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# Unlocking Proterozoic (U)HT Metamorphism in Assam-Meghalaya-Gneissic-Complex, Northeast India: New Constraints on Tectonic Evolution from U-Pb Zircon Geochronology and Phase Equilibria Modeling

**SHUVANKAR SAMANTARAY**[1], ANUJ GHOSH[1], SAIBAL GUPTA[2] AND WILLIAM KUMAR MOHANTY[2]

[1]INDIAN INSTITITE OF TECHNOLOGY KHARAGPUR
[2]Indian Institute of Technology Kharagpur

Understanding the timing and conditions of high-temperature (HT) to ultrahigh-temperature (UHT) metamorphism in the lower crust is critical for reconstructing Proterozoic geodynamics. However, UHT metamorphic records in the Proterozoic lower crust are rare due to later overprinting by high temperature/pressure metamorphism. Accurate determination of peak P-T conditions and their timing requires comprehensive phase equilibria modeling and precise geochronology to establish the P-T-t-D evolution of a terrane. The Central Domain (CD) of the Assam-Meghalaya Gneissic Complex (AMGC), exposed near Nongstoin town in the state of Meghalaya, NE India, preserves evidence of extreme thermal metamorphism (>900°C) in metapelites and two-pyroxene granulites. Phase equilibria modeling indicates peak metamorphic conditions of 930–980°C at 7–8 kbar, stabilizing the assemblage Grt-Opx-Kfs-Plg-Qz-Ilm-Melt in metapelites. Similarly, two-pyroxene granulites record Opx-Cpx-Plg-Ilm-Melt assemblages under comparable P-T conditions. While diagnostic UHT mineral assemblages are absent, robust thermobarometric constraints from two-feldspar thermometry (934°C) and Ti-in-zircon thermometry (924°C) confirm UHT condition. Zircon U-Pb geochronology (using LA-ICP-MS (QQQ) instrument) from metapelites yields a peak metamorphic age of 1631±21 Ma, with Ti-in-zircon temperatures correlating with UHT conditions. The Th/U ratios (>0.1) in zircon cores of the same age, coupled with oscillatory zoning, indicate crystallization from melt generated during UHT metamorphism. Chondrite normalized trace element patterns suggest crystallization of zircon in equilibrium with garnet, reinforcing the zircon's association with peak metamorphism. This study proposes that Proterozoic pelitic sediments were subducted to mid-lower crustal depths, triggering partial melting coeval with the intrusion of mafic dykes (now metamorphosed to mafic-granulite). These mafic intrusions likely acted as heat source, driving HT-UHT metamorphism during a Mid-Proterozoic orogenic event. Subsequent exhumation along N-S trending, east-dipping thrusts facilitated the emplacement of these high-grade rocks over the Western Domain, following a cooling-dominated retrograde P-T evolution.

This study provides the first robust evidence of Mid-Proterozoic UHT metamorphism in the AMGC, offering new insights into the thermal and tectonic evolution of the region in the context of Proterozoic supercontinent dynamics.