Quartz cementation in the Buntsandstein Group in the central Upper Rhine Graben and surrounding outcrops in relation to pre-Tertiary burial depth

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The Buntsandstein reservoir quality in the Upper Rhine Graben (URG) is of major interest for the oil and gas as well as geothermal exploration. Quartz cement with pore-occluding overgrowths partly reduces the porosity significantly. The reason for the regionally different amount of quartz cement in the Buntsandstein in the central URG and surrounding outcrops was investigated and compared to insights from an oil field in the central URG. Buntsandstein quartz cementation data was used from literature references and thin section studies.
The amount of quartz cement in Buntsandstein outcrops in the surroundings of the central URG shows a strong positive correlation to the thickness of the formerly overlying Muschelkalk to Dogger sequence and thus a clear relation to the pre-Tertiary burial depth before the URG formation. The remarkable regional difference in Buntsandstein reservoir properties with western outcrops showing very good porosities (often > 15 - 20 %) and low amounts of quartz cements of usually < 10 % (mean value < 5 %), and eastern URG Buntsandstein rocks showing a significantly lower porosity (of usually < 15 - 10 %) and significantly higher amount of quartz cementation with many samples > 10 % and partly > 30 %, can be attributed to the difference in pre-Tertiary burial depth. 1D models with Liassic maturity data (vitrinite reflectance) as calibration parameter compare the maximum burial depth at the eastern and western side of the URG and reveal that the Buntsandstein at the eastern URG in the area of Heidelberg-Neckargerach-Mingolsheim has been buried significantly deeper than the western URG area (Haardtrand; outrcrop Siebeldingen). The eastern URG Buntsandstein outcrops experienced ca. 130 °C during maximum burial depth which resulted in significantly increased amounts of quartz overgrowths.
The central URG area shows a lower pre-Tertiary burial depth than the eastern outcrops and are rather in-line with western URG outcrops with low mean values of quartz cement (ca. 3 - 5 %). The distribution of quartz cement from wellbore X1 determines two phases of quartz cement. High temperatures during Neogene and Quaternary burial resulted in a second phase of quartz cementation causing partly high amounts of quartz cement (10 to partly > 20 %). An exception are samples, which show radial, fibrous grain-coating illites. The precipitation of grain-coating illites is attributed to Neogene-Quaternary hydrothermal fluid flow. The radial grain-coatings protect against further precipitation of quartz overgrowths and the samples still show low amounts quartz cement (< 5 %) and quite high porosities.