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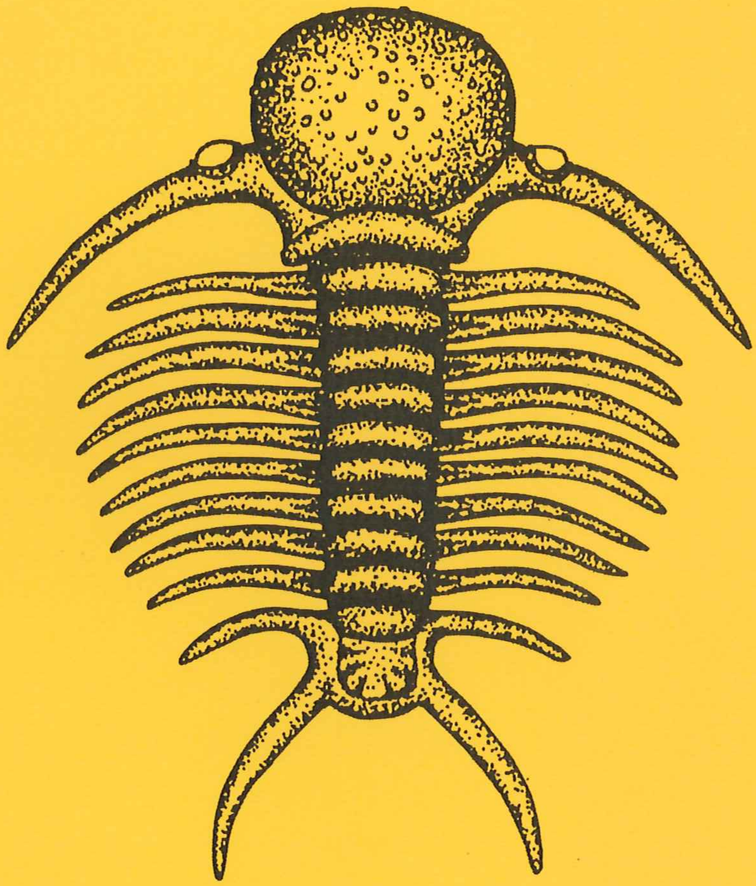

Early Ludlow (Silurian) graptolites from Skåne, southern Sweden

Andreas Nilsson

Examensarbete, 20 p
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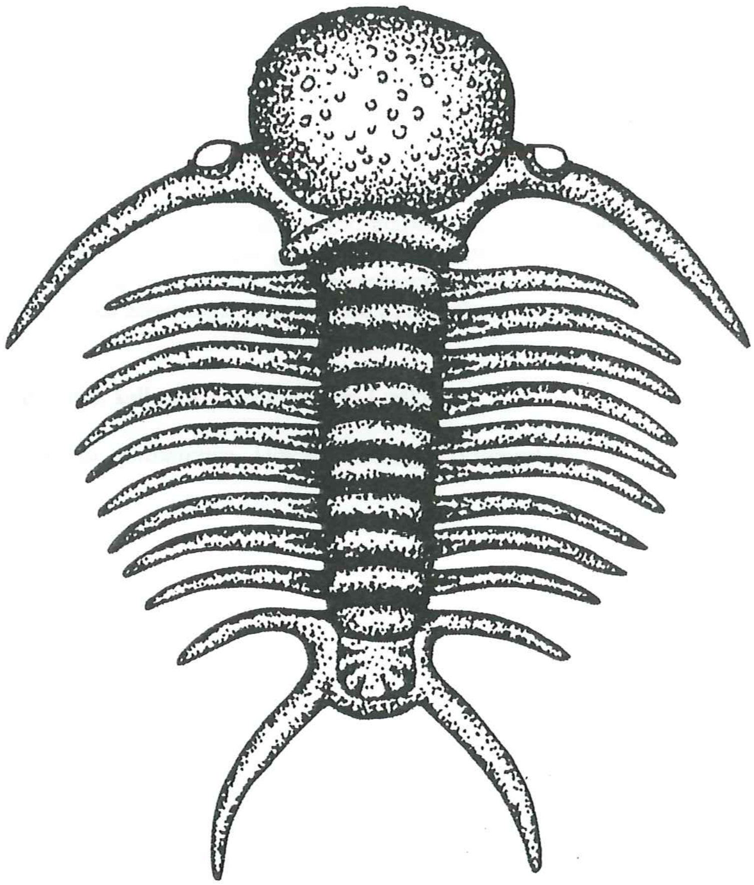

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Graptoliter från Skåne tidig Ludlow (silur)

ANDREAS NILSSON

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Sammanfattning: Colonusskiffern består av ljusgrå, grönaktig eller blåaktig skiffer med en del karbonatinslag. Vid vissa lokaler finns även kalksten och mineralet muskovit i skiffern. Colonusskiffern har en uppskattad tjocklek på mellan 600-1100 m i Skåne.

Graptoliter ur colonusskiffern, från tidig Ludlow, beskrivs från sju olika lokaler i Skåne. En del av de genomgångna lokalerna har beskrivits många år tidigare och behöver därför uppdateras, vad gäller stratigrafisk ålder och taxonomi. Den äldre informationen behandlas och korreleras med nyare från den här studien. Prover från sex kalkstenslokaler har undersökts, storleken på proverna varierar mellan små skifferplattor till stora konglomerat. Skarhult 1 får en ny stratigrafisk ålder, baserat på *Lobograptus progenitor*, istället för *nilssoni* zonen. Förekomsten av *Colonograptus colonus* i Röddinge 1 och 2, samt i Billinge 2 och Bäretofta 1 visar på en ålder hemmahörande i Gorstian, tidig Ludlow. *C. colonus* förekommer även i Skillinge 1, men där tillsammans med *L. scanicus*, varför lagren vid Skillinge 1 kan vara yngre än de ovan nämnda lokalerna. Pinedalen 1 antas vara den yngsta lokalen i undersökningen, med en graptolitfauna vanligt förekommande i Ludfordian. De identifierade graptolitarterna stämmer väl överens med graptolitfauna från Polen, Tjeckien och Storbritannien. Kalkstenlokaler i Skåne, med avseende på graptoliter, kan jämföras med t ex conodont-, chitinozo- och brachiopodfauna i Skåne och på Gotland, för säkrare stratigrafisk zonering. Arbetet visar en korrelation mellan graptolitzoneringen i Skåne och zoneringen av conodonter på Gotland och av chitinozoer i Skåne, i sen Wenlock till tidig Ludlow.

Nyckelord: Skåne, graptoliter, kalksten, colonusskiffer, Ludlow.

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Abstract: The Colonus Shale consists of light grey, greenish or bluish shale with some carbonate. At some localities mica and thin layers of grey limestone are also present. The Colonus Shale has an estimated thickness of 600-1100 m in Skåne.

Early Ludlow graptolites from the Colonus Formation are described from seven localities in the province of Skåne, southernmost Sweden. Some of these limestone localities have been described before, about 100 years ago, and thus needs an update. Earlier data from the localities are discussed and correlated with those of the present study. Samples from six of the discussed localities have been examined, ranging in size from pebbles to small boulders. *Neodiversograptus nilssoni*, which was reported from Skarhult 1, is identified as *Lobograptus progenitor*. The old designation of the Skarhult fauna belonging in the *nilssoni* Zone is correlated to the *progenitor* Zone. The occurrence of *Colonograptus colonus*, in Röddinge 1 and 2, Billinge 2 and Bäretofta 1, demonstrates that the strata are of Gorstian, early Ludlow, age. *C. colonus* also occur in Skillinge 1, but along with *L. scanicus* and therefore this strata could be younger than the localities mentioned above, although still of Gorstian age. Pinedalen 1 probably has a younger fauna than the other limestone localities, which is partly based on graptolite strata. The identified graptolite faunas agree well with faunas described from: Poland, the Czech Republic and Britain. Graptolites in limestone can be correlated with other faunas, for example: conodont- , brachiopod- and chitinozoan faunas, to give an even better zonation. A comparison is made between graptolite zonation in Skåne, in late Wenlock to early Ludlow, to conodont zonation on Gotland and chitinozoan zonation in Skåne.

Keywords: Skåne, graptolites, limestone, Colonus Shale, Ludlow.

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The Silurian of Skåne (Fig.1), the southernmost province of Sweden, can be divided into five formations. In ascending order these are: the Kallholn (earlier named Rastrites), the Cyrtograptus, the Colonus, the Klinta and the Öved formations (Laufeld et al. 1975; Jeppsson & Laufeld 1986). During the Llandovery and Wenlock, the rate of clay sedimentation increased to culminate in the Colonus Shale (Lindström et al. 1991). In the late Ludlow the beds change to a more shelly fossils facies, resembling sedimentation in Gotland, Sweden (Lindström et al. 1991).

The Colonus Shale consists of light grey, greenish or bluish shale with some carbonate. At some localities mica and thin layers of grey limestone are also present (Sivhed et al. 1999). The mudstone, which constitutes the basal part of the Colonus Shale, is the result of shallow-water sedimentation (Laufeld et al. 1975).

The regression responsible for the shallowing is worldwide and may have been caused by glacial events (Laufeld et al. 1975). Sedimentary structures in the Colonus Shale show that the sediment was provided through suspension from the northwest into an elongate, sinking through (Lindström 1960; Lindström et al. 1991), the Colonus Shale Through (Laufeld et al. 1975). The through continues along the Tornquist zone into Poland, where the sediments are even thicker than in Skåne (Lindström et al. 1991).

Due to a fairly thick cover of Quaternary drift material and the large number of faults, the thickness of the five formations is not known accurately (Laufeld et al. 1975). The Colonus Shale has an estimated thickness of 600-1100 m in Skåne indicating rapid sinking, (Tullberg 1880; Hede 1958; Lindström 1971). This large estimate is partly due to the fact that post-*scanicus* zones never have been defined in

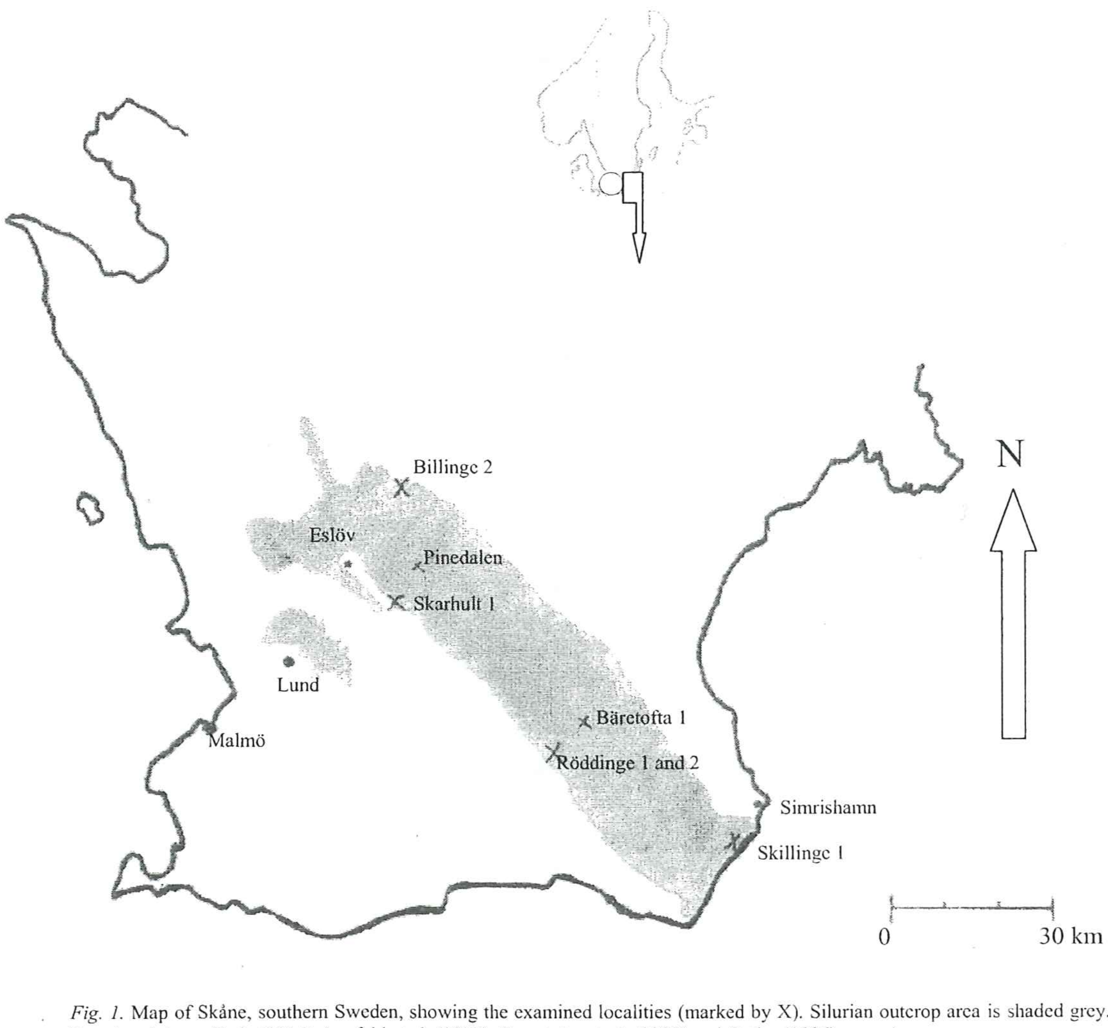

Fig. 1. Map of Skåne, southern Sweden, showing the examined localities (marked by X). Silurian outcrop area is shaded grey. Based mainly on Hede (1915), Laufeld et al. (1975), Bergström et al. (1982) and Grahn (1996).

Skåne (Laufeld et al. 1975).

During the Wenlock and Ludlow epochs, the southern part of Baltica was situated at low southern latitudes, whereas, for instance, the Czech Republic, and parts of Germany, Poland and Britain were situated at higher southern latitudes, in cool-water regions (Kozłowska-Dawidziuk et al. 2001). This could prove to be important because different graptolites, to some degree, tend to prefer different environmental habitats (Kozłowska-Dawidziuk et al. 2001). However, this is not an absolute way to determine where different species lived, but could give some indications of habitats (Kozłowska-Dawidziuk et al. 2001). For example: *Colonograptus gerhardi*, from the uppermost Wenlock and lowermost Ludlow, probably preferred cool-water environments (Kozłowska-Dawidziuk et al. 2001).

The Colonus Shale differs from the older Palaeozoic shales, in being poor in fossils (Tullberg 1883; Sivhed et al. 1999). However, where fossils are present, they are abundant, some levels in the lower part are generally fairly rich in bivalves and graptolites (Tullberg 1883; Grahn 1996). A number of papers describing the fossils of the Colonus Shale have been published, the most important being: Tullberg (1883), Moberg & Grönwall (1909), Moberg & Törnquist (1909), Hede (1915, 1919) and Grahn (1996).

No comparisons between localities exposing the Colonus Shale have been made, particularly in terms of graptolites in limestone. The main purpose of this paper is to clarify findings of graptolites in limestone localities of Skåne. It could prove helpful when correlating with, for example, the condodont zonation. A comparison between chitinozoan and graptolite zonation in Skåne, and to conodont zonation on Gotland is made in Fig. 2. The graptolite zonation used by Grahn (1996) and Jeppsson & Calner (2003) is adapted to the Skåne zonation and is based on this paper and Laufeld et al. (1975).

The taxonomy and nomenclature of graptolites has changed since Hede's (1919) description of Skarhult 1 and Moberg's and Törnquist's (1909) description of Röddinge 1 and thus needs an update. In this paper, the Skarhult 1 locality is the most thoroughly examined of the present seven limestone localities in Skåne (Fig.1). Á more comprehensive study should be made on the graptolite record of Röddinge 1, to fully understand its stratigraphical range and importance.

<table>
<tr><th>SERIES
Stages</th><th>GRAPTOLITE ZONES</th><th>CONODONT ZONES</th><th>CHITINOZOAN ZONES</th><th>SKÅNE</th><th>GOTLAND</th></tr>
<tr><td rowspan="3">LUDLOW
Gorstian</td><td>Lobograptus scanicus</td><td>post Ozarkodina excavata n. ssp. S.</td><td rowspan="2">Angochitina echinata</td><td rowspan="6">Colonus Shale</td><td rowspan="3">Hemse Formation</td></tr>
<tr><td>Lobograptus progenitor</td><td>Ozarkodina excavata n. ssp. S.</td></tr>
<tr><td>Neodiversograptus nilssoni</td><td rowspan="2">K. stauros n.ssp. O. crassa
O. bohemica bohemica
Erika cf. divaricata</td><td rowspan="5">Sphaerochitina lycoperdoides</td></tr>
<tr><td rowspan="5">WENLOCK
Homerian</td><td rowspan="3">Colonograptus ludensis</td><td rowspan="2">Klinteberg Formation</td></tr>
<tr><td>Ctenogathodus murchisoni</td></tr>
<tr><td>Kockelella ortus absidata</td><td rowspan="3">Halla Formation</td></tr>
<tr><td rowspan="2">Pristiograptus dubius-Gothograptus nassa</td><td rowspan="2">Ozarkodina bohemica longa</td><td rowspan="2">Cyrtograptus Shale</td></tr>
<tr><td>Not yet defined</td></tr>
</table>

Fig. 2. Correlation table of the late Wenlock and the early Ludlow of Skåne and Gotland (correlation after Jeppsson et al. (1994), Grahn (1996), Jeppsson & Aldridge (2000) and Jeppsson & Calner (2003).

Historical and stratigraphical review

Tullberg (1883) studied sections at Röstånga, in south-central Skåne, and moved in direction towards Billinge. He reported finds of *Monograptus colonus* and *M. bohemicus* (Tullberg 1883). Between the villages Röstånga and Billinge he reported *M. dubius*, *M. uncinatus* and *M. nilssoni*. Tullberg assumed that this was a boundary layer between the Colonus Shale and the Cyrtograptus Shale as the fauna found deviated from the typical Colonus Shale fauna (Tullberg 1883).

Hede (1915, 1958), Regnéll & Hede (1960), Lindström (1960), Larsson (1979) and Grahn (1996) have published reviews on the Colonus Shale, for instance concerning the thickness and the formation of the Colonus Shale. Laufeld et al. (1975) defined the boundary between the Colonus Shale and the underlying Cyrtograptus Shale in an, at the time, newly opened quarry at Östra Odarslöv, about 5 km ENE of Lund. The quarry is no longer accessible. The base of the Colonus Shale was defined at the base of the *Pristiograptus ludensis* Zone (Fig. 3), which is the last Wenlock graptolite zone (Laufeld et al. 1975). Studies by Grahn (1996) resulted in a new base for the Colonus Shale, the top of the *dubius-nassa* interregnum (Fig. 2).

A "Cardiola limestone" is found in Spain (Gutiérrez-Marco et al. 1996). It is about 50 cm thick and the graptolite record ranges from the base of the Llandovery to the Ludlow, levels younger than the *Saetograptus leintwardinensis* Zone (Gutiérrez-Marco et al. 1996). The Colonus Shale was earlier named the Cardiola Shale (Tullberg 1880) based on the occurrence of *Cardiola interrupta* (see Hede 1919), a widespread Silurian bivalve found in the Wenlock and the Ludlow strata, e.g. in the Cyrtograptus Shale in Thüringen, Germany (Hede 1915). Kříž (1990) also mentions the "Cardiola limestone" as a common occurrence in the graptolitic shale of Bohemia. The "Cardiola limestone" mainly comprises *Cardiola* bivalves and cephalopods, and has been found through the middle Wenlock into the Lower Devonian (Kříž 1998). The examined Skarhult 1 limestone resembles the "Cardiola limestone" since it mostly consists of bivalve and cephalopod shells. The cephalopod limestone of the Prague Basin occurs in, for example, the *colonus* and *chimaera* zones (Kříž 1998). This agrees fairly well with the faunal age of Skarhult 1. Urbanek (1958) and Jaeger (1959) proposed that the "Cardiolaskiffer" from Skåne might be the source for the erratic boulders of Poland. Urbanek (1966) latter disagreed with this assumption, because of the lithological difference between the deposits. The Skåne deposits consist of clayey shales with a small number of marly and calcareous intercalations, whereas the erratic boulders are marly erratic limestones (Urbanek 1966). The limestone at Skarhult 1 and Billinge 2 resemble the erratic boulders found in Poland, described by Urbanek (1966), where the latter assumption not can be confirmed.

Detailed studies of early Ludlow graptolites made by Urbanek (1963), revealed two different *Monograptus nilssoni* species: "*M. nilssoni* A" (true *M. nilssoni*) and "*M. nilssoni* B". The old concept of "*M. nilssoni*" *sensu* Lapworth 1876 developed into *Neodiversograptus nilssoni* and *Lobograptus progenitor* (Urbanek 1966), resolved by the International Commission on Zoological Nomenclature (Palmer 1971). The unusual overall similarity between *N. nilssoni* and *L. progenitor* could be explained by inherited characteristics from a common ancestral species, *M. sherrardae* (Sherwin 1974), from the Homerian *praedeubeli* Zone (Urbanek & Teller 1997). Rickards (1976) concluded that the *nilssoni* and *progenitor* zones *sensu* Urbanek 1966 would receive widespread international recognition or at least a lower and upper *nilssoni* Zone should be recognisable.

Urbanek (1966) introduced the *progenitor* Zone between the *nilssoni* Zone and the *scanicus* Zone. This zonation is used in Poland (Teller 1969; Urbanek & Teller 1997) and in this paper (Fig. 3). The interval corresponding to the *progenitor* Zone in the British Isles (Holland and Palmer 1974, Rickards 1976, Lawson & White 1989) is the upper part of the *nilssoni* Zone *sensu* Lapworth 1876, and the upper part of the *colonus-nilssoni* Zone in Germany (Jaeger 1991). In North Wales, Warren et al. (1971) distinguished an upper *nilssoni* Zone *sensu* Lapworth 1876, based on the appearance of *Saetograptus chimaera*, *Lobograptus scanicus* and *Monoclimacis micropoma* and the disappearance of *Monograptus uncinatus orbatus* and *Spinograptus spinosus*. Warren (1971) correlated the upper *nilssoni* Zone *sensu* Lapworth 1876 with the *progenitor* Zone of Poland. Kozłowska-Dawidziuk et al. (2001) use the *nilssoni* Zone for the Czech Republic, but Přibyl (1983) used the *progenitor* Zone equivalent. This paper follows the zonation of Kozłowska-Dawidziuk et al. (2001). In Arctic Canada (Lenz 1990, 1992, 1995), the *progenitor* Zone is also used, but ranging through the Gorstian, Ludlow (Fig. 3). To clarify: the old zonation, using the *nilssoni* Zone *sensu* Lapworth 1876 is still being used in e.g. Great Britain, the Czech Republic and Germany, whereas the newer zonation *sensu* Urbanek (1963), is used in e.g. Skåne and Poland (Fig. 3) and somewhere in between? there is the *progenitor* Zone of Arctic Canada.

Standard reference zones (Koren 1989) and primary biozones (Cocks & Nowlan 1993) have been proposed for the Ludlow Series. Standard reference zones are intended to provide greater potential for global correlation (Koren 1989). The problem with this zonation is the necessity to subsume a number of local biozones into one standard reference zone (Rickards 1995). Using the graptolite zonation in, for example, the British Gorstian with *nilssoni*, *scanicus* and *tumescens-incipens* (Richards 1976, 1995) would yield the two standard reference zones: *nilssoni* and *scanicus*-

SERIES Stages	Skåne, Sweden (This study; Laufeld et al. 1975)	Baltic/Poland (Teller 1969; Urbanek and Teller 1997)	Czech Republic (Štorch 1994; Kozłowska-Dawidziuk et al. 2001)
LUDLOW Gorstian	*scanicus*	*parascanicus*	*chimaera-scanicus*
	progenitor	*progenitor*	*nilssoni*
	nilssoni	*nilssoni*	
WENLOCK Homerian	*ludensis*	*ludensis*	*ludensis-gerhardi praedeubeli-deubeli*
	dubius-nassa	*nassa*	*parvus-nassa*
	lundgreni	*lundgreni*	*lundgreni*

Fig. 3. Graptolite zonal scheme of the Late Wenlock and the early Ludlow. (Continues on the opposite side).

-chimaera (Koren 1989). Primary biozones are also proposed as global standards, which would subsume zonations of more local value (Cocks & Nowlan 1993).

Material, methods and localities

Material was mainly collected from five localities, viz. Billinge 2, Röddinge 1 and 2, Skillinge 1 and Skarhult 1, in Skåne (Fig. 1). Additional material from Bäretofta 1 has also been examined. Pinedalen, a locality with a possible younger graptolite fauna the other localities, is mentioned because of its important graptolite stratigraphy. The localities are presented in stratigraphical order, starting with the oldest, based on the present identifications. A summary of the identified specimens and the proposed locality zonation is given in Figs. 4 and 10, respectively. The specimens were studied using a light-microscope; some preparation of the graptolites was necessary. Lennart Jeppsson arranged that one sample from Billinge 2 was dissolved in buffered acetic acid, using the method described by Jeppsson et al. (1999). It yielded three-dimensionally preserved specimens of *Colonograptus colonus*. The identified specimens from the rock slabs were photographed with a Nikon digital camera.

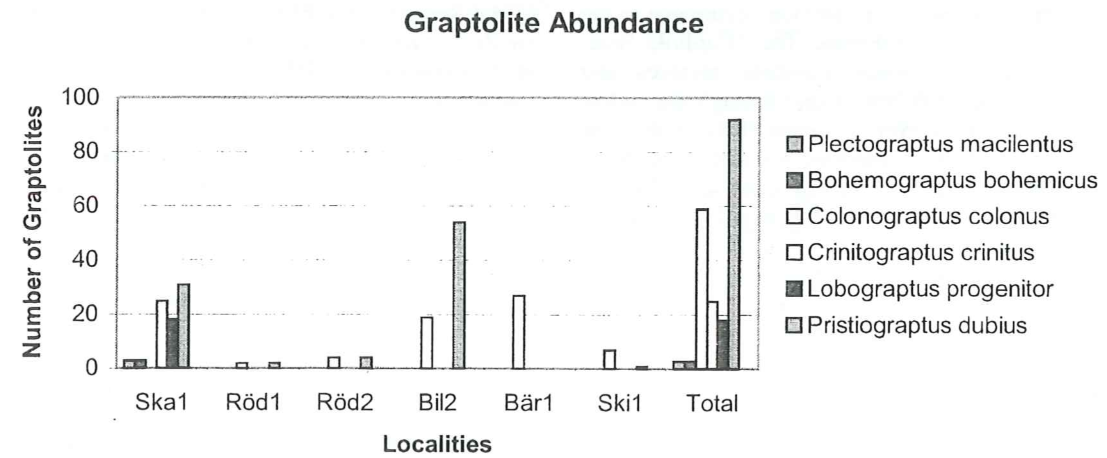

Fig. 4. The graptolite abundance in samples from the examined localities: Skarhult 1, Röddinge 1 and 2, Billinge 2, Bäretofta 1 and Skillinge 1.

Germany (Jaeger 1991)	Great Britain (Holland and Palmer 1974; Rickards 1976; Lawson & White 1989)	Arctic Canada (Lenz 1990, 1995)	SERIES Stages
chimaera-scanicus	*scanicus*	*progenitor*	LUDLOW Gorstian
colonus-nilssoni	*nilssoni*		
ludensis-gerhardi praedeubeli-deubeli	*ludensis*	*ludensis praedeubeli-deubeli*	WENLOCK Homerian
dubius-nassa	*nassa*	*dubius-nassa*	
lundgreni	*lundgreni*	*lundgreni-testis*	

Fig. 3. Graptolite zonal scheme of the Late Wenlock and the early Ludlow. (Continuation from the opposite side).

Skarhult 1

Topographic map sheet 3C Helsingborg SV. Geological map sheet Aa 74 Helsingborg. GPS-coordinates N: 6188544, E: 1348083, when standing on the outcrop in the middle of the rivulet (Fig. 5.). The outcrop is about 1025 m East of Skarhult church, in the bottom of the river Bråån, and hence is only accessible at low water stand (Hede 1919; Larsson 1979; Grahn 1996). The strata consist of shale, dolomite and limestone.

Hede examined the Skarhult 1 locality in 1919 and found that the fauna was rich in species as well as individuals, especially of graptolites, brachiopods and ostracods. He reported the brachiopods *Dalmanella canaliculata*, *Chonetes striatellus*, *Camarotoechia nucula* and *Dayia navicula* from the limestone. *C. nucula* and *D. navicula* also occurred in the shale (Hede 1919). Less common are the brachiopods *Strophonel-*

Fig. 5. The river Bråån mainly flows in an E-W direction but the locality is found at the bend where the rivulet is coming from a N-E direction. The pictures show the surroundings of the outcrop, which is marked in picture B. Picture A shows the rivulet when standing at the bend, facing northeast.

la euglypha, *Leptaena rhomboidalis*, *Ch. scanicus*, *Atrypa reticularis* and *Spririfer crispus*, all of which occurred in the limestone (Hede 1919). Furthermore, the ostracods: *Beyrichia steusloffi*, *Primitia cristata*, *P. mundula*, *Aechimina bovina* and *B. maccoyina* were reported from the both the limestone and the shale (Hede 1919). Less common than the ostracods species above are: *B. jonesi*, *B. nodulosa*, *P. valida*, *Macrocypris vinei* and *Bythocypris symmetrica*, which are exclusively found in the limestone (Hede 1919). He reported the graptolite *Monograptus dubius* from both the limestone and the shale, whereas *M. nilssoni, M. crinitus* and *Plectograptus macilentus* were only found in the shale. He concluded that the graptolites belonged to the *nilssoni* Zone *sensu* Lapworth 1876, in the lower Ludlow (see Fig. 3).

Martinsson (1967) correlated the ostracods from Skarhult 1 with ostracod fauna on Gotland. He identified *Beyrichia jonesi* and *Hemsiella* cf. *hemsiensis* (Martinsson (1967). These co-occur on Gotland, too, at the top of the *nilssoni* Zone *sensu* Lapworth 1876 (Martinsson 1967).

Hede's samples have also been examined, both by myself in 2003 and by Hermann Jaeger in 1981 (Lennart Jeppsson, pers. comm.). Because of poor preservation, no certain identification could be made by Jaeger. He referred to Hede (1919) for identification and concluded that: "specially the rather frequent occurrence of *Retiolites* (*Plectograptus*) *macilentus* speaks in favour of dating the fauna as *nilssoni* Zone (better name: is *colonus* Zone)", (Jaeger in a letter to Lennart Jeppsson in 1981.07.13.). Jaeger did not recognise the *progenitor* Zone and therefore did not place the Skarhult 1 fauna accordingly. I found that Hede's collection contains: *L. progenitor*, *Plectograptus*? sp., *Crinitograptus crinitus* and *Bohemograptus bohemicus*.

In my examination of Skarhult 1, I placed the top of the limestone outcrop as layer 0 and measured ca 1,5 m below and ca 1,5 m above layer 0 (Figs. 6 and 7). The limestone, sample-size about 10 kg, has a very low graptolite abundance in contrast to that of layers 4-5, sample-size about 1 kg. The bedding surfaces of layers 4 and 5 are partly covered by specimens of *Pristiograptus dubius*. The samples contain: *P. dubius* (the only graptolite found in the limestone, as rhabdosome fragments), *Bohemograptus bohemicus*, *Crinitograptus crinitus* and *Lobograptus progenitor*.

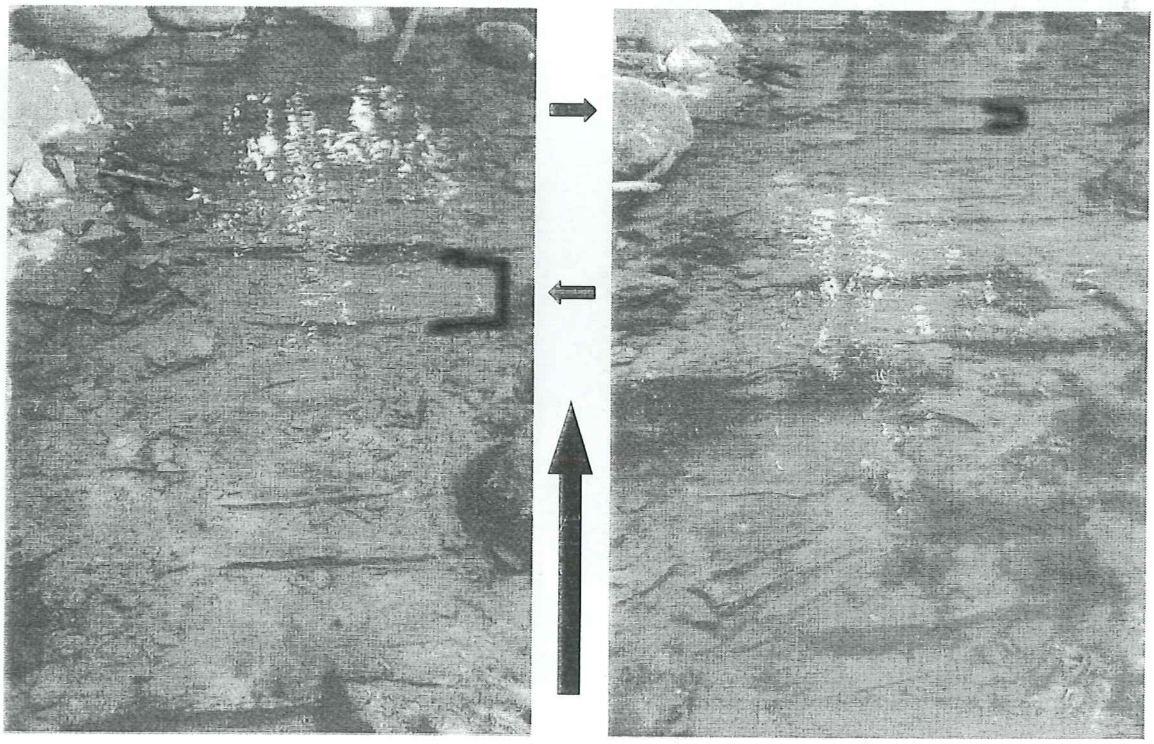

Fig. 6. Profile of the limestone outcrop in Skarhult 1. The marked layer is the limestone bed and is 64 mm thick. The big arrow indicates "up" in the layers.

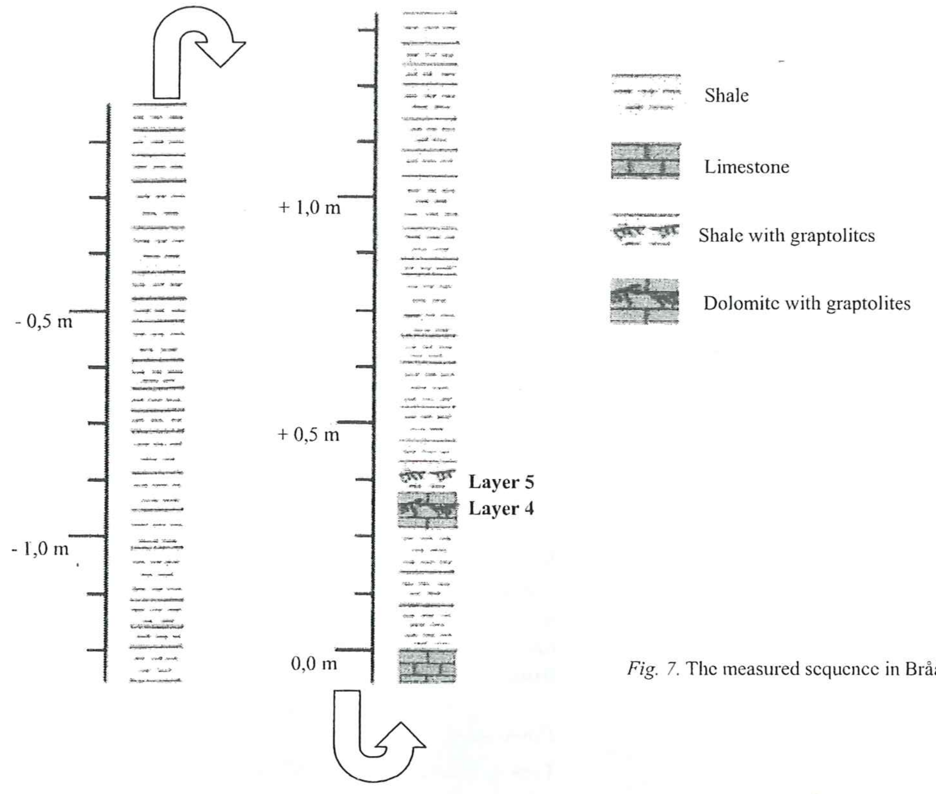

Fig. 7. The measured sequence in Bråån, Skarhult.

Röddinge 1 and 2

Topographic map sheet 1D Ystad NO & 2D Tomelilla SO, Geological map sheet Aa142 Sövdeborg. UTM-coordinates for Röddinge 1 are VB 2695 6000, about 450 m SSW of Röddinge church (Grahn 1996). Temporary excavation on the SW slope of the small plateau, Lerberget, south of Röddinge (Larsson 1979). The bedrock is only accessible by digging (Larsson 1979). On a field trip to Röddinge in the autumn 2002, the Röddinge 1 locality could not be recovered, although the Röddinge 2 locality was discovered. The Röddinge 2 locality is situated in Fyledalen (see Fig. 8). Unfortunately no GPS coordinates could be read.

Moberg and Törnquist (1909) thoroughly examined an 11 m high section at Lerberget in Röddinge. The limestone lenses in that section contain mostly brachiopods. Graptolites are abundant at some levels, or do not occur at all (Moberg & Törnquist 1909). Moberg & Törnquist (1909) reported *Monograptus dubius*, *M. bohemicus*, *M. colonus*, *M. nilssoni*, *M. scanicus*, *Gothograptus nassa*, *Plectograptus macilentus*, *Retiolites spinosus* and *M. roemeri*. *M. dubius* was only identified in the upper layers, but the state of preservation made it difficult to discern *M. dubius* from *M. colonus* (see Moberg & Grönwall 1909). *M. bohemicus* and *M. colonus* were reported to cover the surface on many layers in the section (Moberg & Grönwall 1909), but the former species was absent in the lower part of the section. Other graptolites were more rare, for instance; *M. roemeri* and *M. nilssoni* were only reported from the lower part of the section (Moberg & Grönwall 1909). *M. scanicus* mainly occurred in the middle part of the section, although some specimens were reported from the lower part (Moberg & Grönwall 1909). Moberg and Törnquist (1909) found the brachiopod *Cardiola interrupta* in the same layer as *M. bohemicus*, *M. colonus* and *M. scanicus*, together with *Beyrichia* ostracods, later identified as *B. nodulosa*, *B. buchiana*, *B. scanensis*, *B. steusloffi B. maccoyiana* and *B. cuspidata* (Moberg & Grönwall 1909).

Two samples from Lerberget, Röddinge, were available to me. The sample from Röddinge 1 consists of mud-draped limestones, collected by Arne Klementsson (Department of Geology, Lund). The other sample from Röddinge 2 (Fig. 8), was collected by myself in 2002 and consists of calcareous shale. Considering the size of the samples from the Röddinge localities (15-20 kg), the graptolite abundance is relatively low (compared to Skarhult 1 and Billinge 2). *Colonograptus colonus* and *Pristiograptus dubius*

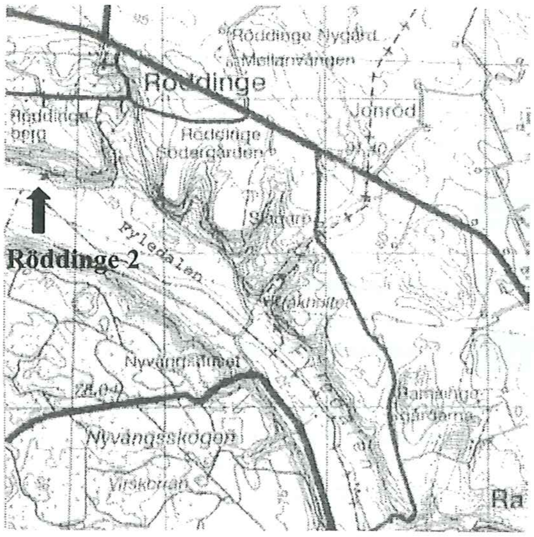

Fig 8. The Röddinge 2 locality. It is situated just south of a small road at Lerberget.

were identified from Röddinge 1 and 2.

Billinge 2

Topographic map sheet: 3C Helsingborg SO, Geological map sheet As 87 Trolleholm. UTM-coordinates UC 62052 13448. 14 Samples from the bottom of a ditch, NE of a small height, collected by SGU (the Geological Survey of Sweden), Lennart Jeppsson and Anita Löfgren (Department of Geology, Lund University) in 1983.

From another locality near Billinge 2, Tullberg (1883) illustrated specimens as *Monograptus colonus.* Those specimens differ from the type specimen from Bohemia, the Czech Republic, in being narrower and having less pronounced thecal lappets (Tullberg 1883). It is also likely that one of the illustrated *M. colonus* (nr 21, Tafl II, in Tullberg 1883) belong to *Saetograptus roemeri*, giving its general appearance of thecaes and rhabdosomal width.

Graptolites are preferably recovered from the limestone; those occurring in the shale are damaged by weathering. The graptolite abundance is relatively high in the 30-40 kg collection. Fragments of *Pristiograptus* cover the slab surfaces on many of the samples. *Colonograptus colonus* and *P. dubius* were identified.

Bäretofta 1

Topographical map sheet 1D/2D Ystad NO/Tomelilla SO. Geological map sheet Aa 142 Sövdeborg. A graptolitic shale with limestone layers is exposed in a rivulet section at Bäretofta, about 3800 m W of Fågeltofta church. Ragnar Nilsson sampled the section in 1964.

Colonograptus colonus is the only graptolite identified in the 5-7 kg collection and is relatively frequent.

Skillinge 1

Topographic map sheet 1E/2E Örnahusen NV/Simrishamn SV. Geological map sheet Aa 110 Sandhammaren. GPS-coordinates are N: 6150734, E: 1404226. Outcrop in the form of conglomerate found ca 50m W of the harbour in Skillinge. The samples comprises conglomerates and shale, some were collected in 1960 by Stig Bergström (today; the Ohio State University) and some in 2002 by myself.

Hermann Jaeger examined a conglomerate from Skillinge 1 in 1981 (Lennart Jeppsson pers. comm.). His acid treatment was unsuccessful since the graptolites disintegrated, but by splitting the sample he identified: *Monograptus dubius*, *M. micropoma* and *Saetograptus chimaera* (Grahn 1996). Lindström (1960) identified *M. colonus*, as the only fossil, from the new harbour in Skillinge. Sigitas Radzevicius (pers. comm. 2003) has found *Lobograptus scanicus* in a conglomerate, by dissolving the sample.

Because of weathering, the preservation of graptolites is poor on the calcareous shale and they are only found in the limestone-grainstone matrix of the conglomerates. *Colonograptus colonus* and *Pristiograptus dubius* were identified in the >20 kg collection from Skillinge.

Pinedalen 1

Topographical map sheet 2D Tomelilla NV. Geological map sheet Aa 92 Lund. Shales with subordinate limestone beds occur 750 m ENE of Gudmuntorp church (Grahn 1996). Hermann Jaeger identified a fauna with *Monograptus haupti* (synonymised with *Pseudomonoclimacis dalejensis* by Lenz 1990) and *Monograptus bohemicus* (pers. comm. to Lennart Jeppsson in 1977). In the same calcareous beds the ostracod *Neobeyrichia lauensis* was found, together with a large *Pristiograptus* (Martinsson 1967). The ostracods *N. scissa*, *N. lauensis* and a *Lophoctenella* species were collected in a ditch 150 above the road bridge Lunnarne, in a calcareous siltstone (Martinsson 1967). The locality Lunnarne 1 is described in Jeppsson (1975). The equivalent ostracod fauna on Gotland, with *N. scissa* and *N. lauensis*, is accompanied by *Bohemograptus bohemicus* (Martinsson 1967).

Systematic Palaeontology

Terminology.- The terms used to describe the morphology and also the classification of the graptolites herein are in accordance with Bulman (1970), unless indicated otherwise. The length of the rhabdosome is exclusive of the virgella and virgula, and the width is the total dorso-ventral width of the rhabdosome.

Repository.- All figured and discussed specimens are deposited at the Department of Geology, Lund University, Sweden.

Fig. 8. Photographs of selected graptolites from the studied localities. **A**. *Plectograptus?* sp. from Skarhult 1; x10.7. **B**. *Bohemograptus bohemicus* from Skarhult 1; x6.3. **C**. *Colonograptus colonus* from Röddinge 2; x8.1. **D**. *Colonograptus colonus* from Billinge 2; x10.4. **E**. *Colonograptus colonus* from Skillinge 1; x5.6. **F**. *Crinitograptus crinitus* from Skarhult 1; x3.6. **G**. *Lobograptus progenitor* from Skarhult 1; x5.2. **H**. *Lobograptus progenitor* from Skarhult 1; x3.1. **I**. *Pristiograptus dubius* from Skarhult 1; x5.6. **J**. *Pristiograptus dubius* from Skarhult 1; x11.5. **K**. *Pristiograptus dubius* from Röddinge 2; x2.8.

Family Retiolitidae Lapworth, 1873
Genus *Plectograptus* Moberg & Törnquist, 1909

Plectograptus? sp.
Fig. 8A, 9A

Material.- 3 poorly preserved flattened specimens in shale from Skarhult 1.

Description.- The length of the rhabdosome is 5.1 mm and the width is 1.87 mm (measured on one specimen). The thecal density is 5.5 per 5 mm in the proximal part. There is an ancora sleeve (Kozłowska-Dawidziuk 1995, p. 278) developed throughout the rhabdosome, composed of zigzag longitudinal axis lists.

Remarks.- The poor preservation of the specimens makes exact identification difficult. According to Hede (1919), it is *Plectograptus macilentus* that occurs in Skarhult 1.

Known range.- *Plectograptus* appears in the *lundgreni* Zone and continues into the *nassa* horizon in Poland (Urbanek & Teller 1997). The *Plectograptus* lineage is temporarily absent in the *progenitor* Zone in Poland, but reappears in the *parascanicus* Zone (Urbanek & Teller 1997), represented by *P. macilentus*. The absence in the *progenitor* Zone is most probably caused by an incompleteness of the collected samples (Urbanek & Teller 1997). *Plectograptus?* sp. has been found in the *L. progenitor* zone in China (Zhang & Lenz 1997). *Plectograptus macilentus* appears in the upper *gerhardi-ludensis* Zone in the Czech Republic and disappears in the upper *nilssoni* Zone *sensu* Lapworth 1876 (Kozłowska-Dawidziuk et al. 2001).

Family Monograptidae Lapworth, 1873
Genus *Bohemograptus* Pribyl, 1967

Bohemograptus bohemicus (Barrande, 1850)
Fig. 8B, 9B-C

Material.- 3 flattened specimens in shale from Skarhult 1.

Description.- Rhabdosome ventrally curved throughout. The width of the rhabdosome is 0.6-0.7 mm in the proximal part, widening to 1.25 in the distal part. The thecal density is 5 per 5 mm. The thecae are tubular and widen slightly from their origin toward their apertures.

Remarks.- The present material resembles that from Poland (Urbanek 1958) and Nevada (Berry & Murphy 1975) in thecal density and width. Lack of morphological detail, especially of the sicular region, complicates differentiation between *Bohemograptus b. bohemicus* and, for example, *B. b. tenuis* (Bouček 1936). *Bohemograptus bohemicus* differs from *B. urbaneki* (Rickards et al. 1995) in being wider and being more ventrally curved (Lenz et al. 1996). The proximal width of *Bohemograptus urbaneki* is 0.45-0.5 mm increasing to 0.8-0.9 mm.

Known range.- *Bohemograptus bohemicus* occurs most frequently in Poland (Urbanek 1958) in association with: *Pristiograptus dubius*, *Neodiversograptus nilssoni* and *Lobograptus scanicus* (Tullberg 1883). The first appearance of *Bohemograptus bohemicus* in Britain is in the Ludlow *nilssoni* Zone *sensu* Lapworth 1876, and it is also found in the *scanicus* and *tumescens* zones but not in the *leintwardinensis* Zone (Rickards 1976). It reappears in the *Bohemograptus* proliferation zone in Britain (Rickards 1976). *Bohemograptus bohemicus* is a common element in Ludlow graptolite faunas in the Prague Basin, Bohemia (Kříž 1992).

Genus *Colonograptus* Pribyl, 1942

Colonograptus colonus (Barrande, 1850)
Fig. 8C-E, 9D-E

Material.- 19 specimens from Billinge 2, 2 from Röddinge 1, 4 from Röddinge 2, 7 from Skillinge 1, of which 4 are from shales and 3 from conglomerates, and 27 from Bäretofta 1. *Colonograptus colonus* fragments partly cover the surface on the examined samples from Bäretofta 1.

Description.- The rhabdosomes are straight, though gently curved ventrally in the proximal end. The thecal density in the proximal portion is 7.7-8 per 5 mm. The first 1-6 thecae differ from the succeeding ones in having curved lappets. The thecal length is about 1.5 mm in the proximal part, and the width across theca 3 (two specimens from Billinge 2 and one from Röddinge 2) is 0.65, 0.83 and 0.94 mm. The medial part of the rhabdosome widens to 1.6-1.7 mm.

Remarks.- *Colonograptus colonus* belongs to a so-called biform type, displaying considerable differences in structure of proximal and distal thecae (Urbanek 1958). The observations on the present material from Skåne agree well with the descriptions by Urbanek (1958) and Lenz (1992).

Known range.- Přibyl (1948) found *Colonograptus colonus* in Bohemia in the *nilssoni–scanicus* zones. Kříž (1992) recognised a number of graptolite zones, including the *colonus* Zone, in Bohemia based on the occurrence of *C. colonus*. According to Kozłowska-Dawidziuk et al. (2001), Kříž work was done in a restricted part of the Všeradice section. The *nilssoni* Zone of Bohemia is defined by the lowest occurrence of *Neodiversograptus nilssoni*, together with *Bohemograptus bohemicus* and *Colonograptus* sp.

(Kozłowska-Dawidziuk et al. 2001). *C. colonus* reaches from the lower *nilssoni* Zone to the base of the *progenitor* Zone in Poland (Urbanek 1966). In Nevada (Berry & Murphy 1975), the *colonus* Zone is characterised by the zonal index together with *B. bohemicus*, *N. nilssoni* and *Pristiograptus dubius*. The base of the *colonus* Zone in Nevada is defined by the first occurrence of *C. colonus* (Berry & Murphy 1975). *C. colonus* has been found in the Gorstian strata in China (Lenz et al. 1996), and throughout the *progenitor* Zone in Canada (Lenz 1992). In Britain the appearance of *C. colonus* coincides with the base of the *nilssoni* Zone *sensu* Lapworth 1876 (Elles & Wood 1901-1918; Rickards 1976).

Genus *Crinitograptus* Rickards, 1995

Crinitograptus crinitus (Wood, 1900)
Fig. 8F, 9F

Material.- 25 flattened specimens, poorly preserved in shale from Skarhult 1.

Description.- Very slender with a width of 0.30-0.35 mm (measured on three specimens) in the proximal part up to 0.45-0.48 in the distal parts. The thecal density is 2.5-3.5 per 5 mm. The thecae resemble those of *Lobograptus scanicus* but are far more slender.

Remarks.- *Crinitograptus crinitus* is found in Hede's original collection and in the shale, sampled by myself. Hede (1919) identified it as *Monograptus crinitus*, based on its width, appearance of the thecae and resemblance with British specimens. The present identification is based on the rhabdosomal width and thecal spacing, because of the poor state of preservation, as often is the case when examining *C. crinitus* as described in Rickards (1995). *Crinitograptus crinitus* resembles the Llandovery/Wenlock species *Barrandeograptus huckei*, but the latter is more robust and has introverted thecal apertures (Rickards 1995).

Known range.- In the *nilssoni* Zone *sensu* Lapworth 1876 in Northern England (Wood 1900; Rickards 1976, Rickards 1995). *Monograptus crinitus* has also been recorded in the *scanicus* Zone in Britain (Warren et al. 1984). *Crinitograptus crinitus* is usually found in the *nilssoni* Zone *sensu* Lapworth 1876 in Poland, Germany and the Czech Republic (Rickards 1995). The zonal occurrence of *C. crinitus* in Poland, Germany and the Czech Republic is based on literature dated before 1963 (Rickards 1995), and hence before the *progenitor* Zone *sensu* Urbanek 1966 was established.

Genus *Lobograptus* Urbanek, 1958

Lobograptus progenitor Urbanek, 1966
Fig. 8G-H, 9G-I

Material.- 18 flattened specimens, mostly rhabdosome specimens, in shale from Skarhult 1.

Description.- The thecal spacing is 4-4.5 in 5 mm and the width is 0.42 mm across theca 1, increasing to 0.73 in the distal part (measured in five specimens). One sample with preserved sicula, but neither a virgella nor dorsal process is visible. The thecae of *L. progenitor* are weakly overlapping, simple tubes.

Remarks.- *Lobograptus progenitor* closely resembles *Neodiversograptus nilssoni* (Lapworth 1876), but the rhabdosome of the latter species ranges from straight to more or less continuously dorsally curved, whereas *L. progenitor* has a straight to ventrally curved rhabdosome, which can be S-shaped (Lenz et al. 1996). Furthermore, *N. nilssoni* often possesses a prominent dorsal process, which may develop into a secondary cladium (Palmer 1971). Palmer noted a few variations regarding the stage at which the sicular cladium was initiated, but he noted a consistent regularity in the development of a secondary cladium. The secondary cladium usually begins when the rhabdosome consists of 15-17 thecae (Palmer 1971). Among the examined specimens there are 6 specimens with more than 35 thecae not showing any sign of a secondary cladium. Only on one specimen a poorly preserved sicula was found, not showing the sicular characteristics of neither *L. progenitor* nor *N. nilssoni*. Owing to the great resemblance of *L. progenitors* to *N. nilssoni* (general appearance of thecae, dorsal curvature of proximal part) and occurrence (immediately below the *scanicus* fauna), *L. progenitor* has often been identified as the latter species (Urbanek 1966; Palmer 1971).

Known range.- In Baltic drift material, consisting of erratic boulders, (Urbanek 1966), *Lobograptus progenitor* has been found in association with *Pristiograptus dubius* and *Plectograptus macilentus* and defines the *progenitor* Zone in Poland. *L. progenitor* is found in the upper *nilssoni* Zone *sensu* Lapworth 1876 in the Czech Republic (Kozłowska-Dawidziuk et al. 2001). *L. progenitor* is present in the upper *nilssoni* Zone in North Wales, together with *Monograptus crinitus, P. comis* and *P. vicinus* (Warren et al. 1971).

Genus *Pristiograptus* Jaekel, 1889

Pristiograptus dubius (Suess, 1851)
Fig. 8I-K, 9J-L

Material.- 54 flattened specimens from Billinge 2, 31 from Skarhult 1, 4 from Röddinge 2, 2 from Röddinge 1 and 1 in the shale from Skillinge 1. The specimens consist mostly of proximal and distal rhabdosomes, as

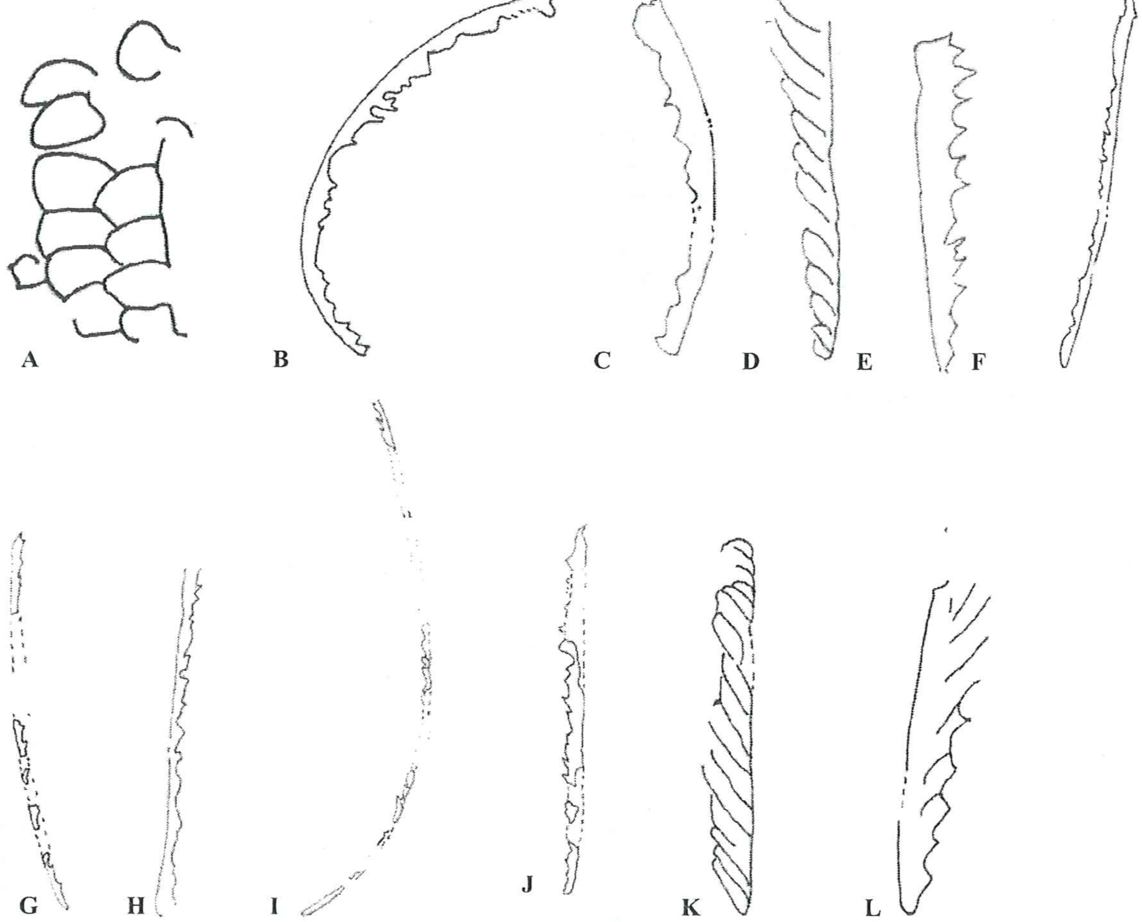

Fig. 9. **A.** *Plectograptus*? sp. from Skarhult 1; x8.6. **B.** *Bohemograptus bohemicus* from Skarhult 1; x5.1. **C.** *Bohemograptus bohemicus* from Skarhult 1; x5.5. **D.** *Colonograptus colonus* from Röddinge 1; x6.8. **E.** *Colonograptus colonus* from Skillinge 1: x4.3. **F.** *Crinitograptus crinitus* from Skarhult 1; x2.5. **G.** *Lobograptus progenitor* from Skarhult 1; x2.2. **H.** *Lobograptus progenitor* from Skarhult 1; x1.9. **I.** *Lobograptus progenitor* from Skarhult 1; x1.7. **J.** *Pristiograptus dubius* from Skarhult 1; x3.6. **K.** *Pristograptus dubius* from Billinge 2; x3.4. **L.** *Pristiograptus dubius* from Skarhult 1; x6.9.

preserved sicula are rare. *Pristiograptus* fragments partly cover the surface on the examined samples from Billinge 2. *Pristiograptus dubius* is the only graptolite found in the limestone at Skarhult 1.

Description.- The thecal spacing is 5.5-6.5 in 5 mm proximally and 5-5.5 in 5 mm distally. The rhabdosome widens from 0.55-0.65 proximally to 1.5-1.7 mm distally. There are some rhabdosomes with a slight ventral curvature in the proximal part.

Remarks.- The examined specimens resemble those described from eastern Poland by Teller (1964) and those from the Czech Republic described by Kozłowska-Dawidziuk et al. (2001), in width and thecal count. The specimens are too poorly preserved as to determine subspecies, due to the lack of sicula and that the thecal spacing overlaps most known subspecies.

Known range.- *Pristiograptus dubius* occurs throughout most of the world and ranges from late the Llandovery to, at least, well into the Ludlow (Kozłowska-Dawidziuk et al. 2001).

Concluding remarks

Examining graptolites on rock surfaces might lead to erroneous conclusions regarding the faunal composition, as delicate species such as retiolitids are less likely to be discovered (Lenz & Kozłowska-Dawidziuk 2002). However, the acid digested sample from Billinge 2 did not yield any retiolitids, they were only identified at Skarhult 1. This coincides with the results of Lenz & Kozłowska-Dawidziuk (2002), who noted an increase in monograptid diversity mirrored by a decrease in retiolitid diversity in Arctic Canada and the Baltic region. In all of the present samples, the graptolite faunal composition is almost exclusively monograptid. Specimens of retiolitid are only identified from Skarhult 1 and Röddinge 1 (*sensu* Moberg & Törnquist 1909). The dominance of e.g. *Pristiograptus dubius* and *Colonograptus colonus* in the samples can have several explanations. Firstly, they may simply be the dominating species, occurring in great numbers in certain environments. Secondly, some species are easier to spot than others, on the basis of their size and general appearance. Thirdly, there is the post mortem transportation effect, causing clusters of the same species to form. The latter phenomenon is observed in Skarhult 1 with *Crinitograptus crinitus*.

When comparing rhabdosome widths and thecal spacing of the graptolites from the different localities discussed herein, with material from Poland (Urbanek 1958, Teller 1964), the Czech Republic (Kozłowska-Dawidziuk et al. 2001) and Britain (Elles & Wood 1901-1918; Palmer 1971; Rickards 1995), no large differences can be observed.

There are two index species, *Lobograptus progenitor* and *Colonograptus colonus*, found in the samples indicating Gorstian, early Ludlow, age. *L. progenitor* appears above the *nilssoni* Zone, in the *progenitor* Zone whereas *C. colonus* appears in the lower *nilssoni* Zone and reaches into the middle *progenitor* Zone in Poland (Urbanek 1966). *C. colonus* is the only graptolite that gives proper stratigraphic information in: Röddinge 1 and 2, Billinge 2 and Bäretofta 1, since *Pristiograptus dubius* is not stratigraphically important in the Ludlow (Kozłowska-Dawidziuk et al. 2001).

According to Hede (1919) the Skarhult 1 fauna is of *nilssoni* age, based on the occurrence of *Monograptus nilssoni*, *M. crinitus* and *Plectograptus macilentus*. The similarities between *N. nilssoni* and *L. progenitor* as pointed out by Urbanek (1966) and Palmer (1971) raise doubts about past identifications of *N. nilssoni*. Palmer (1971) identified *L. progenitor* among specimens previously identified as *N. nilssoni*. The Skarhult 1 fauna with *L. progenitor*, *Crinitograptus crinitus*, *Plectograptus*? sp. and *Bohemograptus bohemicus* indicates an early Ludlow age. *L. progenitor* is found in the *progenitor* Zone in Poland (Urbanek 1966) and China (Zhang & Lenz 1997) and in the upper *nilssoni* Zone *sensu* Lapworth 1876 in the Czech Republic (Kozłowska-Dawidziuk et al. 2001). Correlation based on ostracod fauna by Martinsson (1967) points to the *nilssoni* Zone *sensu* Lapworth 1876, and is well inside the *progenitor* Zone (Fig. 10).

Moberg and Törnquist (1909) reported *Monograptus dubius*, *M. bohemicus*, *M. colonus*, *M. nilssoni*, *M. scanicus*, *Gothograptus nassa*, *Plectograptus macilentus*, *Retiolites spinosus* and *M. roemeri* from the Röddinge 1 locality. The reported fauna by Moberg and Törnquist (1909) has a stratigraphical range from the *dubius-nassa* Zone in the Homerian, Wenlock, to the *bohemicus* Zone in Ludfordian, Ludlow. The present identifications on Röddinge 1, along with Billinge 2 and Röddinge 2, with *Pristiograptus dubius* and *Colonograptus colonus*, and Bäretofta 1, with *Colonograptus colonus*, has a fauna indicative of the lower *nilssoni* Zone to the middle *progenitor* Zone

Graptolite zonation	Skarhult 1	Röddinge 1	Röddinge 2	Billinge 2	Bäretofta 1	Skillinge 1	Pinedalen 1
bohemicus tenuis-kozłowskii Zone							xxxx
leintwardinensis Zone							xx
scanicus Zone	x	xx	xx	xx	xx	xxx	xx
progenitor Zone	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	x
nilssoni Zone	xx	xx	xx	xx	xx	xx	x

Fig. 10. Age of the examined localities based on graptolite zonation. The stratigraphic age is described as: xxxx = most likely, xxx = very likely xx = possible, x = not very likely. Graptolite zonation above the *scanicus* age is from Koren et al. (1995).

(Fig. 10). Skillinge 1 has a possibly younger fauna since Sigitas Radzevicius (pers. comm. 2003) identified *Lobograptus scanicus* in a conglomerate from this locality. *Lobograptus scanicus* is found in association with *Saetograptus chimaera*, *Pristiograptus dubius*, *Neodiversograptus nilssoni*, *Bohemograptus bohemicus* and *Monoclimacis micropoma* in erratic boulders of Poland (Urbanek 1958). Rickards (1976) compared British graptolite zones with those of Poland, and found the first appearance of *L. scanicus* to be in the *progenitor* Zone. The Skillinge 1 fauna has a stratigraphical range from the *nilssoni* Zone *sensu* Urbanek 1963 to the *scanicus* Zone. But since the other localities are all within the *progenitor* Zone, it would be correct to place the Skillinge 1 fauna within this zone. When correlated to Polish strata (Urbanek 1958, 1966), the Skillinge 1 fauna could be of about the same age as Röddinge 1 and 2, Bäretofta 1, Billinge 2 and Skarhult 1, i.e. within the *progenitor* Zone (Fig. 10).

According to Jaeger (see Jeppsson & Laufeld 1986), the Pinedalen 1 fauna is younger than, for example, the Skarhult 1 fauna. Jaeger placed the fauna above the *leintwardensis* Zone, based on the evolutionary level of *Monograptus haupti*, finds of *Bohemograptus bohemicus* and other data. However, *Pseudomonoclimacis dalejensis* has a great stratigraphical range; Urbanek (1958) found *M. haupti* in an assemblage with *Lobograptus scanicus* and *Neodiversograptus nilssoni*. *Pseudomonoclimacis dalejensis* is also found in the *nilssoni* Zone in Spain and Portugal (Guitérrez-Marco et al. 1996) and ranges from the *progenitor* Zone to, at least, the lower part of the *bohemicus-tenuis* Zone in Arctic Canada (Lenz 1992). But given the identifications by Jaeger (see Jeppsson & Laufeld 1986) and Martinsson's (1967) correlation to Gotland, above the *tumescens* Zone, the proposed fauna placement by Jaeger is probably correct (Fig. 10).

Together with conodont and chitinozoan faunas, graptolites give an even better biostratigraphical zonation. This paper presents the graptolite zonation of the uppermost Wenlock and the early Ludlow of Skåne, southernmost Sweden. This data can be used to correlate with zonations based on e.g. conodonts, ostracods and brachiopods.

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