INTERNATIONAL GEOLOGICAL CONGRESS

XXVII SESSION

ESTONIAN SOVIET SOCIALIST REPUBLIC

Excursions: 027, 028

Guidebook

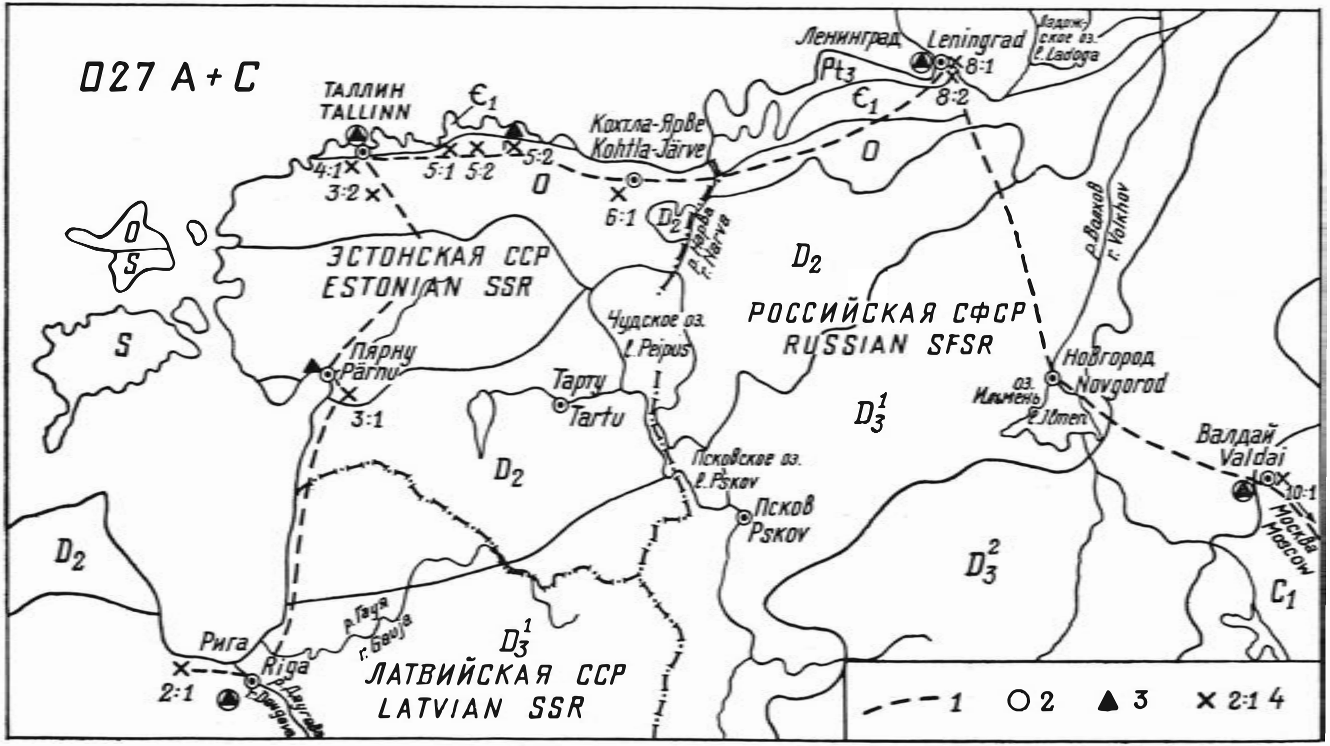

Fig. 1. The route of the excursion 027.

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Excursions:

027 Hydrogeology of the Baltic
028 Geology and mineral deposits of Lower Palaeozoic of the Eastern Baltic area

Guidebook

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Authors of the guide: A. Freimanis, Ü. Heinsalu, L. Hints, P. Jõgar, D. Kaljo, V. Karise, H. Kink, E. Klaamann, O. Morozov, E. Mustjõgi, S. Mägi, H. Nestor, Y. Nikolaev, J. Nõlvak, E. Pirrus, L. Põlma, L. Savitsky, L. Vallner, V. Vanchugov

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INTRODUCTION

The geology of the Estonian Soviet Socialist Republic (Estonia) has become the object of excursions of the International Geological Congress for the second time. It happened first in 1897 when the excursion of IGC visited North Estonia (and the territory of the present Leningrad District) under the guidance of Academician F. Schmidt. Such recurrent interest is justified in view of the classical development of the Lower Palaeozoic in our region and the results of investigations obtained by geological institutions of the republic. The excursions of the 27th IGC are designed, firstly, to provide a review of the stratigraphy, palaeontology and lithology of the Estonian Early Palaeozoic and associated useful minerals in the light of recent investigations (excursion 028), and, secondly, to give a survey of the problems and some results of hydrogeology in a more extensive area of the northwestern part of the Soviet Union (excursion 027).

The routes of the excursions are presented in Figs. 1 and 2 (see the inner side of the covers) against the scheme of geological structure of the excursion area which will include certain parts of the Estonian and Latvian SSR, as well as Leningrad, Novgorod and Moscow Regions of the Russian SFSR.

Excursions 027 and 028 will proceed along the Russian plain characterized by a slightly dissected low relief. Only in a few places absolute height of surface extends to 300 and more metres. The lower areas lie at the coast of the Gulf of Finland serving as the main base of drainage for the whole territory. In the eastern part of the territory the highest places occur in the Valdai Upland. An abrupt bedrock cliff -- the Ladoga-North Estonian Clint proceeds from Lake Ladoga to the west along the southern coast of the Gulf of Finland. The largest rivers are Narva, Neva, Svir and Volkhov. The upper reaches of the Volga River are located in the Valdai Upland.

The climate is moderate or moderately cold and humid. February is the coldest month here, its average temperature drops to -11°C. The highest average monthly temperature,

+18°C occurs in July. The mean amount of annual precipitation ranges from 500 to 750 mm.

Almost the whole territory involved in the route lies in the north-western part of the East European Platform. The latter is composed of the Upper Proterozoic to Permian sedimentary rocks lying upon the Archean and Proterozoic crystalline basement.

The crystalline basement is overlain by the Upper Proterozoic, prevailingly terrigenous rocks, with the lower part of the unit being represented by effusive rocks and the upper one by sandstones. The Cambrian is distributed nearly throughout the whole territory. It is composed of a variety of different sandstones, siltstones and clays. Among them is noteworthy the so-called Blue Clay (Lontova) Formation of about 100—130 m in thickness in the environs of Leningrad; however, in places it is thinned out.

The Cambrian terrigenous rocks are overlain by the Ordovician and Silurian carbonate rocks. Most commonly they are represented by different limestones, marls and dolomites.

The Devonian lies upon the eroded surface of the older Palaeozoic rocks (Fig. 3). In general they consist of different sandstones and siltstones, and in the Upper Devonian also of carbonate rocks.

Carboniferous, mainly sandy-clayey rocks are distributed in the eastern part of the excursion area, while Permian sandstones and silty clays are spread only in a restricted area.

The thickness of the Quaternary cover varies from 0.5 to 5 m in the areas of plateau-like elevations; in lowlands and uplands it usually reaches 10—20 m, sometimes even 100 and more metres. Most frequently they are represented by rubbly loamy till; however, aqueoglacial sands and gravels and lacustrine clays, marine and eolian deposits as well as peat are also distributed.

The study area is related to two vast structural-tectonic regions: the submerged part of the southern and south-eastern slope of the Baltic crystalline shield and the western part of the Moscow syneclise. The basement surface has a low dip to the south-east under the angle of 12—15'. The Valmiera — Lokno swell with the amplitude of about 400 m serves as a well-pronounced tectonic structure of the secondary order at the boundary of the Estonian and Latvian SSR. Dome-shaped structures and archlike elevations as well as tectonic fractured zones are characteristic of the Palaeozoic rocks. In the Palaeozoic carbonate rocks the latter are often complicated by karst phenomena.

D. Kaljo, L. Vallner

A REVIEW OF THE GEOLOGY OF THE ESTONIAN SSR

1. History of Investigation

The first publications on Estonian geology date from the end of the 17th century (these were the descriptions of Narva waterfall and a mineral spring at Koorküla). A hundred years later Academician Georgi reported about the discovery of oil shale in North Estonia; however, geological investigations remained sporadic throughout the 18th and first half of the 19th centuries. Of consequence were the works by E. Eichwald (his first paper appeared in print in 1825) who presented a more or less complete stratigraphic subdivision of bedrock and described a great number of fossil species. He was the first to advance the idea that in the diluvial time a part of Estonian territory was covered by glaciers.

The middle of the 19th century brought about the «Golden Age» of investigations marked by the publication of fundamental works by A. Schrenk, F. Schmidt and K. Grevingk, which laid the foundation of modern stratigraphic scheme; in that period the palaeontological monographs by C. Pander (conodonts, agnathans, etc.), H. Asmuss (fishes), I. Nieszkowski trilobites), W. Dybovski (corals), F. Rosen (stromatoporoids), F. Schmidt (trilobites, brachiopods) and several others were published. In Quaternary geology, beside the above-named A. Schrenk and F. Schmidt (his first works dealt with the drift theory, and later on he made a great contribution to the glacial theory) one should point out G. Helmersen who studied erratic boulders, the structure and development of coasts and several other problems.

As a result, by the beginning of the 20th century an excellent stratigraphic scheme of the Estonian Lower Palaeozoic had been elaborated (Schmidt, 1881) and the main types of Quaternary deposits established. This provided a basis for the compilation of the first geologic sketch maps.

The turn of the century was characterized by a certain slack in scientific activities. Another period of intensive studies began in the 1920s with the first generation of Estonian geologists settling down to work (H. Bekker, A. Luha, A. Öpik, K. Orviku et al.). The stratigraphy of Ordovician and Quaternary deposits underwent an improvement, a considerable number of palaeontological and the first lithological monographs appeared in print. Great attention was paid to the investigations of the mineral wealth of the republic. In the issue, in 1918 an open-cast mining of oil shale (kukersite) was started at Kohtla-Järve. By 1940 a production level of 1.9 million tons of shale annually had been attained. The first phosphorite mine went into operation in 1923 at Ülgase in the vicinity of Tallinn. In 1939 a mine at Maardu was put into use, as a result of which the production level reached 20 thousand tons of phosphorite annually.

After World War II scientific investigations rose to an entirely new level. If before this the leading role was played by the staff of the Tartu University and foreign scientists, after in Soviet Estonia there were several specific organizations established — the Institute of Geology of the Academy of Sciences of the Estonian SSR in 1947, the Board of Geology of the Estonian SSR in 1957; in addition, groups of engineering geology were founded at several designing institutes, which in 1979 were partly joined into the State Engineering Research Institute.

The number of geologists, geophysicists, geochemists and other specialists amounts to more than 300 at such institutions. This enables us to deal with a wide circle of problems concerning different aspects of Estonian geology, providing the national economy of the republic with indispensable raw material. A set of different geological maps of the Soviet Baltic area (10 maps in all) and an explanatory monograph published recently (Григялис, ред., 1982) generalize a considerable amount of new data, especially the results of geological mapping, and may thus serve as a good guide for those wishing to learn about Estonian geology.

D. Kaljo

2. Geotectonic zonation

The Estonian SSR is located in the northwestern part of the East European Platform. Its geology was determined by the development of several different scale tectonic structures dis-

Fig. 3. Main geotectonic structures (according to V. Puura): 1 — isohypses of the surface of crystalline basement; 2 — rupture dislocations; 3 — south-western border of discordance between the Devonian and the underlying Ordovician or Silurian rocks; 4 — geotectonic structures of second orders (1 — West- and 2 — East-Estonian monocline, 3 — Võru saddle).

tinguished by the position of the crystalline basement surface and geological composition of sedimentary rocks.

According to P. Suveizdis, A. Brangulis and V. Puura (Сувейздис, Брангулис, Пуура, 1979) the major part of the Estonian territory lies within the boundaries of the southern slope of the Baltic shield, and only the area adjacent to the current Riga Gulf is referred to the Baltic syneclise (Fig. 3). The above named authors regard the first structure as a transitional zone bordering on the Baltic shield in the north and on the Baltic syneclise and Latvian saddle in the south. It falls into West and East Estonian monoclines, Võru saddle and Valmiera — Lokno swell (Fig. 3).

The above boundaries of tectonic structures are rather distinct in the distribution of Early Palaeozoic facies as well (see next chapter), which accounts for their long-term character. For example, the main facies boundary which in the Ordovician and Silurian divides the Baltic territory into the East and West Baltic structural-facies zones runs close to the boundaries of the Baltic syneclise or along their extensions on the southern slope. The main dislocation zones with a hiatus in continuity are related to these boundaries. For example, the Paide fault zone divides the Estonian monocline into two parts (see above), whereas the Liepaja—Riga—Pihkva zone of echelon-like dislocations and faults borders on the Baltic syneclise and Latvian saddle in the north.

It stands to reason that the geotectonic plan of the territory and the activity of tectonic movements in different parts of the paleobasin have undergone recurrent changes during the Early Palaeozoic (see Figs. 4—8). Fig. 3 shows the final situation.

D. Kaljo

3. Stratigraphy and lithofacial characteristics

The current stratigraphic scheme of the Estonian Lower Palaeozoic and Quaternary is based on a considerable number of recent investigations. The main results obtained through these studies are presented in the following generalizing publications (provided with extensive lists of references as well) on the crystalline basement — Пуура, Вахер, Клейн и др., 1983; on the Vendian and Cambrian — Менс, Пиррус, 1977; on the Ordovician — Мяннил, 1966; Рыымусокс, 1970; on the Silurian — Кальо, ред., 1970; Kaljo, Klaamann, edit., 1982; on the Devonian — Сорокин, ред., 1981; on the Quaternary deposits — Раукас, 1978, etc.

On the grounds of the stratigraphic scheme compiled by preceding investigators, the present generation of stratigraphers has elaborated a new scheme which differs from the previous one by its basin treatment of the problem. The study of sections from subsurface areas has enabled us to establish the spatial relations of stratons and pay much more attention to facies analyses of the rocks.

The results obtained are summarized in stratigraphic schemes accepted in 1976 at the Baltic Stratigraphic Conference in Vilnius. These schemes (with respect to the Estonian SSR) are presented below (in a somewhat generalized form) with some corrections made in recent years. The schemes for the crystal-

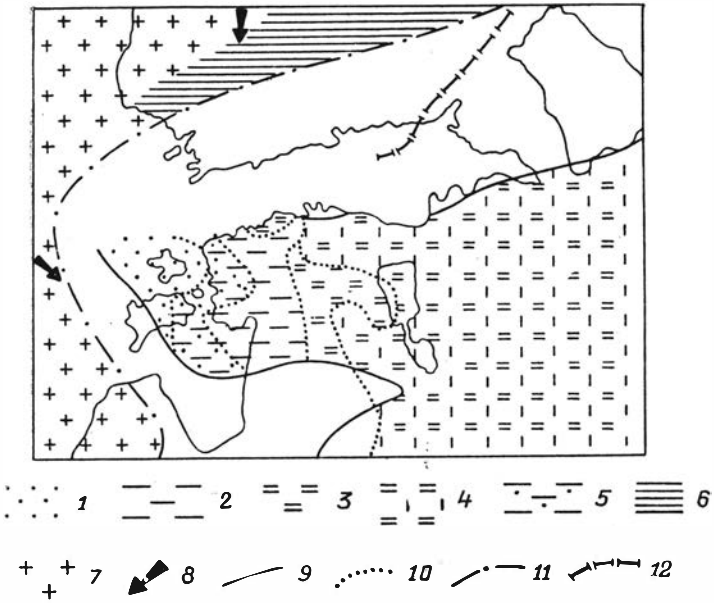

Fig. 4. The lithological-palaeogeographical map of the Lontova time, Early Cambrian (simplified from Келлер, Розанов, ред., 1980): 1 — prevalently clays (up to 50% of rocks); 3 — same, up to 75% of rocks; 4 — same, up to 90% of rocks; 5 — prevailingly silts, clays form 10—25% of the rocks. Composition of continental areas: 6 — sedimentary rocks; 7 — crystalline rocks; 8 — main directions of influx of terrigenous material; 9 — border of the contemporary distribution of rocks; 10 — boundary of lithofacies; 11 — suppositional shoreline; 12 — state border.

line basement, Vendian and Devonian which have not been included in the programme of this excursion are given without subdivisions below the rank of formations. These schemes (Tables 1, 5) are provided with short characteristics of stratons. In Cambrian, Ordovician and Silurian schemes these data are lacking, as they are given in the subsequent text. The schemes show also maximum thickness of the corresponding unit (if there are no other adjustments).

According to the lithology of the rocks, the Estonian Lower Palaeozoic may be divided into two parts, the first of which will include Vendian, Cambrian and Tremadoc dominated by terrigenous, and the second one Ordovician since Arenig and Silurian with carbonate and fine-terrigenous rocks prevailing.

The composition of deposits is rather variable in the section and area. Some idea of it may be derived from the lithologi-

Table 1

Archean and Proterozoic stratigraphy of Estonia

Standard and regional units					Local units	
PROTEROZOIC	UPPER	VENDIAN	Valdai Series	Kotlin Regional Stage	**Voronka Formation:** light quartzose differentsized sandstones (the upper part), multicoloured siltstones and clays (the lower part); up to 45 m	
PROTEROZOIC	UPPER	VENDIAN	Valdai Series	Kotlin Regional Stage	**Kotlin Formation:** grey fine varved clay with siltstone intercalations in the basal part, *Vendotaenia antiqua, Leiosphaeridia* A and B types; up to 50 m	
PROTEROZOIC	UPPER	VENDIAN	Valdai Series	Kotlin Regional Stage	**Gdov Formation:** multicoloured siltstones and clays (the upper part) and polymict sandstones of different grain size (the lower part) with lenses of mixtoliths in the base; up to 60 m	
PROTEROZOIC	UPPER	VENDIAN		Redkino Reg. St.	Hiatus	
PROTEROZOIC	UPPER	VENDIAN	Volynia Series			
PROTEROZOIC	LOWER	1650 ± 50 years			**Hogland Series:** Quartzose porphyries, 0–100 m (the upper part), plagioclase porphyrites, 0–20 m (in the middle part); quartzites, quartzitic conglomerates, 0–10 m (the lower part)	
PROTEROZOIC	LOWER				Hiatus	
PROTEROZOIC	LOWER				**Jägala Series:** alum.-biot., biot.-amphib. quartz-feldspar (leptite) gneisses, magnetic quartzites, over 1000 m	**Alutaguse Series:** alum. and biotite gneisses, over 1000 m (upper part) and alum. gneisses, quartzites, marbles, over 1000 m (lower part)
ARCHEAN					Hiatus	
ARCHEAN					Unit of biot-amphib. alum. and biot. gneisses and amphibolites, over 1000 m	Unit of biot.-amphib.-bipyrox.-alum. gneisses and granite gneisses, magnetic quartzites, over 1000 m

Table 2

Cambrian stratigraphy of Estonia

Standard units		Regional series	Regional stage	Local units: North Estonia	Local units: West Estonia	Local units: South-East Estonia
CAMBRIAN	UPPER			Ülgase Form. 17 m	Hiatus	Petseri Form. 12 m
						Hiatus
	MIDDLE	Deimena		Hiatus	Ruhnu Beds, over 20 m	Paala Beds 40 m
		Aisciai	Kybartai		Hiatus	Hiatus
	LOWER		Rausve Vergale		Irben Form. 50 m	Vaki Form. 30 m
					Soela Form. 30 m	
		Livonian	Talsi	Tiskre Form.: Rannamõisa M. 12 m Kakumägi M. 4 m	Tiskre Form. 18 m	Hiatus
				Lükati Form. 18 m	Lükati Form. 18 m	
				Hiatus	Sõru Form. 50 m	
		Baltic	Lontova	Lontova Form.: Tammneeme M. 11 m Kestla M. Mahu M. 25 m Sämi M.	Voosi Form.: Paralepa M. Kasari M. Taebla M.	Lontova Form.
			Rovno	Hiatus	Hiatus	

Table 3

Ordovician stratigraphy of Estonia

Standard units				Regional Stage	Local units: North and Middle Estonia	Local units: South Estonia
1	2	3	4	5	6	7
ORDOVICIAN	UPPER	Ashgill	?	Porkuni	Erina Form.: Kamariku M. 3 m, Tõrevere M. 4 m, Siuge M. 3 m, Vohilaid M. 4 m, Röa M. 4 m	Saldus Form. 15 m Kuldiga Form. 16 m
		– ? –	*Dicellogr. anceps*		Kabala Form.	Hiatus
				Pirgu	Adila Form. 12 m	Kuili Form. 10 m
			Dicellogr. complanatus		Oostriku Form. 14 m	Paroveja 38 m
					Halliku Form. 24 m	Jelgava Form. 8 m
					Moe Form. 36 m	Jonstorp Form. 19 m
			Pleurogr. linearis	Vormsi	Kõrgessaare Form.: Saxby M. 8 m, Paopa M. 3 m, Hullo M. 11 m	Fjäcka Form. 6 m
				Nabala	Saunja Form. 28 m	
	MIDDLE	Caradoc	*Dicranogr. clingani*		Paekna Form. 16 m	
				Rakvere	Rägavere Form.: Tudu M. 8 m, Piilse M. 24 m, Tõrremägi M. 1 m	Mossen Form. 11 m
				Oandu	Hirmuse Form. 4 m	
			Climacogr. wilsoni		Vasalemma Form. 15 m	Blidene Form. 4 m
				Keila	Keila Form.: Pääsküla M. 7 m, Kurtna M.	Adzes Form. 15 m
			Climacogr. peltifer	Jõhvi	Jõhvi Form.: Madise M. 2 m, Pagari M. 5 m, Aluvere M. 5 m	
				Idavere	Vasavere Form. 7 m	
					Tatruse Form. 8 m	

1	2	3	4	5	6	7
ORDOVICIAN	MIDDLE	Llandeilo	*Nemagr. gracilis*	Kukruse	Viivikond Form.: Peetri M. 10 m, Maidla M. 7 m, Kiviõli M. 6 m	Dreimani Form. 12 m
			Glyptogr. teretiusculus	Uhaku	Kõrgekallas Form.: Erra M. 6 m, Pärtlioru M. 5 m, Koljala M. 4 m	Taurupe Form. 24 m
		Llanvirn	*Didymogr. murchisoni*	Lasnamägi	Väo Form.: Kostivere M. 6 m, Pae M. 1 m, Rebala M. 3 m	Stirnas Form. 10 m
				Aseri	Aseri Form.: Ojaküla M. 2 m, Malla M. 4 m	Segerstad Form.
			Didymogr. bifidus	Kunda	Napa Form. 4 m	Baldone Form. 24 m
					Pakri & Loobu Form. 5–7 m	
	LOWER	Arenig	*Didymogr. hirundo*		Sillaoru Form. 2 m	Ciecere Form. 54 m
				Volhov	Toila Form.: Lahepere & Kalvi M. 2 m, Telinõmme M. 2 m, Saka M. 1,2 m, Päite M. 1 m	
			Didymogr. extensus	Latorp	Leetse Form.: Mäeküla M. 1 m, Iru M. 1 m, Klooga M. 3 m	Zebre Form. 49 m
		Tremadok	*Ceratopyge*	*Ceratopyge*	Varangu Form. 2 m	
			Dictyonema flabelliforme	Pakerort	Türisalu Form.: Toolse M. 2 m, Tabasalu M. 7 m	Hiatus
					Kallavere Form.: Suurjõe M. 6 m, Maardu M. 5 m, Katela, Rannu & Orasoja M. 4 m	Kallavere Form. 1 m
						Hiatus

Table 4

Silurian stratigraphy of Estonia

Standard units			Regional units	Local units: Middle Estonia, Saaremaa	Local units: South Estonia, Ohesaare
UPPER SILURIAN	Pridoli	*P. transgrediens*	Ohesaare	Eroded	Ohesaare Form. 20 m Kaavi Member (top)
		M. ultimus	Kaugatuma	Kaugatuma Form. Lõo Beds 30 m Äigu Beds 38 m	
	Ludlow	*M. formosus*	Kuressaare	Kuressaare Form. Kudjape Beds 20 m Tahula Beds 15 m	
		Neocucullograptidae *S. leintwardinensis* *N. nilssoni*	Paadla	Kihnu Form. 20 m Paadla Form.: Uduvere B. 19 m Himmiste B. 8 m Sauvere B. 14 m	Torgu Form. 23 m
LOWER SILURIAN	Wenlock	*P. ludensis*	Rootsiküla	Kihnu Form. 20 m Sakla F. 22 m Rootsiküla Form. Soeginina B. 5 m Vesiku B. 8 m Kuusnõmme B. 5 m Viita B. 20 m	
			Jaagarahu	Sakla F. 22 m Jaagarahu Form.: Tagavere B. 15 m Maasi Beds 20 m Vilsandi Beds 20 m	Sõrve Form. 55 m
		M. riccarton. *C. murchisoni* *C. centrifugus*	Jaani	Jaani Formation: Ninase Member 23 m Mustjala Member	Riga Form.
	Llandovery	*M. crenulata*	Adavere	Velise Formation 30 m	
		M. sedgwickii		Rumba Formation 20 m	
		D. convolutus *C. cyphus*	Raikküla	Hiatus Raikküla Form. 53 m Saarde Form.	Saarde Form.: Staicele M. 73 m Lemme M. 37 m Ikla M. 62 m Kolka M. 20 m
		D. vesiculosus *A. acuminatus* ?	Juuru	Tamsalu Form. 26 m Varbola Form. 30 m H. Koigi M. (base) 2 m	Õhne Form. 64 m Ruja M. (base) 5 m

Devonian stratigraphy in Estonia

Standard units		Regional Stages	Local units
UPPER DEVONIAN	Frasnes	Dubniki	DUBNIKI FORMATION — clays, domerites, dolomites, founder breccia with gypsum interlayers (in the upper part) or limestone (in the lower) with *Pteria rostrata,* 15 m
		Plavinas	CHUDOVO beds — alternation of organic and chemogenic limestones, dolomites, marls with *Anatrypa heckeri, Ripidiorhynchus tschudovi,* 24,5 m PSKOV beds — organogenous limestones, shells, secondary dolomites and marls with *Ripidiorhynchus pskovensis,* 25 m SNETOGOR beds — interlaying dolomites, domerites and limestones with *Psammosteus meandrinus,* 14,5 m
		Sventoji	AMATA FORMATION — sandstones, siltstones with *Psammolepis undulata,* 35 m GAUJA FORMATION — multicoloured sandstones, siltstones, clays with *Asterolepis ornata,* 56 m
MIDDLE DEVONIAN	Givet	Burtnieki	BURTNIEKI FORMATION — red and light sandstones with interlayers of siltstones, clays, marls, conglomerates, *Pycnosteus tuberculatus,* 100 m
		Aruküla	ARUKÜLA FORMATION — reddish brown sandstones, obliquely laminated siltstones and marls with *Pycnosteus pauli* and *P. palaeoformis,* 80 m
	Eifel	Narva	NARVA FORMATION — dolomitic marls, siltstones, clays, dolomites with *Schizosteus striatus,* 115 m
		Pärnu	PÄRNU FORMATION — sandstones, siltstones, clays, dolomites with *Schizosteus heterolepis,* [illegible] m
— ? —	— ? —		
LOWER DEVONIAN		Rezekne	LEMSI FORMATION — sandstones and siltstones, 15 m REZEKNE FORMATION — sandstones and marls, dolomites with *Skamolepis fragilis,* 26 m
		Kemeri	Hiatus
		Stoniskai	
		Tilze	TILZE FORMATION — sandstones and siltstones with *Turinia pagei,* 22 m

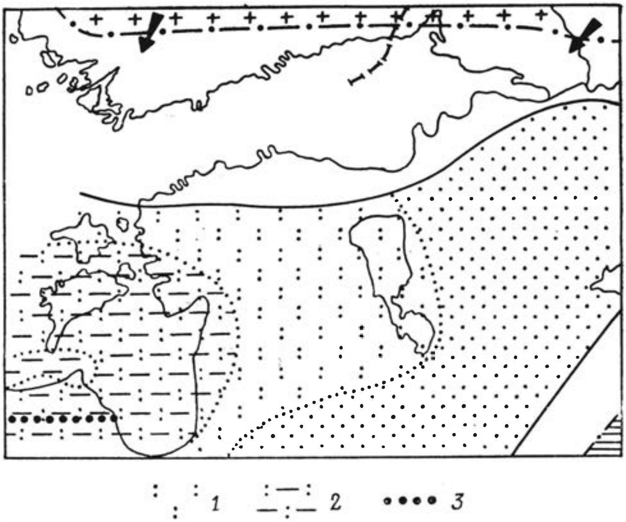

Fig. 5. The lithological-palaeographical map of the Vergale-Rausve time, Early Cambrian (simplified from Келлер, Розанов, ред., 1980): 1 — prevailingly siltstones; 2 — same with clays forming 25—50% of the rock; 3 — iron oolites. For other signs see Fig. 4.

cal facies and palaeogeographic sketch maps presented here according to different authors (see Figs. 4—11). All the maps are simplified; however, the authors' methods and views have been maintained.

Deposits of the Lontova time (Fig. 4) are sandy in the west, but the clay content increases eastwards step by step. The Lontova Sea was a normal shallow (even the areas of the accumulation of clays in the eastern part of the Estonian SSR were considerably shallow) marine basin with a well aerated bottom. There are many evidences in its northwestern area giving proof of a mobile water environment.

Vergale-Rausve deposits (Fig. 5) accumulated during a transgression extending the sea of the Talsi time when a direct connection with the Scandinavian basin was established. The sea was shallow, with some islands in places (Келлер, Розанов, ред., 1980).

At the Volkhov time (Fig. 6) the first extensive Ordovician transgression of the sea took place on the vast low-lying Fennosarmatian continent. It was accompanied by intensive sedimentation of carbonate deposits. Detrital deposits accumulated in shallow inshore areas, red clays prevailed in the axial,

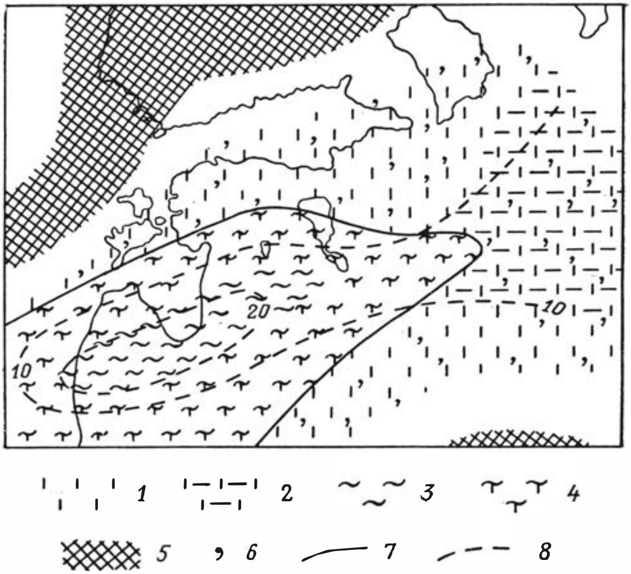

Fig. 6. The lithofacies map of the Volkhov time, Early Ordovician (simplified from Мянниль, 1966): 1 — grey organodetrital calcareous sediments; 2 — grey argillaceous-calcareous sediments; 3 — red-coloured clays and calcareous-argillaceous sediments; 4 — red-coloured calcareous sediments (prevailingly fine muds); 5 — continent; 6 — glauconite; 7 — boundary of lithofacies; 8 — isopachs.

and presumably deeper offshore part of the sea. The red-coloured belt was preserved almost up to the end of the Llandeilo. Later on, in the Middle Ordovician the specific character of the axial zone became less prominent; however, at the end of the period it was again distinctly revealed in the form of dark clayey deposits, often graptolitic argillites (e. g. at the Vormsi time, Fig. 7). At that time those argillites were of their maximum distribution in the East Baltic. Afterwards they were again replaced by red limestones and clays marking the regression of the sea, which started at the end of the Ordovician (Мянниль, 1966).

We have applied the facies sedimentary model (described in greater detail by H. Nestor and R. Einasto (Нестор, Эйнасто, 1977)) to the analysis of the Silurian sedimentation. Fig. 8 shows its supplemented and simplified variant.

Lagoon (including restricted shelf) facies is characterized by onshore quiet water conditions (lagoons, tidal flats) and

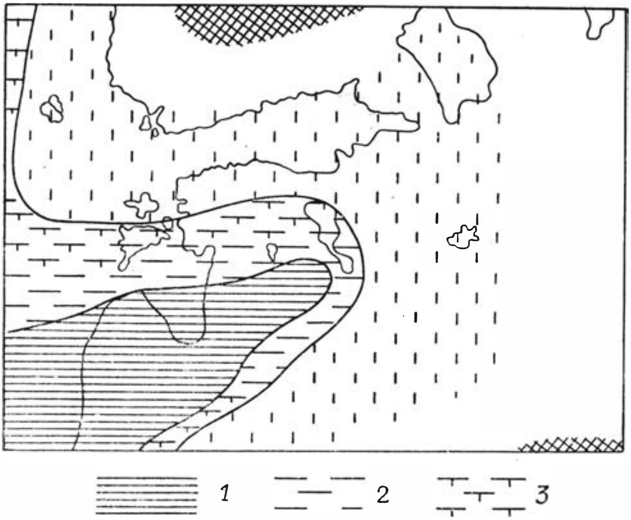

Fig. 7. The lithofacies map of the Vormsi time, Late Ordovician (simplified from Мяенниль, 1966): 1 — black and dark grey graptolitic muds; 2 — grey clays; 3 — grey calcareous-argillaceous sediments. For other signs see Fig. 6. Situation shown north and east of the Estonian SSR extrapolated.

a specific biota (mud-eaters, leperdites, lingulids, eurypterides, etc.).

In the shoal-bar facies the water is in active movement (high energy environment). There occur organic buildups and abundant representatives of sessile benthos (corals, stromatoporoids, brachiopods, etc.).

In the open shelf facies the sea bottom lies below the wave base; hence, the near bottom environment is a quiet water one. This facies is dominated by variegated biota (both benthos and nekton).

The transitional or slope facies belt is characterized by quiet water conditions and a soft muddy bottom. The deposits of this facies comprise fossils of some benthic (trilobites, ostracodes, brachiopods) and pelagic organisms (chitinozoans, graptolites).

In depressional or deep water facies prevail partly stagnant conditions in the near bottom layer of the sea. Most characteristic are graptolites; benthic organisms are practically lacking.

Confining ourselves with the above short supplements to Fig. 8 we should like to refer to the corresponding publications

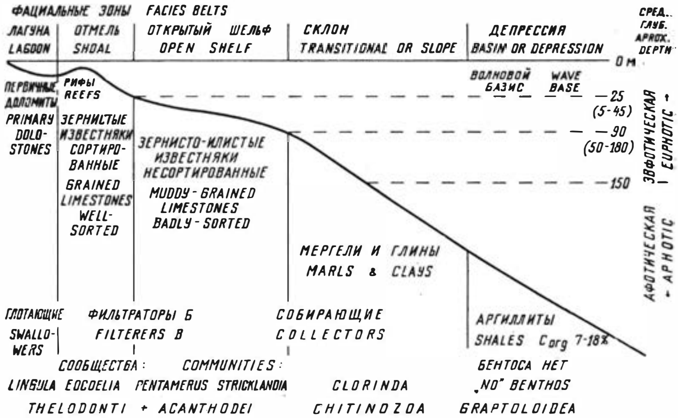

Fig. 8. Facies model of the East Baltic Silurian basin (scheme according to Нестор, Эйнасто, 1977 and Kaljo, 1978).

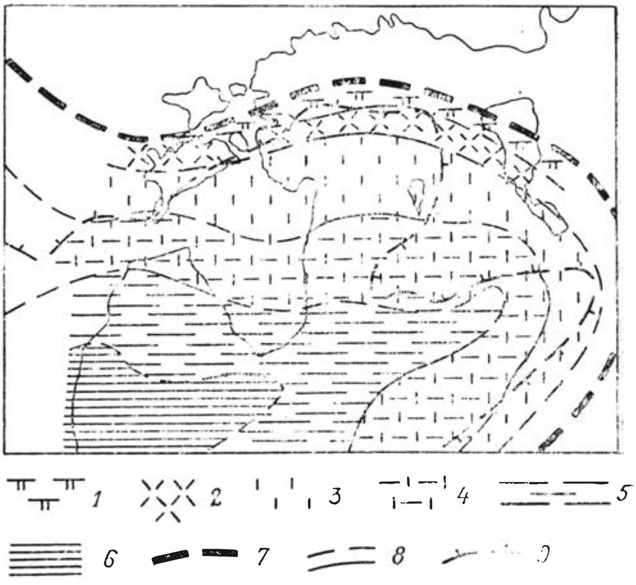

Fig. 9. Facies of the Late Raikküla time (*D. convolutus* Zone) (compiled by H. Nestor): 1 — lagoonal dolomites; 2 — shoaly sparites (grained limestones with skeletal sand); 3 — calcilutites of the open shelf; 4 — intercalation of calcilutites and clays of the transitional (slope) belt; 5 — grey clays with graptolites of the depression belt; 6 — dark graptolitic argillites of the same belt; 7 — suppositional shoreline; 8 — boundary of lithofacies (continuous —certain); 9 — limit of distribution of contemporary rocks.

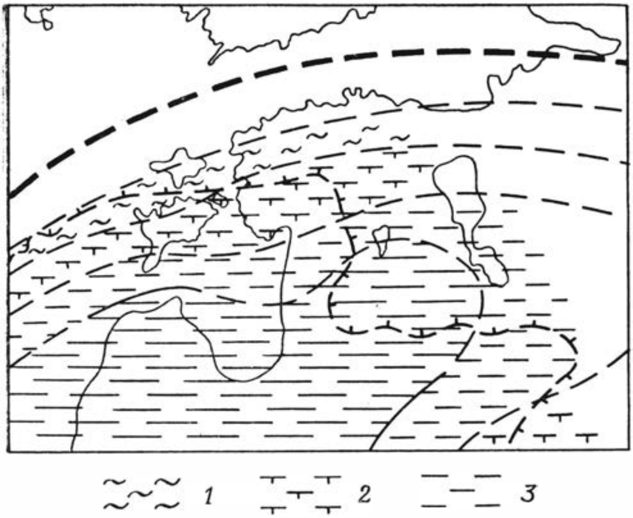

Fig. 10. Facies of the Late Jaani time (*M. riccartonesis* Zone) 1 — biomicritic limestones of the open shelf; 2 — marls and 3 — green clays of the transitional (slope) belt. For other signs see Fig. 9.

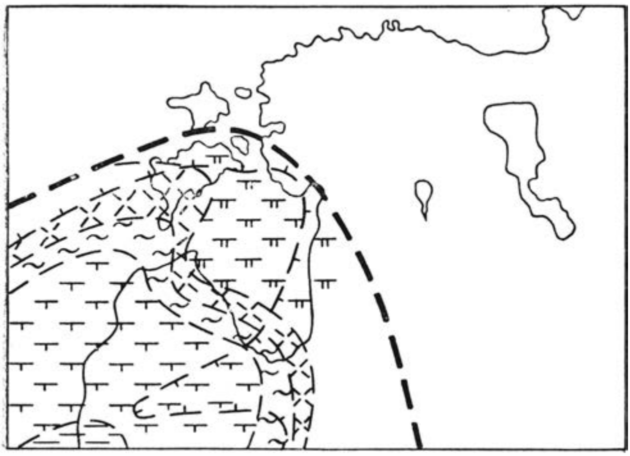

Fig. 11. Facies of the Late Paadla time (*M. leintwardinesis* Zone): For legend see Figs. 9 and 10.

(Нестор, Эйнасто, 1977; Kaljo, Klaamann, edit., 1982; Кальо и др., 1983) dealing with the matter more thoroughly.

Facies maps presented in Figs. 9—11 are based on the above model, and special explanations are hardly needed. Fig. 9 shows the Llandoverian Sea at the beginning of its first substantial regression, Fig. 10 presented the stage of maximal transgression in the basin, when, most likely, there was a direct connection with the Moscow basin. Fig. 11 describes a regression of the Ludlovian Sea. The regression was interrupted by several transgressions and ended with the retreat of the sea from our territory.

In Estonia the Devonian was represented by Old Red facies (see Table 5); glacial, aqueoglacial, marine and lake deposits dominated in the Quaternary cover.

D. Kaljo

4. Earth resources

In the Cambrian terrigenous complex only the clays of the Lontova Formation are of economic significance. These so-called blue clays crop out and form several deposits in a narrow belt in North Estonia. They serve as raw material for manufacturing cement and rough ceramical products (bricks, roof-tiles, drainage pipes). The blue clay deposits are exploited in Tallinn (see excursion 028, stop 2:1, further abbreviated to 028—2:1), in the environs of Loksa, at Kunda and Aseri.

The lowermost terrigenous part of the Ordovician is composed of a fine-grained quartzose sandstone which contains phosphorus-bearing valves and valve fragments of brachiopods. The valves are rich in P_2O_5 (35—37%). In some areas where the content of valves is high in sandstone, they may form large phosphorite deposits. Obolus phosphorite is referred to poor (P_2O_5 content ranges from 6 to 15%) but easily enrichable phosphorites which are used for the production of highly concentrated phosphoric and complex fertilizers. Productive deposits are located in the environs of Tallinn (Maardu deposit, see 028—3:1) and in the Rakvere District (Toolse, Kabala, etc. deposits). In Estonia the total phosphorite reserves are estimated at about 600—700 million tons of P_2O_5.

The Baltic oil shale (kukersite) is related to the carbonate rocks of the Middle Ordovician Kukruse Regional Stage. There are two large oil shale deposits on Estonian territory — the Estonian (see 028—3:3) and Tapa ones. In the productive seam of these deposits, oil shale layers alternate with interlayers of argillaceous limestone. As for its quality, the Estonian oil shale is acknowledged as one of the best in the world. Oil shale occurs in North-East Estonia in an area of about 10 000 km^2. As other kinds of mineral fuel are lacking in the north-western part of the Soviet Union, the Estonian oil shale is of great economic significance, serving as fuel for big electric power stations and as raw material for thermal processing. In the Estonian SSR oil shale is produced both in mines and open-cast pits. Its annual output amounts to 30 million tons of commercial oil shale. Not only the organic matter of oil shale, but also its mineral part is utilized. The latter is used for the production of building materials, and also in agriculture for deoxidating sour soils and in road building as ballast.

Ordovician and Silurian limestones and dolomites are used in the building materials industry for producing Portland cement, building lime, road metal, and facing panels. In Estonia limestones and dolomites are produced in numerous quarries located in the vicinity of towns and industrial centres. The most important deposits are those of Väo, Maardu (see 028—3:1) and Harku in the vicinity of Tallinn (building limestones), Padise and Rummu in the Vasalemma settlement (see 028—4:2) (building limestones and limestones for the production of lime), Aru near the town of Kunda (for cement production), Karinu (see 028—6:1), Rakke in the Rakvere District (limestones for the production of lime), Kadastik near the town of Narva (building limestones) and Anelema (see 028—5:3) in Pärnu District (building dolomites of high resistance).

E. Mustjõgi.

Excursion 027 A+C

THE HYDROGEOLOGY OF THE BALTIC

Itinerary and schedule by days

The hydrogeological excursion 027 will take you to the north-western part of the Soviet Union (Fig. 1). You will leave Moscow by train at night and arrive in Riga the next day, where the excursion actually starts. You will be offered the following programme:

1st day — visit to sites of interest on the outskirts of Riga;

2nd day — survey of mineral water in Kemeri health resort and sightseeing in Riga;

3rd day — leaving Riga for Tallinn by bus, observation of the Uulu melioration site and the Kata karst field, arriving in Tallinn at night;

4th day — sightseeing in Tallinn, lecture on the hydrogeology of Estonia, visit to a station of registration of land subsidence;

5th day — survey of alvars, the North-Estonian Clint and the oligotrophic mire in Lahemaa National Park, talk on the preservation of ground water in Estonia; an ethnographic ensemble show;

6th day — leaving Tallinn for Leningrad by bus; observation of hydrogeological conditions in oil-shale mines, sightseeing in Narva, arrival in Leningrad;

7th day — visit to Petrodvorets architectural ensemble on the outskirts of Leningrad;

8th day — lecture on the hydrogeology of Leningrad area, visit to Polystrovo mineral-water plant, survey of hydrogeological observation wells;

9th day — leaving Leningrad for Valdai, excursion to Valdai lakes;

10th day — visit to Valdai Hydrological Research Laboratory, leaving Valdai by bus, arrival in Moscow.

INTRODUCTION

The utilization of ground water for water supply and salt evaporation in the region of the excursion dates from ancient times. Thus, the still preserved wells at Staraya Russa were founded in 1370. The brine springs in the same place date, according to evidence in manuscripts, from the year 1471 onwards.

The scientific investigation of ground water was initiated in the 19th century. The genesis of brines was studied by A. Karpinsky while A. Inostrantsev investigated the geological structure and hydrogeological conditions of the Petersburg region. The first artesian well in Petersburg was founded on the initiative of G. Helmersen in 1871. After 1917 different aspects of ground water geology were treated by A. Semikhatov, M. Gatalsky, B. Arkhangelsky, G. Meyer, N. Selivanov, H. Tolstikhin, I. Zaitsev, and others.

The first ground water investigations on the territory of Estonia in the 19th century were carried out by C. Schmidt, subsequently the hydrogeological problems of the region were dealt with by J. Kark, A. Luha, K. Orviku, A. Verte, and others.

Today a number of institutions, especially the regional geological surveys of the Ministry of Geology of the Soviet Union are working in the field of regional applied hydrogeology, while theoretical problems are studied at the All-Union Geological Institute (ВСЕГЕИ), Leningrad State University, Leningrad Institute of Mines, Lithuanian Geological Research Institute, the Institute «Soyuzmorinzhgeologia» in Riga, Institute of Geology of the Academy of Sciences of the Estonian SSR, and others.

Hydrogeological survey of the excursion area

The north-western region of the USSR forms a part of the vast East-European (Russian) platform. Here the position of the main units of the large ground water basins of the first order is determined by troughs, syneclises and depressions of the basement. The boundaries between these basins coincide with the elevations of basement (anteclises, saddles). According to the above principles the Baltic-Polish and the Russian ground water basins of the first order are distinguished.

The boundaries of the ground water basins of the second order are determined by the hydrodynamical conditions of formation of the flow and balance of ground water. Hence the Estonian, Latvian, Leningrad and Moscow ground water basins of the second order are distinguished (Архангельский, 1966); Валлнер, 1980; Дзенс-Литовский, 1967; Дзлина, 1970; Зайцев, 1967). The deepest branches of subsurface flow of the above basins take western and north-western directions toward the regional main discharge area — the Baltic Sea.

In the region the following main aquiferous complexes can be distinguished (from bottom to top):

(1) the fracture ground water of the crystalline basement;

(2) the pore-stratal water of the Vendian and Lower-Cambrian terrigenous deposits;

(3) the fracture-karst water of the Ordovician, also the Silurian carbonate rocks in the Estonian SSR;

(4) the pore-stratal water of the Devonian terrigenous and partially carbonaceous deposits (in the so-called main Devonian field);

(5) aquifers of different types of Quaternary deposits.

The water of the crystalline basement has practically not been used so far. As for its chemical composition, the water belongs to the sodium-chloride type* with the mineralization increasing from 1—2 mg/l in the Leningrad Region up to 100 mg/l and more in Latvia.

The crystalline basement is overlain by Vendian and Lower Cambrian sandstones and siltstones with three pronounced artesian pressure aquifers known (from bottom) as the Gdov, Lomonossov (or superlaminarites) and Cambrian-Ordovician ones. The thickness of these aquifers extends from 10—15 to 35 m (in Gdov aquifer up to 80 m), increasing south- and eastwards from the northern part of the Leningrad District and the Estonian SSR. The aquifers are isolated from one another by clay layers of low permeability, of which those of the

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*The nomenclature of the type of chemical composition of water is given here according to the increasing order of anions and cations while the ions with less than 10% of occurrence are not taken into account.

Lontova Formation (the so-called blue clays, thickness up to 130 m) are of the widest regional distribution.

The water from the above aquifers (the Gdov one in particular) is intensely used in the industrial districts of North Estonia as well as in the northern part of the Leningrad Region. In that area the ground water of these aquifers is prevailingly fresh, sterile and well protected from surface contamination. The specific well discharge ranges from 0.6 to 2.5 l/sec m. The wide utilization of Vendian and Lower-Cambrian waters has brought about the forming of vast areas with dropped piezometric levels of ground water. The drop ranges from 25—35 m in Tallinn and Kohtla-Järve up to 65 m in Leningrad.

A network of observation wells allows permanent control over the piezometric level. In the southern direction the water becomes salty.

The Ordovician and Silurian limestones, dolomites and marls with a summary thickness from a few metres in the outcrop area up to 350 m in Central Estonia, provide water for the population of villages and townlets of North and Middle Estonia and the southern part of the Leningrad Region. The Ordovician-Silurian rocks dip southwards under the younger ones and become practically waterless.

The largest water supplies are associated with karst zones of tectonic dislocations, where the specific well discharge ranges from 1 to 5 l/sec m. The water from the carbonate rocks is fresh,of the hydrocarbonate magnesium-calcium type.

The Devonian rocks and corresponding aquifers occur over the vast territory of the Pskov and Novgorod Regions, South Estonia and the northern and eastern districts of the Latvian SSR. The Devonian is subdivided into three lithologically different parts: the lower one — sandstones (thickness attaining 350 m), the middle one — carbonates (limestones and dolomites, thickness ranging up to 90 m) and the upper one — the multicoloured part composed of sandy-argillaceous rocks with limestones and marl interlayers (thickness ranging up to 40 m). The Devonian formations represent a system of many relatively local-bound aquifers and water-bearing layers of different thicknesses and yields of water, which are isolated from one another by clayey rock layers of low permeability.

The specific discharge in the Devonian rocks ranges from 0.01 to 1.5 l/sec m. The water is widely used in the Novgorod and Pskov Regions, in Latvia and South Estonia. The Devonian deposits contain fresh hydrocarbonate magnesium-calcium type of water. In a few shallow wells, water of the chloride-sulphate-sodium type has been detected.

In the Quaternary deposits ground water is confined to sediments of different genesis, composition and age, forming a cover of uneven thickness over the East-European plain. The average thickness of the aquifers confined to the fluvio- and limno-glacial, glacial and alluvial deposits ranges from 3 to 30 m, rarely up to 100 or 200 m (in the Haanja and Valdai Hills). Here the Quaternary deposits often represent complex series of water-bearing horizons, including interstratal aquifers of low-pressure water. The depth of the water table in the Quaternary deposits depends on the relief of the study area, thus ranging from 1 to 2, in places from 20 to 50 m.

Aquifers of fluvio-glacial and alluvial deposits are of the widest distribution and most important from the practical point of view. The wells obtaining water from these sources have a specific well discharge of 3 l/sec m or more. The limnoglacial deposits are not so watery since the widespread loamy tills are often of a low permeability and work as a water-resistant bed.

The recharge of Quaternary ground water proceeds mainly through an infiltration of atmospheric precipitations in the outcrop areas, and partly through a discharge from the overlying aquifers.

The average infiltration intensity in the region ranges from 2 to 3 l/sec per km^2, while in places, particularly in the hills composed of karst and fractured carbonate rocks the infiltration intensity may reach 3—4, in some cases even 8 l/sec per km^2 (Зекцер, 1968). In the recharge of the underlying aquifers, ancient buried valleys are of great importance; such valleys often attain 100 m in depth.

In the region some kinds of table water and medical mineral water are produced. Generally these waters are related to depressions in the crystalline basement. Of the most frequent occurrence is the mineral water of the chloride-sodium type coming from the Lower-Cambrian. The increase in the mineralization of water is regularly accompanied by the growth of bromine content in the water. In a number of regions we come across sulphate waters containing hydrogen sulphide of biochemical origin. Generally this water is derived from relatively low lying gypsiferous Devonian formations. The aquifers of mineral water are tapped in the wells of the health resorts on the Riga Coast, in Valmiera, in the Baldone health resort (the Latvian SSR), at Häädemeeste, Värska (the Estonian SSR) and in the health resorts of Sestroretsk (near Leningrad), Khilovo (Pskov Region) and Staraya Russa (Novgorod Region).

L. Vallner, P. Jõgar

Second day

Stop 2:1 **The mineral water in the Kemeri health resort**

The Kemeri balneological health resort is located some 43 kilometres to the west from Riga and 5 kilometres from the seashore, on a plain covered with a mixed wood. Peat and sapropelic muds as well as hydrogen sulphide springs are at the disposal of patients. At the Kemeri spa such chronic diseases are treated as rheumatism, inflammation of joints, metabolic troubles, neuralgia, heart and blood-vessel diseases, gastric and biliary duct troubles. Each year over 20 thousand people come to be cured or simply recreate here.

The curative property of the water in springs and of peat muds was already known at the end of the 18th century. When the Soviet power was established, great innovations were started in the spa. A number of new sanatoria have been built, «Jaunkemeri» and «Latvia» being the most imposing.

Regular geological investigations during the years 1954—1959 resulted in establishing the boundaries of the resources of hydrogen sulphide water, ascertaining the genesis and determining the exact safe yield, the amount of which is about 23 l/sec.

Currently studies on curative water and mud, their exploitation regime, properties and supplies are in progress.

The Kemeri spa area is located within the north-eastern part of the Baltic syneclise. Here the sedimentary cover is composed of Palaeozoic and Quaternary rocks of about 1000—1100 m in thickness.

Hydrogen sulphide water occurs in the outcrop area of the Upper Devonian Salaspils Formation (Frasne). The Upper Devonian rocks are undisturbed, slightly monoclinally dipping southwest. Minor flat dome-shaped local structures, 8—10 m in amplitude, can be observed in this area. The Salaspils Formation is represented by alternating beds of clays, marls, dolomites and gypsum, its thickness ranging from 1—2 to 20 m. The formation is overlain by an up to 10 m thick Quarternary cover. The latter is made up of morainic loams, different sands, varved clays, gyttja and peat.

The hydrogeological conditions of the region are determined by the confined water in Devonian and Cambrian deposits and unconfined water in Quarternary ones. The formation of hydrogen sulphide appears to be due to complicated biochemical processes characteristic of these areas of the Salaspils aquifer, which are overlain by bog deposits. Swamp water is enriched by organic matter. In the places where its level lies higher than the water of the Salaspils Formation, the former penetrates into the latter and creates favourable conditions for the development of sulphate-producing bacteria which reproduce sulphate-ion up to hydrogen sulphide. The sulphate calcium or bicarbonate sulphate calcium water of the Salaspils Formation is characterized by mineralization 0.6—2.8 g/l. The hydrogen sulphide concentration ranges from 10 to 70 mg/l. Besides, in the Kemeri spa and other sanatoria in the coastal area of the Gulf of Riga, chloride calcium-sodium and sodium mineral waters (mineralization 5.8—12 g/l) of the Lower and Middle Devonian aquifer and Cambrian bromic brines (mineralization up to 120 g/l) are widely used for balneological purposes.

The climatic factors, the specific geological structure and the hydrogeological conditions as a whole make the Kemeri spa unique. The effective healing quality of the Kemeri mineral water is due to the joint biological action of all the dissolved constituents: gases, minerals and organic matter, having a curative influence on the human body.

According to the general reconstruction plan, the Kemeri health resort is to turn into one of the most representative institutions of that kind in the Soviet Union.

A. Freimanis

Third day

Stop 3:1 **An object of amelioration at Uulu**

The agricultural development of the Estonian SSR associates with ameliorative works: the area of cultivated land badly in need of drainage forms 22% out of the total territory of the republic. The main factors responsible for swamping are precipitation and surface waters; however, ground water and the water discharging from confined Ordovician, Silurian and Devonian aquifers, are also of consequence. Such additional ground water feeding of swamps amounts to 500 mm during the vegetational period. About 10% (in karst areas even up to 50%) of the areas to be drained are subject to rather complicated hydrogeological conditions.

Ameliorative works are closely connected with the problem of an economical and rational usage of water and land resources in view of environment preservation. For these purposes an amelioration scheme was compiled in the Estonian SSR in 1980, considering all the aspects of natural conditions and the factors of artificial influence.

The amelioration object «Uulu Suursoo», 2578 ha in area, lies within the boundaries of the Ura River drainage area, 4 km from Pärnu Bay. In this area the bench marks range from 5 to 8 m. The Middle Devonian carbonate and terrigenous rocks are overlain by aqueoglacial, limnoglacial and marine sands. Peaty mineral soils are prevailing. The redundant moisture is first of all due to precipitations and flooding by the Ura River; however, the discharge of ground water and from the underlying Pärnu aquifer are also of consequence. The ground water level lies at 0.1—1 m below the ground surface. The prognosticated modulus of subsurface flow to the drainage system is 0.08 l/sec ha.

Amelioration of the area is performed by means of closed drainage with intervals of 15—20 m between the drains. Supplementary measures include a water reservoir, a pumping-station for showering, and equipment for underground irrigation.

H. Kink

Stop 3:2 **Kata karst field**

On Soviet Estonian territory karst is developed in the outcrops of the Ordovician and Silurian, and less frequently in the Upper Devonian cracked limestones and dolomites. Karst phenomena associate first of all with chemically pure carbonate rocks, being less pronounced in formations with a higher clay content. Karst is of the widest distribution down to a depth of 30 m.

On the surface, karst is represented by three types: sotted, covered and uncovered. The surface forms are principally represented by hollows, sink holes, sink basins and blind creeks. As a rule, the sink holes are rather small, their diameter reaching seldom 20 m and their depth 6 m. A considerable number of sink holes have apertures at the bottom, through which in places the surface water from fields and meadows is drained off. The water-swallowing capacity of these holes amounts to some hundreds of litres per second. Sink basins are considerably rare, they may extend to 120 m in diameter and 4—6 m in depth.

Some sink holes distributed in North-Estonian alvars have flat bottoms and vertical slopes which may be up to 3 m in height. Their formation results from the cracking of large quadrangular blocks separated from the carbonate masses under the influence of solution and erosion of rocks along tectonic joints.

Cavernosity is characteristic of the subterranean karst of dolomites. This phenomenon is most frequent in coarse crystalline and biohermal rocks. Karst hollows in limestones are represented by small caves and canals running along vertical or bedding joints.

A considerable number of preglacial hollows are filled with different Quaternary deposits.

In North-East Estonia, Palaeozoic karst is developed in places along the belts of tectonic joints of north-eastern direction. The limestones, dolomites and carbonaceous oil shale have been changed and crushed here, the space between their particles being filled with clayey matter down to a depth of 60 m. The karst tectonics can be traced in the above area.

In North Estonia several rivers and brooks disappear in karst sink holes, contributing thus to fracture-karst water resources. Some subterranean rivers reappear on the surface at a distance of 0.5 to 2.5 km in the form of springs. They flow under ground along a complicated system of small karst hollows at a depth of down to 10 m. The karst field at Kata may serve here as an example. Here the Tuhala Greek disappears in a sink basin of irregular form with some tens of shallow holes at its bottom and flows underground for 2.5 km. The maximum ground water discharge of this lost creek extends to 3 m^3/sec. The Tuhala Creek has a considerable number of subterranean branches, the three largest of which are distinguishable. The lost creek is overlain by karst sink holes and sink basins up to 60 m in length, and 7 m in depth, and a collapsed valley of about 300 m in length. The thickness of the Quaternary deposits extends from 0.5 m near the shallow holes up to 8 m. The bedrock composed of the Upper Ordovician limestones of the Vormsi Formation underlies the Quaternary deposits.

The creek emerges in the form of springs. One of those is used as a draw-well which in spring shoots over 100 litres per second. In recent five years two collapses of cover have taken place in this karst field.

Ü. Heinsalu

Fourth day

Stop 4:1 **Observation station in Tallinn**

The major part of the city is located within the boundaries of the pre-clint terrace, at an altitude of 2—15 m above sea level. In the city the bedrock is composed of Cambrian and Vendian sandstones, siltstones and clays, which are incised by four buried valleys filled in with Quaternary sand-clayey deposits of varying consolidation. The construction of the town, intensification of the city transport, excessive withdrawal of ground water tell considerably upon the geological enviroment. Geodetic studies performed in the town showed that land is subsiding in some areas related to the ancient buried valleys. The highest value of subsidence appears to be 1 m at a maximum rate of 36 mm annually.

The land subsidence, its dynamics and the condensation of different layers in a geological section is studied by means of reference stations provided with special equipment. These stations consist of 6 pipes with external diameter of 89 mm, laid into different beds of the geological section. The shoes of these pipes are fixed on a special anchor in the study bed. To eliminate the influence of the surrounding rocks, each pipe is placed into a casing of a larger diameter.

The shifts in the position of heads of pipes are measured relative to a deep bench mark seated on the bedrock. The position of the latter is periodically checked by means of geodetic levelling. The data are obtained by reading the records of special devices or automatically at least 6 times a day. The observation of reference wells is accompanied by the measurements of ground water level, atmospheric pressure and air temperature. The data obtained enable to estimate the contribution of single beds to the process of land subsidence, and to prognosticate the development of this process.

L. Savitsky

Fifth day

Lahemaa National Park

Lahemaa National Park, 650 km^2 in area, was established in 1971, being the first wildlife reserve of that kind in the Soviet Union. The predominant part of the park is composed of natural landscapes and reserves; the share of cultivated land does not exceed 5 per cent of the territory. The task of the park is to preserve and protect ecosystems typical of North Estonia and cultural landscapes with historical and cultural monuments.

The park is situated on the coastal lowland of the North Estonian plain. Its Pre-Quaternary bedrock consists of Upper Proterozoic, Cambrian and Lower Ordovician carbonates and terrigenous rocks. The thickness of the overlying marine, glacial, fluvio- and limnoglacial deposits is usually 1—20 or more metres. Natural protection of ground water is lacking or insignificant.

Since 1978 constant checkup of the chemical composition and water table regime of ground water has been carried out in Lahemaa National Park. For these purposes 11 stationary observation sites were established on cultural landscapes, two on natural landscapes and one in the reserve to get an idea of the background values of hydrogeological parameters. A special site was installed for the investigation of the dynamics of swamp waters near the nature study path in Virusoo Mire. On the territory of the park, 52 observation wells have been established in all. The aim of the studies is to work out recommendations on water protection measures to be applied on territories with similar natural conditions.

H. Kink

Stop 5:1 **The North Estonian Clint and alvar at Muuksi**

A steep limestone cliff stretches along the whole northern coastal area of the Estonian SSR — the North Estonian Clint which forms a part of the Baltic-Ladoga Clint — a specific type of denudation relief extending from the Island of Öland up to Lake Ladoga. The maximum height of the clint amounts in Estonia to 56 m above sea level (at Ontika). At Muuksi its absolute height reaches 47 m, the relative height being 20 m. The upper part of the cliff is composed of Middle-Ordovician limestones, while in the lower part the Lower Ordovician limestones and sandstones occur together with Lower Cambrian sandstones. The ground water from Ordovician and Cambrian aquifers, discharging at the foot of the clint, often causes an overmoistening of the soil in places. Springs may likewise occur here. On the limestone plateau in North and West Estonia we can come across a unique terrain type with a specific plant community — alvars. Beside Estonia, alvars occur only in Sweden. The characteristic feature of alvars is the very thin (up to 10—20 cm) but humus-rich soil layer, often directly overlying the Ordovician and Silurian limestones. In summer the soil dries up and the plants wither. Like in steppes, we can observe here two plant-recreation periods a year — one in summer and the other in winter. The ecosystems of alvars have thus much in common with those in steppes. Infiltration of atmospheric precipitation plays the main role in ground water recharge. Karst phenomena can also be observed here. Due to the very thin Quaternary cover or its absence in places, the poorly protected ground water in alvars may suffer from pollution.

V. Karise

Stop 5:2 **Viru oligotrophic mire**

About 11 800 mires are counted in the Estonian SSR. Their area totals 9 150 km^2, forming 20 % of the whole territory of the republic. Estonian mires consist of fens (57 %), raised bogs (31 %) and transitional bogs (12 %). The greatest thickness of peat deposits amounts to 10 m, the average being 3 m. Estonian peat reserves are estimated at 4 milliard tons; at present 2.5 million tons of peat are excavated annually (two-thirds being used as litter and fertilizer and the rest as fuel). Every year 3 000 tons of cranberry are collected in oligotrophic mires and transitional bogs. Drained fens and transitional bogs provide favourable conditions for forests, the cultivated areas are sown with perennial hay plants. Oligotrophic mires serve as compensational nature preserves, contributing greatly to water supplies (they store ca 5 km^3 of the cleanest water). The mineralization of mire water does not exceed 0.1 g/l, its reaction is sour (pH about 4) and has a bactericidal property. The first swamping centres developed in Estonia already as early as in the Preboreal climatic period — almost 10 000 years ago.

The Viru oligotrophic mire is located in the southern part of Lahemaa National Park, 41 km east of Tallinn, north of the Tallinn-Leningrad highway. Here the maximum thickness of peat reaches 6 m, the average being 3.4 m.

H. Kink, V. Karise

Sixth day

Stop 6:1 **October (Oktyabrski) open-cast pit**

The Estonian oil-shale basin is situated in the north-eastern part of the republic. Oil shale is excavated both in mines

(30—60 m deep) and in open pits. A 4 m-thick productive bed slowly dipping southwards is embedded in Ordovician carbonate rocks. The eastern and western parts of the basin where kukersite is mined in open pits, lie within the boundaries of a swamped area. Utilization of the area depends on the dehydration of the Ordovician aquifer related to fissured and karsted limestones, dolomites and marls. In the basin as a whole, 7 m^3 of water must be pumped out on the average to produce 1 ton of oil shale; in the October open-cast pit this figure reaches 11 m^3/t.

Dehydration of pits is performed by means of forestalling drainage, ditch systems which take the water to sumps. From there it is pumped up to the surface and led into water-removing channels. In dependence on its turbidity, the water is held in settling tanks for a certain time before releasing it into network of surface drainages.

October open-cast pit is situated in the western part of the basin where mining is performed on arable land. According to the law the exhausted areas are recultivated by mining organizations and returned to agriculture. Dewatering in the pit is performed by means of a drainage system running from north to south. In the southern part of the system water is pumped up to the surface and released into a water-removing channel. The amount of daily discharged water ranges from 60 000 m^3 in the shallow water period up to 140 000 m^3 during the snow melting.

L. Savitsky

Eighth day

Stop 8:1 **«Polystrovo» mineral-water plant**

The Polystrovo ferrous mineral springs and their curative properties were discovered in 1718 by Areskin, the court physician of Peter the First. At the end of the 18th century foundation was laid of an estate and a park on the bank of the Neva, with pathways leading straight to the mineral springs. The house was designed by architect Quarenghi. Almost all the buildings of the mineral springs were damaged in the great fire of 1870. In 1886 the mining engineer Voislav restored the utilization of Polystrovo mineral springs: water was bottled and put on market in the capital and in the province.

In 1926 engineer G. Meyer initiated the studies on the hydrogeology of the environs of Polystrovo and built a mineral water plant which was put into operation in 1934. Currently mineral water is obtained from two wells, the yield being about 7 l/sec. However, the actual use is considerably lower. The mineral water is derived from a confined sand aquifer lying between clayey till at a depth of about 20—40 m. The piezometric level lies above the earth's surface.

According to the present knowledge, the ferrous mineral water results from the oxidation of pyrite in water-bearing sands. The solution holds iron dioxide due to the high content of carbon dioxide in Polystrovo water. The organic matter comprised in the clayey intercalations of the water-bearing strata serves as a source of carbon dioxide.

The Polystrovo sulphate-chloride-bicarbonate calcium-sodium water is of a low degree of mineralization (0.2 g/l) and its minor constituent being iron (Fe** 0.02 g/l). The water has been used for the treatment of ananemia, chronic catarrhs and dynamic diseases of stomach and bowels.

I. Nikolajev, V. Vanchugov

Stop 8:2 **The network of wells applied for the study of ground water regime**

The network of wells applied for the study of ground water regime in Leningrad is composed of more than 100 wells, four of which are situated on the Zaichiye Island. These wells, 5 to 10 m depth, were taken into use in 1980. The aim of observations is to study the effect of the ground water on the architectural monument — the Peter-Paul's (Petropavlovsk) Fortress — take measures for restricting this effect. In two wells experimental longacting automatic plotters constructed by the organizations of the Ministry of Amelioration and Water Supplies of the USSR have been put to test.

Well no. 342 of a depth of 220 m, is laid out in Moscow Square, serving as a reference point of the network applied for the stationary observation of the ground water regime in the Gdov aquifer. Water level is registered by an automatic plotter TP-38 equipped with a clockwork that is wound up once a month. As this well lies relatively far from the main water consumers, its drawdown does not reveal such great fluctuations in the water level as, for example, that in the centre of the town. In 1945, after a long interval in the ground water consumption, the piezometric level of the Gdov aquifer was rather close to the earth's surface in this area. At present the level lies at a depth of about 55—60 m. Owing to the measures applied for the production of the water of the Gdov aquifer from pollution, its piezometric level has not revealed further lowering.

Close by the above observation well lies another one with its mouth below the earth's surface. The casing of this well is situated at a depth of 148 m and serves as a bench mark for the observation of the land subsidence.

The records by automatic devices installed in the observation wells within the sloping piezometric surface of the Gdov aquifer enable to regulate the exploitation of the latter and provide valuable information for the calculation of hydrogeological parameters.

I. Nikolayev, V. Vanchugov

Tenth day

Stop 10:1 **Valdai Hydrological Research Laboratory**

Valdai Hydrological Research Laboratory (VHRL) named after V. A. Ouryvaev of the State Hydrological Institute is a large scientific and methodological institution dealing with hydrological experimental research in the USSR.

The Laboratory was founded in 1933. The establishment of VHRL marked a new stage in the development of experimental research in the field of land hydrology. The results of these researches considerably increased the possibilities of using the data of the network hydrometeorological observations for the solution of numerous scientific and practical problems.

The Laboratory is equipped with up-to-date measuring devices, instruments and installations, many of which are quite unique.

The results of the investigations in the field of hydrophysics carried out at the Valdai Laboratory have provided better scientific knowledge of the processes of evaporation and served as the basis for the development of practical methods for computation of this water balance element.

The scientists of the Valdai Laboratory have substantially contributed to the improvement of the technique of water balance investigation and to the estimation of the regularities of runoff formation. The results of the research in this field are widely used while studying water balance of dry farming land and irrigated areas for estimation of possible changes in runoff and water balance as a result of human activities as well as while analyzing the process of ground water recharge by precipitation.

It was the Laboratory where valuable information on the process of sediment discharge formation and on the origin of channel forms was received and methods of field investigations concerning these problems were developed.

Much attention is paid to the design of instruments and equipment for experimental investigations. Special runoff and water balance plots, soil and water evaporation installations as well as a number of new measuring devices have been developed in the Laboratory.

The Laboratory has widely participated in the organization of scientific expeditions for the study of various hydrological problems.

Excursion 028

GEOLOGY AND MINERAL DEPOSITS OF THE LOWER PALAEOZOIC OF THE EASTERN BALTIC AREA

The geological excursion 028 will take you to the classical areas of the Lower Palaeozoic in Northern and Central Estonia. Sequences of Southern and Western Estonia, represented by rocks of different facies, will be demonstrated at the Särghaua field station. The route of the excursion is shown in Fig. 2., and some parts of it in greater detail in Fig. 12. The itinerary of the excursion is as follows:

1st day — arrival in Tallinn; in the afternoon introductory lectures on Estonian geology and mineral resources at the hotel «Viru». A short account of the activities of different geological institutions of the republic will also be presented. After the meeting — sightseeing of the old and new town;

2nd day — geological excursion in Tallinn and its outskirts. Subject of study — the Cambrian, Lower and Middle Ordovician;

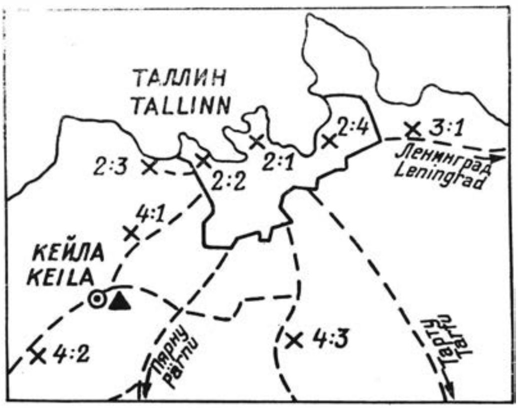


Fig. 12. The route of the excursion 028 in Tallinn and its environs. For legend see Fig. 1.

3rd day — excursion along the Leningrad highway to the east of Tallinn and to the oil shale basin;

4th day — excursion to the western and southern outskirts of Tallinn. Subject of study — the Middle and Upper Ordovician;

5th day — excursion along the Pärnu highway. Subject of study — the Llandovery and Wenlock;

6th day — visit to Särghaua field station of the Institute of Geology, Acad. Sci. of the Estonian S.S.R., near Türi. Subject of study — the boring sections (Cambrian, Ordovician, Silurian of Western and Southern Estonia);

7th day — visit to Lahemaa National Park; leaving Tallinn for Moscow and other towns.

GEOLOGICAL ITEMS OF THE EXCURSION

Second day

The first half of the field excursion will include the study of all the Lower Cambrian subdivisions exposed on Estonia's northern shore. Many geographical names of units used in Cambrian stratigraphy are derived from the classical outcrops in the environs of Tallinn (Fig. 12). The second half of the day will be devoted to the investigation of the Lower and Middle Ordovician (Tremadoc, Arenig, Llanvirn).

Stop 2:1 — **the Kopli quarry**

The range of the quarry of the Tallinn Building Ceramics Plant depends on the seasonal hydrogeological and mining conditions in the quarry.

In the deepest part of the quarry the clays of the Kestla Member of the Lontova Formation crop out. They are represented by multicoloured violet-grey clays. In the higher part a 4—6 m thick unit of grey silty clays of regressive character can be observed, belonging to the Tammneeme Member. These clays are enriched by silty material which occurs in irregular lenses, pockets and scatterings. Independent interlayers of siltstone are not observed here, contrary to the adjoining sections east and south of Tallinn.

In comparison with the underlying Kestla Member this part of the Lontova Formation is poorer in pyritized tracks and trails of burrowing organisms, which, however, are still rather frequent here. Diagenetic enrichments in the form of loose light grey phosphate and glauconite occur in those clays.

Fossils are represented by siliceous fragments of *Platysolenites antiquissimus* Eichw. and *P. spiralis* Posti. A typical Lontova assemblage of acritarchs has been identified.

Above, outwardly with a rather indistinct contact, lies the Lükati Formation. Its lower part is composed of greenish grey silty clays with rare siltstone intercalations. The latter increase in number upwards; however, a series of regularly alternating clays and siltstones is missing in the section — the latter will be demonstrated at the next stop. In the Kopli quarry the siltstone intercalations are generally rather thin; however, they frequently form considerably large lenses with very uneven lower surfaces. As a rule, the siltstones are strongly cemented with poikiloclastic carbonaceous cement; traces of phosphate mineralization can sometimes be observed. Frequently the siltstones are rich in glauconite, and the lower surfaces of the beds contain abundant imprints of bioglyphs.

In the clays of the Lükati Formation the silt component may be represented by thin lenticular intercalations in the form of a scattered admixture in the transitional rocks between the siltstones and clays, or by the filling material of sporadic pockets and tracks of mud-eaters. The pyritized tracks of worm-like organisms are either lacking or represented by very small traces.

The organic remains of the formation include *Volborthella tenuis* Schm., which sometimes forms very rich taphonomic accumulations, by *Luekatiella*, and by unidentified fragments of inarticulate brachiopods and trilobites. An abundant Lükati assemblage of acritarchs has been established in the clay.

Basal conglomerate composed of dark phosphatic siltstone pebbles serves as the contact between the Lontova and Lükati Formations; however, it may be observed in a few places only.

This, at first sight hardly recognizable contact is of utmost interest in the quarry, for it marks an important boundary in Cambrian history: it is underlain by the so-called pre-trilobitic beds — a formation of disputable Cambrian age — and overlain by trilobite-bearing Cambrian with *Schmidtiellus*. A remarkable gab in the sedimentation (in West Estonia the Sõru Formation is missing) and great structural rearrangements in deposition are revealed at this boundary. The apparent resemblance of the sequences below and above this contact is a result of the resedimentation of clayey matter from the underlying rocks during a new Lükati transgression.

At present the clays of the upper Lontova and Lower Lükati Formations available in the Kopli quarry are used as raw material for bricks. They cannot be applied for producing high-grade products since some of their properties, such as fusibility, uneven distribution of the silt component and sulphur content account for white «blooms» on the products.

E. Pirrus

Stop 2:2 — **cliffs at Rocca al Mare**

A great number of small abrasional exposures are situated on the territory of the Open-Air Museum at Rocca al Mare, on the Kakumägi Peninsula.

The Lükati Formation crops out at sea level. It is represented by a sequence of interlayered grey clays and siltstones with clasts of *Volborthella.*

The lowermost 3—4 metres of the Tiskre Formation — the Kakumägi Member — lie upon the preceding unit with a small hiatus, marked by a slightly undulated discontinuity surface and basal conglomerate from dark phosphatic silt pebbles and rounded phosphate valves of brachiopods (so-called *Mickwitzia* conglomerate). Single lenses of conglomerate occur also higher up above the contact — in this exposure they have been established at three levels. The present member is characterized by the presence of an interlayer of coarse-grained siltstone or fine-grained sandstone of 0.8 to 1.4 m thickness, with distinct dolomitic cement of poikiloclastic type («pisolithic sandstone»). Upwards the siltstone becomes richer in clay and less compact, containing single crossbedded series, aggregates and concentrations of pyrite, slump rolls and flat lenticular beds of coarse siltstone with a lower clay content.

In this exposure the Kakumägi Member reveals an impoverished assemblage of acritarchs characteristic of the regressive part of the Livonian Regional Series (Jankauskas, Posti, 1973), *Scenella, Mickwitzia,* and also ostracodes from the family *Bradoridae* (Менс, Пиррус, 1977). Unknown fragments of trilobites have been found as well.

E. Pirrus

Stop 2:3 — **Tiskre cliff**

Tiskre cliff forms a part of the high Rannamõisa clint and serves as a stratotype of the Tiskre Formation, which is exposed here in almost its entire thickness — 16.3 m. Only the lowermost beds of the formation remain below sea level.

The lower part (3.85 m) of the section is referred to the Kakumägi Member, which is made up of massive light grey siltstones with intercalations of pelitic siltstones. The structure of the rocks forming this member is disturbed, lenticular and rapidly changing laterally. Here ripple marks occur with an orientation of ridges towards the northeast, 40—50° and northwest 330° (length 5—7 cm, height 0.7—0.8 cm).

The abovelying Rannamõisa Member is 12 m thick and consists of more homogeneous and well-sorted light grey coarse siltstones. Only the middle part of the unit is richer in clayey matter. The structure of the rocks includes almost horizontal bedding, reflecting a more tranquil sedimentary environment.

The composition of siltstone is nearly monomineralic — quartz. The clayey component is represented by illite with chlorite admixture. Scattered glauconite is found everywhere in rocks; microcrystalline aggregates of pyrite are abundant.

Fossils are rare in the section. Clay intercalations have yielded single acritarchs (leiosphaerides), some bedding planes appear to bear trails of molluscs and *Scolithus* and rare phosphatized detritus of brachiopods. A rounded fragment of phosphatized brachiopod shell resembling *Mickwitzia* (Менс, Пиррус, 1977) has been found in the upper part.

The upper boundary of the formation, very distinct, is denudational: the upper part of the Lower Cambrian as well as the Middle and Upper Cambrian are missing here.

Higher in the section the Lower and Middle Ordovician rocks are inaccessible to immediate study.

E. Pirrus

Stop 2:4 — **Lasnamägi (Suhkrumägi)**

In the area of Suhkrumägi, where the road descends down the clint, a section of Middle and Lower Ordovician rocks is exposed (from the top downward):

Lasnamägi Regional Stage; Väo Formation

0.3+m — Pae Member: grey dolomitic, microcrystalline, fine organodetrital, medium to thick bedded limestone with brownish subvertical burrows.

2.4 m — Rebala Member: grey, unevenly dolomitized, microcrystalline, fine organodetrital, medium bedded limestone with weakly phosphatized discontinuity surfaces, in the lower

(0.2 m) part with white phosphate and brown goethite ooids, characteristic species: *Orthoceras regulare* Schloth, *Christiania oblonga* (Pander), *Tallinoceras lasnamäense* Balashov.

Aseri Regional Stage, Aseri Formation

0.5 m — Ojaküla Member: low to medium argillaceous, fine organodetritic, grey, medium-bedded limestone with abundant goethitic ooids.

Kunda Regional Stage, Loobu Formation

0.7 m — Ubari Member: grey, fine organodetritic, thick-bedded limestone with sparse glauconite grains, with phosphatic discontinuity surfaces in the lower part. Characteristic species: *Ingria expressa Öpik, Pseudoasaphus globifrons* (Eichwald), *Homalopyge stacyi* (Schmidt).

Pakri Formation

0.1—0.2 m — Kallaste Member: yellowish grey, fine organodetritic limestone with grains of quartz and glauconite, also containing gravel and coarse gravel phosphatic material. Discontinuity surfaces with phosphatic and pyritic impregnations are characteristic here. At the lower boundary occurs a flat discontinuity surface with deep (up to 15 cm) pockets filled with grains of glauconite. Characteristic species: *Eoplacognathus? variabilis* (Sergeeva), *Rowellella rugosa* Gorjansky.

Volkhov Regional Stage, Toila Formation

0.07 m — Kalvi Member: grey, fine organodetritic limestone with abundant fine grains of glauconite and *Scolopodus cornuformis* Sergeeva, *Conchoprimitia gammae* Öpik.

1.8 m — Telinõmme Member: alternation of limestones and marls (ratio 1:1). Light grey, low argillaceous, fine organodetritic medium-bedded to seminodular limestone; greenish grey, argillaceous marl. The limestone layers are 5—8 cm and those of the marls 2—10 cm thick. The grains of glauconite are dispersed throughout the whole sequence. Characteristic species: *Productorthis obtusa* (Pander), *Paurorthis parva* (Pander).

0.6 m — Saka Member: grey, pink or yellowish in the lower part, thin to finecrystalline, fine organodetritic, medium bedded calcareous dolomite with big grains of glauconite and limonitic discontinuity surfaces. At the base a flat discontinuity surface with amphora-like holes, up to 5 cm in depth. Characteristic species: *Productorthis aculeata* (Pander), *Prioniodus (Baltoniodus) navis* (Lindström).

Latorp Regional Stage, Toila Formation

0.3 m — Päite Member: grey (in the middle part pinkish), fine to medium crystalline, fine organodetritic, thin to medium bedded calcareous dolomite with dispersed grains of glauconite and rare quartz grains and limonitic, phosphatic and pyritic discontinuity surfaces. Characteristic species: *Megistaspis estonica* (Tjernvik), *Panderina tetragona* (Pander), *Periodon flabellum* (Lindström).

Leetse Formation

0.2 m — Mäeküla Member: greyish green silty quartzose-glauconitic sandstone. In the upper part the sandstone turns into dolomite. In the lower part nodular, in the remaining part from thin to medium-bedded. Characteristic species: *Paurorthina resima* Rubel, *Ranorthis parvula* (Lamansky).

0.55 m — Iru Member: green, sandy-clayey glauconitic silt with dark phosphatized detritus of inarticulate brachiopods, sporadically slightly cemented, rhythmical alternation (after every 5—20 cm) with intercalations (up to 5 cm) of light grey, in places yellowish, microbedded clay. Characteristic species: *Scolopodus rese* Lindström, *Drepanoistodus forceps* (Lindström), *Cordylodus angulatus* Pander.

0,85 m — Klooga Member: dark green glauconitic silt with intercalations of relatively well-cemented organodetritus and also shells of linguloids. The middle part of the member contains thin- and medium-bedded clay intercalations with flat bedding planes. The upper and lower parts are of a rather massive structure. Characteristic species: *Cordylodus angulatus* Pander, *Acodus deltatus* Lindström, *Acodus erectus* Pander.

Ceratopyge Regional Stage

0.2 m — Varangu Formation: beige clay, in the upper part plastic, in the lower part argillaceous with *Bryograptus sf. broegger* Monsen and *Clonograptus sp.*

Pakerort Regional Stage, Türisalu Formation

4.0 m — Tabasalu Member: dark brown kerogen-bearing graptolitic argillite of a fine-plated structure.

Kallavere Formation

0.8 m — Suurjõe Member: yellowish-white quartzose organodetritic («detrite layer») fine- to medium-grained sandstone, strongly pyritized at the top («pyrite layer» — 0.1 m), weakly cemented in the lower part. Phosphatic brachiopod detritus, frequently oriented along the cross-bedding.

0.70 m+ — Maardu Member: quartzose, mainly fine-grained sandstone with thin intercalations of argillite, shells and detritus of inarticulate brachiopods.

In the Kallavere Formation the following species have been identified: *Obolus (O.) apollinis* Eichwald, *O. (O.) ingricus* Eichwald and *O.* (*Schmidtites*) *celatus* (Volborth.).

The Tremadoc is represented by deposits of open (sandstones) or isolated (argillite) shallow shelf sea with a terrigenous type of sedimentation. The sequence beginning with the lower part of the Arenig shows the development of the main Ordovician transgression in the shallow epicontinental shelf basin with a carbonate type of sedimentation.

The carbonate rocks of the Lasnamägi Regional Stage have served for centuries as the main building material for Tallinn. The town wall, the dwelling houses, churches and many other buildings in the old town have been built of these rocks. Currently the carbonates of the Lasnamägi as well as underlying stages are mined in three large quarries (Harku, Väo, Maardu) in the environs of Tallinn.

L. Põlma, S. Mägi

Third day

The main task of the day is to get acquainted with the major Estonian mineral resources — phosphorites and oil shale, and also with the associated Ordovician rocks.

Stop 3:1 — **the Maardu open-cast pit**

The open-cast pit lies east of Tallinn, on both sides of the Leningrad highway.

In the Maardu phosphorite deposit, the reserves of P_2O_5 are small. Phosporite has been excavated here since 1923, and the major part of the reserves is already exhausted. The deposit is subjected to surface mining since the depth of the productive seam does not exceed 20 m. The average section of rocks exposed

Quaternary mellow and sandy loam	0.2—1.0 m
Ordovician limestones and dolomitic limestones (for detailed subdivision see 2:4)	2—16 m

The Leetse Formation

Glauconitic sandstone, more or less argillaceous	1.5—2.2 m

The Türisalu Formation

Bituminous argillite (*Dictyonema* shale)	2.5—4.0 m

The Kallavere Formation, Suurjõe Member

Strongly pyritized fine-grained quartzose sandstone	0.02—0.10 m
Weakly cemented fine-grained quartzose sandstone with fragments of phosphorus-bearing valves of brachiopods	0.60—0.80 m

The Kallavere Formation, Maardu Member

Fine-grained quartzose sandstone with a small amount of valves of brachiopods or their fragments	2.0—3.0 m
Fine-grained quartzose sandstone rich in complete or fragmentary phosphorus-bearing valves of brachiopods	0.2—1.6 m
Fine-grained quartzitic sandstone with occasional valves of brachiopods	2.5 m

In the Maardu deposit the average thickness of the productive seam equals 1.0 m. The mean content of the mineral component (P_2O_5) reaches 10—12 per cent. The phosphorite layer is represented by fine-grained quartzose sands and sandstones containing phosphorus-bearing valves of brachiopods (the so-called *Obulus* conglomerate). The valves consist of phosphatic matter — fluor-carbonate-apatite with an admixture of clayey matter and fine scattered pyrite. The black colour of the valves is due to the latter. P_2O_5 concentration ranges from 35 to 37 per cent in the valves.

The open-cast mining of phosphorite is performed according to a complicated scheme. It starts by removing the top soil which is laid aside for succeeding reclamation of the exploited areas. The upper part of the limestone is subjected to selective processing. The mined limestones are used for manufacturing road metal; for these purposes a special plant has been built. The rest of the ballast matter is excavated by means of a dragline and disposed in a waste dump. The productive seam is loosened by using excavators and transported to the concentration plant. The exploited areas are reclaimed by afforestation or used as kitchengardens by workers of the enterprise.

Estonian phosphorites are easy to concentrate by means of flotation. In the Maardu concentration plant the cation method of flotation is used which allows to extract 80—85 per cent of the useful component. The obtained concentrate with a 27—28 per cent P_2O_5 content is used for manufacturing superphosphate at the chemical plant. The undesirable components (MgO and Fe_2O_3), which as a rule tend to hamper the concentration and the processing of phosphorite, occur in the Maardu phosphorite in insignificant amounts and do not exert any remarkable influence on its processing. In the mining of phosphorites difficulties arise due to the self-ignition of the overlying *Dictyonema* shale in waste dumps. The burning shale pollutes the atmosphere with smoke and eliminates the possibility of land reclamation in the area. At present much attention is paid to the elaboration and application of measures aimed at a safe bedding of *Dictyonema* shale and at preventing its self-ignition. The commercial reserves of Maardu phosphorite are not great. In Estonia the main phosphorite supplies are concentrated in the Rakvere District, where a phosphorite bed (3—10 m thick, mean P_2O_5 content 10—14%) covers an area of 1000 km^2. In the Rakvere District the phosphorites lie at a depth of 10—15 to 200 m; thus they can be produced by underground mining, mostly. At the present time these areas are subject to extensive prospecting. The Rakvere phosphorite area will be taken into exploitation in the nearest future.

E. Mustjõgi

Stop 3:2 — **Aluvere quarry**

In the Aluvere quarry, west of the Rakvere-Kunda railway, immediately south of the Tallinn-Narva highway the following sequence of the Middle Ordovician is exposed:

Jõhvi Regional Stage, Jõhvi Formation

4.8 — Aluvere Member: light grey, in weathered state yellowish, predominantly medium argillaceous, microcrystalline, fine organodetritic, medium-bedded to seminodular limestone. The upper half of the member contains an interbedding of limestones and marls. The lower boundary is characterized by metabentonitic intercalation of up to 4 cm in thickness.

Idavere Stage, Vasavere Formation

2.2+ — thin and medium scale interbedding of argillaceous limestones, marls and metabentonites. Kukersite kerogen is frequently present in limestones and marls, both as scattered grains and thin intercalations. The most distinct kerogen intercalation (3 cm) can be observed at a depth of 6.25 m. At least 5 white to dark grey plastic bands of metabentonitic clays (2—5 cm in thickness) occur. They are described at depths of 5.32; 5.47; 5.55; 6.58 and 6.75 m.

The carbonate rocks in the Aluvere quarry are referred to open shelf deposits of medium depths, related with the stabilization stage of the basin. They have served as raw material for manufacturing cement.

More than 150 species of macrofossils and about 20 species of ostracodes have been reported from the Aluvere quarry. The following species are characteristic of the Jõhvi Formation: *Clinambon anomalus* (Schlotheim), *Estlandia pyron silicificata* Öpik, *«Chasmops» wenjukovi* (Schmidt), *Bothriocidaris pahleni* Schmidt and *Carinobolbina carinata* (Krause) as well as the species in common with the underlying Vasavere Formation: *Clitambonites schmidti epigonus* Öpik, *Porambonites baueri* Noetling, *Platystrophia lynx lynx* (Eichwald), *Polyceratella aluverensis* Sarv.

The Vasavere Formation is characterized by *Phylloporina aluverensis* Männil, *Kullervo aluverensis* Öpik, and others.

L. Põlma, L. Hints

Stop 3:3 — **the October open-cast pit**

The Baltic Oil Shale Field plays an important role as a supplier of fuel to the north-western industrial areas of the European part of the Soviet Union. Three large deposits — the Estonian, Leningrad and Tapa ones — are located on its territory (Fig. 13). The first two are exploited. The kukerites of the Baltic Oil Shale Field are referred to sapropelites and considered to belong to the best in the world (see Бауков, Котлуков, ред., 1973; Бауков, Мустйыги, ред., 1968).

The Estonian deposit is the largest one, forming approximately 80 per cent of the oil shale commercial reserves of the Soviet Union. This deposit covers an area of 3700 km^2 in the northern part of the Estonian SSR. The northern border is erosional in the east; the border conventionally coincides with the Narva River, in the west, and in the south — with the isopach of a 1.4-m-thick oil shale seam.

Oil shale is produced in seven mines and four open-cast pits. The total annual output reaches 30 million tons of commercial oil shale. Mining is hindered by the complicated structure and varied depths of the bottom of the productive seam, strong jointing and abundant karst belts in rocks, erosion of the seam along buried valleys, and heavy water flows in deposits.

All the acting mining enterprises are located in the central and eastern parts, i. e. in the richest areas of the deposit. The lar-

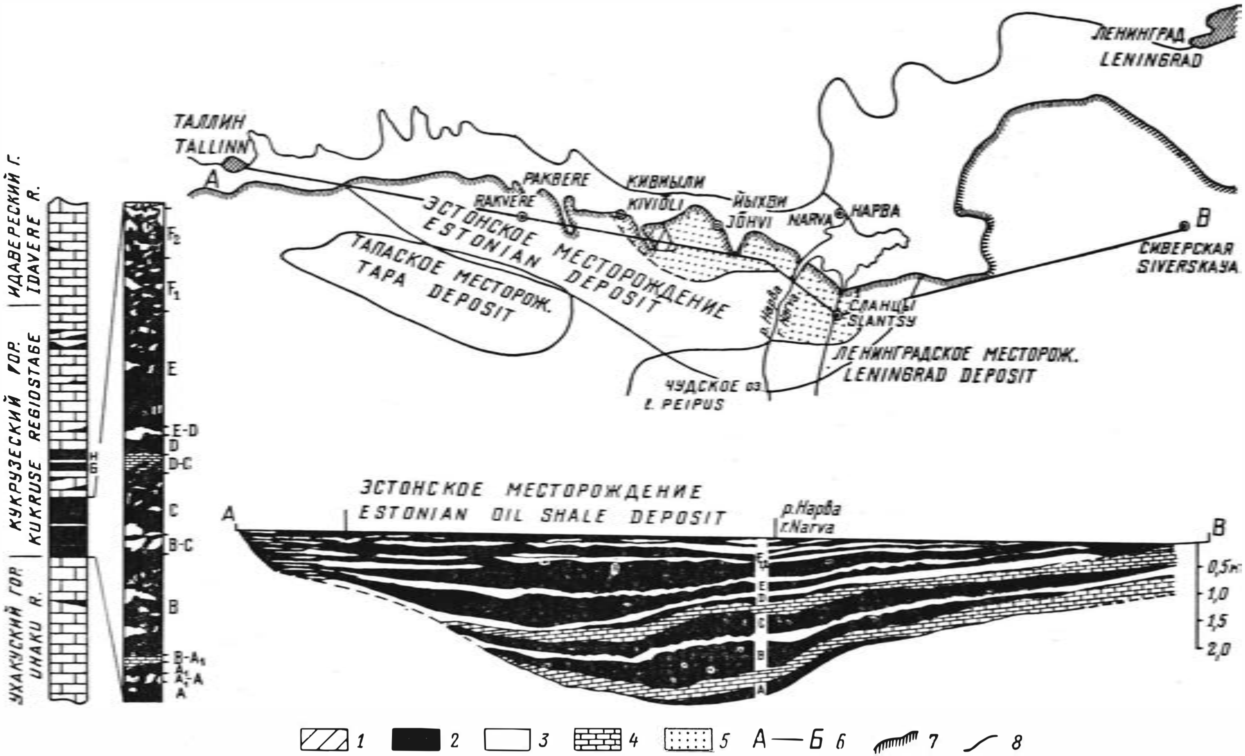


Fig. 13. Sketch map of the Baltic oil shale basin and a profile of the productive seam: 1 — the open-cast pit «October»; 2 — oil shale (content of the organic matter [OM] 15—40%); 3 — kerogen-bearing limestone (OM 5—10%); 4 — limestone (OM 4%); 5 — area of the deposit under exploitation; 6 — line of the profile; 7 — northern border area of the Kukruse Regiostage; 8 — commercial border of the deposit.

gest oil shale producing enterprises are the Estonia mine and the October open-cast pit with their annual outputs of 5 million tons and over 4 million tons, respectively.

The main oil shale consumers are the power engineering (about 80%) and shale processing (about 20%) industries.

Two of the world's largest electric power stations, which work on the basis of thermal energy derived from oil shale combustion, are situated in Estonia. These are the Baltic Thermal Power Station and the Estonian Thermal Power Station with a total capacity of over 3 million MW. The by-product of the combustion of oil shale at power stations is ash, which is widely used in the building materials industry for producing high-quality shale ash Portland cement, shale ash concrete, as well as in the manufacture of silica bricks; in agriculture it serves as an agent for the deoxidation of sour soils, and in road building — for strengthening the road foundation.

Oil shale is processed at two plants in the town of Kohtla-Järve. The main products are shale tar, gas, natural benzine, watersoluble phenols, solvents, antierosive agents for soils — nerosine, etc. The main primary product — shale tar — provides a basis for the production of high-quality fuel oil, oil for impregnating timber, benzine, benzene, coke for carbon electrodes, tanking agents, lacquer-like coating materials, mastics, bitumen-like substances, plug-up resin, etc.

In recent years the application of kukersite has been considerably expanded. Kerogen concentrate (kerogen-70) obtained by the flotation method, is used as a filler in the manufacturing of various plastics, porous, ebonitic and rubber products.

Foundation has been laid to a new direction of kerogen utilization — oxidational destruction. This method yields a mixture of saturated carboxylic acids used in the production of synthetic and fiber materials and serves as a plant growth stimulator — 0.2—1.0 kg per ha increases the yielding capacity about 15—20 per cent.

From the geostructural point of view the Estonian oil shale deposit is located on the southern buried slope of the Baltic Shield of the East European Platform.

Oil shale is related to the Middle Ordovician Uhaku, Kukruse, Idavere, Keila and Nabala Regional Stages. The richest oil shale reserves are connected with carbonate rocks of the Kukruse Regiostage (Upper Llandeilo), where up to 30 oil shale layers are counted within the interval of 12—17 m. The productive beds are related to the lower part of the Kukruse

Regiostage where the thickest and constant oil shale layers form the productive seam of the oil shale deposit (Fig. 13). The complicated structure of the productive seam is caused by frequent interbedding of oil shale layers (from the bottom to the top specified by the indexes A, A_1, B, C, D, E, F_1, F_2) of different quality, and limestones intercalations (from the bottom to the top B-A_1, B-C, D-C, E-D) of different composition. The oil shale layers comprise limestone concretions of variable form (intercalations, lenses, irregular nodules) and size (from some centimetres to 30 cm).

In the oil shale seam the share of limestones increases from the central part of the deposit towards its marginal areas, whereas that of kukersite decreases in the same direction. For these reasons the southern and western geological borders are determined by genetical thinning-out of the oil shale layers; they are replaced by marls, argillaceous limestones and kerogen-bearing limestones.

Oil shale is a sedimentary thin-layered terrigenous-carbonate rock of tawny colour. It is rich in organic matter — kerogen with abundant detritus of marine organisms. Oil shale burns in the flame of a match, and smells of burnt rubber.

Kukersite is made up of three main components: terrigenous (clastic) material, organic matter (kerogen) and carbonates.

The terrigenous material is represented by quartz, orthoclases and hydromica, 2—30 μkm in grain size.

Kerogen is a macromolecular matter, insoluble in common organic and alkaline solvents. Thermal processing of kerogen at 500—550°C yields a relatively large amount of liquid and gas products. The elementary kerogen composition is characterized by a high hydrogen content (9—11%). The organic matter of phytoplankton which has undergone decomposition in the process of sedimentation and diagenesis serves as the initial material for kerogen.

The carbonates of kukersites are dominated by calcite with an inconsiderable amount of aragonite, dolomite and magnesite, with the grain size ranging from 5—20 μkm to some mm.

The research into the Estonian deposit as a large raw material source started as late as 1916, while regular and large-scale investigations have been performed since 1945. The occurrence of one productive seam, its permanence along the strike and capwise, and the gentle dip have enabled to apply the simplest exploration technique —core drilling.

In the course of the exploration and exploitation of the deposit, the main regularities of the variability of parameters of the productive seam have been established. One should point

Prime qualitative and quantitative oil shale characteristics of the Estonian deposit

Indices of the oil shale seam	Unit of measure	In the Estonian deposit as a whole	In the exploited part
Depth of the bottom	m	5—170	5—65
Total thickness of the seam	„	1.35—3.5	2.3—3.5
Summary thickness of oil shale layers (below STL)	„	0.8—2.8	1.6—2.8
Organic matter content on STL	%	15—40	25—40
Ash content on STL	„	58—35	49—35
Specific calorific value on total thickness	ccal/kg	1000—2350	1700—2350
Specific calorific value on STL	„	1250—3450	2000—3450
Tar yield according to Ficher on STL	%	9.0—25.5	14.5—25.5
Commercial oil shale yield	„	35—66	55—66
Specific calorific value of commercial oil shale	ccal/kg	2150—330	2650—3300
Reserves on STL	mlrd. t	8.0	1.3

out here that the thickness of the seam, the capacity of oil shale, and the tar yield decrease, and the share of non-organic matter (rocks) in the seam, the ash content in oil shale, and the bedding depth increase from the central (exploited) part of the deposit towards its margins. At that these tendencies are more rapid southwards than westwards.

Qualitatively the oil shale of the Estonian deposit is referred to low quality, fine-grained rich in ash solid combustible minerals, which gives a high tar yield and serves as a complex raw material.

The section of the October open-cast pit exposes the rocks of the Uhaku, Kukruse (Llandeilo) and Idavere (Caradoc) Regional Stages of the Middle Ordovician (Fig. 13).

The Uhaku Regiostage is represented by greenish argillaceous limestones with interlayers of marls, marly oil shale and kerogen-bearing limestones.

The Kukruse Regiostage is dominated by organodetrital limestones of a thin-layered to nodular structure, often with abundant kerogen-bearing (yellowish grey), seldom with argillaceous (greenish grey) intercalations of oil shale (from thread-like one to 0.6 m in thickness), marls and kerogen-bearing marls. At the base of the stage there are light successive oil shale layers (A-F_2), which form the oil shale deposit (productive seam). The lower boundary of the stage proceeds along the bottom of the oil shale layer A.

The Idavere Regiostage is composed of greenish grey organodetrital argillaceous limestones with abundant marl intercalations and rare bands of oil shale and kerogen-bearing marls. The lower boundary proceeds along a double pyritized discontinuity surface.

In the Kukruse Regional Stage occur numerous well-preserved fossils (according to Rõõmusoks, 1970, more than 300 species have been established). In this respect the Kukruse assemblage is the richest in the Estonian Lower Palaeozoic, and members of the excursion will have a good opportunity to collect different fossils.

O. Morozov

This day will include the study of the Middle and Upper Ordovician in North Estonia from Tallinn to the settlement of Kohila. Of special interest are the bioherms or carbonate mounds of the East Baltic Ordovician in the vicinity of Vasalemma (stop 4:2).

Stop 4:1 — **Peetri**

In the northern slope of Peetri hill. 0.3 km west of the Tallinn-Keila highway, the following Middle Ordovician sequence (from top) is exposed:

Jõhvi Regional Stage, Jõhvi Formation

4.40+ — Aluvere Member: light grey with greenish of blue shades, fine organodetritic, medium-bedded, argillaceous limestone, in the upper part (2 m) with intercalations of marl. The lower boundary is marked by a layer (3—5 cm) of metabentonite.

Rocks of the Jõhvi Regional Stage are rich in fossils. In addition to the species mentioned at stop 3:2, the Jõhvi Formation here is characterized by *Illaenus jevensis* Holm and *Pseudotallinnella scopulosa* Sarv, as well as by species in common with the Idavere Regional Stage: *Platystrophia chama* (Eichwald), *Mastopora concava* (Eichwald), *Rectella zieckerensis* Schallreuter etc.

Idavere Regional Stage, Vasavere Formation

0.42 — light grey, fine organodetritic, medium-bedded, pure to argillaceous limestone with sparse kerogen, in the lower part. 10 cm upwards from the base a metabentonitic layer (3—5 cm) occurs.

In the Peetri locality of the Idavere Regional Stage 23 species have been identified.

Kukruse Regional Stage, Viivikonna Formation

0.70 — Peetri Member: light grey, fine organcdetritic to fine organodetrital ,thin to medium-bedded, in places seminodular, pure to argillaceous limestone with thin (2—3 cm) bands of browncoloured thin to medium-bedded kukersite. At the upper boundary of the Kukruse Regional Stage at least 6 pyritized discontinuity surfaces occur.

An inclinal pit is located at about 50 m north-east of the exposure. According to A. Rõõmusoks (Рыымусокс, 1970) the Kukruse Regional Stage is exposed there in its total thickness (8.25 m). A typical nodular and seminodular structure of rocks may be observed. The 25 described species of macrofossils of the Kukruse Regional Stage in Peetri locality include *Bilobia musca* (Öpik), *Ciitambonites schmidti* (Pahlen) and others.

The rocks cropping out on Peetri hill are referred to openshelf sediments of medium depths.

L. Põlma, L. Hints

Stop 4:2 — **Vasalemma**

In the old quarry of Vasalemma, 40 km south-west of Tallinn, the Vasalemma Formation crops out to a thickness of 4—5 m. The formation includes the upper half of the Keila Regional Stage and the Oandu Regional Stage of the Middle Ordovician (Caradoc) in West Estonia. This quarry contains the uppermost (third) member of the formation (see Table 3). The Vasalemma Formation is distributed as a belt (2—5 km wide) of outcrop between the settlements of Risti (West) and Saku (East) (about 40 km) in NW Estonia (Мянниль, 1966).

The Vasalemma Formation rests upon the Pääsküla or Saue Members of the Keila Regional Stage, which is characterized by the presence of pelletal material (3—15%) in carbonate rocks. On the roof of the formation, in depressions of bedrock topography, a conglomerate layer (up to 12 cm) is rarely

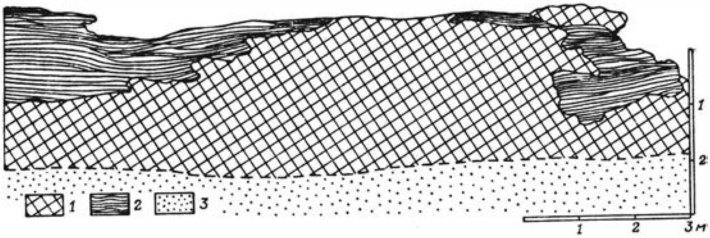


Fig. 14. Section of the Vasalemma Formation in the western part of the quarry: 1— carbonate mound; 2 — bedded grained (cystoid) limestone; 3 — dump.

found, which may be correlated with the Tõrremägi Member of the Rägavere Formation of the Late Oandu age. The conglomerate layer is overlain by cryptocrystalline (aphanitic) limestone of some centimetres in thickness, which is already of a Rakvere age.

The rocks of the Vasalemma Formation are prevailingly typical shoaly granular deposits, which form a narrow belt surrounded by normal-marine shelf sediments. They comprise developments which at different times and by different authors have been named differently: reefs, bioherms, organic buildups, and currently, after V. Jaanusson (1979) carbonate mounds.

The Vasalemma organodetritic limestones have served for centuries as a first-class building material. Currently they are worked up into road metal.

Two main rock types of the Vasalemma Formation (of the upper member, prevailingly) are exposed in the wall of the quarry at the observation point (Fig. 14). These two types are dominated by carbonate mounds, composed of pure (the content of terrigenous material up to 3—6%), cryptocrystalline, with considerably rare (below 10%) predominantly fine unrounded organodetritus, greenish grey (in places bluish), fine-bedded to massive limestones. Pelletal material occurs in small amounts (usually below 2%). In places, especially in the marginal areas of carbonate mounds, greenish grey argillaceous marls are distributed in the form of irregular inclusions, lenses and intercalations. The carbonate mounds vary in form, reaching 10 m in height and 50—60 m (occasionally 300 m) in width. They comprise concentrations of more or less unbroken skeletons of different organisms (bryozoans, echinoderms, algae, receptaculids, tabulate corals), forming in some places 25 or more per cent of the whole bulk of rocks. However, these organisms are likely to have never formed a regular organic buildup in the mounds, and therefore we tend to consider those formations as carbonate mounds.

The second rock type at this stop is represented by pure (the content of terrigenous material usually below 2%), coarse, organodetrital, light grey, in pyritized state dark grey, weathered parts to yellow, medium- to thick-bedded limestone; lamination is predominantly induced by stylolites. The content of organodetritus amounts to 55—65%, the content of medium-crystalline sparry calcite reaches 10—15%. In the lower member, especially in the basal part, detritus consists prevailingly of bryozoan fragments, replaced upwards by echinoderm detritus (mainly cystoid) (Пылма, 1977).

The carbonate mounds and surrounding deposits are characterized by *Cyathocystis rhizophora* Schmidt, *Hemicosmites pulcherrimus* Jaekel, *Herpetocystis vajgatschensis* (Jelt. et Stuk), *Eofletcheria orvikui* (Sokolov), *Stenopareia ava* (Holm), *Solenopora spongoides* Dybowski and more than 40 species of bryozoans. In the Vasalemma Formation the last-mentioned group forms an half out of the total number of macrofossil species.

The third type of rocks is represented in the lower unit. These intercalations are composed of argillaceous, greenish grey, microcrystalline, fine organodetrital, seminodular limestones, which do not crop out at this stop. The following species have been reported from these limestones: *Estlandia pyron silicificata* Öpik, *Horderleyella kegelensis* (Alichova), which serve as reliable evidence of the Keila age of the surrounding rocks.

The study of cores from more than 50 borings shows that coarse organodetrital limestones form 62%, carbonate mounds 31% and argillaceous limestones 7% of the Vasalemma Formation.

L. Põlma, L. Hints

Stop 4:3 — **Paekna (Nõmmküla)**

Aphanitic limestones (calcilutites) crop out in the thickness of up to 2.7 m in the Paekna quarry. They belong to the upper part of the Paekna Formation of the Nabala Regional Stage (uppermost Middle Ordovician).

These rocks may be characterized as light grey (white), slightly yellowish, within the topmost 1 m weakly weathered (yellowish grey), pure, cryptocrystalline (aphanitic), with sparse fine organodetritus, thin to medium-bedded limestones.

Pyritized discontinuity surfaces at depths of 1.80; 1.88 and 1.96 m from the top.

The rocks of the above sequence are referred to shelf deposits of medium depth, where the influx of terrigenous material was limited.

More than 50 species of fossils have been found in the Paekna quarry, including *Nicolella oswaldi mediofida* Alichova, *Vellamo verneuili* (Eichw.), *Chasmops eichwaldi* (Schm.), *Tvaerenella pretiosa* Sarv, *Cyathochitina costata* Grahn, *Conochitina robusta* Eisenack etc.

L. Põlma, J. Nõlvak

Stop 4:4 — **Urge**

Upper Ordovician limestones of the Vormsi Regional Stage referred to the Saksby Member of the Kõrgessaare Formation crop out with thicknesses of up to 1.30 m in the old Urge quarry.

The limestones are pure to medium argillaceous, microcrystalline, fine organodetritic, light grey with yellowish stains (weathered), thin to medium-bedded, in the upper part to lenticular seminodular and even nodular. The thickness of occasional marl bands does not exceed 3 cm. The interval of 0.30—0.40 m below the limestone roof displays at least 6 discontinuity surfaces of different morphology with pyrite-phosphate impregnation.

The limestones of the Urge quarry are referred to the open-shelf sediments of medium depth associated with the transgressive stage in the development of the basin.

In this section have been identified: *Catenipora wrighti* Klaamann, *Porambonites gigas* Schmidt, *Triplesia insularis* (Eichw.), *Acanthochitina barbata* Eisenack etc.

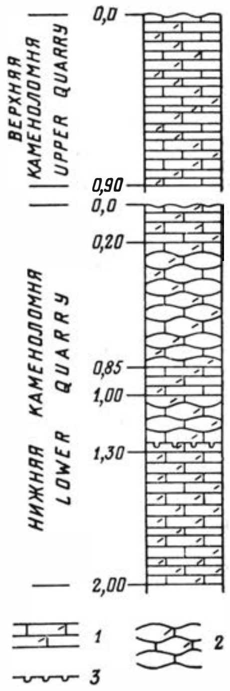
L. Põlma, J. Nõlvak

Stop 4:5 — **Lohu**

On the left bank of the Keila River, 200 m south of the Lohu settlement, there is an old quarry, where in its lower section about 2 m of limestones are cropping out. These sediments are considered as the upper part of the Moe Formation of the Pirgu Regional Stage.

The sequence is characterized (see Fig. 15) by prevailingly pure, micro- to cryptocrystalline, fine organodetritic (predomi-

Fig. 15. Section of the Lohu outcrop: 1 — fine organodetritic limestone; 2 — nodular limestone; 3 — discontinuity surface.



nantly algal fragments), in the lower part fine organodetrital, light grey, with slightly yellowish (in the upper part) or slightly brownish (in the lower part) shades of colour, medium-bedded to medium nodular limestone. A pyritized discontinuity surface is observed at about 0.7 m from the bottom of the quarry.

The section continues immediately in a small overgrown quarry with an old lime-kiln. 50 m towards the road there is an outcrop of pure, prevailingly microcrystalline, fine organodetritic, thin to medium-bedded, light grey limestone of a slightly brownish shade of colour, exposed in a thickness of 0.90 m.

The rocks in Lohu quarries are assigned to the regressive deposits of a partly isolated, relatively shallow-water shelf.

The following fossils have been reported in the Lohu quarry: *Aulacopium aurantium* Oswald, *Stromatocerium canadense* Nichols et Murie, *Plectatrypa sulevi* Jaanusson, *Conochitina wesenbergensis brevis* Eisenack, *Tanuchitina bergstroemi* Laufeld, etc.

L. Põlma, J. Nõlvak

Fifth day

This day is designed to providing a review of the Lower Silurian sequence in Estonia, from the Middle Llandovery (the Raikküla Regional Stage) to the Middle Wenlock (Jaagarahu Regional Stage). Special emphasis is laid on the facies and palaeontology of the Upper Llandovery section in West Estonia, which have much common with the corresponding sections in Scandinavia and Britain.

Stop 5:1 — Laukna (**Pakamägi cliff**)

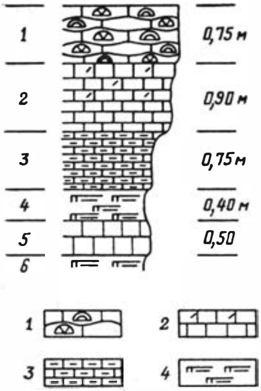


Fig. 16. Section of the Pakamägi Cliff: 1 — coral-stromatoporoid limestone; 2 — calcilutite; 3 — flaggy argillaceous calcilutite; 4 — laminated dolomitic mudstone.

An ancient cliff assigned to the Yoldia stage of the Baltic Sea, 5 km northeast of the Koluvere castle. In the section shallow-water lagoonal dolomitic mudstones, calcilutites and coral-stromatoporoid boundstones from the middle part of the Raikküla Formation (Middle Llandovery) are exposed as follows (Fig. 16):

1. 0.75+ m — coral-stromatoporoid biostromal bank of a nodular structure and micritic matrix, composed of tabulates *Parastriatopora celebrata* Klaam., *Sinopoto operta* Klaam., *Paleofovosites balticus* Sok. and stromatoporoids *Intexodictyon avitum* Nestor, *I. Olevi* Nestor, *Ecclimadictyon macrotuberculatum*(Riab.);

2. 0.80 m — light grey calcilutite; the upper part massive, the lower one thin-bedded;

3. 0.75 m — dirty-grey flaggy argillaceous calcilutite alternating with intercalations and films of dolomitic mudstones. The intercalations thin out progressively downwards, and the rock passes upwards into a laminated one;

4. 0.40 m — greenish grey flaggy to laminated dolomitic mudstone with polygonal mud cracks;

5. 0.50 m — greenish yellowish grey massive, in weathered state brecciform calcilutite;

6. 0.20+ m — greenish grey laminated dolomitic mudstone, the same as layer 4.

The rocks exposed have developed during one of the first regressive phases of the Silurian Sea and are related to the first tongue of lagoonal deposits which is preserved in the Estonian sequence. The section shows the transition from typical lagoonal deposits (bottom) to more or less normal-marine sediments (top).

H. Nestor

Stop 5:2 — **Päri quarry**

A broad, shallow quarry, 5 km south-west of the Kullamaa village and 1 km north-west of the Tallinn-Virtsu highway exposes Pentamerus-limestone of the Rumba Formation marking the beginning of the Late Llandovery transgression in Estonia. These limestones with *Pentamerus oblongus* are assigned by us to the deposits of the inner part of the open shelf. At this stratigraphic level they are characterized by cyclic changes of the clay content, rock structure and composition of organic remains in the section. The lower part of a cycle (rhythm) is usually composed of greenish grey calcareous mudstone; the middle (and the thickest) part consists of grey bioclastic micritic calcarenite of a nodular or seminodular structure, whereas the upper part is made up of yellowish grey calcilutite and brownish bituminous marl. A rich assemblage of tabulate and rugose corals and stromatoporoids is distributed in the middle part of the cycle (rhythm); massive accumulations of *Pentamerus oblongus* define the transition from the middle part of the cycle to the upper one. Note that the *Pentamerus* accumulations are rather often composed of shells of equal size, which are compactly packed one into another.

The Päri quarry, which in the publications of the 19th century was widely known under the name of Kattentack, serves as a type locality of a great variety of fossil species, particularly corals and stromatoporoids. Besides *Pentamerus*, the typical species are *Clathrodictyon variolare* (Rosen), *Mesofavosites obliquus* Sokolov and *Arachnophyllum diffluens* M. Edw. et H.

Flakes of the oldest Baltic vertebrates — *Thelodus sp.* and *Gomphonchus sp.* — have been found in that locality.

The section offers a good opportunity for collecting corals and stromatoporoids which are widely distributed in the Upper Llandovery of the Northern Hemisphere.

E. Klaamann

Stop 5:3 — **Anelema quarry**

The large Anelema quarry, 3 km north-east of the Pärnu-Jaagupi settlement, offers an exposure of yellowish dolomites (the upper 2 m) and greenish grey dolomitized limestones (the lower 3—4 m) of the Wenlock Jaani Formation. According to their structure, the rocks of the upper part of the section are referred to the so-called bahamitic type, consisting of fine pellets.

The lower part of the section is more argillaceous, of an indistinct nodular texture. Local secondary changes in rocks occurring near the vertical cracks often from cream-coloured pockets surrounded by cherry-red impregnation. The scarce, poorly preserved shelly fauna is related to the bedding planes. It is dominated by atrypids, dalmanellids, gastropods and cephalopods. Microorganisms, especially scolecodonts, are abundant. Of conodonts V. Viira has identified *Ozarkodina ranuliformis,* V. Nestor — has determined the chitinozoans *Conochitina claviformis, C. cf. mamilla, C. cf. leptosoma, Ancyrochitina primitiva* and *A. pachyderma.* These data permit us to refer the Anelema section to the level of the chitinozoan zone of *Conochitina claviformis*, corresponding to the upper part of the Jaani Formation. Proceeding from the macrofacies princnple of definition of the Silurian formations in the North Baltic, it seems reasonable to establish a new formation on the basis of the Anelema section, which will be the lateral analogue of the Paramaja Formation.

E. Klaamann

Stop 5:4 — **Jädivere outcrop**

West of the bridge on the Tallinn-Pärnu highway, in the bank of the Enge River, there is a high section of monotonous light grey marls assigned to the relatively deep-water deposits of the Late Llandovery-Wenlock transgression. Benthic macrofauna appears to be entirely lacking. Of microfossils, V. Nestor has found *Conochitina proboscifera* and *Desmochitina densa. Pterospathodus amorphognathoides,* identified by P. Männik, dates the outcropping marls to the corresponding zone at the Llandovery-Wenlock boundary. According to some other data (dipping, hypsometry) the exposed section is conventionally referred to the lower part of the Mustjala Formation of the Jaani Regional Stage.

E. Klaamann

Stop 5:5 — **outcrops in the Valgu village**

Three sections at the drainage canal and in the bank of the Valgu River (see Fig. 17) reflect the development of the Upper Llandovery transgression represented by an alternation of openshelf deposits (the Rumba Formation) with slope deposits (the Velise Formation).

At point 1 light grey argillaceous bioclastic Pentamerus-limestone of the upper part of the Rumba Formation crops out.

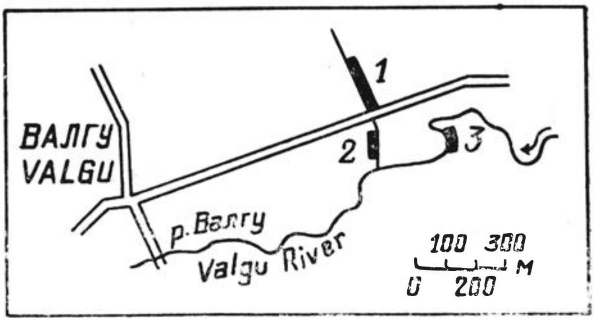


Fig. 17. Localities in the Valgu village.

In the topmost part of the limestone there are abundant discontinuity surfaces (hardgrounds). They are smooth, with abundant variegated holes (up to 2 cm in depth), surrounded by intensive bluish pyrite impregnation. Frequently the abrupt discontinuity surface cuts the shells of *Pentamerus oblongus* buried in life position. The exposure also offers occasional tabulates *(Paleofavosites septosus)*, stromatoporoids *(Actinodictyon suevicum)* and trilobites *(Fragiscutum rumbaense)*. The microorganisms are represented by occasional elements of *Distomodus staurognathoides* etc.

At point 2 Pentamerus limestone is overlain by argillaceous fine-nodular limestones and marls (the Velise Formation). The fauna of the latter is sharply different. A deep-water association occurring here is composed of a variety of brachiopods *(Stegerhynchus borealis, Pentlandella tenuistriata, Dalmanella rosensteinae,* etc.), abundant ostracodes *Beyrichia (Asperibeyrichia) valguensis,* characteristic of the Lower Wisby marls of Gotland. *Apatobolbina simplicidorsata,* and an extremely abundant complex of conodonts: *Pterospathodus cf. celloni, Aulacognathus kuehni, Neospathognathodus ceratoides* etc.

The stratigraphically higher-lying beds of the Velise Formation are exposed in the bank of the Valgu River (point 3). 1.6 m of the section are built up of bluish grey thin-bedded marls with occasional, skeletal detritus and abundant marks of bioturbation. The imprints of large straight or coiled cephalopod shells are to be met in the shelly fauna. A thin (5 mm) cream-coloured metabentonite layer crops out approximately in the middle of the section.

E. Klaamann

Sixth day

Boring sections are the main items of study on the sixth day. They allow to get some idea about the Estonian Lower Palaeozoic in the subsurface area.

Stop 6:1 — **Karinu quarry**

A large quarry of the Rakke Lime Plant, 4 km north-east of the Järva-Jaani settlement. A section of shallow-water limestones and calcarenites, assigned to the Tammiku and Karinu Members of the Tamsalu Formation (Lower Llandovery) is exposed as follows: (from top):

Karinu Member

1. 0.90+ m — light brownish grey laminated slightly dolomitic pelletal limestone. Comprises pebbles of stromatoporoids, biodetritus of brachiopods, bryozoans and echinoderms. *Ecclimadictyon macrotuberculatum* (Riab.), *Clathrodictyon kudriavzevi* Riab., *Paleofavosites limbergensis* Sok., *Mesofavosites bonus* Sok., *Macleodia sp., Heliolites sp., Mendacella sp., Leptostrophia aff. compressa* (Sow.), *Panderodus sp*., have been identified.

In the northern part of the quarry a series of discontinuity surfaces (hardgrounds) occurs in the middle of the bed. They separate thin intercalating layers of yellow calcilutite and multicoloured calcirudite with poorly rounded intraclasts of calcilutite and pebbles of stromatoporoids and corals.

The discontinuity surfaces are coated with a thin goethitic crust of a reddish brown or yellowish colouring. Southwards the complex with hardgrounds thins rapidly out. It contains *Pachystylostroma ungerni* (Rosen), *Catenipora septosa* (Klaam.), *Protaraea sp., Rhynchotrema sp.*

2. 0.30—0.40 m — biostromal stromatoporoid bank composed of densely packed irregular nodular coenostea, for the most part buried in situ. Rounded coenostea occur also rarely. The matrix consists of light grey dolomitic mudstone, in the upper part of light pelletal rock. An even erosional discontinuity surface dissects the coenostea and acts as the upper surface for the bank. In the bed *Clathrodictyon boreale* Riab., *C. kudriavzevi* Riab., *Ecclimadictyon microvesiculosum* (Riab.), *E. macrotuberculatum* (Riab.), *E. pandum* Nest., *Paleofavosites karinuensis* Sok., *Mesofavosites sp., Macleodia sp., Propora sp., Acidolites sp., Panderodus sp., Trichodonella ? sp.* occur.

3. 1.60+m — yellowish white, massive *Borealis* bank, composed of valves of the brachiopod *Borealis borealis*. The matrix contains pellets and skeletal psammite in sparry calcite. Scattered white skeletons of stromatoporoids *(Clathrodictyon boreale* Riab., etc.) and tabulates *(Paleofavosites limbergensis* Sok., *Pf. paulus* Sok., etc.) occur. The upper surface of the *Borealis* bank is a very uneven erosional surface, with single benches and purplish red goethite impregnation.

A considerably thicker section of the *Borealis* bank crops out in the southern part of the quarry. The data of the Karinu boring permit to evaluate its thickness as 8.1 m.

The deposits of the Tamsalu Formation exposed in their typical form in the present outcrop developed during the first remarkable shallowing of the basin at the north-eastern margin of the Baltic Silurian basin. They accumulated in a shallow-water high energy environment.

H. Nestor

Stop 6:2 — **Särghaua field station**

Särghaua field station of the Institute of Geology, Academy of Sciences of the Estonian SSR, situated near the town of Türi, serves for the maintenance and study of boring cores and different geological collections (rocks, fossils). The buildings of the field station are reconstructed 19th-century farmhouses. At the field station the boring sections composed of rocks formed in facies different from those of the outcrop area will be demonstrated.

The Cambrian of the Undva boring

The sequence of the Undva boring (Saaremaa Island, West Estonia) is characteristic of the Lower Cambrian in the northern part of the Baltic syneclise. From the subdivisions investigated in the North Estonian outcrop area we can find here only the Lükati Formation and the Voosi Formation a probable shallow-water analogue of the Lontova Formation. Between them lies the palaeontologically weakly characterized Sõru Formation — a typical subdivision for the north-western areas of the Baltic. Higher up in the sequence the Tiskre Formation is missing — it is eroded in the pre-Aisčiai time. The Aisčiai Regional Series is represented by the Soela and Irben Formations. All the younger Cambrian units are eroded in the pre-Ordovician time.

Description of the section (from top):

Pakerort Formation

271.0: sandstones with phosphatic detritus of brachiopods.

Aisčiai Regional Series

271.0 — 303.4: Irben Formation — alternation of clays and siltstones with bioturbal structure of the «kraksten» type. In the lowermost part (289.7—300.8 m) intercalations of brown ooidal iron ore, from 1 to 60 cm in thickness. The casts of *Volborthella, Luekatiella,* poor phosphatic fragments of brachiopods and small pyritized trace fossils occur. The Vergale assemblage of acritarchs has been established here.

303.4—345.2: Soela Formation — light grey, coarse-grained siltstone (in the core represented mainly by brown mud). Grains of glauconite and muscovite, occasional vertical tracks of organisms in clayey intercalations filled with light siltstone.

Livonian Regional Series

345.2—348.2: Lükati Formation — alternation of silty clay, pelitic and coarse-grained siltstones. The rocks are rich in glauconite. *Volborthella, Luekatiella,* and abundant trace fossils.

348.2—373.4: Sõru Formation — light grey coarse-grained siltstone with occasional clay films and intercalations, in the lower part of the interval siltstone passes into quartzose sandstone with clay rolls. Areas of red and ochre-yellow colour are observed; authigenous minerals reveal traces of weathering in the upper part. Fossils are not observed.

Baltic Regional Series

373.4—391.0: Voosi Formation — the lower part is composed of poorly sorted quartzose sandstone with pellets of kaolinite, which in some areas alternate with muscovite-bearing siltstone and greenish grey clay. The upper part of the interval is characterized by frequent interlayering of clays and siltstones, and abundant trails of burrowing organisms. Occasional grains of glauconite, at some levels traces of a secondary oxidation of rocks. Fossils appear to be missing.

391.0: weathering crust of the crystalline basement.

E. Pirrus

Types of Ordovician facies

Much of the territory of the Estonian SSR is referred to the eastern East Baltic structural-facies zone which falls into the northern and transitional subzone. The latter includes Saaremaa Island and the latitudinal belt proceeding approximately between the towns of Türi and Viljandi. South Estonia belongs to the western East Baltic (axial) structural-facies zone.

All the outcrops studied in previous days are referred to the northern subzone. Their characteristic total Ordovician thickness reaches 200 m, out of which Lower Ordovician deposits form less than 15 m, whereas the Middle and Upper Ordovician deposits are of an almost equal thickness. Tremadoc is dominated by terrigenous deposits comprising detritus of inarticulate brachiopods (as it is throughout the East Baltic); Post-Tremadoc Ordovician is represented by a carbonate sequence. Until the upper Middle Ordovician the skeletal debris of fossils is polydetritic, but higher up algal detritus prevails. Arenig is rich in glauconite, goethitic and francolitic ooids are frequent in Llanvirn. The section is practically completely grey here, except the lowermost Arenig beds, which are multicoloured in North-East Estonia. Sediments of this subzone have prevailingly accumulated under shallow shelf conditions.

In the transitional subzone the thickness of the Ordovician rocks varies from 75 m (Ohesaare section) to 200 m. An increase in the thickness of the lower series is prominent. The rocks are represented by alternating assemblages of rocks of northern or axial structural-facies subzones or by transitional types of rocks characteristic of this subzone only (Пылма, 1967). This is accompanied by a general increase in the content of terrigenous material throughout the whole Ordovician. In the Upper Ordovician the share of algal detritus decreases. The rocks of the Lower and lowermost Middle Ordovician as well as those of the Upper Ordovician, in part, are either multicoloured or reddish brown. Sediments of the transitional subzone belong to the shelf deposits which have formed in the basin of more differentiated bottom topography and more intensive tectonic movements than in the northern subzone.

The maximum thickness of the Baltic Ordovician is revealed in the axial structural-facies subzone in the Latvia (249.5 m in the Skrunda boring) (Ульст и др., 1982). In this subzone the Lower Ordovician reaches its maximum thickness (up to 100 m), the above-lying two series are of almost equal thickness. The rocks with a few exceptions are from hard argillaceous to pure clays. Detritus of different systematic groups of fossils is considerably rare. In the Lower and Upper Ordovician there occur a few levels with monodetritus (trilobites). The same part of sequence yields thick intervals of red-coloured rocks. The deposits of axial subzone have accumulated in the open shelf enviroment the bottom of which remained below the level of active water exchange from time to time (formation of graptolitic argillites).

L. Põlma

Types of Silurian facies

The Silurian in Central Estonia and on Saaremaa Island is referred to the eastern East Baltic structural-facies zone; in South Estonia (the boundary proceeds along the Pärnu-Tartu line) we assign it to the western East Baltic structural-facies zone. The main difference between these zones lies in the prevalence of inshore shallow-water deposits in the former, and deep-water deposits in the latter. The latter offers a more complete section and is characterized by increased thicknesses of stages. Thus, e. g. the thickness of the Lower and Middle Llandovery increases 3—4 times (the thickness of the Juuru Regional Stage is about 20 m in the outcrop area, in the south it reaches 60 m; for the Raikküla Regiostage these values are 35—40 and 170 m, respectively). The same picture may be observed for the Upper Wenlock, whereas the Upper Llandovery and Lower Wenlock are more stable on our territory. It should be pointed out that maximum thicknesses are associated with slope facies (e. g. the Raikküla aphanitic limestones with interlayers of graptolitic argillites in the Ikla section, South Estonia). However, the transition to deep-sea depressional facies is accompanied, as a rule, by a decrease in the thickness of deposits. This can be especially clearly observed in the Middle Llandovery, the thickness of which reaches 150 m at the border of the Estonian and Latvian SSR, whereas in the environs of Riga it does not exceed 10 m (in both cases the boundaries are dated by graptolites).

A detailed description of facial differences in deposits by facies zones was given in Chapter 1.3. in connection with the facies-sedimentary and ecological models. For that reason they are not dealt with here any more.

In the Särghaua field station the main attention will be paid to problems concerning both the facies and stratigraphy of the Upper Silurian. The cores of the Kaugatuma and Ohesaare boreholes will serve as the prime subjects of study. The limited volume of this guidebook does not allow us to describe the sections in detail, and therefore here only the stratigraphic subdivision of the above-named sections is presented (the depth of the bottom of the unit is given in m):

Regional Stage	Ohesaare boring 1+2	Kaugatuma boring
Ohesaare	0,04—4.1 (2)	0.5—37.2
Kaugatuma	1.7—67.7 (1)	57.6
Kuresaare	95.1	82.0
Paadla	118.4	114.2
Rootsiküla	155.1	
Jaagarahu	300.0	
Jaani	345.8	
Adavere	372.7	
Raikküla	410.0	
Juuru	437.7	

D. Kaljo

CONCLUSIONS

The Estonian Lower Palaeozoic has been considered classic since the end of the last century. It exhibits a well-preserved sequence, which is practically neither metamorphosed nor faulted, and contains an abundance of fossils. And the most important thing — it has been subjected to detailed studies.

After World War II investigations were started at the Institute of Geology of the Academy of Sciences of the Estonian SSR and the Board of Geology of the Estonian SSR, as a result of which Estonian geology rose to an entirely new level.

All the preceding generations of geologists had mainly relied upon the data obtained through the study of outcrops, and for this reason they had to confine themselves to linear geological observations performed in outcrop areas of stages (see geological map, Fig. 2). The mapping of the territory and the associated extensive boring programme performed by the Board of Geology of the ESSR enabled the geologists to proceed from «linear» or «outcrop» geology to «spatial» or «basin» geology. It stands to reason that such a profound change brought about renovation of both stratigraphy and palaeogeography as well as all the other regional aspects of Estonian geology. It furnished also a basis for the ecostratigraphical studies being purposefully developed at the Institute of Geology in recent years. For the Board of Geology it has contributed to prospecting extensive new oil shale and phosphorite deposits.

Some results of these activities will be demonstrated during the present excursion.

D. Kaljo

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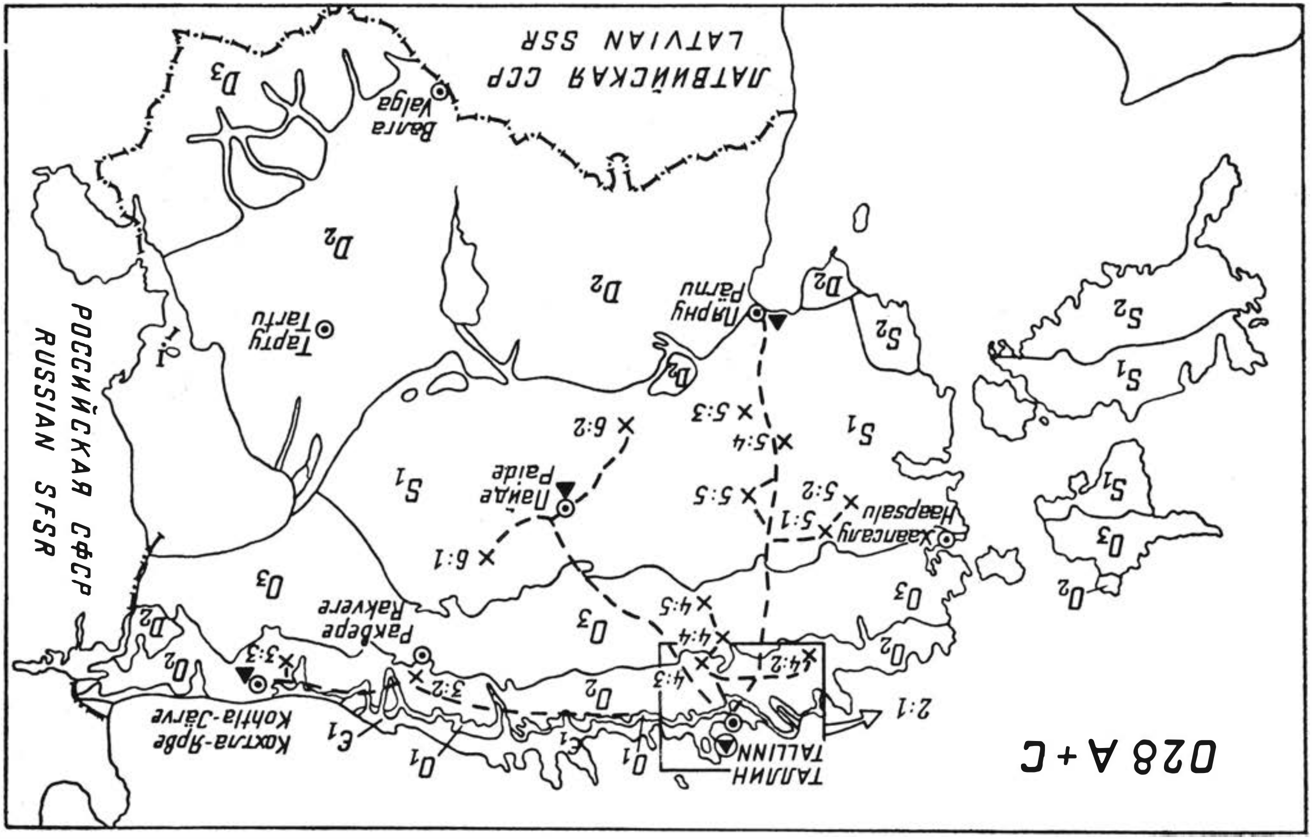

Fig. 2. Geological map of the Prequaternary rocks of Estonia with the route of the excursion 028.

Цена 85 коп.