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A Comparative Study of Antarctic Arctic and Himalayan Ice

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ABSTRACT

Arctic, Antarctic and inaccessible lofty regions of Himalayas, which are geographically diverse areas and have been a constant source of inspiration, envisages a challenging field of study by early adventurers and scientists of the world. Characteristics of ice obtained at Arctic and Antarctic do not possess similar properties. Even the salient properties of snow and ice of western and central Himalayas vary due to its differing free water content. A study has been carried out based on recent Antarctic Expedition by Indian scientists and the data gathered along litho-tectonic regions of Himalayas and their characteristics have been compared, which brings out stratigraphic and metamorphic characteristics of the ice and snow. In the present paper, an analysis of the ice and snow properties of Arctic, Antarctic and Himalayan regions has been presented.

1. INTRODUCTION

The Arctic, Antarctic and upper reaches of Himalayas have remained obscure and very difficult for habitation. There are practically no indigenous people at Antarctica. It is observed that the human spatial pattern is of intrusive pattern and comparatively very sparse at Antarctica unlike Arctic, where preponderance of economic exploitation has been more rampant with the blend of veritable populace. So is the case of inaccessible snow bound regions of Himalayas where living conditions are extremely trying and adverse. However, systematic scientific studies of terrain has been carried out at these places especially over three decades. At Antarctica the studies were based at the Indian stations (Schirmacher Range and Dakshin Gangotri) which have a number of glacier outlets overriding the rock surface. Western Himalayas possess a good potential of glacial and seasonal snow-bound areas. The western upper reaches of Himalayas especially Shyok-Nubra-Suture zone, exhibits dry type of snow

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than the central and eastern Himalayas. In the present paper an attempt has been made to analyse snow and ice characteristics of the three règions and has been suitably compared. The age, metamorphic changes, density of snow/ice and the applied geomorphology relevant to the study has been suitably presented.

2. REVIEW OF LITERATURE

Nature and growth of sea ice has been briefly dealt by Sugden[1]. Sea ice is a thin layer of ice floating on the sea surface and forms when the temperature of the sea falls below its freezing point. Sea ice includes patches of brine and the amount depends on the rate of freezing. If freezing is slow the brine content is low, but if freezing is quick more salts are trapped. The various metamorphic processes are responsible for conversion of a snow particle to growth of ice. Perla[2] and Gray[3], *et al.* have described the thermal and mechanical properties of snow and ice cover. The author has extensively carried out stratigraphic studies on snow, firn and glacier ice. Some of the data is available in the annual reports published by Snow and Avalanche Study Establishment (SASE)[4]. Strength of the snow and ice cover of Himalayan region has been briefly accounted by Upadhyay[5], *et al.* Thermal profiles of Himalayan glaciers have been studied by Vohra[6], *et al.* as early as 1974. The fresh, firn (old) snow and ice densities differ, which primarily is the cause of the hardness of the snow cover or ice-pack. The albedo, ablation, and stratigraphy of the Antarctic ice at the research station of Dakshin Gangotri have been studied by Indian scientists, Katyal[7], *et al.* and Kaul[8], *et al.* Defence Research and Development Organisation (DRDO) is also among the largest R&D Organisations in the country which has a singular contribution towards the scientific study of ice and snow in and around the continent. The formation of glaciers in the geographically and climatically different environments of polar, Antarctic regions (ice sheet and ice shelves) and Himalayan valley glacier ice itself accounts for the varying characteristics of ice. The dynamics of ice and snow has been amply explained by Colbeck[9] and Paterson[10].

2.1 Thermal Characteristics of Glacier Ice

The energy budget due to radiation of short wave, long wave and other characteristics of ground is responsible for total heat budget and ablation of the ice mass which accounts for vital water resources. If there is no horizontal transfer of heat, conservation of energy requires that, at any point of the surface at any instant

$$\Delta G + M = R + H - L_v E + L_f P \quad (1)$$

where,

ΔG is the rate of gain of heat of a vertical column from the surface,

M is the heat used to melt snow and ice,

H is the rate of transfer of heat from air to snow surface (sensible heat) which may be positive or negative,

L_v is the specific latent heat of vaporisation (2.5×10^5 J/kg),

E is the rate of evaporation from surface, is cooled further. Thus it is necessary to cool only a thin surface layer for the formation of ice. The density of sea water, on the other hand, increases with falling temperature down to the onset of freezing. Thus, as the surface layer is cooled towards the freezing point, its density increases and it sinks. As a result of whole column of sea water of uniform salinity must be cooled to the freezing point before sea ice can form. Due to salinity sea water usually freezes at –1.91°C. Some of the common stages and types of floating sea ice are : frazil ice, grease ice, ice rind, congelation ice, anchor ice, ice foot, etc.

Snow plays a more important role in Antarctic ice than in the Arctic. Arctic winter snow fall is light and exceeds 30 cm. Winter in the Antarctic is a stormy season and snow thickness of 1 m are common in a zone fringing the coastline. In Antarctic, wind has been recorded to flow upto 150 kmph. The chill factor (more cooling than the ambient temperature), therefore, plays an important role at Antarctica. This difference in snow cover has several effects. A thinner snow cover is a less effective insulator and thus on an average Arctic ice contains higher properties of congelation ice. Also, surface infiltration is more in Antarctic. The snow cover also affects the rate of freezing. Overall, these contrasts mean that Antarctic ice has a higher component of relatively weak ice structures, when compared to Arctic ice. There is a significant difference in the age of ice of the Arctic and Antarctic regions. Whereas only 15 per cent of Antarctic ice is more than a year old, most Arctic ice other than near Siberia is over one year old and some is over 10 years old. Thus process of age hardening of ice is more important in the Arctic than in the Antarctic.

4.2 Antarctic and Himalayan Ice

Unlike the snow cover in the Himalayas, the Antarctic snow cover exhibits very small variation of albedo with time. This may be contributed to the constant free water content of pack ice and the absence of debris and soil on the Antarctic ice sheets/ice shelves. At Antarctica, the value of albedo varies in the rocky areas (20 to 40 per cent), in summer it remains generally at 80 per cent and in winter 90 per cent. The mean observed value during 1982 was around 80 per cent. The spraying of coal dust on the Antarctic ice shelf has resulted in a dramatic augmentation of ablation. The extent of melting was observed to be many times more than recorded on the Himalayan ice. In the Himalayan ice there is a profuse development of rills of melt water which washes down a part of spray, but in Antarctica it percolates into the pack ice. In the Antarctic ice shelf, the agent which plays a vital role in the conditioning of the micro-relief of ice surface probably appears to be the high blowing wind.

The density variation of ice pack at Antarctica during the years of studies is found between 0.44 (minimum) to 0.90 g/cc (maximum). The higher density at the top of snow surface occurs due to the formation of wind crust. It may range from 0.05 g/cc for dry snow to 0.834 g/cc for firn snow (ice) in Himalayan region. However, density of freshly fallen snow at both the regions is same. A typical pack ice density stratigraphy has been compared in Table 1 for Antarctic and Himalayan conditions Generally, for Himalayan ice it is observed that density of ice increased with depth in a homogeneous pack of snow due to compressive deformability of lower layers and

Table 1 Density comparison of ice pack

Sl. No.	Depth (from snow surface) (cm)	Density (g/cc)		
		Antarctic snow pack	Himalayan snow pack (firn ice)	New snow pack
	00– 15	0.65	0.38	0.13
2.	15– 30	0.53	0.40	0.19
3	30– 50	0.50	0.41	0.35
4	50– 75	0.47	0.45	0.31
5	75– 90	0.47	0.45	0.31
6.	90–100	0.48	0.52	0.38
7	100–125	0.48	0.65	0.47
8.	125–150	0.48	0.71	0.45

metamorphic processes. The graphical presentation of Himalayan and Antarctic ice density is depicted in Figs. 1 and 2. A thermal profile of a glacier in the central Himalayas is given in Fig. 3. The top surface of Himalayan glacier is more of dirty colour than of Antarctic because of more of debris moraine. The environmental conditions are also responsible for this difference. The surface heat fluxes of some of the Antarctic stations and Himalayan glaciers (Chogo-Iungma glacier, lat. 36°N, long. 75.1°E) has been compared in Table 2. The contrast of Himalayan glaciers due to their temperate nature and low latitudes is quite evident if the heat fluxes quantities

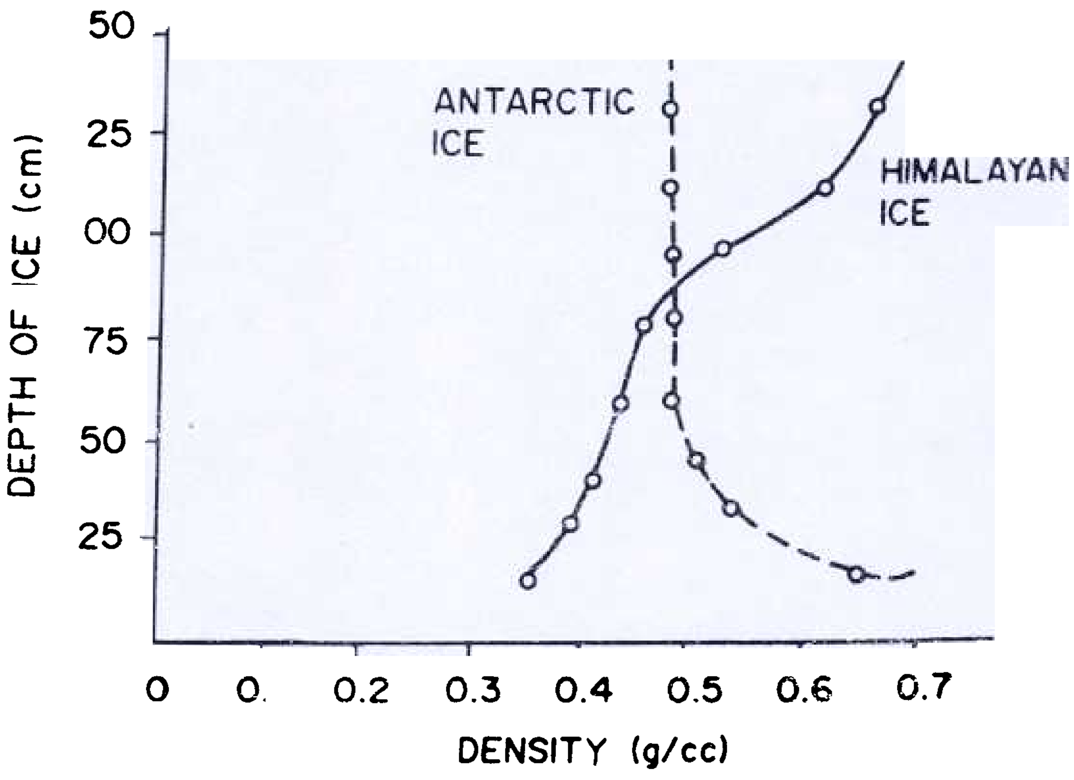

Figure 1 Comparison of densities of Antarctic and Himalayan ice.

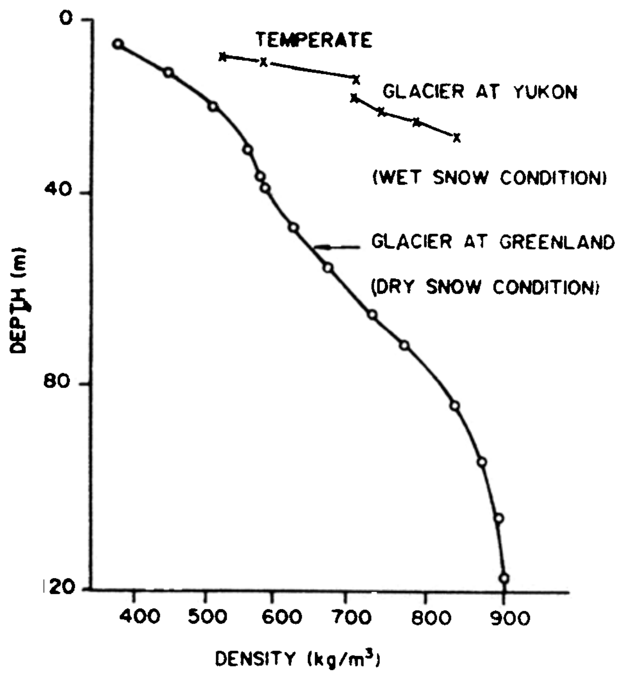

Figure 2. Variation of snow density with depth in a temperate and Greenland glaciers

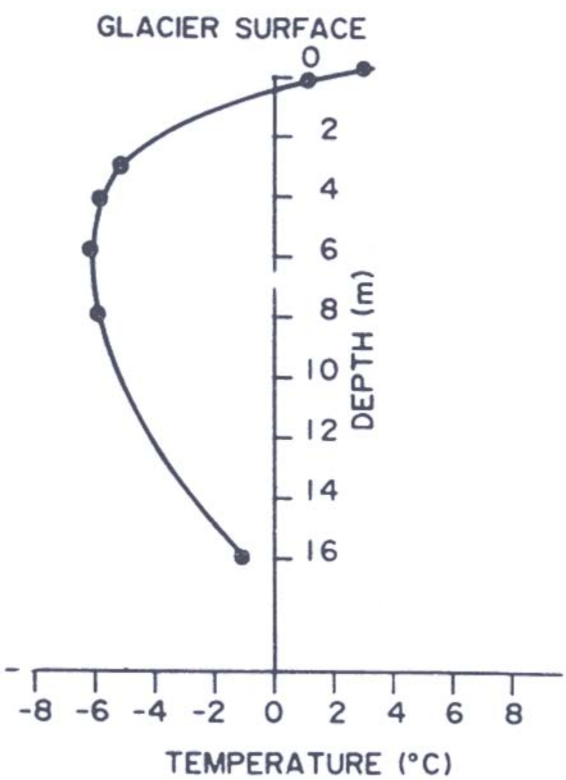

Figure 3. Thermal profile of a Himalayan glacier.

are closely observed. The heat fluxes in Himalayan conditions are much more pronounced than the Antarctic conditions. The quantities have been computed by using Eqn. (1) during the summer months.

Table 2. Surface heat fluxes (units w/m^2)

Station	Elevation (m)	R	H	$-L_vE$	Total (M)
Himalaya					
Station A	4000	279	35	–10	304
Station B	4300	450	23	–8	465
Antarctica					
Vostok	3400	–17	15	0	–2
Byrd	1530	–28	25	1	–2

5. CONCLUSION

Arctic, Antarctic and Himalayan regions exhibit varying characteristics of ice properties which can be primarily attributed due to environmental effects. The fresh water ice and sea water ice differ due to the salinity factors. Though the fundamental process of sea ice formation is the same in Arctic and Antarctic, but the environmental conditions make Antarctic ice significantly weaker and less persistent in the summer months than Arctic ice. A higher density of ice has been observed to be existing at the top surface of snow cover at Antarctic than Himalayan, probably due to wind packing or wind crusting effects. Also, a small range of albedo variation is found in Antarctic ice surface over Himalayan regions. More heat flux has been found to take place in the Himalayan glaciers than Antarctic or Arctic glaciers.

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