Geothermal anomaly at Benedikt, Slovenia, due to strong convective component

The Benediška slatina, Cafova or Capfova slatina, named also Benediški vrelci wells, are natural springs of mineral water which were first tapped in 1932. The water was used for drinking water and mixing with wine. A well BS-2 was drilled to the metamorphic basement rocks at depth of 788 m in 1976. Later, large outbursts of CO2 gas caused the ground to collapse and the formation of a deep depression filled with water. The area was remediated in 1997 when three shallow wells were drilled: Helena (10 m in depth), Pavla (30 m in depth), and Ana (102 m in depth). This mineral water is young and of the Ca-Mg-HCO3 water type, and its mineralisation and temperature rise with depth. The springs can be visited along Čolnikova učna pot (Čolnik interpretative trail). In 2004, the deepest well Be-2 was drilled, producing thermal water of almost 80 °C (Fig. 1).

Fig. 1. Left: Cooling pool at the wellhead of Be-2 (see it right of the wooden house) where pulses due to degassing are evident. Right: Thermomineral water has high scaling potential and even though an inhibitor was injected in the well there was lot of carbonate scaling in the pipes.

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Anomalies

The deepest well Be-2 was drilled in the center of the small town of Benedikt in 2004. It penetrated through fissured Paleozoic metamorphic rocks of mostly mica schist with dolomite marble in depths between 760 and 1,857 m (final depth). This well produced one of Slovenia's hottest thermal waters between 2004 and 2015 when it was active. The temperature reached up to 75 °C at the wellhead and water was used to heat the school's gym in colder periods of the year by plate heat exchangers. The well was shut due to environmental and economical reasons but if it would be exploited as a geothermal doublet (a pair of production and reinjection wells) it would have the highest geothermal potential for exploitation in Slovenia at the moment.

The temperature in Be-2 well at 1,000 m was as high as 80 °C but did not continue to rise further, reaching only 81.4 °C at 1,800 m. The well penetrated a geothermal convection cell within the Raba Fault Zone. This is a vertically permeable area through which heated groundwater can rapidly circulate. A similar phenomenon is also known in Čatež in the Posavska region.

Data

The convective component of heat-flow density (HFD) can be determined in few different ways, here we mention two: (a) with a Peclet number analysis and (b) in a visual manner, that is in a way where a deeper geotherm is drawn so that the convective part is not considered, but only the conductive component down to a deeper geological section. The convection share in the T-z profiles (thermograms) of the boreholes in NE and E Slovenia was determined in a visual manner with a help of calculated deeper temperatures in conductive regime. With our approach of (a) or (b) we may conclude that the HFD values in NE Slovenia are in a rough agreement with the HFD values for the Pannonian Basin in general where at the Mohorovičić (Moho) boundary of the Pannonian Basin, the heat-flow attains 20-30 mW/m2 in Hungary as basal heat flow, for example.

A strong geothermal anomaly at Benedikt can be an example of determination of the convective heat flow density (HFD) component:

For the first deep borehole at Benedikt, a geothermal borehole BS-2/76, an attempt was made to distinguish the HFDconvective from the HFDmeasured. At first, temperature measurements in this borehole have been analysed. Thermal conductivity has been measured on two cores of metamorphic rocks from this borehole and on five rock samples of Miocene age from the nearby surface which easily correspond to the borehole's Miocene section. Thus, after some corrections, this surface HFD value is obtained as q = 145 ± 9 mW/m2.

We consider that the thermal anomaly indicated by the increased HFD at this locality (and well above the average of 69 mW/m2 for continents) is partly related to the regionally elevated heat-flow of the Pannonian Basin due to the thinned Earth's crust. About half of the cause for such elevated q is due to the deep fracture zone with convection, which is confirmed by the warm spring at Benedikt. With a help of the later drilled deeper geothermal production

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borehole Be-2/04 the conductive HFD component has been predicted to be ca q_{cond} = 103 mW/m^2. The measured HFD was 145 mW/m^2, therefore the convective HFD component is at least 42 mW/m^2.

From the measured temperatures in several attempts and different manner in the Be-2/04 borehole it has been predicted that formation temperature at 2000 m depth in this borehole could reach ca 84 °C, and that the *convection cell could expand from some 800 m down to depth of ca 2000 m*.

While the temperature gradient in the Tertiary section reaches 82 °C/km in the BS-2/76 borehole, it is 85 °C/km in Be-2/04 borehole (Fig. 2). No thermal conductivity values are available from the latter (there has been no coring of rock samples). However, the HFD (q) calculation was attempted, but without Peclet analysis, just using thermal conductivity data from the borehole BS-2/76 and mean temperature gradient grad T=0.085 K/m for the entire Tertiary section in the Be-2/04 borehole; the q calculated is 216 mW/m^2 which can be considered very roughly as q1 (therefore as surface HFD), and the convective component for this borehole is then ca 113 mW/m^2.

Regarding the origin and chemical composition of this thermomineral water, the latter is known (Kralj et al. 2009, SzÖcs et al. 2013): this thermomineral water was recharged as meteoric water in the Pleistocene epoch. It is of the Na-HCO_3 water type, high mineralised (7,410 mg of total dissolved solids per litre) and rich in free CO_2 (more than 700 l of gas in 1 m^3 of water). When the gas escapes from water at the surface, it causes the pulsing of water flow in pipes, and also precipitation of carbonate minerals (Fig. 1 right) which is extremely unfavourable for its exploitation.

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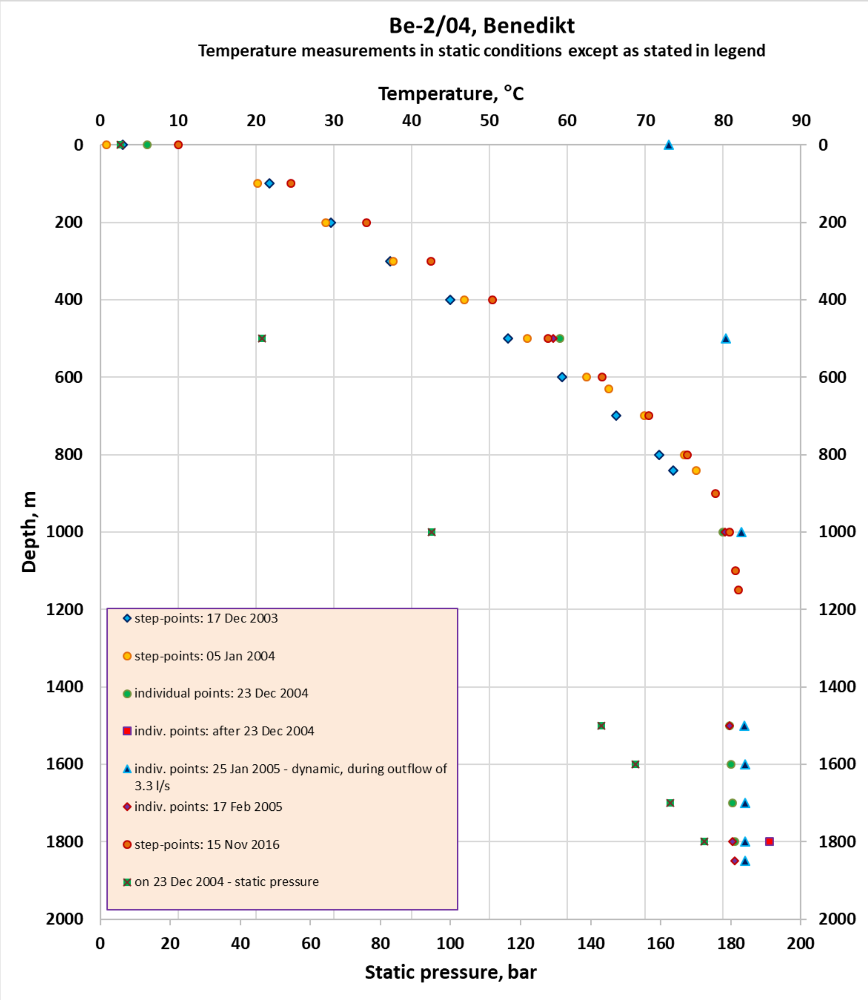

Fig. 2. Thermogram of the borehole Be-2/04 at Benedikt, showing measured temperatures in several phases.

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References

Békési, E., Lenkey, L., Limberger, J., Porkoláb, K., Balázs, A., Bonté, D., Vrijlandt, M., Horváth, F., Cloetingh, S., Wees, J.D. 2018: Subsurface temperature model of the Hungarian part of the Pannonian Basin. Global and Planetary Change, 171: 48-64. DOI.org/10.1016/j.gloplacha.2017.09.020

Lapanje, A. 2006: Origin and chemical composition of thermal and thermomineral waters in Slovenia. Geologija, 49/2: 347-370. http://www.geologija-revija.si/dokument.aspx?id=385

Kralj, P., Eichinger, L., Kralj, P. 2009: The Benedikt hydrothermal system (north-eastern Slovenia). Environmental Geology, 59: 1653-1661.

Ravnik, D., Rajver, D., Uran, B. 1987: Geothermal maps of Slovenia. Geothermal investigations in the BS-2/76 borehole (Benedikt, Slovenske Gorice, NE Slovenia)(in Slovene). GeoZS archive.

Rybach, L. 1981: Geothermal systems, conductive heat flow, geothermal anomalies. In: L. Rybach and L.J.P. Muffler (eds): Geothermal systems: Principles and case histories. John Wiley and Sons, Chichester, New York, Brisbane, Toronto, 3-36.

SzÖcs, T., Rman, N., Süveges, M., Palcsu, L., Tóth, G., Lapanje, A. 2013: The application of isotope and chemical analyses in managing transboundary groundwater resources. Applied Geochemistry, 32: 95–107.

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