Physics and Chemistry of the Earth 138 (2025) 103870

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Understanding the mechanism of shallow crustal fluid-rock interaction in the Deccan Trap basement rocks and its significance in the Koyna-Warna Seismogenic region, Western India

Piyal Halder [a,b], Matsyendra Kumar Shukla [c], Kamlesh Kumar [a,b], Anupam Sharma [a,b,*]

[a] Birbal Sahni Institute of Palaeosciences (DST, Govt. of India), Lucknow, 226007, Uttar Pradesh, India
[b] Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, 201002, India
[c] Govt. of India, Ministry of Earth Sciences (MoES), Borehole Geophysics Research Laboratory (BGRL), Karad, 415105, India

ARTICLE INFO

Keywords:
Koyna-warna seismogenic region
Reservoir-triggered seismicity
Clay minerals
Biotite chloritization
Ripplocations
Fault creep

ABSTRACT

The present study investigates the fluid's interaction with the severely fractured granitoids basement rocks underlying the Deccan Volcanic Province in Western India and its potential contribution to the recurring seismicity in the Koyna-Warna Seismogenic Region, a hotspot of artificial reservoir-triggered-seismicity. The presence of chlorite, epidote, calcite and illite, along the pre-existing faults and fractures, has been identified by the detailed petrologic investigation at mesoscopic and microscopic scales along with X-ray diffraction. This indicates the fluid-rock interaction along these mechanically weak planes and the subsequent propylitic grade of hydrothermal alteration. The microscopic appearance of biotitic remnants within neoformed chlorite indicates the transformation of biotite into chlorite and epidote due to fluid interaction which is further supported by the mass balance calculations. Additionally, the geochemistry also shows that K_2O released during biotite dissolution explains the formation of illite at a particular depth, whereas plagioclase dissolution justifies the production of albite and partially calcite. Furthermore, chlorite, when formed in such highly stressed fault zones, shows ripplocations like intracrystalline deformation in response to the differential behaviour of the hydrogen bonds connecting the talc-like T-O-T layer with the brucite-like sheet and thus accommodates strain that promotes fault creep. Although epidote found here should favour the fault slip, the relatively higher abundance of chlorite suppresses this contrasting impact of epidote. Thus, biotite chloritization due to fluid-rock interaction along faults and fractures facilitates steady fault creep which may be one of the plausible explanations for recurring seismicity in the study area for the last 50 years.

1. Introduction

Faults and fractures act as fluid migration pathways during seismic rupture as well as the inter-seismic creep periods (Duan et al., 2016). The infiltrated fluid interacts with the host rocks and chemically reacts with the constituent minerals to achieve the thermodynamic equilibrium. As a result, a set of new minerals are formed that are stable under the newly attained conditions. The entire process of fracture-scale fluid-rock interaction actually occurs through the dissolution-transportation-precipitation (DTP) mechanism (Glassley et al., 2016). When the percolating fluid is under-saturated in a certain mineral phase, dissolution primarily happens with unstable minerals, whereas precipitation occurs when the fluid is oversaturated with a particular mineral phase. In addition, transportation governing the flow of mass and heat occurs mainly in two ways- Diffusion and Advection (Bons et al., 2012; Glassley et al., 2016).

Diffusion encompasses the small-scale (<1 m) movement of the substances or elements from high concentration to low concentration (concentration gradient) in any chemical activity and thus involves mass gain (Bickle and McKenzie, 1987). For example, the migration of calcium from a calcium-rich or calcareous host rock into another leads to the formation of calcite veins resulting in a mass gain of CaO. Similarly, chemical disequilibrium created by the variation in pressure between the fluid in the fractures and the host rock may lead to diffusion. On the contrary, advection is another method of mass flow through fractures, in which elements or substances from outside are carried by a fluid over the

* Corresponding author. Birbal Sahni Institute of Palaeosciences (DST, Govt. of India), Lucknow, 226007, Uttar Pradesh, India.
E-mail addresses: anupam110367@gmail.com, anupam.sharma@bsip.res.in (A. Sharma).

https://doi.org/10.1016/j.pce.2025.103870
Received 25 April 2024; Received in revised form 18 December 2024; Accepted 10 January 2025
Available online 11 January 2025