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Gamma radiation effects on quartz Al and Ti center electron spin resonance signal intensity: Implications for quartz provenance discrimination

Chuanyi Wei[1,2,*], Gongming Yin[1], Chunru Liu[1], N'dji dit Jacques Dembele[3], Lupeng Yu[2], Huajun Jiang[4], Yawei Li[5], Rujun Guo[5], Li Cheng[1], and Wenpeng Li[6]

[1]State Key Laboratory of Earthquake Dynamics, Institute of Geology, China Earthquake Administration, Beijing 100029, China
[2]Luminescence Research Laboratory, Shandong Provincial Key Laboratory of Water and Soil Conservation and Environmental Protection, School of Resource and Environmental Sciences, Linyi University, Linyi 276000, China
[3]Université des Sciences Sociales et de Gestion de Bamako, Bamako bp2575, Mali
[4]School of Education Science, Hunan First Normal University, Changsha 410205, China
[5]School of Earth Sciences, China University of Geosciences, Wuhan 430074, China
[6]Department of Ocean Science and Engineering, Southern University of Science and Technology, Shenzhen 518055, China

Abstract

Quartz is one of the most common rock-forming minerals and crystallizes over a wide range of temperature and pressure conditions. This diversity of quartz crystallization environments is reflected by trace-element compositional variations, which can be used to distinguish between different source sediments. Trace elements that are incorporated into the quartz lattice form corresponding paramagnetic centers (impurity centers, such as Al and Ti centers), which can be detected using the electron spin resonance (ESR) method. However, whether the quartz impurity center ESR signal intensity (quartz ESR-SI) can be used for quartz sediment provenance tracing remains uncertain. In the present study, five present-day (modern) fluvial sediments from the Songhua, Yellow, Yangtze, Huai, and Pearl rivers in China and eight ancient fluvial sand lenses from the Yichang Gravel Layer (YGL) located in the middle Yangtze River were sampled for major- and trace-element determinations by ICP-OES and ICP-MS for the purpose of provenance discrimination. A total of 1404 ESR spectra were also collected to evaluate the effect of γ-ray dose (varying from 50 to 50 000 Gy) on quartz ESR-SI to establish the relationship between quartz element contents and quartz ESR-SIs and thereby to assess the potential utility of quartz ESR-SI for sediment provenance analysis. Results indicate that: (1) quartz collected from the different studied locations can be distinguished by element contents; (2) the quartz Al center ESR-SI increases with increasing γ-ray dose from 50 to 50 000 Gy; (3) the quartz Ti center ESR-SI increases within a γ-ray dose of 10 000 Gy and decreases beyond 10 000 Gy; (4) quartz Al and Ti center ESR-SIs are closely related to the contents of Al and Ti in quartz; and (5) a plot of quartz Ti center ESR-SI vs. Al center ESR-SI using data for a γ-ray dose range of 4000–7000 Gy is the best indicator of fluvial sediment provenance using the ESR method.

Keywords: Source-to-sink system, provenance tracing, quartz, electron spin resonance (ESR), Al center, Ti center