

RECONNAISSANCE GLACIO-CHEMICAL STUDIES IN THE INDIAN HIMALAYAS

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ABSTRACT

Analysis of reactive silicate, ammonium, phosphate, iron and sodium from cores taken from three glaciers in the Kashmir portion of the Indian Himalayas are reported as the first in a series of glacio-chemical studies designed to produce proxy paleoclimatic data for this region. This study stresses the elevation dependency of such studies and for the chemical species analyzed which are most reliable for the purpose of the study.

Introduction

Glaciers in the temperate and tropical latitudes have the potential for providing paleo-climatological records unsurpassed by other storage mediums for time periods on the order of 10^0 - 10^3 years. The climatological record that evolves when ice cores are chemically analyzed includes information detailing source area of the precipitation as well as year and season in which it was deposited. Reconnaissance studies addressing the feasibility of using glacio-chemical studies on Himalayan glaciers as proxy indicators of climatic change were undertaken during the summer of 1979 in Kashmir India. Background information pertinent to recent (post AD 1812) glacier fluctuation history in this area and possible climatic links is addressed in Mayewski and Jeschke (1979) and Mayewski et. al. (1980).

Core Locations

Three ice cores were collected during the reconnaissance study (Fig. 1). The first was a 2.90 m deep ice core from the highest part, 4427 m, of a small west-facing cirque. The snow surface at this site contained obvious signs of ablation in the form of large sun cups and surface-sorting of fine debris. The second core site, 4329m, was above the equilibrium line, and on the eastern side of a north-flowing alpine glacier, in the Kunyirahan Glacier system. Core 2 penetrated 4.65 m through a granular snow surface and then into alternating layers of nearly horizontal snow layers ranging in density up to solid firn intruded in places by nearly horizontal ice lenses and fine-textured debris layers. The highest core site, 4695 m, was situated above the equilibrium line of a south-west-flowing alpine glacier in the Khel Khod Glacier system. Core 3 began in granular snow and penetrated 4.50m through a sequence similar to that found at core site 2.

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Methods

All cores were collected using a standard stainless steel SIPRE ice auger. The coring apparatus was cleaned thoroughly in distilled-deionized water prior to coring and wrapped in plastic while not in use. To alleviate contamination by the coring apparatus polyethylene scrapers were used to remove the outer 1-2 cm of each sample. Since the 1979 season we have changed to a Teflon-coated SIPRE auger and expect in future seasons to change to all plastic coring devices. All samples were handled with plastic gloves, sectioned in the field and placed in precleaned, acid-washed and several times rinsed with distilled-deionized water, plastic bags. Once in the securely sealed bags the samples were allowed to melt. Immediately upon melting the water was transferred to HCL cleaned 125 ml LPE bottles. Modified sample collections and handling techniques have been employed in our more recent studies to further reduce contamination, but within the scope of the reconnaissance study the 1979 techniques are believed to be suitable.

Upon return to our laboratory the melted samples to be analyzed for iron and reactive silicate were acidified with ultra-pure HNO_3 and allowed to set for at least 10 days. Reactive silicate, ammonium and phosphate were analyzed colorimetrically utilizing auto-analyzer techniques (Gilbert and Loder, 1977). Iron was determined manually using the method of Stookey (1970). Sodium analyses were conducted using atomic absorption spectrophotometry. The analytical precision of the reactive silicate, ammonium, phosphate, iron and sodium at the concentrations observed in these samples and reported as a coefficient of variation are $\pm 8\%$, $\pm 5\%$, $\pm 2\%$, $\pm 8\%$ and $\pm 4\%$ respectively.

Results and Discussion

Examination of the reactive silicate, ammonium, phosphate, iron and sodium values and their distribution in the three cores (Fig. 2) reveals that core site elevation closely controls the paleoclimatological usefulness of the samples. Core 1 collected in an obviously ablation affected area and core 2 collected at an even lower elevation both display relatively 'washed-out' profiles compared with core 3. Cores 1 and 2 probably suffer from the redistribution of chemical species down core through leaching. Core 1 displays almost total leaching as evidenced by the relatively low concentrations of reactive silicate ($<2\mu\text{M}$), phosphate ($<0.1\mu\text{M}$), iron ($<2\mu\text{M}$) and sodium ($<30\mu\text{M}$; majority $10\mu\text{M}$). High ammonium values (range $18-67\mu\text{M}$) in core 1 suggest contamination in this core with respect to ammonium. Core 2 displays the general decay in concentration with depth for all chemical species analyzed noted by Ricq-de Bouard (1977) in his study of soluble ions from samples collected on Glacier Mont de Lans. Core 3 contains neither relatively low concentrations nor a decay in concentration with depth except perhaps in the case of sodium below 150 cm depth, because sodium is one of the most soluble of the chemical species analyzed. From the latter we conclude that core 3 may well contain a relatively undisturbed record of precipitation.

Matching peak alignments exist in the profiles of core 3 samples for all chemical species analyzed except phosphate. Peaks for reactive silicate, iron, ammonium and sodium are approximately 5,4,5 and 3 times respectively, the baseline values of these chemical species. Phosphate peaks are approximately 2 times the baseline value of phosphate.

Four surface samples collected at 3 m increments away from core site 3 were used as a check on the lateral variability of the down-core samples. Expressed as a standard deviation of the four surface samples (Fig. 2) phosphate and ammonium are seen to be unreliable as down-core indicators. Reactive silicate, iron and sodium have lateral variabilities, considerably lower than their peaks values.

Chemical analysis of the cores collected during the 1979 reconnaissance season suggest that the relatively insoluble chemical species such as reactive silicate and iron collected from elevations at or above 4696 m in this area may be used as time stratigraphic markers. In addition the Khel Khod Glacier core chemistry reveals the probable source area and time of deposition of the precipitate entering the region and the net mass balance at the core site. The peak concentrations of reactive silicate and iron as well as those of sodium, although the latter is potentially leachable, are probably brought into the area during the summer season. During the summer reactive silicate and iron influxes increase due to an increase in snow-free terrain while sodium increases due to the increased influence of

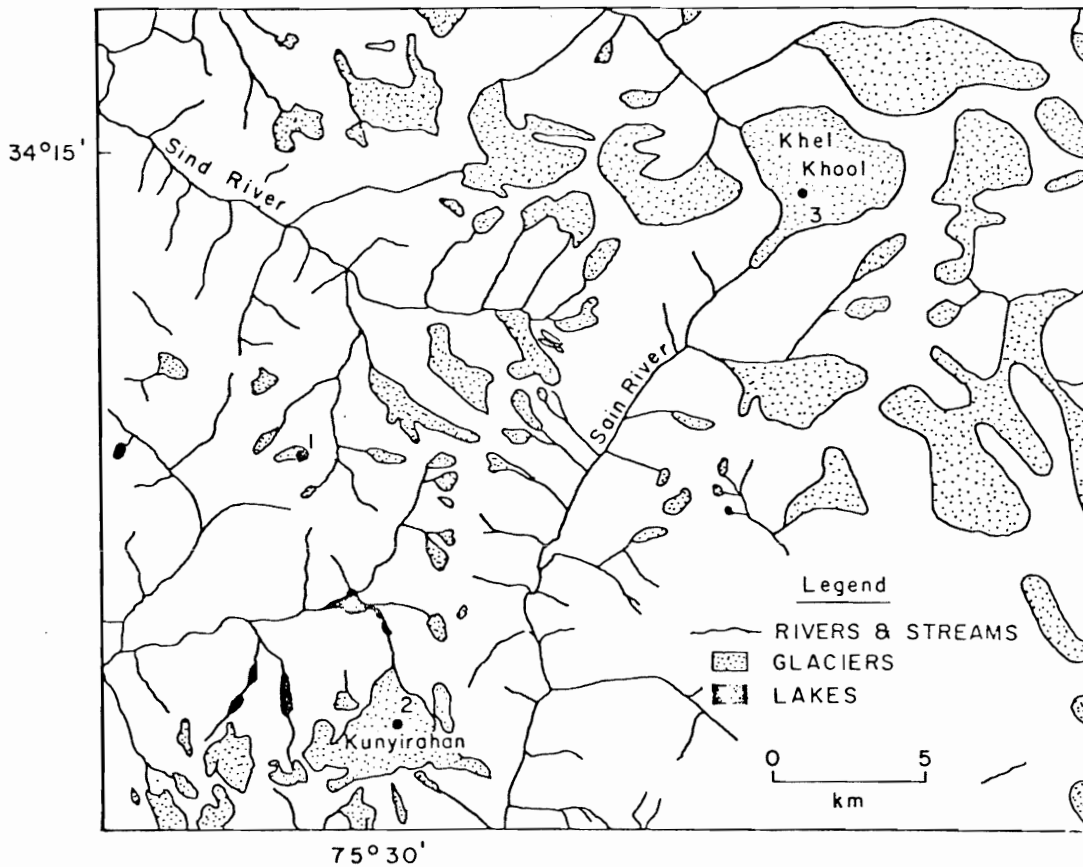


Figure 1. Location map

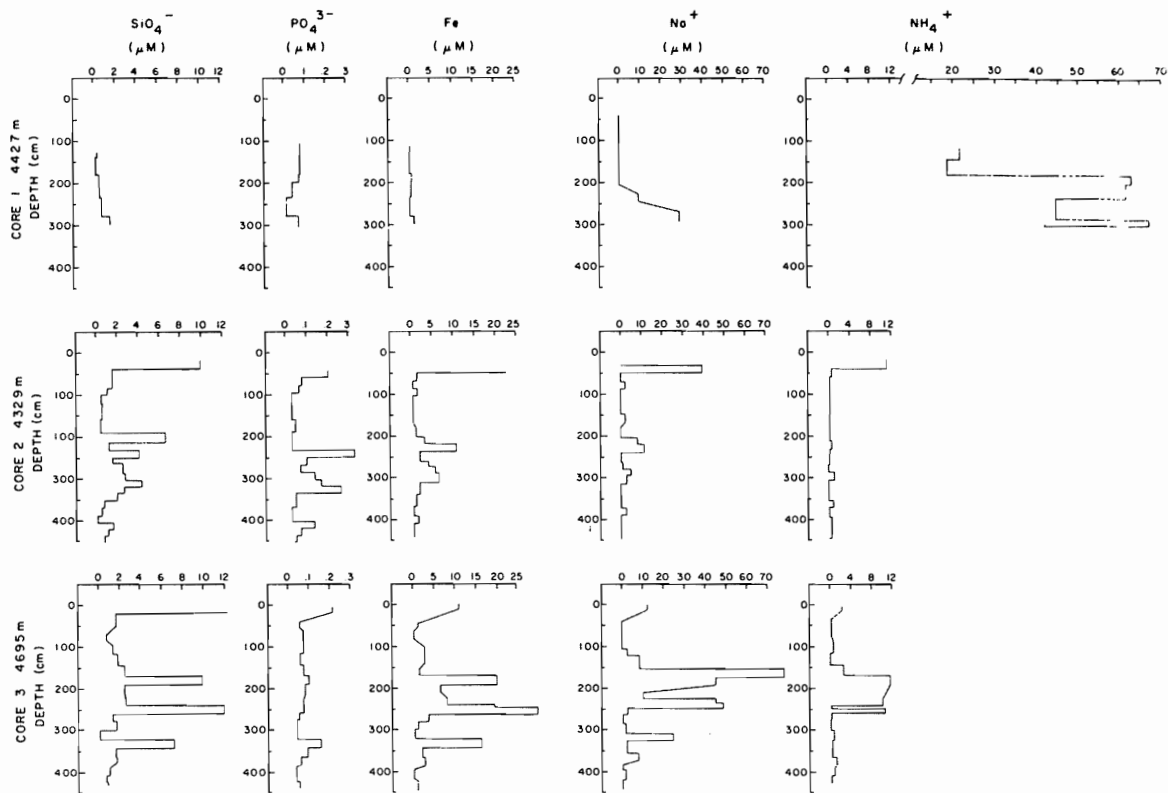


Figure 2. Chemical species distribution with depth for the 3 cores.

Bar lengths on bottom of figure are standard deviations based on four surface samples

the marine-based summer nonsoonal precipitation. Final validation of the source for the sodium contained in core 3 requires companion chloride data which are unfortunately unavailable from this core, but will be available for future cores from the region. If the peaks discussed are summer peaks then the total core age is 3 to 4 years, depending upon the species used, 4 years using reactive silicate and iron. Using the reactive silicate, iron and sodium peaks the net annual balance for the 1979 balance year is + .78 m H₂O equivalent, the 1978 balance year + .29 m H₂O equivalent and the 1977 balance + .38 m H₂O equivalent, assuming an average core density of .45 gm · cm⁻³. In addition at this site net winter mass balance appears to be roughly 2 to 3 times net summer mass balance. The only mass balance study comparable in the region was undertaken in 1974-1975 on Gara Glacier (Rania and others, 1977) some 450 km southeast of the Khel Khod Glacier system. Winter precipitation was also found to be the dominant component in the resultant positive net balance of that glacier.

In conclusion we feel that the glacio-chemical plot study discussed demonstrates great promise as a proxy tool for determining source area and time of deposition of precipitate entering high elevation portions of Himalayan glaciers. Future studies will emphasize the time-series capability of this type of investigation and should result in the production of paleoclimatic records for the Himalayas.

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