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Modern and Holocene aeolian dust variability from Talos Dome (Northern Victoria Land) to the interior of the Antarctic ice sheet

B. Delmonte [a,*], C. Baroni [b,c], P.S. Andersson [d], B. Narcisi [e], M.C. Salvatore [b], J.R. Petit [f], C. Scarchilli [e], M. Frezzotti [e], S. Albani [a], V. Maggi [a]

[a] DISAT – Department of Earth and Environmental Sciences, University Milano-Bicocca, Piazza della Scienza 1, 20126 Milano, Italy
[b] Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, 56126 Pisa, Italy
[c] CNR, Istituto di Geoscienze e Georisorse, Via S. Maria 53, 56126 Pisa, Italy
[d] LIG – Laboratory for Isotope Geology, Swedish Museum for Natural History, Box 50007, 104 05 Stockholm, Sweden
[e] ENEA, CR Casaccia, SP. Anguillarese, 301, I-00123 Roma, Italy
[f] LGGE-CNRS-Université Joseph Fourier, UMR 51230, BP 96, 38402 St Martin d'Hères Cedex, France

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ABSTRACT

High-elevation sites from the inner part of the East Antarctic plateau sample windborne dust representative of large portions of the Southern hemisphere, and are sensitive to long-range atmospheric transport conditions to polar areas. On the periphery of the ice sheet, conversely, the aeolian transport of particles from high-elevation ice-free areas can locally represent a relatively important additional input of dust to the atmosphere, and the interplay of atmospheric dynamics, dust transport and deposition is strictly related to the regional atmospheric circulation behaviour both at present-day and in the past. The understanding of the spatial extent where local sources can influence the mineral dust budget on the ice sheet is fundamental for understanding the atmospheric dust cycle in Antarctica and for the interpretation of the dust history in marginal glaciological settings.

In this work we investigate the spatial variability of dust flux and provenance during modern (pre-industrial) and Holocene times along a transect connecting Talos Dome to the internal sites of the Antarctic plateau and we extend the existing documentation of the isotopic (Sr–Nd) fingerprint of dust-sized sediments from Victoria Land source areas.

Dust flux, grain size and isotopic composition show a marked variability between Talos Dome, Mid Point, D4 and Dome C/Vostok, suggesting that local sources play an important role on the periphery of the ice sheet. Microscope observations reveal that background mineral aerosol in the TALDICE core is composed by a mixture of dust, volcanic particles and micrometric-sized fragments of diatoms, these latter representing a small but pervasive component of Antarctic sediments. A set of samples from Victoria Land, mostly consisting of regolith and glacial deposits from high-elevation areas, was collected specially for this work and the isotopic composition of the dust-sized fraction of samples was analyzed. Results reveal a close relationship with the parent lithologies, but direct comparison between source samples and firn/ice core dust is problematical because of the ubiquitous volcanic contribution to the environmental particulate input in the Talos Dome area.

The frequency of events potentially suitable for peripheral dust transport to Talos Dome appears relatively high for present-day conditions, according to back trajectories calculations, and the related air flow pattern well-defined from a seasonal and spatial perspective. Also, as expected from palaeo-data, these events appear extremely uncommon for internal sites.

1. Introduction

The aeolian deflation of continents and the mineral dust transport long-range responded to the major climate and environmental changes during the Quaternary (e.g. Petit et al., 1999; Lambert et al., 2008; Maher et al., 2010). Dust particles can be transported around the globe in suspension in the troposphere at a wide variety of heights, and their deposits can be far away from their origins (Kohfeld and Harrison, 2001). The long and detailed aeolian sequences obtained from ice cores drilled onto the interior of the Antarctic ice sheet allowed assessing the past atmospheric

* Corresponding author. Tel.: +39 02 6448 2847; fax: +39 02 6448 2895.
E-mail address: barbara.delmonte@unimib.it (B. Delmonte).

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circulation variability on a variety of timescales and the related environmental changes that occurred at high southern latitudes (Petit et al., 1999; Lambert et al., 2008). During glacial/interglacial cycles, most of the variability in dust concentration in central East Antarctica (Vostok, Dome C) was related to the supply of small mineral particles from the remote continental sources, to the snow accumulation rate, and to the atmospheric transport efficiency (lifetime of aerosol), all factors related to temperature and to the hydrological cycle (Petit and Delmonte, 2009).

On the periphery of the Antarctic plateau, an additional input of fine dust particles to the atmosphere and to the ice sheet can derive from ice-free terrains frequently occurring in mountain ranges or protruding above the ice sheet surface as nunataks (e.g. Tedrow and Ugolini, 1966). The supply of sediments from proximal sources was likely faint or nil for inner, high elevation sites such as Vostok and Dome C both during glacial periods, when the dust signature is consistent with a South American origin (Grousset et al., 1992; Basile et al., 1997; Delmonte et al., 2008; Gabrielli et al., 2010; Vallelonga et al., 2010), and during the Holocene, when dust is believed to derive from multiple remote sources (Revel-Rolland et al., 2006; Marino et al., 2009; Gabrielli et al., 2010). Conversely, the contribution from these areas may become important for peripheral areas (Bory et al., 2010; Delmonte et al., 2010a; Albani et al., 2012a), in particular those that are close to the Transantarctic Mountains, that represent the sole extensive area with important rock outcrops in this sector of East Antarctica. Under cold climate conditions such as those of Antarctica, moreover, it is known that dust mass transport rates may be significantly higher than for the equivalent wind speed in warm and hot climates, in relation to the extremely low air humidity, to air density and turbulence (McKenna Neuman, 2004); thus, the export of sediments from Antarctic ice-free terrains can be relevant. Furthermore, even small amounts of dust have the potential to influence the overall budget in low deposition environments such as the East Antarctic ice Sheet.

At the site of Talos Dome, located in the Ross Sea sector of East Antarctica in Northern Victoria Land (Frezzotti et al., 2007), some physical-chemical properties of dust (grain size, concentration, Sr–Nd isotopic composition) suggested a contribution from local sources, mostly represented by unconsolidated Pleistocene glacial deposits and regolith located at high elevation and outcropping above the ice sheet surface in Victoria Land (Delmonte et al., 2010a). Data also suggested that this local contribution was relatively more important during the Holocene – at a time when the remote dust input was extremely low – with respect to the Last Glacial period (Albani et al., 2012a).

Under the peculiar conditions of the Talos Dome site, the entrainment and transport of local dust particles to the site is influenced by local meteorological conditions, in turn related to regional climate (Albani et al., 2012a). Thus, the dust and climate record from the uppermost 670 m of the ~1620 m deep TALDICE (TALos Dome Ice CorE drilling project) ice core (Stenni et al., 2011) offers an extraordinary opportunity to investigate in detail the regional atmospheric circulation changes during the Holocene and their relationship with the deglaciation history of the Ross Sea.

Despite the demonstrated importance of aeolian dust transport to Antarctica, still little information exists on the entrainment, transport and deposition of mineral aerosol from marginal ice-free areas towards the Antarctic interior, one major difficulty consisting in the extremely low dust concentration in firn and ice cores during interglacial climate conditions (Petit and Delmonte, 2009). In order to form a better view of the spatial extent where peripheral, high-elevation dust sources can play a significant role with respect to the mineral dust input on the ice sheet during modern (pre-industrial) times, we investigate in this work the flux, grain size and $^{87}Sr/^{86}Sr$–$^{143}Nd/^{144}Nd$ isotopic composition of aeolian dust from different firn and ice cores drilled along a transect from Talos Dome all through the interior of the ice sheet (Dome C – Vostok area, Fig. 1a). These measurements are complemented by a number of microscopic (SEM) morphological observations that provide fundamental indications for data interpretation. In addition, the isotopic composition of the dust-sized fraction of sediments collected for this study in some target potential source areas located inside northern Victoria Land (NVL) and southern Victoria Land (SVL) is presented. This work represents the expansion of a former study (Delmonte et al., 2010a), and a contribution to the documentation of local mineral aerosol fingerprint, which can be of use for the interpretation of dust origin in peripheral East Antarctica in the past. We also investigate the modern frequency and pathways of air masses flowing from Victoria Land potential source areas (PSAs) to the selected drilling sites in order to obtain a first assessment of the occurrence of events potentially suitable for peripheral dust transport and an overview of air mass flow paths at present-day, which can be compared with evidences from palaeo-data.

2. Materials and methods

This study was carried out in different steps:

1. Sampling of firn cores and dust measurements
2. Field sampling of PSAs in Antarctica, sample preparation

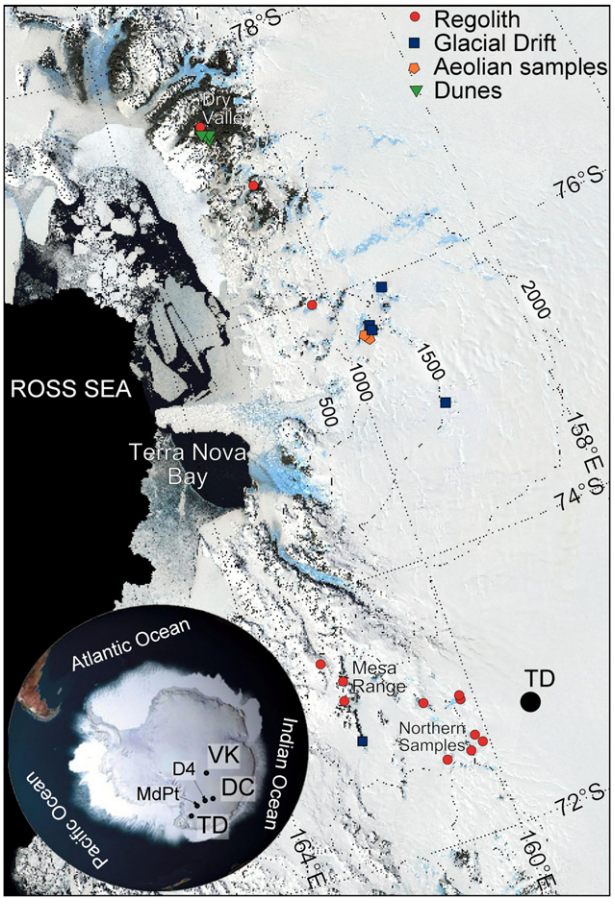

Fig. 1. Satellite image (Landsat image mosaic of Antarctica project) of Victoria land with indication of the TALDICE ice core drilling site at Talos Dome (TD), typology and location of the dust source samples analyzed for Sr and Nd isotopic composition (this work and Delmonte et al., 2010a) and topography. Insert: Antarctica and ice core drilling sites mentioned in the text. TD (Talos Dome), MdPt (Mid Point), D4, DC (Dome C), VK (Vostok).