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A BORING THROUGH THE ORDOVICIAN-SILURIAN BOUNDARY IN WESTERN SCANIA, SOUTH SWEDEN

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ABSTRACT

Nilsson, R., 1979: A boring through the Ordovician-Silurian boundary in western Scania, South Sweden. SGU C 766.

The biostratigraphy of the Tommarp Stage (the Scanian *Dalmanitina* Beds) and the Lower Llandovery, the *Glyptograptus persculptus* Zone, the *Akidograptus acuminatus* Zone and the lower part of the *Rhaphidograptus extenuatus* Zone, is reviewed. It is questioned, whether *Dalmanitina mucronata* should be used as a zone fossil of the Tommarpian, because the species is found already in the *Staurocephalus clavifrons* Zone. The Tommarp Stage is considered to be included in the *S. clavifrons* Zone and ought to be obmitted as a unit of its own. The Ordovician-Silurian boundary is drawn at the base of the *G. persculptus* Zone.

INTRODUCTION

In 1961 Skånska Cement AB carried out a number of shallow core drillings in western Scania, South Sweden, one of which (no. 27), is situated about 850 m W 7° N Södra Sandby church (about 150 NNW of Lindegård, Fig. 1). The diameter of the core is 50 mm. On the late Professor A. Hadding's initiative the core was subjected to a biostratigraphical examination.

The boring reached a depth of 22.15 m below the surface and the cored interval includes beds from 2.50 m to the bottom at 22.15 m, i.e. a thickness of 19.65 m. The drilling penetrated the lower part of the Llandoverian Rastrites Shale including the lower part of the *Rhaphidograptus extenuatus* Zone, the *Akidograptus acuminatus* Zone and the *Glyptograptus persculptus* Zone, as well as the upper part of the Ashgillian, in Scania commonly classified as the *Dalmanitina* Beds and the uppermost part of the Jerrestad Formation, which has been defined as the sequence of mudstone between the *Pleurograptus linearis* Zone and the base of the Tommarp Stage (*Dalmanitina* Beds).

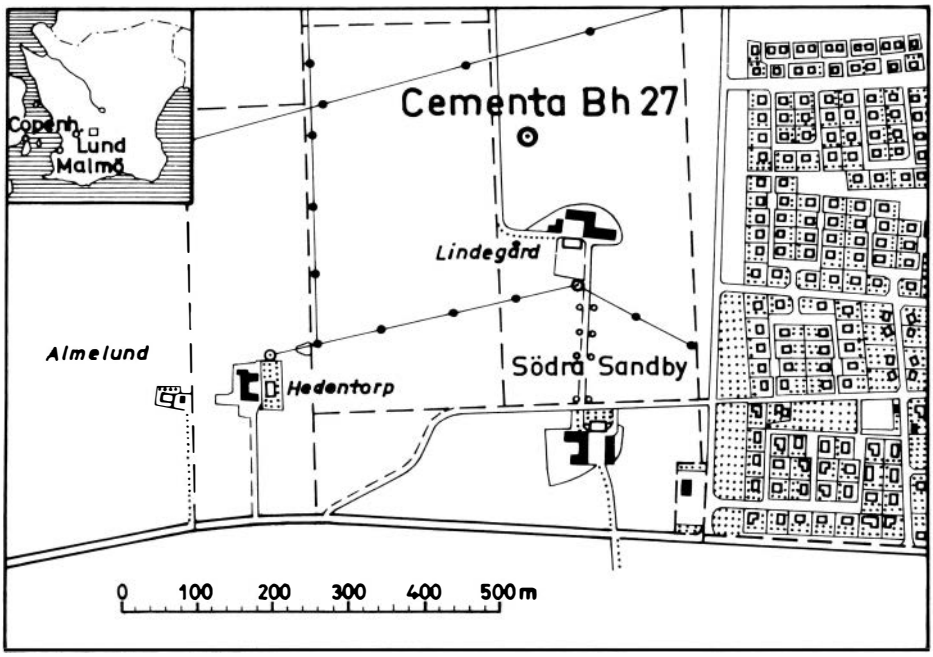

Fig. 1. Map of the Lindegård region (with outline map of Scania) showing the site of the boring.

GENERAL DESCRIPTION

0–2.50 m Quaternary deposits.

2.50–6.23 m. Black, fine-grained, not calcareous or pyritic mudstone with rather numerous, very small flakes of light mica, sometimes also with single flakes of biotite. The rock is crushed between 2.50 and 4.90 m and also between 4.90 and 5.75 m it is badly splittered. Rust-coloured surfaces are common.

Fossils: *Climacograptus balticus* Pedersen, *C. medius* Törnquist, *C. miserabilis* Elles & Wood, *C.* ex.gr. *C. normalis* Lapworth, *C. rectangularis* (McCoy). There are also many fragments of climacograptids belonging either to *C. medius* or *C. rectangularis* – the state of preservation makes it difficult to distinguish the two species – *Diplograptus* cf. *D. modestus modestus* (Lapworth), *D. modestus parvulus* (H. Lapworth), *Cystograptus vesiculosus* (Nicholson), *C. penna* (Hopkinson), *Glyptograptus* sp.?, *Orthograptus* cf. *O. truncatus abbreviatus* Elles & Wood, *O.* sp., *Pseudoclimacograptus* (*Clinoclimacograptus*) aff. *P. retroversus* Bulman & Rickards, *Akidograptus acuminatus acuminatus* (Nicholson), *Rhaphidograptus extenuatus* (Elles & Wood). See Fig. 2 for lithologies and fossils.

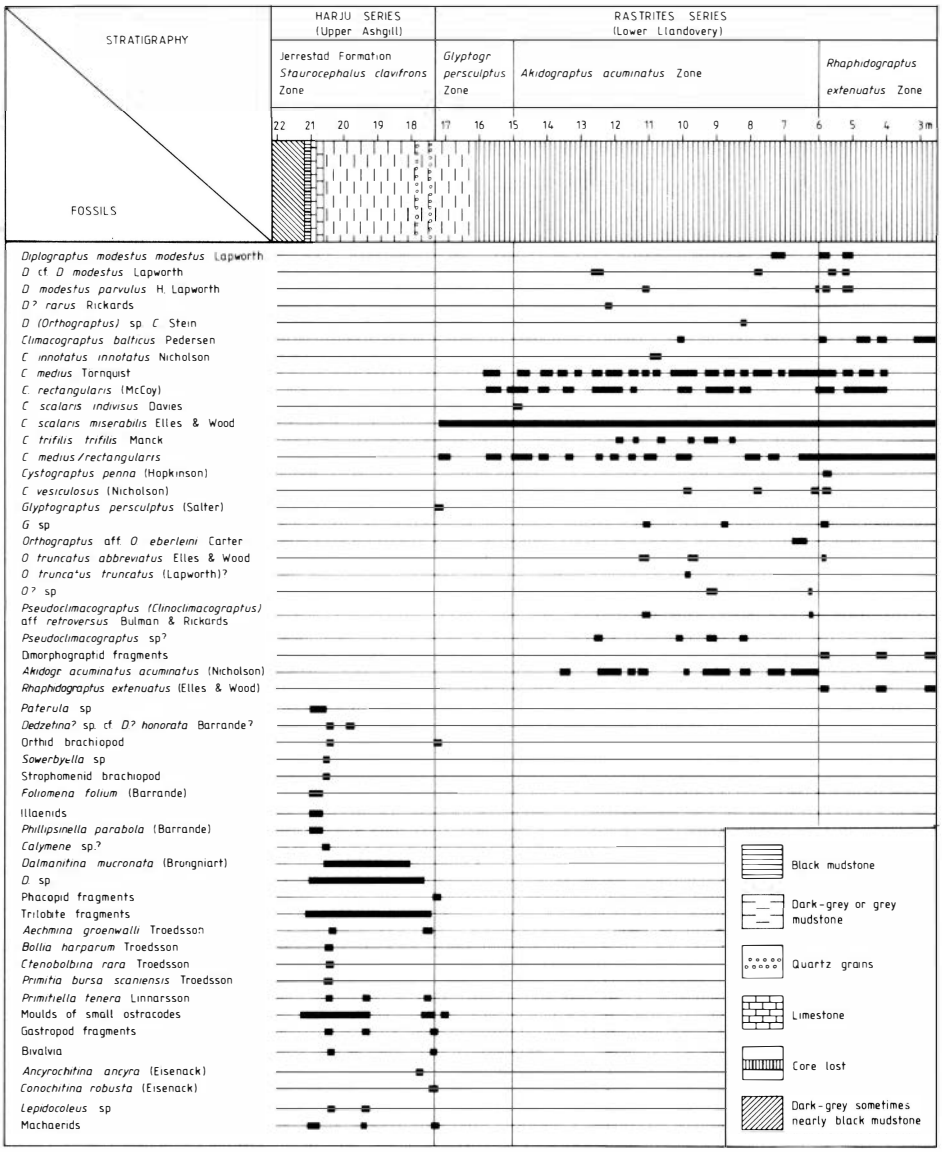

Fig. 2. Vertical ranges of fossils in the Lindegård core no. 27 and lithologies and biostratigraphic subdivisions.

6.23–16.10 m. Black, sometimes slightly calcareous mudstone with beds of limestone of a thickness not exceeding 1 mm, which become more frequent downwards. Small flakes of light mica are often conspicuously numerous. Pyrite sparse.

Fossils: *Climacograptus balticus* Pedersen, *C. indivisus* (Davies), *C. in-*

notatus innotatus Nicholson, *C. medius* Törnquist, *C. miserabilis* Elles & Wood, *C. rectangularis* (McCoy), *C. medius/rectangularis*, *C. trifilis trifilis* Manck, *Diplograptus* aff. *D. modestus modestus* Lapworth, *D. modestus parvulus* (H. Lapworth), *D.* cf. *D.? rarus* Rickards, *D.* (*Orthograptus*) sp. C. Stein, *D.* sp., *Cystograptus vesiculosus* (Nicholson), *Glyptograptus* sp.?, *Orthograptus* aff. *O. eberleini* Churkin & Carter, *O. truncatus abbreviatus* (Lapworth), *Pseudoclimacograptus* (*Clinoclimacograptus*) aff. *P. retroversus* Bulman & Rickards, *Akidograptus acuminatus acuminatus* (Nicholson), indeterminate brachiopods, and fragments of orthoconic cephalopods.

16.10–16.84 m. Grey, fine-grained, slightly calcareous mudstone in which small concretions of pyrite, 0.5 to 5 mm in diameter, are common. In the lower part of the sequence, the amount of pyrite concretions increases and they reach a diameter of 10 mm. Very small, mostly light flakes of mica are common between 16.10 and 16.28 m.

Fossils: Some indeterminable fragments of climacograptids have been observed.

16.84–17.09 m. Darker, grey, sometimes nearly black, slightly calcareous mudstone with small isolated flakes of light mica.

Fossils: Only isolated ostracodes have been found between 16.84 and 16.925 m.

17.09–17.13 m. Grey, very fine-grained, not calcareous or pyritic mudstone.

Fossils very sparse: *Climacograptus miserabilis* Elles & Wood, a fragment of *C. medius/rectangularis*.

17.13–17.34 m. Dark-grey, fine-grained, calcareous, in places slightly calcareous mudstone.

Fossils: *Diplograptus modestus parvulus* (H. Lapworth), *Diplograptus* sp.?, *Climacograptus medius* Törnquist, *C. miserabilis* Elles & Wood, *C.* sp. indet., *Glyptograptus persculptus* (Salter), fragments of phacopids, ostracodes, orthid and strophomenid brachiopods, gastropod fragments, *Conochitina robusta* (Eisenack), and a machaeridian.

17.34–17.60 m. Dark-grey, rather hard, fine-grained, slightly calcareous mudstone, between 17.40 and 17.60 m strongly splittered.

Fossils: *Dalmanitina* sp. (pygidium and pleura), indeterminable trilobite fragments, *Aechmina groenwalli* Troedsson, *Primitia bursa scaniensis* Troedsson, *Primitiella tenera* Linnarsson, *Ostracoda* gen. et sp. indet., orthids, gastropod fragment, bivalves, *Lepidocoleus* sp., and problematica.

17.60–17.72 m. Dark-grey, rather hard, calcareous mudstone, rich in small flakes of mica and isolated flakes of biotite. At 17.63 m rather numerous worn angular quartz grains (maximum size 2 mm). Pyrite occurs but is not common.

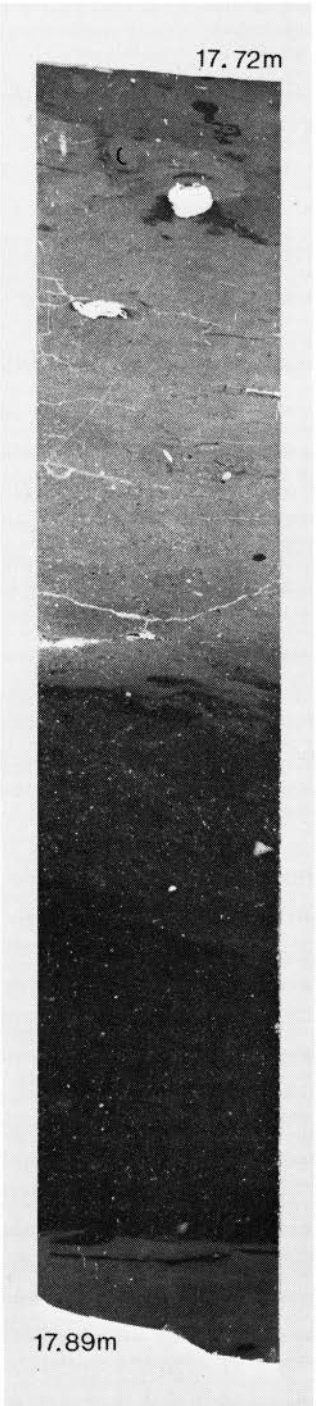

Fig. 3. Vertical section of the core between 17.89 and 17.72 m showing the dark band of quartz grains (between 1.5 and 9 cm above the base of the figure). Uppermost part of the *Staurocephalus clavifrons* Zone (former *Dalmanitina* Beds).

Fossils: Rare ostracodes and fragments of trilobites, *Ancyrochitina ancyrea* (Eisenack).

17.72–17.80 m. Grey, rather hard, calcareous mudstone without fossils (Fig. 3).

17.80–17.87 m. Darker sediment of numerous small, worn angular grains of quartz without fossils (Figs. 3–4).

17.87–18.00 m. Grey, fine-grained, calcareous mudstone with isolated, angular, worn quartz grains of less than 1 mm size and small flakes of light mica.

Fossils: A couple of ostracodes and some fragments of trilobites, possibly *Dalmanitina* sp. (Fig. 3).

18.00–20.60 m. Grey to dark-grey, fine-grained, more or less calcareous mudstone. At 20.36 there is a 5 mm thick layer of isolated pyrite crystals. Between 20.36 and 20.41 m finely crystalline limestone without fossils.

Fossils in the mudstone: *Dalmanitina mucronata* (Brongniart), *Dalmanitina* sp. including protaspis and meraspid stages, hypostome, *D.* fragments, Trilobita gen. et sp. indet. (*Calymene* sp.?), *Aechmina groenwalli* Troedsson, *Bollia harparum* Troedsson, *Ctenobolbina rara* Troedsson, *Primitia bursa scaniensis* Troedsson, *Primitiella tenera* Linnarsson, Ostracoda gen. et sp. indet., *Dedzetina?* sp. cf. *D.? honorata* (Barrande)?, orthid brachiopod, strophomenid brachiopod, *Sowerbyella* sp., Brachiopoda indet., planispiral gastropod, gastropod fragments, Bivalvia sp., *Lepidocoleus* sp., and problematica.

20.60–21.00 m. Strongly crushed, grey, hard, fine-crystalline limestone, intercalated by a thin layer of grey, fine-grained, slightly calcareous mudstone.

Fossils: Illaenids, phacopid?, *Phillipsinella parabola* (Barrande) (free cheek and cranidium), *Dalmanitina* fragments, indeterminable trilobite fragments, *Primitia bursa scaniensis* Troedsson, Ostracoda gen.et sp. indet., mostly small specimens, preserved as internal moulds increasing in number downwards, *Paterula* sp., *Foliomena folium* (Barrande), Brachiopoda gen. et sp. indet., *Lepidocoleus* sp., and problematica.

21.00–21.17 m. Core loss.

21.17–22.15 m. Dark-grey, sometimes nearly black, fine-grained, as a rule not calcareous mudstone. Pyrite uncommon. Strongly calcareous mudstone or laminae of calcite have been observed between 21.90 and 21.97 m.

Fossils are rare. Only a couple of indeterminable ostracodes and a small fragment of a brachiopod have been seen.

The dip of the strata is insignificant.

STRATIGRAPHICAL AND FAUNAL REMARKS

THE JERRESTAD STAGE
22.15–21.17 m

The very lowest portion of the core lacks a diagnostic fauna. The lithology and stratigraphic position agree with the so-called "Lindegård Mudstone" at Fågelsång (Glimberg 1961) and this interval probably belongs to the uppermost part of the Jerrestad Formation of Jaanusson (1963). Between 21.17 and 21.00 m the core is lost.

DALMANITINA BEDS OF THE TOMMARP STAGE
21.00–17.34 m

The base of the lowest part of the sequence between 21.00 and 20.60 m is marked by a hard, finely crystalline limestone with a small layer of grey mudstone. It is overlain by a grey to dark-grey, more or less calcareous, fine-grained mudstone between 20.60 and 17.34 m together with a thin bed of limestone. In the absence of a suitable formational term this interval is here referred to as the *Dalmanitina* Beds. Outside Scania, equivalent strata occur in Sweden also in Västergötland, Östergötland, Dalarna, and Jämtland. Further, some strata in the Caledonides of Västerbotten are correlated with the Tommarpian. It may be mentioned, that a shelly fauna of this age recently has been found also on Bornholm (Bjerreskov 1975:4; Poulsen 1976). The current subdivision of the Tommarp Stage comprises three trilobite zones, viz.

The *Brongniartella platyonota* Zone
The *Dalmanitina mucronata* Zone
The *Dalmanitina olini* Zone

The *D. olini* Zone is recognized only in Scania (Nyhamn, Röstånga and Tommarp), the species occurring together with *D. mucronata*. In Scania, the *B. platyonota* Zone up to now has been recorded solely at Tommarp, SE Scania.

The occurrence of quartz grains in the mudstone between 18.00 and 17.63 m (Figs. 3–4) and the sometimes abundant flakes of mica, indicate change of conditions of sedimentation and suggest deposition in shallowing water. Similar Tommarpian sequences at Tommarp and Röstånga, as well as such deposits father north in Västergötland, Östergötland, Jämtland, the Scandinavian mountain region, and on Bornholm, Denmark, have been regarded as a manifestation of the oscillatory movements or repeated transgressions and regressions which took place all over the world during latest Ordovician time. In recent years these movements have been considered to be connected with sea-level changes related to the Ashgillian glaciation in Africa and northern South America, that is, they represent glacial eustatic changes in sea-level.

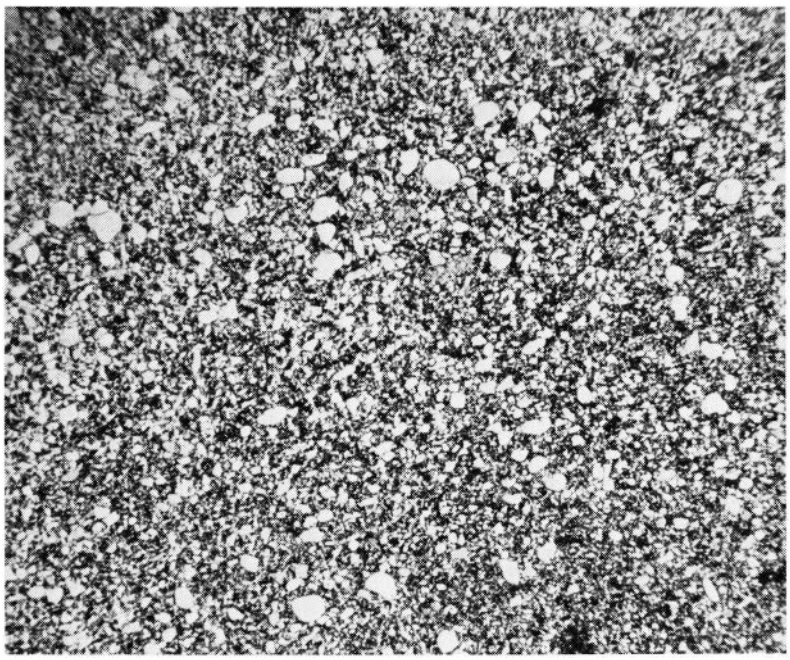

Fig. 4. Quartz grains between 17.83 and 17.803 m of the core. Thin section 8 ×.

The bed of quartz grains between 17.87 and 17.80 m (Figs. 3–4) is sharply delimited against the underlying and overlying mudstone, even if the grains are scattered, and small grains occur in the mudstone immediately below and above the bed mentioned. The grains are angular or subangular, rarely rounded, with a worn surface. In the lower part of the bed most of them range in size from 0.25 to 0.5 mm, and only rare grains are up to 1 mm across. In the middle of the bed grains with a size of at most 0.25 mm predominate; upwards they decrease in frequency.

Pyrite is present sparsely as separate, very minute disseminated grains. Other minerals were not observed.

The fauna of the interval is a shelly one, no graptolites having been recorded. Trilobites are common throughout the sequence, mostly preserved as fragments, among which *Dalmanitina mucronata* dominates. Some *Dalmanitina* specimens of protaspis as well as meraspid stages have been found. *D. mucronata*, which has a great vertical range and a wide geographical distribution, occurs together with *Staurocephalus clavifrons* in Sweden, Norway and Poland, being predominant and common in equivalent zones of the latest Ashgillian all over Europe (Kielan 1959: 41). It is accepted as an index fossil for the middle part of the Tommarpian only, or the *D. mucronata* Zone. *Phillipsinella parabola* makes its first appearance in the Jerrestad Formation

(*Eodindymene pulchra* Zone) at Koängen, and in the *Staurocephalus clavifrons* Zone at Röstånga and Tommarp. The species has not been found in the *D. olini* Zone, nor is it known anywhere in Europe in that zone (Kielan 1959:7). It appears for the second time in the *D. mucronata* Zone between 21.00 and 20.60 m together with some indeterminate illaenids. *P. parabola* occurs in Poland in the *E. pulchra* and *S. clavifrons* Zones and in the *Dalmanitina* Beds. In Bohemia it is recorded from the lower and middle parts of Králův Dvůr beds (Kielan 1959: 17), which are equivalent to the first-mentioned zones in Poland. The species has also been encountered in the Ashgillian of the Oslo Region, Great Britain, and Portugal (Kielan 1959:38).

Among the ostracodes *Aechmina groenwalli* (1 specimen), *Primitia bursa scaniensis* (14 specimens) and *Primitiella tenera* (10 specimens), first appear in the Jerrestad Formation. *Ctenobolbina rara* (1 specimen) is known previously only in the *D. olini* Zone at Röstånga and *Bollia harparum* (1 specimen) in the same zone at Röstånga and Tommarp as well as in the *D. mucronata* Zone at Röstånga. The ostracodes appear to be more frequent downward in the sequence and between 21.17 and 19.21 m small ostracodes, mostly preserved as internal moulds, appear in great numbers, constituting 92 % of the whole ostracode fauna of the Tommarp beds.

The brachiopods are few. Apart from some indeterminate specimens and a couple of orthids and strophomenids, *Dedzetina*? cf. *D.*? *honorata* (7 specimens) occurs between 19.90 and 19.70 m. *Foliomena folium* (1 specimen) is recorded between 21.00 and 20.60 m and has been found elsewhere only in the Jerrestad Formation at Koängen, W. Scania, and in the Králův Dvůr Formation in Bohemia (Sheehan 1973: 65). A species of *Sowerbyella* appears between 20.60 and 20.45 m.

In addition to the fossils mentioned, the fauna includes 7 indeterminate fragments of gastropods, i.a. 4 planispiral forms, and 5 indeterminate bivalves as well as 10 *Lepidocoleus* sp. and 1 specimen of *Ancyrochitina ancyrea*.

Lithologically this part of the core is rather uniform, and the sedimentation seems to have proceeded continuously from the deposition of the Jerrestad Formation. The interval recognized as the *Dalmanitina* Beds shows no prominent lithological or palaeontological difference vertically above the basal limestone. The observations made indicate that the interval most closely ought to be assigned to the Zone of *Dalmanitina mucronata* in the current sense.

The impoverishment of the fauna at close of the *Staurocephalus clavifrons* Zone time is reflected also in this sequence of Tommarp beds which contains a markedly poor fauna. This decline in faunal diversity is met with also in other parts of Europe, and characterizes the *D. olini* Zone as well as the *D. mucronata* Zone.

Most of the Tommarpian species appear already in the *S. clavifrons* Zone or earlier. They are: *Dalmanitina mucronata, Phillipsinella parabola, Aechmina*

groenwalli, *Primitia bursa scaniensis*, *Primitiella tenera*, *Dedzetina?* cf. *D? honorata*, *Sowerbyella* sp., *Foliomena folium*, and *Ancyrochitina ancyra*. Only *Bollia harparum* and *Ctenobolbina rara* first appear in the Tommarp beds. *Dalmanitina olini* was not recorded in the core.

The general aspect of the fauna seems to correspond to that of the *S. clavifrons* Zone. There is no species exclusively restricted to the *Dalmanitina* Beds apart from two ostracod species which possibly are restricted to that unit.

From this point of view it can be questioned, whether it is appropriate to use the designation Tommarp Stage or *Dalmanitina* Beds for the beds in the core because they may well be equivalent to the top of the *S. clavifrons* Zone. It may be mentioned that Thorslund (1943:10) stated that a *Tretaspis* sp., very likely *T. latilimbus* (Linnarsson), has been found in Jämtland in beds with *D. mucronata*. He thinks that the association *Dalmanitina–Tretaspis* must be considered to represent the *S. clavifrons* Zone.

Dalmanitina mucronata, which occurs already in the *S. clavifrons* Zone is not very suitable as an "index fossil" for a part of the Tommarp Stage in Scania. It is well known that the stock of dalmanitids is very plastic. The amount of variation reached local maxima, e.g. in Sweden at Nyhamn, perhaps depending on a change of environment at the base of the *Dalmanitina* Beds at a time probably corresponding to the transition between the *D. olini* and *D. mucronata* Zones (Temple 1952:7). Troedsson suggested that *D. olini* was an immature stage of *D. mucronata* (Troedsson 1918:97) and thus, that the two are conspecific (Troedsson 1924:222).

According to Temple (1952:27) "The earliest found dalmanitids in the *Staurocephalus* Zone of Sweden and the equivalent strata of Britain, although variable, possessed the characters common to all *D. mucronata*. During the period corresponding to the Lower Brachiopod Beds, the *D. olini* Zone, the other end of variation was predominant, and almost all the Dalmanitinae from this zone in Northern England, North Wales, and Scania are *D. olini* itself. Later the amount of variation increased and reached local maxima as at Nyhamn, and at Deganwy in North Wales, at a time probably corresponding to the transition between the zones of *D. olini* and *D. mucronata:* at both these places the two species are found with a range of intermediate forms. Later still, at the time of the *D. mucronata* Zone and the lowest Silurian, the *D. mucronata* type became predominant everywhere, although still with much variation and with occasional individuals approaching *D. olini*".

In any case, *D. mucronata* and *D. olini* are very closely allied species or varieties, and they are found together with a wide range of intermediate forms. In my opinion the two species do not have the ranges suitable for zone fossils, and the designation "the *Dalmanitina mucronata* Zone" and "the *Dalmanitina olini* Zone" should be avoided. The Scanian sequence, including the *Brongniartella platynota* Zone is according to Jaanusson (1963) referable to the

Tommarp Stage. However, lithologically these strata are hardly distinctive enough to be distinguished as a separate unit and it seems appropriate to consider them as the topmost part of the Jerrestad Formation, i.e. the *Staurocephalus clavifrons* Zone.

In this connection it should be stressed that the definition of a zone is by fossil assemblages, as a rule, and the presence of a zone may be recognizable even where the fossil after which it has been named is absent, provided the composition of the assemblage has been preserved in its main features (Teichert 1950).

RASTRITES SHALE

Glyptograptus persculptus Zone
17.34–15.00? m

The Tommarpian beds pass into the *Glyptograptus persculptus* Zone without obvious break. The beds of this zone are lithologically similar to the beds next below and the boundary between these divisions can be distinguished by faunal criteria only.

The base of the *G. persculptus* Zone is taken to be at the appearance of the index species at 17.34 m (6 specimens). This species has also been found between 17.34 and 17.22 m (17 specimens) and it is the most common and characteristic graptolite form. Up to now *G. persculptus* has not been found elsewhere in Sweden. Waern (1948) considers the zone to be present in Västergötland but without any record of the zone fossil. In places outside Sweden, the species ranges into the *A. acuminatus* Zone. *G. persculptus* is not found above the level 17.22 m. Between 17.22 and 17.13 m the graptolites are few. Two specimens of *Climacograptus medius* and two specimens probably belonging to that species, as well as *Diplograptus modestus parvulus*, appear for the first time in this interval.

In addition to the graptolites, there occurs a sparse shelly fauna, including two fragments of phacopids, four indeterminated ostracodes, a couple of brachiopods, a gastropod fragment, a machaeridian, and *Conochitina robusta*. *C. robusta* is rather common between 17.34 and 17.13 m (52 specimens) but has a wide vertical distribution, occurring both in the Ashgill and the Lower Llandovery (Grahn 1978).

From the level 17.13 m there is a change in the fauna inasmuch as the frequency of graptolites, which in the underlying layers is relatively low, increases remarkably upward through the sequence with climacograptids as dominant elements. Prominent are especially *Climacograptus miserabilis*, which is common, and climacograptids of *medius/rectangularis* type. Specimens of the last-named species are mostly fragmentary and flattened and therefore, they are not easy to distinguish. Further, there is some confusion

about the characteristics of *C. medius* and *C. rectangularis*.

According to Legrand (1976) who has subjected i.a. the climacograptids of the Lower Llandoverian of L'Oued in Djerane, Sahara algérien, a thorough investigation pointed out that it can be difficult to distinguish *Climacograptus rectangularis* and *C. medius* and that it is not impossible that subspecies occur.

A graptolite of special interest is *Climacograptus indivisus*, which has been found in one specimen at a level near 15 m. In Great Britain, this species is recorded at the base of the Birkhill (Davies 1929:8), i.e. in the *G. persculptus* Zone. In Sweden Waern (1948) has found *C. indivisus* in the lower part of the *A. acuminatus* Zone at Kinnekulle.

A couple of indeterminated diplograptids have also been seen in the interval between 15.85 and 15.40 m. Shelly fossils do not occur.

The upper boundary of the *G. persculptus* Zone is not easy to establish owing to the lack of both diagnostic fossils and a sedimentological break. Accepting that *C. indivisus* according to Waern (1948) belongs to the *A. acuminatus* Zone and in spite of the fact that only one specimen is found, the zonal boundary may tentatively be drawn at 15 m, where *C. indivisus* makes its first appearance, i.e. 2.22 m above the presently known last appearance of *Glyptograptus persculptus*.

Akidograptus acuminatus Zone
15.00?–6.00 m

Lithologically the present zone shows no change from the *G. persculptus* Zone. Palaeontologically the interval is characterized by the predominance of graptolites. Trilobites or other shelly fossils are entirely absent.

As noted above a single specimen of *Climacograptus indivisus* was found at 15 m and that level may at least provisionally be regarded as the base of the *A. acuminatus* Zone. *Akidograptus acuminatus* itself makes its first entrance between 13.54 and 13.32 m and seems to be most common between 11.25 and 8.23 m, where 37 specimens of the total 61 collected are recorded.

The climacograptids are predominant, especially *Climacograptus miserabilis* with 146 specimens or about 63 % of the graptolites, closely accompanied by *C. medius* (Fig. 5A) and *C. rectangularis*. *C. balticus* was found in one specimen at 10.21 and *C. innotatus innotatus* in 15 specimens between 10.99 and 10.77 m. The climacograptids, except *C. balticus* and *C. innotatus innotatus*, range throughout the sequence. *C. balticus* passes up into the zone next above, whereas *C. innotatus innotatus* as well as *C. trifilis trifilis*, which occurs with 29 specimens between 10.99 and 8.65 m, are confined to the zone. Some diplograptids, i.a. *Diplograptus* cf. *D. modestus*, *D. modestus parvulus* and *D.? rarus* have all sporadic occurrences and are found mainly in the lower half of the zone. Seven specimens of *Cystograptus vesiculosus* were met with in the

Fig. 5. A. *Climacograptus medius* Törnquist, 1897. Level: 6.05–6.00 m. The *acuminatus* Zone. Lindegård. 10 ×.
B. *Climacograptus rectangularis* (M'Coy, 1850). Level: 15.40–15.35 m. The *extenuatus* Zone. Lindegård. 10 ×.

upper part of the zone and this species ranges into the succeeding *Rhaphidograptus extenuatus* Zone. A couple of specimens of *Glyptograptus* sp.? occur in the upper part of the zone. *Orthograptus truncatus abbreviatus* is found with few specimens between 11.25 and 9.60 and three specimens of *O.* aff. *O. eberleini* are met with in the uppermost part of the interval. The remaining forms found in the present zone, viz. *Pseudoclimacograptus* sp.? as well as *Pseudoclimacograptus* (*Clinoclimacograptus*) aff. *P. retroversus* occur in some specimens between 12.64 and 6.20 m.

Up to now *Diplograptus*? *rarus*, *Climacograptus balticus*, *C. innotatus innotatus*, *C. trifilis trifilis*, *Orthograptus* aff. *O. eberleini*, and *Pseudoclimacograptus* (*Clinoclimacogratus*) aff. *P. retroversus* have not been recorded from Sweden.

Rhaphidograptus extenuatus Zone
6.00–2.50 m

Lithologically the layers of the *R. extenuatus* Zone are similar to the beds of the underlying *A. acuminatus* Zone and there is a continuous sedimentary transition.

The fauna consists solely of graptolites and, as is the case in the *A. acuminatus* Zone, the climacograptids predominate. *Climacograptus medius* and *C. rectangularis* (Fig. 5B) are common throughout the sequence and *C. miserabilis* is also fairly frequent. *C. balticus* (six specimens) occurs sporadically between 5.98 and 2.50 m. Some specimens of *Diplograptus modestus modestus* were found between 5.98 and 5.00 m and *D. modestus parvulus* is represented by two specimens between 5.81 and 5.80 m. There are also a few specimens of *Diplograptus* sp. indet. in the lower half of the interval. Eight specimens of *Cystograptus vesiculosus* were met with in the lowermost part of the zone between 5.98 and 5.81 m as well as one specimen of *C. penna*. A single individual of *Orthograptus truncatus* cf. *O. truncatus abbreviatus* was found between 5.85 and 5.81 m. The zone fossil, *Rhaphidograptus extenuatus*, appears fairly sparsely in scattered specimens for the first time between 5.95 and 2.50 m.

CONCLUSIONS

1. The sequence of the core represents the following stratigraphic units in ascending order:
   (a) A practically unfossiliferous part of the *Staurocephalus clavifrons* Zone of the Jerrestad Formation and the uppermost part of the zone up to now designated *Dalmanitina* Beds of the Tommarp Stage.
   (b) The lowermost zones of the Rastrites Shale (Llandovery), viz. the *Glyptograptus persculptus* Zone, the *Akidograptus acuminatus* Zone and a lower part of the *Rhaphidograptus extenuatus* Zone.

2. Palaeontologically the poor fauna without graptolites of the "Tommarpian Formation" seems to be a continuation of the also impoverished fauna of the *Staurocephalus clavifrons* Zone. It is considered to be the topmost part of the Ordovician Jerrestad Formation and ought to be included in the *S. clavifrons* Zone and be omitted as a unit of its own.

3. The lithology of the core shows a continuous sedimentation without any real break. There is, however, evidence of changes of the sealevel and of deposition in shallow water in the uppermost part of the *S. clavifrons* Zone (former the *Dalmanitina* Beds) which contains a bed of quartz grains.

4. A change to graptolitic facies occurs in the overlying *G. persculptus* Zone, even if a sparse shelly fauna is also found in that zone.

   In England the fauna of this zone shows a significant change expressed, among others, in the fact that the earliest monograptid appears (Rickards & Hutt 1970), a most distinctive element. Monograptids persisted through a large stratigraphical and time interval to their extinction in Early Devonian time.

   The *Glyptograptus persculptus* Zone forms the base of the Silurian system.

5. The *A. acuminatus* and *R. extenuatus* Zones have a fauna consisting exclusively of graptolites.

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REFERENCES

GFF = Geologiska Föreningens i Stockholm Förhandlingar
SGU = Sveriges geologiska undersökning

BJERRESKOV, M., 1975: Llandoverian and Wenlockian graptolites from Bornholm. – Fossils and Strata, 8, pp. 1–94.

COCKS, L.R.M., and PRICE, D., 1975: The biostratigraphy of the Upper Ordovician and Lower Silurian of South-West Dyfed, with comments on the *Hirnantia* Fauna. – Palaeontology 18, pp. 703–724.

DAVIES, K.A., 1929: Notes on the graptolite faunas of the Upper Ordovician and Lower Silurian. – Geol. Mag. 66, 1, pp. 1–27.

GRAHN, Y., 1978: Chitinozoan stratigraphy and palaeoecology at the Ordovician–Silurian boundary in Skåne, southernmost Sweden. – SGU C 744.

HEDE, J.E., 1951: Boring through Middle Ordovician–Upper Cambrian strata in the Fågelsång district, Scania. I. Succession encountered in the boring. – Lunds Univ. Årsskr. N.F. 2, 46, 7, pp. 1–80.

JAANUSSON, V., 1963: Classification of the Harjuan (Upper Ordovician) rocks of the mainland of Sweden. – GFF 85, pp. 110–144.

KIELAN, ZOFIA, 1959: Upper Ordovician trilobites from Poland and some related forms from Bohemia and Scandinavia. – Paleontologia Polonica 11, pp. 1–198.

LEGRAND, PH., 1976: Contribution a l'etude des Graptolites du Llandoverien inferieur de L'Oued in Djerane (Tassili N'Ajjer oriental, Sahara algérien). – Bull. Soc. d'Hist. Naturelle de l'Afrique du Nord, 1, 2, pp. 141–196.

LESPÉRENCE, P.J., 1968: Ordovician and Silurian trilobite faunas of the White Head Formation, Percé Region, Québec. – Journ. Palaeontology 42, pp. 811–826.

POULSEN, V., 1976: *Dalmanitina* beds (late Ordovician) on Bornholm. – Danmarks Geol. Unders. Årbog 1976, pp. 53–87.

RICKARDS, R.B., and HUTT, J.E., 1970: The earliest monograptids. – Proc. Geol. Soc. London, pp. 115–119.

SHEEHAN, P.M., 1973: Brachiopods from the Jerrestad Mudstone (Early Ashgillian, Ordovician) from a boring in southern Sweden. – Geologica et Palaeontologica, 7, p. 65.

TEICHERT, C., 1950: Zone concept in stratigraphy. – Bull. Am. Soc. Petrol. Geologist, 14, 7, pp. 1585–1588.

TEMPLE, J.T., 1952: A revision of the trilobite *Dalmanitina mucronata* (Brongniart) and related species. – Lunds Univ. Årsskr. N.F. 1, 48, 7, pp. 1–33.

THORSLUND, P., 1935: Über den Brachiopodenschiefer und den jüngeren Riffkalk in Dalarne. – Nova Acta Reg. Soc. Scient. Upsaliensis IV, 9, 9, pp. 1–50.

— 1943: Gränsen Ordovicium–Silur inom Storsjöområdet i Jämtland. (English Summary: The Ordovician–Silurian Boundary in the Jemtland Storsjön Area, Sweden.) – SGU C 455, pp. 1–14.

TROEDSSON, G.T., 1918: Om Skånes brachiopodskiffer. – Lunds Univ. Årsskr. N.F. 2, 15, 3, pp. 1–108.

— 1921: Bidrag till kännedomen om Västergötlands yngsta Ordovicium jämte ett försök till parallellisering av de ordovicisk-gotlandiska gränslagren i Sverige och N. Amerika. – Lunds Univ. Årsskr. N.F. 2, 17, 3, pp. 1–18.

— 1924: Remarks on the ontogeny of *Illaenus*. – GFF 46, pp. 215–224.

WAERN, B., THORSLUND, P., and HENNINGSMOEN, G., 1948: Deep boring through Ordovician and Silurian strata at Kinnekulle, Vestergötland. – Geol. Inst. Uppsala Bull. 32, pp. 337–447.