Stratigraphic Results of the Borings through the Alum Shales of Scania made in 1941—1942.

By

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The regional investigations of the alum shales of Sweden commenced in 1939 and carried out by the Geological Survey in co-operation with the Academy of Engineering (Ingeniörs-Vetenskapsakademien) were continued in the late autumn and winter of 1941—42 in Scania. Five borings were made in different areas where the alum shale crops out in order to find out whether the shale in this province shows any stratigraphical and chemical differences. A detailed account of the borings with complete fossil lists, diagrams of the cores, and chemical and spectrographic analyses is being prepared. Thus this communication, published by due permission of the Director of the Geological Survey, should be considered preliminary.

The diameter of the cores is 7 cm.

To Mr. SETH NILSSON and Mr. BERTIL WÆRN who have carried out part of the splitting of the cores and the preliminary examination of the fossils the writer wishes to express his gratitude for the manner in which they performed the task.

Åkarpsmölla.

At Åkarpsmölla, parish of Konga, (about 35 km N of Lund), where alum shale of late Upper Cambrian age crops out within a small area, a boring was placed 100 m N of the bridge of Bolebro and 7 m W of a little canal running from a bog called Konga mosse to the mill of Åkarpsmölla.[1] Layers bearing *Parabolina megalops* and dipping about 5° to S 65° E are accessible in the canal and approximately the same dip predominated in the core. The shale in the canal as well as at different levels of the core is pierced by closely set fissures dividing

[1] Compare the sketch map published by MOBERG & MÖLLER, 1898, p. 222, and republished by WESTERGÅRD, 1922, p. 28.

it into very narrow pencil-shaped pieces. In spite of the drilling being carried out with great caution some portions of the core thus suffered great losses, even exceeding 50 %, *e.g.* in the zone of *Leptoplastus* and *Eurycare,* in the barren beds immediately below the zone of *Parabolina spinulosa,* and between the zones of *Olenus* and *Agnostus pisiformis*. The youngest alum shale strata of the core were crowded with *Peltura scarabaeoides* and did not yield any other species. Between these and the strata with *Parabolina megalops* accessible in the canal there is consequently a small gap which in the complete section may be filled up by the subzone of *Parabolina longicornis* (cf. p. 14). — Between 37.1 and 37.35 m there is a layer of contact-metamorphic limestone heated by the diabase. Although characteristic fossils are absent its position immediately above the zone of *Triplagnostus lundgreni* discloses it to be a poor equivalent of the Andrarum limestone (zone of *Centropleura lovéni* and *Solenopleura brachymetopa*) of other areas.

At 38.9 m diabase was met with. Whether it belongs to a sill coming from a dyke 80 m SW of the boring or constitutes the very top of a distinct dyke not reaching the surface cannot be decided.

The sequence obtained by the boring is as follows.

	Level and approx. thickness in metres.		
Soils	0 — 3.3		3.3
Upper Cambrian			
Zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge*			
Peltura scarabaeoides (WAHL.), *Sphaerophthalmus alatus* (BOECK), and, in the lower portion, several species of *Ctenopyge*	3.3 —14.0	10.7	
Sphaerophthalmus major LAKE and *Peltura minor* (BRÖGGER)	14.0 —16.0	2.0	
Sphaerophthalmus major LAKE, *Ctenopyge tumida* WESTERG., and *Peltura scarabaeoides acutidens* BRÖGG.	16.0 —18.0	2.0	
Ctenopyge flagellifera (ANG.)	18.0 —19.7	1.7	
Ctenopyge neglecta WESTERG. and var.	19.7 —20.5	0.8	17.2
Zone of *Leptoplastus* and *Eurycare*			
Leptoplastus stenotus ANG. *Eurycare angustatum* ANG. *Leptoplastus ovatus* ANG. and *Eurycare* of the *latum* group *Leptoplastus paucisegmentatus* WESTERG.	20.5 —22.0		1.5

Zone of *Parabolina spinulosa* (WAHL.) and *Orusia lenticularis* (WAHL.)	22.0 —23.5		1.5
Fossils absent	23.5 —26.9		3.4
Zone of *Olenus* and *Homagnostus obesus* (BELT)			
Polyphyma angelini (BARR.) and undescribed conchostraca	26.9 —27.9	1.0	
Homagnostus obesus (BELT) alone	27.9 —30.5	2.6	
Olenus of the *truncatus* group	30.5 —30.7	0.2	
Olenus gibbosus (WAHL.)?	30.7 —31.0	0.3	4.1
Fossils absent	31.0 —32.1		1.1
Zone of *Agnostus pisiformis* (L.)	32.1 —35.5		3.4
Middle Cambrian			
Fossils absent	35.5 —37.1		1.6
Contact-metamorphic limestone lacking characteristic fossils (Andrarum limestone)	37.1 —37.35		0.25
Zone of *Triplagnostus lundgreni* (TULLB.)	37.35—38.5		1.15
Fossils absent	38.5 —38.9		0.4
Diabase	38.9 —39.35+		

Södra Sandby.

A boring was placed 300 m S of S. Sandby church, about 10 km E of Lund, were the bedrock was found to consist of Ceratopyge limestone covered with a thin layer of soils. Unfortunately the boring happened to be placed very close to a diabase dyke not reaching the surface, and thus a complete section through the alum shale was not obtained. At three different levels, viz. 30.4—30.6, 40.8—41.2, and 57.3—57.7 m, the boring pierced thin sills of dense diabase; between 93.3 and 97.7 m it followed the contact of diabase and shale and at the latter level it came into rather coarse-crystalline diabase which was penetrated to 107 m. Close to the diabase and in a few other thin layers, too, the shale was fairly strongly contact-metamorphic and hardened, the fossils being too poorly preserved to be safely determinable.

The bedding of the drilled complex was horizontal or nearly so. Broadly speaking the core was complete or had suffered but small losses, less than 10 %. In some small portions, however, mainly in the upper and middle parts of the Dictyonema zone and below the 87 m level, the core was crushed into pieces and the losses amounted to 50—60 %. The sequence is as follows.

	Level and approx. thickness in metres.		
Soils	0 — 2.5		2.5
Lower Ordovician			
Ceratopyge limestone	2.5 — 2.8		0.3
Dictyonema shale			
Graptolites absent	2.8 — 5.2	2.4	
Clonograptus tenellus (Linrs.) and var. *callavei* (Lapw.) and, in the lowest portion, *Dictyonema flabelliforme* (Eichw.) f. typ. Brögg.	5.2 — 9.0	3.8	
Dictyonema flabelliforme f. typ. alone	9.0 —12.4	3.4	9.6
Upper Cambrian			
Fossils absent	12.4 —14.0		1.6
Zone of *Acerocare, Westergårdia,*[1] *Cyclognathus,* and *Parabolina* of the *heres* group			
Acerocare ecorne Ang. and *Parabolina acanthura* (Ang.)	14.0 —14.5	0.5	
Fossils absent	14.5 —16.8	2.3	
Westergårdia illaenopsis (Westerg.) and *W. scanica* (Westerg.)	16.8 —17.5	0.7	
Cyclognathus granulatus (Moberg & Möller)	17.5 —19.2	1.7	
Parabolina heres Brögg. and var. alone	19.2 —20.0	0.8	6.0
Fossils absent	20.0 —25.3		5.3
Zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge*			
Parabolina (*megalops* Moberg & Möller?)	25.3 —26.0	0.7	
Parabolina longicornis Westerg. and var. and, in the lower portion, *Peltura scarabaeoides* (Wahl.)	26.0 —29.0	3.0	
Peltura scarabaeoides, (Wahl.), *Sphaerophthalmus alatus* (Boeck), and, in the lower portion, species of *Ctenopyge*	29.0 —35.0	5.8 [2]	
Sphaerophthalmus major Lake, *Peltura minor* (Brögg.), and *Ctenopyge tumida* Westerg.	35.0 —38.5	3.5	
Ctenopyge angusta Westerg.	38.5 —39.1	0.6	
Ctenopyge flagellifera (Ang.)	39.1 —40.5	1.4	
Ctenopyge neglecta Westerg. and var.	40.5 —40.8	0.3	15.3
Diabase	40.8 —41.2		

[1] Cf. Raymond, 1924, p. 402.

[2] A diabase sill excluded.

Zone of *Leptoplastus* and *Eurycare*			
Leptoplastus stenotus Ang.	41.2 —41.5	0.3	
Eurycare angustatum Ang.	41.5 —41.9	0.4	
Eurycare of the *latum* group and *Leptoplastus ovatus* Ang., in the lowest portion replaced by *L. raphidophorus* Ang.	41.9 —42.2	0.3	
Leptoplastus paucisegmentatus Westerg.	42.2 —42.5	0.3	1.3
Zone of *Parabolina* of the *spinulosa* group and *Orusia lenticularis* (Wahl.)			
Parabolina spinulosa (Wahl.)	42.5 —47.0	4.5	
Protopeltura aciculata (Ang.) and *Parabolina brevispina* Westerg.	47.0 —50.0	3.0	7.5
Zone of *Olenus* and *Homagnostus obesus* (Belt)			
Polyphyma angelini (Barr.) and undescribed conchostraca	50.0 —57.0	7.0	
Homagnostus obesus (Belt) alone	57.0 —58.9	1.5 [1]	
Olenus dentatus Westerg.	58.9 —59.1	0.2	
Olenus attenuatus (Boeck)	59.1 —59.4	0.3	
Homagnostus obesus (Belt) alone	59.4 —60.5	1.1	
Olenus wahlenbergi Westerg. (or *truncatus* Brünn.?)	60.5 —60.6	0.1	
Fossils very rare: *Homagnostus obesus* (Belt) and conchostraca	60.6 —62.9	2.3	
Olenus gibbosus (Wahl.)	62.9 —63.1	0.2	12.7
Fossils absent	63.1 —65.9		2.8
Zone of *Agnostus pisiformis* (L.)	65.9 —69.2		3.3
Middle Cambrian			
Fossils absent	69.2 —72.2		3.0
Zone of *Lejopyge laevigata* (Dalm.) and *Aluta primordialis* (Linrs.)	72.2 —77.3		5.1
Zone of *Centropleura lovéni* (Ang.) and *Solenopleura brachymetopa* (Ang.) (Andrarum limestone)	77.3 —78.5		1.2
Zone of *Triplagnostus lundgreni* (Tullb.)	78.5 —82.0		3.5
Fossils absent	82.0 —82.8		0.8
Zone of *Ptychagnostus punctuosus* (Ang.)	82.8 —88.5		5.7
Fossils rare and indeterminable	88.5 —93.3		4.8
Diabase	93.3—107.0+		

Andrarum.

In the quarries of the old alum works only parts of the alum shale — Upper Cambrian and late Middle Cambrian — are cut through. The

[1] A diabase sill excluded.

Dictyonema shale in solid rock is not accessible in this area where the cover of soils as a rule is fairly thick. In the Explanation of the map sheet of Övedskloster Orthoceras limestone is said to crop out at Kaneledshus, about 1 km SE of the alum works; however, renewed investigations at the locality proved this statement to be incorrect and founded on a large block of limestone embedded in moraine. Thus, as it was not possible without expensive excavations to find a boring place promising a complete section through the alum shales, we had to content ourselves with a section as complete as circumstances allowed, and for several reasons it was found appropriate to drill two borings supplementing each other.

Boring Andrarum No. 2.

The boring was placed 500 m SE of the palace of Christinehov. The core was on the whole complete; some portions showed losses of about 5 %, none more than 10 %. Gliding planes parallel to the bedding plane or nearly so were observed at different levels but did not seem markedly to influence the original thickness of the beds. The bedding was practically horizontal and was nowhere found to exceed 5°. The sequence is as follows.

Surface (= 0) 109.9 m above sea-level	Level and approx. thickness in metres		
Soils	0 — 5.6		5.6
Lower Ordovician.			
Dictyonema shale			
Bryograptus kjerulfi Lapw.(?) and, in the lowest portion, *Dictyonema flabelliforme* (Eichw.) f. typ. Brögg.	5.6 — 8.0	2.4	
Dictyonema flabelliforme f. typ. alone	8.0 —14.3	6.3	8.7
Fossils absent	14.3 —16.0		1.7
Upper Cambrian.			
Zone of *Acerocare, Westergårdia, Cyclognathus,* and *Parabolina* of the *heres* group			
Acerocare sp. and *Parabolina* (*acanthura* [Ang.]?)	16.0 —16.3	0.3	
Fossils absent	16.3 —19.8	3.5	
Westergårdia illaenopsis (Westerg.) and *W. scanica* (Westerg.)	19.8 —21.0	1.2	
Cyclognathus granulatus (Moberg & Möller)	21.0 —22.1	1.1	
Parabolina heres Brögg. and var. alone	22.1 —23.0	0.9	7.0
Fossils absent	23.0 —27.1		4.1
Zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge*			
Parabolina (*megalops* Moberg & Möller?)	27.1 —27.5	0.4	
Parabolina longicornis Westerg. and var.	27.5 —28.2	0.7	
Peltura scarabaeoides (Wahl.), *Sphaerophthalmus alatus* (Boeck), and, in the lower portion, several species of *Ctenopyge*	28.2 —30.5	2.3	
Sphaerophthalmus major Lake, *Ctenopyge tumida* Westerg., and *Peltura minor* (Brögg.)	30.5 —31.7	1.2	
Ctenopyge angusta Westerg.	31.7 —32.7	1.0	
Ctenopyge flagellifera (Ang.)	32.7 —34.1	1.4	
Ctenopyge neglecta Westerg. var.	34.1 —34.5	0.4	7.4
Zone of *Leptoplastus* and *Eurycare*			
Leptoplastus stenotus Ang.	34.5 —35.0	0.5	
Eurycare angustatum Ang.	35.0 —35.9	0.9	
Leptoplastus ovatus Ang. and *Eurycare* of the *latum* group	35.9 —36.2	0.3	
Leptoplastus raphidophorus Ang.	36.2 —36.4	0.2	
Leptoplastus paucisegmentatus Westerg.	36.4 —36.7	0.3	2.2
Zone of *Parabolina spinulosa* (Wahl.) and *Orusia lenticularis* (Wahl.)	36.7 —40.7 +		4.0 +

Boring Andrarum No. 1.

The boring was placed in a well about 100 m S of the ruined boiler-house (pannhuset) of the ancient alum works. In the parts of the core above the Andrarum limestone the bedding surfaces dipped about 5° to the south-east, as is the case in the neighbouring quarries, whereas a dip of 10°—12° predominated in the lower beds. In the sequence down to the Andrarum limestone gliding planes were fairly rare and did not seem markedly to influence the original thickness of the beds. Below the limestone mentioned, however, many core portions were rich in gliding planes and crumbled into small pieces. In such portions the core yielded but few or no identifiable fossils, nor did the boring yield safe figures of thickness of the shale beds between the Andrarum limestone and the greywacke (zone of *Holmia kjerulfi*).

As regards the lowest Middle Cambrian the sequence in the core differs from the one known of old from Forsemölla, 1300 m distant from the boring, in lacking the layer of grey limestone crowded with fragments of fossils (»fragmentkalk») which in the section at Forsemölla is intercalated in the alum shale 0.5—1.0 m above the greywacke.

The sequence of the core is seen from the following table.

Surface (= 0) 91.0 m above sea-level	Level and approx. thickness in metres			
Well	0	— 6.8		6.8
Upper Cambrian.				
Zone of *Peltura, Sphaerophthalmus* and *Ctenopyge*				
Peltura scarabaeoides (WAHL.), *Sphaerophthalmus alatus* (BOECK), and, in the lower portion, species of *Ctenopyge*	6.8	— 9.3	2.5	
Sphaerophthalmus major LAKE, *Ctenopyge tumida* WESTERG., and *Peltura scarabaeoides acutidens* BRÖGG.	9.3	—11.3	2.0	
Ctenopyge angusta WESTERG.	11.3	—11.7	0.4	
Ctenopyge flagellifera (ANG.)	11.7	—13.3	1.6	
Ctenopyge neglecta WESTERG. and var.	13.3	—14.2	0.9	7.4
Zone of *Leptoplastus* and *Eurycare*				
Leptoplastus stenotus ANG.	14.2	—14.7	0.5	
Eurycare angustatum ANG.	14.7	—15.4	0.7	
Leptoplastus ovatus ANG. and *Eurycare* of the *latum* group	15.4	—15.9	0.5	
Leptoplastus raphidophorus ANG.	15.9	—16.2	0.3	
Leptoplastus paucisegmentatus WESTERG.	16.2	—16.5	0.3	2.3
Zone of *Parabolina* of the *spinulosa* group and *Orusia lenticularis* (WAHL.)				
Parabolina spinulosa (WAHL.)	16.5	—23.0	6.5	
Protopeltura aciculata (ANG.) and *Parabolina brevispina* WESTERG.	23.0	—27.0	4.0	10.5
Fossils absent	27.0	—29.8		2.8
Zone of *Olenus* and *Homagnostus obesus* (BELT)				
Polyphyma angelini (BARR.) and undescribed conchostraca	29.8	—32.7	2.9	
Homagnostus obesus (BELT) alone	32.7	—35.0	2.3	
Olenus dentatus WESTERG.	35.0	—35.3	0.3	
Olenus attenuatus (BOECK)	35.3	—35.8	0.5	
Olenus wahlenbergi WESTERG.	35.8	—36.3	0.5	
Olenus truncatus (BRÜNN.)	36.3	—36.9	0.6	
Olenus transversus (LINRS.) WESTERG. and *O. gibbosus* (WAHL.)	36.9	—38.4	1.5	8.6
Fossils absent	38.4	—39.6		1.2
Zone of *Agnostus pisiformis* (L.)	39.6	—42.9		3.3
Middle Cambrian.				
Fossils absent	42.9	—43.9		1.0
Zone of *Lejopyge laevigata* (DALM.)	43.9	—45.9		2.0

Zone of *Centropleura lovéni* (ANG.) and *Solenopleura brachymetopa* (ANG.) (Andrarum limestone)	45.9	—46.8		0.9
Zone of *Triplagnostus lundgreni* (TULLB.)	46.8	—48.0		1.2
Zone of *Ptychagnostus punctuosus* (ANG.)	48.0	—51.5		3.5
Zone of *Hypagnostus parvifrons* (LINRS.)	51.5	—55.0		3.5
Zone of *Tomagnostus fissus* (LINRS.) and *Triplagnostus atavus* (TULLB.)	55.0	—58.5		3.5
Exsulans limestone	58.5	—58.8		0.3
Shale poor in bituminous matter and lacking characteristic fossils	58.8	—62.8		4.0
Lower Cambrian.				
Greywacke. Zone of *Holmia kjerulfi* (LINRS.)	62.8	—65.8		3.0
Coarse quartzitic sandstone or quartzite	65.8	—68.1 +		2.3 +

Gislövshammar.

The boring was placed on the northern shore of the point with the little fishing-place of Gislövshammar, about 10 km S of Simrishamn. The core was on the whole fairly complete. Some small portions were badly crushed, however, the loss there being up to 50 %. The predominant dip of the beds of the core was about 6° to the south-east, *i.e.* the same as seen in the Orthoceras limestone cropping out on the point and in the Lower Cambrian sandstone exposed on the shore 600 m farther to the north. At a depth of 25—26 m the alum shale dipped 25—30° and was pierced by narrow fissures filled with calcite. Similar narrow fissure fillings were observed at many other levels too but did not seem to be combined with faults.

Between 90.7 and 91.4 m and between 91.7 and 92.0 the core lengthwise consisted partly of alum shale and partly of grey, rather coarse calcareous sandstone. Possibly the sandstone should be interpreted as fissure filling but it should be borne in mind that the boring may have happened to touch the steep and angular wall of a monadnock of Lower Cambrian sandstone.

The boring revealed the following sequence.

Surface (= 0) 2.7 m above sea-level.	Level and approx. thickness in metres.			
Soils	0	— 7.2		7.2
Lower Ordovician.				
Lower Didymograptus shale	7.2	—19.4		12.2
Ceratopyge limestone	19.4	—19.5		0.1

Dictyonema shale			
Dictyonema flabelliforme norvegicum KJER. and *Bryograptus kjerulfi* LAPW.	19.5 —20.7	1.2	
Graptolites absent	20.7 —22.9	2.2	
Clonograptus tenellus (LINRS.) and var. *callavei* (LAPW.) and, in the lowest portion, *Dictyonema flabelliforme* (EICHW.) f. typ. BRÖGG.	22.9 —29.6	6.7	
Dictyonema flabelliforme f. typ. and. var.	29.6 —36.0	6.4	16.5
Upper Cambrian.			
Fossils absent	36.0 —39.0		3.0
Zone of *Westergårdia, Cyclognathus* and *Parabolina heres* BRÖGG. s. l.			
Westergårdia illaenopsis (WESTERG.) and *W. scanica* (WESTERG.)	39.0 —39.5	0.5	
Cyclognathus granulatus (MOBERG & MÖLLER)	39.5 —40.0	0.5	
Parabolina heres BRÖGG. var. alone	40.0 —40.6	0.6	1.6
Fossils absent	40.6 —44.5		3.9
Zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge*			
Parabolina (*megalops* MOBERG & MÖLLER?)	44.5 —45.0	0.5	
Parabolina longicornis WESTERG. and var.	45.0 —47.4	2.4	
Peltura scarabaeoides (WAHL.), *Sphaerophthalmus alatus* (BOECK), and, in the lower portion, several species of *Ctenopyge*	47.4 —54.5	7.1	
Peltura minor (BRÖGG.), *Sphaerophthalmus major* LAKE, and *Ctenopyge tumida* WESTERG.	54.5 —57.8	3.3	
Ctenopyge angusta WESTERG.	57.8 —58.8	1.0	
Ctenopyge flagellifera (ANG.)	58.8 —60.3	1.5	
Ctenopyge neglecta WESTERG. and var	60.3 —61.0	0.7	16.5
Zone of *Leptoplastus* and *Eurycare*			
Leptoplastus stenotus ANG. *Eurycare angustatum* ANG. *Eurycare* of the *latum* group and *Leptoplastus ovatus* ANG., in the lower portion replaced by *L. raphidophorus* ANG. *Leptoplastus paucisegmentatus* WESTERG.	61.0 —62.1		1.1
Zone of *Parabolina* of the *spinulosa* group and *Orusia lenticularis* (WAHL.)			
Parabolina spinulosa (WAHL.)	62.1 —65.2	3.1	
Protopeltura aciculata (ANG.) and *Parabolina brevispina* WESTERG.	65.2 —67.6	2.4	5.5

Zone of *Olenus* and *Homagnostus obesus* (BELT)			
Polyphyma angelini (BARR.) and undescribed conchostraca	67.6 —71.2	3.6	
Homagnostus obesus (BELT) alone	71.2 —73.0	1.8	
Olenus wahlenbergi WESTERG.	73.0 —73.1	0.1	
Olenus truncatus (BRÜNN.)	73.1 —73.8	0.7	
Olenus transversus WESTERG. (?) and *O. gibbosus* (WAHL.)	73.8 —74.4	0.6	6.8
Characteristic fossils absent	74.4 —75.4		1.0
Zone of *Agnostus pisiformis* (L.)	75.4 —78.3		2.9
Middle Cambrian.			
Fossils absent	78.3 —79.1		0.8
Zone of *Lejopyge laevigata* (DALM.) and *Aluta primordialis* (LINRS.)	79.1 —80.8		1.7
Zone of *Centropleura lovéni* (ANG.) and *Solenopleura brachymetopa* (ANG.) (Andrarum limestone)	80.8 —81.6		0.8
Zone of *Triplagnostus lundgreni* (TULLB.)	81.6 —82.1		0.5
Zone of *Ptychagnostus punctuosus* (ANG.)	82.1 —86.0		3.9
Zone of *Hypagnostus parvifrons* (LINRS.)	86.0 —89.0		3.0
Zone of *Tomagnostus fissus* (LINRS.) and *Triplagnostus atavus* (TULLB.)	89.0 —93.5		4.5
Zone of *Triplagnostus gibbus* (LINRS.) and *Ctenocephalus exsulans* (LINRS.)	93.5 —94.2		0.7
Alum shale poor in organic matter and lacking characteristic or safely determinable fossils	94.2 —96.4		2.2
Grey phosphoritic limestone rich in indeterminable fossil fragments (»fragmentkalk»)	96.4 —96.9		0.5
Lower Cambrian.			
Green glauconitic sandstone	96.9 —97.3		0.4
Greywacke, partly calcareous	97.3 —98.5		1.2
Coarse phosphoritic sandstone (Rispebjerg sandstone)	98.5 —98.7 +		0.2 +

Summary and Conclusions.

The alum shales of Scania comprising the sequence from the base of the Paradoxides paradoxissimus [tessini] beds to the top of the Dictyonema shale are poor in bituminous limestone (orsten) compared with the unit in other Swedish areas. On the other hand limestone and shale are less sharply separated in Scania, where layers of calcareous shale and greatly argillaceous limestone are far more

common than elsewhere. It should also be noted that especially in the shale of the Andrarum area, the bedding surfaces very often have thin coatings of calcite, less than 1 mm thick, which on the surface of the boring cores appear as white lines.

In contradistinction to the alum shale of the middle Swedish districts and Öland the Scanian shale, when heated, does not yield any oil. This may be due to the organic matter having been decomposed by the action of the swarms of narrow post-Silurian (probably Permian) diabase dykes that pierce the Cambro-Silurian deposits of Scania. The decomposition is also mirrored by the fact that the Scanian shale blackens much more than for instance the shale of Närke, even more than the shale of Halleberg and Hunneberg in Västergötland which was heated and distilled by the immediately overlying diabase sheet.

Safe figures of the thickness of the alum shale in Scania have hitherto been lacking. Of the five borings only one, Gislövshammar, penetrated the whole of the alum shale series and proved it to have a thickness of 76—77 m at this locality. At Andrarum, where the uppermost part of the Dictyonema shale is absent due to erosion, the two borings yielded a thickness of about 77 m, but for reasons stated above, the thickness of the part below the Andrarum limestone as disclosed by the boring is not reliable. Provided that the Dictyonema shale has the same thickness at Andrarum as at Gislövshammar, the total thickness at the former locality may be about 83 m. At S. Sandby, where the boring did not penetrate the lower part of the Middle Cambrian due to it meeting a diabase dyke, the total thickness may be estimated at approximately 100 m. Thus the unit decreases in thickness from the Sandby area to the south-east. This is in accordance with the conditions on Bornholm where the alum shale has a total thickness of but 27—28 m (Dictyonema shale 2.5, Upper Cambrian 21, and Middle Cambrian c. 4 m). The decrease consequently takes place more rapidly in the Baltic area between Scania and Bornholm.

The alum shale of Scania has a greater thickness and allows of the discrimination of a larger number of zones and subzones than the corresponding sequence in any other Scandinavian area. Neither lithological nor faunistical data indicate the existence of any break. Thus we may conclude that in Scania the sedimentation proceeded continuously from the beginning of the Paradoxissimus age into the Lower Ordovician period.

Dictyonema Shale.

The borings reveal that the thickness of this zone is much greater — at S. Sandby 9.6 and at Gislövshammar 16.5 m — than hitherto supposed. The latter figure is remarkably high; probably it is true, however, and, as stated above, it does not seem to be influenced by any fault producing a repetition of strata. The division of the zone into three subzones (WESTERGÅRD, 1909) is applicable to the core sections. It is true that the index fossils of the uppermost subzone, *Dictyonema flabelliforme norvegicum* and *Bryograptus kjerulfi,* were not found in the core from S. Sandby, but this may be due to this portion of the core having been crushed and having suffered great losses. At any rate the fossils mentioned are common in the uppermost strata at neighbouring localities. At Andrarum *Bryograptus kjerulfi* or a closely related form appears already in the uppermost layers with *Dictyonema flabelliforme* f. typ., *i.e.* at a lower level than usually the case. In the core from Gislövshammar but a few poor fragments of *Dictyonema flabelliforme norvegicum* and two identifiable specimens (possibly numerous fragments) of *Bryograptus kjerulfi* were found. In the lowest subzone there appears a form associated with, and earlier than, *D. flabelliforme* f. typ., which is characterized by thickened as well as thin and fairly closely set dissepiments and accordingly approaches var. *norvegica.* It agrees fairly well with some specimens illustrated by BULMAN (1927, p. 26, text-fig. 14) and STÖRMER (1940, figs. 9—10). At any rate it is remote from *D. flabelliforme sociale,* according to STÖRMER the index fossil of the lowest subzone of the Dictyonema shale in the Oslo region.

No evidence has hitherto come forth indicating that the very topmost portion of the Scanian alum shale might belong to the Ceratopyge beds proper as is the case *e.g.* on Öland, and at one locality at least, H 2 b in the Sandby—Fogelsång area (MOBERG, 1910 b), alum shale with *Bryograptus kjerulfi* is immediately overlain by grey shale and limestone belonging to the Shumardia zone.

Upper Cambrian.

The fossils of the Upper Cambrian, most of them common or abundant, have as a rule a sharply limited and narrow range and, consequently, an adequate division of the series into zones and subzones was readily found. As a rule the index fossil of a subzone is confined to the bed given its name and in many cases the subzones are separated

by a thin non-fossiliferous stratum. The borings have supplemented the detailed scheme of the sequence at Andrarum advanced by the present writer in 1922, have rectified an error as regards the position of the Acerocare subzone, and have proved the scheme otherwise to have general validity for Scania; the inconsiderable differences seen from the tables above may be only apparent due to incomplete core portions.

The Dictyonema shale seems to be constantly separated from the zone of *Acerocare* and *Parabolina* of the *heres* group by a barren bed varying in the cores from 1.6 to 3.0 m. The latter zone was divided by MOBERG & MÖLLER (1898) into the following four subzones in descending order (generic names those employed by the present writer in 1922):

4. Subzone of *Cyclognathus micropygus*
3. » » *Parabolina heres* (at Åkarpsmölla associated with *Peltura paradoxa,* at Sandby and Andrarum with *Cyclognathus granulatus*)
2. » » *Parabolina megalops*
1. » » *Parabolina acanthura* (and *Acerocare ecorne*).

The Sandby boring proves, however, that subzone No. 1 does not form the base but the top of the zone and also in the section Andrarum No. 2 the zone upwards terminates in a bed with an *Acerocare,* unfortunately too imperfectly preserved to allow of a safe specific identification. Thus it is still uncertain whether *Acerocare tullbergi* MOBERG & MÖLLER, so far known only from the latter area, replaces *A. ecorne* or occurs in some of the lower subzones. No bed with *Acerocare* was found in the core from Gislövshammar.

Thanks to the courtesy of Dr. J. E. HEDE the writer had the opportunity of examining the type specimens of *Parabolina megalops* and arrived at the result that MOBERG & MÖLLER included in this species specimens of three distinct species probably collected from different strata. Of the specimens illustrated in their pl. 13, fig. 2 and probably figs. 6 and 8 belong to one species of *Parabolina,* figs. 1, 4, 7, and 10 may be identified as *P. longicornis* WESTERGÅRD, 1922, and fig. 9 displays the pygidium of a form of *Peltura scarabaeoides* characterized by long and straight marginal spines which predominates in the youngest strata of the Peltura beds. To gain better knowledge of the species in fig. 2 it will be necessary to collect additional material at the type locality, Åkarpsmölla. At present it seems probable that the species is identical with a form found in the cores from S. Sandby, Andrarum, and Gislövshammar in a distinct subzone immediately above the subzone of *Parabolina longicornis.*

Limestone lenses are rare in the Acerocare-Parabolina heres zone and the fossils in the shale are indistinct throughout and more poorly preserved than in the underlying zones. Thus the material collected from the cores does not elucidate hitherto imperfectly known species, *e.g.* those of *Westergårdia.* The sequence is seen from the above tables of the cores from S. Sandby and Andrarum. The total thickness is 6.0 at the former and 7.0 at the latter locality, over- and underlying barren beds not counted. At Gislövshammar it was found to be but 1.6 m; in reality it is probably somewhat thicker, however, as the overlying barren bed was almost twice as thick as in the former sections and, on the other hand, the subzone of Acerocare was not encountered.

The bed with *Parabolina* (*megalops*?) is regarded as the youngest subzone of the zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge.* Even though the species may be more closely allied to *Parabolina heres* than to *P. longicornis* this division seems to be justifiable since the bed in which it occurs directly covers the bed with the latter species but is separated from the subzone of *P. heres* by a barren layer 3.9—5.3 m thick. In the lower portion of the subzone of *P. longicornis* a variety of the latter predominates which is distinct from the type by longer glabella quite or almost touching the rim. In the subzone of *Peltura scarabaeoides, Promegalaspides pelturae* WESTERG. was found at Gislövshammar (level 47.95 m) and *P. kinnekullensis* WESTERG. at Åkarpsmölla (level 10.4 m). The predominant form in the upper portion of the subzone of *Ctenopyge neglecta* differs from the type of the latter by longer glabella and shorter free cheeks (in a transverse direction). The total thickness of the zone is remarkably small at Andrarum, 7.4 m, compared with the thickness in the other areas, 15.3 to >17.2 m.

The sequence of the zone of *Leptoplastus* and *Eurycare* published by the present writer in 1922 was stated to be incomplete in the lowest portion. On account of that the writer excavated and re-examined the old sections at Andrarum in 1924 and found the sequence seen from the tables of the borings. Several complete specimens of *Leptoplastus paucisegmentatus* are present, all with ten thoracic segments, and a re-examination of the holotype (WESTERGÅRD, 1922, pl. VIII, fig. 22) has led to the result that the number may be the same in this specimen too, the first segment being concealed by the cranidium. *L. minor* WESTERG., which was recorded from the lower part of the zone in Östergötland, Västergötland, and Jämtland but not from Scania and no complete specimen of which is as yet known, is in all probability

synonymous with *paucisegmentatus*. The total thickness of the zone is constantly small, 1.1—2.3 m.

The upper limit of the zone of *Parabolina* of the *spinulosa* group is sharp but the lower one is not very well-defined due to the lower portion being very poor in fossils. The fauna is monotonous. Usually only the index fossils are found, those of the upper subzone in great abundance. The figures seen from the table on p. 19, all minima, demonstrate that the thickness varies rather considerably, from 1.5 at Åkarpsmölla to 10.5 m at Andrarum. The former figure may in reality be 2—3 m higher, however.

The last-mentioned zone merges downwards into a bed very poor in fossils, almost exclusively conchostraca, *viz. Polyphyma angelini* and a couple of undescribed forms. At Andrarum the former is associated with *Olenus scanicus* WESTERG. (not found in the cores) and thus this bed is regarded as the youngest subzone of the *Olenus* zone. The total thickness varies between 4.1 m at Åkarpsmölla and 12.7 at S. Sandby.

The zone of *Agnostus pisiformis* has a fairly constant thickness of about 3 m, over- and underlying barren beds not counted. In addition to the abundant index fossil but one species was been met with in the cores, *viz. Proceratopyge nathorsti* WESTERG., at Åkarpsmölla. According to the prevailing opinion the zone is counted to the Upper Cambrian, though reasons can be advanced for including it in the Middle Cambrian.

The minimum thickness of the Upper Cambrian disclosed by the borings is 54.2 m at Sandby (the diabase sills, 1.0 m, excluded), 47.2 m at Andrarum, and 39.3 m at Gislövshammar. If we include the barren bed between the Acerocare zone and the Dictyonema shale, the figures are 55.8, 48.9, and 42.3 m respectively.

Middle Cambrian.

A complete section through the Middle Cambrian of Scania was wanting until the borings at Andrarum and Gislövshammar were made. At Andrarum numerous small and discontinuous sections (earlier uncovered to a greater extent than at present) are to be found, however, in which most of the beds can be studied. For this area TULLBERG (1880, 1883) advanced the following scheme of the Middle Cambrian sequence, which was accepted by subsequent writers.

a. Zone of *Lejopyge laevigata*
b. » » *Paradoxides forchhammeri*
c. » » *Triplagnostus lundgreni*
d. » » *Paradoxides davidis*
e. » » *Bailiella aequalis*
f. » » *Condylopyge rex*
g. » » *Triplagnostus intermedius*
h. » » *Eodiscus scanicus*
i. Zone of *Ctenocephalus exsulans*
k. » » *Triplagnostus atavus*
l. Fragment limestone (with *Paradoxides hicksii*?)
m. Alum shale lacking characteristic fossils (only brachiopoda)
n. Zone of *Holmia kjerulfi* [later included in the Lower Cambrian].

In one respect this scheme is incorrect, however, and, with the exception of the four uppermost zones, it may be applicable but to the sequence at Andrarum.

Triplagnostus atavus was known by TULLBERG only from a limestone (orsten) boulder at Forsemölla which was erronously supposed to originate from the shale bed below the Exsulans limestone. As pointed out by the present writer (WESTERGÅRD, 1940, p. 62, foot-note) *T. atavus* is not specifically distinct from *T. intermedius* and the zone of *T. atavus* should be substituted for the zone of *T. intermedius*. *Eodiscus scanicus* is not infrequent in a thin stratum a little above the Exsulans limestone at Andrarum — in the core 4 cephala and 2 pygidia were found at 58.4 m —; at Gislövshammar it seems to be rare, however. In the core but 2 specimens were found (at 89.4 and 93.4 m) and not a single specimen has been met with in the limestone (orsten) boulders on the shore between Brantevik and Gislövshammar, several hundreds of which have been thoroughly examined by the present writer. *Condylopyge rex* is fairly common in a thin stratum at Andrarum; otherwise it is rare but seems to have a comparatively great range: in the core two cephala were found at 51.1 m and 58.4 m respectively. At Gislövshammar this species may be very rare or possibly absent; at any rate no specimen was found either in the core or in the boulders mentioned above. *Bailiella aequalis* is fairly infrequent and seems to be confined to a thin stratum; it was not met with in any of the cores. Of *Paradoxides davidis* as well as of other species of this genus safely identifiable specimens are rarely obtained.

Agnostids are beyond comparison the most common fossils in the Middle Cambrian except in the Andrarum limestone and the Exsulans limestone. As a rule they are easily determinable, and, accordingly, satisfy the claims on good index fossils. Thus the scheme of the sequence advanced in this paper is founded almost exclusively on the agnostids. It is less detailed than the one given by TULLBERG, but on the other hand it has general validity for Scania and is applicable to other

Scandinavian areas, too, where, however, the sequence displays minor or greater breaks. It seems probable that some of the zones may conveniently be divided into subzones, a task which claims further investigations, however. As regards the range and frequency of the index fossils the following notes should be made.

Lejopyge laevigata, Triplagnostus lundgreni, and *Hypagnostus parvifrons* do not occur abundantly in Scania as do the remainders but each of them is the most common in its zone. The last-mentioned species has a particularly great range, from the base of the Triplagnostus atavus zone into the lowest portion of the Ptychagnostus punctuosus zone. It is very rare in these zones and comparatively common but on solitary bedding surfaces in the bed given its name. *Tomagnostus fissus* appears earlier — in the Exsulans limestone — than *Triplagnostus atavus* and survives the latter. It is common in many strata but is never as abundant as the latter. *Triplagnostus gibbus* has a narrow range: it is as a rule not very common in the Exsulans limestone but abundant in a thin bed immediately above the latter. Not a single specimen was found in the core from Andrarum, however, which may be due to the core being crushed and incomplete at this level. At any rate *T. gibbus* is common in the corresponding strata at Forsemölla.

The alum shale, 2—4 m thick, below the Exsulans limestone has in its uppermost portion yielded a few specimens of the forms common in the limestone but is otherwise very poor in fossils, almost exclusively *Acrotreta* and *Lingulella*. In the core from Gislövshammar a small fragment of *Acrothele granulata* (identified by the sculpture of the shell) and a thoracic segment of a *Paradoxides* of the *oelandicus* group, *i.e.* forms common in the Œlandicus beds, were met with at 96.2 m. They do not determine the age of the bed, however, since one or both occur also in the lowest portion of the Paradoxissimus beds in other areas, *viz.* Öland, Östergötland, Västergötland, and Jämtland. As, furthermore, no safely identifiable fossils of stratigraphic value have so far been found in the so-called fragment limestone, it is still uncertain whether the basal strata of the Middle Cambrian of Scania should be included in the Paradoxissimus or Œlandicus beds. The former suggestion may, however, be the more probable one.

The total thickness of the Middle Cambrian at Gislövshammar was found to be about 17.8 m, or 18.6 m if the overlying barren bed is included. The figure yielded by the boring at Andrarum, about 19 m, is uncertain for reasons quoted above.

Tabular view of the borings, showing the thickness of the zones in metres.

	Åkarps-mölla	S. Sandby	Andrarum No. 2.	Andrarum No. 1.	Gislövs-hammar
Dictyonema shale	—	9.6	> 8.7	—	16.5
Upper Cambrian					
Fossils absent	—	1.6	1.7	...	3.0
Acerocare, Westergårdia, Cyclognathus, and *Parabolina heres* group	—	6.0	7.0	—	1.6
Fossils absent	—	5.3	4.1	—	3.9
Peltura, Sphaerophthalmus, and *Ctenopyge*	> 17.2	15.3	7.4	7.4	16.5
Leptoplastus and *Loriolare*	1.5	1.3	2.2	2.3	1.1
Parabolina spinulosa group and *Orusia lenticularis*	1.5	7.5	> 4.0	10.5	5.5
Fossils absent	3.4	...	—	2.8	...
Olenus and *Homagnostus obesus*	4.1	12.7	—	8.6	6.8
Fossils absent	1.1	2.8	—	1.2	1.0
Agnostus pisiformis	3.4	3.3	—	3.3	2.9
	> 32.2	55.8	48.9		42.3
Middle Cambrian					
Fossils absent	1.6	3.0	—	1.0	0.8
Lejopyge laevigata	?	5.1	—	2.0	1.7
Centropleura lovéni and *Solenopleura brachymetopa*	0.25	1.2	—	0.9	0.8
Triplagnostus lundgreni	1.15	3.5	—	1.2	0.5
Fossils absent	0.4	0.8	—	...	—
Ptychagnostus punctuosus	—	5.7	—	3.5	3.9
Hypagnostus parvifrons	—	—	—	3.5	3.0
Tomagnostus fissus and *Triplagnostus atavus*	—	—	—	3.5	4.5
Triplagnostus gibbus and *Ctenocephalus exsulans*	—	—	—	> 0.3	0.7
Characteristic fossils absent	—	—	—	4.0	2.7
				19.9	18.6
Lower Cambrian					
Green glauconitic sandstone	...	...	...	—	0.4
Greywacke. Zone of *Holmia kjerulfi* and, at Gislövshammar, *Strenuella linnarssoni*	—	...	...	3.0	1.2
Coarse quartzitic sandstone.					

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