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POST-STRIPPING PROCESSES AND THE LANDSCAPE OF MINED AREAS IN ESTONIAN OIL SHALE OPEN CASTS

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The present study describes creating a digital map of oil shale surface mining technology and evaluating mining influences on the landscape. The data from the digital map of the Sirgala *open cast show a constant increase in the overburden thickness. Overburden material thickness influences directly the future landscape but it also sets limits to stripping equipment parameters and productivity. The present open cast landscape was divided into four classes: afforested area, area with poor vegetation, graded area, and spoils. The second purpose of the study is saving information in an easily accessible form for the future. For this purpose geographic information system for mining is used.*

Introduction

The minerals of Estonia are excavated in the amount of 10.5 million m^3 per year. Yearly 7.4 million m^3 of oil shale is mined, and half of this is mined in the open cast mines. The total surface mining amount in Estonia is 6.7 million m^3 per year, and 54 % of it stands for oil shale mining. From this data a general rule follows: 1/3 of the volume of mined minerals comes from oil shale underground mining, 1/3 from oil shale surface mining, and 1/3 from surface mining of other minerals.

Mining areas could be divided into five reclamation categories. First – mud excavation area – where mining takes place under water, is no subject for reclamation. Second – clay mining pits – are reclaimed to water storages, ponds or landfills. Third – sand and gravel quarries – are graded or formed as ponds. Fourth – limestone and dolostone quarries – form relatively deep ponds or are filled with waste. Among small-scale mining their reclamation is the most problematical one. Fifth – oil shale, phosphate rock and peat mining areas – are large due to thin horizontal bedding and require special reclamation.

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The largest Estonian surface mines are described as an example of large-scale mining operations and post-stripping processes. These open cast mines are largest by both area and production capacity and so cause also the largest influence to the environment and landscape. These three are the *Aidu*, *Sirgala* and *Narva* oil shale open casts, situating in the deposit wings where overburden thickness is smallest (Fig. 1). On the whole 120 km² of overburden have been stripped in these mines.

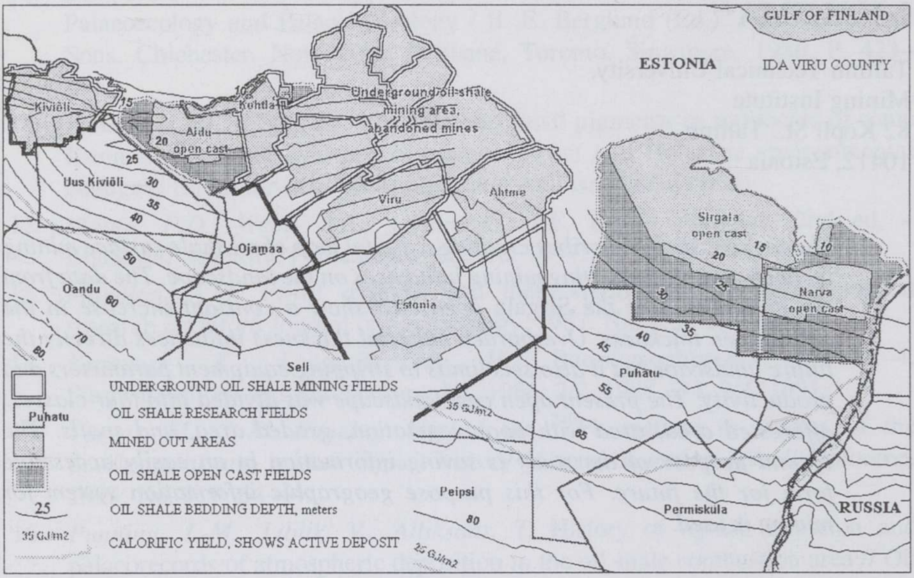

Fig. 1. Estonian oil shale deposit

Calculations and charts in the present paper describe mostly the *Sirgala* open cast as the largest open cast mine in Estonia. Detailed description of the past processes in the mined-out areas let us understand, predict and save the information about several technological and environmental influences. Many of processes explain the reasons of forming the present landscape in these areas. The data about the equipment can help planning next trenches working in similar conditions. The data about steps of technological development of surface mining help us to retain historical data about large mineral extraction areas. A geographically referenced database represents a most suitable tool to study all these problems.

Methods

Geographic information system (GIS) for mining is used for describing and analysing spatial mining-related data. GIS is used for describing, in addition to technological problems, also post-technological processes. The main result is a digital map illustrating the oil shale mining technology. The

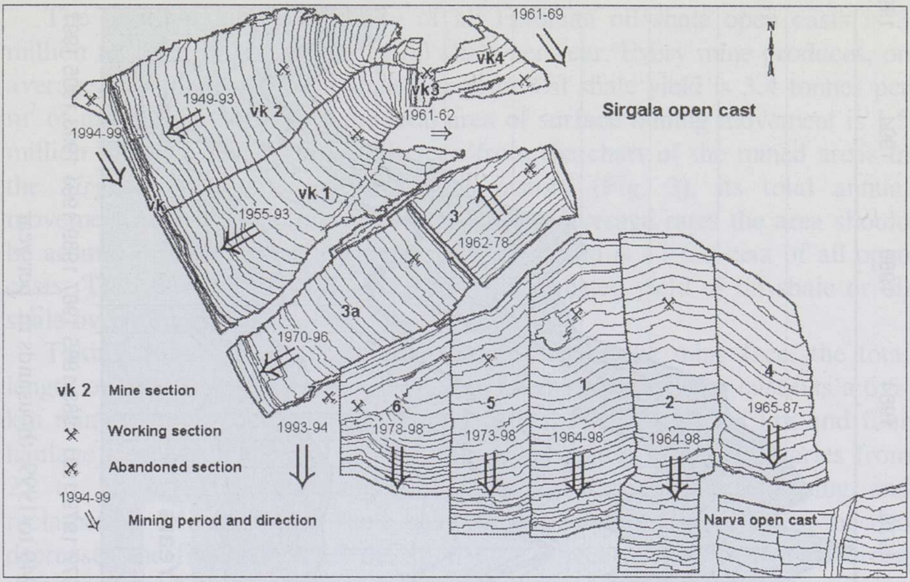

Fig. 2. Mining sections in the *Sirgala* open cast

present study presents the second stage of the map creation at the Mining Institute of Tallinn Technical University. During the first stage underground mining technology was mapped, the second stage includes the map of surface oil shale mining [1, 2]. Information on the map was taken from the technological maps of oil shale open casts, geological investigations, and aerial photographs and from the digital Estonian base map.

The study included the following steps: collecting maps and references about the area, scanning, digitising and vectorising map data. The contours of the blocks mined in every mine section during a year were extracted and mapped. The database includes, in addition, the year of mining, height of the ground above the sea level and overburden thickness. As the result a digital surface mining map was created. The map (Fig. 2) includes stripping data and also aerial photographs and represents a basis for studying stripping dynamics, areas, volumes and landscape situation.

Discussion

Mapping calculations show that the total area of the mined sections in the *Sirgala* open cast is 6,532 ha. Aerial photographs from the year 1996 cover all the area except section No. 4*. Therefore in examples section No. 4 is excluded.

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* Aerial photographs of the eastern zone are missing because of the country border existing there.

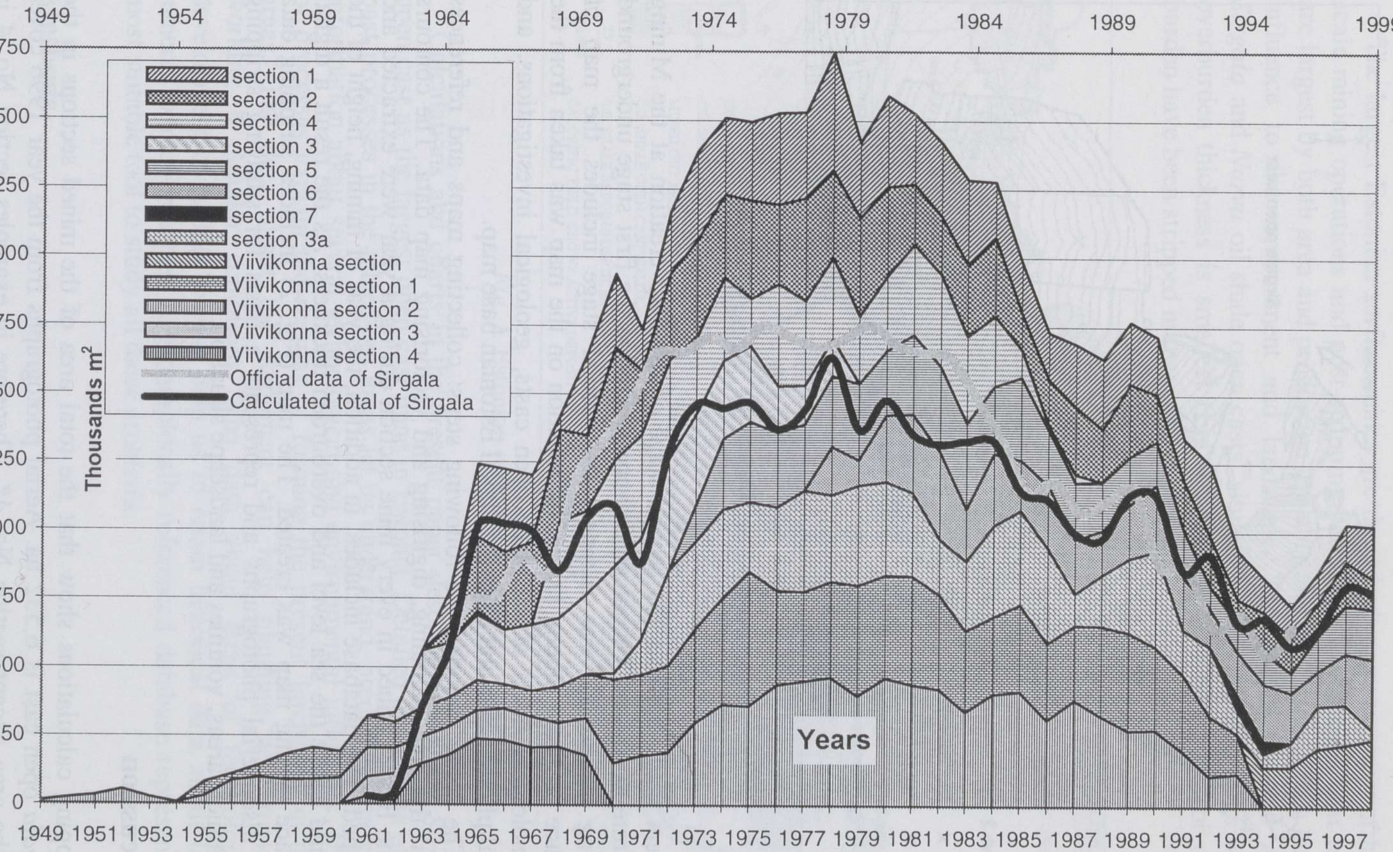

Fig. 3. Stripping areas of the *Sirgala* open cast from 1949 to 1999, thousands m² per year

The total production capacity of all Estonian oil shale open casts is 3 million m^3 or 5 million tonnes of oil shale per year. Every mine produces, on average, 1 million m^3 of oil shale per year. Oil shale yield is 3.4 tonnes per m^2 of mined area; therefore, the total area of surface mining movement is 1.5 million m^2 per year. As could be seen from the chart of the mined areas in the *Sirgala* open cast throughout its history (Fig. 3), its total annual movement area is 1 million m^2. In the case of average rates the area should be around 0.5 million m^2. In reality *Sirgala's* load is 44 per cent of all open casts. This situation reflects either an overestimated yield of oil shale or oil shale overproduction.

Taking 80 m per year for an average shift of the mine face, the total length of operating sections is 20 km. On average, every open cast has a 6.5-km mining front, four mining sections with the length of 1.6 km and four haulage trenches. The width of the mining and haulage trenches varies from 25 to 55 m. The total height of the spoil forms after stripping and reclamation. Mined out oil shale bed with a thickness from 2.5 to 3 m also decreases the final height of the spoil by its thickness. Blasted overburden that consists of lime- and dolostone with clay requires 1.4 times more space than in the bank. The average loosening coefficient of quaternary sediments such as sand, peat, clay and moraine is 1.2. It means that the final height of the spoil surface in the *Aidu* open cast (see Fig. 1), where the total overburden thickness is 17 and the soft part of it 3 m, will be 4 m higher than the ground surface. In the *Sirgala* open cast the raise will be 4 m and in the *Narva* open cast 6 m. The height of the spoils of the overburden material is 3 m higher beside haulage trenches because of the additional material from the trench.

The relative change in the surface height in other Estonian surface oil shale mines does not exceed 1 m. These mines are *Kohtla*, *Kohtla-Vanaküla* and northern section No. 4 of the *Narva* open cast. Possible surface mines like *Tammiku-Kose*, *Sonda*, *Ubja* and partly *Aidu* section No. 2 have the same parameters. For example, in the *Kohtla* open cast, in the beginning where the overburden thickness is less the spoil height is one metre lower, and after ten years the stripped spoil will be 1 m higher than the original ground.

The data from the digital map of the *Sirgala* open cast show a constant increase in the overburden thickness. Weighted average of thickness of all sections show a constant increase from 6 m in 1950 to 9 m in 1962. Since 1963 till 1978 the thickness increased from 9 to 12 m varying from 6.5 to 16 m. Today the average thickness is 17 m, varying from 15 to 20 m. The overburden material thickness influences directly the future landscape but it also sets limits to stripping equipment parameters and productivity. Stripping capacities (Fig. 4) are therefore influenced by production demand, overburden thickness and equipment capacities. The graph shows the amount and dynamics of casting overburden material in the *Sirgala* mine area.

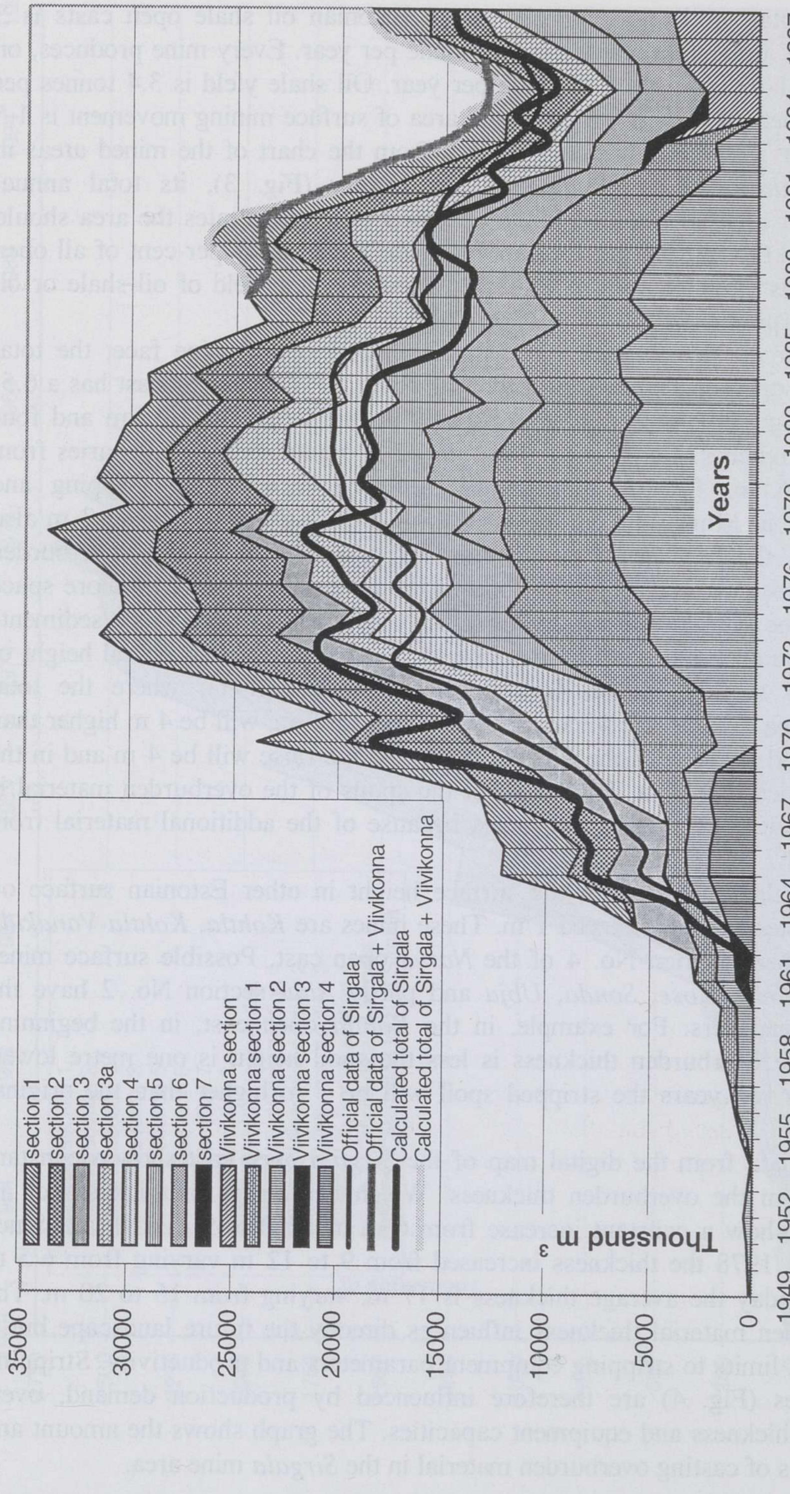

Fig. 4. Stripping volumes in the *Sirgala* open cast, thousands m^2 per year

From the beginning of mining, the area of a mine is influenced by haulage trenches. On average two trenches are excavated for every section. They follow the depth of the oil shale bed and are used for mineral haulage and process maintenance.

Trenches will be open to the air for the rest of the lifetime of an open cast. They are the most changed elements of the landscape after mining. The area of open casts will be flooded. The depth and width of the trenches are greater than those of most of Estonian natural lakes or rivers. The surface area of the bottom of trenches is 1 ha per 400 m or 2.5 ha per 1 km. The average length of trenches in Estonian open casts is 5 km that makes their average area 12 ha. The relative depth of trenches varies from 8 to 38 m. Comparing to the lakes it equals the water depth in the Estonia's deepest lake Rõuge Suurjärv. Question is, what the maximum water table height in trenches could be. The water table level depends on the level of water table in the Narva River that is 24 m above the sea level. The surface height of the mining area is 30 m above the sea level, and the minimum height of the bottom of oil shale bed equals the sea level. Due to this the depth of water in trenches will be up to 24 m. In the case of coagulation, the depth of water could reach 25 m or even more. The *Sirgala* open cast area has 18 such trenches.

In practice, abandoned *Maardu* phosphate rock open cast is a good example of flooded trenches and reclaimed area. Although the overburden materials of these two mined minerals are different, the general view will be the same. The *Maardu* open cast abandoned in 1991 is surrounded by water channels with a width of 80 to 120 m and water depth of about 3 m. The angle of the trench walls is 35 to 40° like in the oil shale area.

When trenches will be flooded in *Sirgala* and in other oil shale open casts, their water surface area will be 1.5 to 3 times greater than the present haulage road area. In surrounding and deeper trenches the width of the water table in channels could reach 150 m. However, the fact of their existing there causes another remarkable situation. Like in the *Maardu* mine area today, the channels will surround the reclaimed area and limit the accessibility of the area by transport facilities, which means less human impact on large afforested areas. From the point of view of environmental protection this will be one of favourable influences of surface mining on large and also remote areas.

Another similarity with the *Maardu* mine concerns saving mining process data. Today only few maps and documents are available about the *Maardu* mine. Mapping its underground part is almost impossible due to the lack of map and other information, caused by changes in the enterprise ownership. The same situation could easily happen to oil shale industry. This brings out another aspects of the importance of the present study – saving information in an easily accessible form for the future.

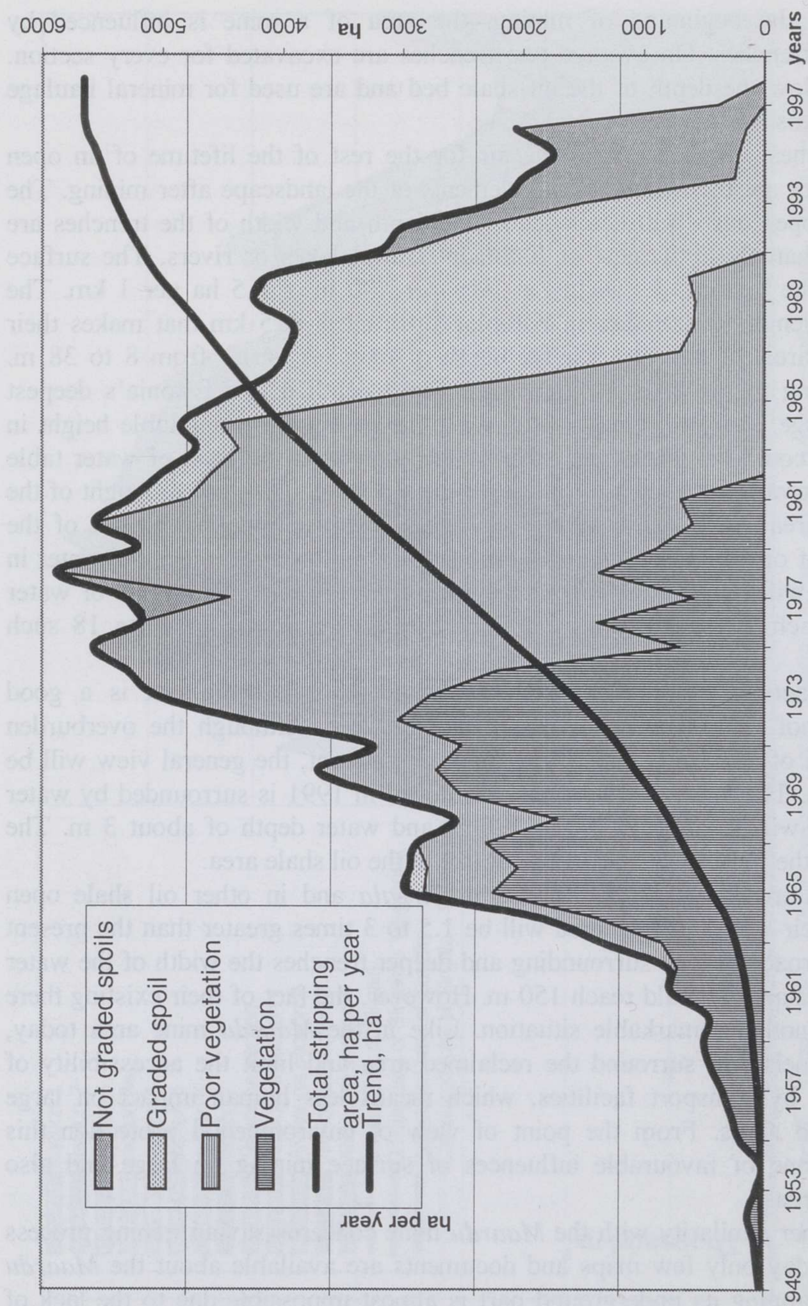

Fig.5. Reclamation dynamics of the *Sirgala* open cast area

The present open cast landscapes could be divided into four classes (Fig. 5). The first one is the afforested (mainly with pines) area. The second one is the area with poor vegetation, small trees and bushes, fifty per cent of it being a rocky surface. Aerial photographs show it as a striped area. The third one is a graded area, mainly without vegetation but ready for planting. The fourth area has spoils that are not graded and have no vegetation, their surface angles reaching the angle of the repose, maximum 45°. In the presented aerial photograph one-year stripping equals to 1–3 trenches (Fig. 6).

Oil shale surface mining has influenced northeastern Estonian landscape since the first days of oil shale industry. From 1916 to 1927 handwork was used for stripping [3]. Due to this the material of spoils was fine enough for reclaiming, and today this area is afforested or urbanized. Depending on the technology, depth of oil shale bed and political circumstances [3–6], the landscape and surface material varies slightly (the Table). Which of these stages has been best for recovering the nature, is a question for ecologists.

In surface mines the same range of equipment is used for stripping low-bedded deposits as for construction, amelioration and agriculture. The maximum reach of construction excavators is usually 6 m; the height of the blasted rock bench can be 1.5 of the excavator reach. This limits the oil shale mining area where such technology could be used to the bedding depth from 2 to 10 m. This 10-metres-limit was reached in the *Viivikonna** open cast in 1967 and in the *Sirgala* in 1970.

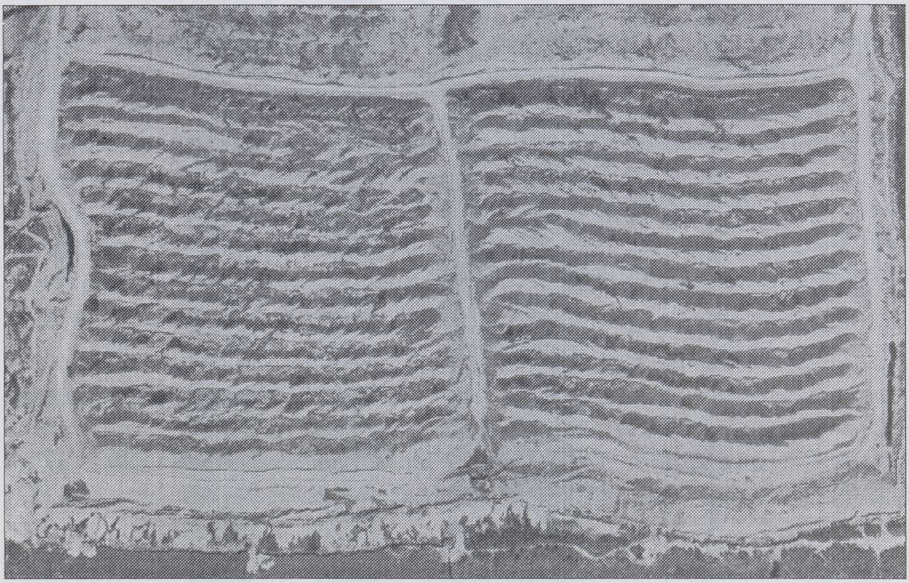

Fig. 6. Sharp spoils in the *Sirgala* open cast

* *Viivikonna* open cast was joined to *Sirgala* in 1987.

Estonian Oil Shale Open Cast Stripping Technology and Characteristics of Spoils

Open cast	Years	Overburden thickness, m	Stripping technology	Overburden material, mm	Spoil characteristics, local unevenness, m
Pavandu, Vanamõisa, Käva, Kiviõli, Küttejõu, Ubja, Kohtla	1916–1927	<6	Partial blasting, hand barrows	<150	Flat, afforested, urban area
Küttejõu, Kohtla, Viivikonna	1928–1947		Steam excavator	<150	Uneven, danger of ignition, afforested
Viivikonna	1936–1944	5.5–6	Hand barrows	<150	Flat, afforested
Viivikonna	1949–1955	6–8	0.5 m^3 excavator, dragline, 1–3 m^3, partially outer spoils	<500	Uneven, afforested, limestone in the upper part of spoil, therefore uneven, 1 m
Viivikonna	1958–1964	8–10	4 m^3 dragline with 4.6 m^3 shovel, double or triple casting	<1000	Limestone partly in the upper part of spoil, therefore uneven, 1.5 m
Viivikonna	1960	8–10	4 m^3 shovel, grading with 1 m^3 draglines and bulldozers	<1000	Spoil peaks levelled, 0.5 m
Viivikonna, Sirgala	1964	10 and more	10–15 m^3 dragline, 4–6 m^3 dragline for grading	<1000	0.5 m

In the *Narva* mine the mining started in 1970 in the depth of 18 to 19 m, and in 1992 in the northern section – in the depth of 6 to 7 m. In the *Aidu* open cast, half of section No. 2 (stopped today) has the overburden thickness below 10 m, which could be compared to the present situation in the *Narva* open cast.

Conclusion

Oil shale surface mining forms 1/3 of 10.5 million m^3 of minerals excavated yearly in Estonia. The *Sirgala* open cast produces 44 per cent of the surface-mined oil shale. Due to its large area, average mining conditions and remarkable production capacity *Sirgala* is the best example for illustrating the method of open cast mining, post-mining processes and landscape formed in the oil shale surface mining area. The present study describes creating a digital map of oil shale surface mining technology and evaluating mining influences on the landscape. The data from the digital map of the *Sirgala* open cast show a constant increase in the overburden thickness. Overburden material thickness influences directly the future landscape but it also sets limits to stripping equipment parameters and productivity. Stripping capacities are therefore influenced by production demand, overburden thickness and equipment capacities.

Reclamation technology has reached a nature-friendly level and causes no harm, except trenches, to the landscape. Trenches are the most changed elements of the landscape after mining. Their depth and parameters are greater than those of most of Estonian natural lakes or rivers. Their depth of water could reach 24 m. Oil shale mines, due to shale thin horizontal bedding require special reclamation after their exhausting. The present open cast landscapes could be divided into four classes: afforested area; area with poor vegetation; graded area; spoils.

Another aspect of the present study is saving information in an easily accessible form for the future. For this purpose GIS for mining is used. This study is a part of the development plan of Ida-Viru County and Estonian Oil Shale Company.

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REFERENCES

1. *Valgma, I.* Mapping potential ground subsidence areas of Estonian oil shale deposit // Proc. of Conference on Mining Law and Mining Safety. Tallinn, 1999 [in Estonian].
2. *Valgma, I.* Mapping potential areas of ground subsidence in Estonian underground oil shale mining district // Proc. of the 2nd International Conference - Environment. Technology. Resources. Rezekne, Latvia, 1999.
3. Fifty Years of Oil Shale Mining in Estonian SSR / Valgus. – Tallinn, 1968 [in Estonian].
4. Sirgala 35 / Disantrek. – Tallinn, 1997 [in Estonian].
5. Work of the Open Cast – Result of the Work of Team and Shift / Valgus. – Tallinn, 1986 [in Russian].
6. *Teetlok, K.* Reclamation of Land Disturbed by Mining of Mineral Resources and Their Influence to the Environment of Estonia / Institute of Geography, UT, Tartu, 1995 [in Estonian].

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