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Spatial variation of radiogenic heat production related to the crystalline rock types in the western Himalaya-Karakoram region of Pakistan

Muhammad Anees[1], Jonas Kley[1], Bernd Leiss[1], Bianca Wagner[1], and Mumtaz Muhammad Shah[2]
[1]Department of Structural Geology and Geodynamics, Georg-August-Universität Göttingen, 37077 Göttingen, Germany (muhammad.anees.pk@gmail.com)
[2]Department of Earth Sciences, Qauid-i-Azam University Islamabad, Pakistan

The western Himalaya-Karakoram region in northern Pakistan has such hydrothermal features as hot springs and alteration zones. The heat source for these features remains unclear, with suggested mechanisms including radiogenic heat production from minerals, frictional heating caused by shearing along faults, residual heat from Miocene plutonic intrusions, metamorphic heat caused by tectonic collision, and heat advection related to rapid exhumation. In this study, we provide a quantitative estimation of the radiogenic heat production of 158 locations from different crystalline lithologies exposed in the three distinct tectonic domains of the western Himalayan-Karakoram region, i.e., Nanga Parbat-Haramosh Massif, Kohistan-Ladakh Batholith, and Karakoram Batholith. The radiogenic heat production values are calculated from the concentrations of the uranium (ppm), thorium (ppm), and potassium (wt%), which are determined directly in the field using a portable gamma spectrometer on exposures of Proterozoic to Tertiary crystalline rocks. The radiogenic heat production in the Nanga Parbat-Haramosh Massif ranges between 0.72 and 18.46 μWm^{-3}, with mean and median values of 7.12 and 6.74 μWm^{-3}, respectively. Furthermore, Proterozoic gneisses, Tertiary granites, and pegmatites within the Nanga Parbat-Haramosh Massif have mean radiogenic heat production values of 7.86, 10.67, and 6.47 μWm^{-3}, respectively. The radiogenic heat production in the Kohistan-Ladakh Batholith ranges between 0.42 and 5.16 μWm-3, averaging at 2.49 μWm^{-3} with the highest mean of 3.68 μWm^{-3} in granites and lowest 0.74 μWm^{-3} in tonalites. The radiogenic heat production of the Karakoram Batholith ranges between 1.04 and 23.54 μWm^{-3} with a mean of 5.84 μWm^{-3} and a median of 4.45 μWm^{-3}. Within the Karakoram Batholith, the Tertiary granites have the highest mean radiogenic heat production of 11.17 μWm^{-3}, while the lowest mean radiogenic heat production of 2.86 μWm^{-3} is found in the Cretaceous diorites. Our results suggest that the Nanga Parbat-Haramosh Massif, which is composed of Proterozoic Indian plate basement rocks, has high concentrations of uranium, thorium, and potassium, and consequently a higher radiogenic heat production. This also correlates with similar high radiogenic heat-producing basement rocks exposed in southern India. The presence of high radiogenic heat production in Tertiary granites and pegmatites indicates mobilization and enrichment of incompatible uranium and thorium due to crustal evolution processes related to the Himalayan Orogeny. We suggest that high radiogenic heat

production in Proterozoic rocks may have contributed significantly to the enhanced heat flux in the active Himalayan Orogen.