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Research paper

Origin of the saline paleofluids in fault-damage zones of the Jabal Qusaybah Anticline (Adam Foothills, Oman): Constraints from fluid inclusions geochemistry

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A B S T R A C T

The Jabal Qusaybah Anticline, in north Oman, is affected by syn-folding strike-slip and extensional fault zones developed during foreland deformation ahead of the Northern Oman Mountains thrust wedge, in Cenozoic times. Migration of fluids in fault-damage zones is recorded in complex calcite vein networks. By employing the microthermometric and compositional microanalysis of the fluid inclusions (crush-leach), two distinct generations of veins have been studied. The aim was to determine the source of elevated salinity in fluids involved in their cementation and explain their compositional evolution through fluid-rock interactions. The ionic ratios (Na/Br and Cl/Br) obtained from crush-leach analysis give supporting evidence that the elevated salinity of fluid inclusions in both vein groups originated from an evaporated seawater beyond the onset of halite precipitation (residual brines). The results reveal a gradual increase in salinity of the fluids, F/Cl molar ratios, as well as Li/Cl molar ratios. These results imply the progressively increasing contribution of evaporitic residual brines and fluids that interacted with, or were derived from siliciclastic rocks. We suggest that the most likely origin of the former fluids is provided by residual brines associated with precipitation of the Ara evaporites (Cambrian). The regional driving mechanism for such a significant fluid migration is believed to be compaction-driven upward flow that was channeled into faults and fractures during major deformational events.

1. Introduction

Networks of syn-tectonic calcite veins and fault-infilling crystals within fault-damage zones are widely exposed in the Jabal Qusaybah Anticline (Adam Foothills, Oman) providing the opportunity to study the paleofluid evolution associated with these zones (Fig. 1). The clear-cut relationship between the vein systems, deformational episodes and the nature of fluids involved in cementation has been comprehensively discussed in Storti et al. (2015) and Mozafari et al. (2015). Based on Mozafari et al. (2015), the contribution of brines associated with the Ara evaporites (Cambrian) (Fig. 2) was proposed for the high salinity of the fluids preserved in inclusions of the vein cementing calcites. Nevertheless, differentiation between an evaporative and evaporite-dissolution origin based on the obtained data was complicated by the potential for modification of the fluids chemical composition through mixing with fluids of a different source (e.g. meteoric, interstitial brines) and by fluid-rock interactions (Davisson and Criss, 1996; Banks et al., 2002; Heijlen et al., 2001, 2003; Hendry et al., 2015). The source of salinity has major implications to constrain the role of the Ara evaporites in providing the fluids, the nature of their contribution and the regional significance of fluid migration in the north Oman Mountains and, specifically, in the Adam Foothills. It is therefore essential to apply sufficiently accurate analyses to reduce the uncertainties regarding the source of

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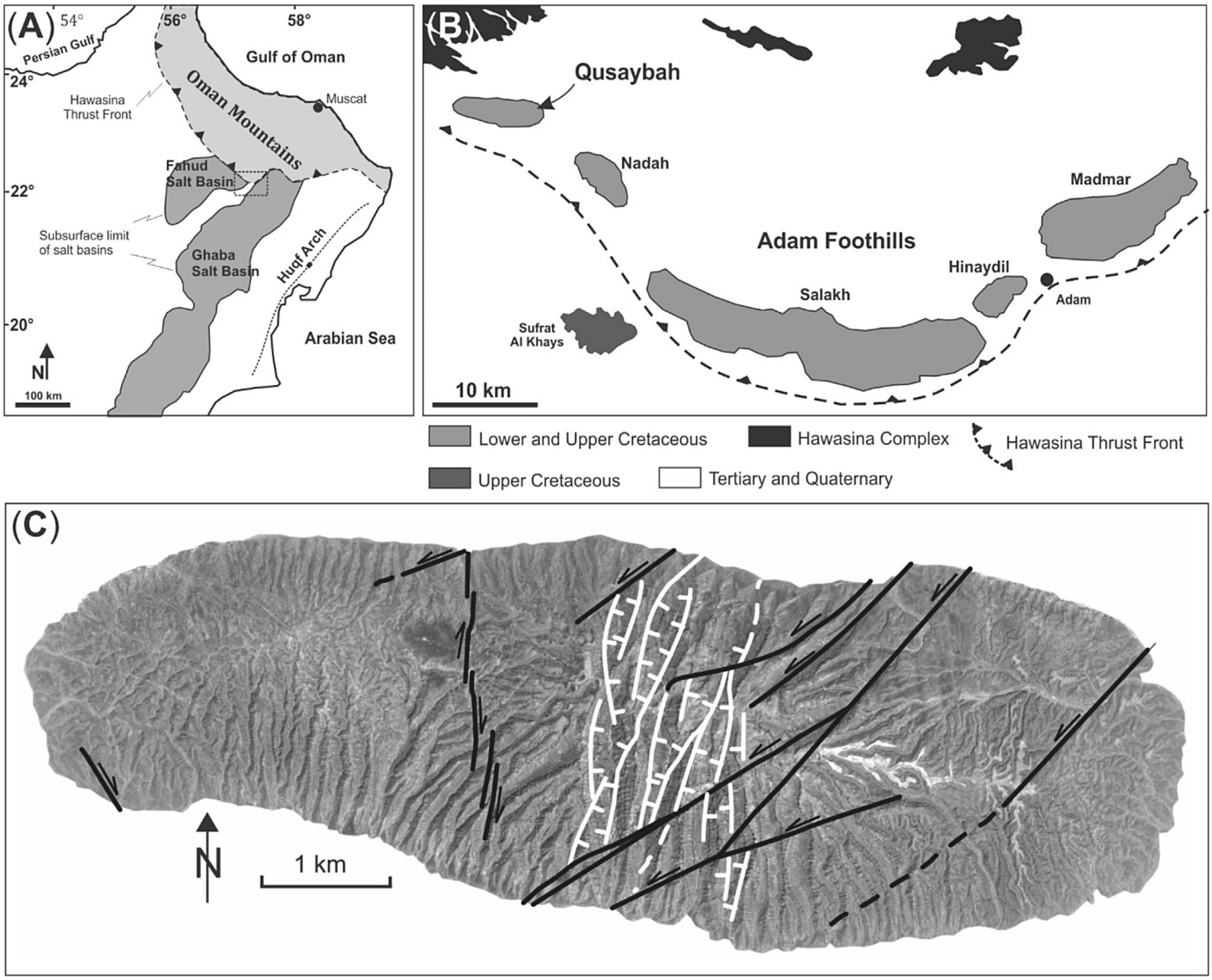

Fig. 1. The study area on regional and local scales. A) Simplified geological map of Oman Mountains (modified after Loosveld et al., 1996) showing the study area (rectangle). B) Schematic geological map of the Adam Foothills (modified after Filbrandt et al., 2006) including Jabal Qusaybah in westernmost side (indicated by the arrow). C) Satellite image of the Jabal Qusaybah Anticline showing the traces of the studied major fault zones (strike-slip faults and extensional faults are shown in black and white color, respectively).

salinity. The current research, by recalling the existent data, and combining microthermometry of fluid inclusions with their quantitative chemical microanalysis (crush-leach), constrains the most likely origin of the saline fluids and their secondary evolution through fluid-rock interactions.

2. Geological setting

The E-W trending Jabal Qusaybah Anticline is located in the Adam Foothills, at the southern toe of the north Oman Mountains (Fig. 1), which formed from Late Cretaceous to Pliocene times due to the convergence between the Arabia and Eurasia tectonic plates (Loosveld et al., 1996). This event led to the closure of the NeoTethys Ocean, the obduction of the Semail ophiolites, the termination of passive margin carbonate sedimentation (Wasia Group; Fig. 2), and the formation of the Oman foreland basin system, where initial exhumation and erosion were replaced by subsidence and deposition of syn-tectonic sediments (Aruma Group; Fig. 2) in the subsiding foredeep basin. Opening of the Red Sea and Gulf of Aden in Late Eocene-Oligocene times, renewed deformation in the Oman Mountains and eventually caused the formation of the Adam Foothills (Glennie et al., 1974; Moseley and Abbotts, 1979; Robertson and Searle, 1990; Loosveld et al., 1996; Terken, 1999).

Based on Glennie et al. (1974), the present-day stratigraphic succession in the footwall of the ophiolitic nappes (Fig. 2) starts with the igneous and metamorphic basement of the Arabian-Nubian shield covered by sequences of siliciclastics, carbonates and thick evaporites of the Pre-Cambrian to Lower Cambrian Huqf Supergroup. The latter evaporites typically provide a very effective regional décollement layer (Loosveld et al., 1996; Storti et al., 2015). The evaporites are overlain by marginal marine and continental siliciclastic sediments of the Cambrian to Lower Silurian Haima Supergroup and Haushi Group (Permian). The Permian succession is followed by the Hajar Supergroup (Permian to Upper Cretaceous shelf sediments), composed of dominant carbonates and subordinate siliciclastic rocks of the Akhdar Group, the Triassic to Jurassic carbonates of the Sahtan Group, the Lower Triassic carbonates of the Kahmah/Thamamah Group, and the Lower to Upper Cretaceous