

ARTIFICIAL MOUNTAINS IN NORTH-EAST ESTONIA: MONUMENTAL DUMPS OF ASH AND SEMI-COKE

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The most distinguished landforms in East-Viru County, Estonia, apart from the Baltic Klint, are the artificial landforms¹ generated by mining and processing of oil shale. The data in scientific literature about the height of artificial mountains is poor and sometimes controversial. Ambiguous estimations exist regarding the highest mountain. In the present paper the height of the artificial landforms in North-East Estonia is investigated. Kohtla-Järve semi-coke mountain is found to be the highest artificial landform in the Baltic States. In addition, typology, history, and future of artificial mountains are studied.

Introduction

Processes of oil shale mining, combustion in power plants, and thermal processing in chemical plants generate huge amount of solid waste. After mining the oil shale layer from the mine, limestone is separated from mining mass and stored in the waste piles near separation plant. As the Estonian oil shale contains 15–70% organic matter [1] and the average ash content in the combustible mass varies between 40–50%, about half of the total mass becomes waste after combustion or chemical processing [2].

Waste piles are characteristic in places where oil shale industry exists. Such landforms remain in the landscape and give evidence of closed mines and human activities for a long time after the termination of mining. Frequently, waste piles of oil shale industry become a part of local habitants' identity [3].

A good example of this are the tailing piles from oil shale mining in the West Lothian district near Edinburgh in Scotland dating from the 19th–20th centuries, the “shale bings” as the locals call them. “Large red shale bings stand prominently near Broxburn, Livingston and West Calder.” Several

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¹ In the present paper, we use the word ‘mountain’ to represent the artificial positive landforms in North-East Estonia.

artificial formations are protected as industrial heritage monuments there. The most famous group of mountains is The Five Sisters beside the Freeport Business Park [4].

Artificial formations in North-East Estonia have obtained the status of the monument of local industrial heritage. Furthermore, they are regarded as attractive sights and landmarks. Therefore, it is essential to know their history of origin, composition, and dimensions.

In everyday language all artificial positive landforms of oil shale industry, despite their genesis, are called “ash mountains”. Even greater confusion prevails regarding the dimensions of these formations (i.e. the height, area and volume) that play a significant role in the plain landscape of the region. Different sources present contradictory information about the height, area, and volume of waste piles. Curiously, it is not even clear which of the mountains is the highest. In this paper, we try to bring some clarity in this issue, disclosing the results of a study carried out to identify the height of artificial landforms of North-East Estonia. Besides, we present some facts about their history and actual usage.

Study Area

Most of the artificial landforms of oil shale industry lie in the north-eastern Estonian Plateau (Fig. 1) [5]. Quaternary deposits, the thickness of which is mostly less than 2 m, cover the limestone bedrock in this landscape region. The absolute height of the generally flat plateau reaches 30–50 m above the sea level, making the artificial landforms of oil shale industry conspicuous landmarks in the surrounding. The western ones lie near the town of Kiviõli, while the eastern ones are situated south from the town of Narva. Such landforms with similar origin are also found near the town of Slantsõ in Russia. Industrial mining of oil shale in Estonia began in 1916, and the total output has reached at 850 million tonnes by today.



Fig. 1. Study area in Ida-Viru County

Methods and Data

Regardless of the plurality of concepts in Estonian for describing morphologically different positive landforms, the word ‘mountain’ is the most frequently used word, both in everyday language and in toponymy. Likewise, the expression ‘ash mountain’ is used to denote any waste pile of oil shale mining and processing in spoken language and as well as in popular-scientific literature, in spite of evident differences in the shape and composition of these landforms.

Toomik and Liblik [6] classify the artificial landforms of oil shale industry in North-East Estonia as follows:

- Land surface deformations, so-called depressions above the underground mines, which occur after the collapse of mined-out cavities. The depressions may fill with water and turn into water bodies when the level of surface water is naturally high. Otherwise, if the cleavages of land surface are not concurred with the collapse of cavities, the deformations are not notable for an inexperienced eye. The probability and character of the deformations depend on the mining technology [7, 8].
- Spoils in the mined-out areas of opencasts, which are generated from the mixture of quaternary sediments and overburden after stripping the oil shale layers. Today this wasteland is surfaced and reclaimed, only a small part of this area is preserved as a record of human endeavor. In earlier times it was a common practice to leave mined-out areas in such a condition as they were turned into after the depletion of the oil shale layer. Such areas exist in the *Küttejõu* opencast mining area near the town of Kiviõli, and in some places in the *Narva* opencast mining area. The relief of unreclaimed spoils is irregularly hilly, with maximum slopes of 20 degrees and with relative height of 10–15 m. After reclamation, the land surface looks like wavy plain; solely the texture of soil is entirely different from the initial one. Ten years later, forest covers the spoils irrespective of whether the biological restoration has taken place on account of human activity or by natural succession [9–11].
- Ash heaps near thermal power plants combusting oil shale. The shape of such heaps depends on the technology of ash removal from boilers. If ash is transported to heaps with wagons, the mountains have conic shape. This technology has not been very common and nowadays it is not used at all. In the modern power plants, wet ash removal system is the main technology. In this case, the shape of ash heaps is plateau-like. There are four thermal power plants in East-Viru County: two of them lie near the town of Narva, with ash plateaus occupying 860 and 570 hectares, respectively; the other two plants with smaller ash fields are found in Kohtla-Järve and Ahtme. In addition, another conspicuous ash mountain lies in the vicinity of Püssi near the former power plant.

- Dumps of residues near oil shale separation plants, which consist mainly of limestone dug up from mines with oil shale layer and of residual oil shale. These dumps lie mostly near the outlets of underground mines. The share of oil shale in the older dumps was higher, and some of the dumps have ignited spontaneously (near Kukruse, Sompa and Jõhvi). Therefore, the recent dumps are formed like plateaus.
- Semi-coke dumps surrounding the plants of oil shale thermal processing. Semi-coke is a residue classified as environmentally harmful due to its components like sulphides, volatile phenols, benzo(a)pyrene, etc. [6]. These mountains have a shape of excentric cones, dark-gray or black color, and specific smell. The semi-coke mountains are also the highest and most conspicuous landforms. In further sections of this paper we will primarily concentrate on them.

We examined the elevation data of artificial landforms presented on different large-scale topographic maps and in literature. The latter included tourist guidebooks and technical reports of enterprises. During the fieldwork, we measured the height of the Püssi ash mountain, as the exact data about it was missing on maps. We also collected data about the recent use of mountains. Consequently, we give an overview of elevation data of the highest artificial landforms in Estonia, i.e. the mountains around Kiviõli, Püssi, and Kohtla-Järve.

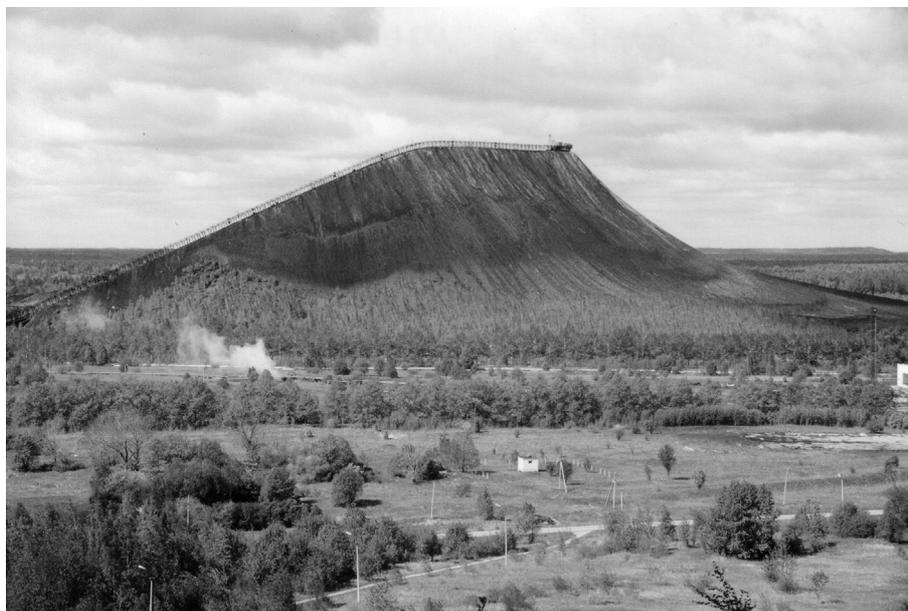


Fig. 2. New semi-coke mountain near the town of Kiviõli (relative height 116 m) (author of the photo: Riina Vaht)

Results

Kiviõli Mountains

Two semi-coke mountains near the northern border of Kiviõli, known as the old and new mountain, are the most notable among the artificial landforms of North-East Estonia (Fig. 2).

They have been given a lot of attention both in popular-scientific books and in tourist guides. Disposal of semi-coke was launched at the old mountain in 1927 and at the new mountain in 1951. In the beginning, the waste was transported to the preliminary plateau by horses; later a cableway with wagons was constructed. After discharging the wagon on the top of the mountain, semi-coke was washed down with water. In this manner, the mountains gained the shape of oblong and wide foot, rapid slope, and long, sharp crest. The piling on the old mountain was finished in 1975; the new one was closed down in the mid-nineties. By 1992, the total amount of semi-coke heaped up to the old and new mountains was 10,000,000 and 9,167,000 m³, respectively [12].

The most common figures suggested to represent the relative height of Kiviõli mountains in popular literature are 100 and 115 meters. However, for the most part, it is not clear whether the old or the new mountain is the highest. In the Encyclopedia of Soviet Estonia [13], it is presented, without further specification, that the highest ash mountain (115 m) in Estonia lies near the town of Kiviõli. According to Kont [14], two really high (107 and 101 m) cone-like mountains lie close to the town of Kiviõli, representing the landforms with the greatest relative height in Estonia.

The Altitude Data from Different Sources about Four Highest Artificial Mountains in Ida-Viru County

Source	Kohtla-Järve	Kiviõli		Püssi
		Old	New	
Estonian Base Map 1996	no data	Abs. 146 m	Abs. 145 m	no data
Fieldworks [12]	Abs. 173.65 m [19] Rel. 110 m	Abs. 143 m; rel. 96 m (2004) Rel. 96 m	no data Rel. 116 m	Rel. 61 m (2004) no data
Topographical map 1982	no data	Rel. 101 m	Rel. 110 m	Rel. 56 m
Topographical map 1977; 1980	Abs. 177 m; rel. 127 m	Abs. 146 m; rel. 96 m;	Abs. 145 m; rel. 95 m	no data
Topographical map 1960	Abs. 146 m; rel. 96 m	Abs. 143 m; rel. 93 m	Abs. 108 m; rel. 58 m	Abs. 96 m; rel. 56 m
Topographical map 1947	Abs. ca 115 m; rel. 65 m	Abs. ca 120 m; rel. 70 m	no data	Rel. 10 m

In the Estonian Encyclopedia [15] it is claimed that the relative height of the old ash mountain is 101 m, and that of the new one is 115 m. Also in earlier writings this information is quite indefinite. For example, Laigna and Treial [16], as well as the Kohtla-Järve tourist guidebook [17] note that the height of one of the Kiviõli ash mountains is “about one hundred meters”. One of the earliest records about the Kiviõli mountain as the highest artificial landform in the Baltic States can be found in the work of Marksoo [18]. More detailed databases are presented in the technical report [12] concerning the mountains as the source of a secondary raw material. According to this, the old mountain has a relative height of 96 m, and the new one is 116 m high. The height figures as provided on different topographic maps are presented in the Table.

There is a datum mark of 126 m above sea level at a knoll on the northern slope of old mountain of Kiviõli. The top of the knoll raises 79 m above the surrounding terrain and lies about 20 m lower from the top of the mountain itself. During the planning of a proposed ski centre on the old mountain in 2004, the relative height measured with GPS was 96 m. In summary, the relative heights of Kiviõli semi-coke mountains are 96 and 116 meters, respectively.



Fig. 3. Kohtla-Järve semi-coke mountains, known as North-East Estonian Central Ridge. The highest summit is the third from left (relative height 122 m) (author of the photo: Riina Vaht)

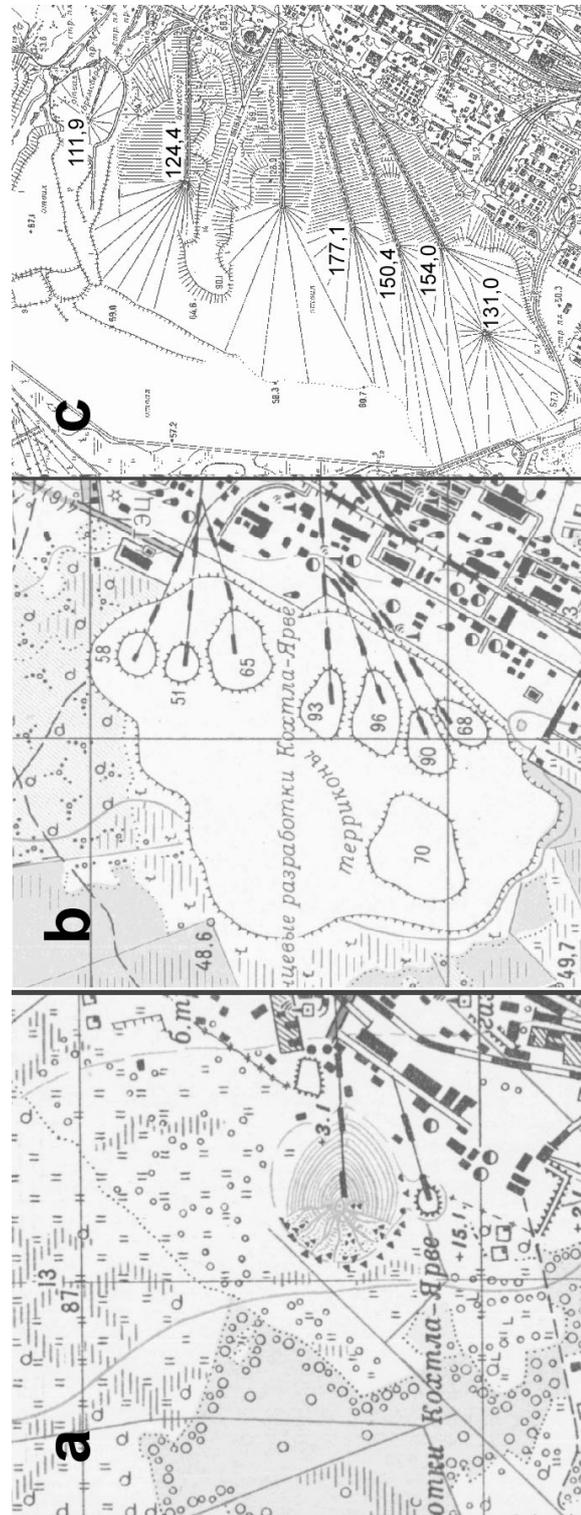


Fig. 4. The development of Kohtla-Järve semi-coke mountains in the maps from different periods: a – 1947, b – 1960, c – 1980

Kohtla-Järve Mountains

A group of five larger semi-coke mountains and several smaller hills, terraces between them and an ash plateau of power plant lie in the north-western border of Kohtla-Järve (Fig. 3).

In local popular speech, the group is known as North-East Estonian Central Ridge. At 1992, the landform consisted of 53,639,000 tonnes of semi-coke, and its total area comprised 0.93 km² [12]. Within the chain, the highest mountain lies third from the south.

The formation of Kohtla-Järve mountains began in the 1930s [20]. Like in Kiviõli, the transportation of waste was at first carried out by horses and was later replaced with cableway transportation and spreading out with water. Nowadays, semi-coke is transported up with lorries and is laid onto the terrace at the foot of the ridge, so that the height of the mountains does not increase anymore. In the beginning, there were several separate mountains, as the cableways came from different factories.

Since the 1950s, we can talk about a mountain chain. As the piling up to the top of the Kohtla-Järve mountains was finished in the middle of the 1990s, the exact height numbers are absent from earlier literature. Furthermore, the lack of information on elevation is probably caused by hard access to the mountains: they are encircled by closed territories of enterprises and swamps. Nevertheless, the height data are quite well presented on topographical maps of different times (Fig. 4; the Table), and in the technical report (110 m) [12].

At the end of the 1980s the Research Institute of Construction of Estonian SSR carried out a survey of the geodetic data of Kohtla-Järve mountains. The maximum absolute height of the chain was 173.65 m [19]. As the average height of the land surface near this site is about 50 m, the relative height of the mountain should be about 124 m. In 1980, the absolute height of 177.1 m on the higher top of the mountain was measured (relative height 127 m; see the Table). In 2004, a digital plan of the mountains was made on the basis of aero photos, on the scale of 1 : 2000. In this plan, the maximum absolute height of the mountains is 172 m. The height has been diminished probably because of the removal of the equipment by which semi-coke had been transported up.

Püssi Ash Mountain

The Püssi mountain lies on the left bank of the Purtse River and consists of oil shale ash transported with wagons from the local power plant. The plant started operation at the end of the 1930s. Until the 1950s, ash was transported by horses, and during this period a preliminary, 10-meters-high plateau was formed on the bank of the river. While one of the mountains in Püssi is widely known, there is another, a smaller pile on the southern slope of the major mountain. It was formed during the repair works of the main mountain, and in winter when the way to the main mountain became closed

by drifting snow after heavy north winds. Consequently, there are only two ash mountains in Estonia. Other landforms of oil shale ash are plateaus by shape.

The data about the height of the Püssi mountains is absent from guidebooks. However, large-scale maps provide some data (see the Table). During the fieldworks carried out in autumn 2004, we measured the relative height of the piles, consequently the main mountain is 61 m high, and the lower one is 32 m high. As the 40-m contour line in the large-scale map is placed on the foot of the mountains, the absolute height must be 101 m.

Discussion

Our study establishes that the highest artificial mountain in Estonia is situated in Kohtla-Järve and not in Kiviõli as it has been suggested according to the common knowledge. This fallacy springs from history. The Kiviõli mountain was the first to rise higher than 100 m, and so it has deserved more attention. Later, the Kohtla-Järve mountain grew higher than the piles situated in Kiviõli, but the status of the highest had already become fixed in literature. This subsequently resulted in misguiding tourist signs leading to Kiviõli, the location of the highest artificial landform in the Baltic States. Roots of this inaccuracy could be pursued from the fact that the old mountain of Kiviõli was the first one to become closed, and thus, the ultimate elevation of it could be established. Other mountains, i.e. the new semi-coke dump in Kiviõli and the mountains in Kohtla-Järve were closed down only in the middle of the 1990s.

Another intriguing topic to discuss is the post-closure usage of waste piles. In essence, landforms of this kind comprise waste, imposing real hazards to the environment. Though, not all waste landforms are dangerous. For example, the oil shale ash and residues of oil shale separation plants (if never burned) have no serious impact on the environment. Although spoils in the opencast mining area have similar composition as residuals of separation plants, they are not regarded as waste spoils according to the Waste Charge Act if they lie in the mined-out area [21]. At the same time the rainwater still washes oil residues out from the semi-coke mountains, and combustion processes in the oil shale separation residues pollute air and subsoil water [22].

On the other hand, the new landforms have become a part of identity and self-consciousness of local inhabitants, and the restoring the pre-industrial state of landscape is now impossible [23]. Moreover, the mountains have become habitats for several endangered species. Over 35 years forest scientists have been working with the topic of the recultivation of artificial surface forms; as a result the scenic value of several mountains has increased. Local people have been eager to look for possibilities to use artificial landforms for alternative activities, such as extreme sports and

recreation. For instance, in the 1980s, the Kiviõli old mountain was used by paraplane flyers. At present, a ski center is planned there.

In Ida-Viru County, all the hills and mountains are regarded as valuable view sights and landmarks on the flat landscape. On the other hand, the same landforms are the potential stocks of building or raw material. However, the height of the Kiviõli old mountain is proposed to decrease by 6 m. From the foot of the Püssi ash mountain, the ash has been excavated and the initial regular shape has become damaged. Similar and often illegal activities are noticeable also in the case of other artificial landforms. We argue that development projects on the usage of artificial mountains in North-East Estonia, those of the higher piles in particular, require careful planning.

Acknowledgements

We would like to thank Ain Vellak for his kind help during fieldworks and Age Poom and Egle Kaur for correcting the manuscript. Also, we greatly appreciate financial support from the Estonian Ministry of Education (theme No. 0282119s02).

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Maps

Topographical maps of the former Soviet Union:

- 1 : 25,000; O-35-19-B-Г (1947)
- 1 : 25,000; O-35-18-Г-Г (1947)
- 1 : 25,000; O-35-19-B-Г (1960)
- 1 : 25,000; O-35-18-Г-Г (1960)
- 1 : 25,000; O-35-19-B-b (1960)
- 1 : 10,000; C-59-28-B-B-I (1980)
- 1 : 10,000; C-59-28-Г-B-I (1980)
- 1 : 2,000; 189-B (1977)
- 1 : 50,000; O-35-18-Г (1982)

Estonian Base Map 1996:

- Kohtla-Järve 6444
- Kiviõli 6443

Presented by A. Raukas

Received February 28, 2005