P228

Geological Storage of CO2 – Prospects in the Baltic States

A. Shogenova* (Tallinn University of Technology), S. Sliaupa (Institute of Geology and Geography, Vilnius), K. Shogenov (Tallinn University of Technology), R. Vaher (Tallinn University of Technology) & R. Sliaupiene (Institute of Geology and Geography, Vilnius)

SUMMARY

According to Kyoto Protocol CO2 emissions should be reduced in European countries by 8% by 2008-2012. One of options is CO2 geological sequestration. In 2006 three Baltic States together with other European countries started inventory of major CO2 emission sources, assessment of CO2 geological storage capacity and dissemination of information about CO2 capture and storage in the frame of EU GEOCAPACITY and CO2NETeast projects supported by EU Commission FP6. 24 sources of CO2 emissions exceeding 100000 t/y are registered in the Baltic States. The heaviest loading on greenhouse effect is in Estonia (oil-shale utilisation). Lower Devonian and Middle Cambrian siliciclastic reservoirs are considered prospective formations for CO2 trapping. The structural trapping is an option in Latvia having large anticlinal structures with total potential 200 Mt in the Cambrian aquifer. The western cluster of CO2 sources is located within prospective area of Cambrian reservoir and one big CO2 source is within the Devonian prospective area in Lithuania. Immature solubility and mineral trapping technologies can be considered prospective here. Only that amounts tens of gigatons, enough to store all produced CO2 emissions for hundreds of years. Geological conditions in Estonia, located in the shallow periphery of the basin, are not favourable for CO2 geological sequestration.

Introduction

CO_2 is a main agent affecting the Earth`s climate. According to Kyoto protocol, the greenhouse emissions should be decreased by 8% by 2008-2012 and much deeper reductions will be probably required in the future. Estonia, Latvia, and Lithuania have joined the protocol along with other countries. Compared to 1990 the emissions decreased in the Baltic countries due to cut in energy and industrial production. However, the changing energy market and increasing industrial growth urges to evaluate different options seeking to reduce CO_2 emissions, including application of the geological sinks. The inventory and dissemination of information on geological capture and storage (CCS) options is an integrated part of the number of projects funded by European Commission such as CASTOR, GESTCO, EU GEOCAPACITY, CO2NETeast, and others.

After capture and transport CO_2 could be stored in the various underground formations: depleted oil and gas reservoirs, deep saline aquifers, coal beds, caverns and mines (Lokhorst and Wildenborg, 2005). Compared to the other European countries, the Baltic States are in a rather unique geological setting. Most of the countries contain a number of small basins that have different characteristics. Lithuania, Latvia, and Estonia are situated within the common Baltic sedimentary basin. Therefore, the joint study is required for assessment of the geological sinks. The source types, emission amounts, geographical trends are different in the Baltic countries depending on the socio-economic conditions. Also, the geological conditions are different, as these countries represent different parts the Baltic basin.

Location and type of CO_2 sources

24 big sources of CO_2 emissions (>100000 tons per year) are registered in the Baltic States. In 2005 these sources produced 11,5 Mt in Estonia, 5,6 Mt in Lithuania and 1,9 Mt of acid gas in Latvia. The greatest CO_2 emissions were produced by energy sector. They are clustered around the capital cities and big industrial centers, like Tallinn, Kohtla-Järve and Narva in Estonia, Riga and Liepaja in Latvia, Vilnius, Kaunas and Šiauliai in Lithuania. The largest part of emissions is produced by energy sector in Estonia (92%), Latvia (66%), and Lithuania (50%) (Fig.1, 2). Location of the biggest CO_2 sources in Estonia is connected with oil-shale deposit, which is a main fossil fuel there. Estonian oil-shale deposit is located in the north-east of the country where the greatest Estonian power stations are distributed. The largest source of CO_2 in Lithuania is the oil refinery (33%) located in the northwestern part of Lithuania (1.87 Mt in 2005). Significant source of CO_2 is a steel-iron industry in Latvia (0.37 Mt, 2005), comprising 19% of the biggest Latvian emissions and is produced by Liepaja metallurgical enterprise. Cement production is also a significant source of CO_2 in Latvia (15%) and Lithuania (14%), they are located in the south-western part of Latvia (Broceni) and northern Lithuania (Akmenė). Other industries (mainly chemical) make only several percents among greatest emissions in Estonia and Lithuania.

The big emissions (Fig. 2) could be divided into three main geographical groups in the Baltic States. The northernmost group (11.5 Mt) is located in the northern and north-eastern parts of Estonia, the central group is located near and around Riga, south-western Latvia and close to the western part of the Latvian-Lithuanian border, and the southern group is located in the south-eastern part of Lithuania close to and between Vilnius and Kaunas. The smallest sources are located in the northern and central parts of Estonia, associated mainly with Riga district and south-eastern part of Latvia and more or less evenly distributed in Lithuanian territory.

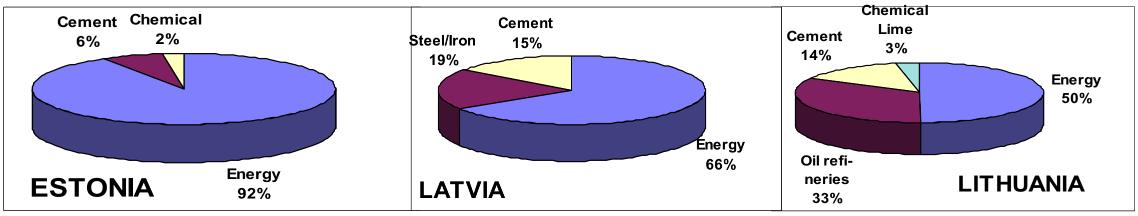

Figure 1. Distribution of CO_2 emissions (>100000 tons per year) by industrial sectors in 2005.

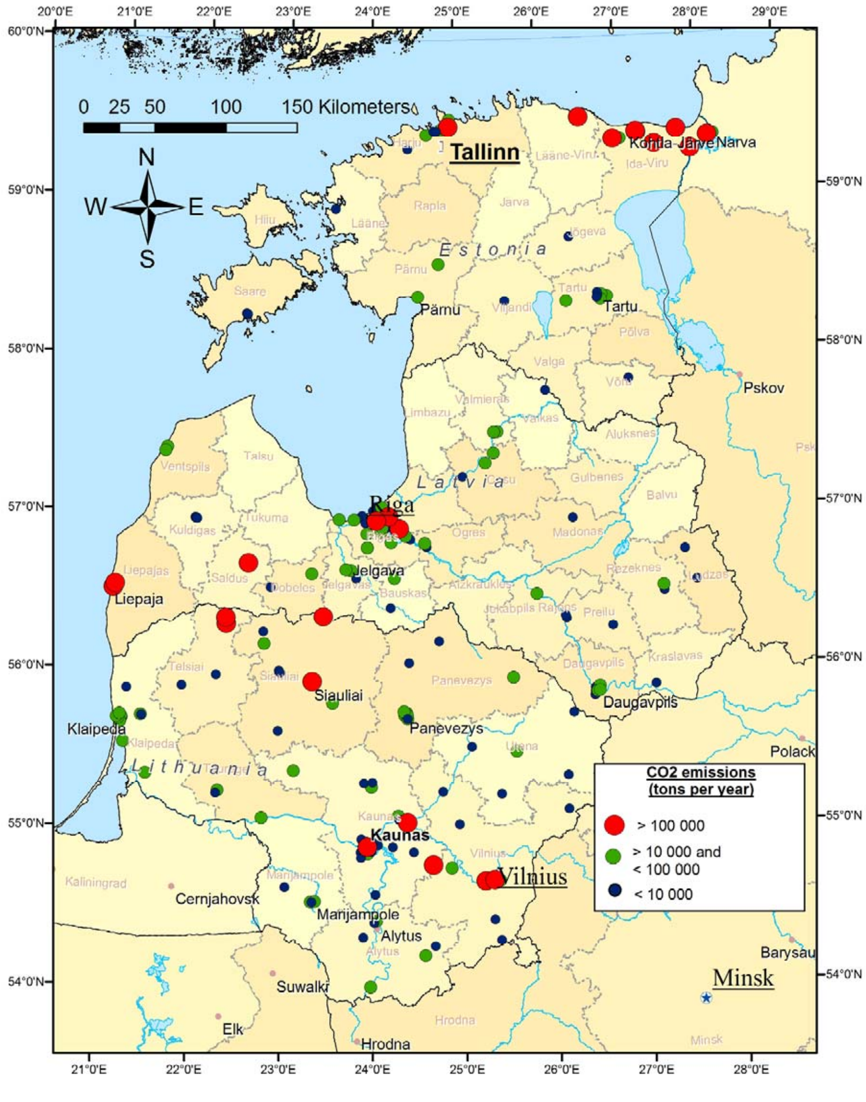

Figure 2. Location of CO_2 sources of Estonia, Latvia and Lithuania registered in the European trade system.

Geological setting

The Baltic countries are situated in the eastern half of the Baltic sedimentary basin located on the southwestern margin of the East European Craton of Early Precambrian consolidation. The basin contains Ediacaran (Vendian) and all Phanerozoic systems and is only weakly tectonized, the sedimentary layers are gently inclined to the southwest. The thickness of the sedimentary pile is less than 100 m in northern Estonia, increasing to 1900 m in southwestern Latvia and 2300 m in western Lithuania (Figs. 3, 4).

The oldest sediments are represented by Ediacaran siliciclastics dominated by arkosic conglomerates and sandstones of up to 200 m thick. They are distributed in the eastern part of the Baltic countries. The Cambrian is composed of triple alternation of the quartz sandstones, siltstones, and shales that show different proportions across the basin, with general increase of the shale layers to the west. The thickness of the Cambrian attains 170 m in western Lithuania and is overlain by 40-250 m thick Ordovician shaly-carbonaceous succession which is in most part of the basin a regional aquitard except for the eastern and northern periphery of the Baltic basin (east Lithuania, Estonia) dominated by limestones and dolostones. It grades into thick package of Silurian shales reaching 800 m in thickness in western Lithuania. In the shallow periphery of the basin they give way to dominating carbonates.

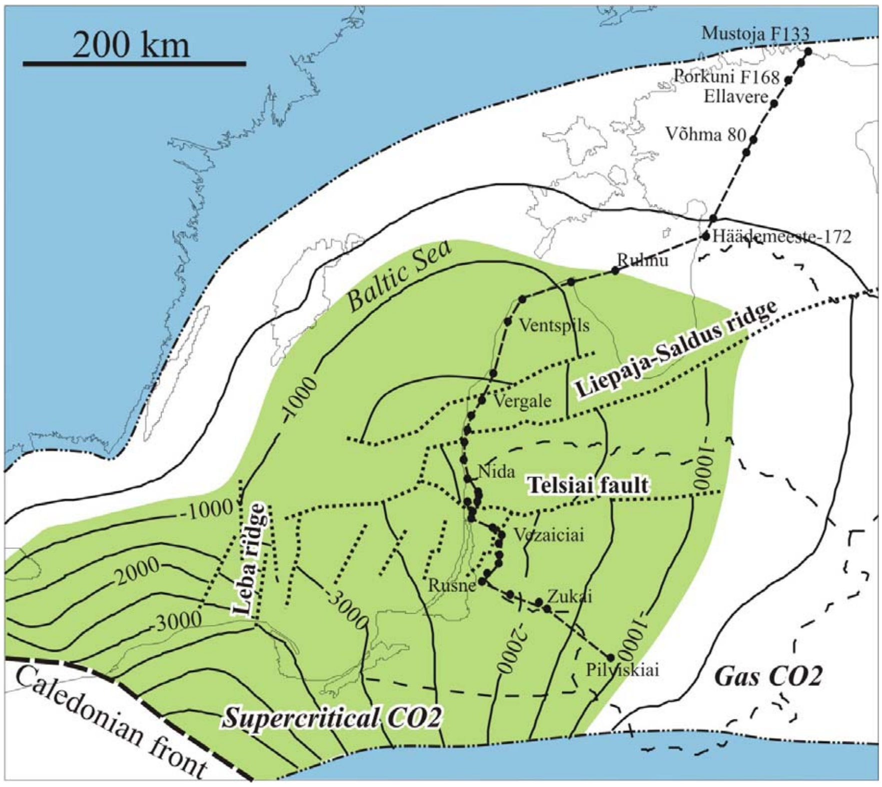

Figure 3. Depths of top of the Cambrian aquifer. The P-T fields of gaseous and supercritical state of CO_2 (P = 73.8 bars, T = 31^{o}C) are shown. The line of the geological cross-section shown in Fig.4 is indicated.

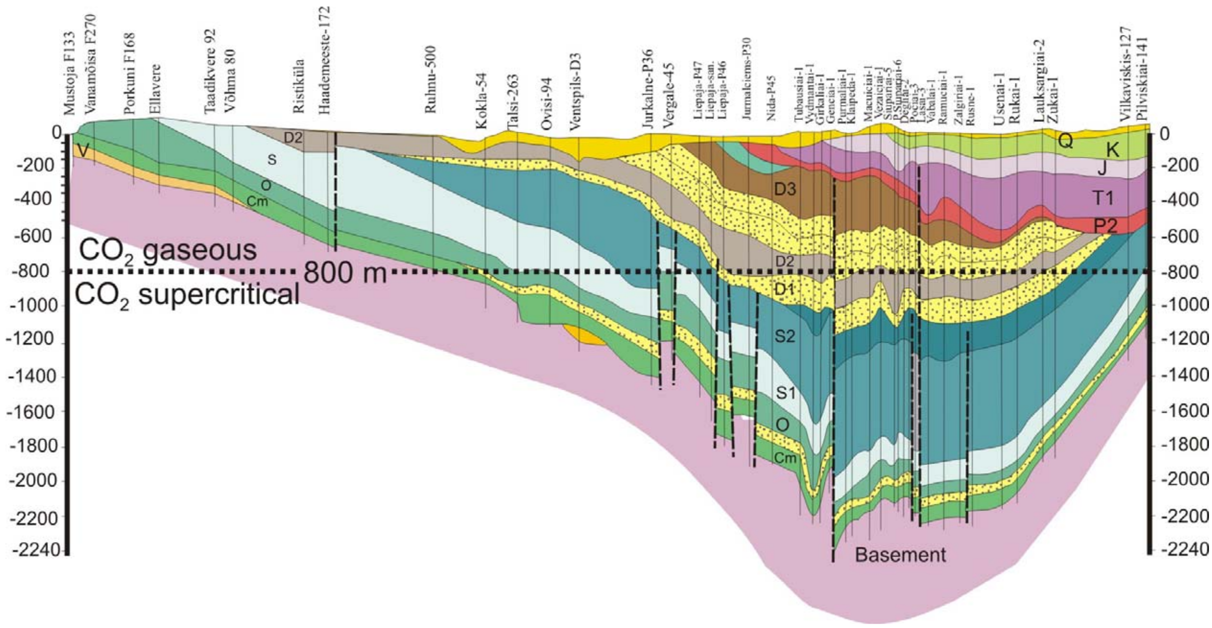

Figure 4. Geological cross-section across Estonia, Latvia, and Lithuania. Major siliciclastic aquifers are shown in yellow.

The Devonian sediments show less wide distribution in the Baltic region. They cover the whole territory of Latvia, southern Estonia, most of Lithuanian territory, except for the southern part. The composition of the Devonian system is highly variable up the section. The maximum thickness is reported from western Lithuania where it is of up to 1100 m thick. The lowermost Carboniferous sediments of sandy-shaly-carbonaceous composition are mapped locally in northwest Lithuania and southwest Latvia, they are up to 110 m thick. The thickness and depths of younger sediments of Permian, Mesozoic, and Cenozoic ages increase to the southwest, reaching 600 m in the southwestern Lithuania. These sediments are absent in Estonia and most territory of Latvia.

CO_2 storage potential

The Baltic sedimentary basin contains a number of aquifers. However, only Lower-Middle Devonian of west Lithuania and Middle Cambrian siliciclastic reservoirs fit the basic requirements for geological formations for CO_2 storage. The prospective areas are limited by P-T conditions required for supercritical state of CO_2 (P = 73.8 bars, T = 31^{o}C) that roughly coincides with 800 m depth. The Cambrian prospective area includes western Lithuania and western Latvia and most of the Baltic Sea (Figs. 3, 4). Estonia is outside the limits of potential formations for CO_2 sequestration. Only far-distance transport of carbon dioxide from north Estonian sources can be considered. It is about 250-400 km to the potential sites in Latvia (Middle Cambrian) and 500 km to the potential sites in Lithuania (Devonian). All sources of Latvia are located within the prospective Cambrian area. The most prospective storage of CO_2 is related to large uplifts (11) the total potential of which is assessed as much as 200 Mt that covers 100 years of the large-source emissions in Latvia. All structures are close to pipe lines and CO_2 sources, the closest structures (less than 30 km) are the Degole, Dobele, Blidene, Aizupe, Liepaja uplifts. It is important that one of such structures the Inčukalns UGS is used for underground gas storage and operating since 1968, the working gas volume is 2.3 MMm^3. No gas escape was reported. It is important evidence, as the structures of this order are confined to large-scale faults that provide potential path-ways for the gas escape (Davis et al, 2006).

Only the western cluster of CO_2 sources is located within prospective area of Cambrian reservoir and only one source is within the Devonian prospective area in Lithuania.

The structural trapping is not an option for Lithuania, as the uplifts are small and can store less than one year's emission amount.

Alternatively, the solubility trapping can be considered as having high potential that together with the mineral trapping should cover industry needs for hundreds of years. The prospective area of the Cambrian aquifer comprises central and western parts of the Baltic basin. Assuming average conditions of the aquifer for west Lithuania and central part of the Baltic Sea T=75°C, P=200 bars, TDS=150 g/l, the solubility is 29 kg/m^3. Assuming porosity 10% and effective thickness 20 m the potential of 1 km^2 is assessed 0.06 Mt of CO_2. The prospective area is 400×500 km. Calculated total sequestration potential is 12 Gt of CO_2 and onshore it is 4.6 Gt of CO_2. The Pärnu-Ķemeri aquifer with higher reservoir properties but less spatial extension has total potential of 24 Gt of CO_2 (average 0.85 Mt per 1 km^2) and onshore potential (western Lithuania) is 4 Gt of CO_2. The sequestration potential within the gaseous state field of CO_2 is even larger. The Pärnu-Ķemeri sandstones contain clay admixture (up to 10%) and feldspar grains (up to 15%). Therefore it has a potential for permanent immobilisation of the carbon dioxide in the mineral form. Assuming rock capacity 10 kg/m^3 (Bachu, Adams, 2003) their potential can be evaluated more than 19.5 Gt (Šliaupa et al, 2005).

Acknowledgments

This study was supported by two projects funded by European Commission FP6 (EUGEOCAPACITY and CO2NETeast) and by project T-05012 of Lithuanian Science Foundation.

References

Bachu S., Adams J.J. (2003) Sequestration of CO_2 in geological media in response to climate change: capacity of deep saline aquifers to sequester CO_2 in solution. Energy Conversion and Management 44. 3151–3175.

Davis A., Jesinska A., Kreslins A., Zebergs V., Zeltins N. 2006. Increasing role of underground gas storages for reliable supply of gas to Latvia, Lithuania, Estonia, Finland and NW Russia and prospects of development of Incukalns underground gas storage. 23rd World Gas Conference, Amsterdam 2006. CD.

Lokhorst, A. and Wildenborg, T. (2005). Introduction on CO2 Geological Storage. Classification of Storage Options.Oil and Gas Science and Technology, Rev. IFP, Vol.60, No3, p. 513-515.

Šliaupa S., Satkūnas J., Šliaupienė R., (2005) Prospects of geological disposal of CO_2 in Lithuania. Geologija, 51, 20-31.