POTENTIAL FOR A TIME-SEQUENCED 100,000-YEAR RECORD OF MICROMETEORITES AT SOUTH POLE.

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Introduction: A neutrino observatory planned for South Pole offers an opportunity to collect a time-sequenced 100,000-yr record of micrometeorites and terrestrial dust deposited in Antarctic ice with 20–100-yr resolution. This unprecedented record bears on numerous studies including the evolution of near-Earth cosmic-dust and the provenance of micrometeorites, the relationship between ET influx and global climate change, and the provenance of biogenic materials in Antarctic ice. We describe here a proposed collection system and selected science plans for the project.

Collection System

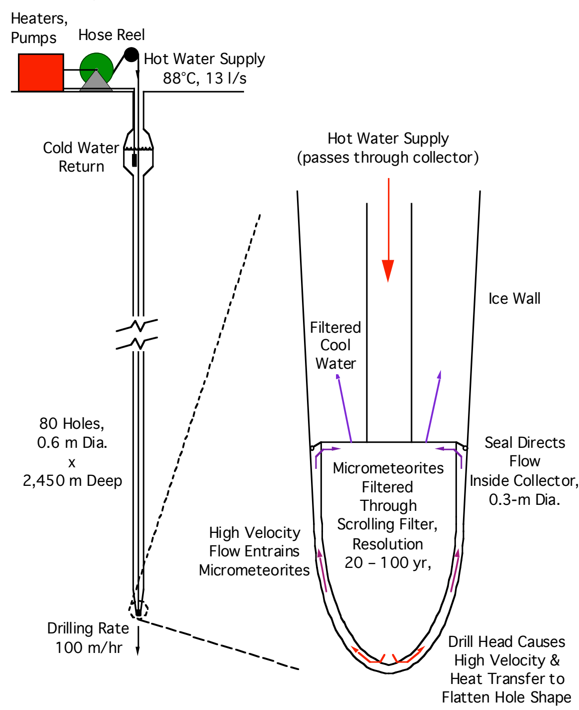
Context - IceCube is a planned $200M astrophysics project consisting of strings of downward-looking photo-multipliers, frozen into the ice at South Pole, to observe the passage of high-energy neutrinos (www.ssec.wisc.edu/a3ri/). The University of Wisconsin has been awarded $15M to build an Enhanced Hot-Water Drill (EHWD) to install the strings. A heating plant will deliver hot water through a continuous hose to a nozzle in the drill head to melt ice ahead of the drill. Cool water will return up the melted hole to a pump near the surface and thence to the heating plant for re-injection (Fig. 1). Each of the 80 holes drilled will measure 2,450-m-deep x 0.6-m-diameter and will terminate in ice that is ~ 100,000 years old [1].

Preliminary Collector Design - A major requirement is compatibility with routine drilling operations, allowing particle-collection from all 80 drill holes. The collector must operate at the drill's 100-m/hr descent rate, preserve vertical alignment, and permit hole-changeover times of 2.5 days. Other requirements include high collection efficiency (>90%), fine time resolution, minimum contamination, and efficient post-collection particle handling.

Essentially, the collector will replace the EHWD drill head. Its main features are a shaped body to flatten the hole bottom (to improve time resolution) and an internal scrolling filter (to extract and sequence the particles). Hot water will flow through the 2-m-long collector body and discharge horizontally. The body will confine flow and entrained particles to a 1-cm annulus adjacent to the ice wall for high heat-transfer rates. A seal at the top of the collector body (0.3-m-dia.) will direct flow inside (minimum flow velocity 1.4 m/s or ~ 3 times the fall velocity of a 2,000-µm iron spherule). The flow will manifold into single pipe that spirals downward. A 30-m-long x 150-mm-dia. tube filter will be bunched up over this pipe. As the collector descends, spiked wheels engaged against ice walls will rotate a spool that pulls the filter, at a rate of 25 mm per 2 m of drill descent, through a sleeve and over the discharge end of the pipe. A second sleeve will limit the open length of the filter to 25 mm and flatten the filter as it winds onto the spool. Entrained particles will deposit on the inside of the tube filter, with each 25-mm of filter length preserving a 2-m depositional interval. The flow will then exit the collector above the seal and continue its ascent. After the drill completes a hole, we will open the collector body, retrieve the spooled filter and install a new one.

Heat-transfer analyses indicate that a shaped collector body can achieve a 0.3-m hole diameter within 2 m of the drill tip (versus > 8 m for the EHWD drill head) at 100 m/hr drilling rate. This 2-m interval represents uncertainty in particle depositional ages of 20 yr near the surface and 100 yr near the bottom of the hole [1]. We measured pressure losses for 1-µm to 53-µm membrane filters and conducted tests to confirm that a scrolling tube filter will preserve the time sequence of entrained particles. Pressure loss through a 1-µm tube filter will be less than the losses developed by the EHWD components that the collector replaces.

Figure 1. Schematic of drill and collection system



Selected Science Plans

Collection Characterization - The entire 80-hole, 100,000-yr collection will have ~ 800 micrometeorites > 50 µm per 100-yr interval [2] and several times this many smaller particles. Using optical and scanning-electron microscopes, S. Taylor will characterize the collection by determining the flux, size distribution and particle types in 100- to 500-yr increments. This will provide contextual linkage to other micrometeorite collections [2,3]. E. Jessberger (U. of Muenster) will use an automated Laser Plasma Spectrometer coupled to an automated optical microscope to spot and chemically characterize particles directly on the filters. This technique does not require any sample preparation and thus is capable of chemically characterizing the surfaces of millions of particles. Unique particles such as those from periodic comets, the Moon and Mars should stand out.

Provenance of micrometeorites - Interplanetary dynamics affects the types of micrometeoroids reaching earth. It is likely that < 10-µm and > 50-µm micrometeorites might sample different parent-body reservoirs. D. Brownlee (U. of Washington) will test this possibility by comparing elemental composition, mineralogy and oxygen-isotope composition of IceCube micrometeorites with interplanetary dust particles (IDPs) collected in the stratosphere. Ramifications include the role of asteroids and comets as sources of dust, water and carbon reaching Earth and the role of transient events, such as large comet apparitions or asteroid disruptions, in changing the flux.

Space exposure times of micrometeorites rest on relatively few cosmogenic-radionuclide measurements [4]. Modeling calculations [5] suggest much shorter transit times for most particles. G. Herzog (Rutgers U.) will measure the cosmic-ray exposure histories of IceCube micrometeorites. The samples will provide particles covering a long time span relative to the particle exposure ages – perhaps one long enough to discern changes in the exposure histories that might accompany, for example, the dissipation of one source of particles and the rise of another. These radionuclide measurement will also independently date the samples.

ET influx and global climate change - The existence of large temporal variations in the flux of extraterrestrial (ET) matter is a controversial topic of importance to climate change [6,7,8]. By combining He and Os isotopic measurements in IDPs recovered from the IceCube samples B. Peucker-Ehrenbrink and M. Kurz (Woods Hole Oceanographic Institute) will evaluate temporal variability in ET flux to the earth. ^{3}He is a sensitive tracer for ET particles smaller than ~ 20 µm [9] as well as dust-poor cometary matter. In contrast, refractory Os is not lost during atmospheric entry [10,11] and is thus sensitive for the entire size spectrum of ET matter (except dust-poor cometary matter). The temporal resolution of 20-100 years surpasses that of marine sediment cores by 2 orders of magnitude. This will bring closure to the debate about variations in the delivery of ET He on glacial-interglacial time scales.

S. Kortenkamp (U. of Maryland) will use He measurements to resolve a discrepancy between the sea floor data and the predicted ^{3}He input. The variations in the sea floor ^{3}He are 180 degrees out of phase with those predicted by an IDP accretion model [5]. If climate influences the retention of ^{3}He in IDPs then not only should the 100,000-yr periodicity appear in the ^{3}He record but the 40,000-yr and 21,000-yr periodicities associated with climate change should also be present. The IceCube temporal resolution will reveal the two shorter periodicities if they are present.

Provenance of biogenic materials – D. Kellogg (U. of Maine) will use the IceCube samples to document changes in assemblages of marine and non-marine diatoms. Diatoms in ice cores from inland locations in Antarctica are proxies for the paleo-air masses that transported them to these sites. However, low concentration of diatoms in ice cores has made it impossible to relate rapid changes in diatom abundance and species content to the decadal changes in atmospheric circulation patterns seen by electro-conductivity in some cores. The IceCube samples would have a diatom time resolution ~ 100 times finer than ice cores and would allow correlation of diatom and atmospheric signals.

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