Malani suite and Trans-Aravalli sedimentary basins to the west and Vindhyan basin to the east are described under the Chapter on Western India. The geophysics, tectonics and evolution of the terrain as proposed by several workers are referred here. In the next chapter on the Purana basins, the meso to neo Proterozoic platformal sediments represented in the Cuddapah – Kurnool, Pakhal, Kaladgi, Bhima, the Chattisgarh, Indravati, Ampani, Keskal, and Khariar, are described together. Regarding the Vindhyans, the basins to the north of the Son-Narmada-Tapti lineament are considered to have been deposited in a single large basin where as the occurrences in the south are believed to be separate basins. As with the Purana basins, one chapter contains information about all of the Gondwana basins. A host of stratigraphic terminology presently in vogue in the different basins is cited. In the next chapter the 'Deccan Continental Basalt Volcanism' the extent, development, associated infra and intertrappeans and age are briefly described. The widely accepted plume model for the formation of the trap rocks is discussed.

The next chapter on the Himalayas describes the general stratigraphy of the metasedimentary rocks that constitute the mountain range and the complex tectonic processes that created the Himalayas. Cenozoic formations are discussed in the last two chapters. The Pre-Quaternary rocks in the east coast basins - Bengal, Mahanadi, Krishna-Godavari, Kaveri Basins, and the west coast basins of Kerala, Cambay, and others are briefly described and their oil and gas potential are pointed out. The final chapter on Quaternary describes the evolution of the Ganga basin and the large deltas of Bengal and the smaller ones along the other river courses. The author has successfully compiled a fairly wide bibliography incorporating some of the older as well as new publications. His compilation of isotopic ages (on which he is an undisputed expert) is highly noteworthy.

The International Association for Gondwana Research (IAGR) has fully exploited the modern techniques of DTP in producing such an aesthetically attractive book. The text, the figures and tables have been reproduced on luxurious glossy print to excellent clarity and deserve appreciation. Yet a few drawbacks are felt. The author has made a highly anxious attempt to put all information available on geology, geophysics, tectonics, isotopic data, evolution and mineral resources within the limited volume of the book. As a result, the book appears very much crammed with too many details and difficult to comprehend easily. For students of geology who have always enjoyed reading the classic works of Pascoe, Krishnan, Wadia and others on Indian Geology for the sheer joy they radiate, MNB's book may be less exciting and trifle disappointing.

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## PROCEEDINGS OF THE WORKSHOP ON GANGOTRI GLACIER, Lucknow, 26-28 March, 2003; Edited by Deepak Srivastava, K.R. Gupta and S. Mukerji. Special Publication No. 80, Geological Survey of India, 2004, 239p. Price: Inland Rs. 295.00; Foreign: $16.0.

Nestled in the lap of mighty mountains overlooked by awesome peaks of the High Himalaya and situated in the northwestern part of Uttaranchal, the Gangotri glacier is the source of the Bhagirathi river, which downstream meets the Alakananda at Devprayag and together flow down as the Ganga river. The Ganga, the holiest of holy rivers evokes great emotions, intense religious fervour, a sense of detachment and feeling of tranquility among the people of India. The Gaumukh, the snout of the Gangotri glacier, is a holy site for millions of Indians as the source of the Ganga. It was appropriate that the Geological Survey of India, jointly with the Deparatment of Science and Technology, organised a workshop on the Gangotri glacier which was held in March 2003 at Lucknow. Besides the GSI, sixteen more organisations participated in the workshop. The proceedings of the workshop has been brought out as a Special publication of the GSI.

There are 27 papers included in the volume, which cover topics of the recession of the Gangotri Glacier, morphology of the glacier and the basin, avalanches, snowcover in Uttaranchal, stream flow and hydrology, landslide, vegetation, climate, lake history, on lichens and on the geology of the Gangotri area. Thus, the volume provides a broad coverage of the glacier and related aspects.

The historical documentation on the Gangotri Glacier is traced from the time of sage *Bhagiratha* through medieval period down to the survey carried out by the GSI as late as 1977 (V.K.Raina). Resession of the Gangotri Glacier is well documented by surveys carried out by the GSI since 1935 when Auden prepared the map of the snout of the glacier,

down to 1997 by Sangewar and by analysing this data it has been found that the Glacier is in a state of continuous recession since nineteenth century (Deepak Srivastava) The Gangotri Glacier has several tributary glaciers and one of them, the Meru Bamak glacier, is the subject of study on its recession pattern since 1977 (Alok Chitranshi et al ) The study of ice melt in the snout area of the Gangotri glacier has indicated that there is very little vertical shrinkage but there is general loss of the ice front by calving which has resulted in recession (Maruthi et al ) The flow parameters from the snout to Kirti Bamak tributary glacier and from the snout upto its near confluence with the Raktvarn tribulary glacier during two separate period from 1971 to 1977 have been computed to study the impact on the net recession of the Gangotri glacier (Sangewar et al ) By the application of both multispectral discriminabilities of glacial features and finer details observed through high resolution panchromatic images obtained from Indian Remote sensing satellites, the snout position of the Gangotri galcier has been precisely identified (Bahuguna et al ) One significant study has shown that the major part of the snow and ice in the basin is concentrated between 4500 m and 6200 m asl with lakes, six of them are ice-dammed, mainly concentrated between elevation 4507 m and 4663 m asl , the average rate of recession over the last 16 years being 23 m per year, with supraglacial debries having formed over hundreds of years (Sarafraz Ahmad and Hasnain)

In any study of glaciers, the information regarding the morphology assumes great importance There are five papers on this aspect Satellite imageries have greatly contributed to our understanding of the morphological features The study of physiography and geomorphology of Gangotri glacier area indicates the presence of three levels (5100, 4900 and 4700 m asl ) of left lateral moraines near the central part of the glacier which point to three stages of shrinkage of the glacier in the recent past (Dutta et al ) The geomorphic evolution of the Gangotri glacier valley has been found to be controlled by the glacial, fluvioglacial, avalanche and lacustrine processes evolved under the influence of neotectonic activity during the later part of the Quaternary period (Rameshwar Bali et al) The study of glacial morphology of the Gangotri group of glaciers has brought out that the main glacier is under process of retreat whereas the tributary glaciers show slow retreat or static position (Nainwal et al ) In another effort on the study of glacial landforms and geomorphology of the valley, stress is laid on glacial, fluvial, glaciofluvial, lacustrine and pluvial environments operating as having contributed to the present geomorphic architecture of the Gangotri glacier (Dhruv Sen Singh) Glaciers of the Ganga Basin in the Himalaya are presently confined only to the higher altitude area though during the Quaternary period the spread of glaciation had reached the lower altitude This has been confirmrd by the detailed geomorphological studies undertaken in different parts of the Ganga catchment and elsewhere in the Himalaya, and accordingly a model has been prepared (Puri et al )

Avalanches are common in glacier and heavy snowfall regions and two papers deal with this aspect In glacier formation and its dynamics avalanches play a major role in bringing snow from higher to lower altitudes and contribute towards accumulation and ablation of ice Such a study in the Gangotri glacier and its catchment area has been carried out by using high resolution satellite imageries and change detection algorithms (Sharma et al ) The avalanches are destructive outside the periphery of glaciers as happened on March 2, 2002, when an avalanche struck Gangotri town damaging a portion of the temple and a few other structures As this area is located in the proglacial regime of the Gangotri glacier, the area is susceptible to mass wasting and erosional processes and the Bhairon Jhanp nala, located to the east of Gangotri temple complex, as the most vulnerable geomorphic feature responsible for the avalanche activity (Shukla et al ) Certain remedial measures are suggested by the authors for containing the damages that may be caused in future

The Gangotri pilgrim route is suceptible to frequent landslides Therefore a landslide hazard zonation mapping was undertaken which brought out that the slopes in about 3 km wide corridor along 119 km Uttaranchal-Gangotri-Goumukh route are susceptible for land slide, needing preventive measures (Bhatnagar and Gupta)

Climate variability studies are important to our understanding of the secular movement of glaciers Such a study in the Gangotri glacier areas, based on instrumental records available has brought out that there has been a steady fluctuation in recession after the Last Ice Age and it has been much more since 1950 (Borgaonkar and Pant) In another attempt to decipher climate variability of the Gangotri glacier area by multidate satellite data, it has been found that it is best reflected by the depletion of snow cover, glacial volume, snout and equilibrium line fluctuations (Tangri et al )

Snow cover study in Uttaranchal Himalaya requires monitoring of temporal and spatial variations and such a study has been undertaken in the Bhagirathi and Alaknanda watersheds and results reveal that the quantum of snow melting which in ultimate analysis decides the quantum of discharge emanating from the watershed (Ankani K, Tangri) The anlysis of meteorological data collected for a

period of four years from the Gangotri glacier basin for the ablation seasons of May-October has shown features like little rainfall, very high wind velocity during day-time and high evaporation at high altitude. Based on this data a modelling of stream flow is prepared for the Gangotri glacier (Pratap Singh et al.).

The study of hydrology and suspended sediment transport of Gangotri glacier has brought out that the discharge variations in individual months were significantly different during the three years – 1999-2000-2001 (Kireet Kumar).

Information on experimental study of the Gangotri Glacier and also the Dokriani glacier in the district of Uttarkashi in Uttaranchal by dry tracer tests was conllected during 2001 and 2002 seasons (Shresth Tayal et al.). This has shown that in Gangotri glacier there is existance of one or more large pools underneath the ablation zone of glacier leading to excessive chemical weathering of bedrock, and in the Dokriani glacier sub-glacial system evolves through the ablation season.

There are two papers dealing with lichenometric studies of moraines of Gangotri glacier which help in dating the moraines. Absolute ages of various moraines have given ages of 1865, 1849 and 1782 AD respectively for three moraines (Deepak Srivastava et al.). However, another study has shown that certain species like *Dimelaena oreina* shows a variable growth rate and provide dates of 1897 AD and 1881 AD respectively for two different moraines (Divya Darshan Awasthi et al.).

As part of the programme of palaeoclimatic studies of the Gangotri glacier area, the study of the fluvio-lacustrine deposit of the Topoban Paleolake, 200 m above the Gangotri glacier snout, by radiocarbon dating and analysis of pollen spores, has indicated that lake conditions might have existed even prior to 9000 years B.P. under fluvio-lacustrine conditions (Ranhotra and Bhattchryya).

The morphometric study of the Bhagirathi suggests it is a seventh order stream. The valley characterizes high to moderate relief, and hyposmetric analysis brings out that it is to be in younger stage as 'V' profile at an elevation below 2000 m asl (Sangewar et al.). The hydrogeochemical study of the meltwater of the Gangotari glacier and of the Bhagirathi river snowstream has brought out that bulk of $SO_4$ in glacier melt water has been derived from the oxidation of sulphides further upstream and hence lithogenic (Deepak Srivastava et al.).

The geology of the Gangotri-Gaumukh area is briefly discussed in a short note (U.K.Bassi). The glacier area mainly centres in the Badrinath Granite, dated 495±50 Ma by Rb-Sr method.

Geological Survey of India has a great history of glacier studies in the Himalaya. The establishment of Glaciological Division in the GSI in 1974 has given a fillip to these studies. However, during the last about three decades, the glacier studies in the developed countries have become more intensive in the context of global climate change studies, by adopting new techniques and technological innovations. The rapid recession of glaciers in the Himalaya due to changes in the global climate pattern is a matter of great concern as it will affect the socio-economic aspects of the people inhabiting the Indus-Ganga belt of Northern India, which is dependent on the glacier melt water of the Himalayan rivers. The workshop on the Gangotri glacier held at Lucknow, though imely, touches only the fringe of the problem. The papers presented, though many, are repetitive and some even sketchy. Excepting for the application of remote sensing as detailed in a few papers and dry tracer tests there is not much utilisation of modern techniques. There is need for drilling for ice-cores and also application of geophysical methods for understanding the variation in ice layers and also to obtain the accurate thickness of ice for assessing the total volume of ice and for obtaining ablation and acuumulation ratio. We do not have accurate data regarding the level of snow-line in different sectors of the Himalaya. There is a need for more intensive study of each glacier in the Himalaya as a National Programme by multidisciplinary approach, joint investigations by pooling available resources and quick publication of research results as memoirs. The Proceedings of the Workshop on Gangotri Glacier, though a small beginning, is a laudable effort.

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