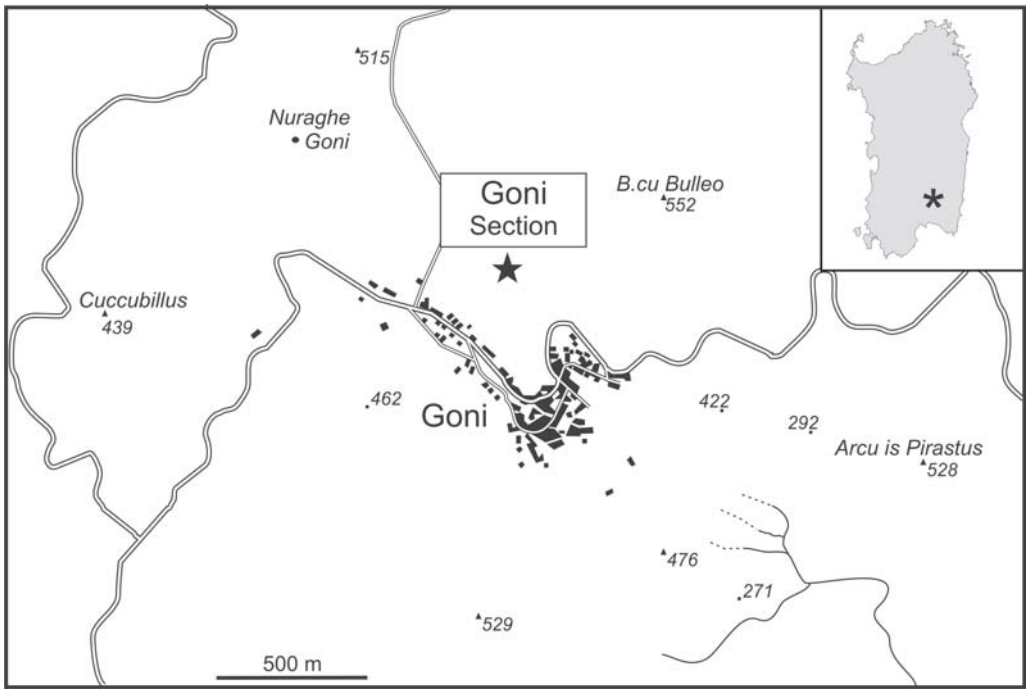


Fig. 1 - Location map of the Goni section.

Fig. 2 - General view of the Goni section.

How to get there

Silurian black shales crop out in a fenced land (previously pig-paddock) at northern periphery of Goni and can be reached from the main road by an upward climbing paved path (via dei Graptoliti). Minor outcrops are situated across the path, opposite to the classical section.

The main locality is now protected in a small park, estabilished by the municipality of Goni.

The Goni section is a classical graptolite locality, *locus typicus* of several graptolite species, and a reference section of the late Homerian biotic crisis – Mulde (*lundgreni*) Event. The black shale succession is complicated by several subordinate but stratigraphically significant thrust faults.

Historical Outline

General La Marmora first collected fossils from Silurian black shales exposed along the local road in Goni village. The outcrop has been considered a classical locality of mid-Wenlock graptolites since the early works by Meneghini (1857) and Gortani (1923) (Fig. 3). Several important species were first described from this section, including the zonal index *Monograptus belophorus* (Meneghini). Barca & Jaeger (1990) described adjacent pig-paddock section and revealed tectonic imbrication of the succession sandwiched

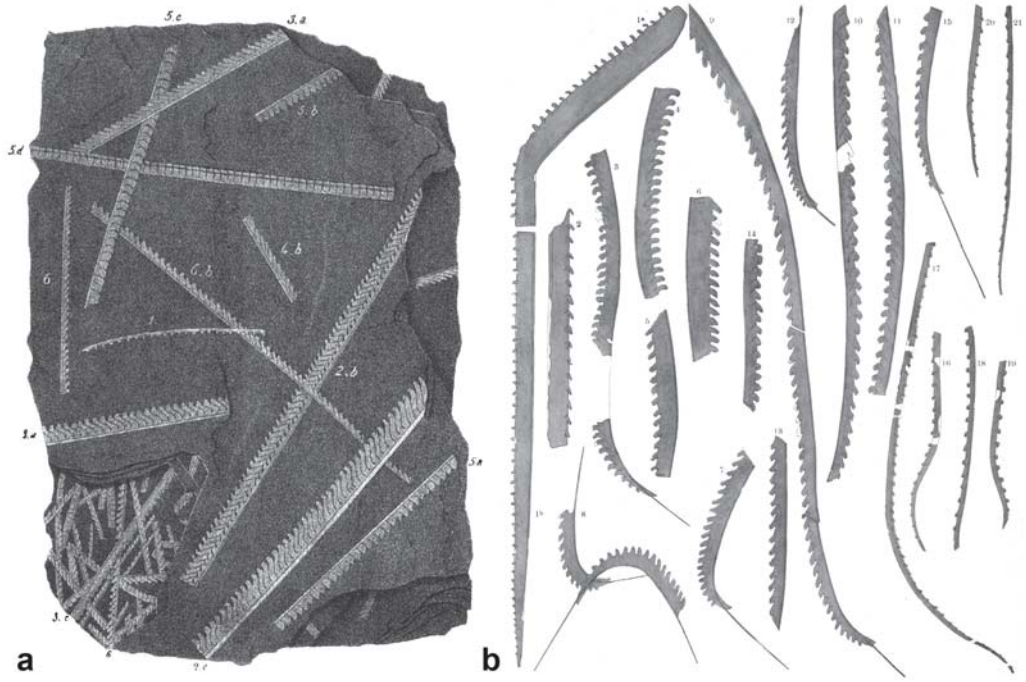


Fig. 3 - a) Meneghini's original drawings of graptolites collected in the Goni section (Meneghini, 1857, Pl. B-I). b) Gortani's original drawings of graptolites collected in the Goni section (Gortani, 1923, Pl. X, III).

between two blocks of Ockerkalk limestone (Fig. 4). Barca & Jaeger (1990) also distinguished several widely correlatable graptolite biozones – those of *M. parvus, M. dubius-R. nassa, M. praedeubeli, M. deubeli* and *M. vulgaris-M. gerhardi* – in the post-*lundgreni* part of the section, which they referred to Ludlow Series. In according to internationally agreed formal stratigraphy, Rickards et al. (1995) reassigned all of these biozones to late Homerian since the Wenlock-Ludlow boundary coincides with the base of stratigraphically higher *Neodiversograptus nilssoni* graptolite Biozone. Pittau & Del Rio (2000) studied chitinozoans and described new taxa from Goni section, Pittau et al.

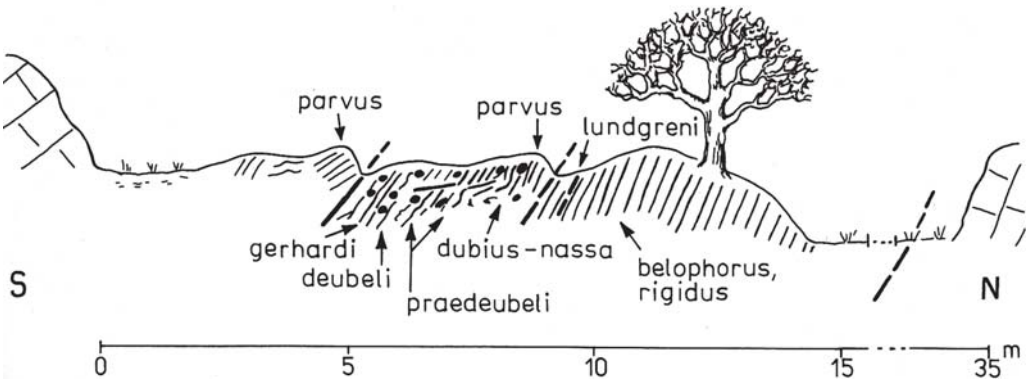


Fig. 4 - Sketched scheme across the upper Sheinwoodian and Homerian succession (Wenlock) in the Goni section (drawing after Barca & Jaeger, 1990).

(2002b) recognized several chitionozoan biozones in Goni section and Pittau et al. (2002a) described some organic walled microfossil problematica, nowadays recognized as agglutinated foraminifera and radiolaria. Pittau et al. (2006) paid attention to *lundgreni* Event - biogeochemical changes and mass extinction at the top of the *Cyrtograptus lundgreni* Biozone.

Lithology

Black alum shale with whitish graptolite rhabdosomes, dispersed pyrite fromboids and, in the late Homerian part of the section, with minute phosphorite nodules and millimetric layers (Barca & Jaeger, 1990; Pittau et al. 2002b).

Fossil content

Graptolite assemblage of the *Monograptus belophorus – Cyrtograptus rigidus* Biozone comprises: *Pristiograptus dubius* (Suess), *Pristiograptus meneghinii* (Gortani) – topotypical specimens (TS), *Monograptus flemingii* (Salter), *Monograptus belophorus* (Meneghini) – (TS), *Monoclimacis flumendosae* (Gortani) – (TS), *Monoclimacis hemipristis* (Meneghini) – (TS), "*Streptograptus*" *antennularius* (Meneghini) – (TS), *"Streptograptus" retroflexus* (Tullberg) and *Cyrtograptus rigidus* Tullberg. Further sedimentary succession is discontinued by a thrust fault above which graptolites of *Cyrtograptus lundgreni – Testograptus testis* Biozone, namely *Cyrtograptus lundgreni* Tullberg, have been reported by Barca & Jaeger (1990).

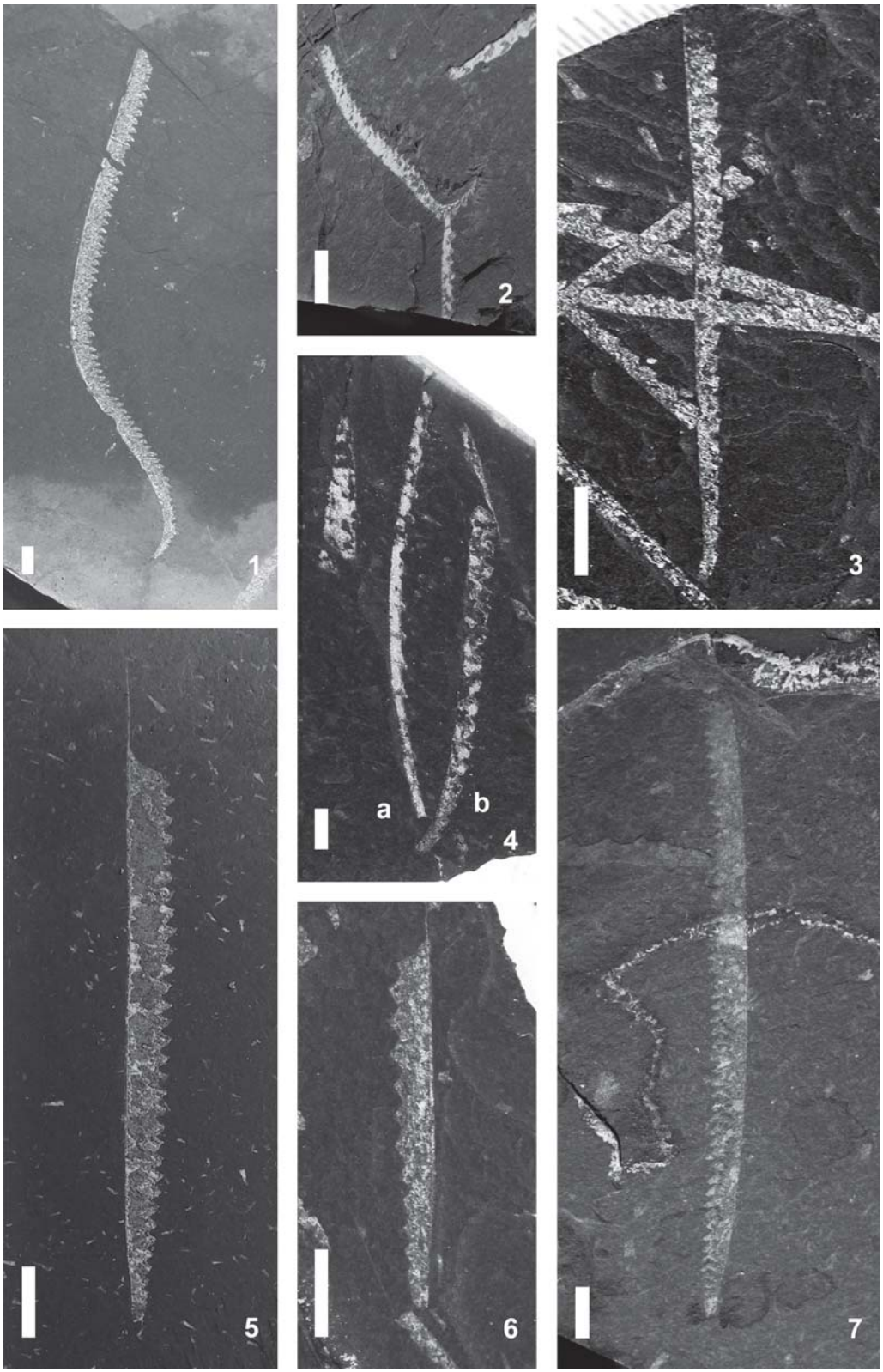
Upper part of the *C. lundgreni – T. testis* Biozone is missing, presumably due to another imbrication. Faunal succession continues with *Pristiograptus parvus – Gothograptus nassa* Biozone which is marked by a dwarf form *Pristiograptus parvus* Ulst, replaced upwards by ?*Pristiograptus dubius* (Suess), and *Gothograptus nassa* (Holm).

Graptolite faunal succession continues with an oligospecific assemblage typified by *Gothograptus nassa* and *Colonograptus praedeubeli* (Jaeger). The latter species is replaced by *Colonograptus deubeli* (Jaeger) in the upper part of this combined *C. preadeubeli – C. deubeli* Biozone. The uppermost Wenlock, assigned to *Colonograptus ludensis – Colonograptus gerhardi* Biozone, is represented by a low diversity assemblage of *P. dubius*, *Colonograptus* cf. *ludensis* (Murchison) and *Colonograptus gerhardi* (Kuehne).

Plate 1

Fig. 1 - *Monograptus belophorus* (Meneghini, 1857).
Fig. 2 - *Cyrtograptus rigidus* Tullberg, 1883.
Fig. 3 - *Monoclimacis flumendosae* (Gortani, 1923).
Fig. 4 - a) *"Streptograptus" antennularius* (Meneghini, 1857); b) *Monoclimacis flumendosae* (Gortani, 1923).
Fig. 5 - *Monograptus praedeubeli* (Jaeger, 1990).
Fig. 6 - *Pristiograptus dubius* (Suess, 1851).
Fig. 7 - *"Colonograptus" flemingii* (Salter, 1852).

Scale bar = 5 mm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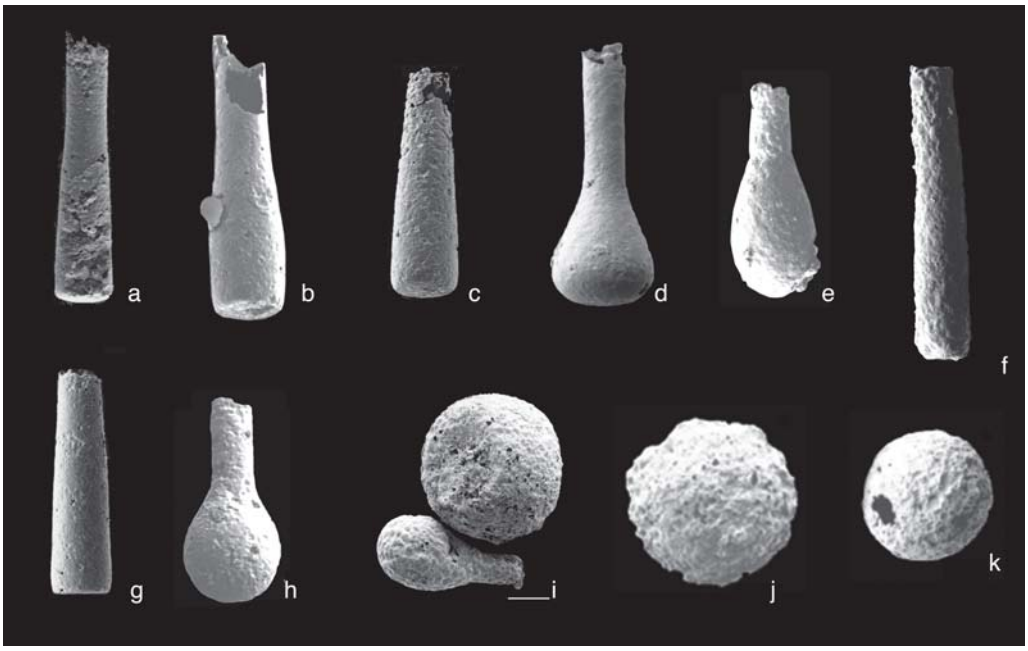

Fig. 5 - Chitinozoans and problematic microfossils from Goni section. a) *Conochitina* sp.a; L= 286 µm. b) *Conochitina subcyatha* Nestor, 1982; L = 320 µm. c) *Conochitina goniensis* Pittau, 2000, L = 226 µm. d) *Sphaerochitina jaegeri* Pittau, 2000, L= 180 µm. e) *Sphaerochitina serpaglii* Pittau, 2000; L = 160 µm. f) *Tanuchitina* sp.a; L= 193 µm. g) *Conochitina goniensis* Pittau, 2000; L = 265 µm. h) *Sphaerochitina ichnussae* Pittau, 2000; L = 180 µm. i) *Sphaerochitina serpaglii* Pittau, 2000; L= 192 µm and organic-walled problematica, Morphotype C; D = 178 µm. j) Organic-walled problematica Morphotype B; D = 160 µm. k) Organic-walled problematica Morphotype A; D = 100 µm.

The latter two species are difficult to distinguish from each other but *C. gerhardi* with lobate thecal apertures predominates in Goni.

Microfossils studied by (Pittau et al. 2006) in the section at Goni comprised chitinozoans and organic walled spherules and hemispheres (probable linings of agglutinated foraminifera and radiolarian capsular membranes after Pittau et al., 2002a). Chitinozoan fauna is represented by *Conochitina subcyatha* (Nestor), *Conochitina* cf. *tuba*, *Conochitina goniensis* Pittau, *Sphaerochitina ichnussae* Pittau, *Sphaerochitina jaegeri* Pittau, *Sphaerochitina serpaglii* Pittau, *Conochitina* sp.?, *Eisenackitina ampulla* Pittau, *Conochitina* cf. *Pachycephala* Eisenack, *Tanuchitina* sp. and *Rhabdochitina* sp. (Fig. 5).

Biostratigraphy

Graptolite biozones of *Monograptus belophorus – Cyrtograptus rigidus, Cyrtograptus lundgreni – Testograptus testis, Pristiograptus parvus – Gothograptus nassa, Colonograptus praedeubeli – Colonograptus deubeli,* and *Colonograptus ludensis – Colonograptus gerhardi.*

Chitinozoan biozones of *Conochitina subcyatha* (corresponds with *M. belophorus – C. rigidus* graptolite Biozone), *Conochitina goniensis* (lower part of *C. lundgreni – T.*

testis graptolite Biozone), and *Sphaerochitina serpaglii* that characterizes the upper part of *C. lundgreni – T. testis* Biozone preserved in Goni section.

The Mulde (*Lundgreni*) Event

Graptolites

Moderately diversified early Homerian graptolite fauna suffered from severe world-wide extinction at the end of *lundgreni* Biozone (see e.g. Jaeger, 1991 and Melchin et al., 1998). Multiramose cyrtograptids and a number of other monograptid taxa vanished. A uniform graptolite association that survived the extinction event was identified by Barca & Jaeger (1990) in the Goni section. Graptolite extinction was coupled with prominent changes in organic walled microfossils, carbon isotope composition and very high enrichment in Cobalt, Cadmium and organic matter (SOM) (Pittau et al. 2006).

Microfossils

A large number of spherical and hemispherical organic microfossils recorded from *C. rigidus* through to *C. lundgreni* zones of Goni section has been tentatively referred to agglutinated forams *Saccamina* and *Hemisaccamina* and radiolarian *Coenosphaerocapsula*. These microfossils reach epibole proportions (many thousands of specimens /50g of rock) in the lower part and in the uppermost part of the *C. lundgreni* Zone. The microplancton disappears in the two consecutive zones: *P. parvus – G. nassa, Co. praedeubeli – Co. deubeli,* and returns in the *Co. ludensis – Co. gerhardi* Zone.

The extinction event (der Grosse Krise) that affected giant graptolites was recognized at the last occurrence of the *C. lundgreni* (Barca & Jaeger, 1990), and another, minor

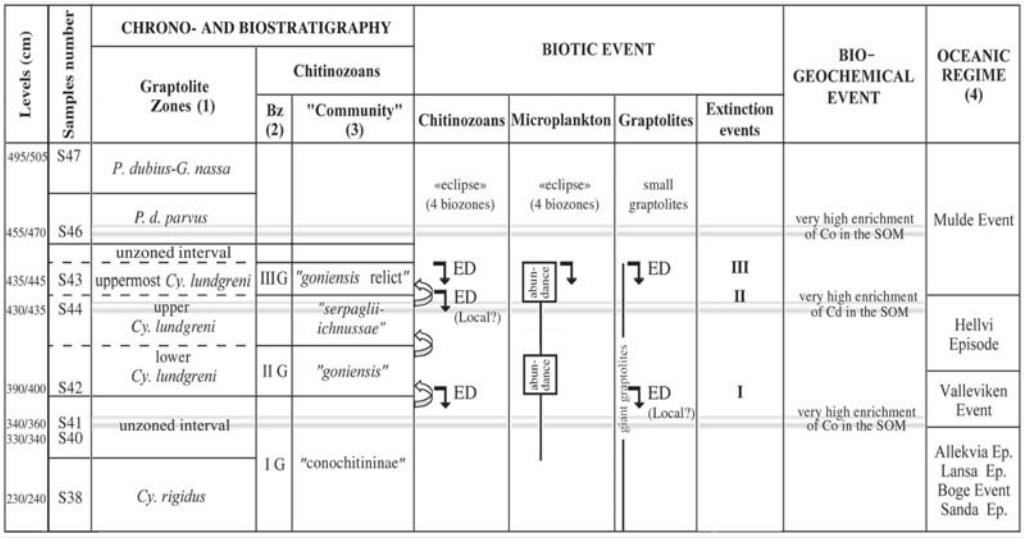

Fig. 6 - Biostratigraphy, biotic and biogeochemical events and oceanic regime in the Mulde event interval in the Goni Section. Grey stripes indicate geochemical anomalies in the sedimentary organic matter (increased concentration of Cd, Co, Ni). Curved arrows indicate changeover in the chitinozoan comunities. Abbreviations: ED = Extinction datum; Bz = Biozone. 1) Barca & Jaeger, 1990; 2) Pittau & Del Rio, 2000b; 3) Pittau & del Rio, 2000a; 4) Jeppsson, 1997. (After Pittau et al., 2006).

one, occurred at the base of the *lundgreni* Zone with extinction of *Monoclimacis* gr. *vomerina*. Also chitinozoans disappear above the *lundgreni* Zone and return in the *ludensis-gerhardi* Zone (Fig. 6). The species characterizing assemblages from the *rigidus* Zone, notably *Conochitina subcyatha* disappear at the base of the *lundgreni* Zone. This extinction event (ED I) appears to preceed Datum 1 of Gotland (Jeppsson & Calner, 2003) and, in Goni, is followed by a second extinction event (ED II) which eliminated *Sphaerochitina serpaglii, S. jaegeri*, and *S. ichnussae*. A third event (ED III) occurred at the end of the *lundgreni* Zone, with the extinction of *C. goniensis* and the giant graptolites. The assemblage incoming with the *ludensis-gerhardi* Zone is mainly composed of *Conochitina pachycephala*.

Geochemical data (trace elements analysis) has shown significantly elevated, up to doubled values for Co and Cd in the organic matter (SOM) compared to the whole rock. A distinct relationship between metal enrichment, faunal changes, extinction events and oceanic events may be inferred after Pittau et al. (2006).

It must be taken in account, however, that the upper part of the *lundgreni* Biozone and the critical extinction level of the *lundgreni* Event may be missing in Goni section due to a minor thrust fault (see Barca & Jaeger, 1990 for discussion).

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