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Hydrogeochemical signatures of thermal springs compared to deep formation water of North Germany

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Thermal springs and hot deep formation waters can be used for geothermal energy production. Depending on the chemical composition of the used waters, the geothermal power plants have to deal with scaling and corrosion effects. Therefore, the understanding of the hydrogeochemical behaviour of such waters can be helpful for a more effective energy production. In our study, hydrogeochemical characteristics of thermal springs in the Harz Mountains (North Germany) and deep formation water of the North German Basin are compared.

Regional setting

The lithological and stratigraphical development of North Germany is summarised in Figure 2. The Harz Mountains consist of uplifted Palaeozoic rocks, whereas the North German Basin consists of sedimentary layers of Permian, Mesozoic and Cenozoic age. Volcanic rocks are included in the Permian layers of the basin. The thickness of the sedimentary basin varies between 2 and more than 8 km. Deep aquifers within Permian (Groß Schönebeck), Triassic (Horstberg, Hamburg) and Jurassic layers are investigated and tested for geothermal energy production. Upper Triassic sandstone aquifers are already geothermally used (e.g., Neustadt-Glewe, Neubrandenburg).

Fig. 1: Regional setting of the Harz Mountains and the North German Basin
http://www.udo-leuschner.de/basiswissen/SB112thermalwasser1.gif

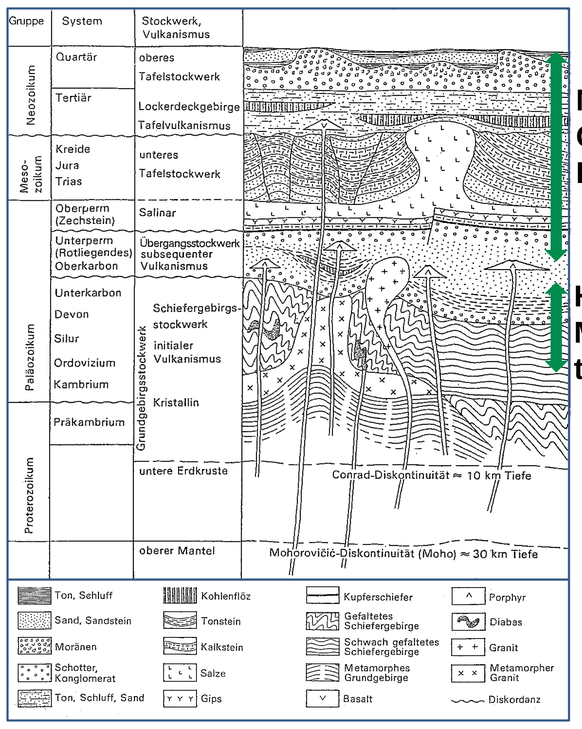

Fig. 2: Geology of North Germany
(Kugler et al. 1988)

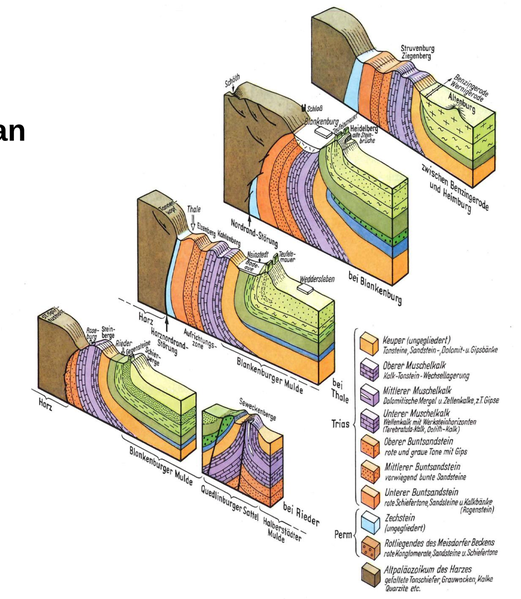

Fig. 3: Geological profiles of the North Harz Mountains
(Wagenbreth & Steiner 1982)

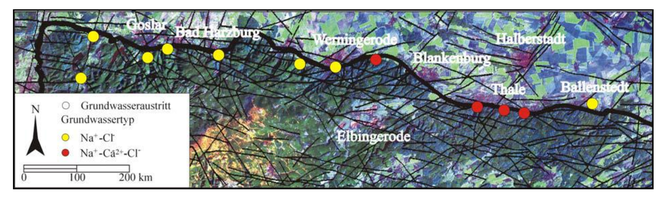

Fig. 4: Springs of Harz Mountains
(Kübeck 2004)

Hydrogeochemical characteristics

The deep aquifers of the North German Basin are mostly not involved in the recent meteoric water cycle. Their contents of Total Dissolved Solids (TDS) reach up to about 400 g L^{-1}. Thermal springs of the Harz Mountains are situated close to the main fracture system of the region. According to the connection to the meteoric water cycle, the thermal springs display lower contents of TDS (< 25 g L^{-1}). In both geological systems the TDS content is increasing with depth and temperature. The elemental ratios of the water (e.g. Na/Cl, Cl/Br, Na/Ca) indicate similar formation processes in the Harz Mountains and the North German Basin. Hydrogeochemical differences due to salt dissolution and feldspar transformation (albitisation) are found in the thermal springs as well as in the deep formation water. Mixing with meteoric waters leads to higher the sulphate concentrations in the spring water.

Conclusions:

According to the stratigraphical knowledge, hydrogeochemical data from the North German Basin can be used to predict the geological origin of the thermal springs in the Harz Mountains. Spring waters in contact with rocks of Permian and deeper Triassic layers are influenced by albitisation processes and display the typical Ca enrichment.

Table 1: Hydrogeochemical characteristics of waters from the Harz Mountains and the North German Basin
Data: Kübeck (2004), Kühn et al. (1998), Naumann (2000), Tischner et al. (2009), Seibt (2004), Lüders et al. (2010)

Harz Mountains		North German Basin	
Na-Cl-Type	Na-Ca-Cl-Type	Na-Cl-Type	Na-Ca-Cl-Type
Langelsheim *Harzer Kristallbrunnen* 950 mg/L	**Darlingerode** *Rammelsbachtal* 2.530 mg/L 10°C	**Neubrandenburg** 136.000 mg/L 55°C 1200 m	**Horstberg** 294.000 mg/L 150°C 3800 m
Oker *St. Conrad Brunnen* 1.097 mg/L	**Thale** *Hubertusbrunnen* 14.685 mg/L 9°C [12.5°C]	**Neustadt-Glewe** 217.000 mg/l 98°C 2200 m	**Groß Schönebeck** 265.000 mg/L 150°C 4200 m
Bad Harzburg *Dr. H. Schneider Quelle* 22.000 mg/L 26°C *Dr. H. Schneider Brunnen* 24.115 mg/L 25°C 840 m	**Bad Suderode** *Quambachtal* 19.501 mg/L 11°C *Behringer Brunnen* 19.498 mg/l 9°C	**Hamburg** 222.000 mg/L 128°C 3250 m	**Husum-Schneeren** 50.000 - 275.000 mg/L 3000 - 3500 m

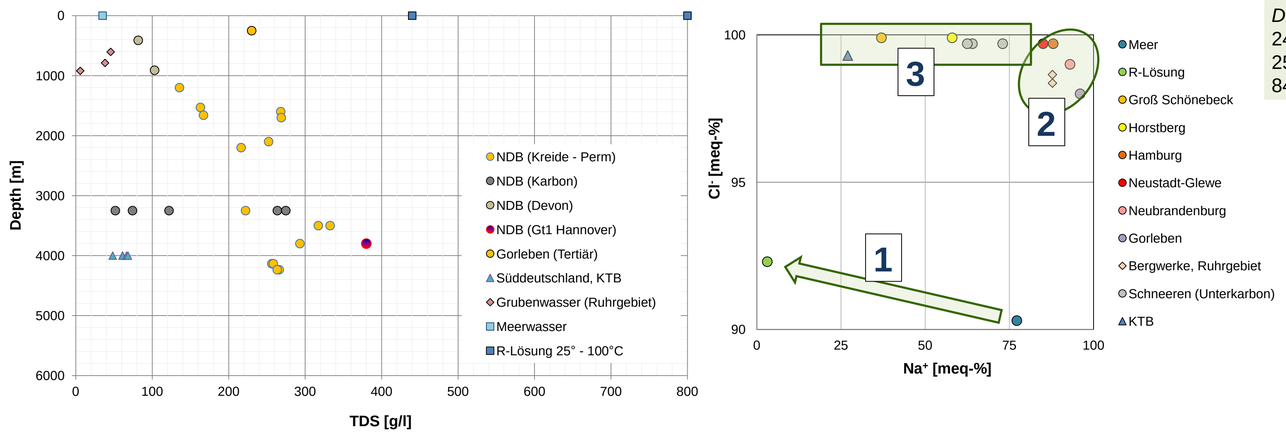

Fig. 5: Hydrogeochemical characteristics of deep formation water in North Germany
Different processes leading to specific water compositions are:
1) Evaporation of seawater and precipitation of salt minerals (rising Mg and SO_4 concentrations),
2) Dissolution of salt layers (rising Na and Cl concentrations),
3) Feldspar transformation = Albitisation (rising Ca concentrations).

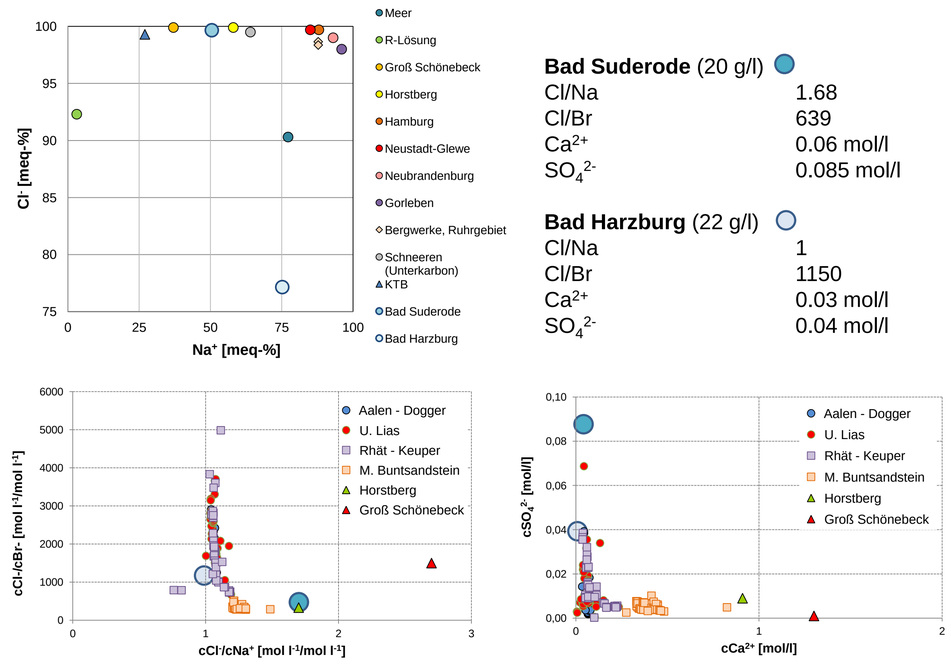

Fig. 6: Springs compared to deep formation water
Na-Cl and Na-Ca-Cl waters are found in both geological units and can be related to the stratigraphical classification displayed by the GeotIS data (Schulz et al. 2009). The spring “Bad Harzburg” (situated in “Muschelkalk”) is influenced by salt dissolution, whereas albitisation (typical for Permian and lower Triassic layers) is indicated for the spring “Bad Suderode”.

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