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Glaciochemical Studies at Siple Dome, West Antarctica, during the 1996–1997 Season

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Deep ice cores collected from the interior of the west antarctic ice sheet and the interice stream ridges along the Siple Coast potentially contain long time-series records of Southern Hemisphere environmental change. One such location is Siple Dome, an approximately 120-kilometer (km) × 250-km ice dome located between ice streams C and D (figure 1). Because of promising results from reconnaissance glaciochemical (Mayewski, Twickler, and Whitlow 1995) and geophysical (Raymond et al. 1995) research, current U.S. deep ice-coring efforts are focused in the area. Drilling at Siple Dome is advantageous for several reasons, including the site's relatively simple geometry and internal layering (Raymond et al. 1995) and its sensitivity to changes in South Pacific lower atmospheric circulation (Kreutz and Mayewski in press). Changes in the strength of these circulation conditions over the last millennium have been documented using glaciochemical measurements from a 150-meter (m) ice core collected at Siple Dome in 1994 (Kreutz et al. 1997). As part of the U.S. WAISCORES program, the approximately 1,000-m ice core recovered from Siple Dome will extend such well-dated, multiparameter, high-resolution environmental reconstructions back about 100,000 years and be used to investigate several issues, including

- local and regional climatic change through comparison with deep ice cores recovered from the west and east antarctic plateaus,
- the global timing and extent of rapid climate changes based on comparison with Greenland ice cores, and
- past west antarctic ice sheet ice dynamics and their impact on global sea level.

In preparation for the recovery, analysis, and interpretation of the Siple Dome deep core, a thorough understanding of the modern glaciochemical spatial variability in the area is essential. Spatial studies were begun during the 1994–1995 season, when five snowpits were collected on a 10-km × 10-km surveyed grid centered on the Siple Dome summit (Mayewski et al. 1995). Sampling during the 1996–1997 season expanded the glaciochemical spatial investigation completed in 1994–1995 and, in addition, collected clean surface snow and firn samples from the deep-core site. In addition to snowpits covering approximately 4–10 years of deposition, shallow (approximately 100-m) ice cores collected on the same spatial grid will allow investigation of modern and longer term changes in the spatial patterns of chemical deposition, source regions, moisture flux, and the relationship between glaciochemical and other measurements (e.g., stable isotopes and physical stratigraphy).

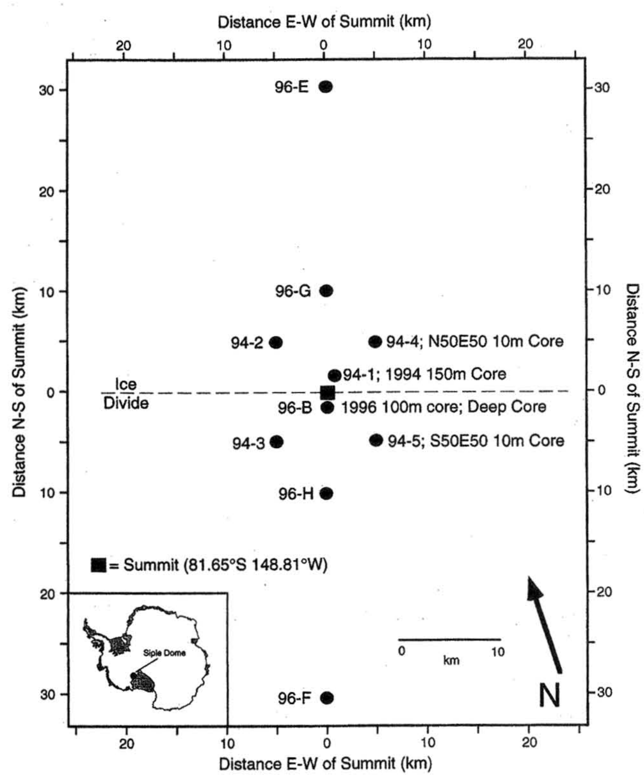

Figure 1. Location map for Siple Dome. Snowpits and cores collected during the 1994–1995 and 1996–1997 seasons are shown.

During the 1996–1997 season, four 2-m snowpits were sampled on a transect from 30 km north to 30 km south of the ice divide (figure 1). In addition, a 4-m snowpit and a 100-m, 10.16-centimeter-diameter ice core were collected approximately 0.5 km south of the summit, at the deep-core site (figure 1). All snowpit and core sample collection was performed by workers using nonparticulating suits, polyethylene gloves, and particle masks to avoid chemical contamination. Snowpits were sampled in conjunction with other investigators (C. Shuman, J. McConnell) so that all measurements are co-registered. The 100-m core is being sampled at high resolution (subannual sampling in the upper 15 m; biannual sampling in the bottom 85 m) to provide accurate firn measurements that overlap the deep core. Concentrations of major anions, cations [sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), ammonium (NH_4^+), chloride (Cl^-), nitrate (NO_3^-), and sulfate ($SO_4^{2=}$)], and methanesulfonic acid (MSA; measured in core samples by the University of Miami) are measured via ion chromatography at the University of New Hampshire.

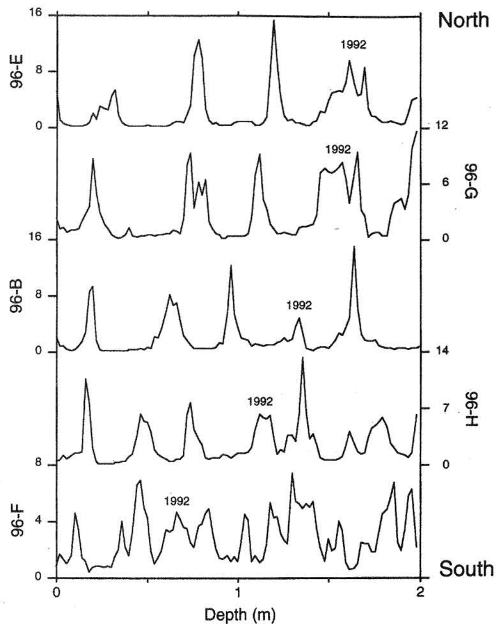

Figure 2. Measurements of $xsSO_4^=$ (in microequivalents per liter) in 1996–1997 Siple Dome snowpits. 96-B through 96-G refer to pit locations on figure 1.

An example of the well-preserved glaciochemical signals present in the Siple Dome snowpack is given in figure 2. Concentrations of both excess (xs) $SO_4^=$ and MSA (both byproducts of the oxidation of phytoplankton-produced dimethylsulfide) peak in the summer in the antarctic atmosphere (Wagenbach 1996). Therefore, $xsSO_4^=$ maxima in the Siple Dome snowpack likely record peaks in summer biogenic activity. Such annual glaciochemical peaks can be used to assign dates to strata in snowpits (figure 2) and ice cores. Cores collected from Siple Dome thus far have been dated using a combination of high-resolution discrete chemical sampling, continuous measurements of Cl^-, NO_3^-, and liquid conductivity, and physical properties (Kreutz et al. 1997). This technique will be used in conjunction with other measurements (e.g., electrical conductivity, dielectric properties, and stable isotopes) to date the Siple Dome deep core.

Based on the dating technique outlined above, a gradient in the number of years contained in each snowpit along the 30-km north/30-km south transect over Siple Dome is apparent (figure 2). This gradient in years, likewise, suggests a gradient in accumulation rate (b) whose dominant moisture source is from the north. Average chemical concentration values for 1994–1995 and 1996–1997 pits are similar (Kreutz et al. in preparation); however, flux (concentration*b) calculations also show a distinct gradient in all species going from north to south across the dome (figure 3). It appears that the major source of marine [seasalt (ss) Na^+, MSA, and $xsSO_4^=$] species, like moisture, is from the north. This finding is consistent with previous work (Kreutz and Mayewski in press; Kreutz et al. 1997) and suggests the source of marine chemical species at Siple Dome is the Amundsen/Ross Sea region, with advection of lower tropospheric marine air across the Ross Ice Shelf to Siple Dome. Statistical investi-

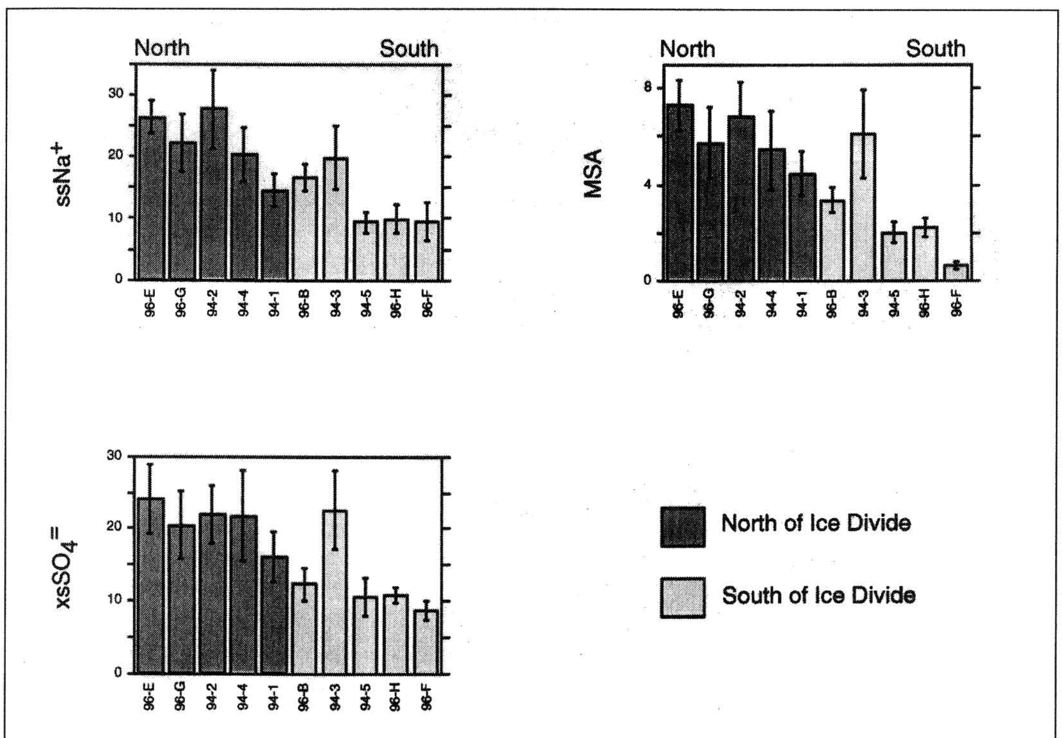

Figure 3. Mean annual chemical flux (in kilograms per square kilometer per year) in 1994–1995 and 1996–1997 Siple Dome snowpits (error bars represent standard error). The order of snowpits on the figure is along the transect from 30 km north (96-E) to 30 km south (96-F) of the ice divide. The method used to separate seasalt (ss) from nonseasalt [or excess (xs)] chemical fractions is given in Kreutz et al. (1997).

gation of glaciochemical variability on a range of spatial and temporal scales is currently being investigated (Kreutz et al. in preparation).

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Characterization of wind-generated snow surface features on the Ross Ice Shelf, Antarctica

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A snow surface with mobile snow grains is essentially a sediment bed that is influenced by a turbulent air flow. The formation and evolution of snow surface features (e.g., ripples) caused by wind-driven snow grains have been previously examined and classified by Kobayashi and Ishida (1979). The impact of snow grains on the surface by saltation results in the formation of ripples (Kosugi, Nishimura, and Maeno 1992) as well as the liberation of small snow grains, which may be transported by suspension (Anderson and Hallet 1986). The dynamic processes of surface-feature formation display self similarity but are essentially nonlinear and chaotic processes (Tufillaro, Abbott, and Reilly 1992) in which the redistribution of snow grains forming snow-surface features distorts the turbulent flow, which in turn distorts the features.

Although cold-temperature wind-tunnel studies suggest that eolian snow ripples are comparable to corresponding ripples formed in other sediments such as sand (Kosugi et al. 1992), there are some differences in the observed morphology. An important difference between snow grains and sand grains is that snow grains are subject to interparticle cohesive forces and to sublimation during transport unlike sand grains (Schmidt 1986; Pomeroy and Gray 1990). Snow surface features are also hypothesized to play a role in near-surface ice-sheet ventilation processes known as wind pumping (Waddington, Cunningham, and Harder 1996) by the production of high-frequency, micropressure fluctuations caused by the turbulent air passing over the surface features.

A detailed characterization of snow surface features on the Ross Ice Shelf was carried out during the 1996–1997 field season to characterize the morphology of naturally occurring snow ripples, a morphology that could be compared to ripple features in other sediments and would provide a data set against which numerical snow-surface feature simulation models could be validated. Snow-surface features were characterized using a new technique that involved capturing ripple cross-section shapes in digital images in the field for later analysis.

Snow-surface feature measurements were made adjacent to the Willie Field automatic weather station (AWS) (77.85°S 167.08°E) between 3 and 5 December 1996. The field team members responsible for these measurements were J. Stewart and C. Bennett. The features were characterized soon after a precipitation period that was associated with high wind speeds. The snow surface features observed were primarily transverse features (aligned perpendicular to the prevailing winds) such as snow ripples that were produced by winds 24 to 48 hours prior to the field measurements in the range of 8 and 14 meters per second. The basic sampling technique used in this investigation was initially devised by Werner et al. (1986) to characterize sand ripples.

This technique requires an apparatus (figure) consisting of a metal straight edge (on which is mounted a bubble level), a ruler, and a short post on the end of the apparatus. The straight edge is suspended above the snow surface by two