View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by SZTE Publicatio Repozitórium - SZTE - Repository of Publications

ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Earth and Planetary Science 00 (2012) 000–000
Procedia Earth and Planetary Science
www.elsevier.com/locate/procedia

Water Rock Interaction [WRI 14]

The hydraulic behavior of a crack-seal vein producing fluid-rock system

Gergely Dabi[a,]*, György Czuppon[b], Félix Schubert[a], Tivadar M. Tóth[a] *

[a]*Department of Mineralogy, Geochemistry and Petrology, University of Szeged, Szeged, Egyetem street. 2-6.*
[b]*Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Budapest, Budaörsi street 45.*

Abstract

The Mecsekalja Zone crystalline metamorphic rocks are crosscut by a crack-seal texture vein generation. Crack-seal textures are indicative of intermittent hydraulic behavior of a fluid-rock system and of the fluid pressure fluctuation. Herewith microthermometric and δD composition data from primary fluid inclusions of the crack-seal veins are presented together with earlier published stable isotope compositions of the vein calcite to reveal some features of the hydraulic behavior of the fluid-rock system during the crack-seal process.

© 2012 The Authors. Published by Elsevier B.V.
Selection and/or peer-review under responsibility of Organizing and Scientific Committee of WRI 14 - 2013

Keywords: crack-seal; fluid-rock hydraulics; vein texture; fluid inclusion; stable isotope

1. Introduction

Crack-seal textures occur in veins in various geological setting, they are considered to be the indicators of the intermittency during formation, i.e. textures that form as a succession of opening increments and subsequent precipitation from the fluid intruded in the newly opened vein volume [1]. Studies concerning the above process generally focus on the formation of the crack-seal geometry on a local scale without the aim to understand the hydraulic behavior of the fluid-rock system and its interrelation with the local phenomenon. Herewith stable isotope and fluid inclusion data from crack-seal veins are presented with the aim to reveal some important features of a fluid-rock system characterized by intermittent behavior. The features discussed here are successfully explained by the seismically related fluid-redistribution models of [2] and [3] and shed light on some aspects of a seismically driven hydraulic system.

* Corresponding author. Tel.: +36 62 544 058; fax: +36 62 426 058.
E-mail address: dabi@geo.u-szeged.hu.

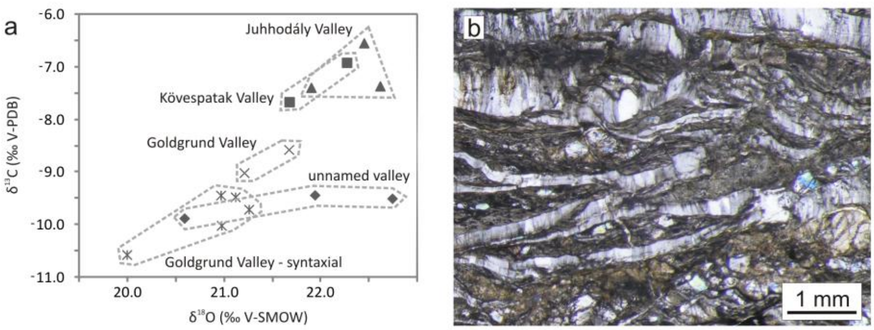

Fig. 1. (a) Stable isotope compositions of the discussed crack-seal vein generation and their syntaxial counterparts, published by [6]. (b) pervasive crack-seal vein system in a feldspathic gneiss sample.

3. Geological background

The Mecsekalja Zone (from here on abbreviated as MZ) is a narrow metamorphic belt that can be tracked in the south foreland of the Mecsek Mountains (SE Hungary). At the outcrops near Ófalu village the MZ is built up of crystalline limestone, serpentinite and amphibolite bodies as enclaves in a gneissic mass. The metamorphic belt has tectonic contacts both towards the Jurassic marl to the north and towards the Carboniferous granite to the south. In the Early Cretaceous time vigorous volcanic activity occurred in the region, what was preceded by pelagic marl deposition in the Jurassic from the Sinemurian [4]. Subvolcanic dykes are frequent in the MZ and in the Mórágy Granitoid Complex to the south, where related hydrothermal phenomena are also described [5].

The gneissic rocks of the MZ are cross cut by a generation of antitaxial crack-seal calcite veins, the parent fluid of which is related to the Early Cretaceous dyke emplacement [6]. The same fluid produced a vein generation with syntaxial vein geometries, the stable isotope composition of which suggest different flow paths and degrees of fluid-rock interactions from those of the crack-seal veins (Fig. 1a) [6].

4. Methods

Fluid-inclusion studies were carried out at the Department of Mineralogy, Geochemistry and Petrology, University of Szeged, on a Linkam THMSG 600 heating-freezing stage mounted on an Olympus BX41 microscope. Calibration of the heating-freezing stage was carried out using synthetic inclusions of pure H_2O [T_m(Ice) = 0°C, T_h = 374°C] and H_2O-CO_2 inclusions [$T_m(CO_2)$ = 56.6°C] entrapped in quartz.
The δD values of the inclusion-hosted fluids were measured at the Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences. Details of the procedure can be found at [7]. These δD data are presented and interpreted here with $\delta^{13}C$ and $\delta^{18}O$ values of the studied vein generation, published by [6].

5. Results

5.1. Macroscopic and microscopic vein geometries

Field experience and sampling campaigns suggest that different gneissic types are transected by antitaxial crack-seal vein systems with different vein densities. Micaceous gneisses seem to be rarely intersected by this vein generation, while the studied feldspathic gneiss contains pervasive vein system with a range of vein thicknesses from the submillimeter scale to several millimeters (Fig. 1b).

The veins microscopic structure is generally characterized by bands and trails of solid inclusions dragged off from the vein wall (Fig. 1b), indicative of the crack-seal process during growth. Average distances between solid inclusion bands (ca. 6 μm), and the maximum vein widths of 3-5 mm suggests several hundred subsequent opening increments.

5.2. Fluid inclusion microthermometry

Primary inclusions homogenize to the liquid phase between 50 and 240 °C (*N*=103). Most of these inclusions are metastable, i.e. fail to nucleate vapour during subsequent lowering of the temperature back to room temperature or lower. Those inclusions in which nucleation of the vapour phase occurred after homogenization temperature measurements (*N*=11) were capable to yield final melting temperatures. The measured inclusions final melting temperatures are in a very narrow range between -0.3 and -0.1 °C (inclusions with homogenization temperatures between 70 and 192 °C), i.e. the fluids are of uniform salinity.

5.3. Hydrogen isotope compositions of the fluid inclusions

Only four samples contained fluid inclusions in sufficiency for the measurement of the entrapped fluids hydrogen isotopic composition. These fluids have δD values between -39.6 and -75.8 ‰ (*N*=4), what is basically the composition range of magmatic fluids (from -80‰ to -40‰, [8]).

6. Discussion

The very narrow range of final melting temperatures in samples from different locations confirms that a fluid of uniform composition flushed the system during the flow event. The very wide range of homogenization temperatures can hardly be explained by the temperature drop of the fluid alone. Since the homogenization temperatures represent fluids of different densities, it is plausible to assume that the wide range of homogenization temperatures represent changing fluid pressures and densities during vein growth, which is inherent in crack-seal models [1]. However the validity of the data is problematic, since stretching of the fluid inclusions is possible during the recurrent pressure drops (vein opening).

Fig. 1a shows stable isotope compositions of the vein calcite. It can be seen that samples from different outcrops display clustered isotope compositions. This implies local, possibly rock type dependent fluid-rock systems, a feature of the data set not discussed in [6].

The fluids magmatic origin (as discussed by [6] and as constrained here by the measured δD values) can explain its overpressure but does not explain the dynamics of the crack-seal process, i.e. several hundred recurrent drop and subsequent increase of the fluid pressure. It is also a striking feature of the vein systems that they remain closed during subsequent opening increments. Taking together the above features the crack-seal process cannot be well explained as being governed by the fluid pressure alone and an external factor should be evoked to explain the crack-seal process.

Sedimentary features of Cretaceous limestones contemporaneous with the Eastern Mecsek volcanism are indicative of vigorous seismicity in the area [4]. Scholz et al. [2] have evolved a model that explains a group of phenomena precursory to earthquakes with microcrack dilatancy in the broader environment of an active fault. Herewith we propose that the same model satisfactorily explains several features of the crack-seal process at the study area. The very similar salinities of the fluids at different locations where isotope compositions suggest local water-rock systems implies that the fluid effectively flushed the system, but could not homogenize isotope perturbations due to local isotope exchange. The efficiency of fluid flushing was probably aid by enhanced microcrack porosity during the pre-earthquake dilatancy. The release of stress accompanying the earthquake results in the elastic closure of the microcrack system [3] which causes the fluid pressure to rise and the antitaxial veins to reopen. However the newly formed fracture porosity systems are closed local systems, what implies that the main flow media is the dilatant microcrack system in the pre-earthquake stage of the seismic cycle.

7. Conclusions

The above described model rests on the early seismic fluid redistribution models, the relevance of which is constrained by sedimentary features contemporaneous with the Early Cretaceous volcanism [4]. Fluid inclusion data suggest the enhanced efficiency of the fluid in flushing the system, what can be explained by enhanced microcrack porosity during the pre-earthquake period [2]. The recurrent opening increments along the veins can be interpreted as local hydraulic failures due to the increase of fluid pressure associated with the elastic closure of the microcracks due to earthquake stress release [3].

The available data only make some qualitative ascertainments to be deduced, and are not capable to constrain the boundary conditions of the process narrower, i.e. depth, fluid pressure at vein opening, etc… The authors find reasonable to assume that the mechanical properties of the host rock determine its sensibility to the crack-seal process, and provide the possibility to adumbrate in its details.

References

[1] Bons PD. The formation of veins and their microstructures. *Journal of the Virtual Explorer*;2000:**32**;2.

[2] Scholz CH, Sykes LR, Aggarwal YP. Earthquake prediction: a physical basis. *Science* 1973;**181**:803-11.

[3] Sibson RH, Moore JMcM, Rankin AH. Seismic pumping – a hydrothermal fluid transport mechanism. *J Geol Soc London* 1975;**131**:653-59.

[4] Jáger V, Molnár F, Buchs D, Koděra P. The connection between iron ore formations and „mud-shrimp" colonizations around sunken wood debris and hydrothermal sediments in a Lower Cretaceous continental rift basin, Mecsek Mts. Hungary. *Earth Sci Rev* 2012;**114**:250-78.

[5] Balla Z, Császár G, Gulácsi Z, Gyalog L, Kaiser M, Király E, et al. *Geology of the North-eastern part of the Mórágy Block*. Budapest:Geological Institute of Hungary;2009.

[6] Dabi G, Siklósy Z, Schubert F, Bajnóczi B, M. Tóth T. The relevance of vein texture in understanding the past hydraulic behaviour of a crystalline rock mass: reconstruction of the palaeohydrology of the Mecsekalja Zone, South Hungary. *Geofluids*; 2011;**11**:309-27.

[7] Demény A, Siklósy Z. Combination of off-line preparation and continuous flow mass spectrometry: D/H analyses of inclusion waters. *Rapid Communications in Mass Spectrometry* 2008;**22**:1329-34.

[8] Sheppard S. Characterization and isotopic variations in natural waters. In: Valley JW, Taylor Jr.PH, O'Neil JR, editors. *Reviews in Mineralogy, Stable isotopes in high temperature geological processes*, Mineralogy Society of America; 1986. p. 165-84.