Darriwilian (Ordovician) graptolite faunas and provincialism in the Töyen Shale of the Krapperup drill core (Scania, southern Sweden)

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ORDOVICIAN OF THE WORLD







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Editors: Juan Carlos Gutiérrez-Marco
Isabel Rábano
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Upper left: outcrops of the Late Ordovician glaciomarine Melaz Shuqran Fm, overlying Cambrian sandstones (Tihemboka Arch, Sahara desert, SW Libya).

Upper right: giant traces (> 11 m long) of marine worms in Early Ordovician quartzites from the Cabañeros National Park (central Spain), which serve as logo for the symposium.

Middle left: outcrops of the Late Ordovician Calapuja Fm (foreground mountains) in the Peruvian Altiplano, more than 4,500 m high.

Middle right: Global Stratotype Section at Point for the base of the Middle Ordovician series and of Dapingian stage, Huanghuachang section, Hubei province (South China).

Lower left: Early Ordovician shales (San José Formation) at the Inambari river, Amazonian basin (Eastern Peru).

Lower middle: A view of the Mount Everest (Tibet), whose summit (8,848 m) is formed by the Early-Middle Ordovician limestones of the Qomolangma Fm.

Lower right: Middle Ordovician dolomitic marls and mudstones of the Middle Guragir Fm at the key Kulyumbe river section (northwestern part of the Siberian Platform, Russia).

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This book is dedicated to our mentors **Wolfgang Hammann**
(Germany, 1942-2002) and **Michel Robardet** (France, 1939),
who dedicated an important part of their lives to the
Geology and Paleontology of the Ordovician of Spain

Both bestowed upon us their passion for the rocks and fossils of
this period, and showed us how to study them with a
modern vision and an open mind

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DARRIWILIAN (ORDOVICIAN) GRAPTOLITE FAUNAS AND PROVINCIALISM IN THE TØYEN SHALE OF THE KRAPPERUP DRILL CORE (SCANIA, SOUTHERN SWEDEN)

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INTRODUCTION

In Scania, southern Sweden, Lower Palaeozoic strata are preserved mainly in the Colonus Shale Trough, an elongated, fault-bounded and NW-SE-trending structure within the Sorgenfrei-Tornquist Zone. The relatively condensed Ordovician succession consists predominantly of graptolitic shales deposited in a foreland basin on a marginal portion of the Baltic plate. Outcrops are generally small and restricted to uplifted fault-blocks. Hence, our knowledge of the stratigraphy and spatial and temporal distribution of the succession is to a large extent based on drillings.

A core drilling at Krapperup, northwestern Scania, in 1946 reached a depth of 155.06 m and penetrated a significant portion of the Lower–Middle Ordovician succession. The drilling was carried out by Wargön AB at a site 1.0 km west of the Krapperup castle. The core has diameter of 63 mm, shows no evidence of significant core loss, and is housed at the Division of Geology, Lund University. Graptolites from the lower part of the core, spanning the upper Tremadocian *Hunnegraptus copiosus* Biozone through the lower Dapingian *Pseudophyllograptus angustifolius elongatus* Biozone, have been studied by Lindholm (1981, 1991a, 1991b). The succession in the Krapperup core is the only one representing an unbroken shaly sequence across the boundary between the Tøyen Shale and the Almelund Shale, two units that in Scania are usually separated by the early Middle Ordovician (Darriwilian) Komstad Limestone.

BIOSTRATIGRAPHY

The graptolite succession in the Krapperup drill core is only explored in parts, but has already provided important insights into the biostratigraphy and biogeography of the Lower to Middle Ordovician graptolite faunas of southern Scandinavia and beyond. Lindholm (1981) first recognized the base of the *Kiaerograptus supremus* [*Kiaerograptus* sp. A] Biozone at 151.56 m, followed by the *Araneograptus murrayi* [*Dictyonema* ex. gr. *murrayi*] Biozone at 147.66 m. It is followed by a considerable fault zone

(132.20–113.40 m) and overlain by the *Tetragraptus phyllograptoides* Biozone starting at 112.57 m. The bases of the *Didymograptus balticus* Biozone (88.15 m), the *Pseudophylograptus densus* Biozone (80.78 m) and the *Pseudophyllograptus angustifolius elongatus* Biozone (75.30 m) have also been determined, but the higher part of the succession was not investigated. Lindholm (1991a) described the *Kiaerograptus supremus* and *Araneograptus murrayi* biozones for the first time from Scandinavia based on data from this drill core. The *Hunnegraptus copiosus* Biozone was not recognized in the core, but is known from surface outcrops (Lindholm, 1991a).

The Upper Dapingian (Yapeenian) may be recognized by the presence of *Arienigraptus jianxiensis* sensu Cooper and Ni (1986) at 62.95–62.98 m (Fig. 1J), as the species is neither known from Castlemainian nor from Darriwilian strata. The species is very robust and large, reaching dimensions usually only attained by the genus *Pseudisograptus*. It bears an isograptid development and possesses strong prothecal folds in the manubrium.

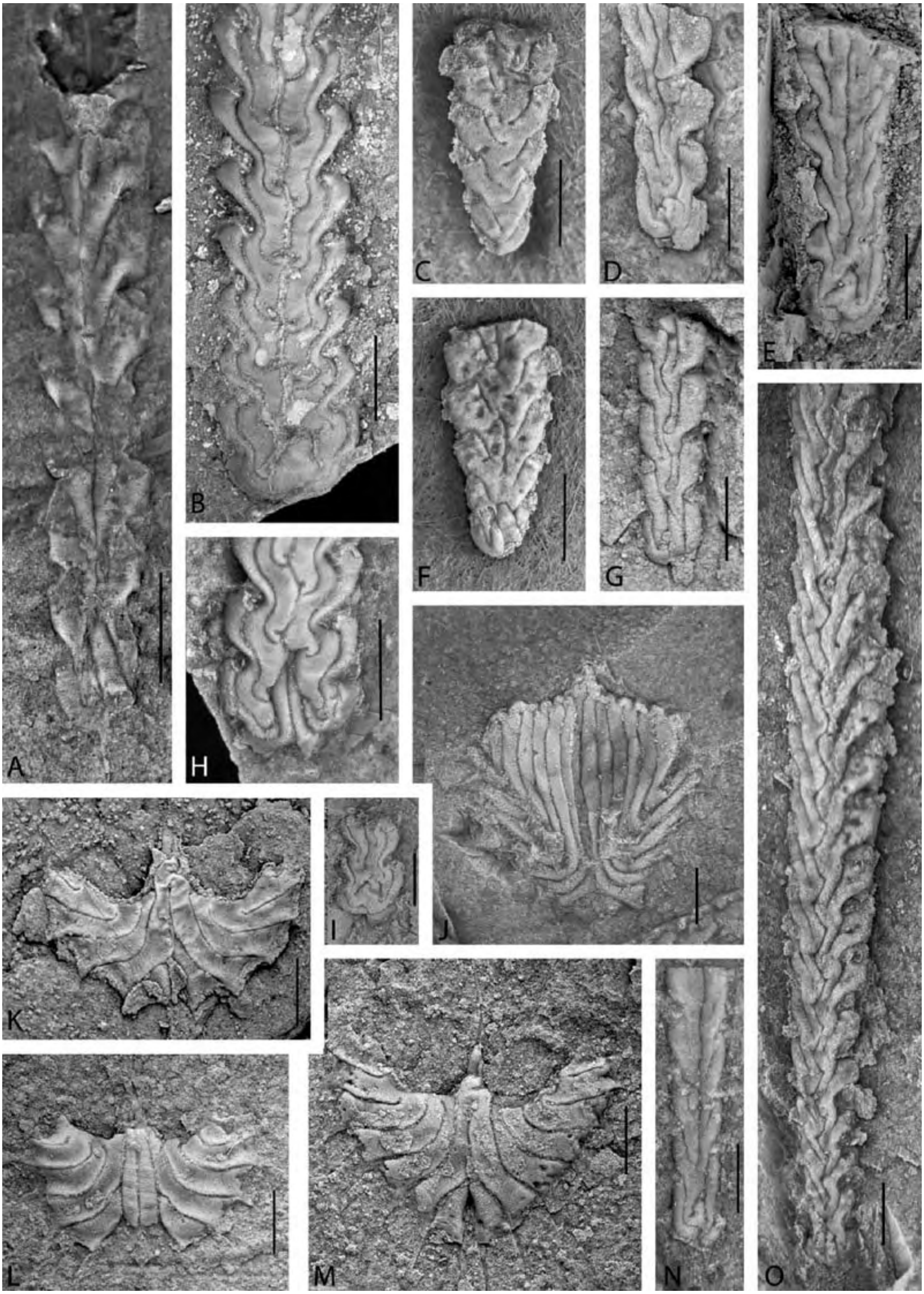
The base of the Darriwilian is here recognized by the presence of *Arienigraptus zhejiangensis* Yu and Fang at 60.67–60.68 m, where the genus is associated with *Pseudisograptus manubriatus* spp. Biserial graptolites of the genus *Levisograptus* (*L. austrodentatus* in particular) are not present and the oldest known biserial, *Levisograptus mui* (Fig. 1B, H) was found only at 54.10–54.20 m. Mitchell (1992, 1994) illustrated specimens of *Levisograptus sinicus* from 48.88–48.53 m and 50.5 m. Maletz (2005) already recognized the late appearance of biserials in the Albjära and Lovisefred drill cores of Scania. The differentiation of the early Darriwilian is difficult, even though numerous biserials of the genus *Undulograptus* are present and the next definitively identifiable level is the base of the *Holmograptus lentus* Biozone in the 24.85–25.15 m interval. The *Holmograptus lentus* Biozone includes a number of different *Holmograptus* species, some of which appear to be new. The excellent relief preservation (Maletz, 2011: figs. a, b) of a number of specimens allows to recognize the specific differences, the presence/absence of prothecal folds, and apertural differentiations.

The *Nicholsonograptus fasciculatus* Biozone is defined by the FAD of its index species at 18.88 m. All specimens are completely flattened. It is interesting to note, that in the Krapperup drill core there is a number of *Holmograptus* specimens in the *Nicholsonograptus fasciculatus* Biozone, and such a biostratigraphic overlap of both genera has not been noted before.

DARRIWILIAN FAUNAS AND BIOGEOGRAPHY

The graptolitic succession of the Krapperup drill core provides some interesting insights into the faunal diversity and composition of early to mid-Darriwilian graptolite faunas of the Atlantic Faunal Realm (Fig. 1). The faunal composition of the Floian to early Dapingian time interval is well known from the Lerhamn drill core (Maletz and Ahlberg, 2011). The interval includes a variety of characteristic *Baltograptus* species

Figure 1. A. *Normalograptus*(?) sp. nov., 22.73–22.74 m. B, H. *Levisograptus mui* (Rickards), 54.00–54.10 m. C, F. *Skanegraptus janus* Maletz, 20.95–21.00 m. D, G. *Proclimacograptus* sp. 20.15–20.19 m. E. *Undulograptus* sp. nov., robust species with straight median septum, 45.65–45.66 m. I. *Undulograptus* sp, small exposed patch of crossing canal and incomplete median septum, 46.01–46.04 m. J. *Arienigraptus jiangxiensis* sensu Cooper (1973), 62.95–62.98 m. K. *Arienigraptus* sp. with diminished manubrium and shortened arienigraptid suture, 58.86 m. L, M. *Arienigraptus zhejiangensis* Yu and Fang, 59.30–59.35 m. N. *Eoglyptograptus* sp.?, delayed median septum, short interthecal septae, LO 6435t, 28.37–28.39 m. O. *Undulograptus* sp., zig-zag median septum, high thecal overlap, 20.40–20.44 m. All specimens are shown in reverse view, except for A, F-H, L (obverse views). All specimens are originals, coated with ammonium chlorite, except for (A) which is a latex cast of a low relief mould. The precise magnification is provided by a 1 mm long bar in each photo.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as the most important biostratigraphic and biogeographic marker species, restricted to the Atlantic Faunal Realm and providing important biostratigraphic marker species (Toro and Maletz, 2007; Maletz and Ahlberg, 2011).

The base of the Darriwilian interval is not identified by the presence of the earliest biserials of the *Levisograptus austrodentatus* group, but the species *Arienigraptus zhejiangensis* (Fig. 1 L, M) and related forms are extremely common and often occur in nearly monospecific assemblages. A similar *Arienigraptus* species with a shorter arienigraptid suture can be differentiated (Fig. 1K). It can easily be mistaken as an isograptid in flattened specimens in which the manubrium is unrecognizable. Specimens of *Pseudisograptus* are also common at a number of levels in the basal Darriwilian of Baltoscandia (Maletz, 2005) and have been found in the Krapperup drill core.

The axonophoran (biserial) faunas are dominated by members of the genus *Undulograptus* with a rounded proximal end and lacking the typical apertural spines on $th1^1$ and $th1^2$ of the genus *Levisograptus*. A number of species can be differentiated in the Krapperup drill core, some of which are preserved in full relief, showing the proximal development in reverse and obverse views. Due to the poor taxonomic documentation of basal Darriwilian graptolite faunas, a specific identification is impossible to provide at the moment for most of the species. The earlier members often show indications of a $th1^1$ spine and the species *Undulograptus cumbrensis* has been identified in the 41.88–46.42 m interval. Species of *Undulograptus* possess a simplified proximal end development with a possible dicalycal theca at $th2^1$ and a connecting arch between $th2^1$ and $th2^2$ (Fig. 1E). The thecal shapes vary between a strongly geniculate type and a straight to curved, outward inclined, ventral thecal side without evidence of a geniculum. The thecal apertures are outwards inclined to horizontal. The thecae possess a double-sigmoid shape. The median septum is strongly zigzag (Fig. 1O) to straight (Fig. 1E). The genus *Proclimacograptus* with a modified pattern C astogeny (Mitchell, 1987) and short interthecal septae appears first in the upper part of the *Holmogratus lentus* Biozone (Fig. 1D, G), much earlier than the record from the Oslo Region of Norway (Maletz ,1997) suggested.

The evolution of a derived simple proximal end development, resembling Mitchell's (1987) pattern G and pattern H astogenies, can be seen in the genus *Skanegraptus* (Fig. 1C, F) and in a single obverse view of a *Normalograptus* specimen (Fig. 1A) from the 22.73–22.74 m level. This material may provide early evidence of a transition from complex proximal development types to simple types in the early Darriwilian. As comparable faunal elements are not found in the Pacific Faunal Realm, it may be assumed that the transition and early evolution of the Normalograptidae (sensu Mitchell et al., 2007) may have taken place in the cold water Atlantic Faunal Realm and the normalograptids invaded the Pacific Faunal Realm much later during their evolutionary history.

CONCLUSIONS

The Krapperup drill core in Scania (southern Sweden) represents one of the longest and stratigraphically most complete successions of the Scandinavian Tøyen Shale Formation and its direct transition into the Middle Ordovician Almelund Shale. A preliminary investigation indicates the presence of a number of graptolite biozones that range from the late Tremadocian *Kiaerograptus supremus* Biozone to the mid-Darriwilian *Nicholsonograptus fasciculatus* Biozone. The typical southern Swedish Komstad (Orthoceras) Limestone is not present in the succession and the Tøyen Shale Formation grades into the overlying Almelund Shale. This unusual development has not been recognized in any outcrop in

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Scandinavia, where the Orthoceras limestones in general attains a thickness of at least a few meters. The Darriwilian graptolite fauna includes largely endemic biserial elements with a number of *Undulograptus* and *Proclimacograptus* species. The *Levisograptus austrodentatus* group of early Darriwilian biserials makes a late and only sporadic appearance in the succession, while species of the genus *Arienigraptus* are common and indicative for the basal Darriwilian strata.

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