Estonian georesources in the European context

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Received 11 February 2008, accepted 22 April 2008

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 principles1.

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:

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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 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.
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

<table>
<thead>
<tr>
<th>Useful minerals</th>
<th>Unit of measurement</th>
<th>Extraction</th>
<th>Reserves/resources of useful minerals as of 01.01.2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2005</td>
<td>2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil shale</td>
<td>thousand tonnes</td>
<td>11 310</td>
<td>11 977</td>
</tr>
<tr>
<td>Phosphorite</td>
<td>thousand tonnes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Limestone</td>
<td>thousand m³</td>
<td>335</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td>Limestone for cement</td>
<td>86</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Technological limestone</td>
<td>1 922</td>
<td>2 344</td>
</tr>
<tr>
<td></td>
<td>Construction limestone</td>
<td>155</td>
<td>128</td>
</tr>
<tr>
<td>Dolostone</td>
<td>thousand m³</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Decorative dolostone</td>
<td>2 200</td>
<td>2 900</td>
</tr>
<tr>
<td></td>
<td>Construction dolostone</td>
<td>260</td>
<td>378</td>
</tr>
<tr>
<td>Crystalline building stone</td>
<td>thousand m³</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clay</td>
<td>thousand m³</td>
<td>37</td>
<td>139</td>
</tr>
<tr>
<td></td>
<td>Clay for cement</td>
<td>152</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>Ceramic clay</td>
<td>1 157</td>
<td>1 265</td>
</tr>
<tr>
<td>Gravel</td>
<td>thousand m³</td>
<td>54</td>
<td>51</td>
</tr>
<tr>
<td>Sand</td>
<td>thousand m³</td>
<td>2 070</td>
<td>2 949</td>
</tr>
<tr>
<td></td>
<td>Technological sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Construction sand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mud (seamud)</td>
<td>thousand tonnes</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Peat</td>
<td>thousand tonnes</td>
<td>1 074</td>
<td>1 257</td>
</tr>
</tbody>
</table>
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-ignition);
   - gaseous emissions from the utilization of oil shale and phosphorite (SO₂, NOₓ, 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.

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.
REFERENCES


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 mastaabas tähedapanu vääriv maavara. Sellisteks on põlevkivi (Eesti põlevkivimaardla on suurim ja kõige paremini uuritud põlevkivimaardla maailmas), fosforiit (Rakvere fosforiidimaardlas on suurim omataolist 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 fosforiit on kaevandatud ning keskkonnale ebasõbralikult kasutatud, saastatud suur osa Põhja- ja Kirde-Eestist. Ploomised probleemid, mis maavarade kasutamisega kaasnevad, on tehnoloogilised ja tehnilised, keskkonnaalased ning sotsiaalsed.