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Anoop Kumar Singh

High Resolution Palaeoclimatic Changes in Selected Sectors of the Indian Himalaya by Using Speleothems

Past Climatic Changes Using Cave Structures

Doctoral Thesis accepted by
the Kumaun University, Uttarakhand, India

Springer

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Supervisor's Foreword

The Himalaya not only influences the rainfall pattern in India but also obstructs the path of the cold winds coming from the north because of altitude and location. The Inner Asian high-pressure systems and winter Westerlies are main components of the Himalayan climate, and a combined impact of rainfall, latitude, and altitude mainly affects the climate pattern. The region mainly experiences two seasons, i.e., summer (June to September) and winter (October to May). The Indian Summer Monsoon (ISM) decreases toward northwest India where Western Disturbances (WDs) play a major role in the annual precipitation. Therefore, the role of the WDs cannot be overlooked while using any archive or proxy for the past climatic changes in the Indian Himalaya. Taking this into account as well as knowing that the high-resolution palaeoclimatic records are scarce from the Indian Himalaya, Anoop Kumar Singh was given an assignment on high-resolution past climatic changes in selected sectors of the Indian Himalaya employing cave speleothems, particularly for the last ~15 ka period and undoubtedly the results should be very helpful to develop the models for ISM variability and WDs through an improved understanding of the monsoon–climate interaction.

The doctoral thesis encompasses study of six cave stalagmites, chronology of which was constructed on the basis of 35 U/Th and 5 AMS dates. Other proxies used were SEM analysis, XRD, and Mg/Ca ratio in order to differentiate calcite from aragonite, in addition to about 1500 samples for $\delta^{18}O$ and $\delta^{13}C$ isotopes for reconstructing past precipitation model. Three major events were identified, e.g., Older Dryas (OD), Bølling–Allerød (BA) period, and Younger Dryas (YD) at ca. 14.3–13.9, 13.9–12.7, and 12.7–12.2 ka BP, respectively. While comparing NW Himalayan record with Central Himalaya, there appears a similar trend in general but a shift in the duration of YD event, proving that the past climate of these two sectors also does not co-vary. The study also showed a gradual reduction in the precipitation from 4.0 ka BP onward for about a millennium with a peak arid period between 3.2 and 3.1 ka BP—a period correlated with fall of the Harappan–Indus civilization which finally collapsed due to severe scarcity of water reserves at 3.1 ka BP.

Considering very high variability in the $\delta^{18}O$ and $\delta^{13}C$ values, Anoop believes that the precipitation in the Himalayan foothills was a result of two sources of moisture and therefore he suggests that the WDs contributed significantly in the total rainfall during the Holocene period in the Indian Himalaya. This must be a reason for anti-correlation in the climatic pattern from Mid-Holocene onward between Himalaya and Peninsular India, the former received substantial precipitation from WDs.

Interestingly, the LIA in the Indian Himalaya was wetter compared to that in the post-LIA period. This is because during ISM break conditions, the moisture winds moved directly from the south to the Himalayan foothills and the WDs extended to the southern edge of the Tibet Plateau. As a result, during this period, the Himalayan southern slopes received high precipitation than the core monsoon zone.

I was deeply impressed by Anoop's excellent and matchless depth of understanding of the Holocene climatic process. During the doctoral programme, he visited several well-known laboratories in India and abroad as well as attended several training programmes to get skilled in this subject, refine his research, and get exposed to variety of climate archives and proxies.

Nainital, India
August 2017

Prof. B. S. Kotlia

Parts of this thesis have been published in the following journal articles:

1. Kotlia BS, Singh AK, Zhao J, Duan W, Tan M, Sharma AK, Raza W (2017) Stalagmite based high resolution precipitation variability for past four centuries in the Indian Central Himalaya: Chulerasim cave re-visited and data re-interpretation. Quaternary International 444 (A): 35–43
2. Kotlia BS, Singh AK, Sanwal J, Raza W, Ahmad SM, Joshi LM, Sirohi M, Sharma AK, Sagar N (2016) stalagmite inferred high resolution climatic changes through Pleistocene-Holocene transition in Northwest Indian Himalaya. Journal of Earth Science and Climate Change 7:3 http://dx.doi.org/10.4172/2157-7617.1000338
3. Kotlia BS, Singh AK, Joshi LM, Dhaila BS (2015) Precipitation variability in the Indian Central Himalaya during last ca. 4,000 years inferred from a speleothem record: Impact of Indian Summer Monsoon (ISM) and Westerlies. Quaternary International 371: 244–253
4. Joshi LM, Kotlia BS, Ahmad SM, Wu C-C, Sanwal J, Raza W, Singh AK, Shen C-C, Long T, Sharma AK (2017) Reconstruction of Indian monsoon precipitation variability between 4.0 and 1.6 ka BP using speleothem $\delta^{18}O$ records from the Central Lesser Himalaya, India. Arabian Journal of Geosciences http://dx.doi.org/10.1007/s12517-017-3141-7

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Nainital, India
August 2017

Anoop Kumar Singh

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Abbreviations

$\delta^{18}O$	Stable oxygen isotope ratio ($^{18}O/^{16}O$) in a sample relative to that in a standard
$\delta^{13}C$	Stable carbon isotope ratio ($^{13}C/^{12}C$) in a sample relative to that in a standard
AMS	Accelerator Mass Spectrometry Radiocarbon Dating
ASM	Asian Monsoon System
BA	Bølling–Allerød
EASM	East Asian Summer Monsoon
EDS	Energy Dispersive X-ray Analysis
ENSO	El Niño–Southern Oscillations
GNIP	Global Network of Isotopes in Precipitation
IOD	Indian Ocean Dipole
ISM	Indian Summer Monsoon
ITCZ	Inter-Tropical Convergence Zone
LIA	Little Ice Age
LLJ	Low-Level Jet streams
Mg/Ca	Magnesium/Calcium ratio
NAO	North Atlantic Oscillation
OD	Older Dryas
SEM	Scanning Electron Microscope
U/Th	Uranium–Thorium dating
XRD	X-ray Diffraction
WDs	Westerlies or Western Disturbances
YD	Younger Dryas