e-Journal Earth Science India, Vol. I (III), 2008, pp. 167-174
http://www.earthscienceindia.info/

Speleothems from the Himalaya and the Monsoon: A Preliminary Study

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Abstract

Speleothems (stalagmites, stalactites) have great potential for the records of past climate, environment and monsoon on a global scale particularly in the Asian region. Speleothems are found in all parts of the world and grow continuously through many glacial – interglacial cycles and their stable isotopic ratios and annual growth bands are useful for decadal to seasonal variations in rainfall. Some important speleothems from the Himalayan region such as Sahastradhara, Dehradun; Brahmakhal, Uttarkashi; Bhagirathi valley, Garhwal and Mawasmai caves from the Meghalaya have been studied. In the present paper, the oxygen and carbon isotope ratios from the Sahastradhara, Brahmakhal, Nagni and Pratapnagar speleothems and cave drip water has been recorded for the first time. The significance of speleothems and their relationship with the monsoon is discussed.

Introduction

Speleothems are abundantly found in the Himalayan caves from NW to NE India, where calcium carbonate is precipitated as stalactites and stalagmites (Fig.1 and Fig. 2 a,b,c,d,). The Himalayan speleothems may provide important record of paleomonsoon as they are not subjected to erosion and terrestrial deposits. The Holocene paleomonsoonal studies from the tropical and monsoonal regions of the Indian subcontinent and the southeast Asia has been attempted in recent years (Fleitmann *et al.,* 2003; Cheng *et al.,* 2005, 2006; Wang *et al.,* 2008; Johnson *et al.,* 2006; Sinha *et al.,* 2005; Yadav and Ramesh, 2005). Carbon and oxygen isotopic variations in speleothems especially stalagmite growth laminae are used for interpreting the amount of rainfall (Fleitmann *et al.,* 2003; Johnson *et al.,* 2006; Sinha *et al.,* 2005, 2007; Wang *et al.,* 2008). In the present scientific highlight, three very important speleothem deposits are being described from the Brahmakhal (Prakateshwar), Sahastradhara and Mawsmai caves from NW to NE Himalaya (Fig.1 localities 1, 2 and 3; Fig. 2, a,b,c,d). The sedimentological microfacies of the speleothems, radiaxial fabric of cave calcite and carbon and oxygen isotopic ratios of the stalactites and stalagmites have been discussed for paleoenvironmental and paleoclimatic interpretations. All these caves lie in the high monsoonal region therefore, it is quite significant to study the strength of Indian Summer Monsoon (ISM) and decadal scale seasonal variations. It is proposed to do the high resolution 230 Th dating of stalagmites from these unexplored caves to calculate the amount of rainfall due to west ISM. The Mawsmai cave lies in the Sohra (Cherrapunji) area of the Shillong Plateau, Meghalaya where highest annual rainfall is 11931.7 mm. It is the wettest place on planet earth.

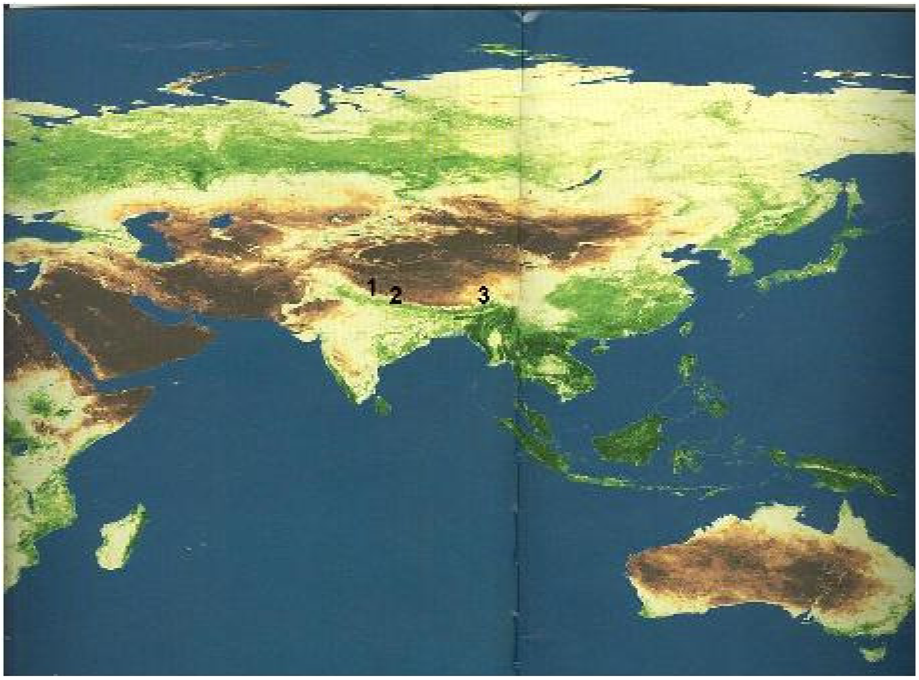

Fig.1: Map of India (Himalaya in the north), Tibetan Plateau and Indian Ocean showing the locations of caves from where speleothems have been studied:
Locality- 1. Brahmakhal (Prakateshwar) cave discovered in 1998 from Uttarkashi district, Garhwal Himalaya, Uttarakhand; Locality- 2. Sahastradhara cave, Dehradun district Garhwal,Himalaya, Uttarakhand Locality - 3. Mawsmai cave, 6 km from Cherrapunji, Shillong Plateau, Meghalaya

Lesser Himalayan Speleothems from Garhwal, Uttarakhand Region

Sahastradhara cave system:

The Sahastradhara cave is situated at a distance of 14 km from the city of Dehradun, the state capital of a newly carved hilly state Uttarakhand in the NW Himalaya. (Fig 1, locality 2). The Doon valley is separated by the Lesser Himalayan Neoproterozoic Krol belt carbonate sediments in the north (Tewari, 2007) by Main Boundary Thrust (M.B.T.). The Siwalik foreland basin sediments are found in the south of the Doon valley thrust over the Indo – Gangetic Plains along Himalayan Frontal Thrust (HFT). The GPS location of the Sahastradhara cave is N 30 23 . 145 and E 78 07 .741. The Doon valley is between the river Ganga in the east and Yamuna river in the west. Both these rivers have their origin from two different Himalayan glaciers, namely Gangotri for Ganga and Yamunotri for Yamuna. Sahastradhara in Indian language means *thousand fold springs*.

Williams a British naturalist had described this beautiful place in his words " The only other holy spot worthy of special notice is the Suhusra Dhara (pronounced as *Sahastradhara*), a place of the thousand drippings which is a very simple phenomenon has invested with peculiar sanctity in the eyes of the people from the side of a charming valley to the east of Rajpur , oozes a mountain stream , distilling its waters over a precipice thirty feet high , and leaving a crust of lime on everything it touches. Particles, thus accumulating for continuous, have made a projecting ledge forming a sort of cave, from the roof of which falls a perpetual rain that turns every glade of grass coming in contact with it into a petrification. From above hang stalactites innumerable (Fig.2 a,b). Stalagmite covers the ground beneath. Opposite, there is a sulphur spring also possessing powers of petrification." The seven caves of the Sahastradhara are small in size approximately, 10m long, 2m wide. The smallest one is 2.5m long and 2m wide.

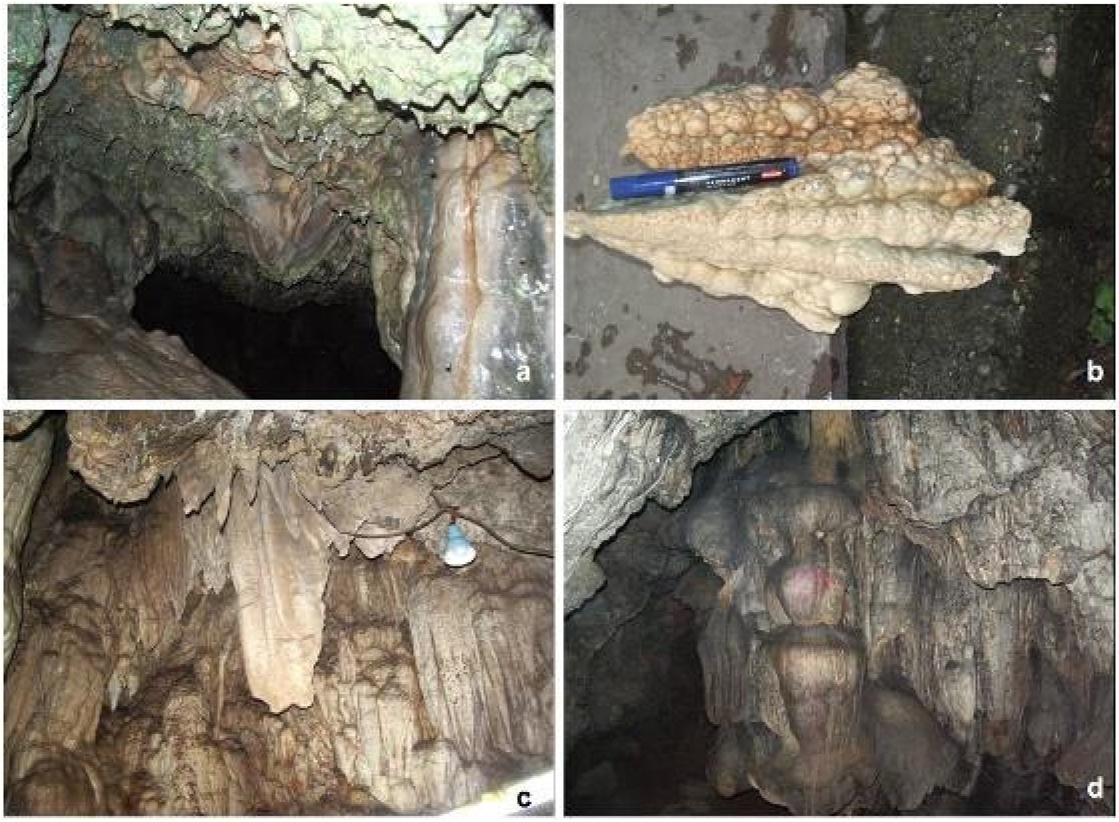

Fig. 2 : a. Dripping water in the Sahastradhara cave showing stalactites and stalagmites during monsoon studied for oxygen isotope (location 2) b. Stalactite column from Sahastradhara cave studied for carbonate microfacies and C and O isotope ratios (location 2 in Fig. 1) c. Speleothems in Brahamakhal (Prkateshwar) cave studied for microfacies and C and O isotope ratios (location 1 in Fig. 1) d. Speleothems from Mawsmai cave showing pillar like structures near Cherrapunji, Meghalaya, (Location 3 in Fig. 1)

Microfacies of the Speleothems:

The Sahastradhara speleothems are made up of stalactites and stalagmites (Fig. 2 a, b). The stalactites show the presence of bacteria to form calcite precipitation. The microfacies of the Sahastradhara stalactites show radiaxial fibrous calcite (Fig. 3c, d). The Sahastradhara caves are located in the Neoproterozoic Krol Dolomite host rock (Tewari, 2007); Mg has triggered the formation of radiaxial fabric. Microbial precipitation of the carbonate is confirmed by the presence of microstromatolites and cellular microbiota (Fig. 3d). The culture experiments have demonstrated the role of microbes (PCR amplification of 16Sr RNA genes; 16Sr DNA) in the stalactite formation (Baskar *et al.,* 2006). The radiating fibrous calcite and finely laminated calcite and organic microbial laminae are also recorded in the Prakateshwar (Brahmakhal) cave speleothem (Fig. 3 a, b). Other carbonate mineral present is aragonite formed in fresh water. Various types of light (carbonate) and dark (organic) laminae are related to the microclimatic decadal scale seasonal variations.

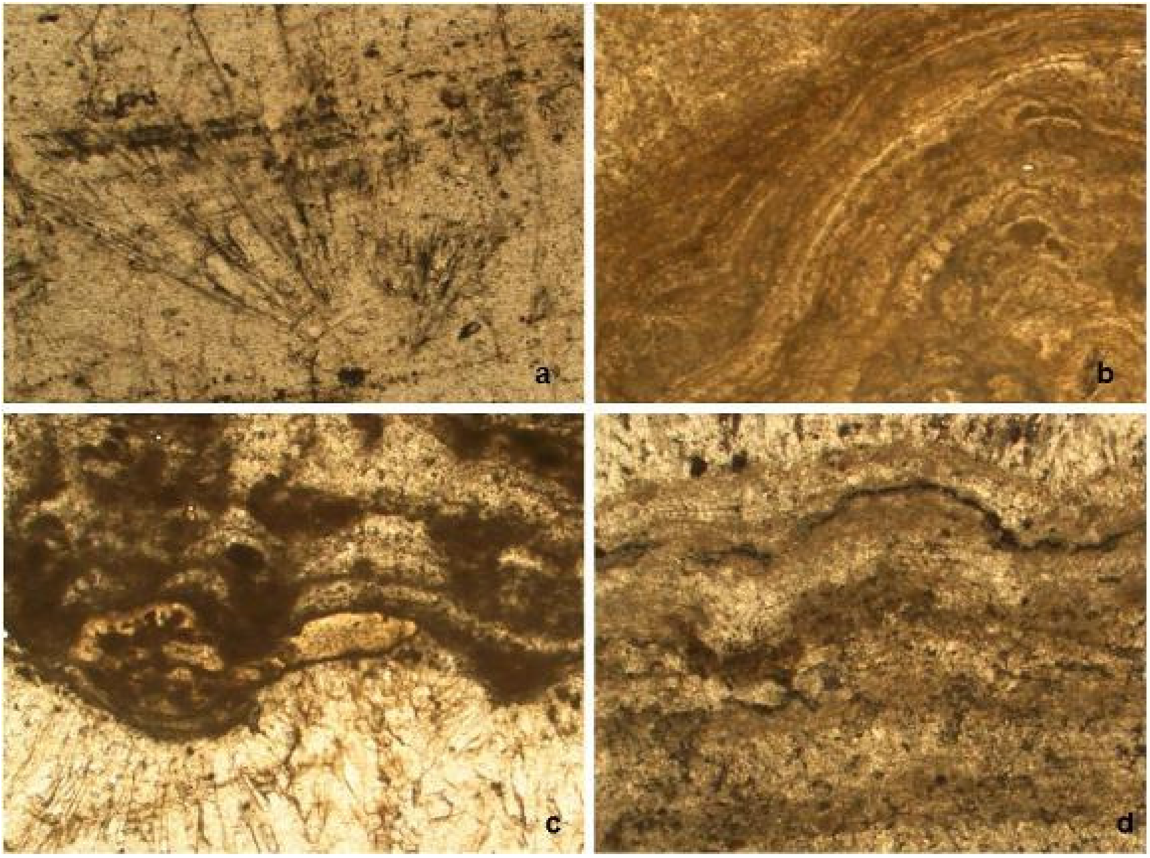

Fig.3: Microfacies of the Speleothems from the Himalaya , India a. photomicrograph of radiating fibrous calcite in Brahmakhal (Prakateshwar) cave, Uttarkashi b. Finely laminated calcite (white) and dark (organic) laminae in the Brahmakhal (Prakateshwar cave), Uttarkashi c. photomicrograph of fibrous calcite in Sahastradhara stalactite showing radiaxial fabric (below) and dark (organic/microbial) microstromatolitic laminae (above) d. photomicrograph of microstromatolitic light and dark laminae and cellular and filamentous microbiota indicating microbial precipitation of carbonate, Sahastradhara caves , Dehradun.

Stable isotopes and Palaeomonsoon reconstruction:

The carbon isotopic ratios of the Sahastradhara stalactites range from – 2.47 % (PDB) to -6.06 % (PDB) and oxygen isotope values range from 22.99% (SMOW) to 26.21% (SMOW). In Brahmakhal cave the $\delta\ ^{13}C$ vary from -5.34 % (PDB) to -7.65% (PDB). $\delta\ ^{18}O$ vary from 20.67% (SMOW) to 22.84% (SMOW). The $\delta\ ^{13}C$ value of Pratapnagar modern stalactite calcite varies from -4.85% (PDB) to -9.23% (PDB) and the $\delta^{18}O$ range from 19.50 to 21.57 % (SMOW). The variation of $\delta\ ^{18}O$ in stalagmites is related to the precipitation amount during the monsoon season. The oxygen isotopic composition of speleothem calcite from tropical and monsoon locations are primarily controlled by the $\delta\ ^{18}O$ value of precipitaton. $\delta\ ^{18}O$ values of regional precipitation and that changes in calcite $\delta^{18}O$ over time primarily reflect changes in the amount of monsoonal precipitation. Study of modern cave drip waters and stalagmites demonstrates that stalagmite was deposited in or very near to isotopic equilibrium (Fleitmann *et al.* 2003). The $\delta^{18}O$ isotopic data of drip water from Sahastradhara cave in Dehradun measured during the months of monsoon (August and September , 2007) varies from - 4. 58 % (V- SMOW) to – 5. 14 % (V- SMOW). Cave calcite also contains information about the isotopic composition of meteoric precipitation, is widespread and can be dated with 230^{Th}. Thus, a detailed high resolution O isotope speleothem data from the Himalaya may yield well dated record of paleomonsoon history.

The speleothems show microscopic laminae similar to marine and lacustrine sediments and could be of annual origin and can demonstrate seasonality. In order to establish such a relationship, continuous cave monitering is essential. Stable C isotope ratios of the light and dark laminae vary in speleothems and may be linked with warm and cold seasons. Table-1 shows the bulk carbon isotope values from different caves. The C- isotope values are mostly negative. The detailed carbon isotopic study of individual light and dark laminae will explain the growth dynamics of the speleothems.

Discussions and Conclusion

Fleitmann *et al.*2003, (and the references therein) have interpreted that the western part of Indian Summer Monsoon (ISM) in Oman and Yemen , the oxygen isotope ratios of stalagmite calcite primarily show variations in the amount of rainfall with more negative $\delta^{18}O$ indicating higher monsoon rainfall. In the present preliminary study also negative $\delta\ ^{18}O$ values have been recorded from the Himalayan speleothems (Brahmakhal and Sahastradhara caves). The $\delta^{18}O$ data is also in agreement with Sinha *et al.* (2005) who have studied Timta cave in the Uttarakhand, NW Himalaya and interpreted that $\delta\ ^{18}O$ reflect varying ISM strength. The Indian Monsoon and East Asian Monsoon systems represent a part of the larger Asian Monsoon System. The East Asian Monsoon system is well documented by oxygen isotope records of the Hulu cave stalagmite (Cheng *et al.* 2005). However, a detailed study of the known Indian Himalayan cave stalagmites and other unexplored caves in this region is essentially required to further confirm these results and propose a model for paleomonsoonal variation. There are very thick carbonate (karstic) sequences in the entire Himalayan belt from Jammu in the NW to Meghalaya in NE and needs to be studied in detail (Tewari, 2007, 2008).

Table-1: Carbon (permil) of $\delta^{13}C_{PDB}$ and Oxygen $\delta^{18}O_{PDB\ and\ SMOW}$ isotope ratios from the Lesser Himalayan Speleothems (Brahmakhal cave , Bhagirathi valley , Garhwal, BK1 to BK 3) , Nagni (NC2), Pratapnagar, Garhwal (P1 to P6), and Sahastradhara , Dehradun (SD1 to SD8).

Sample Number	$\delta^{13}C_{PDB}$	$\delta^{18}O_{PDB}$	$\delta^{18}O_{SMOW}$
BK 1	-5.37	-9.43	20.67
BK 2	-6.68	-7.49	22.61
BK 3	-7.65	-7.26	22.84
NC 2	1.03	-7.55	22.64
P1	-5.64	-8.31	21.79
P2	-9.23	-9.94	20.16
P3	-4.85	-9.01	21.09
P4	-5.21	-8.53	21.57
P5	-9.22	-10.60	19.50
P6	-6.55	-10.08	20.02
SD 1	-5.97	-6.95	23.15
SD 2	-2.30	-4.12	25.98
SD 3	-3.76	-3.99	26.11
SD 4	-2.47	-3.96	26.14
SD 5	-6.06	-6.98	23.12
SD 6	-3.60	-3.89	26.21
SD 7	-6.07	-6.80	23.30
SD 8	-5.47	-7.11	22.99
Drip Water, Sahastradhara		∂D (V $-_{SMOW}$)	$\delta^{18}O$ (V-$_{SMOW}$)
SD1	-	- 34.83	- 4.58
SD2	-	- 37.15	- 5.14

There is a plan to explore these caves for boosting geotourism in the fragile Himalayan mountains. Although such cave tourism is very popular in the America and Europe, however, the cave tourism in the Himalaya may be harmful to the environment. There will be tremendous increase in CO_2 in caves and such elevated CO_2 may cause destruction of speleothems within the cave. The speleothem may be at risk from the increased crowd of tourists where the calcium ion concentration of the drip water is low. Therefore, before such cave tourism is finally planned in the Himalayan region, the anthropogenic effects of tourists has to be considered. However, there is a need to explore these caves in detail in India and a state level or national effort in this direction will advance the scientific knowledge of speleothems, paleoclimate and paleomonsoon.

Acknowledgements: I am grateful to Padmashree Dr. B.P.Radhakrisna, ex. President , Geological Society of India , Bangalore for inspiration and encouragement and thank Prof. B.R.Arora, Director, W.I.H.G., Dehradun for facilities and permission to publish the article. Professor D. Fleitmann, Switzerland is thanked for general comments on the speleothem photographs from the Himalaya. The anonymous referee is thanked for the critical review of the paper and useful suggestions.

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