

Springer Theses

Recognizing Outstanding Ph.D. Research

Aims and Scope

The series “Springer Theses” brings together a selection of the very best Ph.D. theses from around the world and across the physical sciences. Nominated and endorsed by two recognized specialists, each published volume has been selected for its scientific excellence and the high impact of its contents for the pertinent field of research. For greater accessibility to non-specialists, the published versions include an extended introduction, as well as a foreword by the student’s supervisor explaining the special relevance of the work for the field. As a whole, the series will provide a valuable resource both for newcomers to the research fields described, and for other scientists seeking detailed background information on special questions. Finally, it provides an accredited documentation of the valuable contributions made by today’s younger generation of scientists.

Theses are accepted into the series by invited nomination only and must fulfill all of the following criteria

- They must be written in good English.
- The topic should fall within the confines of Chemistry, Physics, Earth Sciences, Engineering and related interdisciplinary fields such as Materials, Nanoscience, Chemical Engineering, Complex Systems and Biophysics.
- The work reported in the thesis must represent a significant scientific advance.
- If the thesis includes previously published material, permission to reproduce this must be gained from the respective copyright holder.
- They must have been examined and passed during the 12 months prior to nomination.
- Each thesis should include a foreword by the supervisor outlining the significance of its content.
- The theses should have a clearly defined structure including an introduction accessible to scientists not expert in that particular field.

More information about this series at <http://www.springer.com/series/8790>

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

Author

Dr. Anoop Kumar Singh
Centre of Advanced Study (CAS)
in Geology
Kumaun University
Nainital, Uttarakhand
India

Supervisor

Prof. B. S. Kotlia
Centre of Advanced Study (CAS)
in Geology
Kumaun University
Nainital, Uttarakhand
India

ISSN 2190-5053

Springer Theses

ISBN 978-3-319-73596-2

<https://doi.org/10.1007/978-3-319-73597-9>

ISSN 2190-5061 (electronic)

ISBN 978-3-319-73597-9 (eBook)

Library of Congress Control Number: 2017962981

© Springer International Publishing AG 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ 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 $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ 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 $\delta^{18}\text{O}$ records from the Central Lesser Himalaya, India. *Arabian Journal of Geosciences* <http://dx.doi.org/10.1007/s12517-017-3141-7>

Acknowledgements

For me, doing the research work was a real lifelong experience. This thesis is a crop of helping hands and support of a number of individuals. Foremost, I am extremely grateful to Prof. B. S. Kotlia for supervising the thesis and for being the driving force behind the present study. His cosmic supervision, motivation, support, and appreciation in every way was unforgettable.

I would like to convey my sincere thanks to Prof. A. K. Sharma, Head, Department of Geology, Kumaun University, Nainital for providing me the departmental facilities. I sincerely thank Prof. Santosh Kumar, Dean, Faculty of Science for his fruitful suggestions. I am pleased in recording my sincere gratitude to Director, CSIR-National Geophysical Research Institute, Hyderabad for providing the laboratory and other necessary facilities during the analytical procedures. My heartiest thanks to Prof. Augusto Mangini, University of Heidelberg (Germany) for providing most of the U/Th dates.

I gratefully acknowledge Dr. Lalit M. Joshi for his multiple help, emotional support, and constant backup that cannot be expressed in words. I am highly indebted to Mr. Bachi S. Dhaila for his kind support and encouragement during my research period. It is my great pleasure to express my sincere gratitude to Dr. Syed Masood Ahmad, Mr. Netramani Sagar, Mr. Waseem Raza, Mr. Tabish Raza from NGRI, Hyderabad, and Dr. Mahjoor Lone (presently at National Taiwan University Taipei, Taiwan) for their generous help during sample analysis. In addition, I express my sincere thanks to G. Suseela, Sadia Farnaaz, Shiva, Shivasis, and Santosh from NGRI, Hyderabad for helping me during the isotopic analysis. I am beholden to Prof. D. C. Pande (Registrar and Chief Warden Kumaun University, Nainital) for moral support and help in various ways in completing the thesis. I am also obliged to the ISRO, Ahmedabad for financial assistance. Additionally, I am also grateful to the MoES (MoES/P.O./Geosci/43/2015), New Delhi for the financial help during later half of my research period.

Nainital, India
August 2017

Anoop Kumar Singh

Contents

1	Introduction	1
1.1	Indian Summer Monsoon (ISM) Variability	2
1.2	Origin of Monsoon over Indian Subcontinent	4
1.2.1	Dynamic Theory	4
1.2.2	Thermal Theory	4
1.2.3	Jet Stream Theory	5
1.3	Important Teleconnections with ISM Variability	6
1.3.1	El Niño-Southern Oscillations (ENSO)	6
1.3.2	North Atlantic Oscillations (NAO)	7
1.3.3	Indian Ocean Dipole (IOD)	8
1.4	Himalayan Climate and Its Difference from Core Monsoon Zone	8
1.5	ISM and WDs in Himalaya	9
1.6	Previous Palaeoclimatic Research in Brief in Indian Himalaya and Adjoining Areas	10
	References	14
2	Speleothems and Climate	21
2.1	Cave Structures	21
2.2	Formation of Speleothems	23
2.3	Ideal Stalagmites for Palaeoclimatic Study	25
2.4	Limitations in Speleothem Research	25
2.5	High Precision Uranium-Series Dating	26
2.5.1	Oxygen Isotopes in Speleothems	26
2.5.2	Carbon Isotopes in Speleothems	27
2.5.3	Trace Elements and Mineralogy	28
2.6	Speleothem Research in India	28
2.6.1	Stalagmite Records from China and Nearby Areas	29
2.7	Objectives of the Present Study	31
	References	31

3	Studied Speleothems and Methodology	39
3.1	Description and Geology of Cave Sites	39
3.2	Meteorological Data Around Cave Sites	45
3.3	Methodology Adopted in the Present Study	46
3.3.1	U/Th Dating	46
3.3.2	AMS Dating	47
3.3.3	$\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ Isotopes	49
3.3.4	Petrography and SEM	50
3.3.5	Abbreviations of Studied Cave Stalagmites	50
	References	51
4	Results	53
4.1	Kalakot (KL-3) Stalagmite	53
4.1.1	Age/Depth Model	53
4.1.2	Hendy Test Results	53
4.1.3	Mineralogy and Growth Rate	55
4.1.4	Isotopic Results	58
4.2	Sainji (SA-1) Stalagmite	59
4.2.1	Age/Depth Model	59
4.2.2	Drip Water	61
4.2.3	Mineralogy	61
4.2.4	Isotopic Results	61
4.3	Chulerasim (CH-1) Stalagmite	63
4.3.1	Age/Depth Model	63
4.3.2	Hendy Test Results	65
4.3.3	Mineralogy and Growth Rate	66
4.3.4	Laminae Counting	67
4.3.5	Isotopic Results	67
4.4	Dharamjali (DH-1) Stalagmite	69
4.4.1	Age/Depth Model	69
4.4.2	Mineralogy and Growth Rate	69
4.4.3	Isotopic Results	72
4.5	Tityana (TCS) Stalagmite	73
4.5.1	Age/Depth Model	73
4.5.2	Hendy Test Results	73
4.5.3	Mineralogy	73
4.5.4	Isotopic Results	76
4.6	Borar (BR-1) Stalagmite	77
4.6.1	Age/Depth Model	77
4.6.2	Hendy Test Results	79
4.6.3	Isotopic Results	80
	References	83

- 5 Summary and Conclusion 85**
 - 5.1 Pleistocene to Holocene Transition (16.2–9.5 Ka BP) 85
 - 5.2 Mid Holocene—Present (4 Ka BP—Present) 88
 - 5.3 Conclusion 95
 - References 97
- Annexure A 103**
- Annexure B 111**
- Annexure C 119**
- Annexure D 131**
- Annexure E 135**
- Annexure F 139**

Abbreviations

$\delta^{18}\text{O}$	Stable oxygen isotope ratio ($^{18}\text{O}/^{16}\text{O}$) in a sample relative to that in a standard
$\delta^{13}\text{C}$	Stable carbon isotope ratio ($^{13}\text{C}/^{12}\text{C}$) 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