Speleothem Records of Monsoon Intensity: Evaluating Proxy Fidelity via Cave Process Monitoring in the Shillong Plateau, NE India

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The Indian monsoon delivers intense summer rainfall to southern Asia and so affects the survival of many millions of people, yet the underlying causes that determine its intensity on interannual to decadal timescales remain poorly understood. Climate modellers require a knowledge of how the distribution and intensity of the Indian summer monsoon (ISM) has varied through a range of timescales and to compare these variations with known astronomical and terrestrial cycles in order to identify the mechanisms that drive monsoon evolution.

Geochemical records of atmospheric processes, primarily rainfall and temperature, are preserved in carbonate formations formed within caves (speleothems); for example variations in oxygen isotopes provide a memory of the original oxygen-isotope composition of rainfall. Annual variations in speleothem growth, like those of tree rings, provide a record of temperature and rainfall, but interpretation of their oxygen-isotope record in terms of real climatic processes requires detailed knowledge of how the climate signal is passed from rainfall through the soil and groundwater system and into the cave, to be recorded as a stalagmite grows from the dripwater. Our primary objective is to obtain pilot data to improve understanding of processes that transfer and modify the $\delta^{18}O$ climate signal via the precipitation-soil-karst-speleothem system. Using proven cave monitoring techniques developed in Gibraltar (Mattey and others, 2008) we are employing both oxygen- and carbon-isotope proxies that reflect climatic variations and we hope to decipher profiles of trace-elements such as Mg, Sr and P that record processes in the soil and bedrock.

The Shillong plateau of NE India captures the early rainout of the ISM air mass moving north from the Bay of Bengal. The plateau is a fragment of Indian crystalline basement overlain by a Late Proterozoic-Cambrian cover sequence, uplifted as a rigid pop-up structure between 8-14 Ma, in response to the India-Asian collision and continued convergence (Clark and Bilham, 2008). Tertiary deposits from the southern plateau include the Late Paleocene Lakadong carbonates, a 200-m sequence of hard nummulitic limestone that hosts a labyrinth of speleothem-rich caves distributed in an E-W sequence along the southern plateau (Jauhri and Agarwal, 2001). A recent study of Shillong rainfall (Breitenbach and others, 2010) has established a strong seasonal variation in $\delta^{18}O$ reflecting changing water-vapour source dynamics. During the summer monsoon, depleted $\delta^{18}O$ (average = -7.16) reflect marine sources from the Arabian Sea and Bay of Bengal, whereas pre-monsoon values ($\delta^{18}O$ = -2.41) reflect recycled continental moisture. Post-monsoon values are extremely depleted ($\delta^{18}O$ = -11.78) indicating an increased runoff component from the flooded Ganges-Brahmaputra catchments. This strong seasonal variation provides a geochemical signature for assessing changing monsoon intensity through time.

Since this study exploits the potential of speleothems for proxy-mapping past precipitation intensity in the core of the South Asian Summer monsoon it requires close monitoring of the relationship between the cave environment, groundwater chemistry and surface climate in order to quantify atmospheric processes back through time. During a field campaign in January 2010 we have identified a promising site for climate research near Cherrapunjee (Krem Mawmluh) from which we have recovered suitable speleothem deposits and dripwater samples and have installed monitoring equipment within the cave to record diurnal temperature and humidity changes, established strategies for monitoring variations in air composition on a monthly basis and, on the surface, have installed a soil-sampling site and weather station with a view to providing robust linkage between underground and surface conditions throughout the year. Currently we are establishing isotopic profiles through the speleothems and are embarking on a U-series dating programme to identify the time period represented by the proxy.

Our study will generate new information on tropical carbonate processes, fundamental to the quantitative interpretation of speleothem climate records, leading to the development of reliable geochemical proxies as a measure of the changing temperatures and intensities of the monsoon. Depending on the time interval recorded by speleothem growth we believe that this work will provide precisely dated quantitative meteorological records over centennial timescales and so provide a vital land-based record of variations in the Indian monsoon during the Holocene.

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Cite as: Mattey, D.P., Harris, N.B.W., Ahmad, T., Mipun, B.S., Mawlong, A. and Diengdoh, G., 2010, Speleothem Records of Monsoon Intensity: Evaluating Proxy Fidelity via Cave Process Monitoring in the Shillong Plateau, NE India, *in* Leech, M.L., and others, eds., Proceedings for the 25th Himalaya-Karakoram-Tibet Workshop: U.S. Geological Survey, Open-File Report 2010-1099, 2 p. [http://pubs.usgs.gov/of/2010/1099/mattey/].