2nd INTERNATIONAL COLLOQUIUM ON THE MIDDLE PALAEOZOIC FISHES ESTONIA, LATVIA, SEPTEMBER 1989

EXCURSION GUIDEBOOK

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THE SILURIAN OF SAAREMAA AND THE DEVONIAN OF SOUTH ESTONIA AND NORTH LATVIA

BY

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INTRODUCTION

An international colloquium on the Middle Palaeozoic fishes was held for the first time in Tallinn in 1976. It was organized by the Institute of Geology, Academy of Sciences of the Estonian SSR. Three institutions, the Institute of Geology of Estonian Academy of Sciences, Nature Museum of the Latvian SSR and the Geology Department, Latvian State University, Riga take part in the organization of the 2nd colloquium in September 1989. This time the colloquium programme is more comprehensive. In addition to lectures, discussion and the study of collections in Tallinn it includes two field excursions enabling the participants of the colloquium to examine the Silurian on the largest Estonian island Saaremaa (previously Ösel) and the Devonian in South Estonia and North Latvia. Both routes, A and B are similar but run in opposite directions: the first stop of the excursion A is on Saaremaa, that of the excursion B in South Estonia. Grouping of the participants is arranged to avoid "crowding" in outcrops: some Saaremaa localities are too small to find enough space for a large group. Besides, the excursion A includes some more stops on Saaremaa to permit additional sampling from the Silurian.

Leaders: Tiiu Märss, Erika Jürgenson and Rein Einasto (on Saaremaa), Visvaldis Kuršs and Elga Mark-Kurik (in Latvia and South Estonia).

On our routes there will be several stops for sight-seeing in order to get some idea of the historical places and buildings in Estonia and Latvia. There will also be a possibility to visit Nature Museum of the Latvian SSR and to get acquainted with its rich collections including the most remarkable fish fossils from Lode and other localities.

Our itinerary will be as follows:

Note: overnight and lunch stops are underlined, stops for sight-seeing with asterisk, nos of geological stops in brackets.

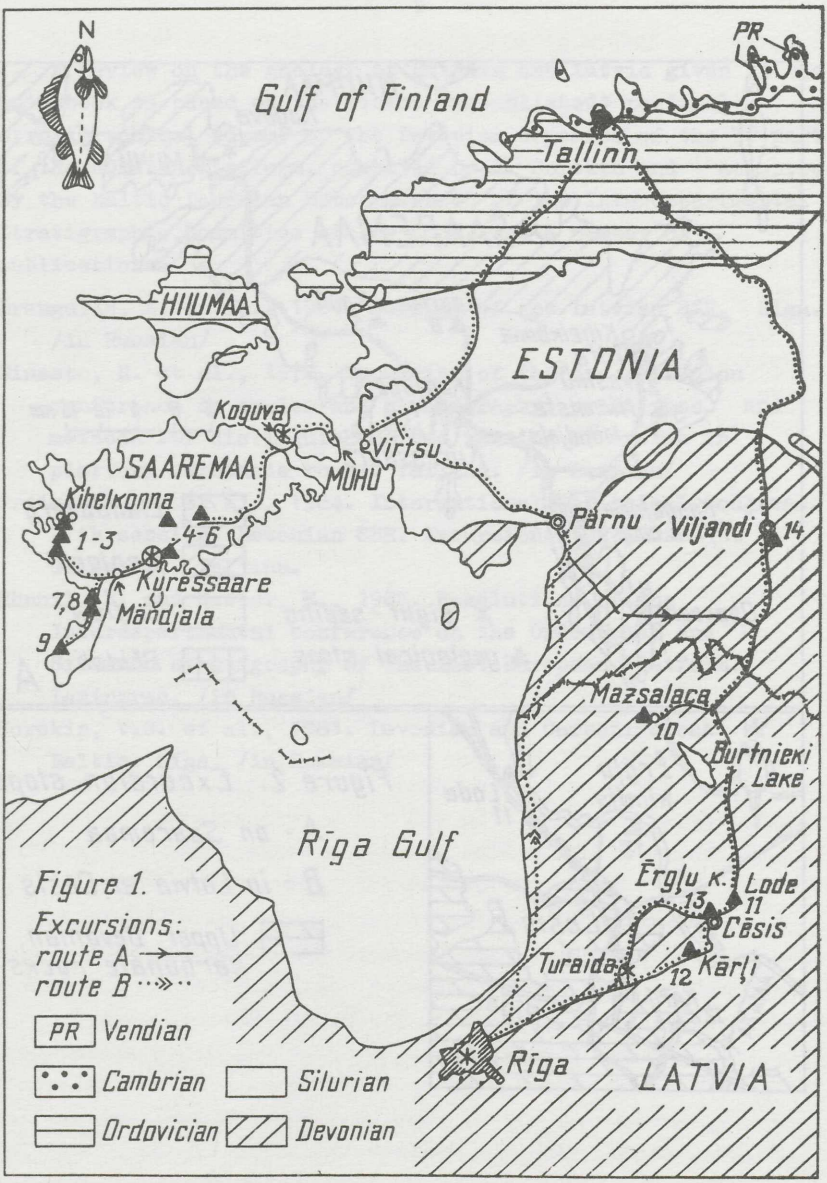
Excursion A (see Figs 1, 2)

Saturday, Sept 16th	Tallinn, Koguva[x], Kuressaare, Viita (1), Vesiku (2), Himmiste (3), Mändjala.
Sunday, Sept 17th	Kudjape (4), Kaali (5), Kaarma (6), Kuressaare[x], Kaugatuma cliff (7), Kaugatuma cape (8), Ohesaare (9), Mändjala.
Monday, Sept 18th	Pärnu, Mazsalaca (10), Lode (11), Rīga.
Tuesday, Sept 19th	Kārļi (12), Ērgļu klintis (13), Cēsis, Turaida[x], Rīga[x].
Wednesday, Sept 20th	Viljandi (14), Tallinn.

Excursion B

Saturday, Sept 16th	Tallinn, Viljandi (14), Mazsalaca (10), Lode (11), Rīga.
Sunday, Sept 17th	Kārļi (12), Ērgļu klintis (13), Cēsis, Turaida[x], Rīga.
Monday, Sept 18th	Pärnu, Kaali (5), Kuressaare[x], Mändjala.
Tuesday, Sept 19th	Himmiste (3), Viita (1), Kihelkonna, Kaugatuma cliff (7), Ohesaare (9), Mändjala.
Wednesday, Sept 20th	Koguva[x], Tallinn.

NB! On September 18th there will be a possibility to return to Tallinn from Pärnu.


N
PR
Gulf of Finland
Tallinn
HIIUMAA
ESTONIA
Koguva
Virtsu
SAAREMAA
MUHU
Kihelkonna
1-3
4-6
Kuressaare
7,8
Mändjala
9
Pärnu
Viljandi
14
Mazsalaca
10
Burtnieki
Lake
Rīga Gulf
Ērgļu k.
13
Lode
11
Cēsis
Turaida
12
Kārļi
Rīga
LATVIA
Figure 1.
Excursions:
route A
route B
PR Vendian
Cambrian
Silurian
Ordovician
Devonian

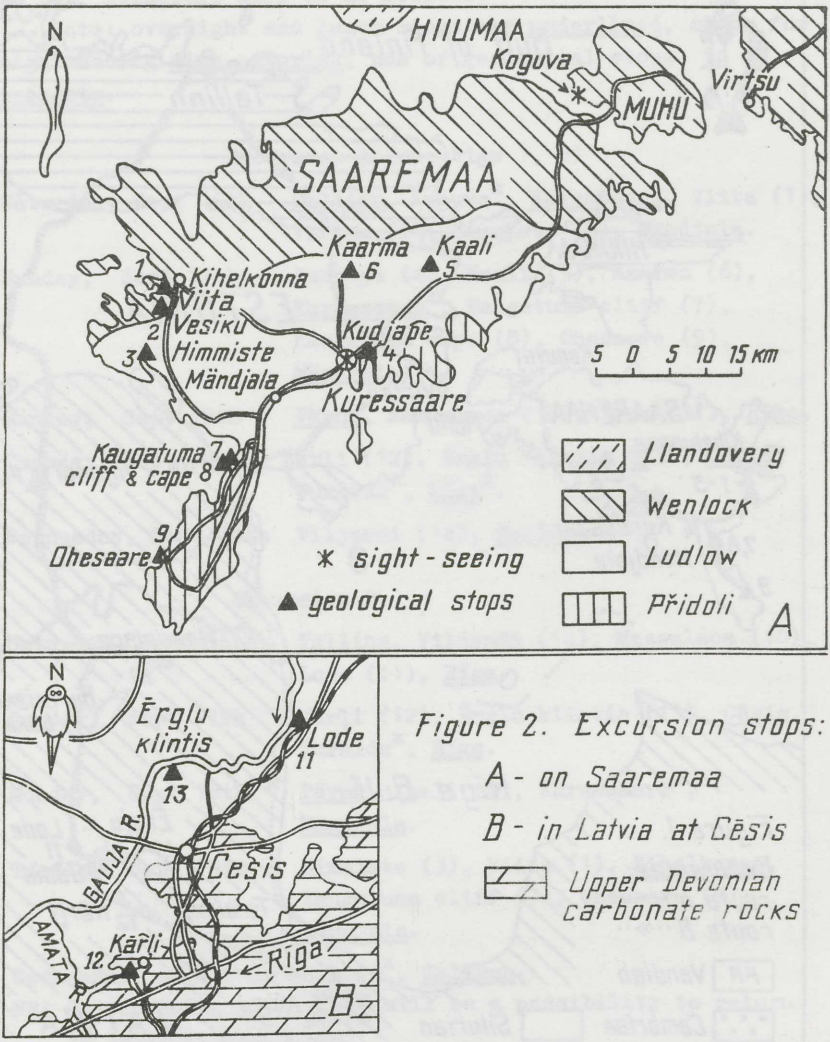


Figure 2. Excursion stops:

A - on Saaremaa

B - in Latvia at Cēsis

Upper Devonian carbonate rocks

A review on the geology of Estonia and Latvia given in the guidebook is based on the recent (unpublished) regional stratigraphical scheme of the Devonian deposits of the NW part of the Russian Platform, compiled by V. Sorokin and accepted by the Baltic Devonian Subcommission of the Interdepartmental Stratigraphic Committee of the USSR, and a number of publications:

Brangulis, A. et al., 1981. Geology of the Latvian SSR. Riga. /in Russian/

Einasto, R. et al., 1978. Excursion of the 3rd All-Union conference on cycles and stratigraphy; principles and methods for distinguishing and tracing of cycles in platform carbonate rocks, Tallinn. /in Russian/

Freimanis, A. et al., 1984. International Geological Congress. 27th session. Estonian SSR. Excursions: 027, 028. Guidebook. Tallinn.

Männil, R. and Nestor, H., 1987. Resolutions of the Interdepartmental conference on the Ordovician and Silurian stratigraphy of the East European Platform. Leningrad. /in Russian/

Sorokin, V.S. et al., 1981. Devonian and Carboniferous of Baltic. Rīga. /in Russian/

A REVIEW OF THE GEOLOGY OF ESTONIA AND LATVIA

The territory of Estonia and Latvia belongs to the north-western part of the East European Platform, in the northwest and north bordering with the Baltic Shield. The northern and central parts of Estonia represent the south slope of the shield, SW Estonia and W Latvia the Baltic Syneclise and E Latvia the Latvian Saddle. The platform has an Archean and partly Proterozoic crystalline basement overlain by the Upper Proterozoic and Palaeozoic, Cambrian to Permian, sedimentary rocks. The Upper Proterozoic (Vendian) and Cambrian (and the lowermost Ordovician, Tremadocian) are represented by predominantly clastic rocks: sandstones, siltstones and clays with a thickness of up to 300 m and 500 m, respectively (in Latvia). Overlying Ordovician and Silurian deposits are mostly carbonate: limestones, marls and dolostones. The thickness of the Ordovician exceeds 360 m (in Estonia) and that of the Silurian 630 m (in Latvia).

The Devonian lies upon the eroded surface of the older Palaeozoic rocks of different age. It is represented both by clastic and carbonate rocks. The latter ones prevail in the older parts of the Middle Devonian and particularly of the Upper Devonian. The average thickness of the Devonian reaches more than 900 m in Latvia, that of the Lower, Middle and Upper Devonian is 250, 270 and 415 m, respectively.

In the very South-West of Latvia there occur the Carboniferous and Permian terrigenous-carbonate rocks, their thickness being 80 m on the average. They are overlain by clastic Mesozoic, i.e. the Triassic and Jurassic, with a mean thickness of 70 m and of a similar distribution in the same south-western part of Latvia. The Quaternary deposits, particularly the glacial deposits cover all older sedimentary rocks. They are represented by tills, aqueoglacial sands and gravels, lacustrine clays, peat, different marine and aeolian deposits, which reach the maximum thickness (up to 300 m) in

deep ancient Prequaternary valleys and hilly areas of South Estonia and Latvia.

The Archaic and Proterozoic rocks (except the Vendian ones) are not exposed southwards of the Gulf of Finland. In North Estonia the crystalline basement lies approximately at a depth of 100 - 200 m. One can get an idea of its rocks by the erratic boulders brought by glaciers from the Baltic Shield. The boulders are especially large and numerous in the northern coastal region of Estonia.

The Vendian and Cambrian crop out in the North Estonian Clint area that presents also magnificent Ordovician exposures. Younger Ordovician and Silurian strata crop out in the northern and central parts of Estonia and on its western islands (Hiiumaa, Saaremaa and others), whereas South Estonia and Latvia represent the outcrop area of the Devonian and younger Prequaternary deposits.

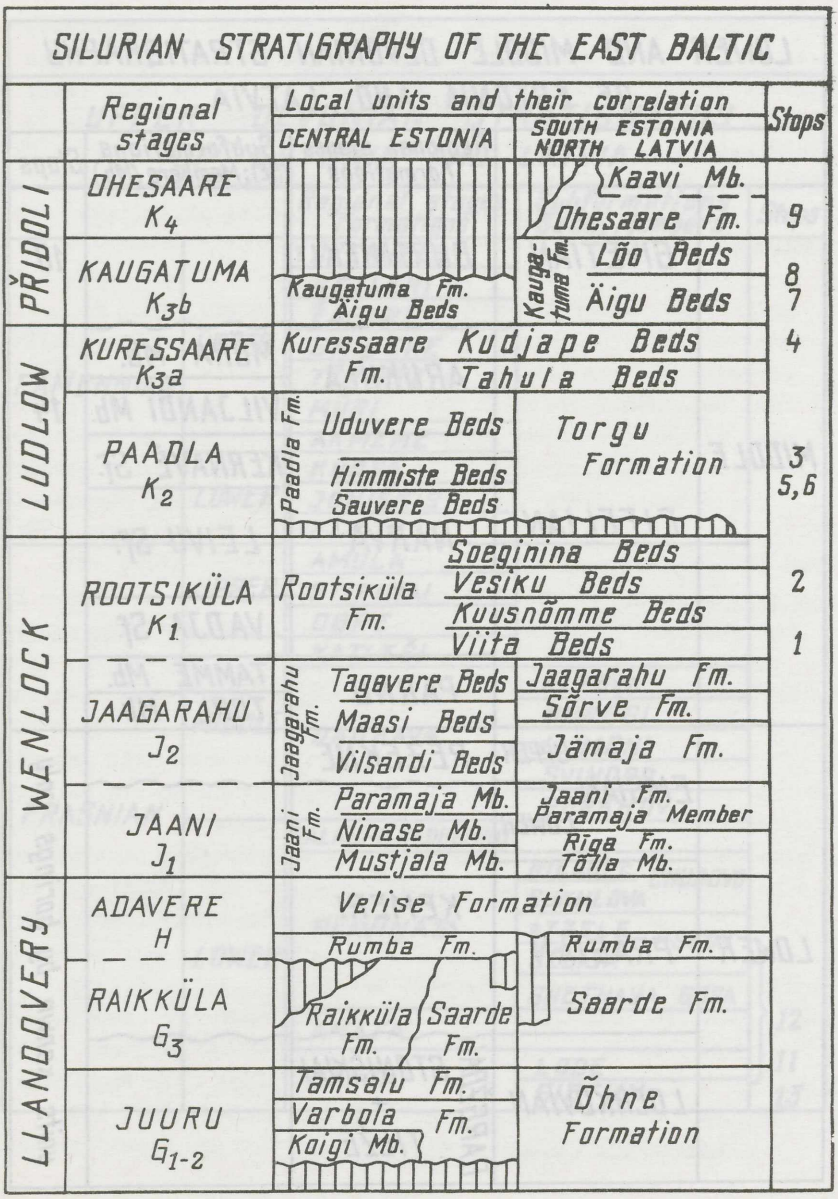
GEOLOGICAL STOPS

Stratigraphy of the Silurian and Devonian of Estonia and Latvia is given in three tables. The Silurian sequence is a complete one, all series are represented: Llandovery to Přidoli. Changes from near-shore, lagoonal and shoal facies to these of open shelf, slope and basin (depression) can be studied using exposures in Estonia and numerous core sections from both republics. The Silurian of the East Baltic area, as well as the Ordovician, is very rich in fossils of excellent preservation. Most of these localities and many other natural and artificial outcrops of scientific value and interest are under nature protection.

The colloquium excursions allow to get an idea on the rocks and fossils, including vertebrates of the upper Wenlock to Přidoli, i.e. the Rootsiküla, Paadla, Kuressaare, Kaugatuma and Ohesaare Regional Stages and their subdivisions (stops 1 - 9).

In the East Baltic all stages of the Lower, Middle and Upper Devonian are present. The Lower Devonian units, known only by core sections, are somewhat incomplete. There occur hiatuses on the boundary of the Lochkovian and Pragian, and the Lower and Upper Emsian. Numerous Middle and Upper Devonian exposures are known both in Estonia and Latvia, the most magnificent ones being located in the Gauja River basin in Latvia. An extensive section of this river area, called the Gauja National Park, is under protection. Among others, a large protection area was established in the Salaca River region. The Devonian clastics contain mainly vertebrate fossils and plant remains, whereas carbonate rocks reveal both invertebrates and vertebrates. Recent studies of the Devonian sedimentology and vertebrate fauna have demonstrated that not only carbonate but also clastic deposits in the East Baltic area are of marine origin.

During the excursions the characteristic outcrops of the


SILURIAN STRATIGRAPHY OF THE EAST BALTIC
Regional stages
Local units and their correlation
CENTRAL ESTONIA
SOUTH ESTONIA NORTH LATVIA
Stops
PŘIDOLI
LUDLOW
WENLOCK
LLANDOVERY
OHESAARE K4
KAUGATUMA K3b
KURESSAARE K3a
PAADLA K2
ROOTSIKÜLA K1
JAAGARAHU J2
JAANI J1
ADAVERE H
RAIKKÜLA G3
JUURU G1-2
Kaugatuma Fm.
Äigu Beds
Kaavi Mb.
Ohesaare Fm.
Kauga-tuma Fm.
Lõo Beds
Äigu Beds
Kuressaare Fm.
Kudjape Beds
Tahula Beds
Paadla Fm.
Uduvere Beds
Himmiste Beds
Sauvere Beds
Torgu Formation
Rootsiküla Fm.
Soeginina Beds
Vesiku Beds
Kuusnõmme Beds
Viita Beds
Jaagarahu Fm.
Tagavere Beds
Maasi Beds
Vilsandi Beds
Jaagarahu Fm.
Sõrve Fm.
Jämaja Fm.
Jaani Fm.
Paramaja Mb.
Ninase Mb.
Mustjala Mb.
Jaani Fm.
Paramaja Member
Riga Fm.
Tõlla Mb.
Velise Formation
Rumba Fm.
Rumba Fm.
Raikküla Fm.
Saarde Fm.
Saarde Fm.
Tamsalu Fm.
Varbola Fm.
Koigi Mb.
Õhne Formation
9
8
7
4
3
5,6
2
1

LOWER AND MIDDLE DEVONIAN STRATIGRAPHY OF ESTONIA AND LATVIA

		Regional stages Formations	Subformations (Sf.); Members (Mb.)	Stops
MIDDLE	GIVETIAN	BURTNIEKI		10
	EIFELIAN	ARUKÜLA	MÕRA Mb.	14
			VILJANDI Mb.	
		NARVA	KERNAVĖ Sf.	
			LEIVU Sf.	
			VADJA Sf.	
		PÄRNU	TAMME Mb.	
			TORI Mb.	
LOWER	EMSIAN UPPER	RĒŽEKNE		units known by borings only
	EMSIAN LOWER	ĶEMERI		
	PRAGIAN			
	LOCHKOVIAN	GARGŽDAI	STONIŠKIAI + TILŽĖ	

UPPER DEVONIAN STRATIGRAPHY OF ESTONIA AND LATVIA

		Regional stages Formations	Subformations Beds; Members	Stops
FAMENNIAN	UPPER	?ŠKERVELE		
		KETLERI		
		ŽAGARĖ		
		SNIĶERE		
		TĒRVETE		
		MŪRI		
		AKMEME		
	LOWER	KURSA		
		JONIŠKIS		
		ELEJA		
FRASNIAN	UPPER	AMULA		
		STIPINAI		
		OGRE		
	MIDDLE	KATLEŠI		
		DAUGAVA	ALTOVA	
			BUREGI	
			IL'MEN'	
			SVINORD	
			PORKHOV	
	LOWER	SALASPILS=DUBNIKI		
		PĻAVIŅAS	RIEŽUPE CHUDOVO	
			SUKHLOVA	
			ATŽELE PSKOV	
			SĒLIJA	
			SNETNAYA GORA	
		AMATA		12
		GAUJA	LODE	11
			SIETIŅI	13

terrigenous Middle and Upper Devonian (Eifelian to Frasnian), i.e. the Aruküla, Burtnieki, Gauja and Amata Regional Stages will be visited (stops 10, 11 and 13, 14). In one case (stop 12) the lowermost part of the carbonate section, belonging to the Pļaviņas Regional Stage, can be studied. Lode quarry (stop 11) gives the best possibility for fossil hunting.

Explanations for figures of the stops 1-14 see on the supplementary sheet.

Stop 1. VIITA SEQUENCE

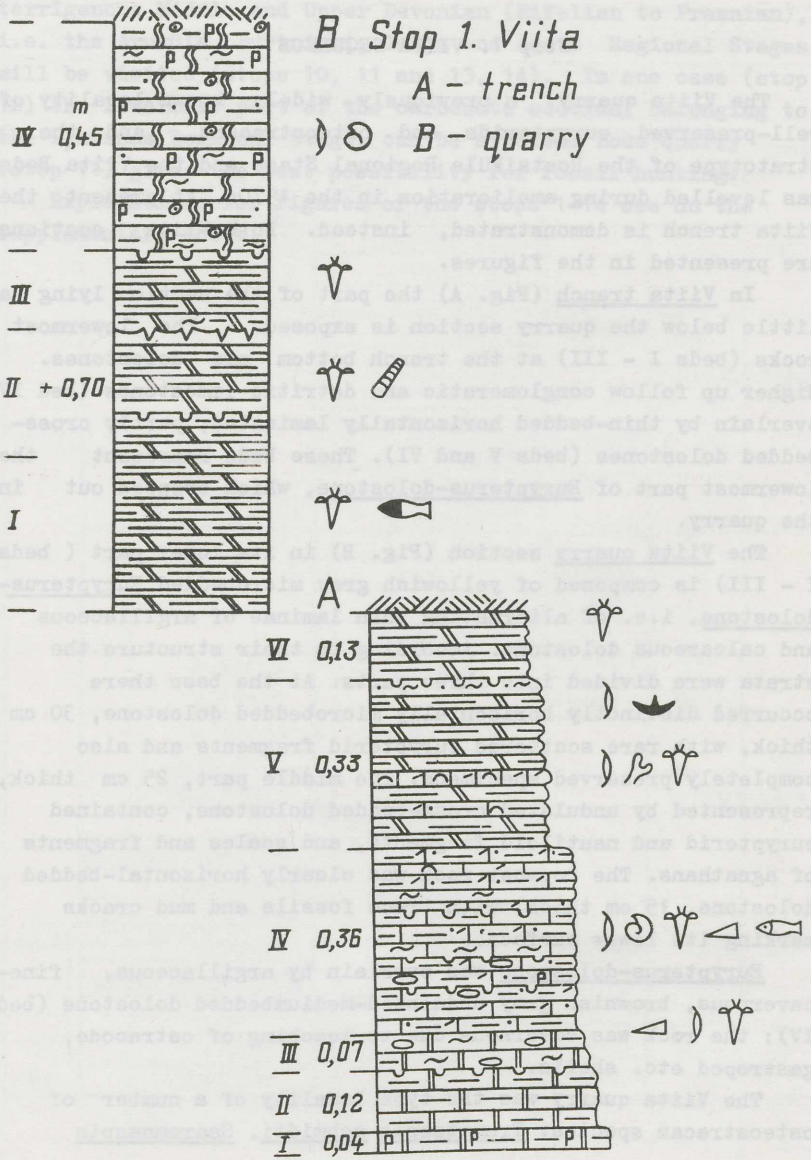
The Viita quarry, a previously widely known locality of well-preserved eurypterids and osteostracans, and the stratotype of the Rootsiküla Regional Stage and the Viita Beds was levelled during amelioration in the 1970s. At present the Viita trench is demonstrated, instead. Both Viita sections are presented in the figures.

In Viita trench (Fig. A) the part of the section lying a little below the quarry section is exposed. The lowermost rocks (beds I - III) at the trench bottom are dolostones. Higher up follow conglomeratic and detritic limestones (bed IV) overlain by thin-bedded horizontally laminated, partly cross-bedded dolostones (beds V and VI). These beds represent the lowermost part of Eurypterus-dolostone, which cropped out in the quarry.

The Viita quarry section (Fig. B) in its lower part (beds I - III) is composed of yellowish grey microbedded Eurypterus-dolostone, i.e. of alternating thin laminae of argillaceous and calcareous dolostone. According to their structure the strata were divided into three parts. At the base there occurred distinctly horizontally microbedded dolostone, 30 cm thick, with rare scattered eurypterid fragments and also completely preserved specimens. The middle part, 25 cm thick, represented by undulated cross-bedded dolostone, contained eurypterid and nautiloid fragments, and scales and fragments of agnathans. The topmost rock was clearly horizontal-bedded dolostone, 15 cm thick, with trace fossils and mud cracks marking its lower surface.

Eurypterus-dolostone was overlain by argillaceous, fine-cavernous, brownish grey undulated-mediumbedded dolostone (bed IV); the rock was cavernous due to leaching of ostracode, gastropod etc. shells.

The Viita quarry was the type locality of a number of osteostracan species: Trematapis schmidti, Saaremaaspis


B Stop 1. Viita
A - trench
B - quarry
m
IV 0,45
III
II + 0,70
I
A
VI 0,13
V 0,33
IV 0,36
III 0,07
II 0,12
I 0,04

mickwitzi, Witaaspis schrenkii and Thyestes verrucosus.

The Viita Beds (in the quarry and in the trench) constitute shallow-water carbonate sediments, deposited in near-shore environment. Pebbles, oolites, mud cracks, discontinuity surfaces give evidence of shallow-water conditions. The sequence is rich in fossils: ostracodes, gastropods, brachiopods, bryozoans, tentaculites and eurypterids. Of recent fish-finds the most valuable one is the tail of Trematapis schmidti. Dissolved limestone samples of the lower part of the trench section have yielded Thelodus laevis, Thelodus sp., Logania martinssoni, Trematapis schmidti, Tr. milleri, Oeselaspis pustulata, Birkeniida sp. C, Birkeniida sp. D and C?

Stop 2. VESIKU OUTCROP

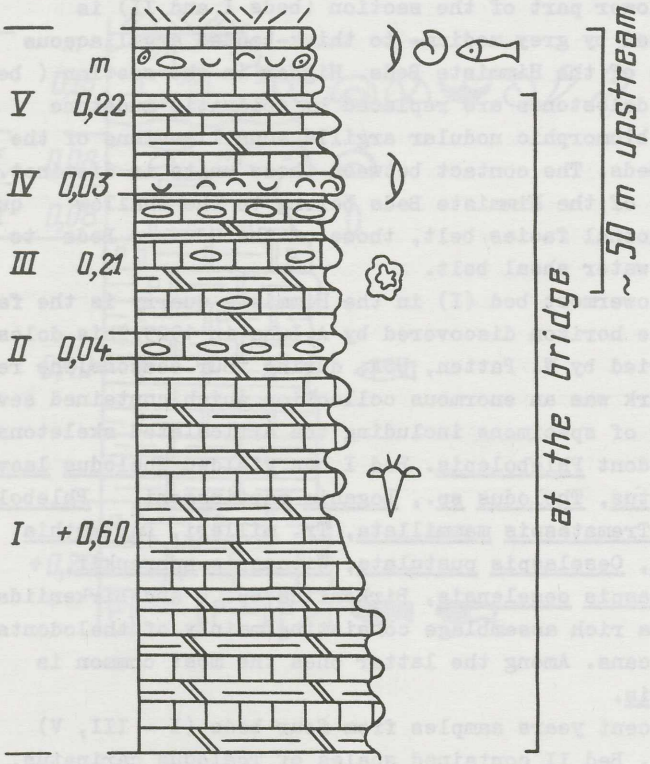
The middle part of the Vesiku Beds of the Rootsiküla Regional Stage is exposed in sections located near the mouth of the Vesiku brook (the sequence is the stratotype of these beds).

In the outcrop thin layers of light grey aphanitic limestone and Eurypterus dolostone are alternating with frequent thin conglomerate layers consisting of flat pebbles. In the uppermost part of the sequence there occurs a horizontally persistent limestone layer with abundant shells of gastropod "Platyschisma" helicites, scales and fragments of agnathans forming a bone-bed. The rocky surface of the topmost layer bears glacial striation.

Rocks of the Vesiku outcrop belong to the lagoonal and shoal facies belts.

Of vertebrates the bone-bed contains Thelodus laevis, T. cf. carinatus, Thelodus sp., Logania martinssoni, Trematapis schmidti, Tr. milleri, Oeselaspis pustulata, Thyestes verrucosus, Birkeniida sp. C and C? and Birkeniida sp. D. Aphanitic limestone and Eurypterus dolostone have not yielded vertebrates.

Stop 2. Vesiku sequence



Stop 3. HIMMISTE QUARRY

In a small peasant quarry the Himmiste and Uduvere Beds of the Paadla Regional Stage are partly exposed. The lower part of the outcrop is the stratotype of the Himmiste Beds.

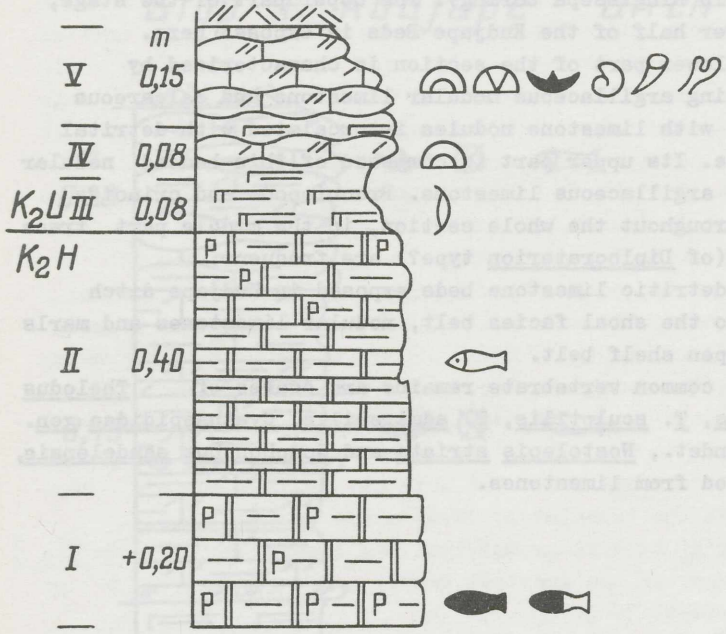
The lower part of the section (beds I and II) is represented by grey medium- to thick-bedded argillaceous dolostone of the Himmiste Beds. Higher in the section (beds III - V) dolostones are replaced by dolomitic mudstone and skeletal biomorphic nodular argillaceous limestone of the Uduvere Beds. The contact between these units is distinct.

Rocks of the Himmiste Beds belong to the shallow quiet-water lagoonal facies belt, those of the Uduvere Beds to the agitated water shoal belt.

The lowermost bed (I) in the Himmiste quarry is the famous vertebrate horizon discovered by A.Luha in 1929.This dolostone was quarried by W. Patten, USA, during four seasons.The result of his work was an enormous collection which contained several thousands of specimens including the articulated skeletons of the thelodont Phlebolepis. Bed I has yielded Thelodus laevis, T. carinatus, Thelodus sp., Logania martinssoni, Phlebolepis elegans, Trematapis mammillata, Tr. milleri, Dartmuthia gemmifera, Oeselaspis pustulata, Witaaspis schrenkii, Procephalaspis oeselensis, Birkeniida sp. C and Birkeniida sp. D?, i.e. a rich assemblage consisting mainly of thelodonts and osteostracans. Among the latter ones the most common is Trematapis.

In recent years samples from four beds (I - III, V) were dissolved. Bed II contained scales of Thelodus carinatus, Thelodus sp., Logania martinssoni and Phlebolepis elegans, whereas samples from beds III and V, characterized by numerous invertebrates, did not reveal vertebrate fossils.

Stop 3. Himmiste quarry



Stop 4. KUDJAPE DITCH

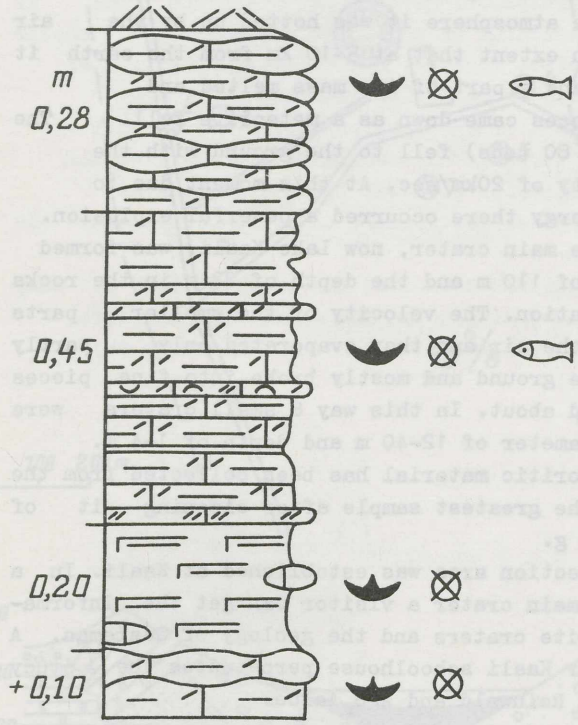
The section of Kudjape ditch is the parastratotype of the Kuressaare Regional Stage (its stratotype is the interval 1.5 -13.4 m in Kingissepa boring). The upper part of the stage, i.e. lower half of the Kudjape Beds is exposed here.

The lower part of the section is characterized by alternating argillaceous nodular limestone and calcareous mudstone with limestone nodules intercalated with detrital limestone. Its upper part is composed of thin-bedded nodular detritic argillaceous limestone. Brachiopods and crinoids occur throughout the whole section, in the middle part trace fossils (of Diplocraterion type?) are frequent.

The detritic limestone beds exposed in Kudjape ditch belong to the shoal facies belt, nodular limestones and marls to the open shelf belt.

Most common vertebrate remains are scales of Thelodus parvidens, T. sculptilis, T. admirabilis, Cyathaspididae gen. et sp. indet., Nostolepis striata and Gomphonchus sandelensis, identified from limestones.

Stop 4. Kudjape ditch



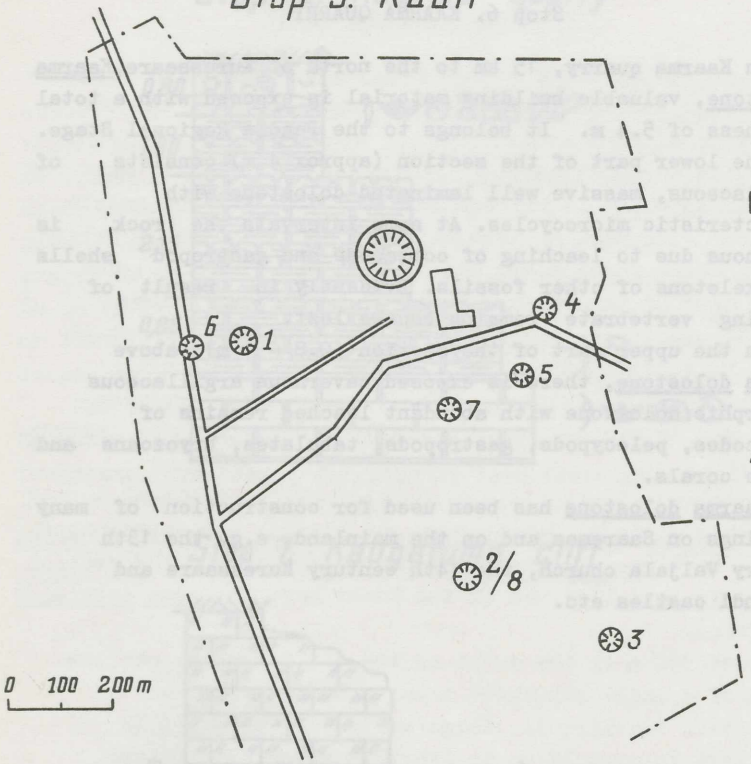
Stop 5. KAALI METEORITE CRATERS

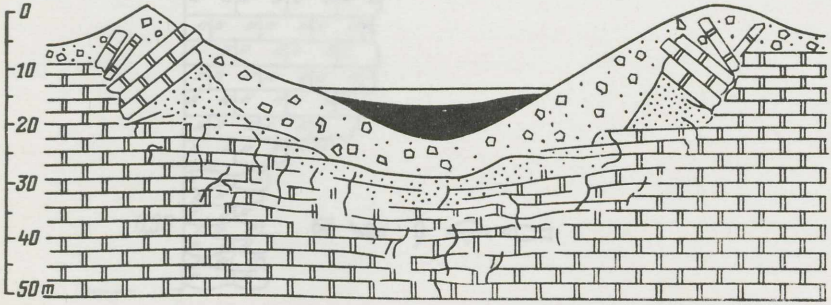
The Kaali iron meteorite fell about 3500 years ago. The dating is based on the palynological method. The structure of the craters shows that the gigantic meteorite fell from the east-northeast under the angle of approx 35°. The initial weight of the meteorite may have been about 1000 tons. In passing through the atmosphere it was hotted up by the air pressure to such an extent that at 5-10 km from the earth it broke into pieces and a part of its mass melted and evaporated. The pieces came down as a meteorite fall. The greatest piece (ca 80 tons) fell to the ground with the approximate velocity of 20km/sec. At this moment due to immense kinetic energy there occurred a powerful explosion. In result of it the main crater, now Lake Kaali, was formed with the diameter of 110 m and the depth of 22 m in the rocks of the Paadla Formation. The velocity of the smaller parts decreased more in the air and they evaporated only partly when falling to the ground and mostly broke into fine pieces that were scattered about. In this way 8 small craters were formed with the diameter of 12-40 m and depth of 1-4 m.

2.5 kg of meteoritic material has been collected from the craters. Mass of the greatest sample after cleaning it of rust was almost 30 g.

In 1959 a protection area was established at Kaali. In a pavilion near the main crater a visitor can get the information on the meteorite craters and the geology of Saaremaa. A memorial stone near Kaali schoolhouse perpetuates the study of craters by Ivan Reinwald and Ago Aaloe.

Stop 5. Kaali





Stop 6. KAARMA QUARRY

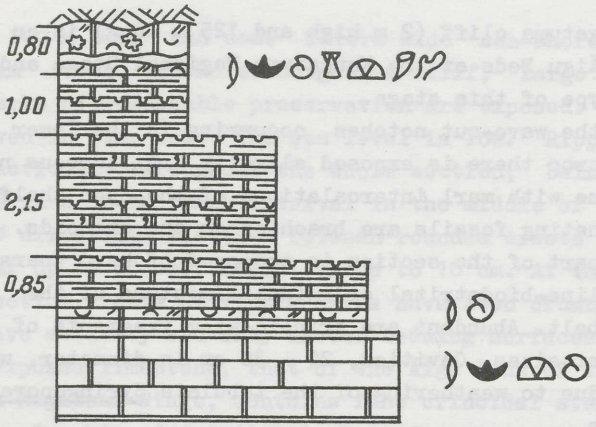
In Kaarma quarry, 15 km to the north of Kuressaare, Kaarma dolostone, valuable building material is exposed with a total thickness of 5.4 m. It belongs to the Paadla Regional Stage.

The lower part of the section (approx 4 m) consists of argillaceous, massive well laminated dolostone with characteristic microcycles. At some intervals the rock is cavernous due to leaching of octracode and gastropod shells and skeletons of other fossils. Evidently in result of leaching vertebrate remains became lost.

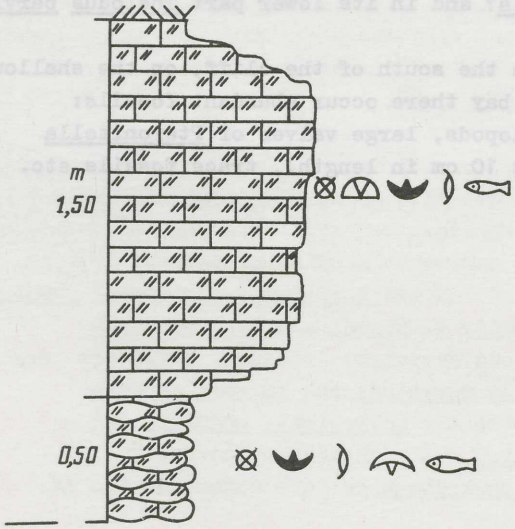
In the upper part of the section (0.8 - 1 m), above Kaarma dolostone, there is exposed cavernous argillaceous biomorphic dolostone with abundant leached remains of ostracodes, pelecypods, gastropods, tabulates, bryozoans and rugose corals.

Kaarma dolostone has been used for construction of many buildings on Saaremaa and on the mainland, e.g. the 13th century Valjala church, the 14th century Kuressaare and Viljandi castles etc.

Stop 6. Kaarma quarry



Stop 7. Kaugatuma cliff



Stop 7. KAUGATUMA CLIFF

Kaugatuma cliff (2 m high and 125 m long) is an exposure of the Äigu Beds of the Kaugatuma Regional Stage and the stratotype of this stage.

In the wave-cut notches, occurring in the lower part of the outcrop there is exposed slightly argillaceous nodular limestone with marl intercalations of the open shelf origin. Predominating fossils are brachiopods and crinoids. The higher part of the section is composed of hard coarse-crystalline-biodetrital crinoidal limestone of the shoal facies belt. Abundant are crinoid stem fragments of different sizes. Cavities, 20 - 30 cm in diameter, were formed due to weathering of the tabulate Syringopora blanda colonies.

Vertebrate fragments are scarce; only single scales of Nostolepis striata, Gomphonchus sandelensis and Poracanthodes porosus have been recorded. In the upper part of the section Nostolepis gracilis? and in its lower part Thelodus parvidens were found.

About 500 m to the south of the cliff, on the shallow bottom of a small bay there occur abundant fossils: trilobites, brachiopods, large valves of Pteronitella retroflexa (almost 10 cm in length), trace fossils etc.

Stop 8. KAUGATUMA CAPE

On a 200 m long and some meters wide sea-shore, lying about 1 km to the south of Kaugatuma cliff, large Silurian ripple marks of remarkable preservation are exposed. They can be observed in the case the sea level is low. Ripple marks occur practically throughout the whole section, being better preserved in a 30 cm thick interval in the middle of it. They are of EW direction. Distance between rounded crests is 40 - 60 cm (max up to 80 cm), height is up to 10 cm. At the base of the section crests of ripple marks have been crumbled by recent wave activity and only uneven bedding surfaces are left.

The exposed limestone, that of the Äigu Beds of the Kaugatuma Regional Stage, contains fine crinoidal stem fragments. Brachiopod detritus is less frequent. Well-preserved are elongated, flat colonies of the bryozoan Ptilodictya lanceolata, shells of the bivalve Pteronitella retroflexa and trace fossils of unknown origin.

Stop 9. OHESAARE CLIFF

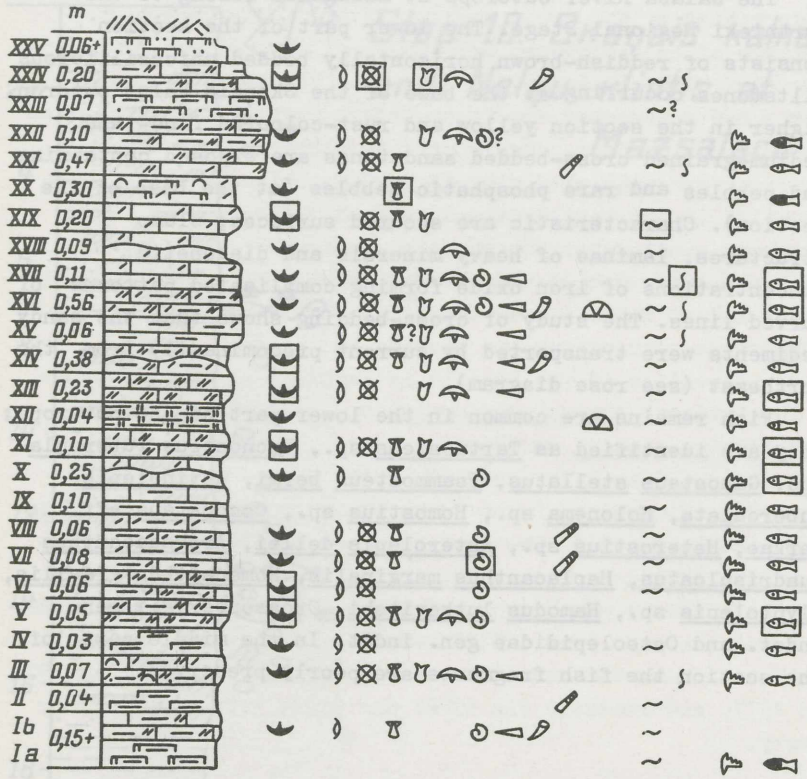
The largest cliff on the west coast of Sõrve Peninsula is the stratotype of the Ohesaare Regional Stage and a formation of the same name. It is about 700 m long and up to 4 m high, composed of variable carbonate rocks: biomorphic and nodular limestones, marls and dolostones. Laminated silty domerite occurs at the very top of the section. The latter can be subdivided into 24 beds with different lithological character and fossil content.

Practically all groups of invertebrate fossils known in the Silurian of Saaremaa can be found in Ohesaare section. Especially numerous are articulate brachiopods, ostracodes, crinoids, bivalves, bryozoans and trilobites. The occurrence of gastropods, tentaculites and nautiloids is noteworthy. They are concentrated on two levels and their shells are often oriented. Inarticulate brachiopods, tabulate and rugose corals occur on some levels. Trace fossils, particularly the horizontal ones are common. Five levels are also marked by vertical trace fossils. Very characteristic are thick marls in the upper part of the section that contain large shells of the bivalve Grammysia obliqua.

Almost all beds, with the exception of the topmost silty domerite contain vertebrate remains. They are particularly abundant in beds XVI and XVII coinciding with the maximum occurrence of invertebrates. Bed XVII is a bone-bed. Conodonts occur exactly on the same levels as vertebrates.

Scales of the acanthodians Nostolepis striata, N.gracilis, Gomphonchus sandelensis, G. hoppei and Poracanthodes punctatus prevail among vertebrate remains. Often are scales of thelodonts Thelodus parvidens and Logania cuneata, fragments of heterostracans Tolypelepis undulata and Strosipherus indentatus and acanthodian spines. The actinopterygian (?) Lophosteus is more common in bed XX.

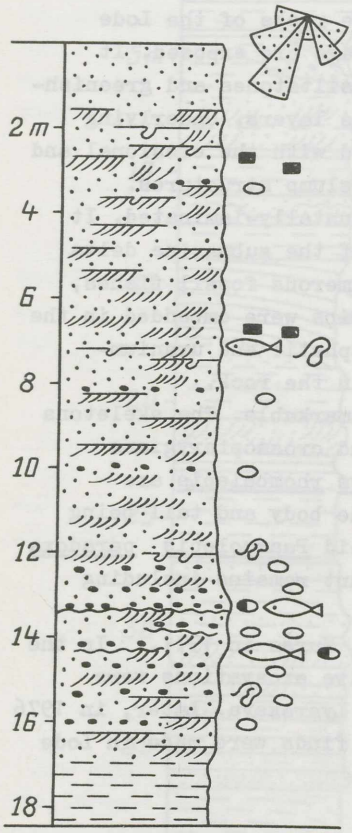
Stop 9. Ohesaare cliff



Stop 10. SKAŅAIS KALNS AND NELĶU KLINTIS EXPOSURES AT MAZSALACA

The Salaca River outcrops at Mazsalaca belong to the Burtnieki Regional Stage. The lower part of the section consists of reddish-brown horizontally bedded unfossiliferous siltstones occurring at the base of the Skaņais kalns outcrop. Higher in the section yellow and rust-coloured fine- and medium-grained cross-bedded sandstones are exposed containing mud pebbles and rare phosphatic pebbles (at the base of the section). Characteristic are scoured surfaces, slump structures, laminae of heavy minerals and diagenetic concentrations of iron oxide forming complicated patterns of curved lines. The study of cross-bedding shows that the sandy sediments were transported by current predominantly from the northeast (see rose diagram).

Fish remains are common in the lower part of the outcrops; they are identified as Tartuosteus sp., Pycnosteus tuberculatus, Ganosteus stellatus, Psammosteus bergi, Actinolepis tuberculata, Holonema sp., Homostius sp., Coccosteus aff. markae, Heterostius sp., Asterolepis dellei, Archaeacanthus quadrisulcatus, Haplacanthus marginalis, Homacanthus gracilis, Glyptolepis sp., Hamodus lutkevitshi, Crossopterygii gen. indet. and Osteolepididae gen. indet. In the middle part of the section the fish fragments are poorly preserved.



Stop 10. Skaņais kalns and Nelķu klintis at Mazsalaca

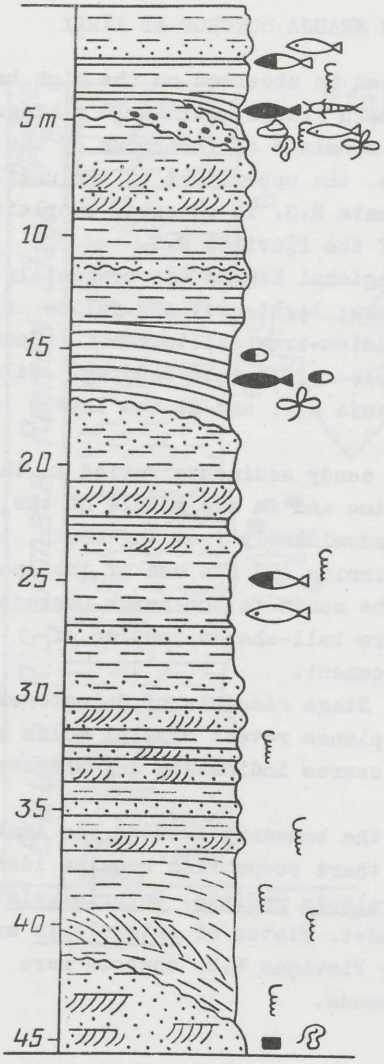
Stop 11. LODE QUARRY

In the quarry at Liepa village the rocks of the Lode Subformation of the Gauja Regional Stage are exposed. It consists of reddish-brown and violet siltstones and greenish-grey clay with multicoloured sandstone layers. Underlying mostly red sandstones are cross-bedded with the erosional and uneven upper surface, complicated by slump structures. Overlying greenish-grey clay is horizontally-laminated. It deposited in the bottom depressions of the submarine delta region in quiet water environment. Numerous fossil fishes, conchostracans, misids and plant remains were embedded in the clayey mud of these depressions. Phosphatic and uranium-molybdenian concretions are present in the rock.

Preservation of the fossils is remarkable. The skeletons of the antiarch Asterolepis ornata and crossopterygians Laccognathus panderi and Panderichthys rhombolepis are articulated, the posterior part of the body and tail being preserved. Fragments of the psammosteid Psammolepis paradoxa have also been found. The perfect plant remains including sporangii belong to Archaeopteris.

The locality was discovered by V. Kurš in 1971. In the same and the next year (1972) extensive excavations were completed under the leadership of L. Lyarskaya. Later, in 1976 and 1977, and recently (in 1988) new finds were made in Lode quarry.

Stop 11. Lode quarry



Stop 12. AINAVU KRAUJA OUTCROP AT KĀRĻI

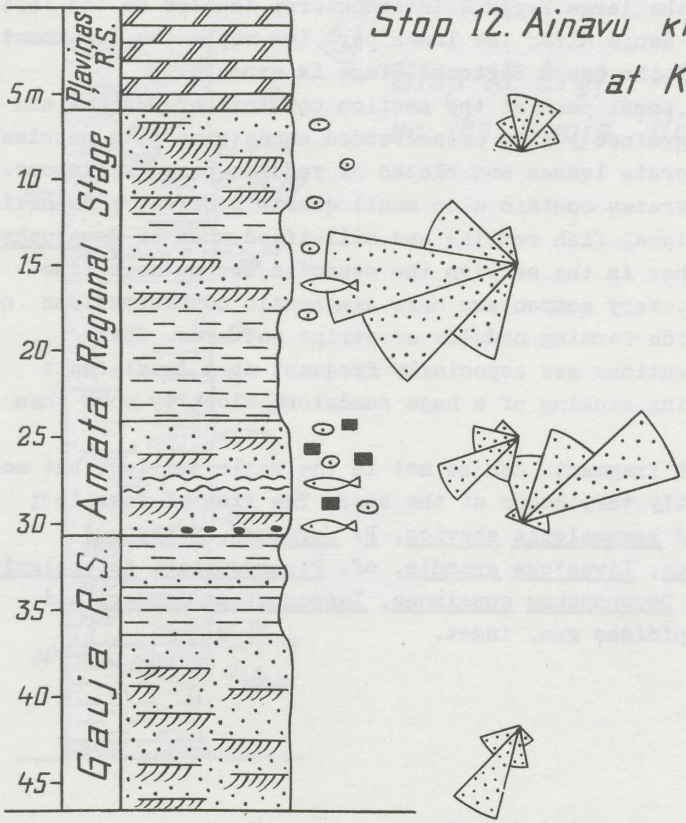
Three Frasnian units can be observed on the high bank of the Amata River called Ainavu krauja near Kārļi village. The lower part of the outcrop consists of the rocks of the Gauja Regional Stage (R.S.), i.e. the upper part of the unit. Higher the type section of the Amata R.S. is exposed, overlain by two lower subformations of the Pļaviņas R.S.

The Gauja and Amata Regional Stages are completely represented by clastic rocks: light-grey and yellow fine-grained sandstones and reddish-brown siltstone. Sandstones show cross-bedding or ripple-drift cross-bedding. Siltstones occur at the top of the Gauja R.S. and at two levels of the Amata R.S.

Currents transporting sandy sediments varied in their direction. In the Gauja time and in the middle of the Amata time the currents flew predominantly from the north to the south, whereas at the beginning and the end of the Amata time they were directed from the south to the north. Characteristic of the Amata sandstones are ball-shaped nodules of poikiloclastic carbonate cement.

The Pļaviņas Regional Stage consists of dolostones and dolomitic marls. Bedding planes reveal crystal molds of halite and desiccation fissures indicating dry climate and high water salinity.

About 8 - 10 m below the boundary between the Amata and Pļaviņas Regional Stages there occur fish remains identified as Psammolepis sp., Asterolepis radiata, Bothriolepis? sp. and Holoptychiidae gen.indet. Plates of Asterolepis are very common. Dolostones of the Plaviņas R.S. contain rare poorly preserved casts of gastropods.


Stop 12. Ainavu krauja
at Kārļi
Pļaviņas R.S.
Amata Regional Stage
Gauja R.S.
5m
10
15
20
25
30
35
40
45

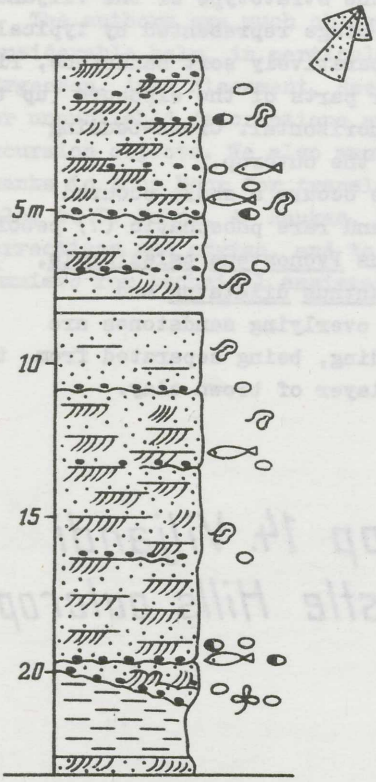
Stop 13. ĒRGĻU KLINTIS ON GAUJA RIVER

In the large Ērgļu klintis outcrop located on the left bank of Gauja River the lower part (or maybe the lowermost part) of the Gauja Regional Stage is exposed.

The basal part of the section consists of medium- and coarse-grained yellow cross-bedded sandstones with pebbles, conglomerate lenses and blocks of reddish-brown siltstone. Conglomerates contain also small quartz pebbles, phosphatic concretions, fish remains and silicified wood of Nematophycus.

Higher in the section the deposits become more fine-grained. Very common are here diagenetic concentrations of iron oxide forming nodules or stripe patterns. These concentrations are especially frequent at a local fault indicating sinking of a huge sandstone block by more than 20 cm.

Fish fragments can be met in the whole section, but most abundantly they occur at the base. The list of fossils includes Psammolepis abavica, P. paradoxa, Ganosteus stellatus, Livosteus grandis, cf. Plourdosteus, Asterolepis ornata, Devononchus concinnus, Laccognathus panderi and Osteolepididae gen. indet.

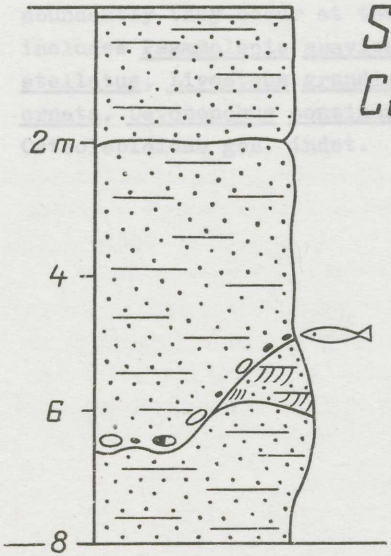


Stop 13. Ērgļu klintis on the Gauja River

Stop 14. VILJANDI CASTLE HILLS OUTCROP

The outcrop, 8 m high, is the stratotype of the Viljandi Member of the Aruküla Regional Stage represented by typical reddish-brown fine-grained comparatively soft sandstone, rich in mica. In the basal and lower parts of the exposure (up to 2 m) bedding is indistinct or horizontal. Cross-bedding appears in the eastern part of the outcrop.

Higher in the section there occurs a sharp scoured surface. It is marked by silt and rare phosphatic (?) pebbles and fish fragments identified as Pycnosteus palaeformis, Heterostius sp. indet., Byssacanthus dilatatus and Osteolepididae gen. indet. The overlying sandstones are massive or with indistinct bedding, being separated from the Quaternary deposits by a thin layer of brown clay.



Stop 14. Viljandi Castle Hills outcrop

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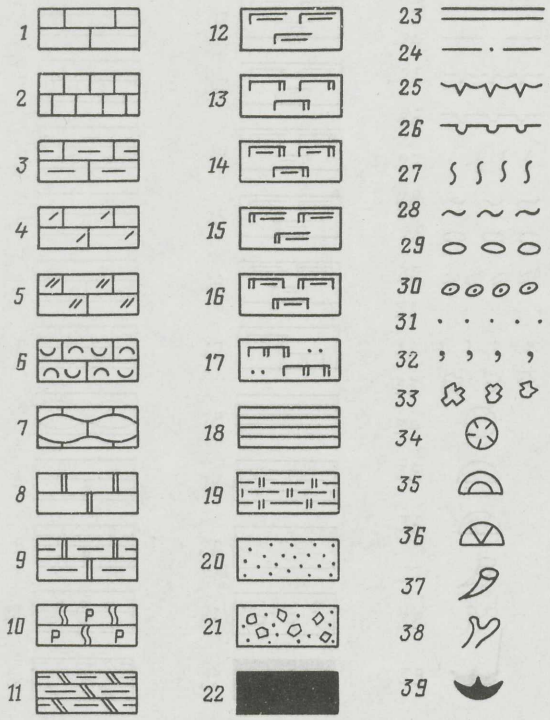
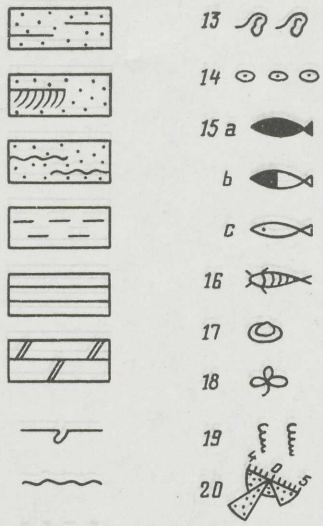
Explanation for figures

Stops 1-9



Stops 10-14



limestones
1 in general
2 aphanitic
3 argillaceous
4 fine-biodetrital
5 coarse-biodetrital
6 biomorphous 7 nodular dolostones
8 in general
9 argillaceous
10 with pyritized spots
11 Eurypterus-dolostone
mudstones: a-marls
12 argillaceous
13 magnesian calcareous
14 magnesian argillaceous b-domerites
15 argillaceous
16 calacitic argillaceous
17 silty calcareous c-clays
18 thin clay layers
19 magnesian
20 dolomitic meal
21 till 22 gyttia

23 roads
24 boundary of reservation
25 mud cracks
26 discontinuity surfaces
27 vertical trace fossils
28 horizontal trace fossils
29 pebbles 30 ooids
31 pellets 32 glauconite
33 caverns
34 meteorite craters
35 stromatoporoids
36 tabulate corals
37 rugose corals
38 bryozoans 39 brachiopods
40 gastropods 41 bivalves
42 nautiloids 43 trilobites
44 ostracodes 45 eurypterids
46 echinoderms 47 oncolites
48 tentaculites 49 conodonts
50 fossils occurring in abundance
51 fish remains:
a-scales and fragments
b-articulated shields
c-articulated specimens

1 massive and horizontal-bedded sandstones
2 cross bedded sandstone
3 sandstone with ripple-drift cross-bedding
4 siltstone 5 clay
6 dolostone
7 slump structure
8 scoured surface
9 silt and mud flocules
10 silt and mud pebbles
11 phosphatic pebbles
12 ferrous sulfids
13 diagenetic concentrations of iron oxide
14 ball-shaped nodules of poikiloclastic cement
15 fish remains:
a-articulated skeleton, b-armour only, c-fragments
16 Misidae 17 conchostracan
18 plant macrofossils
19 trace fossils
20 cross-bedding direction measurements in rose diagram

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