Characteristics of till transported by the Byrd and Nimrod Glaciers, Antarctica

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Summary Particle size distributions were measured from till samples collected at seventeen moraines along the Byrd and Nimrod Glaciers. All sites are dominated by sand- and gravel-sized material with distinct spatial patterns in the silt and clay content. Till from the north side of Byrd Glacier and tills along the trunk of Nimrod glacier have variable modes in the sand fraction and <5% clay. The tills are primarily derived from locally eroded bedrock. Moraines at the base of nunataks found at the head of both glaciers contain 15% -70% fines (silt plus clay) and are interpreted to represent the presence of subglacially-derived sediment.

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Introduction

Glaciers are powerful agents of erosion and deposition and their deposits provide important information about past climate changes. Glacial deposits are abundant on the continental margins around Antarctica and their characteristics are used to infer information about ice sheet behavior and flow characteristics (Anderson, 1999). Glacial till on the western and central Ross Sea continental shelf, which has been studied in detail (e.g., Licht et al., 1999, 2005; Farmer et al., 2006), is delivered by East Antarctic outlet glaciers of the central Transantarctic Mountains (TAM). Sediment generated by erosion of the TAMs likely combines with subglacial material eroded from rocks buried by the East Antarctic ice sheet further upstream. The goal of this study was to characterize the particle size of till in moraines at the head and along the sides of the Byrd and Nimrod Glaciers to assess changes during transport and delivery to the continental shelf.

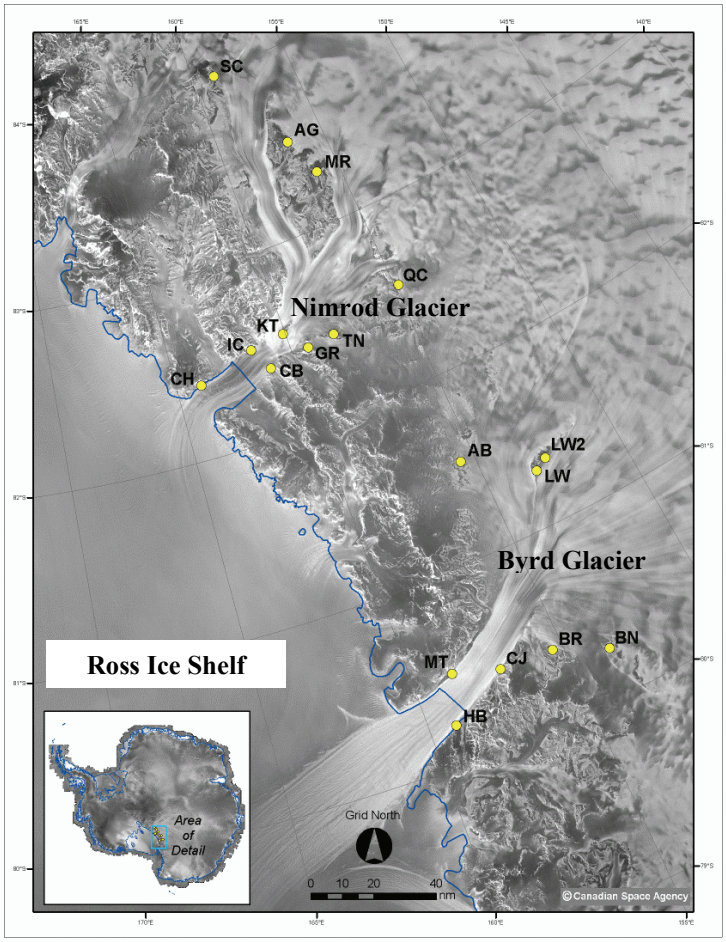

Figure 1. Radarsat image showing sampling locations along the Byrd and Nimrod Glaciers emanating from the East Antarctic ice sheet and draining into the Ross Ice Shelf.

Methods

Replicate samples were collected from seventeen moraines at the head and along the length of the Byrd and Nimrod Glaciers, which drain from the East Antarctic ice sheet, cut across the TAM and discharge into the Ross Ice Shelf (Figure 1). Approximately 2 g of material was separated from the bulk till samples for particle size analysis. Samples were sieved to obtain the <2000 µm fraction, and treated with 35% H_2O_2 to remove organic material, and stored in sodium metaphosphate. Each sample was analyzed 3 – 5 times on a Malvern Mastersizer 2000 laser particle size analyzer and the average particle size value for samples is discussed.

Preliminary results

Till from moraines at all sites is dominated by sand and gravel, which usually makes up >60 percent of the sampled material, with values ranging from 30% to >97% of the total. At lateral moraines along the trunks of both glaciers, the clay size fraction typically comprises <5% of the total, whereas the most upstream sites

contain a relatively higher proportion of clay. Two outliers in clay content are the Mt. Tuatara (MT) site, which is flanked by carbonate bedrock, and the Lonewolf (LW and LW2) sites, which averages just over 30% clay. Silt is always more abundant than clay, except in regions of carbonate bedrock.

Byrd Glacier

Particle size distributions from Byrd Glacier vary substantially between the northern and southern sides of the glacier. Considering only the fraction <2000 µm, all samples from the northern margin, including the one from Bates Nunatak (BN) are dominated by sand-sized material (Figure 2). The bedrock is composed of Ferrar and Granite Harbor Intrusive igneous rocks and some sandstones of the Beacon Group. On the southern side, where limestone outcrops dominate, the till is >50% silt plus clay. The till from Lonewolf Nunatak, where the bedrock is mapped as Ferrar dolerite and Beacon Group rocks, shows a much different distribution with 50 - 75% silt plus clay (Figure 2). A small, but distinct peak at ~2.5 µm is common to all LW samples.

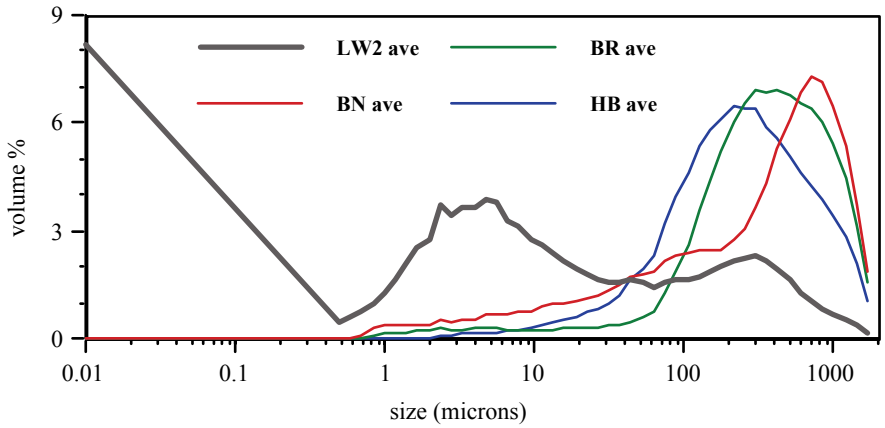

Figure 2. Particle size distributions of Byrd Glacier tills. LW2 shows a dominance of silt and clay with a minor mode at 300 µm. BN, BR, and HB form a progression down the northern margin of Byrd Glacier and show a progressively finer peak in the sand fraction.

Nimrod Glacier

Till from Nimrod Glacier moraines have more variability in the <2000 µm fraction than samples from Byrd Glacier, but show consistent differences in samples collected at the head and along the main trunk of the glacier. Samples collected from nunataks SC, MR, TN and KT all contain at least 15% silt plus clay and lack a common mode in the sand fraction. All samples from these four sites also contain the small peak at 2.5 µm, similar to LW. Aamples along the trunk of the Nimrod Glacier lack this peak. Assessing changes is particle size down the Nimrod is complicated by spatial variability in the bedrock and requires further analysis.

A comparison of two Nimrod Glacier moraine sites, both adjacent to exposed Beardmore Group rocks, do not have similar particle size distributions. The KonTiki Nunatak (KT) site, which outcrops in the midstream of Nimrod Glacier and forms a medial moraine, is significantly finer-grained than its lateral moraine counterpart (GR). A simple proportional model of size distributions from three surrounding upstream sites (Figure 3) shows that the KonTiki till appears to be a mixture of sediment eroded from the Geologists Range metamorphic rocks, Beacon Supergroup volcanic and sedimentary rocks (25-90km upstream), plus a locally-derived component from Beardmore Group rocks. This three-component mixture accounts for the details observed in the KonTiki particle size distribution but slightly overestimates the coarse sand fraction.

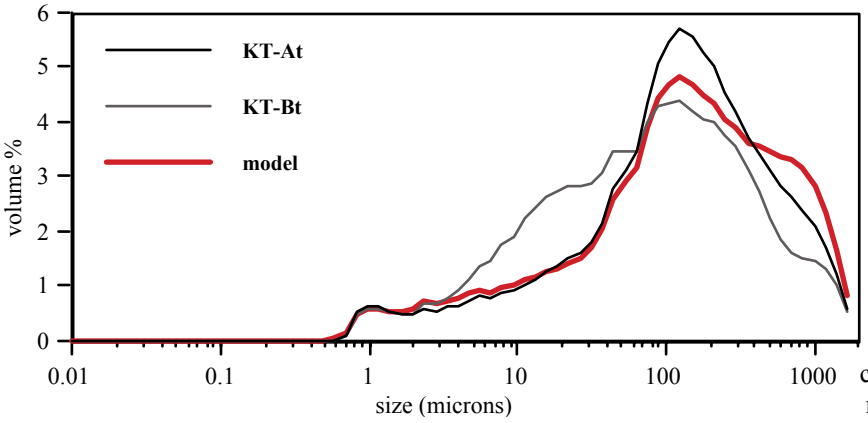

Figure 3. Particle size distributions of two KonTiki till samples and distribution created by 3-component mixing model.

Discussion

The presence of abundant fine sediment in upstream and midstream Byrd and Nimrod Glacier till is interpreted to

represent a subglacial component, whereas lateral moraines lack fines and are dominated by locally eroded bedrock. This observation is supported by preliminary analysis of the sand composition (Palmer and Licht, this volume), which is dominated by local bedrock outcrops in lateral moraines from the trunks of both glaciers, whereas upstream sites contain a component of non-locally derived material. Previous studies have shown that the particle size distribution of till changes during transport (e.g., Dreimanis and Vagners, 1971). However, Tulaczyk et al. (1998) observed little evidence of comminution in Antarctic sub-ice stream till. In comparison with lateral moraines from East Antarctic outlet glaciers, subglacial till collected from beneath West Antarctic streams show very different proportions of sand, silt and clay (Figure 4). The similarity in sand, silt and clay proportions between material being transported subglacially in West Antarctica and that collected from nunataks at the head of East Antarctic outlets, particularly the Lonewolf samples (Figure 4), lend support to the interpretation that at least part of this material is subglacially derived. Understanding glacial transport is essential to interpreting Ross Sea provenance data used to provide constraints on past Antarctic ice sheet flow paths. Particle size distributions in sub-ice stream tills are comparable to those measured in Ross Sea tills, with distinct modes at 0.2 μm, 8 μm and 40 μm, as well as a broad peak in sands at 400-700 μm (Licht et

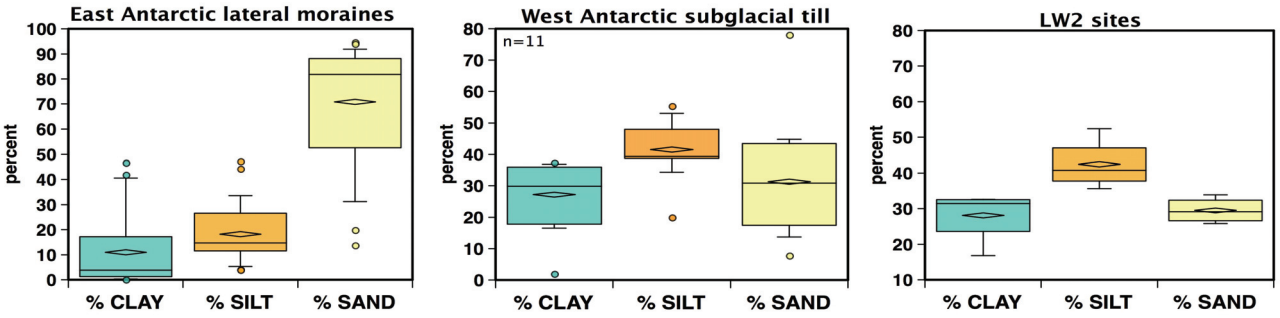

Figure 4. Sand, silt and clay content of till from (A) East Antarctic lateral moraines along the Byrd and Nimrod Glaciers, (B) West Antarctic sediment collected beneath the Whillans, Kamb and Bindschadler ice streams, and (C) moraines at modern ice level at Lonewolf Nunataks (head of Byrd Glacier).

al., 2005). These data suggest that material incorporated into the outlet glaciers via lateral moraines during transport through the TAM comprises only a part of the debris load of the ice and that the subglacial till deposited in the Ross Sea from outlet glaciers contains substantial basal debris derived from the East Antarctic craton that is mixed with material eroded as glaciers cross the TAM. Samples from an additional 21 moraines southward to the Reedy Glacier were collected in 2007 and will be used to further constrain models of till evolution during transport.

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