9. A Section from the Upper Chasmops Series to the Lower Tretaspis Series at Fjäcka Rivulet in the Siljan Area, Dalarne.

A Preliminary Report

By

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Introduction.

In order to obtain a more precise knowledge of the Middle and Upper Ordovician stratigraphy and lithology in the so-called »normal facies»[1] of the Siljan area in Dalarne, a complete section from the Lower Chasmops limestone to the grey limestone above the black Tretaspis shale (»the Middle Tretaspis limestone»[2]) has been exposed by excavations at the rivulet Fjäcka in the summer of 1946 by the present authors. Previously only generalized descriptions of a few sections of the strata in question in the Siljan area have been published by TÖRNQUIST (1871, 1883 a. o.), and partly supplemented by WARBURG (1910) and THORSLUND (1935, 1936). Since the now exposed section mentioned above provides some new stratigraphical and lithological data, a preliminary description of it is given in this paper.

It is exposed along the Fjäcka rivulet at the farm Moldå, 1 km west of the village Dalbyn in the parish of Ore (see map in THORSLUND 1936, pl. 3). The Fjäcka rivulet has here eroded a in some places rather deep valley in the Ordovician limestones. On the steep slopes of the valley strata beginning with the Asaphus limestone unto the »Middle Tretaspis limestone» are exposed, and there is a small quarry present (loc. 6 and 7, see fig. 1)

[1] In Dalarne the »normal facies» is the usual denomination (cf. THORSLUND 1935, 1936) of the beds of the Chasmops and Tretaspis series and of the Dalmanitina limestone deposited outside the »reef facies» (Kullsberg and Boda limestones, THORSLUND 1935).

[2] »The Middle Tretaspis limestone» is here proposed as a provisional denomination of limestones and marls between the black Tretaspis shale and the red Tretaspis limestone; these beds with unknown fauna have earlier been called »grey limestones above black Tretaspis shale» which appears too inconvenient as a term.

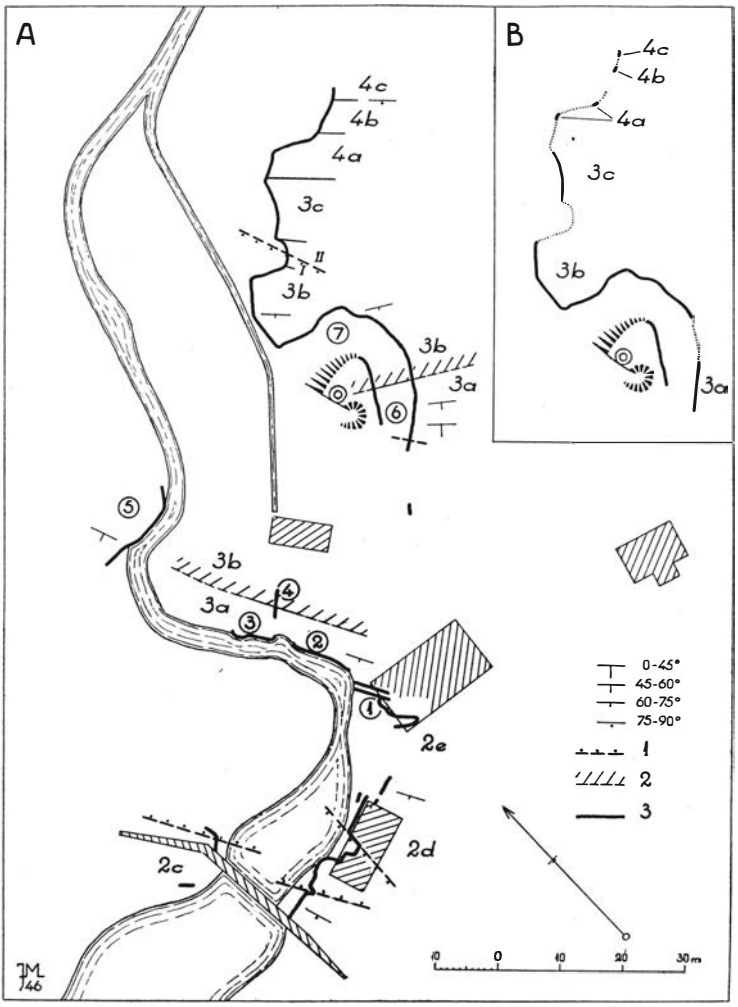


Fig. 1. Geological map of the exposures at Fjäcka rivulet. A, the exposures after the excavations in 1946. B, the exposures in 1945 previous to the excavations. ①, ②, ③ etc. numbers of exposures.

1, dislocation plane; 2, the limit between the Crassicauda and the Lower Chasmops limestones; 3, exposure.

Stratigraphical divisions (the numbers according to TÖRNQUIST 1883):

4 c, »Middle Tretaspis limestone»
4 b, Black Tretaspis shale
4 a, Slandrom limestone
3 c, Macrourus limestone (Upper Chasmops limestone)
3 b, Lower Chasmops limestone s. lato
II, Beds with undetermined stratigraphic position
I, The clay (probably bentonite) bed group
3 a, Crassicauda limestone
2 e, Schroeteri limestone
2 d, Upper red limestone (= Gigas + Platyurus limestones)
2 c, Asaphus limestone

in the Crassicauda (JAANUSSON 1946, Flagkalk in TÖRNQUIST 1883) and Lower Chasmops limestone (Cystid limestone in TÖRNQUIST 1883). A generalized section of the Ordovician beds at the Fjäcka rivulet has been published by TÖRNQUIST (1867, 1871, 1883).

The beds at Fjäcka are inverted, mostly striking about N 30—45° W and dipping about 50—70°, although the range of strike is from N 20° W (loc. c) to N 65° W and that of dip from inverted horizontal (loc. 6) to 85°. Some small faults cut the section (fig. 1) and somewhat west of loc. 6 there may have occurred a bigger thrust without being exposed yet causing a repetition of parts of the Crassicauda and Lower Chasmops limestones.

A continuous section has been excavated from loc. 6 (Crassicauda limestone) to the lower part of »the Middle Tretaspis limestone». Strata upward hereof could not be exposed, as they are covered by mighty Quaternary deposits. The present description covers the strata from the upper part of the Lower Chasmops limestone to the topmost beds exposed.

Before the excavations the beds to be described were exposed as a discontinuous row of small outcrops on the steep bank of the rivulet (fig. 1, B); and TÖRNQUIST (1883, p. 44) in his generalized description of the Fjäcka section based himself upon them. This locality was the only one in the Siljan area where he could follow the strata from the Macrourus limestone to the black Tretaspis shale in its natural sequence of beds (TÖRNQUIST 1883, p. 20—21), and for this reason Fjäcka has become a classical locality of these beds in the »normal facies» of the Siljan area. At present Fjäcka is the only locality known in the »normal facies» of the area, with exposure of a section of Macrourus limestone and Slandrom limestone[1] (the other localities mentioned by TÖRNQUIST 1883 are now covered by vegetation).

In the present preliminary description of the section only the macroscopical properties of the rocks have been considered, although in order of a preliminary orientation and check a number of thin sections, mainly from different horizons of the Slandrom limestone, have been examined. As the rocks of the section (the excavated parts of which are 0.3—1 m high) are unevenly and in parts intensely weathered, the details of several beds and contacts are not quite cleared up. Of fossils only a few stratigraphically important specimens are mentioned as well as determinable finds derived from beds with earlier more or less unknown fauna.

[1] THORSLUND (1943, p. 6) proposes the denomination Slandrom limestone for beds between the Upper Chasmops limestone (= Macrourus limest.) and the black Tretaspis shale in Jämtland (Storsjö area), previously called Masur limestone. The present authors propose the use of the name Slandrom limestone also for this division in Dalarne.

Description of the section (fig. 2).

(The thicknesses of the beds are given in cm)

200 + **»Middle Tretaspis limestone».** Argillaceous limestone, greenish-grey, with trails and nests of green marl. Lowermost 50 cm, harder, bluish-grey limestone. There are no thick layers of marl between the individual beds of limestone. Small macroscopical fragments of fossils locally abundant. Of the few determinable fossils found *Sulevorthis* cf. *lyckholmiensis* (Wys.) should be emphasized.

The contact with the underlying black Tretaspis shale is an approximately even bedding plane on top of a thin layer of clay.

Black Tretaspis shale 580

1—2 Greenish-brown, occasionally mottled, somewhat plastic clay.

560 Thinbedded shale, dark brown to black (= the typical black Tretaspis shale with *Flexicalymene trinucleina* (Linnars.), *Tretaspis seticornis* (His.), *Onniella argentea* (His). a. o.[1]).

Contact with the underlying shale sharp.

20 Calcareous shale, greenish-grey, rich in fossil fragments. Above the contact with the underlying limestone brownish, the contact sharp.

Slandrom limestone 840

12. 120 For the most part nearly compact sublithographical[2], more seldom fine-grained and argillaceous limestones. Individual limestone beds varying from 3 to 14 cm in thickness, in most parts cleanly separated by layers of greenish marl, calcareous shale, or clay 0.5—6 cm thick.

11. 75 Strongly weathered masur limestone.[3] The lithographical part is light

[1] The graptolites from the black Tretaspis shale (Amtjärn, Dalarne) indicate the presence of the zone of *Climacograptus styloideus* and *Pleurograptus linearis*, cf. Thorslund 1935 (p. 48).

[2] The term lithographical is used provisionally in this paper for a compact, hard, cryptocrystalline limestone with conchoidal fracture, characterized by small amounts of argillaceous material and a few relatively small fragments of fossils. This type of limestone forms the main part of the sediments of the Estonian Rakvere (E) (Sauramo 1929) and Saunja (F_1a) stages and occurs as typical »Östersjö limestone» in the North and Middle Baltic areas (Wiman 1907, Kulling 1926, a. o.). This limestone bears a great resemblance to the Bavarian lithographical limestones (Sauramo 1929, p. 27—28). The origin of the lithographical limestone is thought to be calcareous mud derived for the most part from calcium carbonate chemically precipitated from sea-water.

Sublithographical is a provisional denomination for limestones, which lie between the argillaceous fine-grained limestone and the lithographical limestone, and which are characterized *inter alia* by subconchoidal fracture.

These provisional names have been introduced to facilitate the description of the section and to avoid repetitions. It is, however, very difficult if not almost impossible to characterize the different variations of limestones with sufficient precision and clarity without extensive microscopical descriptions.

[3] The masur limestone is a peculiar textural type of rock, in which the main part is usually composed of irregular and partly connected nodules or irregular layers of lithographical limestone, embedded in a varying amount of more or less argillaceous lime-

brown to grey and tends to somewhat sublithographical, as conchoidal fracture is not distinctly developed. The argillaceous part greenish, richly developed.

Uppermost 8 cm an almost homogeneous yellowish lithographic limestone. Locally on the upper contact a crust of glauconite has been observed between nodules of lithographical limestone.

10. 35 Three beds of fine-grained argillaceous limestone with thicknesses in descending order 9, 7 and 14 cm. In the limestone locally there occur small macroscopical fragments of fossils. Individual beds of the limestone are separated by layers of marl or calcareous shale measuring 2—3 cm. From the uppermost bed a fragmentary cheek of *Tretaspis* sp., a headshield of *Trinodus* sp., *Leptelloidea?* sp., and from the lowest a headshield of *Tretaspis seticornis* (His.) have been collected.

9. 125 Masur limestone. The lithographical part is brown, apparently bituminous, often intersected by fissures filled with calcite. The argillaceous part is very weakly developed and usually occurs as a dark brown bituminous shale.

8. 125 Uppermost 27 cm is an indistinctly bedded argillaceous limestone with bedding planes very uneven interbedded with green marl or calcareous shale and disintegrated into thin layers (Pl. II, fig. 1 f). The lower part consists of thick-bedded and fine-grained argillaceous limestones (individual beds in ascending order 40, 33 and 15 cm, cf. Pl. II, fig. 1 a, c, e), interbedded with greenish-grey marl (4 cm, cf. Pl. II, fig. 1 b) and clay (6 cm, cf. Pl. II, fig. 1 d).

7. 14 Masur limestone. In the upper part resembles bed 1, passing downwards into sublithographical limestone.

6. 90 In the upper (30 cm) and lower (25 cm) parts sublithographical to fine-grained argillaceous limestone with thin irregular laminae of marl. In the central 35 cm irregularly bedded limestone with green marl. Very disintegrated, details, especially in the lower part, indistinguishable.

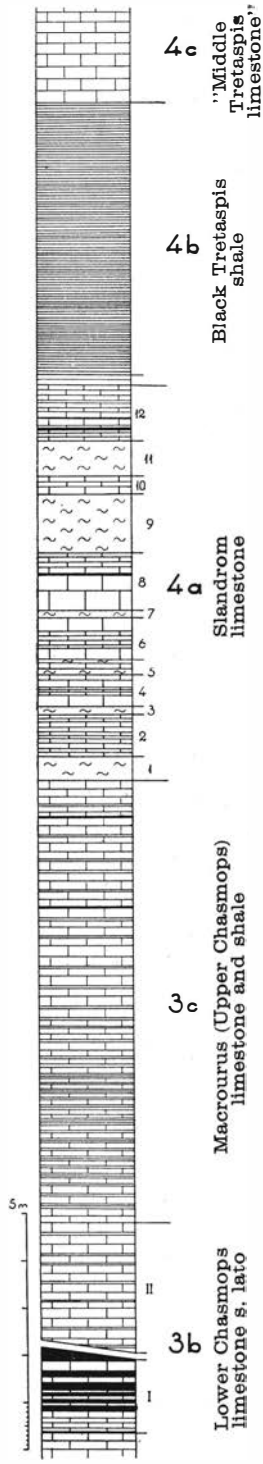
5. 30 In the upper 7—8 cm and lower 10 cm masur limestone. The lithographical part is light brown and tending towards sublithographical as the conchoidal fracture is not typically developed. The more argillaceous part is greenish, dense and well represented. Intermediate 12—13 cm sublithographical(?). The upper 20 cm of the division very disintegrated.

4. 70 Fine-grained argillaceous to sublithographical limestone. It is difficult to distinguish macroscopically anything more precise, because of strong disintegration especially in the lowermost 20 cm.

3. 15 Masur limestone. In the middle 7 cm »typical» masur limestone, like bed 1 (Pl. I, fig. 1), with the argillaceous part developed as thin irregular laminae of grey marl and shale. In the uppermost 4 cm masur limestone like bed 5. In the lowermost 4 cm a more homogeneous

stone, marl or shale (Pl. I, fig. 1). In every single bank of the masur limestone the bedding is obscure or invisible. When disintegrated the masur limestone has a fine-nodular appearance.

The local population in Dalarne calls this type of limestone »masurkalk» (= »curly birch limestone»; »knyckelkalk» in Östergötland), a name picked up by Törnquist (1883, p. 21) both for this peculiar type of limestone and for the stratigraphical division between the Macrourus limestone and the black Tretaspis shale (Slandrom limestone of Thorslund 1943).



sublithographical limestone. In some pits on the rough and uneven bedding plane between the middle and the lowermost part of the bed a crust of glauconite has been observed.

2. 90 Argillaceous thin-bedded (individual beds 0.5—4 cm) limestone, light greenish-grey and fine-grained, with uneven bedding planes and irregular layers and laminae of grey marl. Occasionally small grains of glauconite occur. Some fossils have been collected, inter alia *Remopleurides* sp. On the boundary between beds 2 and 3 a layer of limestone with an irregular Fe_2O_3-impregnation has developed (Pl. I, fig. 2).

1. 50 Masur limestone (Pl. I, fig. 1). Lithographical part occasionally somewhat sublithographical and brownish. The argillaceous part is developed as thin laminae of grey shale and marl. Small grains of glauconite have been observed in the marl.

Macrourus limestone and shale (Upper Chasmops limestone) 870

Argillaceous limestone, greenish-grey and fine-grained, usually abounding in terrigenous material compared with the limestone of the lower Chasmops beds. The calcareous shale between the limestone layers is greyish-green, soft and contains small grains of glauconite.

The following lithological subdivisions pass into each other without any sharp boundaries:

190 Irregularly bedded limestone, in the upper 45 cm with irregular laminae of marl, in the lower part with irregular layers and nests of marl to calcareous shale.

Fig. 2. Generalized section of the Upper Chasmops and Lower Tretaspis series at Fjäcka.

The stratigraphic divisions (numbers according to TÖRNQUIST 1883):

4 c, »Middle Tretaspis limestone»
4 b, Black Tretaspis shale
4 a, Slandrom limestone
3 c, Macrourus limestone (Upper Chasmops limestone)
3 b, Lower Chasmops limestone s. lato
II, Beds with undetermined stratigraphic position
I, The clay (probably bentonite) bed group

Shale
Masur limestone
Limestone interbedded with marl or shale
Plastic clay

65 cm from the top a layer of a somewhat plastic greenish clay with a thickness of 3—4 cm has been observed.

At 40 cm from the top the highest level of *Chasmops macrourus* ANG. was met with.

165 Like the previous, yet the layers of calcareous shale are thicker and more pronounced.

65 cm from the top a 3 cm layer of clay occurs.

275 Regularly bedded limestone, intercalated with thick layers of calcareous shale. In the upper 1 m the layers of both limestone and shale vary from 3 to 7 cm. The lower part shows increasing thicknesses (limestone unto 15 cm, shale unto 25 cm at max.).

240 Irregularly thinbedded limestone, intercalated with layers of calcareous shale. Individual layers of both about 1—3 cm thick.

Lower Chasmops limestone *s. lato.*

Beds with undetermined stratigraphic position 270 +

270 + Argillaceous grey limestone, relatively thick-bedded and fine-grained, intercalated with thin layers of marl and greenish-grey calcareous shale. Macroscopically, the limestone and shale of this division is rather like the superimposed one. The fossils found — inter alia *Echinosphaerites aurantium* (GYLL.), *Asaphus cf. ludibundus* TÖRNQ. — show a certain faunistic connection with the underlying Lower Chasmops limestone. Yet owing to the small number of fossils found it is for the present difficult to decide the certain stratigraphic position of these beds. In this paper these beds and the underlying beds of plastic clay only provisionally have been included in the Lower Chasmops limestone.

Tectonic discordance N 20° W (a small dislocation).

Beds of plastic clay (probably bentonite), interbedded with argillaceous limestone (fig. 3 and Pl. II, fig. 2) 180 +

13. 26 + (maximal observed thickness. The bed is cut off obliquely by a fault, real thickness not observed.) Almost white to light yellowish, occasionally mottled, strongly weathered plastic clay. When dry, hard, compact and talky on touch. Absorbs water to about twice its original volume (according to a provisional test) and crumbles easily. Probably bentonite.

In the uppermost part pieces of calcite occur.

12. 20 Argillaceous limestone, very disintegrated and greenish-grey. Possibly one bed.

11. 12 Clay like bed 13.

10. 12 One bed of limestone like bed 12.

9. 15 Clay like bed 13. Lower part harder, shaly.

8. 6 Limestone like bed 12.

7. 6 Clay like bed 13.

6. 8 Limestone like bed 12, with uneven bedding planes.

5. 7 Clay like bed 13.

4. 5 Limestone like bed 12 with very uneven bedding planes.

3.	12	Clay like bed 13, greenish-grey and partly shaly. Lower 4 cm dark grey with a lilac tint.
2.	50	Argillaceous limestone, greenish-grey and fine-grained, irregularly interbedded with thin layers of greenish marl and calcareous shale.
1.	1	Clay like bed 13, greenish.

Lower Chasmops limestone *s. str.* Thickness about 18—19 m.

ab. 18—19 m. Argillaceous limestones, grey and fine-grained, often with uneven bedding planes, intersected by irregular layers and laminae of marl grading into calcareous shale. Macroscopical fossil-fragments are locally abundant. 9.5 m from the top a 3—5 cm bed of plastic clay rather like the previous ones was met with.

In the uppermost 1.5 m *Asaphus ludibundus* TQT., *Bimuria* n. sp., *Leptelloidea cf. musca* ÖPIK, *Sowerbyella cf. undosa* ÖPIK a. o. were found.

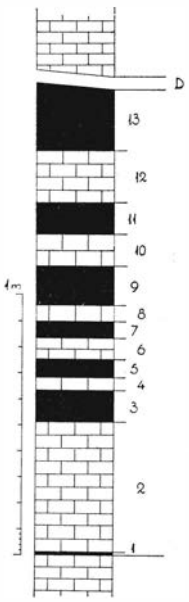
Crassicauda limestone 6 m +.

6 m + Argillaceous limestones, grey and fine-grained, macroscopically like the Lower Chasmops limestones, but as a rule more dense and with fewer fragments of fossils, interbedded by layers and irregular laminae of marl grading into calcareous shale.

The Crassicauda limestone appears to be contemporaneous with the zone of *Nemagraptus gracilis*. As to the fauna cf. JAANUSSON 1946.

Stratigraphic remarks.

An interesting discovery is the occurrence of relatively thick beds of a plastic clay below the typical Macrourus limestone. It is probably a bentonite, although further laboratory investigations are needed for exact determination.



The clay beds occur approximately at the same stratigraphic level as the bentonite beds in the bore holes in Gotland (THORSLUND & WESTERGÅRD 1938, THORSLUND 1945) and at Kinnekulle in Västergötland (THORSLUND 1945).

A similar clay was also discovered in the region of the Kullsberg limestone (»older reef limestone») in Amtjärn and Kullsberg. In Amtjärn, a section was excavated into the underlying beds of the Kullsberg limestone to the west of the old southern quarry (see map in THORSLUND 1936, Fig. 6 b). A plastic clay, strongly weathered and macroscopically similar to that of Fjäcka occurs there at the same stratigraphic horizon as at Fjäcka forming a bed 5—6 cm thick. 0.5—2 cm below the clay bed a strong, uneven discontinuity surface[1] is met

[1] This term is used in the same sense as the German »Diskontinuitätsfläche» (cf. ORVIKU 1940).

Fig. 3. Schematic section of the clay bed group at Fjäcka. Black = clay (probably bentonite). The numbers correspond to the description of the section.

with showing a black phosphoritic impregnation. The limestone above the discontinuity surface shows grains of glauconite and some phosphoritic nodules. At Kullsberg two analogous clay beds 3—7 cm thick occur at the same level as at Amtjärn. Here the clay shows only weak weathering and is more like the bentonite of Kinnekulle and File Haidar (Gotland), macroscopically, being light grey in colour and containing numerous flakes of mica, often with hexagonal contours.

In the upper part of the Macrourus limestone and in the Slandrom limestone (beds 8 and 12) there occur also thin layers of plastic clay, when weathered grey, brownish or mottled, when dry hard, somewhat talky at touch and crumbling rapidly in water. These clay layers also are in need of special investigation.

The new excavations show that the beds of masur limestone of different variations represent only about 30 % of the total thickness of the Slandrom limestone at Fjäcka. Before these excavations, however, of the Slandrom limestone only parts, *i. e.* the masur limestone beds 9 and 11, were exposed.

The fossils mentioned from the Slandrom limestone (bed 10) are the first ones found in it of the Siljan area. THORSLUND (1940, p. 22, 90) had earlier obtained some fossils from the upper part of the Slandrom limestone in Jämtland, inter alia *Tretaspis seticornis* (HIS.). The discovery of *T. seticornis* also in the upper part of the Slandrom limestone at Fjäcka confirms the conclusion drawn by THORSLUND (1940, p. 71), that at least the upper part of the Slandrom limestone should be included in the Tretaspis series.

Of interest is also the discovery of a fairly rich and rather well preserved ostracode fauna in the Slandrom limestone. The ostracodes, most of them probably undescribed species, have been found in the argillaceous limestones between the masur limestone beds, especially in the bed 10.

It is not yet possible to perform any more precise stratigraphic division of the beds described. The reason is the small quantity of macrofossils found, in spite of systematic searching during three summers. It depends mainly upon the smallness and scarcity of the exposures. In the authors' opinion it is very difficult to collect enough macrofossils from the localities of the Middle and Upper Ordovician »normal facies» now exposed in the Siljan area, with purpose to establish a division into zones, or in some parts even into stages, comparable with those of the Estonian Middle Ordovician (cf. JAANUSSON 1945); this applies also to strata comparatively rich in fossils, as f. i. the Lower Chasmops limestone and the Macrourus limestone. The present stratigraphical division of the sequence in question is largely based on lithological distinctions (although lithology and its group limits may correspond to faunistic ones); accordingly the limits in the described section are drawn on lithological marks. The limit between the Lower Chasmops limestone and the Macrourus limestone, without appreciable lithological boundary, could not be fixed owing to the scarcity of fossils met with in the section.

Appendix.

It may be mentioned, that in the Viru (or Chasmops) series of Estonia beds of plastic clay also occur, which macroscopically are similar to the bentonite beds in the Chasmops series of Sweden. The clay is almost white, when weathered brownish, sometimes it contains small dark flakes of mica. In connection with the clay beds there occur thin layers of fossiliferous sandstone, which usually form the roof, but sometimes also the floor of the clay beds. The sandstone is white, when weathered brownish yellow, and composed mainly of angular quartz and feldspar grains (the grain size varying from about 0.2 mm downward), pyrite and occasional biotite flakes, dark brown, fresh and often with hexagonal contours.

Although nothing has been published about these beds, some of them are well known to Estonian stratigraphers as providing excellent key horizons to be traced across the whole area of Estonia.

These beds of plastic clay (probably bentonite) together with the sandstone are known at three horizons of the Viru series of Estonia (for stratigraphy cf. JAANUSSON 1945):

1. At the boundary region between the stages Idavere and Jõhvi, two layers eastward increasing in thickness;

2. At the boundary between the stages Jõhvi and Keila, one bed about 15—20 cm thick, eastward probably decreasing in thickness;

3. In the Keila stage at the boundary region between the Ristna and Pääsküla beds, two thin layers.

Acknowledgements.

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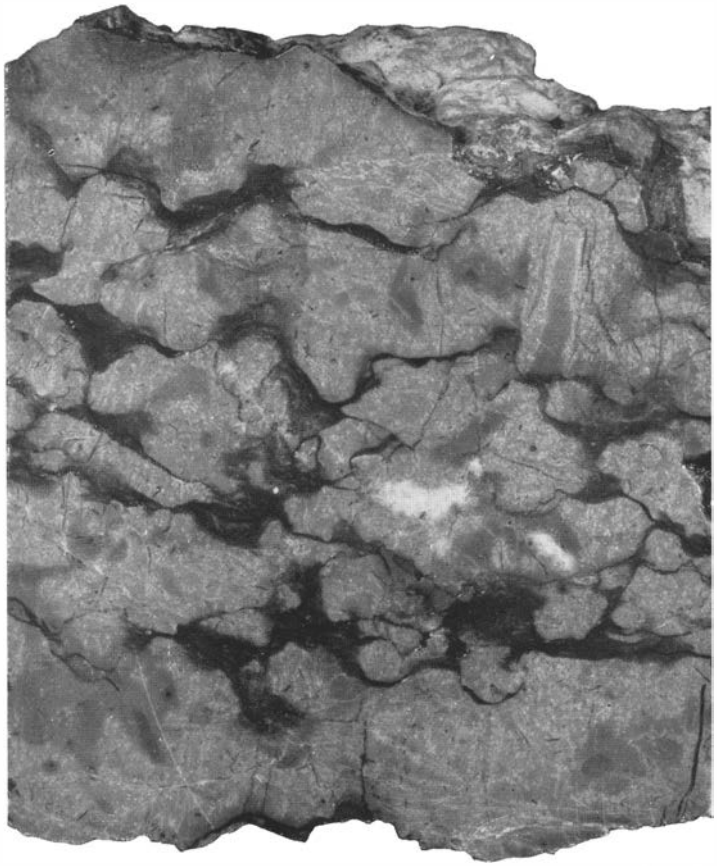

Fig. 1. Masur limestone, 15—25 cm from the lower limit of bed 1 of the Slandrom limestone at Fjäcka. Black laminae are irregular intercalations of marl and shale. × 1. Ilford filter Micro N:o 8. N. Hjorth phot.

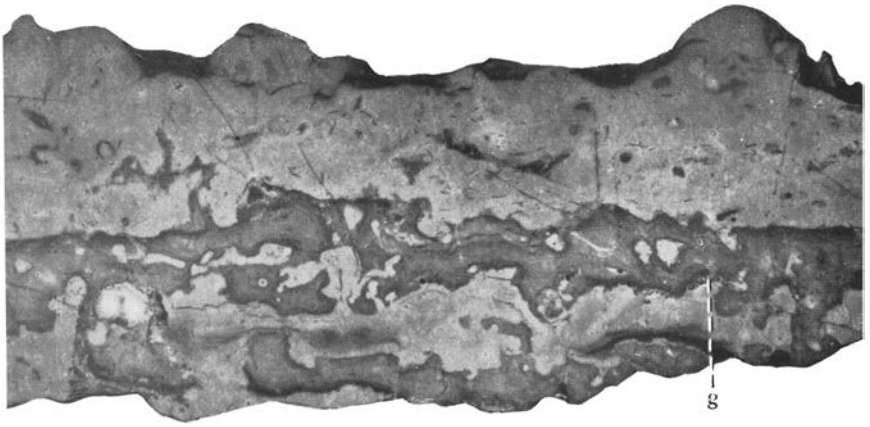

Fig. 2. A layer of limestone with irregular Fe_2O_3-impregnation from the limit between beds 2 and 3 of the Slandrom limestone at Fjäcka. g, glauconite crust. The Fe_2O_3-impregnation appears rather dark and strong in the figure, because the photograph was taken with Ilford filter Micro N:o 2 (blue) in alcohol. × 1. N. Hjorth phot.

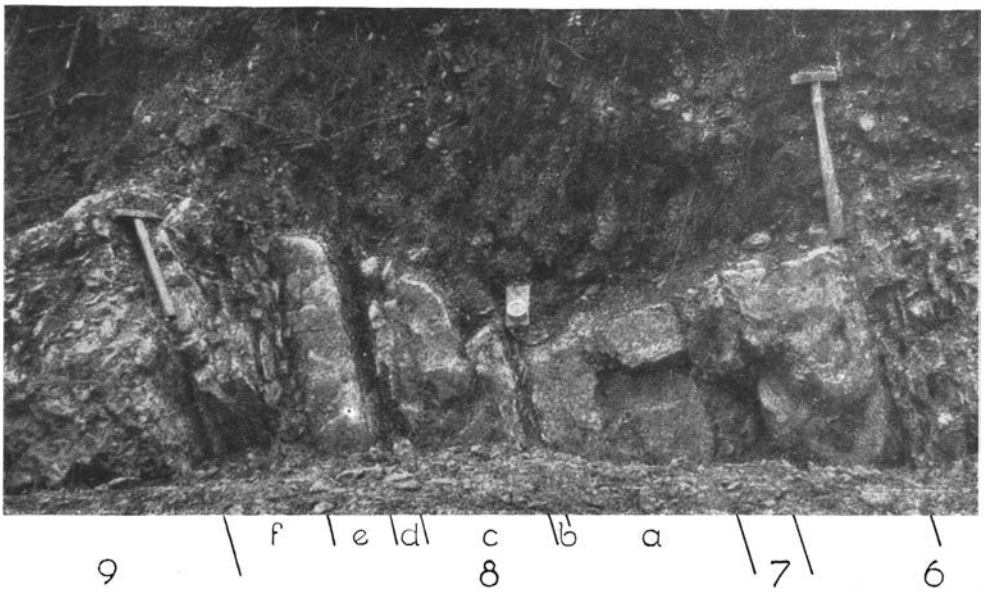

Fig. 1. The thick-bedded middle part (beds 6—9) of the Slandrom limestone at Fjäcka. For explanation see description p. 189. J. Martna phot.

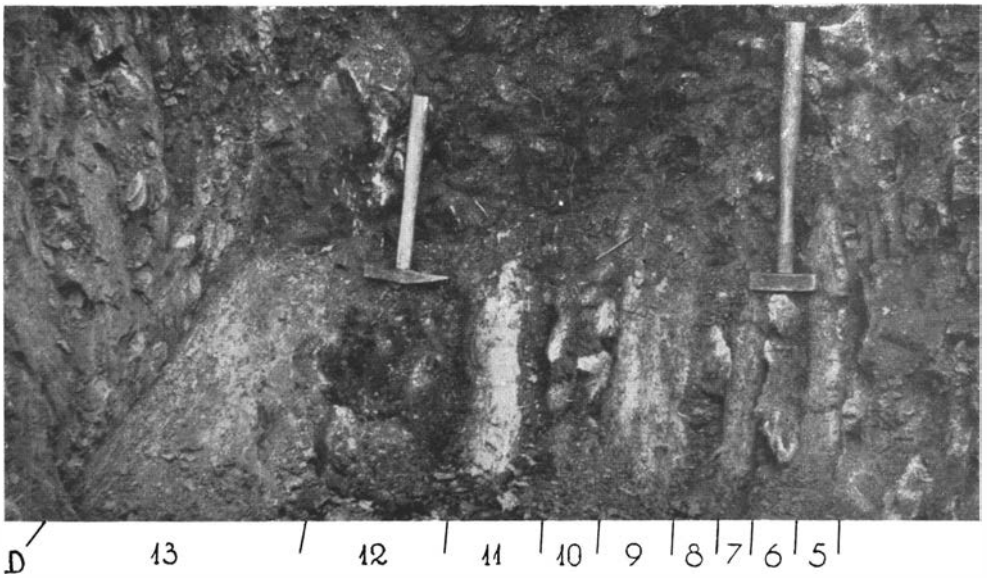

Fig. 2. The upper part of the clay bed group at Fjäcka. D = dislocation plane. 5, 7, 9, 11 and 13 are the clay (probably bentonite) beds. The figures correspond to the description of the section. J. Martna phot.