Late Quaternary paleoenvironmental reconstruction using sedimentological parameters and quartz grains from lacustrine sediments of Schirmacher Oasis, East Antarctica

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INTRODUCTION

- Lacustrine and marine sediments from Antarctica offer tremendous potential to understand the different sedimentary processes under harsh climatic conditions.
- Terrigenous sediments provide a true reflection of the different geological processes (provenance, type and intensity of weathering and erosional processes) acting in the catchment.
- In the Polar Regions, quartz content in sediments has been widely used for paleoclimate reconstruction, as they are products of physical weathering processes.
- Surface micro features, angularity & chemical features on quartz grains and particle-size analysis of sediments collectively reveal the sedimentary and physicochemical processes that acted on the grains during different stages of their geological history.
- Quartz grains in lake sediments can have different sources i.e., locally derived quartz grains due to mechanical and chemical weathering of catchment rocks, aeolian quartz, that has been transported by wind.

OBJECTIVES

- In this study, we present the results of particle size studies and morphological features of quartz grains deposited in the sediments of Sandy Lake, Schirmacher Oasis (SO), East Antarctica, with an aim to evaluate the modes of transport, weathering characteristics and effect of regional climate on these sediments.

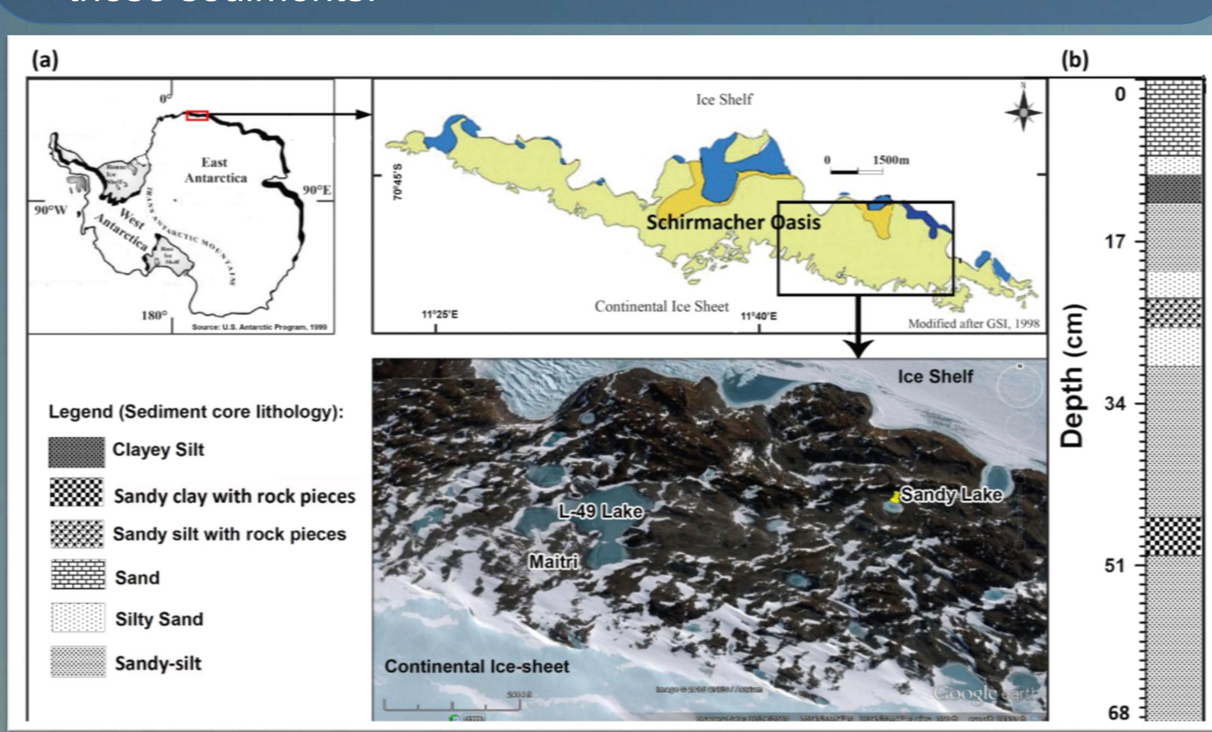

Fig. 1. (a) General map of Antarctica showing the location of Schirmacher Oasis. Map of Schirmacher Oasis (modified after Geological Survey of India (1998)) showing the location of Sandy Lake and satellite image of the area around Sandy Lake (obtained from Google Earth); (b) litholog of the Sandy Lake sediment core (Warrier et al., 2014).

MATERIALS AND METHODS

- A 68-cm sediment core was retrieved from Sandy Lake in Schirmacher Oasis during the 28th Indian Scientific Expedition to Antarctica and sub-sampled at 1 cm interval.
- AMS ^{14}C dates were obtained on bulk organic matter present in sediment samples.
- Environmental magnetic (Warrier et al., 2014) and organic geochemical (Mahesh et al. in press) measurements have been made on the sediments.
- Organic matter and carbonate content were eliminated before the analysis. Particle size analysis for the entire sediment core was made on a Beckman-Coulter LS-13320.
- Quartz grains were separated from thirty five sediment samples. The grains were observed and counted under a stereo zoom magnifying microscope (Nikon SMZ-1500).
- Scanning electron microscopic observations (a JEOL-JSM-6360 LV SEM operated at 5-15 keV) and elemental analysis (OXFORD INCA 200 EDS) of the quartz extracts.

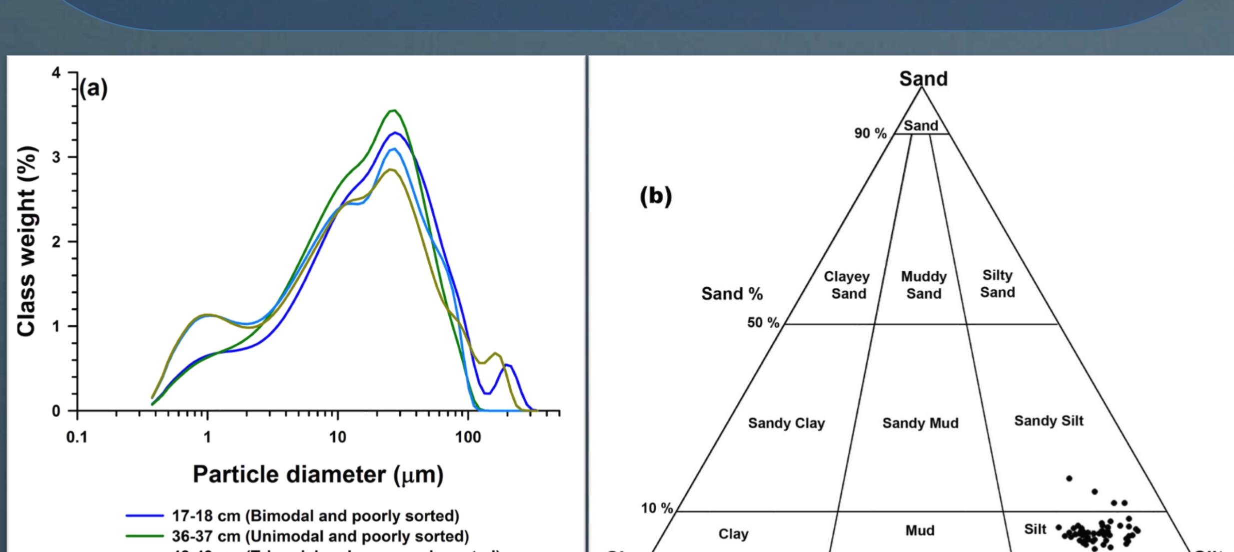

Fig. 2. (a) Plot of grain-size data for representative samples from the Sandy Lake sediment core and (b) Ternary plot showing the distribution of sand-, silt- and clay sized sediments.

RESULTS AND DISCUSSION

Sedimentological data:

- The grain size distribution patterns suggest that the sediments of Sandy Lake have different modes (bimodal, unimodal, trimodal and polymodal) of distribution.
- The sediments are silty in texture with a few samples plotting in the sandy silt section (Refer Ternary diagram).
- The MGS values show a decreasing trend from 43 cal ka B.P. to 24 cal ka B.P. after which it increases towards the core-top.
- The sorting index indicates that the Sandy Lake sediments are very poorly sorted from 43 cal ka B.P. to 24 cal ka B.P. after which the sediment texture is poorly sorted.
- During the last glacial period, D10, D50 and D90 particle sizes were low. However, after ~ 24 cal ka B.P. there is a steady increase in these three parameters suggesting an increase in sediment grain size and hence indicating a change in the energy conditions of the transporting medium.
- Sedimentation in Antarctic lakes are primarily due to movements of glaciers, melt-water streams (during austral summer) and aeolian transport. The statistical parameters of the sedimentary grain size data indicate that the sediments in Sandy Lake could have been transported either by glaciers, melt-water streams and also wind.

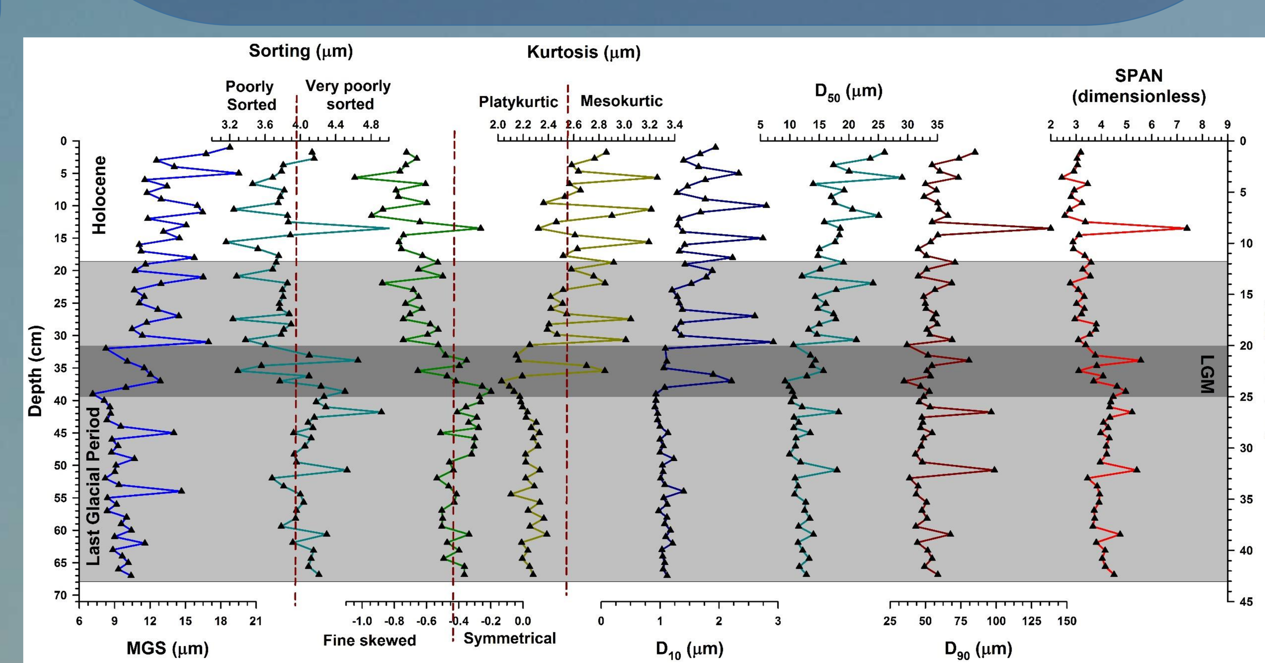

Fig. 3. Down-core variations in the mean grain size, sorting, skewness, kurtosis, D10, D50, D90 and SPAN index parameters for the Sandy Lake sediments during the past 43 cal ka B.P.

Scanning Electron Microscopic data:

- The quartz grains show features representing mechanical breakage. A large amount of quartz grains show angular to sub-angular grain outline that are indicative of glacial action.
- Rounded grains are very few in terms of percentage when compared with the angular grains hence suggesting that quartz grains are primarily derived from within the catchment and suggestive of shorter distance of transport.
- Small-scale conchoidal fractures, broken surfaces, adhered particles, straight and arcuate steps, mineral precipitation, surface alteration in the form of surface etching, upturned plates, collision pits etc. are other significant micro-textures that can be seen in the quartz grains of Sandy Lake.
- The features observed on the quartz grains of Sandy Lake sediments indicate that they are primarily derived due to actions of glacier movement, meltwater streams and aeolian activity.

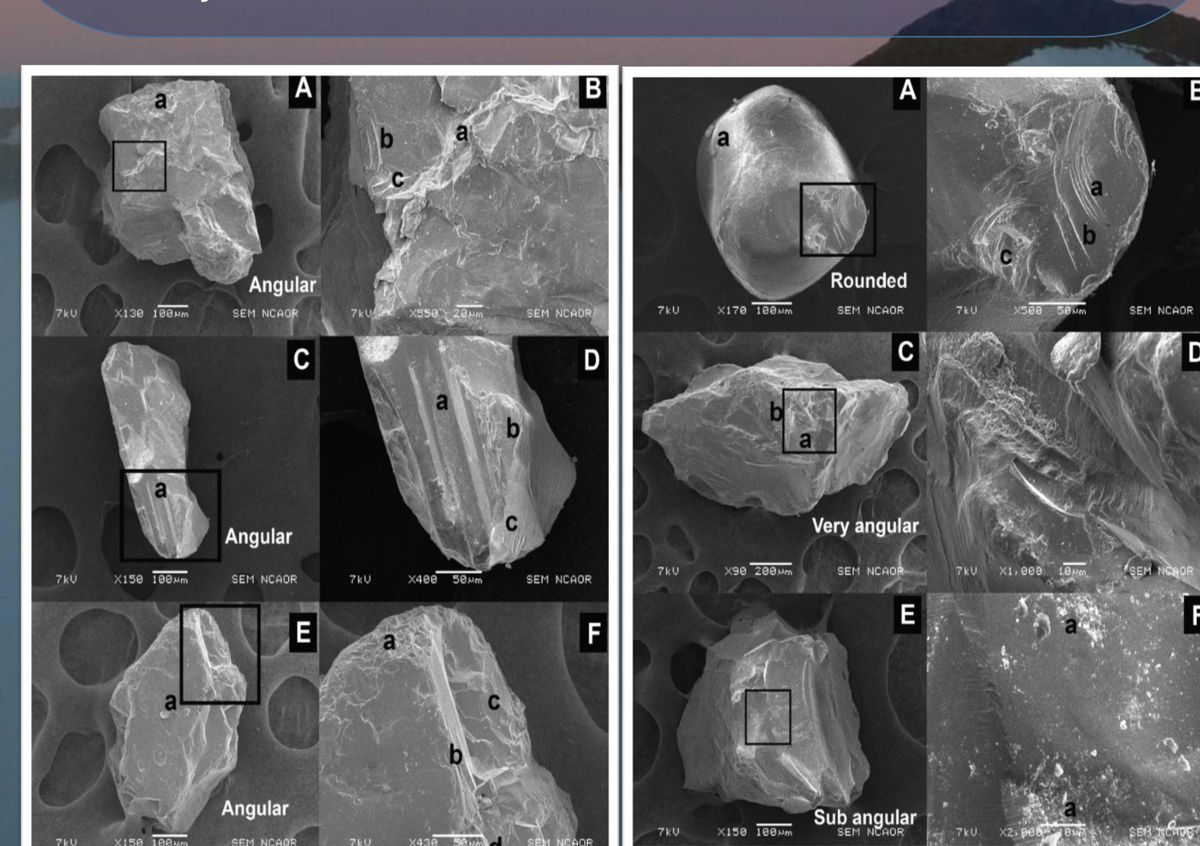

Fig. 4. Scanning electron micrographs of quartz grains from Sandy Lake sediment core.

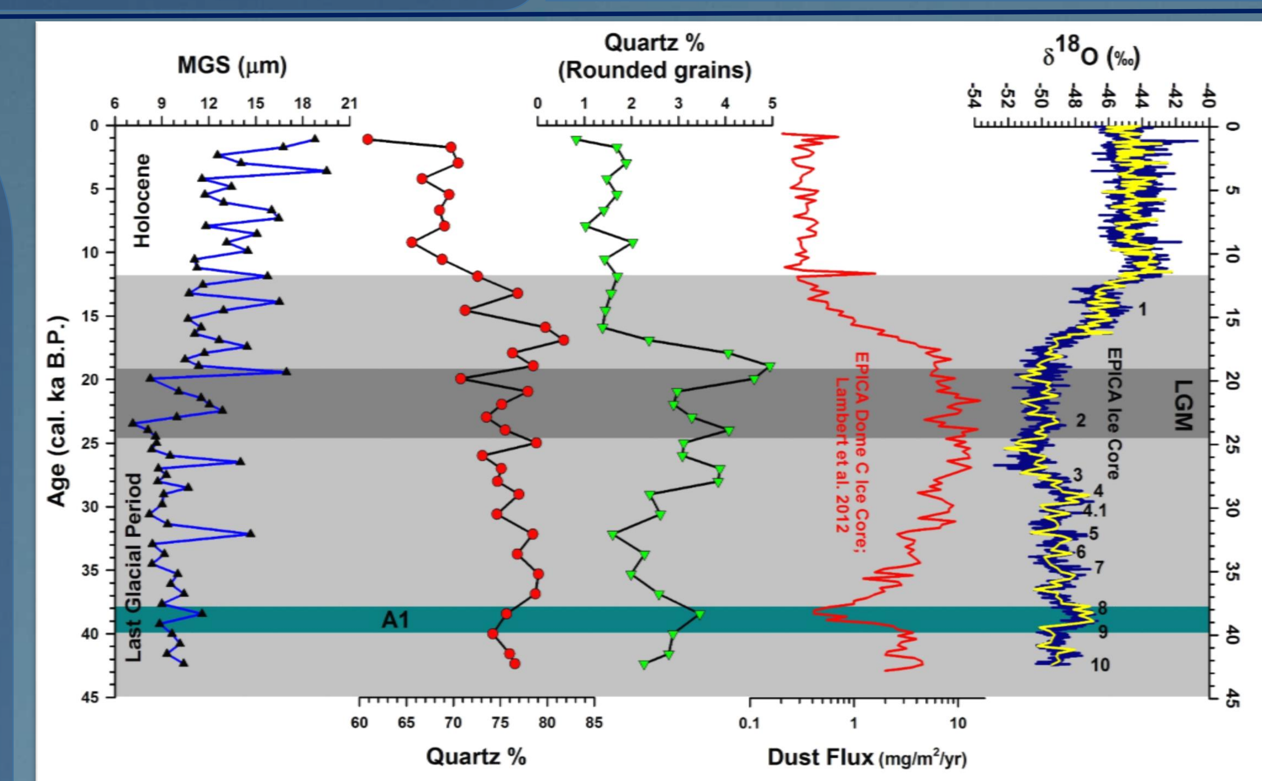

Fig. 5. Comparison of mean grain size, % quartz, and % rounded quartz grains with dust flux (Lambert et al., 2012) and oxygen isotopic data (EPICA Community Members, 2006) from EPICA ice-core data.

Palaeoclimatic Implications:

- Extremely cold climatic conditions prevailed in SO during 43 cal ka B.P. to ~24 cal ka B.P.
- Low values of MGS, D_{10}, D_{50} & D_{90} suggest the deposition of fine-grained sediments indicating a lower intensity of erosional process in the catchment.
- The Antarctic warming event (A1; Blunier and Brook, 2001) at 38 cal. ka B.P., which is present in the ice-core records, is also seen in the MGS data of Sandy Lake.
- Several other peaks in the MGS data (35.29, 33.73, 32.16, 28.52, 22.45 and 13.89 cal ka B.P., respectively) are also correlatable with the Antarctic Isotope Maximum events (7, 6, 5, 3, 2 and 1, respectively) recorded in the EPICA ice-core data (Fig. 5).
- Rounded quartz grains show a relatively higher percentage when compared with angular quartz grains (Fig. 5). This could be attributed to the peak in aeolian activity as seen by a fairly good correlation between the dust flux data (EPICA ice-core; Lambert et al., 2012) and the rounded % quartz data (Fig. 5).
- Deglaciation in SO occurred from ~19 cal ka B.P. as evident by the increased values of sedimentological parameters.
- The Holocene period is characterized by the deposition of coarse-grained sediments (relatively higher values of MGS, D_{10}, D_{50} & D_{90}).
- During the Holocene period, SO was characterized by alternating periods of relatively warm and cold climatic conditions which is also evident in other lake sediment records from SO and other ice-free regions in East Antarctica.

CONCLUSIONS

- Sediments are primarily deposited due to glaciofluvial activity. However, during the last glacial period, Aeolian activity was also strong as seen by an increase in rounded quartz grains.
- SEM studies of selected quartz grains and the analyses of various surface textures indicate that glacigenic conditions must have prevailed at the time of their transport to the lake basin.
- There is a major shift in climatic conditions from the LGM into the Holocene as evident by increase in sedimentological parameters.
- Deglaciation in SO occurred at ~19 cal ka B.P. as evident by an increase in the values of sedimentolgical parameters.
- MGS can be used as a suitable proxy for past climate reconstruction in high-latitude lakes.

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