International Geothermal Days POLAND 2004. Zakopane, September 13-17, 2004
International Workshop on Geothermal Energy Resources in Central and Eastern European Countries: State-of-the-Art and Possibilities for Development

INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy
POLISH GEOTHERMAL ASSOCIATION
International Geothermal Days
POLAND 2004
EUROPEAN BRANCH
Under the auspice of Division of Earth Sciences

6. GEOTHERMAL RESOURCES AND EXPERIENCE IN APPLICATION IN SLOVENIA

Peter Kralj

Gejzir Consulting
SI-1113 Ljubljana, Turnerjeva 17, Slovenia
Tel.: +386 40 20 36 05, Fax: +386 1 56 56 494, e-mail: peter.kralj@siol.net

Abstract

Exploitation of thermal waters has a long tradition on the territory of Slovenia. Archeological findings indicate that Old Romans used thermal water for bathing and swimming, and very possibly, the oldest populations, too. In Slovenia, thermal water was captured for the first time by welling in 1973.

Slovenia has 60 locations, where thermal water is captured having total installed capacity (T_0= 25ºC) of thermal power 118 MW_t. 41 MW_t or 34,7 % of the total installed power in use.

The present estimations indicate that Slovenia already disposes of 50.000 PJ of theoretical heat resources, of which about 12.000 PJ are exploitable and occur in geothermal aquifers only.

1. INTRODUCTION

Slovenia is a young Central European coun-try with Italy, Austria, Hungary and Croatia as bordering countries. It encompasses an area of 20.256 sq. km and has 1.966.000 inhabitants. On the territory of Slovenia, four main geographic units are encountered: the Mediterranean in the southwest, the Alps in the north, the Dinarides in the south and the Pannonian lowland in the east. The average annual temperature range is between 5,7 ºC and 13,5 ºC; the minimum and maximum temperatures are –31,0 ºC and +35,6 ºC respectively. These variations are mainly due to climatic changes and are most extreme in NE Slovenia where the continental climate predominates. In the Alpine regions and the Mediterranean coast the temperature differences are minor.

Geology and tectonic setting of Slovenia are rather complex. The territory is a juncture area where three great tectonic units meet: the Alps, the Dinarides and the Pannonian basin. Their present situation is mainly related to Late Cretaceous subduction and collision of the African lithospheric plate beneath Europe, accompanied by extensive folding and thrusting. Deep-seated faults - grabens developed, enabling deep circu-lation of waters.

For heat convection towards the Earth's surface the lithospheres thickness is of great importance. In Slovenia the thickness decreases from the West, where it amounts to approx. 50 km. it gets thinner to the East where it is appreciably 30 km thick.

Waters suitable for heat extraction are encountered in Slovenia in both, fractured aquifers (mainly carbonate rocks, dolomites and limestones, also to less extent crystalline rocks, sandstones or dolomitied tuffs), as well as in aquifers with intergranular porosity (sands, gravels). Fractured aquifers are common in the rocks older than Tertiary, mostly of Mesozoic age. In Neogene basins, where sediments are only consolidated partially intergranular sandy aquifers which can be developed at depths exceeding to 1.000 m.

2. LEGAL ASPECTS

Covering legislation on environmental protection adopted in 1993, it’s the first law of the Republic of Slovenia treating concessions for natural goods. Main operative tasks of the environmental protection includes step-by-step transition to the use of renewable resources, prevention and diminishing of environmental risks along with the development and use of suitable environment-friendly technologies.

The field of exploration and exploitation of geothermal energy in Slovenia is encompassed in two legislation acts the Law on Waters and the Law on Mining. They are both based on concession principles, as thermal waters and geothermal energy are both natural and common (national) goods. A concession is given by the Government of the Republic of Slovenia, or the responsible Ministry, respectively at the present, the Ministry of Environment, Space Planning and Energy. A concession is given for a limited and specified time.

The Law on Waters regulates the use of thermal waters in a case, that the user (concessionar) intends to utilize thermal water itself, i.e. in swimming pools, for aquacultures, and in that manner causing water contamination or deterioration (i.e. by adding chemicals etc.). In that case, it is required to clean the used thermal water to such an extent, that it can be disposed in the sewage system or the environment. Eventual impact to the environment should be in accordance with the legislation. Concession duties are higher according to this act that the Law on Mining, but the concessionar does not need to construct rein-jection well and reinjection pipeline. The concession is given by the Ministry of Environment, Space Planning and Energy on the basis of tenders. The highest bidder fulfilling the following requirements is selected:

- The bidder must dispose with the premises (ownership or long-term rent which is longer than the given concession time),
- The bidder who performed previous explo-ration activities of this water resource, and
- The bidder who is initiator of a certain con-cession tender

The Law on Mining deals with the field of geothermal energy use in the case, when the user (concessionar) only takes away the water's thermal energy, while the water itself remains intact, or the user only extracts some components or minerals from the water. Concession duties are lower in that case, but the water must reinject intact water into the primary aquifer. The concession is given by the Agency of the republic of Slovenia for Energy at the Ministry of Environment, Space Planning and En-ergy of the Republic of Slovenia on the basis of ten-ders. The bidder must fulfill the same requirements as specified by the Law on Waters, but the procedure of gathering of preliminary permissions is more compli-cated. Prior to the tender appearance, the initiator of a tender must obtain a permission of the local govern-ment unit to perform and then accomplish prelimi-nary research. Based on the results obtained, the initiator must submit a proposal for a tender for a re-search concession to the Agency of the Republic of Slovenia for Energy at the Ministry of Environment, Space Planning and Energy. The Agency carries out the tender, and selects the concessionaire for research. Based on the research results, the owner of a certain re-search concession makes a proposal for a tender for concession obtainment at the same Agency.

3. HYDROGEOTHERMAL SYSTEMS

Hydrothermal systems in Slovenia encompass three main types of aquifers:

a). Unconsolidated sands and gravelly sands of the Neogene Mura basin (NE Slovenia) with pri-mary intergranular porosity.

b.) Fractured Mesozoic carbonate rocks, occur-ring in the basement of the Neogene basins. Lo-cally, dolomitised andesitic tuffs of the Oligocene age or weathered metamorphic crystalline rocks can also appear as thermal aquifers.

c.) Fractured and locally karstified Mesozoic carbonate rocks of the Julian Alps and Dinarides, commonly overlain by Paleogene flysch deposits.

4. TEMPERATURE FIELD

The geological structures on the territory of Slovenia are characterized by the tendency of in-crease in temperature from south-west to north-east. The highest measured temperatures are known in the Mura basin and in the western parts of the Kshko basin. Besides the mentioned areas there are also other promising areas like Rogatec, the Celje basin and Lashko, Zagorje and Senovo synclines, the Ljubljana basin and the Mediterra-nean coast (Primorje). At depths of 1.000 m two anomalies stand out: In the Kshko basin at the town of Chatez (>50 ºC) and in the Mura basin (>70 ºC). Temperature gradients range is from less than 10mK/m to over 70 mK/m. The Earth's thermal field on the territory of Slovenia is shown in the chart of temperature distribution at the depth of 1.000 m below the surface (Fig.1).

5. GEOTHERMAL RESOURCES

According to our agreement all waters are called thermal of which temperature is 5ºC higher than the average annual temperature on the site of the spring.

Thermal waters can be captured in almost all places where underground aquifers occur. With the exception of the Mura basin and the Rogatec area, where thermal waters are also mineralized.

Slovenia has and 60 locations (Table 1, 2), where thermal water is captured (28 natural springs) having a total installed capacity (T_0=25ºC) of thermal power of 118 MWt. 41 MWt or 34,7 % of the total installed power is in use.

The term "shallow geothermal exploitation" comprises the use of the heat of the Earth's crust at shallow depths. The exploitation is performed thro-ugh shallow, subsurface aquifers or by gauges. Recent use in Slovenia is thoroughly based on gauge sys-tems water-water, which use the heat from shallow aquifers mainly for heating of one-family dwellings. The number of such users is estimated to more than 500 and the energy supplied to approx. 14 GWht of heat.

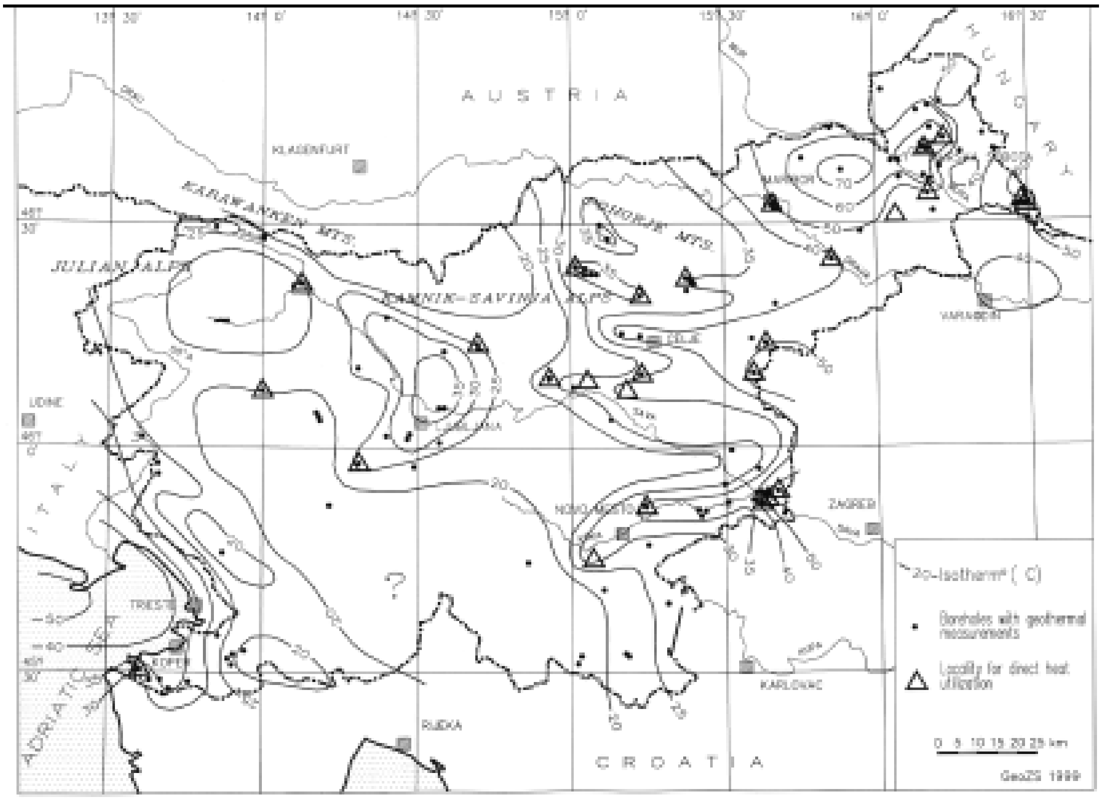

Fig. 1. The profile of formation temperatures at a depth of 1000

Table 1: Natural thermal springs

No	Name of location	Altitude (m)	T_w (ºC)	Yield (l/s)	Thermal power T_0=25ºC (kW_t)
1	Zatolmin	250	22	2-3	0
2	Bled (+ Staretov vodnjak)	482	19-22	5	0
3	Hotavlje (ob Kopacnici)	500	20-21	1-5	0
4	Zgornja Besnica	410	18	1-2	0
5	Vrhnika (Furlanove toplice)	295	21-22	5	0
6	Spodnje Pirni_e	309	18-23	3	0
7	Vaseno	435	22	1,5-2,5	0
8	Medija	320	21	6	0
9	Zagorje – Toplice	255	33	48	1.607
10	Rimske Toplice	247	36-41	6	339
11	Topol_ica	374	28-31	28-30	546
12	Dobrna	367	35	8	335
13	Frankolovo	310	14-21	10-50	0
14	Zbelovo (Polj_ane)	280	18,7	5	0
15	Toplicnik (Smarjeske Toplice)	166	16-18	230	0
16	Kleve_	175	22-25	6-15	0
17	Smarjeta	164	33,8	20	0
18	Otocec na Krki	197	19	<1	0
19	Dolenjske Toplice	180	36-38	12-13	628
20	Malence pri Kostanjevici	152	17-20	<3	0
21	Toplicnik pri Kostanjevici	152	14-23	7	0
22	Kostanjevica	155	15-23	20	0
23	Bu_e_a vas	155	20-28	10-12	0

24	Peri__e pri _ate_u	150	32	2	59
25	Benedikt	243	20	0,5	0
26	Radenci	199	16,6	1,9	0
27	Podpe_ pri Ljubljani	290	12-15	0,5-3	0
28	Preserje pri Ljubljani	289	14-15	5-8	0
	Total:			482	3.514

Table 2: Thermal boreholes

No	Name of location	Altitude (m)	T_w (ºC)	Yield (l/s)	Thermal power T_0=25ºC (kW_t)
29	Zre_e (B-1,2,3)	350-387	21-32	56	352
30	Moravske Toplice (Mt-1,4,5,6,7)	190	60-70	40	6.698
31	Lendava	160	46-72	13-52	4.626
32	Banovci (Ve-1,2,3)	181	58-61	22,5	3.249
33	Murska Sobota (SOB-1,2)	190	50	50	5.233
34	Radenci (T-4/87, T-5/04)	210	41 - 52	4,2	419
35	Moravci v Slov. goricah (MO-1)	220	42	6	427
36	Ptuj (P-1,2)	220	29-34,5	18	509
37	Maribor (MB-1,2,3,4,5,6)	257	43	9	678
38	Roga_ka Slatina	220	29-59	11,6	923
39	Dobrna (V-7,8)	365	36	13	599
40	Podlog pri _alcu (P-1)	266	20	4,5	0
41	La_ko (V-5, R-1, K-2)	220	30-35,5	55	1.784
42	Pod_etrtek (V-1,3,4)	196	33-43	33	5.249
43	Topol__ica	375	29-32	40	921
44	Laj_e	389	48	27	2.600
45	Rimske Toplice	220	38	50-60	2.993
46	Medijske Toplice (V-1,2,3)	310	23,5-25	50	0
47	Chatez (K-1,2,3, V-3,15, L-1)	140	53-62,5	180	24.677
48	Dobova (AFP-1)	138	62,5	15	2.355
49	Kostanjevica (SI-1)	154	35,5	45	1.978
50	_marje_ke Toplice (V-1-11)	170	32	40	1.172
51	Dolenjske Toplice	180	30-38	25	942
52	Vaseno (V-1-16)	450	22-30	21	88
53	Bled (T-8,9)	490	19-22	25-30	0
54	Ljubljana (TB-3)	292	23	50	0
55	Furlanove Toplice	292	21,5	20	0
56	Cerkno (Ce-2,3)	325	30-40	61	2.553
57	Shempeter (_e-1)	74	22	2	0
58	Portoro_ (LU-1, Pal-1)	1	23-24	41	0
59	*Dobrovnik (Do-1)	174	45	6	502

6. EXPERIENCE IN APPLICATION

In the last decade (since 1994), six large geothermal projects were planned in Slovenia. With an exception of the project in Murska Sobota, none of them is operating yet, and four of them were abandoned.

6.1 Ljutomer Geothermal Project

Investor: Municipality of Ljutomer
Executive institutions: Geological Survey of Slovenia
IBE CONSULTERS, Ljubljana
Geotherma, Paris
Utilization purpose: Electricity production
Direct use
Balneology
Investment cost: 10.641.000,00 €
Simple Pay Back: 6 years
State-of-the art: Inactive since 1996

6.2 Geothermal Pilot Project Murska Sobota

Investor: City Council of Murska Sobota
Executive institutions: Geological Survey of Slovenia
IBE CONSULTERS, Ljubljana
Geoproduction consultants, Paris
VIRKIR-ORKINT Consulting group Ltd., Reykjavik
Utilization purpose: Direct use
Balneology
Investment cost: 10.730.000,00 €
Simple Pay Back: 7,4 years
State-of-the-art: Inactive since 1996, two geothermal wells operate - SOB–1/88 and SOB–2/89, which were constructed in the framework of feasibility study.

6.3 Bukovnica Health Resort

Investor: Police Syndicate of Slovenia
Executive institutions: Geological Survey of Slovenia
Biro 71 d.o.o., Ljubljana
Utilization purpose: Balneology
Direct use
Investment cost: 180.000.000,00 €
Simple Pay Back:
State-of-the-art: Inactive since 1998

6.4 Integrated use of Geothermal Energy for sustainable Development

Investor: PETROL d.d.
Executive institutions: Nafta Lendava
Geological Survey of Slovenia
RRA Mura, Murska Sobota
NITG-TNO Delft
Gaudriot Geotherma SA, Paris
Frauenhofer Institut, Karlsruhe
Utilzation purpose: Electricity production
Direct use
Cooling
Aquacultures
Balneology
Investment cost: 30.712.000,00 €
Simple Pay Back: 6,8 years
State-of-the-art: Closed in the year 2000

6.5 Geothermal Project Tolmin

Investor: GEJZIR CONSULTING
Executive institutions: Gejzir d.o.o., Ljubljana
IBE Consulting Engineers, Ljubljana
Geoproduction consultants, Paris
Geoteam, Gleisdorf
Poso_ki razvojni center, Kobarid
Utilization purpose: Electricity production
Direct use
Balneology
Investment cost: 91.980.000,00 €
Simple Pay Back: 6-10 years
State-of-the-art: Looking for Investors

6.6 Geothermal Project Benedikt

Investor: Municipality of Benedikt
Executive institutions: Gejzir d.o.o., Ljubljana
IBE Consulting Engineers, Ljubljana
Utilisation purpose: Electricity production
Direct use
Investment cost: 11.830.000,00 €
Simple Pay Back: 5,5 years
State-of-the-art: Started in the year 2003

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