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Procedia Earth and Planetary Science 17 (2017) 81 – 84

Procedia
Earth and Planetary Science

15th Water-Rock Interaction International Symposium, WRI-15

Ascending deep fluids into shallow aquifer at hydraulically active segments of the Western Boundary Fault of the Rhine Graben, Germany: Constraints from $^{87}Sr/^{86}Sr$ ratios

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Abstract

$^{87}Sr/^{86}Sr$ ratios have been used as a tracer of fault-controlled fluid ascent into shallow aquifers at the Western Boundary Fault (WBF) of the northern upper Rhine Graben in Germany, a major rift system of the European continent. The $^{87}Sr/^{86}Sr$ ratios and Sr contents from the Quarternary groundwater conducting sediments of the uppermost aquifer increase with decreasing distance to the WBF. The $^{87}Sr/^{86}Sr$ ratios and Sr contents of the shallow groundwater range from 0.70877 to 0.71022 and 0.41 to 2.30 mg/l, respectively. The Strontium isotope ratios are important tracers of hydrological processes such as water-rock interaction and groundwater mixing at active faults and thus a powerful geochemical tool for the detection of the ascent of deep fluids at hydraulically active segments of faults and its mixing with shallow recharged groundwater.

Peer-review under responsibility of the organizing committee of WRI-15

*Keywords:*Rhine Graben; Fault; Fluid; Aquifer; Tracer; Strontium isotopic ratios;

1. Introduction

Deformation along faults introduces permeability heterogeneity which has an important impact on hydrothermal fluid circulation. Fault zones are hydraulic conduits connecting shallow and deep geological environments[1]. Strontium isotopes are applied as an isotopic fingerprint of the aquifer rock because present day $^{87}Sr/^{86}Sr$ ratios in

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Peer-review under responsibility of the organizing committee of WRI-15
doi:10.1016/j.proeps.2016.12.001

groundwater reflect the Sr isotopic composition of the environment through which the water migrates. The degree of Sr dissolved during reservoir water-rock interaction mostly depends on chemical composition, solubility of the rocks, reservoir temperature and residence time of the water. In this study the ^{87}Sr/^{86}Sr ratios and Sr contents have been used as tracers of fault-controlled fluid ascent into shallow aquifers at the Western Boundary Fault (WBF) of the northern upper Rhine Graben in Germany.

2. Geological setting

The study area is situated at the northwestern margin of the Upper Rhine Graben (URG), a major part of the European Continental Rift system. The WBF of the northern URG is striking through the study area in SSW-NNE direction in the north, where the fault terminates at the SW-NE striking Hunsrück-Taunus Boundary Fault (HTBF), see Fig. 1. The fault divides the Mainz Basin in the west from the URG in the east and enables the ascent of deep saline groundwater. The latter mainly represents fossil seawater which intrudes into the shallow aquifer[2].

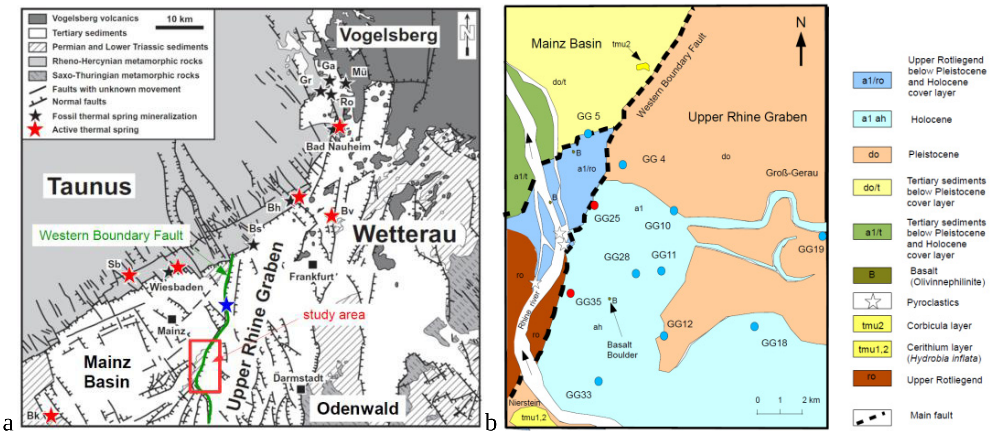

Fig. 1. (a) Geological map adapted from[3]. Localities where active thermal waters and fossil thermal spring mineralization occurs are shown by red and black stars, respectively. The frame shows the location of the study area. Artesian mineral springs are aligned on the WBF terminating at the HTBF about 10 km northward. The soda-lithium (QBW1) and sulphur springs (QBW2) from Bad Weilbach are indicated by a blue star; (b)Schematic geological map of the study area. Indicated are localities of groundwater sampling and the NNE striking WBF. The Holocene and Pleistocene fillings of the Central Graben are in contact to Rotliegend and Tertiary sediments. Included are localities of Paleogene phreatomagmatic volcanism[4] and the locality of numerously basaltic rock fragments observed during own field studies. Localities with high ^{87}Sr/^{86}Sr ratios and Sr contents are indicated by red symbols.

3. Sampling

Eleven water samples were collected during October and November 2013 in a region about 30 km southwest of Frankfurt, close to the city of Groß-Gerau (SW Germany) (Fig. 1a). Two samples from flowing artesian springs of Bad Weilbach were collected in July 2014. Samples were collected from flowing and pumped 6.75 to >30 m deep monitoring and production wells from Quaternary alluvial sediments. The depth of the water table ranges from 0.81 to 3.8 m below ground. Groundwater was filtered on site through pre-cleaned 0.45 µm pore size MF-Millipore MCE Membrane filters. For each groundwater sample about 1 l was taken.

Sample handling was performed in clean rooms under laminar flow clean air benches of at least class 100 to minimize the potential risk of contamination. Samples were heated in Teflon bottles to ~ 60 °C reducing the volume to about 50 ml. Subsequently, 1 ml of the solution was evaporated to dryness. The precipitate was dissolved in 0.5 ml 3N HNO_3 for chromatographic column separation.