JOGAMAYA DEVI COLLEGE

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92, Shyama Prasad Mukherjee Road, Kolkata 700026 and
5A, Rajeswar Dasgupta Road, Kolkata 700026

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☺ PLEASE CONSIDER THE ENVIRONMENT BEFORE PRINTING THIS VOLUME

EDITORS

Dr. Debopam Acharya

Dr. Debopam Acharya is presently working as an Assistant Professor in the Department of Zoology, Jogamaya Devi College, Kolkata. He received his Ph. D from Jadavpur University, Kolkata, in 2009. He worked under the mentorship of Dr. Tarun K. Dhar at the Indian Institute of Chemical Biology (CSIR), Kolkata, on "Improved immunoassay strategies for the determination of mycotoxins and steroid hormones". His knowledge in the field of research has spawned several original research articles in the area of diagnostic immunology, published in reputed international journals. His research interest includes immunochemistry, high throughput analytical device development, and invertebrate immunology.

Dr. Soma Mandal

Dr. Soma Mandal is presently working as an Assistant Professor in the Department of English, Jogamaya Devi College, Kolkata. Her doctoral thesis was on Indigenous Roots of Ecofeminism in India. Her area of interests includes Eighteenth Century British Fiction, Ecocriticism, Ecofeminism and Postcolonial Studies.

Dr. Kaushik Kiran Ghosh

Kaushik Kiran Ghosh is an Associate Professor in the Department of Geology, Jogamaya Devi College, Kolkata. He received his bachelor's degree in Geology from the Presidency College, Kolkata and his master's and Ph.D. degree in Geology from the University of Calcutta, Kolkata. Dr. Ghosh has been engaged in teaching for around 25 years. His research fields cover major areas in geochemistry, petrology and ore geology with special emphasis on iron ore.

MEMBERS OF THE EDITORIAL BOARD

Dr. Sushree Chakraborty

Dr. Sushree Chakraborty is an Assistant Professor in the Department of Sanskrit at Jogamaya Devi College, Kolkata. A persevering student throughout her life, she received 'The President of India Medal for General Proficiency' in 2003. She was awarded with Ph.D degree from Jadavpur University in 2013. She enjoys spending her leisure with books, plants and her children. Dr. Chakraborty is currently the Joint Convenor of Research Committee, Jogamaya Devi College.

Dr. Bhaskar Ghosh

Dr. Bhaskar Ghosh is presently working as an Assistant Professor in the Department of Geology at Jogamaya Devi College, Kolkata. His areas of interest include the analyses of field structures and microstructures of deformed rocks, and the studies of the compositions, structures and socio-economic applications of clay minerals. He received Ph.D. degree from the University of Calcutta for his research on stratigraphy and tectonics of Precambrian rocks of the Singhbhum Craton, Eastern India. Dr. Ghosh is currently the Joint Convenor of Research Committee, Jogamaya Devi College.

Piali Mondal

Piali Mondal is an Assistant Professor in the Department of English at Jogamaya Devi College. She is currently pursuing her Ph.D on "Violence as Dialogue in Early Germanic Literature" in Department of English, Jadavpur University. Her areas of interest include Medieval European Literature, Queer Studies, Graphic Novels (Manga and Manhwa, in particular), and Food History.

PUBLISHER

Dr. Srabani Sarkar

Dr. Srabani Sarkar, Principal of Jogamaya Devi College, has an experience of 25 years of student interaction. She received her Ph.D. on Fuzzy Mathematics in 2012. Working is her favourite pastime. She loves to read too. She has a very amicable and congenial personality.

FROM PRINCIPAL'S DESK

Jogamaya Devi College has long tradition of organizing Seminars, Special Lectures, Invited Talks where renowned professors and research scholars of different universities and educational institutions are invited to express their thoughts on current trends of interdisciplinary and multidisciplinary topics. Unfortunately, many such enlightening speeches got lost in oblivion due to lack of scope of preservation.

It is of great delight that Jogamaya Devi College Research Committee has taken the initiative to recover and preserve such speeches given by speakers during different seminars / webinars organized by college in the form of E-Book the very first volume of which is going to be published in January, 2023. We hope that this endeavour will continue and such E-Booked-Speeches would continue to make readers speechless.

With thanks
Principal

FROM THE RESEARCH COMMITTEE, JOGAMAYA DEVI COLLEGE

The research Committee, Jogamaya Devi College gladly announces the publication of its first-annual seminar volume, titled *Jogamaya Devi College Multidisciplinary Seminar Volume 1, 2021 – 2022*. This is the first ever attempt of the committee to preserve the knowledge disseminated through the seminars, colloquiums and invited lectures organised by various departments and statutory bodies our college. Some of these academic discourses were the specialised lectures describing the state-of-the-art researches and developments in the emerging fields of various disciplines. Others were for a general audience, to spread awareness on different important medical, environmental, and socio-economic issues. In both cases, we have requested the speakers to submit an article on the subject, which can be used for the future references of the intended readers. Such articles are expected to help the students of the present and also of the future to select the fields for specialisation in their higher studies, inspire them to explore various new fields of researches, and encourage discussions between the teachers and students of different subjects that may be rewarding for all.

In the present age, the most critical economic, environmental and social challenges ask for a multidisciplinary approach of researches, for which the students and the budding researchers should be equipped with holistic and multidisciplinary education. However, since the present status of our college as an affiliated institution does not allow us to introduce a flexible, multidisciplinary curriculum, we have to explore other ways for this purpose. This volume is a humble contribution of the Research Committee to this end, which gives the students an opportunity to explore the disciplines other than those they are pursuing. To make their work easier, the basic ideas of all the articles have been explained in the introductory notes given with them, which are expected to help the students of humanities to explore the latest researches on earthquake or climate change, and those studying physical sciences and earth sciences would not have much difficulties to understand the articles of biological sciences and vice versa.

This is the seventh electronic book featuring the articles of different disciplines published by the committee so far. But in contrast to its six predecessors, the articles given here are not reviewed by specialist academicians and researchers, neither do they highlight a common theme. This first attempt of ours could not fulfil some of our objectives, and the articles of a substantial number of academic discourses could not be published here due to some unavoidable circumstances. The committee has therefore decided to include in the seminar volume of the next academic session the article we had missed in the previous session. If we can collect more articles for the next volume, we will try to organise it in a different way to make it more useful to the intended readers.

The Research Committee is grateful its members, *Dr. Kaushik Kiran Ghosh, Dr. Debopam Acharya*, and *Dr. Soma Mandal,* who were the editors of this volume. Sincere thanks to all our respected resource persons for submitting the articles, and all the teachers of our college who have written the introductory notes. All these teachers are the members of the editorial board of this volume. The publisher of this e-book, our respected Principal, *Dr. Srabani Sarkar*, deserves special thanks for her guidance and cooperation in all the stages of this work.
Finally, we thank all our esteemed colleagues for their continued encouragement and help, and hope for their continued support in all our future endeavours.

Sushree Chakraborty
and
Bhaskar Ghosh,
Joint Convenors,
Research Committee,
Jogamaya Devi College

FROM THE EDITORS' DESK

A great while ago the world begun, / With hey, ho, the wind and the rain,
But that's all one, our play is done, / And we'll strive to please you every day.
William Shakespeare

Symposiums, seminars, musings - all are integral parts of academia to keep its spirit vibrant and living. Jogamaya Devi College with its motto 'আত্ম দীপ ভব' has always endeavoured to enkindle the lamp of learning through academic interrogations articulated in various seminars, courses and workshops. In order to preserve the invaluable knowledge generated in these academic discourses, Jogamaya Devi College Research Committee proposed to publish a seminar volume each year. This volume, comprising the lectures delivered in the 2021-2022 academic years, is our first attempt to achieve that aim. We are forever indebted to the distinguished researchers and academicians who with their lectures have enriched us all and once more have taken pains to etch their thoughts in letters.

The volume is enriched with articles from departments of Sanskrit, English, Zoology and Geology. As envisaged originally this issue was to be over flooded with papers since 2021-22 academic session witnessed a plethora of seminars organised by all departments. But due to time constraint all papers cannot be submitted. However, the idea of publishing a second issue is also germinating so that all can find a forum for outreaching a wide range of readers.

The papers have been arranged according to the chronology of the dates of the seminars, preceded by an introductory note. Dr Gangadhar Kar's paper 'ন্যায়দর্শনের দৃষ্টিতে কারণ' (Analysing Causes from the Perspective of *Nyaya* Philosophy) illuminates theories of cause and effects in the light of Nyaya Philosophy. This lecture was delivered on April 05, 2022 as a part of Asha Gupta Endowment Lecture organized by the department of Philosophy. Dr. Chandreyee Goswami Chakrabarti's article 'Role of Earth – Scientists in Earthquake Studies' preserves her online lecture on several aspects of earthquake studies delivered on April 21, 2022. The article 'A Review on Recent Trends in Fish Immunology Elucidating the Innate and Adaptive Immune System in Fish' records the lecture by Dr. Subharthi Pal delivered on May 12, 2022. This article uniquely unveils different perspectives of fish immunology. Mr. Animesh Sinha in his paper 'সুন্দরবনে লবণাম্বু উদ্ভিদের কৃত্রিম সৃজন ও তার প্রভাব' (An Analytical Study of the Impact of Artificial Cultivation of Mangroves in Sundarban) foretells the danger that underlies the artificial cultivation of Mangroves in Sundarban. This lecture was delivered on June 05,2022 in a seminar to celebrate World Environment Day. The article 'Transpose Schistosity: A Conspicuous Structure in Geology' records the lecture delivered by Dr Chandrabali Mukhopadhyay on June 9, 2022. This article highlights the transposition of schistosity and can be informative for those with special interests on structural geology and metamorphic petrology. Dr Angana Mitra delivered her paper titled '"We wol been at oure

large": Chaucer, the Wife of Bath, and Medieval Womanhood' in an online seminar organized by the department of English on June 20, 2022.Her paper uniquely interrogates how Geoffrey Chaucer's Wife of Bath's Tale in The Canterbury Tales can posit as a feminist discourse addressing the plurality of his time. The article " Unravelling the Quaternary Climactic History: A Speleothem based Multiproxy Approach" by Sm Dipanwita Sengupta focuses the climactic variation of the Quaternary Period, and the application of speleothems for paleoclimactic reconstruction- a reflection of her investigation on climactic studies which she shared with students and teachers in an online lecture held on September 06, 2021.

We sincerely thank our Honourable Principal for her support and encouragement. The contribution of the convenors of the Research Committee is gratefully acknowledged, without their engagements and guidance this endeavour could not be materialised. A heartfelt gratitude for all our colleagues at Jogamaya Devi College who were always with us in this new journey.

Debopam Acharya
Soma Mandal
Kaushik Kiran Ghosh
(Editorial Team)

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শ্রী গঙ্গাধর কর ন্যায়াচার্য

যাদবপুর বিশ্ববিদ্যালয়ের দর্শনবিভাগের প্রথিতযশা অধ্যাপক ড. গঙ্গাধর কর মহোদয় ২০২২ সালের ৫ই এপ্রিল যোগমায়া দেবী কলেজ-কর্তৃক আয়োজিত 'Asha Gupta Endowment Lecture'-এ 'ন্যায়দর্শনের দৃষ্টিতে কারণ' শীর্ষক একটি অসাধারণ উপস্থাপনে ন্যায়দর্শনের মতানুসারে কার্য-কারণতত্ত্বের পর্যালোচনা করেছিলেন।

কার্যের সাপেক্ষতা সর্বসম্মত। কার্য যদি নিজ উৎপত্তির জন্য কাউকে অপেক্ষা না করতো, তাহলে আকাশাদির ন্যায় কার্যও সর্বদা অস্তিত্বশীল হত। সহেতুক কার্যপদার্থ নিজ উৎপত্তির জন্য যাকে অপেক্ষা করে, তা কারণ। কারণ এক অভিন্ন হলে কার্যও একই হবে, ভিন্ন হবে না। কিন্তু বাস্তবে কার্যের ভিন্নতাই দৃষ্ট হয়। কারণ ভিন্ন ভিন্ন হলে কার্যও ভিন্ন ভিন্ন হয়। সুতরাং কারণের ভিন্নতা স্বীকার করা ছাড়া গত্যন্তর নেই। এই প্রবন্ধে প্রথমে কারণের লক্ষণ এবং পরে ফলোপাধায়ক ও স্বরূপযোগ্যভেদে কারণের দ্বৈবিধ্য আলোচিত হয়েছে। অত্যন্ত সঙ্গতভাবে অন্যথাসিদ্ধের প্রসঙ্গ-ও এই আলোচনায় এসেছে। সর্বদা কার্যের পূর্ববর্তী হলেও যে বস্তুগুলিকে কারণরূপে স্বীকার করা যায় না, সেইগুলিকে অন্যথাসিদ্ধ বলা হয়ে থাকে। অন্যথাসিদ্ধের লক্ষণ এবং ভেদও এই প্রবন্ধের অন্যতম আলোচ্য বিষয়।

সুশ্রী চক্রবর্তী
সংস্কৃত বিভাগ, যোগমায়া দেবী কলেজ।

ন্যায়দর্শনের দৃষ্টিতে কারণ

শ্রী গঙ্গাধর কর ন্যায়াচার্য
অধ্যাপক
দর্শন বিভাগ, যাদবপুর বিশ্ববিদ্যালয়, কলকাতা

নিখিল বিশ্বসংসারে পৃথিবী, জল, পাহাড়, নদী, বৃক্ষ, লতা, ঘট, পট প্রভৃতি বস্তু প্রতিনিয়ত উৎপত্তি ও বিনাশের ধারায় প্রবহমান। যা উৎপন্ন হয়, তা উৎপত্তির পূর্বে যেমন থাকে না, তেমনি যা বিনষ্ট হয়, তা বিনাশের পরে থাকে না। সুতরাং বলা যায়, উৎপত্তি ও বিনাশের মধ্যবর্তিকালে যার অবস্থিতি, তা কার্য। এভাবে উৎপত্তির পূর্বে ও বিনাশের পরে কার্য না থাকায়, কার্যমাত্রই কাদাচিৎক। যা কোনওকালে বিদ্যমান, কোনওকালে অবিদ্যমান – অর্থাৎ কদাচিৎ থাকে, কদাচিৎ থাকে না – এরূপ পদার্থই কাদাচিৎক বা কার্য। কোন একটি ঘট উৎপন্ন হয়ে কিছুকাল থাকে ও পরে বিনষ্ট হয় বলে ঘটাদি উৎপত্তি ও বিনাশের মধ্যবর্তিকালেই সত্তাবান হয়। এরূপ কাদাচিৎক পদার্থমাত্রেই সাপেক্ষ অর্থাৎ কোনও কিছুকে অপেক্ষা করে। কার্যপদার্থ নিজ উৎপত্তির জন্য যাকে অপেক্ষা করে, তা কারণ।

কার্যের সাপেক্ষতা সর্বসম্মত। কার্য যদি নিজ উৎপত্তির জন্য কাউকে অপেক্ষা না করতো, তাহলে আকাশাদির ন্যায় কার্যও সর্বদা অস্তিত্বশীল হত। কিন্তু লোকব্যবহার থেকে আমরা জানতে পারি, কার্যপদার্থ সর্বদা থাকে না, কিছুকাল অবস্থান করে মাত্র। মনে হতে পারে, ঘট-পটাদি পদার্থ উৎপত্তির পূর্বে কেন উৎপন্ন হয় না। উত্তর – কার্যটি নিজ উৎপত্তির জন্য যাকে অপেক্ষা করে, সেই কারণকূট বা কারণসমূহ সমবহিত হয়নি বলে। যখন কার্যবিশেষের সমূহ কারণ সমবহিত হয়, তার ঠিক পরক্ষণে কার্যটি উৎপন্ন হয়। সুতরাং 'কার্যং সহেতুকং কাদাচিৎকত্বাৎ' অর্থাৎ কার্যমাত্রই সহেতুক, যেহেতু কার্যে কাদাচিৎকত্ব রয়েছে।

যাই হোক, জগতের অসংখ্য কার্য স্বীকার করলে তাদের নিজ নিজ কারণকেও স্বীকার করতে হবে। জগতের এই কার্যকারণভাবপ্রবাহ অনাদি।

মনে হতে পারে, সমস্ত কার্যের প্রতি এক অভিন্ন কারণ স্বীকৃত হলে অসুবিধা কোথায়? যেমন একটি প্রদীপশিখা যুগপৎ বাতি পোড়ায়, অন্ধকার দূর করে এবং বস্তুকে প্রকাশ করে। এস্থলে আমরা এক অভিন্ন কারণ হতে তিনটি কার্যের উৎপত্তি প্রত্যক্ষ করি।

এর উত্তরে আচার্যগণ বলেন, জগৎ বিচিত্র – জাগতিক পদার্থসমূহ বৈচিত্রে ভরা। কার্যের এই যে বৈচিত্র, তা কারণের বৈচিত্র ছাড়া সম্ভব নয়। কারণ ভিন্ন ভিন্ন হলে কার্যও ভিন্ন ভিন্ন হয়। একটি বইয়ের যা কারণ, তা কখনও পায়সের কারণ হতে পারে না। কারণ এক অভিন্ন হলে কার্যও একই হবে, ভিন্ন হবেই না। বাস্তবে কিন্তু কার্যের ভিন্নতাই দৃষ্ট হয়। সুতরাং কারণের ভিন্নতা স্বীকার করা ছাড়া গত্যন্তর নেই। যাই হোক, কার্যের কারণকে অস্বীকার করার উপায় নেই। এখন আমরা কারণের দার্শনিক আলোচনায় প্রবৃত্ত হচ্ছি –

লক্ষণ ও প্রমাণের দ্বারা বস্তু সিদ্ধ হওয়ায় প্রথমে কারণের লক্ষণনিরূপণ একান্ত আবশ্যক। কারণের লক্ষণপ্রসঙ্গে আচার্যগণ বলেছেন, 'অনন্যথাসিদ্ধ-নিয়ত-পূর্বভাবিত্বং কারণত্বম্'। অর্থাৎ যার বিদ্যমানতা ঘটাদি কার্যোৎপত্তির পূর্বে নিশ্চিত হবে এবং যে অন্যথাসিদ্ধ হবে না, সেই-ই সেই কার্যের প্রতি কারণ। যেমন, ঘটকার্যের প্রতি কপাল-কপালিকা, দণ্ড, চক্র, কুম্ভকার প্রভৃতি; পটকার্যের প্রতি তন্তু, বেমা, তন্তুবায় প্রভৃতি। ঘটাদি কার্যোৎপত্তির পূর্বে দণ্ড, চক্র প্রভৃতি নিয়তভাবেই উপস্থিত থাকায় এগুলিই ঘটকার্যের প্রতি কারণ।

কারণলক্ষণে 'পূর্বভাব', 'নিয়ত' ও 'অন্যথাসিদ্ধ' – এই পদত্রয় বিশেষ তাৎপর্যপূর্ণ। পটের উৎপত্তিকালে সহসা কোনও রাসভ সেখানে উপস্থিত হলে রাসভ পটের পূর্বভাবী হয়ে যায় বটে, কিন্তু সর্বত্র পটোৎপত্তির অব্যবহিত পূর্বে রাসভের উপস্থিতি নিয়ত না হওয়ায় পটকার্যের প্রতি রাসভকে আর কারণ বলা যাবে না। 'নিয়ত' শব্দের অর্থ হল নিয়ম বা ব্যাপ্তিযুক্ত। ব্যাপ্তিসম্বন্ধের আশ্রয় হওয়ায় ব্যাপ্য যেমন ব্যাপ্তিযুক্ত হয়, তেমনি ব্যাপ্তিসম্বন্ধের নিরূপক হওয়ায় ব্যাপকও ব্যাপ্তিযুক্ত হয়। কারণলক্ষণঘটক 'নিয়ত' শব্দের অর্থ ব্যাপক। যেখানে ঘট-পটাদি কার্য উৎপন্ন হয়, সেখানে যদি রাসভ অবশ্যই পূর্বভাবী হত, তাহলে রাসভ ঘটাদির ব্যাপক হত। বাস্তবে তা হয় না বলে রাসভকে ঘট-পটাদির প্রতি কারণ বলা যায় না। লক্ষণীয়, কার্যতাবচ্ছেদকসম্বন্ধে কার্যাধিকরণে কার্যোৎপত্তির অব্যবহিত পূর্বক্ষণে কারণতাবচ্ছেদকসম্বন্ধে যে পদার্থের অভাব পাওয়া যায় না, সেই পদার্থ ঐ কার্যের প্রতি ব্যাপক অর্থাৎ নিয়ত-পূর্ববৃত্তি হয়। কার্যতাবচ্ছেদকসম্বন্ধে কার্য যেখানে থাকে, কারণতাবচ্ছেদকসম্বন্ধে কারণও সেখানে থাকে বলে কার্য-কারণের সামানাধিকরণ্য সম্ভব হয়। ঘটরূপ কার্য নিজ আশ্রয়ীভূত কপালে সমবায় সম্বন্ধে থেকে উৎপন্ন হয় বলে কার্যতাবচ্ছেদকসম্বন্ধ হয় সমবায়। আর ঐ আশ্রয়ে অর্থাৎ কপালে, কপাল তাদাত্ম্যসম্বন্ধে থেকে ঘটের উৎপাদক হয় বলে কারণতাবচ্ছেদকসম্বন্ধ হল তাদাত্ম্য। তাই বলা হয়, 'যত্র সমবায়েন কার্যং, তত্র তাদাত্ম্যেন কারণম্'।

কোনও কার্যের প্রতি কোনও পদার্থ নিয়তপূর্ববৃত্তি হলেও সব সময় তাকে কারণ বলা যায় না, যেমন ঘটের প্রতি দণ্ডরূপ। ঘটের প্রতি দণ্ড নিয়তপূর্ববৃত্তি হওয়ায় দণ্ডগত রূপ ও দণ্ডগত জাতি অবশ্যই ঘটের পূর্ববৃত্তি হবে। তথাপি ঘটকার্যের প্রতি দণ্ডের রূপ প্রভৃতি অন্যথাসিদ্ধ হওয়ায় কারণ হতে পারে না। অনুরূপভাবে তন্তুর রূপ প্রভৃতি পটের প্রতি অন্যথাসিদ্ধ হওয়ায় কারণ নয়, যেহেতু তন্তুর রূপ পটের রূপকে উৎপন্ন করে হীনবল অর্থাৎ উপক্ষীণ হওয়ার ফলে পটের প্রতি কারণ হতে পারে না। পটরূপের প্রতি তন্তুরূপের কারণতা স্বীকার করার পরেও যদি পটকার্যের প্রতি তার কারণতা স্বীকার করা হয়, তাহলে কল্পনাগৌরব অনিবার্য – যা দোষরূপে গণ্য।

ঘটকার্যের প্রতি দণ্ড কারণ হলেও দণ্ডরূপ বা দণ্ডত্বজাতি অন্যথা সিদ্ধ হওয়ায় কারণ হতে পারে না। এখানেও সেই গৌরবদোষ বর্তমান। কিন্তু নৈয়ায়িকগণের প্রাণ হল কল্পনালাঘব। বিষয়টি পরিষ্কার করা হচ্ছে –

আচার্যগণের মতে অন্যথাসিদ্ধিকল্পনারমূলে রয়েছে লাঘবচিন্তা। এই লাঘব শরীরহেতুক, উপস্থিতিহেতুক এবং সম্বন্ধহেতুক ভেদে তিন প্রকার। শরীরহেতুক লাঘব যথা – প্রত্যক্ষের প্রতি মহত্ত্ব এবং অনেকদ্রব্যসমবেতত্বএই উভয় কারণরূপে উপস্থিত হলেও, অনেকদ্রব্যসমবেতত্ব অপেক্ষা মহত্ত্ব শরীরকৃত (আকারগতভাবে) লঘু হওয়ায় কারণ হয়, অনেকদ্রব্যসমবেতত্ব আকারে গুরু হওয়ায় কারণ না হয়ে অন্যথাসিদ্ধ হয়। উপস্থিতিহেতুক লাঘব যথা – উৎপত্তিকালীন দ্রব্য গুণহীন হওয়ায় যে দ্রব্যে দ্বিতীয় ক্ষণে গন্ধ, রূপ, স্পর্শ প্রভৃতি গুণ উৎপন্ন হবে, সেই দ্রব্যের উৎপত্তিক্ষণে (প্রথম ক্ষণে) সেই দ্রব্যে গন্ধসমবায়িকারণে গন্ধপ্রাগভাবের ন্যায় রূপ-রসাদিরও প্রাগভাব থাকে। কাজেই গন্ধ নামক কার্যের উৎপত্তির পূর্বক্ষণেই ঐ দ্রব্যে গন্ধপ্রাগভাবের ন্যায় রূপপ্রাগভাব, রসপ্রাগভাব প্রভৃতি নিয়তপূর্ববৃত্তি হয়। তথাপি গন্ধরূপ কার্যের প্রতি গন্ধপ্রাগভাবই কারণ, যেহেতু গন্ধকার্যের উপস্থিতির পরেই গন্ধপ্রাগভাবের উপস্থিতি শীঘ্র অর্থাৎ সর্বপ্রথম হয়। অভাবজ্ঞানের প্রতি প্রতিযোগীর জ্ঞান কারণ হওয়ায় এবং গন্ধাত্মক প্রতিযোগীর জ্ঞান থাকায় গন্ধপ্রাগভাবেরই প্রথম উপস্থিতি অর্থাৎ বোধ হয়। রূপাদির প্রাগভাব প্রথম উপস্থিত না হওয়ায় গন্ধকার্যের নিয়তপূর্ববৃত্তি হয়েও অন্যথাসিদ্ধ হয়। পাকজগন্ধস্থলে যদিও রূপ এবং গন্ধের যুগপৎ উৎপত্তি হয় বলে গন্ধপ্রাগভাবের ন্যায় রূপপ্রাগভাবও যুগপৎ উপস্থিত হয়, তথাপি অপাকজগন্ধস্থলে গন্ধপ্রাগভাবই প্রথম উপস্থিত হয়। সম্বন্ধহেতুক লাঘব যথা – ঘটকার্যের প্রতি দণ্ড 'স্বজন্যভ্রমিমত্তা' সম্বন্ধে কারণ হয়। কিন্তু দণ্ডত্ব কিংবা দণ্ডরূপাদি 'স্বাশ্রয়জন্যভ্রমিমত্তা' সম্বন্ধে কারণ হয়। এই উভয় সম্বন্ধের মধ্যে 'স্বজন্যভ্রমিমত্তা' সম্বন্ধ লঘু হওয়ায় দণ্ডই ঘটের প্রতি কারণ, দণ্ডত্বাদি অন্যথাসিদ্ধ। এই কারণে আচার্যগণ বলেন, যা অন্যথা অর্থাৎ অন্যভাবে লঘুনিয়তপূর্ববর্তিভিন্নত্বরূপে সিদ্ধ, তা অন্যথাসিদ্ধ। লঘুনিয়তপূর্ববৃত্তি হল কারণ, তদ্ভিন্ন

অন্যথাসিদ্ধ। অনেকের মতে, প্রস্তাবিত কার্যের উৎপত্তি ব্যতীতও যা প্রমাণসিদ্ধ বা প্রতিষ্ঠিত, তা অন্যথাসিদ্ধ।

ভাষাপরিচ্ছেদ গ্রন্থে পাঁচ প্রকার অন্যথাসিদ্ধির কথা বলা হলেও এই পাঁচ প্রকারকে অন্নম্ভট্ট তিনটি ভাগে ভাগ করে তিন প্রকার অন্যথাসিদ্ধির কথা বলেছেন। এতে পদার্থের তারতম্য ঘটেনি। ঘটাদি কার্যবিশেষের প্রতি কারণতাবচ্ছেদক দণ্ডত্বাদি ধর্ম, কারণের গুণ অর্থাৎ দণ্ডরূপাদি, আকাশ, কুলালপিতা (কুম্ভকারের পিতা) এবং রাসভ – এই পাঁচ প্রকার অন্যথাসিদ্ধ সর্বসম্মত। ভাষাপরিচ্ছেদে এই পাঁচটিকে পৃথক পৃথক ভাবে দেখানো হয়েছে। তবে ভাষাপরিচ্ছেদকার নিজেই বলেছেন, উক্ত পাঁচ প্রকার অন্যথাসিদ্ধকে এক কথায় একটি বলেও স্বীকার করা যায়। তাই তিনি স্বকৃত সিদ্ধান্তমুক্তাবলীতে পঞ্চম অন্যথাসিদ্ধের দ্বারাই অন্য চার প্রকার অন্যথাসিদ্ধকে গতার্থ (সংগ্রহ) করেছেন। অন্নম্ভট্ট তিন প্রকার অন্যথাসিদ্ধির কথা বলেছেন। তিনি উল্লিখিত পাঁচটির প্রথম ও দ্বিতীয়কে প্রথমের, তৃতীয় ও চতুর্থকে দ্বিতীয়ের এবং পঞ্চমকে তৃতীয়ের অন্তর্গত করেছেন। অন্নম্ভট্টের মতে কারণতাবচ্ছেদক ধর্ম ও কারণের গুণ প্রথম অন্যথা সিদ্ধ, আকাশ ও কুলালপিতা দ্বিতীয় অন্যথাসিদ্ধ, আর রাসভ তৃতীয় অন্যথাসিদ্ধ।

সিদ্ধান্তমুক্তাবলীকারের মতে যে কার্যের প্রতি কারণের পূর্ববর্তিতা, যে ধর্মপুরস্কারে জ্ঞাত, সেই কার্যের প্রতি সেই ধর্মটি প্রথম অন্যথাসিদ্ধ। যেমন – ঘটের প্রতি দণ্ডত্ব। দণ্ডত্ব দণ্ডেই থাকে, দণ্ডভিন্নে থাকে না। তাই দণ্ডের দ্বারাই দণ্ডত্বের ঘটপূর্ববৃত্তিত্ব জানা যায় বলে দণ্ডত্ব ঘটকার্যের প্রতি অন্যথাসিদ্ধ। যার কোনও কার্যের প্রতি স্বতন্ত্র অর্থাৎ কারণনিরপেক্ষ অন্বয়-ব্যতিরেক নেই, কিন্তু নিজ কারণকে অপেক্ষা করেই অন্বয়-ব্যতিরেক জ্ঞাত হয়, সেই পদার্থটি দ্বিতীয় অন্যথাসিদ্ধ। যেমন – ঘটের প্রতি দণ্ডের রূপ। দণ্ডনিরপেক্ষভাবে ঘটকার্যের প্রতি অন্বয়-ব্যতিরেক না থাকায় দণ্ডের রূপ ঘটকার্যের প্রতি অন্যথাসিদ্ধ। যদিও দণ্ডত্ব ও দণ্ডরূপ উভয়ই দণ্ডকে অবলম্বন করেই ঘটকার্যের প্রতি অন্বয়-ব্যতিরেকশালী হয়, তথাপি দণ্ডত্ব নিজের আশ্রয় দণ্ডকে এবং দণ্ডরূপ নিজের সমবায়িকারণ দণ্ডকে অবলম্বন করে জনক হয় বলে এরূপ ভেদবশতঃ এরা পৃথক অন্যথাসিদ্ধরূপে পরিগণিত হয়। প্রকৃত ঘটাদি-কার্যভিন্ন অন্য কোনও কার্যের প্রতি পূর্ববর্তিত্ব জেনেই যার ঘটাদি কার্যের প্রতি পূর্ববর্তিত্ব জ্ঞাত হয়, সেই পদার্থটি সেই ঘটাদি কার্যের প্রতি তৃতীয় অন্যথাসিদ্ধ। অনুমানপ্রমাণের দ্বারা শব্দের সমবায়িকারণরূপে আকাশের অস্তিত্ব সিদ্ধ হয়। কাজেই আকাশের একমাত্র পরিচয় হল শব্দসমবায়িকারণত্ব বা শব্দজনকতা। এই শব্দসমবায়িকারণত্ব বা শব্দপূর্ববর্তিত্বরূপ আকাশত্বের জ্ঞানের অনন্তর আকাশে ঘটপূর্ববর্তিত্ব গৃহীত হয় বলে ঘটের প্রতি আকাশ অন্যথাসিদ্ধ। কুলালপিতা কুলালপিতৃত্বরূপে ঘটের প্রতি অন্যথাসিদ্ধ হলেও কুলালত্বরূপে ঘটের কারণ। কুলালপিতায় ঘটজনক কুলালের পূর্ববর্তিত্ববোধের পর

ঘটপূর্ববর্তিত্বের জ্ঞান হয় বলে, যাতে প্রথমে কার্যজনকের পূর্ববর্তিত্বজ্ঞান হয়ে পরে কার্যের পূর্ববর্তিত্বের জ্ঞান হয়, তা সেই কার্যের প্রতি অন্যথাসিদ্ধ – এরূপ বলতে হবে।

সাধারণতঃ কারণের কারণ চতুর্থ অন্যথাসিদ্ধ হলেও কার্যজনক ব্যাপারের যে জনক, তা কিন্তু কার্যের প্রতি অন্যথাসিদ্ধ নয়। যেমন প্রথমে কুঠারে ছেদনের পূর্ববর্তিত্বজ্ঞানের পর কাষ্ঠ-কুঠার সংযোগরূপ ব্যাপারে ছেদনের পূর্ববর্তিত্বের জ্ঞান হওয়ায়, কুঠার ছেদনের প্রতি জনকের জনক হলেও অন্যথাসিদ্ধ নয়। অনুরূপভাবে যাগের স্বর্গসাধনত্ব নির্বাহের জন্য যাগের ব্যাপার অপূর্ব (অদৃষ্ট) কল্পিত হওয়ায় ঐ অপূর্বের দ্বারা যাগ অন্যথাসিদ্ধ হয় না। তাই বলা হয়, ব্যাপারের দ্বারা ব্যাপারী অন্যথাসিদ্ধ হয় না।

বিশ্বনাথের মতে অবশ্যক্লপ্ত-নিয়তপূর্ববর্তিভিন্নই হল পঞ্চম অন্যথাসিদ্ধ। সুতরাং যা কার্যবিশেষের প্রতি অবশ্যক্লপ্ত অর্থাৎ লঘু ও নিয়তপূর্ববর্তী – তা কারণ, তদ্ভিন্ন সবই সেই কার্যের প্রতি অন্যথাসিদ্ধ। বিশ্বনাথ অন্যথাসিদ্ধকে পাঁচ প্রকার বললেও বস্তুতঃ তাঁর মতে অন্যথাসিদ্ধ মাত্র একটি। প্রাচীনমতে কারণরূপে সম্ভাবিত পদার্থগুলিকে অন্যথাসিদ্ধ বলা হলেও নব্যমতে কারণভিন্ন সব কিছুই অন্যথাসিদ্ধ।

আমরা যদি উক্ত কারণলক্ষণটিকে বিশেষভাবে পর্যবক্ষেণ করি, তাহলে বেশ কিছু সমস্যার উদ্ভব হবে। কারণের লক্ষণটি হল, 'অনন্যথাসিদ্ধত্বে সতি নিয়তপূর্ববর্তিত্বম্'। এক্ষেত্রে আপত্তি হতে পারে যে, কারণলক্ষণের বিশেষ্যাংশ 'নিয়তপূর্ববর্তিত্ব' নিষ্প্রয়োজন। যেহেতু কারণভিন্ন পদার্থমাত্রই অন্যথাসিদ্ধ হওয়ায় অন্যথাসিদ্ধভিন্ন সমস্ত পদার্থই কারণ হতে পারে। সুতরাং 'অন্যথাসিদ্ধত্বভিন্নত্বং কারণত্বম্' – এরূপ লঘু লক্ষণই শ্রেয়ঃ।

কিন্তু কারণের লক্ষণবিষয়ে এরূপ আপত্তি সঙ্গত নয়। যেহেতু একের প্রতি যা কারণ, তা অন্যের প্রতি অন্যথাসিদ্ধ হওয়ায় জগতের সমস্ত পদার্থই চালনীন্যায়ে অন্যথাসিদ্ধ হতে পারে। যেমন পটের কারণ তন্তু ঘটের প্রতি অন্যথাসিদ্ধ; আবার ঘটের কারণ দণ্ড পটের প্রতি অন্যথাসিদ্ধ। এভাবে জগতের সমস্ত পদার্থ ঘুরিয়ে-ঘুরিয়ে অন্যথাসিদ্ধ হয়ে যায় বলে অন্যথাসিদ্ধভিন্ন পদার্থ অপ্রসিদ্ধ। এমনকি কার্যমাত্রের প্রতি ঈশ্বর, ঈশ্বরেচ্ছা প্রভৃতি সাধারণ কারণ যে নয়টি, সেগুলিকেও অন্যথাসিদ্ধ করা যায়। ঘটাদি কার্যের প্রতি ঈশ্বর, ঈশ্বরেচ্ছা প্রভৃতি যথাক্রমে ঈশ্বরস্বরূপে ঈশ্বরেচ্ছাস্বরূপে সাধারণ হলেও দ্রব্যত্বরূপে ঈশ্বর কিংবা গুণত্বরূপে ঈশ্বরেচ্ছা কার্যমাত্রের প্রতি অন্যথাসিদ্ধ। সুতরাং বিশেষভাবে চিন্তা করলে বোঝা যায় স্বরূপে নয়টি সাধারণ

কারণ ছাড়া বিশ্বের সবকিছুই অন্যথাসিদ্ধ হওয়ায় তদ্ভিন্ন কারণরূপে কাউকে খুঁজে পাওয়া যাবে না।

কারণের সামান্যলক্ষণ এভাবে অপ্রসিদ্ধ হওয়ায় বিশেষ বিশেষ কার্যের কারণের লক্ষণেও 'অন্যথাসিদ্ধভিন্নত্ব' নিবেশ করা যাবে না। অর্থাৎ ঘটকার্যের প্রতি যা যা অন্যথাসিদ্ধ, সে সব অন্যথাসিদ্ধ পদার্থের প্রত্যেকটি হতে ভিন্ন যে বা যারা হবে, সে বা তারাই ঘটের প্রতি কারণ – এভাবেও কারণের লক্ষণ বলা যাবে না। কারণ ঘটকার্যের প্রতি জগতে কত সংখ্যক অন্যথাসিদ্ধ পদার্থ আছে, তা জানা স্বল্পজ্ঞ, স্বল্পায়ু মানুষের পক্ষে সম্ভব নয়। সুতরাং লক্ষ লক্ষ কোটি কোটি এই সব পদার্থগুলির প্রত্যেকটির ভেদজ্ঞানও ঈশ্বরভিন্ন মানুষের পক্ষে কখনও সম্ভব নয়, যেহেতু ভেদ বা অভাবজ্ঞানের প্রতি প্রতিযোগীর জ্ঞান কারণ। এই সব নানা অসুবিধার জন্য কেবল 'অন্যথাসিদ্ধভিন্ন' এরূপ না বলে 'নিয়তপূর্ববৃত্তিত্বে সতি অন্যথাসিদ্ধভিন্নত্বম্' এভাবে কারণের লক্ষণে নিয়তপূর্ববৃত্তিকে অন্যথাসিদ্ধের বিশেষণরূপে নিবেশ করে বলতে হবে – ঘটকার্যের প্রতি নিয়তপূর্ববৃত্তি অথচ অন্যথাসিদ্ধত্ববিশিষ্ট দণ্ডত্ব, দণ্ডরূপ, আকাশ, কুলালপিতা, রাসভ প্রভৃতি যে কটি অন্যথাসিদ্ধ আছে, তার প্রত্যেকটি হতে ভিন্ন দণ্ড, চক্র, কুম্ভকার, মৃত্তিকা প্রভৃতি হল ঘটের কারণ।

এভাবে 'নিয়তপূর্ববৃত্তিত্ব' নিবেশ করেও রক্ষা পাওয়া যাবে না, অর্থাৎ কারণলক্ষণটিকে দোষমুক্ত করা যাবে না। কারণ, নিয়তপূর্ববৃত্তি-অন্যথাসিদ্ধভিন্ন যেমন কারণগুলি হয়, তেমনি অসংখ্য অকারণ পদার্থও কারণলক্ষণাক্রান্ত হয়ে যায়। যেমন, ঘটকার্যের প্রতি অন্যথাসিদ্ধ যে পট, সেই পটও নিয়তপূর্ববৃত্তি হয়ে অন্যথাসিদ্ধ যে দণ্ডত্ব প্রভৃতি, তাদের থেকে ভিন্ন হওয়ায় ঘটকার্যের প্রতি কারণ হয়ে যায়।

এই সব অসুবিধা থেকে রক্ষা পাওয়ার জন্য কার্যবিশেষের কারণের লক্ষণে বলতে হবে, 'নিয়তপূর্ববৃত্তি-অন্যথাসিদ্ধিশূন্যত্বে সতি নিয়তপূর্ববৃত্তিত্বং কারণত্বম্'। লক্ষণে নিয়তপূর্ববৃত্তিত্বকে একবার বিশেষণের কুক্ষিতে নিবেশ করে পুনরায় একবার বিশেষ্যরূপে নিবেশ করতেই হবে। ফলে কারণলক্ষণটির অর্থ হবে – ঘটাদি বিশেষ কার্যের প্রতি নিয়তপূর্ববৃত্তি যে সব অন্যথাসিদ্ধ পদার্থ আছে, তা থেকে ভিন্ন হয়ে যারা নিয়তপূর্ববৃত্তি হবে, তারাই ঘটাদি কার্যের কারণ হবে। ঘটকার্যের প্রতি পট প্রভৃতি পদার্থগুলি নিয়তপূর্ববৃত্তি অথচ অন্যথাসিদ্ধ পদার্থসমূহ হতে ভিন্ন হলেও ঘটের প্রতি নিয়তপূর্ববৃত্তি না হওয়ায় পটাদিকে আর ঘটের প্রতি কারণ বলা যাবে না।

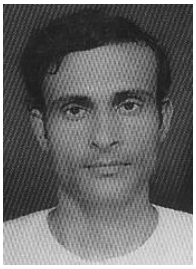
ফলোপধায়ক ও স্বরূপযোগ্যভেদে কারণ দ্বিবিধ। ফলের উপধায়ক অর্থাৎ জনক যে কারণ, তা ফলোপধায়ক কারণ। যে কারণ হতে ফল উৎপন্ন হয়েছে, সেই কারণই ফলোপধায়ক। 'কার্যাব্যবহিতপ্রাক্ক্ষণাবচ্ছেদেন কার্যসমানাধিকরণাভাবাপ্রতিযোগিত্বং ফলোপধায়কত্বম্', অথবা বলা যায়, 'অব্যবহিতপূর্বত্বসম্বন্ধেন ফলবিশিষ্টকারণত্বং ফলোপধায়কত্বম্'। যেমন ঘটকার্যের প্রতি ঘটোৎপত্তিস্থানে স্থিত দণ্ড।

কার্যোৎপাদনের যোগ্যতাশালী বস্তুই স্বরূপযোগ্য কারণ। 'কারণতাবচ্ছেদকধর্মবত্ত্বং স্বরূপযোগ্যত্বম্' অর্থাৎ যে ধর্মরূপে কোনও বস্তুতে কার্যের কারণতা স্বীকৃত হয়, সেই ধর্মযুক্ত বস্তুমাত্রই সেই কার্যের স্বরূপযোগ্য কারণ। যেমন ঘটকার্যের প্রতি দণ্ডত্বরূপে দণ্ডের কারণতা স্বীকার করা হয় বলে দণ্ডত্ববিশিষ্ট সমস্ত দণ্ডই ঘটের স্বরূপযোগ্য কারণ। ঘটকার্যের প্রতি অরণ্যস্থ দণ্ড হল স্বরূপযোগ্য কারণ, যেহেতু তার ঘটনির্মাণযোগ্যতা আছে। সুতরাং বলতে হবে, ফলের উৎপাদক না হলেও যাতে ফলোৎপাদনের যোগ্যতা আছে, তা সেই ফলের অর্থাৎ কার্যের স্বরূপযোগ্য কারণ। এই স্বরূপযোগ্য কারণ অনিত্য হলে পরবর্তিকালে ফলের উৎপাদক হতেও পারে, নাও হতে পারে। যদি ফলোৎপাদক হয়, তখন সে ফলোপধায়ক কারণরূপে গণ্য হবে।

লক্ষণীয়, শাস্ত্রে একটি নিয়ম আছে, 'নিত্যস্য স্বরূপযোগ্যত্বে ফলাবশ্যম্ভাবনিয়মঃ' অর্থাৎ নিত্যবস্তুতে স্বরূপযোগ্যতা থাকলে তা কোনও না কোনও দিন ফলোৎপাদন করবে। অতএব যে নিত্যবস্তুতে ফলোৎপাদনের সম্ভাবনাই নেই, তার স্বরূপযোগ্যকারণতা স্বীকার করা হয় না। যেমন, সুখ-দুঃখাদির সমবায়িকারণ আত্মা, কারণতাবচ্ছেদক ধর্ম আত্মত্ব। এই আত্মত্ব ধর্ম জীবাত্মার ন্যায় ঈশ্বরেও থাকায় ঈশ্বরে স্বরূপযোগ্যতা স্বীকার করতে হয়। অথচ ঈশ্বরের ধর্মাধর্মরূপ অদৃষ্টাদি না থাকায় ঈশ্বরে কখনও সুখাদির উৎপত্তি হতে পারে না। অতএব সুখাদির প্রতি তাঁর স্বরূপযোগ্যতা স্বীকার করা যায় না। এই কারণে অনেকে বলেন, আত্মত্ব জাতি কেবল জীবেই আছে, ঈশ্বরে নেই। স্বরূপযোগ্য হলে কদাচিৎ ফলোৎপত্তি অবশ্যম্ভাবী – এই নিয়ম অনিত্য বস্তু সম্বন্ধে বলা যায় না। কেন না, সহকারী কারণের সমবধানের পূর্বেই অনিত্য বস্তুটির বিনাশ ঘটতে পারে। অরণ্যের সমস্ত দণ্ডে ঘটের স্বরূপযোগ্যকারণতা থাকলেও সব দণ্ড ঘটোৎপাদক হয় না।

সাধারণ ও অসাধারণ ভেদে কারণকে আবার দু'ভাগে ভাগ করা যায়। ঈশ্বর, ঈশ্বরের জ্ঞান, ঈশ্বরের ইচ্ছা, ঈশ্বরের প্রযত্ন, দিক্, কাল, অদৃষ্ট, প্রাগভাব ও প্রতিবন্ধকাভাব – এই নয়টি যাবৎ কার্যের প্রতি কারণ হওয়ায় সাধারণ কারণ। এছাড়া বিশেষ বিশেষ কার্যের প্রতি কারণই অসাধারণ কারণ। যেমন ঘটের প্রতি মৃত্তিকা, পটের প্রতি সূত্র প্রভৃতি। অন্যভাবে সমবায়ী, অসমবায়ী ও

নিমিত্তভেদে কারণ আবার ত্রিবিধ। ঘটের প্রতি কপালদ্বয় সমবায়িকারণ, কপালদ্বয়সংযোগ অসমবায়িকারণ, এছাড়া কুম্ভকার, মাটি, ঈশ্বর, দণ্ড প্রভৃতি অবশিষ্ট সমস্ত কারণই নিমিত্তকারণ।



Dr. Gangadhar Kar Nyayacarya (শ্রী গঙ্গাধর কর ন্যায়াচার্য)

অবিভক্ত মেদিনীপুর (বর্তমান পশ্চিম মেদিনীপুর) জেলার অন্তর্গত মোহনপুর থানার অধীন আমরদা গ্রামে ড. গঙ্গাধর কর জন্মগ্রহণ করেন। যাদবপুর বিশ্ববিদ্যালয় থেকে সংস্কৃত অনার্সে প্রথম বিভাগে প্রথম স্থান এবং এম.এ.-তে সমগ্র কলা অনুষদে সর্বোচ্চ স্থান লাভ করে সতীশ চন্দ্র দে, গৌরীনাথ শাস্ত্রী প্রমুখের নামাঙ্কিত স্বর্ণপদক ও বিশ্ববিদ্যালয়-স্বর্ণপদক প্রাপ্ত হন। সর্বভারতীয় ন্যায়াচার্য পরীক্ষাতে-ও ইনি প্রথম স্থানের অধিকারী। ইনি রবীন্দ্রভারতী বিশ্ববিদ্যালয় থেকে শব্দবিজ্ঞানে (ভাষাদর্শনে) পি এইচ্.ডি. ডিগ্রি লাভ করেছেন। এতদ্ব্যতীত তর্কতীর্থ এবং ব্যাকরণতীর্থ উপাধিতে-ও ইনি ভূষিত। পণ্ডিতপ্রবর ড.গঙ্গাধর করের কর্মজীবনের সূচনা 'প্রাচ্যবাণী সংস্কৃত মহাবিদ্যালয়'-এ ন্যায়শাস্ত্রের অধ্যাপকরূপে। পরে ইনি 'প্রাচ্য শিক্ষা সদন'-এ ন্যায়াচার্যপদে যোগদান করেন। তারপর রবীন্দ্রভারতী বিশ্ববিদ্যালয়ের সংস্কৃত বিভাগে এবং সম্প্রতি যাদবপুর বিশ্ববিদ্যালয়ের দর্শন বিভাগে ইনি অধ্যাপনারত। বিখ্যাত দার্শনিক, প্রসিদ্ধ প্রাবন্ধিক ড.গঙ্গাধর করের অদ্যাবধি প্রকাশিত গ্রন্থগুলির মধ্যে '*মহাভাষ্যম্*', '*শব্দার্থসম্বন্ধ-সমীক্ষা*' ইত্যাদি বিশেষ উল্লেখের অপেক্ষা রাখে।

2 Role of Earth-Scientists in Earthquake Studies

Chandreyee Goswami Chakrabarti

The present state of knowledge does not enable us to predict the date or time of the future earthquakes accurately. The only way to evade (or at least, to decrease) the earthquake-induced losses of lives and properties therefore lies in the precise delineation of the earthquake-prone zones, where mass settlements and large constructions should be reduced. One of the major role of Earth Scientists is to demarcate such zones, and to categorize them based on their vulnerabilities to earthquakes. They also help in the proper land use planning of the earthquake-prone areas. Dr. Chandreyee Goswami Chakrabarti, Research Assistant of the Czech Academy of Sciences, Prague, has delivered an online lecture on April 21, 2022 to explain the role of the Earth Scientists in the studies of earthquake. The next article features the salient points of her lecture, in which the latest researches on earthquake are presented in a lucid, easily understandable manner. In the context of earthquake studies, the author has briefly explained the applications of a number of emerging branches of Earth Sciences, like tectonic geomorphology, interpretation of satellite imageries and aerial photographs, digital terrain model, paleoseismology, geochronology, low-temperature thermochronology, geophysical methods etc. The article is enriched with five diagrams, comprising some field photograph taken by the author, and a portion of a satellite imagery processed by her.

The students and researchers of geology, geography, geophysics, disaster management, and environmental studies will be able to enrich their knowledge on earthquakes with this highly informative article.

Bhaskar Ghosh
Department of Geology, Jogamaya Devi College

Role of Earth-Scientists in Earthquake Studies

Chandreyee Goswami Chakrabarti
Institute of Rock Structure and Mechanics, Prague

Earthquake is considered to be the worst natural hazard. As the time of the earthquake still cannot be predicted, neither people get time to escape it, nor can the government evacuate people from the affected area prior to the earthquake, as they can do nowadays very efficiently in case of cyclones or floods.

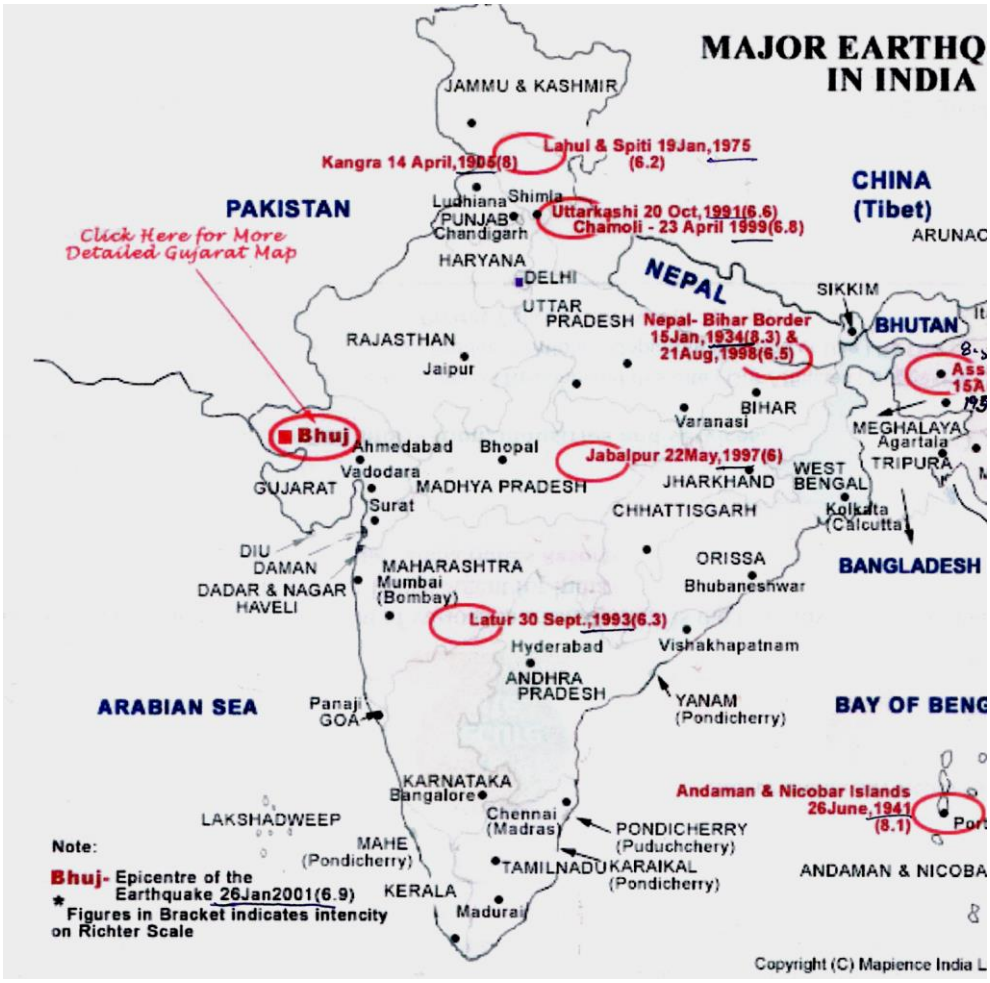


Figure 1: Major Earthquakes in India in recent years.
Source: https://crl.du.ac.in/Publication/E-Resources%20in%20Public%20Domain-Final/Geography/A-India%20Map/5.htm

An earthquake is the shaking of the surface of the earth due to the sudden release of energy in the earth's crust. As a result, seismic waves are created. The seismic activities in an area determine the type and intensity of the earthquake. The release of the accumulated elastic strain energy by the sudden rupture of the fault is the cause of the earthquake shaking.

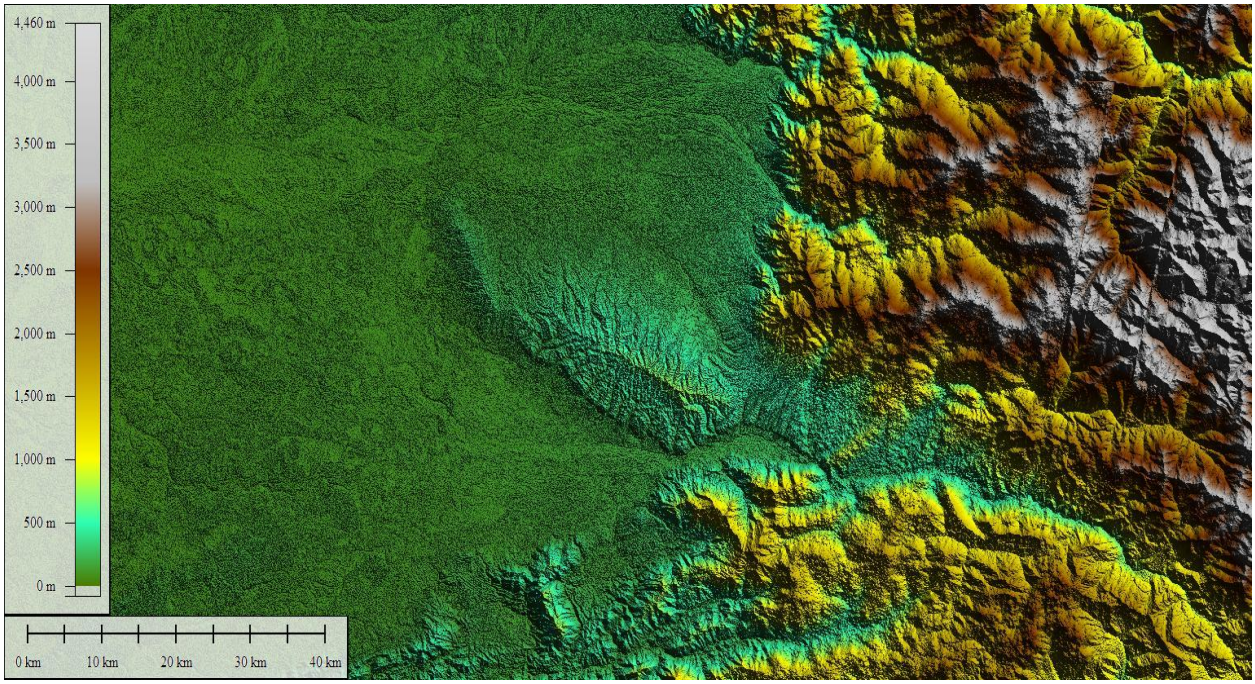


Figure 2: Digital Elevation Model of an area along the northeastern boundary of India.
Source: Prepared by the author, from Cartosat 1 stereo image in ERDAS imagine software and displayed in Global mapper software.

In India, some areas are much more prone to earthquakes than the others. As we all know that earthquakes are largely related to the plate boundaries and mountain building, the whole northern boundary of India including the Himalayan mountain region is prone to earthquakes (Figure 1). The northeastern boundary and the western boundaries are also places of many earthquakes due to the presence of plate boundaries between the Indian and Burmese plates and Indian and Arabian plates. The Andaman region is also very much vulnerable to earthquakes due to the presence of rifting plate boundary. The most intensive inland earthquake recorded so far in the world happens to be the 8.3 Mw Assam earthquake of 1950, which is related to Himalayan orogeny.

Earth Scientists have a great role in studying different aspects of earthquakes, their cause, effect, and most importantly their impact on human beings.

Although the exact date or time of future earthquakes cannot be predicted till now, but studying the past earthquakes can identify the vulnerable areas and hence can help in land use planning.

Tectonic Geomorphology is one such subject that has been developed a lot in the last fifty years in which earth scientists study the effect of earthquakes on the landforms. In other words, they can identify the landforms affected by earthquakes. The main objective of studying tectonic geomorphology is to use the landscape to establish tectonic conditions of surface uplift and surface deformation and to use tectonic information to predict landscape response. The relation between the climate and tectonic effect on the landform is also studied to understand the tectonic-climate coupling.

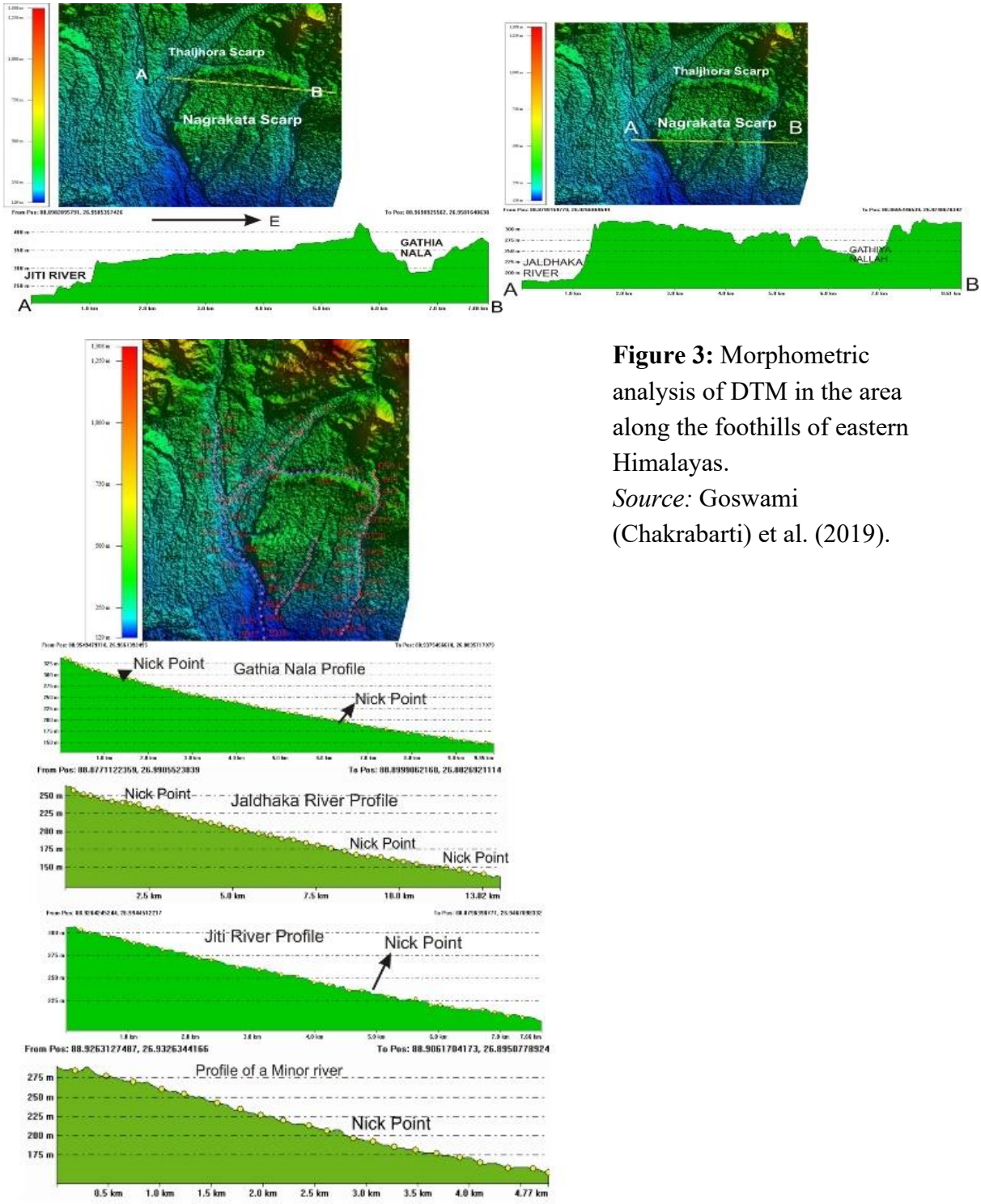


Figure 3: Morphometric analysis of DTM in the area along the foothills of eastern Himalayas.
Source: Goswami (Chakrabarti) et al. (2019).

Remote sensing data. e.g. satellite imageries, and aerial photographs play a major role in tectonic geomorphology. In recent years not only two-dimensional data but 3-dimensional data also developed a lot. One can get millimeter-scale resolution satellite images, and three-dimensional Digital Terrain Model (DTM) can be created from stereoscopic satellite images with centimeter-scale resolution (Figure 2). Earth scientists can identify and analyze the behavior of different geomorphic markers like glaciers, rivers, streams, terraces, fan surfaces, coastal dunes, etc. from these remotely sensed data and can create a detailed geomorphic map to show the earthquake-affected landforms. These maps are used for land-use planning,

building new bridges, roads, dams, etc. The lineaments, tilting of land surfaces, change of slopes in rivers, and anomalous slope changes of fan surfaces; all can be understood from these analyses. There are some good examples of such works from the foothills of the Eastern Himalayas along with other places (Figure 3).

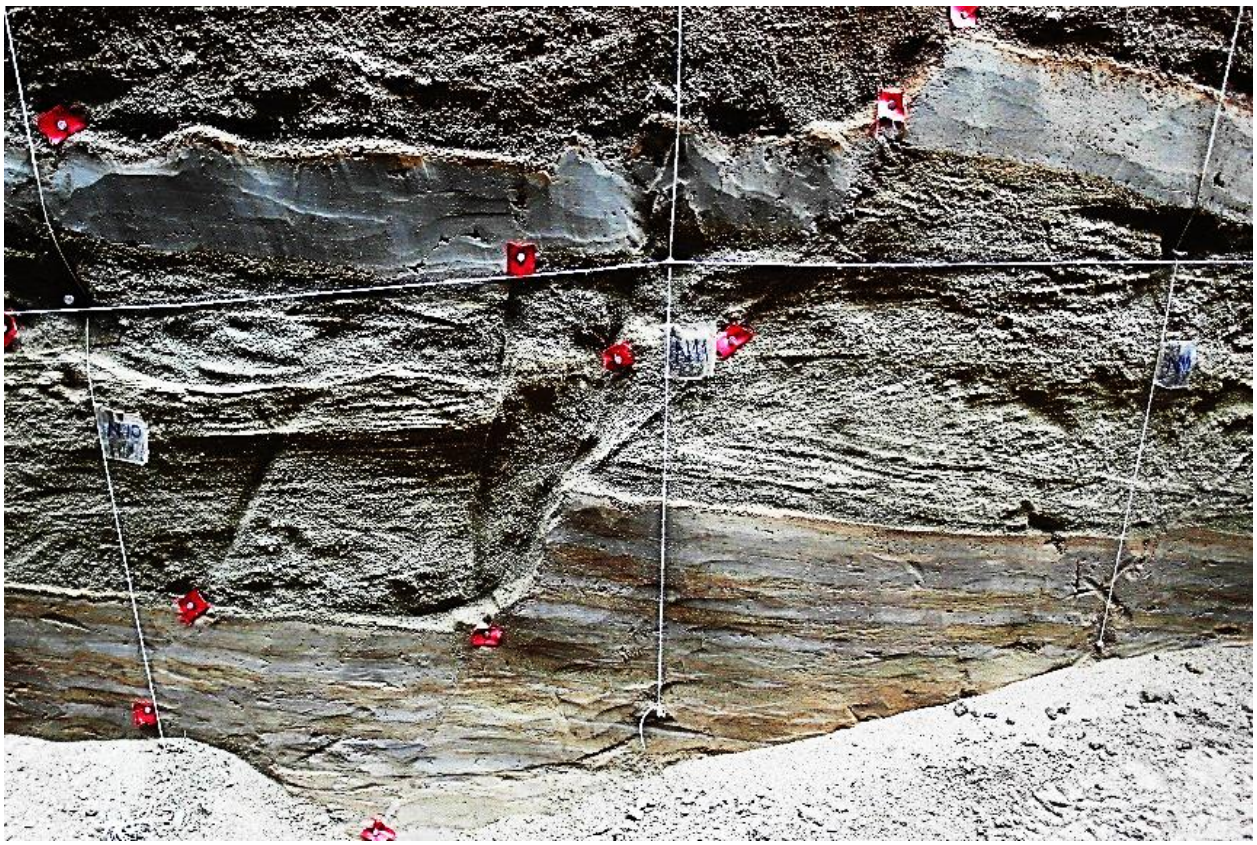


Figure 4: Displacement of strata along the fault plane in a trench in Kashmir.
Source: The photograph was taken by the author, from the trench in Kashmir.
Fieldwork was sponsored by: Institute of Rock Structure and Mechanics, Prague. Principal Investigator: Dr Hamid Sana.

Paleoseismology is a more intense way to study earthquakes. After identifying the earthquake-prone areas and the fault line, scientists try to find out the displacement of different strata along the fault plane and try to understand the kinematics of the fault plane through time. They often excavate trenches across the faults to identify and analyze their effects on the sedimentary rock record. It helps in identifying the recurrence interval of earthquakes on that fault (Figure 4).

Geochronology also plays an important role in earthquake studies. The historical earthquake events can be dated by C14 dates. In fact, the events up to 50 thousand years can be dated through the method if the sediment contains carbon. Optically Stimulated Luminescence (OSL) dating is another widely used dating process as it can be used with the sediments having quartz or feldspar which is easily available and the sediments of nearly 250 thousand years can be dated through this method (Figure 5).

Figure 5: Sampling for OSL geochronology.
Photo Courtesy: Dr Manoj Jaiswal, IISER Kolkata and author herself

Low-temperature thermochronology using zircon and apatite is another emerging method to know the upliftment rate across a thrust fault.

The present-day crustal movement is measured very efficiently through the Global Positioning System (GPS) and Global Navigation Satellite System (GNSS) geodesy. Scientists use both real-time GPS-GNSS data and post-processing GPS data to measure the differential ground movement and accumulation of stress over a certain time. Many aspects of earthquakes can be measured through GPS-GNSS survey. There are some GPS stations that are permanent on a fixed point in some critical process that measures crustal data continuously and is shared by scientists from different places. Along with that earth scientists use campaign mode GPS data in which the GPS is fixed on a fixed point across the identified fault lines for three to four days in six months of interval and calculate the change in ground position over that time.

Presently Interferometric Synthetic Aperture Radar (InSAR) data is used to identify the change in land use and land cover along with the vertical adjustment of the ground after an earthquake along with the GPS data.

Different geophysical methods like Ground Penetrating Radar (GPR), Electric Resistivity Tomography (ERT) are also used to identify the fault if it is near the surface. Although till now working with thrust faults is most complicated using these procedures and hence study of Himalayan tectonics remains to be a challenge to earth scientists.

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Dr. Chandreyee Goswami

Dr. Chandreyee Goswami is presently working as a Research Assistant in the Institute of Rock Structure and Mechanics, Czech Academy of Sciences, Prague. She was awarded Ph. D. from the University of Calcutta for her works on Active Faults and Crustal Deformation in parts of the Frontal Himalayas. Her other research interests include Paleoseismology, Remote Sensing, Geographic Information System, and low temperature thermochronology.

3 Introductory Note on: A Review on Recent Trends in Fish Immunology elucidating the Innate and Adaptive Immune System in Fish

Subharthi Pal

To sustain life every organism has had to interact with other organisms. Some of those interactions provide beneficial effects and some pose detrimental effects to the organism. Throughout our life we are exposed to a continuous stream of disease causing microorganisms such as bacteria, parasites, fungi and microbial particles such as viruses which have the ability to wreak havoc to our bodily processes. Without efficient protective machinery each of us soon succumbs to diseases caused by an array of pathogenic microorganisms or to the harmful effects of toxic substances produced by them. In the warfare with microbial intruders, humans and other vertebrates, including fishes have evolved multifaceted range of defensive measures collectively termed the immune system. Vertebrates are able to generate variety of cells and soluble molecules, capable of specifically recognizing and eradicating foreign invaders. The coordinated reaction of these cells and soluble molecules against infectious agents generates immune response. The Latin term immunis*, meaning "free from", is the origin of the English word immunity, which signifies protection from infectious diseases and can be categorized into two broad components. The primitive nonspecific component that generates innate immunity is a group of disease resistance mechanisms that can mount its effects on variety of pathogens. On the contrary, the specific component develops highly evolved adaptive immunity that portrays a high degree of specificity against a particular pathogen as well as the remarkable property of memory. Adaptive immune response against any foreign substance typically requires five to six days to get activated after its first exposure to that substance. Contact to the foreign substance some time in the future produces a memory response.*

As adaptive immune responses require some time to act, innate immunity provides the first line of defense during the emergency just after the host's exposure to a pathogen. In most cases, pathogens encountered by a healthy individual are readily eliminated within a few days by defense mechanisms of the innate immune system before they activate the adaptive immune system. These two immune systems do not function independently; rather operate as a highly interactive and cooperative system, producing a combined response more efficient than either could alone.

Dr. Subharthi Pal, an Assistant Professor in Zoology, Bhairab Ganguly College has spawned the comprehensive review article concentrating on the current trends in fish immunology, based on his online lecture, delivered during an Add-on Course organized for the students of Zoology of our college on May 12, 2022.

*The article starts with the aim to explain the reasons of increasing interest to study fish immunology besides higher vertebrates, choice of zebrafish (*Danio rerio*) as a model organism, robustness of innate immune system over adaptive immune system in fish and finally the concept of nano-delivery systems and nano-encapsulation as novel tools for immunomodulation.*

In next sections readers may find detailed information and scientific development about ontogeny of the immune system, organs involved to develop immunity, the cells, molecules and pathways involved to activate nonspecific and specific immunity in fish.

The author tried to deliver information on compounds introduced in fish through diet, whose pivotal objective is to augment innate immune system or specific defense mechanisms and therefore are important as preventive measures in pisciculture (the controlled breeding and rearing of fish). At the end of the review the author discussed the importance of nanoparticles as a new tool to deliver immustimulants and vaccines that target the immune system.

Hope, the review presented herein on fish immunology will not only impart knowledge to students and researchers of Biological Sciences, but also enrich those who are curious to know the immune system of animals.

Debopam Acharya
Department of Zoology, Jogamaya Devi College

A Review on Recent Trends in Fish Immunology elucidating the Innate and Adaptive Immune System in Fish

Subharthi Pal
Department of Zoology, Bhairab Ganguly College, Kolkata
subharthipal.cu@gmail.com

Abstract: Fish, as the first vertebrate group appearing in evolution after adaptive radiation during the Devonic period, still represent the most successful and diverse group of vertebrates. This heterogeneous group of organisms occupy an apparent crossroads between the innate immune response and the appearance of the adaptive immune response. The immune system of fish is very similar to vertebrates, although there are some important differences. Their structural complexity isles, potentially limiting the capability to generate fully functional adaptive immune responses against pathogen invasion. The ability of fish to mount successful immune responses with apparently more robust innate responses than that observed in higher vertebrates has been described in this review article. The components of the innate immune response are divided into physical, cellular and humoral factors and include humoral and cellular receptor molecules that are soluble in plasma and other body fluids. The lymphoid organs found in fish include the thymus, spleen and kidney. The aim of this review is to provide a detailed insight of the immune system in fish, including the ontogeny, mechanisms of unspecific and acquired immunity, action of some immunomodulators. Some recent trends in worldwide fish immunology research including nano-delivery systems and nano-encapsulation as novel tools for immunomodulation has also been discussed in the review article. Here we have also highlighted the advances in the application of nanoparticles to fish disease prevention including: the type of biomaterial, the type of immunostimulant or vaccine loaded into the nanoparticles, and how they target the fish immune system.

Keywords: Fish; immune response; nanoparticles; immunostimulation; immunomodulators; evolution.

1. Introduction:

Immune systems protect animals from threats by parasites, bacteria and viruses. Most of what we know today about the composition, function and regulation of the two fundamental branches of the immune system — innate immunity and adaptive immunity — comes from studies on mice and humans. However, recently there has been an increased interest in fish immunology for several reasons. For evolutionary biologists, fish immune systems provide important comparative outgroups for understanding the evolution of the immune system. Such comparisons should eventually lead to an increased understanding of general principles of immune system design. At the same time, fish immune systems are also interesting in their own right, as in fish very different mechanisms may have evolved as solutions to immunological problems. Additionally, there are practical reasons, as the cost of infections to aquaculture can be great, making failure of immunity a major risk for commercial fish farming. In biological research, several small fish species have increased in popularity as model organisms for developmental, physiological, and biomedical research.

Particularly prominent among these has been the zebrafish (*Danio rerio*), a small cyprinid teleost (Figure 1), which offers researchers the attractive combination of genetic tractability,

rapid ex vivo development, optical transparency, a genome sequencing and annotation project nearing completion, and a rapidly expanding resource of genetic and biochemical reagents including numerous mutant and transgenic lines.

Figure 1: Zebrafish (*Danio rerio*)

The study of immunology in aquatic organisms is as old as the immunology itself, as Metchnikoff's observations in the wounded larvae of starfish initiated his interest in the phagocyte and stimulated his exploration of the cellular basis of the interaction between an organism and invasions from its environment. In 1883, Elie Metchnikoff demonstrated that cells contribute to the immune state of an animal. He observed that certain white blood cells, which he termed phagocytes, were able to ingest (phagocytose) microorganisms and other foreign material. The active phagocytic cells identified by Metchnikoff were likely blood monocytes and neutrophils. He hypothesized these cells more active than serum components (Cell mediated Immunity), thus the major effector of immunity.

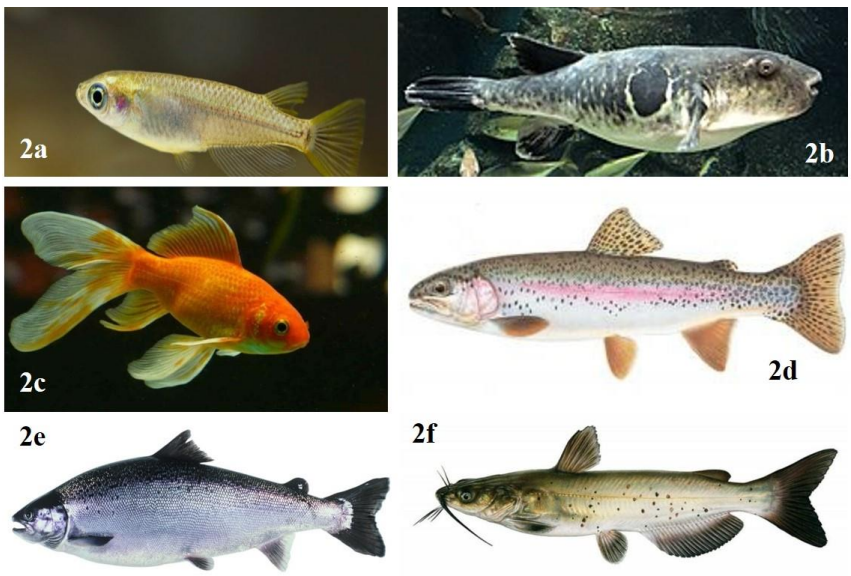

Figure 2: The study of immunology is now conducted in many other species of fish. 2a. Medaka (*Oryziaslatipes*), 2b. The pufferfish (*Takifugurubripes*), 2c. Goldfish (*Carassius auratus*), 2d. Rainbow trout (*Oncorhynchus mykiss*), 2e. Atlantic salmon (*Salmo salar*), 2f. Channel Catfish (*Ictalurus punctatus*).

The study of immunology is now conducted in many other species of fish, including other teleosts (Figure 2) employed in biological and genomic research, e.g., Medaka (*Oryziaslatipes*), the Pufferfish (*Takifugurubripes* and *Tetraodon nigroviridis*), Goldfish (*Carassius auratus*), and Rainbow trout (*Oncorhynchus mykiss*); other species are studied because of their value to the aquaculture industry, e.g., Atlantic salmon (*Salmo salar*) and Catfish (*Ictalurus punctatus*).

The immune system of fish is physiologically similar to that of higher vertebrates, despite certain differences. In contrast to higher vertebrates, fish are free-living organisms from early embryonic stages of life and depend on their innate immune system for survival (Rombout et al., 2005). Nonspecific immunity is a fundamental defence mechanism in fish. In addition, it plays a key role in the acquired immune response and homeostasis through a system of receptor proteins. These receptor proteins identify molecular patterns that are typical of pathogenic microorganisms, including polysaccharides, lipopolysaccharide (LPS), peptidoglycan bacterial DNA, viral RNA and other molecules that are not normally on the surface of multicellular organisms. This response is divided into physical barriers and cellular and humoral immune response. These immunological parameters include growth inhibitors, lytic enzymes, the classic complement pathways, the alternative and lectin pathway, agglutinins and precipitins (opsonins and primary lectins), antibodies, cytokines, chemokines and antibacterial peptides. Various internal and external factors can influence innate immune response parameters. Temperature changes, stress management and density may have suppressive effects on this type of response, while several food additives and immunostimulants can enhance their efficiency (Magnadottir, 2006, 2010). The aim of this review is to provide some background on the immune system of fish, describing the ontogeny and core components, the nonspecific and adaptive immune mechanisms and elements that promote their actions as immunomodulators.

2. Ontogeny of the immune system

The ontogeny of the immune system of teleost fish has been studied in various species, including rainbow trout (*Oncorhynchus mykiss*), catfish (*Ictalurus punctatus*), zebrafish *(Danio rerio*) and grouper (*Acanthistius brasilianus*). Teleosts have been described as primitive models of hematopoiesis. The first hematopoietic organ is called the intermediate cell mass (ICM). The sequence of lymphomyeloid organ development in marine teleosts is as follows: kidney, spleen and thymus (Mulero et al., 2007), but larval spleen has a greater erythropoietic function than lymphopoetic function (Nakanishi, 1986; Schroder et al., 1998).

The first appearance of IgM in lymphocytes varies considerably among fish species (Magnadottir et al., 2005). However, the first appearance of B-lymphocytes and immunoglobulins is late in marine species compared to fresh water species. Dalmo (2005) mentioned that the transfer of maternal antibody to eggs and embryos has been demonstrated in several species. Further, Magnadottir et al. (2005) suggest that the primary role of maternal

antibodies is to protect the eggs against vertical transfer of certain pathogens or that maternal IgM may aid phagocytosis or the activation of complement pathways in early developmental stages; IgM may even function simply as a nutritional yolk protein. Complement component C3 has been found in unfertilized eggs in the spotted wolfish (*Anarhichas minor* Olafsen) indicating maternal transfer (Ellingsen et al., 2005). Using immunohistochemistry techniques, C3 has been found in several different organs and tissues of developing cod and halibut (Lange et al., 2004). These studies suggest that complement may play a role in the generation of different organs and not only in the defense against invading pathogens (Dalmo, 2005).

3. Lymphoid organs

The thymus, kidney (anterior and middle) and spleen are the largest lymphoid organs in teleosts (Zapata et al., 2006). In freshwater teleosts, the thymus is the first organ to become lymphoid, but before this event, the anterior kidney may contain hematopoietic progenitors, but not lymphocytes (Lam et al., 2004).

3.1. Thymus

This organ has two lobes, is homogeneous, and is represented by a thin sheet of oval lymphoid tissue that is arranged subcutaneously in the dorsal commissure of the operculum and is lined by mucous tissue of the pharyngeal epithelium. The differentiation of the thymic structure is highly variable in teleosts, and in many species, it is not possible to observe a clear differentiation between the cortex and medulla that is found in higher vertebrates (Bowden et al., 2005). The thymus is responsible for the production of T cells. The early development of the thymus has been studied in several teleost fish species, and development time differs between species according to the effects of temperature on growth. Furthermore, myeloid cells and eosinophilic granular cells can be found in this organ. Other studies described the appearance of focal epithelial nests, known as Hassal's corpuscles (Zapata et al., 2006).

3.2. Kidney

The kidney in teleost fish is the equivalent of the bone marrow in vertebrates and is the largest site of haematopoiesis until adulthood (Zapata et al., 2006). Structurally, the anterior kidney is composed of a network of reticular fibres that provide support for lymph tissue and are found scattered among hematopoietic system cells that line the sinusoid reticuloepithelium. The main cells found in the anterior kidney are macrophages, which aggregate into structures called melanomacrophagecenters (MMCs), and lymphoid cells, which are found at all developmental stages and exist mostly as Ig+ cells (B cells) (Press et al., 1994). Reticular cells play an important role in supplying the interactions necessary for the function of lymphoid cells and endothelial cells of sinusoids.

3.3. Spleen

The spleen is composed of a system of splenic ellipsoids, MMCs and lymphoid tissue. In most species, ellipsoids are clustered together and are organized around the other two components (Ferguson, 1989). The ellipsoids are thick-walled capillaries that open in the pulp and result from the division of the splenic arterioles. The cells along the walls are actively involved in the macrophage phagocytosis of antigens. Usually in the form of antibodies or metabolic products, antigens may be detained for long periods of time, which has an important role in immunological memory.

3.4. Cells involved in immune response

Fish possess lymphocyte populations that are analogous to T cells, B cells, cytotoxic cells (similar to natural killer cells), macrophages and polymorphonuclear leukocytes. The immune system of teleosts has sub-populations of T lymphocytes that exhibit differential responses to mitogens, B cell acute allograft reactions, mixed leukocyte reactions and cooperative interactions between T cells, B cells and macrophages that are essential for the production of antibodies. Moreover, elasmobranch and teleost fish are the most primitive groups that possess the Major Histocompatibility Complex (MHC) and T cell receptor (TCR) (Manning and Nakanishi, 1996).

4. Nonspecific immunity

In fish, the innate response has been considered an essential component in combating pathogens due to limitations of the adaptive immune system, their poikilothermic nature, their limited repertoire of antibodies and the slow proliferation, maturation and memory of their lymphocytes (Whyte, 2007).It is commonly divided into three compartments: The epithelial/mucosal barrier - the skin, gills and alimentary tract is an extremely important disease barrier in fish, being constantly immersed in media containing potentially harmful agents(Magnadottir, 2010); the cellular components; and the humoral parameters - humoral factors may be cellular receptors or molecules that are soluble in plasma and other body fluids. This type of response requires a series of mechanisms that involve humoral factors, cell and tissue, antimicrobial peptides and complement factors.

4.1. Physical barriers

Flakes, skin mucus and gills act as the first barrier to infection (Ellis, 2001). The mucus of fish contains lectins, pentraxins, lysozymes, complement proteins, antibacterial peptides and immunoglobulin M (IgM), which have an important role in inhibiting the entry of pathogens (Saurabh and Sahoo, 2008). In addition, the epidermis is able to react to different attacks (thickening and cellular hyperplasia), and its integrity is essential for osmotic balance and to

prevent the entry of foreign agents. On the other hand, defending cells are present, such as lymphocytes, macrophages and eosinophilic granular cells (Fischer et al., 2006).

4.2. Nonspecific cellular cytotoxicity

In mammals, nonspecific response situations are mainly executed by cytotoxic cells, known as natural killer cells. Although the nonspecific cytotoxic cells of catfish are morphologically distinct from the large granular lymphocytes of mammals, they are suggested to be functionally similar (Evans and Jaso-Friedmann, 1992). These cells are able to eliminate a range of spontaneously xenogeneic targets, including parasites in fish and traditional targets of natural killer cells in mammals (Hasegawa et al., 1998). Unlike the natural killer cells of mammals, the nonspecific cytotoxic cells of catfish are agranular, small lymphocytes that are commonly found in lymphoid tissues, such as the anterior kidney and spleen, but are rarely found in the blood. In addition to the case in catfish, nonspecific cytotoxic cells have shown activity in other fish species, including rainbow trout (Greenle et al., 1991), common carp (*Cyprinus carpio*) (Suzumura et al., 1994), damsel fish (*Dascyllusalbisella*) (McKinney and Achmale, 1994) and tilapia (*Oreochromis spp*.) (Faisal et al., 1989).

4.3 The humoral parameters

4.3.1. Antimicrobial peptides

Studies of the integument and integument secretions of fish (Hellio et al., 2002) have demonstrated an important role for this system in host defence against viruses and bacteria. These peptides have been found in the mucus, liver and gill tissue of teleost fish. These low molecular weight polypeptides have the ability to break down bacterial walls.

4.3.2. Phagocytosis

Phagocytosis is one of the most important processes in poikilothermic animals because it is the process that is least influenced by temperature (Blazer, 1991; Lange and Magnadottir, 2003; Magnadottir et al., 2005). The main cells involved in phagocytosis in fish are neutrophils and macrophages. These cells remove bacteria mainly by the production of reactive oxygen species (ROS) during a respiratory burst. In addition, neutrophils possess myeloperoxidase in their cytoplasmic granules, which in the presence of halide and hydrogen peroxide kills bacteria by halogenation of the bacterial cell wall. Moreover, these cells have lysozymes and other hydrolytic enzymes in their lysosomes. Similarly, macrophages can produce nitric oxide in mammals and can be as potent as antibacterial agents, peroxy-nitrites and hydroxyl groups.

4.3.3. Complement

The complement system in teleosts, as well as that in higher vertebrates, can be activated in three ways: a) The classical pathway - which is triggered by antibody binding to the cell surface. b) The alternative pathway: which is independent of antibodies and is activated

directly by foreign microorganisms. c) The lectin pathway: which is activated by the binding of a protein complex consisting of mannose/mannan-binding lectin in bacterial cells.

However, the mechanisms and molecules involved in this system in teleosts are not well understood, with the exception of the genetic sequence of the mannose-binding lectin protease that is associated with serum. Studies suggest that the alternative complement pathway is of great importance in the innate immune response in teleost fish. The activity of complement-opsonized teleosts has been documented in a variety of species, such as common carp, catfish and salmonids. Salmonid antibodies, in the presence of complement proteins, are able to neutralize enveloped viruses, including the infectious hematopoietic necrosis virus (IHNV) and the viral haemorrhagic septicaemia virus (VHSV). In bacterial infections, complement activation by lipopolysaccharide found in the cell wall of gram-negative pathogenic bacteria stimulates C5a factor production, a powerful chemokine to macrophages and neutrophils that have receptors for C3, the central complement molecule which is a part of all three pathways, and which remains attached to the bacteria, favouring phagocytosis (Jenkins and Ourth, 1993). Teleost C3 is composed of a disulphide-linked two-chain (a and b) glycoprotein containing a thioester bond comparable to C3 from several vertebrate species (Magdanottir et al., 2005).

4.3.4. Tumor necrosis factor (TNF)

Several studies in fish have provided direct evidence suggesting that TNF-α and TNF-β are important activators of macrophages. Studies in rainbow trout, turbot, sea bream (*Sparus aurata*), goldfish (*Carassius auratus*) and catfish have shown that TNF causes the activation of macrophages, leading to increased respiratory activity, phagocytosis and nitric oxide production (Tafalla et al., 2001).

4.3.5. Interferon (INF)

INFα and INFβ are cytokines with a nonspecific antiviral function that is based on the inhibition of nucleic acid replication within infected cells. INF plays an important role in the defence against viral infection in vertebrate host cells, which secrete INFα/INFβ upon recognition of viral nucleic acid (Robertsen, 2006). These INFs protect other cells from viral infection by binding to different receptors, which results in the induction of several hundred genes that are stimulated by INF (ISGs). Some of these genes encode antiviral proteins, such as protein MX (MX), protein kinase dsRNA activated (PKR) and 2,5-oligoadenylate synthetase (OAS) (Samuel, 2001).

4.3.6. Interleukins (IL)

IL-1 in mammals is comprised of 10 ligands and 10 protein receptor molecules and plays an important role in inflammation and host defence (Dinarello, 1997). IL-1β has been detected in 13 teleost fish species and is involved in the regulation of immunity through the stimulation of T cells. The function of IL-1β in these fish species is analogous to mammalian IL-1β. In teleost fish, IL-1 receptors have been cloned and sequenced from the rainbow trout and

Atlantic salmon. The expression of the IL-1 receptor in salmon appears to be constitutive in all tissues tested and is regulated in the anterior kidney, spleen, liver and gills after stimulation with LPS and TNF-α, suggesting a role for the IL-1 receptor in regulating IL-1β during the inflammatory response (Sangrador-Vegas et al., 2000; Subramaniam et al., 2002).

4.3.7. Others cytokines and chemokines

As described earlier, TNF-α and IL-1β are cytokines involved in the induction of inflammatory responses to Gram negative bacteria in fish. In addition, it has been demonstrated that IL-6 is also involved in the cascade leading to an inflammatory response for this type of bacteria. Further, cytokines involved in leukocyte differentiation, including granulocyte colony stimulating factor (CSF), macrophage-CSF and IL-7 are all identified in fish. On the other hand, chemokines are also present and in some fish species considerable numbers of genes have now been identified; however, many have no clear homologues in other vertebrate groups and their function remains to be determined (Secombes, 2008).

4.3.8. Protease inhibitors

Several protease inhibitors are present in the serum and other body fluids of fish. The main function of protease inhibitors is to maintain body fluid homeostasis. These molecules are involved in acute phase reactions and defence against pathogens that secrete proteolytic enzymes (Magdanottir, 2010). The most widely studied of the protease inhibitors is the α-2 macroglobulin, which has a high specificity for inhibiting the physical encapsulation of protease.

4.3.9. Lysozyme

Lysozyme is a bacteriolytic enzyme that is widely distributed throughout the body and is part of the nonspecific defence mechanisms in most animals. In salmonids, lysozyme has been detected in serum, secretions, mucous membranes and tissues rich in leucocytes, mainly the kidney and intestine. Apparently, the main sources of lysozyme are monocytes/macrophages and neutrophils. The bactericidal action of this enzyme involves the hydrolyzation of the peptidoglycan of bacterial cell walls resulting in cell lysis. Lysozyme was initially associated with the defence against Gram-positive bacteria, but has been found to lyse Gram-negative bacteria as well. Furthermore, this enzyme is known to trigger an opsonin of the complement system and phagocytic cells (Magnadottir, 2006).

4.3.10. Natural antibodies

Natural antibodies are produced in fish at a level that is regulated in the absence of antigenic stimulation of cells that are equivalent to B1 cells. These natural antibodies are found in high levels in the serum of fish, where they provide immediate and broad protection against bacterial and viral pathogens, making these factors key components of nonspecific immunity. Natural antibodies are also linked to adaptive immunity. Teleost fish are capable of generating specific IgM-type natural antibodies against various antigens. The intensity of this

response, however, has been shown to vary between different species and environmental conditions (Whyte, 2007).

4.3.11. Pentraxins

C-reactive protein (CRP) and serum amyloid protein (SAA) are present in the body fluids of vertebrates and invertebrates and are commonly associated with the acute phase response of inflammation. The expression of CRP has been reported in several teleost fish species, including rainbow trout, catfish, Atlantic salmon, common cod (*Gadus morhua*), halibut (*Hippoglossus hippoglossus*) and dog fish (*Hopliasmalabaricus*) (Lund and Olafsen, 1998). The levels of these proteins are increased upon tissue injury, trauma or infection. These proteins play an active role in the immune system, activation of the classical complement pathway and the removal of apoptotic cells. Different stimuli, such as tissue damage, trauma or infection, have been shown to generate various patterns of CRP production in teleost fish, in which either the level of CRP is decreased in serum (negative acute phase protein) (Liu et al., 2004) or the level of CRP is increased in serum (positive acute phase protein) (Kodama et al., 2004).

4.3.12. Transferrin

Iron is an essential element in the establishment of infection by many pathogens, but the availability of iron in the tissue fluids of vertebrates is extremely low due to its high affinity for the blood protein transferrin. Only bacteria with high affinity systems for iron absorption are able to maintain sufficient iron levels to grow in vivo (Ellis, 2001). Transferrin is a globular glycoprotein with a high iron chelator activity. This protein is the major iron ion transport protein in animals and plants. Transferrin has a high degree of genetic polymorphism in all species and is found in the serum and secretions of all vertebrates.

5. Specific immunity

The specific immune response occurs through mechanisms that involve a complex network of specialized cells, proteins, genes and biochemical messages that provide the means necessary for the body to respond specifically to antigens, antibodies and effector cells with high specificity and affinity.

5.1. Antibodies

The predominant immunoglobulin in teleosts is a tetramer of the IgM class and contains eight antigenic combining sites. Some teleosts have a monomer of IgM in their serum, although the factors leading to its expression are still unknown (Wilson and Warr, 1992). The binding affinities of monomeric and tetrameric IgM in rainbow trout are similar, but tetrameric IgM activates complement more effectively than the monomeric form due to a structural difference in the Fc portion of the molecule. IgD was the second immunoglobulin isotype identified in fish, specifically catfish, due to sequence similarity with IgD in mammals, its

location immediately under the IgM gene and its expression in B cells (Wilson et al., 1997). Moreover, the concentration of IgM in the serum of salmonids is extremely low compared to that of other teleosts such as Japanese eel (*Anguilla japonica*), cyprinids and some Perciformes (Uchida et al., 2000). However, the amounts of IgM in the serum of brown trout (*Salmo trutta*) and rainbow trout that are infected or acclimated to high temperature (19°C) reach values similar to those of the common cod and haddock (*Melanogrammus aeglefinus*). In addition, IgM levels in salmon and Atlantic cod (*Gadus morhua*) vary with size, temperature and water quality season (Magnadottir et al., 2001). Teleost antibodies are found in the skin, intestine, gill mucus, bile and systemically in the plasma. The immune response of the skin and gills is important because these organs are in direct contact with the environment. Specific antibodies can be generated in the skin, intestine, and gills without necessarily generating a systemic response (Cain et al., 2000).

5.2. Immunological memory

Fish develop a memory response before a second exposure to an antigen (Whittington et al., 1994). Rainbow trout respond to suboptimal doses of both T lymphocytes in an antigen-dependent and independent manner after an initial exposure to the same antigen (Arkoosh and Kaattari, 1991). It is remarkable that it takes two exposures before the fish responds to the second administration of T-dependent antigens, whereas T-independent antigen requires only one exposure. Additionally, while response is faster and of larger magnitude than the primary response, the number of antigen-specific B cells in the spleen is directly proportional to the frequency of B-cell specific antigen precursors. This finding suggests that the secondary response is caused by the expansion of the pool of memory B cells and not a specific difference in the antibodies (Kaattari, 1992).

5.3. Cellular Cytotoxicity

The leukocytes of fish are capable of generating cellular cytotoxicity reactions, which has been demonstrated in several fish species. However, the cells that are responsible for cell-mediated cytotoxicity in fish are difficult to characterize due to the lack of appropriate tools for cellular and molecular recognition (Fisher et al., 2006). The sequencing of fish homologues of MHC class I and CD3+ T cells suggests that CD8+ MHC class I presentation is similar to that which occurs in higher vertebrates. Like other vertebrates, fish acquire immunocompetency during ontogeny. In sea bass (*Dicentrarchuslabrax* L.), T cells appear early in larval development, at least five days after the start of incubation (Dos Santos et al., 2000). MHC class I molecules and CD8 are expressed from the larval stage, suggesting that very young fish can be vaccinated to develop cellular immunity.

5.4. Cytokines involved in adaptive immunity

Cytokines have been described in adaptive immunity in fish and with the recent discovery of CD4 in teleosts in it seems likely these cytokines will drive the activation and differentiation of T helper cell subsets to release different cytokine repertoires (Secombes, 2008). As stated above, type I and type II IFN are present that could potentially drive Th1 cell differentiation, with IFN-g a potential effector of Th1 responses altogether with IL-12, IL-15 and IL-18. In relation to Th2-type cytokines, a molecule which is claimed to be a homologue of IL-4 has been found recently; however, it has no obvious similarity to known vertebrate IL-4 genes. Finally, both IL-10 and TGF-β are present in fish, and thus may form the effectors of potential T regulatory cells (Secombes, 2008).

6. Components and specializations of fish immune systems

6.1. Phylogeny

Innate immunity **-** Many mechanisms shared with all animals; some mechanisms are also shared with plants. *Adaptive immunity*- jawless fish have a form of lymphocyte and divergent type of rearranging immune receptor; jawed fish mark the appearance of the thymus and recombinase- activating genes (RAGs).

6.2. Anatomical features

Innate immunity - surface barrier with mucus coating containing secreted protective antibacterial molecules; cells and soluble factors distributed in endothelium-lined circulation. *Adaptive immunity* - no lymph nodes or germinal centres; lymphatic circulation; secondary lymphoid organs: paired thymic organ, anterior and posterior kidney, spleen, gut-associated lymphoid tissue.

6.3 Key cell types

Innate immunity – macrophages; granulocytes: neutrophil, eosinophil, basophil; natural killer cell equivalent (diverse genomic library of novel immune type receptors, NITRs); thrombocytes (work with coagulation pathways to maintain host integrity). *Adaptive immunity* - B lymphocytes (re-arranging B cell receptor); T lymphocytes (re-arranging T cell receptor); detailed lymphocyte subtypes not yet characterized; antigen-presenting cells etc.

6.4. Cellular immunity

Innate immunity - phagocytosis (predominantly macrophages); microbicidal/static biochemical pathways (e.g., peroxide, nitric oxide production); hematopoietic growth factors regulate leukocyte precursor proliferation, leukocyte function. *Adaptive immunity* - compared

to tetrapods, conserved T cell receptor structure; specificity diversification by RAG-dependent V(D)J recombination; characteristic cytotoxic T-cell responses demonstrable, e.g., mixed lymphocyte reaction, graft rejection, antiviral response etc.

6.5. Humoral immunity

Innate immunity - Complement systems i.e., classical, alternative and mannose lectin pathways; highly evolved diversity; coagulation pathways; natural antibodies; induced cytokines, e.g., interleukin-1, tumor necrosis factors, interferons, chemokines; ligand and receptor families characterized by highly evolved diversity. *Adaptive immunity* -compared to tetrapods, less conserved B cell receptor structure; immunoglobulin classes (μ, ζ, δ isotypes); specificity diversification by RAG-dependent V(D)J recombination; somatic hypermutation contributes to a lesser extent; no class switching.

6.6. Activation and key signalling pathways

Innate immunity - pathogen-associated molecular patterns (PAMPs) interact with pattern recognition receptors (PPRs), e.g., Toll-like receptors (TLRs), lectins, peptidoglycan recognition proteins, cytokine receptors. *Adaptive immunity*- immune receptor engagement with antigen

6.7. Immunological memory

Innate immunity - fixed repertoire, entrenched in the genome. *Adaptive immunity* - adapts to environmental history of the individual; mechanisms for adaptation entrenched in genome.

6.8. Cellular ontogeny

Innate immunity - phagocytes are present and functional from early segmentation; hematopoiesis has primitive and definitive phases, at distinct locations during development; adult hematopoiesis in the kidney interstitium (not bone marrow). *Adaptive Immunity* - lymphocytes appear first during late organogenesis; T lymphocytes precede B lymphocytes; T lymphopoiesis resides in the thymus throughout life; B lymphopoiesis resides in adult kidney interstitium (embryonic location not certain).

6.9. Comparison with mammals

Innate immunity - appears highly evolved and richly diversified. *Adaptive immunity* - appears less highly evolved and possibly less flexible.

7. Environmental effect on immune response

The immune system and response of fish can be greatly influenced by various external factors like temperature, light, water quality, salinity and different stress inducers (Magnadottir, 2010). Decreases in temperature, which are important due to the poikilothermic nature of fish, affect the rate of their physiological functions. In the rainbow trout, photoperiod has also been shown to impact the immune response through a reduction in the number of circulating leukocytes that is caused by increasing daylight hours; in turn, leukocytes are increased to reduce the hours of exposure to this factor. An increase in the photoperiod can also generate increase in the activity of lysozyme and the circulating levels of IgM (Bowden, 2008).

Oxygen levels in the environment may modulate the immune response; hypoxia depresses the respiratory burst activity of macrophages and lowers the levels of circulating antibodies, which in turn, are elevated by hyperoxia. Increased levels of suspended solids in the fish environment help to raise hematocrit levels to compensate for the diminished ability of the gills to capture oxygen. This factor also increases the activity of lysozyme and the levels of circulating IgM as a response to elevated levels of pathogens that are expected in an environment rich in particles. Increased salinity also affects immune parameters by increasing the activity of lytic enzymes, the respiratory burst of macrophages and the circulating levels of IgM. Changes in environmental pH levels show conflicting results for immune system parameters, such as levels of lysozyme and IgM in the circulation (Bowden, 2008). Stress in fish as a result of population density associated with cultivation and production management can increase circulating cortisol levels, generating a decrease in specific and nonspecific immunity and, therefore, making the fish prone to opportunistic pathogens (Ramsay et al., 2009).

8. Compounds that modulate the immune system in fish

Another approach to immunoprophylactic control is the use of probiotics and immunostimulants including specific dietary manipulation (Magnadottir, 2010). These compounds are defined as chemicals, drugs, stress generators or other actions that raise nonspecific defence mechanisms or the specific immune response and include nucleotides, glucans and probiotics. These treatments are primarily aimed at enhancing the innate system and therefore are of value as general preventive measures in aquaculture.

8.1. Nucleotides

Nucleotides are composed of a purine or pyrimidine base, a ribose or deoxyribose sugar and one or more phosphate groups. The term nucleotide in this context refers not only to a specific form of the compound, but also to all forms that contain purine or pyrimidine bases (Rudolph, 1994). These compounds are essential in many physiological and biochemical functions, among which are included the encoding and decoding of genetic information, the

mediating of energy metabolism and cell signals, and also forming components of coenzymes, allosteric effectors and cellular agonists (Cosgrove, 1998). Dietary supplementation with nucleotides confers increased resistance on salmonids to viral, bacterial and parasitic diseases and improves the effectiveness of vaccination and the ability to osmoregulate.

Further, the binding of these compounds to Toll- like receptor 9 (TLR-9) is thought to stimulate the activity of intracellular bacterial DNA and trigger innate and adaptative responses (Dalmo, 2005). With respect to the innate immune response, it is known that dietary nucleotides may influence the activity of macrophages and natural killer cell. In addition, nucleotides also influence the activity of lymphocytes and immunoglobulin production. Ramadan et al. (1994), were the first to observe the effect of dietary supplementation with nucleotides, and described a stimulatory effect on the humoral and cellular immune response in tilapia after intramuscular injection or bath with formalin-killed *Aeromonas). With* titres and lymphocyte mitogenic responses of fish supplemented with nucleotides were significantly higher in fish that were fed the basal diet. Similar phenomena have been observed in rainbow trout, hybrid striped bass and Atlantic salmon. However, the mechanisms of action of these compounds are still not well understood.

8.2. Glucans

One of the most used substances in immuno-stimulation experiments in fish are various forms of β-glucans from different sources, normally introduced in the feed but also by intraperitoneal injection or as a vaccine adjuvant (Dalmoand Bogwald, 2008). Glucan-linked glucans β1-3 and β1-6 are the major components of the cell walls of yeasts and mycelial fungi. These polysaccharides are not antigenic to animals, but have been proven to be potent activators of nonspecific mechanisms of antibacterial defences in fish. The injection of glucans generates improvements in the fish innate immune response by increasing the activity of macrophages, complement activation and levels of lytic enzymes (Ai et al., 2007). Furthermore, several studies have shown that injection of glucans improves antibacterial defences and efficiency of vaccination (Rorstad et al., 1993). Similarly, when administered orally, these compounds are capable of stimulating the immune response and disease resistance (Siwicki et al., 1994).

8.3. Probiotics

Probiotics are organisms or substances that contribute to the intestinal microbial balance. Fuller (1989) defined probiotics as live microbial feed supplements which exert beneficial effects on the host animal by improving its intestinal microbial balance. Research on the use of probiotics in aquatic animals has increased the demand for sustainable aquaculture. Many of the probiotics used in aquaculture belong to the Lactobacillus, the genus Bacillus, photosynthetic bacteria or yeasts, although other genera or species have also been employed,

including nitrifying bacteria, streptococci and Roseobacter (Wang et al., 2008). These have been tested in aquaculture with generally good results. The benefits of supplements include improvements in feed values, contribution to enzymatic digestion, inhibition of pathogenic microorganisms, anti-mutagenic and anti-carcinogenic activity, growth-promoting factors and an augmentation of the immune response. Probiotics may also stimulate the innate defence through TLR, other cellular receptors or humoral factors (Magnadottir, 2010).

9. Nanodelivery systems as new tools for immunostimulant or vaccine administration targeting the fish immune system

Fish disease treatments have progressed significantly over the last few years and have moved from the massive use of antibiotics to the development of vaccines mainly based on inactivated bacteria. Today, the incorporation of immunostimulants and antigens into nanomaterials provide us with new tools to enhance the performance of immunostimulation (Table 1). Nanoparticles are dispersions or solid particles designed with specific physical properties (size, surface charge, or loading capacity), which allow controlled delivery and therefore improved targeting and stimulation of the immune system. The use of these nano-delivery platforms in fish is in the initial steps of development.

Table 1: Few examples of nanoparticles used as delivery system in fish.

Nanoparticle	Size	Encapsulated molecule	Mode of administration	Fish species	Reference
Calcium phosphate	224.98 ± 14.62 nm	S-layer protein from *Aeromonas hydrophila*	i.p. injection	*Labeo rohita*	(Behera and Swain, 2011)
Chitosan	185.4 ± 2.1 nm	Vitamin C	Oral	*Onchorhynchus mykiss*	(Alishahi et al., 2011)
	287.1 ± 1.49 nm	Bare RNA	Oral	*Labeo rohita*	(Ferosekhan et al., 2014)
Liposomes	200 nm	LPS from *Aeromonas salmonicida*	i.p.injection	*Onchorhynchus mykiss*	(Nakhla et al., 1997)
PLGA	300–400 nm	β-glucan	i.p.injection	*Salmo salar*	(Fredriksen et al., 2011)
SLN	141–335 nm	6-Coumarin	In vitro, SAF-1 cell line and HK leukocytes	*Sparus aurata*	(Trapani et al., 2015)

PLGA: poly (lactic-co-glycolic acid); SLN: Solid Lipid Nanoparticles.

Altogether, nano-encapsulation is a very promising strategy with a potential to substantially improve the development of effective vaccines for farmed fish. The research on the delivery of viral vaccines using nanoparticles will be the more important milestone in fish vaccinology. In this context, more traditional biomaterials such as alginate and chitosan have shown good results but new materials such as CNTs or solid lipid NP could improve the delivery of DNA vaccines. More research is still needed to specifically design encapsulation systems adapted to the fish immune system and to decipher the basis of the fish immune system.

10. Some other recent trends in worldwide fish immunology research

Monitoring and understanding the changes in antioxidant enzyme activities and gene expression profiles in various fish models after artificial infection with different pathogens (Wu et al., 2017); understanding the early immune response of lymphoid and myeloid cells/tissues in different fish models (Sarais et al., 2022); biochemical and functional insights into the integrated regulation of innate immune cell responses by teleost leukocyte immune-type receptors in various fish models (Fei et al., 2016); understanding the evolution of MHC molecules in different teleost fish models (Grimholt, 2016); understanding the detailed process of phagocytosis in teleosts and searching the implications of the new cells involved in that process (Esteban et al., 2015); immunomodulation in fish by usage of pro-biotics and other phytochemicals and/or immunostimulants (Ahmadifar et al., 2021); application of phage therapy as alternate disease control measure in aquaculture (Pal S., 2015) to name a few.

11. Conclusion

Fish have well developed immune systems, with full representation of all known fundamental components of innate and adaptive immunity, although with some specializations and unique features. In general terms, compared to mammals, fish innate immunity appears highly evolved with potentially enhanced functionality, whereas fish adaptive immunity appears to be possibly less sophisticated. There is a rapidly expanding research effort employing fish models; in zebrafish these particularly exploit its elegant embryology, genetic tractability and optical transparency. Significant future contributions to immunology from research using piscine models can be anticipated.

In the last years, great progress has been made in understanding the immune response of fish which has benefitted the growing aquaculture industry worldwide. One critical element of this area of research has been established: the immunomodulation of larval fish. The production of fish larvae is often hampered by high mortality rates and economic loss due to infectious diseases. As is well known, in fish the innate response has been considered an essential component in combating pathogens due to limitations of the adaptive immune system. Therefore, the immunomodulation of larval fish has been proposed as a potential

method for improving larval survival by increasing the innate responses of developing animals until their adaptive immune response is sufficiently developed to mount an effective response to the pathogen.

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Dr. Subharthi Pal

Dr. Subharthi Pal was awarded his Ph.D. from the University of Calcutta, in 2018. He worked under the able guidance of Prof. Sumit Homechaudhuri at the Aquatic Bio-resource Research Laboratory, Ballygunge Science College on Fish Immunology. He has more than 15 publications in different national and international journals and 1 book chapter to his credit. He was awarded the Young Scientist Award in the International Research Awards on Science, Technology and Management, held on 14 & 15-May-2022, Chennai, India, organized by VDGOOD Professional Association, India. His current research interest includes understanding the cellular and molecular aspects of nonspecific and specific immunity in various fish models against viral and microbial pathogens; Immunomodulation in fish by usage of pro-biotics and other phytochemicals and/or immunostimulants; application of Phage Therapy as alternate disease control measure in Aquaculture etc. He is currently serving the position of an Assistant Professor in the Department of Zoology, Bhairab Ganguly College, Belghoria.

3 সুন্দরবনে লবণাম্বু উদ্ভিদের কৃত্রিম সৃজন ও তার প্রভাব

অনিমেষ সিংহ

অনিমেষ সিংহ সুন্দরবন-কেন্দ্রিক পরিবেশ আন্দোলনের এক পরিচিত মুখ। উষ্ণায়ন সমস্যায় জর্জরিত বর্তমান পৃথিবীতে সমুদ্র জলতলের বৃদ্ধি এক স্বাভাবিক ঘটনা। আবার সুন্দরবন অঞ্চলের দ্রুত পলির অবক্ষেপণ জলতলের বৃদ্ধিকে প্রতিহত করছে, গবেষণার মাধ্যমে যার সার্বিক মূল্যায়ন এখনও হয়নি। এই বনাঞ্চলে ভূমিতলের সার্বিক উত্তোলন বা অবনমনের কোনটি শেষপর্যন্ত পরিলক্ষিত হবে, তার সঠিক তথ্য এখনও আমাদের অজানা। কিন্তু এটা ঠিক যে সুন্দরবনের খাঁড়ি অঞ্চলের পরিবেশের দ্রুত পরিবর্তন হচ্ছে। সাথে যোগ হয়েছে মনুষ্যকৃত নানা সমস্যা। ফলে ওই অঞ্চলের লবণাম্বু উদ্ভিদ ও বনভূমির স্বাভাবিক বৃদ্ধি ব্যাহত হয়েছে। খাদ্যশৃংখলের স্বাভাবিক নিয়মে তার প্রভাব পড়েছে ওই অঞ্চলের নানা ক্ষেত্রে। বর্তমান আলোচনায় সেই সমস্যাগুলির উপর আলোকপাত করা হয়েছে এবং সদর্থক সমাধানের প্রয়োজনীয়তার কথা জানানো হয়েছে।

কৌশিক কিরাণ ঘোষ।

ভূতত্ত্ব বিভাগ, যোগমায়া দেবী কলেজ।

সুন্দরবনে লবণাম্বু উদ্ভিদের কৃত্রিম সৃজন ও তার প্রভাব

অনিমেষ সিংহ

animeshhsinha@gmail.com

'ভারতীয় সুন্দরবনে লবণাম্বুজ উদ্ভিদের কৃত্রিম সৃজন ও সুন্দরবনের উপর তার প্রভাব' বিশ্ব পরিবেশ দিবস উপলক্ষে আয়োজিত আলোচনায় এই বিষয়টি বেছে নেবার কারণ একটু ব্যাখ্যা করা প্রয়োজন। আরো সব অরণ্যের মতোই সুন্দরবন এক প্রাকৃতিক জঙ্গল-ভূমি। যে উদ্ভিদ আচ্ছাদনে সুন্দরবন গড়ে উঠেছে তা এক বিশেষ বৈশিষ্ট্যযুক্ত। নদী কেন্দ্রিক সেই বৈশিষ্ট্যগুলো জানলে বোঝা যাবে এমন একটি বিষয় নিয়ে কেন আজকের এই আলোচনা।

ব্রহ্মপুত্র ও মেঘনা নদীর বৈশিষ্ট্য

গঙ্গা নদীর উৎসের মধ্যেই লুকিয়ে আছে তার সবিশেষ বৈশিষ্ট্য যা বিশ্বের অন্য সুবিশাল নদীগুলো থেকে তাকে বৈশিষ্ট্যময়ী করে তুলেছে। গঙ্গা নদীর জলপ্রবাহ, পলির চরিত্র ও পরিমান, অববাহিকার সুবিশাল ব্যাপ্তি, ঢাল, মাটির চরিত্র বিশ্বের অন্য দীর্ঘ নদীগুলো থেকে সম্পূর্ণ আলাদা। সুস্থায়ী বরফাচ্ছাদিত বিশ্বের সর্ববৃহৎ পর্বতমালা হিমালয়ের দক্ষিণ ঢালে জন্ম নিয়ে সেই বরফ নিঃসৃত অগণিত ঝর্ণার কেবল জলই নয়, বলা যায় পর্বত কণা সমৃদ্ধ বিপুল জলরাশি নিয়ে নেমে এসেছে সমতল ভূমিতে। সুদীর্ঘ যাত্রার পথের পলিকে জড়িয়ে নিয়েছে নিজের সঙ্গে। এই সম্পদের বৃহত্তম অংশ মিলিত হয়েছে উপত্যকার পূর্ব প্রান্তে ব্রহ্মপুত্র আর মেঘনা নদীর সঙ্গে। গঙ্গা-ব্রহ্মপুত্র-মেঘনা মিলিত জলরাশি বাহিত পুলির পরিমাণ এখন বছরে ১৬৭ কোটি টন, যা সম্পূর্ণ ইউরোপ আমেরিকা মহাদেশের সমস্ত নদীর মিলিত পলি পরিমাণের চেয়ে বেশি। প্রসঙ্গক্রমে একথা বলা যায়, মেঘনা নদী পলি বহন করে বিশ্বের সব নদীর তুলনায় অনেক বেশি।

গঙ্গা নদী ভারতের ১১টি অঙ্গরাজ্য – উত্তরাঞ্চল, উত্তর প্রদেশ, হিমাচল প্রদেশ, দিল্লি, হরিয়ানা, রাজস্থান, মধ্যপ্রদেশ, ছত্রিশগড়, বিহার, ঝাড়খণ্ড ও বাংলার বিভিন্ন রাজ্য থেকে বাঁদিক বরাবর রামগঙ্গা, গাড়া, গোমতী, ঘাঘড়া, গণ্ডক, বুড়ি গণ্ডক, কোশী, মহানন্দা এবং ডান দিকের যমুনা, তমসা, কর্মনাশা, শোন, পুনপুন, ফল্গু, কিউল, চন্দন নদীর জলরাশি নিজ অঙ্কে গ্রহণ করে উত্তরাখণ্ড, উত্তর প্রদেশ, বিহার, ঝাড়খণ্ড ও বাংলার উপর দিয়ে প্রবাহিত হয়ে এসেছে। বাংলা মুলুকে এসে দ্বিধাবিভক্ত হয়ে পূর্বশাখা পদ্মা নদী নাম নিয়ে বাংলা দেশের উপর দিয়ে প্রবাহিত

হয়েছে দুর্বার গতিতে। আর মূল ধারা নাম পালটে ভাগীরথী এবং আরো পরে ভাগীরথীর একটি কৃত্রিম ধারা হুগলি নাম নিয়ে সাগরে নিজেকে সমর্পণ করেছে।

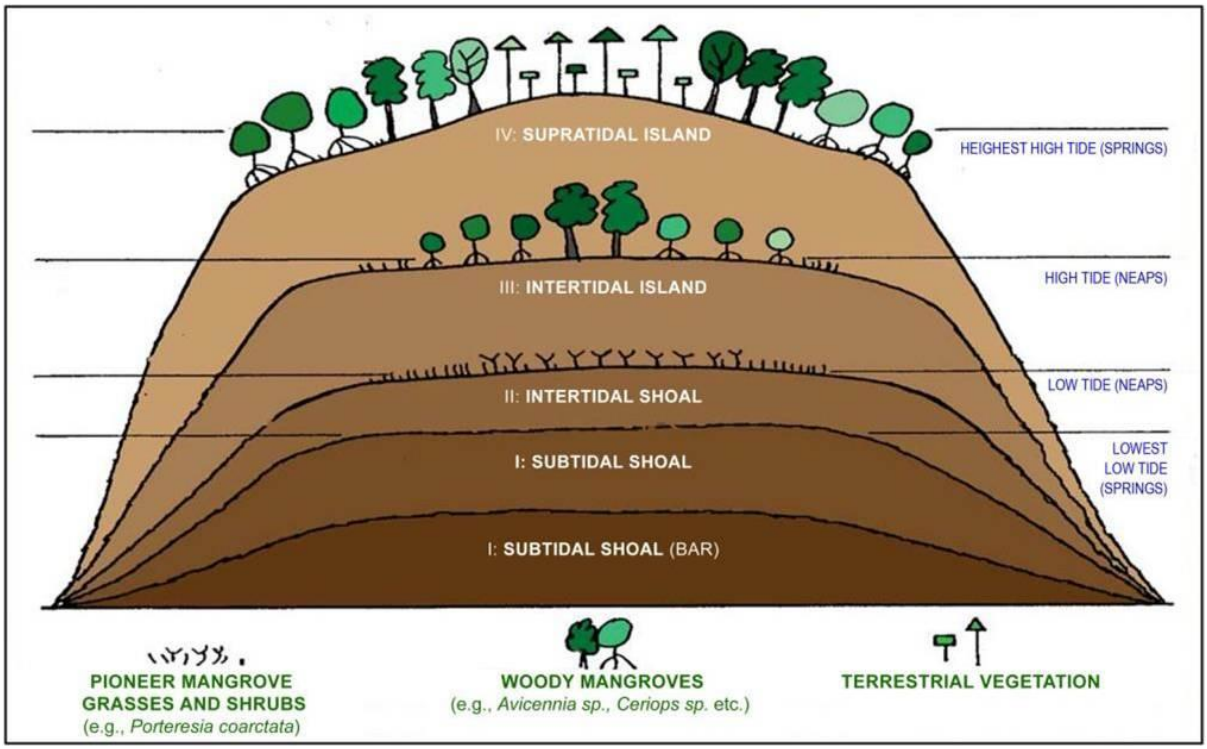
ভূমির উর্বরতা গড়ে তোলার মুখ্য উপাদান

লবণাম্বুজ উদ্ভিদ অরণ্য

এই অববাহিকার উপর উত্তর দিক থেকে প্রবাহিত মহানন্দা, তিস্তা, জলঢাকা, তোর্ষা, রায়ডাক, সংকোশ উপনদী সমূহ পলি বহন করে জমা দিয়েছে পদ্মা আর যমুনা সঙ্গমে। ব্রহ্মপুত্র ও তার নানা উপনদী বাহিত পলি-ভারাক্রান্ত জলরাশি এই সঙ্গম-বাহিত জলধারায় মিলেমিশে ছুটে গেছে বঙ্গোপসাগরের কোলে। উত্তরে গঙ্গা বিভাজন-স্থল থেকে যমুনা-ব্রহ্মপুত্র সঙ্গম পর্যন্ত ২০০ কিমি দীর্ঘ এই সম্মিলিত স্রোতধারা থেকে নির্গত অসংখ্য শাখাপ্রশাখা দিয়ে পলিসমুদ্ধ জলরাশি দক্ষিনে বয়ে গেছে। আর পশ্চিমে ভাগীরথী নদী তার চলার পথে ডানদিকে পশ্চিমের মালভূমি থেকে নেমে-আসা বাঁশলোই, পাগলা, ময়ূরাক্ষী, অজয়, খড়ি, গাঙুর, বেহুলা, সরস্বতী, দামোদর রূপনারায়ণ ও হলদি নদী আর বামদিকে গঙ্গা-পদ্মার শাখা জলঙ্গি, চূর্ণী নদীর পলি সমৃদ্ধ জলরাশি নিয়ে বঙ্গোপসাগরে বিলীন হয়েছে। শাখা-প্রশাখা-উপশাখায় বিভাজিত এই বেগবতী জলধারাবাহিত পলিরাশিতে সৃষ্টি হয়েছে চর-ভূমি, নদীর গতি হয়েছে সর্পিল। চলার পথে দূ-কুল প্লাবিত করে পলি ছড়িয়েছে, উপর্যুপরি পলির আস্তরণে ক্রমশ উচ্চ হওয়া চর-ভূমি জমাট বেঁধেছে। গড়ে উঠেছে গোটা সুন্দরবন বদ্বীপাঞ্চল।

প্রসঙ্গত বলে রাখা দরকার, দ্বাদশ থেকে চতুর্দশ শতকের মধ্যে সুন্দরবনের এই অববাহিকার নিচে থাকা টেকটনিক প্লেটটি ভূ-আলোড়নের ফলে পূর্ব দিকে বসে যেতে শুরু করেছে, স্বাভাবিকভাবে পশ্চিম দিক উঁচু হয়ে পড়ায় গঙ্গাবাহিত পলি-সমৃদ্ধ বিশাল জলরাশি পূর্বঢালে অর্থাৎ

পদ্মা নদী দিয়ে বহে যাচ্ছে। ফলে ভারতীয় সুন্দরবন বঞ্চিত হতে থাকলো গঙ্গা নদীর বিপুল পলি সম্পদ থেকে।



চরভূমিতে লবণাম্বুজ উদ্ভিদ আচ্ছাদনের ক্রমপর্যায়

(সুত্র – অধ্যাপক সুনন্দ বন্দোপাধ্যায়, ভূগোল বিভাগ, কলিকাতা বিশ্ববিদ্যালয়)।

লবণাম্বু উদ্ভিদের আচ্ছাদন

বিশ্বের বৃহৎ তিনটি লবণাম্বু উদ্ভিদ অরণ্যের মধ্যে সুন্দরবন অন্যতম। হুগলি নদীর মোহনা থেকে সমুদ্র উপকূল বেয়ে পূর্ব দিকে বলেশ্বর নদী মোহনা পর্যন্ত প্রায় ২০০ কিলোমিটার বিস্তৃত আর সমুদ্র থেকে উত্তরে গড় ৭০ কিলোমিটার জুড়ে যে বনরাজীর অস্তিত্ব গত শতাব্দীর প্রথম দিকেও ছিল তা এক বিশেষ বৈশিষ্ট্যের অধিকারী। সাধারণ উদ্ভিদ কুল থেকে সম্পূর্ণ আলাদা বৈশিষ্ট্য বৈশিষ্ট্য মধ্যপ্রাচ্যের আদি বাসিন্দা লবণাম্বু এই উদ্ভিদ শ্রেণীর আবাসভূমি সমুদ্রের লবণাক্ত জল মাটি সমৃদ্ধ এলাকা এই এলাকার যদি সামান্যতম মিষ্টি জলপ্রবাহের ছোঁয়া থাকে তবে এই বনানীর স্বর্গভূমি হয়ে ওঠে সেই বনভূমি সুন্দরবনের বদ্বীপভূমি তাই সম্পূর্ণ আদর্শ এক ক্ষেত্র লবণাম্বু উদ্ভিদ অরণ্য গড়ে ওঠার জন্য

লবণাম্বুজ উদ্ভিদের প্রাকৃতিক সৃজন

লবণাম্বুজ উদ্ভিদের শিকড় বিন্যাস

সুন্দর বনে লবণাম্বু উদ্ভিদের বিস্তার সংক্রান্ত আলোচনায় স্বাভাবিকভাবে প্রয়োজন হয় এই উদ্ভিদের উৎপত্তি ও বিশ্বজুড়ে তার ছড়িয়ে পড়া ইতিহাস এবং বিশেষ এই এলাকায় তার এমত বিস্তারের কারণ গুলির খোঁজ করা লবণামবু উদ্ভিদের উৎপত্তি ও ভৌগোলিক বিন্যাসের গবেষণা ও বিশ্লেষণে জানা গেছে ইন্দুমালয় অঞ্চলের সমুদ্র উপকূলবর্তী এলাকায় লবণাম্বু উদ্ভিদের প্রথম উৎপত্তি এবং পরে প্রবল ক্ষমতাশালী সমুদ্রস্রোতের টানে এই অঞ্চলের পশ্চিমবঙ্গে ভারত ও পূর্ব আফ্রিকায় এই উদ্ভিদ বন বিস্তার ঘটায় লবণাম্বু উদ্ভিদের ফসিল পরীক্ষায় দেখা যায় সৃষ্টির যুগে প্রায় শতাধিক মিলিয়ন বছর আগে ইন্দুমালয় অঞ্চল থেকে লবণাম্বুজ উদ্ভিদের বিশ্ব পরিক্রমা ও বনবিস্তারের শুরু আর এ কাজে মুখ্য ভূমিকা নিয়েছে সমুদ্র স্রোত প্রথম পর্যায়ে ভারত ও পূর্ব আফ্রিকার সমুদ্র তটে লবণাম্বু উদ্ভিদের ইতস্তত এবং বিক্ষিপ্তভাবে কিছু কলোনি গড়ে ওঠে আবার সমুদ্র স্রোতের বিপরীত টানে বিস্তার ঘটায় আমেরিকা ক্যারিবিয়ান দ্বীপপুঞ্জ কিছু পরে দক্ষিনে অস্ট্রেলিয়া নিউজিল্যান্ড এবং দক্ষিণ প্রশান্ত মহাসাগরে ছড়িয়ে পড়ে সারা বিশ্বে পরম বিস্ময়কর এই উদ্ভিদ বীজের জীবনশক্তি দীর্ঘসাগর-মহাসাগর পাড়ি দিয়েও নবজন্মে এরা সদা তৎপর এখানে উল্লেখ করা প্রয়োজন। জোয়ার ভাটা বিধত এই উদ্ভিদের বীচ অন্য উদ্ভিদের মতো পুষ্ট পরিপক্ক হয়ে ভূমিতে খসে পড়লে তা জোয়ারে জলে বা ভাটার টানে সাগর-মহাসাগরের ভেসে যাওয়া যাবার সমূহ সম্ভাবনা থাকে। তাই প্রকৃতি এই সমস্যার সমাধান করেছে সুন্দরভাবে। বীজের অঙ্কুরোদগম কাণ্ডটি ঘটে যায় গাছের উপরে যাতে পতিত বীজ ভূমির স্পর্শ করেই প্রথিত করতে পারে তার শিকর আঁকড়ে ধরতে পারে মাটি আবার ভেসে যাওয়া বীজের মধ্যে এমনও দেখা গেছে কিছু কিছু উদ্ভিদের বীজ এই অঙ্কুরোদ গম অবস্থাতেও জলে ভেসে যেতে পারে বৎসরাধিকার ধরে সাগর পাড়ে মাটির খোঁজে ভারত মহাসাগর থেকে ভারতের পূর্ব পশ্চিম দুই প্রান্তে বঙ্গোপসাগর ও আরব সাগর ধরে ছড়িয়ে পড়েছিল এই উদ্ভিদের বীজ উপকূল প্রান্ত ছুঁয়ে ছুঁয়ে সুবিধামতো জায়গায় শিকড় গেড়েছে লবণামবুজ উদ্ভিদ। ভারতের সমগ্র পশ্চিম উপকূলজুড়ে তার নিদর্শন ছড়িয়ে আছে আর পূর্ব উপকূল জুড়ে বীজ বপন করতে করতে বঙ্গোপসাগরের

উত্তর প্রান্তে এসে ঘটে গেল এক বিপ্লব আমরা জেনেছি এই দ্বীপ মন্ডলের প্রকৃতিগত বৈশিষ্ট্য প্রথম পর্বে তাই ভেসে আসা বীজ সমূহ জোয়ার স্রোতে মোহানা দিয়ে উত্তর বরাবর ঢুকে পড়ে ভেসে যায় আরো উত্তরে আরো ব্যাপকভাবে ভাটার স্রোতের টানে দক্ষিণা মুখে ফেরার পথে বদ্বীপের ক্রমশ স্ফীত হওয়া দ্বীপের গায়ে মাটি ছুঁয়ে ফেলা বীজ জন্ম দেয় নতুন উদ্ভিদের প্রকৃতির লীলা খেলায় ঘন সন্নিহিত হয়ে ওঠে এ উদ্ভিদ অরণ্য মাকড়সার জালের মত উত্তর থেকে দক্ষিনে ছড়িয়ে থাকা হালখাড়ি দেওয়ানি ভারানি আর নদী জড়িয়ে থাকা দ্বীপ ভূমি গুলোতে সমুদ্রের জোয়ারের স্রোতে ভেসে আসা এই উদ্ভিদের বীজ ভূমির স্পর্শ পেয়ে মুহূর্তকালেই প্রথিত করেছে তার শিকড়। মোহনা থেকে উত্তর দিকে ক্রমশ বনবিস্তার ঘটে গেছে লবণাম্বু উদ্ভিদের অন্যতম বৈশিষ্ট্য তার শিকড়ের বিন্যাস উদ্ভিদের মাটি দিনে দুবার জোয়ার ভাটায় প্লাবিত হয়। তীব্র স্রোতের টানকে সামাল দিতে তার শিকড়ের বিন্যাসে তাই দেখা যায় বিশেষ বৈশিষ্ট্য কখনো কাণ্ড থেকে বের হওয়া ঠেসমূল বা শিকড় থেকে লম্বা ভাবে সরসজ্জার মত বেরিয়ে আসা শ্বাসমূল pneumato force মাটিকে শক্ত করে ধরে রাখে স্রোতের তীব্র টান থেকে যাতে ভূমিচূত না হতে হয় আবার ভূমিক্ষয় বা ভাঙ্গন প্রতিরোধের সহায়ক এই শ্বাসমূল পাশাপাশি জলের লবণাক্ততা ও ঘনত্ব বেশি হওয়ায় বাতাস থেকে অক্সিজেন গ্রহণে সাহায্য করে। বিশ্বজুড়ে ৩৩৪ প্রজাতির লবনামবুজ উদ্ভিদ থাকলেও সুন্দরবনের পরিবেশ পরিস্থিতিতে টিকে আছে ১০৫ টি প্রজাতির উদ্ভিদ তার মধ্যে ২৫ টি মূল লবণাম্বু উদ্ভিদ প্রজাতি true mangrove species ত্রিশটি সহযোগী লবণাম্বু উদ্ভিদ প্রজাতি mangrove associated species ৩৭টি খারি লবণাম্বু উদ্ভিদ প্রজাতি Batman group species ছটি বিলভূমি লবণাম্বু উদ্ভিদ প্রজাতি which flora এবং সাতটি প্রজাতির পরভুজি পরজীবী পরগাছা লবণাম্বু উদ্ভিদ parasites epiphytes missed latest বর্তমান

সুন্দরবনের কাঁকড়া, উর্বরতা গড়ে তোলার মুখ্য কারিগর

সাইক্লোনের চিহ্ন (ছবি: জুঁই কোলে)

এই বিচিত্র অরণ্য প্রকৃতি তার জল মাটি পরিবেশেও এক অতি গুরুত্বপূর্ণ পরিস্থিতি গড়ে তুলেছে নোনা ও মিষ্টি জলের সঙ্গমস্থলে গড়ে ওঠা এ অরণ্য উপত্যকায় জিবিক্রিয়াজনিত কারণে ক্রম বিবর্তিত বন্যপ্রাণ তার আবাসস্থল মোহানা জোয়ার-ভাটা অধ্যুষিত চরভূমি জলাভূমি নদী বাঁধ ইত্যাদি সমূহে অপরিসীম প্রভাব ফেলেছে। স্বাভাবিক ক্রিয়া জনিত কারণে এখানের ভূমি অত্যন্ত গুরুত্বপূর্ণ ভূমিকা পালন করে। ব্যাকটেরিয়া আলগি পোকামাকড় মেরুদন্ডী, অমেরুদন্ডী প্রাণী জলজ প্রাণী পাখি এখানে পাই খাদ্য আশ্রয় আর সুরক্ষা, এসব প্রাণীকুলের সঙ্গে উদ্ভিদ কুলের যে অঙ্গাঙ্গি মেলবন্ধন সে সূত্রে সুন্দরবন হয়ে উঠেছে বিপুল এক খাদ্য ভান্ডার বিপুল পরিমাণে খাদ্য শক্তি তৈরি হয়ে চলেছে উদ্ভিদের পাতা ছাল ফুল ফল উত্তর থেকে দক্ষিণ বাহিনী সাগর চোয়ানো বলি রাসায়নিক নানা খনিজ পদার্থের মিলেমিশে নানা বিক্রিয়ায় এই খাদ্য ভান্ডার গড়ে তুলেছে। ছোট্ট একটি হিসেবে দেখা যায় সুন্দরবনের একটি গাছ তার তলদেশে এক বছরে এক বর্গ মিটার এলাকায় প্রায় এক কিলোগ্রাম বর্জ্য খাদ্য তৈরি করে এই সুবিশাল খাদ্য ভান্ডারী মাছ খেয়ে খাদ্য সুরক্ষা দেয় মাছের মিনকে তার প্রয়োজনীয় সব রকমের প্রোটিন সমৃদ্ধ খাবার সরবরাহ করে অন্যদিকে অরণ্যভূমি হয়ে ওঠে উর্বর

সুন্দরবনের সমস্যা সুন্দরবনের সমস্যাকে আমরা প্রাকৃতিক সমস্যা আর মনুষ্য কৃত সমস্যা হিসেবে দুভাগে আলাদা করতে পারি।

প্রাকৃতিক সমস্যা মিষ্টি জলের অপ্রতুলতা

সুন্দরবনের সবচেয়ে বড় বিপদ বা সমস্যা হল মিষ্টি জলের প্রবাহ ভীষণভাবে কমে যাওয়া বা প্রায় বন্ধ হয়ে যাওয়া। আমরা আগেই জেনেছি এই উপত্যকার পূর্ব ঢাল ক্রমশ নিচু হয়ে চলার কারণে মিষ্টি জলের প্রবাহ গড়িয়ে যাচ্ছে পূর্ব প্রান্তে ফলে গঙ্গাবাহিত সমস্ত পুলিশ সমৃদ্ধ মিষ্টি জলের প্রবাহ এখন পূর্বমুখী হয়ে বাংলাদেশ সুন্দরবন অভিমুখে গড়িয়ে চলেছে।

লবণামবুজ উদ্ভিদ অরণ্যের সুস্থভাবে টিকে থাকার অন্যতম শর্তই হলো পর্যায়ক্রমে মিষ্টি ও নোনা জলের প্রবাহ ঘটে চলবে বদ্বীপ ভূমির উপর দিয়ে স্বাভাবিক কারণেই আজ ভারতীয় সুন্দরবনের লবণাম্বু উদ্ভিদের শরীর স্বাস্থ্য ভীষণ রকমের অস্বাভাবিক অবস্থার মধ্যে বিরাজ করছে।

প্রাকৃতিক প্রাকৃতিক দুর্যোগ

আমরা দেখেছি সুন্দরবন তৎসংলগ্ন বঙ্গোপসাগরীয় অঞ্চলে প্রায়শই নিম্নচাপ খনীভূত হয়ে চলেছে। এর সঙ্গে কোনোভাবেই বিশ্ব উষ্ণায়নের যোগাযোগ নেই সাধারণত সমুদ্রের জলপৃষ্ঠের উষ্ণতা ২৭ ডিগ্রি সেলসিয়াসের কাছাকাছি থাকে তার বেশি উষ্ণতা বৃদ্ধি পেলে স্বাভাবিকভাবে জলীয় বাষ্প তৈরি হবে বেশি এবং সেখানকার বাতাস গরম হয়ে আরো উপরে উঠে যাবে আর সেই শূন্যস্থান পূরণ করার জন্য তীব্র গতিতে ব্যাপক অংশ জুড়ে বাতাস ধেয়ে আসবে। তৈরি হবে ঘূর্ণাবর্ত। আমাদের বঙ্গোপসাগরের জলপৃষ্ঠের উষ্ণতা বেশি থাকে প্রায়শই ২৮ ২৯ ডিগ্রি সেলসিয়াসে পৌঁছে যায় নিম্নচাপের প্রকোপ হামেশাই এখানে দেখা মেলে।

এখানে আরও একটি প্রসঙ্গের অবতারণা করা দরকার তা হল সুন্দরবনের দক্ষিণের সাগর হবার কারণে দখিনা বাতাস যে ঢেউয়ের জন্ম দেয় তার অভিঘাতে জঙ্গল সীমান্তের লবণস্বুজ উদ্ভিদের উপরে এক বিশ্বময় প্রভাব ফেলেছে তীব্র ঢেউ যখন জঙ্গল তীরে আছড়ে পড়ে তার অভিঘাতে সাইক্লোনের আঘাতে জলস্ফীতি ও সুবিশাল ঢেউয়ের আঘাতে যে লবণাক্ত জলকণা ফোয়ারার মতো ছড়িয়ে তীর সংলগ্ন গাছগুলোর উপর আছড়ে পড়ে তখন সেই সল্ট স্প্রে তে গাছের পাতা বাকল ঝলসে যায় সে দৃশ্য তখন মনে করিয়ে দেয় যেন এক দাবানল ঝুলছে দিয়েছে জঙ্গলের সমস্ত উদ্ভিদ আসলে দাবানল কে স্থিমিত করার জন্য যে জলের ফোয়ার শেখানো হয় তেমনি এক কাণ্ডে লবণাক্ত জলের ফোয়ারা দাবানলের মত দৃশ্য রচনা করে সুন্দরবনের কুলে কুলে।

কৃত্রিম বন সৃজন

চারা উৎপাদন

পলি সম্পর্কিত সমস্যা

আমরা আলোচনার প্রথমার্ধে অলিবাহিত মিষ্টি জল প্রবাহের কথা বলেছি, গঙ্গা তার নিজের এবং সমস্ত উপনদীর পলি বহন করে এনে তুলে দিয়েছে পূর্বমুখী পদ্মার অঙ্কে আজ শেষ পূর্ব দিকে ব্রহ্মপুত্র ও মেঘনা বাহিত বিপুল পলি রাশি সাগর অভিমুখে বয়ে নিয়ে চলেছে। এই উপত্যকার পূর্ব প্রান্তে শ্রীহট্ট খাত এবং দক্ষিণ পূর্বসাগর বুকে অতন স্পর্শ শিখাত থাকায় সেই খাত পূরণ করার তাগিদে পলির ভূমিকা হয়ে উঠেছে অত্যন্ত গুরুত্বপূর্ণ শ্রীহট্ট খাত পূরণ করতে গিয়ে সময় লেগেছে প্রায় হাজার খানিক বছর। সেই সময় উপত্যকার পশ্চিম প্রান্ত সক্রিয় ভূমিকা নিয়ে দীপ গঠনে আরো এগিয়ে গেছে সাগর বুকে দক্ষিণ দিকে যদিও সেদিক গঠনে সবচেয়ে বড় অন্তরায় হয়ে দাঁড়িয়েছে উপত্যকার পূর্ব ঢালে পলির আধিক্য বেড়ে যাওয়ায় প্রথমে শ্রীহট্ট খাদ পরে আরো দক্ষিণে অতস্পর্শী খাত ভরাট করতে গিয়ে স্বাভাবিকভাবেই পলির ভারী ও মোটা দানা খাত গভীরে নিবোচিত হয়ে পড়েছে স্রোতের অভিঘাতে পূর্ব মুখী হয়ে ভারতীয় সুন্দরবনের দিকগুলোর উপরে ছড়িয়ে পড়েছে ফলে দেখা যায় বাংলাদেশ সুন্দরবনের তুলনায় ভারতীয় সুন্দরবনের দিকগুলির মধ্যে গড়ে ওঠার চেয়েও ক্ষয়িষ্ণু প্রবণতা অনেক বেশি।

মনুষ্য কৃত সমস্যা

এ তো গেল প্রাকৃতিক বৈষম্যের কথা মানুষ তার লোভের ভর্তি হয়ে জঙ্গলের বড় অংশকে নির্মূল করেছে আবাদ গঠন করেছে বসতি গড়ে তুলেছে ১৪৪২ খ্রিস্টাব্দে খান জাহান আলীর সময়কাল থেকে পরবর্তীতে প্রতাপাদিত্য সুজাসহ ইংরেজদের সবকিছুর মতো প্রকৃতিক উপরেও লুব্রতরাজ আর সবশেষে স্বাধীন ভারতে শরণার্থী সমস্যা মোকাবিলা করতে গিয়ে ব্যাপক এবং বিশাল অংশ অরণ্য ছেদন ঘটে গেছে

লবণামবুজ উদ্ভিদ সম্বন্ধে খুব পরিষ্কার করে বলা যায় যে প্রতিমুহূর্তে পাল্টে যাওয়া পরিবেশ পরিস্থিতির সঙ্গে মানিয়ে নেওয়া তাদের একটি অন্যতম ধর্ম তাই তারা খড়িমাটির যুগ হিমবাহ যোগ অবলীলায় পার হয়ে এসে দাঁড়িয়েছে আজ এই উষ্ণায়ন বা জলবায়ু পরিবর্তনের যুগে এ লড়াই এই বিশেষ বৈশিষ্ট্য ধর্মী লবণামবুজ উদ্ভিদ রাশির নিজেকে টিকিয়ে রাখার লড়াই হাজার হাজার বছর ধরে আরো অনেক বেশি প্রতিকূল পরিবেশ পরিস্থিতি সামাল দিয়ে আজ যখন এই সমস্যার সামনে এসে দাঁড়িয়েছে পুরোনো দিনের দিকে তাকিয়ে নির্দ্বিধায় বলতে পারি এই লড়াইটা এই বিশেষ বৈশিষ্ট্য ধর্মী লবনামবুজ উদ্ভিদ রাজি হবেই।

অনেকবার বলেছি, যে বিশেষ বৈশিষ্ট্যধর্মী লবণামবুজ উদ্ভিদ এই কথার অন্যতম ব্যাখ্যা হল যে কোন খারাপ প্রতিকূল পরিস্থিতিকেই তার প্রাণশক্তি দিয়ে সে সামাল দিতে সক্ষম দীর্ঘকাল ধরে প্রাকৃতিক বিপর্যয় যখনি লবণ উদ্ভিদ আচ্ছাদিত অরণ্য বিপর্যস্ত হয়েছে দ্রুত সেই অরণ্যকে স্বাভাবিক অবস্থায় ফিরিয়ে এনেছে স্বীয় ক্ষমতায় তার অফুরান প্রাণশক্তি দিয়ে সামান্য অতীতে আমরা সুনামির পরিণতিতে দেখেছি মধ্যপ্রাচ্যের বিশাল লবণামবুজ অরণ্যকে ধ্বংস করে দিয়েছে সুনামির মহাপ্রলয় তখন সেই অরণ্যভূমিতে মানুষ প্রকৃতির শক্তির উপর ভরসা রাখতে না পেরে এই উদ্ভিদের বনসৃজন করেছে সেই ভূমিতে। তা কিন্তু যথাযথ গ্রহণ করেনি সেই বনাঞ্চল। পাশাপাশি আমরা দেখি সারা বিশ্ব জুড়ে যেখানেই নতুন করে এই উদ্ভিদ রাজীর কৃত্রিম সৃজন করার চেষ্টা হয়েছে তা কখনোই সুন্দরভাবে রূপায়িত হতে পারেনি এর পিছনে যে কারণগুলি আছে সেগুলি যদি বিশ্লেষণ করি দেখব।

যেকোনো নতুন জেগে ওঠা চড় ভূমি পূর্ণতা পেতে সময় লাগে দীর্ঘকাল তারপর ধীরে ধীরে প্রাকৃতিক নিয়মেই নরম পুলির উপর জন্ম নেয় ধানি ঘাস তার গুচ্ছ মূল দিয়ে আঁকড়ে থাকে নরম মাটি পলিমাটি মাটি একটু জমাট বাঁধলে সেখানে আসে খরগোশ আইন গেরুয়া গাছেরা ধীরে ধীরে সেই জেগে ওঠা নতুন চরকে পরিণত দিক হিসেবে গড়ে উঠতে সাহায্য করে এই প্রাকৃতিক পদ্ধতি সেখানে ভুল করে আমরা অযাচিতভাবে এই লবনামবুজ উদ্ভিদ রোপন করতে গিয়ে বারবার ব্যর্থ হয়েছি অতি স্বাভাবিক কারণে স্বাভাবিক শৃঙ্খলা মেনে চলে প্রকৃতি ইচ্ছে মতো বিশৃঙ্খলা আনলে তারপরে নতুন জেগে ওঠা চরের নতুন নদীর সম্পদ তারও দীর্ঘকাল ধরে গড়ে ওঠা বৈচিত্র সম্পূর্ণ ধ্বংস করে দিচ্ছে কতিপয় অবুঝ মানুষ জোয়ার-ভাটা বহমান সেইসব চর ভূমি সুন্দরবনে জীবন্ত ফসিল রাজ কাঁকড়া horse shoe crab মেনু মাছ mudskipper এদের আবাসস্থলকে ধ্বংস করে দিচ্ছি সুন্দরবনের অন্যতম সম্পদ বিশেষ কিছু প্রজাতির কাঁকড়া, যারা তাদের অসামান্য জীবন পদ্ধতির কারণে সুন্দরবনকে বিশ্বের অন্যতম মাছ ও গাছের খাদ্য ভান্ডার পরিণত করতে পেরেছে সেই কাঁকড়াদের আবাসভূমিকে কেড়ে নেওয়া হচ্ছে। সুন্দরবনের স্বাভাবিক জীববৈচিত্রের এই যে শৃঙ্খল তার উপরে আমরা অযাচিত এবং অবৈজ্ঞানিক মানসিকতায় হস্তক্ষেপ করে সুন্দরবনকে টিকিয়ে রাখা নয় ধ্বংস করে ফেলার চেষ্টায় মেতে উঠেছি।

Animesh Sinha

He was born in 1950 at Canning, South 24 Parganas. His love for nature was nurtured by his parents. Despite being born in a village, he was brought up with knowledge in politics and literature. Among all turmoils during his college days, a deep relationship with Sundarbans had begun. Since last five decades his life revolves around Sundarbans. Though he had to take a job at State Bank of India but he left the job for Sundarbans. His essays have been published by some esteemed magazines and periodicals like Anandabazar Patrika, Desh, Anandamela, Sandesh, Banabithi, Bhraman, Jara Parijayi, Jara Jajabor and many more. "Sundarban O Nadi Katha", his book, is basically an extract from his lifelong research on Sundarbans which has gained popularity among readers and has been adored by many scientists and experts.

5 Transpose Schistosity: A Conspicuous Structure in Geology

Chandrabali Mukhopadhyay

Each rock type has a distinctive mineral composition and texture of its own. ***Texture*** *or* ***fabric*** *of a rock refers to the shapes, arrangements and orientation of the mineral grains present in that rock (Vernon 2004). For the metamorphic rocks, the term '****microstructure****' has been recommended by the IUGS Subcommission on the Systematics of Metamorphic Rocks (Vernon 2004 and references therein). Any type of planar and linear fabric in a rock are known as foliation and lineation respectively. A foliation may be* ***primary****, like sedimentary bedding, which occurs in undeformed rocks, or* ***secondary*** *(tectonic), produced in a solid, consolidated rock by deformation. When a body of rock is deformed, its shape, size and texture may be subjected to change, depending on the extent of deformation and the grade of metamorphism. At high metamorphic grade,* ***ductile deformation*** *of a rocks is favoured, in which the mineral grains change their shapes or move relative to each other without fracturing at the grain scale (Vernon 2004). The platy or tabular mineral grains (those having thicknesses much less than lengths and widths) may be randomly oriented in an undeformed rock. Ductile deformation tends to align these grains parallel to one another, thus producing a* ***preferred dimensional orientation*** *among them. Such microstructural changes lead to the development of different types of secondary foliations in a rock. With increasing grade of metamorphism, ductile deformation may successively produce rock cleavage, schistosity, and gneissosity in a rock. The term rock cleavage refers to the secondary foliation, formed under low-temperature conditions, that imparts to the rock a tendency to split along parallel planes (after Van der Pluijm & Marshak 2004). Those parallel planes are known as* ***cleavage planes****. Slate is a common type of rock that has well-developed rock cleavage, and by virtue of this microstructure, slates can be split easily into very thin, almost sheet-like fragments. Schistosity, on the other hand, is formed at intermediate to high temperatures, and is defined by the parallel alignment of micas and other thin, platy or tabular mineral grains. The rocks having well developed schistosity also have the tendency to break along the mutually parallel* ***schistosity planes****. Mica schist is a common type of rock with prominent schistosity, in which the schistosity planes have a shiny appearance due to the abundance of medium to coarse-grained micas (after Van der Pluijm & Marshak 2004). Gneissosity is the secondary foliation in feldspar-rich high-grade metamorphic rocks, formed at high temperatures, that is defined by*

compositional banding. *The light-coloured felsic minerals (quartz, feldspar etc.) and the dark coloured mafic minerals (pyroxene, amphibole etc.) are arranged in separate zones in the gneissic rocks. These compositional zones may be tabular-shaped* ***bands****, or eye-shaped* ***augen****. However, in contrast to rock cleavage and schistosity, a gneissic rock cannot be split easily along the gneissosity planes.*

Various aspects of the rock foliations, including their morphological characteristics and the mechanisms for their development, are widely studied by the geologists throughout the world. The next article highlights one such aspect, the transposition of schistosity, which is the strong modification and realignment of a schistosity into a new orientation (Vernon 2004). This highly informative article, written by Dr. Chandrabali Mukhopadhyay, Department of Geology, Jogamaya Devi College, is based on her online seminar held on June 9, 2022 and attended by the teachers and students of geology of our college. A total of 14 line diagrams and photographs, collected from different text books and academic websites, have been given in this article to make it easily understandable to the readers.

This article is highly recommended for all the undergraduate and post-graduate students of geology, especially those having special interests on structural geology and metamorphic petrology.

Bhaskar Ghosh
Department of Geology, Jogamaya Devi College

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Transposed schistosity: A conspicuous structure in geology

Chandrbali Mukhopadhyay,
Department of Geology, Jogamaya Devi College,
chandrabali@yahoo.com

Abstract: Foliation is a planar fabric element. They are associated with tectonic deformation and are common in all grades of metamorphic rocks. The parallel alignment of platy minerals is believed to be the principal cause of formation of these foliations. It provides clues to the geometry of large-scale structures, kinematics, strain, and conditions of deformation. Mechanical rotation, solution / precipitation, crystallization, and recrystallization are involved in the development of diverse foliations including transposed schistosity. All of the mechanisms tend to produce a preferred dimensional orientation of non-equant grains and/or aggregates of grains that define a planar structural element. Differentiated types are increasingly obvious as the metamorphic grade increases. In case of transposed schistosity, transposition is a mechanical transformation of layers from an initial orientation into another orientation. An essential part of this is the rotation of a pre-existing plane by tight folding into an orientation approximately parallel to the axial plane of the resulting isoclinal folds. Extreme flattening, development of discontinuities parallel to axial surfaces, development of axial plane foliation, elimination of fold closures and segmentation of marker beds or layers achieve transposition.

Keywords: fabric, crystallization, recrystallization, transposition

1. Microstructure

Microstructure are material structures which includes the texture of a rock. Typically, the microstructure / textures are defects, impurities, grains, and grain boundary. It provides information of conditions of formation, different phases of deformation, as well as pressure temperature changes with time. Textures are penetrative fabrics of rocks which is present throughout the rock, generally down to the grain scale. So metamorphic rocks can be classified on the basis of texture of minerals as well as the mineral assemblages (Figure 1).

2. Foliation

Foliation is a planar structural element in metamorphic rock and it results from the alignment of micaceous platy minerals, as for example amphibole, chlorite etc. (Figure 2). They are caused by extreme stress in the form of high temperatures and pressure on metamorphic rocks (Figure 3). There are three types of foliations: slaty cleavage, schistosity, and gneissosity. To differentiate between these types, the characteristics of mineral grain size, mineral layer thickness, and mineral grades are categorized (Figure 4).

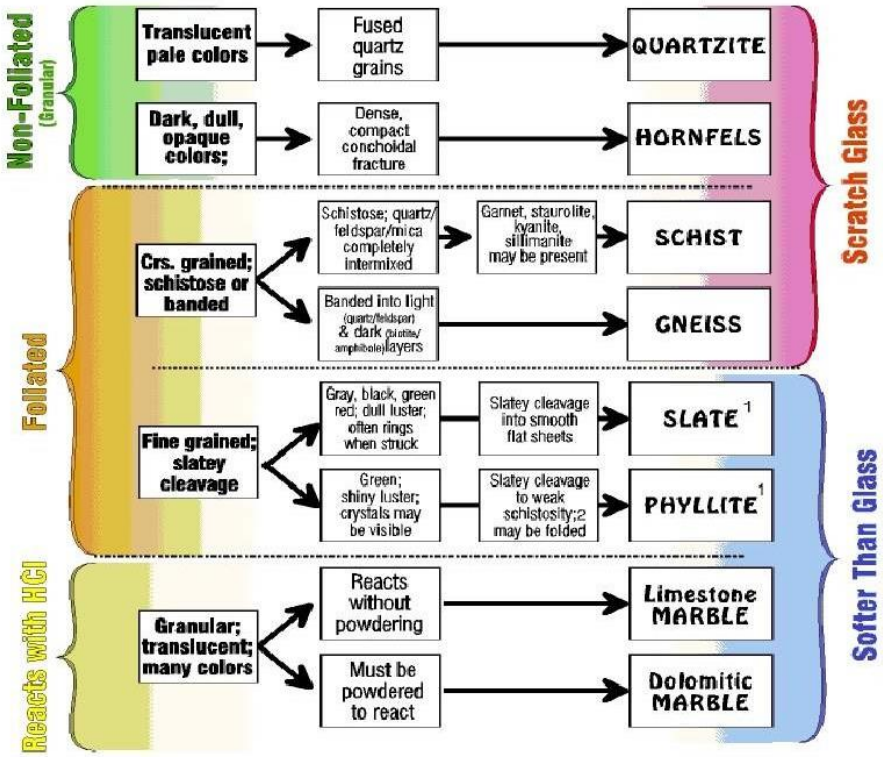

Figure 1: Classification of metamorphic rocks is based on mineral assemblage, texture, protolith, and bulk chemical composition of the rock.
Reference: https://www.geologyin.com/2014/07/classification-of-metamorphic-rocks.html

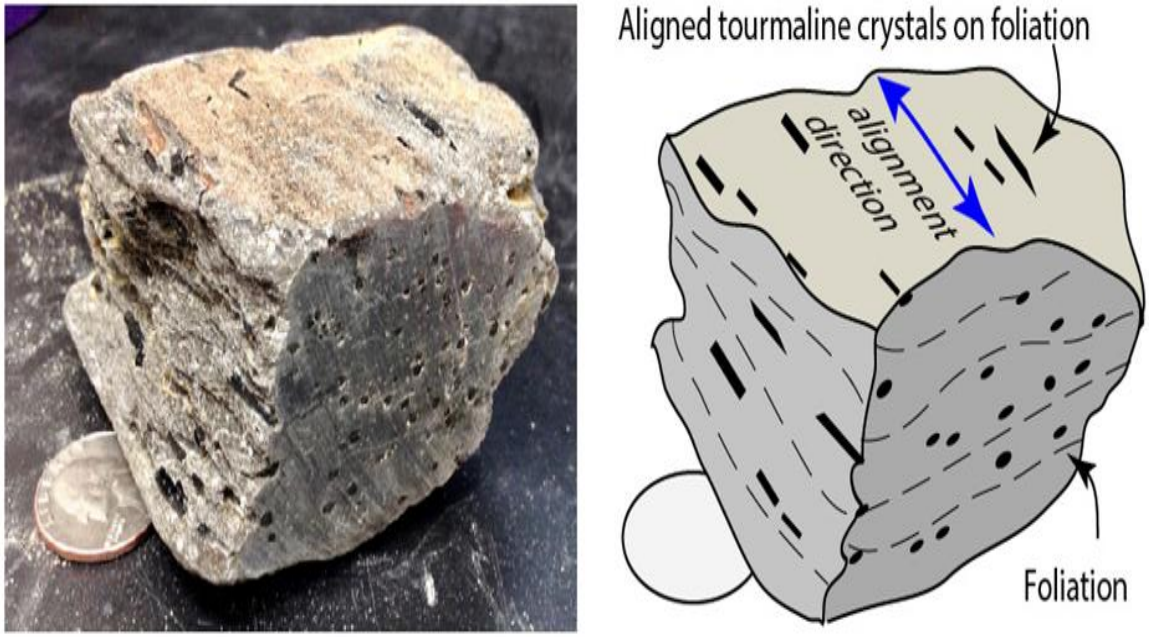

Figure 2: Planar set of minerals, or banding of mineral concentrations, especially the planar structure that results from flattening of the mineral grains, like micas is the foliation.
Reference: https://opengeology.org/textbook/6-metamorphic-rocks/

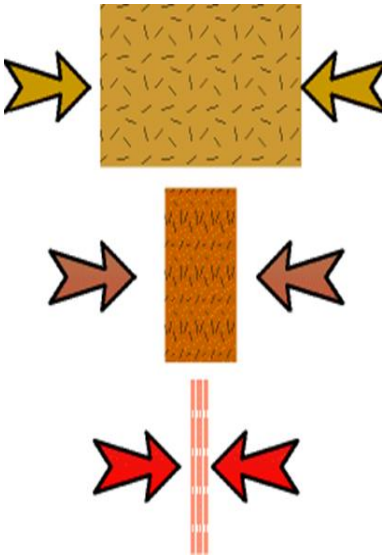

Figure 3: Foliation results from flattening of the mineral grains, like micas.
Reference: https://csmgeo.csm.jmu.edu/geollab/fichter/metarx/metatexture.html

2.1 Schistosity

In schistosity, platy grains of minerals like micas and amphiboles are strongly oriented in a preferred direction which forms a very thin parallel layer. The ease with which the rock splits along the aligned grains accounts for the schistosity. These flakes are often gathered in a way that they form a special type of texture called felted arrangement. Schistosity is well-developed in the rock layers which have experienced the greatest amount of flattening at temperatures above 320°C (approximately). It forms during regional metamorphism and reflects a low to medium grade of metamorphism (Figure 4).

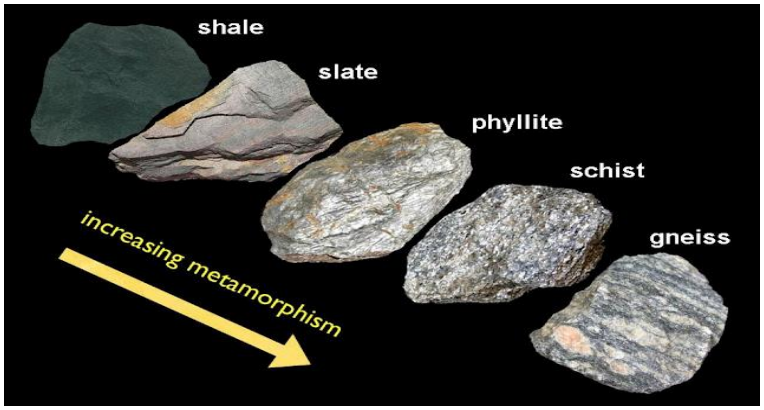

Figure 4: The formation of foliated metamorphic rock.
Reference: https://www.geologyin.com/2014/05/the-formation-of-foliated metamorphic.html

3. Formation of a foliation

The development of formation of a foliation involves a combination of various mechanisms dependent on the rock composition, tectonic processes, and metamorphic conditions. The magnitude and orientation of stress coupled with pressure and temperature conditions determine how a mineral is deformed. Foliation may be formed by realignment of micas and clays via physical rotation of the minerals within the rock. Often this foliation is associated with diagenetic metamorphism and low-grade burial metamorphism. The mechanisms currently believed to control the formation are metamorphic differentiation rotation of mineral grains, solution transfer, dynamic recrystallization, and static recrystallization.

3.1 Metamorphic differentiation

It is caused by chemical and compositional banding within the metamorphic rock mass. Differentiation is a process that results in the concentration of certain minerals in one part of a rock and other minerals in another part of the rock. Usually, this represents the protolith chemistry, which forms distinct mineral assemblages. However, compositional banding can be the result of nucleation processes which cause chemical and mineralogical differentiation into bands (Figure 5). This is typically same as that of mica growth, perpendicular to the principal stress. Crenulation foliation may occur under conditions that are also favourable for pressure solution. In such cases, as crenulations form, quartz may preferentially move from the limbs of the micro folds and be precipitated along the hinge areas of the folds.

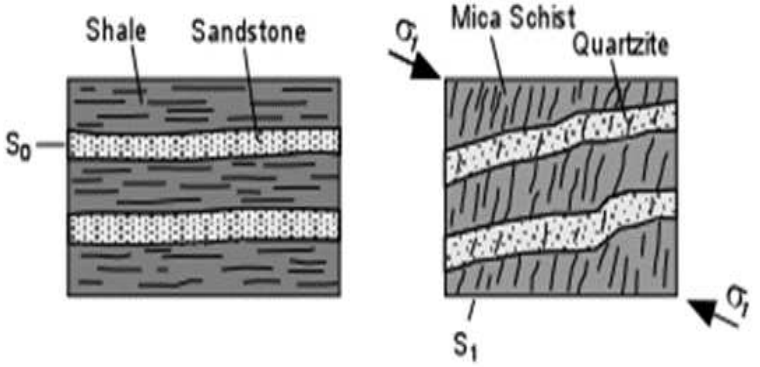

Figure 5: Metamorphic Differentiation
Reference: https://www2.tulane.edu/~sanelson/eens212/metatexture.htm.

3.2 Rotation of mineral grains

Foliation forms what mineral grains orient themselves in such a way that they create repetitive planar structures. It is best observed on a surface perpendicular to foliation layers (Figures 6 & 7)

Figure 6: Foliation forms where mineral grains orient themselves
Reference: https://www.quora.com/What-is-foliation-What-causes-it.

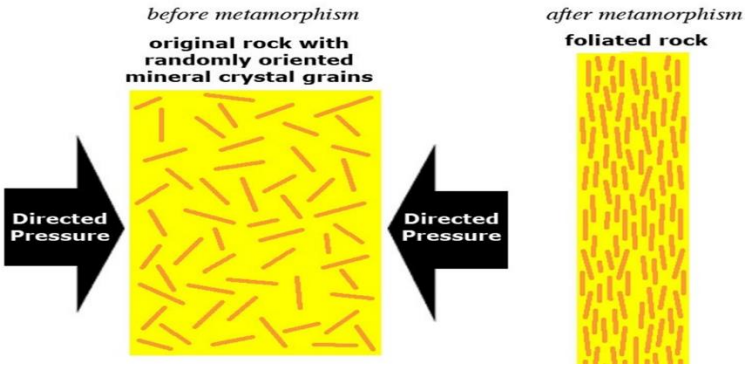

Figure 7: Foliation forms due to directed pressure and minerals orient themselves
Reference: https://www.quora.com/What-is-foliation-What-causes-it.

3.3 Solution transfer

Removal of dissolved material by solution transfer is aided by the geometry of shearing of phyllosilicates in an active anastomosing foliation (Figure 8). Interlayers and interfaces on boundaries lying at a low angle to the direction of shearing, and oriented relative to the sense of shear such that they can open, gape by small amounts. Water present in these interlayer spaces becomes restructured, considerably enhancing diffusion rates along the foliation (Figure 8). Close examination of this structure shows that the quartz/feldspar-rich portions contain small fold hinges, whereas the more eroded micaceous portions form fold limbs. The bedding is well preserved in the hinge regions, suggesting that there has been little or no addition of silica. Dissolution and solution transfer is significant process during deformation at low metamorphic grades, but this deformation is dominated by crystal-plastic processes at higher grades (e.g., Rutter 1983).

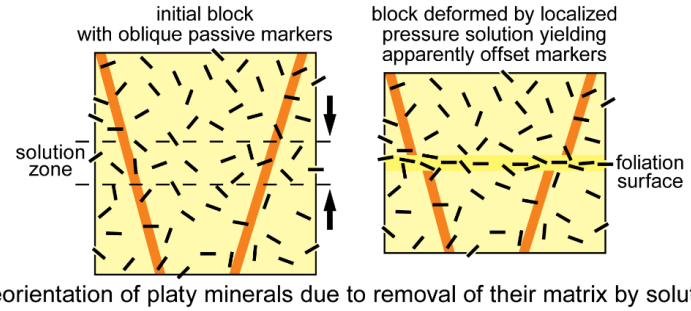

Figure 8: Reorientation of grains due to solution transfer
Reference: https://www.files.ethz.ch/structuralgeology/JPB/files/English/9foliation.pdf

3.4 Mass transfer

Considerable mass transfer has also been recorded in ductile shear zones in granitic rocks with removal of Si, Ca and Na and consequent concentration of Al, Fe, Mg and Ti (Crevola, 1987).

3.5 Recrystallization

The fabrics which develop during dynamic recrystallization are essentially deformation fabrics, although recrystallization processes can accelerate or modify the fabric (Figure 9). When recrystallization starts with deformation it is called dynamic recrystallization. In the absence of concurrent deformation, it is called static deformation.

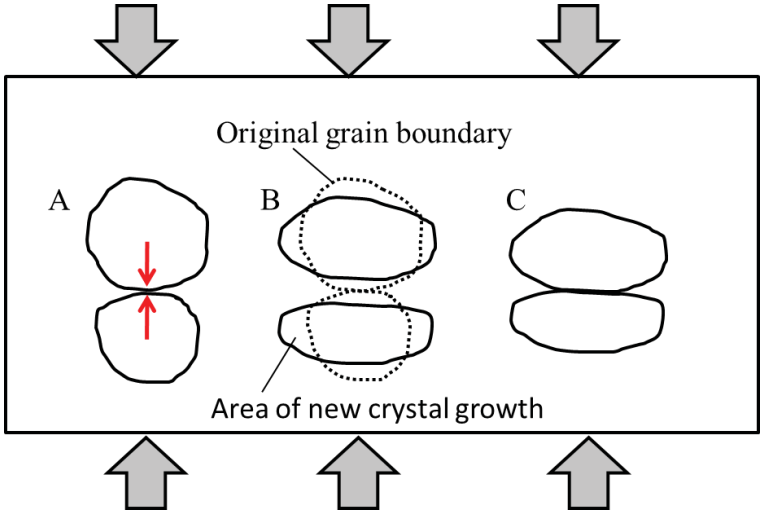

Figure 9: Recrystallization in case of formation of foliation

References: https://pressbooks.bccampus.ca/geolmanual/chapter/overview-of-metamorphic-rocks/

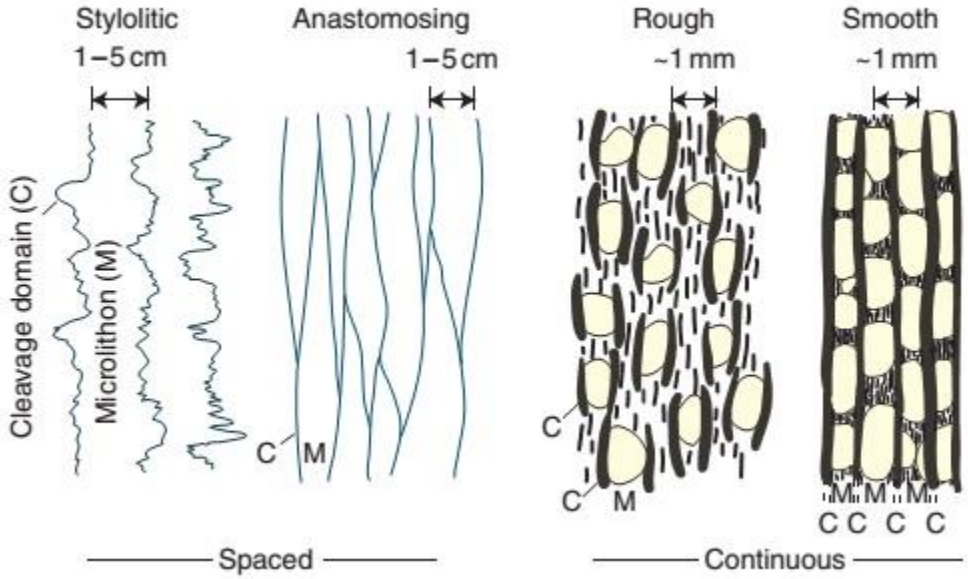

Figure 10: Different types of crenulation cleavage

Reference: http://geologylearn.blogspot.com/2015/08/cleavage-development.html

4. Crenulation cleavage

Crenulation cleavages are zones of mineral differentiation and are coincident with the limbs of microfolds in crenulated fabrics. They consist of sub-planar domains of highly oriented micaceous material that constitute proffered sites of parting in the rock (Figure 10). It is restricted to lithologies with a pre-existing well-developed foliation that at least partly is defined by phyllosilicate minerals. It is commonly seen in micaceous layers while absent in neighbouring mica-poor layers. Crenulation cleavage is created when an earlier foliation is folded and an early planar fabric is overprinted by a later planar fabric. An already established tectonic foliation can be affected by a later deformation (D_2 or higher).

If the orientation of the Instantaneous Stretching Axes changes locally or regionally at some point during the deformation, or if a later cleavage-forming deformation phase occurs growth of new micas on the foliation planes will create a new foliation plane perpendicular to the plane of principal axes.

According to Flinn's diagram strain ellipsoid are plotted which also helps to understand the strain pattern during cleavage formation (Figure 10). Cleavages tend to form perpendicular to the maximum shortening direction, a new cleavage will form that overprints the pre-existing one.

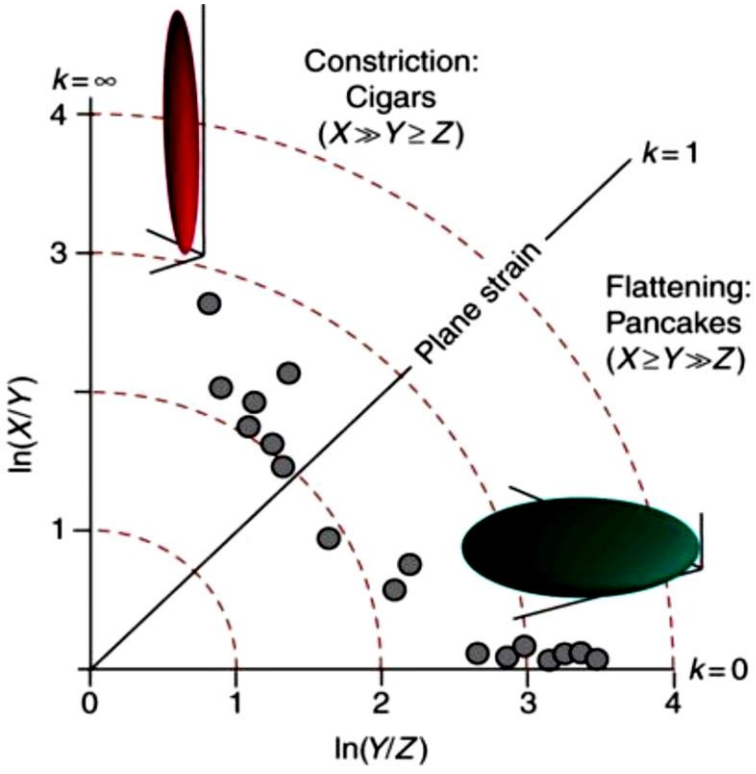

Figure ?: Flinn diagram (logarithmic axes)
Reference: Fossen (2016)

The angular intersection of the two foliations causes a diagnostic texture which is the so-called crenulations. This is a series of microfolds at the centimetre scale or less with parallel axial surfaces. Depending on the angle between the existing foliation and the secondary stress field, the crenulation cleavage is classified as symmetric and asymmetric (Figure 11). A symmetric crenulation cleavage has limbs of equal length, while an asymmetric crenulation cleavage is composed of small, asymmetric folds with S- or Z-geometry.

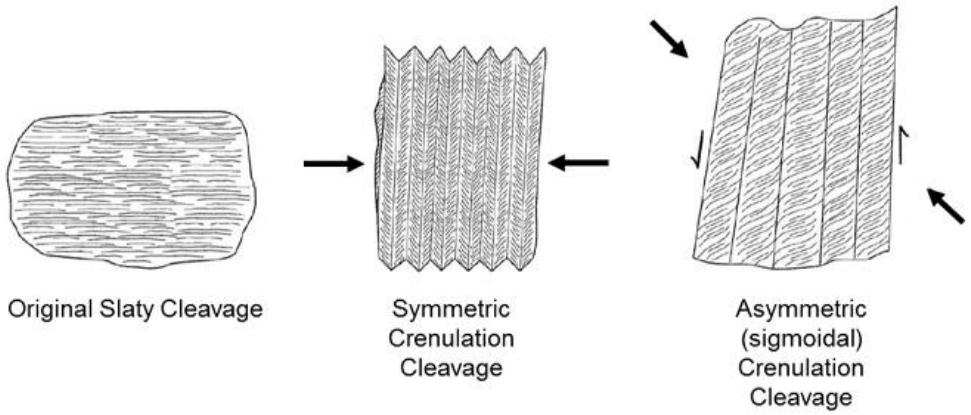

Figure 11: Symmetric and asymmetric crenulation cleavage.
Reference: https://www.alexstrekeisen.it/english/meta/crenulation.php

Transposed Schistosity

A foliation might develop in the shale layers due to the recrystallization of clay minerals or the crystallization of other sheet silicates with a preferred orientation controlled by the maximum stress direction. In the initial stages a new foliation begins to develop in the rock as a result of compressional stress at some angle to the original bedding. As the minerals form, the foliation grows and they begin to break up the original beds into small pods which are compressed and extended, partly by recrystallization and eventually intersect again to form new compositional bands parallel to the new foliation. As the microfolds become more closely compressed, the limbs become progressively thinned out and parallel while the fold hinges become relatively thicker. The new crenulation cleavage is parallel to the aligned limbs of stacked microfolds. Micas within the limbs of crenulations remain approximately parallel to the earlier fabric. They are still parallel to the earlier foliation but have been rotated toward parallelism with the new foliation. In this manner, the development of crenulation cleavage likely involves the mechanical rotation of existing grains accompanied by chemical processes such as modification of grain shapes and sizes by diffusive processes and growth of new grains with an orientation and shape compatible with the local strain history (Figure 12).

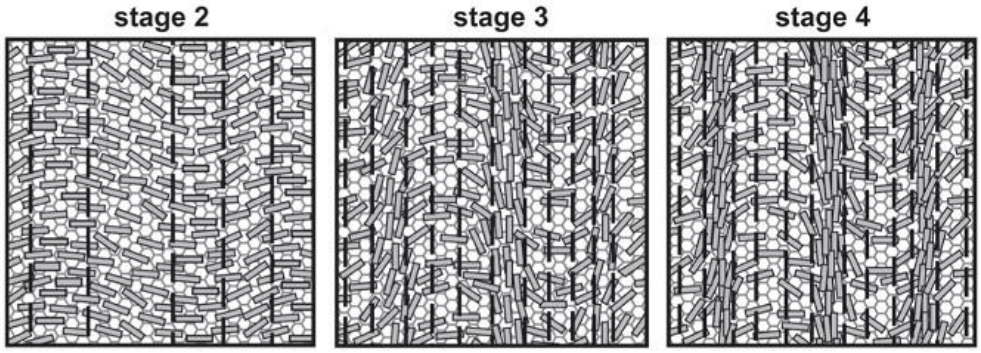

Figure 12: Distribution of mica crystals in a crenulated rock. The grey rectangles represent muscovite grains and the grey lines outline the quartz grains.
Reference: Naus-Thijssen, F. M., Johnson, S. E., & Koons, P. O. (2010)

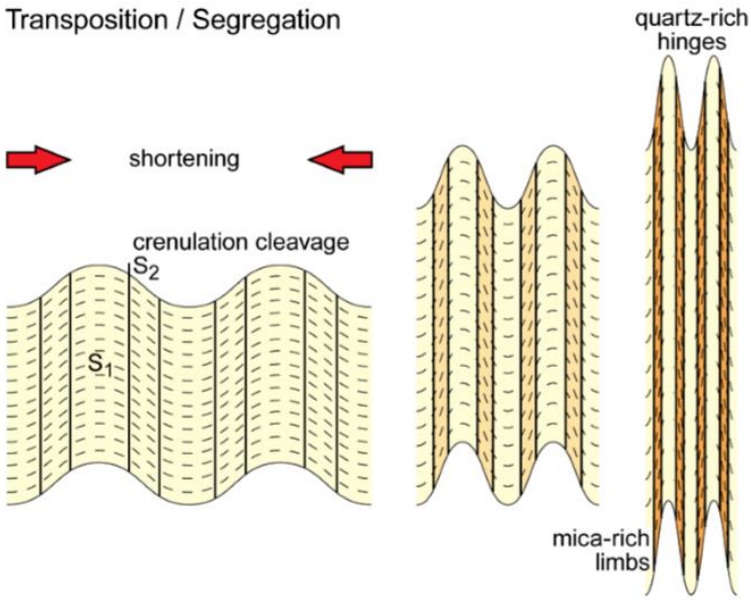

Figure 13: Development of quartz-rich hinges and mica-rich limbs.
Reference: https://www.files.ethz.ch/structuralgeology/JPB/files/English/9foliation.pdf

Several foliation types involve compositional layering. This layering (i.e., banding in two-dimension observations) is attributed to some metamorphic differentiation (or segregation) during the foliation development as discussed earlier. The solution, mass transfer and re-deposition of material (pressure-solution) cause segregation. Dissolution (removal) occurs on grain-to-grain or layer boundaries in porous rocks under non-hydrostatic stress at a rate controlled by the magnitude of normal stress across the boundary. Boundaries perpendicular to the direction of the greatest compression dissolve into the aqueous pore fluid most rapidly. The dissolved material re-precipitates, often as fibrous minerals on low-stress intergranular boundaries and opening veins. Quartz and feldspar may dissolve under pressure solution in the highly compressed limbs and be reprecipitated at the hinges where pressure is lower. As the process continues, the new foliation aligns itself perpendicular to maximum shortening and bands of micas or sheet silicates (limb sites)

alternating with bands of quartz or feldspar (hinge sites) define a differentiation layering parallel to the new foliation (Figure 13)

While discussing about transposed schistosity it should be noted that transposition is a mechanical transformation of layers from an initial orientation into another orientation. It gives a striped appearance to the rock. Transposition layering is defined by parts of a pre-deformation surface (bedding or an older foliation) which are rotated independently into a new orientation; after intense deformation all of these parts are sub-parallel. Physical transformation of layers of one orientation into another is due to the fact of isoclinal or very tight folding. If the shortening during formation of the crenulation foliation is very strong, the earlier foliation may become completely overprinted and / obliterated or transposed. In such cases the only evidence of the earlier foliation may form inclusion trails trapped inside metamorphic porphyroblasts. Intense deformation produces tight isoclinal folds through rotation and stretching / thinning of limbs. Fold hinges are sharp and folds are intra-folial. Hinges may be torn apart along the stretched limbs that ultimately disappear. There is then practically no variation in the orientation of the transposed bedding. A transposed foliation may be mistaken very often.

In fine-grained metamorphic rocks, crenulation cleavage develops along the limbs of microfolds deforming an earlier planar fabric. Quartz and feldspar may dissolve under pressure solution in the highly compressed limbs and be re-precipitated at the hinges where pressure is lower. As the process continues, the new foliation aligns itself perpendicular to maximum shortening and bands of micas or sheet silicates (limb sites) alternating with bands of quartz or feldspar (hinge sites) define a differentiation layering parallel to the new foliation. Fold limbs and hinges may completely disappear when strain-induced solution transfer is extreme. The resulting bands constitute a transposition of the old structures (Figure 14).

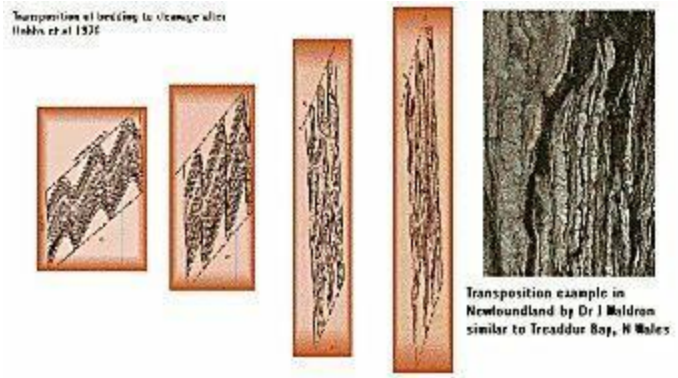

Figure 14: Transposed schistosity and its mechanism of formation
Reference: https://www.files.ethz.ch/structuralgeology/JPB/files/English/9foliation.pdf
http://structuralgeology.50webs.com/TRANSPOS.JPG

So, it appears from the above discussion that an essential part of the mechanical transposition process is the rotation of a pre-existing plane by tight folding into an orientation approximately parallel to the axial plane of the resulting isoclinal folds. Extreme flattening, development of discontinuities parallel to axial surfaces, development of axial plane foliation, elimination of fold closures and segmentation of marker beds or layers achieve transposition. In some instances, recrystallization is accompanied by metamorphic differentiation along foliation planes: thus, foliation domains may become enriched alternately in segregated material, such as quartz, and micaceous minerals. This is a chemical transposition. So, this mineralogical differentiation can be so complete that the old foliation disappears entirely and is replaced entirely by a new foliation, that is defined not only by preferred orientation of the phyllosilicates, but also by micro-compositional layering. This process is a type of transposition, by which a pre-existing foliation is transposed into a new orientation (Figure 15).

Transposition process is so strongly developed that sometimes in field it is impossible to recognize the earliest schistosity very often. With the aid of microscope and very rarely with pocket lens it becomes evident that it is the latest schistosity which has already almost completely obliterated the earlier schistosity and we become confused.

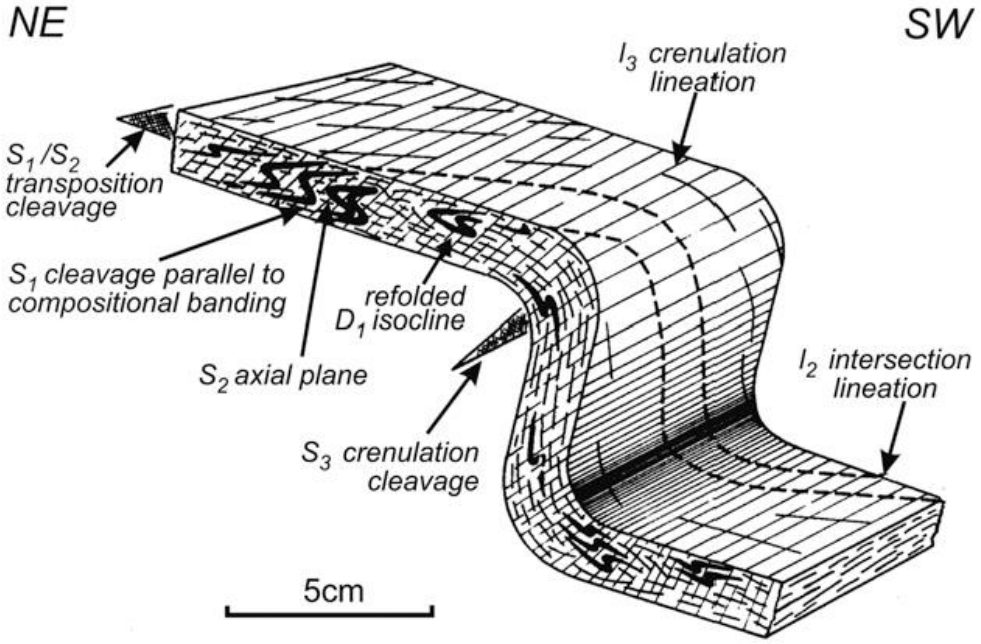

Figure 15: Transposed schistosity.
Reference: https://www.semanticscholar.org/paper/Structural-geology-of-the-Fuegian-Andesand-belt-Menichetti-Lodolo/c331487a13f45c6d0dad63f95a74027c48c9f42a

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Dr. Chandrabali Mukhopadhyay
Dr. Chandrabali Mukhopadhyay is presently working in the Department of Geology at Jogamaya Devi College, Kolkata. She was awarded with Ph.D. degree from the University of Calcutta in 2008. Her research interest includes Metamorphism and Structure of North Singhbhum Fold Belt of India. She is also interested in Mineralogy and Metamorphic Petrology.

6 "We wol been at oure large": Chaucer, the Wife of Bath, and Medieval Womanhood

Angana Moitra

Dr Angana Moitra is Assistant Professor at O.P. Jindal Global University. She delivered her lecture on "We wol been at oure large": Chaucer, the Wife of Bath, and Medieval Womanhood in an online seminar organized by the department of English on June 20, 2022. "The Wife of Bath's Prologue and Tale", a part of Chaucer's seminal work The Canterbury Tales, has long been at the centre of many polarising critical narratives- for both the story it tells and for the character who tells it. From being a radical feminist narrative to an exercise in misogynistic rhetoric on medieval womanhood, there is hardly a label that has not been applied to this much-debated text. Dr. Moitra, in this paper, seeks to see this text as more of a mirror than a mouthpiece, where Chaucer tries to replicate the plurality of his time as opposed to favouring one rhetoric over another.

This paper starts with acknowledging the complexity of the position of Wife of Bath's character as a married woman, both within the context of the frame-narrative of The Canterbury Tales, and the medieval world wherein it is set. In doing so, it takes into consideration the arbitrary expectations from women as fostered by Classical and Biblical scholarship in medieval England. Adding to the Aristotlean idea of a woman as an incomplete man who perpetually lusts for the male seed to seek completion, the Christian concept of Original Sin posits women as creatures of caprice who tend to gentleness and meekness only under the yoke of men's guidance in either religious or marital vocations; this, naturally, would justify from a medieval perspective a woman's subordination in both clerical life and wifehood. Marriage in medieval Europe, then, while prioritising reproduction, is also prescribed as a measure to keep 'sin' or 'lust' in check where chastity, the ideal condition, may not be preserved. However, due to her subordinate position in the marriage, it is the woman who is called upon more often to pay the conjugal debt (ironically so, as she is presumed to be more lustful/sinful), punished more severely for polygamy or bigamy though both husband and wife are supposed to remain monogamous, and has severely limited legal rights over property owned through her marital connection. As the Wife of Bath is the only married woman in the party of pilgrims in The Canterbury Tales, the other women being of clerical vocation, through

both her character and speech Chaucer may be seen to examine this complex position of women (and moreover of women in marriage), as Dr. Moitra illustrates in the following sections of the paper.

In the General Prologue of The Canterbury Tales, as the paper discusses, the Wife of Bath is nowhere near an ideal representative of the married woman in medieval times. She is garrulous, ferociously independent, and an unashamed show-off. Her sexual licentiousness is hinted at through her appearance and her 'wandering' habits, which she herself seems to confirm later in the Prologue to her Tale. Her purpose behind pilgrimages is also made questionable in light of her other attributes- she is hardly to be compared to the other 'devoted' women of clerical vocation in the party whose chastity and morality are barely questioned. While her character, for her fierce zeal for independence, can be considered to have a feminist undertone, the mockery in the presentation of her character is unmistakable.

This duality makes defining the Prologue to the Tale as feminist or anti-feminist to be very problematic, as this paper shows. While she addresses the uneven hand dealt to women in the medieval society of England, she bases the rhetoric of her argument on the anti-feminist rhetoric of classical antiquity and Christian theology, which problematises the appeal and success of her venture. However, as Dr. Moitra states, the Wife's rhetorical skill is extraordinary, and through her exemplum of the lion who suggests that its portrayal as perpetually defeated in paintings is due to the painter being a man, she can suggest effectively that this anti-feminist rhetoric prevails due to the absence of women's voices in their own portrayals.

The Tale, as the paper observes, seeks to return some of the 'maistrie' to women. The term 'maistrie', which, as per Dr. Moitra, loosely translates to autonomy and self-governance in the medieval context, is seen as a way out of the power imbalance that Alisoun or the Wife of Bath complains against in the Prologue. Though rewarding the rapist knight with a beautiful and 'chaste' woman may be seen as problematic, the fact that this 'reward' could be obtained only after surrendering 'maistrie' to the wife may make it symbolic rather than literal- that is, conjugal happiness may only be obtained if the relationship is grounded in mutuality.

The paper, then, concludes with conflating the intentions of Chaucer, the creator, and the Wife of Bath, the character. As the Wife of Bath says that she only intends to 'play', Chaucer, here, may also be seen as toying with the social mores of medieval society rather than contributing in a heavy-handed manner to any social or political ideological rhetoric.

Piali Mondal
Assistant Professor
Department of English

"We wol been at oure large": Chaucer, the Wife of Bath, and Medieval Womanhood

Angana Moitra
Jindal School of Languages and Literature, O.P. Jindal Global University
angana.moitra@jgu.edu.in

Abstract: This paper will attempt to offer an interpretation of the Wife of Bath's Tale and Prologue within the broader context of medieval ideas about femininity, womanhood, and women's position within the institution of marriage. By paying close attention to the ways in which Geoffrey Chaucer builds up readerly expectations through the visual portrait of the Wife in the General Prologue and her subsequent self-representation in her Prologue, this paper will argue that Chaucer's characterisation of Alisoun is a self-conscious exercise in literary signification, one which is deliberately multivalent and evocative of different (and often differing) registers. This representative strategy, it will be argued, is a deliberate choice which is a testament to the poet's powers of imaginative polysemy and to his awareness of the multiple discourses and debates surrounding the status of women in medieval society. In adopting such an intermediate approach, this paper hopes to offer a corrective to existing views in Chaucerian scholarship which advocate either a radical feminist poetics of reclamation and assertion of female agency or focus on Chaucer's (ostensible) inability to transcend the hetero-patriarchal cultural politics of fourteenth century English society. This paper aims to situate Chaucer as a poet who was not only alert to the various levels of signification which could bear upon literary representations of character, but one who actually pushed the semantic and ontological limits of the figures which populate his colourful fictive universe.

Key Words: Chaucer; medieval women; medieval marriage; medieval society; *Canterbury Tales*; medieval England

1. Introduction

The Canterbury Tales is widely regarded as Chaucer's best work on account of its scope, breadth, intricacy of characterisation, and masterful use of language. This poem, which is a veritable snapshot of the dynamism and colourfulness of medieval society, contains many interesting characters, but perhaps none more so than the Wife of Bath. This intriguing character who, unlike the other female pilgrims in the *Canterbury Tales*, is identified not by her vocation but by her marital status, has attracted scholarly attention for decades, if not centuries. Scholars have been endlessly fascinated by her presentation as the object of both male desire and derision, by her powers of articulation, and by her attempts to carve out a certain measure of autonomy within the emphatically patriarchal contours of medieval society. By her own admission, she is a scold and a harangue, qualities which are entirely in keeping with medieval antifeminism and which *almost* reduce her to the status of caricature – almost, but not quite. For all her stereotyped femininity, the Wife of Bath presents a certain strength of character, a refreshing frankness and a hardy resilience which are impossible not to admire. Much has been said about the Wife of Bath's – and, by extension, Chaucer's – status as a 'feminist,' and in this paper I will attempt to touch upon a few of these aspects with the hope

of sparking new avenues of thought and new ways of reading this character, her Prologue, and her Tale. Beginning with a very brief discussion of the status of women in medieval society, I wish to consider the question of how far the Wife of Bath fits (or doesn't fit) within the mould that we can construct about medieval womanhood. In order to do this, I will briefly discuss her presentation in the General Prologue before moving on to an analysis of her Prologue. Having discussed the Prologue, I will move on to a discussion of her Tale before closing with some thoughts about how we can continue to engage with the character as a literary and cultural entity in her own right and as an embodiment of Chaucerian subjectivity.

2. Women in medieval society

I would first like to begin with the caveat that despite the summary nature of this section, women should not be seen as constituting an undifferentiated, homogenous mass of individuals but rather as a marginal social group which, although very much a part of the fabric of medieval society, was nonetheless almost always systematically excluded from most dominant heteropatriarchal discourses. In the medieval cultural and literary imagination, women were almost always categorised separately. They were described as a distinct class, subdivided either according to their social-economic (as opposed to socio-professional) position or, more tellingly, according to their personal (that is, marital) status (Farmer 2006). This latter distinction, in particular, was never applied to men. A cursory look at the list of pilgrims in the *Canterbury Tales* seems to bear out this division. Unlike the male pilgrims who are identified with the lively spectrum of professional classes – the Miller, the Cook, the Knight, the Squire, the Yeoman, the Shipman, the Manciple, the Man of Law – the female pilgrims are identified either with their calling (which, it can be argued, is indicative more of their socioeconomic status rather than as a 'profession' per se) or, as in the Wife of Bath, with their marital status. Not only are the only other female characters all associated with religion and religious orders (the Prioress, the Second Nun), but the married male characters are not identified as such (for instance, the Merchant, though married, is not explicitly highlighted as, say, the Merchant of London). Thus, the Wife of Bath is the only married figure who is explicitly identified as such by her title itself as well as the only secular female pilgrim on her way to Becket's shrine.

Women were not only ranged together as a distinct class but were also believed to embody special faults and sins, vices that were an organic extension of their gender. These included vanity, pride, greed, promiscuity, gluttony, drunkenness, bad temper, fickleness, and suchlike. Women were also subjected to various rules and prescriptions, such as being kept away from public office, from positions of authority and intercession (such as judges), as well as from councils and public assemblies. They were commanded to devote themselves wholeheartedly to domestic duties, since a good woman was believed to be one who loved and served her husband and brought up her children as good Christians (Murray 2006). They were also denied access to one of the routes by which men of the lower classes could rise, namely, education at a church school, admission into the service of the Church, and an ecclesiastical career. Even

within the fold of Christianity, women were cloistered and limited to positions of servitude, such as nuns, anchoresses, abbesses, and so on. They could not, for instance, be the head of a parish or a diocese (such as a bishop, a prelate, a deacon, a pastor) or even preach or deliver sermons (such as priests) (Renate Blumenfeld-Kosinski 2006).

Much of these views of women were not creations of the Middle Ages (although they were certainly amplified and extended by clerics and Church Fathers) but stemmed from Aristotelian views of women and gender. Aristotle, the fourth-century BCE Greek philosopher, consistently emphasised the inferiority of women in relation to men. Unlike men who belonged to the *polis* or the city-state and took an active political role, Aristotle relegated women to the *oikos* or the domestic sphere, limited to playing the passive roles of wife and mother. Men were the rulers and women were the ruled, and this distinction of status arose from women's natural and innate sexual inferiority. In the reproductive process, the female supplied only unformed matter which was transformed and shaped into a living being by the male seed. The female, unable to produce anything more than unformed matter or blood, was definable only by an incapacity and was thus a deformed male. The female was also always in search of the male seed which, with its warmth and fulness, could complete the process of procreation. Thus, according to Aristotle, women were inferior, could only be defined by their sexual and gynaecological inferiority, and were also always hungry to compensate such inferiority by seeking out the perfection of the male seed (William F. MacLehose 2006). Aristotle's ideas were transmitted to the Latin West by a two-step process of translation (the Greek translated into Arabic and consequently into Latin) and became enormously influential, particularly in the early universities. At this point, it is perhaps relevant to bear in mind that Jankin, the Wife of Bath's fifth husband and also the most wildly misogynistic of all five, was educated at Oxford which, together with the universities at Paris and Bologna, was one of the places where such Aristotelian ideas would have been in popular currency.

The second bit of context that needs to be considered is the medieval Christian view of marriage and the status of women within such marriages. Christianity privileged chastity as the ideal way of life, although marriage was permitted by St. Paul as a preferable alternative to adultery and lascivious behaviour. In the Middle Ages, marriage was transformed by the Catholic Church into a sacrament, and it had the dual purpose of preventing sinful conduct as well as the production of offspring and the fostering of companionship between the partners. Although marriage provided a legitimate outlet for the urges of the body, canonists and theologians were at pains to emphasise that the goal of marriage was not the consummation of sexual desires for the purpose of pleasure but rather the generation of children. Sexual relations for the sake of pleasure were seen as an unclean remnant of the pagan past and were denounced by St. Augustine (another enormously influential Church Father) as lust or *concupiscentia* stemming from Original Sin. Yet another seminal theologian, John Chrysostom, observed that since mankind's Fall introduced death into the world, marriage was founded as a consolation so that through the propagation of progeny, man might enjoy the perpetuation of his being despite the

perishing of his physical body. Thus, if chastity could not be committed to, marriage was allowed. However, although sexual relations within marriage were permitted, their only purpose was to be the perpetuation of the bloodline through the production of children (Brundage 2006; Murray 2006).

Within the marital relationship, the wife occupied a subordinate position, subject to her husband's control and governance. Since marriage was a solution for the sin of lust, both parties owed each other the 'conjugal debt', that is, sexual intercourse (Reid, Jr. 2006). However, extant records indicate that it was typically men rather than women who demanded payment of the conjugal debt, and although both men and women were held to the promise of monogamy, women were punished much more severely for adultery than men were. In many legal traditions of the age, men had the explicit right to beat their wives and even the Church, which enjoined husbands to treat their wives gently, did not forbid them from using force. In effect, women also lost legal personhood when they married. They could not bring lawsuits independently, could not testify in criminal court without their husbands' permission, and could not conduct trade in their own name. Even if they brought property into the marriage – and many women did – that property was merged into a collective marital fund which was subsequently transferred to the management of the husband. There were even stronger limitations placed upon widows. Laws curtailed widows' property rights, compelling them to administer their share of the marriage property under the watchful eye of her children or their legal agents or even returning her dowry to her kin so that they could arrange another marriage for her. Despite the limitations imposed by marriage, many women considered it preferable to widowhood. The only other suitable alternative was to enter religious orders (Howell 2006).

Throughout the medieval period, therefore, marriage remained a secure expression of the gender hierarchy of that age. According to the dominant ideology (fed in large part by Aristotelian tenets), women were men's natural inferiors, constitutionally incapable of male honour and dangerous if not properly governed because they could not contain their desires. However, at the same time, women were also valued for their labour and the children they could bear. They were even praised for their capacity for gentleness, meekness, and charity, although it was generally accepted that such virtues only emerged when women were properly governed – by men.

3. The Wife of Bath in the General Prologue

Given this very cursory background to the status of women in medieval society, we can begin to engage with the figure of the Wife of Bath. She speaks most forcefully in the Prologue and it is the Prologue which has attracted the bulk of critical attention, but it is important to note that Chaucer's portrayal of the Wife of Bath in the General Prologue is a crucial index to reading her character. It helps to establish a framework for the reader's expectations so that

when the reader later encounters the Wife of Bath's Prologue and Tale, they are free to decide for themselves whether their expectations have been upheld or subverted.

A good wif was ther of biside Bathe,
But she was somdel deef, and that was scathe.
Of clooth-makyng she hadde swich an haunt
She passed hem of Ypres and of Gaunt.
In al the parisshe wif ne was ther noon
That to the offrynge bifore hire sholde goon;
And if ther dide, certeyn so wrooth was she
That she was out of alle charitee.
Hir coverchiefs fol fyne weren of ground;
I dorste swere they weyeden ten pound
That on a Sonday weren upon hir heed.
Hir hosen weren of fyn scarlet reed,
Ful streite yteyd, and shoes fol moyste and newe.
Boold was hir face, and fair, and reed of hewe.
She was a worthy womman al hir lyve:
Housbondes at chirche dore she hadde fyve,
Withouten oother compaignye in youthe—
But thereof nedeth nat to speke as nowthe.
And thries hadde she been at Jerusalem;
She hadde passed many a straunge strem;
At Rome she hadde been, and at Boloigne,
In Galice at Seint:Jame, and at Coloigne.
She koude muchel of wandrynge by the weye.
Gat-tothed was she, soothly for to seye.
Upon an amblere esily she sat,
Ywympled wel, and on hir heed an hat
As brood as is a bokeler or a targe;
A foot-mantel aboute hir hipes large,
And on hir feet a paire of spores sharpe.
In felaweshipe wel koude she laughe and carpe.
Of remedies of love she knew per chaunce,
For she koude of that art the olde daunce.

There was a Wife, from near Bath,
But, more's the pity, she was a bit deaf;
So skilled a clothmaker, that she outdistanced
Even the weavers of Ypres and Ghent.
In the whole parish there was not a woman

Who dared precede her at the almsgiving,
And if there did, so furious was she,
That she was put out of all charity.
Her headkerchiefs were of the finest weave,
Ten pounds and more they weighed, I do believe,
Those that she wore on Sundays on her head.
Her stockings were of finest scarlet red,
Very tightly laced; shoes pliable and new.
Bold was her face, and handsome; florid too.
She had been respectable all her life,
And five times married, that's to say in church,
Not counting other loves she'd had in youth,
Of whom, just now, there is no need to speak.
And she had thrice been to Jerusalem;
Had wandered over many a foreign stream;
And she had been at Rome, and at Boulogne,
St James of Compostella, and Cologne;
She knew all about wandering – and straying:
For she was gap-toothed, if you take my meaning.
Comfortably on an ambling horse she sat,
Well-wimpled, wearing on her head a hat
That might have been a shield in size and shape;
A riding-skirt round her enormous hips,
Also a pair of sharp spurs on her feet.
In company, how she could laugh and joke!
No doubt she knew of all the cures for love,
For at that game she was a past mistress.

One of the first things that we are told about the Wife of Bath (apart from the cursory mention of her physical handicap – that she was a "bit deaf") is that she was a clothmaker. This is an interesting insight into her socio-economic position since the textile industry was one of the trades in which many women were involved in the Middle Ages (Munro 2006; Owen-Crocker 2006; Slover 1996). Ypres and Ghent were cities in Flanders (present-day Belgium) which were renowned for their excellence in clothmaking and weaving. At first glance, it looks like a very positive appraisal of the Wife's vocational skills. However, with Chaucer, things are almost always deeper than what is suggested by the surface. As Ruth Mazo Karras points out, the fact that the Wife is said to come from Bath but is praised as 'outdistancing' both Ypres and Ghent in clothmaking might be mockery of her boasting rather than genuine appreciation of her skills since Bath was not a major centre for clothmaking (Karras 2014). This is probably an early bit of foreshadowing which indicates that there is a gulf between how the Wife sees herself, how others see her, and what she actually is.

The second bit of information that we are provided is about the details of her clothing and accessories. Exquisitely woven handkerchiefs which weigh a lot, stockings which are coloured bright scarlet, new shiny shoes, enormous hat, a skirt which accentuated her hips – these details are not provided for mere embellishment. Clothing was highly symbolic in medieval society and was tightly controlled by means of sumptuary legislation (Karras 2014). They could signify not only one's wealth and economic standing but also offer clues to decoding one's character. The Wife's clothing seems to suggest a kind of ostentation which is not simply the hallmark of a boisterous character but one whose purpose is to draw attention to the individual. The Wife dresses extravagantly, a sumptuary extravagance which was in contravention of clerical injunctions. Preachers frequently extolled the virtues of dressing modestly and unostentatiously, claiming that simplicity of garb went hand-in-hand with such feminine virtues as chastity and humility. However, married women's clothing, while not being too florid, should also not be too plain – they were also expected to be an external representation of their husbands' financial status. The fact that the Wife dresses extravagantly is thus a double offence: not only does this extravagance stem from wealth that is clearly her own rather than her husband's (she is, as we learn later, currently a widow), it is also intended to attract praise and masculine attention. We are already being encouraged to formulate an impression of the Wife as someone who enjoys the limelight, as someone coquettish. These details also make us question the sincerity of her devotion. We are told that she had been on pilgrimages multiple times before – from Rome and Santiago de Compostela to Jerusalem and Cologne. However, has she been on these pilgrimages because of her Christian fervour, or has she done so to seize every possible opportunity of showing off her figure, her economic prosperity, and her charms?

The likelihood of it being the latter is provided by Chaucer's telling comment that the Wife knew all about wandering and straying. This heavily implies that on her former pilgrimages, the Wife had 'wandered' – that is, both physical wandering (in the sense of geographical travel) as well as metaphorical wandering (in the sense of sexual promiscuity). Several other details seem to bolster this observation – the Wife being gap-toothed, of bold demeanour, and ruddy complexion, all of which were believed to be external markers of a lustful disposition (Karras 2014). Chaucer remarks that she knew "all the cures for love" – a task which she had especial expertise in. This is clearly no ordinary, meek clothmaker from Bath but a gregarious, boisterous lady; one who likes dressing well and being the centre of attention; one who is well-versed in the amatory arts, is well-aware of her charms, and is unafraid to display them for the world to see ("In company, how she could laugh and joke").

4. The Wife of Bath's Prologue

The detail about the Wife's five marriages is probably the biggest thematic link between the Wife's portrait in the General Prologue and her autobiographical fulminations against contemporary antifeminism in her Prologue. Recounting her encounters with her five

husbands, the Wife rails against oppressive patriarchal structures which have constrained her right and desire for self-determination and autonomy. However, it would be oversimplistic and even a little incorrect to suggest that Chaucer was championing medieval women's rights through the Wife of Bath's Prologue (and Tale) since the Wife is also clearly presented, at least partially if not entirely, through the lens of mockery and ridicule. Chaucer carefully toes the line between the antidote of feminist self-assertion and the placebo of patriarchal control, and how well he does this balancing act is a matter of subjective interpretation.

The antifeminist authorities that the Wife quotes in her Prologue were a well-established part of the literary and ecclesiastical canon of the Middle Ages. Although the bulk of it builds upon St. Jerome's *Against Jovinian* (*Adversus Jovinianum*), including Jerome's quotations of the *Golden Book on Marriage* (*Liber Aureolus de Nuptiis*) of the pagan author Theophrastus, it also contains echoes of such other texts as the *Letter from Valerius to Rufinus* (*Epistola Valerii ad Rufinum*), purportedly written by the Welsh poet Walter Map, Eustace Deschamps' *Mirror for Marriage* (*Miroir de Mariage*), Jehan le Fèvre's translation of Matheolus' *Lamentations*, passages in John of Salisbury's *Policraticus*, and that exemplary work of medieval secular literature, the *Romance of the Rose* (*Le Roman de la Rose*). The Wife's refutations of antifeminist clichés themselves build upon the format in which most antifeminist literature was written: the *dissuasio* or dissuasion (Mann 2002). Although most antifeminist *dissuasio* took the form of the dissuasion against marriage (*dissuasio de non ducenda uxore*), exemplified by such works as the *Letter of Valerius* and, more surprisingly, Heloise's address to Abelard (reported in the *Historia Calamitatum* of the latter), the Wife's dissuasion takes the form of a dissuasion against singlehood. The Wife builds upon established authority in order to lend solidity and credence to her own views. Some critics have said that her resorting to the language and semiotics of medieval antifeminism – or, to use Lee Patterson's phrase, "the prison-house of masculine language" – shows how the feminist project is doomed by the very structures it aims to dismantle (Patterson 1983). Others, however, have claimed that Chaucer's aim is more modest than visionary – which is to expose antifeminist stereotyping as well as acknowledge the attempt of women to renounce such stereotyping. I find myself in agreement with Jill Mann when she observes that the Wife's struggle is not so much with men – indeed, it could not be, because by her own admission, it was her fifth husband's physical attractiveness that caught her attention – but with the stereotypes of her sex (Mann 2002).

One of the aspects that I wish to draw attention to is the Wife's skill as a rhetorician. Given what we know about women's lack of access to education in the Middle Ages, it is remarkable not only how well-versed the Wife is about the existing body of antifeminist literature but also how persuasively she can appropriate it for her own purposes. It is, in a certain sense, irrelevant whether one sees her arguments as a feminist failure to transcend the language of patriarchal control or as a sort of ground-breaking proto-feminist exercise in self-determination. What is unmistakable is her rhetorical skill, and it is impossible not to admire the intensity of her impassioned argument – she is almost like a medieval preacher delivering an exemplum. One

of the best examples is the wonderfully pithy but pointed question in line 692: “Who drew the picture of the lion? Who?” (“Who peyntede the leon, tel me who?”) This is a reference to the medieval story of the lion and the man, a sort of beast fable where the lion, upon being shown a picture of a lion being killed by a man, wished to know who had drawn the picture. When the man answered that the picture had been drawn by a man, the lion retorted that that is why the man had been depicted as a victor and the lion as the vanquished. If it was the other way round – that is, if the picture had been drawn by a lion – it would have shown the man getting killed instead. Women, for the Wife of Bath, are in the same position as the lion: they are powerless to correct the distorted image of themselves produced by clerical misogynists and given the weight of bookish authority. The Wife’s concern is to strip off the mask of impersonality that is donned by patriarchy and reveal the biases and bigotry that lie beneath (Mann 2002).

5. The Wife of Bath’s Tale

The Wife of Bath’s tale is the lion finally allowed to wield the paintbrush. This almost fairy tale story tells us about an Arthurian knight who, having raped a maiden, is condemned to death by King Arthur. Arthur’s queen, however, offers him the opportunity for reprieve if he can answer the crucial question of what it is that women most desire. Through much searching, the knight encounters a magical lady who promises to tell the knight the answer to the question in return for his unconditional acceptance of whatever she demands. This demand is revealed only once the knight has rightly answered the question posed by the queen and escaped with his head intact – the demand is that the knight must marry her. This demand is repugnant to the knight since the lady is enormously – almost grotesquely – ugly, but having learnt a sobering lesson, the knight lives up to his side of the bargain. In return, he is rewarded by the magical transformation of the ugly crone into a beautiful lady and the restitution of perfect marital harmony and bliss.

The Wife of Bath’s Tale is a fictive extension of the pattern of surrender and reconciliation that is traced in miniature form at the end of her Prologue (Mann 2002). The Prologue closes with the Wife recounting how, after things came to a head with Jankin after she tore out three pages from his precious Book of Wicked Wives, he had responded with violence by boxing her ears. This violence, which was serious enough to occasion permanent deafness in the Wife, was expiated only when Jankin had asked for forgiveness and given over the reins of the household to the Wife. The wider moral of both the end of the Prologue and the Tale is that domestic felicity and spousal loyalty can only be won once men have renounced ‘maistrie’ and transferred it to the woman. The full semantic range of meanings encapsulated by the word ‘maistrie’ is almost impossible to capture in modern English, although it can be loosely translated as a combination of autonomy, governance, and self-rule.

Some critics have seen the Wife of Bath’s Tale as not only a let-down after her tall claims in the Prologue, but also problematic, given that it not only forgives a rapist but actually rewards

him, that too in the terms of male fantasy: a wife who is not only beautiful but also obedient and loyal. However, once again, Jill Mann's interpretation probably makes the most sense: that the transformation of the rapist into a chastened husband is only possible in a fairy tale (Mann 2002). The Wife of Bath's Tale, she cautions, is not to be read as a realistic proposal for the rehabilitation of sexual offenders and truant husbands but rather as the imaginative embodiment of what an ideal society could be. The fairy tale format is needed *precisely because* reality is so very different from the scenario presented in the Tale.

In the terms of this line of interpretation, the loathly lady's demand for marriage is actually the perfect punishment for the knight's crime – it is a fantasy realisation of rape-in-reverse as the knight is forced into sexual congress with a partner he does not desire (Mann 2002). However, unlike the actual rape where the maiden had absolutely no choice, female domination is more forgiving: the knight is given the semblance of choice since his acquiescence to the terms of the loathly lady's contract is voluntarily undertaken. What is more, the Tale actually legitimises the female desire for 'maistrie' – which the antifeminist writers view with such fear and suspicion – as the just response to male oppression and patriarchal aggression. The knight is not only given the possibility of a deserving punishment for the crime of rape – death – but he is also offered a way out of such punishment. That he can escape with his life is reward enough; the fact that the precise terms of that reward are not to his liking is the knight's problem, not the reader's. Within this context, the knight's surrender of 'maistrie' to the woman seems moderate, even justified.

How, then, is the loathly lady's transformation into the beautiful wife justified? It is justified because it is less of a capitulation to male fantasy than a realisation of an ideal marital relationship founded on trust, loyalty, and mutual obedience. When the knight surrenders to female 'maistrie', he surrenders not to the romanticised woman projected by male desire but to a woman conceived within the pessimistic terms of antifeminism (Mann 2002). The magical nature of the woman's transformation once the knight has acquiesced underlines the fact that such good fortune is a gift rather than a masculine right. It suggests that male desires can be fulfilled only once they are relinquished. Male surrender, genuinely performed, elicits female obedience as a symbiotic response. Reformulated in these terms, wifely obedience becomes, not an obligation or compulsion, but an emotional mark of thanksgiving. This, ultimately, is the backbone of a fulfilling marital relationship built on mutuality, and even though the reality of medieval society would have meant that such truly mutual relationships were more of a pipe dream than a potentially realisable opportunity, the Wife of Bath's Tale furnishes the ground where such a dream is instantiated and made viable.

6. Conclusion

To read Chaucer is to be alert to the many levels of signification suggested by his works without ascribing any one particular stance to him. To do so would be to engage in an unfair and

ultimately pointless exercise in ventriloquism. It would be as futile to label Chaucer a 'feminist' as it would be to denounce him as a slave to patriarchy. Instead, what Chaucer does in the *Canterbury Tales* is to hold up a mirror to medieval society, a mirror in which the reflections of his pilgrims are not only laterally but also vertically inverted. He can distort and reshape the images in the mirror as he pleases because that is the privilege granted to the artist, the maker of fictions. It would be equally fruitless to read autobiographical intent in the *Canterbury Tales*. For instance, it might be tempting to read the Wife of Bath's Tale as a sort of creative penance for the actual charge of rape that was brought upon Chaucer by one Cecily Chaumpaigne in 1380. However, this is a fallacious enterprise not only because it has never been conclusively proved what the precise nature of that charge was – the root word for rape was the Latin *raptus* and could have a range of meanings other than sexual assault, the predominant interpretation of the word today (Saunders 2001) – but also because to do so is to make Chaucer say what we want him to say rather than what he was actually trying to say. Perhaps we will never know what Chaucer was actually thinking or what he actually meant, but we don't have to. It is entirely possible to read the Wife of Bath without deciding for ourselves whether Chaucer was or wasn't a feminist. What we can do instead is read the Wife with feminist sympathies and feminist concerns. It is my conviction that the key to reading the *Canterbury Tales* lies in the Wife of Bath's assertion in line 192 of her Prologue that "All that I'm trying to do is amuse" ("For myn entente nys but for to pleye"). Amusement or "pleye" is what the *Canterbury Tales* is all about. The word 'amuse' or 'pleye' is significant, not only because it thematically links the Wife's Prologue with the General Prologue where she was described as the mistress of playing 'games,' but also because the verb captures the broader mechanics of Chaucer's poetry and his craft: he is a consummate artist 'playing' with the mores of medieval society with the purpose of delighting and entertaining.

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Dr. Angana Moitra

Dr. Angana Moitra is Assistant Professor at O.P. Jindal Global University. She completed her PhD in 2020 on the Erasmus Mundus TEEME (Text and Event in Early Modern Europe) Joint-Doctoral Programme, defending a thesis entitled "A Spirit of Another Sort: The Evolution and Transformation of the Fairy King from Medieval Romance to Early Modern Prose, Poetry, and Drama." Her research interests span the length and breadth of the literary, religious, and political culture of the European medieval and early modern periods, and she is particularly interested in exploring the continuities and correspondences between the two. She is currently exploring the representation of fairies in witchcraft trials and revising her doctoral thesis for publication.

7 Unravelling the Quaternary climatic history: a speleothem based multiproxy approach

Dipanwita Sengupta

The Quaternary Period, comprising the Pleistocene and the Holocene Epochs, represents the time interval from 2.58 million years before present (commonly called Million Annum or Ma) to the present time. The temperature of the Earth varied considerably during this period, with the occurrence of alternate phases of cold and warm climatic conditions. During the cold phases, large glacial ice sheets of regional dimensions covered a major part of Earth's surface, which contracted substantially during the warm phases. For this reason, the cold and the warm phases are known as the glacial and interglacial periods respectively.

The evidences of climatic variations of the past are recorded in a few rocks and minerals. Study of those geological features not only help in the detection of such palaeoclimatic events, but also enable us to determine their ages, thus facilitating the ***palaeoclimatic reconstruction*** *(Greek palaeos: ancient). Among the most useful of those "natural archives" are the speleothems, which are the mineral deposits that accumulate over time in natural caves (Greek spḗlaion: cave, théma: deposit). They are most common in the calcareous caves, forming by the precipitation of carbonate minerals. They have different shapes, sizes, and modes of occurrence, like the stalactites, stalagmites, flow stones, cave crystals etc. (White 2019). Stalactite and stalagmite are elongated forms of various minerals, mostly carbonates, which were precipitated from the water that drip slowly into the caves. A stalactite hangs like an icicle from the ceiling or sides of a cavern at the points where the water drips in. A stalagmite is a cone-shaped mineral deposit, with its base on the cavern floor and vertex pointing upward, thus appearing like an inverted stalactite rising from the cavern floor (after Britannica 2018). Their chemical composition, growth rate, and preservation in caves make them useful indicators of the palaeoclimate. When the speleothems are preserved properly, the compositions of isotopes of the dripping water (from which they were precipitated) are recorded in their laminae. The ratio of those isotopes is related to the precipitation of that time. Analysis of the speleothem laminae and determination of their isotopic ratios thus indicate the variations of the annual precipitation with time in a region. The ratio of two isotopes of oxygen,* ^{16}O *and* ^{18}O*, is particularly useful for this purpose. This method can be utilised in the*

palaeoclimatic studies of monsoon influenced places like India, and is a valuable tool in deciphering the past variations of the Indian summer monsoon.

Sm. Dipanwita Sengupta, a researcher of the Wadia Institute of Himalayan Geology, Dehradun, is carrying out extensive investigations on reconstruction of variability of the Indian Summer Monsoon (ISM) using the speleothem. In an online lecture held on September 06, 2021, she has given a glimpse of one of her latest research projects, in which the speleothems from twenty-two Himalayan limestone caves were analysed to determine their 18O/16O ratios. The Isotope Ratio Mass Spectrometry (IRMS) was used in the analysis, which is a specialized technique of spectrometry that provides information about the geographic, chemical, and biological origins of a substance. The present article, giving a comprehensive account of that lecture, highlights the climatic variation of the Quaternary Period, and the application of speleothems for palaeoclimatic reconstruction. The state-of-the-art investigation on climatic studies described here will not only enlighten the students and researchers of Earth Sciences and Environmental Studies, but also the other readers who are concerned about the climate changes and related environmental issues.

Bhaskar Ghosh
Department of Geology, Jogamaya Devi College

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Unravelling the Quaternary climatic history: a speleothem based multiproxy approach

Dipanwita Sengupta
Wadia Institute of Himalayan Geology
sgdipa13@gmail.com

Abstract: The global climate in the Quaternary has oscillated between glacial and interglacial conditions. In such a state of fluctuating climate, the focus of Quaternary research lies on determining the time of climatic events and their impact on the environment and inhabitants of the earth. The chronology of climatic events has been established through various archives that gives clue to the past climate before the instrumental era. Cave carbonate is one such archive for palaeoclimatic reconstruction through its preserved stable isotopes. It depicts the variability history of precipitation which is important for palaeoclimatic studies in monsoon influenced places such as India. Studies from ~22 caves in India have helped to draw a picture of the behaviour of the Indian Summer Monsoon during notable global climatic events such as the Marine Isotope Stages, Younger Dryas, 4.2 ka event, Medieval Climate Anomaly, Little Ice Age and so on and its forcing factors and effects.

Keywords: stalagmite, isotope ratio mass spectrometry, Asian monsoon, global teleconnections, speleothem petrography

1. Introduction

Climate change especially in the latest epoch, Quaternary, is a problem being extensively studied although the earth's climate has often changed throughout its history. This is because one of the most significant aspects of Quaternary is the appearance and evolution to man and the consequence of climate change on them and the question of survival. In addition to natural causes, in the recent past, anthropogenic effects are considerably affecting the climate of the earth, unlike earlier. Therefore, the need to scientifically study climate change, its causes and effects and future predictions became important. However, climate datasets are unobtainable beyond instrumental tracking began but proper understanding of climate is difficult or impossible without studying palaeoclimate (Gupta et al. 2020). To solve this problem, a number of natural archives are being used to reconstruct palaeoclimate such as sediments, tree rings, speleothems, lichens etc. (Walker 2005). Based on these studies, it has been discovered that climate change is not always a gradual millennial to centennial scale process but can also change over in time scales as short as few years (Adams et al. 1999).

Speleothem or cave deposit is a Quaternary palaeoclimatic archive of growing popularity which keep a record of precipitation and variation in precipitation can be reconstructed using speleothem samples even up to seasonal resolution (Baker et al. 1993; Baker et al. 2008; Orland et al. 2012). This important terrestrial archive is crucial for studying the palaeoclimatic variability and associated cultural changes in India whose climate is largely influenced by the south west monsoonal rains also known as the Indian Summer Monsoon

(ISM). The ISM contributes to 20% of the Indian GDP, i.e., for about 1/3rd of the population of the world, and sustains the livelihood of the people of the heavily populated subcontinent. In order model the ISM for future benefits, it is necessary to extensively study the past variability of ISM, its controls and impacts which is possible through speleothems (Gadgil 2003; Gupta et al. 2020). This article focuses on the climate of the Quaternary and how speleothems can be used to reconstruct the same.

2. Climate Change and Quaternary Climate

Climate is the long term (>30 years) pattern of the weather of a region and a persistent alteration of that pattern is termed climate change. Climate is dynamic and governed by various controlling factors such as the oceanic and atmospheric circulations and solar radiation and the global climate is a well-connected mechanism through teleconnections. Consequences of climate change on human life have kindled the interest to study the present- and past-climate to better understand it and develop models.

The Quaternary Period encompasses the final 2.58 Ma in the history of the Earth and is the latest period in the Cenozoic era. The Quaternary comprises two epochs, Pleistocene (2.58-0.0117 Ma) and Holocene (0.0117 Ma-present) whose boundary is defined by climatic events or abrupt climate change, and so are the age boundaries between the three ages in the Holocene (Greenlandian/Northgrippian boundary at 0.0082 Ma and Northgrippian/Meghalayan boundary at 0.0042 Ma) (Walker 2005).

The climate of the Earth fluctuates between glacials and interglacials, i.e., cold and usually dry and warm and usually wet climatic periods which spans for more than 10,000 years. Within these larger climatic cycles, smaller cycles of <10,000 years occur of which the colder (warmer) intervals are called stadials (interstadials). Even smaller (millennial to centennial scale) periodicities may be noticed. The climate cyclicity at longer timespan (millennial to astronomical) is controlled by the Milankovitch cycles whose dominant periodicities are 23 kyr (precession), 41 kyr (obliquity) and 100 kyr (eccentricity) and is based on sun-earth relationship, i.e., variation in incoming solar radiation due to changes in earth's inclination and orbit. Smaller scale climatic variations are controlled by sunspot activities, changes in thermohaline circulation, volcanic eruptions, movement of the ITCZ etc. (Clemens & Prell 2003; Laskar et al. 2004; Walker 2005; Gupta et al. 2020).

The Quaternary glaciation began at 2.58 Ma and continues today as permanent polar ice exists. The Quaternary is overall a cold epoch with continental glaciers extending up to 40 degrees latitude during the Last Glacial Maximum (LGM; 26-19 kyr BP) also commonly known as Last Ice Age during which the temperature of the Earth dropped by ~6°C compared to the present. This LGM is a part of the Last Glacial Period (110-11.7 kyr BP) in which various cold events (Oldest Dryas: ~18000-15000 yr BP, Older Dryas: ~14400-13500 yr BP, Younger Dryas or YD or Loch Lomond stadial: ~12900-11700 yrs BP etc.) and few warm

events (Bolling event and Allerod event often spoken together as the Bolling-Allerod or B/O interstadial event at 14500-12900 yrs BP. The Older Dryas or OD is a cold interval in between) occurred. The Quaternary glaciation is the cause of extinction of several mammals such as the woolly mammoth. Abrupt changes in climate divide the Quaternary into the four ages: Gelasian, Calabrian, Chibanian and Late Quaternary (Adams et al. 1999; Walker 2005; Gupta et al. 2020).

The end of YD cold event (~11700 yr BP) marks the beginning of the Holocene interstadial with a broadly stable climate with minor fluctuations. Holocene starts with warm climatic events such as the Holocene Climatic Optimum (HCO; ~8000-3600 yr BP) wherein the temperature was higher than present by 4°C at some places. Within this occurs the ~200-year-long cold 8.2 kyr event marking the end of the Early Holocene (Greenlandian age). Temperature dropped in the Chianina Middle Holocene (Northgrippian age) compared to the Early Holocene (Walker 2005; Gupta et al. 2020). The 4.2 kyr global arid event (extending ~200-300 years from northeast Indian speleothems and ~1000 years from western Himalayan speleothems), especially recorded in the northern hemisphere, marked the end of Middle Holocene and beginning of Late Holocene (Meghalayan age) in which we presently exist. This event led to the disintegration and depopulation of many prosperous civilizations such as the Indus Valley Civilization, Akkadian empire, Chinese empire and so on. The expression of this event has been reported from the record of a speleothem archive from Mawmluh cave, Meghalaya, thus rendering the name of Meghalayan age. This is also the only Global Boundary Stratotype Section or Point (GSSP) from India. The Late Holocene (Meghalayan age) is the time of modern man and several civilisations and the climatic events occurring here are Roman Warm Period (RWP; ~3300-2900 yr BP), Medieval Warm Period (MWP; ~2200-1600 yr BP), Dark Ages Cold Period (DACP; ~1600-1200 yr BP), Medieval Climatic Anomaly (MCA; ~1200-800), Little Ice Age (LIA; ~500-300 yr BP), Current Warm Period (CWP; ~200 yr BP-recent) etc. (Gupta et al. 2020; Kaushal et al. 2018 and references therein; Dutt et al. 2021; Rawat et al. 2021).

3. The South Asian monsoon

Monsoon is a system of moisture bearing winds bringing precipitation to various regions of the world. It is a persistent complex ocean-climate coupled phenomenon operating due to pressure differences and is an annual event with advancing and retreating phases. The South Asian Monsoon is one such system (the others being North American monsoon, South American monsoon, African monsoon and Australian monsoon) and is responsible for shaping the distinct climate of south Asia (Gadgil 2003).

3.1. Domain and mechanism

The Asian Monsoon has a wide domain from the Arabian Peninsula in the west to Japan in the east. South Asian monsoon is further divided into the ISM and the East Asian Summer

Monsoon (EASM) (Li et al. 2014a, b). The ISM and EASM show both coupling and decoupling (Maher 2006; Li et al. 2014a). While the ISM is isotopically more depleted due to longer transport paths, greater continental effect and Rayleigh fractionation, the EASM is isotopically enriched due to less transport and fractionation and has a dominant marine source (Maher 2008). The Indian Summer Monsoon or the South-West Monsoon operates as the Inter Tropical Convergence Zone (ITCZ) shifts in the northern hemisphere from the tropics during boreal summer because of the maximum solar insolation received at the Tropic of Cancer, creating a low pressure in northern India (Agnihotri et al. 2002; Gupta et al. 2005, 2013). A high pressure is created near the Madagascar island in the southern hemisphere and moisture laden south easterly winds travel towards the low pressure in northern hemisphere and upon crossing the equator changes their direction to south westerly due to the Coriolis force. These winds divide into the Arabian Sea branch and the Bay of Bengal branches owing to the shape of the peninsula. They strike the orographic barriers in India such as the Western Ghats, the Shillong Plateau and the Himalayas and bring heavy rain upon moisture condensation and cloud formation due to orographic lifting (Fein and Stephens 1987; Quade et al. 1995; Webster et al. 1998; Gadgil 2003; Wanner et al. 2008). The presence of Tibetan plateau is not much influential to the ISM mechanism (Boos & Kuang 2010, 2013). The ISM precipitation lasts June to September. Strong jet streams often bring a stronger monsoon while the Westerlies dominance weakens it (Sikka 1980; Gadgil 2003; Krishnan et al. 2009; Rajeevan et al. 2010). Various physical atmospheric parameters are responsible for the variation in the amount of rainfall, its persistence and behaviour on land and ocean (Chakraborty et al. 2006; Jalihal et al. 2019). During the monsoon retreat or northeastern monsoon, the high pressure lies at Siberia and the low pressure at Indonesia (Gadgil 2003). The ISM is also influenced by the teleconnections from the Arctic, Atlantic, Pacific and Indian oceans and the European and Himalayan snow covers at different time scales (Gupta et al. 2020). A positive phase of Indian Ocean Dipole (IOD) favours a strong monsoon and a negative phase result in weak monsoon rainfall (Ashok et al. 2001; Gadgil 2014; Krishnaswamy et al. 2014). The relation of ISM with El Nino Southern Oscillation (ENSO; comprising El Nino and La Nina conditions) of the Pacific is still baffling as some El Nino phases correspond to weak ISM while others do not (Ashok et al. 2001; Sinha et al. 2011; Berkelhammer et al. 2012). The timing of the long-term relationship set up between ENSO and ISM was ~2-1.3 ka BP (Prasad et al. 2014). Interrelation between ENSO and IOD also impacts the ISM (Saji et al. 1999; Ashok et al. 2001; Kumar et al. 2006). The North Altantic Oscillation (NAO) significantly affects the ISM: ice rafting or cooling events in the north Atlantic, known as Heinrich events (and Bond events in the Holocene) hamper the NAO by bringing in a flux of cold freshwater and weaken ISM either by disrupting the thermohaline circulation and land-sea thermal contrast or by strengthening the westerlies (Gupta et al. 2003; Dutt et al. 2015). These cooling events have often been followed by abrupt warming and these rapid but cyclic climate fluctuations are known as Dansgaard-Oeschger (D/O) events. IOD, ENSO and NAO influence the ISM in annual to centennial time scales. Increased snow cover in Himalayas and in Europe increases the albedo and more solar heat is utilised to melt the snow than heating up the land. This weakens the low pressure in north

India and subsequently the monsoon (Blanford 1886; Bamzai & Shukla 1999). In the anthropogenic era, increase in atmospheric CO_2 and global warming is also seen to intensify monsoon convection and rainfall (Officer & Drake 1983; Prell & Kutzbach 1992).

The ISM initiated and evolved sometime between 55 ma to 7.5 ma (based on continental records) with the surface upliftment of the Himalayas however its intensification is mostly said to be in the Miocene, i.e., ~24-8 ma (based on marine records) with the rapid upliftment rate of the Himalayas. After ~5 ma, the monsoon weakened and stabilised and attained its present nature. After the Mid Pliocene Warm Period (MPWP; ~5-3 ma), the glacial condition at Plio-Pleistocene (Northern Hemisphere Glaciation or NHG; ~3.5-2.5 ma) strengthened the winter monsoon and weakened the summer monsoon (Gupta & Thomas 2003). The ISM was strong in the early Holocene during the HCO and weakened at the cold, arid 8.2 ka event. Since then, the ISM has broadly shown a comparatively weakening pattern with a sudden precipitation reduction at 4.2 ka arid event. However, the behaviour of ISM in the middle Holocene and 4.2ka event is asynchronous in Asia. In the last 1000 years, during the RWP and the CWP the ISM is observed to have regained its strength while being punctuated by a weak phase during LIA. In the recent decades, intensity and frequency of extreme rainfall events are increasing according to meteorological records with consequent floods and droughts causing famine condition (Gupta et al. 2020 and references therein). The present relation between climate change and south Asian monsoon has been reviewed by Turner & Annamalai, 2012.

3.2. Significance of ISM studies

The ISM is a significant part of climate of the Indian subcontinent and therefore its variability provides an insight into the climate variability of this region. The ISM varies both temporally and spatially, i.e., its pattern is not uniform throughout India and is driven by external and internal forcing factors. The ISM brings 70-80% of the rainfall to India and is the backbone of the agrarian economy of India and the regional ecology. 10% increase in ISM causes floods and 10% decrease leads to droughts whereas a 30% fluctuation can be quite disastrous. Therefore, an extensive study of past and present behaviour of monsoon is necessary to understand its forcing factors, associated short- and long-term changes and to develop a model for the future (Gadgil 2003; Shewale & Kumar 2005; Gupta et al. 2020).

4. Palaeoclimatic studies

While the climate of the last few hundred years can be directly measured, there are no measured data available before the instrumental era. Thus, to study and reconstruct long term palaeoclimate, natural archives and stored proxies in them have to be relied upon. Lake sediments, ice cores, tree rings and speleothems are some of the commonly studied Quaternary archives. The proxies of climate variability are physical, chemical and biological. Some examples are oxygen, hydrogen, nitrogen and carbon stable isotopes, environmental

magnetism, organic carbon content, pollens, microfossils and so on. Variations in these proxies are caused by certain natural changes as a response to climate change and thus they provide indirect evidence of climate variability. The dating limit of the techniques used for these archives are usually confined within the Quaternary and they are capable of providing high resolution palaeoclimatic data. The dating techniques (four broad types: radiometric, annual increments, relative dating and age equivalence) used are C-14, U-Th disequilibrium series, Optically Stimulated Luminescence (OSL), Thermoluminescence (TL), Exposure dating using cosmogenic radionuclides (Be^{10}, Al^{26}), amino acid racemisation, Electron Spin Resonance (ESR) dating, tephrochonology, lichenometry etc. Foraminifera in ocean cores have been used to develop oxygen isotope stratigraphy based on which 103 Marine Isotope Stages (MIS) have been identified which has divided the Quaternary into glacials and interglacials. MIS $10^4 – 10^6$ extend into the Pliocene. The odd numbers represent interglacials (enriched $\delta^{18}O$) and the even numbers, glacials (depleted $\delta^{18}O$) (Walker 2005; Gupta et al. 2020 and references therein). The LGM is represented by MIS 2 while the end of YD is MIS 1. Some stages such as the MIS 5 has been divided into five substages: a to e. the MIS 5e, also known as Eemian was the warmest interval in the last 150 ka (Adams et al 1999). More and more palaeoclimatic studies from different archives and proxies help to build a reliable inventory of climate variability at different resolutions and time frames.

4.1. Speleothems as an archive

Speleothem (speleos-cave; them-deposit; Greek) is the term used for cave deposits and study of caves is known as speleology. Speleothems are useful tools for palaeoclimatic reconstruction because they are terrestrial (this is important because the incidents like floods and droughts that affects civilizations occur on land and should reflect better in a terrestrial archive), can be precisely dated, geographically widely distributed, multiple proxies can be used, and are less susceptible to contamination as they form in protected cave environments (Gupta et al. 2020 and references therein).

4.1.1. Formation and types

Speleothems are laminated deposits composed of secondary calcium carbonates. It grows by the following process: Carbonate dissolves upon the action of organic acids e.g., humic and fulvic acids, or carbonic acid which is produced by dissolution of soil CO_2 in meteoric water.

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Carbonate host rock reacts with the carbonic acid to form soluble bicarbonate.

$$H_2CO_3 + CaCO_3 \rightarrow Ca(HCO_3)_2$$

Carbonate rich solution then percolates down into the cave which has lower partial pressure of CO_2 than the soil as drip water. Then CO_2 degasses from the drip water due to difference in pCO_2 and partly due to the evaporation in the cave chamber, leading to the precipitation of calcium carbonate in the form of cave deposits or speleothems (Fairchild et al., 2006; Jon et al., 2021).

$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$

Speleothems in caves are a common feature of carbonate karstic terrains. There are numerous types of speleothems, named on the basis on their formation, shape or appearance such as stalagmite, stalactite, soda straw, helictite, cave curtains, moonmilk, column, cave popcorn and so on. Of these, stalagmites are most suitable for palaeoclimatic studies because of their regularity.

4.1.2. Sampling

Caves can be few metres to kilometres deep. Deep caves have three zones, the entrance zone, the twilight zone and the dark zone. Deep caves with thin epikarst or thin soil cover are most suitable to minimise fractionation of rainwater in the soil zone or epikarst. Sampling is preferred from the deep internal chambers of the cave because they are protected from external contamination and grow in a stable microclimate (temperature and humidity) of the cave with limited air circulation from outside. Stalagmites which are regular and cylindrical in shape and are fed by a single drip source are considered the best samples. Samples from monsoon transition zones such as north-western Himalayas are more sensitive to short term climate changes those from high rainfall zones such as the Shillong Plateau in India. Sampling should be done sustainably for continuation of future studies.

4.1.3. Analytical methods, multiproxy approach and dating

As speleothems accrete, they keep recording the isotopic composition of the carbonate precipitating drip water which in turn is related to the precipitation of that time. Oxygen isotopes are a useful tool for palaeoclimatic studies (Dansgaard 1964). Oxygen has three isotopes, ^{16}O (99.76%), ^{17}O (0.04%) and ^{18}O (0.20%) of which ^{16}O and ^{18}O are utilised. Analysis of the $^{18}O/^{16}O$ of the speleothem sample's laminae and comparing it with a standard [Vienna Standard Mean Ocean Water (VSMOW) or Vienna Pee Dee Belemnite (VPDB)] ($\delta^{18}O$) in Isotope Ratio Mass Spectrometer help to interpret the variability of rainfall in the past. Speleothem samples are longitudinally cut in $1/4^{th}$ sections for multiproxy studies and dating. Analysis is done by reacting the drilled powders from along the central axis of a sample with orthophosphoric acid in any peripheral attachment to an IRMS such as the Gas Bench to generate CO_2 which then goes to the Isotope Ratio Mass Spectrometer (IRMS) (Sengupta et al. 2022). $\delta^{18}O$ is a parameter whose value, if more depleted represents high precipitation and if enriched represent low precipitation. Enrichment and depletion of $\delta^{18}O$ happens due to Rayleigh fractionation as water evaporates from a source like ocean or sea and go through subsequent cloud formation and precipitation or 'rainout'. Rayleigh fractionation can be modified by continental effect, source effect, temperature effect, altitude effect and amount effect (Fairchild et al. 2006; Lachniet 2009; Gupta et al. 2020 and references therein). Since India lies in the ISM domain, the speleothems from different parts

of the country speak about ISM variability and the isotopic signal is mostly modified by the amount effect, i.e., higher the precipitation, more depleted is the $\delta^{18}O$ value (Dutt et al. 2015). Other proxies used in speleothem based palaeoclimatic studies are petrography, architectural element analysis, UV fluorescence, $\delta^{13}C$, trace elements and fluid inclusion. Petrography helps to understand drip water chemistry, drip rate, organic matter and particulate influence and diagenesis in speleothems (Frisia 2014). Architectural element analysis aids in understanding the genesis of speleothem, estimating their age, correlating and inter-comparing with other samples, providing additional palaeoclimatic information, and research planning and understanding the suitability of samples (Muñoz-García et al. 2016; Martin-Chivelet et al. 2017). UV fluorescence helps to identify presence of organic acids such as humic and a fulvic acid which, along with $\delta^{13}C$ gives an idea of the vegetation in the cave region and indirectly, the climate that supported that vegetation (Baker et al. 2008). Trace elements often reflect the geochemistry of the drip water precipitating the sample, the seasonality of the laminae and in turn the climate (Fairchild et al. 2000; Verheyden 2004; Fairchild & Treble 2009). δD of fluid inclusion studies can help to determine the source of the moisture (Lopez-Elorza et al. 2021).

Speleothems are dated using C-14 (dateable up to ~50kyrs BP) and/or U-Th disequlibrium methods (dateable up to ~500kyrs BP). Consideration of dead carbon and other effects such as reservoir effect and hard water effect are essential after C-14 dating and it produces quite reliable results with an error bar of few decades. U-Th method can be applied when there is enough initial U and negligible Th, negligible impurity and in a closed system. The error bar is higher than C-14 method. Precise and reliable dating of speleothems is possible with these methods (Walker, 2005).

4.1.4. Speleothem based palaeoclimatic studies from the Asian monsoon domain

Speleothems from 22 caves from India from core monsoon zone as well as monsoon transitional zones have been studied which present fragmented climatic data of variable resolution of hundreds to thousands of years mainly from the Holocene and some from the Pleistocene and these have been published since 2004. These caves are Sahiya, Bittoo, Timta, Tityana, Dharamjali, Chulerasim, Sainji and Panigarh in Uttarakhand; Borar in Himachal Pradesh; Kalakot in Jammu and Kashmir; Mawmluh, Wah Shikar and Umsynrang in Meghalaya; Dandak. Kotumsar and Jhumar in Chattisgarh; Akalagavi in Karnataka; Munagamanu, Belum, Nakarallu and Valmiki in Andhra Pradesh; and Baratang in Andamans. The longest (although discontinuous) speleothem based climatic record from India is of 280 ka from Bittoo cave (Kathayat et al. 2016). The youngest date from an Indian speleothem is AD 2012 from Wah Shikar cave (Gupta et al. 2019). Thus, it is possible to understand even decadal scale climatic variability from speleothems up to very recent past. Indian speleothems have shown proxy response of some major climatic events such as the 8.2

ka event, 4.2 ka event, MCA, LIA, OD, B/O, D/O events, RWP, HCO, Heinrich events, YD and few MIS (Singh et al. 2018 and references therein; Kaushal et al. 2018 and references therein). Workers have tried to correlate civilizational changes with ISM intensity changes and throughout the history of India it has been observed that empires strengthened, prospered and consolidated during strong ISM periods (e.g., Gupta empire which corresponds to MCA) and disintegrated and weakened during weaker periods of ISM (e.g., end of Vedic era prior to RWP) (Dutt et al. 2015; Kathayat et al. 2017; Rawat et al. 2021).

Important speleothem studies from other areas in the Asian monsoon domain are from Hoti, Defore and Qunf cave in Oman and Socotra and Moomi cave in Yemen (Fleitmann et al. 2007; Liu et al 2014. and references therein). Wanxiang, Xiaobailong and Tianmen caves in China lie in the ISM domain. Important studies from the EASM domain are from Sanbao, Heshang, Hulu, Dongge, Jiuxian, Lianhua, Shiago, and Yamen caves in China (Liu et al 2014 and references therein).

4.1.5. Conservation of caves

Caves are important for different branches of scientific studies. Apart from palaeoclimate, the delicate cave environment with distinct flora and fauna are important for biological studies as well. From a palaeoclimatic point of view, every speleothem is unique and cannot be replicated. Hence any damage to cave samples might mean a permanent loss of a climatic record. Therefore, it is imperative to conserve caves and protect them from anthropogenic damages. Caves attract many tourists for adventure because of their stunning interiors and also for religious causes but studies have shown that unmanaged and unmonitored tourism alter the cave environment. Though most studies say these alterations are reversible as nature adjusts itself but continual exposure to damaging activities may leave a long-lasting or permanent impact (Baker & Genty, 1998; Šebela & Turk, 2014; Dominguez-Villar et al., 2010; Hendy et al., 2022; Faimon et al., 2006; Lang et al., 2015; Lang et al., 2017). Awareness about importance of caves, sustainable tourism or geotourism and cave conservation must be promoted (Baeza et al. 2018).

5. Conclusion

Speleothem based multiproxy approach for palaeoclimatic reconstruction is a powerful and promising tool for understanding the Quaternary climate. These studies together with other archives and proxies can give fair insight into the controls on climate variability and causes of changes in regional societies. Studies from a large number of caves in different parts of India, positioned in the domain of south Asian monsoon that influences billions of people, have proven that most major climatic events are global in nature, contemporaneous in many places and influences the ISM through teleconnections. However, more studies remain to be done in this sector and thus it is important to conserve caves and sustainably develop them.

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Dipanwita Sengupta

Dipanwita Sengupta is presently working as a Senior Research Fellow in the Wadia Institute of Himalayan Geology, Dehradun. She is enrolled in the Academy of Scientific and Innovative Research, Ghaziabad. Her postgraduate dissertation was on facies and petrographical analysis of sedimentary Barakar Formation in Raniganj Basin. Her doctoral thesis focuses on reconstruction of variability of the Indian Summer Monsoon (ISM) during the Holocene using speleothem archive, the forcing factors and teleconnections affecting the ISM and the socio-economic consequences of ISM fluctuations on human societies.

Her other research interests include Holocene climate variability determination using other proxies such as lake deposits and macrocharcoal, spreading awareness about sustainable geotourism for conservation of geoheritage sites, and geohazards in the Himalayas.

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