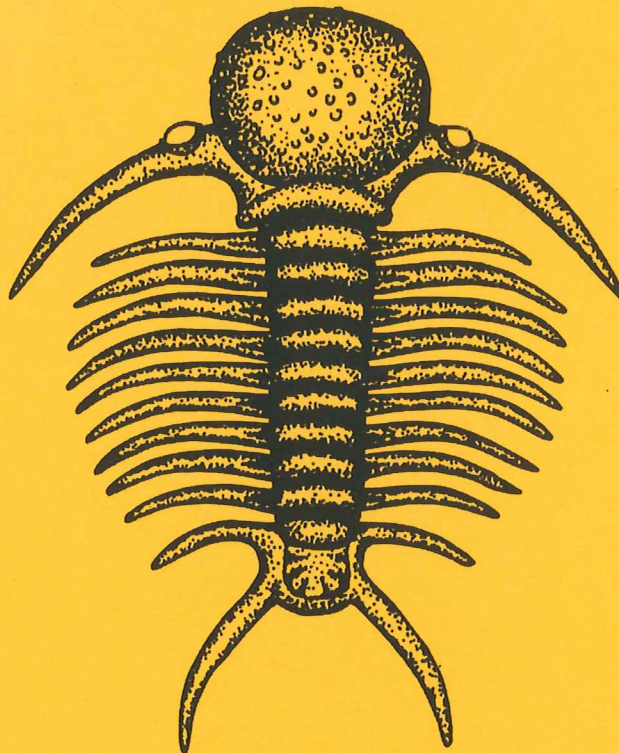


EXAMENSARBETE I GEOLOGI VID LUNDS UNIVERSITET

Historisk geologi och paleontologi



Middle-Upper Ordovician trilobites and stratigraphy
along the Kyrkbäcken rivulet in the Röstånga area,
southern Sweden

Christian Pålsson

Lunds univ. Geobiblioteket



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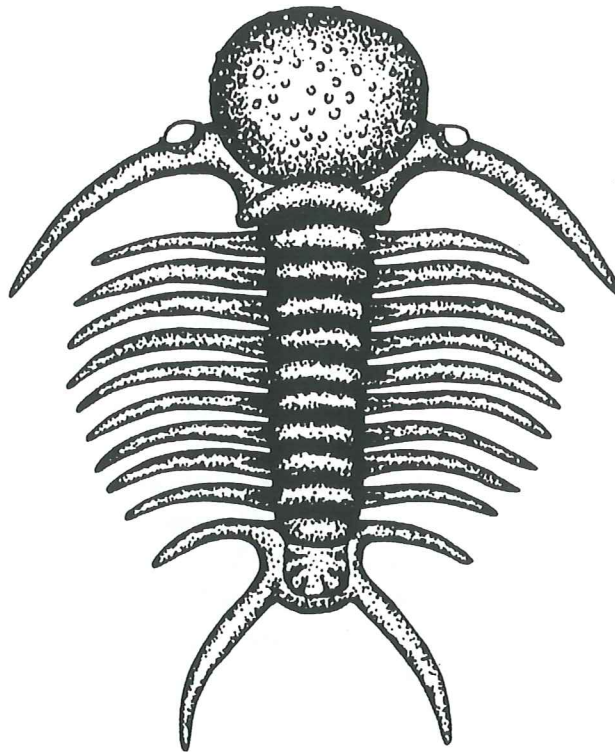
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**Middle-Upper Ordovician trilobites and stratigraphy
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MIDDLE - UPPER ORDOVICIAN TRILOBITES AND STRATIGRAPHY ALONG THE KYRKBÄCKEN RIVULET IN THE RÖSTÅNGA AREA, SOUTHERN SWEDEN

CHRISTIAN PÅLSSON

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Abstract: Middle-Upper Ordovician strata are well exposed along the Kyrkbäcken rivulet in the Röstånga area of Scania. The investigated sequence dips about 40° towards the south, and comprises about 26 m of strata. It consists largely of siliceous limestones, mudstones, shales, and bentonites. The section is generally richly fossiliferous and has yielded bivalves, brachiopods, cephalopods, gastropods, graptolites, ostracodes, and trilobites. Eighteen trilobite species have been identified. The stratigraphical subdivision is based on the succession of trilobites and on lithological characters. The lower part of the section contains a great number of bentonites and it represents the Sularp Shale. It is overlain by the Skagen Limestone. Black, bituminous limestones containing, e. g. *Tretaspis ceriodes*, are designated as the Mossen Fm. The middle and upper part of the section is represented by shales of the Jerrestad Fm. It has yielded a diverse trilobite fauna containing, amongst others, *Amphitryon radians*, *Opsimasaphus jaanussoni*, *Liocnemis recurvus*, *Lonchodomas portlocki*, *Panderia megalophthalma*, and *Raphiophorus tenellus*.

Keywords: Middle-Upper Ordovician, Röstånga, Kyrkbäcken rivulet, stratigraphy, lithology, taxonomy, trilobites, Skagen Limestone, Sularp Shale, Mossen Fm, Jerrestad Formation.

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Epicontinental Ordovician rocks are widely distributed in Baltoscandia (e. g. Jaanusson 1982). In the east, from the Moscow Basin to Öland, the deposits are continuous and undisturbed tectonically. On the mainland of Sweden, Ordovician deposits are preserved in a number of outliers, from southern Lapland in the north to Scania (Skåne) in the south (Jaanusson 1982). Confacies belts, which differ faunistically and in many cases lithologically, have been discerned. The Scanian confacies belt is dominated by graptolite shale, normally no more than 200 m thick (Bergström 1982).

The Middle Ordovician of Scania (Fig. 1) is initiated by the Upper Didymograptus Shale, which occurs exclusively in Scania (Regnéll 1960; Bergström 1982). It is well developed in the Röstånga and the Fågelsång areas where it comprises soft shales. The Upper Didymograptus Shale is overlain by the Lower Dicellograptus Shale, which is composed of graptolite shales with silt- and limestone intercalations. This unit can be divided into the *Glyptograptus teretiusculus* and the *Nema-graptus gracilis* Zones (Regnéll 1960). In south-east Scania the Killeröd Fm constitutes an equivalent to the middle part of the Lower Dicellograptus Shale. This 0.7 m thick formation consists of alternating limestones and mudstones (Bergström 1982). The Middle Dicellograptus Shale contains several layers of bentonites in the lower part, which is designated as the Sularp Shale (Lindström 1953; Regnéll 1960) and one or two of these bentonites appear to be the Big Bentonite (Bergström & Nilsson 1974). The Sularp Shale is found in the Fågelsång, Tommarp, and Röstånga areas (Regnéll 1960). In south-east Scania a thin

Baltoscandian		Scanian units	
Series	Stages	NW	SE
Upper Ordovician (Harjuan)	Hirnantian	Tommarp Mudstone	
	Jerrestadian	Jerrestad Fm	
	Vasagaardian	Mossen Shale	
Middle Ordovician (Viruan)		Skagen Lst	
		Dicellograptus Shale	Sularp Shale
	Uhakuan	Killeröd Fm	
	Lasnamägian	Upper Didymograptus Shale	
	Aserian	Lower Didymograptus Shale	

Fig. 1. The Middle-Upper Ordovician of Scania, mainly after Bergström (1982). The Mossen Fm appears to be recognizable in Scania.

limestone unit is developed in the Middle Dicellograptus Shale. This unit consists of dark-grey, siliceous limestones, and it is recognized as the the Skagen Limestone (previously referred to as the Ampyx Limestone; Regnéll 1960; Bergström 1982). The Middle-Upper Ordovician transition is represented by graptolite shale. In this paper the uppermost part of the Middle Ordovician is recognized as the Mossen Formation. This unit has previously been described from Västergötland (Skoglund 1963). The Upper Ordovician is mainly represented by the Jerrestad Formation and the Tommarp Mudstone. In the Röstånga area, the Tommarp Mudstone is 5- 6 m thick (Regnéll 1960).

The Röstånga area exhibits some classical localities for studying Lower Palaeozoic, especially Ordovician deposits. The sequence

of strata was examined by S. A. Tullberg, J. C. Moberg, E. Olin, and A. Hadding in the late 19th and early 20th centuries. Ordovician rocks in the Röstånga area are mainly recorded from the Kvarnbäcken, the Trappbäcken, and the Kyrkbäcken rivulets (Tullberg 1880, 1883; Olin 1906; Moberg 1910; Hadding 1913, 1922; Fig. 2 herein).

Along the Kvarnbäcken rivulet, Tullberg (1883) reported an occurrence of Orthoceratite Limestone (Komstad Limestone), overlain by Middle-Upper Ordovician strata. The Sularp Shale was recorded here by Moberg (1910), who also noted the presence of "Trinucleus beds" further to the south. At the Trappbäcken rivulet, Tullberg (1880, 1883), Moberg (1910) and Troedsson (1918) described the Jerrestad Fm and the Tommarp Mudstone. The Lower *Dicellograptus* Shale has been recorded along the Kyrkbäcken rivulet, and the boundary between the *Glyptograptus teretiusculus* and the *Nemagraptus gracilis* Zones was described by Hadding (1913). Younger Ordovician rocks are well exposed further to the south along the Kyrkbäcken rivulet, and these strata are described in detail herein.

Tullberg (1880) examined the section along the Kyrkbäcken rivulet and found that the Sularp Shale (formerly *Orthis* Shale) was overlain by shales with *Dicellograptus* and *Climacograptus*. Using specimens of *Beyrichia costata* and *Lonchodomas portlocki*, he (Tullberg 1880) correlated the lower part of the Kyrkbäcken section to some part of the Chasmops Limestone in Västergötland and the Cystoid Limestone in Dalarna. The upper parts of the Kyrkbäcken section were referred to as the Trinucleus Shale and specimens of various trilobites, such as *Pandertia megalophthalma* and *Phacops mucronata* (= *Dalmanitina mucronata*) were recorded (Tullberg 1880). Olin (1906) separated the Brachiopod Shale (the *Dalmanitina* beds or Tommarp Mudstone) from the Geminus Shale (Upper *Didymograptus* Shale) and stated that they must be divided

by a fault. Black shales containing *Diplograptus pristis* were regarded as the transition beds between the Chasmops and the Trinucleus beds (Olin 1906). Olin (1906) also recorded the *Dicellograptus complanatus* and the *Stau-rocephalus clavifrons* Zones. Moberg (1910) stated that the bentonite-containing part of the section belongs to the Upper Chasmops Beds or to the Zone of *Calymene dilatata* (= *Platycalymene dilatata*). When examining the Lower *Dicellograptus* Shale in Scania, Hadding (1913) carried out some excavations at the Kyrkbäcken rivulet and he discerned the *Nemagraptus gracilis* Zone. The Kyrkbäcken section has recently been investigated by S. M. Bergström, who noted the presence of strata identified as the Sularp Shale, the Skagen Limestone, and the Mossen Fm (Stig M. Bergström, Columbus, Ohio, personal communication, 1994).

Locality description

The village of Röstånga is situated about 40 km north of Lund. The section described herein is situated along the Kyrkbäcken rivulet, in the south-eastern part of Röstånga (Fig. 2). The Kyrkbäcken section dips about 40° towards the south, and the oldest rocks have been found 140 m south of the church. They consist of soft black shales. Moberg (1910) designated these shales as Upper *Didymograptus* beds, because of their rich content of *Didymograptus geminus*. Some 60 m further up the stream, the brook slightly bends to the south-east towards the old railway embankment. In the black shales that can be found here, *Climacograptus scharenbergi*, *Glyptograptus teretiusculus* and various other graptolites occur. These graptolites indicate that this is the Lower *Dicellograptus* Shale (Hadding 1913). After some 60 m, when the rivulet runs parallel with the old embankment, a distinctive unit can be followed for 16 m. It consists of grey, hard, fossiliferous limestones, intercalated with bentonites. Moberg (1910) recorded *Re-*

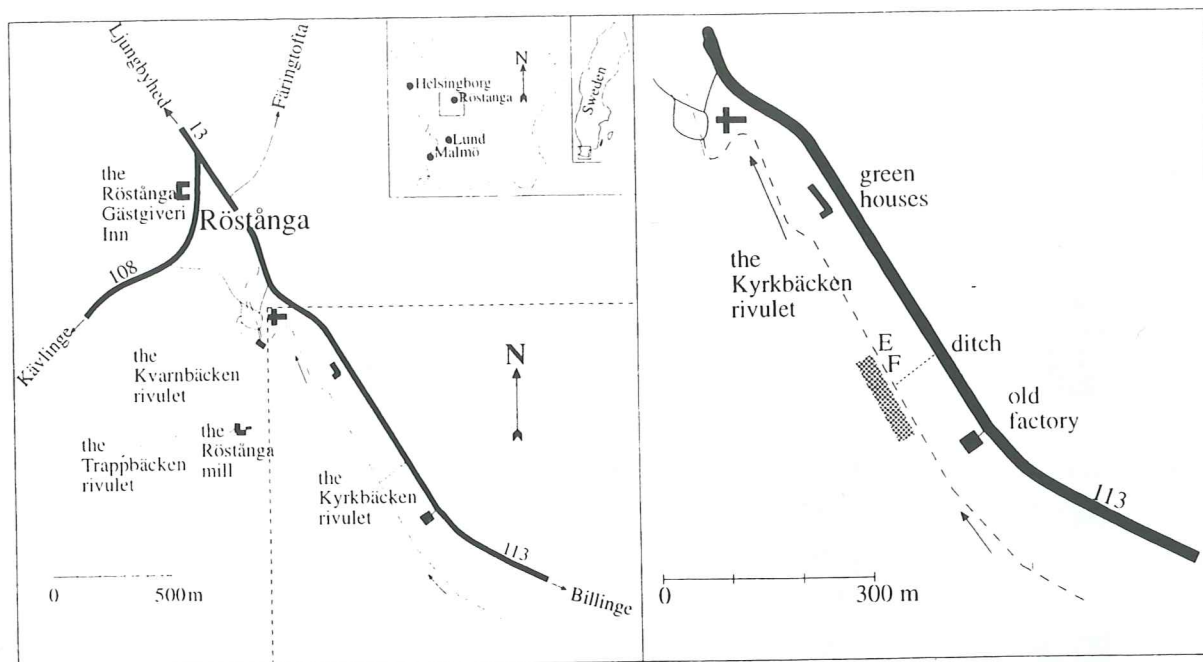


Fig. 2. The location of the Kyrkbäcken rivulet in the Röstänga area. The grey area shows the investigated section. The letters, e and f, represent the localities distinguished by Moberg (1910).

mopleurides sexlineatus, *Ptychopyge glabrata* (= *Asaphus glabratus*), *Ampyx rostratus* (= *Lonchodomas rostratus*) and *Calymene dilatata* (= *Platycalymene dilatata*) in the limestones, and therefore this part was referred to the upper part of the Chasmops beds or the Zone of *Calymene dilatata*. This unit is overlain by black shales, that can be followed for a distance of 10 m along the rivulet, containing the boundary between the "Chasmops and Trinucleus beds" (Olin 1906). The Trinucleus beds were divided into the *Ampyx portlocki* (= *Lonchodomas portlocki*) and the *Staurocephalus clavifrons* Zones by Moberg (1910). The Zone of *A. portlocki* follows the brook for 30 m and is divided into a lower and an upper division. The lower division was designated as the lower Trinucleus beds with grey shales containing trilobites such as *Tretaspis bucklandi* and *Phillipsinella parabola*. The upper division is a black graptoliferous shale with *Remopleurides radians* (= *Amphitryon radians*). At the top of this division, *Dicellograptus complanatus* has its first occurrence (Moberg 1910). The shales that follow for the next 8 m are soft and greyish-green. According to Moberg (1910) they are rich in well preserved graptolites. *Staurocephalus clavifrons* has its first appearance here, which implies that

this is the upper Jerrestad Fm. The remaining part of the Kyrkbäcken section consists of grey shales, almost devoid of fossils, except for one specimen of *Lingula* reported by Olin (1906). The section described below begins about 300 m south-east of the church where the brook turns easterly towards the old railway embankment (Fig. 2). This part comprise the lower part of the section and was referred to as the Upper Chasmops beds by Moberg (1910). The section can be followed upstream for about 100 m until it ends at the same level as where the old Secco Tork factory is situated. Tullberg (1880) and Olin (1906) mentioned a marl pit with Upper Ordovician strata, north-east the Kyrkbäcken rivulet. It is no longer accessible.

Description of the section

(cf. Fig. 3)

I. 0-6.10 m: Grey, fine-grained silicified limestones and calcareous mudstones. The individual beds range in thickness from 5 to 38 cm. The basal layers are rich of biotite and pyrite. The sequence is interbedded with bentonites and the individual bentonites range in thick-

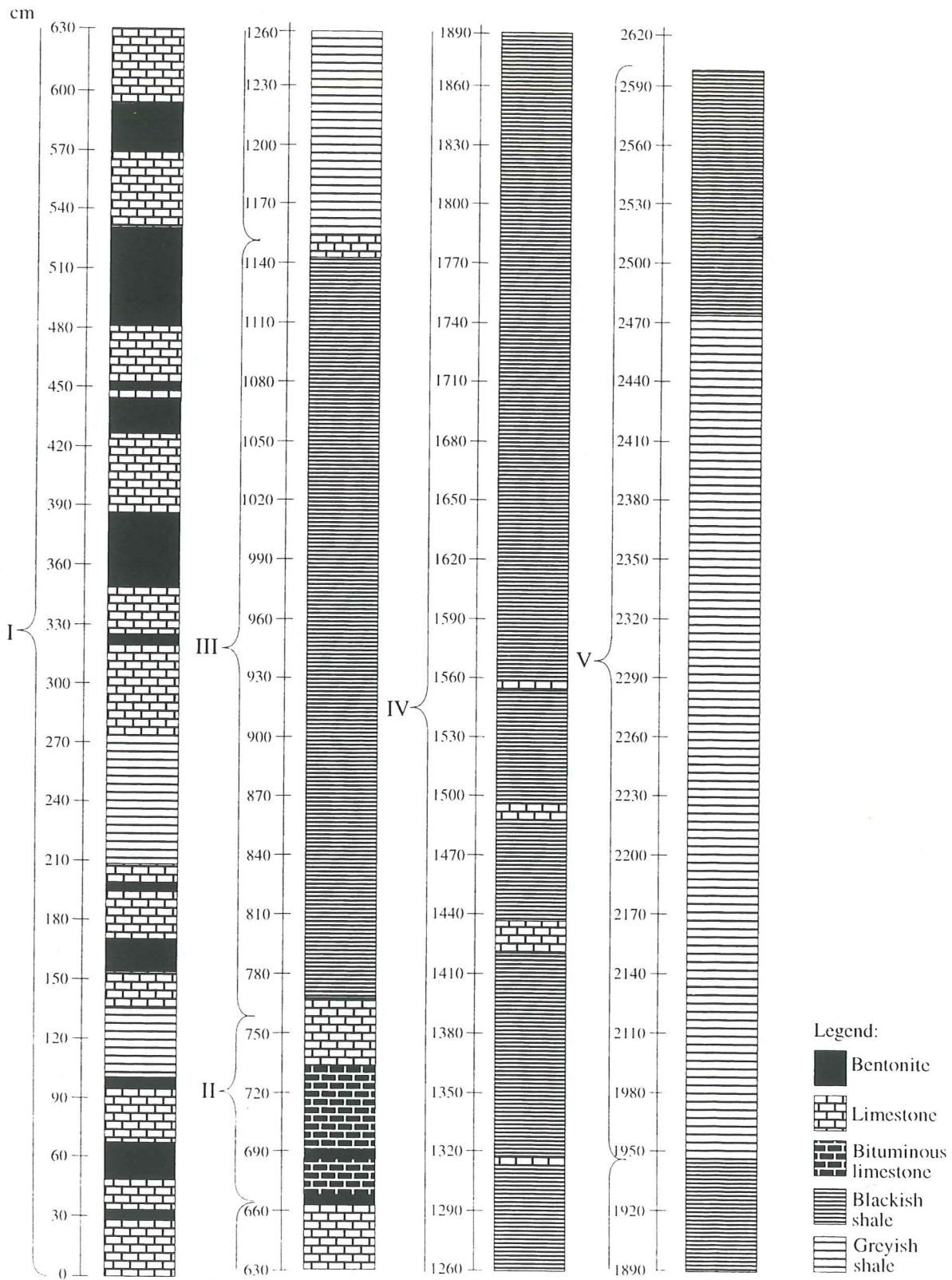


Fig. 3. The measured sequence along the Kyrkbäcken rivulet in Röstanga, southern Sweden. Roman numbers indicate the units mentioned in the text.

ness from 5 to 64 cm. Fossils: *Remopleurides* sp., *Asaphus (Neoasaphus) glabratus*, fragments of echinoderms, unidentified gastropods, and graptolites.

6.10-6.66 m: Black fine-grained limestone with *Lonchodomas rostratus* as the only recorded fossil.

II. 6.66-7.38 m: Black porous bituminous limestone, with a 5 cm thick bentonite bed. The limestone is very rich in fragments of trilobites, ostracodes, bivalves, brachiopods and gastropods. Trilobites recorded: *Platycalymene dilatata*, *Sphaerocoryphe* sp., *Flexicalymene* sp., *Arthrorhachis* sp., *Tretaspis ceriodes*, *Remopleurides* sp., *Pseudosphaerexochus* cf. *densigranulatus*, and *Pharostoma foveolatum*.

7.38-7.61 m: Dark grey, fine-grained limestone, which is silicified between 7.46-7.49 m. The only fossils found were small unrecognizable fragments of trilobites and pieces of orthoconic cephalopods.

III. 7.61-9.84 m: Black shales. The sequence is rich in brachiopods and ostracodes in the lower 76 cm. Graptolites occur between 8.83-9.84 m.

9.84-10.64 m: Dark grey shale, which is enriched in pyrite, mainly in the shape of nodules. Pyritized spicules and brachiopods are common. Other fossils found are a few graptolites.

10.64-11.43 m: Black shale, in the lower 10 cm interbedded with thin layers of white shell fragments. Fossils are very rare but fragments of orthoconic cephalopods occur sporadically.

11.43-11.52 m: Black nodular limestone. The nodules have a radial structure. No fossils were found.

IV. 11.52-13.16 m: Greyish-brown shale with calcareous nodules. Fossils: *Tretaspis granulata* (frequent), *Pseudosphaerexochus laticeps*, *Lonchodomas portlocki* and *Amphitryon radians*.

13.16-13.19 m: Grey, fine-grained limestone. No fossils found.

13.19-15.58 m: Blackish-brown, very dense shale, interbedded with three fine-grained, dark-grey limestone beds. In the limestones and upper shales no fossils were found. The lower shale, however, contains fragments of *T. granulata*.

15.58-18.83 m: This part is covered with scree and vegetation. However, at low water level, a black sequence can be observed.

18.83-19.48 m: Black shale with trilobites such as *T. granulata*, *Liocnemis recurvus*, and *Panderia megalophthalma*.

V. 19.48-23.04 m: Grey, soft shale, which is light grey in the upper part. Fossils: *Tretaspis granulata*, *Liocnemis recurvus*, *Opsimasaphus jaanussoni*, *Panderia megalophthalma*, *Illaemus angelini*, and *Lonchodomas portlocki*.

23.04-24.76 m: Greyish-green very soft shale, which contains a lot of well preserved trilobites with their exoskeletons still intact. Fossils: *I. angelini* and *Raphiophorus tenellus*.

24.76-26.02 m: Dark-grey, hard, and dense shale with no fossils.

Systematic palaeontology

Terminology.- The terminology used here is that advocated by Harrington (*in* Moore 1959). The term rachis is used instead of axis. For sake of convenience, taxa are arranged according to the scheme used by Harrington et al. (*in* Moore 1959). Under the heading "Material", only specimens collected by the author are included.

Repository.- Specimens illustrated are deposited at the Department of Geology, Lund University, Sweden.

Family Metagnostidae Jaekel, 1909

Genus *Arthrorhachis* Hawle & Corda, 1847

Arthrorhachis sp.

Plate I, Fig. A

Material.- Internal moulds of two pygidia and one cephalon.

Discussion.- The specimens are small, incomplete, and poorly preserved. This makes identification difficult. The rachis is comparatively short, however, and the specimens probably belong to a species of *Arthrorhachis*. Olin (1906) recorded *A. tarda* from the Jerrestad Fm along the Kyrkbäcken rivulet. This species has recently been revised by Ahlberg (1989), who discussed its stratigraphical and geographical distribution.

Occurrence.- Along the Kyrkbäcken rivulet, the specimens were recorded between 6.66-7.38 m (Mossen Fm).

Family Remopleurididae Hawle & Corda, 1847

Genus *Remopleurides* Portlock, 1843

Remopleurides sp.

Not figured

Material.- External moulds of two free cheeks with eyes.

Discussion.- The material is poorly preserved and the eyes are oriented in the rock so that they can only be seen from a lateral view. The specimens resemble a free cheek figured by Owen (1981, Pl. I, Fig. 17) as *Remopleurides granensis*. The Kyrkbäcken specimens are left under open nomenclature.

Occurrence.- The specimens at the Kyrkbäcken rivulet were found in the intervals 0.5-1.0 and 6.82-7.38 m.

Genus *Amphitryon* Hawle & Corda, 1847

Amphitryon radians (Barrande, 1846)

Plate I, Figs. B-C

Material.- Two incomplete cranidia, one preserved with the exoskeleton and the other as an external mould.

Discussion.- *A. radians* has 3 pairs of clearly marked glabellar furrows and they are orientated towards an imaginary point on the posterior part of the glabella. The external exoskeletal surface is provided with fine concentric striae. The Scandinavian specimens differs from the Bohemian in the length of the tounge, but this difference appears to be due to

the preservation, at least in part, and they are regarded as conspecific (Kielan 1960).

Occurrence.- *A. radians* is known from the pre-Hirnantian Ashgill of Bohemia, Poland, Sweden, and Bornholm, Denmark (Kielan 1960). In Poland it occurs in the *Staurocephalus clavifrons* and *Eodindymene pulchra* Zones (Kielan 1960). In Scania, it is a characteristic species in the Jerrestad Fm (Olin 1906; Nilsson 1977). Along the Kyrkbäcken rivulet it occurs between 11.92-13.16 m.

Family Asaphidae Burmeister, 1843

Genus *Asaphus* Brongniart, 1822

Subgenus *Asaphus* (*Neoasaphus*), Jaanusson, 1953

Asaphus (*Neoasaphus*) *glabratus* (Angelin, 1854)

Not figured

Material.- An internal mould of an incomplete pygidium.

Discussion.- This species was originally described by Angelin (1854) as *Ptychopyge glabrata*. Jaanusson (1953) reviewed the Baltoscandian asaphids and transferred it to *Asaphus* (*Neoasaphus*). *A. (Neoasaphus) glabratus* is included in a group of asaphids with *A. (Neoasaphus) ludibundus* as a characteristic species. These trilobites have weakly developed occipital furrows and shallow glabellar furrows (Jaanusson 1953, p. 398).

Occurrence.- *A. (Neoasaphus) glabratus* is known from the Upper Viruan of Västergötland and Scania (Thorslund 1948). In Västergötland it occurs in the lower part of the *Dicranograptus clingani* Zone (Thorslund 1948). In Scania it is recorded from the Sularp

Shale at the Tommarp, Röstånga, Fågelsång and Koängen areas (Olin 1906; Funkquist 1919; Lindström 1953; Nilsson 1977). Along the Kyrkbäcken section it is found between 2.0-2.12 m.

Genus *Opsimasaphus* Kielan, 1960

Opsimasaphus jaanussoni Kielan, 1960

Plate I, Fig. E

Material.- Partially exfoliated thorax and pygidium.

Discussion.- A well preserved, slightly flattened specimen was collected at the Kyrkbäcken rivulet. The tip of the left genal spine is still *in situ* but the remainder of the cephalon is missing. Specimens from Bornholm, Bohemia, and Bornholm have an average length of 3 cm (Kielan 1960). Since many fragments, identified as *Niobe lata* (= *O. jaanussoni*) by Olin (1906) are larger, Kielan (1960) doubted the occurrence of *O. jaanussoni* in Scania. In a later survey, Nilsson (1977) recorded *O. jaanussoni* at Koängen, western Scania.

Occurrence.- *O. jaanussoni* is known from the Upper Ordovician of Bohemia, Poland, Bornholm, and Sweden (Kielan 1960). In Poland it occurs in the Zones of *Staurocephalus clavifrons* and *Eodindymene pulchra* (Kielan 1960). In Sweden, it is known from the Lower Jonstorp Fm, Västergötland, and in Scania from the *E. pulchra* Zone (Nilsson 1977). Along the measured section it occurs in the black shale between 19.48-23.04 m.

Family Illaenidae Hawle & Corda,
1847

Genus *Illaenus* Dalman, 1826

Illaenus angelini (Holm, 1882)

Plate I, Fig. D

Material.- Internal moulds of three pygidia.

Discussion.- A characteristic feature in this species is the ornamentation of small pits (Kielan 1960).

Occurrence.- *I. angelini* is known from Scania, and Västergötland. In Poland a closely related form is recorded from the *Staurocephalus clavifrons* Assemblage Zone. In Västergötland this species occurs in the Upper Jonstorp Mudstone (Kielan 1960). In Scania Olin (1906) recorded it in the *Eodindymene pulchra* Zone. Specimens from the Kyrkbäcken section were collected in the interval 19.48-23.15 m.

Genus *Panderia* Volborth, 1863

Panderia megalophthalma Linnarsson,
1869

Not figured

Material.- Two cephalae preserved with the exoskeleton.

Discussion.- According to Kielan (1960), the cephalon of *Symphysurus superstes* Olin, 1906 (pl. 3, Fig. 6) belongs to *P. megalophthalma*.

Occurrence.- *P. megalophthalma* has been recorded from the Ashgill of Poland, Born-

holm, Västergötland, and Scania. Polish specimens are known from the *Staurocephalus clavifrons* Zone. In Bornholm it occurs in the Tretaspis beds, and in Västergötland in the *S. clavifrons* Zone (Kielan 1960). In Scania it is a characteristic species in the *S. clavifrons* Zone (Olin 1906; Regnéll 1960; Nilsson 1977). At the Kyrkbäcken section, it occurs in the interval 18.82-21.94 m.

Family Trinucleidae Hawle & Corda,
1847

Genus *Tretaspis* McCoy, 1849

Tretaspis ceriodes (Angelin, 1854)

Plate I, Fig. F

Material.- External moulds of two cephalae.

Discussion.- The specimens recorded from the Kyrkbäcken rivulet lack most of the fringe, but four rows of pits are possible to count. The number of pit rows on the fringe of *T. ceriodes* varies between 4 and 5, and the total number of pits in a row have an intraspecific variation (Owen 1980). Well preserved specimens show a prominent reticulation on the external surface. It should be noted that *T. ceriodes* has one tubercle situated on the highest part of the glabella and one eye tubercle placed on the centre of each cheek.

Occurrence.- *T. ceriodes* is recorded from the upper Caradoc and correlative strata in Britain, Norway and Västergötland, Jämtland and Scania in Sweden. In Norway it is known from the upper Solvang Fm, and the lower Gagnum Shale Member of the Lunner Fm (Owen 1980). In Västergötland it is a characteristic species in the Mossen Fm (Jaanusson 1964; Owen 1987). This formation constitutes the type stratum for *T. ceriodes*. Along the Kyrkbäcken rivulet it occurs in the interval 6.66-6.82 m.

Tretaspis granulata (Wahlenberg, 1818)

Plate II, Fig. A

Material.- External moulds of 35 fragmentary cephalo, external moulds of two pygidia, and four cheeks preserved with parts of the exoskeleton.

Discussion.- Within this species, Størmer (1930) recognized two subspecies, *T. granulata granulata* (Wahlenberg) and *T. granulata bucklandi* (Barrande). They were separated by the arrangement of the pits in the fringe. In *T. granulata bucklandi* the fringe is also narrower than in *T. granulata granulata*. Kielan (1960) examined the original specimen of *T. granulata* and a lot of other specimens from Poland, Bornholm, Scania and Västergötland, and some specimens from Bohemia. She (Kielan 1960) concluded that they were all conspecific and that *T. granulata* possesses a wide intraspecific variation in the fringe structure. Olin (1906) illustrated a complete cephalon from the Kyrkbäcken section. It is reillustrated herein (Pl. II, Fig. A). *T. granulata* has a tubercle on the mid-point of the frontal glabellar lobe.

Occurrence.- *T. granulata* is known from the pre-Hirnantian Ashgill of Poland, Bohemia, Bornholm, Scania, and Västergötland (Kielan 1960). Along the Kyrkbäcken rivulet its first appearance at 11.52 m and it occurs frequently upwards to 23.04 m. Family Raphiophoridae Angelin, 1854

Genus *Raphiophorus* Angelin, 1854

Raphiophorus tenellus (Barrande, 1872)

Plate II, Fig. B

Material.- An internal mould of a cranidium.

Discussion.- The collected cranidium is very small and one cheek is missing. The glabella is egg-shaped and widest in the anterior half. The occipital furrow is comparatively broad. Olin (1906) briefly discussed specimens from the Jerrestad Fm of Scania.

Occurrence.- *R. tenellus* has been recorded from the Ashgill of Bohemia, Poland, and Scania (Kielan 1960). In Poland and Scania it is a characteristic species in the *Staurocephalus clavifrons* Zone (Kielan 1960; Nilsson 1977; Olin 1906). Along the Kyrkbäcken rivulet, the specimen was collected between 22.94-24.04 m (upper Jerrestad Fm).

Genus *Lonchodomas* Angelin, 1854

Lonchodomas portlocki (Barrande, 1846)

Plate II, Fig. C-E

Material.- An internal mould of a flattened pygidium and external moulds of two cephalo.

Discussion.- This species was described in detail by Kielan (1960). It exhibits intraspecific variation in the shape of the genal spines, which can be entirely straight to posteriorly bent. There is, however, no reason to treat the various forms as different species (Kielan 1960).

Occurrence.- *L. portlocki* is known from the Upper Ordovician of Poland, Bohemia, Bornholm, Västergötland, and Scania. In Poland it is a common species in the *Eodindymene pulchra* and *Staurocephalus clavifrons* Zones. In Bornholm and Västergötland it occurs in the Tretaspis beds (Kielan 1960). In Scania it has been recorded from the *E. pulchra* Zone (Olin 1906; Regnéll 1960; Nilsson 1977). Along the Kyrkbäcken rivulet it occurs between 11.92-13.16 and 19.48-23.04 m.

Lonchodomas rostratus (Sars, 1935)

Plate II, Fig. F

Material.- One external mould of a cephalon.

Discussion.- The latex cast shows longitudinal striae on the glabella and fixed cheeks. *L. rostratus* has a more elongated glabella than *L. portlocki*. The fixed cheeks are extending from the broadest part of the glabella. On the pygidium identified by Olin (1906) the exoskeleton and muscle scars are preserved. The arrangement of these scars is similar to that of *Ampyx*.

Occurrence.- *L. rostratus* is known from the upper Viruan Series of Norway and Scania. In Norway it is recorded in the Skagen Limestone in the Oslo region (Whittington 1950). In Scania it is a common species in the *Diplograptus multidentis* and *Dicranograptus clingani* Zones. These graptolite zones embrace the Sularp Shale and the Skagen Limestone (Olin 1906; Regnéll 1960; Nilsson 1977; Schallreuter 1983). Specimens identified in this paper were collected between 6.10-6.66 m.

Family Cheiruridae Salter, 1864

Genus *Pseudosphaerexochus* Schmidt, 1881

Pseudosphaerexochus cf. *densigranulatus* (Nikolaisen, 1965)

Not figured.

Material.- An external mould of a pygidium.

Discussion.- The specimen is small and poorly preserved. This makes identification difficult. Four pairs of pleural ribs, produced as posteriorly directed spines, were present, but unfortunately they were destroyed during preparation.

Occurrence.- *P. densigranulatus* is known from the Solvang Fm and the Gagnum Limestone of Norway (Owen & Bruton 1980; Owen 1981). Along the Kyrkbäcken rivulet it occurs between 6.66-6.82.

Pseudosphaerexochus laticeps (Linnarsson, 1866)

Plate III, Fig. A

Material.- An internal mould of a pygidium.

Discussion.- The pleurae are produced into short, triangular spines. The first pleurae become narrower anteriorly. A pair of distinct pits is present at the junction between the third and the fourth pleurae. In a recent revision by Kielan-Jaworowska et al. (1991) four species of *Pseudosphaerexochus* from Västergötland are compared and their stratigraphical distributions are discussed. From the Kyrkbäcken section, Olin (1906) reported some well preserved pygidia from the Jerrestad Fm.

Occurrence.- *P. laticeps* is known from the pre-Hirnantian Ashgill in Poland, Bornholm, Västergötland and Scania. In Poland it is known from the *Eodindymene pulchra* Zone (Kielan 1960). In Västergötland, it is known from the Upper Jonstorp Mudstone (Kielan-Jaworowska et al. 1991). From the Kyrkbäcken section the specimen was collected in the interval between 11.92-13.16 m.

Genus *Sphaerocoryphe* Angelin, 1854

Sphaerocoryphe sp.

Plate III, Fig. B

Material.- An internal mould of an incomplete pygidium.

Discussion.- The specimen is small, poorly preserved, and incomplete, which makes identification difficult. It is provided with a pair of stout spines, and most likely belongs to a species of *Sphaerocoryphe*.

Occurrence.- The specimen was collected in the interval between 6.66-6.82 m (Mossen Fm).

Family Calymenidae Milne Edwards, 1840

Genus *Flexicalymene* Shirley, 1936

Flexicalymene Sp.

Plate III, Fig. C

Material.- An internal mould of a nearly complete pygidium.

Discussion.- The rachis, which occupies 85 % of the whole pygidial length and 33 % of the

width of the pygidium, is provided with a triangular terminal piece. The five pleurae are strongly bent backwards towards the posterior border. The surface is covered with tubercles. It strongly resembles species of the genus *Flexicalymene* from the upper Caradoc-lower Ashgill of Norway (see Owen & Bruton 1980).

Occurrence.- This pygidium is from the interval 6.82-7.38 m at the Kyrkbäcken section (Mossen Fm).

Genus *Platycalymene*, Shirley, 1936

Platycalymene dilatata (Tullberg, 1882)

Plate III, Fig. D

Material.- Internal moulds of four pygidia.

Discussion.- The pygidia are slightly distorted. Their surfaces are covered with fine tubercles. Siveter (1979) compared *Platycalymene* and *Metacalymene* and discussed the taxonomic significance of their differences. He concluded that the stratigraphically nearest *Platycalymene* to *Metacalymene* is *P. dilatata*.

Occurrence.- The type material of *P. dilatata* is from silicified mudstones (Sularp Shale) in the *Diplograptus multidentis* Zone. The species is widely distributed in Scania and it has been recorded from the Röstånga, Rävatofta, and Fågelsång areas (Olin 1906; Lindström 1953; Siveter 1979). In the measured section along the Kyrkbäcken rivulet it has been recorded between 6.66-7.38 m (probably the Mossen Fm). In addition, Olin (1906, p. 24) has recorded specimens from the Sularp Shale in the same section.

Genus *Pharostoma* Hawle & Corda, 1847

Pharostoma cf. *foveolatum* (Törnquist, 1884)

Plate III, Fig. E

Material.- An external mould of a cranidium.

Discussion.- *P. foveolatum* is according to Siveter (1977) closely related to *P. narinosus*. Both have an unusually long preglabellar field and very similar glabellar morphology, and eye positions. The main differences are that at *P. foveolatum* has a more strongly convex upwards preglabellar field and a shorter, more steeply upturned anterior border than *P. narinosus* (Siveter 1977). The cranidium collected at the Kyrkbäcken rivulet sequence is incomplete and shows none of the above-mentioned features. The glabellar tubercles appear to be more prominent in *P. foveolatum* than in *P. narinosus*, and for this reason the material from the Kyrkbäcken section is tentatively assigned to the first named species.

Occurrence.- *P. foveolatum* is known from the Kullberg Limestone in Dalarna, Sweden, and possibly from the Mjøsa Formation in the Nes-Hamar district in Norway (Siveter 1977). Along the Kyrkbäcken rivulet *P. cf. foveolatum* was found between 6.66-7.38 m (Mossen Fm).

Family Dalmanitidae Vogdes, 1890

Genus *Liocnemis* Kielan, 1960

Liocnemis recurvus (Linnarsson, 1869)

Plate III, Fig. F

Material.- External moulds of two pygidia.

Discussion.- The pygidium is sub-semicircular, and the posterior part is pointed and directed slightly upwards. It agrees well with the detailed description of the species given by Kielan (1960).

Occurrence.- *L. recurvus* is a common species in the Upper Ordovician of Poland, Bornholm, Västergötland, and Scania. In Poland it is a characteristic species in the *Eodindymene pulchra* and *Staurocephalus clavifrons* Zones. On Bornholm and in Västergötland it occurs in the Tretaspis beds (Kielan 1960). In Scania it occurs frequently in the zone of *E. pulchra* (Olin 1906; Nilsson 1977). The material described herein was collected in interval 18.45-20.33 m.

Trilobite faunas and correlation

18 trilobite species have been identified in the Kyrkbäcken section. They can be used for a biostratigraphic classification of the sequence. Several species occur in abundance (Fig. 4) and the most common species is *Tretaspis granulata*, which is found in almost every bed between 11.52-23.04 m. Recent studies show that the Sularp Shale, the Skagen Limestone, and the Mossen Fm can be identified in the lower part of the sequence (Stig M. Bergström, Columbus, Ohio, personal communication, 1994).

Viruan Series

The unit between 0-6.10 m consists of greyish-black, hard siliceous limestones with flakes of mica, interlayered with bentonite beds. A specimen of *Asaphus* (*Neoasaphus*) *glabratus* was recovered from this unit. This species and the lithological character strongly suggest that this interval comprises the Sularp Shale.

The interval 6.10-6.66 m consists of a dark-grey, siliceous limestone. It contains

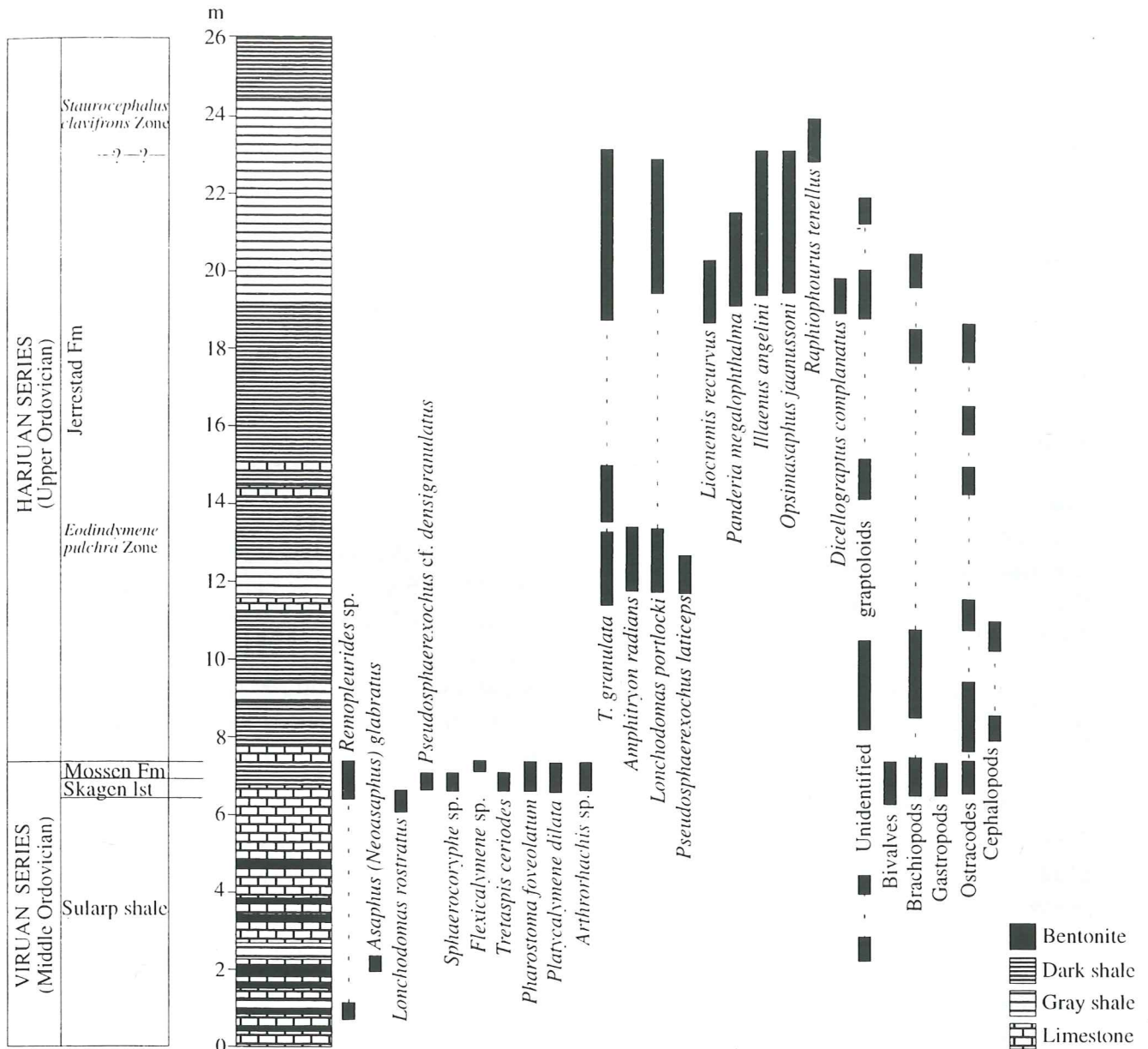


Fig. 4. Ranges of trilobites and other fossils in the section along the Kyrkbäcken rivulet in the Röstanga area. Bentonites thinner than 5 cm are not indicated in the lithological column.

Lonchodomas rostratus is. Distinctive species in the Skagen Limestone are *A. (Neosaphus) glabratus*, *Remopleurides sexlineatus*, and *L. rostratus* (Regnéll 1960; Jaanusson 1964). The occurrence of *L. rostratus* in the mentioned interval indicates that this is the Skagen Limestone. An older name in Scania was the Ampyx Limestone, but it is obvious that this unit is a thin tongue of the Skagen Limestone as developed in Västergötland (Bergström 1982). In the Kyrkbäcken section, the Sularp Shale and the Skagen Limestone seem to cor-

respond to unit e (or locality e) of Moberg (1910).

The interval 6.66-7.38 m contains a more diverse trilobite fauna. Specimens of *Arthrorhachis* sp., *Flexicalymene* sp., *Pharostoma foveolatum*, *Platycalymene dilatata*, *Pseudosphaerexochus cf. densigranulatus*, *Sphaerocoryphe* sp., and *Tretaspis ceriodes* are found in a black graptoliteiferous shale. The lithological character and the presence of *T. ceriodes* indicate that this interval represents the Mossen Formation as described by Skog-

lund (1963) in Västergötland. This formation constitutes the type stratum for *T. ceriodes* (Owen 1987). In the Kyrkbäcken section, strata here assigned to the Mossen Fm seem to correspond to unit f of Moberg (1910).

Harjuan Series

In Scania, the Upper Ordovician (Harjuan Series) consists predominately of shales and mudstones (Regnéll 1960; Bergström 1982). The lower part consists of dark grey or black graptolitic shales (*Pleurograptus linearis* Zone), which seem to be absent in western Scania (Bergström 1982). These shales are overlain by the Jerrestad Mudstone (formerly *Tretaspis* beds), which can be subdivided into the *Eodindymene pulchra* and the *Staurocephalus clavifrons* Zone (Regnéll 1960). The *Eodindymene pulchra* Zone appears to be equivalent to the *Dicellograptus complanatus* Zone (Nilsson 1977).

The trilobites recorded from the interval 7.38- 23.04 m in the Kyrkbäcken section include *Tretaspis granulata*, *Lonchodomas portlocki*, *Iliaemus angelini*, *Pseudo-sphaerexochus laticeps*, *Amphitryon radians*, *Liocnemis recurvus*, and *Opsimasaphus jaanussoni*. In Scania, *L. portlocki*, *A. radians*, *L. recurvus*, and *O. jaanussoni* are widely distributed in the Zone of *E. pulchra*, but according to Kielan (1960) they range upwards into the *S. clavifrons* Zone in Poland. The four species mentioned above occur, however, in association with specimens of *Dicellograptus complanatus* in the Kyrkbäcken section, and together they strongly indicate that the Zone of *E. pulchra*, i. e. the lower Jerrestad Fm, occurs between 7.38-23.04 m. It is very tempting to draw the boundary between the *E. pulchra* and the *S. clavifrons* Zones in the transition between the dark shale and the soft greyish green, somewhere around 19 m. The trilobites indicate, however, that the boundary must be drawn higher up in the sequence. In the interval 23.04-24.76 m, *Raphiophourus*

tenellus and *I. angelini* were recorded (Fig. 4). These species seem to indicate the upper Jerrestad Fm, i.e. the *S. clavifrons* Zone, and the boundary between the two trilobite zones is tentatively placed at around 23.0 m.

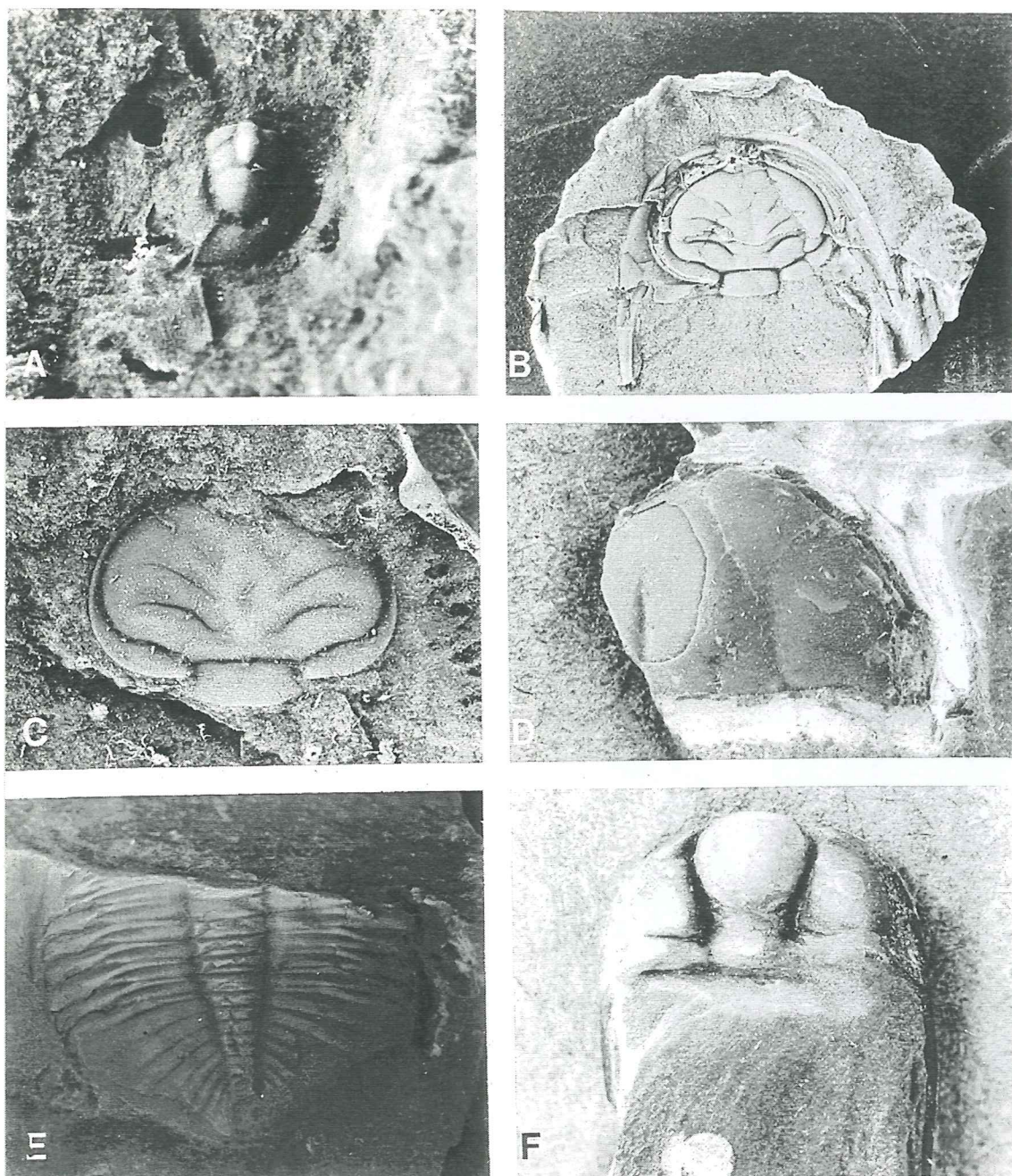
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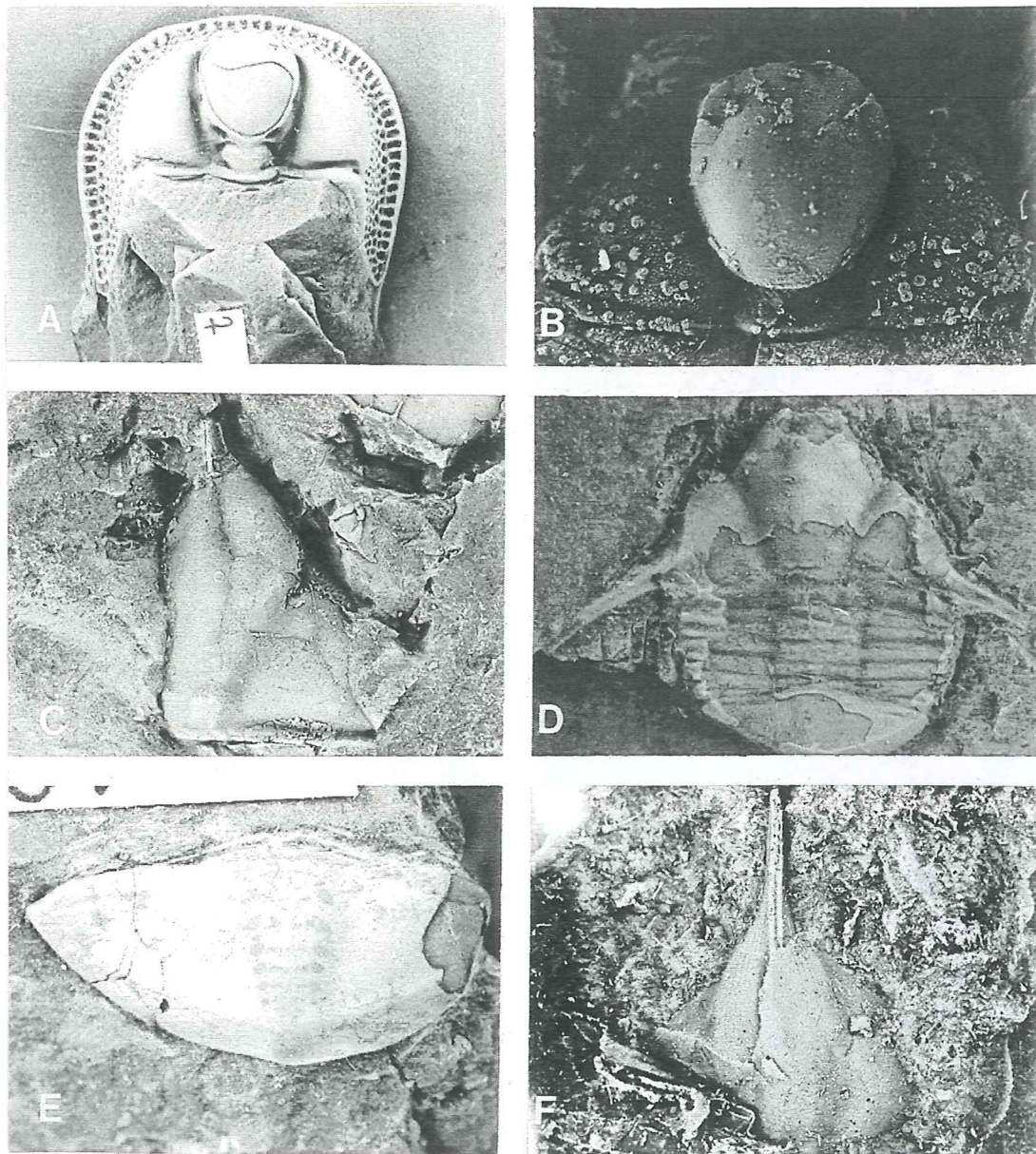
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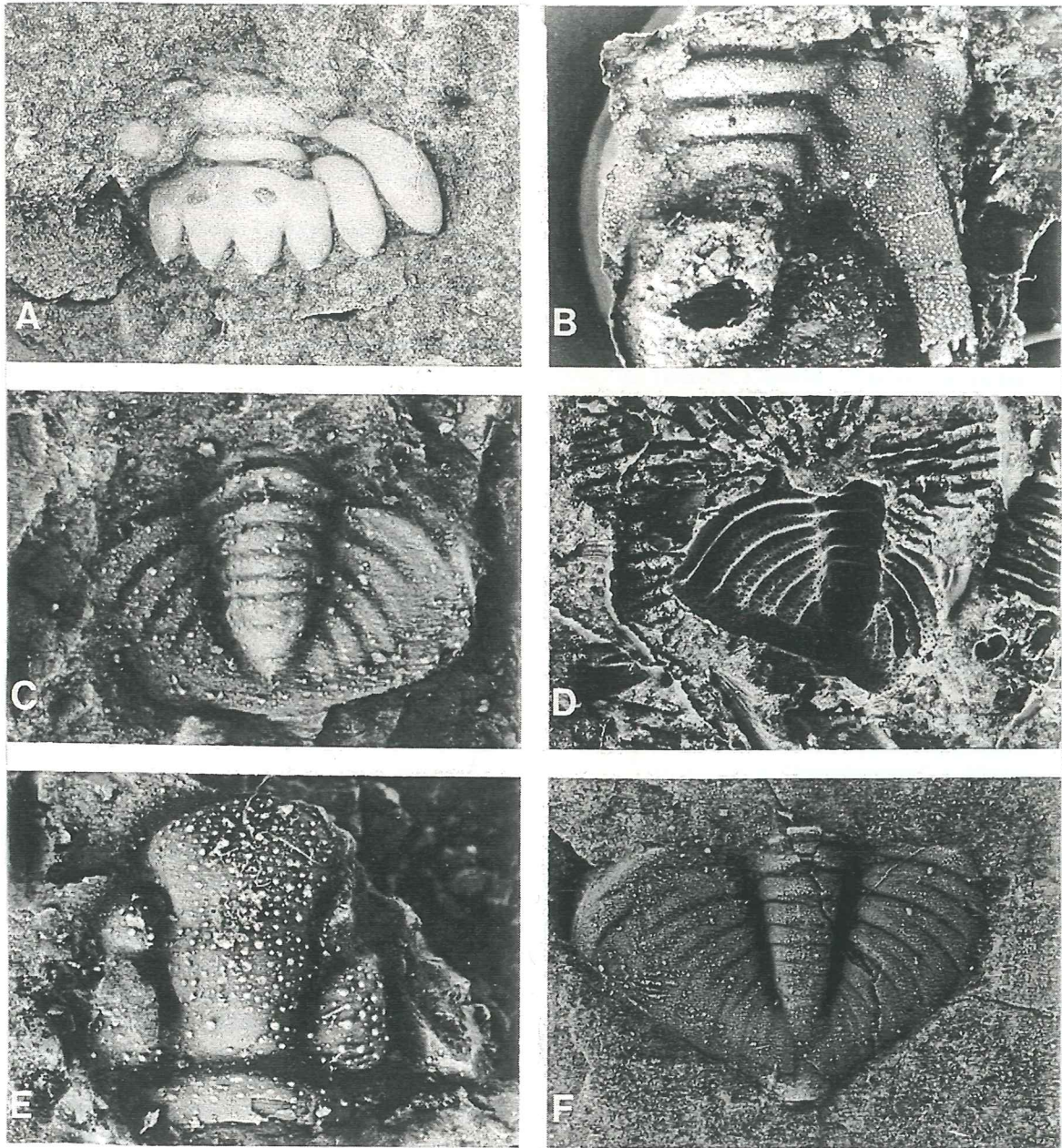
Explanation of Plate I

- **A.** *Arthrorhachis* sp., dorsal view of a pygidium, Mossen Fm, 6.66-7.82 m Kyrkbäcken rivulet, Röstånga. x10.
- **B-C.** *Amphitryon radians* (Barrande, 1846) **B.** dorsal view of a cephalon, latex cast from external mould, Jerrestad Fm. Kyrkbäcken rivulet, Röstånga, LO1924t, original of Olin (1906. Pl.II, Fig 1), x3. **C.** dorsal view of a glabella, latex cast from external mould, Jerrestad Fm, 11.92-13.16 m. Kyrkbäcken Rivulet. x6.
- **D.** *Iliaenus angelini* (Holm, 1882). dorsal view of a cephalon, Jerrestad Fm. Kyrkbäcken rivulet, Röstånga, LO1959t, original of Olin (1906. Pl.III, Fig. 11), x3.5.
- **E.** *Opsimasaphus jaanussoni* Kielan, 1960, internal mould, Jerrestad Fm, 15.60-19.50 m, Kyrkbäcken rivulet, Röstånga. x1.8.
- **F.** *Tretaspis ceriodes* (Angelin, 1854), cephalon. Mossen Fm, Kyrkbäcken rivulet, Röstånga. LO 1966t, original after Olin (1906. Pl. IV, Fig. 2 a, b), x3.5.



Explanation of Plate II

- **A.** *Tretaspis granulata* (Wahlenberg, 1818), cephalon, internal mould, Jerrestad Fm, Kyrkbäcken rivulet, Röstånga, LO 1965t, original after Olin (1906, Pl. IV, Fig. 1 a, b), x1.6. ■ **B.** *Raphiophorus tenellus* (Barrande, 1872), cephalon, *Staurocephalus clavifrons* Zone, Kyrkbäcken rivulet, Röstånga, LO 1976t, original after Olin (1906, Pl. IV, Fig. 13 a, b), x8. ■ **C-E** *Lonchodomas portlocki* (Barrande, 1846), **C.** Cephalon, latex cast from internal mould, *E. pulchra* Zone, 13.05-19.00 m, the Kyrkbäcken rivulet, Röstånga, x2.5. **D.** Entire specimen, Jerrestad Fm, Kyrkbäcken rivulet, Röstånga, LO 1969t, original after Olin (1906, Pl. IV, Fig. 5), x6. **E.** Partly exfoliated pygidium, Jerrestad Fm, Kyrkbäcken rivulet, Röstånga, LO 1972t, original after Olin (1906, Pl. IV, Fig. 8), x4.5. ■ **F.** *L. rostratus* (Sars, 1935), cephalon, latex cast from external mould, Skagen Limestone, 6.09-6.66 m, Kyrkbäcken rivulet, Röstånga, x4.



Explanation of plate III

- **A.** *Pseudosphaerexochus laticeps* (Linnarsson, 1866), pygidium, partly exfoliated, Jerrestad Fm, 11.92-13.16. Kyrkbäcken rivulet, Röstånga, x4. ■ **B.** *Sphaerocoryphe* sp., pygidium, latex cast from internal mould, Mossen Fm, 6.66-6.82, Kyrkbäcken rivulet, Röstånga, x11. ■ **C.** *Flexicalymene* sp., pygidium internal mould, Mossen Fm, 6.70-7.38 m, Kyrkbäcken rivulet, Röstånga, x11. ■ **D.** *Platycalymene dilatata* (Tullberg, 1882), internal mould of a pygidium, Mossen Fm, 6.70-7.38 m, Kyrkbäcken rivulet, Röstånga, x7. ■ **E.** *Pharostoma* cf. *foveolatum* (Törnquist, 1884), dorsal view of a cranidium, Mossen Fm, 6.66-6.82 m, Kyrkbäcken rivulet, Röstånga, x11. ■ **F.** *Liocnemis recurvus* (Linnarsson, 1869), dorsal view of a pygidium, *Eodindymene pulchra* Zone, 18.45-20.33 m, Kyrkbäcken rivulet, Röstånga, x10.

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