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$^{87}Sr/^{86}Sr$ ratios in shallow and deep aquifers and thermal water from the Eastern Boundary Fault of the northern Upper Rhine Graben at the Heidelberg Basin, Germany

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Abstract

Strontium isotopic ratios are important tracers of hydrological processes such as water-rock interaction and the detection of the ascent of deep fluids at hydraulically active faults. The $^{87}Sr/^{86}Sr$ ratios have been measured in shallow and deep aquifers (n=19) and thermal water at the Eastern Boundary Fault (EBF) of the northern Rhine Graben Rift in Germany. $^{87}Sr/^{86}Sr$ ratios and Sr contents from Quaternary groundwater conducting sediments of the shallow aquifers range from 0.70896 to 0.70965 and 0.23 to 0.67 mg/l, respectively. Strontium contents of the shallow groundwater are low and highly variable in their $^{87}Sr/^{86}Sr$ ratios. No unequivocally hints of ascending deep fluids at the EBF fault have been found in the shallow aquifers of the Heidelberg Basin. However, groundwater from production wells of up to 205 m deep aquifers and the 1100 m deep thermal well show radiogenic $^{87}Sr/^{86}Sr$ ratios and high Sr contents in the range from 0.70984 to 0.71074 and 0.39 to 319 mg/l, respectively. The radiogenic Sr ratios are clear indications for ascending deep fluids into deep aquifers at the EBF fault of the northern upper Rhine Graben.

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Keywords: Rhine Graben; Heidelberg Basin; Fault; Fluid; Aquifer; Strontium isotopic ratios

1. Introduction

This study is part of a multidisciplinary research project to identify possible imprints of deep fluids in the shallow aquifers. Fault zones are hydraulic conduits at active segments connecting shallow and deep geological

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environments. Strontium isotopes are applied as tracer of fault-controlled fluid ascent at the Eastern Boundary Fault (EBF) of the northern upper Rhine Graben in Germany.

2. Geological setting

The study area is located in the Heidelberg Basin at the eastern margin of the Upper Rhine Graben (URG), as major part of the European Continental Rift system (Fig. 1). During the Plio-Quaternary, the major subsidence shifted towards the eastern part of the Graben around the city of Heidelberg. The Heidelberg Basin is supposed to host one of the longest continuous successions of Quaternary sediments in Europe. The Plio-Quaternary infill mainly consists of relatively fine alpine material and coarser local material. The primary sediment sources are the fluvial systems of Rhine and Neckar[1-3]. The Eastern Boundary Fault divides the Odenwald in the east from the URG in the west.

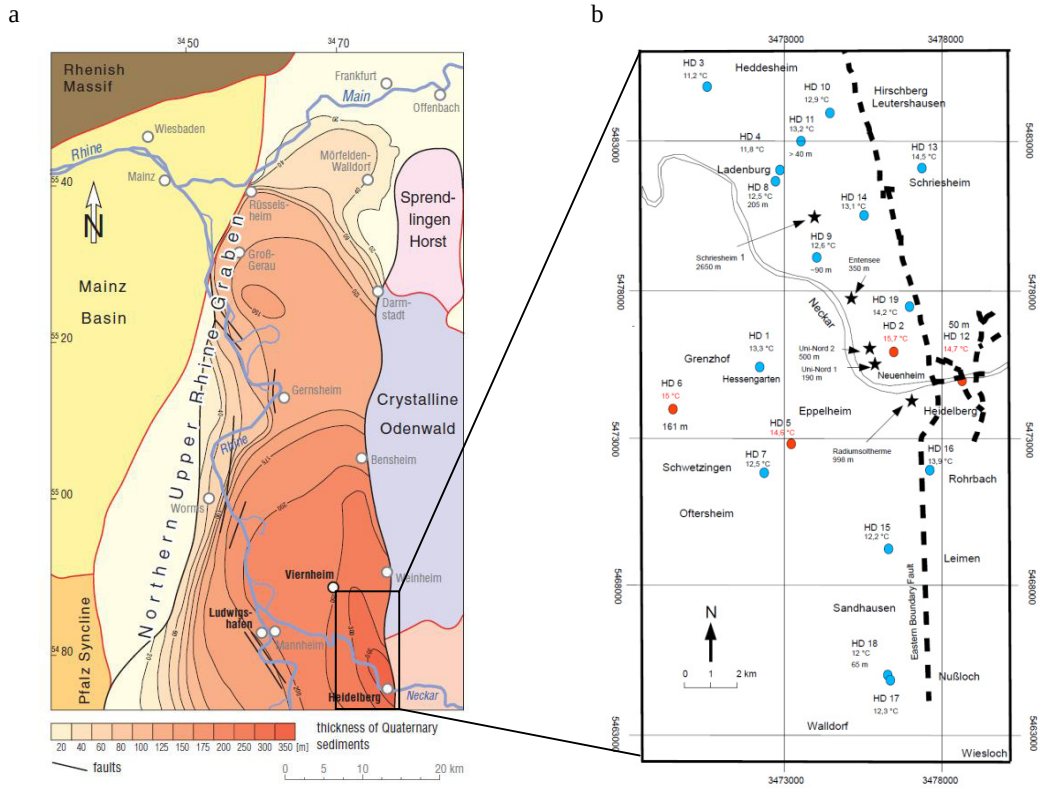

Fig. 1. (a) Map of the northern Upper Rhine Graben with thickness of Quaternary sediments (Heidelberg Basin) and geological structural zones adapted from Hoselmann[2]. The frame shows the location of the study area. The city of Weinheim is located some 15 km north of Heidelberg; (b) Schematic map of the study area showing the Eastern Boundary fault and sampling localities of deep and shallow ground waters. Thermal water sample location HD24 from Weinheim is not shown on the map. The Holocene and Pleistocene fillings of the Central Graben are in contact to crystalline basement of the Odenwald, Permian volcanic rocks and Mesozoic sediments. Localities with high groundwater temperatures are indicated by red symbols (e.g. HD 2: 15.7 °C). Research boreholes in the study area are indicated by stars.

3. Sampling

Nineteen water samples were collected in June 2014 in a region about 8 km around Heidelberg (SW Germany) (Fig. 1a). Samples were collected from pumped 12 to 65 m deep monitoring and production wells from Quaternary alluvial sediments (Mannheim-Formation: 0 m to 56.9 m depth; Ladenburg Horizon: 56.9 m to 126 m). Samples HD6 and HD8 are sampled from 161 m and 205 m deep production wells drilled into the Kurpfalz-Formation (56.9 m to 299 m depth)[3]. HD24 was sampled in February 2015 from the thermal well (T = 60.5 °C) in Weinheim, a city