Estonian georesources in the European context

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Abstract. Estonia is situated on the southern buried slope of the Baltic Shield where the sedimentary bedrock overlies the Precambrian crystalline basement. The Cambrian section contains mainly sandstone and clay (e.g. famous “blue clay”), Lower Ordovician is represented by sandstone, including phosphate *Obolus* sandstone (shelly phosphorite), and Upper Ordovician by oil shale (kukersite). Estonia is not very rich in useful minerals, but we have some georesources sizeable in European context: oil shale (the Estonia deposit is the largest commercially exploited and best-studied oil shale deposit in the world), phosphorite (the well-studied Rakvere deposit is the largest phosphorite deposit in Europe, but not exploited), and peat (Estonia is considered as a country richest in peatlands in North Europe). Unfortunately, for more than 80 years oil shale and phosphorite have been mined and industrially used in environmentally hazardous ways, devastating large regions in northern and northeastern Estonia. The mining is mainly causing technological and technical, environmental, economic and social problems.

Key words: Estonia, useful minerals, exploration, excavation, oil shale, phosphorite, peat.

INTRODUCTION

Estonia is situated on the southern buried slope of the Baltic Shield where the sedimentary bedrock overlies the Precambrian crystalline basement (Fig. 1). The thickness of the bedrock, composed of Ediacaran, Cambrian, Ordovician, Silurian, and Devonian strata, ranges from 100 m near the coast of the Gulf of Finland to 800 m in southern Estonia. The Ediacaran, Cambrian, and Devonian complexes consist of terrigenous rocks – sands, sandstones, and clays. The Ordovician and Silurian are represented by different limestones, dolostones, and marls. The bedrock is covered by Quaternary sediments that have formed in the glacial and postglacial periods.

The Cambrian section contains mainly sandstone and clay (e.g. famous “blue clay”), Lower Ordovician – sandstone, including phosphate *Obolus* sandstone (shelly phosphorite), and Upper Ordovician – oil shale (kukersite). Deposits of the most important mineral resources – oil shale, phosphorite, and carbonate rocks – are located in the northern and northeastern part of Estonia. Peat, sand, and gravel resources are distributed almost evenly over the country.

According to the Earth’s Crust Act of Estonia, mineral resources are clay, dolostone, gravel, lacustrine lime, mud, limestone, oil shale, peat, phosphate rock (phosphorite), and sand. By the Act the Earth’s crust the upper layer of the ground is accessible for human activity on land, in transboundary water bodies, on the territorial sea, in inland maritime waters, and in the exclusive economic zone. The Mineral Resource Classification System developed in Estonia (by the Estonian Commission on Mineral Resources) is based on internationally accepted principles[1].

Estonia is not very rich in useful minerals (Raudsep et al. 1991; Raudsep & Räägel 1993; Mustjõgi et al. 1994; Raukas & Teedumäe 1997), but in European context we have the following sizeable georesources:

[1] The Estonian classification is founded on international principles. The United Nations (UN) Framework Classification has been developed by the UN Economic Commission for Europe (UN 1996). That classification includes definitions of stages of geological study and also definitions for reserves/resources. For example, the definitions for proved mineral reserve and inferred mineral resource are as follows:

Proved mineral reserves – demonstrated to be economically mineable by a feasibility study or actual mining activity, usually undertaken in areas of detailed exploration.

Inferred mineral resource – estimated to be of intrinsic economic interest, based on prospecting having the objective to identify a deposit. Estimates of quantities are inferred, based on outcrop identification, geological mapping, indirect methods, and limited sampling.

1. **oil shale** – the Estonia deposit is the largest commercially exploited and best-studied oil shale deposit in the world (Kattai et al. 2000);
2. **phosphorite** – the Rakvere deposit (well studied but not exploited) is the largest phosphorite deposit in Europe (Raudsep 1982; Puura 1987);
3. **peat** – Estonia is considered as a country richest in peatlands in North Europe, with 9836 bogs and mires covering a total of one million hectares (about 22% of the Estonian territory), and more than 300 registered peat deposits.

EXPLORATION AND EXTRACTION OF USEFUL MINERALS

The Earth's Crust Act provides rules and principles of the exploration, protection, and use of minerals, with the purpose of ensuring economically efficient and environmentally sound use of mineral resources. The Act regulates: (1) geological investigations; (2) geological explorations; (3) extraction of mineral resources, except in the part regulated by the Mining Act; (4) rights of the owner of an immovable property upon use of mineral resources within the boundaries of the owner's property; and (5) reclamation of the land disturbed by geological investigation, geological exploration or mining. Geological exploration requires a permit (exploration permit) and may be carried out by an authorized person pursuant to the procedure prescribed by the Mining Act. In Estonia, a permit for a geological exploration could be issued for up to **five** years by the Ministry of the Environment.

The procedure for geological exploration is established by the Minister of the Environment. It includes (1) classification of mineral resources according to the areas of use and the requirements for determination of such areas; (2) requirements for the preparation and carrying out of geological exploration, topographic work, and the calculation of mineral reserves; (3) requirements for compilation of geological exploration reports and preparation of a mineral deposit for exploitation; and (4) special requirements for the geological exploration of each mineral resource.

The situation with the issue of exploration permits (licencing) is different in European countries (Table 1; also unpublished data by J. Green and C. Hebestreit, Euromines report 2006).

In Estonia, useful minerals in the bedrock, mineral resources in deposits of national importance, and mud (curative mud) belong to the state, and the immovable property ownership of other persons does not extend to these. Mineral resources located on immovable property or in internal water bodies in state ownership belong to the state.

Natural bodies of bedrock, sediments, liquid or gas not included in the environmental register also belong to the state and the immovable property ownership of other persons does not extend to these, unless required by the purpose of use of this property. Mineral resources in state ownership are not in commerce in their natural form.

If a permit is required for extracting mineral resources in state ownership, the ore generated by mining belongs to the miner. If the same takes place without permit, the mined ore belongs to the state. Records of mineral resources are kept in the Environmental Register in the form of mineral reserves by each mineral deposit separately, pursuant to the procedure provided for in the Environmental Register Act.

The natural body of rock, sediments, liquid or gas explored and delimited by a geological exploration may be entered in the Environmental Register as a mineral deposit. The entry will be decided by the Minister of the Environment on the basis of the results of the geological investigation or geological exploration, taking account of the opinion of the Commission on Estonian Mineral Resources.

Mineral deposits are of national or local importance (Fig. 1). The list of mineral deposits of national importance is established by the Government of Estonia. Mineral deposits of national importance should meet the following criteria: (1) are located in a transboundary water body, on the territorial sea or in inland maritime waters, in the exclusive economic zone; (2) the quality or quantity of mineral resources is of significant importance in view of the economic development of the state; (3) are used for the manufacture of products with export potential; and (4) the significant environmental impact of the extraction of mineral resources extends to several counties or crosses the state border. At present the use of useful minerals and amount of studied reserves are increasing in Estonia (Table 2).

The mining right arises from an extraction permit for mineral resources (hereinafter extraction permit), unless otherwise provided for in the Earth's Crust Act. An extraction permit could be issued for up to 30 years for the extraction of useful minerals such as dolostone, phosphorite, crystalline building stone, limestone, oil shale, clay, or peat and sand in deposits of national importance and for up to 15 years for lacustrine lime, mud, gravel, and sand deposits of local importance. If, upon processing an application for an extraction permit, it becomes evident that the mineral reserves in a mineral deposit cannot be exhausted within the period established

Table 1. Exploration of useful minerals in the European countries

Country	Permit for exploration of minerals			Exploration data are computerized or not
	Permit for exploration is needed: yes or no	Initial permit limit, years	Duration of extension permit, years	
Austria	Yes	nd	nd	nd
Belgium	No	nd	nd	nd
Bulgaria	Yes	3	2	nd
Czech Republic	Yes	2	2	Yes
Estonia	**Yes**	**5**	**0**	**Partly**
Finland	Yes	2	5	Yes
France	Yes	nd	nd	nd
Germany	No	nd	nd	Yes
Greece	Yes	2	nd	No
Hungary	Yes	nd	nd	nd
Ireland	Yes	6	6	Yes
Italy	Yes	2	nd	No
Latvia	Yes	nd	nd	nd
Lithuania	Yes	nd	nd	nd
Luxemburg	Yes	nd	nd	nd
Netherlands	Case by case	nd	nd	nd
Poland	Yes	nd	nd	nd
Portugal	Yes	3	2	Partly
Romania	Yes	5	nd	No
Slovenia	Yes	5	nd	Yes
Spain	Yes	nd	nd	nd
Sweden	Yes	3	12	Yes
United Kingdom	nd	3	15	Yes
European average			5.5	

nd, no data.

by the extraction permit and use of the remaining reserves on the basis of another extraction permit is economically unjustified, the issuer of permits has the right to issue the permit for a period which is longer by up to five or ten years.

The most important useful mineral of Estonia is oil shale (kukersite). Estonian oil shale has the best quality (the content of organic matter in the oil shale is up to 65%, calorific value 9–11 MJ/kg, and yield of oil 22–24%) among the oil shales of the world (Kattai et al. 2000). The mining conditions of the Estonia deposit are relatively simple – small depth (10–90 m), laterally stable thickness (1.6–2.9 m) of the productive seam, horizontal bedding. The Estonian shale oil obtained by the retorting of oil shale has unique composition. Most (about 80–85%) of oil shale is used for energy production and the rest part in chemical industry. Although exploitation of oil shale decreased during the 1990s, it is increasing now.

Oil shales are widely distributed in the whole world. Over 600 deposits are known, but worldwide use of oil shale is not very common. The oil shale industry developed first in France (1838) and the United Kingdom (in Scotland in 1850). Later oil shale has been mined and used in different countries, e.g. Australia, Austria, Sweden, China, and Russia. Nowadays oil shale is mined in few countries in Europe (Table 3).

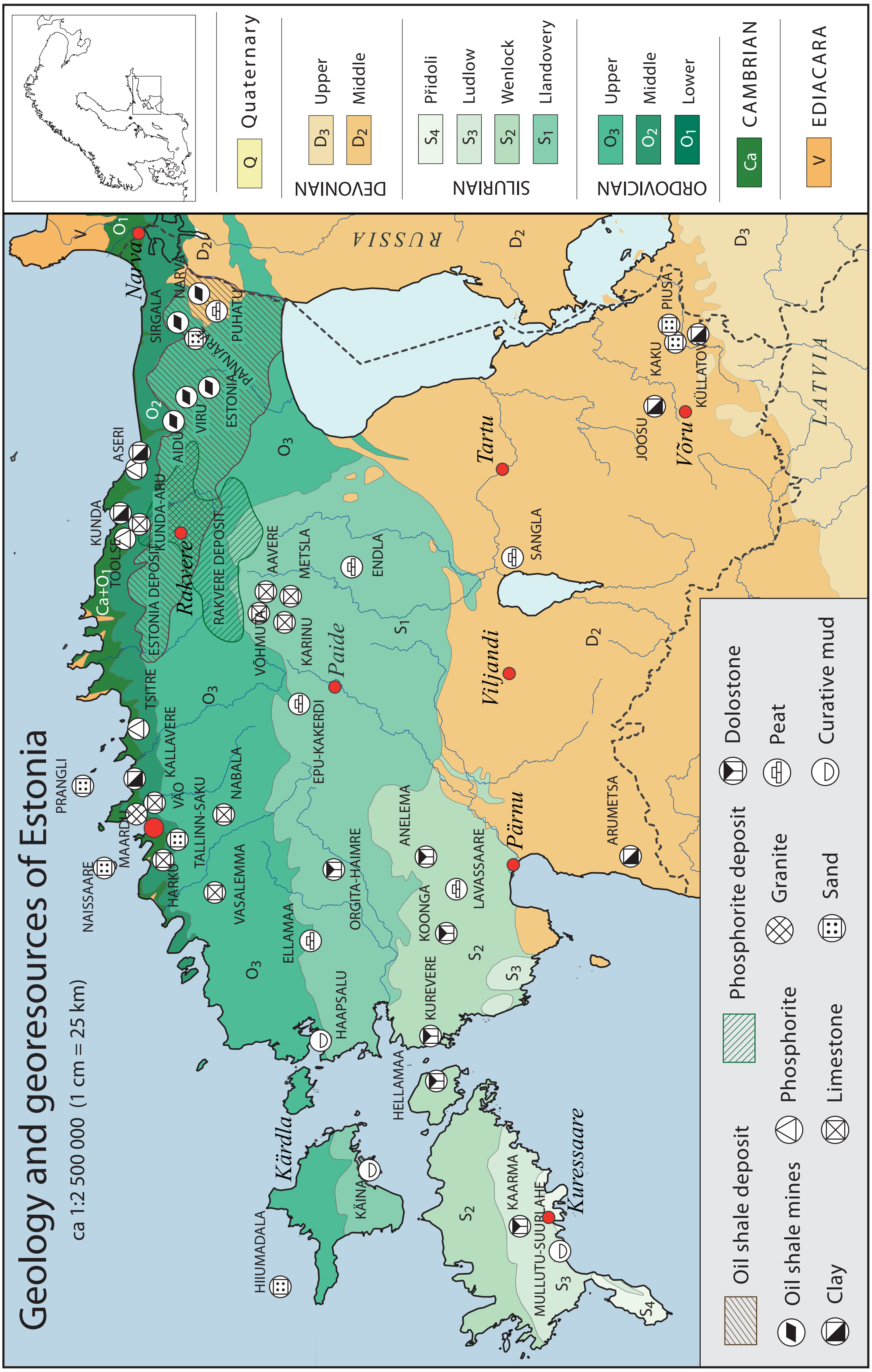

Fig. 1. Distribution of main deposits of useful minerals, shown on the background of the geological map of Estonia.

Table 2. Extraction of useful minerals in 2005–2006 and the amount of registered reserves/resources as of 01.01.2007

Useful minerals		Unit of measurement	Extraction		Reserves/resources of useful minerals as of 01.01.2007		
			2005	2006	Mineable reserves		Submarginal mineral resources (Estonian categories Tp + Rp)
					Proved reserves (Estonian category T_a)	Inferred mineral resources (Estonian category R_a)	
Oil shale		thousand tonnes	11 310	11 977	1 129 200	268 600	3 502 700
Phosphorite		thousand tonnes	0	0	0	0	2 935 700
Limestone	Limestone for cement	thousand m^3	335	344	9 400	87 900	51 300
	Technological limestone	thousand m^3	86	84	14 500	40 000	73 400
	Construction limestone	thousand m^3	1 922	2 344	110 500	304 000	236 200
Dolostone	Technological dolostone	thousand m^3	155	128	12 600	83 500	0
	Decorative dolostone	thousand m^3	2	2	2 900	21 500	1 400
	Construction dolostone	thousand m^3	260	378	32 900	98 800	83 500
Crystalline building stone		thousand m^3	0	0	1 245 100	1 723 900	0
Clay	Clay for cement	thousand m^3	37	139	15 500	11 200	489 000
	Ceramic clay	thousand m^3	152	149	10 600	236 200	13 400
Gravel		thousand m^3	1 157	1 265	32 000	76 500	15 000
Sand	Technological sand	thousand m^3	54	51	3 400	4 000	2 100
	Construction sand	thousand m^3	2 070	2 949	165 600	457 200	168 400
Mud (seamud)		thousand tonnes	1	1	1 356	0	1 667
Peat		thousand tonnes	1 074	1 257	217 000	822 700	561 000

Table 3. Oil shale production in Europe in 2001–2005 (Weber & Zsak 2007)

Country	Production, t					Rank 2005	Share, %
	2001	2002	2003	2004	2005		
Estonia	12 000 000	10 513 000	12 459 000	11 328 000	11 310 000	1	84.79
Russia (Europe)	1 600 000	1 500 000	1 400 000	1 300 000	1 700 000	2	12.74
Germany	340 000	366 841	295 853	282 408	292 385	3	2.19
Italy	23 800	23 500	23 200	23 000	24 000	4	0.18
France	15 000	14 000	13 000	12 500	12 200	5	0.10
Austria	408	336	432	248	0	–	–
Total	13 979 208	12 417 677	14 191 485	12 946 156	13 338 585		100.00

–, mining was stopped.

PROBLEMS OF MINING INDUSTRY

Unfortunately, for more than 80 years oil shale and phosphorite have been mined and industrially used in environmentally hazardous ways, devastating large regions in northern and northeastern Estonia. In 1991, considering the environmental impact and exhaustion of mineable phosphorite reserves at the Maardu deposit, phosphorite mining and enrichment of phosphorite were terminated. Phosphorite reserves were excluded from the list of mineable mineral reserves (proved reserves) in the middle of the 1990s.

Several problems are connected with the mining and use of georesources:

1. Technological and technical problems
   - high losses of resources related to oil shale mining – to support the roof of mining shafts, about 25–30% of mineable oil shale is left underground as pillars;
   - formation of water-filled depressions on the ground, which may cause collapses of oil shale mining shaft roofs).
2. Environmental problems
   - pollution of surface and groundwater by polluted mine and drainage waters;
   - lowering of groundwater level and formation of large depression cones;
   - changes in soil properties and overall landscape;
   - formation of solid waste dumps of oil shale industry (where residual organic matter is prone to self-ingnition);
   - gaseous emissions from the utilization of oil shale and phosphorite (SO_2, NO_x, etc.) contaminating ambient air.
3. Economic problems
   - the concentrates from Estonian phosphorite will not pay off;
   - competition between the landusers and mining companies;
   - rational use of mineral resources: as complete and complex mining as possible and the most effective utilization of the explored resources (for example, peat in the overburden of oil shale resources; oil shale in the overburden of the phosphorite layer);
   - insufficiency of natural building resources (limestone, dolostone, sand, gravel, etc.) caused mainly by different environmental and social problems of mining.
4. Social problems
   - one part of the population is affected by mining activities;
   - most of the Estonian population is against the mining at all.

FUTURE DEVELOPMENTS

The Estonian Government has decided to find a complex solution to different problems related to mining and utilization of georesources. In the future special strategies will be built up and established, for example, *State strategy of oil shale utilization for 2008–2015*, which is in the final stage of completion. After approval by different ministries and the Government, it will be validated by the Estonian Parliament (Riigikogu). Another document, *State strategy of use of natural building resources for 2010–2020*, is planned to be compiled in 2008–2009. Future plans include also establishing a strategy for the protection and sustainable use of peatlands and peat.

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Eesti maavarad Euroopa kontekstis

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Eesti asub Balti kilbi mattunud lõunaserval, kus aluspõhja settekivimid katavad Prekambriumi kristalset aluskorda. Kambriumi ladestu läbilõige on esindatud peamiselt liivakivi ja saviga (sh laialt tuntud sinisaviga). Alam-Ordoviitsiumi ladestiku liivakivide hulgas on oobolusliivakivi (sh oobolusfosforiit) ja Ülem-Ordoviitsiumi ladestikus põlevkivi (kukersiit). Eesti ei ole maavarade poolest väga rikas, aga meil on mõni Euroopa mastaabis tähelepanu vääriv maavara. Sellisteks on põlevkivi (Eesti põlevkivimaardla on suurim ja kõige paremini uuritud põlevkivimaardla maailmas), fosforiit (Rakvere fosforiidimaardla on suurim omataoliste hulgas Euroopas, geoloogiliselt hästi uuritud, kuid ei ole kasutusele võetud) ning turvas (Eesti kuulub Põhja-Euroopas kõige rikkalikumaid turbaalasid omavate maade hulka).

Kahjuks on rohkem kui 80 aasta jooksul, mil põlevkivi ja fosforiiti on kaevandatud ning keskkonnale ebasõbralikult kasutatud, saastatud suur osa Põhja- ja Kirde-Eestist. Peamised probleemid, mis maavarade kasutamisega kaasnevad, on tehnoloogilised ja tehnilised, keskkonnaalased ning sotsiaalsed.