# Morphology and surface textures of quartz grains from freshwater lakes of McLeod Island, Larsemann Hills, East Antarctica

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**The Larsemann Hills area in the eastern Antarctica constitutes a few of the small islands apart from the mainland. Many freshwater lakes are identified in the main land of the Larsemann Hills and in the McLeod Island. We have collected sediment samples from the exposed freshwater lakebeds during the special expedition of February–April 2006. In this article, we discuss the micro-textures of quartz grains studied under scanning electron microscope. We have recorded angular, sub-rounded and rounded grains, and varied surface textural features showing flow patterns, fractured/crushed features, etc. We have also analysed grains to understand the possible elemental composition of the grains with the help of energy dispersive spectrometer.**

**Keywords:** Antarctic lakes, erosion, quartz grains, surface texture.

## Introduction

THE Larsemann Hills (69°23′S, 76°53′E), in the Prydz Bay, is an ice-free oasis on the Ingrid Christensen Coast, Princess Elizabeth Land, located approximately midway between the eastern extremity of the Amery Ice Shelf and the southern boundary of the Vestfold Hills[1] (Figure 1 *a*). It is the second largest (area of 50 $km^2$) of only four major ice-free oases found along East Antarctica's 5000 km coastline. The region includes two main peninsulas, the western named Stornes and the eastern named Broknes, together with a number of scattered offshore islands (Figure 1 *b*). It has been suggested that the Larsemann Hills was not heavily glaciated at the LGM[2].

More than 150 freshwater lakes are found in the Larsemann Hills[3], ranging from small ephemeral ponds to large water bodies. Some of these water bodies are ice free for brief periods or partially ice free in the summer months when their water temperatures increase rapidly, reaching +8°C in some of the shallower ones. For the remainder of the year (8–10 months), they are covered with ca 2 m of ice. Some lakes have evidence of past shorelines up to 2 m above the present water levels. They do not exhibit highly elevated salinities in the Vestfold Hills[4] and Rauer Islands[5]. We have identified four freshwater lakes (Figure 2) and two saline lakes, which have a connection to the sea at one end in McLeod Island. The lakes of McLeod Island also exhibit past elevated shorelines up to about 2 m above the present water level.

Large amount of sediments, ranging from boulders to glacially abraded particles, occur during glacial retreat. In eastern Antarctica, during astral summer, the proglacial milieu is characterized by numerous melt-water streams that carry sediments derived from the ice mass itself[6]. The streams redistribute earlier deposited glacial debris. The sediments get deposited in the lakes and such lacustrine deposits are commonly called glaciolacustrine or glaciolimnic sediments[7]. These sediments preserve a rich repository of information regarding the provenance and environmental conditions. The grain morphology and micro-textural features imprinted on the detrital quartz grains have been used as an important tool in understanding the transportation and depositional history of sediments.

## Material and methods

In this article, we present the shape and surface textures of quartz grains with an attempt to understand the sedimentary processes – transport and deposition – in glacial environments. For this purpose, we have collected sediment samples along the exposed shorelines of two freshwater lakes in McLeod Island by penetrating a pvc pipe. The samples were prepared for analysis following standard methods[8]. Twelve grains were selected and photographed under stereozoom binocular microscope connected to a CCD camera. Further, each grain was mounted on a brass stub and coated with platinum (100 Å) in a sputter coater and were scanned using JEOL 6360 LV under secondary electron image and the same was used for energy dispersive spectrometer (EDS) analysis (OXFORD INCA 200) to ascertain the major elements present.

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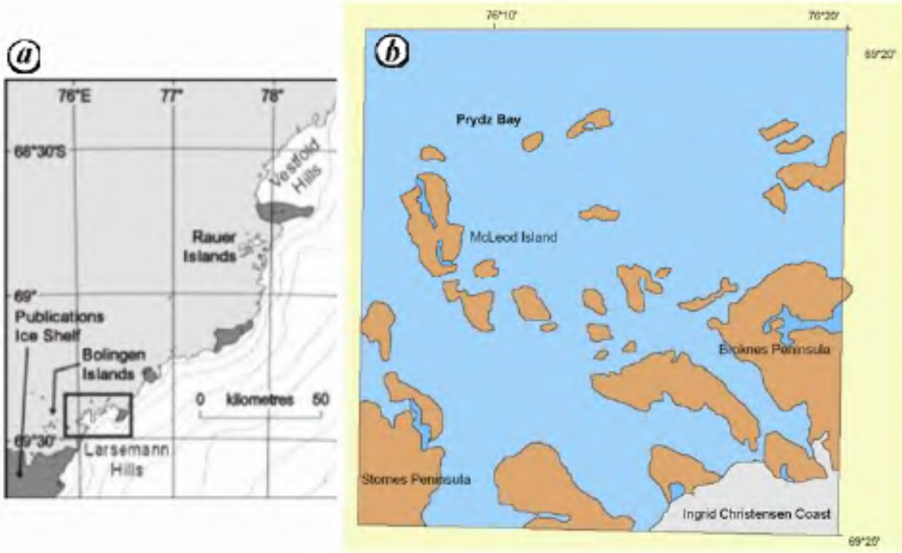


**Figure 1.** *a*, Location of Larsemann Hills in the eastern Antarctica. *b*, Enlarged map (coloured) showing McLeod Island in the Prydz Bay area of Larsemann Hills.

**Figure 2.** Freshwater lake in McLeod Island. Note the gravel and sand on the foreground.

## Results and discussion

The quartz grains exhibit four shapes – angular, sub-angular, sub-rounded and rounded (Figure 3) – and these grain shapes suggest their varied distance and duration of transport. Edges of the grains are sharp and show high relief. Some grains exhibit smooth surfaces, suggesting that the grains are subjected to continuous glacial action, whereas others exhibit rough surfaces, indicating that these grains must have been subjected to limited glacial action.

Quartz grain surface textures depend on the physical and chemical processes which the sand particles have been subjected to during erosion, transport and deposition[9]. Hence, they are useful tools to unravel the history of sedimentary deposits[10,11]. Studies of surface structure of quartz have been applied to continental polar sedimentary sequences to characterize glacial sediments from different sub-environments[12], and to reconstruct transport and weathering mechanisms[13,14].

The various microsurface textures of quartz grains captured by scanning electron microscope are presented in Figures 4 and 5. The grains bear mechanical breakage features of various sizes (Figure 4 *a*, *b*). The surfaces of quartz grains reveal diagnostic microfeatures of glacial and aeolian action that include high relief, sharp-edged angular to sub-angular outline, conchoidal breakages and fractures, deep angular grooves, arcuate fracture patterns, parallel and sub-parallel striations, dish-shaped concavities and breakage blocks (Figure 4 *a–e*). The most common aeolian feature, the edge rounding that imparts a high degree of roundness and sphericity to the detrital quartz grains, is also observed. Small scale conchoidal fractures, meandering ridges, dish-shaped concavities, random scratches, collision pits and smooth surfaces are other significant aeolian micro-textures. Some grains show microblock textures, which are indicative of glacial erosion and/or transport.

The embedment of fossil diatoms in quartz grains is a conspicuous feature. They include the diatom *Luticola muticopsis* (Figure 5 *h*), which is endemic to coastal waters near Davis station, Larsemann Hills, East Antarctica; type locality 65°15.05′S 64°30.0′E, and *Trachyneis aspera* (Figure 4 *f*) is known to occur near Casey station and Davis station, Larsemann Hills, East Antarctica[15]. The silt-like poroids are the distinctive features of these species. Some of the specimens found in the current study were in the size range (apical axis) of 70–80 μm. Diatoms and green algae living within the mats on the lakebeds have been also reported by Sabbe *et al.*[16].

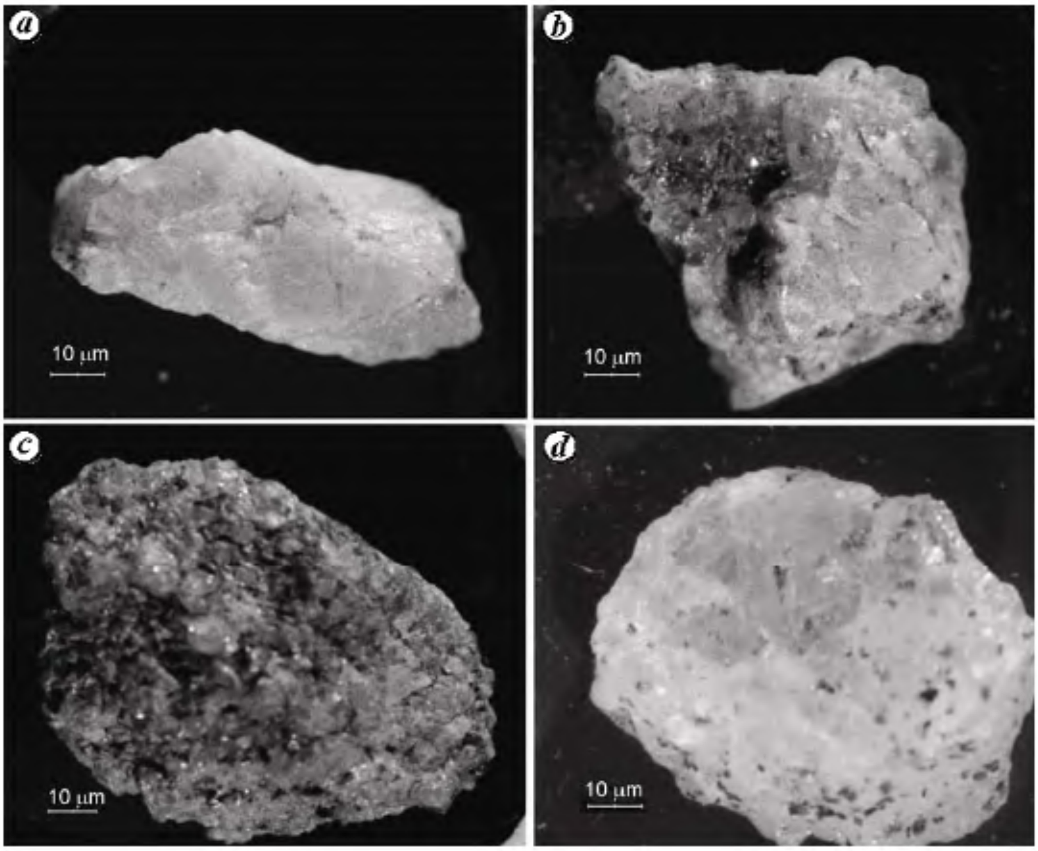


**Figure 3.** Quartz grains of various shapes and impurities. ***a***, Sub-angular grain with smooth surface. ***b***, Angular grain with inclusions. ***c***, Sub-rounded grain with rough surface and black impurities. ***d***, Smooth rounded grain.

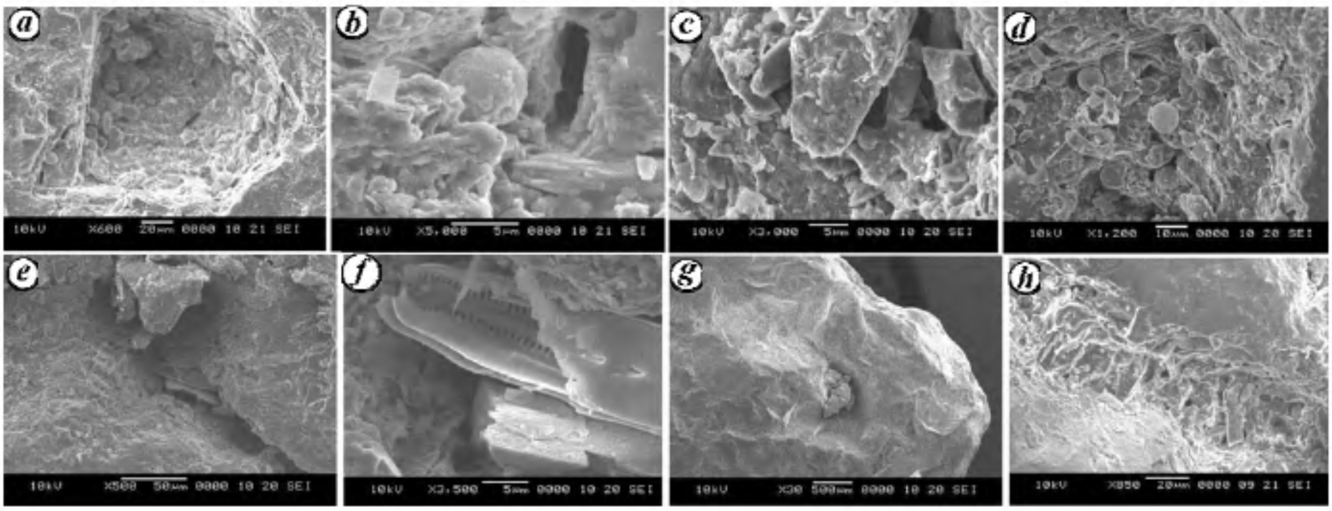

**Figure 4.** Scanning electron photomicrographs showing different surface textures. ***a***, Conchoidal fracturing and dish-shaped concavity; chemical alteration along the borders of pit is observed. ***b***, Pellicles, cavities indicating intense glacial action; over-growth of silica can be seen. ***c***, Flow texture depicting the movement of glaciers; angular over-growth of silica is also seen. ***d***, Glacial flow pattern with inclusion of pellicles. ***e***, Emplacement of diatoms in microfractures. ***f***, *Trachyneis aspera*, emplaced in a silica grain; on the bottom portion a rectangular platy grain showing the effect of glacial grinding. ***g***, Secondary precipitation of silica in a cavity and high relief edges are also seen. ***h***, Grain showing glacial features – ridge-shaped flow textures with a number of parallel to sub-parallel striations showing chemical alteration. Elongated grooves, conchoidal fracturing show intense grain to grain collision.

The forms of chemical alteration are very moderate, usually in the form of solution pits and etching. Some surfaces show chemical features as solution pits and silica pellicles (Figure 4 *a*, *b*). These quartz grains exhibit features of glacial processes that were later exposed to low-energy subaqueous transport. Chemical precipitation/solution features obliterated partially their surfaces. Some grains present a coat of amorphous silica (Figure 5 *a*).

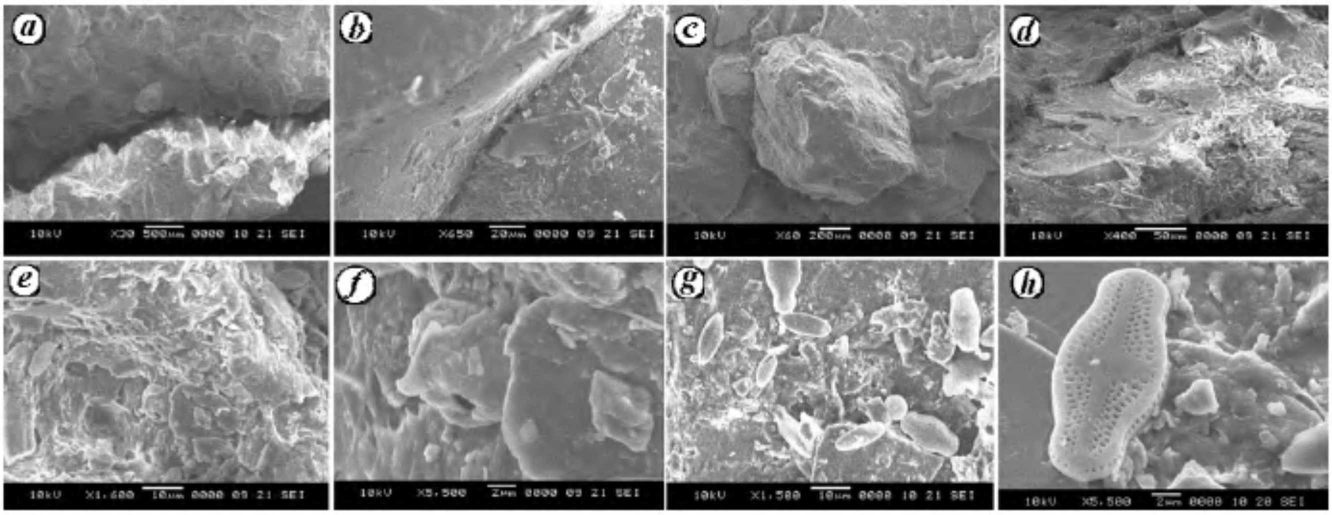


**Figure 5.** Scanning electron photomicrographs showing different surface textures of quartz grains. ***a***, Two types of silica precipitation (probably one is amorphous) on either side of a microfracture. ***b***, Intrusion feature depicting glacial flow. Flat surface on the left bottom may be due to impact of glacial transport. ***c***, Abraded and sinuous flow patterns, attributable to rotational effect during intense glacial grinding. ***d***, Fractured, sharp-edged, high relief and etched surfaces. ***e***, Etched surfaces and over-growths. ***f***, Glacial flow impacted surface showing over-growth and etching. ***g***, Embedded microfossil diatoms in a ground mass of silica. ***h***, Close-up view of a fossil diatom *Luticola muticopsis*. Crushed and fragmented surface of quartz grain is seen on the right side of the photograph.

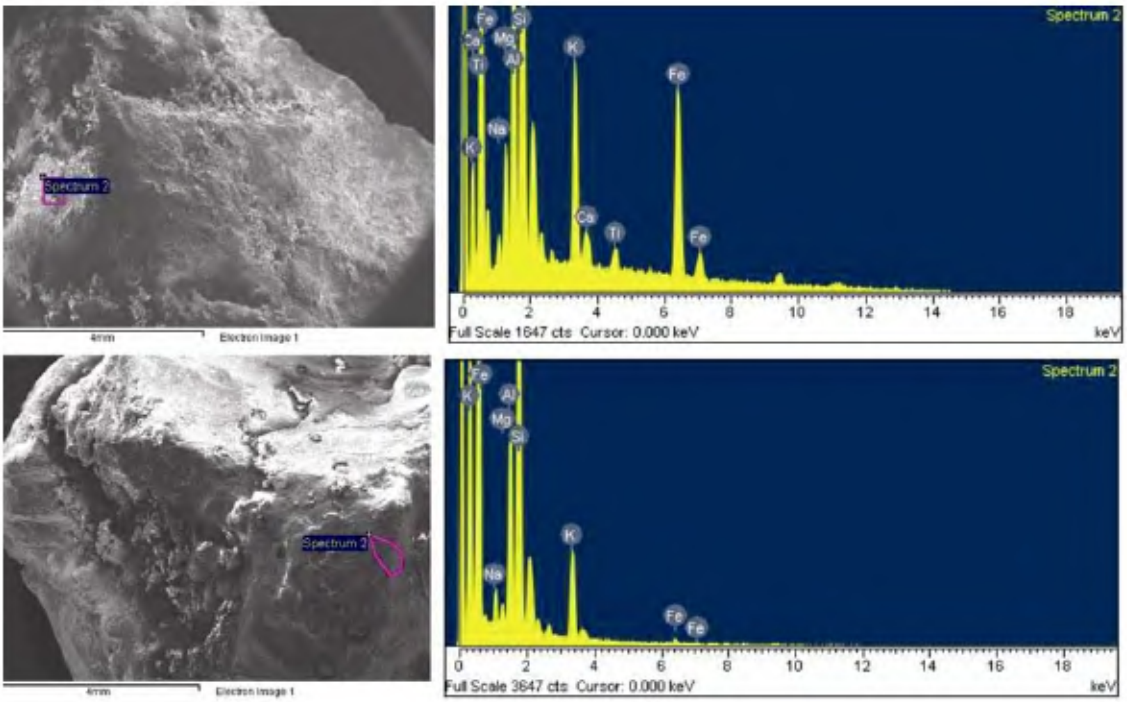


**Figure 6.** Selected scanning electron photomicrographs and elemental peaks derived from energy dispersive spectrometer.

The surfaces of some grains show irregular depressions of varying sizes, with straight or slightly curved grooves (Figure 5 *b*–*d*). Evidence of chemical solution crevasses, etch pits and precipitation of silica are present (Figure 4 *g*, *h* and Figure 5 *a*, *e*, *f*). Some grains show solution pits, and these textures are generally representative of grains in a diagenetic environment. Globules and silica overgrowths, present in various stages of formation, are predominantly silica precipitation features (Figure 5 *g*). Precipitation of silica over diatom surfaces is also observed (Figure 4 *f*).

The grains with sharp edges, fresh surfaces and chemical alteration forms reflect a proximal glacial source, short transport and rapid deposition[17]. Probably most of the quartz grains are derived from glacial grinding or crushing of granites and granitoids, which are seen as outcrops in the McLeod Island. In glacial environments, the roundness and the edge abrasion of the original grains can be caused by a melt-water stream below glaciers, suggesting that grains are exposed to low energy subaqueous transport. As Van Hoesen and Orndorff[18] suggest, sub-parallel and linear fractures, curved troughs, crushing features and arc-shaped steps are indicative of glacial environments.

We have studied the elemental composition of grains, and the spectra derived from the EDS for selected grains are shown in Figure 6. As seen from the spectra, the micro-particles are basically composed of silica followed by Fe, Al, K, Na and other elements. The elemental composition suggests that the sediments are derived from gneissic complex rocks. Aluminium is a less mobile element and is generally locked within aluminosilicate rocks. The percentage of K is higher than that of Na, indicating the lower mobility of K as compared to Na. The results further suggest that silica denudation rates are distinctly lower in glacier-covered catchments than in their non-glacial counterparts. Disruption of mineral lattices by grinding increases dissolution rates; this and high surface area should make glacial sediments exceptionally weatherable[19]. Glacial abrasion produces mineral surfaces not unlike those from mechanical grinding[20]. The influence of chemical activity is evident in the form of secondary replacement, dissolution pits and hollows, secondary growth and surface etching. A few grain surfaces showed precipitation, which leads to the adherence of smaller particles. Silica precipitation is also high in some grains. This indicates that quartz grains released from the rock in cold weather conditions have stagnated in cold water, where extensive deposition of silica has taken place. This sample could thus represent glacial lake environment.

## Conclusion

The present study suggests that the sediments are derived from the nearby source area to the freshwater lakes and the distance of transport is short. The sediment has been subjected to repeated glacial action, which resulted in physical and chemical alterations of the particles.


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