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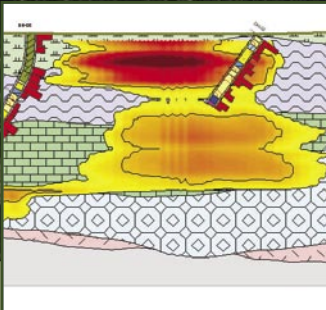
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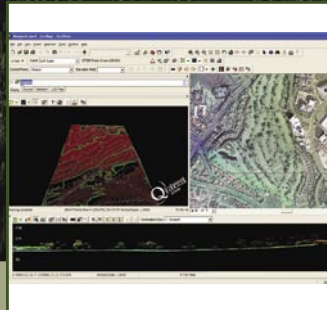
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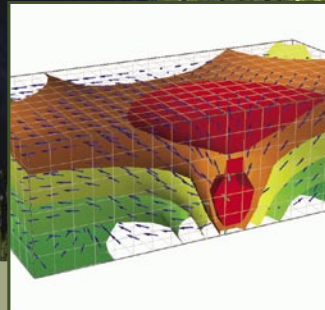
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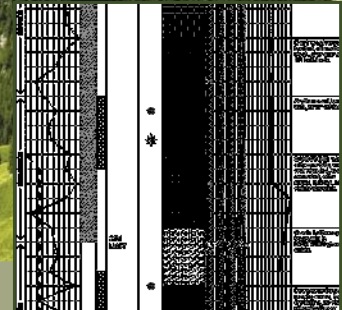
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# Contents *European Geologist 29*

	Page
Foreword... <i>Ruth Allington</i>	4
<b>Renewables</b>	
Deep geothermal potential in Spain... <i>Raul Hidalgo</i>	5
The GTR-H project... <i>R. Goodman et al.</i>	10
Deep geothermal potential in N. Ireland... <i>Derek Reay and John Kelly</i>	14
Induced seismicity associated with exploitation of deep geothermal ... <i>T. Kraft et al.</i>	19
Geothermal energy and CO <sub>2</sub> sequestration... <i>Umberto Puppini</i>	21
Transboundary geothermal resources of the Mura-Zala Basin ... <i>A. Nádor and A. Lapanje</i>	24
Alternative energy in the Crimea and Carpathians, Ukraine ... <i>G.I. Rudko</i>	28
<b>Topical</b>	
Interview with Martin Blunt... <i>Sarah Day</i>	32
Opinion: Politically correct geology... <i>D. Navarro Vázquez</i>	33
<b>Feature</b>	
Mining in Hungary... <i>Gábor Szabados and Tamás Hámor</i>	34
<b>News and Events 2010</b>	
Record permeability in UK granite; Geotrained; Euro-Ages	38-39
Geologos sin Fronteras	40
<b>Book Review</b>	
Cyprus... <i>by Stephen Edwards et al.</i> ... <i>review by Howard Armstrong</i>	41



p. 28

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Cover photo: Irish Drilling Ltd. rig on Kilroot borehole, Northern Ireland, with coal and gas fired Kilroot power station in the background (Photo: Kelly, 2010)

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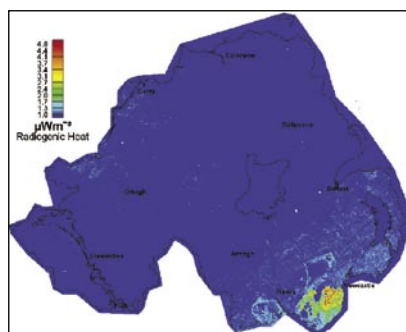
Clockwise from top: hydrothermal reserves, Ukraine; orphanage, completely destroyed in the earthquake, Ca Ira village, Haiti; the Pannonian Basin in Central Europe; radiogenic heat potential in Northern Ireland.

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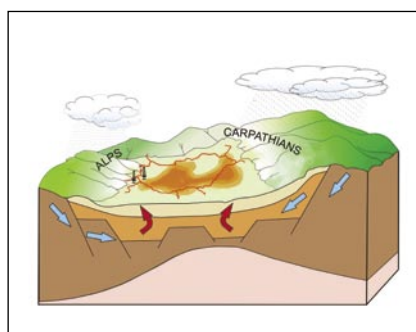
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p. 40

p. 14



p. 24



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## Foreword

# Projecting the EFG

by EurGeol. Ruth Allington, President

This issue of European Geologist is published to coincide with a conference in Potsdam, Germany on 28 May 2010: Energy Supply - Status and Strategies, organized jointly by BDG, GFZ and EFG. The collection of papers in this issue are relevant to that theme and we are expecting a stimulating day. EFG will take the opportunity to present an update on the GEOTRAINET project which has just passed its half way point.

One of the main objectives for the first half of the GEOTRAINET project was to prepare curricula for training designers and drillers involved in the specification and installation of ground source heat pumps (GSHP). To support the work of the expert platforms which were set up to work on the curricula, existing training and reference materials for professionals involved in the shallow geothermal sector were collected and reviewed in order to create a directory of the existing courses in Europe.

A further objective was to identify sources of geological data available in the EU for GSHP implementation. The outputs of this include a database on geological information; guidelines to facilitate the acquisition of relevant geological data; and posters on shallow geothermal potential in Europe.

During this period, work on a certification framework at European level was started. In this context the project team established contact with the European standardization Centre (CEN) and began the process towards a certification of GSHP installers, with a proposal for standardization of this certification.



Training courses for trainers and drillers were organized and delivered in 2009 and a calendar was established for all training courses to be delivered throughout the project period, including those planned for designers.

EFG has been responsible for the management and co-ordination of this project as well as some specific expert inputs. The other partners in the project are: European Geothermal Energy Council (Belgium); Österreichisches Forschungs und Prüfzentrum Arsenal Ges.m.b.H (Austria); BRGM (France); GT Skills (Ireland); Romanian Geoexchange Society (Romania); Universidad Politécnica de Valencia (Spain); Lund University (Sweden); University of Newcastle-upon-Tyne (UK).

The project is already making a valuable impact in training professionals involved in shallow geothermal energy; a vitally important element of the energy mix in lower carbon societies. It is raising the profile of professional geologists amongst kindred professionals and, ultimately, the public involved in this field and is bound to improve recognition of the importance of geology and geologists in developing this area further for the benefit of Society.



*The EFG Board 2009 - 2010  
From left: Marino Trimboli,  
Seppo Gehor, Ruth Allington,  
Piers Gardiner, Dirk de  
Koster*

# Deep geothermal potential in Spain

by *EurGeol. Raul Hidalgo*<sup>1</sup>

Spain offers several favourable environments with the potential to host volcanic convective hydrothermal, conductive sedimentary and enhanced geothermal systems suitable for generating electricity. There are also many low-temperature resources close to noticeable heat demand areas, such as Madrid and Barcelona, which makes them very favourable for direct heat uses and the development of Geothermal district heating grids. In order to develop this geothermal potential, a combination of measures including adequate feed-in tariff schemes, drilling risk mitigation programmes, grant-assisted demonstration projects, research & development programmes and improvements to existing regulations are needed, in a coordinated effort from government (federal, regional and local), research bodies (universities, technological institutes) and the private sector.

Spanish geothermal potential began to be investigated in the 1970s by the Geological Survey of Spain (IGME) within the framework of the PEN (National Energy Plan) that aimed to define alternative and local solutions to the then world energy crisis. This especially affected the Spanish economy, due to its dependence on external energy resources. Studies undertaken by IGME involved basic geology, geochemistry, geophysics and in some cases geothermal wells. Several areas with relevant geothermal anomalies in both islands and mainland environments were defined. A very preliminary estimation made by IGME in the 80s on the potential for conventional geothermal resources that could be leveraged in Spain was 600 kToe/year of energy that could be produced

Potentiellement, l'Espagne offre plusieurs environnements géothermiques favorables par la présence de systèmes volcaniques avec fluides de convection hydrothermale, sédiments conducteurs et sources de chaleur de haute enthalpie, capables de produire de l'électricité. Il existe aussi nombre de sites de basse enthalpie, proches de régions avec forte demande en chaleur, telles que Madrid et Barcelone, ce qui les rend très favorables à une utilisation directe de la chaleur et au développement de réseaux locaux de distribution de chaleur. Pour développer ce potentiel géothermique, il est nécessaire d'associer des mesures incluant une politique tarifaire adéquate, des programmes de réduction du risque de forage, des projets de démonstration subventionnés, des programmes de recherche et développement ainsi que des améliorations apportées à la réglementation existante, cela, dans un effort gouvernemental de coordination entre les autorités fédérales, régionales et locales, les unités de recherches (universités, instituts technologiques) et le secteur privé.

if appropriate conditions were in place.

In the Canary Islands, IGME carried out important research in collaboration with other institutions, between the late 1970s and the mid 1990s. Their work was mainly focused on ground water geochemistry and temperature analysis, followed by geophysical techniques, such as magnetotelluric (MT) and thermometric studies between 1977 and 1990 on Tenerife and Lanzarote islands respectively (IGME, 1987; ITGE, 1993). Four geothermal wells were drilled, one in Tenerife, one in Lanzarote and two in Gran Canaria on the most interesting anomalies.

Almost 50% of the mainland is covered by undeformed Cenozoic basins associated in many cases with rich U, Th and K granitic rocks (ITGE, 1991). The combination of low thermal conductive thick sediment cover with thermally active granite provides a good geological setting to produce sedimentary geothermal and enhanced geothermal systems. Several geothermal potential areas were defined, associated with the main Tertiary basins;

España presenta varias zonas favorables para albergar sistemas volcánicos hidrotermales convectivos, sistemas sedimentarios conductivos y sistemas geotérmicos mejorados para la generación de electricidad. Hay muchos recursos de baja temperatura cerca de áreas con una notoria demanda de calor, tales como Madrid y Barcelona, lo que las hace favorables para usos de calor directo y el desarrollo de redes de suministro de calor geotérmico regionales o municipales. Con objeto de desarrollar este potencial geotérmico es necesaria la combinación de una serie de medidas incluido planes de tarifas incentivadas, programas de mitigación de los riesgos de perforación, proyectos de demostración subvencionados, planes de investigación y desarrollo y mejoras en las normativas existentes, en un esfuerzo combinado del gobierno (nacional, regional y local), de los centros de investigación (universidades, institutos tecnológicos) y el sector privado.

Guadalquivir, Tajo, Duero, Ebro with associated geothermal potential along the basin boundaries. In the Madrid and Pyrenees Basins, temperatures above 150 °C have been measured from historical oil wells at depths from 3,500 to 4,000 m.

## Types of Geothermal Systems

Spain hosts a diverse range of geothermal possibilities in terms of geological origin and geothermal characteristics. These occur both on the Spanish mainland, the Balears Islands and the Canary Islands. Resources are classified according to temperature and geological setting, with subdivisions including magmatic-related high temperature systems.

## Magmatic-related systems

Magmatic-related systems are characterized by predominantly high temperature geothermal resources, though there could be lower enthalpy zones on the margins or at shallow levels. Magmatic-related systems in Spain are present only in the

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<b>Magmatic Hydrothermal Systems</b>		<ul style="list-style-type: none"> <li>Canary Islands</li> </ul>
<b>Hot Sedimentary Aquifers</b>	<b>Main Cenozoic Basins</b>	<ul style="list-style-type: none"> <li>Tajo Basin: Madrid</li> <li>Duero Basin: León, Burgos and Valladolid</li> <li>Guadalquivir Basin</li> </ul>
	<b>Small-Medium Basins</b>	<ul style="list-style-type: none"> <li>Catalonian Ranges: Vallés, Penedés, La Selva, Ampurdán</li> <li>Betic Range Internal Basins: Granada, Guadix, Baza,</li> <li>Pyrenees Internal Basins: Jaca-Sabiñánigo</li> </ul>
<b>Enhanced Geothermal Systems</b>		<ul style="list-style-type: none"> <li>Associated to the crystalline granitic basement of the above described basins; Hercynian thermal active granites associated to deep fault convective systems: Galicia.</li> </ul>

Table 1. Classification of types of geothermal energy in Spain. (Modified from Garcia de la Noceda et al., 2005)

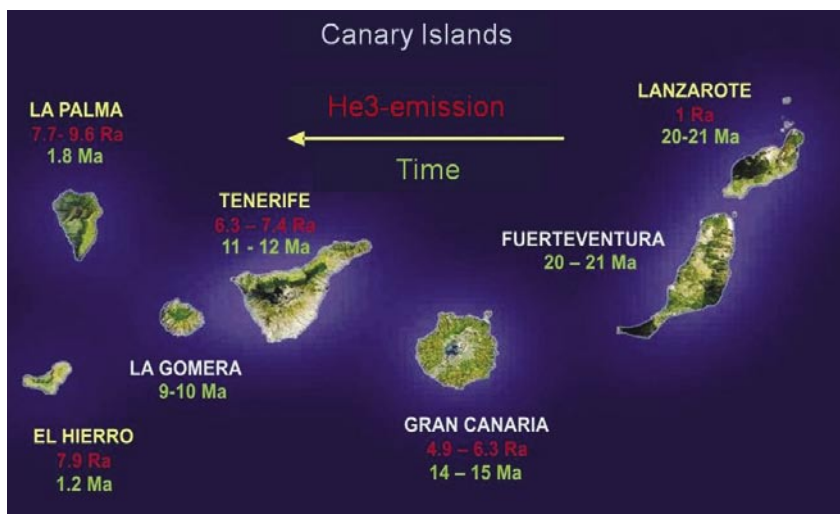


Figure 1. He<sub>3</sub>/He<sub>4</sub> ratios, a good indicator of magmatic activity (Pérez et al., 1994, 1996)

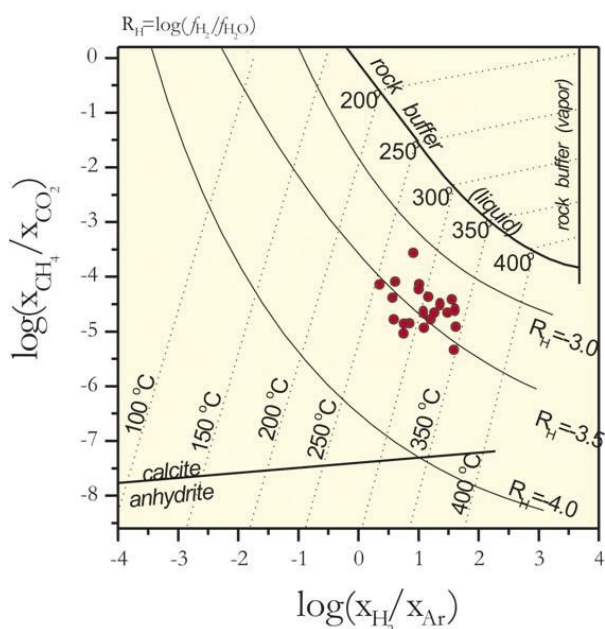


Figure 2. CH<sub>4</sub>/CO<sub>2</sub>-H<sub>2</sub>/Ar Geothermometer calculated from Teide summit fumarole (Hernandez et al., 2000)

Canary Islands, which are a series of shield volcanoes. The eastern islands are oldest, with volcanic activity commencing about 20 and 16 Ma. on Fuereventura and Lanzarote, 8 to 15 Ma. on Gran Canaria, Tenerife and Gomera, and less than 5 Ma. on La Palma and Hierro. However, the Canary Island volcanoes have remained intermittently active, with eruptions from all except Gomera in the past <1 Ma. The most active of these volcanic islands in historic times has been Tenerife, near the centre of the group (Fig. 1). Here, gas analyses of the fumaroles at the summit of the Teide volcano are consistent with steam derived from a mature liquid-dominated geothermal reservoir with temperatures in the range of 250-300 °C (Hernandez et al., 2000) (Fig. 2).

**Mainland Spain**

Mainland Spain hosts a number of areas characterized by anomalous heat flow (Fig. 3). In a geological sense the geothermal resources of mainland Spain can be classified into two main types: low-medium temperature hot sedimentary aquifers (HSA) and enhanced geothermal systems (EGS).

**Hot sedimentary aquifers**

There are two geological settings favourable to the development of these geothermal systems; the undeformed Cenozoic basins and the small internal basins (Fig. 4)

Over 50% of peninsular Spain consists of large Cenozoic basins that cover thermally active Hercynian granites (ITGE, 1991). The superposition of substantial thicknesses of low thermal conductivity sedimentary materials over these heat-producing granites result in an adequate geological framework for the development of geothermal systems associated with deep sediments. Oil exploration boreholes have been drilled in the Madrid and Pyrenean basins that have measured temperatures over 150-180 °C at 3,500 and 4,500 m depth, associated with limestones of Jurassic and Cretaceous age.

Geothermal areas associated with the main basins are:

**Ebro Basin**

- Lérida: Triassic aquifer lodged in limestones and other detritic rocks at 1,500 m depth with a temperature of 60 °C
- Huesca: Jurassic aquifer in limestones with temperatures near 90 °C starting at 2,000 m depth
- Vitoria-Treviño: Cretaceous aquifer in limestones showing temperatures of up to 60 °C at 2,000 m depth.

**Guadalquivir Basin:**

- Jurassic dolomite aquifers from 2,000 to 3,500 m depth showing temperatures from 80 to 130 °C.

**Duero and Tajo Basins:**

- Detritic Paleogene aquifers located from 1,500 to 2,500 m depth with 70 to 90 °C temperatures
- Cretaceous limestone aquifers at the limit with the basement from 3,500 m depth showing temperatures between 120 and 150 °C.

**Internal Basins:**

**Betic range**

- Includes several basins such as Granada, Guadix-Baza, Almería, Mula, Mazarrón, Cartagena, Guadalestín, Lluchmajor (Mallorca), etc. The general lithological sequence of these basins consists of Tertiary sediments underlying an allocthonous carbonate formation which is relatively permeable and highly complex. Aquifers with temperatures of 50 °C have been identified at depths greater than 1,000 m.

**Central Pyrenean zone. Jaca-Sabiñanigo**

- A thermal aquifer (>140 °C) has been detected through oil borehole drilling

in Paleocene-Miocene materials at over 3,000 m depth.

**Catalan Coastal Ranges:**

A series of basins (grabens) in the north-eastern margin of the Peninsula showing important geothermal characteristics:

- Vallés-Penedés Graben: thicknesses of 1,000-3,000 m composed of Miocene materials. The geothermal resource is located in the main fault (NW) including temperatures of 90 °C measured at 1,000 m depth in well Samalus 6
- La Selva Graben: located to the north of Valles-Penedes; it shows similar characteristics to Vallés-Penedés
- Ampurdán Graben: carbonate aquifer of Eocene age with a thickness of 4,000 m and temperatures of up to 150 °C.

**Enhanced geothermal systems**

These systems are located in deeply-fractured granitic zones through which hot fluids circulate and which, upon reaching the surface, give place to natural manifestations such as the Caldas de Montbui thermal springs in Cataluña and Orense in Galicia, with temperatures of 75 to 80 °C (Fernández *et al.*, 1990).

Deep zones (>3,000 m) associated with these convective systems represent favourable environments for the development of medium-enthalpy enhanced geothermal systems (>150 °C). In areas of low permeability, stimulation of existing fractures will be necessary to allow the circulation of fluids through the hot dry rock.

**Projects in Development**

These Geothermal areas could be used for electricity generation where sufficient temperatures and flows are found (generally above 140 °C and over 30 l/s respectively). In the case of medium to high-temperature resources (Canary islands) and low medium temperature sedimentary aquifers, perspectives appear to be highly favourable since the technology developed for enhanced systems will enable a better leveraging of these resources. As already mentioned, the Spanish geological framework favours the development of enhanced geothermal projects. In fact, several studies have been initiated in a number of areas in the country - led by business initiatives - aimed at localizing favourable areas and assessing the eventual potential of the resources, an essential step before the decision to move ahead with the development

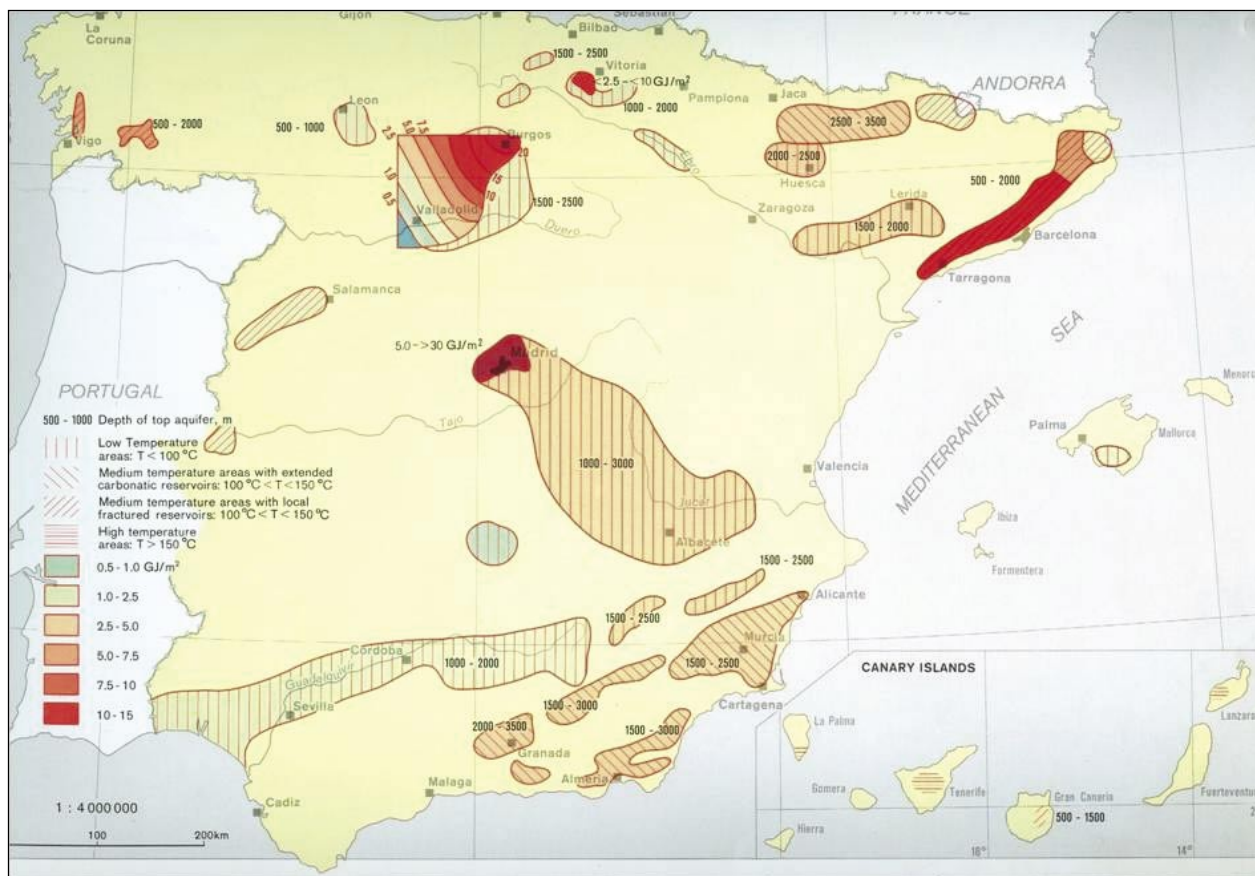


Figure 3. Distribution of geothermal areas in Spain (modified from Haenel & Staroste, 1998)

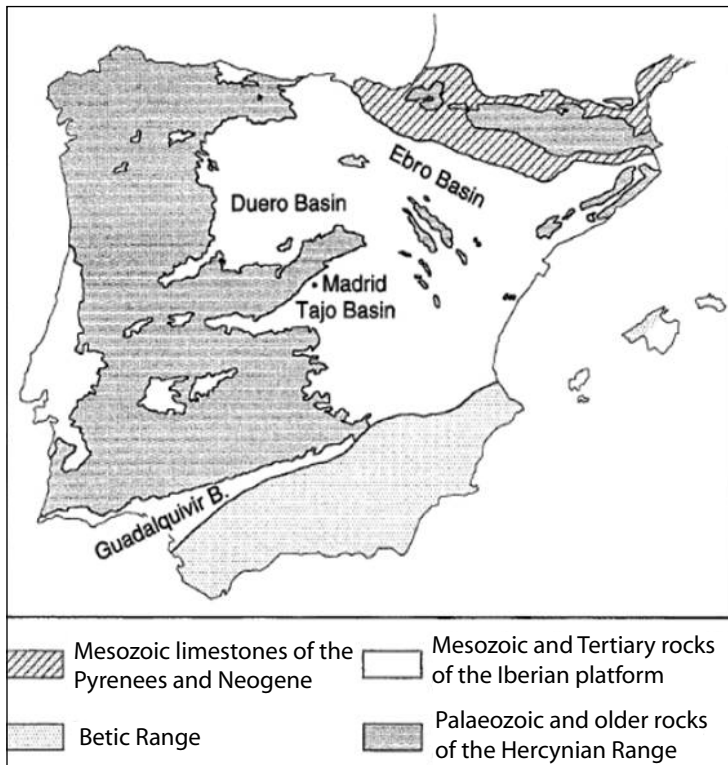


Figure 4. Main geological units of the Iberian Peninsula (from Cuchi-Oterino et al., 2000)

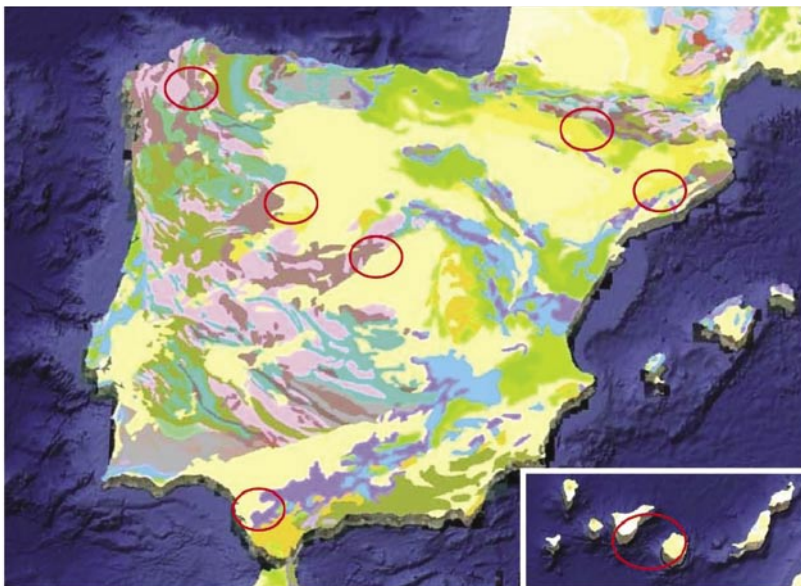


Figure 5. Main areas of current geothermal exploration activities in Spain

stage. Detailed basin structural reconstruction is being conducted by private initiative in several zones utilizing drilling information together with seismic profiles, gravity and MT data. This existing data is being used to build 3D geological models that define deep geothermal drilling targets.

A few exploration and investigation pre-drilling programmes (including geochemistry, geophysics and 3D modelling) are currently being carried out by private

exploration companies in the Madrid, Catalonia, Galicia and Castilla-Leon and Andalucía regions and on the Canary Islands (Fig. 5).

Low-temperature resources (<120 °C) with adequate discharge could also be subject to thermal use, whether for heating-cooling applications or for agricultural and industrial purposes, as long as they are found near the areas where demand is required. Most basins in mainland Spain

have associated hot aquifers that could be exploited for direct thermal use in industrial processes and district heating grids. In the Burgos (Duero Basin) and Madrid (Tajo Basin) areas, two projects are currently in the advance feasibility study stage: the Cantoblanco project in Madrid, an 8 MW Thermal District heating grid to provide heat and sanitary hot water to Autonomía University Campus (Ungemach, 2008) (Fig. 6) and the Villalonguejar project in Burgos to provide heat in an industrial process.

**The future**

The Geothermal energy sector is reviving after several decades of low development in Spain. Between the late 1980s and the mid 2000s there was no geothermal investigation and development; however interest has just recently restarted. Exploration Companies, Technological Institutes, Universities, regional and federal governments have become active in the last year and are starting to coordinate joint initiatives to promote the development of geothermal energy in Spain.

Two main initiatives have been developed within the last two years in order to promote the geothermal sector in our country:

Firstly, the creation in 2008 of a geothermal section within APPA, the association of Producers of Renewable energy of Spain. This group, currently with 11 members, is focusing efforts to obtain a detailed definition of geothermal resources, validation of the technical and economic parameters that will make the geothermal resources viable, and development of an appropriate legal and administrative framework for the industry. This is the aim of the study that consulting firms SKM and Geo-Thermal Engineering are undertaking and which concludes in March 2010 on behalf of APPA to determine the Geothermal Potential in Spain and Support Schemes Necessary to Facilitate Geothermal Development

Secondly, the launch of GEOPLAT, the Spanish Geothermal Technology platform, in May 2009. The group is led by the Ministry of Science and Innovation of Spain, IDAE (institute for energy diversification and energy saving), IGME, Universities, APPA and another private initiatives. GEOPLAT will present the vision Document 2030 ([http://www.geoplat.org/main\\_in.html](http://www.geoplat.org/main_in.html)) at the last Annual General Meeting held in April 2010 and is now in the process of developing The Strategic Research Agenda for Spain that will include all



relevant geothermal R&D objectives and the necessary programmes to be implemented in order to achieve these targets.

The following geothermal R&D activities are suggested in both APPA and GEOPLAT recent reports:

- Funding of proof-of-concept projects and demonstration plants
- Filling the gaps on the Spanish heat flow map
- Improved understanding of the national resource (e.g. geothermal information systems, public geophysical databases)
- Improved exploration, reducing exploration risk
- Improvements in deep drilling technologies, reducing drilling costs
- Improvements in low enthalpy power plant technology
- Improvement of petro-thermal technologies, increasing mass flow rates.

The recent independent study prepared for APPA (APPA, 2010) estimates, in a high support scenario, that about 1050 MW geothermal power plus 700 MW geothermal heat could be developed by 2020. This energy is available 24 hours a day and can serve as base load energy. It substitutes power and heat from fossil energy sources and thus leads to a significant reduction

of greenhouse gases. The development of geothermal energy will lead to the setup of a new industry branch.

This development will only be achievable if an appropriate feed-in tariff

scheme, combined with a risk mitigation programme, incentives for heat projects, demonstration projects and basic R&D support are developed within the near future in Spain.



Figure 6. Detailed logging on geomadrid 1 (Cantoblanco project) July 2008 to check well integrity

#### References

- APPA, 2010. *Geothermal potential in Spain and support schemes necessary to facilitate geothermal developments*. Internal report prepared on behalf of SKM's / GeoThermal Engineering GmbH for APPA.
- Cuchi-Oterino, J.A., Baeza Rodriguez-Caro, J., Garcia de la Noceda-Marquez, C. 2000. Overview of Hydrogeothermics in Spain. *Environmental Geology*, 39 (5).
- Donoghue, E., Troll, V.R., Harris, C., O'Halloran, A., Walter, T.R., Pérez Torrado Fernandez, M., Marzán, I., Correia, A., Ramalho, E. 1998. Heat flow, heat production and lithospheric thermal regime in the Iberian Peninsula. *Tectonophysics*, 291, 29-53.
- Fernandez, M., Banda, E. 1990. Geothermal anomalies in the Valles-Penedes graben master fault: Convection through the horst as a possible mechanism. *J. Geophys. Res.*, 95, 4887-4894.
- Fernandez, M., Garcia de la Noceda, C., Marzán, I., Sanchez-Guzman, J. 2002. *Spain, Atlas of Geothermal Resources in Europe*. (Eds: Haenel, R., Hunter, S.), European Commission, Research Directorate-General, 56-57.
- García de la Noceda, C., Sanchez-Guzman, J. 2005. Geothermal Energy Development in Spain - Country Update Report. *Proceedings World Geothermal Congress 2005*, Antalya, Turkey, 24-29 April 2005.
- Hernández, P.A., Pérez N.M., Salazar J., Sato, M., Notsu, K., Wakita, H. 2000. Soil gas CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub> distribution in and around Las Cañadas caldera, Tenerife, Canary Islands, Spain. *Journal of Volcanology and Geothermal Research*, 103 (1-4), 425-438.
- IGME. 1987. Investigación geotérmica en las islas Canarias y evaluación de recursos y reservas geotérmicas en España - Prospección geofísica, métodos magnetotérmico y SOFREM.
- ITGE. 1993. Investigación geotérmica en el área central de la isla de Tenerife - informe final.
- ITGE. 1990. Trabajos de medición e inventario de datos de flujo de calor en áreas seleccionadas del Macizo Ibérico Español. Instituto Tecnológico Geominero de España. Madrid, 53 pp.
- ITGE, 1991. Análisis de la utilización de recursos geotérmicos en España. Situación actual. Instituto Tecnológico Geominero de España. Madrid, 111 pp.
- Ungemach, P., Hidalgo, R., Antics, M. 2008. Geothermal Potential of the Madrid Area, a Tentative Resource/ Reserve Assessment. *I Congreso de Energía Geotérmica en la edificación y la Industria*, GEOENER Conference 15-16 October, Madrid, Spain.
- GEOPLAT. 2010. *Vision for 2030*. [www.geoplat.org/main\\_in.html](http://www.geoplat.org/main_in.html) Geoplat.

# The GTR-H project

## The IEAA-funded GeoThermal Regulation for Heat project 2006-2009

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Irish based geoservices consultancy SLR Consulting (Ireland) Ltd, together with seven EU partners initiated the GTRH project (GeoThermal Regulation - Heat) to develop a framework of geothermal heat legislation/regulation. GTRH focused on four target countries, Hungary, Ireland, Northern Ireland and Poland, and best practice experience in the implementation of geothermal regulation in France, Germany and the Netherlands (Best Practice Countries). The results were used to formulate a geothermal energy regulation framework template to guide the implementation of regulations across the EU. The resultant template and its dissemination aimed at increasing overall sectoral investment in geothermal energy for the exploration and exploitation of heat across the EU.

Les Services en géosciences du Bureau SLR Consulting Ltd, basés en Irlande, en association avec sept partenaires européens ont lancé le Projet GTRH (GeoThermal Régulation - Heat) pour développer une structure traitant de la législation et de la réglementation en matière d'énergie géothermique. Le Projet GTRH est coordonné par 4 pays cibles, la Hongrie, l'Irlande, l'Irlande du Nord et la Pologne qui bénéficient de la grande expérience de la France, de l'Allemagne et des Pays Bas (pays experts) pour la mise en œuvre d'une réglementation en géothermie. Les résultats ont servi à établir un code de réglementation en énergie géothermique pour guider la mise en œuvre de cette réglementation en Europe. L'objectif du document résultant et de sa diffusion était d'accroître de façon globale les investissements en énergie géothermique pour l'exploration et l'exploitation de la chaleur naturelle, en Europe.

La consultora geológica irlandesa SLR Consulting (Irlanda) Ltd. junto con siete socios de la UE, iniciaron el proyecto GTRH (Normas geotérmicas- calor) para desarrollar un marco reglamentario y legislativo para el calor geotérmico. El GTRH se centra en cuatro países objetivo: Hungría, Irlanda, Irlanda del Norte y Polonia y en experiencias de buenas prácticas en la implementación de las normas geotérmicas en Francia, Alemania y Holanda (países con buenas prácticas). Los resultados se utilizaron para un marco de referencia de reglamentos para la energía geotérmica con objeto de guiar la puesta en marcha de normas en toda la UE. El modelo resultante y su difusión tiene por objetivo aumentar las inversiones sectoriales en la energía geotérmica para la exploración y explotación del calor en toda la UE.

Deficient and, in some cases, effectively absent geothermal regulations in Poland, Hungary, Ireland and the UK (Northern Ireland) were reviewed in the project and used to identify the barriers to development of the geothermal energy sector not addressed by regulations and legislation. The key elements of international best practice particularly in Germany, France and the Netherlands

were reviewed to place the framework in context. The subsequent development of a geothermal framework included broad consultation and dissemination to maximize the applicability of the results. The GTRH template has been designed to have broad transferability to the remaining EU-27 countries and has been published on the GTRH and partner websites. The project aimed to help increase the geothermal contribution to the targets for renewable energy in the EU by providing a more robust legislative and regulatory infrastructure for the geothermal sector in the EU, contributing to the security of investment, competitiveness and environmental protection and closing the gap between the front runner countries and other EU member states.

### Key advances in the geothermal sector during the GTRH project

During the course of the project, the level of geothermal activities increased strongly across the EU and real progress was made

in most of the 'Target' countries of the consortium in various degrees of implementation of new or reviewed geothermal regulation (Fig. 1). Also the policies and Legal Frameworks in the best practice countries developed – generally in a beneficial direction (for geothermal). Examples are the revised feed-in tariffs in Germany and the greatly improved policies for geothermal district heating grids in France (Fig. 2). There is obviously not a one to one relationship between the GTRH project and these developments but the timing of GTRH was particularly expedient and GTRH therefore could very effectively contribute to these developments. Some further details are presented below:

In Poland, improved regulations related to the geothermal sector (induced both by GTRH tasks and by other initiatives) were introduced into the new Geological and Mining Law (2008) and are awaiting adoption by the Polish Parliament (2009). Solutions from the best practice countries and relevant information rising from the

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GTRH project helped to frame proposals by PAS MEERI for the new geological and mining law and the proposed 'principles of geothermal projects' funding from the sources of National Fund for Environmental Protection and Water Management. In addition, during 2007 and 2008 some decrees were issued by the Minister of Environment that simplify and shorten some administration procedures. These followed, among others, the suggestions and best practice examples made on the basis of GTRH process. In Poland, from 2007 to 2009, there was growing interest in geothermal development (heating, recreation) as reflected in the growing number of licenses issued per year for geothermal water exploration/assessment (3 - 7 licenses from 2007 - 2009 as compared with 1 - 2 licenses in earlier periods).

In Ireland, the process of drafting a regulation which will allow deep geothermal exploration is underway by the Department of Communications, Energy and Natural Resources and a first draft of these regulations is available and may be in place by late 2010. Also, the evaluation of deep geothermal resources at Newcastle, Co. Kildare is underway.

The Geological Survey of Northern Ireland began a programme of assessment of geothermal resources in Northern Ireland and promotion of geothermal energy in advance of progress being made on regulation. Two new commercially funded EGS projects in the southwest of England are in gestation and have applied for government support from the 'Challenge Fund for Deep Geothermal Energy' announced in July 2009.

In the Netherlands, a decision was made and announced to develop a guarantee scheme to cover (a major part of) the geological risks involved in deep geothermal projects – a direct consequence of the efforts of the Dutch Geothermal Platform (SPG) over the past years in the context of encouraging the adoption of geothermal regulations for the geothermal sector. In the Netherlands, the number of license applications for deep geothermal drillings rose from one per year from 2006 - 2008 to >50 applications in 2009.

In Hungary, at the end of 2009, several legislative actions were accomplished, partly engineered by the momentum generated by the GTRH activities and framework recommendations. In November 2009 the Water Act was amended by introducing a waiver for the existing thermal water users in the agri-sector, giving a certain degree of freedom for the competent authorities to

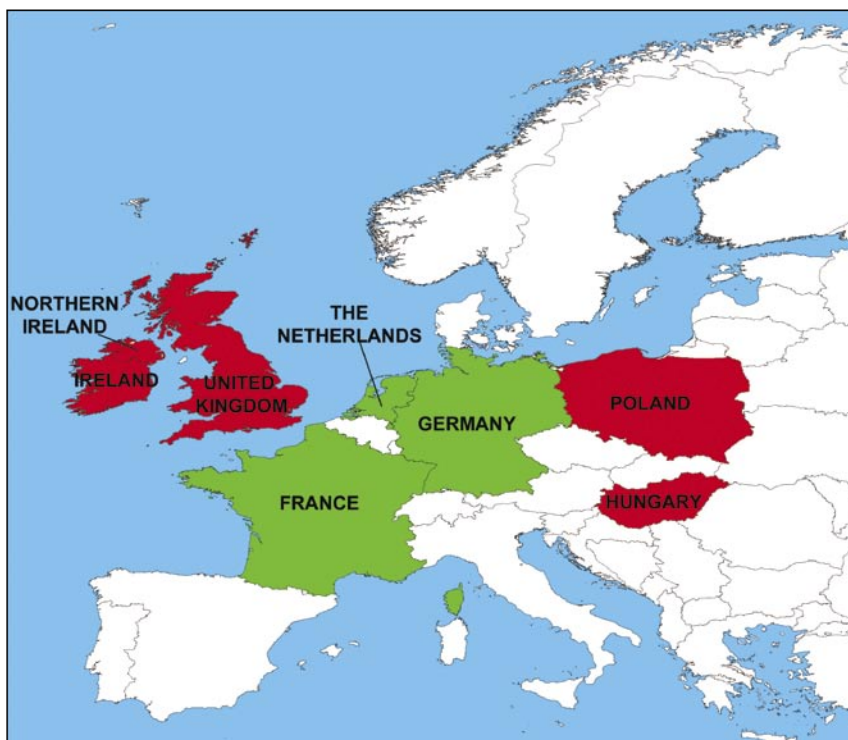


Figure 1. GTRH partner countries; best practice (green) target (red)

judge the absolute obligation for re-injection. On 14th December 2009 the Hungarian Parliament amended the Mining Act by excluding the thermal water extractions from the scope of the Mining Act and by prescribing the concessional (leasing) way of licensing for geothermal energy reserves below 2500 m. Unfortunately, a royalty obligation for geothermal energy extractors has remained in force (contrary to the recommendations of the GTRH framework). The detailed, implementing Government Decree is being prepared. During Autumn 2009 the Heat Pump Association separated from the Construction Engineers Society, and became an independent and powerful association. The preferential electricity tariffs for heat pump utilities are now routinely applied all over the country. Commercial projects in Hungary are developing rapidly as follows: Pannergy is developing several deep geothermal projects in Budapest, Miskolc, Pécs, Komló, Szentlőrinc, Bonyhád, Mohács, Tamási, Dombóvár, Kaposvár, Csurgó, Körmend, Nagykanizsa, Győr, Gödöllő, Gyöngyös, Eger, Mezőkövesd, Füzesabony, Egyek, Debrecen, Nagyrábé, Kaba, Nyiregyháza, Záhony, Csenger, Nyírbátor, Tótkomlós, Kiskunhalas, Jászberény, Tiszaújváros, Csongrád.

EGEC continues to provide legal recommendations to several Member States where geothermal energy is not regulated. The approach consists of providing the contact associations and individuals with GTRH results and additional inputs for development of their NREAPs. EGEN has already met with officers from the National Ministry of Energy from Spain, Portugal,



Figure 2. Geothermal drilling in the Paris Basin



Figure 3. Stakeholder study tour group in Germany

Slovakia and Slovenia. An important issue being raised currently is the competition on underground use between geothermal and CCS. EGEN has provided legal recommendations in a position paper in order to help solve this problem for which relevant inputs from GTRH were used. An important success of the GTRH project is the inclusion of a clear definition of geothermal energy in the new RES Directive which has primarily been the result of lobbying by the EGEN during the term of the project. The RES Directive will be the basis of future geothermal regulations in the EU Member States. New geothermal regulations have been adopted or are under preparation in some of the other EU-27 countries, and EGEN continues to liaise with them and provide support to encourage new legislation. In particular, in Lithuania a new renewable energy law is under discussion and in Spain, EGEN member (APPA) has been consulted by the government, and published a National Plan for RES including geothermal for which they liaised with EGEN regarding geothermal regulations. The increase in the geothermal energy contribution to RES heat in the EU has been 500MWt since the implementation of the framework in the unregulated countries.

#### Other geothermal advances in the EU

- Belgium: the “Geother-Wall” project to enlarge the geothermal district heating in Mons
- Greece: several deep geothermal projects on Greek islands
- Italy: a new geothermal district heating in Milano and deep geothermal projects with binary plants fed by shallow geothermal sources in Campania

and Tuscany Regions of Italy

- Latvia: The City of Riga wants to develop its district heating systems with combined heat & power geothermal plants. An EGS project is under preparation
- Lithuania: deep geothermal projects to enlarge the geothermal plant in Klaipeda
- Portugal: deep geothermal projects in the Lusitanian Basin
- Romania: deep geothermal projects in Satu Mare, Oradea, Arad, Timisoara
- Slovakia: deep geothermal projects in Velky Meder, Komarno, Kralovsky Chlmec
- Slovenia: deep geothermal projects in Ptuj
- Spain: a geothermal district heating is actually built in Madrid, and other deep geothermal projects are planned in Madrid and Barcelona regions.

It is not true to say that this is all as a result of the GTRH project but it indicates that the timing for the project was very apt, bearing in mind the stage of development of the sector in each case. Additionally, a number of unforeseen events such as problems with gas supply and the cost of hydrocarbons reaching record levels in the period of the project meant that it became easier to access the necessary contacts at government level and attract them to participate in discussion and workshops (Fig. 3).

#### Continuation of activities after the end of the GTRH project

A presentation of the GTRH framework has been approved and accepted for the World Geothermal Congress 2010 in Bali, the key conference of the International Geothermal Association (IGA) and the

International geothermal industry, which is held every five years. A paper with the full text of the final GTRH framework will be available in the proceedings of this conference. EGEN, as the Brussels based partner of the GTRH consortium, will continue its ongoing work to draw from the findings of the GTRH project, as appropriate, in future submissions on RE and geothermal in particular and also present aspects of the GTRH framework to its members in industry, government and geothermal associations.

#### Key lessons learnt during the project

Considering the beneficial impact that GTRH has had on policy developments and, through this, on the future growth of the sector, it has become clear that this, or similar, cooperation structures are very cost-effective. Especially the exchange of information on policies between Best Practice and less developed countries (in the sense of Legal Frameworks) proved to be a success factor and some continuation of this approach is encouraged – certainly now that new and important ‘geothermal entrants’ appear to be joining the scene.

An important aspect of the project was the broad consortium, as it was important to have all of the project partners available in order to make a full comparison of the European situation and to exchange on best practices. This good consortium with an active participation of all partners allowed the development of solid legal recommendations on geothermal energy with a European perspective.

In general, feedback from presentations of the interim results of the GTRH project at conferences showed agreement on the need for the geothermal framework or regulation initiative and anticipation of the results. However, there was also an acknowledgement that some of the recommendations of the framework, though positive aspirations or goals, would be difficult or impossible to implement in the short to medium term in many of the countries of Europe. Nevertheless, there are many aspects of the core recommendations of the framework that will work regardless of the current regulatory difficulties in any one country.

#### Conclusions

The project completed its work in December 2009 and as such the GTRH results were available to help facilitate the realization of the National Renewable Energy Action Plans currently in progress.

Though the policy environments were

rather diverse in the investigated countries, a number of common requirements for a geothermal regulation emerged as follows:

- the necessity of sound and enduring legal structures for ownership and licensing of geothermal heat exploration & production
- the presence of a level playing field for incentives for geothermal energy compared to other RES
- appropriate organizational structures to develop a vision on geothermal energy potential and the roadmaps to implement this potential.

A number of specific conclusions are elaborated as follows:

#### **Barriers to geothermal energy development**

The main barrier to enhanced geothermal

deployment is a lack of appropriate legislation and financial incentives. A lack of clarity in legal framework and administrative procedures for geothermal exploitation means long lead times for obtaining the necessary permits and licences and uncertainties for investors, such as in the right to own and use geothermal energy.

#### **Needs of the geothermal sector**

There is a need for coherency in the various financial support mechanisms already in existence in different Member States, and a need to create additional financial (incentives) and regulatory (standards) support instruments. With regard to administrative barriers; legal frameworks and regulations, concerning the ownership and exploitation of geothermal energy, must be clarified and permit procedures harmonized. Increasing the acceptance of geothermal energy will require education and awareness campaigns

at all levels, as well as R&D for minimizing the environmental impacts of geothermal exploitation.

#### **Importance of stakeholder engagement process and international cooperation**

Despite the fact that various countries of the GRT-H consortium are characterized by specific and often different legislation and financial conditions - the basis for geothermal activities and investments - the GTRH common tasks have proved that one can learn from each other, identify common opportunities and barriers, and most importantly, find and elaborate solutions leading to the synergy effect and benefits for geothermal deployment both in any particular country and at EU-level as a whole.

The GTRH Framework is available at:  
[www.gtrh.eu](http://www.gtrh.eu)



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# Deep geothermal energy resource potential in Northern Ireland

by Derek Reay<sup>1</sup> and John Kelly<sup>2</sup>

Northern Ireland has potential low and medium enthalpy deep geothermal energy resources suitable for direct heating and, possibly, power generation. One of the major barriers to the development of these resources is the scarcity of data about the deep geology. This article outlines recent geological and geophysical investigations that provide valuable new information about the deep geological structure and the characteristics of potential geothermal aquifer and granitic Enhanced Geothermal System targets. The research was funded by the Northern Ireland government in support of its energy strategy to increase the contribution of renewable energy resources to the NI energy market and reduce its dependence on imported fossil fuels.

It has long been recognized that there may be some potential for using geothermal energy from deep aquifers in the sedimentary basins of Northern Ireland. Temperature measurements from a handful of deep boreholes drilled for petroleum and mineral exploration, or as stratigraphic tests, indicated the presence of low to medium enthalpy resources. The Larne No. 2 borehole was drilled in 1981 to test this potential as part of the 1980s UK deep geothermal energy research programme into geothermal aquifers and granitic 'hot dry rocks'. Although a bottom hole temperature of 88 °C was recorded in basal Permian conglomerates at 2880 m, the base of the target Triassic Sherwood Sandstone aquifer came in 800 m higher than prognosed and both units had poorer porosities and permeabilities than

L'Irlande du Nord dispose d'un potentiel énergétique sous forme de ressources géothermiques profondes de basse et moyenne enthalpie, capables de fournir directement du chauffage et peut-être de l'électricité. Un des obstacles majeurs au développement de ces ressources réside dans la rareté des données de géologie profonde. Cet article fait le point sur les recherches récentes en matière de géologie et de géophysique fournissant une information nouvelle et précieuse sur les structures géologiques profondes et sur les caractéristiques des réservoirs géothermiques potentiels et des cibles d'un Système Géothermique de haute enthalpie dans les formations granitiques. Cette recherche est financée par le gouvernement d'Irlande du Nord, au titre de l'aide à sa stratégie énergétique, pour accroître sa contribution en ressources énergétiques renouvelables auprès du marché intérieur de l'Énergie et pour réduire sa dépendance vis-à-vis des hydrocarbures importés.

Irlanda del Norte tiene potenciales recursos geotérmicos profundos de baja y media entalpia adecuados directamente para calefacción y posiblemente la generación de energía. Una de las mayores barreras para el desarrollo de estos recursos es la escasez de datos sobre la geología profunda. Este artículo resume las investigaciones geológicas y geofísicas más recientes que proporcionan una información muy valiosa sobre la estructura geológica profunda y las características de acuíferos geotérmicos potenciales y posibles Sistemas Geotérmicos Mejorados en granitos. La investigación ha sido financiada por el gobierno de Irlanda del Norte en apoyo de la estrategia energética para aumentar la contribución de los recursos de energías renovables al mercado energético de Irlanda del Norte y reducir su dependencia de los combustibles fósiles de importación.

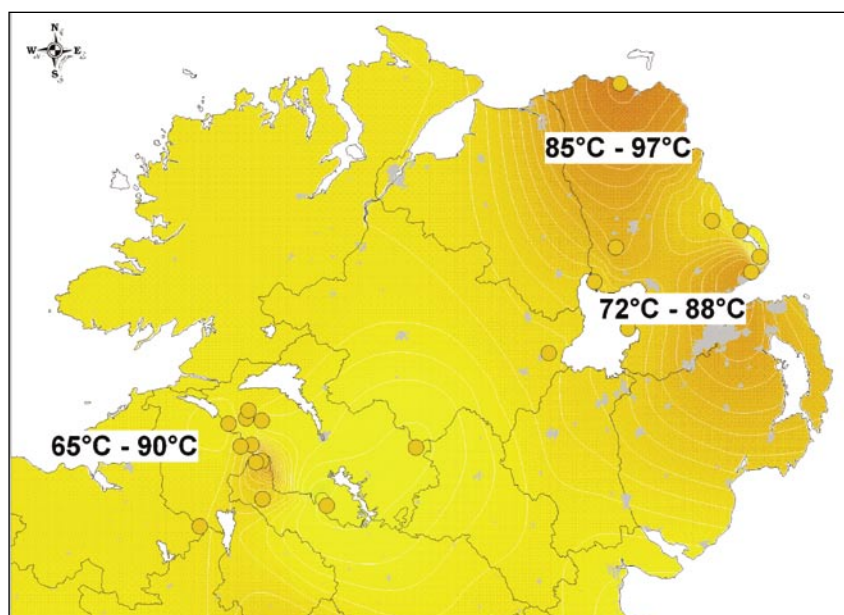


Figure 1. Modelled temperature at 2,500 m based on borehole temperatures in Northern Ireland (Kelly et al., 2005)

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expected. Two shallow boreholes, less than 200 m deep, were also drilled into the Paleogene Mourne Mountains granite and relatively high heat flows derived from the

temperature gradients measured. The UK research programme yielded much useful data but resulted in the development of only one deep geothermal energy project,

in Southampton, where the Sherwood Sandstone aquifer has been used in a district heating scheme since 1986.

**Northern Ireland's energy strategy**

Recently, the Department of Enterprise, Trade and Investment (DETI) has developed an energy strategy for Northern Ireland which combines increased energy efficiency with increasing use of renewable energy sources, thus reducing both carbon emissions and the dependence on fossil fuel (mainly gas) imports. Wind energy is the primary renewable energy source and DETI has set a target of 40% of total electricity generation from wind by 2020. However, following recent developments elsewhere in Western Europe and a re-appraisal of the deep geology of Northern

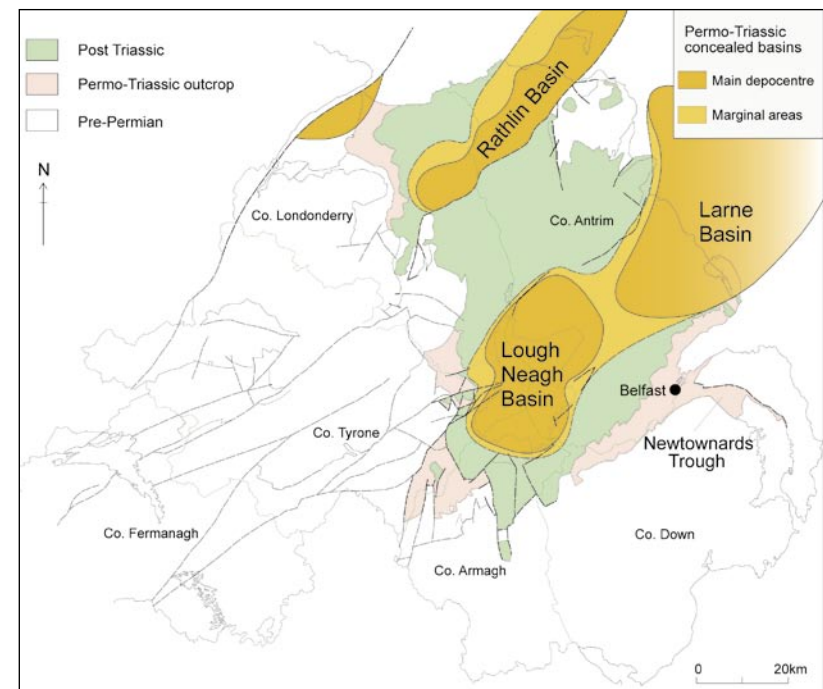
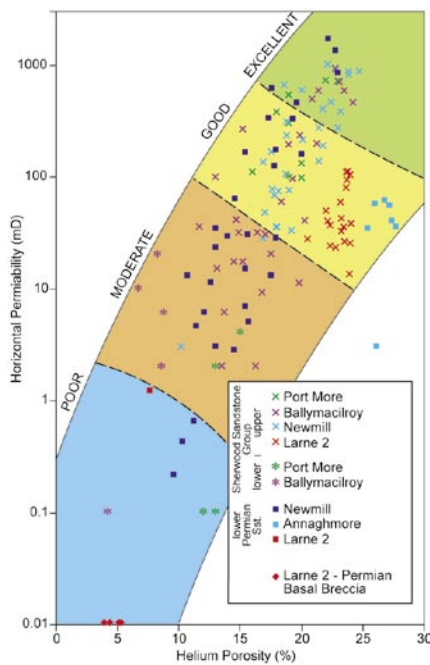


Figure 2. (Above) Location of Rathlin, Lough Neagh and Larne Basins, Northern Ireland (modified from Mitchell, 2004)

Figure 3. (Left) Porosity-permeability cross-plot for Sherwood Sandstone Group and Early Permian sandstones in deep boreholes (Reay, in Mitchell, 2004)

Figure 4. (Below) Location of 2009 MT survey in the north of the Lough Neagh Basin (triangles – MT stations, red lines – seismic lines, yellow dots - boreholes; from Soyer, 2009)

2008), looking specifically at deep geothermal energy, identified the most prospective areas and recommended further research to reduce the geological risks associated with geothermal exploration. As a result, the Geological Survey of Northern Ireland was successful in obtaining £604k from the Northern Ireland Innovation Fund to carry out research designed to improve our knowledge of the prospective deep geothermal targets.

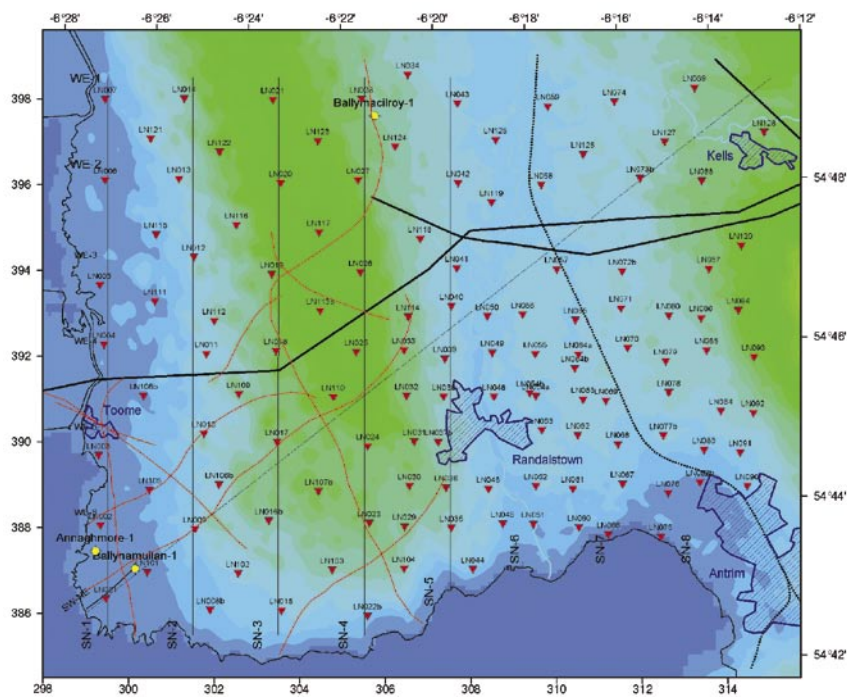
The most prospective areas for geothermal aquifers are the three Permo-Triassic

Ireland, the potential for geothermal energy to provide a reliable source of baseload electrical and heat energy for Northern Ireland has also been recognised.

**Deep geothermal energy potential in Northern Ireland**

DETI commissioned CSA Group (a Dublin-based geological consultancy, now part of SLR Consulting) to review the geothermal energy potential in Northern Ireland and their INTERREG-funded report (Kelly *et al.*, 2005) identified widespread potential for the use of shallow geothermal energy and a significant, but more restricted, potential for deep geothermal aquifers and granite-based Enhanced Geothermal Systems (Fig. 1).

A follow-up report (Pasquali *et al.*,



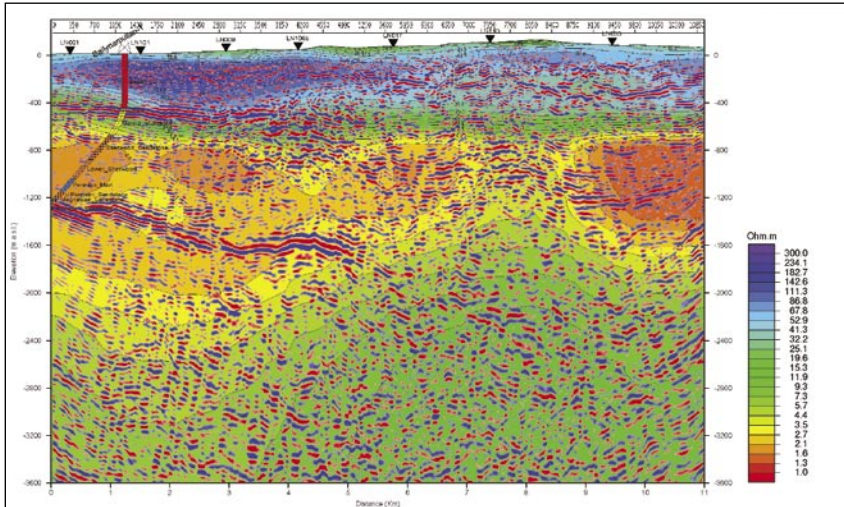


Figure 5. Seismic line UNR91-01 superimposed on 3D MT blind inversion (Soyer, 2009)

sedimentary basins (Rathlin, Larne and Lough Neagh basins) concealed beneath the thick Paleogene basalts of the Antrim Lava Group (Fig. 2). The geothermal gradients, based mainly on bottom hole temperatures (BHTs), range from 17 °C to 38 °C per km. The highest values are recorded from the Rathlin Basin where the equilibrated formation temperatures were recorded in the Portmore borehole several months after drilling was completed, in contrast to the BHTs measured during logging runs in other boreholes and still depressed by the effects of previous drilling mud circulation.

The main sandstone aquifers are, in order of increasing age and depth, the Triassic Sherwood Sandstone Group (SSG), Early Permian Enler Group and Carboniferous sandstones. The Sherwood Sandstone is the main aquifer used for water abstraction in the Greater Belfast area but

both it and the Permian sandstones can retain good aquifer properties to considerable depths (Fig. 3). The Carboniferous sandstones generally have lower porosities and permeabilities but samples from the Magilligan borehole in the Rathlin Basin exhibit significant secondary porosity down towards the bottom hole depth of 1,343 m.

The highest borehole temperature recorded so far in Northern Ireland is 99 °C at 2,650 m depth in the Rathlin Basin. In the deepest undrilled parts of the three basins, the SSG, Enler Group and Carboniferous sandstones, may reach depths of 2,500, 3,000 and 3,500 m respectively. Temperatures in excess of 100 °C are therefore to be expected in these aquifers in favourable locations.

The GSNI decided that the deep geothermal energy research project should have two main objectives - firstly, to

acquire new geophysical data which could be used to extend existing data coverage and to produce an integrated geophysical model of the deep structure of one of the basins and, secondly, to drill moderately deep boreholes to obtain core samples and geophysical logs through the target rock lithologies in order to improve the physical and thermal characterization of these units.

### Geophysical studies

For the geothermal aquifers, the geophysical study area chosen was the northern part of the Lough Neagh Basin, north of the present-day lough. Here the basin was predicted to be deepest under the north-east corner of the lough, near the town of Antrim, and a small 2D seismic survey and three boreholes formed a reasonable existing database (Fig. 4).

A magneto-telluric (MT) survey, covering the area of the seismic survey and extending eastwards towards Antrim, was designed to allow modelling of the 3D geological structure down to at least 4 km. The MT survey was carried out by Geosystem of Milan who acquired data at 128 stations across the 15 km x 10 km project area. The UNR91 seismic survey data was re-processed by Western Geophysical and the results from the 3D inversion of the MT data can be compared to the seismic data (Fig. 5). The low resistivity sedimentary rocks, including the target aquifers, are picked out in the yellow and orange colours and this shows reasonable correlation with the seismic data. On the left hand (southwest) end of the section the deepest orange colours (lowest resistivity) from the MT coincide with the Sherwood Sandstone drilled in the Ballynamullan well, whilst the low resistivity values appear to persist to depths of about 2,400 m in the Permian-Carboniferous section below the prominent reflector (the Permian 'Magnesian Limestone').

An additional 480 gravity stations were recorded over the project area to augment the existing regional gravity dataset and this has resulted in an improved gravity anomaly map which will be used with existing high resolution aeromagnetic data, seismic, borehole and the new MT data to produce more accurate and reliable models of the deep geological structure of the north Lough Neagh sedimentary basin. Geoscientists from GSNI, the British Geological Survey (BGS) and the Dublin Institute of Advanced Studies (DIAS) will collaborate on the interpretation phase of the project.

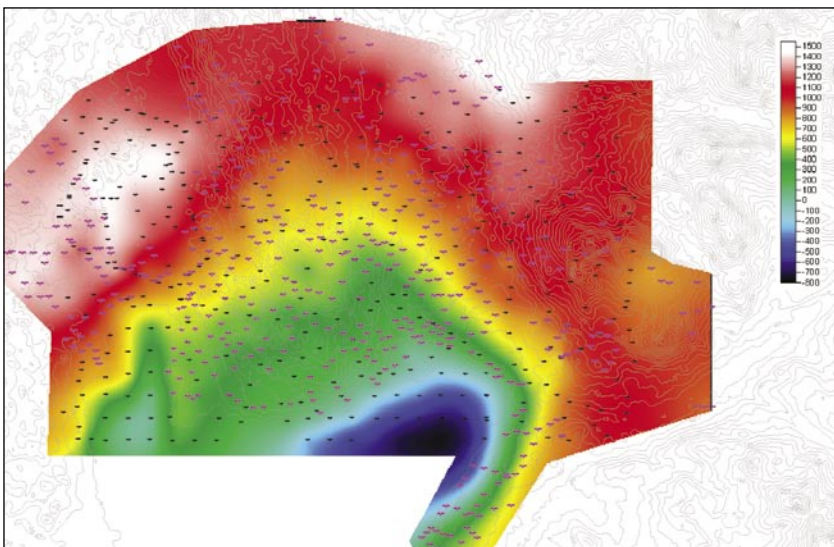


Figure 6. Bouguer Gravity anomaly map of north Lough Neagh Basin. Deep blue colour indicates lowest anomaly values corresponding to deepest part of basin (from O'Connell, 2009).



### Drilling to characterize the geothermal targets

Two boreholes were drilled as part of the project; one at Kilroot Power Station near the southern margin of the Larne Basin, on the northern shore of Belfast Lough, and the other at Silent Valley, near the southern margin of the Paleogene Mourne Mountains granite. The Kilroot borehole was designed to core through the Triassic Mercia Mudstone Group, the Sherwood Sandstone Group and the underlying Permian strata and then to run geophysical logs through the section. Despite some drilling problems associated with unconsolidated intervals within the SSG, the borehole reached 868 m depth, bottoming in Permian conglomerates containing well-rounded clasts of Lower Palaeozoic greywackes. The logging programme was restricted by the eventual diameter of the hole but valuable data was obtained.

The temperature log data at Kilroot showed a significant temperature inflection at 60 m where a temperature of 11.95 °C was recorded, marking the limit of meteoric influence. A second inflection was recorded at approximately 240 m depth, roughly coincident with the contact between the Mercia Mudstone Group and the Sherwood Sandstone Group. A third and noticeable inflection occurs at 740 m with a noticeable increase in the gradient.

Calculations indicate a thermal gradient within the Mercia Mudstone Group of 30.83 °C/km and a gradient within the Sherwood Sandstone Group of 21.59 °C/km, increasing to 28.82 °C/km from 740 m.

### Geothermal potential of Mourne granites

The granites of the Mourne Mountains are believed to fall into the High Heat Production (HHP) type, characterized by relatively high concentrations of radioactive elements as expressed by their uranium, thorium and potassium content. The GSNI's Tellus Project, comprising a regional geochemistry and high resolution airborne geophysical survey of Northern Ireland, collected airborne radiometric data which were used to calculate the Radiogenic Heat "A" associated with the Mourne Mountains granites, using the equation in Carmichael (1989)

$$A = 0.337(0.74eUppm + 0.199eThppm + 0.26K\%)\mu W/m^3$$

The calculated values of A (van Dam, 2007) reached a maximum value of 4.8  $\mu W/m^3$ , which is similar to calculations of heat generated at other Hot Dry Rock locations

in the UK (Manning *et al.*, 2007).

Outcrop samples collected from the Mournes complex were analyzed by XRF and the calculated values of A from these samples are higher, mostly in the range 4.8 to 7.8  $\mu W/m^3$ , with a maximum value of 14.6  $\mu W/m^3$  associated with a sample with U content of 26 ppm.

The Silent Valley borehole was cored to a depth of 601.5 m and then a suite of geophysical logs run. The temperature log showed a modest geothermal gradient (21.07 °C/km) but granite core samples sent for thermal conductivity analysis show typical values. The potential for the Mourne Mountains granite complex to be used for an Enhanced Geothermal System (EGS) is, of course, reduced by the fact that the granite forms the surface outcrop rather than being covered by a blanket of low thermal conductivity insulating sedimentary rocks. The geothermal gradient and the temperatures at a given depth will be lower than for 'buried' granite. Nonetheless, the fact that the Mourne Granites appear to have a relatively high radiogenic heat potential warrants further investigation of the 3D structure of the complex. The gravity anomaly data in the area is dominated by high positive Bouguer anomaly values, indicating a dense mafic body below the granite. The existing regional gravity data is confined to the roads and sparse over the mountainous granite complex so the granite bodies cannot be modelled accurately. Infill gravity data was acquired by Terradat as part of the project and this additional data should help to improve the 3D modelling. GSNI also hope to work with DIAS and the University of Birmingham to acquire MT



Figure 7. Irish Drilling Ltd. rig on Kilroot borehole with coal and gas fired Kilroot power station in the background (Kelly, 2010)

profile data across the Mourne complex. This data should help to constrain the depth to the base of the granite and also to test the model (Stevenson *et al.*, 2007), based on magnetic fabric data, that the Eastern Mourne pluton is a laterally fed laccolith, emplaced from the south.

### De-risking geothermal exploration through better understanding of the deep geology

In summary, the new geophysical and borehole data will improve our understanding of the deep geological structure

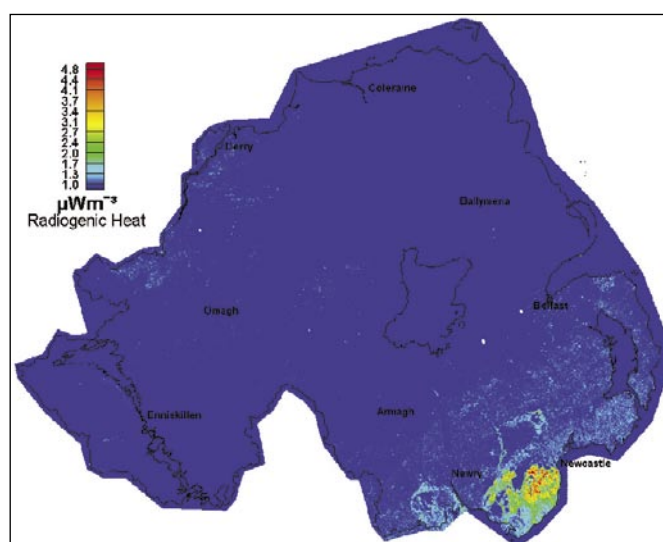


Figure 8. Radiogenic heat potential in Northern Ireland, calculated from airborne radiometric data. High values in yellows to reds over the Mourne Mountains (from van Dam, 2007)

of the Lough Neagh Basin and help to further characterize the potential geothermal aquifer and EGS target rock types in Northern Ireland. The results have demonstrated how magnetotelluric data can be used in conjunction with seismic reflection data, or in advance of more focused seismic data acquisition, to refine the aquifer depth models in basalt-covered sedimentary basins where acquisition of good quality seismic data is difficult. The data from the north Lough Neagh surveys have already been licensed by Irish company, GT Energy, who are exploring the potential for using deep geothermal energy in district heating systems with local authorities in the area.

The Mourne granites have been shown to have relatively high radiogenic heat potential although their extent at depth has yet to be established. If similar granites can be located beneath the sedimentary basins then their potential to host Enhanced

Geothermal Systems capable of generating electricity will be significantly greater.

#### Conclusions

The research described in the article illustrates how our understanding of the deep geological structure can be improved, and the geological risk reduced, prior to drilling. However, the introduction of a suitable regulatory system, and financial support or incentives at levels appropriate to an emerging energy sector (which the deep geothermal energy sector is in the UK), are also required to facilitate the development of deep geothermal energy resources in Northern Ireland.

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#### References

Carmichael, R.S. 1989. *Practical Handbook of Physical Properties of Rocks and Minerals*. CRC Press, Inc.

Kelly, J. 2010. Deep Geothermal Exploration Drilling Programme. Completion Report. *SLR Consulting Report to the Geological Survey of Northern Ireland No. 419*, 2941.

Kelly, J., Goodman, R., Jones, G.L.I., O'Neill, N., Pasquali, R. 2005. Geothermal Energy Review of Northern Ireland. *CSA Group Report to INTERREG No. 3194*.

Manning, DAC, *et al.* 2007. A deep geothermal exploration well at Eastgate, Weardale, UK: a novel exploration concept for low-enthalpy resources. *Journal of the Geological Society, London*, 164, 371-382.

Mitchell, W.I. (ed.). 2004. *The Geology of Northern Ireland - Our Natural Foundation*. Belfast.

O'Connell, Y. 2009. Report on the Lough Neagh Gravity Survey. *Apex Geoservices report for the Geological Survey of Northern Ireland*, No. AGL09048.

Pasquali, R., Goodman, R., Jones, G.L.I., O'Neill, N., Leacy, L., Kelly, J. 2008. Report on the potential for deep geothermal energy in Northern Ireland. *CSA Group Report to Action Renewables*, No. 3774.

Soyer, W. 2009. Magnetotelluric survey, Lough Neagh, Northern Ireland. Final Report: 3D Inversion Modelling. *Geosystem Report to Geological Survey of Northern Ireland*.

Stevenson, C.T.E., Owens, W.H., Hutton, D.H.W., Hood, D.N., Meighan, I.G. 2007. *Journal of the Geological Society, London*, 164, 99-110.

Van Dam, C.L. 2007. Radiogenic Thermal Heat Potential of Northern Ireland. *Geological Survey of Northern Ireland Internal Report*.



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# Induced seismicity associated with the exploitation of deep geothermal resources

by T. Kraft<sup>1</sup>, K. Evans<sup>2</sup>, D. Giardini<sup>1</sup>, N. Deichmann<sup>1</sup> and S. Wiemer<sup>1</sup>

With the global challenge to satisfy an increasing demand for energy while at the same time stabilizing or reducing carbon dioxide (CO<sub>2</sub>) concentrations in the atmosphere, deep geothermal resources are being increasingly recognized by society as an attractive alternative energy source.

Deep hydrothermal resources, such as aquifers at depths greater than 2 km with sufficiently high productivity, have been successfully exploited for many years, but their distribution and potential for supplying electricity is limited. Artificially created Enhanced or Engineered Geothermal Systems (EGSs) do not suffer this restriction. EGS technology involves pumping fluids under high pressure into a low-permeability rock whose temperature exceeds 100 °C. This raises the fluid pressure in the rock mass, thereby weakening the fractures in the rock and promoting their shearing and attendant dilation. In this way the permeability of the rock is increased and an artificial reservoir for the fluid is created. The shearing movement also generates microearthquakes. In general, deep geothermal resources are exploited by circulating fluids through a geothermal reservoir using a number of deep injection and production wells, thereby extracting heat from the permeable or fractured rock mass. This operation invariably alters the stress and pore pressure in the subsurface. The changes tend to be most pronounced during the EGS reservoir creation (i.e. stimulation) phase, but they also occur in the operational phase of EGS and deep hydrothermal systems.

It has been realized over the last 20 years, that the Earth's crust generally supports high shear stress levels and is often close to failure. Thus, even small changes of the stress and pore pressure in the sub-

surface due to Earth engineering endeavours or even anomalously heavy rainfall can be sufficient to induce seismicity in natural systems (e.g., Hainzl *et al.*, 2006; Husen *et al.*, 2007). Historically, the most damaging events, which have sometimes caused fatalities, are associated with the impoundment of reservoirs (Gupta, 1992). However, earthquakes of sufficient size to cause damage to localities have also been associated with mining activity (Gibowicz, 1990), long-term fluid withdrawal wells (Segall, 1989), and long-term fluid injection wells (Nicholson and Wesson, 1990; Evans *et al.*, 2010). Nevertheless, massive stimulation injections have routinely been performed at EGS sites since the early 70s, the issue of the seismic hazard associated with these operations has only recently come to the fore. This is because the pioneering EGS developments at Fenton Hill (USA), Rosemanowes (UK), Hijiori (JP) and Soultz (F, 3.5 km reservoir) did not produce events large enough to disturb the local population. Recent attempts to develop EGS at 4.5-5.0 km at Soultz (F), Cooper Basin (AUS) and Basel (CH), and deep (~3 km) hydrothermal systems in Landau (D) and Unterhaching (D) produced events approaching or exceeding magnitude ml=3. A recent review of induced seismicity associated with deep fluid injections in Europe, including recapitulatory case histories, is given by Evans *et al.* (2010).

In natural seismicity, a magnitude of approximately ml=3 corresponds to the threshold above which earthquakes can be felt by humans. This observation motivated common seismological practice that classifies earthquakes of magnitudes ml < 3 as "microearthquakes". If, however, earthquake sources are very shallow (depth < 5 km) and in populated areas, as is usually the case with deep geothermal projects in Western Europe, even events as small as ml=2 can be weakly felt.

After the ml=3.4 earthquake on 8 Dec. 2006, induced by the "Deep Heat Mining" Basel (CH) EGS project (Haering *et al.*, 2008), minor non-structural damage was

claimed by more than 2000 homeowners, with a damage sum of €6 million. The maximum macroseismic intensity reached for this event was V(MSK) (Ripperger *et al.*, 2009), which is well below the intensity threshold of VII(MSK) covered by insurance in Switzerland. For a natural event, the damage would have been covered by the homeowners, but for a man-made event, the entire cost was picked up by the geothermal company's liability insurance. Recently, a risk analysis came to the conclusion that similar minor earthquakes are likely to occur during the lifetime of a plant in this particular seismotectonic setting (Baisch *et al.*, 2010). Based on these findings, the city council of Basel has decided to abandon the project.

It is not only EGS projects that have suffered from felt induced seismicity. At Landau i.d. Pfalz (D) a deep faulted hydrothermal aquifer at a depth of ~3 km has been exploited by a well-doublet system since late 2007. After ~1 year of operation, small earthquakes with magnitudes larger than ml=1.6 were recorded in the area by the Seismological Services of Baden-Württemberg and Rheinland-Pfalz, culminating in a locally felt ml=2.7 event on 15 Aug. 2009 that led to a temporary halt in operations. The event hypocenter was provisionally located by an expert group as 500 m north from the plant at a depth of 2.5±1.5 km (Mittelzwei, 2009). The plant resumed operation in Nov. 2009, after local authorities had reduced the operational pressure limit and raised the insurance.

The processes and conditions underpinning induced seismicity associated with deep geothermal operations are still not sufficiently well understood to make useful predictions as to the likely seismic response to reservoir development and exploitation. The empirical data include only a handful of well-monitored EGS experiments; models are consequently poorly constrained. The European Commission project "Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs" (GEISER) is intended to improve the knowledge base

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and suggest procedures and regulations for the future exploitation of deep geothermal energy. At ETH-Zurich, the multidisciplinary research project GEOTHERM ([www.geotherm.ethz.ch](http://www.geotherm.ethz.ch)) is investigating the dataset of the Deep Heat Mining Basel project. First results have recently been published (Bachmann *et al.*; Bethmann *et al.*; Deichmann and Ernst; Deichmann and Giardini; Giardini; Kraft *et al.*; Ripperger *et al.*; Valley and Evans, all 2009). Unfortunately, datasets of well-monitored deep hydrothermal experiments are missing and empirical constraints of induced seismicity models for these cases do not exist. Given that the majority of the projects underway or planned in Europe are of the hydrothermal

type, there is hope that this deficit can be remedied in the near future through a close cooperation of geothermal industry, science and public authorities.

### Conclusions

The seismic risks associated with the development of deep geothermal resources in urban areas constitute a significant challenge for the widespread implementation of this technology. From their outset, deep geothermal projects need to be thought of both as pilot projects with scientific unknowns and as commercial ventures with technological and financial risks. Companies need to have allocated enough of their budget to scientific investigations

not directly related to the exploitation of heat. Risk needs to be evaluated before the projects begin and have to be communicated objectively to the public and to decision makers. It is clear to many scientists that the exploitation of deep geothermal resources carries a small but non-zero risk – as do most technologies, especially in the energy sector. Dams can break, nuclear power plants may fail, CO<sub>2</sub> released from oil and gas contributes to global warming, and the development of deep geothermal resources can occasionally create damage through induced earthquakes. The open question is whether or not we are able to find ways to balance and accept the risk associated with the exploitation of these resources.

### References

- Bachmann, C., Wössner, J., Wiemer, S. 2009. A New Probability-Based Monitoring System for Induced Seismicity: Insights from the 2006–2007 Basel Earthquake Sequence. *Seismological Society of America, Annual Meeting*, Monterey, USA.
- Baisch, S., Martin, Ch., SERIANEX group. 2010. Seismic Risk Analysis of the Basel Geothermal (EGS) project. *European Seismological Commission, 32<sup>nd</sup> General Assembly*, 6-10 September 2010, Montpellier, France.
- Bethmann, F., Deichmann, N., Allmann, B., Giardini, D., Mai, P.M. 2009. Mw-MI Scaling Relations for Earthquake Sequences in Switzerland. *Seismological Society of America, Annual Meeting*, Monterey, USA
- Deichmann, N., Ernst, J. 2009. Earthquake focal mechanism solutions of the induced seismicity in 2006 and 2007 below Basel (Switzerland). *Swiss J. Geosci.*, 102/3, 457-466.
- Deichmann, N., Giardini, D. 2009. Earthquakes induced by the stimulation of an Enhanced Geothermal System below Basel (Switzerland). *Seismol. Res. Lett.*, 80/5, 784-798.
- Evans, K.F., Zappone, A., Kraft, T., Deichmann, N. 2010. Injection-induced seismicity in Europe, submitted to *Geothermics*.
- Giardini, D. 2009. Geothermal quake risks must be faced, *Nature*, 461, 848-849.
- Gibowicz, S.J. 1990. Seismicity induced by mining. *Advances in Geophysics*, 32, 1-74.
- Gupta, H.K. 1992. *Reservoir-induced Earthquakes*. Elsevier, Amsterdam, 364 pp.
- Hainzl, S., Kraft, T., Wassermann, J., Igel, H. 2006. Evidence for rain-triggered earthquake activity, *Geophys. Res. Lett.*, 33, L19303. (<http://dx.doi.org/10.1029/2006GL027642>).
- Haering, M.O., Schanz, U., Ladner, F., Dyer, B.C. 2008. Characterisation of the Basel-1 Enhanced Geothermal System. *Geothermics*, 37, 469-495.
- Husen, S., Bachmann, C., Giardini, D. 2007. Locally triggered seismicity in the central Swiss Alps following the large rainfall event of August 2005. *Geophys. J. Int.*, 171, 1126-1134.
- Kraft, T., Mai, P.M., Wiemer, S., Deichmann, N., Ripperger, J., Kästli, Ph., Bachmann, C., Fäh, D., Wössner, J., Giardini, D. 2009. Enhanced Geothermal Systems in urban areas - lessons learned from the 2006 Basel ML 3.4 earthquake, *EOS*, 90/32, 273-274.
- Mittelzwei, S. 2009. Expertengruppe analysiert seismische Ereignisse um Landau. *State of Rheinland-Pfalz Press release*.
- Nicholson, C., Wesson, R.L. 1990. Earthquake hazard associated with deep well injection. *US Geological Survey Bulletin* 1951, 74 pp.
- Ripperger, J., Kästli, Ph., Fäh, D., Giardini, D. 2009. Ground motion and macroseismic intensities of a seismic event related to geothermal reservoir stimulation below the city of Basel - observations and modeling, *Geophys. J. Int.*, 179/3, 1757-1771.
- Segall, P. 1989. Earthquakes triggered by fluid extraction. *Geology*, 17/10, 942-946.
- Valley, B., Evans, K.F. 2009. Stress orientation to 5 km depth in the basement below Basel (Switzerland) from borehole failure analysis. *Swiss J. Earth Sci.*, 102/3, 467-480.

# Geothermal energy and CO<sub>2</sub> sequestration

## CNG initiatives in Italy

by Umberto Puppini<sup>1</sup>

A summary of items discussed within the Geothermal Panel is presented with regard to criteria defining the main features of geothermal exploitation systems. A short presentation of the main regulations on ground sources at work in Italy and the work done by CNG is given.

In Italy, competent professional bodies, such as Consiglio Nazionale dei Geologi, the Italian Register of Geologists, are regulated under the Ministry of Justice umbrella. Registration by CNG is done by examination and automatically bestows the title of Professional Geologist. In accordance with the law, CNG can prepare regulations dedicated to registered geologists, such as a code of ethics, a code of practice, etc. Among others, one of the most relevant duties of CNG is to promote Geology as a cultural tool helpful in respect of the public needs and of environmental protection.

Therefore CNG is also strongly committed to promoting the proper uses of natural resources, namely renewable sources and CO<sub>2</sub> sequestration sustainable applications.

CNG fulfils these obligations by:

- since 2008, setting a Continuous Professional Development system dedicated to all 15,000 Registered Italian Geologists, based on a credit system
- promoting relationships with Academic and Research bodies at all levels
- participating in a number of working groups in Italy and in Europe

<sup>1</sup>Member of CNG Board ([www.consiglionazionalegeologi.it](http://www.consiglionazionalegeologi.it))  
Coordinator of CNG Geothermal Energy Development Committee  
Member of EFG Panel of Experts in Geothermal Energy ([www.eurogeologists.eu](http://www.eurogeologists.eu))  
Coordinator of FG3-WG1 in Geothermal Panel

Un résumé des points de discussion abordés au cours de la table ronde sur la géothermie est présenté en regard des critères définissant les caractéristiques principales des systèmes d'exploitation géothermique. Est fourni un court exposé traitant des règlements principaux concernant les sites d'exploitation active en Italie et le travail accompli par le CNG.

- giving information to national and local media
- running a permanent Committee on Geothermal Development together with UGI (Unione Geotermica Italiana)
- organizing national and local conferences, courses and training on Geothermal Resources and on CO<sub>2</sub> Sequestration
- editing a peer reviewed magazine.

As mentioned, CNG has demonstrated a strong commitment to promoting Geothermal Energy sustainable exploitation, helping geologists to act correctly in supporting designers, engineers and drillers by running geological, hydrogeological, environmental and geothermal courses at all levels. Geological, hydrogeological and hydrogeochemical conceptual models are recognized as the first correct approach to draw a sound Geothermal Conceptual Model useful to schemes for any thermal exchange and CO<sub>2</sub> sequestration sites.

A special goal of CNG's CPD system is to help in accrediting or qualifying future drillers and, on the other hand, to make them confident on relying on contributions provided by professional geologists with long track records and experience in Earth Sciences, together with a robust understanding of technical issues, based on competence and good practice.

Therefore Geologists can be considered among Competent Persons to deal with and be legally liable for:

- definition of geothermal resources and ground source temperature of different regions

Se presenta un resumen de los temas discutidos en el Panel de Geotermia con respecto a los criterios que definen las principales características de los sistemas de explotación geotérmica. Se incluye una presentación breve de la reglamentación vigente en Italia sobre los recursos térmicos del terreno y el trabajo realizado por el CNG.



Milan (Lombardy): Pirellone skyscraper heating and cooling demand is covered by a ground source open loop system working since 1998

- soil and rock identification for thermal conductivity identification
- contributing to CO<sub>2</sub> sequestration scheme design
- technical advice on regulations for using geothermal resources
- feasibility of using and running GCHP and GSHP, at least dealing with expected temperature changes impacts and groundwater abstraction rates estimation.

Competent persons are key in providing a really independent judgement on technical

and economical long-term sustainability of projects using geothermal resources.

### Contribution to RES Directive implementation on geothermal sources

Recently, CNG has contributed to the Discussion Document on Geothermal Regulation Framework, which deals with:

- discussing technical definitions
- presenting the Italian current legal framework and licensing bodies
- focusing on independent experts and competent professional bodies.

Regarding technical definitions, within the Geothermal Panel CNG proposed harmonizing the criteria to be applied within the Discussion Document on Geothermal Regulation Framework with the proposals made within the RES Directive e.g. the definition of shallow GSH (Ground Source Heat systems) which is based on depth (e.g. less than 500 m rather than 400 m) and temperature criteria (e.g. under 30 °C rather than 25 °C).

The CNG proposal aims to make definitions based on:

- technical criteria i.e. depth, source temperature, kind of energy and potential to be installed
- magnitude criteria i.e. small, large, etc.

as listed below in detail:

#### Depth

Shallow	0-100/500 m
Deep	>100/500 m

The justification for the proposal is the variation in geological conditions all over Europe. A larger range of values and/or more harmonized with the RES Directive would be better than applying more strict criteria.

#### Temperature

<30 °C for GSHP/GCHP use

>30 °C for direct use or power production use

The justification is based on Mechanical & Electrical design needs, usually dividing non-direct and direct use of the geothermal sources along the 30 °C range line.

#### Energy produced

##### Thermal energy

<30 kWth installed - small-sized scheme

30-1000 kWth installed - medium-sized scheme

>1000 kWth installed - large-sized scheme.

The justification is that 30 kWt is a practical and commonly accepted (e.g. SUPSI-Switzerland) delimitation for domestic needs. In a recent regulation, the Lombardy Regional authority set this limit at 50 kWth for GCHP systems. Even in this case it was suggested that applying a range of values could be more convenient in dealing with different local conditions.

##### Power (electrical energy)

<2000 kW installed - small-sized scheme

>2000 kW installed - large-sized scheme.

The final user destination (domestic, residential, commercial, industrial) of energy produced should not affect the definition of the kind of exploitation of ground source.

As far as quality issues are concerned, because of past and present experience, monitoring groundwater and soil involved in heat exchange should take into account hydrogeological (e.g. aquifer porosity, hydraulic conductivity, transmissivity, gradient, flow rate, etc.) and hydrochemical (e.g. pH, Dissolved Oxygen, Fe, Mn, heavy metals, etc.) parameters.

### Ground Sources exploitation legal framework at work in Italy

The Italian Law 896/1986 and its very recent implementation (D. Lgs. 22/2010) states that 2000 kW is the delimitation between small and large schemes for the production of electrical energy with geothermal source. The definition of small and large schemes also determines the fees to be paid for electrical energy production.

There are no definitions for thermal energy production. From experience, the permanent Committee on Geothermal Development is considering proposing to government authorities a lower value (1000 kWt) because most geothermal energy users actually have smaller needs whilst large commercial developments quite easily exceed this limit.

In Italy, the Regional Authorities (20 in all) are liable for permitting and licensing the larger schemes, by laws in force since 1933, 1986 and 2010, depending on the kinds of abstraction and of energy produced. The Provinces (180 in all) carry out the task of permitting and licensing for smaller schemes, by laws in force since 1933, 1999 and 2006, depending on the kind of abstraction and of energy produced.

Application of a fee is based on the principle that the exploitation of underground temperature, both by mass transfer (water abstraction) and by circulating a fluid into the soil, affects a property owned by the State. This pre-condition makes it compulsory to obtain permits and licences from the local relevant authority for proper research and use of the resource.

In 2006, the 1999 regulation was amended accepting the option to reinject groundwater abstracted to feed GSHP into the same groundwater body.

There could be a need to run an EIS if the amount of abstracted groundwater exceeds 50 l/s and a definite need for EIA procedure over 100 l/s. Similar criteria



Bergamo (Lombardy): drilling borehole to serve an open loop system by a large commercial mall (total heat power installed over 5 MWth).

apply to surface water exploitation. It is worth remembering that in Italy more than 75% of freshwater comes from groundwater. Therefore in principle groundwater resources are strongly protected by regulations, their quality being monitored by local EPAs.

CNG is working for a likely update of existing legislation to help recognize better RES and, among them, Geothermal Source as a great opportunity to be practised together with the full understanding and sustainable management of resources whilst approaching 20-20-20 objectives.

#### CO<sub>2</sub> sequestration policy in Italy

CNG has recognized CO<sub>2</sub> and greenhouse gases as a major environmental task to be faced straight away, allowing the next generation to cope with climate change issues, most likely using the robust experience already achieved.

CNG now works in a Committee comprising ENEA ([www.enea.it/index.html](http://www.enea.it/index.html)) and the University of Rome La Sapienza. A dedicated course was launched and run on October 2009 within CERI programmes ([www.ceri.uniroma1.it/cnen/index.do](http://www.ceri.uniroma1.it/cnen/index.do)). The consequences of CO<sub>2</sub> overproduction

are expected to be massive even in Italy at least in the case of predicted sea level rise. Previous conferences on Climate Change have recognized that counter measures are both adaptative (say, building barriers to deal with sea level rises) and preventative (e.g. CO<sub>2</sub> sequestration)

In 2009, ENEA published a report called 'Energia e Ambiente 2008' and a Report called 'CO<sub>2</sub> Capture and Storage' is now available. A Proposal for a new Act on energy made in Italy in 2008 was approved by the Parliament in July 2009 (L. 99/2009).

According to the report, CO<sub>2</sub> sequestration in Italy could be made in:

- salt rock deep geological units
- oil and gas abandoned boreholes
- deep coal mines
- geothermal fields unlikely to be exploited.

In Italy, the current estimation of CO<sub>2</sub> sequestration capacity in deep aquifers, including geothermal areas, is close to 440 Mt (80% onshore and 20% offshore) and to 1790 Mt within oil and gas onshore reservoirs, giving a total figure of 2230 Mt.

The main tasks of the ongoing research projects are, firstly, to start a demonstration project on CO<sub>2</sub> capture and sequestration, from emissions by thermal power plants, by means of a contribution from the main national industrial and research partners. Secondly, to participate in several international programmes on nuclear energy: Generation IV International Forum (GIF), Global Nuclear Energy Partnership (GNEP), International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), Accordo bilaterale Italia-USA di cooperazione energetica and International Thermonuclear Experimental Reactor (ITER).

With regard to CO<sub>2</sub> sequestration, the final goals of both research and governative actions are to improve best practices and to set standards for any of the operational steps needed for CO<sub>2</sub> sequestration aimed at defining:

- permits procedure
- responsibilities for site selection
- sequestration scheme realization
- short and long term monitoring
- site decommissioning.

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# Transboundary geothermal resources of the Mura-Zala basin

## Joint thermal aquifer management of Slovenia and Hungary

by Annamária Nádor<sup>1</sup> and Andrej Lapanje<sup>2</sup>

The growing energy demand of the world, restricted reserves of fossil fuels, efforts to reduce the emissions of greenhouse gases, thus contributing to the mitigation of global climate change made clear that within 20-30 years a significantly growing proportion of energy has to come from renewables. In March 2007, EU leaders endorsed an integrated approach to climate and energy policy that aims to reduce energy consumption and greenhouse gas emission by 20% and increase the proportion of renewables by 20% by 2020. This ambitious goal is manifested in the 2009/28/EC Directive on the promotion of the use of energy from renewable sources which, among other types of renewables, defines geothermal energy as "the energy stored in the form of heat beneath the surface of the solid Earth".

La demande mondiale croissante en énergie, les réserves limitées en combustibles fossiles, les efforts entrepris pour réduire les émissions de gaz à effet de serre, contribuant ainsi à la réduction du changement climatique global, indiquent que dans les 20 à 30 prochaines années, une partie significative et croissante de l'énergie devra provenir de sources renouvelables. En Mars 2007, les Chefs d'Etats européens ont approuvé une approche intégrée associant climat et politique énergétique dont le but est, d'une part, la réduction de 20% de la consommation d'énergie et de l'émission de gaz à effet de serre et, d'autre part, une augmentation de 20% des énergies renouvelables, à l'horizon 2020. Cet objectif ambitieux est clairement exprimé dans la Directive 2009/28/EC concernant la promotion de l'utilisation de l'énergie provenant de sources renouvelables qui, parmi d'autres sources renouvelables, définit l'énergie géothermique comme l'énergie stockée sous forme de chaleur, sous la surface de la Terre.

La creciente demanda de energía del mundo, las restricciones de las reservas de combustibles fósiles, los esfuerzos para reducir las emisiones de gases de efecto invernadero contribuyendo a la mitigación del cambio climático global, indica que dentro de 20 o 30 años una proporción creciente de la energía deberá proceder de fuentes renovables. En marzo de 2007, los líderes de la UE aprobaron un enfoque integrado a la política climática y energética que tenía como objetivo reducir el consumo de energía y las emisiones de efecto invernadero en un 20% y aumentar la proporción de energías renovables en un 20% para 2020. Estos objetivos ambiciosos se pusieron de manifiesto en la Directiva 2009/28/EC sobre la promoción del uso de energía procedente de recursos renovables que, entre otros tipos de renovables, define la energía geotérmica como "la energía almacenada en forma de calor bajo la superficie de la Tierra"

**G**eothermal energy is restricted to areas with appropriate geological conditions: heat source (high geothermal gradient), hot permeable rock volume at depth (fractured or porous reservoir) and carrying medium (deep circulating groundwater flows that extract and transport heat). The geothermal flow system is governed by convection. Heated fluids expand and have lower density, therefore they rise and are replaced by higher density cold water recharging the system along the margins. The recharge areas typically lie in mountain regions,

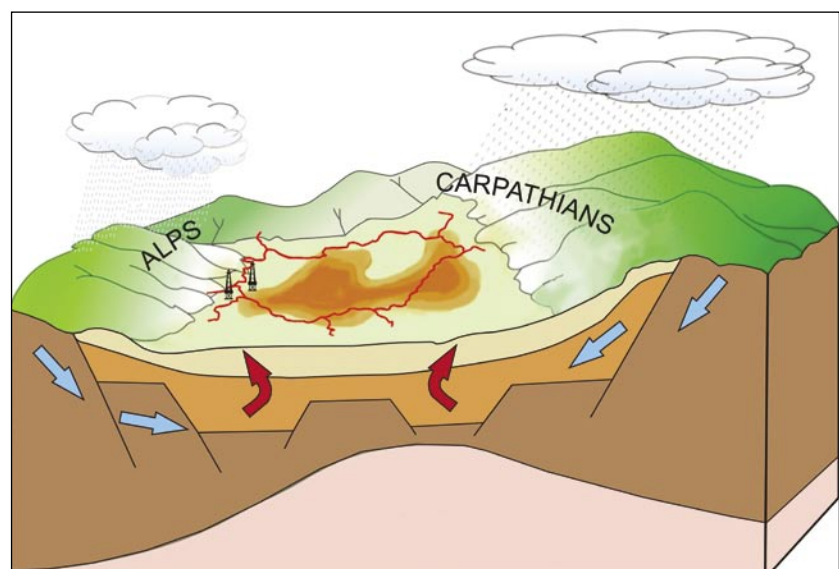


Figure 1. The Pannonian basin in Central Europe has many transboundary thermal water aquifers, as the geological-hydrogeological units hosting deep groundwater flow systems are cut by state borders

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then infiltrating water follows geological structures towards the basin and discharges as thermal water from deeply buried reservoirs. Although the different sections of these large geothermal systems are connected in geological-hydrogeological terms, they are often cut cross by state-borders, and various parts of these integrated systems are shared by neighbouring countries, such as the Pannonian basin in Central Europe (Fig. 1). When neighbouring countries exploit the same geothermal aquifer, water extraction at a national level without cross-border harmonized management strategies may cause negative impacts (depletion or overexploitation) leading to economic and political tensions between countries. Therefore only a transboundary approach and the establishment of a multinational management system can handle the assessment of geothermal resources and their sustainable use, rational water use and integrated river basin management plans as set up in the Water Framework Directive (2000/60/EC). This can only be based on joint research and evaluation of available information on the entire geothermal system, regardless of state borders. The T-JAM project (Thermal Joint Aquifer Management: Screening of geothermal utilization, evaluation of thermal groundwater bodies and preparation of joint aquifer management plan in the Mura-Zala basin) running in the frame of the Slovenia-Hungary Operational Programme 2007-2013 aims to provide such a complex assessment with harmonized data and tools for decision makers in the transboundary region of Pomurje, Podravje (Slovenia) and Vas and Zala (Hungary) at the southwestern part of the Pannonian basin (Figs 2, 3, 5).

### Geology and geothermics of the Pannonian basin

The Pannonian basin in Central Europe lies on a characteristic positive geothermal anomaly, with heat flow ranging from 50 to 130 mW/m<sup>2</sup> with a mean value of 100 mW/m<sup>2</sup> (Fig. 2) and geothermal gradient of about 45 °C/km. This increased heat flux is related to the Middle Miocene back-arc style extension (rifting) of the Pannonian basin, coeval with the thrusting of the Carpathian belt, when the lithosphere thinned and the hot asthenosphere got closer to the surface (Horváth and Royden, 1981). During the post-rift thermal subsidence of the basin in the Late Miocene, a single large depression developed, which was occupied by the brackish to freshwater Lake Pannon. The uplift and erosion of the surrounding Alpine-Carpathian mountain belt

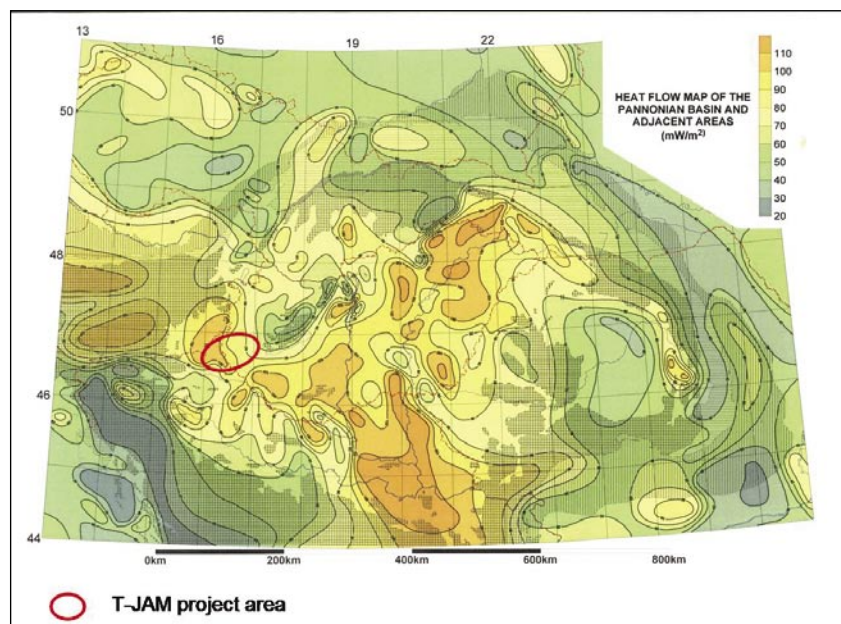


Figure 2. Heat flow density map of the Pannonian basin and its surroundings (Lenkey et al., 2002)

supplied a significant amount of sediments via large fluvio-deltaic systems into the Lake Pannon (Bérczi and Phillips, 1985; Juhász, 1994) resulting in the accumulation of a 5000-7000 m thick sedimentary succession. River deltas that entered the basin from the northwest and northeast prograded to the south, so that, by the Pliocene, the lake basin was filled (Magyar et al., 1999) (Figs 3, 4).

This vast porous basin fill complex is the main reservoir of geothermal fluids (heated groundwater recharging from the surrounding Alpine and Carpathian mountain belts), as well as many hydrocarbon accumulations. Within this several thousand meters thick sedimentary succession, the best reservoirs are those large sand bodies which once deposited on the front of

the delta-systems filling up the basin (Fig. 4). These 50-300 m thick sand bodies with an aerial extent of 200-2000 km<sup>2</sup> have good connectivity due to the continuous delta prograd from 50-70 °C (Dövényi and Horváth, 1988) and are considered as the main thermal-water bearing aquifers. Basin floor turbiditic sands (Fig. 4) were deposited during distinctive slumping events on the delta slopes, and are, therefore, thinner individual bodies with less connectivity; however they are also considered as good thermal water aquifers at some locations. In addition to these porous reservoirs, the karstified zones of the Palaeozoic-Mesozoic carbonates in the basement, as well as fractured zones along main regional tectonic faults in the crystalline rocks, are also very good thermal water reservoirs. At



Figure 3. Gradual filling up of Lake Pannon during the Neogene (after Magyar et al., 1999)

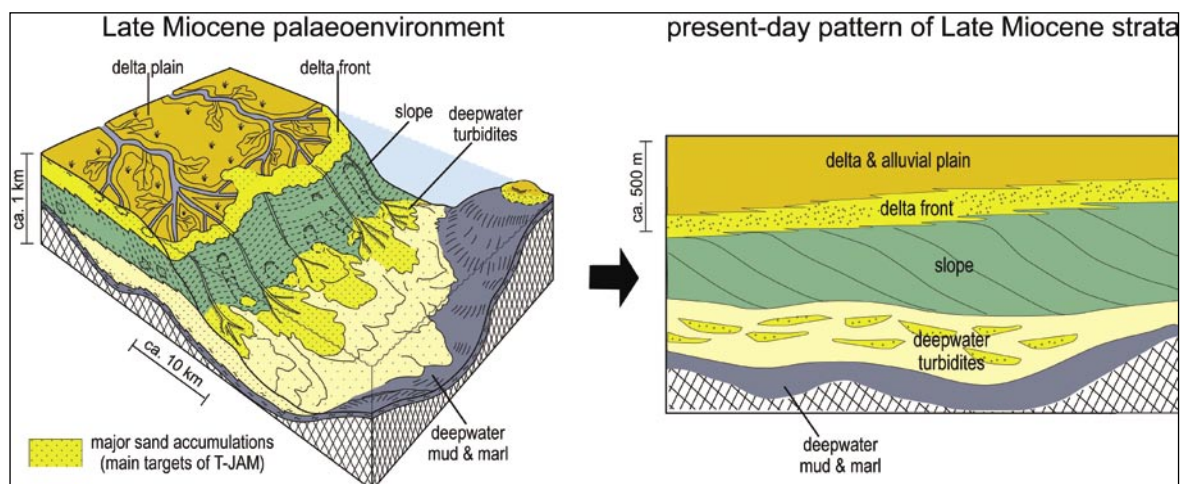


Figure 4. Depositional model of the Upper Miocene delta systems filling up Lake Pannon (after Juhász, 1994). Best thermal water reservoirs (targets of the T-JAM project) are delta sands and to a less extent turbiditic sands

this depth (on average 2,000 m or more) temperature can exceed 100 °C, reaching 120-140 °C in some areas (Dövényi and Horváth, 1988).

#### Transboundary geothermal resources of the Mura-Zala basin

The Mura-Zala basin is one of the deep sub-basins in the south-western part of the Pannonian basin. The pre-neogene basement is built up of Palaeozoic low-grade metamorphic crystalline rocks and non-metamorphic Permo-Mesozoic carbonates belonging to various alpine nappe systems and is bounded by two large tectonic lines

(Fodor *et al.*, 2003) (Fig. 5). The basement is overlain by Lower and Middle Miocene clays, clayey marls, calcareous sandstones and limestones which crop out on the surface in Slovenia. The prograding delta systems of Lake Pannon reached the area about 8-9 Ma ago from the north (Fig. 3) (Uhrin *et al.*, 2009) and deposited a Late Miocene-Pliocene basin fill up to 2,500-3,000 m thickness (Fig. 5).

The heat-flow map (Fig. 2) shows that the eastern part of the Mura-Zala basin (Hungarian part) forms a transitional zone between the karstic block of the Transdanubian Central Range, where heat flow is as low as ~50 mW/m<sup>2</sup> as a result of the cooling effect of recharging cold karstic waters. Towards the west, a positive heat-flow anomaly with ~100 mW/m<sup>2</sup> characterizes the Slovenian part of the Mura-Zala basin. This is also reflected by the temperature distribution at various depths: it is about 60-70 °C at -1,000 m and 100-120 °C at a depth of 2,000 m in the north-easternmost part of Slovenia (Ravnik *et al.*, 1995) with lower values in the Hungarian parts of the basin, 40-60 °C at -1000 m

and 90-100 °C at -2,000 m (Dövényi and Horváth, 1988).

As a result of these favourable geothermal conditions, the Mura-Zala basin is rich in thermal waters which are stored both in the karstified basement rocks (mostly in the Hungarian part) and the porous Late Neogene sandstone reservoirs. The recent use of geothermal resources has been surveyed by the T-JAM project based on questionnaires following the methodology of the International Geothermal Association. At the moment, thermal water is used for balneological purposes, as well as for heating and combined use with no electricity generation (Table 1). However these preliminary results show that the proportion of utilization is quite different in the two countries. While in Hungary the overwhelming majority of thermal water is used for balneological purposes, in Slovenia more than a half of the installed thermal capacity is used for heating. The distribution of spas clearly shows that many of them utilize the same aquifer in the transboundary area. Water temperature (measured at well-head) ranges between 30-55 °C on average in Hungary with a few wells providing water as hot as 70°C while in Slovenia it is 40-70 °C with a maximum produced temperature of 82 °C (Rajver *et al.*, 2010). The temperature of the abstracted thermal water depends on several factors, such as reservoir temperature, discharge rates and cooling. These temperature values are solitary measurements and therefore represent single production situations. Although time series of different parameters (e.g. yield, temperature) would reflect dynamic changes of the reservoir (e.g. effects of production) and would be essential for a sustainable and harmonized use of geothermal resources in

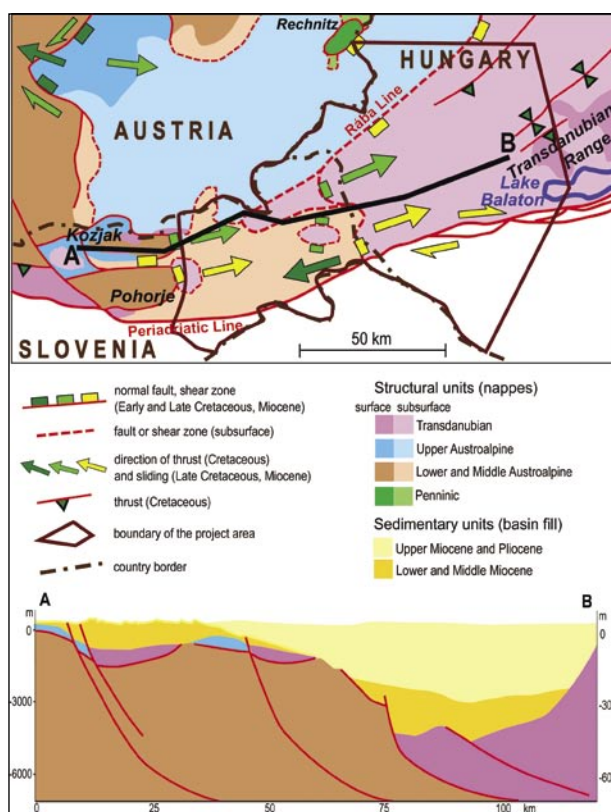


Figure 5. Geological setting of the Mura-Zala basin and a simplified cross-section (after Fodor *et al.*, 2003)

Use	Installed capacity (MWt)		Annual energy use (TJ/yr)	
	NE-Slovenia	SW-Hungary	NE-Slovenia	SW-Hungary
Individual space heating	11.69	1.76	131.55	12.46
District heating	3.29		43.98	
Air conditioning (cooling)	0.13		2.04	
Greenhouse heating	7.06		25.59	
Bathing & swimming (incl. balneology)	16.38	65.17	176.52	591.03
<b>Subtotal</b>	<b>38.55</b>	<b>66.93</b>	<b>379.68</b>	<b>603.49</b>
Geothermal heat pumps at thermal spa centers (used to raise water temperature for further use)	0.26		4.75	
<b>Total - direct use without ground-source GHPs</b>	<b>38.81</b>	<b>66.93</b>	<b>384.43</b>	<b>603.49</b>
Geothermal (ground-source) heat pumps (estimated number)	10	no data	50	no data
<b>TOTAL</b>	<b>48.81</b>	<b>66.93</b>	<b>434.43</b>	<b>603.49</b>

Table 1. Summary of geothermal utilization in the Mura-Zala basin (preliminary results of questionnaire survey of the T-JAM project)

the neighbouring countries, they are unfortunately missing at the moment. The acquisition of such further parameters is one of the key goals of the T-JAM project and will be implemented in the summer of 2010 by sampling 24 wells in both countries with hydrodynamic testing in 5 key-wells.

The preliminary results of the utilization (Table 1) highlighted the problem of lack of information on heat pumps, especially in Hungary. In Slovenia, heat pumps are either used to raise water temperature for further utilization (swimming pools, sanitary water, etc.) at spa centers (usually of greater capacity), or as ground-source heat-pumps. However there is no information on the exact number of the latter and their types (open-loop, closed-loop, dry systems), so their installed capacity and energy use is just an estimation (Table 1) (Rajver *et al.*, 2010). Nevertheless in Hungary even such estimations are missing at the moment. Therefore the T-JAM project aims to promote heat-pump technology in both countries by installing a demonstration heat-pump with the monitoring equipment in Martjanci near Murska Sobota, organizing workshops and preparing information leaflets for the stakeholders in the region.

#### What T-JAM project can offer?

The final aim of the T-JAM project is to provide decision makers and stakeholders of the region with up-to-date information on future perspectives of sustainable use of geothermal resources in the Mura-Zala basin, to help to enhance cooperation between strategic thermal water users on both sides of the border. The project intends to delineate a joint thermal groundwater body in the border zone, which hasn't been done so far and which would serve as the basis for future joint management strategies. It will prepare guidelines for the rational utilization and joint monitoring

of thermal aquifers in the transboundary area and will also prepare a critical evaluation of the existing legislation (Slovenian, Hungarian and EU) on geothermal energy. To achieve these goals, partners establish a joint multi-lingual database and elaborate

geological-hydrogeological and geothermal models for the entire project area. Results of the project can be followed on the [www.t-jam.eu](http://www.t-jam.eu) website.

#### References

- Bérczi, I., Phillips, R.L. 1985. Processes and depositional environments within deltaic-lacustrine sediments, Pannonian Basin, Southeast Hungary. *Geophysical Transactions*, 31, 55-74.
- Dövényi, P., Horváth, F. 1988. A review of temperature, thermal conductivity and heat flow data from the Pannonian Basin. In: Royden, L.H., Horváth, F. (eds): *The Pannonian Basin a Study in Basin Evolution. American Association of Petroleum Geologists memoirs*, 45, 195-233.
- Fodor, L., Koroknai, B., Balogh, K., Dunkl, I., Horváth, P. 2003. A Dunántúli-középhegységi egység ("Bakony") takarós helyzete szlovéniai szerkezeti-geokronológiai adatok alapján (Nappe position of the Transdanubian Range Unit ("Bakony") based on structural and geochronological data from NE Slovenia). *Földtani Közlemény*, 133, 515-546.
- Horváth, F., Royden, L.H. 1981. Mechanism for formation of the intra-Carpathian basins: A review. *Earth Evolutionary Sciences*, 1, 307-316.
- Juhász, Gy. 1994. Magyarországi neogén medencérezek pannóniai s. l. üledéksorának összehasonlító elemzése (Comparison of the Pannonian s.l. sedimentary successions of the Neogene sub-basins in Hungary). *Földtani Közlemény*, 124, 341-365.
- Lenkey, L., Dövényi, P., Horváth, F., Cloetingh, P.L. 2002. Geothermics of the Pannonian basin and its bearing on the neotectonics. *EGU Stephan Muller Special Publication Series*, 3, 29-40.
- Magyar, I., Geary, D.H., Müller, P. 1999. Paleogeographic evolution of the Late Miocene Lake Pannon in Central Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 147, 151-167.
- Rajver, D., Lapanje, A., Rman, N. 2010. Geothermal Development in Slovenia: Country Update Report 2005-2009. *Proceedings World Geothermal Congress 2010*. Bali, Indonesia, 25-29 April 2010 (In press).
- Ravnik, D., Rajver, D., Poljak, M., Zivcic, M. 1995. Overview of the geothermal field between the Alps, the Dinarides and the Pannonian basin. *Tectonophysics*, 250, 135-149.
- Uhrin, A., Magyar, I., Sztanó, O. 2009. Az aljzatdeformáció hatása a pannóniai üledékképződés menetére a Zalai-medencébe (Control of the Late Neogene (Pannonian s.l.) sedimentation by basement deformation in the Zala Basin). *Földtani Közlemény*, 139, 273-282.

# Alternative energy in the Crimean and Carpathian regions of Ukraine

by G.I. Rudko<sup>1</sup>

The growing dependence on the export of hydrocarbon raw materials, intense energy output by industrial enterprises, the necessity to use modern approaches in the usage and assessment of energy resources, the present ecological problems in mining regions, and the distance factor between energy consumers and the sources of energy have defined the development of non-traditional energy in Ukraine. This review outlines the prospects of geothermal resources of the Crimean and Carpathian regions of Ukraine and their energy potential.

The Carpathian region and the Autonomous Republic of Crimea are the most promising regions for implementation and application of alternative (non-traditional) energy resources, which could result in improved life and working conditions for the population and the increased recreational potential of the region.

Legislation favours the application of non-traditional energy resources in the fuel-energy industry, guaranteed by the Alternative Energy Resources Act and the Programme of governmental support of non-traditional and renewable energy resources and small hydro- and heat power industries.

The alternative energy resources in this region are from wind, solar, biomass, soil heat (including geothermal), river and sea power.

The potential for non-traditional and renewable energy resources in Ukraine for the Carpathians (by districts) and Autonomous Republic of Crimea is shown in Table 1 according to the Atlas of energy potential (see also Fig. 1).

To provide the required development of non-traditional energy sources in the Crimean and Carpathian regions of Ukraine the following steps must be taken:

- Zoning of the territory by potential and

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La dépendance croissante en matières premières et hydrocarbures exportés, la forte production d'énergie par les entreprises industrielles, la nécessité d'utiliser une approche moderne dans l'utilisation et l'évaluation des ressources énergétiques, les problèmes écologiques actuels propres aux régions minières et le facteur distance entre consommateurs et sources d'énergie ont défini le développement, en Ukraine, d'une énergie non traditionnelle. Cet article met l'accent sur les futures ressources géothermiques de la Crimée et des Carpates ukrainiennes ainsi que sur l'aspect financier de cette énergie.

efficiency of application of the corresponding type of energy; development of an informational-analysis system of monitoring and power equipment control system

- Implementation of modern wind and solar accumulating power plants for energy supply to individual consumers (reducing dependence on energy may result in cheaper tourism services) with the possibility of energy network charging
- Development of small water power plants on mountain rivers
- Development of hydrothermal resorts and the possibility of heating houses from hydrothermal power plants.

Ucrania La creciente dependencia en las exportaciones de hidrocarburos, el uso intensivo de la energía por las empresas industriales, la necesidad de utilizar enfoques modernos en el uso y evaluación de los recursos energéticos, los actuales problemas ecológicos en las regiones mineras y el factor distancia entre los consumidores de energía y las fuentes de energía son los factores que han definido el desarrollo de las energías no convencionales en Ucrania. Este trabajo de revisión bosqueja los posibles recursos geotérmicos de las regiones de Ucrania de Crimea y Carpatia y su presupuesto energético.

The advantage of developing alternative energy resources in these regions is the possibility of using a combination of several resources and reducing the amount of expensive imported energy resources

This will:

- provide an independent energy supply to remote energy consumers, which is very important for mountain regions
- stimulate the development of many industrial branches dealing with microelectronics, electrical engineering, hydromechanics and special construction (it is a positive factor for job creation and supply of energy equipment to the regions)

No.	Administrative district	The quantity of extracting heat carrier under conditions of exploitation with the formation pressure maintenance, thousand m <sup>3</sup> /day	Thermal potential of thermal water, megawatt	Economy, thousand of tonnes of standard fuel per year
1.	Thanscarpathian	239.4	490	510
2.	Mykolayiv	1620	2820	1900
3.	Odessa	1350	2350	1600
4.	Poltava	5.9	9,2	9.9
5.	Sumy	4.2	15.8	17
6.	Ternopil	–	–	–
7.	Charkiv	0.4	1.3	1.4
8.	Cherson	2430	4230	2900
9.	Chernihiv	37.2	58.3	62.7
10.	Autonomous Republic of Crimea	21600	37600	25600
	TOTAL	27287.1	47574.6	32601

Table 1. The energy potential of non-traditional and renewable energy sources of standard fuel equivalent (millions of tonnes of standard fuel) and volume replacement of fuel-energy resources

- will improve production efficiency due to cheap energy
- will improve the ecological situation and save huge amounts of scarce organic fuel
- will improve the life conditions of the population especially in mountain and rural areas.

#### Hydrothermal resources

Thermal water is characterized by many factors: mineralization, acidity, gas composition, pressure, depth of occurrence, temperature.

According to the predictive regional estimate the thermal water resources in Ukraine consist of (Fig. 2):

**Spouting deposits** - 23,000 m<sup>3</sup> per day with a total geothermal energy of 0.6 million Gcal per year.

**Pumped deposits** - 137,000 m<sup>3</sup> per day with a total energy of 2.14 million Gcal per year.

**Formation pressure maintenance deposits** - 27.166 million m<sup>3</sup> with a total energy of 453 million Gcal per year.

The area of the flat Transcarpathian region provides the most favourable conditions for thermal water usage. Economically efficient reserves of thermal water were found in Berehove, Kosynske, Zaluzhske, Tereblya deposits, and the most cost-efficient in Veliatyn, Velyka Palad, Velyka Bakta and Uzhgorod deposits. The fields of the Berehove area are the most rewarding, where it is possible to extract water at a temperature of 45- 65 °C from a depth of 800 - 1300 m.

The total amount of thermal water reserves is more than 50,000 m<sup>3</sup>/day, and the total amount of heat energy reserves accumulated in that water reaches 1012 kcal/year, which is equal to 100,000 tonnes of standard fuel. In general, the most productive areas can provide a volume of geothermal energy of  $1.52 \cdot 10^{20}$  joules even with a 4% extraction ratio.

According to some evaluations of the geothermal heat resources including explored reserves and efficiency factor, the conversion of geothermal energy may potentially support the operation of a thermal power plant with total power of up to 200-250 million kW (with a drilling depth up to 7 km and plant cycle up to 50 years. This exceeds the present energy supply in the Ukraine 4-5 fold).

According to predictive evaluation, 10 km of the top part of Ukraine's subsoil contains  $6.9 \cdot 10^{22}$  joules or  $2.38 \cdot 10^{12}$  tonnes of standard fuel and 3 km contains  $3.3 \cdot 10^{22}$  joules or  $1.12 \cdot 10^{12}$  tonnes.



Figure 1. Perspectives of hydroelectric power application

The most potential territories are located in the area of the Transcarpathian trough, the NW part of the external Bilche-Volytsya zone of the Precarpathian trough, the Predobrogea trough, steppe Crimea, the Kerch peninsula, the Donetsk folded structure and bordering areas of the Dnipro-Donetsk depression.

Of these, the best potential area for geothermal energy is the Transcarpathian region, where the rock temperature is 230-275 °C at 6 km depth. The dry rock isotherm in nearby Zakalyuhy is +200 °C in an area of 30 km<sup>2</sup> at a depth of 4 km. These reserves can maintain the operation of several small geothermal power plants and greenhouse agricultural sectors. The use of residual heat from the power plants for heat supply to nearby settlements, and to meet the demands of agro-industrial and

industrial complexes doubles the profitability of the plant.

Considerable resources of petro-geothermal energy are accumulated in Crimea. The most promising are the Tarchankut and Kerch peninsulas, where the temperature of mountain rocks at a depth of 3.5-4.0 km may be 160-180 °C. It is likely, however, that not more than 4% of the expected resources of petro-geothermal reserves may be used for energy purposes.

The advantage of geological heat power plants is their ecological compatibility. The discharged water is pumped back to underground horizons, which maintains ecological safety in the region and stability of the technological cycle. These power plants cause less hazardous waste in the atmosphere. For example the



Figure 2. Hydrothermal reserves



Figure 3. Hydroelectric potential of small rivers of Ukraine

typical geothermal plant wastes 1 VMt per hour of energy which amounts to 0.45 kg, while natural gas plants waste 464 kg, fuel oil, 720 kg, and coal, 819 kg. The plant itself requires less area for its construction, and may be designed and located on any land including agricultural land.

Though the application of geothermal resources is rather complicated due to their non-competitiveness comparing with traditional sources, the cost of geothermal plants with a total power of 2,000-2,500 MW fluctuates between 1.5 and 2.0 billion US \$. According to calculations, the cost can be recouped in less than five years, much faster than for solar energy (longest recoument time), followed by atomic, hydro and heat energy.

Exploration results indicate that the expected resources of thermal water on the territory of Crimea exceeds 27 million m<sup>3</sup>/day, which makes it possible to meet a considerable part of the region's demands in energy resources at the cost of hydro-thermal energy.

There are 310 spouting thermal resources in Crimea, 240 of them fully explored. In order to improve the energy supply in the Crimea it will be necessary to construct several geothermal power plants with a power of 6 MW each in the western part of the peninsula, where the water resources are deposited at a depth of 4 km and a temperature of 250 °C. Their total power will comprise more than 100 MW.

The optimum well depth for the most economical heat extraction systems is suggested as up to 3 km. The thermal potential of 90% of thermal water at the mentioned depth will not exceed 100 °C. In this case the hydrothermal supply is prevalent which results in a greater replacement of organic fuel compared to electric power

production.

Even low-temperature thermal water (up to 40 °C), the reserves of which exist in sufficient amounts in many regions, can be used in the Crimea. The application of thermal water energy, however, is complex at the moment due to the high cost of well drilling and return pump-out of waste water as well as construction of corrosion-resistant heat engineering equipment. There is also the risk of development of wells with low reserves of water which leads to rising costs.

#### Hydroelectric potential of small hydropower plants

There are more than 63,000 rivers and streams in Ukraine with a total length of 135,800 km, 60,000 of which are very small (95%) with a length of less than 10 km. Their total length is 112,000 km and the average length of such streams is 1.9 km (Fig. 3). The majority of small rivers with a length of less than 10 km have a catchment area from 20.1 km<sup>2</sup> to 500 km<sup>2</sup> (87% of the total quantity and 72% of the total length of small rivers which flow in Ukraine). There are 890 small rivers with a catchment area from 50.1 km<sup>2</sup> to 100 km<sup>2</sup> (28% from the total quantity), and 797 rivers (25%) - from 20.1 km<sup>2</sup> to 50 km<sup>2</sup>.

The technical hydroelectric potential of small rivers is 0.7 million kW (6.4 billion kWh) or 30% from the total technical potential of all rivers in Ukraine (21.5 billion kWh). Economical hydroelectric potential of small rivers of Ukraine may be 1.3-1.6 billion kWh.

At the start of the 1920s there were 84 hydropower plants in Ukraine with a total output of 4000 KW, and at the end of 1929 there were 150 plants with a total output of 8400 kW including Voznesensk (840 kW),

Bug (570 kW), Suty (1000 kW) and other hydropower plants. In 1934 the Korsun-Sevchenko hydropower plant (2650 kW) began operation, which was one of the best in the world at that time according to its engineering performance.

In the post-war period, the electrification of agriculture was based on output growth and improvement of technical economical characteristics of small power plants. In the beginning of the 1950s the quantity of constructed small hydropower plants comprised 956 units with a total output of 30,000 kW. Nevertheless, with the development of a centralized system of electricity supply and the tendency to concentrate electricity production in powerful heat and hydropower plants, the construction of small hydropower plants was stopped.

Between 1984 and 1988 the examination of the equipment and construction condition of existing hydropower plants took place. The analysis of data showed that at the moment of examination there were 150 low-functioning and non-functioning hydropower plants (49 and 101 units correspondingly).

More than 75% of the general output of hydropower plants is used for operative power plants. Almost 80% of these plants are owned by the Ministry of Fuel and Energy of Ukraine. They are comparatively powerful plants, such as Tereblya-Rika, Gayvoron, Korsun-Shevchenko, Stebliv, Ladygy among others. The technical condition of operative hydropower plants is characterized by partially or completely worn out waterpower, hydro technical and electro technical equipment; defects in the forcing front constructions which may cause incidents; silting of water; increase in water catchment for non-energy purposes; washing out of spillway and shore strengthening of the channel downstream, etc.

The small generators of Ukraine with small specific weight (around 0.2%) cannot greatly influence the energy supply situation of the country in the total energy balance. Nevertheless, the exploitation of small hydropower plants gives the opportunity to produce around 250 million kWh of electricity, which is equal to an annual economy of 75,000 tonnes of organic fuel, itself in short supply.

The potential of hydroelectric resources of the Transcarpathian region has been evaluated and exceeds 10-fold that of Ukraine in general (specific reserves of hydroelectric power per head per year are 8250 kW per year in the Transcarpathians, and the average in Ukraine is 820 kWh).

The biggest hydroelectric reserves refer to Teresva, Tereblya, Rika, Uzh, Latoritsya rivers, which comprise 40% of all hydroelectric resources. The potential of small rivers up to 100 km in length is 330,000 kWh of average annual output or 2900 million kWh of energy in an average water content year. The total length of the recorded rivers is 1,748 km with the total catchment basin of 9,240 km<sup>2</sup>. The obtained value of the linear hydroelectric power resources is slightly understated as small rivers were not taken into account due to their insignificant role in energy supply, though their total output is of interest for the total evaluation of energy resources in the Transcarpathian region.

The analysis of hydroelectric resources of the small rivers of the Transcarpathians shows that only nine rivers have an output which exceeds 10,000 kW, 5% have an output of 5-10,000 kW and 86% have an output of less than 5000 kW.

The analysis of small Carpathian rivers was conducted in a similar way. According to energy potential, a comparative analysis was made of potential hydroelectric resource characteristics for a selection of small rivers and particular parts of rivers. An important characteristic of hydroelectric resources is their specific output, which is determined by the consumption of water, the fall and the length of the particular part of the river. This will show the parts of the rivers with the highest potential for energy use.

A part of the river Brusturyanka is characterized by the highest specific output of 266,000 kW/km, the length of the part of the river is 1200 m, river fall is 33.3 m/km, drop is 40 m/km; a part of the Yablunitsya river has an output of 233,000 kW/km, the length of the part of the river is 600 m, river fall is 60 m/km, drop is 100 m/km; a part of the Lyuta river has an output of 231,000 kW/km, the length of the part of the river is 600 m, river fall is 40 m/km, drop is 66.7 m/km.

The change from channel output of potential resources of particular parts of rivers is possible due to the flat energetic characteristic i.e. hydroelectric module determining the output of basin/unit area:

$$M = N/F$$

where: N = output in thousands of kW

F = area of basin in km<sup>2</sup>

With the help of this value, a hydroelectric zoning of the region was conducted (it was divided into six zones).

The majority of rivers (84) are in zones 4, 5 and 6 (in descending order according to hydroelectric output). The following rivers are in zone 1: Keveliv - hydroelec-

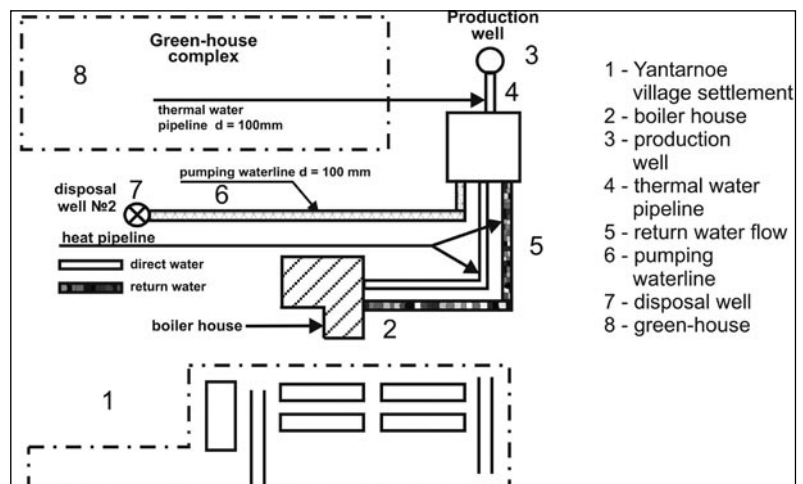


Figure 4. Geothermal supply system draft (Yantarnoe)

tric module - 100 kW/km<sup>2</sup>, potential output is 28,000 kW; Kisovska - hydroelectric module - 100 kW/km<sup>2</sup>, potential output is 1,601,000 kW; Mala Shopurka - hydroelectric module - 100 kW/km<sup>2</sup>, potential output is 122,000 kW.

Five rivers fall within zone 2 and their modules comprise 100-80 kW/km<sup>2</sup>. The third zone consists of rivers with the hydroelectric module of 60-80 kW/km<sup>2</sup>. Thus, those with the highest potential output per unit area are the rivers from the first zone, and they are the most promising for energy supply at microhydro power plants and mini-hydro systems.

#### Usage of geothermal energy in Ukraine

Main aims:

- Localization of deposits with ample reserves of geothermal energy for hot water application, heating purposes or hot domestic water production
- Submission of technical-and-economic decisions, which will be subjected to preliminary technical and financial estimates.

#### Location of geothermal resources

Geothermal resources are localized at the Crimea and within Transcarpathian and Precarpathian regions, where subsurface water-bearing horizons with high potential resources of geothermal energy are placed. The usage of geothermal energy in regional heating systems or for electric-power production takes place in some cities and towns of Ukraine, e.g. Yantarnoe village settlement (the Crimea); Berehovo village settlement (Transcarpathian region).

#### Technical-and-economic analysis of geothermal areas in Crimea and Transcarpathian regions

Area I: Yantarnoe village settlement

It has an existing geothermal heating

supply. The turnover of regional heating company accounts approximately 2 million US \$ and the revenue is 1 million US \$.

At present the geothermal water is used during the winter season supplying hot water to urban settlements. During the spring and summer season, geothermal water may be partially used for greenhouse warming (Fig. 4). In Yantarnoe the replaceable fuel is heavy fuel oil.

#### Area II: Berehovo village settlement

Hot water, which is extracted from three geothermal wells, has been used in Berehovo for several years, for heating. Geothermal energy is used for sanatorium needs. The subsurface reservoir consists mainly of volcanic tuff, which creates very good geological conditions for thermal energy usage in regional heating systems.

#### Conclusions

In conclusion, the exploration of hydroelectric resources of rivers in the Carpathian region is relevant and necessary for the production of cheap and ecological electricity. Additionally, the hydroelectric structures could also function as anti-flood structures.

The Crimea region is characterized by the presence of geothermal systems and regional heat-supply networks, heated by heavy fuel oil. The total heat requirement is 34 400 mWh, 65 % of which is geothermal energy. The total investment sum is 1,325,000 US \$. Payback time is approximately 6 years and 2 months. In the Transcarpathian region, the Berehovo village settlement has the best potential and is recommended for implementation of and application of alternative energy resources.

# Carbon capture and storage

Professor Martin Blunt<sup>1</sup> talks to Sarah Day<sup>2</sup>

Over the past few months, carbon capture and storage (CCS) has been generating a lot of excitement as a potential tool in the fight to reduce carbon emissions. As an idea, it is wonderfully simple - instead of allowing CO<sub>2</sub> to enter the atmosphere, it is collected at large point sources and injected back underground.

Some, however, have questioned whether it is possible to overcome the engineering challenge this presents. In March 2010, the Telegraph published an article claiming that 'it is impossible to inject such huge quantities of CO<sub>2</sub> into underground aquifers without fracturing the surrounding rock...this finding is confirmed in a study by the Grantham Institute at Imperial College'.

Professor Martin Blunt is head of the Department of Earth Sciences and Engineering at Imperial, and is working on CCS injection design. He was astonished by the claim.

*'It's simply not true to claim we supported that argument - our studies show quite the opposite. CCS on a large scale is challenging, but it can be done. With careful injection design it's possible to inject very large amounts safely.'*

So, if it's possible, why aren't we doing it now? Perhaps, although injection can be done in theory, we have yet to find any suitable sites. But Professor Blunt denies this.

*'I'm not worried about storage space. It needs to be looked at very seriously from an engineering and geological perspective, but I think we have sufficient capacity. In the UK we're particularly fortunate that offshore, underneath the North Sea, there are very extensive saline aquifers in sandstones, and we also have a large number of now depleting mature oil and gas fields.'*

Nor is he concerned about the potential hazards of CCS.

*'If some of the CO<sub>2</sub> were to leak, that would be unfortunate, yes. But not*

*intrinsically a disaster. It's only potentially hazardous if a large amount is released quickly into a depression, when the CO<sub>2</sub> could asphyxiate you. But it's almost impossible to design a system where that happens - and of course, we're going to design a system where that's unlikely! So I don't think it's hazardous. The other option, of course, is to allow 100% of the CO<sub>2</sub> to leak. That's what we do now.'*

And, most importantly, CCS isn't just a theoretical possibility.

*'We have the components of the technology. We're ready to begin pilot plants now. BP had a scheme to sequester CO<sub>2</sub> in the North Sea that would have been up and running last year; had the government decided to support it.'*

Professor Blunt is convinced that, although CCS is by no means the only way we can reduce our emissions, it is a potentially vital tool.

*'It would be very difficult to reach our emission reduction targets without CCS. It's certainly not the only tool - we need to be thinking about energy efficiency, renewables, other options too. But CCS could make a major contribution within the next 10 - 15 years.'*

And if that's going to happen, we need to move fast.

*'We need to do pilot plants, see that they work and iron out the problems. That's going to take ten years before you can have another round, possibly a third, with more extensive deployment of the technology. Now we're talking about almost 30 years, so we need to start now. Really, by 2030, CCS needs to be making a serious contribution to reducing atmospheric emissions of CO<sub>2</sub>.'*

Like many, he is frustrated by the progress which has been made so far.

*'We are certainly not on the right track. It's a growing concern among people working in this area. There seems to be a lack of political imagination and public will to move us onto a different track.'*

*'It may sound a little undemocratic', he admits, 'but as far as CCS goes, I don't view it really as a "personal choice". It's a part of the chain that most people are not really aware of, as are many*



*things to do with climate change.*

*'In the end, you walk into an office and turn on the light. If you're in Britain, that electricity comes from burning coal and gas. Turn the light on in France, and it comes from nuclear power, with virtually no emissions. Where's the lifestyle choice there?'*

Does that mean it's all up to the government?

*'I'd certainly like to see governments take responsibility by mandating CO<sub>2</sub> emissions limits, cradle to grave, and then allowing power generators to use whatever method works within those limits, whether it's renewables, nuclear or fossil fuels with CCS. But the government does need to feel it's taking leadership which is supported by the public. So public understanding, communication with the public, is an important thing too.'*

Which brings us back to the Telegraph article. How frustrated are scientists by misunderstandings like these?

*'There can be honest miscommunications, or situations where a finding is exaggerated. That's fine, it happens all the time. But we're seeing another type, where comments are taken out of context, and even a cursory look at the primary material would indicate that it is being taken out of context and used to support essentially a political agenda. That really is quite alarming for scientists, because it's a misrepresentation of what we're doing and what we're trying to say.'*

<sup>1</sup>Professor and head of Earth Science and Engineering department, Imperial College, London

<sup>2</sup>Earth Science Communicator, Geological Society, London



From the scientists' point of view, our next step is clear.

*'From an engineering perspective, we should just be doing it! Trying it, seeing if it works. The longer we delay the implementation of CCS, the more CO<sub>2</sub> we emit into the atmosphere. We're heading towards a situation where we simply burn fossil fuels unabated, and*

*only switch to renewables once fossil fuels become much more expensive. By that time, CO<sub>2</sub> concentrations in the atmosphere will be very, very high.'*

But whilst the technology is ready, it seems that political support still has a way to go. Whilst CCS may not be a practical solution in the long term, or the only tool we need, it could play a vital role in our adaptation

to alternative energy sources. Without it, Professor Blunt warns,

*'there may come a time when we are committed to dangerous climate change, and there's nothing we can do. We have to avoid that'.*

Now is the time for governments to take note of Professor Blunt's message, and 'just do it'.

## Opinion

# Politically correct geology

by David Navarro Vázquez<sup>1</sup>

There are several issues that society and the media are currently debating. These are issues that have a geological background, but for which, surprisingly, geologists remain silent. I wonder if these issues are considered 'politically incorrect' and we, as geologists, are afraid to oppose the viewpoint of the majority? But, is the opinion of the majority necessarily the most reliable opinion?

Let's get to the point. First of all, the "boogeyman" of climate change. I trust that there are few matters for which the vision of geologists is so wide and well-founded. I think we have a better perspective to judge the evolution of geologic history and in the same way that historians seek the keys to the human past, we are able to understand the terrestrial evolution and changes that have occurred throughout the Earth's history, the present situation, as well as to predict its possible future. Sedimentologists can inform us about the atmosphere-ocean ionic exchange, the carbon cycle and, therefore, about the true facts of global warming. Palaeontologists, in their study of the evolution of the species, can comment on the disappearance of some or the appearance of others, etc. Geomorphologists provide information about the recent and actual modelling of the Earth's surface, for example, ice evolution in the Quaternary, which can provide many clues about the global retreat of glaciers and answer the key questions: is that really happening and since when?

In summary, many people are talking about the future of the Earth but, where are the geologists? How many conferences and debates are organized about climate change, without their presence? And, most important, how and by whom are research budgets managed?

<sup>1</sup>Member of ICOG (Spanish Association of Professional Geologists)

It is as if when the World Health Organisation (WHO) were dealing with the issue of influenza A, there were no medical doctors, or when the "mad cow" case was debated, veterinarians were not represented.

And this does not mean, not at all, that we do not believe in a clean and unpolluted planet. Nothing about the climatic evolution of the Earth has one single direction, and definitively that evolution cannot be viewed with the uniform and simplistic outlook that today seem to exist in our society.

I want now to focus on nuclear energy. In Spain today, we are covering the mountains with wind mills and tiling the plains with photovoltaic plants. And all these renewable energy facilities produce energy that is costing us about four times the cost of nuclear energy, putting aside its environmental impacts, etc, etc.

It seems to be that the advances in nuclear technology in the last twenty years have been very important. Nuclear plants have minimized risks and their activity is considered as safe as any other industry. The only thing missing is solving the issue of radioactive waste, while new reprocessing technologies come. But it is in the storage issue where geologists can participate almost exclusively, and where as a collective we have much to say.

We have to look for a sizeable geological massif, impermeable, free of seismic activity and at sufficient depth. To these we have to add that the waste containers used must be as hermetic as possible. If we are successful, we will have participated effectively in one of the main challenges of our present society, particularly in these times of economic crisis.

In Spain, some years ago, our radioactive waste state-company (Enresa) had already done much in this research area, but in the rest of Europe, except France,

they remained paralyzed by ideological arguments.

Finally I want to talk about the mining industry the "bete noire" of political correctness. Today any mining project or mining initiative is received with displeasure by society in general not taking into account the fact that it is compulsory for all mining projects to present a reclamation project.

Nobody argues that our current way of life needs -in order to maintain our welfare- to have available mineral raw materials, so the question is: if we ban exploitation, where are we going to bring them from, Mars?

It is clear that nobody wants to have a quarry or a mine near their backyard (NYMBY), even if remediation is guaranteed. But, what everybody wants, without exception, is to take advantage of the minerals obtained from mines and quarries, as these are the basis of many technologies.

Perhaps the problem is that geologists don't want to get into controversies. From my point of view, this does not favour our community and our future, because after all we are professionals in geosciences.

In the last few years we have seen huge advances in the geological community at all levels (communications, magazines, professional associations, etc..) both in Spain and in Europe. But I always miss the other views I have talked about above, which are the views of most geologists - as ICOG's on-line web-polls clearly show - but which are rarely reflected in the "media" or in our own professional media.

I would like that geology and especially geological associations were a little more "incorrect".

*The English version of this text has been revised by Manuel Regueiro y González-Barros.*

# Mining in Hungary

by Gábor Szabados<sup>1</sup> and Tamás Hámor<sup>2</sup>

Since May 2004, Hungary has been a Member State of the European Union and at least half of its national legislation is of Community origin. However, two important legislation and policy fields highly relevant to mining, namely, minerals management and spatial development (or "land use") planning, are out of the scope of the Community legislation ("acquis communautaire"). In this way an important segment of the mining industry governance is left to the sovereign decision-making of the Member States.

The present situation has developed rapidly in this century (Fig. 1), due to the prompt reaction by the European Commission, Council, and the European Parliament to mining accidents in Spain (1998), and in Romania (2000) leading to serious environmental impacts. *Inter alia*, the Seveso Directive was amended, the Mining Waste Directive and implementing Commission Decisions were published, the European Waste Catalogue with a mining waste chapter was issued, the Environmental Liability Directive was formulated, and a best available technology reference document was elaborated on the major part of the mining industry under the scope of the IPPC Directive.

The Hungarian mining industry could cope with the requirements of environmental protection and water management, but the Community's nature conservation policy established a serious barrier to mining, the so-called "Natura 2000" framework, based on the Birds Directive and on the Habitats Directive. The national implementation of this policy generated a close-to-absolute prohibition of exploration and exploitation activities on ca. 25 % of Hungarian territory (Fig. 2).

Due to the unprecedented dependence of Europe on raw materials and energy imports from external sources, and of the remarkable expansion of other competitive global players, the European Commission has published a series of communications

Depuis Mai 2004, la Hongrie est un Etat membre de l'Union Européenne et au moins la moitié de sa législation nationale est d'origine communautaire. Cependant, deux domaines importants touchant la législation et la politique, directement liées au secteur minier, c'est-à-dire la gestion des ressources minières et l'aménagement de l'espace territorial restent en dehors de l'acquis communautaire. Ainsi un volet important de contrôle et de gestion de l'industrie minière est laissé aux Etats membres, souverains dans leurs décisions.

in order to reinforce related EU policies and measures. The most relevant action involving the mining industry was initiated by the Commissioner Mr. Verhaugen. In 2008 "The raw materials initiative — meeting our critical needs for growth and jobs in Europe" {SEC(2008) 2741} was published: ([http://ec.europa.eu/enterprise/non\\_energy\\_extractive\\_industries/docs/communication/com699en.pdf](http://ec.europa.eu/enterprise/non_energy_extractive_industries/docs/communication/com699en.pdf)).

## General profile of the mining industry

In the last 20 years, following political and socio-economical changes in 1989, the mining industry experienced dramatic changes. In the fossil fuel and metallic ores sector, the big state-owned mining companies collapsed and/or transformed into private companies and many mines were closed, especially the sub-economic underground coal mines. Tens of thousands of mine workers lost their jobs, took early retirement or trained in other professions. The state spent tens of billions of HUFs for mine closure, remediation and decontamination activities at mining sites (Fig. 3).

## Reserves and production

Although Hungary possesses substantial

Desde mayo de 2004 Hungría es un estado miembro de la UE y al menos la mitad de su legislación nacional es de origen comunitario. Sin embargo hay dos campos de la legislación y de la política que son importantes para la política minera, a saber la gestión minera y la planificación del territorio, están fuera del campo de la legislación europea ("acquis communautaire"). De este modo una parte importante de la gestión de la minería se deja en manos de la soberanía y decisión de los estados miembro.



Figure 1. Mining in the „acquis communautaire” (Hámor, 2004)

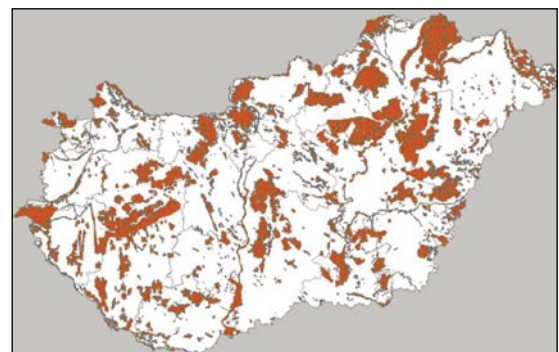


Figure 2. Natura 2000 areas in Hungary, from Ministry for Environment and Water ([www.kvvm.hu](http://www.kvvm.hu))

reserves of coal, bauxite, industrial minerals and construction materials, it is dependent on imports of oil, gas, uranium and metallic commodities. As of 1 January, 2008 the 3,646 known mineral occurrences or mining areas/deposits bear 37.7

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<sup>2</sup>Hungarian Office for Mining and Geology

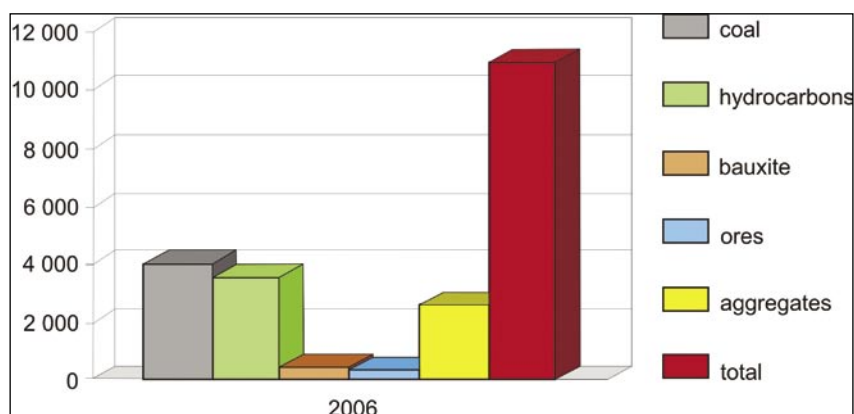


Figure 3. Number of mine workers in 2006, after Hungarian Mining Association (www.mabsz.hu)

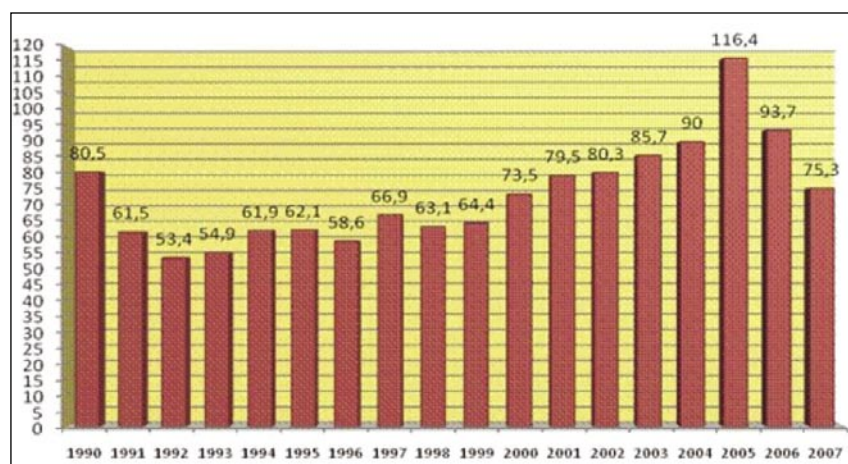


Figure 4. Mineral production in Hungary 1990-2007 (Mtons)

Type of mineral resources	Reserve million tons	Contracted with working mines (from reserve)		Production in 2007 <sup>a)</sup> million tons	Supply on rate of production of previous year	
		%	%		on basis of reserve of working mines	on basis of total reserve
Crude oil	19,2	17,3	90	0,84	21	23
Natural gas <sup>b)</sup>	3355,3	56,6	17*	2,65	21	25 (>50*)
<sup>b)</sup> Carbon dioxide gas <sup>b)</sup>	32,4	21,7	67	0,11	> 100	> 100
Hard coal	1986,2	-	-	-	x	
Brown coal	2245,5	85,6	3,8	1,45	59	> 100
Lignite	4376,8	585,1	13,4	8,35	70	> 100
Bauxite	82,0	7,2	8,8	0,5	14	> 100
Precious ores	36,5	-	-	-	x	
Copper ore	726,5	-	-	-	x	
Manganese ore	52,6	51,8	98,5	0,05	> 100	> 100
Industrial minerals	1002,4	548,6	55	3,0	> 100	> 100
Cement and lime industry	1301,0	691,2	53	5,5	> 100	> 100
Building and decoration stones	2362,7	1323,1	56	13,0	> 100	> 100
Sand and gravel	4855,0	2646,9	55	34,8	76	> 100
Ceramic industry	1074,5	452,5	42	4,9	92	> 100
Peat, paludal lime mud	110,4	4,3	4	0,1	43	> 100
<b>Total</b>	<b>23789,6</b>	<b>6492,2</b>	<b>27</b>	<b>75,3</b>	<b>x</b>	<b>x</b>

a) Raw mining products  
b) 1,000 m<sup>3</sup> gas = 1 ton.  
\* together with Mako deposit

Table 1. Mineral reserves as of 1 January, 2007

billion tons of geological and 23.8 billion tons extractable reserve. Of these deposits, 27% (6.5 billion tons of reserve) are being exploited with an annual production of 75 million tons. In the past 10 years, operating deposits have grown by 36% - growth mainly in the number of non-metallic (especially for the construction industry) mineral deposits (Tables 1 and 2). (Production data in all cases refer to raw mining products. For natural gas, 1,000 m<sup>3</sup> natural gas is equivalent to 1 ton of reserve.)

The aggregates segment of the mining industry (construction sand, gravel, crushed rocks, decorative stones) and the industrial minerals companies adopted more easily to the changes. This is reflected in the record of the bulk mineral production of Hungary during this period. The annual production volumes are influenced a lot by the aggregates production which is a direct function of the infrastructure development supported by national state budget or EU funding and associated incentives (Fig. 4).

In 2008, according to the mining royalty registry of the Hungarian Office for Mining and Geology, 879 mining companies carried out active mineral and geothermal energy production in 1858 mining sites. The mining royalty provided by the extractive industry (ca. 400 m€ equivalent) is a significant contribution to the central state budget income (Fig. 5).

## Policy and regulations

### Mining legislation

There is a separate law on mining called "Act No. XLVIII of 1993 on Mining" approved by the National Assembly (Parliament) and announced (published in the Official Journal) on 13 May 1993. It came into force on 14 June 1993 and has been amended several times. Among the numerous implementing legislation (mainly decrees of the Ministry of Economy and Transportation), the most important is the Government Decree No. 203/1998. (XII. 19.) on the implementation of the Mining Act.

The scope of the Mining Act covers the complete mining-related activity chain: geological survey, mining exploration, exploitation, break in operation, mineral processing, closure, and remediation. It extends to all mineral commodities (including oil and gas); establishment, utilization and termination of waste rock heaps; maintenance, utilization and closure of open spaces of closed underground mines; underground activities of non-mineral exploitation purposes using mining

Type of mineral resources	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Crude oil	1,5	1,4	1,2	1,3	1,1	1,1	1,1	1,1	1,1	0,9	0,9	0,8
Natural gas <sup>a)</sup>	4,8	4,5	4,0	3,6	3,3	3,3	3,1	3,1	3,2	3,2	3,2	2,7
Hydrocarbons	6,3	5,9	5,2	4,9	4,4	4,4	4,2	4,2	4,3	4,1	4,1	3,5
Hard coal	1,0	0,9	0,9	0,7	0,7	0,6	0,6	0,7	0,3	-	-	-
Brown coal	7,0	7,2	6,6	6,5	5,7	5,4	4,6	4,1	2,5	1,4	1,4	1,5
Lignite	7,5	8,1	7,6	7,7	7,9	8,1	7,6	8,6	8,5	8,2	8,5	8,4
Total coals	15,5	16,2	15,1	14,9	14,3	14,1	12,8	13,4	11,2	9,6	9,9	9,9
Uranium ore	0,2	0,2	-	-	-	-	-	-	-	-	-	-
Total fuels	22,0	22,3	20,3	19,8	18,7	18,5	17,0	17,6	15,6	13,7	14,0	13,4
Carbon dioxide gas <sup>a)</sup>	0,2	0,1	0,2	0,1	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,1
Iron ore	-	-	-	-	-	-	-	-	-	-	-	-
Manganese ore	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
Bauxite	1,1	0,7	0,9	0,9	1,1	1,0	0,7	0,7	0,6	0,5	0,5	0,5
Pb-Zn ore	-	-	-	-	-	-	-	-	-	-	-	-
Copper ore	-	-	-	-	-	-	-	-	-	-	-	-
Total ores	1,2	0,8	1,0	1,0	1,1	1,0	0,7	0,7	0,7	0,6	0,6	0,6
Industrial minerals	2,5	3,4	2,4	2,9	2,7	3,2	3,1	2,9	2,9	3,5	3,6	3,0
Cement and lime industry	5,7	5,6	5,6	5,9	6,0	6,1	6,1	5,8	5,4	5,0	5,7	5,5
Building and decoration stones	5,3	6,3	7,2	8,0	8,2	8,6	9,8	10,1	13,0	15,1	17,9	13,0
Sand and gravel	17,5	24,9	22,4	22,6	29,7	32,2	35,4	42,0	46,4	69,0	46,5	34,8
Ceramic industry	4,1	3,3	3,9	4,2	6,9	9,7	7,9	6,3	5,9	9,3	5,2	4,9
Construction raw materials	32,6	40,1	39,1	40,7	50,8	56,6	59,2	64,3	70,7	98,4	75,3	58,2
Peat, paludal lime mud	0,1	0,1	0,1	0,1	0,1	0,1	0,2	0,1	0,1	0,1	0,1	0,1
Nonmetallic minerals	35,2	43,7	41,6	43,6	53,6	59,9	62,5	67,3	73,7	102,0	78,9	61,3
<b>Total</b>	<b>58,6</b>	<b>66,9</b>	<b>63,1</b>	<b>64,4</b>	<b>73,5</b>	<b>79,5</b>	<b>80,3</b>	<b>85,7</b>	<b>90,0</b>	<b>116,4</b>	<b>93,7</b>	<b>75,3</b>

\*Raw mining products  
a) 1,000 m<sup>3</sup> gas = 1 ton.

Table 2. Production of mineral resources (million tons)

methods (as shafts, deep drillings, tunnels and galleries); establishment and operation of pipelines conveying hydrocarbons; the utilization of geothermal energy with the exception of groundwaters; all facilities and equipments necessary for the above activities (mining railways, cableways, stringways, electric cables, explosives). Water, even groundwater, holding geothermal energy, works of water management in general, and manual gold-washing are out of the scope (Article 1).

In Hungary, the original owner of mineral resources is the state, according to the Civil Code (Act IV of 1959) under Article 96, "The ownership of land shall not extend to the "treasures of the earth", nor does it extend to natural resources"; and under Article 177: "Unless otherwise provided by law, the following shall remain under exclusive state ownership: a) the treasures of the earth, b) underground waters ..."

This is repeated by Article 3 of the Mining Act that mineral raw materials and

geothermal energy in their natural occurrence are the property of the state. As minerals are exploited they are transferred to the property of mining entrepreneurs. In Hungary this holds true for all mineral commodities. The owner is the State; it practices this right by delegation, licensing to local mining authorities (in the first instance) or to the Minister (in the case of concession contracts). Municipalities and local governments are involved in the licensing process as co-authorities.

Hungary does not have a definite national minerals policy, either in legal or other official format. The Mining Act cites mineral resources management under several articles (Art. 2 - among general aims of the act; Art. 20 - royalty payment exceptions; Art. 27 - criteria of technical operation plans; Art. 43 - competence of the Hungarian Office for Mining and Geology) and gives a definition under Article 49: "includes the activities, measures, production programmes, prospecting, exploration and working systems and methods, which serve the economical exploitation of mineral raw materials in such a way that they do not damage the parts of the occurrence not included in the mining activity, and protect them for the purpose of future exploitation; and enable at the same time the reduction of losses, as well as the exploitation of mineral resources so complete as technically feasible and as justified by the market conditions".

The Mining Act gives an authorization for the Minister, under Article 27, to issue detailed prescriptions on management of mineral resources in a decree. However, all attempts have failed to reach a general consensus on the working documents that have been prepared.

In practice, the major legal tool of minerals management is the concession procedure described under Articles 8-19. The state can plan and control mineral exploitation in the longer term by deciding whether to open certain areas for the exploitation of certain minerals in the form of announcing these for open concession tenders. Later, during the evaluation of bids, it is a concern how minerals management is proposed by the applying companies. However, due to the limited success of concession, in 1998 the country adopted simple licensing on a "first-come-first-served" basis.

Another tool for controlling mineral management is provided by Article 4 of the implementing Government Decree No. 203/1998. (XII. 19.) which prescribes obligations for paying extra mining royalty in cases where the mining operator produces

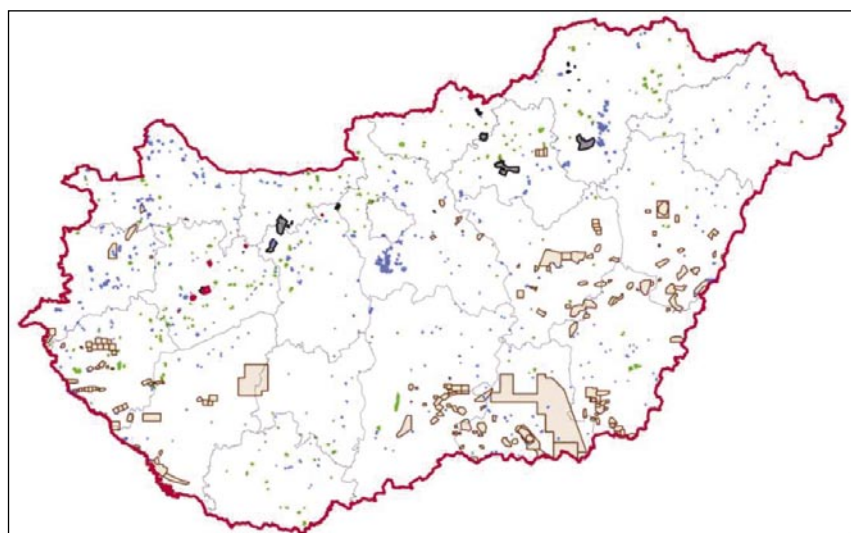


Figure 5. Mining plots (licensed exploitation areas) in Hungary, June 2009  
(Legend: brown: oil and gas, black: coal, red: ore, blue: aggregates, green: other)

more cut-off than licensed in the technical operation plan or causes unreasonable damage to the mineral reserve itself.

The National Mineral and Geothermal Energy Resource Inventory (and Balance) of Hungary is managed by the Minerals Inventory Department of the Hungarian Office for Mining and Geology and its predecessors since the 1950s, as defined in Articles 25, and 48 of the Mining Act. It is updated each year. The Inventory includes more than 2700 deposits and mines and contains quantitative data (resource, reserve, production, status of mine, etc.) and some qualitative data (type of mineral, main constituents, etc.). According to Article 25 of the Mining Act and Article 3 of the Government Decree No. 267/2206 (XII. 20.) of the Hungarian Office for Mining and Geology, the said office is the National Archive for all geological data. Data are to be submitted on a yearly basis. According to Annex 4 of the Mining Act, data to be submitted include primary (field) data, and processed and interpreted data as well as reports, maps, etc. Data can be delivered both in traditional (paper or printed) and in digital format.

Other terms of the concession contract/mining licence are confidential. Data provided by the concession holder/licensee are confidential for the whole duration of the concession contract/mining licence. Confidentiality concerns only new data obtained by the present concession holder/licensee or its legal predecessor. After the termination of the concession contract/mining licence, all data become public.

The Mining Act acknowledges three types of exploration. The first type is a preliminary surface survey (Article 4) which does not require a licence. The company has to have an agreement with the landowner of the area and to report the locality, duration, methodology, etc. to the mining and the geological authorities 30 days in advance. If the mining authority does not reply within 15 days, the works can start. This type of survey does not pose any exclusive rights for the operator concerning mineral exploitation.

The second type of exploration is defined by Articles 5-7 and 22-23. In areas which are opened for the mining of certain minerals, the mining authority grants exploration licences with the involvement of other co-authorities (*inter alia*, Environmental Inspectorate, local municipality). This licence gives an exclusive right to the entrepreneur to explore for the given mineral in the defined area and to initiate the establishment of a mining plot within

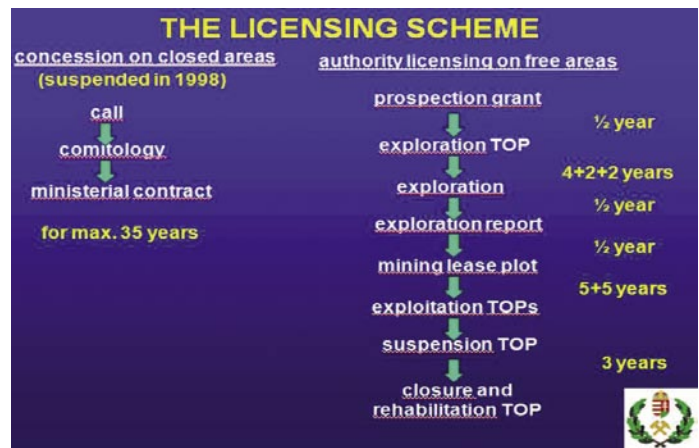


Figure 6. The licensing scheme in Hungary

a certain timeframe. In case of two or more applications for the same area and type of mineral, the order of submitting the documentation is decisive if the other requirements are fulfilled equally.

The third type is the concession (or leasing) as prescribed in Articles 8-19. In areas which are closed, the only way to have access to minerals is through the concession contract. The Minister may designate concession areas for which he/she announces an open tender. After evaluation of the bids by a ministerial panel, the winner and the Minister sign a concession contract in which they agree to a work programme and the guarantees of good performance. This contract gives exclusive rights to mineral exploitation for a longer term than a simple exploration licence but does not replace other licences which are prescribed e.g. establishing mining plot, submitting technical operation plans, etc.

Whether the right of exploration was granted by a licensing process or through a concession, the first obligatory step to the exploitation is the establishment of a mining plot, as defined by Article 26 of the Mining Act. The documentation to support the application is the final report of the geological exploration, which should prove the existence of economic mineral reserves

and that the planned mining activity is viable. The licence is issued by the mining authority, with the involvement of professional co-authorities (as listed above), the representative of the local government and the owners of the surface land.

In addition, in order to start the mining activity a technical operation plan (Art. 27) and construction licences (Art. 31) have to be approved by the mining authority based on the consent of other authorities. The Mining Act gives provisions for the duration of technical operation plans (TOP). In the case of underground mines, an accepted TOP is valid for two years, and for five years in case of open pits. However TOPs have to be revised annually and have to be submitted to the mining authority in case of modification (Fig. 6) (Art. 27).

The mining licence is transferable to another company, both in the case of concession contracts and where the licence is granted by the authorities. Whilst in the first case the consent of the Minister is required, in the latter case the consent of the mining authority is sufficient (Articles 18, 26). According to Government Decree No. 203/1998. (XII. 19.), on the implementation of the Mining Act an environmental licence based on environmental impact assessment is required before the



Figure 7. The organogram of the Hungarian Office for Mining and Geology

technical operation plan is submitted to the mining authority.

Mining companies have to pay mining royalty as defined by Article 20 of the Mining Act after exploited minerals and geothermal energy even if the activity is illegal or was licensed as water works (e.g. dredging), or the mineral is mined during the exploration, or extracted during the secondary use of waste rock heaps. The rate of the mining royalty is defined individually and can be a subject of negotiation in the case of concession contracts. In the case of exploitation licensed by the authorities, the rate of the royalty shall be the following, with regard to the value of the quantity of mineral raw material exploited:

- 12 % for oil and gas
- 5 % for non-metalliferous minerals mined in open-pits, with the exception of energy minerals
- 2 % for other solid minerals and geothermal energy
- 100 % for the quantities mined illegally.

The basis of the calculation of the mining

royalty is the market value of the unprocessed minerals leaving the mining works. The payment shall be done monthly in the case of hydrocarbons and quarterly for other minerals.

#### Competent regulatory authority

The Hungarian Office for Mining and Geology (Fig. 7) is the prime authority which supervises the mining industry. In 2006, the governing coalition brought the resolution on the merger of the Hungarian Geological Survey into the Mining Bureau of Hungary thus forming the Hungarian Office for Mining and Geology. Via the integration, an especially strong government regulatory agency came into force, that is the prime supervisor and licensing body of all geological and mining activities as well as the monopolistic host and supplier of geoinformation, including mineral resources and whose regulatory competence extends beyond the classic spheres of authority, such as:

- mineral exploration and exploitation, mining waste management

- technical safety of mines and workers health
  - geotechnics and specific constructions
  - national inventory of mineral resources
  - geospace management
- over to fields such as:
- gas pipelines and pressure equipments
  - explosives management
  - occupational issues
  - market surveillance
  - professional experts titles
  - geothermal energy, etc.

Moreover, the agency with its staff of 180 personnel is involved in numerous other licensing actions as a co-authority, e.g. environmental protection, water management, land-use planning, nuclear affairs and construction.

#### Bibliography

Hámor T. 2004: Sustainable mining in the European Union: The legislative aspect – Environmental Management, Vol. 33., pp. 252-261.

## News and Events 2010

### News from the UK

#### Record permeability in UK granite is good news for geothermal energy

Hopes have been raised for the viability of geothermal energy in the UK, after exploratory drilling in Weardale, County Durham, revealed record levels of permeability in granite. Whilst the results are promising for the search for low carbon energy resources, they may have less welcome implications for safe disposal of radioactive waste in deep repositories.

Scientists from Newcastle University were investigating potential sources of geothermal energy, which is becoming increasingly popular in the search for low-carbon energy resources. Granite can be particularly useful as it can be rich in radioactive elements that generate heat as they decay. The permeability of the rock is important, as heat is extracted by pumping 'working fluids' such as water into the rock and drawing it back up again.

'Hydrogeologists have traditionally viewed granite as poorly permeable, and this has led to a bit of a "counsel of despair" over the chances of finding decent permeability in granite' says Professor Paul Younger from the Sir Joseph Swan Institute for Energy Research at Newcastle University, who led the research, due to

be published on 19 February in the Quarterly Journal of Engineering Geology and Hydrogeology.

*'We decided to challenge that pessimistic assumption, to see if we could find permeability at depth. And, eureka, we found it: as far as we can tell, the highest permeability ever recorded for a granite anywhere in the world'.*

The results were obtained by pumping naturally-occurring saline groundwater from an exploratory borehole and monitoring the change in water levels. A permeability of almost 200 darcies - a unit of permeability - was recorded. This is far higher than most prolific oil and gas reservoirs, and on a par with water wells in the Chalk that supplies London. The scientists believe the find is not unique to the Weardale granite, as there are similar granites worldwide which may display equally high levels of permeability.

*'This is great news for geothermal energy because high natural permeability means that time and money won't need to be sunk into artificially developing permeability by means of hydraulic stimulation – a costly and uncertain business',* says Professor Younger.

However, the research also suggests that caution needs to be taken when selecting sites for nuclear waste disposal. Granite is

a popular rock in which to site repositories, and the higher than expected permeability of the rock suggests that safety estimates previously made may have to be reconsidered. Although repositories will obviously be located in areas where there is no large-scale faulting, more care will have to be taken to ensure that excavations will not enter ground that is more permeable than expected.

*'The discovery that granite can in places be as permeable as the Chalk Aquifer is a little disquieting for repository construction in granite',* says Professor Younger.

*'If these structures are avoided, it ought to be possible to construct successful repositories in granite; however, it will require more detailed geological mapping than might otherwise have been undertaken – which is not entirely bad news for us geologists of course!'*

Younger, P. L., Manning, D. A. C. 2010. Hyper-permeable granite: lessons from test-pumping in the Eastgate Geothermal Borehole, Weardale, UK. *Quarterly Journal of Engineering Geology and Hydrogeology*, 43, 1-7.

Sarah Day  
*Earth Science Communicator, Geol. Soc.*

**News from GEOTRAINET (Geo-Education for a sustainable geothermal heating and cooling market). Intelligent Energy Europe Project: IEE/07/581/S12.499061**

vided a very rich forum for the GSHP sector. The feedback of the participants in the courses has allowed refinement and improvement of the course programmes.



GEOTRAINET is a European initiative supported by European Commission's "Intelligent Energy". As was presented in the European Geologists n° 26 and 28 the objective of this project is to develop European Education programme as an important step towards the certification of geothermal installations. From the different groups of professionals involved in a GSHP, the GEOTRAINET project is focused on two target groups: designers (those who carry out feasibility and design studies) and drillers (who make the boreholes and insert the tubes).

The duration of the project is 30 months from 1 September 2008.

It will result in an education programme, didactic materials, training courses and development of an e-learning platform. Training structures in eight EU countries will be established for professionals of the geothermal sector. A programme and all registration details for all the courses is available on the Geotraining webpage: [www.geotraining.eu](http://www.geotraining.eu)

So far, we have conducted five training courses of the eight courses under his project.

The main preliminary lessons learnt from this first half part of the project are:

The group of experts was drawn from professionals with the full range of qualifications and experience relevant to the sector of GSHP. The expert platforms created provided a very complete vision of the curricula necessary for designers and drillers. By working together, experts from different countries have provided a very rich exchange of practice between the countries. Similarly, the involvement of participants from different countries and with a range of experience and qualifications has pro-

A strong demand exists from the GSHP market for training activities for designers and for drillers. The two courses held during this period could not accommodate the large number of applications who wished to attend. The demand for certification also appears to be very high, especially in the countries with less developed GSHP markets.

The demand for courses in European countries is also high: there have been more countries expressing interest in organizing courses than the eight countries planned during the GEOTRAINET project period. Based on the impact of the European Directive on promotion of the use of energy from renewable sources, there is a very high demand to provide training courses in all EU countries. The first and third courses of GEOTRAINET were oriented to prepare trainers in Europe and they have been a success. The work on the Education structure in Europe carried out in the WP5 of this project will be an important reference for this demand.

*Dr. Isabel Fernandez Fuentes, EFG Office Director*

**News from Euro-Ages (European Accredited Geological Study Programmes).**

**Euro-Ages Final Conference, 22 October 2010 at the Hotel Ében, 15-17 Nagy Lajos király str., 1148 Budapest, Hungary. [www.euro-ages.eu](http://www.euro-ages.eu).**

Over the past year, the partners in the EURO-AGES project have worked towards developing a European qualification framework for geology, in the first and second cycles defined by the Bologna process, based on learning outcomes rather than input factors

(course curricula). The objectives of the work are to increase transparency of Earth Sciences qualifications across Europe and therefore to facilitate improved academic and professional mobility across Europe. At the same time, the project aims to encourage students and graduates in the field of geology, as well as professional geologists, to pursue Life Long Learning. The project objectives are being achieved through a structured exchange of best practices, expertise and country characteristics of professional practices in geology in the different European countries. The project has identified important reference points for quality assurance and related recognition issues focused on learning outcomes.

The project is supported by the European Commission, DG Education and Culture.

The final conference will be held on the occasion of the conclusion of the Euro-Ages project in Budapest, Hungary on 22 October 2010.

During the plenary session on the first day, participants will be briefly introduced to the Euro-Ages Framework Standards and Accreditation Criteria that have been elaborated and tested by the Project Consortium.

The nature and objectives of a future Euro-Ages Quality Network will be presented. The latter is envisaged to ensure the sustainability of the Euro-Ages project results through the award of a Euro-Ages Quality Label for successfully evaluated first and second cycle programmes in the field of geology. Aspects of field-specific quality assurance will be discussed by a panel drawn from academics and representatives of industry.

The conference programme and registration form are available on the Euro-Ages website: <http://www.euro-ages.eu>

**News from GsF**

**The Haiti Disaster Two Water Supply Projects to start basic reconstruction**

During January and part of February 2010, the whole World followed with great concern the Haiti Disaster and many have taken direct part in humanitarian aid.

Most Countries have been represented on site, with volunteer organizations and also Army personnel.

But, at present there is a great "media



silence"! No more television, no more articles/interviews in newspapers and magazines!!

Most of the problems have not yet been solved and the so called "reconstruction" will surely take more than 10 years.

International Aid has reached many areas of the destroyed country, but many poor villages and communities are still without homes and many are almost abandoned.

Between February and March 2010, a preliminary mission was put in place by GsF - Italia - Onlus, who were asked to intervene, by the local ODEMIHF NGO, a non-profit organization helping Haitian people, both in Haiti and the Dominican Republic.

The huge and as yet unsolved problem of water supply and water distribution has begun to be tackled. Two water projects have been discussed with the local authorities and technicians; they both concern very poor communities in two different areas:

**Tabarre area**

Water supply by means of five drilled wells, equipped with solar pumps, suspended water storage tanks and water distribution systems to users, located in the areas of five poor communities in Tabarre Municipality (Port-au-Prince).

**Leogane area**

Water supply by means of two drilled wells, equipped with solar pumps, suspended water storage tanks and water distribution systems to users: Commune of Ca-Ira and Commune of Guerin, Municipality of Leogane.

Tabarre is an independent Municipality on the outskirts of the capital Port-au-Prince. Drinking water availability is the most urgent problem. The local Partner

ODEMIHF NGO has been asked by the Tabarre Mayor for water supply interventions in some areas, where very poor communities are located and where refugees from completely destroyed areas are continuously arriving.

Five Tabarre areas have been selected, where living conditions are really very miserable and where water is almost completely lacking.

All the Communities in the selected areas have been fully informed about the possible project, are ready to set up appropriate "Water Committees" and are prepared to provide assistance and in-kind contribution to achieve the best results for the different types of work (drilling, pumping tests, submersible pump and solar panels installation, construction of water tanks and water distribution systems). A total population of nearly 30,000 will benefit from the planned project.

The estimated total costs of the Tabarre Project are €254,600. With the local in-kind contribution of around €34,600, the total amount to be financed is of the order of €220,000.

In the Leogane area, two interventions are planned in two different very poor villages: Ca-Ira and Guerin.

In Ca-Ira (about 2,000 people are living in very poor conditions), an orphanage, where 90 little boys and girls were housed, has been completely destroyed and seven of the children were killed.

The two existing shallow-water wells, used by the inhabitants, have been destroyed. The only existing water resource is at present a very shallow hand-dug well, where water is collected with buckets; but the water level dries up quickly and it takes two - three hours before the level is restored and water can again be collected!

A drilled water well is foreseen here (40/50 m deep) with solar panels and solar pump. A water tank and simple water distribution system by means of 4/5 public fountains will complete the project.

In Guerin village, a total population of around 4,000-4,500 is scattered around a large area, living in huts and small houses. No drinking water is available here. People have to walk, or ride bicycles, for 1.5 km. to get to a Shell Petrol Station, where water can be distributed.

The aim of the project is to drill a water well in the village centre (which has been chosen because of favourable hydrogeological conditions), provide the well with a solar system pump, build a

*CA-IRA Village: people queueing for water in the only existing shallow well of the village*



*An existing water well in one of the communities included in the project, with hand pump, now completely dry, closed and out of use*

suspended water tank (capacity around 20 m<sup>3</sup> ) and install a gravity water distribution system by means of public fountains (8/10), located in convenient places for the beneficiaries use.

The estimated total cost of the Leogane area project is €110,600. With the local in-kind contribution estimated at €20,600, the total amount to be financed is €90,000.

The future sustainability of both projects (Tabarre and Leogane), once they have been handed to the beneficiaries, will be absolutely guaranteed by the continuous presence on site of GsF local Partner ODEMIHF NGO, by the support of Local Authorities, who greatly appreciate the aim of both projects, and the continuous work and assistance of the different "Water Committees", who will follow up on all project installations.

Locally, resident Friends have also assured their assistance during the different phases of the works and the follow up of both projects.

In order to be completed, the above projects need contributions. For more information:

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## Cyprus

Book review by Howard Armstrong<sup>1</sup>

Classic Geology in Europe 7. Cyprus  
by Stephen Edwards, Karen Hudson-Edwards, Joe Cann, John Malpas, Costas Xenophontos

Published by: Terra Publishing [www.terrapublishing.net]

ISBN-13: 978-1-903544-15-0

Date: January 2010, 288 pages

Price: £17.95 (stg), paperback



Cyprus has long been recognized as an outstanding place to take geological fieldtrips. It boasts the world's most complete and intensively researched ophiolite, a varied Cenozoic sedimentary cover succession and hosts a wealth of mineral deposits. These, added to the good weather, abundance of cheap out of season holiday packages, good maps and local coach drivers who know the localities, have resulted in Cyprus becoming a mecca for undergraduate fieldtrips. This book is aimed directly at the undergraduate market.

The book is well organized and includes what can now be regarded as classic localities, derived mainly from the "Troodos 87, Ophiolites and Oceanic Lithosphere conference field excursion." The sections on water, resources and wastes provide useful background and new localities for environmental geologists, and have not been covered in such detail in previous guides. The book is well written and has a crisp and easy to read style, smoothly integrating geology, archaeology and cultural information. Directions to localities are easy to follow and access and parking information is provided. The GPS coordinates will prove useful in locating many of the stops since new tracks can appear

almost overnight in Cyprus. Figures are clear and maps are generally at a regional scale. Photographs are a mix of landscape views and outcrop details and whilst these are helpful, the quality of the plates in my copy was poor, a likely consequence of transcribing colour pictures to black and white.

I like the structure of this guide. Following a general introduction, successive chapters describe the geology and key localities for each part of the geological section: the mantle sequence, sheeted dykes and volcanic sequence, faulting, the Mamonia Terrane, sedimentary cover succession, resources, wastes and hazards. The final chapter suggests a number of excursions manageable in a day from most of the major tourist resorts. Each chapter gives both geological background, detailed descriptions of the outcrops, interpretations and notes on nearby sites of archaeological and cultural interest. A glossary of terms provides useful background and there is a rather limited bibliography.

Not surprisingly, there is a strong bias towards the "hard rock geology" of the Troodos Massif, exhibited not only in the number of localities described, but also in the depth of treatment. The geology of the Troodos Massif is well understood and is founded on a mature body of research. This is not the case for the other areas of the geology, the details of which are buried in the primary scientific literature and PhD theses, and here lie the weaknesses of an otherwise excellent guide. In keeping with the modern approach to teaching, there is an underlying theme of geological processes that, unfortunately, breaks down in the sections on sediments. Alternative, geological interpretations are glossed over in favour of those published by the authors. For example, whilst the Mamonia Terrane is structurally complex,

it does contain a coherent stratigraphy and when originally mapped was interpreted as part of a major transpressional strike-slip system. This model is ignored in favour of subduction and accretion published by Malpas and Xenophontos. The upper part of the Neogene succession warrants only a superficial treatment yet is much more lithologically varied and instructive of the regional geology than the underlying Lefkara and parts of the Pakhna formations. Particularly, the Pleistocene Gilbert-style fan-delta and raised beach deposits on the coast near Pissouri village figured elsewhere as world class examples, and the Plio-Pleistocene fan-delta to alluvial fan succession exposed to the east of Limassol between Choroikoitia village and Vasilico on the coast. There is little detailed sedimentology, facies characterization and the facies interpretations are rather basic, following the regional work published by Alistair Robertson and his students up to the 1990s. The results from the offshore ODP Leg 160 could have also been included as background.

Despite these, this is a valuable new guide to the geology of Cyprus. It will be bought by fieldtrip leaders, researchers, students and many informed amateurs who wish to study the geology of Cyprus for the first time. This field guide is good value for money and will become a best seller. To do justice to all the excursions would take 10 to 14 days, ideal for the typical undergraduate field trip, and I suspect the book will prompt significant rewriting of existing undergraduate field guides. Hopefully this new guide will also encourage others to explore the spectacular geology Cyprus has to offer.

<sup>1</sup>Dr Howard Armstrong is Senior Lecturer in Earth Sciences at the University of Durham and Secretary of the Palaeontological Association



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Deadline for submission 30 March and 30 September.

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## European Federation of Geologists (EFG)

The European Federation of Geologists was established in Paris in 1980 during the 26th International Congress of Geology. In the same year the Statutes were presented to the European Economic Community in Brussels.

The Council of the EFG is composed of the representatives of the national associations of geologists of Belgium-Luxembourg (UBLG), Czech Republic (CAEG), Finland (YKL), France (UFG), Germany (BDG), Hungary (MFT), Iceland (GSI), Ireland (IGI), Italy (CNG and ANGI), Netherlands (KNGMG), Poland (PTG), Portugal (APG), Slovakia (SGS), Slovenia (SGD), Spain (ICOG), Sweden (N), Switzerland (CHGEOL), United Kingdom (GS), whilst the American Institute of Professional Geologists (AIPG) is an Associate Member. The EFG currently represents about 40,000 geologists across Europe.

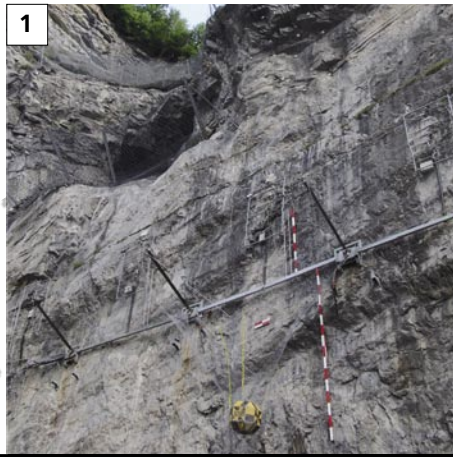
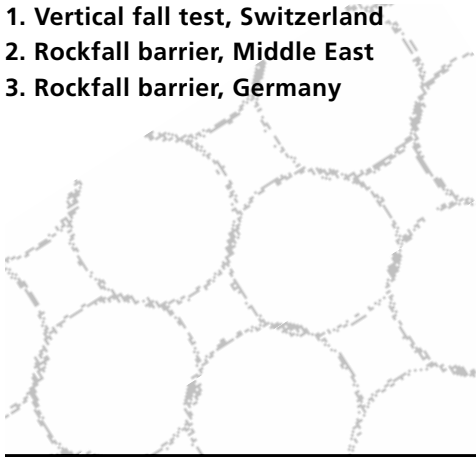
### Mission

To promote the profession and practice of geology and its relevance.

### Objectives

1. To promote and facilitate the establishment and implementation of national arrangements for recognizing geologists who, through academic training and appropriate periods of relevant experience in the profession and practice of geology, are qualified to be designated as EurGeol.
2. To organize meetings and conferences to discuss issues related to the profession and practice of geology.
3. To co-ordinate the activities of member national organisations in preparing briefing papers on geological issues and presenting these to European bodies, national governments and other relevant organisations.
4. To maintain contact with the European Commission and respond in timely manner to requests for information.
5. To communicate, through meetings and other means, the relevance of geology to the resolution of issues of concern to society.
6. To promote the establishment of best practice for training of geologists.
7. To safeguard and promote the present and future interests of the geological profession in Europe, including:
  - to guarantee the free movement of geologists in Europe, with the mutual recognition of their academic and professional qualifications by the adoption of the title of European Geologist (EurGeol.).
  - to promote the harmonisation of education and training.
  - to define and protect the title of geologist and related professional titles.
  - to promote the code of professional ethics of the EFG.
  - to provide advice and assistance to constituent member National Associations.

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2. Rockfall barrier, Middle East
3. Rockfall barrier, Germany



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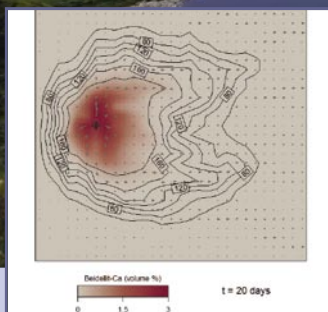
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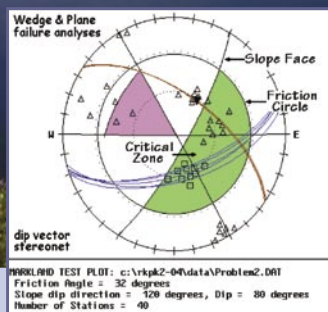
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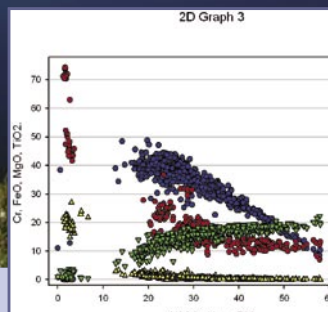
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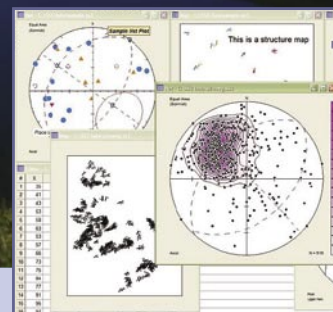
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