INSOLUBLE IMPURITIES IN POLAR ICE CORES

Proxies for past climate and environment

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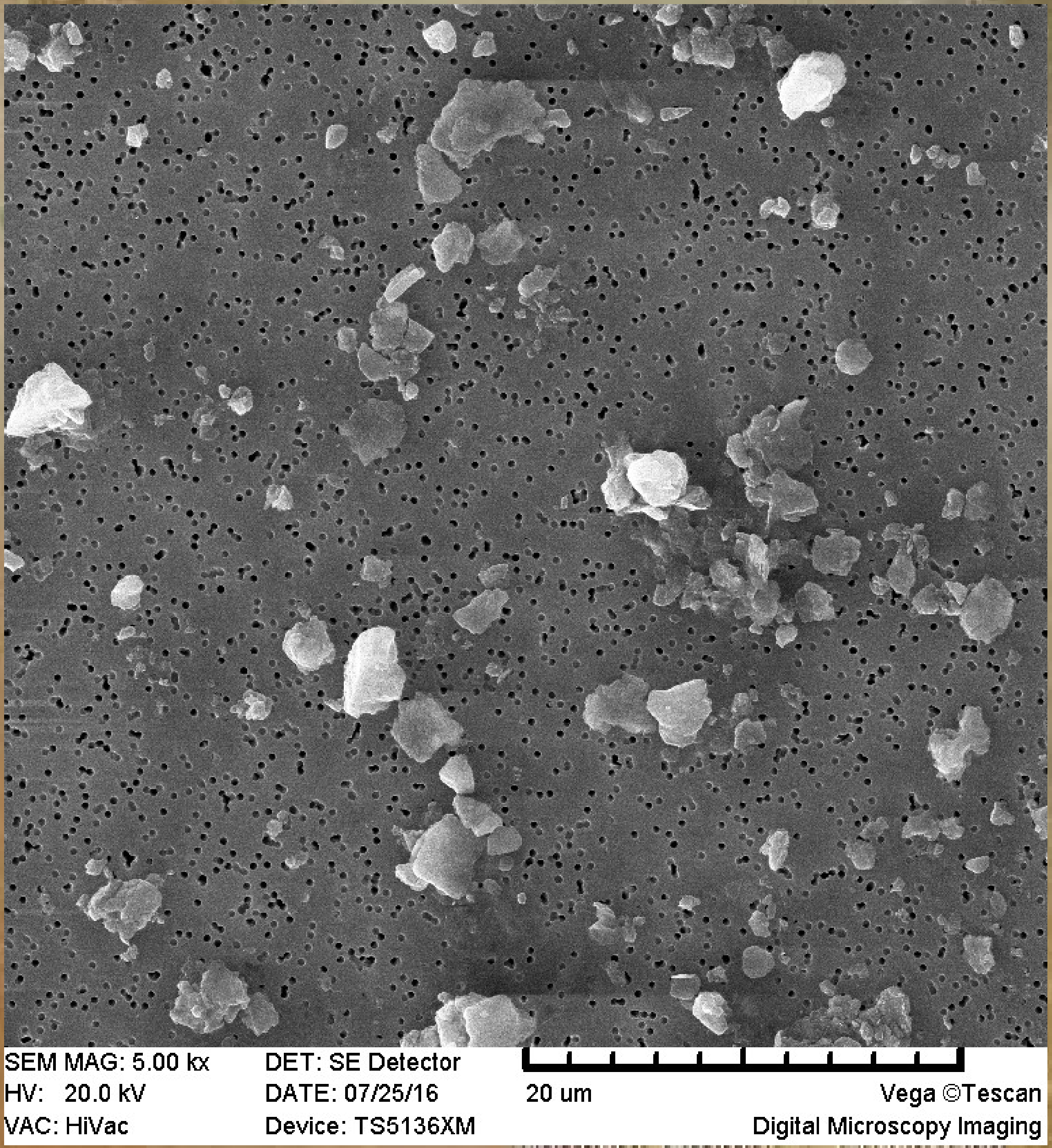
MINERAL DUST

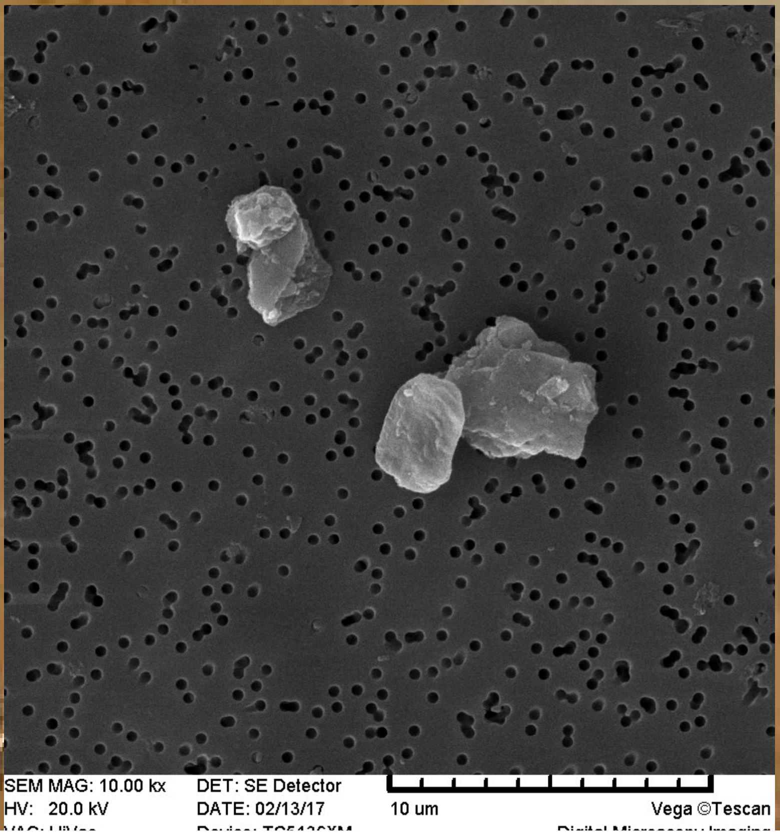
Dust is a major constituent of airborne particles in the global atmosphere.

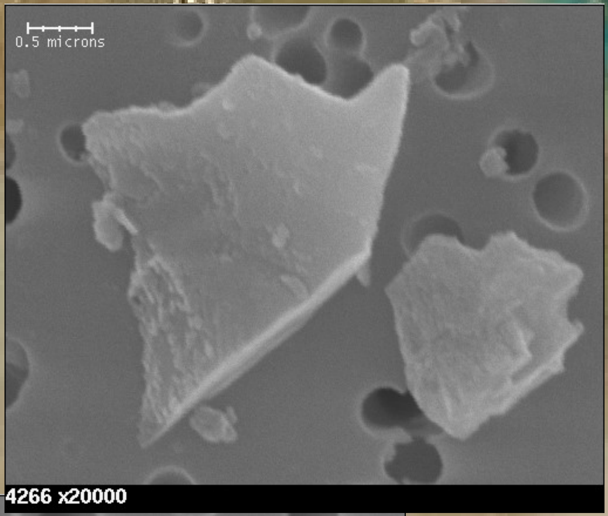
It consists of insoluble, small-sized minerals mainly deflated from arid and semiarid regions.

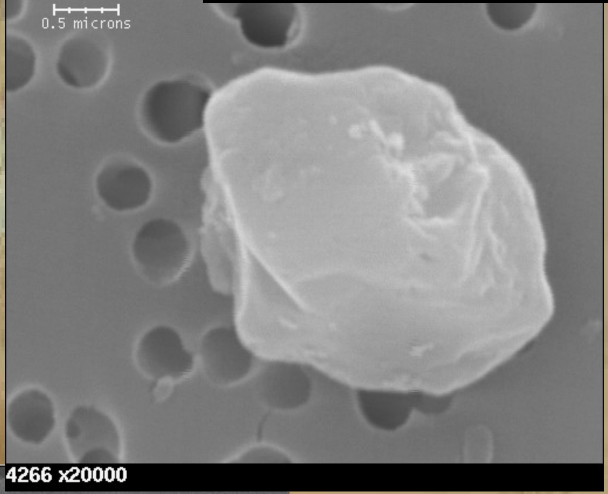


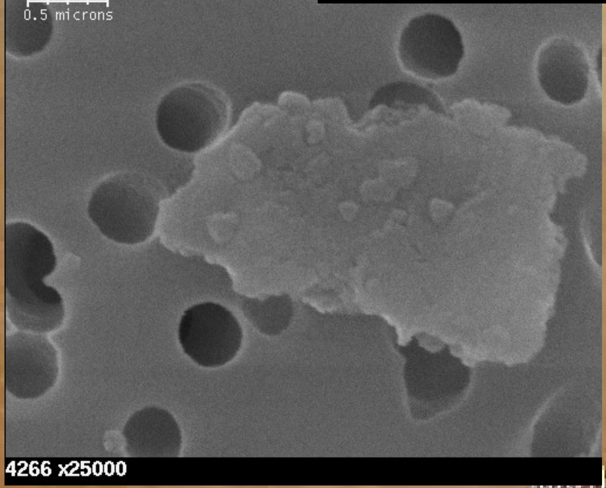
MINERAL DUST

Dust grains are typically dominated by (alumino) silicates such as clays, quartz and feldspars with varying amounts of carbonates, and iron-bearing minerals.



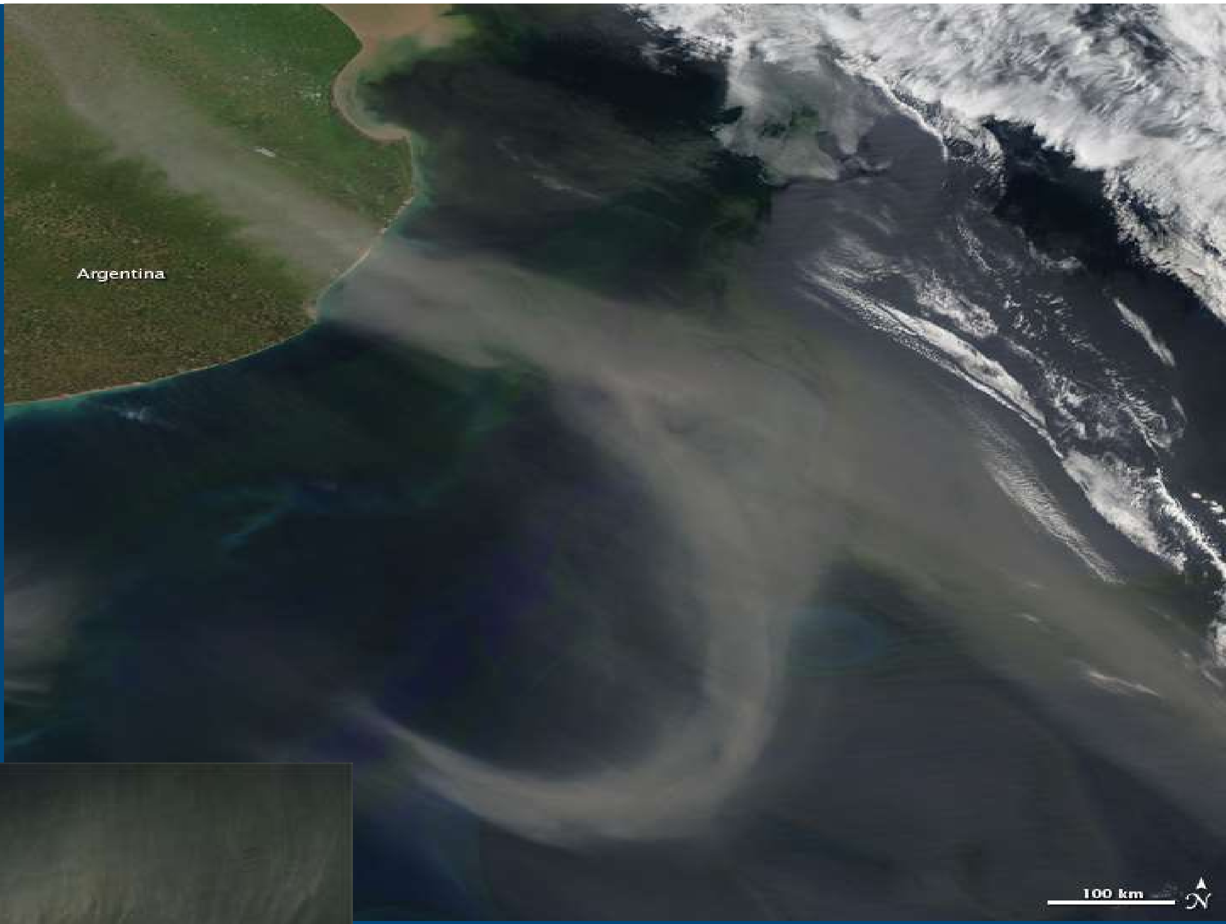




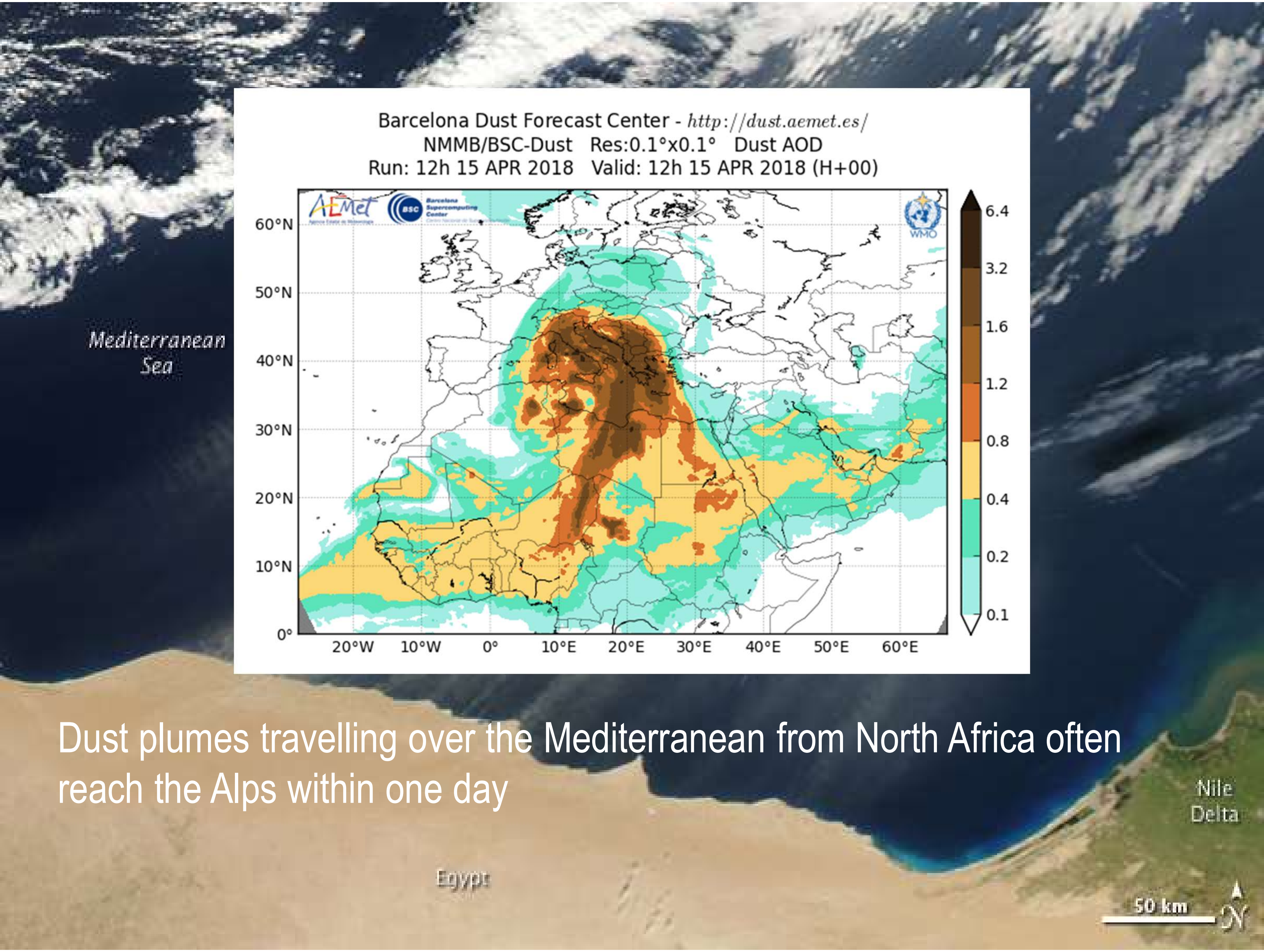


Dust plumes frequently cover huge areas of the Earth

They represent one of the most prominent and commonly visible features in satellite imagery.

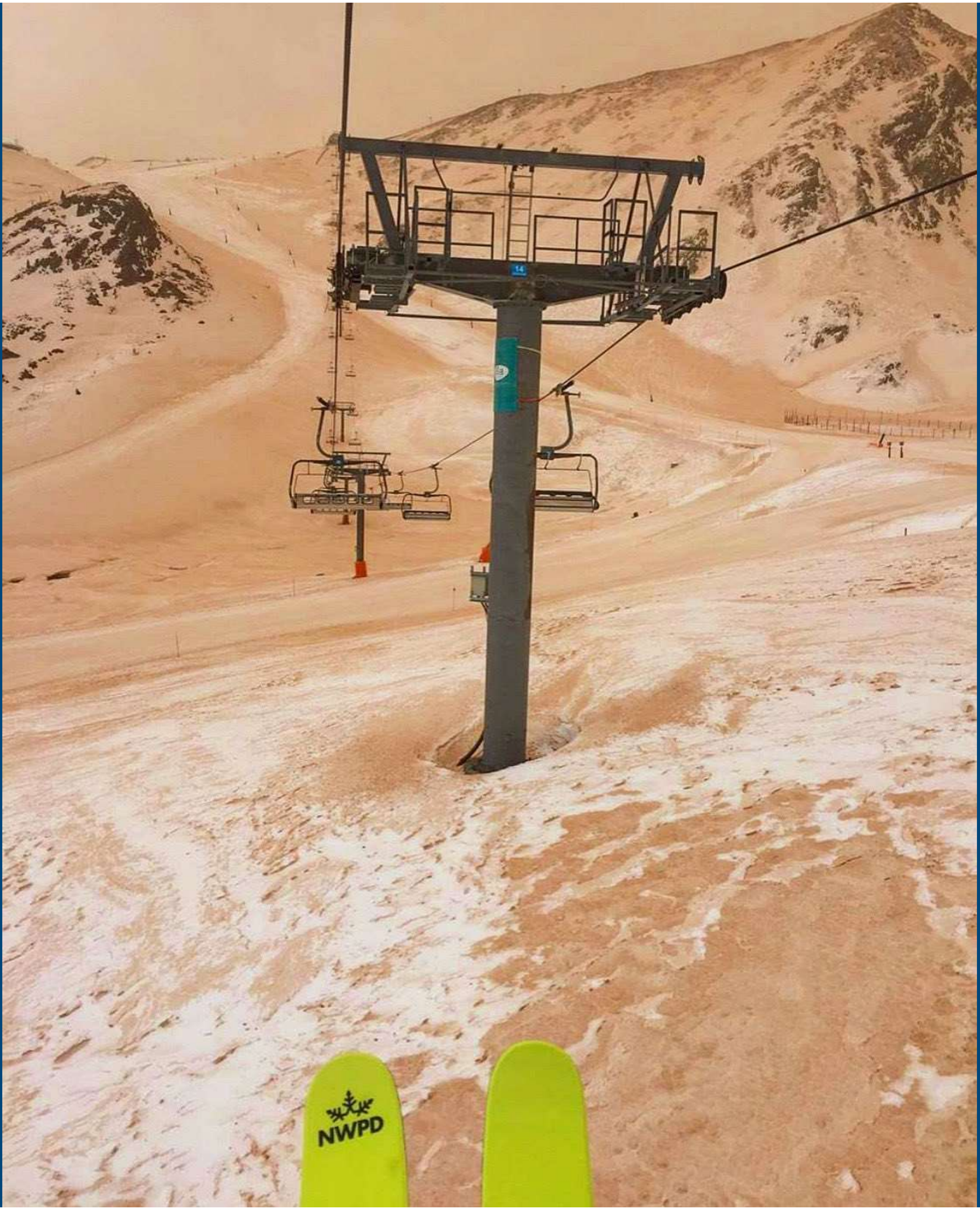


Dust plumes often arise from discrete source points sometimes coalescing into large veils of dust



Barcelona Dust Forecast Center - *http://dust.aemet.es/*
NMMB/BSC-Dust Res:0.1°x0.1° Dust AOD
Run: 12h 15 APR 2018 Valid: 12h 15 APR 2018 (H+00)

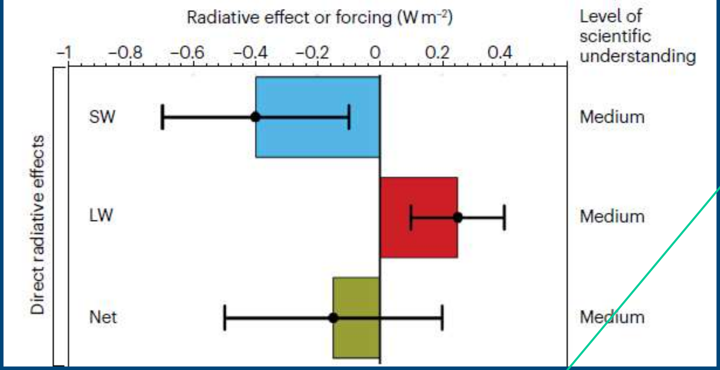
Dust plumes travelling over the Mediterranean from North Africa often reach the Alps within one day


14
NWPD

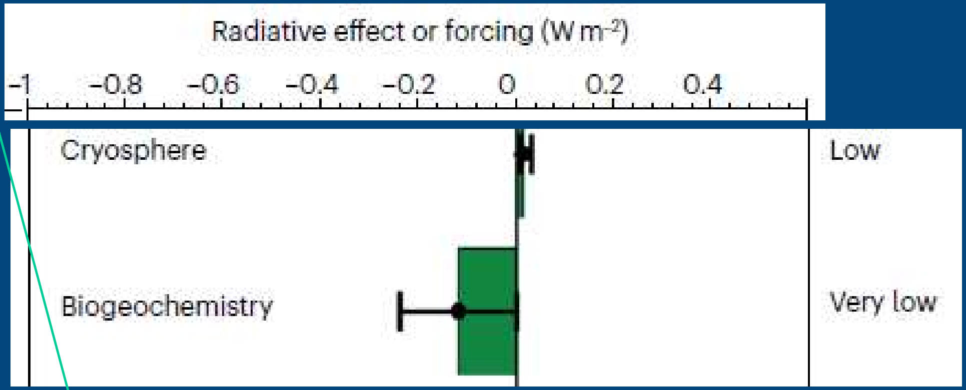
These events often become stratigraphically-visible in Alpine snow and ice cores

Dust perturbs the energy balance of the Earth through various mechanisms...

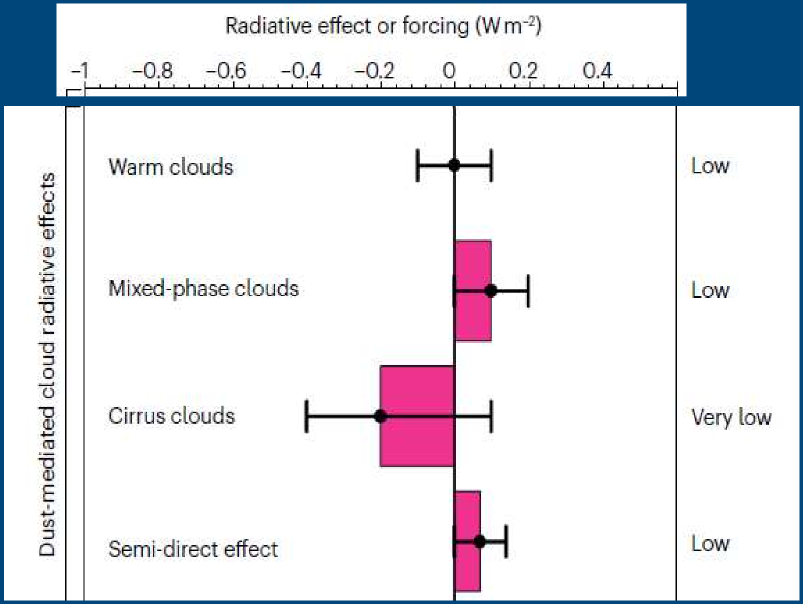
Interaction with solar radiation



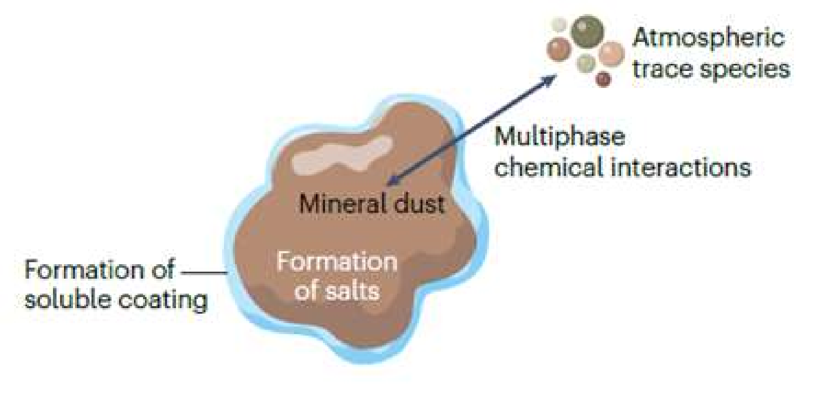
Interaction with the cryosphere & biogeochemistry



Interaction with clouds



Interaction with Atmospheric chemistry

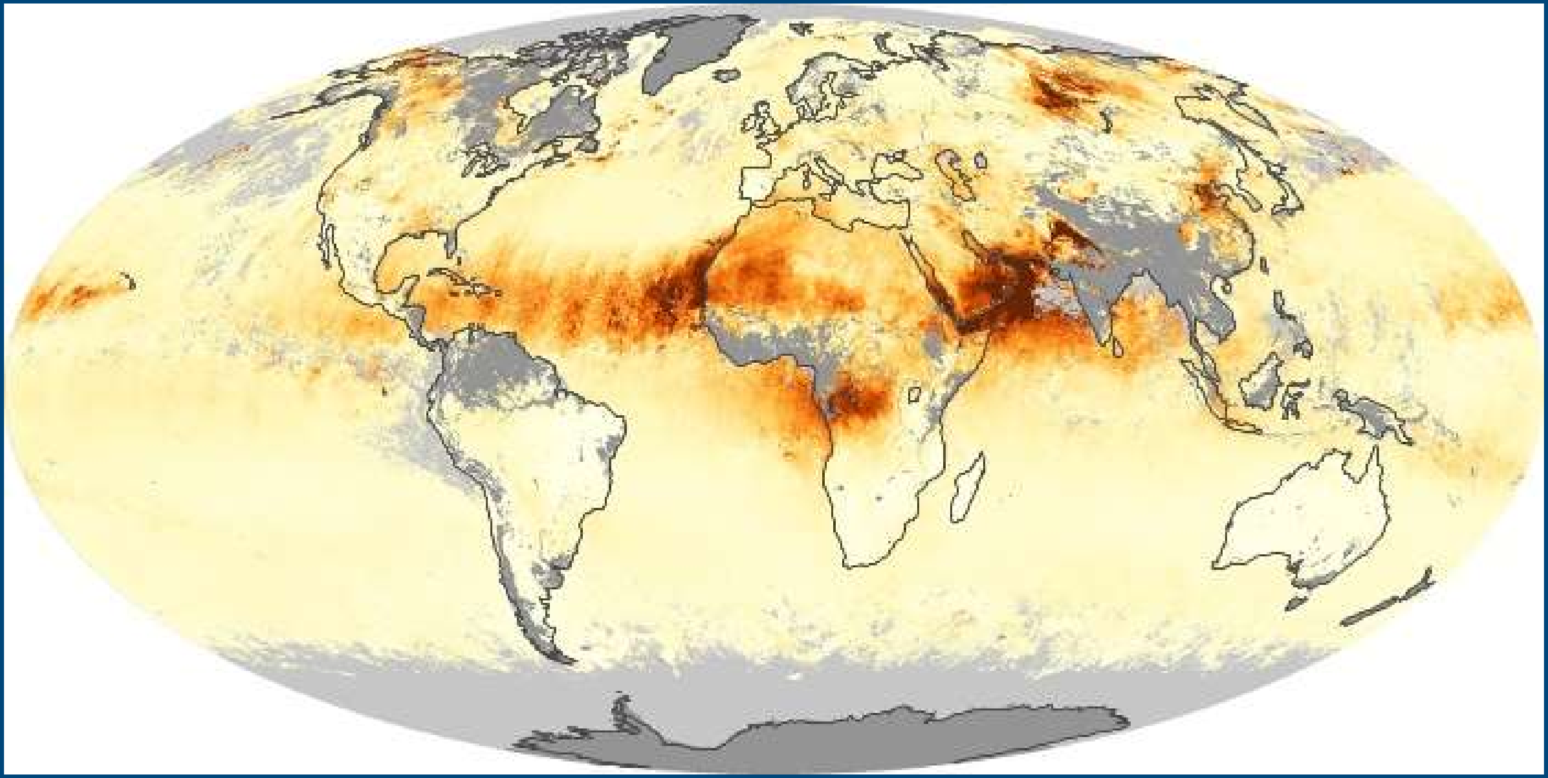


Dust sources

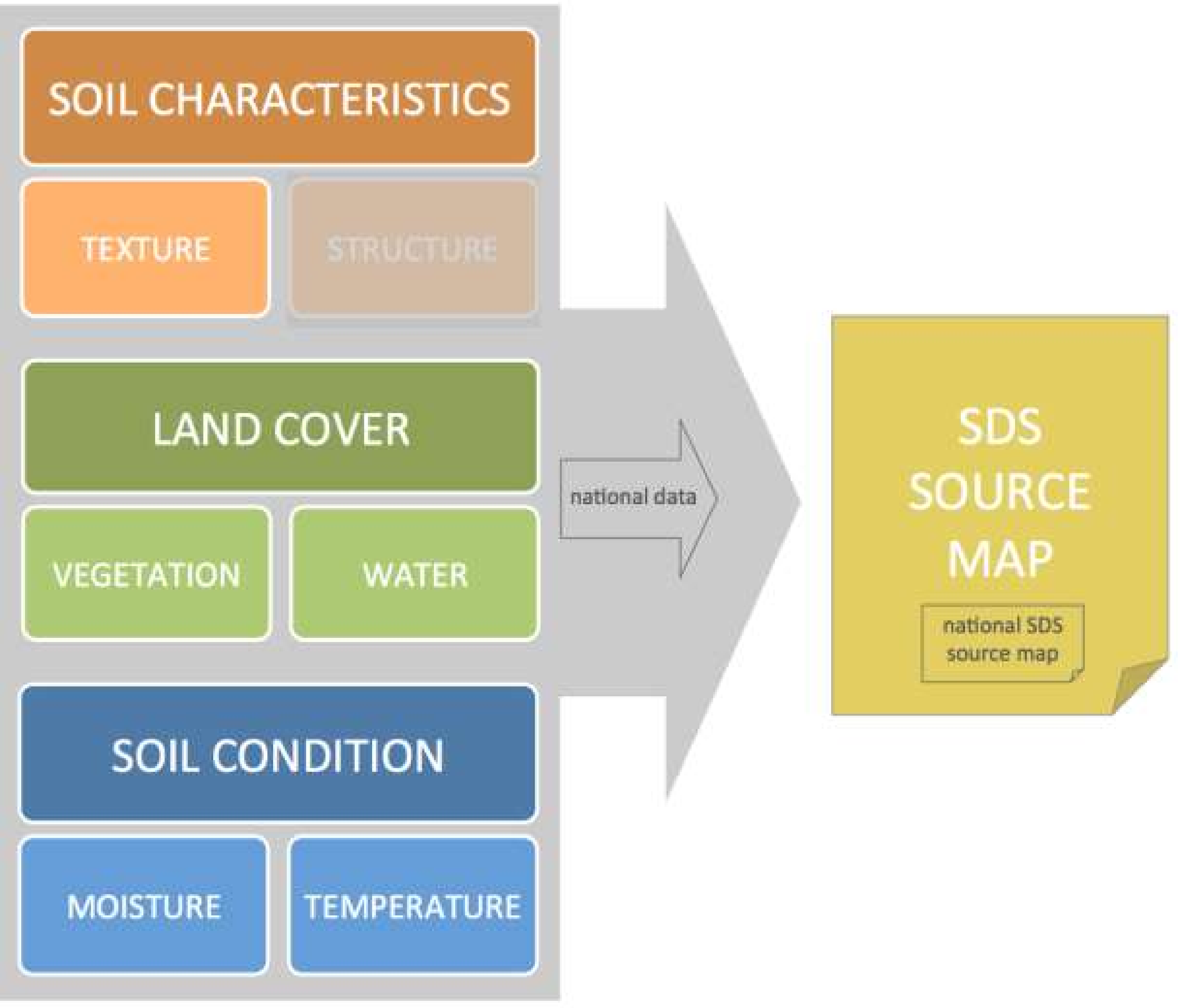
MAJOR DUST SOURCES WORLDWIDE

Field and satellite observations

The largest and most persistent sources are located in the Northern Hemisphere, mainly in a broad "dust belt" that extends from the west coast of North Africa, over the Middle East, Central and South Asia, to China.

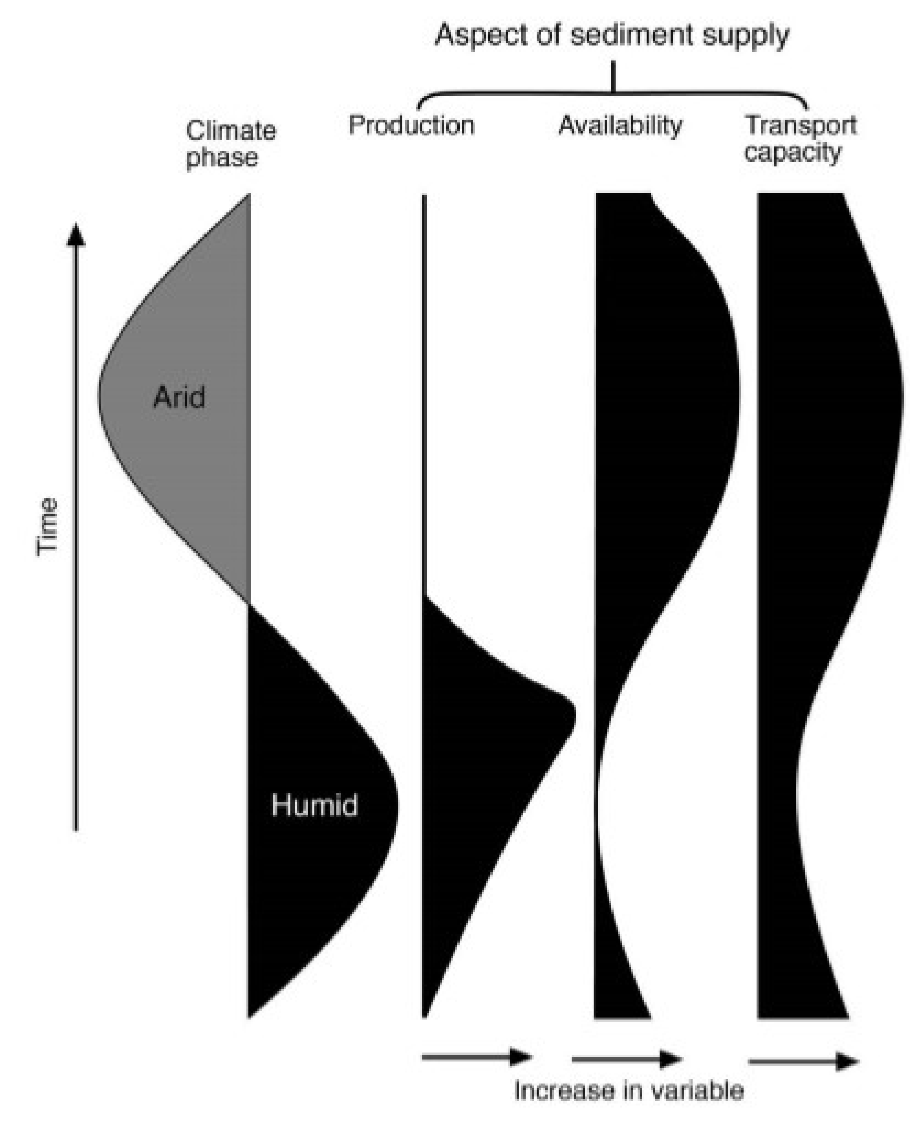


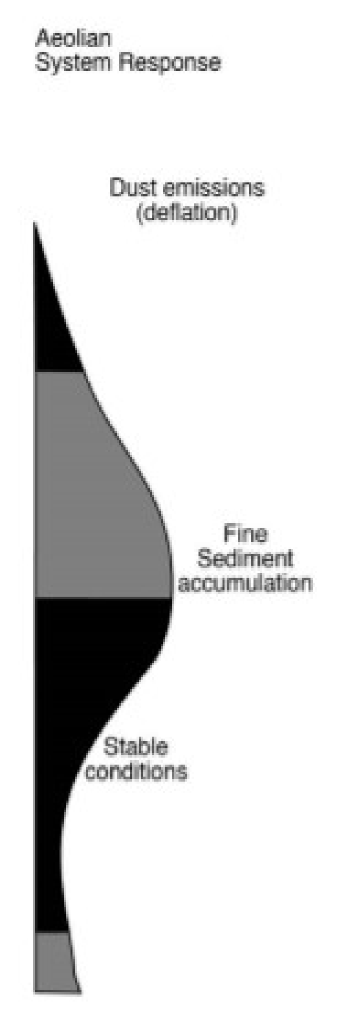
https://earthobservatory.nasa.gov/



After Vukovic Vimic,
https://cost-indust.eu/sites/default/files/2021-04/vukovic_indust_webinar_april2021.pdf

Major dust sources worldwide are typically associated with specific geomorphological settings and environments.





Dust Source Terrains: general characteristics

Dust sources are located in arid regions; they are often located on topographical lows or on lands adjacent to reliefs.

The action of WATER is evident (ephemeral rivers, streams, alluvial fans, playas, saline lakes), although the source regions themselves are arid or hyperarid.

Fluvial processes are much more efficient in the production of small particles (Ø<10 µm) than aeolian processes (grinding and impaction).
Fluvial action transports small particles away from the parent rocks & soils into depositional basins or alluvial plains. After drying, these are subject to wind deflation.

In general, areas where the recent geomorphological history has favored the concentration of fine-grained material and the creation of large areas with low surface roughness are preferential sources

Dry lake beds

glacial outwash plains

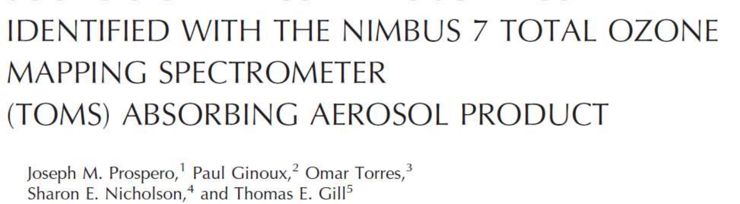
riverine floodplains

alluvial fans

If you want to know more .. Please read:

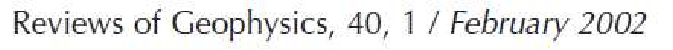
Middleton et al.,1986;
Ginoux et al., 2001;
Prospero et al., 2002;
Mahowald et al., 2003;
…..

Prospero et al. 2002

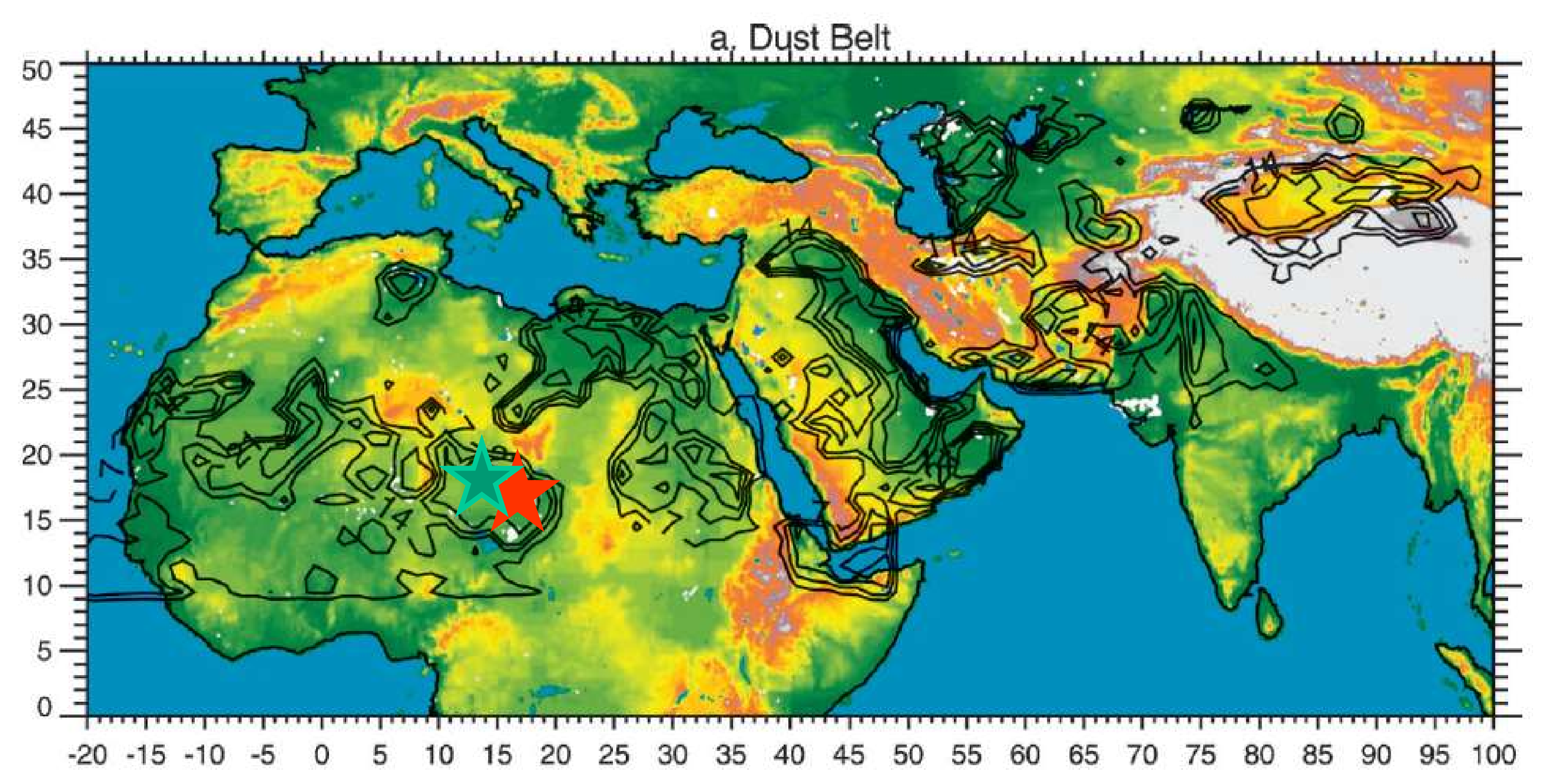


ENVIRONMENTAL CHARACTERIZATION OF GLOBAL SOURCES OF ATMOSPHERIC SOIL DUST IDENTIFIED WITH THE NIMBUS 7 TOTAL OZONE MAPPING SPECTROMETER (TOMS) ABSORBING AEROSOL PRODUCT

Joseph M. Prospero,[1] Paul Ginoux,[2] Omar Torres,[3]
Sharon E. Nicholson,[4] and Thomas E. Gill[5]



Reviews of Geophysics, 40, 1 / *February 2002*



★ ★ Bilma and Bodélé depressions

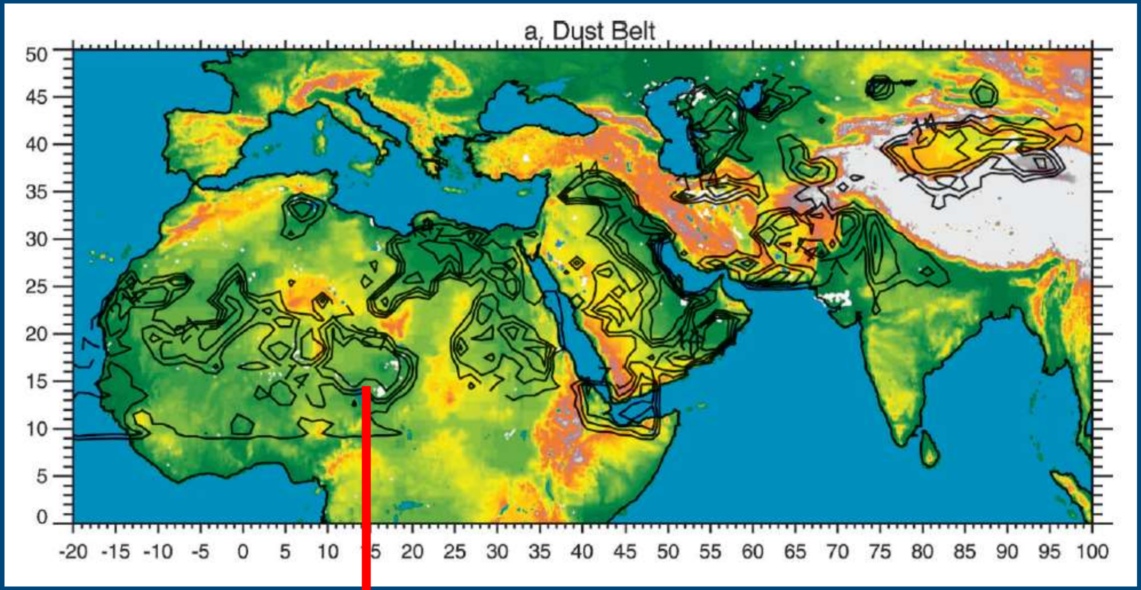
Present-day **Lake Chad** lies in the southern end of a large drainage basin.

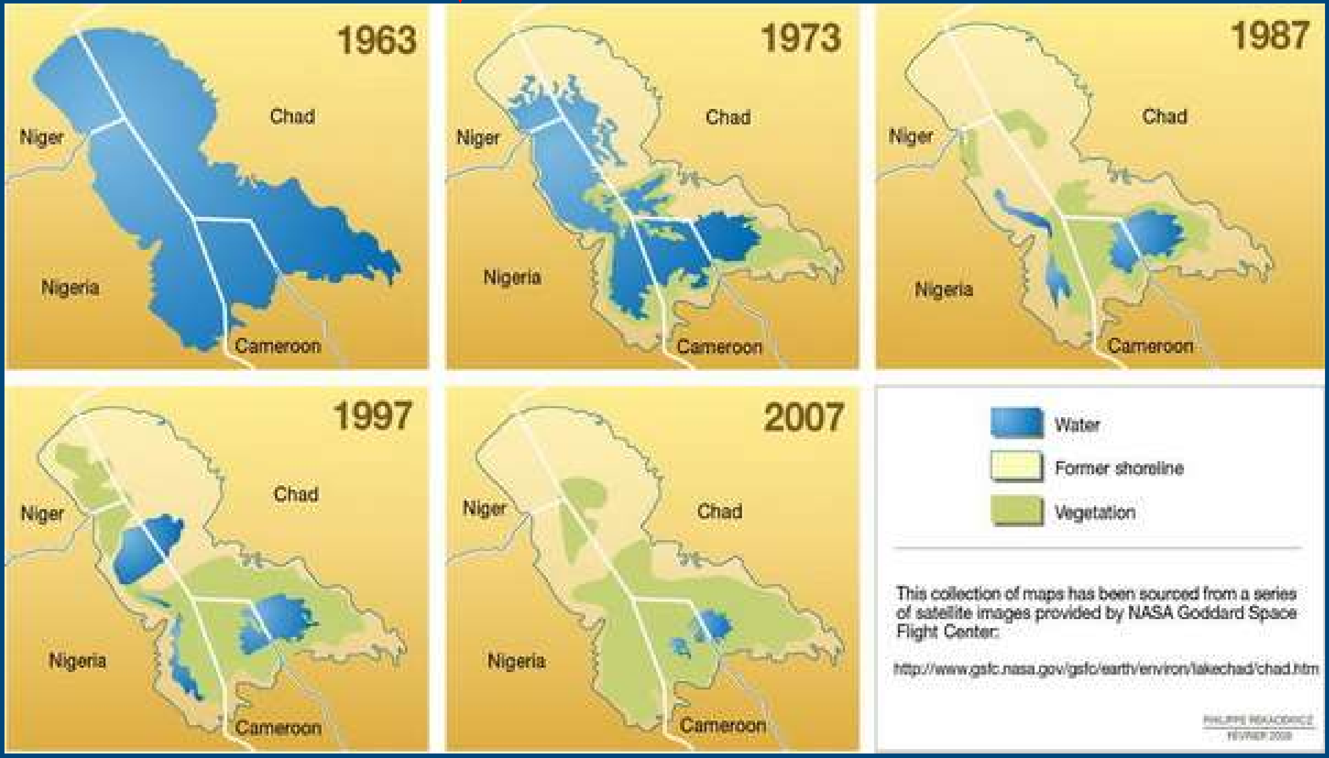
In the past, Lake Chad was quite large, covering an area that is roughly comparable in size to the area of present-day intense dust activity.

Today the basin is covered with a complex variety of:

- sandy sediments
- saline playas with evaporites
- Fine-grained lacustrine deposits

rich source of dust





This collection of maps has been sourced from a series of satellite images provided by NASA Goddard Space Flight Center:

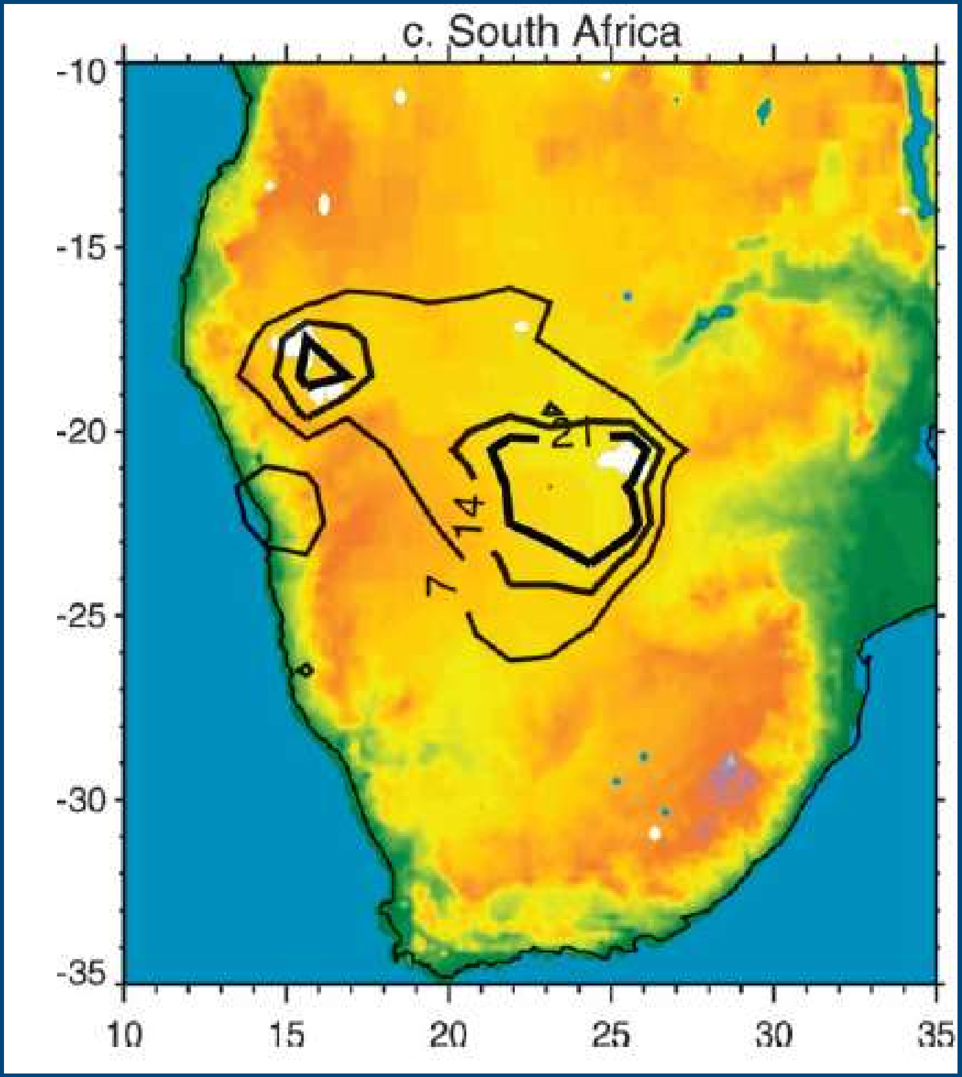
http://www.gsfc.nasa.gov/gsfc/earth/environ/lakechad/chad.htm

PHILIPPE REKACEWICZ
FEVRIER 2008

SOUTH AFRICA

A continuous source for dust is located in Botswana (region centered at 21°S, 26°E). Dust activity is centered over the western end of the Makgadikgadi Depression, occupied during the Pleistocene by a great lake, the Palaeo-Makgadikgadi (Goudie, 1996).

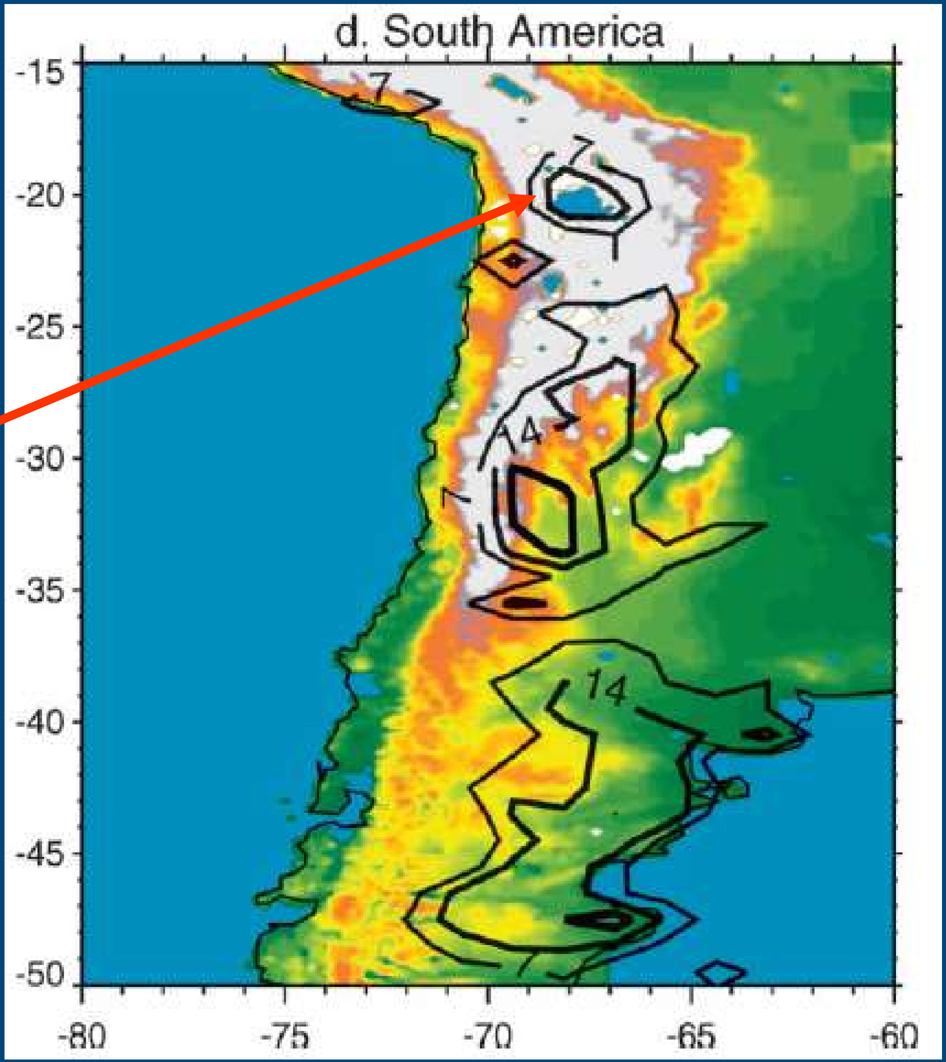
A second small but persistent source is centered at 16°E, 18°S over the Etosha Pan, Northern Namibia, at the extreme northwest of the Kalahari basin. During the Pleistocene also the Etosha Pan basin was occupied by a large lake (Goudie, 1996).



South America

Three dust source regions can be observed.

(1)
Bolivian Altipiano, arid intermountain basin situated at about 3750-4000 m altitude that includes two of the largest salt flats (salars) of the world. A large part of the Altipiano was occupied in the Pleistocene by a lake, whose sediments are exported today by the strong winds blowing over the region.

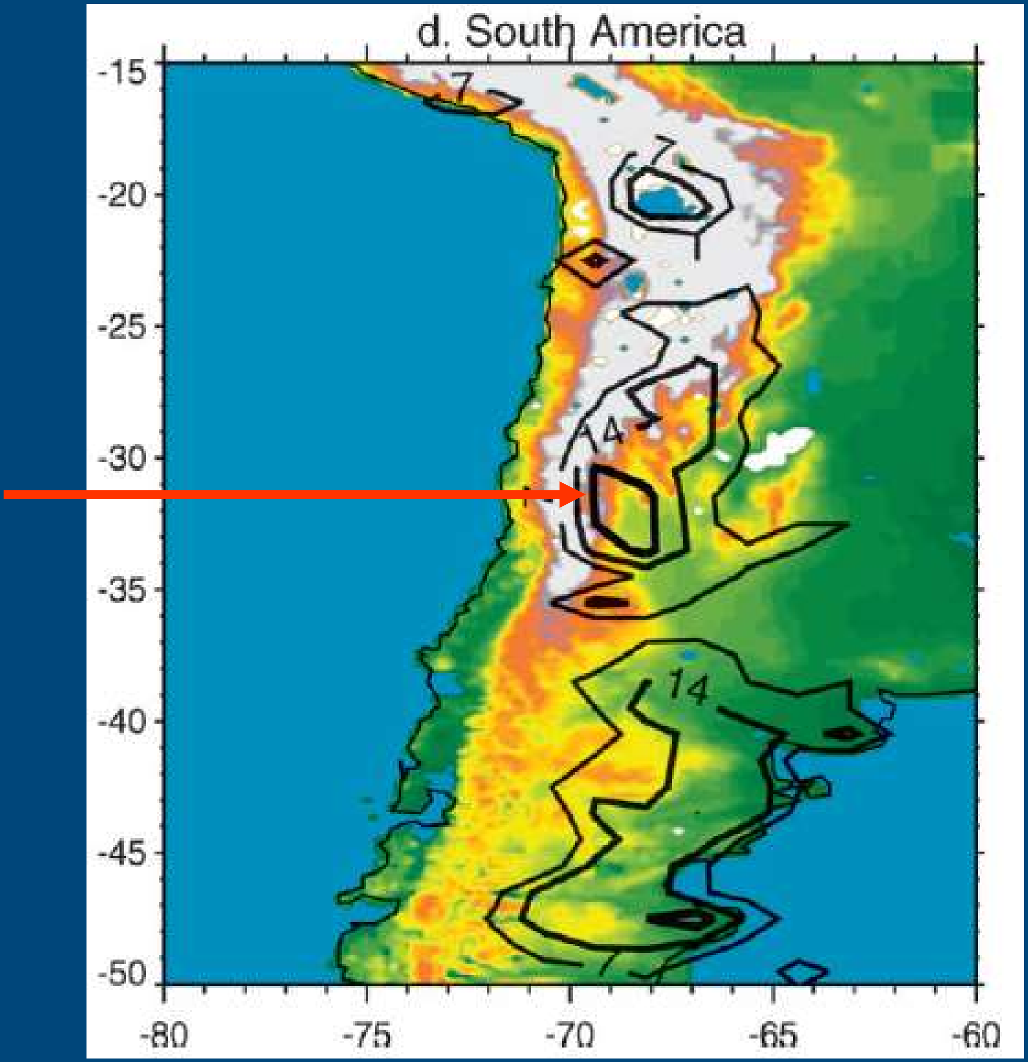


(2)

Argentina along the eastern flanks of the Andes (27-34°S, 67-70°W).

Dust activity is centered in an intermountain area between the Andes (West) and the Sierra de San Luis/Sierra de Cordoba (East).

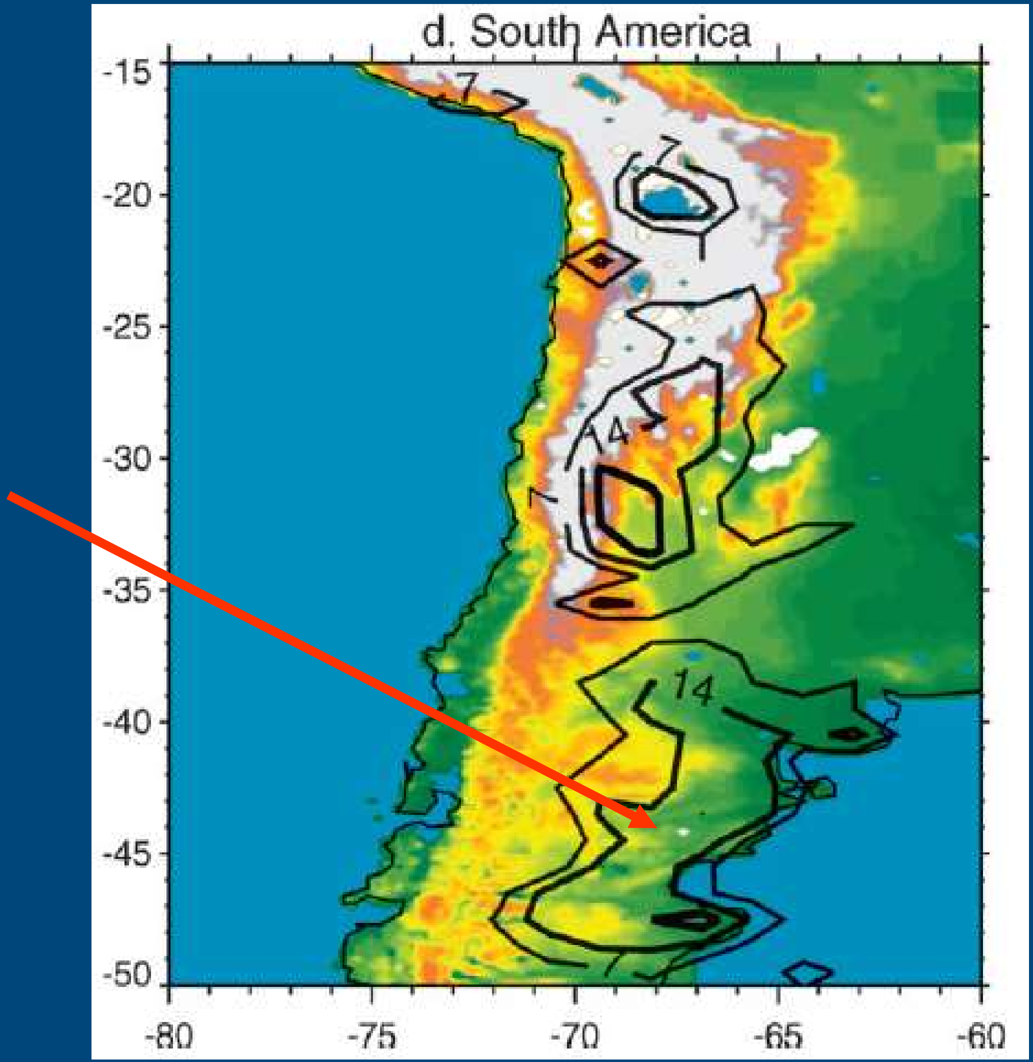
It can be observed that the most active area lies in the western part of this region.



(3)

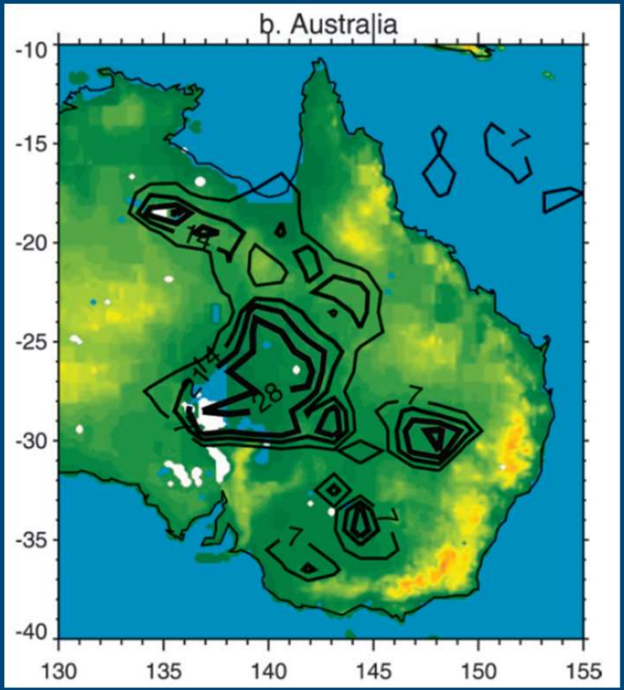
Finally, a large dust source region includes the Southern Pampas and Northern Patagonia

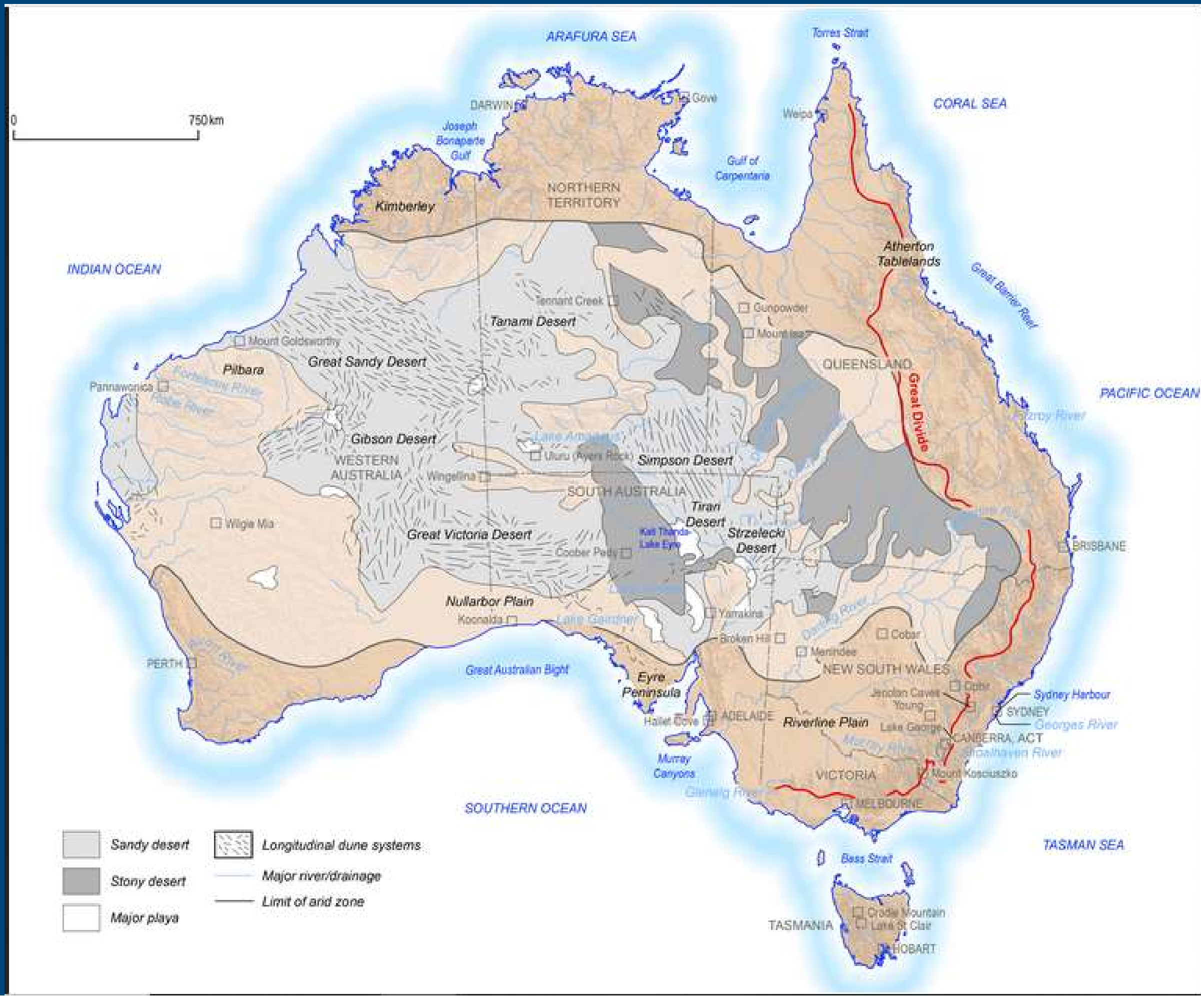
Arid-to-semiarid region spanning from the eastern flanks of the Andean Cordillera to the Atlantic coast.



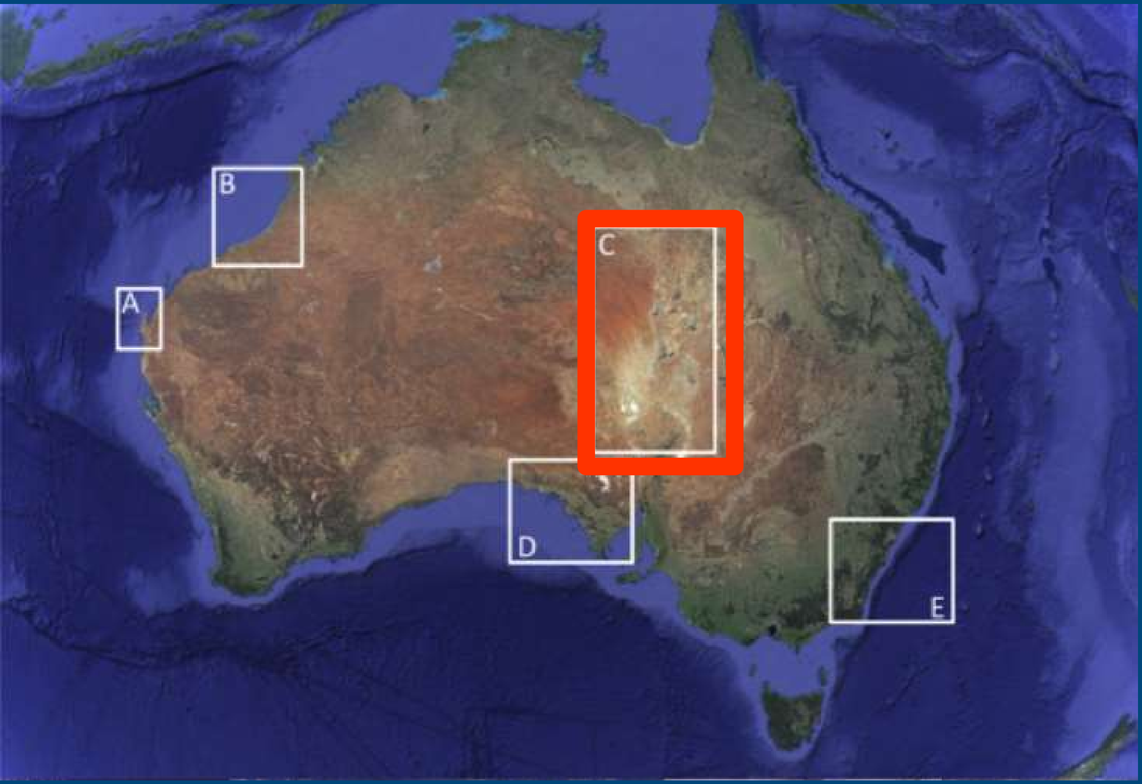
Example: the case of Australia

Sand dune systems are not good sources of dust transported long-range as they are not rich in fine particles that can be carried by winds to high altitudes and over great distances. At first glance, it could seem surprising that such a large and arid continent is devoid of major sources for long-range transported dust. Some authors found an explication for this in the flat topography of the continent, and the lack of renewal of small particles.



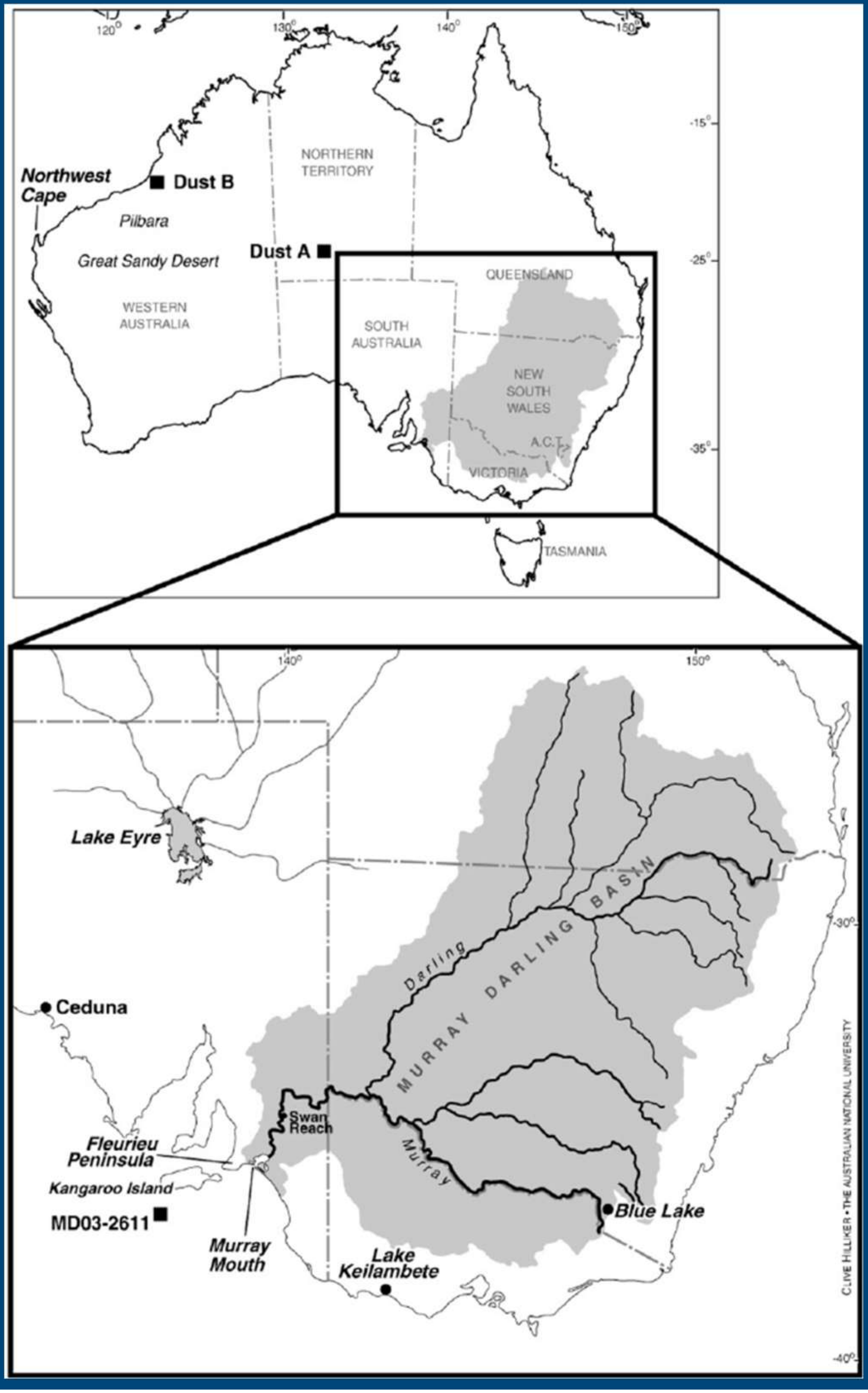


Kati Thanda-Lake Eyre



Today, the most active dust area is located North-East of present-day Lake Eire, corresponding to the pluvial Lake Dieri (ancestral Lake Eire).

Murray and Darling Basins



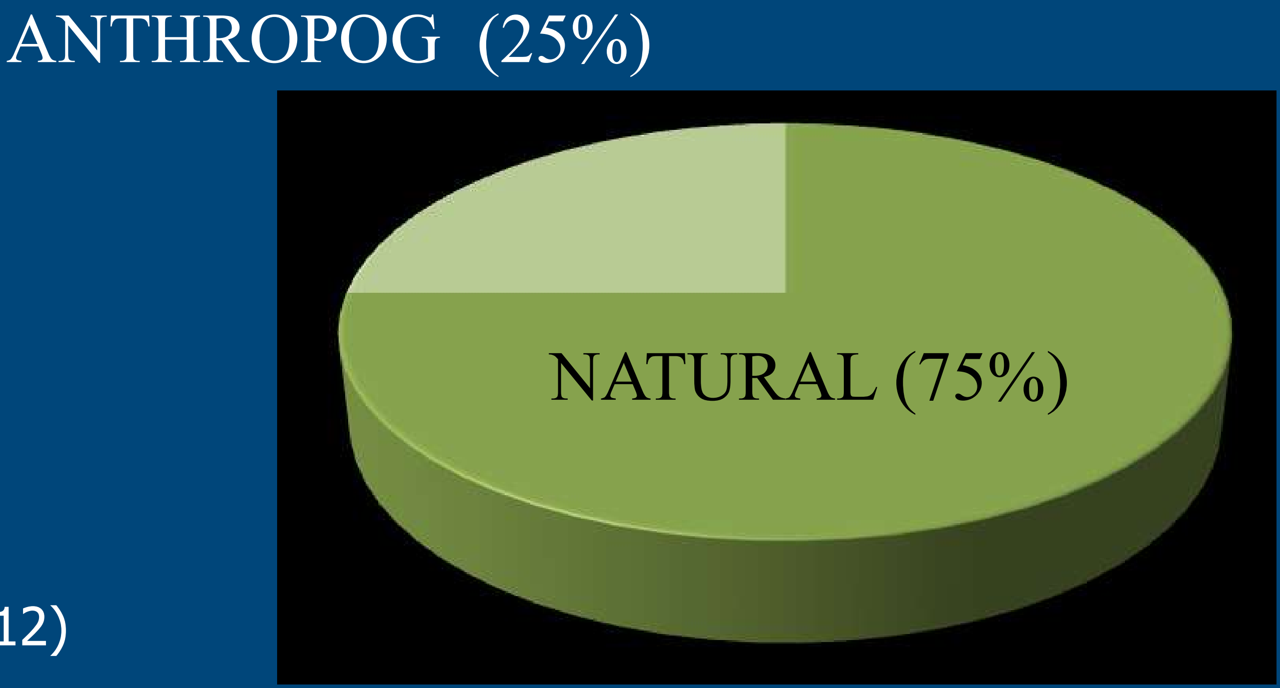
Global dust sources at present-day

Natural

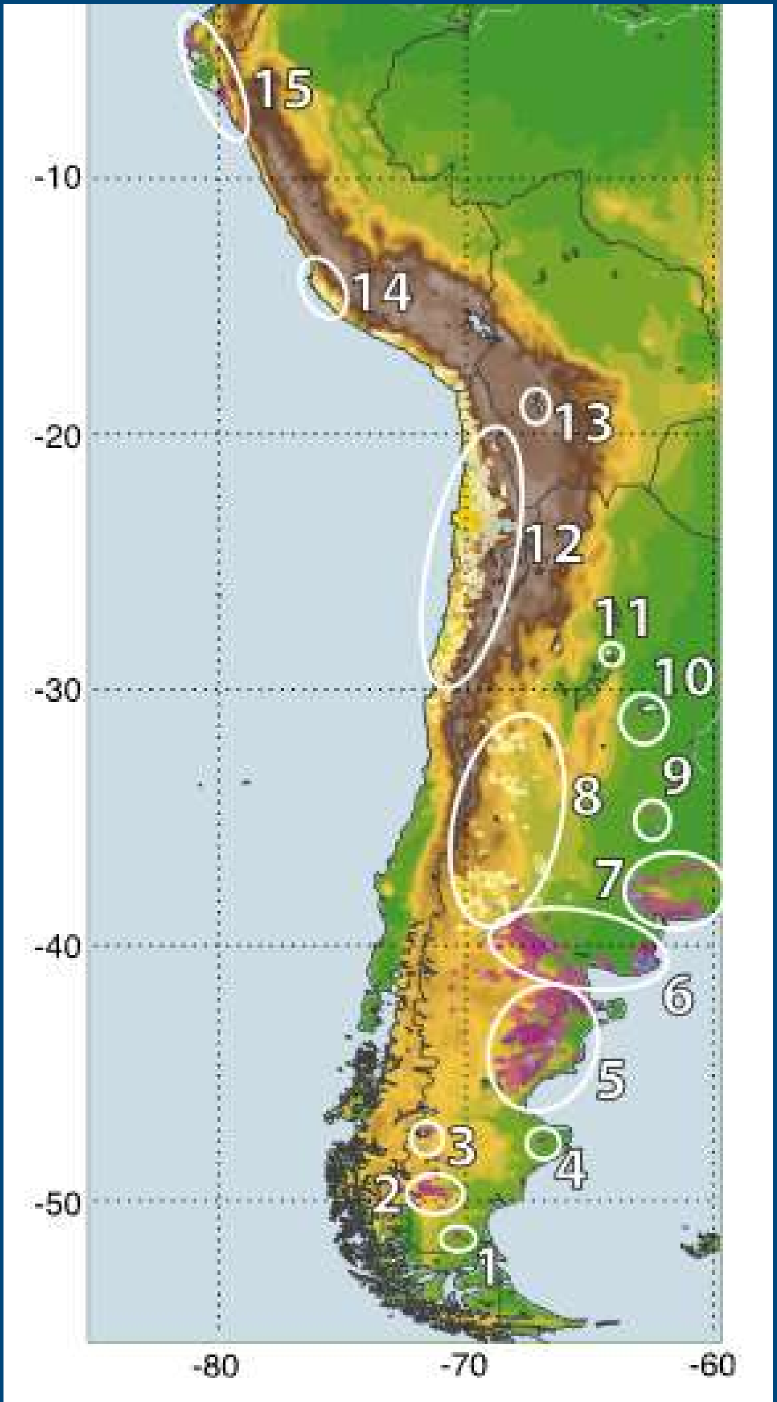
Bare, dry surfaces, fine texture
Dry river beds, ephemeral lakes,
paleo-lakes, seabeds.

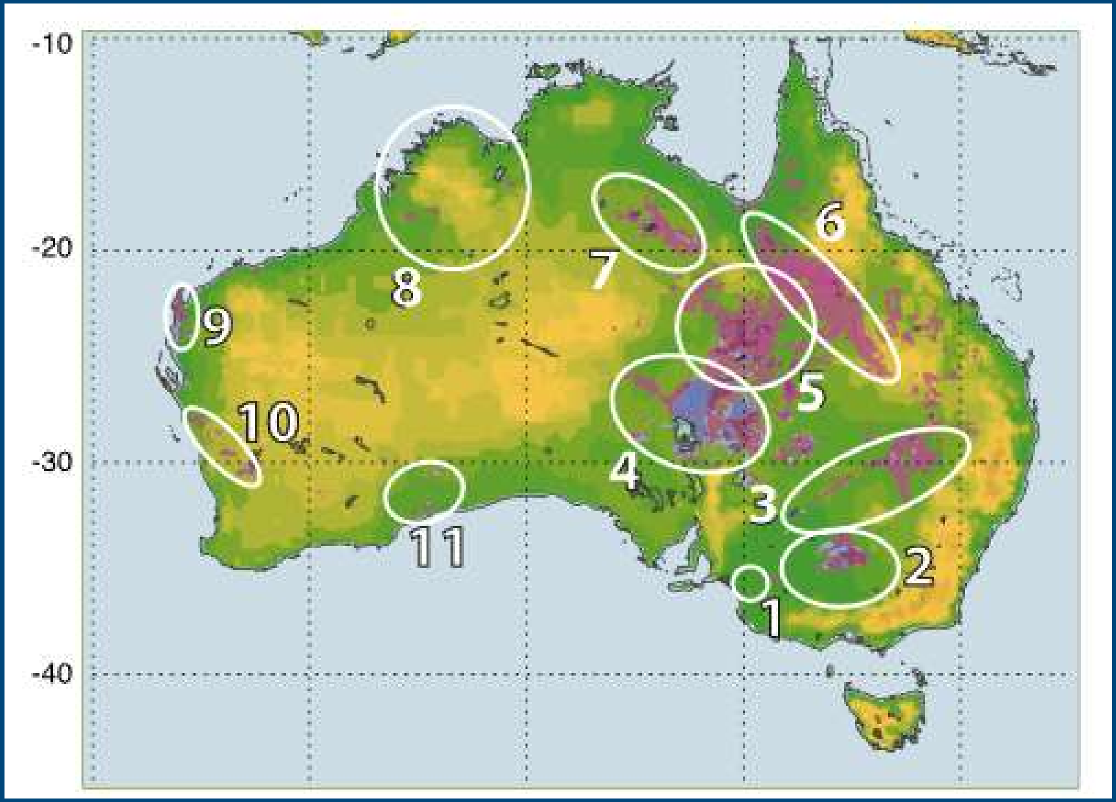
Anthropogenic

No geochemical differences with natural sources, but associated to land use or land use change

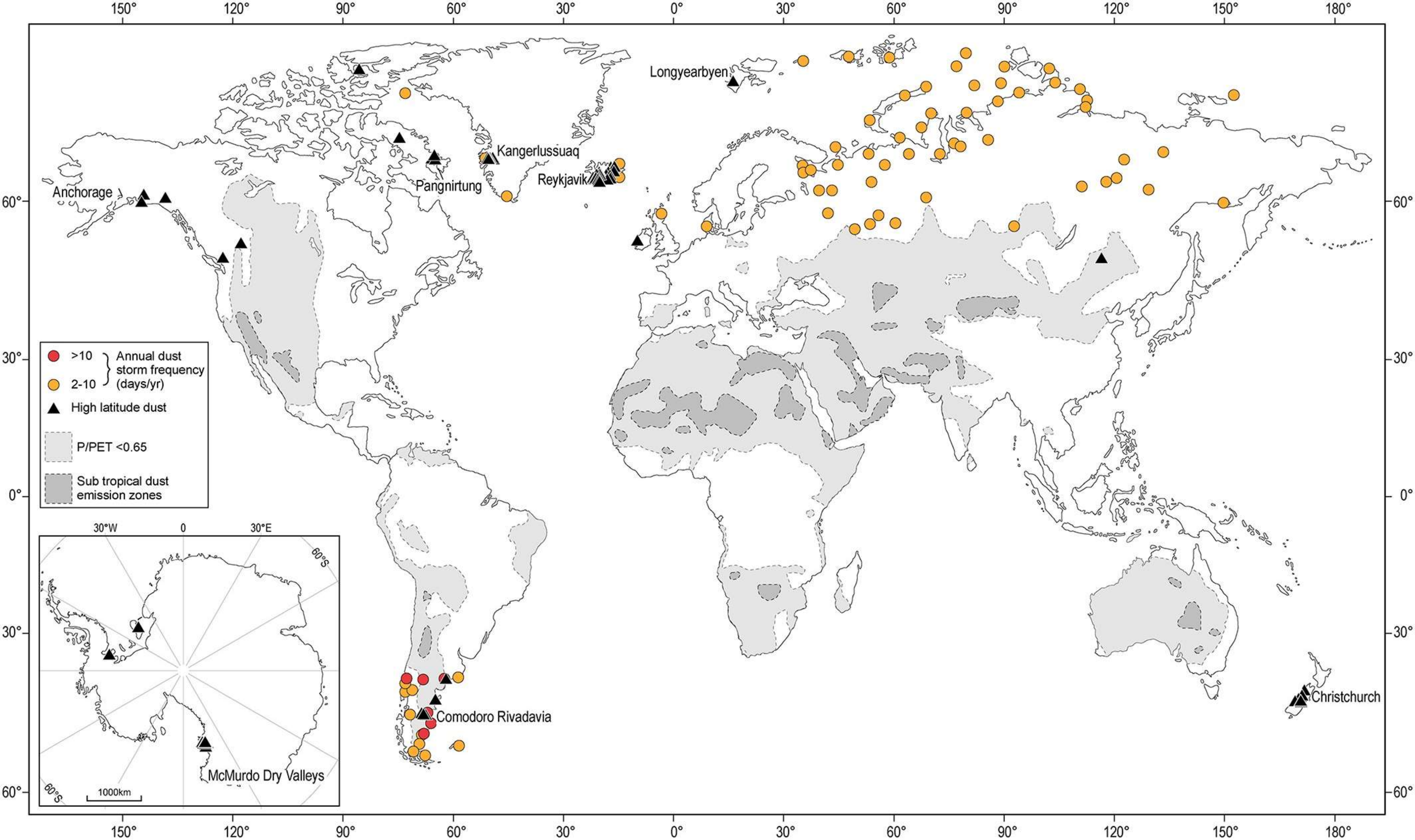


(Ginoux et al., 2012)





Since anthropogenic dust sources are associated with land use and ephemeral water bodies, both in turn linked to the hydrological cycle, their emissions are affected by climate variability. Such changes in dust emissions can impact climate, air quality, and human health.

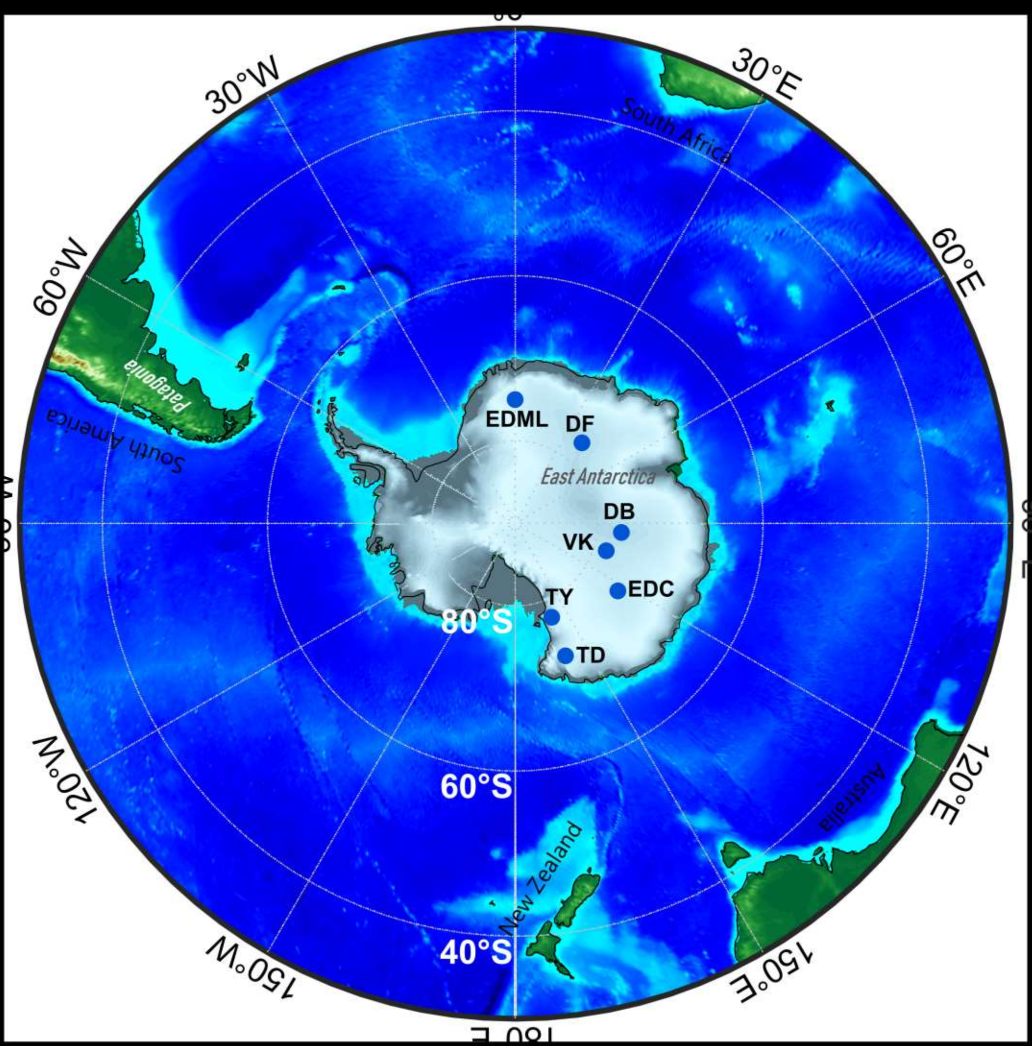


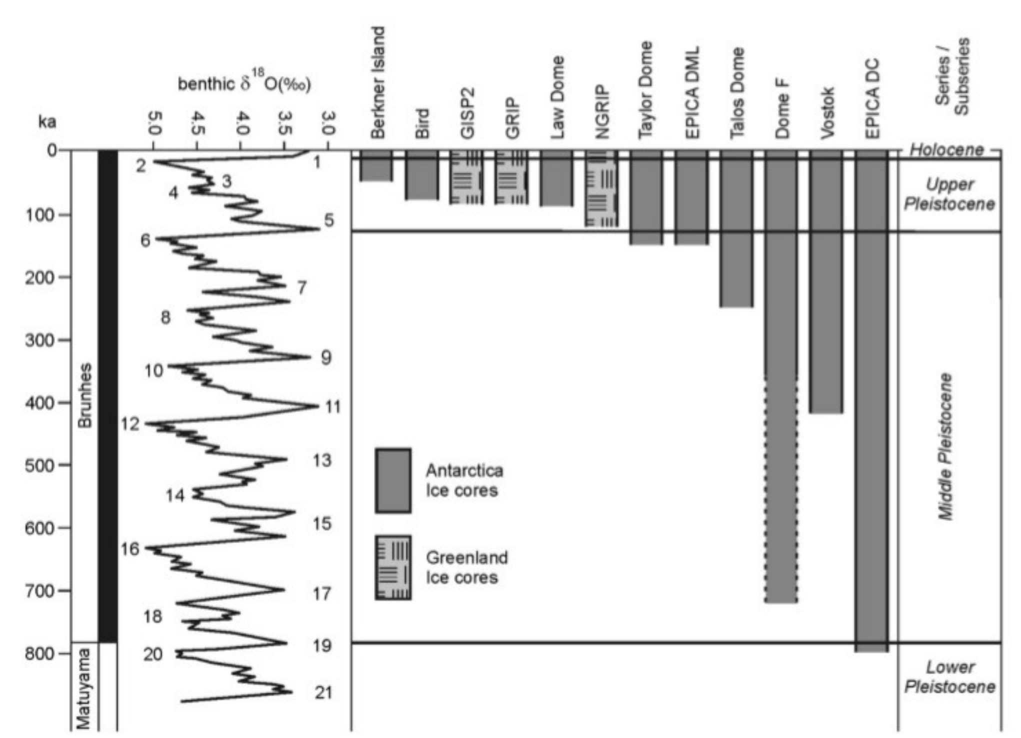
150°
120°
90°
60°
30°
0°
30°
60°
90°
120°
150°
180°
60°
30°
0°
30°
60°
Anchorage
Pangnirtung
Kangerlussuaq
Reykjavik
Longyearbyen
Comodoro Rivadavia
Christchurch
McMurdo Dry Valleys
● >10
● 2-10
Annual dust storm frequency (days/yr)
▲ High latitude dust
▨ P/PET <0.65
▨ Sub tropical dust emission zones
30°W
0
30°E
60°S
60°S
1000km

Back in time:
the longest dust records from polar ice cores

NATURAL ARCHIVES of EARTH’S CLIMATE HISTORY

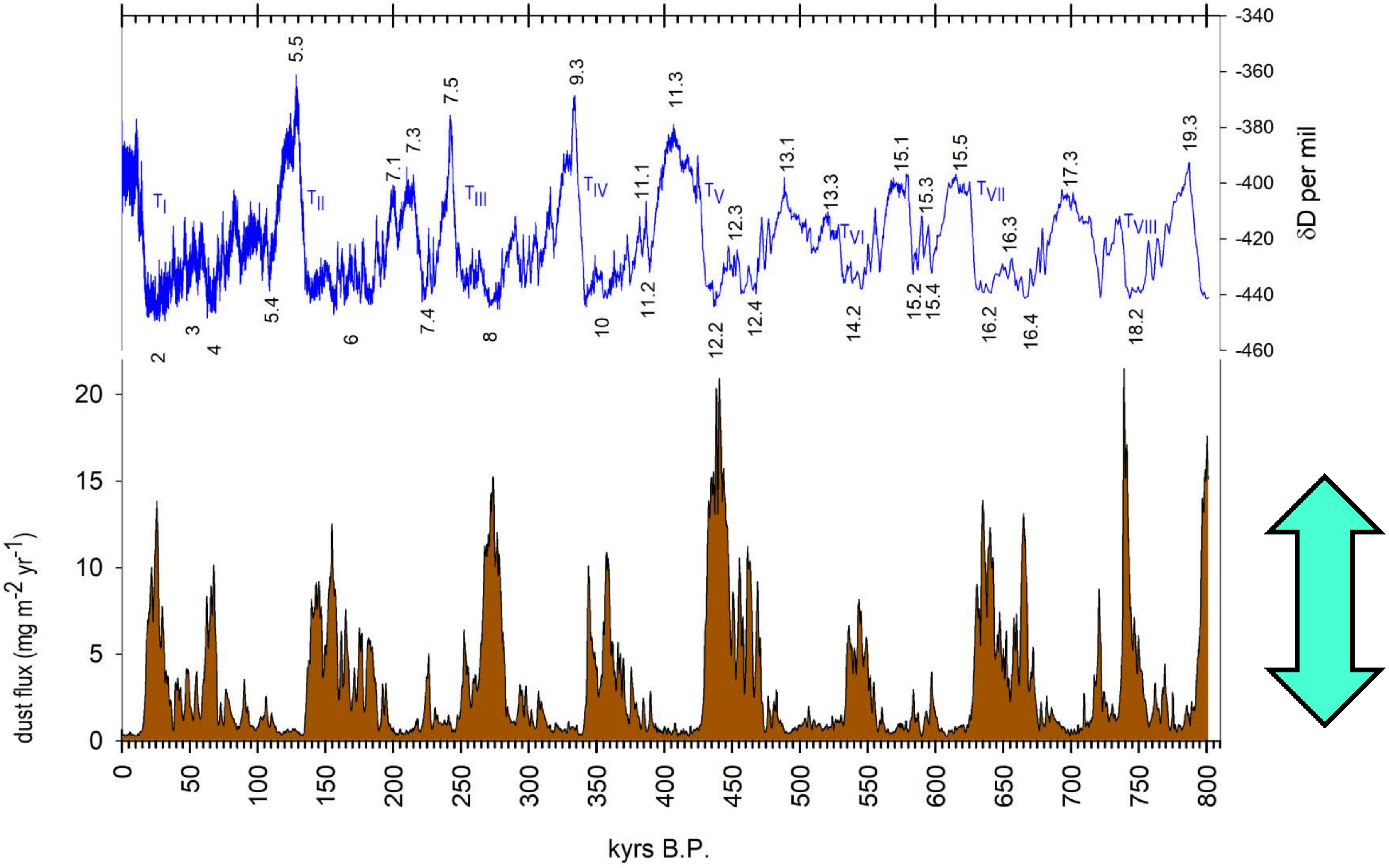
Natural materials accumulating progressively in time and responding to climate and environmental changes.





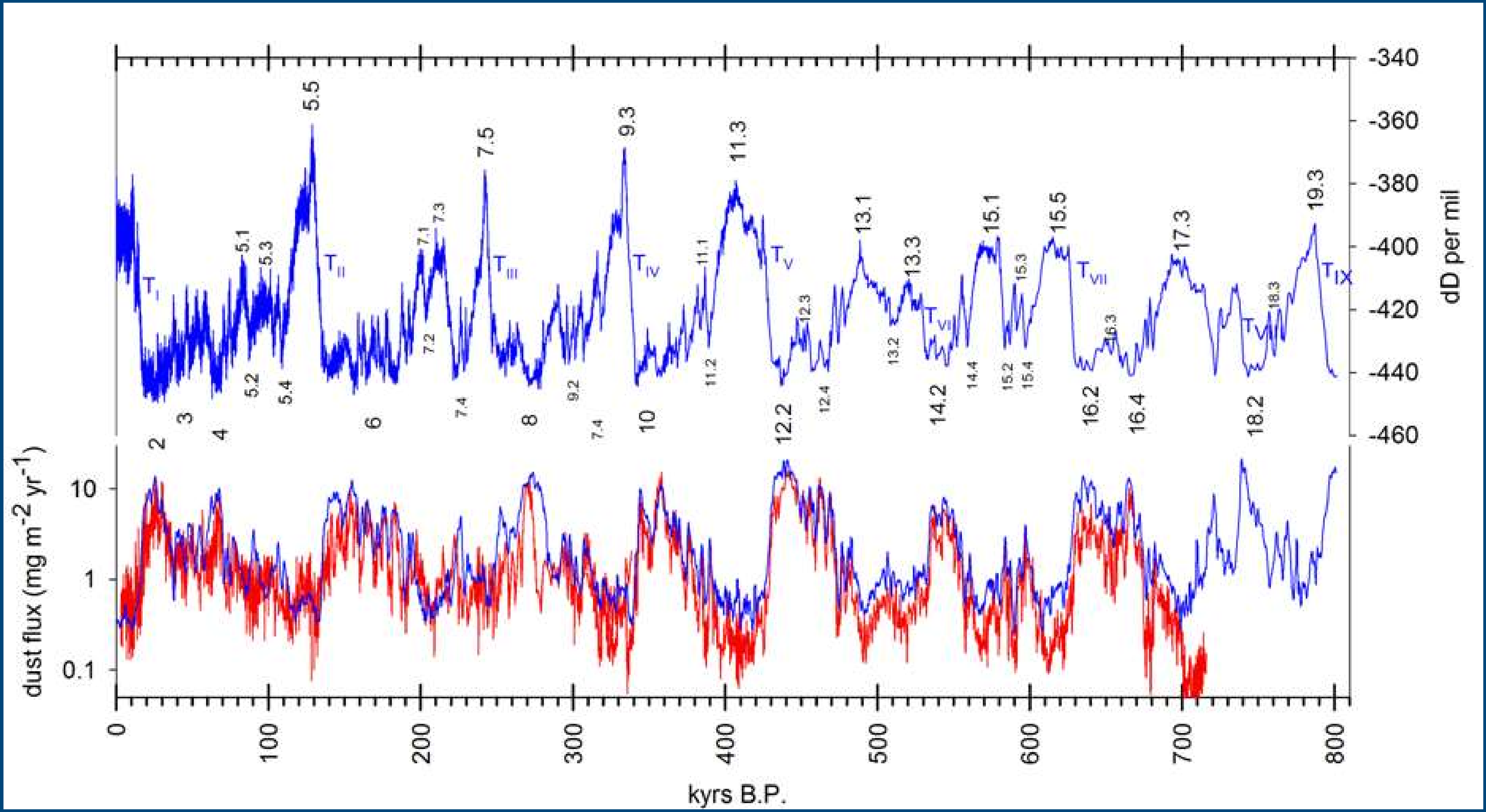
Orombelli et al., 2009

800.000 years of dust



~25 (flux)
=50 (concentration)

On G/I timescale, eolian dust records from central East Antarctica reflect climate changes in the Southern Hemisphere (Lambert et al., 2008)



Dome Fuji

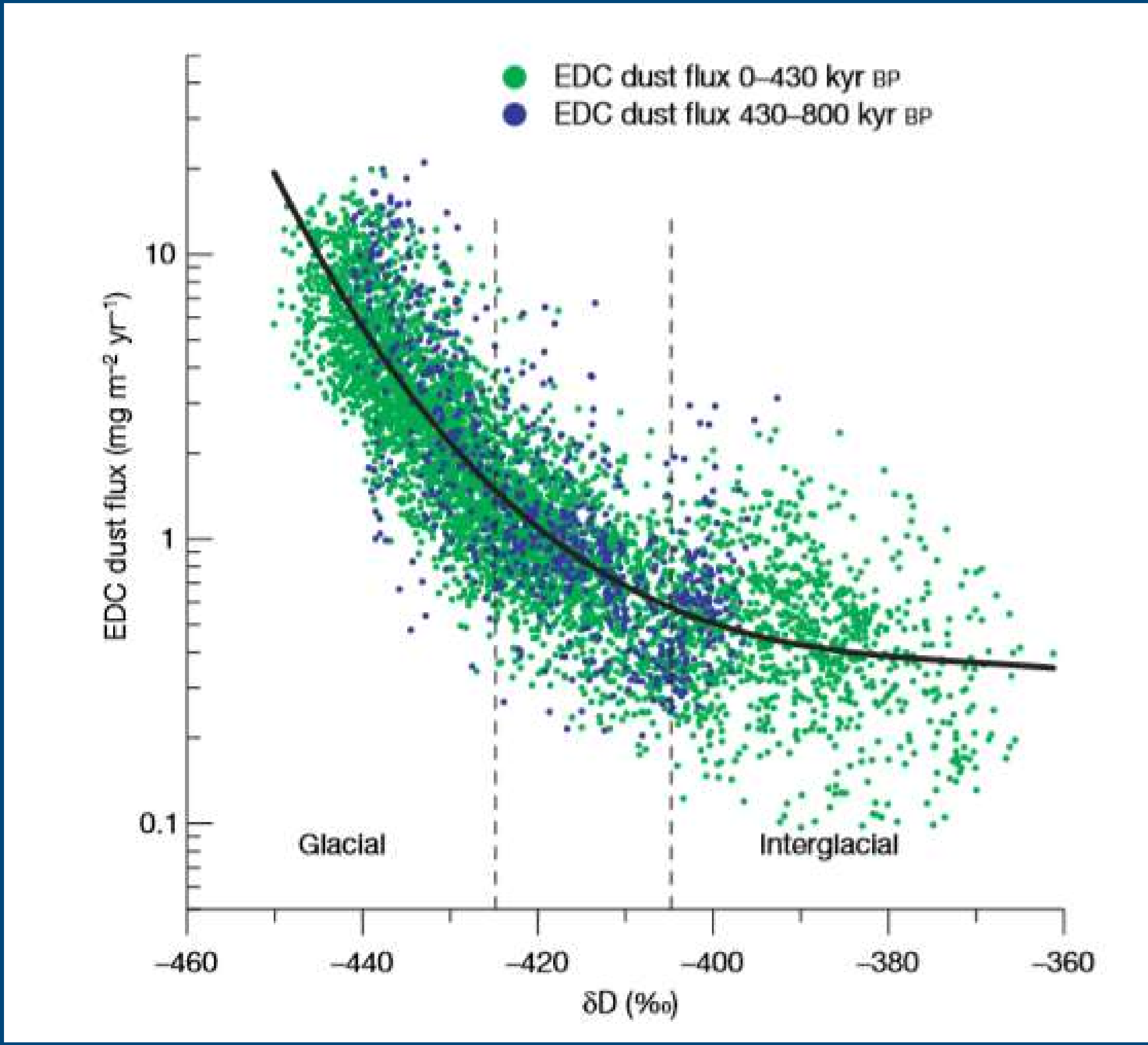
EPICA Dome C

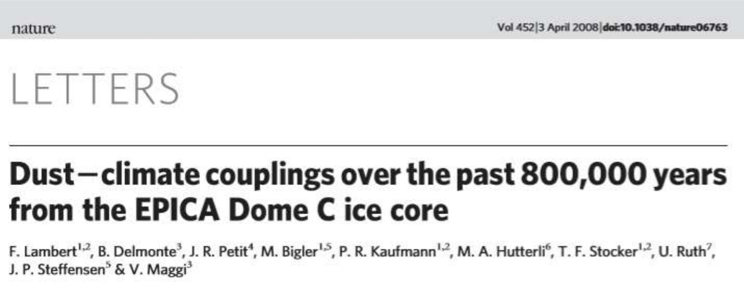
Redrawn from:
Lambert et al., 2008 - EDC
Kawamura et al., 2017 – Dome F

Expression of a progressive coupling between high- and low-latitude climate as temperatures become colder

dust fluxes have a higher temperature sensitivity as the climate becomes colder

direct influence of the Antarctic climate on mid-latitude climate coincident with the significantly extended sea ice over the Southern Atlantic





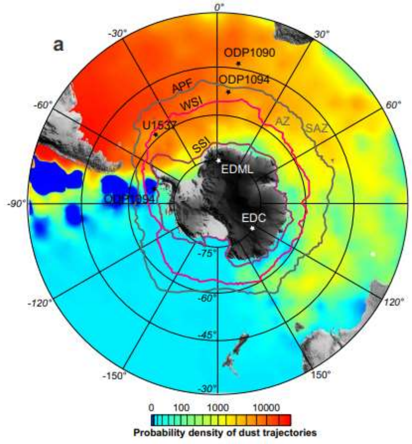
nature Vol 452|3 April 2008|**doi:10.1038/nature06763**

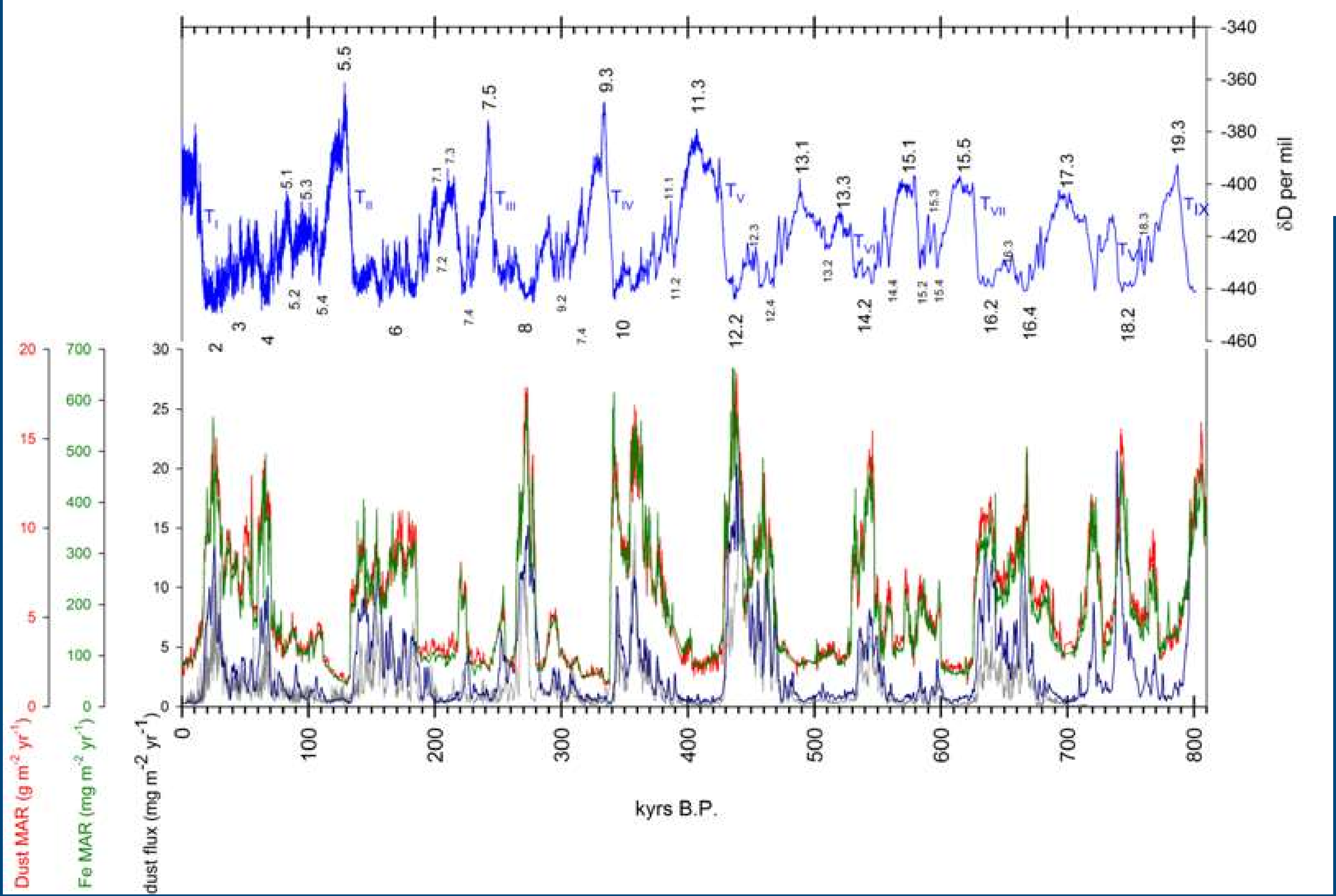
LETTERS

Dust–climate couplings over the past 800,000 years from the EPICA Dome C ice core

F. Lambert[1,2], B. Delmonte[3], J. R. Petit[4], M. Bigler[1,5], P. R. Kaufmann[1,2], M. A. Hutterli[6], T. F. Stocker[1,2], U. Ruth[7], J. P. Steffensen[5] & V. Maggi[3]

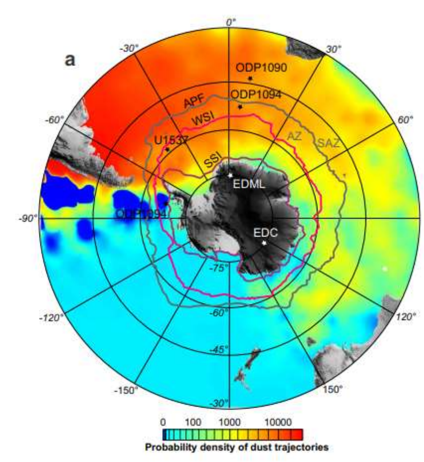
South Atlantic records of dust: ODP1090

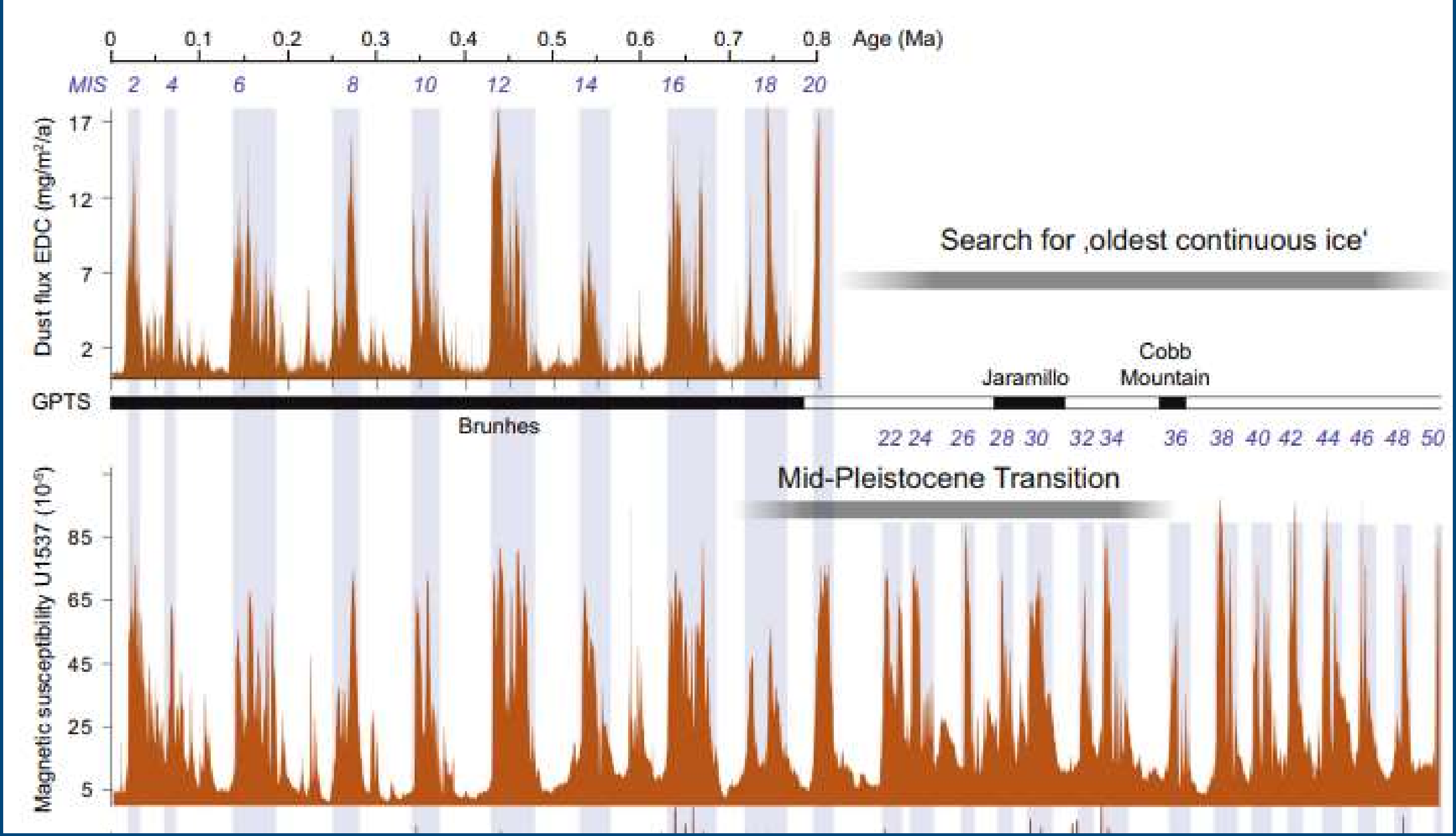




Redrawn from Martinez-Garcìa et al., 2011

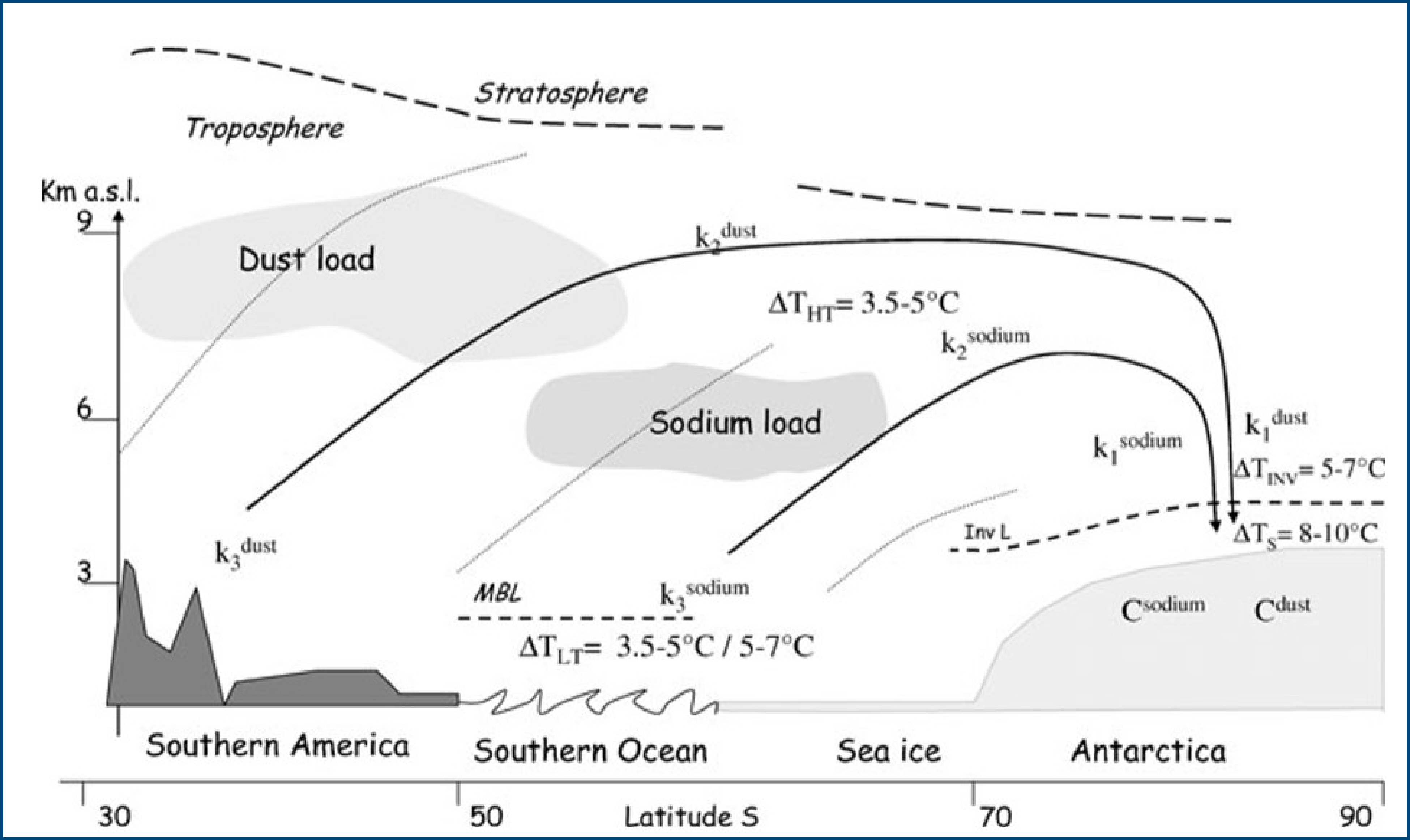
South Atlantic records of dust: U1537





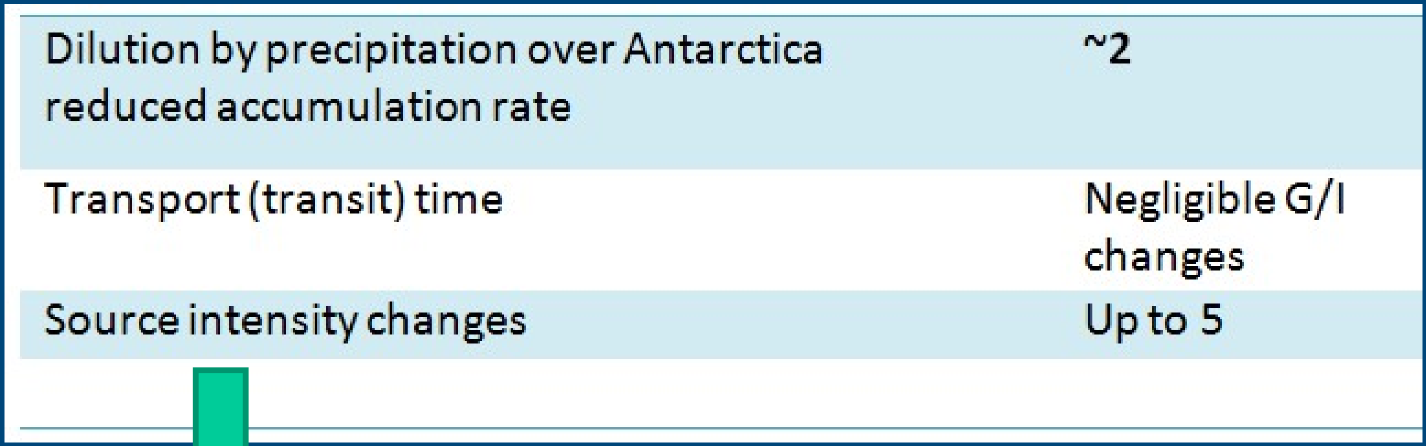
Weber et al 2022

Dust reaching Antarctica is transported at high altitude, well above the marine boundary layer



small dust particles likely follow a long and complex trajectory at high altitude prior to reaching the poles.

G/I concentration changes (~50)



Dilution by precipitation over Antarctica reduced accumulation rate	~2
Transport (transit) time	Negligible G/I changes
Source intensity changes	Up to 5

“SOURCE INTENSITY CHANGES DURING GLACIAL CONDITIONS” include:

(I) increased dust production and deflation resulting from enhanced aridity and reduced continental vegetation
(II) intensified surface winds
(III) increased amount of fine sediments resulting from glacial activity
(IV) expansion of deflation areas following exposure of continental shelves during glacio-eustatic low stand

Dilution by precipitation over Antarctica reduced accumulation rate	~2
Transport (transit) time	Negligible G/I changes
Source intensity changes	Up to 5
Dust lifetime	Up to 5

x50

Reduction of the hydrological cycle during glacial periods (compatible with ocean temperatures) leads to a factor **up to 5** in Antarctic dust concentrations and may solve the dust problem

Glacial dust input for Antarctica could be reproduced by assuming an atmospheric water vapor reduced by a factor of 2, along the dust pathway

(Yung et al., 1996, Petit & Delmonte 2009)

$$C/C_0 = \exp(-t\_t/\tau).$$

‘t_t’mean dust transit time

~1 month

NOT changing with climate

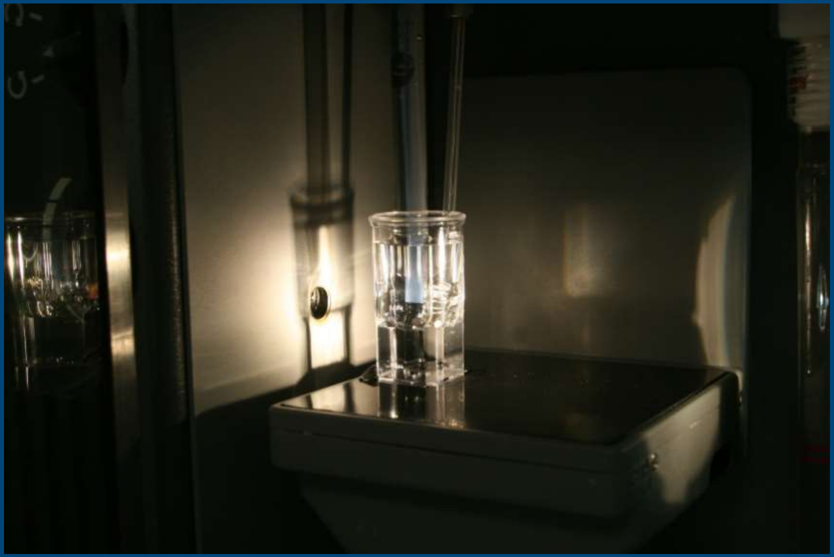
e-folding time (τ)
~1 week

changing with climate

Dust microphysical properties

Measurement techniques typically used are:

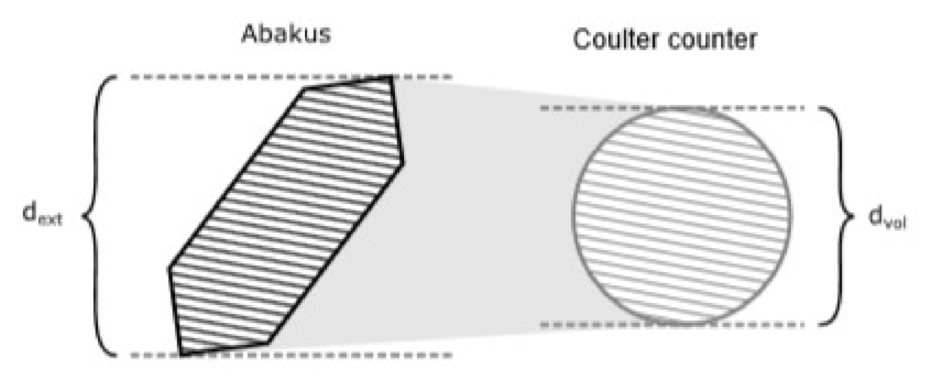
COULTER COUNTER



a tube with a small aperture is immersed into the sample and two electrodes are placed one inside the aperture tube and one outside the aperture tube but inside the beaker. As a particle passes through the aperture, a short-term change in the impedance across the aperture is generated; as the pulse height is proportional to the volume of the particle, the number of particles, volume and size distribution can be measured

ABAKUS LASER SENSOR

The Abakus measures the optical extinction cross section of the particle and can measure particles in the range 1–15μm. It is much less sensitive to electrical noise than the Coulter counter and can be applied in continuous



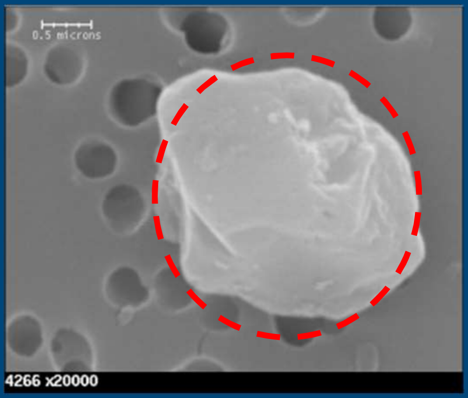
	Abakus	Coulter Counter
principle	Optical (laser 680 nm)	Electrical impedance
parameter measured	EXTINCTION CROSS SECTION	VOLUME (SPHERICAL EQUIVALENT)
concentration measurements	Relative concentration measured: calibration with CC is necessary for absolute values	Yes (reference values)
application	continuous flow systems	discrete samples
size distribution	pseudo-distribution biased by particle shape	Yes, high resolution (400 channels)

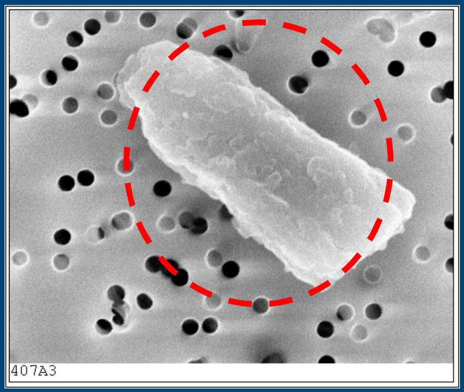
Antarctic dust is the small-sized end-member of dust emission

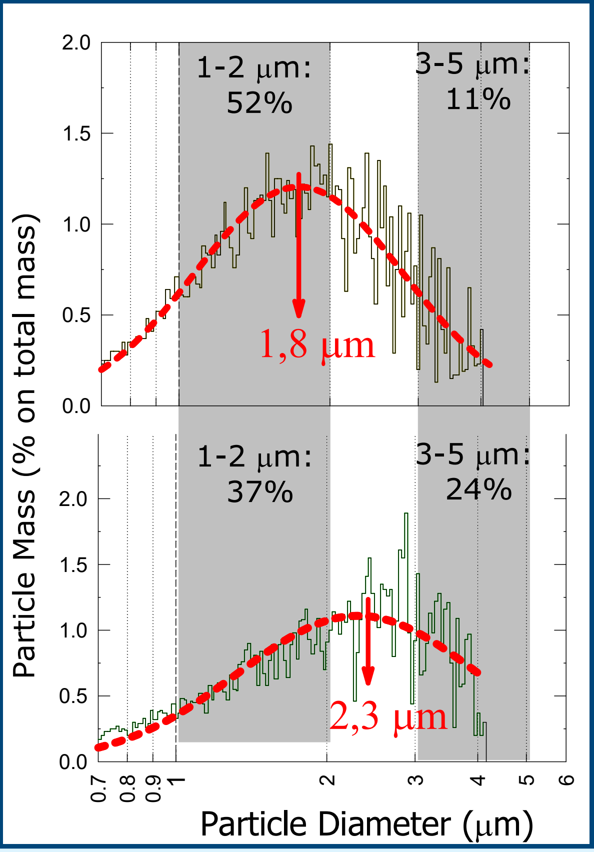
mode around 2 µm → significant time for larger size particles to settle

↓

long transport time within the atmosphere



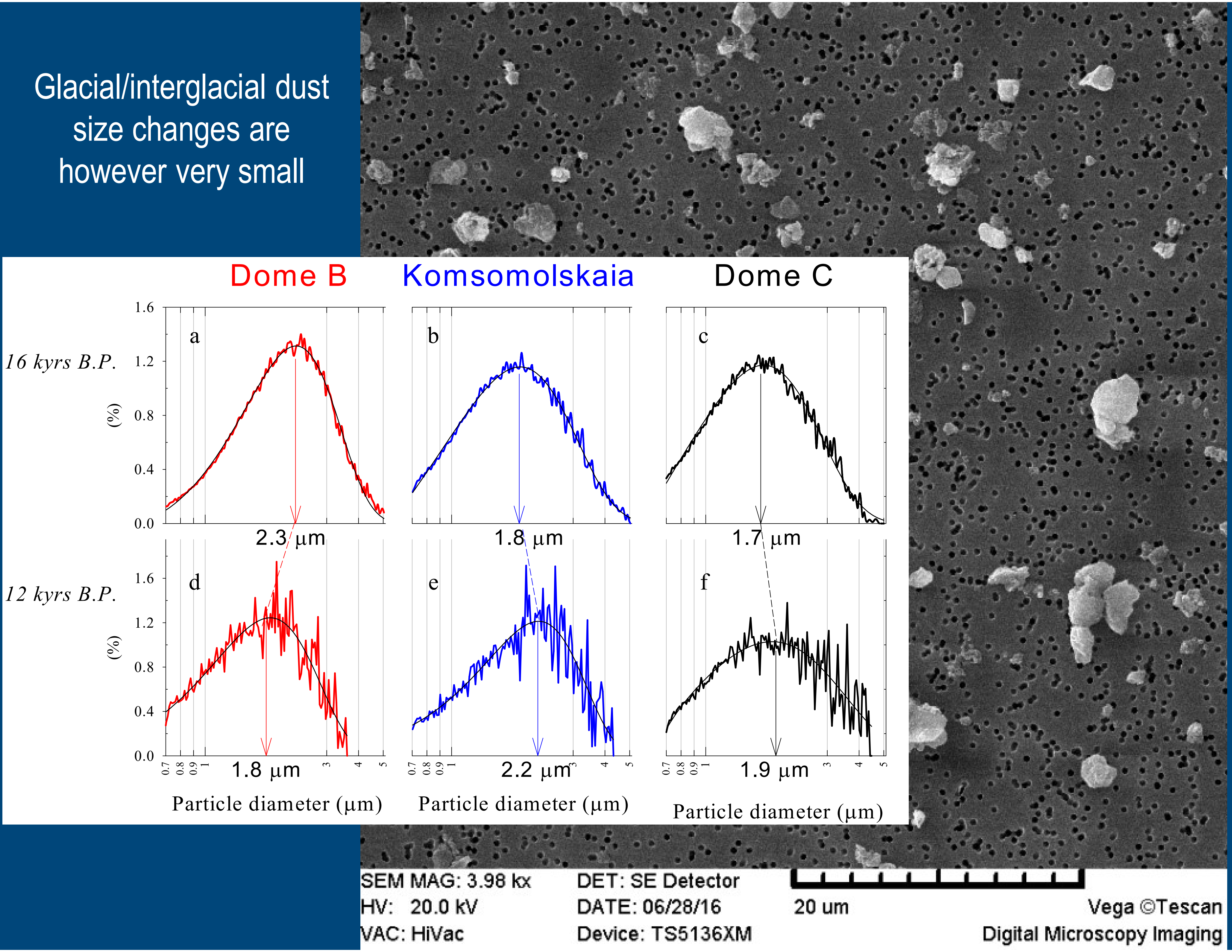




Small dust grain size changes are related to transport patterns and subsidence

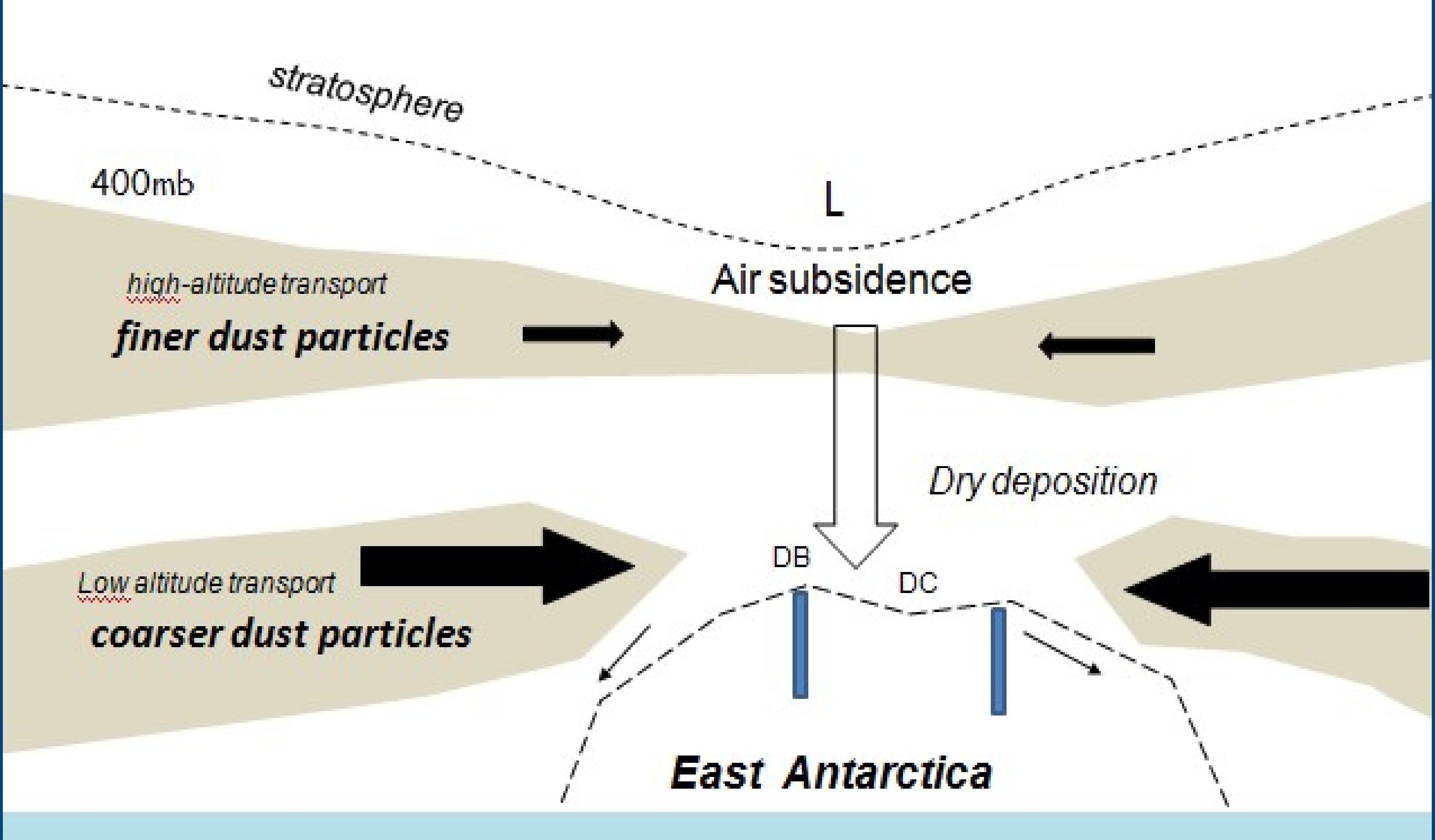
(Delmonte et al., 2017; 2004;2005)

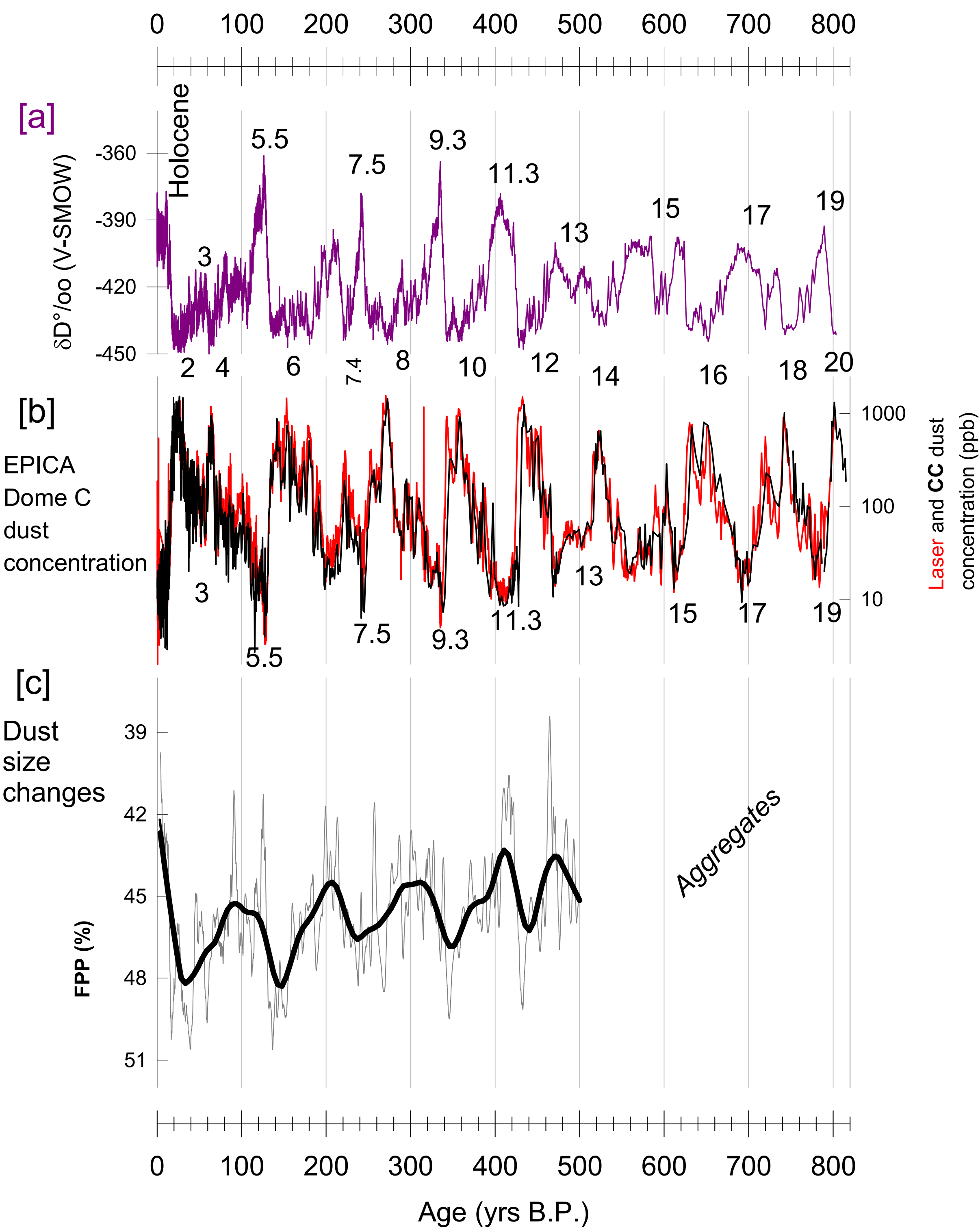
Glacial/interglacial dust size changes are however very small



Plateau sites

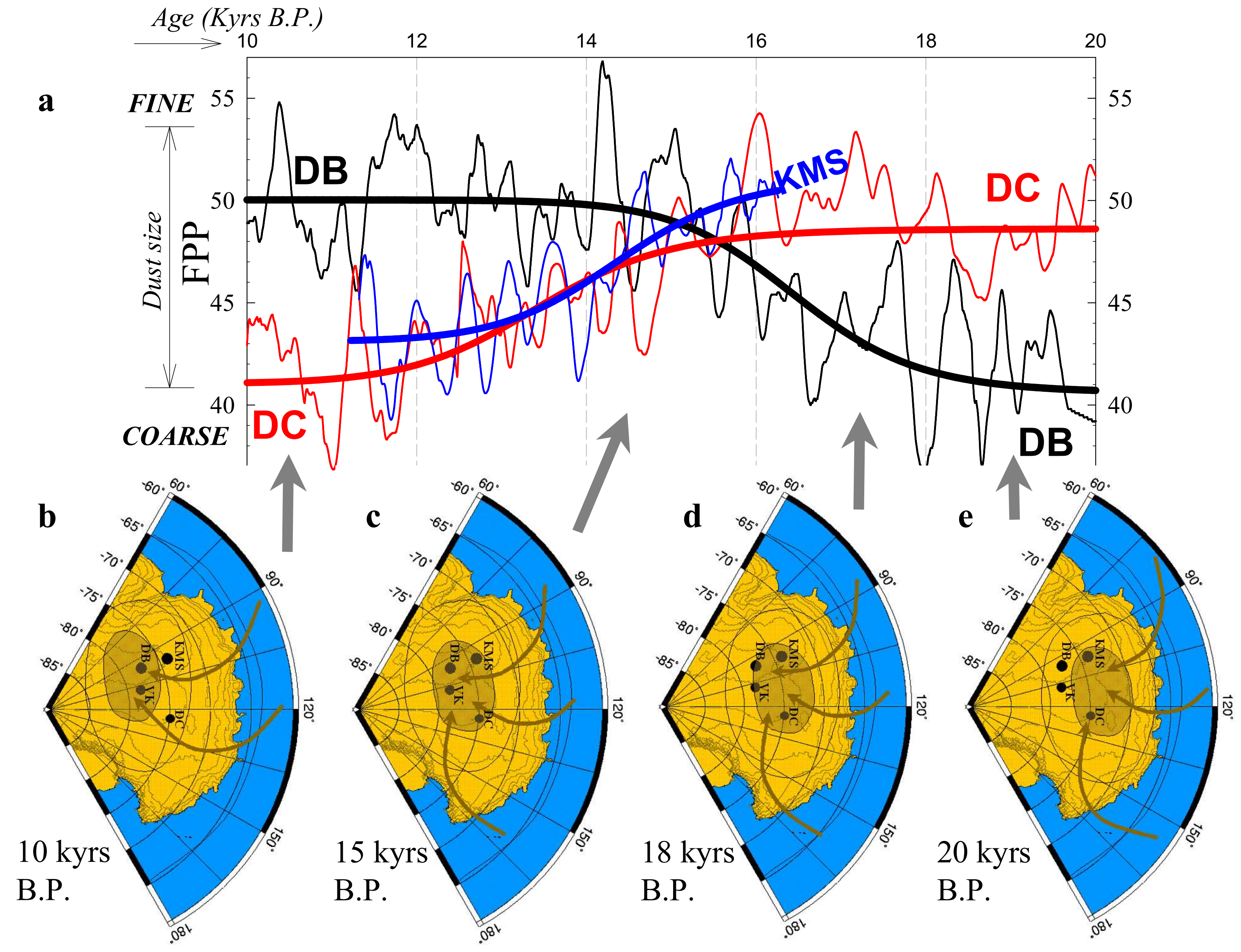
Small dust grain size changes in time have been observed.
These are related to transport patterns and atomspheric circulation above Antarctica (Delmonte et al., 2017; 2004;2005)




0
100
200
300
400
500
600
700
800
[a]
δD°/oo (V-SMOW)
-360
-390
-420
-450
Holocene
5.5
7.5
9.3
11.3
13
15
17
19
3
2
4
6
7.4
8
10
12
14
16
18
20
[b]
EPICA
Dome C
dust
concentration
3
5.5
7.5
9.3
11.3
13
15
17
19
1000
100
10
Laser and CC dust
concentration (ppb)
[c]
Dust
size
changes
39
42
45
48
51
FPP (%)
Aggregates
0
100
200
300
400
500
600
700
800
Age (yrs B.P.)

Plateau sites

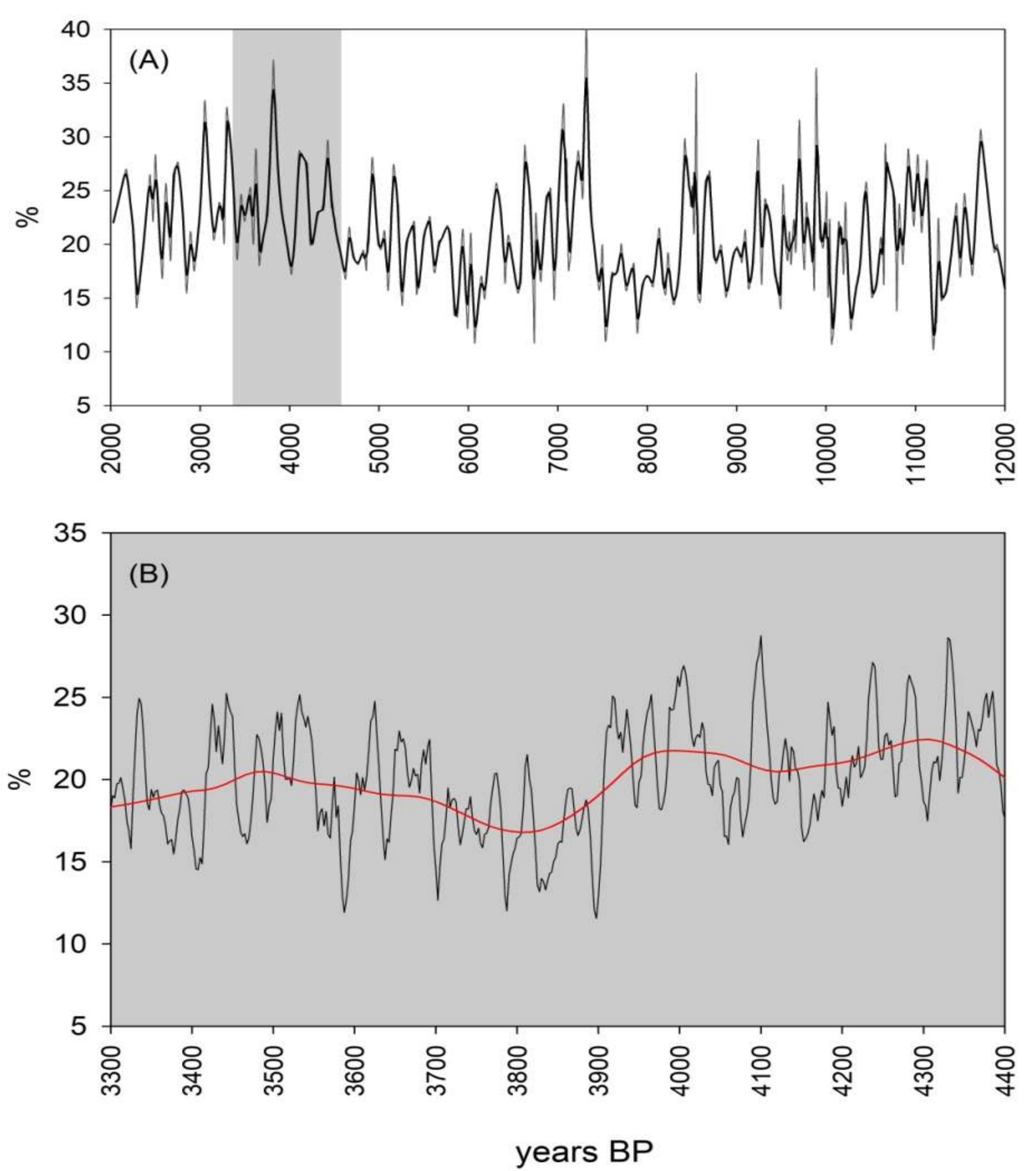
Small dust grain size changes over the last climatic transition have been associated to subsidence and polar vortex migration (Delmonte et al., 2004)



DOME C

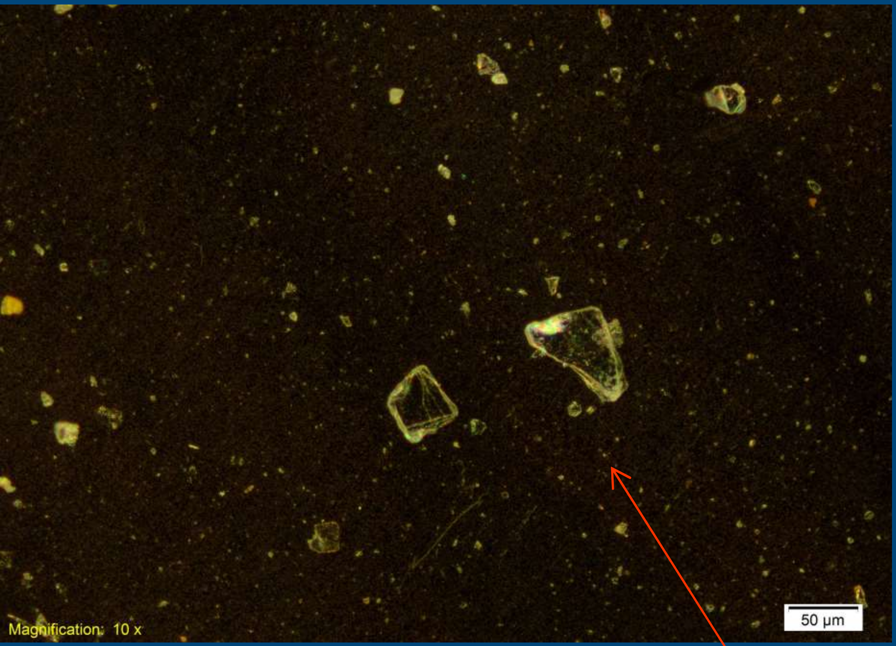
EPICA

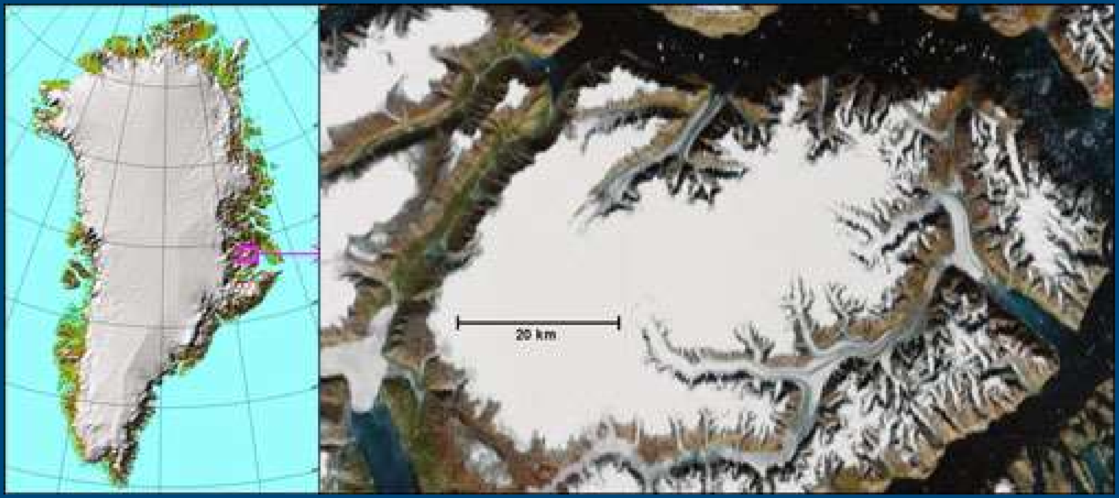
SOLARICE



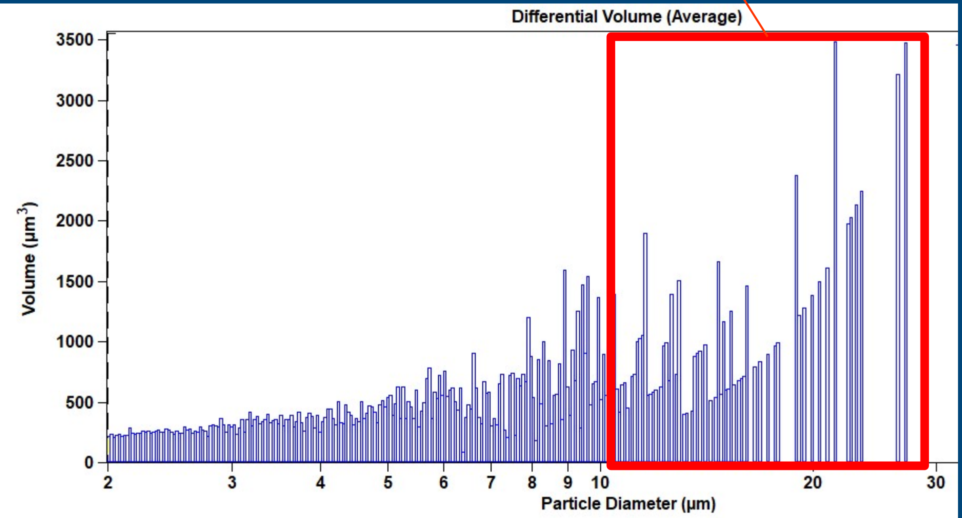
ice sheet margin

Case study: Renland ice cap in Greenland





https://recap.nbi.ku.dk/about/

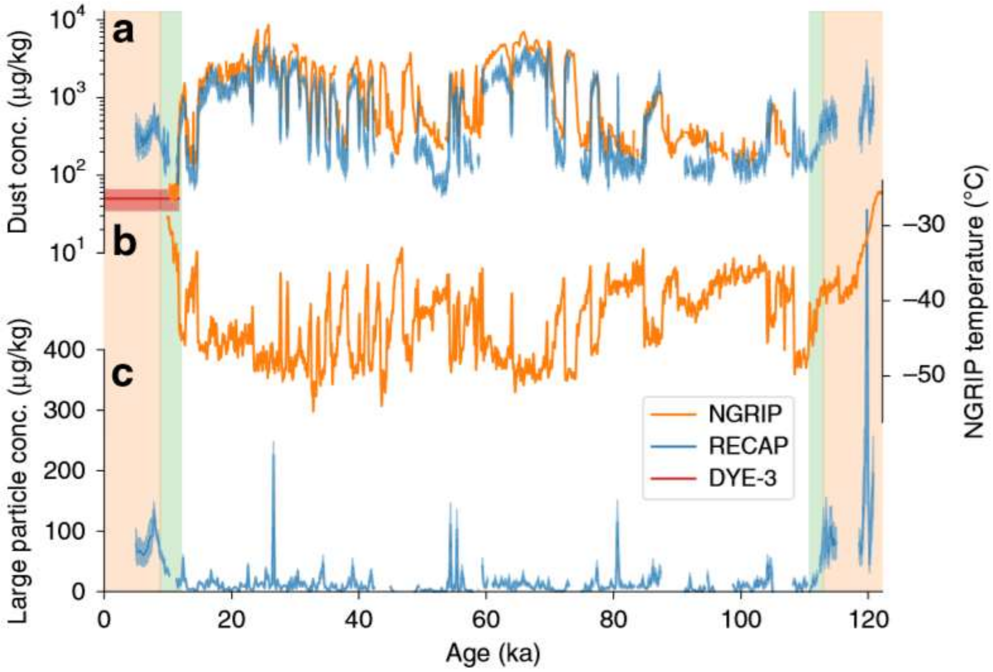


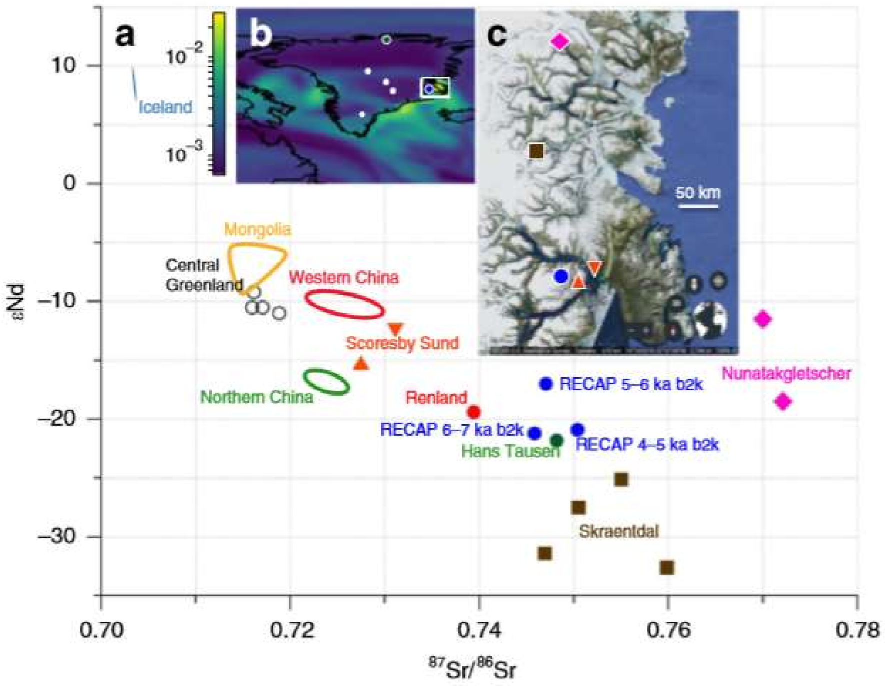
ARTICLE

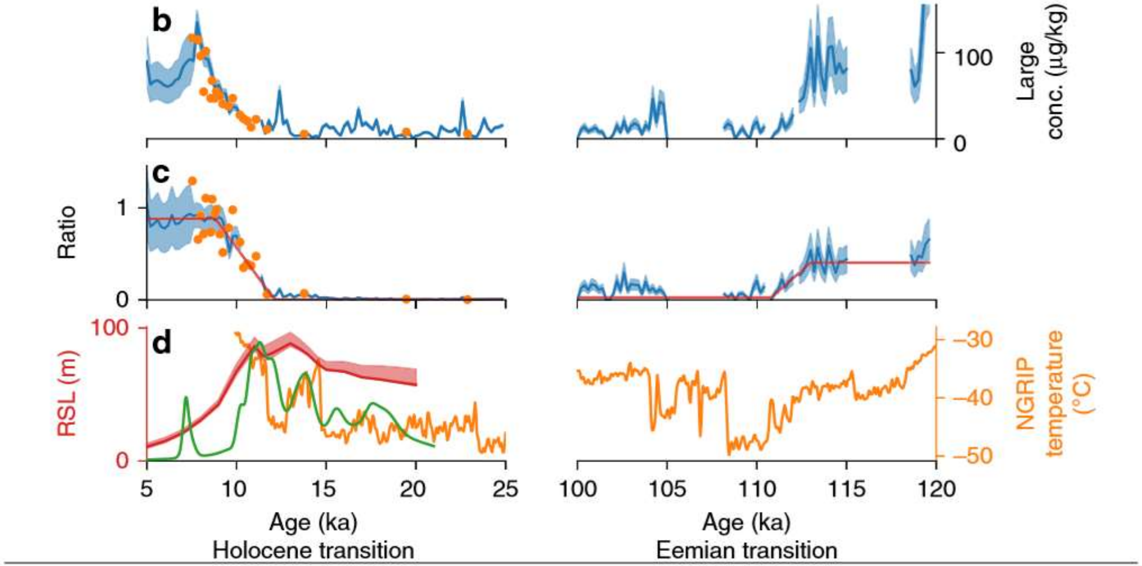
https://doi.org/10.1038/s41467-019-12546-2 OPEN

East Greenland ice core dust record reveals timing of Greenland ice sheet advance and retreat

Marius Folden Simonsen[1], Giovanni Baccolo[2], Thomas Blunier[1], Alejandra Borunda[3,4], Barbara Delmonte[2], Robert Frei[5], Steven Goldstein[3,4], Aslak Grinsted[1], Helle Astrid Kjær[1], Todd Sowers[6], Anders Svensson[1], Bo Vinther[1], Diana Vladimirova[1], Gisela Winckler[3,4], Mai Winstrup[7] & Paul Vallelonga[1*]





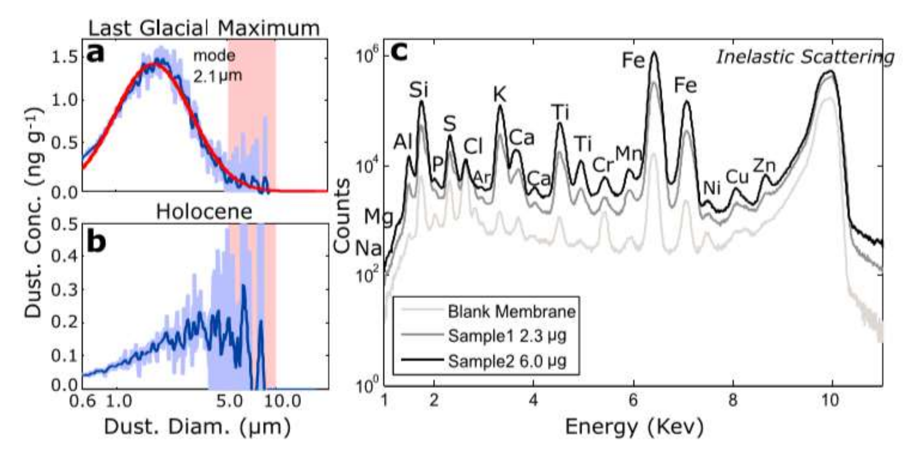


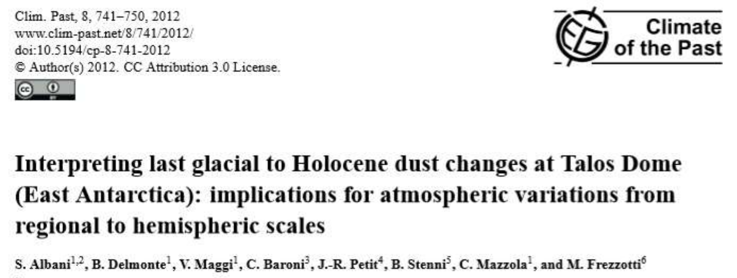
Dust grain size allowed to constrain Greenland ice sheet margin advance and retreat with unprecedented precision

East Greenland ice sheet margin advanced **from 113.4±0.4 to 111.0±0.4 ka BP during the glacial onset** and retreated from **12.1±0.1 to 9.0±0.1 ka BP during the last deglaciation.**

ice sheet margin

Case study: Talos Dome in Antarctica





Clim. Past, 8, 741–750, 2012
www.clim-past.net/8/741/2012/
doi:10.5194/cp-8-741-2012
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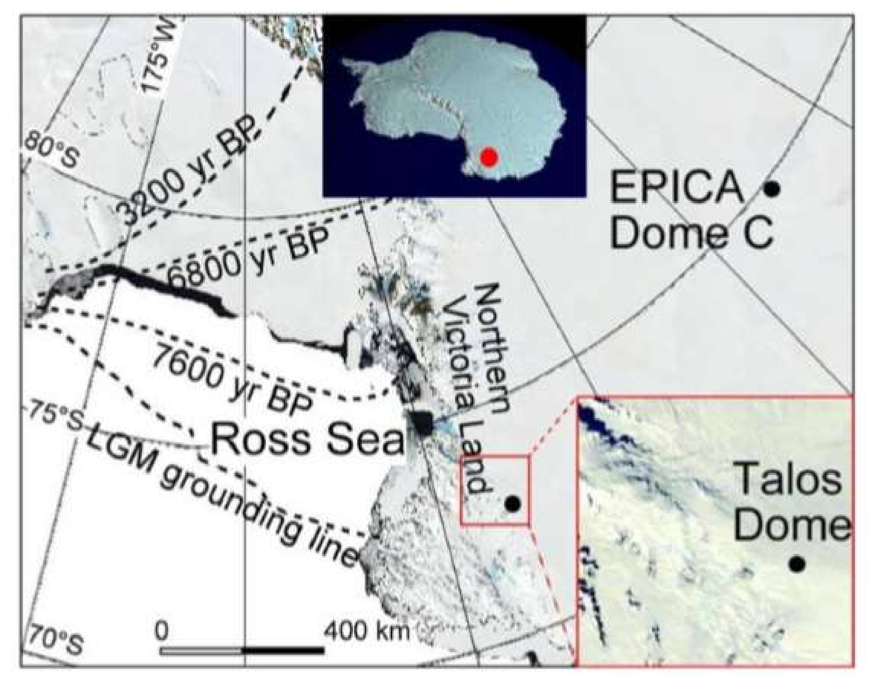
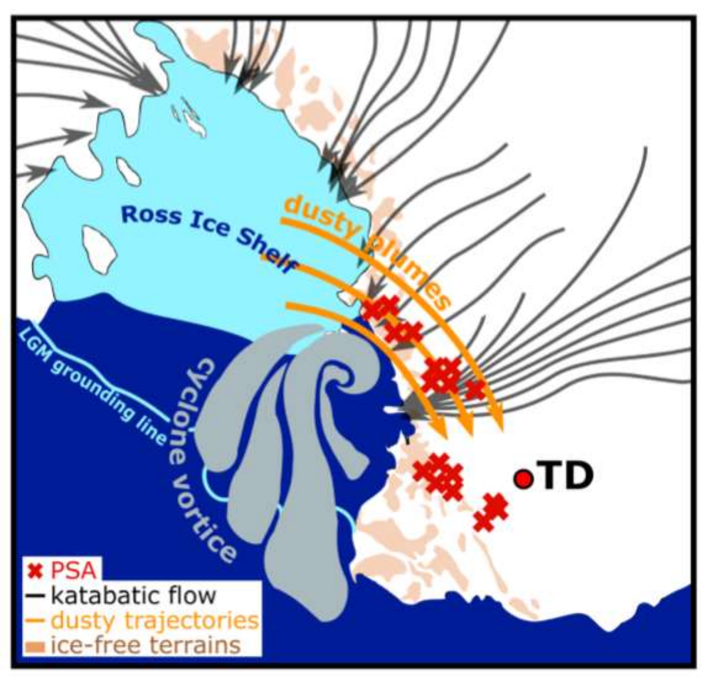
Climate of the Past

Interpreting last glacial to Holocene dust changes at Talos Dome (East Antarctica): implications for atmospheric variations from regional to hemispheric scales

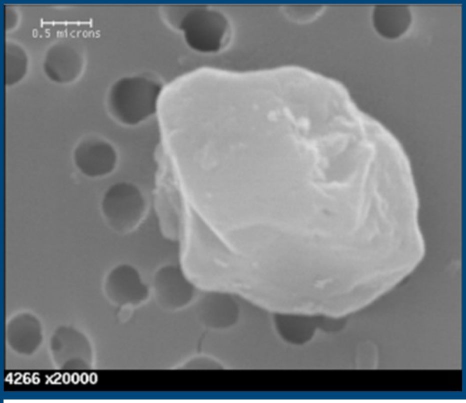
S. Albani[1,2], B. Delmonte[1], V. Maggi[1], C. Baroni[3], J.-R. Petit[4], B. Stenni[5], C. Mazzola[1], and M. Frezzotti[6]

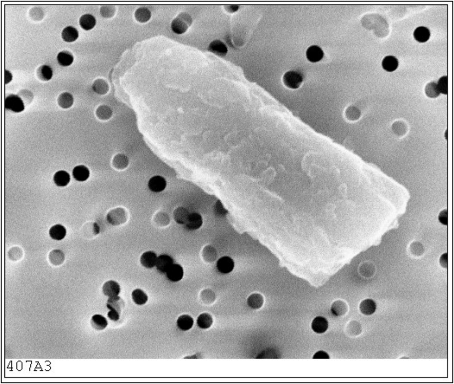


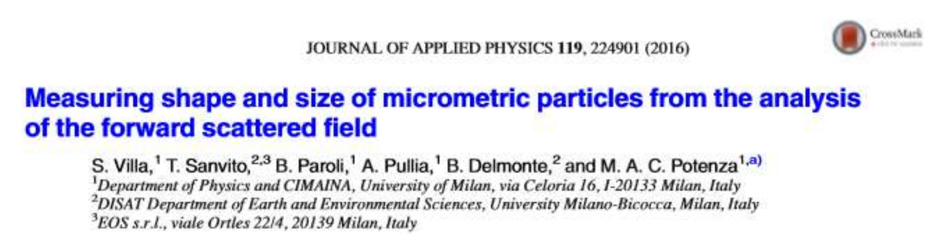


Dust grain size allowed to reconstruct the history of the Ross Sea opening after LGM

►Dust microphysics: shape

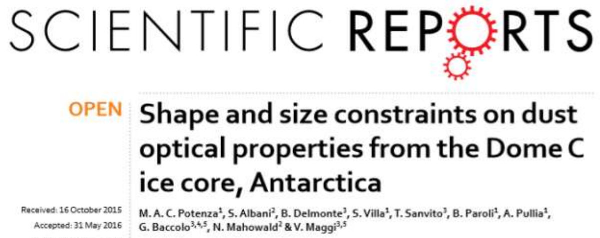





JOURNAL OF APPLIED PHYSICS **119**, 224901 (2016)

Measuring shape and size of micrometric particles from the analysis of the forward scattered field

S. Villa,[1] T. Sanvito,[2,3] B. Paroli,[1] A. Pullia,[1] B. Delmonte,[2] and M. A. C. Potenza[1,a)]
[1]*Department of Physics and CIMAINA, University of Milan, via Celoria 16, I-20133 Milan, Italy*
[2]*DISAT Department of Earth and Environmental Sciences, University Milano-Bicocca, Milan, Italy*
[3]*EOS s.r.l., viale Ortles 22/4, 20139 Milan, Italy*

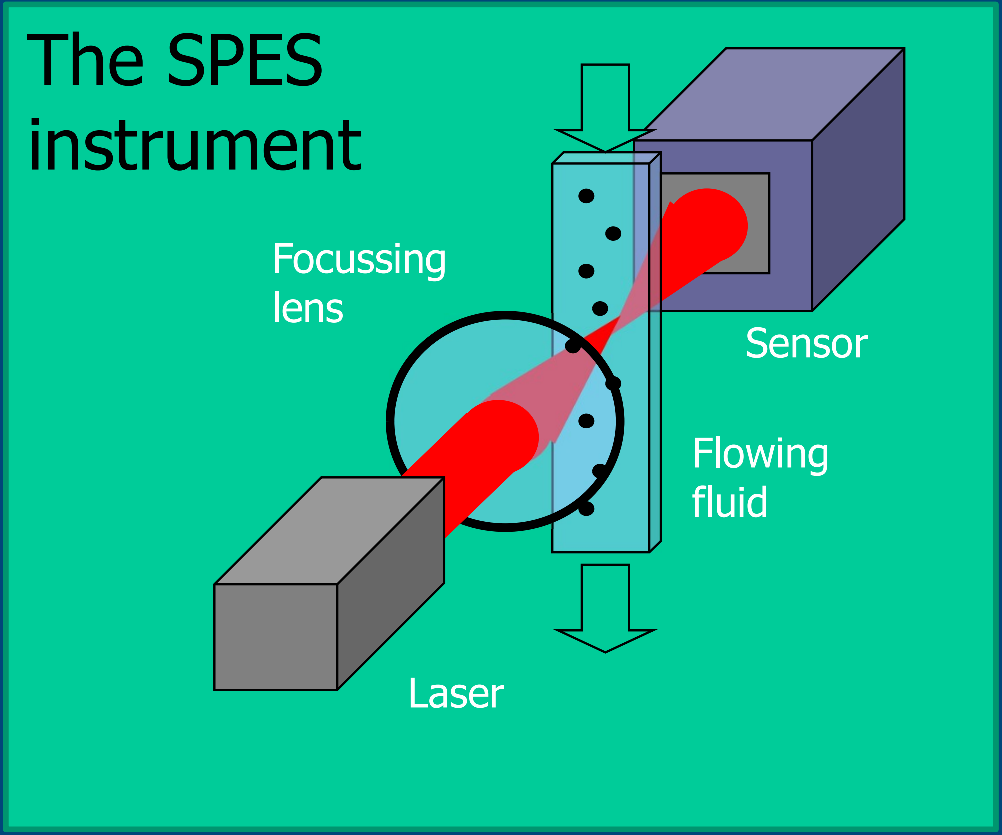

SCIENTIFIC REPORTS

OPEN

Shape and size constraints on dust optical properties from the Dome C ice core, Antarctica

Received: 16 October 2015
Accepted: 31 May 2016
Published: 16 June 2016

M. A. C. Potenza[1], S. Albani[2], B. Delmonte[3], S. Villa[1], T. Sanvito[3], B. Paroli[1], A. Pullia[1], G. Baccolo[3,4,5], N. Mahowald[2] & V. Maggi[3,5]

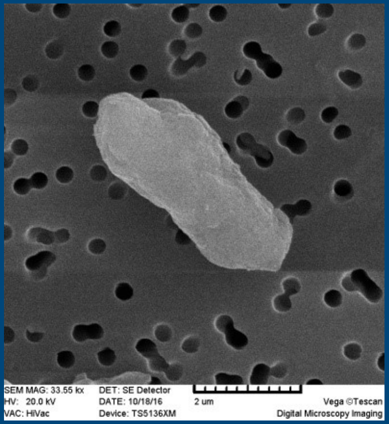

The SPES instrument

Single Particle Extinction and Scattering (SPES) method

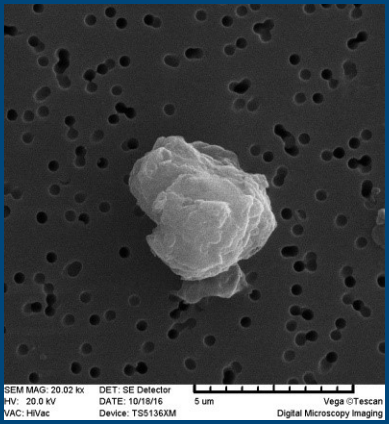
Information about dust particle shapes (aspect ratio) that is critical to determine the intrinsic optical properties of dust, needed by radiative transfer models.

DUST SHAPE

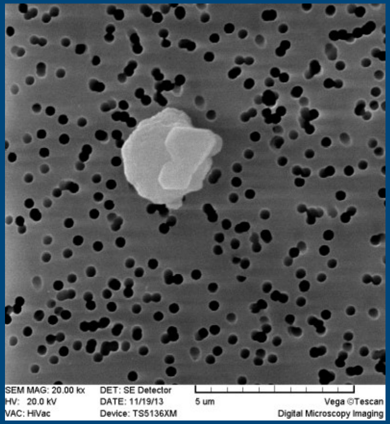
High elevation plateau sites



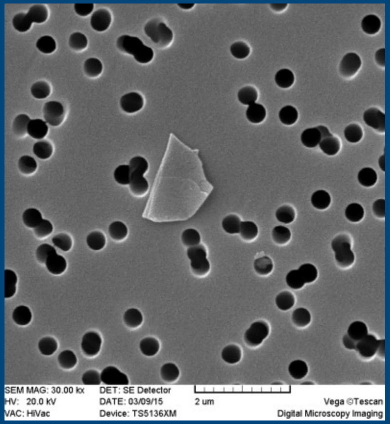
prolate



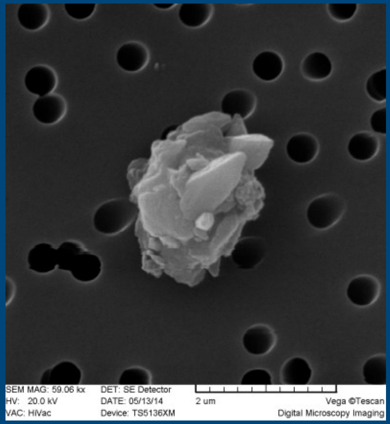
Pseudo-cubic



oblate

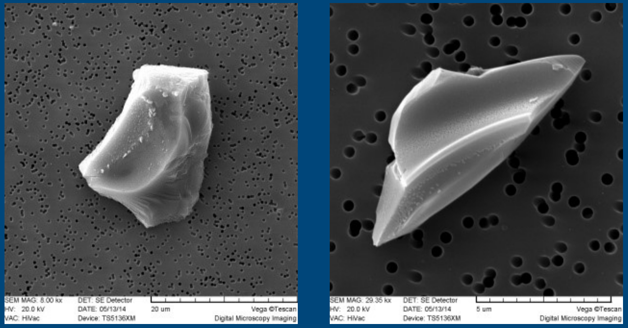


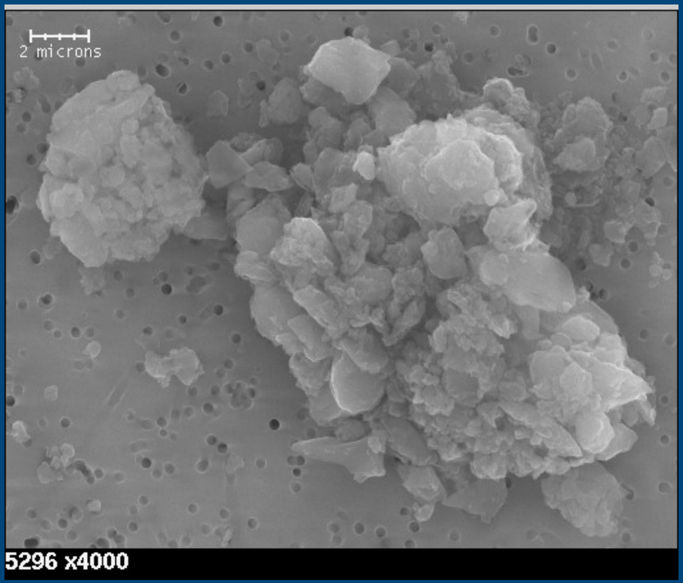
platy shard



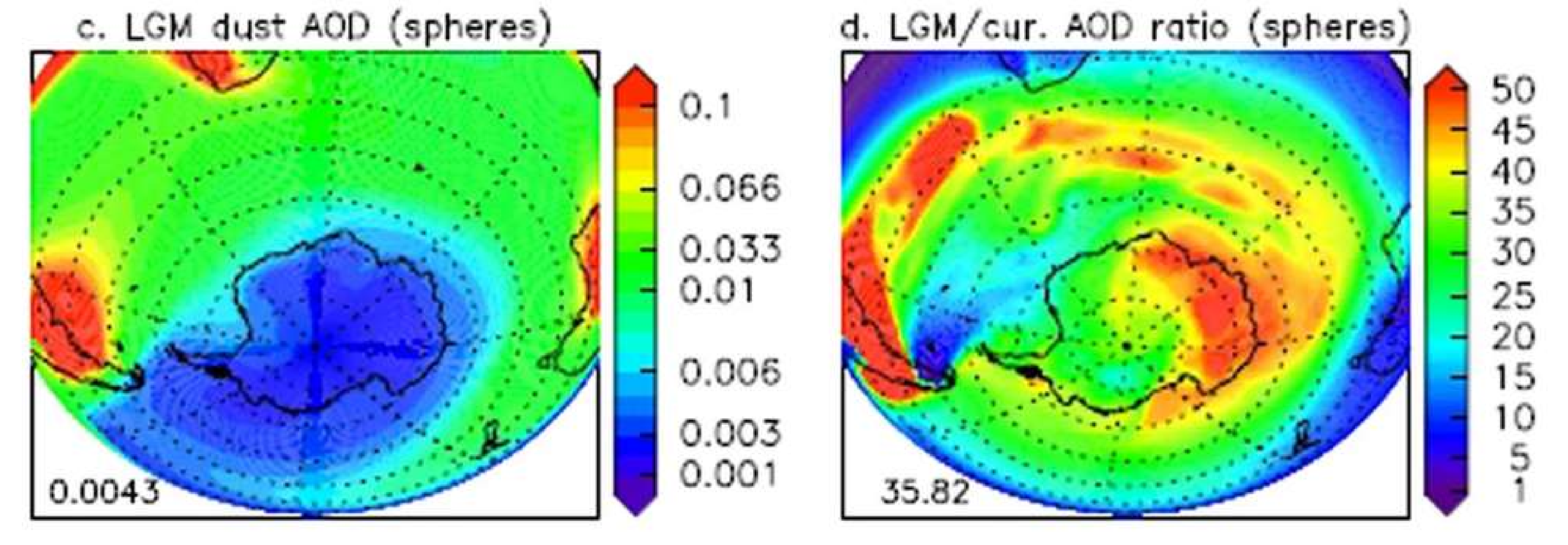
microaggregate

volcanic products

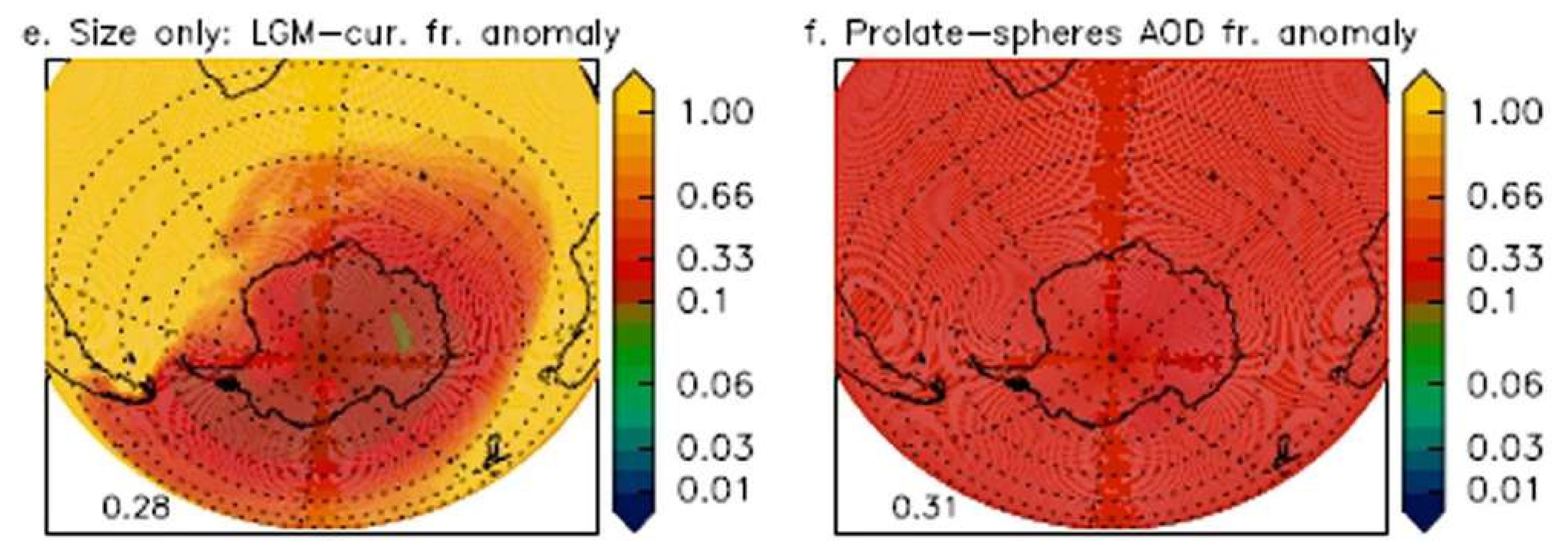




Aggregates from diagenetic processes



The amplitude of the change in AOD due to size is the same as of considering real particles shapes instead of assuming spheres



Dust provenance:

geochemical
and mineralogical *tracers*

a ***tracer*** for dust provenance must be:

1) Geographically representative

2) Distinctive among multiple regions

3) Conservative from the source to the sink

Provenance studies on ice core dust:

Extensive work using $^{87}Sr/^{86}Sr$ versus $^{143}Nd/^{144}Nd$ radiogenic isotopes

$^{208}Pb/^{207}Pb$ vs $^{206}Pb/^{207}Pb$
also used although volcanic Pb complicates

REE patterns

Attempts with other methods (e.g. $\delta^{18}O$ quartz, $^{176}Hf/^{177}Hf$, …)

Geographic provenance

Major elements

Mineralogy (major and trace minerals)

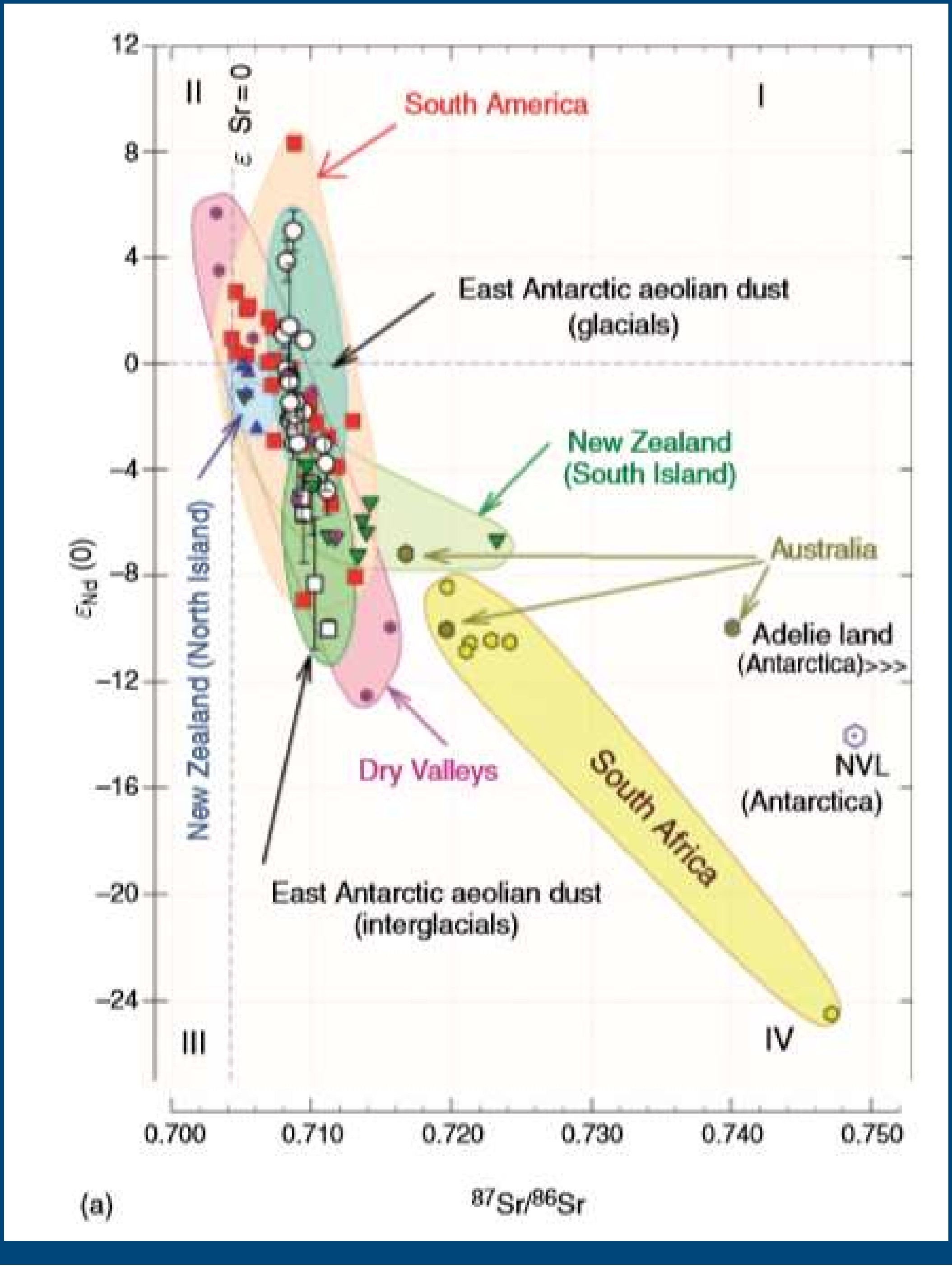
Dust magnetic properties

Environmental conditions

$^{87}Sr/^{86}Sr$ versus $^{143}Nd/^{144}Nd$ radiogenic isotopes

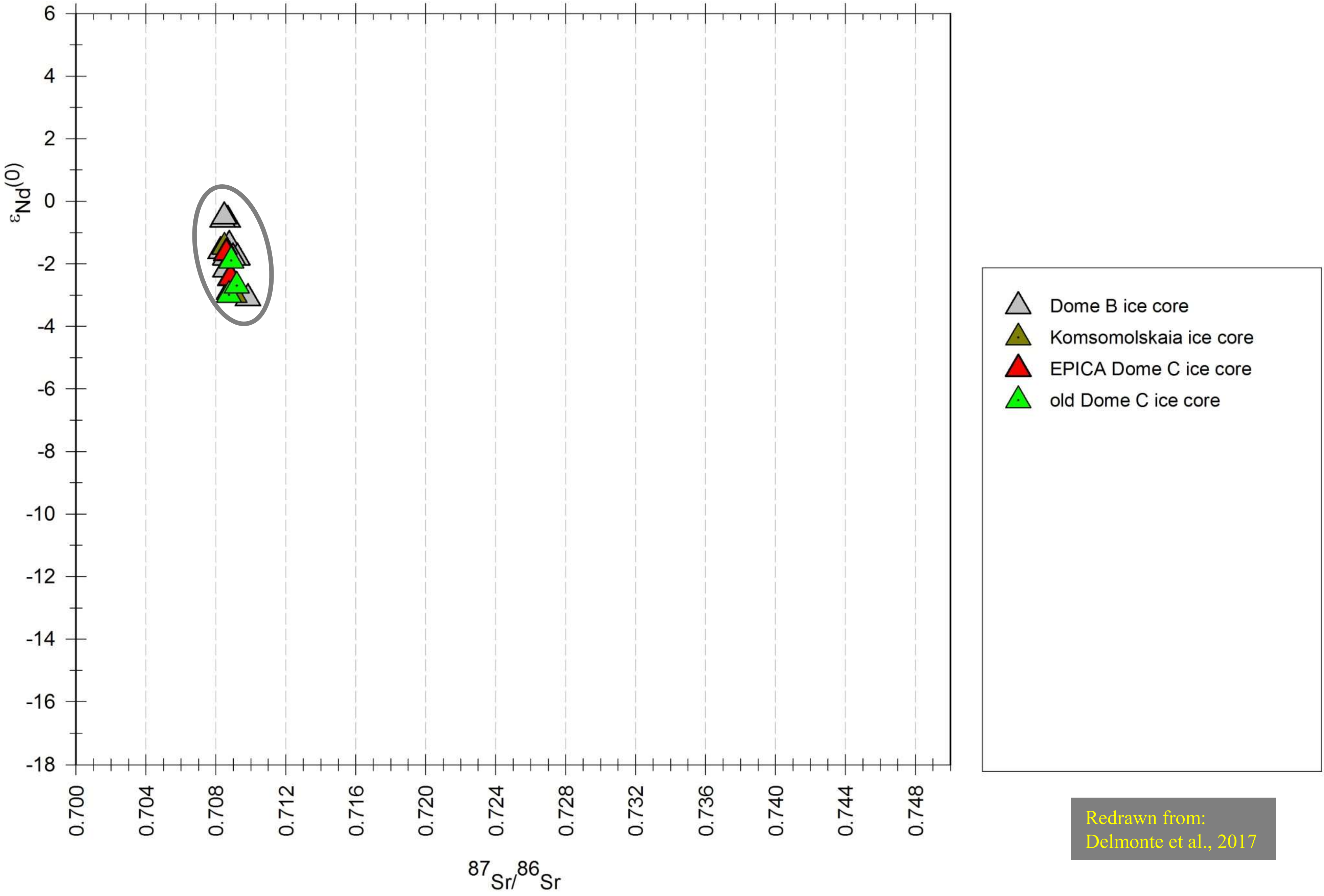
(Grousset et al., 1992; Basile et al., 1997; Delmonte et al., 2004, 2007)

Delmonte et al., 2004, 2007

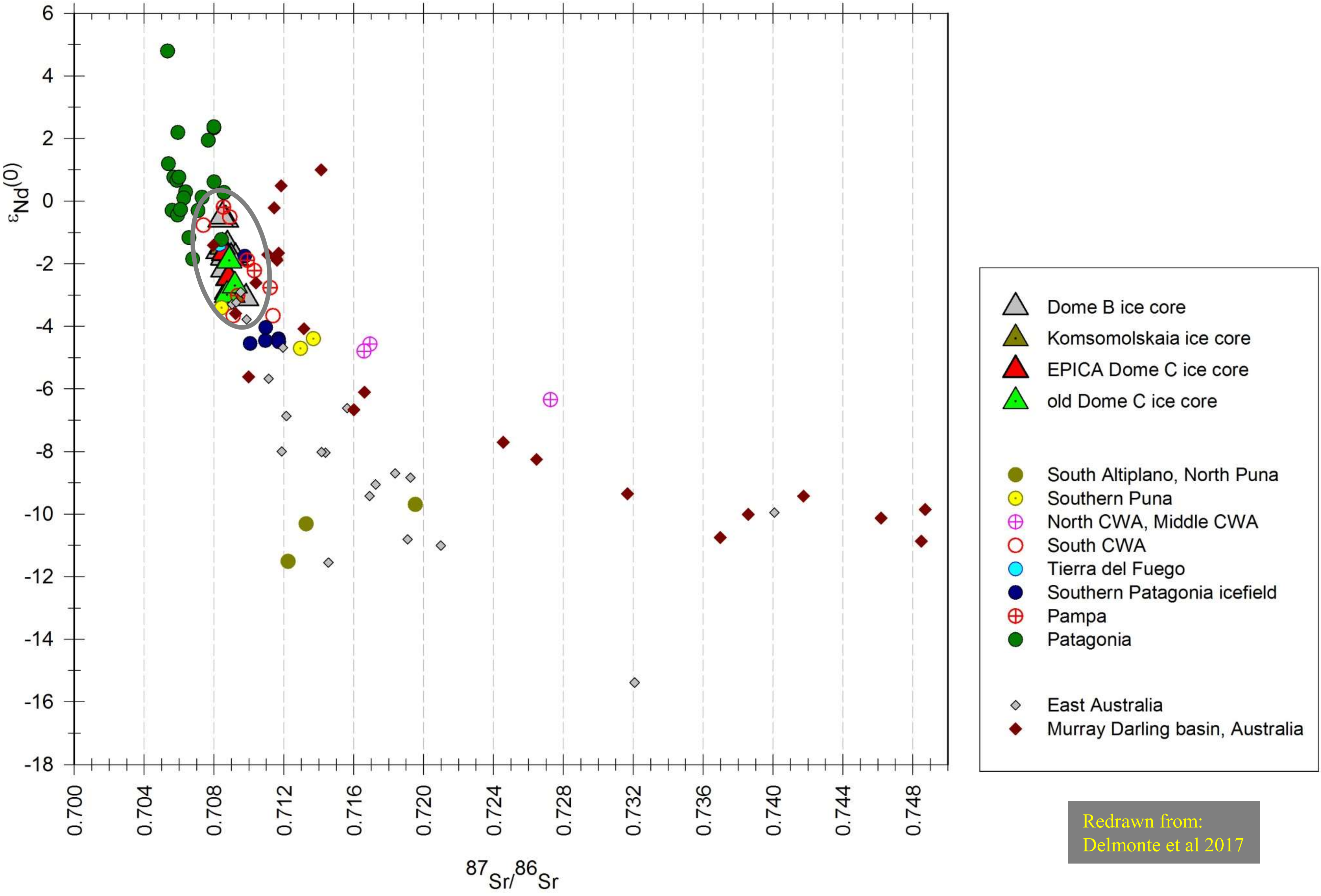


Clarifying dust provenance in East Antarctica during LGM

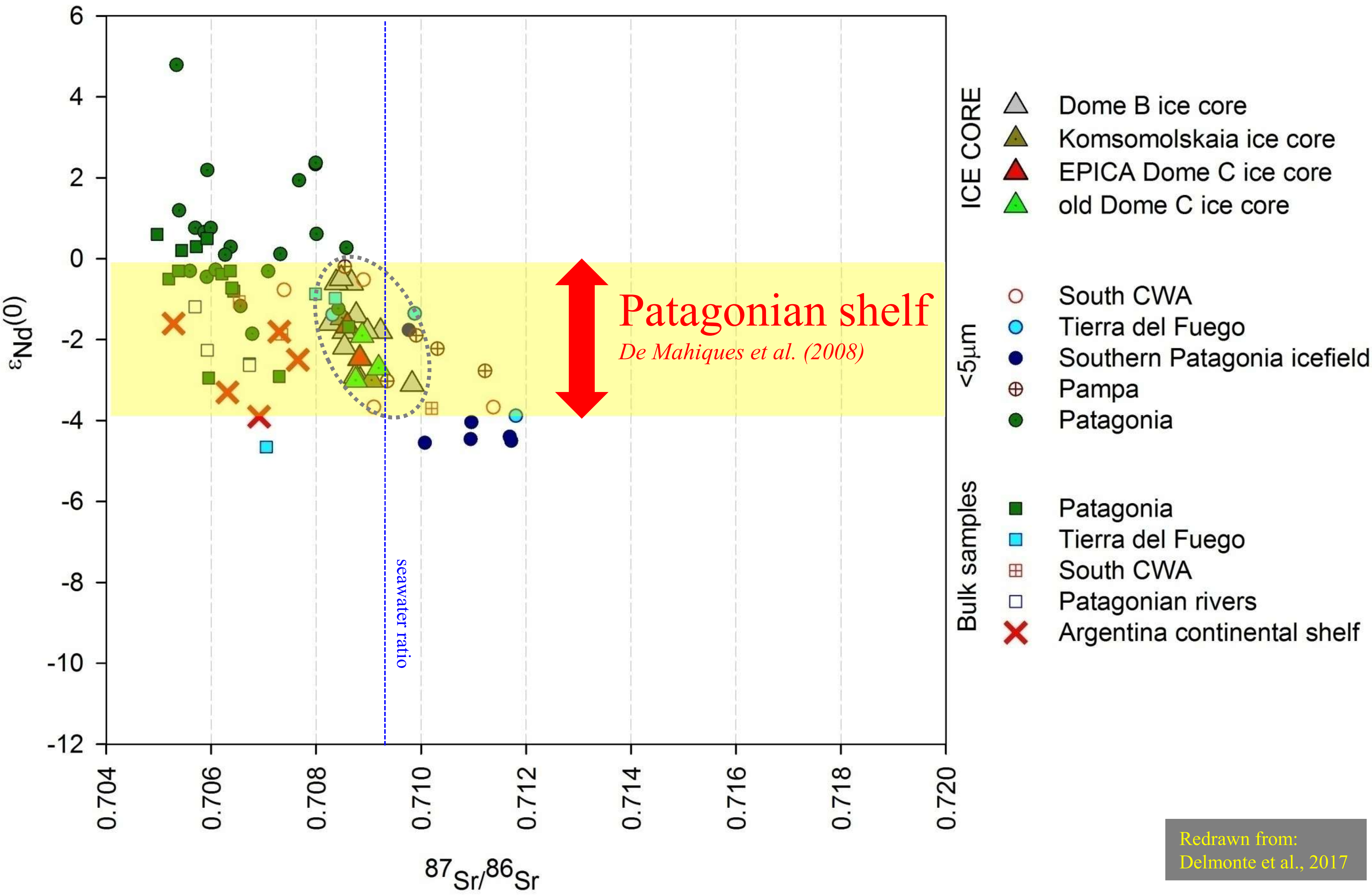
(Delmonte et al., 2017)



Redrawn from:
Delmonte et al., 2017



Redrawn from:
Delmonte et al 2017

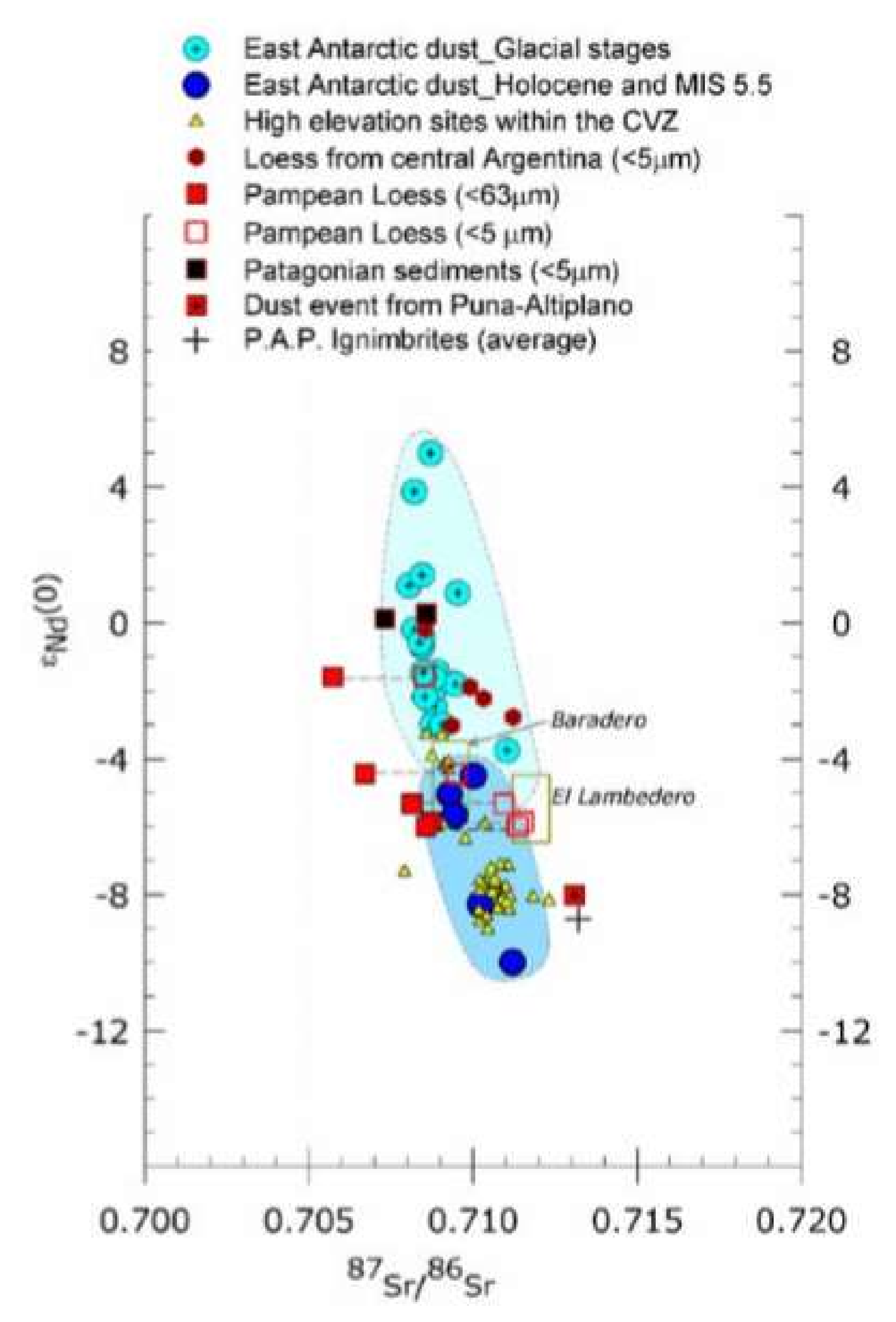


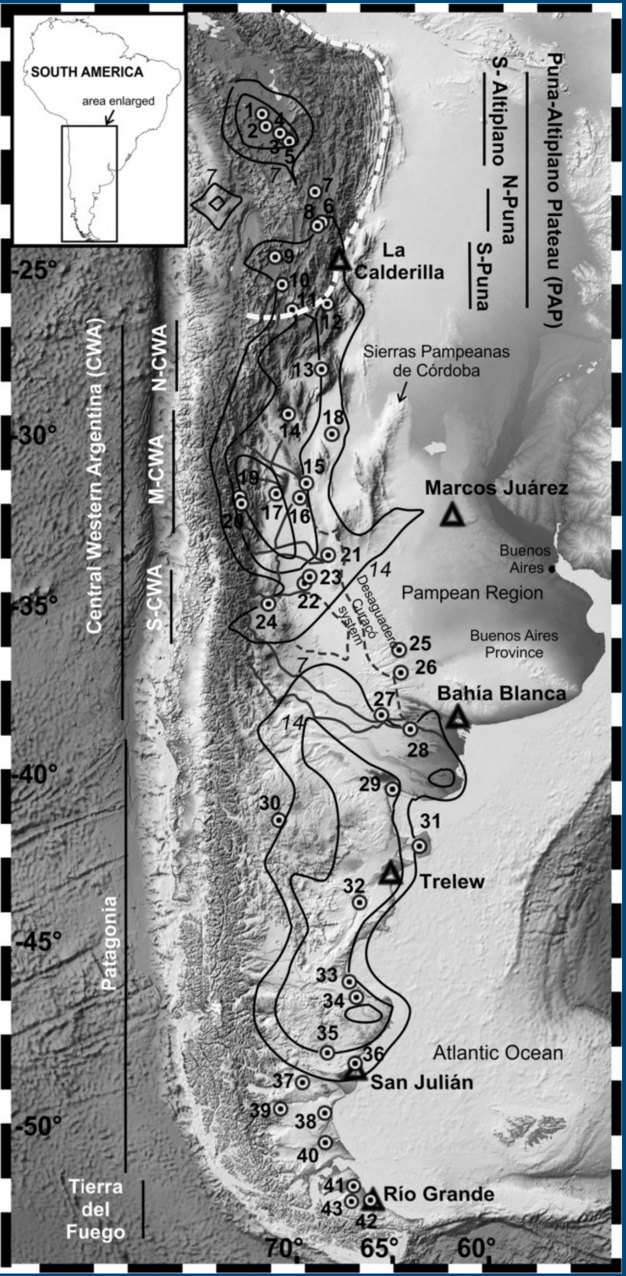
Patagonian shelf

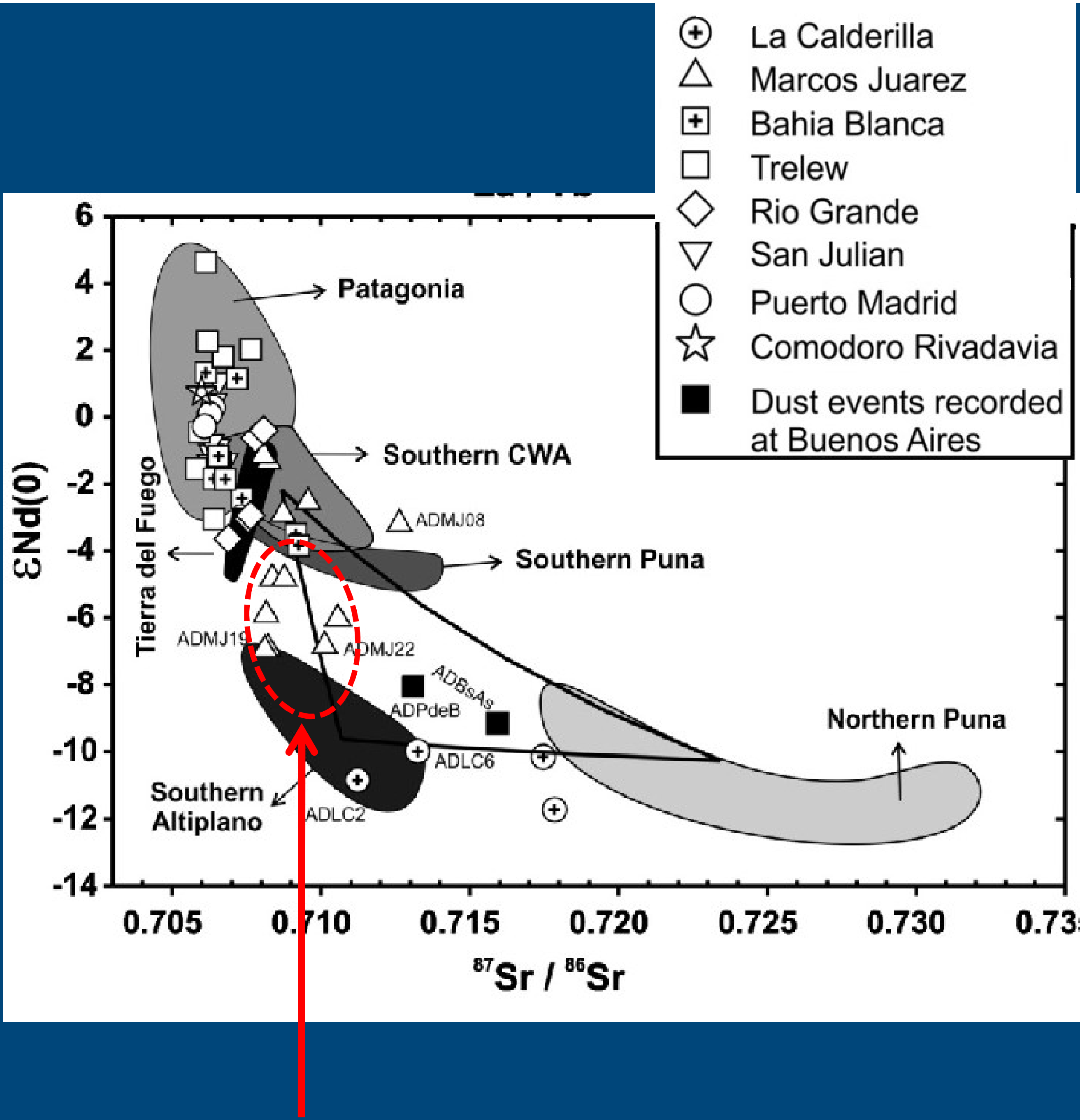
De Mahiques et al. (2008)

Redrawn from:
Delmonte et al., 2017

Delmonte, Petit, Delmas 2008

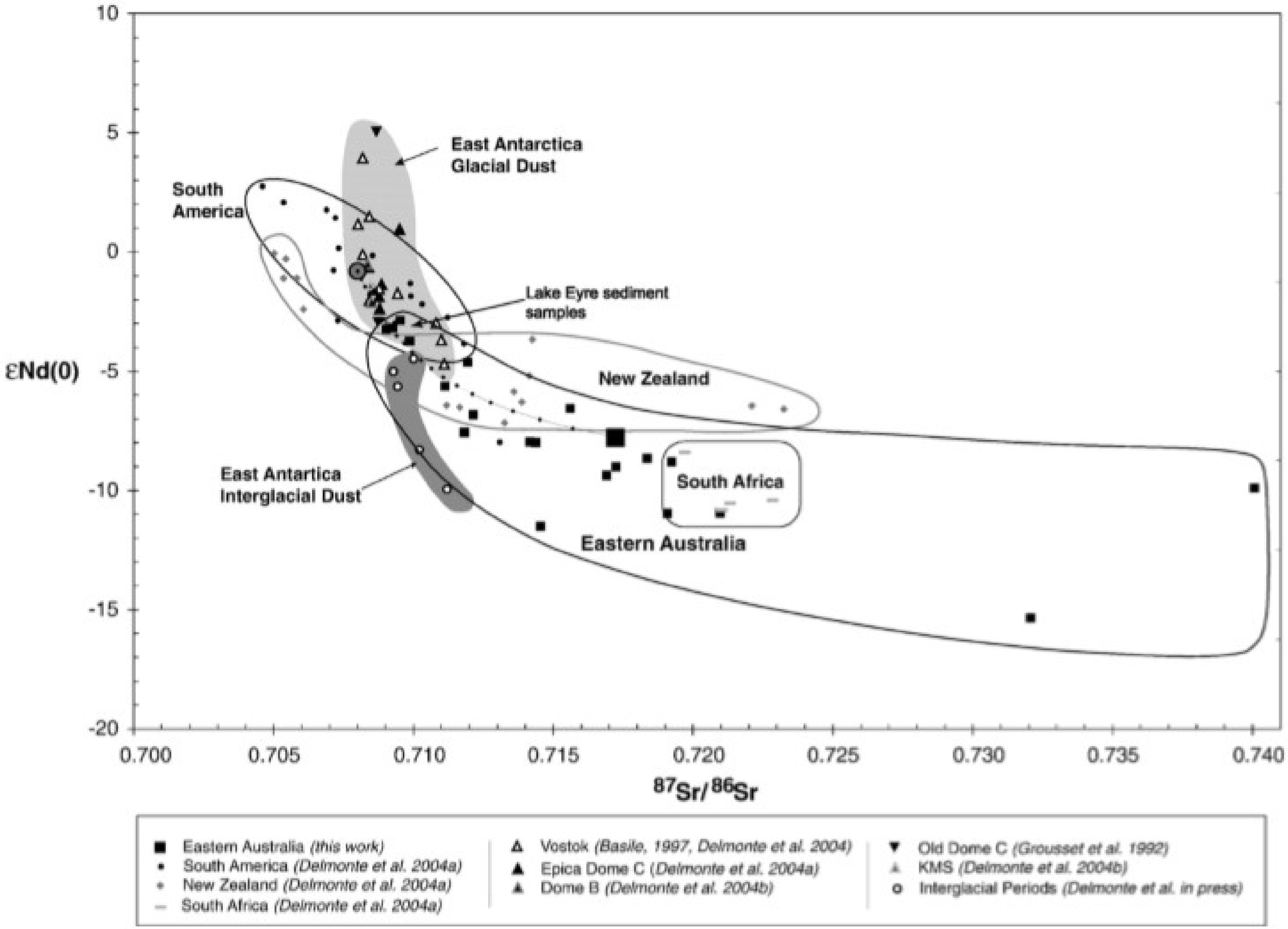


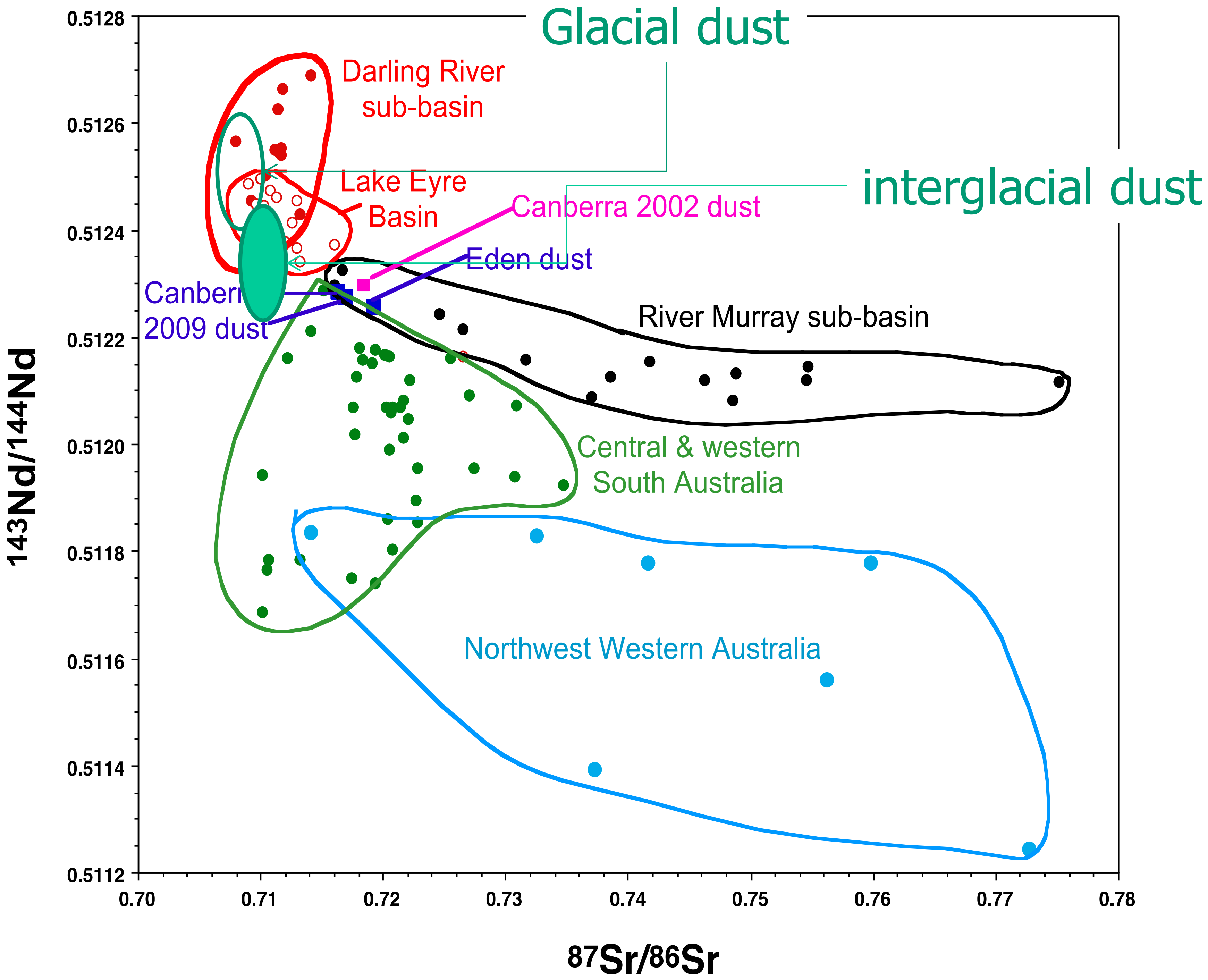




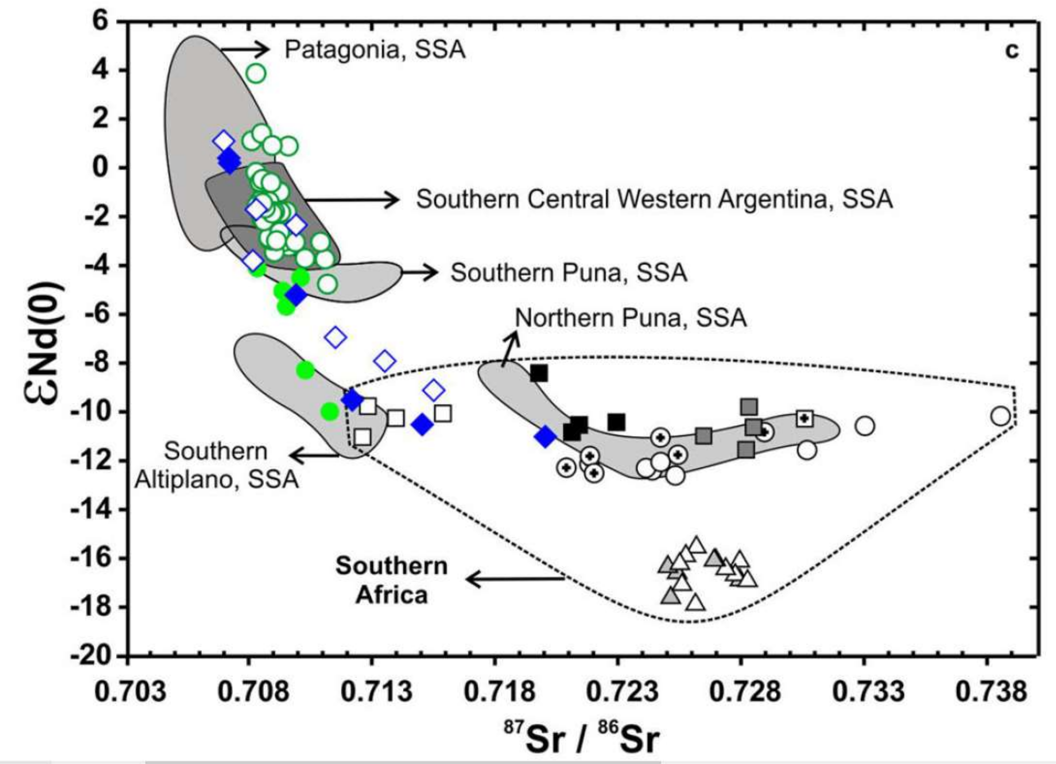
Interglacial dust

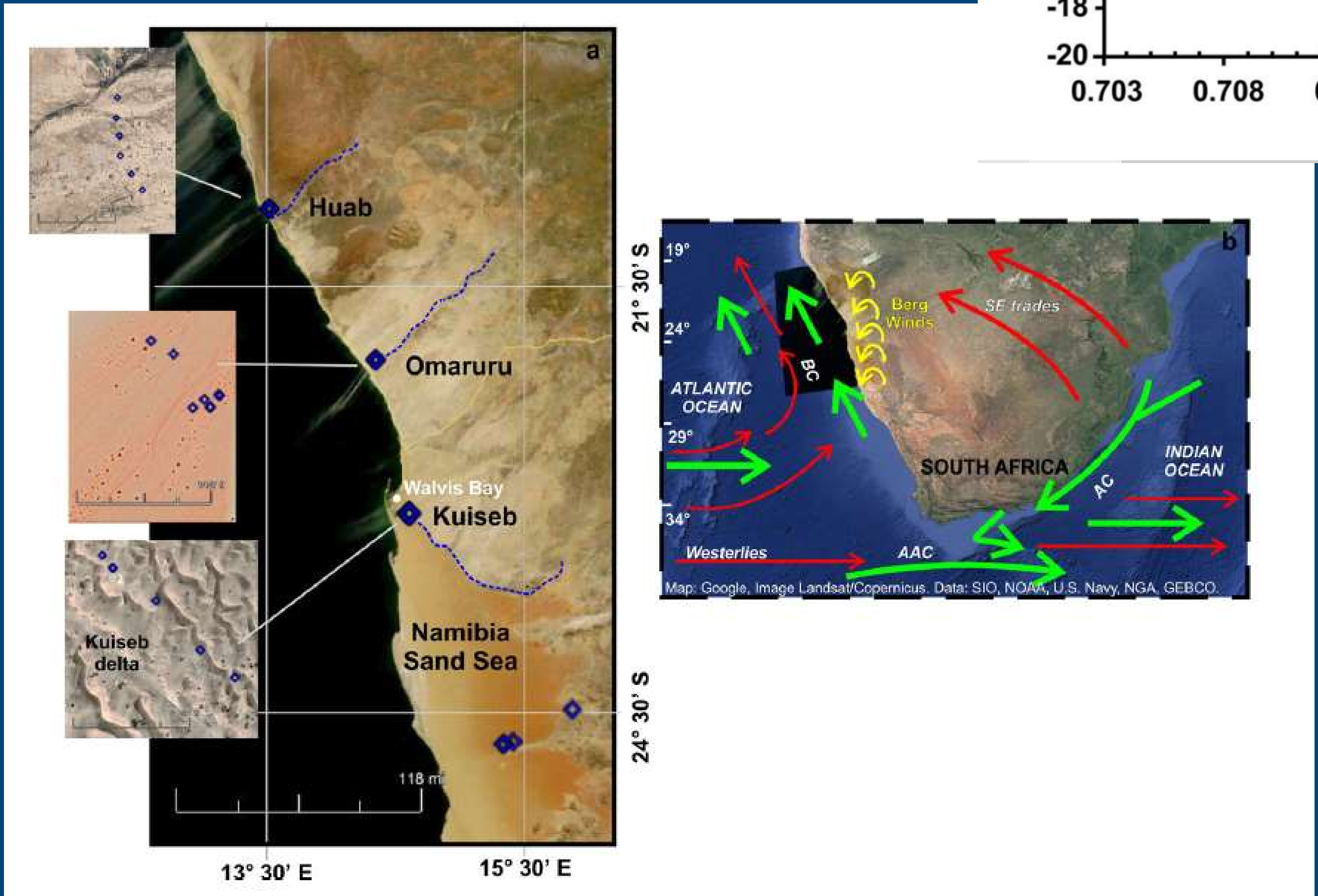
Revel-Rolland et al., 2007




Glacial dust
interglacial dust
Darling River sub-basin
Lake Eyre Basin
Canberra 2002 dust
Eden dust
Canberr
2009 dust
River Murray sub-basin
Central & western South Australia
Northwest Western Australia
143Nd/144Nd
0.5128
0.5126
0.5124
0.5122
0.5120
0.5118
0.5116
0.5114
0.5112
0.70
0.71
0.72
0.73
0.74
0.75
0.76
0.77
0.78
87Sr/86Sr

South Atlantic sector
Gili et al., 2021



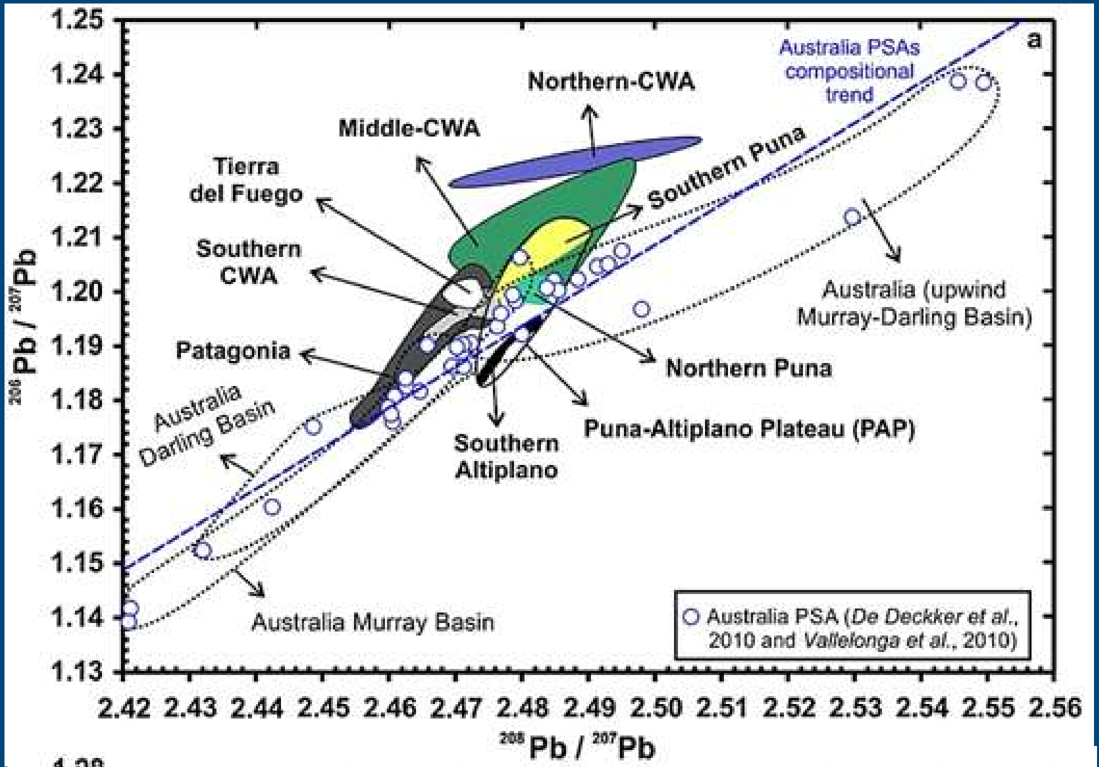


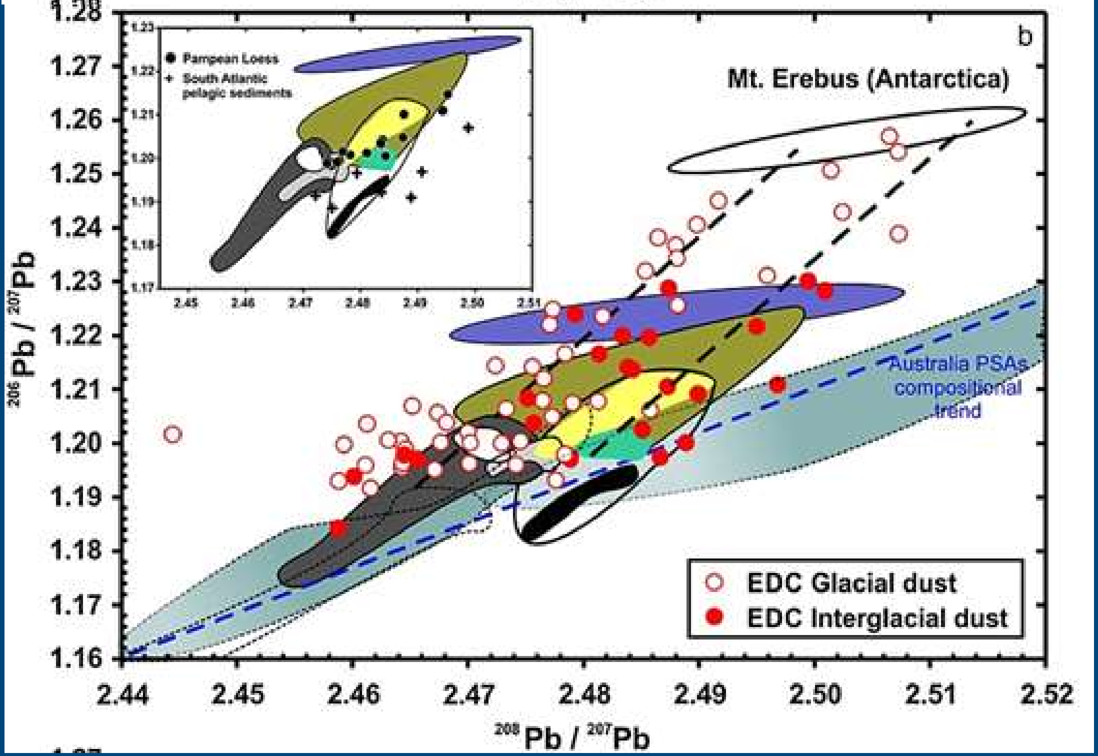
Lead (Pb) isotopes

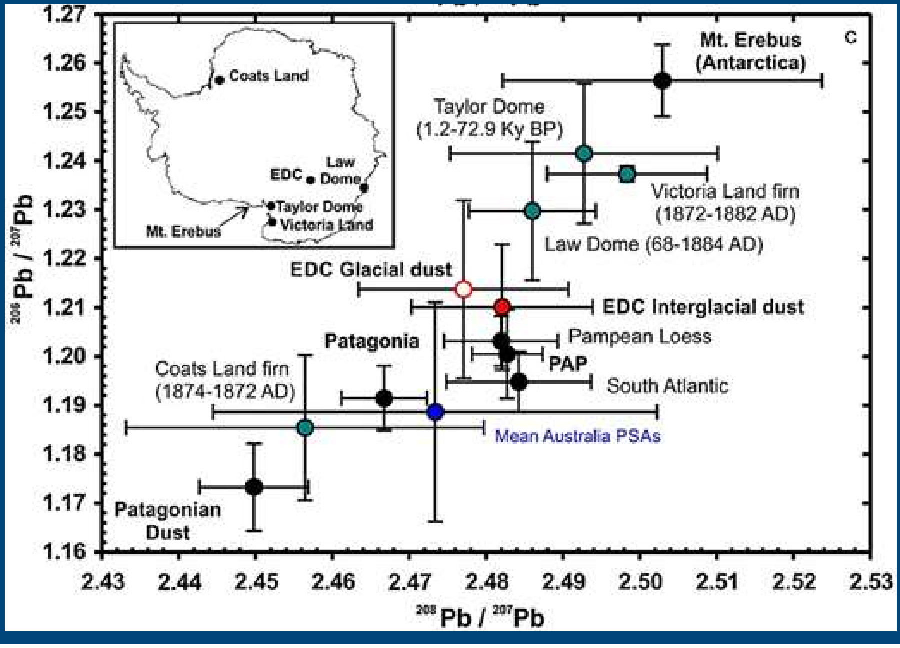
$^{208}Pb/^{207}Pb$ vs $^{206}Pb/^{207}Pb$
mixture of Pb from mineral dust and volcanism

Vallelonga et al., 2005; 2010
Gili et al., 2016

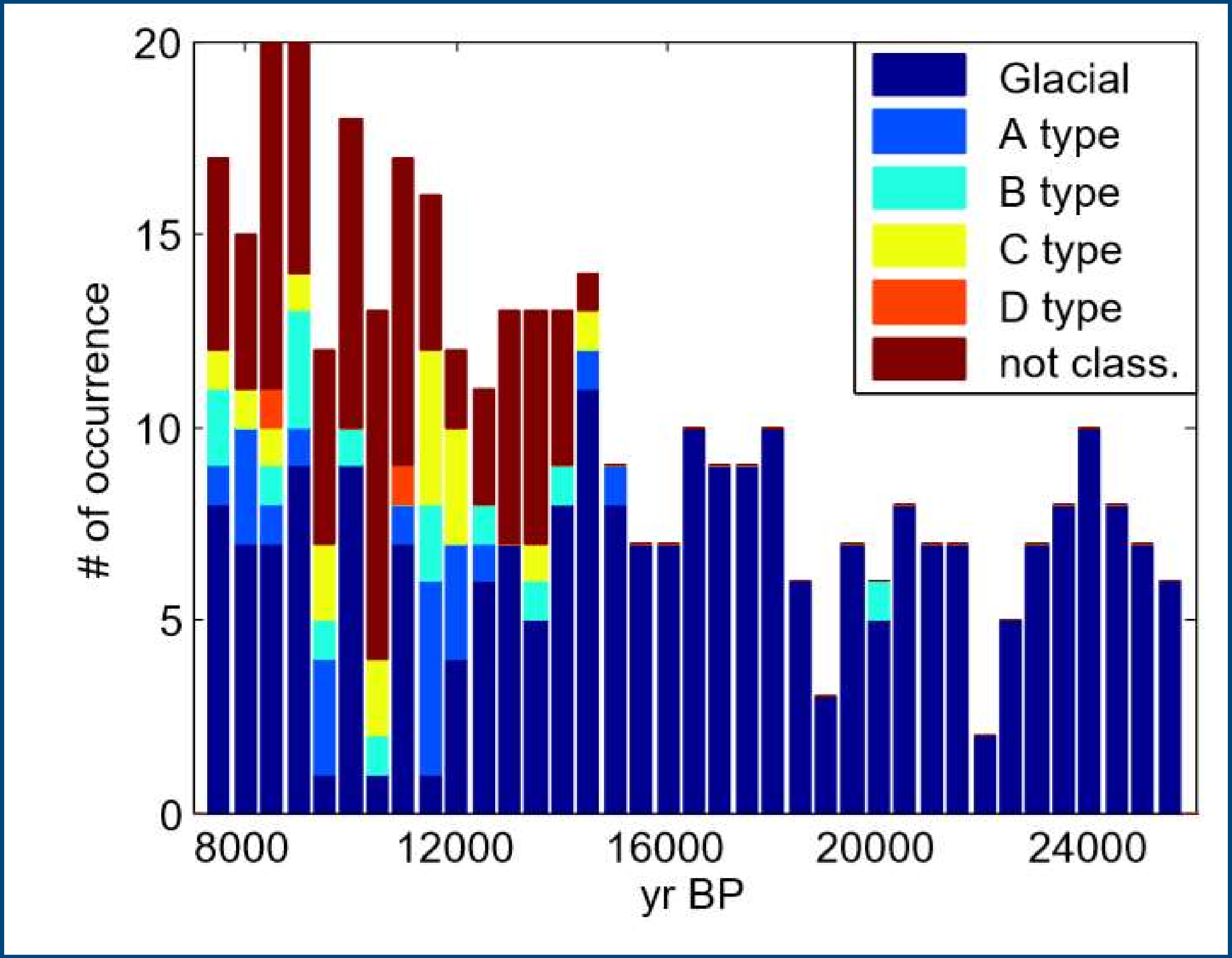
For Pb isotopes the situation is complicated.
Volcanoes also emit Pb, and hence in Antarctic ice, the Pb isotope data usually fall along a mixing line between the dominant dust source in SSA and the dominant volcanic Pb source attributed to Mt Erebus in Antarctica.







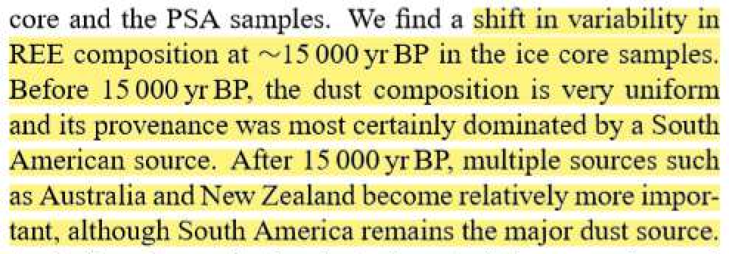
Rare Earth Elements (REE) record determined on the EPICA ice core drilled at Dronning Maud Land (EDML)

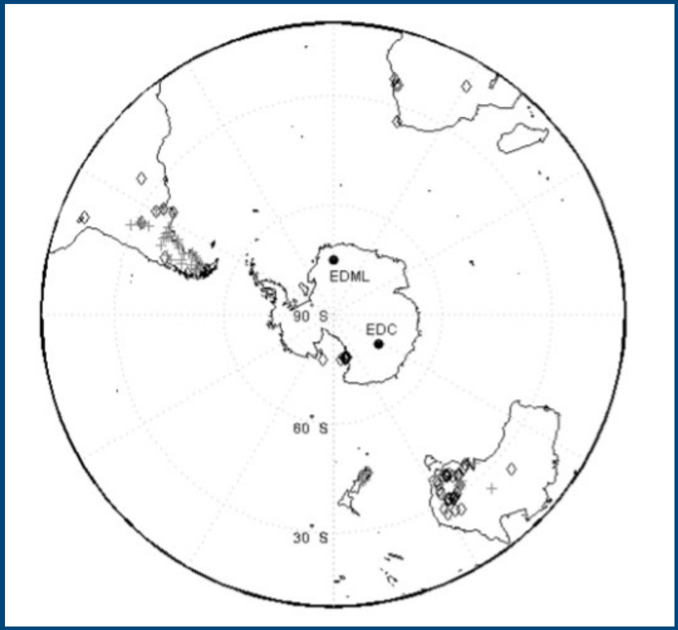



Clim. Past, 8, 135–147, 2012
www.clim-past.net/8/135/2012/
doi:10.5194/cp-8-135-2012
© Author(s) 2012. CC Attribution 3.0 License.

Change in dust variability in the Atlantic sector of Antarctica at the end of the last deglaciation

A. Wegner[1], P. Gabrielli[2,3], D. Wilhelms-Dick[1,*], U. Ruth[4], M. Kriews[1], P. De Deckker[5], C. Barbante[2,6], G. Cozzi[2,6], B. Delmonte[7], and H. Fischer[1,8,9]


core and the PSA samples. We find a shift in variability in REE composition at ~15 000 yr BP in the ice core samples. Before 15 000 yr BP, the dust composition is very uniform and its provenance was most certainly dominated by a South American source. After 15 000 yr BP, multiple sources such as Australia and New Zealand become relatively more important, although South America remains the major dust source.



Raman spectroscopy

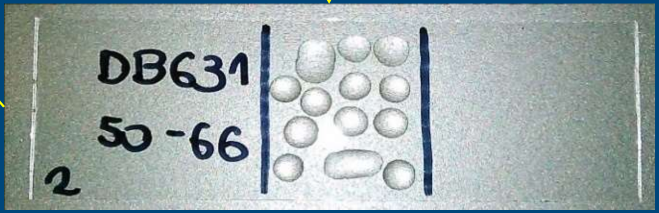
SINGLE-GRAIN technique for identifying dust mineralogy

Ice core

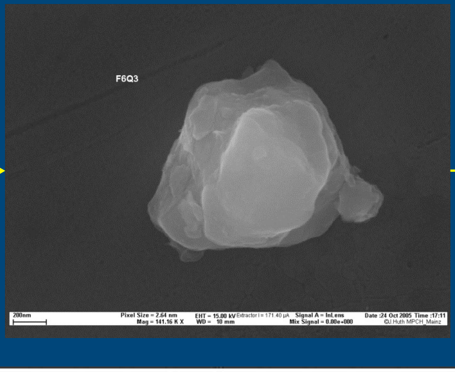
filtration

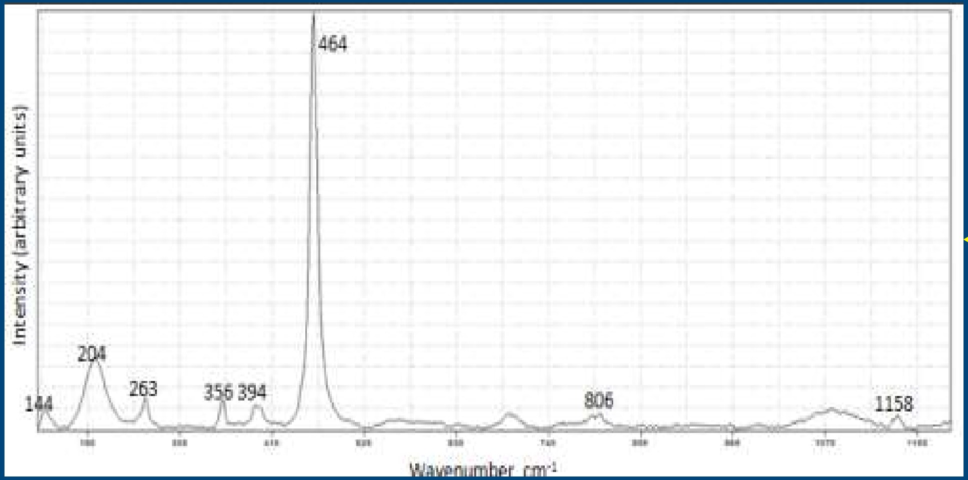
concentration

deposition



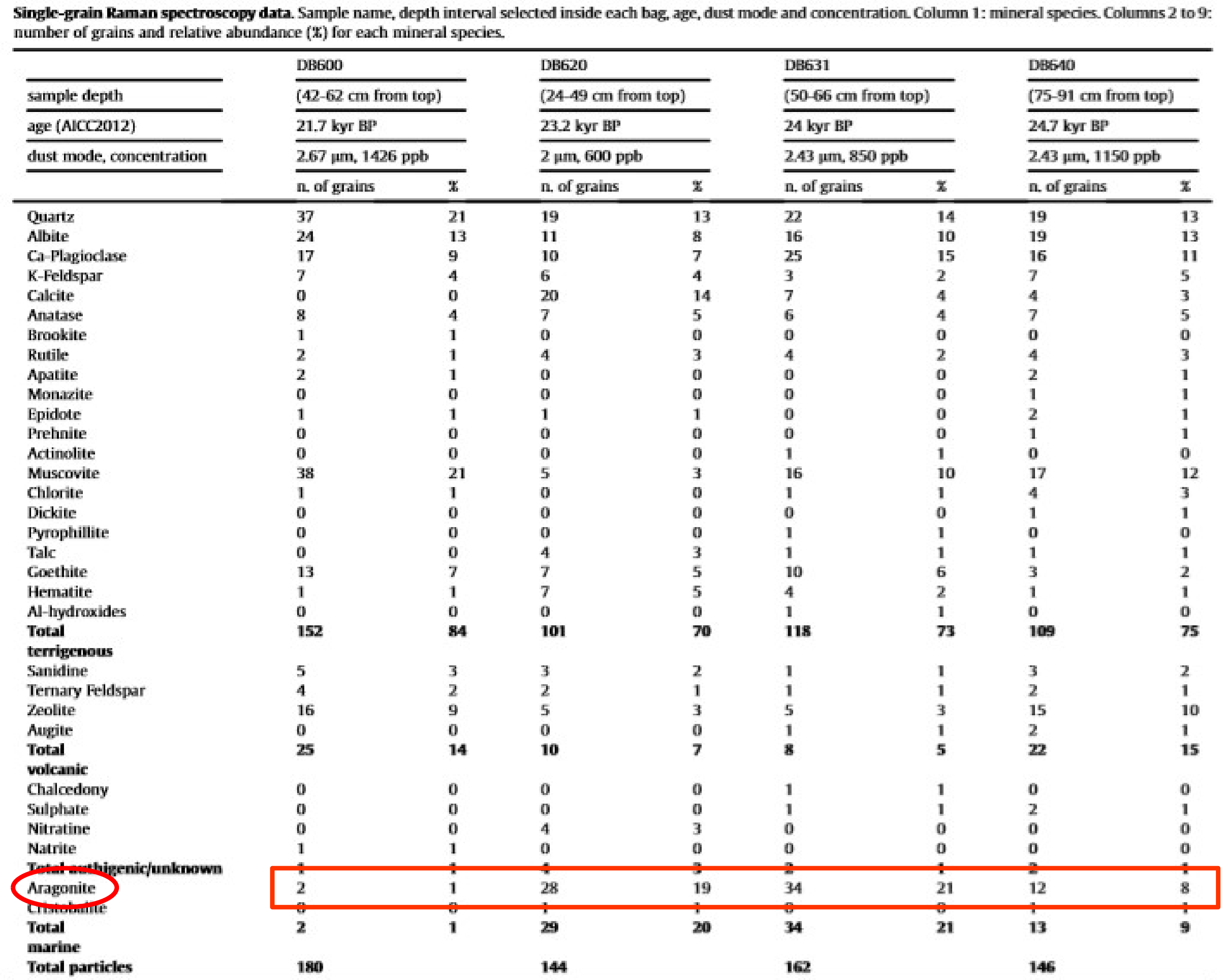
Nd YAG laser source, λ=532 nm





- ►mineral species and polymorphs
- ►light and heavy minerals

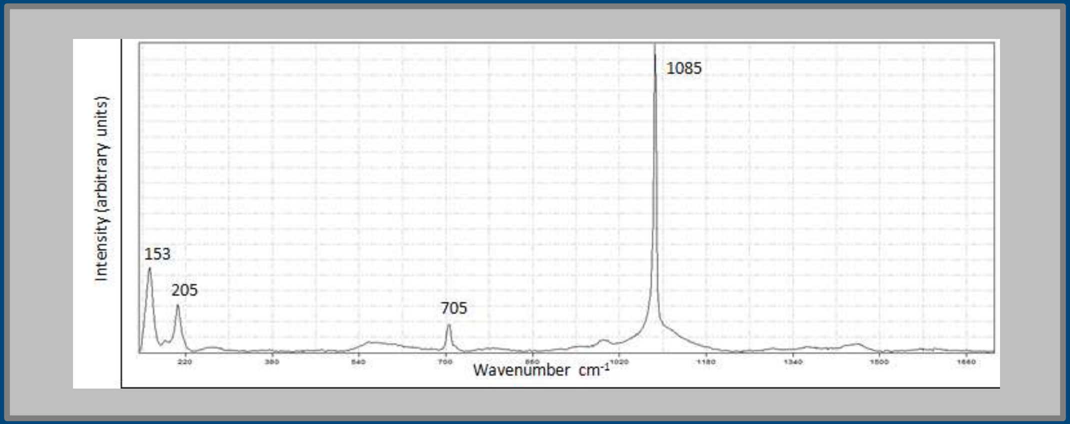
More than 630 particles of >30 mineral species have been identified including light and heavy minerals



Single-grain Raman spectroscopy data. Sample name, depth interval selected inside each bag, age, dust mode and concentration. Column 1: mineral species. Columns 2 to 9: number of grains and relative abundance (%) for each mineral species.

	DB600		DB620		DB631		DB640	
sample depth	(42-62 cm from top)		(24-49 cm from top)		(50-66 cm from top)		(75-91 cm from top)	
age (AICC2012)	21.7 kyr BP		23.2 kyr BP		24 kyr BP		24.7 kyr BP	
dust mode, concentration	2.67 µm, 1426 ppb		2 µm, 600 ppb		2.43 µm, 850 ppb		2.43 µm, 1150 ppb	
	n. of grains	%	n. of grains	%	n. of grains	%	n. of grains	%
Quartz	37	21	19	13	22	14	19	13
Albite	24	13	11	8	16	10	19	13
Ca-Plagioclase	17	9	10	7	25	15	16	11
K-Feldspar	7	4	6	4	3	2	7	5
Calcite	0	0	20	14	7	4	4	3
Anatase	8	4	7	5	6	4	7	5
Brookite	1	1	0	0	0	0	0	0
Rutile	2	1	4	3	4	2	4	3
Apatite	2	1	0	0	0	0	2	1
Monazite	0	0	0	0	0	0	1	1
Epidote	1	1	1	1	0	0	2	1
Prehnite	0	0	0	0	0	0	1	1
Actinolite	0	0	0	0	1	1	0	0
Muscovite	38	21	5	3	16	10	17	12
Chlorite	1	1	0	0	1	1	4	3
Dickite	0	0	0	0	0	0	1	1
Pyrophillite	0	0	0	0	1	1	0	0
Talc	0	0	4	3	1	1	1	1
Goethite	13	7	7	5	10	6	3	2
Hematite	1	1	7	5	4	2	1	1
Al-hydroxides	0	0	0	0	1	1	0	0
Total terrigenous	**152**	**84**	**101**	**70**	**118**	**73**	**109**	**75**
Sanidine	5	3	3	2	1	1	3	2
Ternary Feldspar	4	2	2	1	1	1	2	1
Zeolite	16	9	5	3	5	3	15	10
Augite	0	0	0	0	1	1	2	1
Total volcanic	**25**	**14**	**10**	**7**	**8**	**5**	**22**	**15**
Chalcedony	0	0	0	0	1	1	0	0
Sulphate	0	0	0	0	1	1	2	1
Nitratine	0	0	4	3	0	0	0	0
Natrite	1	1	0	0	0	0	0	0
Total authigenic/unknown	**1**	**1**	**4**	**3**	**2**	**1**	**2**	**1**
Aragonite	2	1	28	19	34	21	12	8
Cristobalite	0	0	1	1	0	0	1	1
Total marine	**2**	**1**	**29**	**20**	**34**	**21**	**13**	**9**
Total particles	**180**		**144**		**162**		**146**	

Ponce et al., 2011



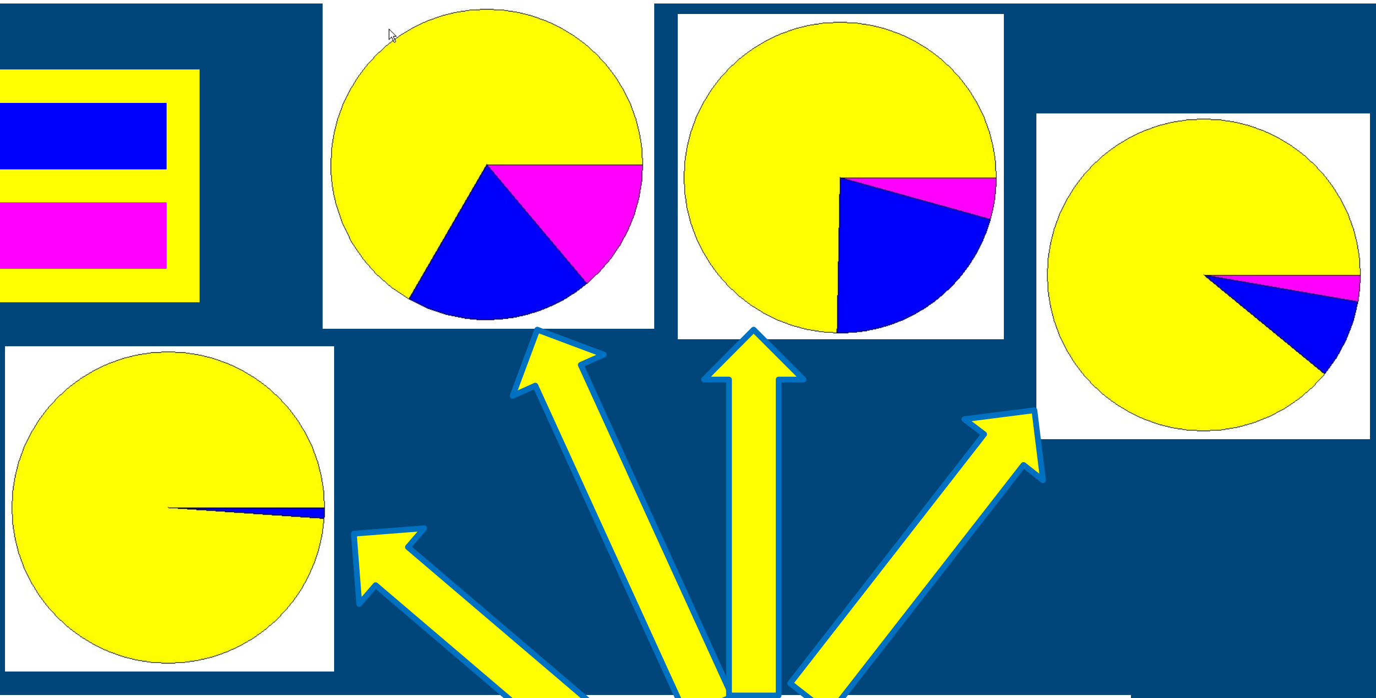
19%   CALCITE

71% ARAGNONITE

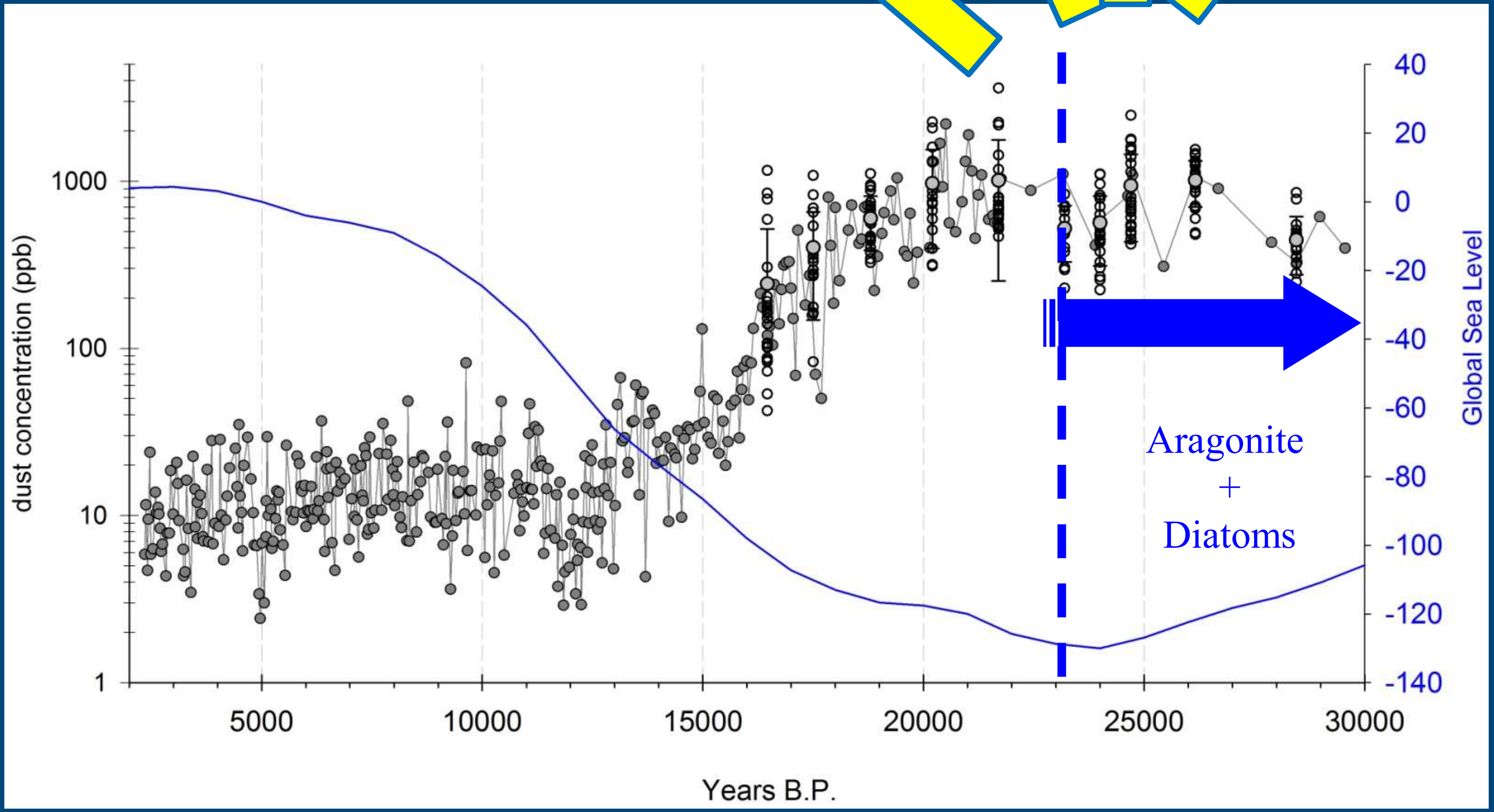
►provenance from shallow sea-floors

% ARAGONITE 🟦

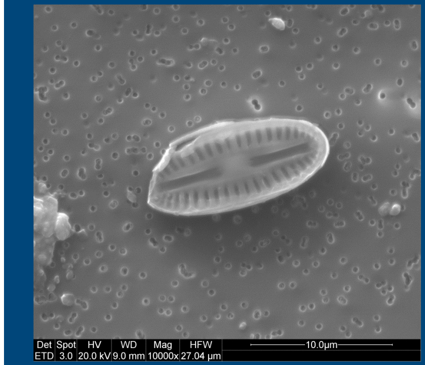
% CALCITE 🟪

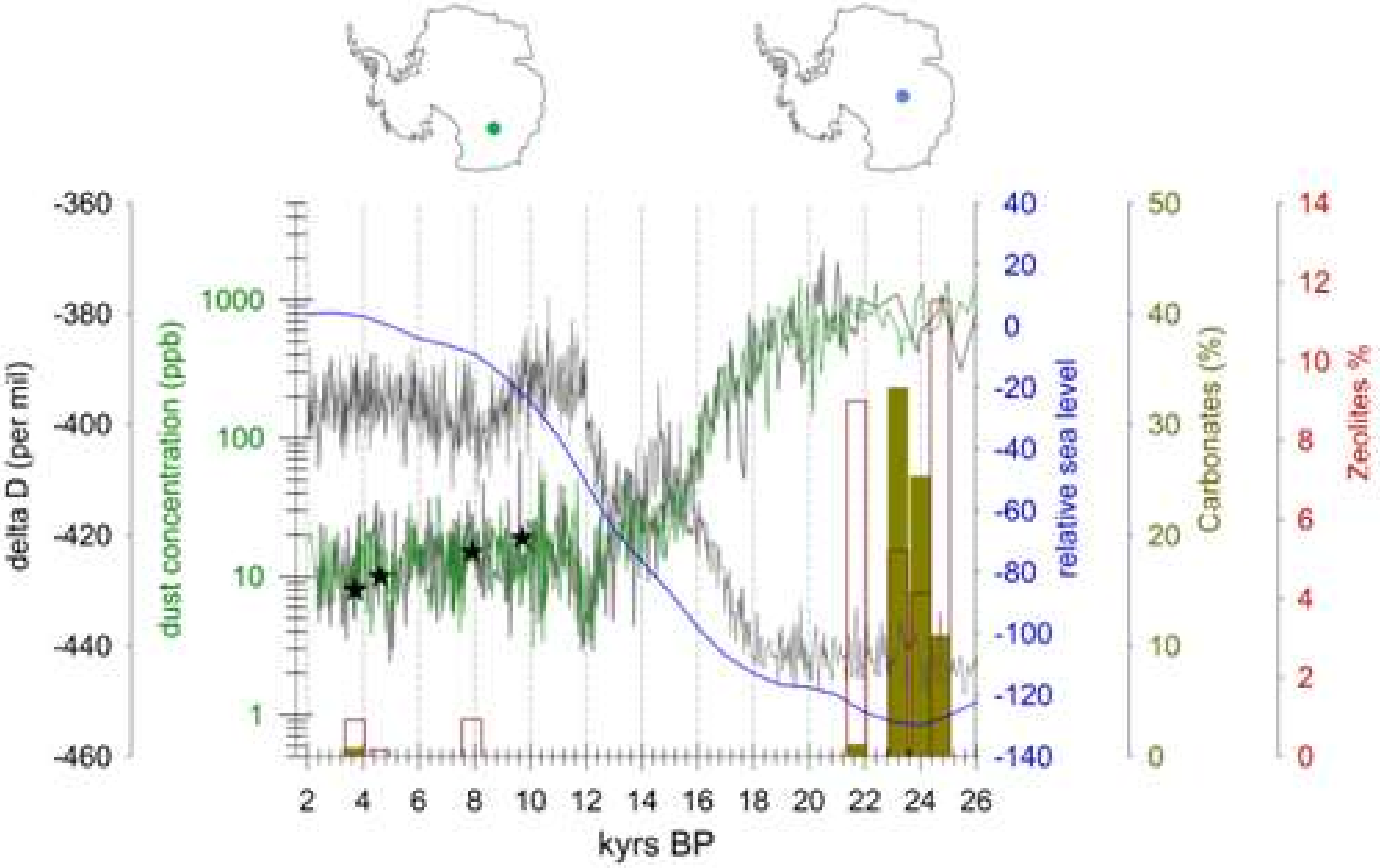


Redrawn from:
Delmonte et al., 2017



Aragonite
+
Diatoms

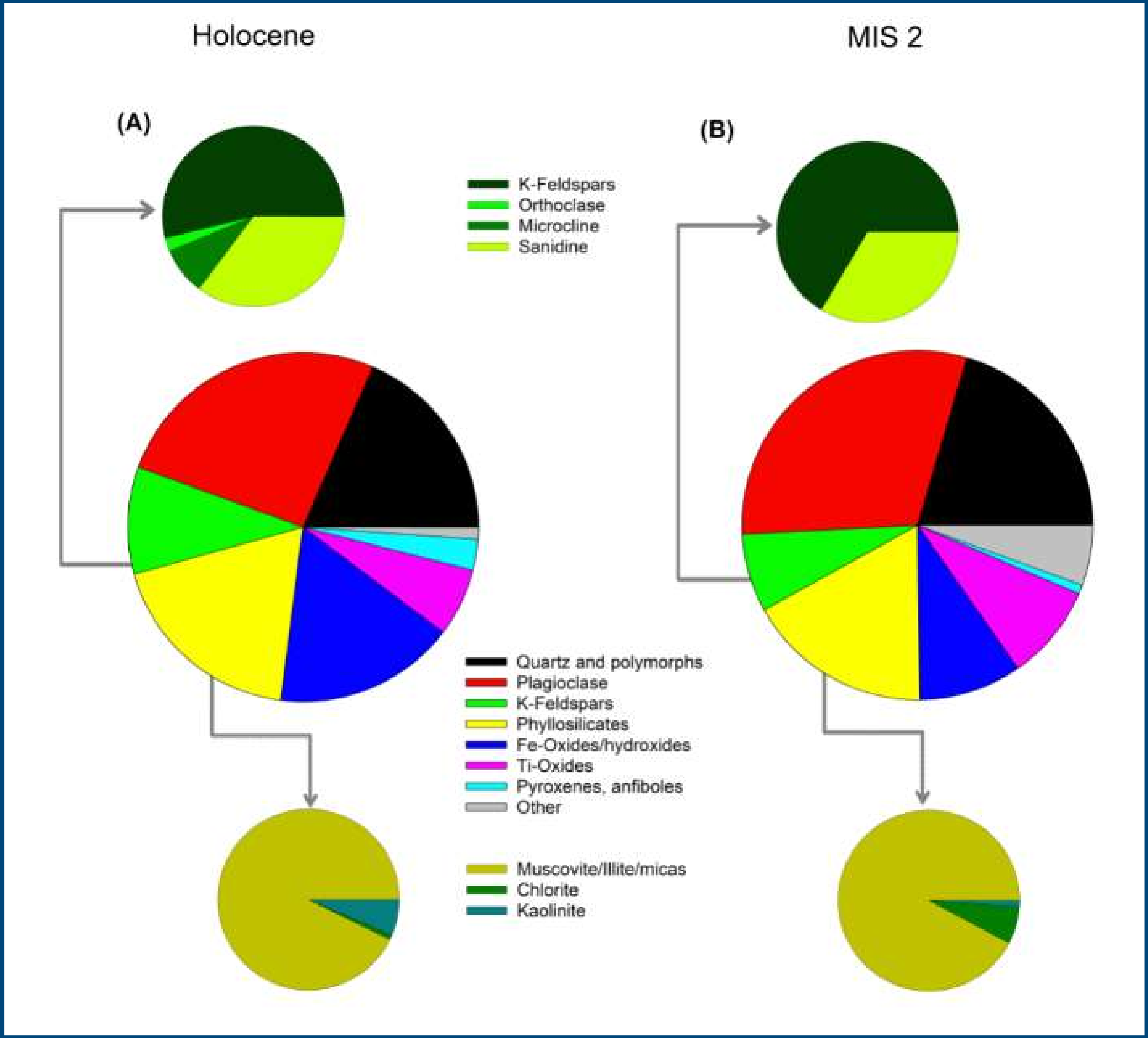



delta D (per mil)
-360
-380
-400
-420
-440
-460
dust concentration (ppb)
1000
100
10
1
relative sea level
40
20
0
-20
-40
-60
-80
-100
-120
-140
Carbonates (%)
50
40
30
20
10
0
Zeolites %
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
kyrs BP

quartz/feldspar ratio
systematically
around 0.5

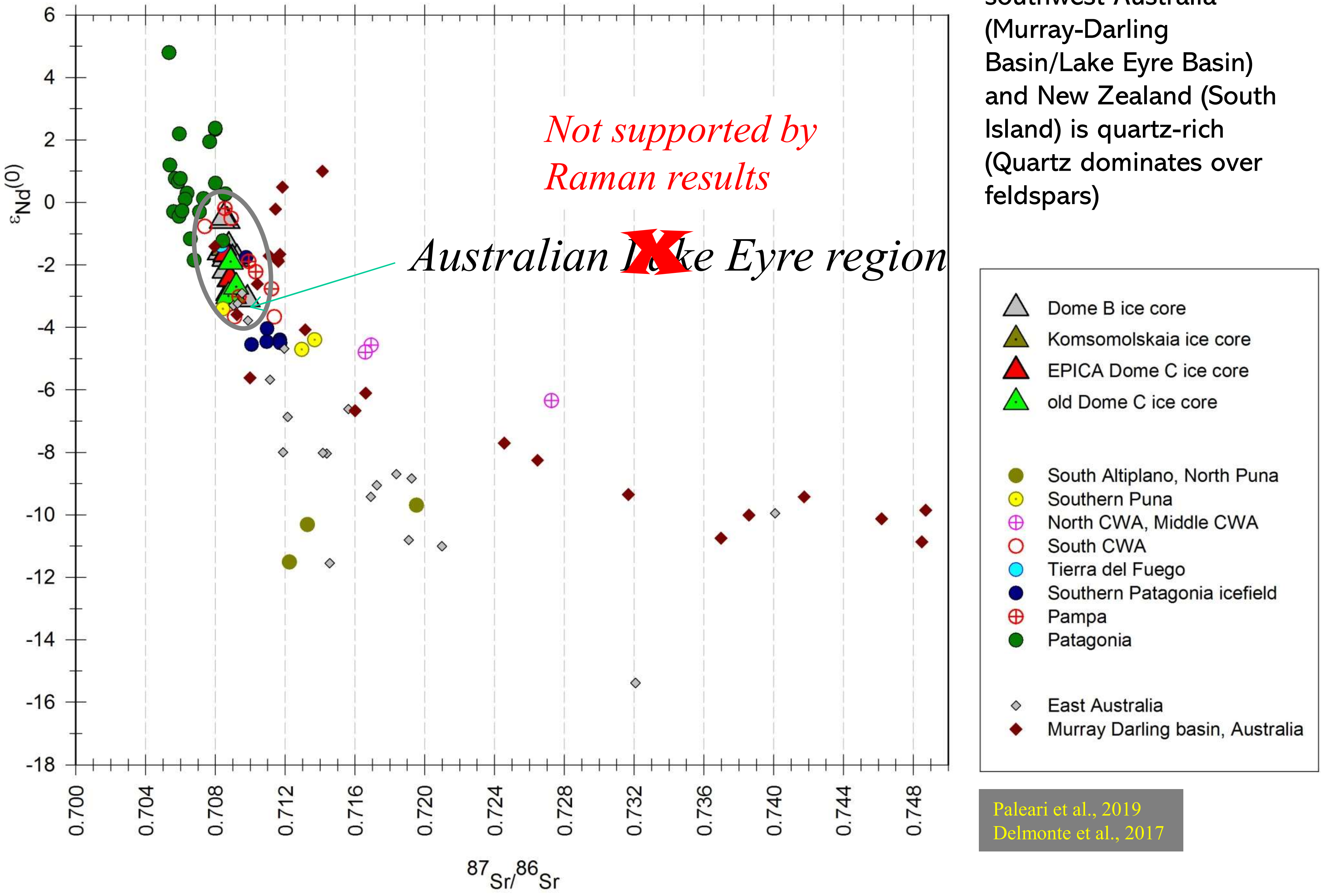
typical mark of volcano-plutonic suites shed from magmatic arcs (Garzanti, 2018)

consistent with an Andean provenance of Antarctic dust



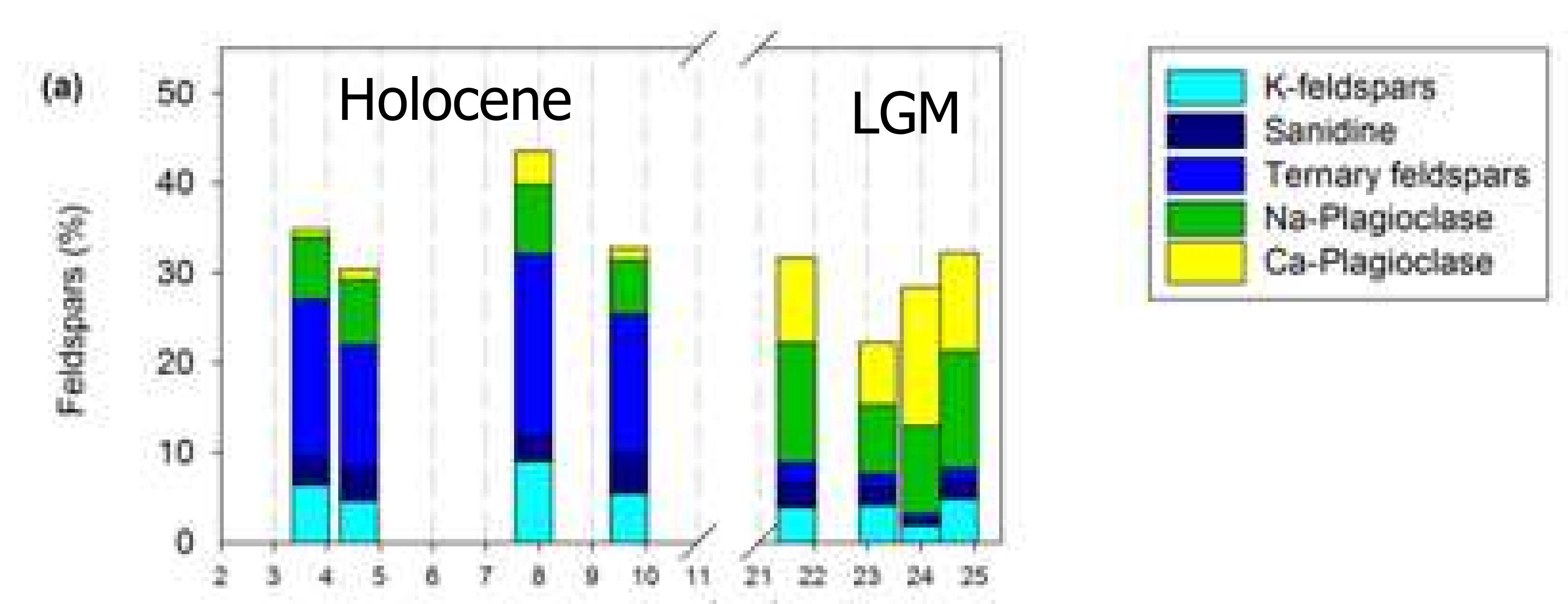
(quartz+feldspars)/phyllosilicates
very similar between Holocene (2.9) and MIS 2 (3.3).
no major glacial/interglacial changes in the overall mean dust transit time

Aeolian dust deflated from southwest Australia (Murray-Darling Basin/Lake Eyre Basin) and New Zealand (South Island) is quartz-rich (Quartz dominates over feldspars)



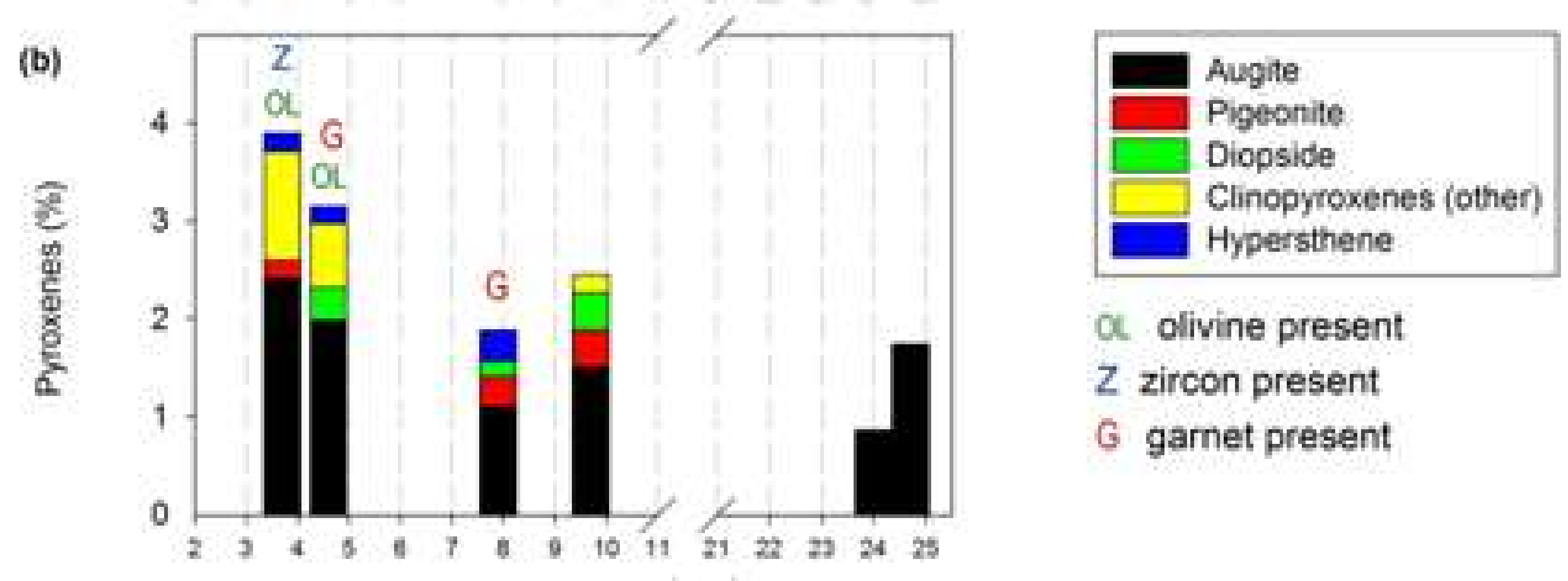
Paleari et al., 2019
Delmonte et al., 2017

In addition:



Glacial and interglacial samples show a mainly volcanic/subvolcanic component, suggesting an important contribution from volcanic rocks, which is slightly more pronounced during the Holocene.

Paleari et al., 2019



Further evidence for an increased volcanic contribution:
-increasing **abundance of augitic clinopyroxenes**
- new species including **pigeonite** in Holocene dust samples
- **hypersthene** is also present in trace in Holocene samples

contribution from andesitic and basaltic volcanic sources

Abundant augite associated with hypersthene is typical of modern Andean-derived sediments found across Patagonia

Accessory heavy minerals (including olivine, garnet, spinel, zircon,..)

-absent in glacial samples
-detected in trace amounts in interglacial dust

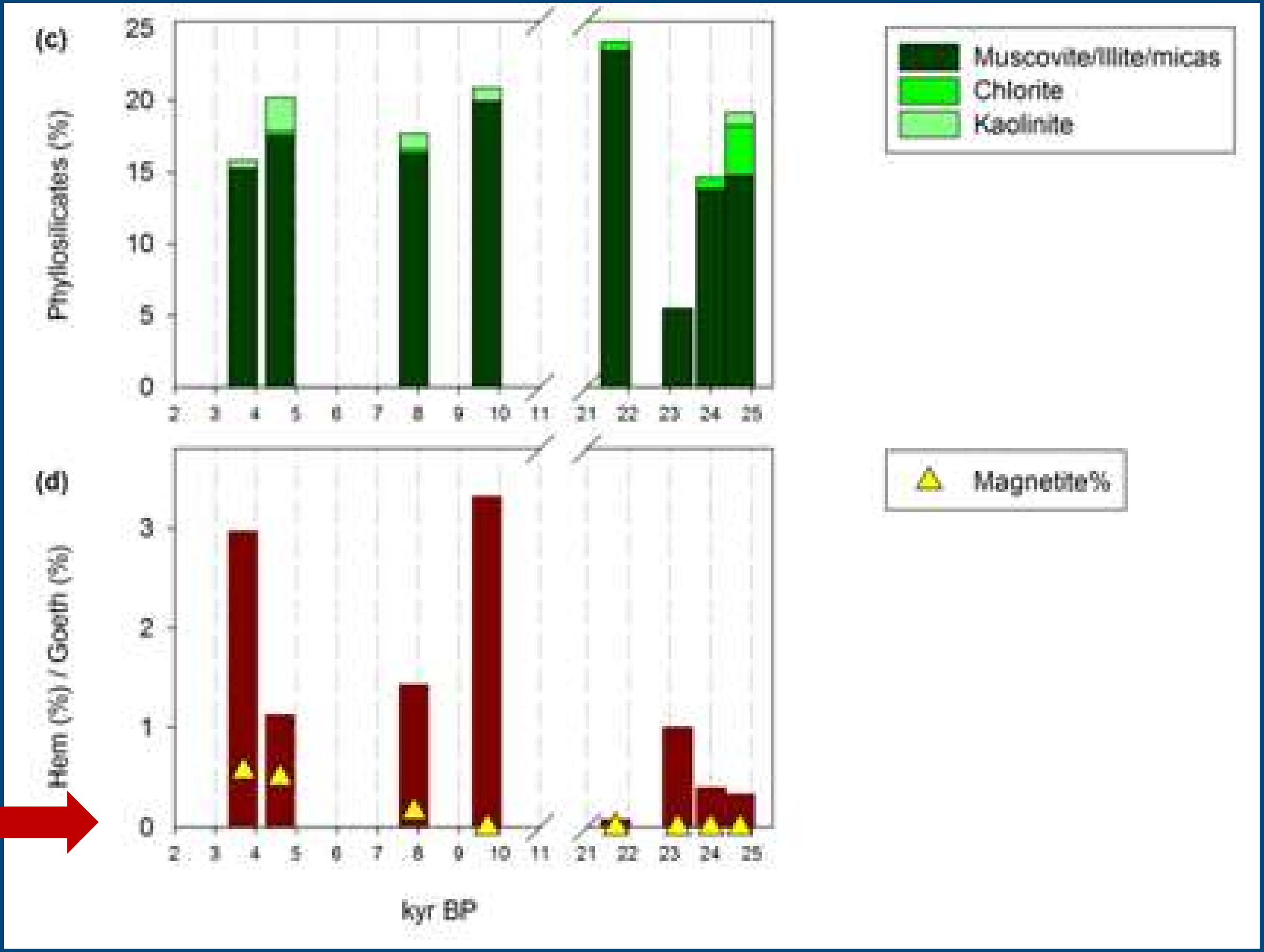
Kaolinite is typically formed by intense weathering in wet subequatorial climates

Alternating chlorite and kaolinite thus suggests physical erosion during glacial conditions, and enhanced chemical weathering during the Holocene

Hematite (product of weathering)

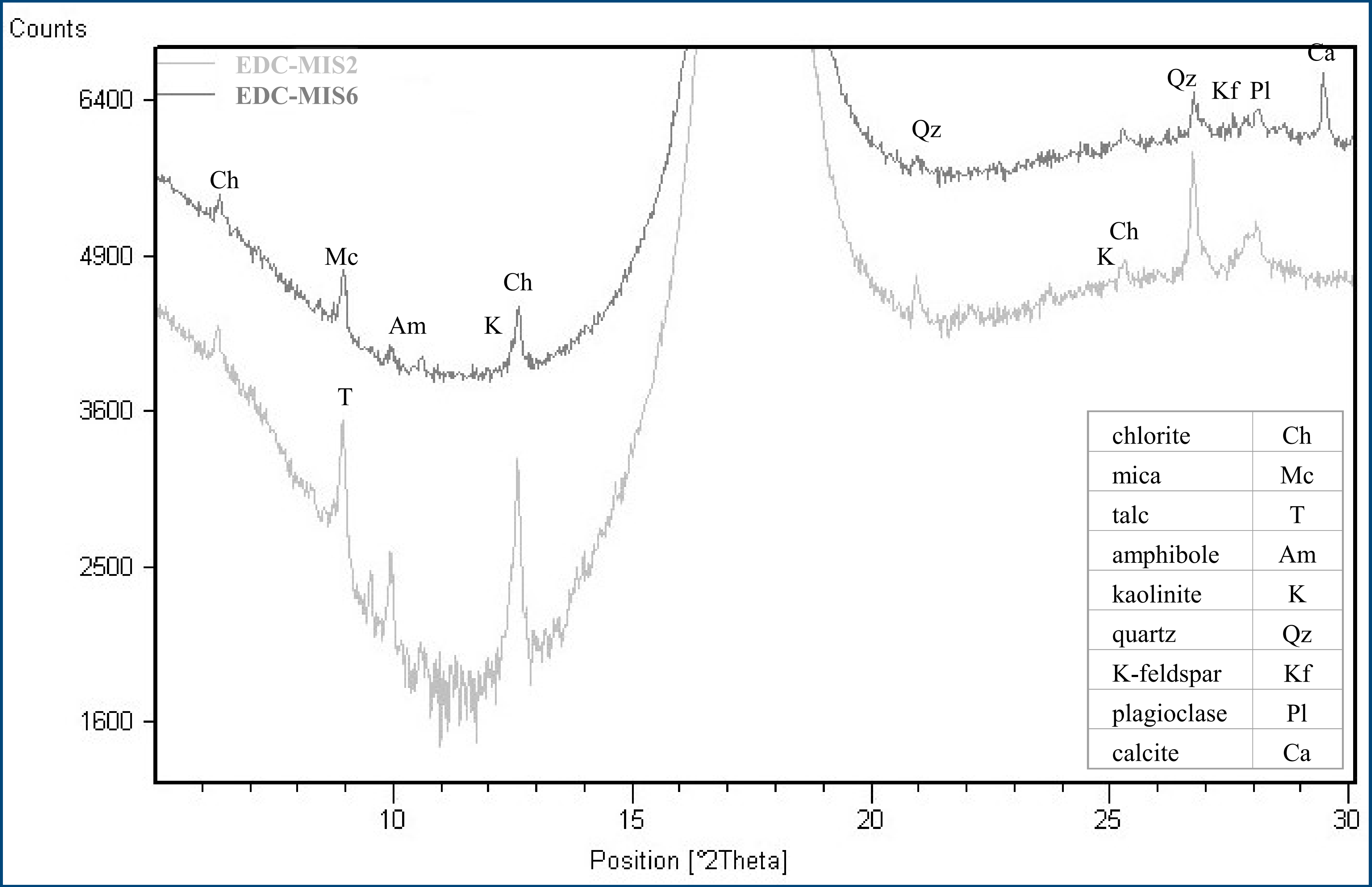
Forms under warm low-latitude regions dominated by arid climate or experiencing a longer warm/dry season followed by a shorter period of soil wetness

Goethite
forms under cool/wet climates or climates characterized by higher or less seasonal precipitation than required for hematite formation



Bulk dust powder diffraction is more difficult and much material is required

(*trace minerals not detected*)



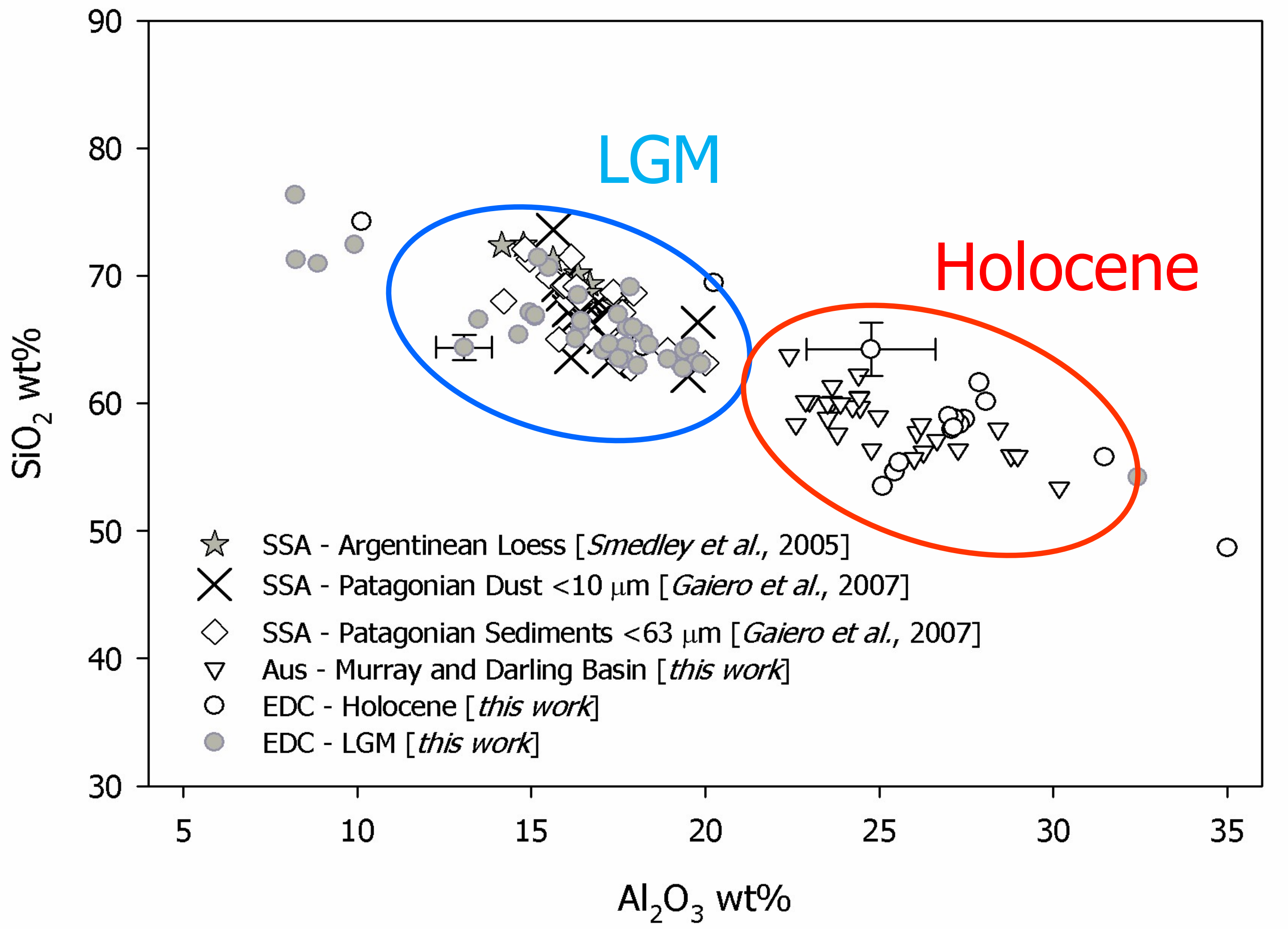
chlorite	Ch
mica	Mc
talc	T
amphibole	Am
kaolinite	K
quartz	Qz
K-feldspar	Kf
plagioclase	Pl
calcite	Ca

MAJOR ELEMENTS:

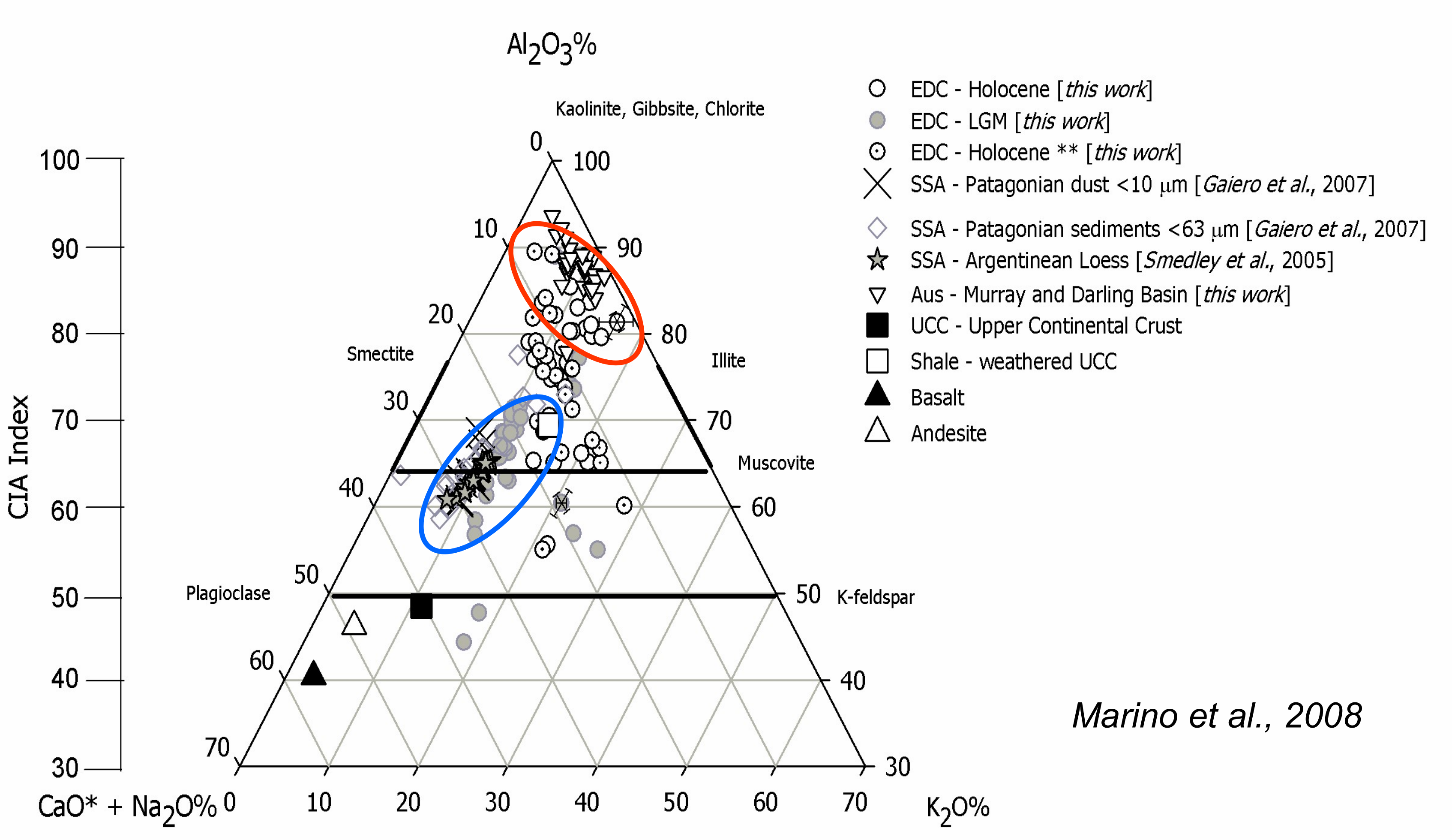
Antarctic glacial dust and South American sediments

Support to the hypothesis of a dominant role of this area as major dust supplier during cold conditions.

Glacial and interglacial dust reveals different geochemical compositions.



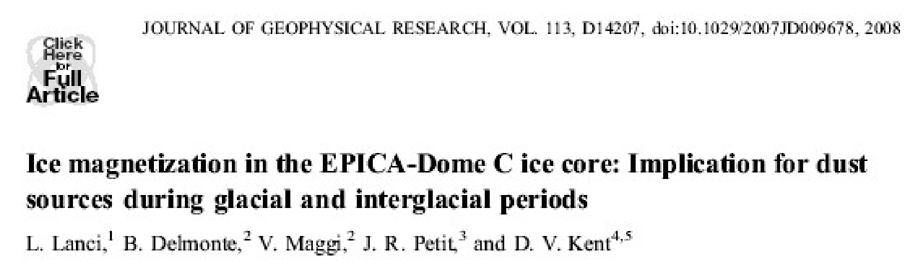
Marino et al., 2008



Marino et al., 2008

The major element composition of Holocene dust implies enhanced weathering at the source region during interglacials

MAGNETIC PROPERTIES OF ICE CORE DUST & PSA

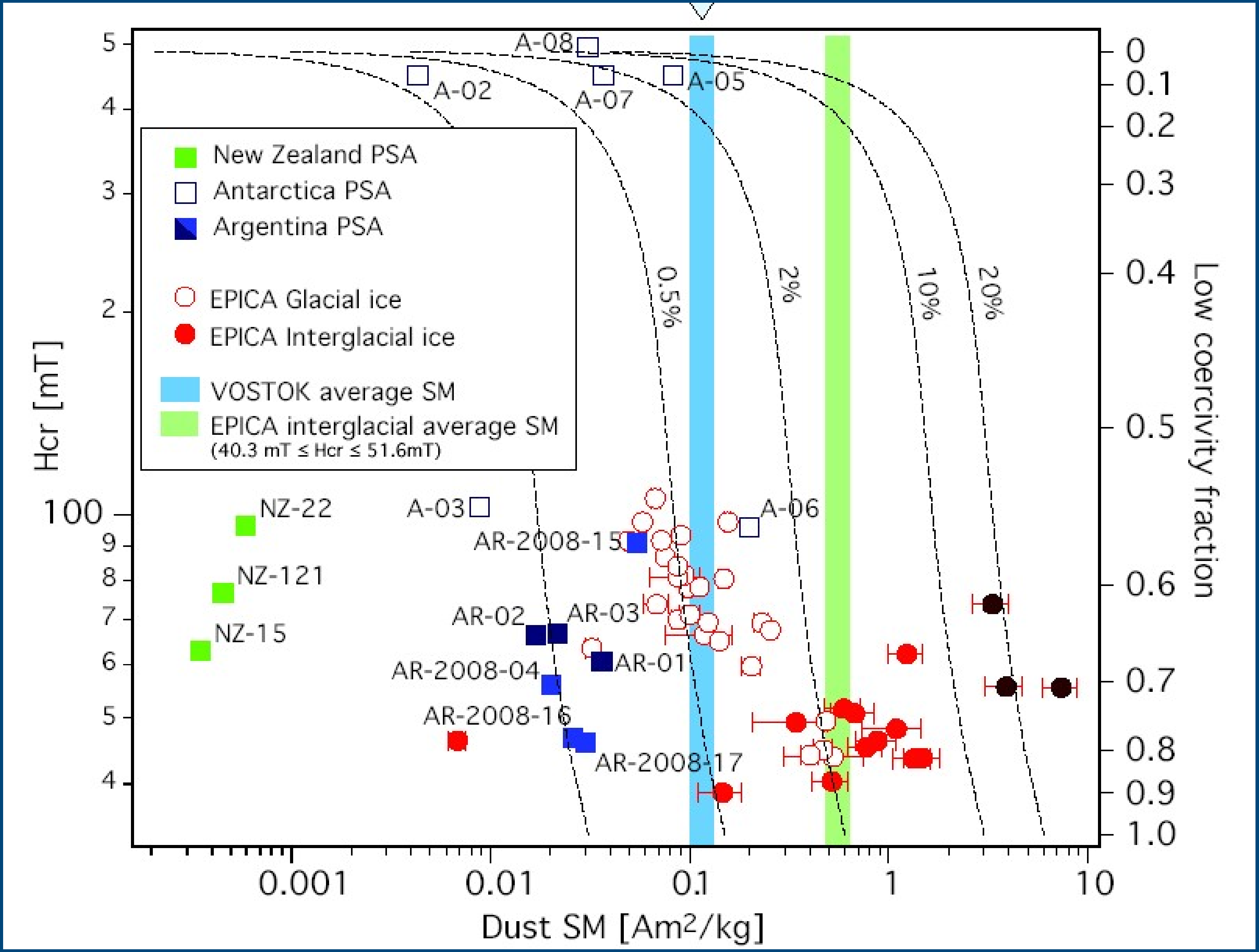


JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D14207, doi:10.1029/2007JD009678, 2008

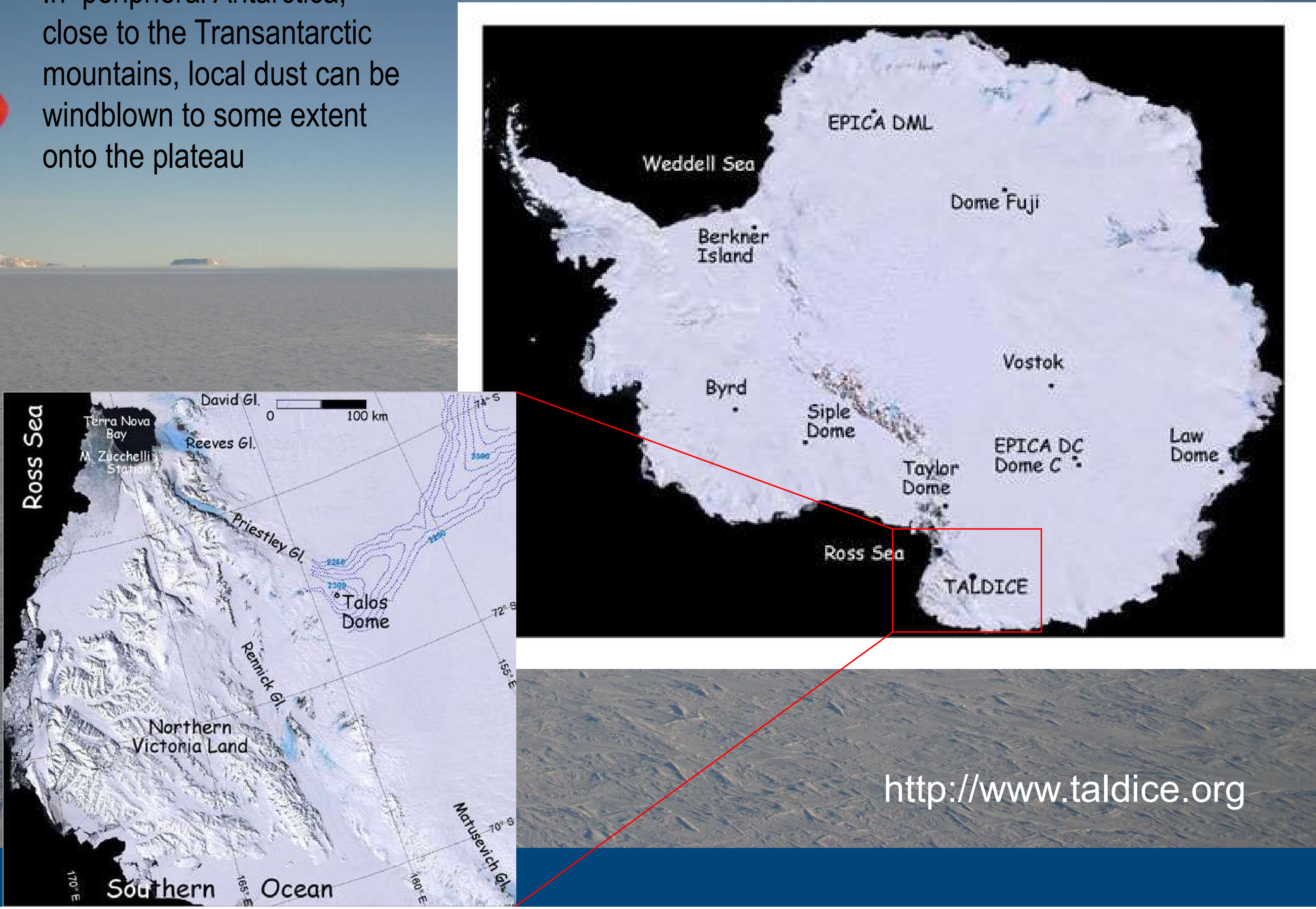
Click Here for Full Article

Ice magnetization in the EPICA-Dome C ice core: Implication for dust sources during glacial and interglacial periods

L. Lanci,[1] B. Delmonte,[2] V. Maggi,[2] J. R. Petit,[3] and D. V. Kent[4,5]



In peripheral Antarctica, close to the Transantarctic mountains, local dust can be windblown to some extent onto the plateau



http://www.taldice.org

A case study

Local dust sources from Victorial Land

(1) Regoliths

(2) Quaternary glacial deposits

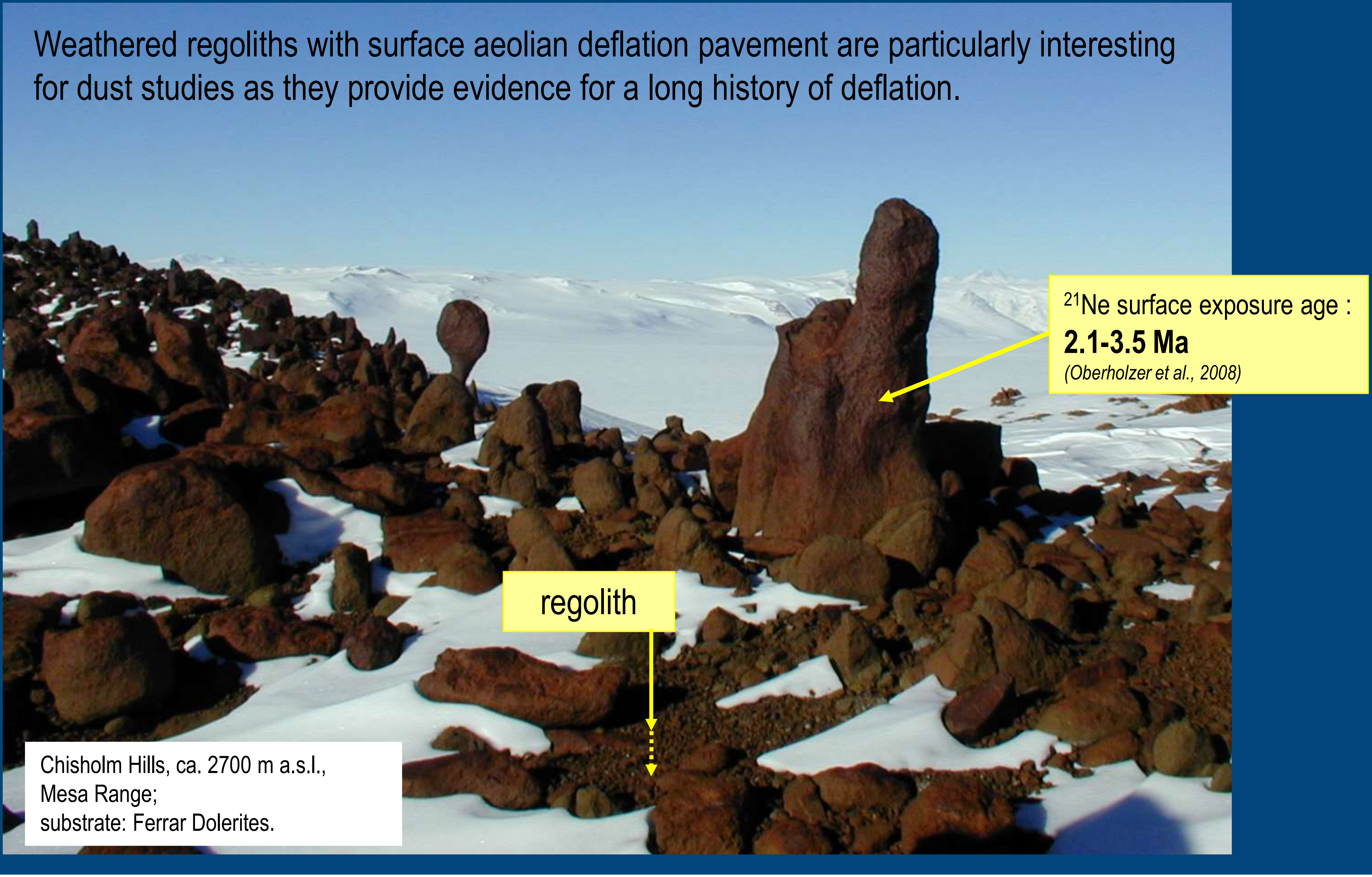
(3) Aeolian materials

(4) Sands from emerged beaches

Photo source:
http://www.taldice.org

Regoliths

Regolith can form in Antarctica through physical weathering and mechanical rock disintegration (wind, water, salts, radiation…). Chemical weathering is very limited.



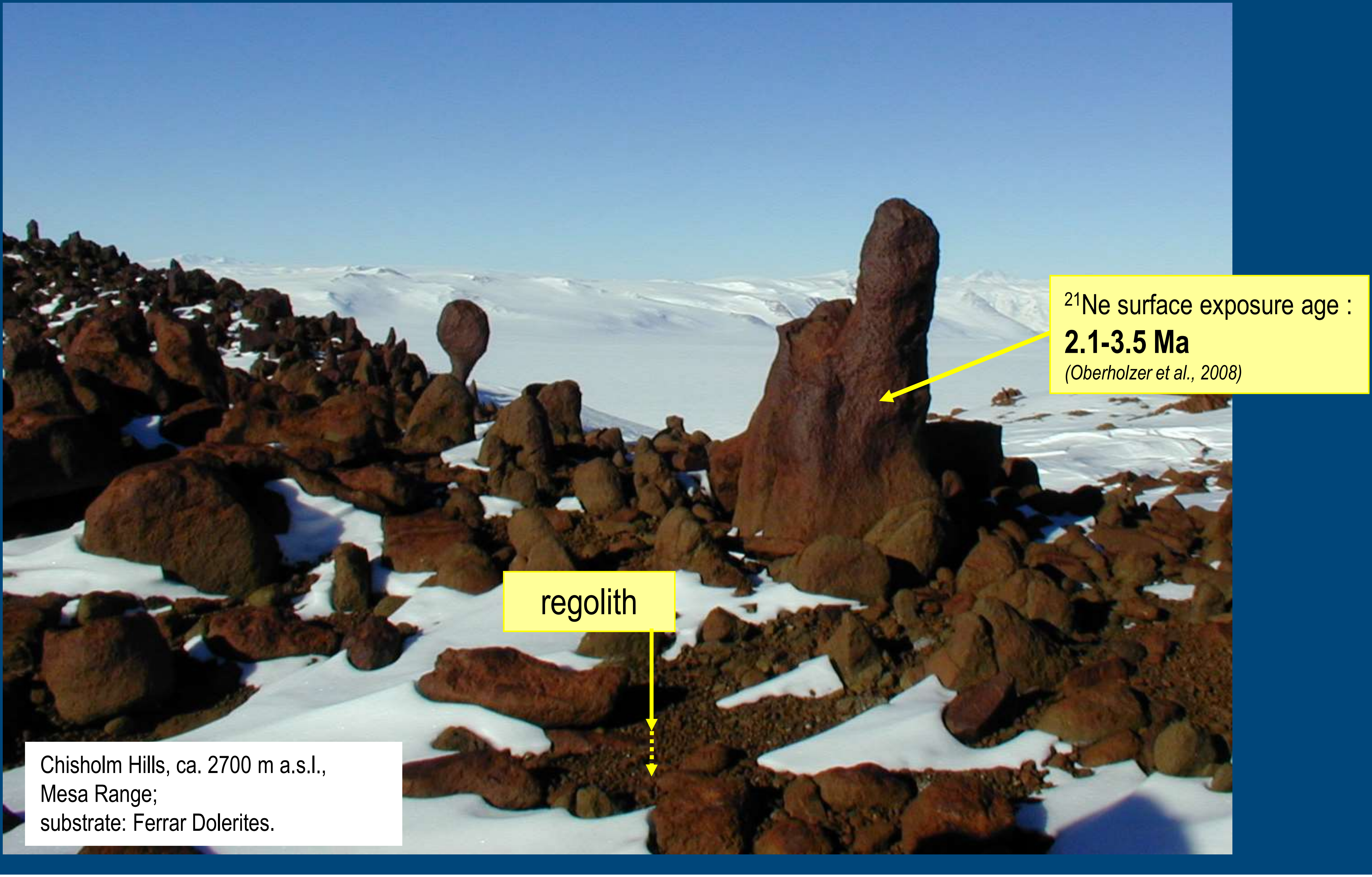
Weathered regoliths with surface aeolian deflation pavement are particularly interesting for dust studies as they provide evidence for a long history of deflation.

^{21}Ne surface exposure age :
2.1-3.5 Ma
(Oberholzer et al., 2008)

Chisholm Hills, ca. 2700 m a.s.l.,
Mesa Range;
substrate: Ferrar Dolerites.

Regoliths

The EAIS has not attained the elevation of the tors anymore after since 3.5 Ma; as consequence, many nunataks at the margin of the EAIS have been potential dust source areas since at least the Pliocene.



^{21}Ne surface exposure age :

2.1-3.5 Ma

(Oberholzer et al., 2008)

regolith

Chisholm Hills, ca. 2700 m a.s.l.,
Mesa Range;
substrate: Ferrar Dolerites.

Photo: C. Baroni

Mesa Range, 72° 54’ 41” S, 162° 54’ 50” E, 2120 m

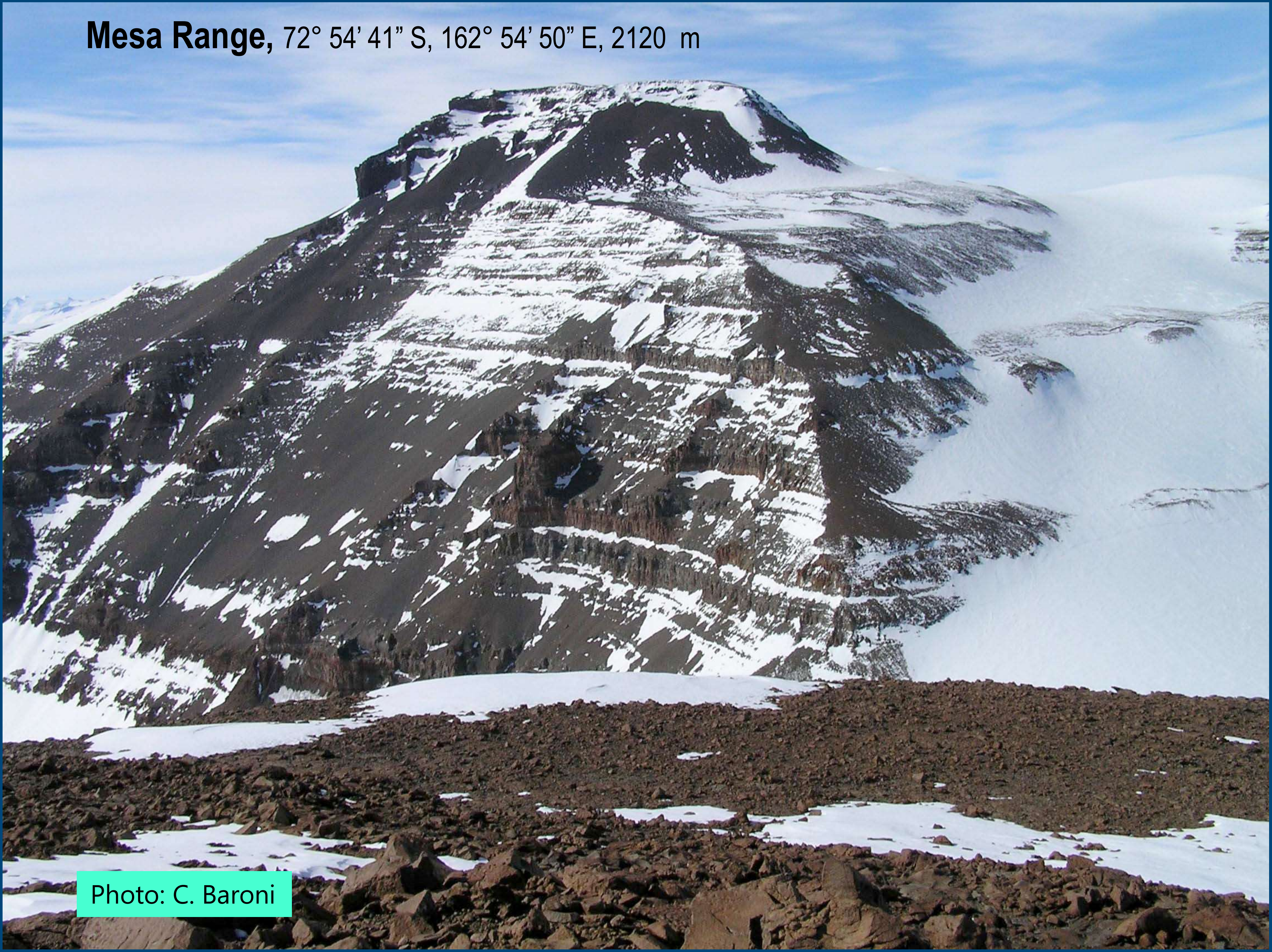
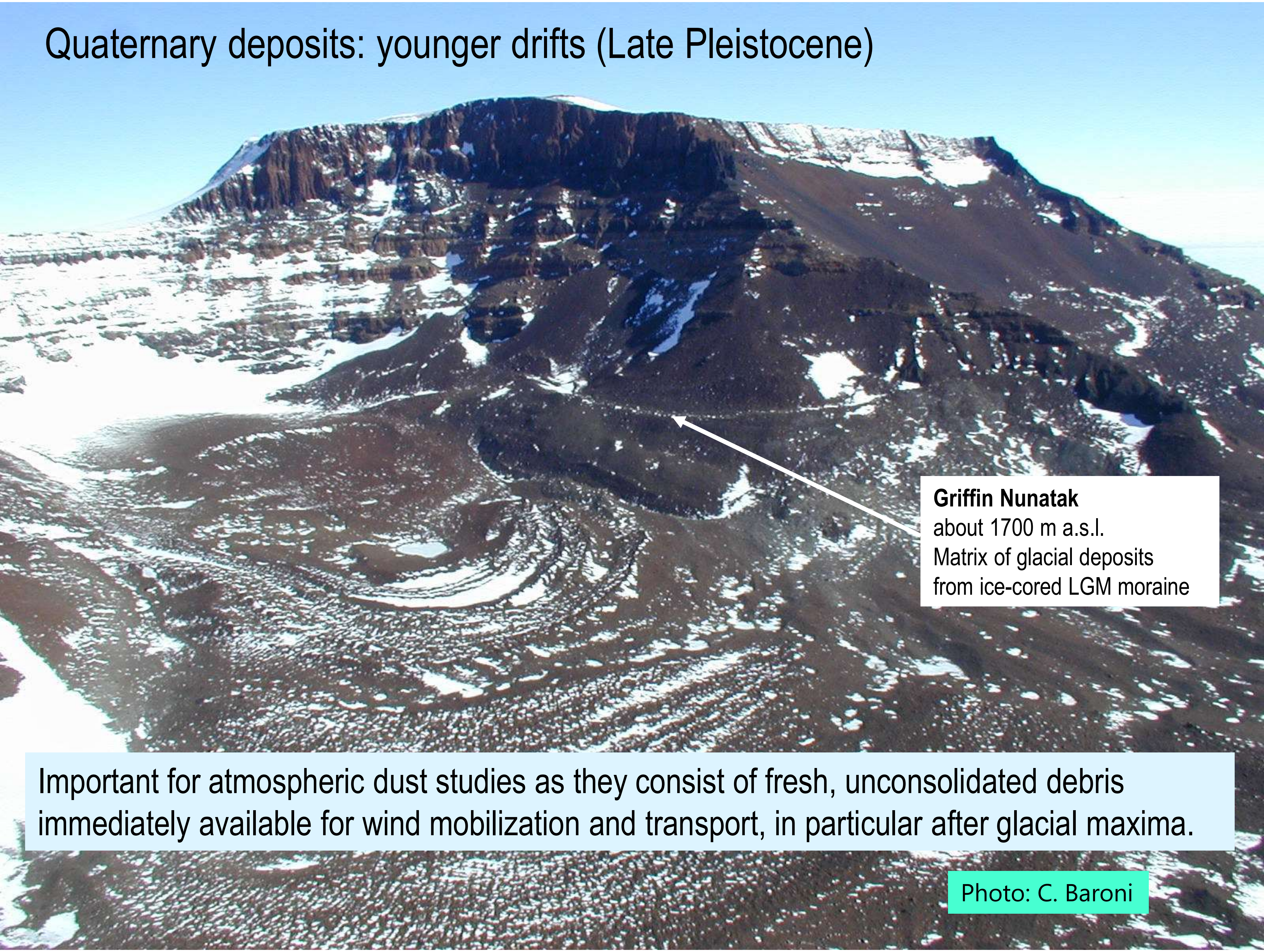


Photo: C. Baroni

Quaternary deposits: younger drifts (Late Pleistocene)



Griffin Nunatak
about 1700 m a.s.l.
Matrix of glacial deposits
from ice-cored LGM moraine

Important for atmospheric dust studies as they consist of fresh, unconsolidated debris immediately available for wind mobilization and transport, in particular after glacial maxima.

Photo: C. Baroni

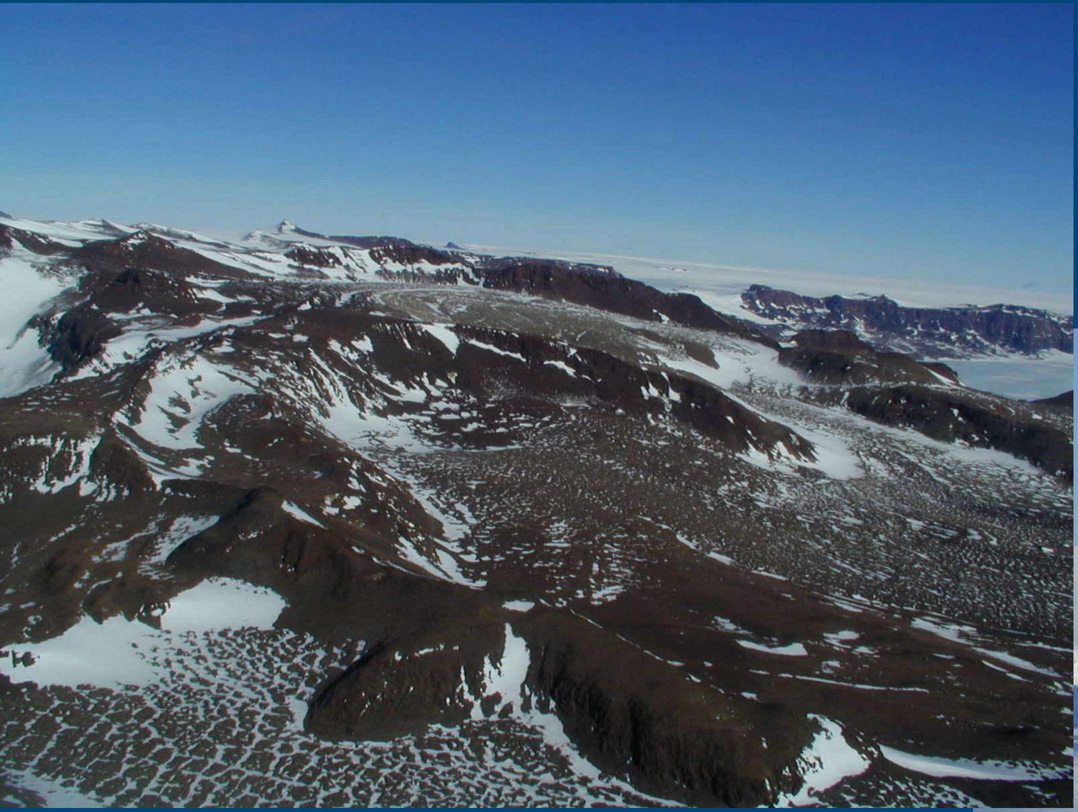
Quaternary deposits: older drifts (Mid-Early Pleistocene)

Photo: C. Baroni

Photo: Older drift from Ricker Hills

Older drift is clast-supported to matrix-supported diamicton
with a sandy–silty matrix ranging in colour from dark greyish brown to olive-grey.
Surface clasts are deeply weathered and oxidized with yellowish-red or red colour of staining.

natural sediment traps



Ricker Hills area

Photo: C. Baroni

Mt. Browning, Northern Foothills

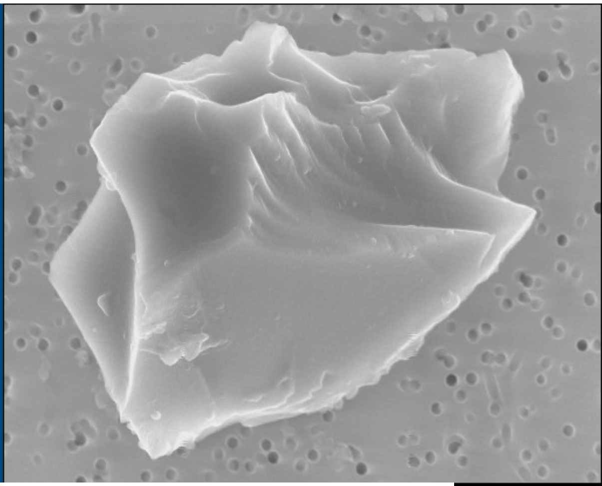
Aeolian sands are important for dust studies as they provide a “natural” sample of local mineral aerosol already subjected to a first phase of deflation, atmospheric selection, transport and re-deposition.

Emerged beaches (Holocene)

Inexpressible Island
74° 54’ 16” S, 163° 41’ 11” E , 30 m

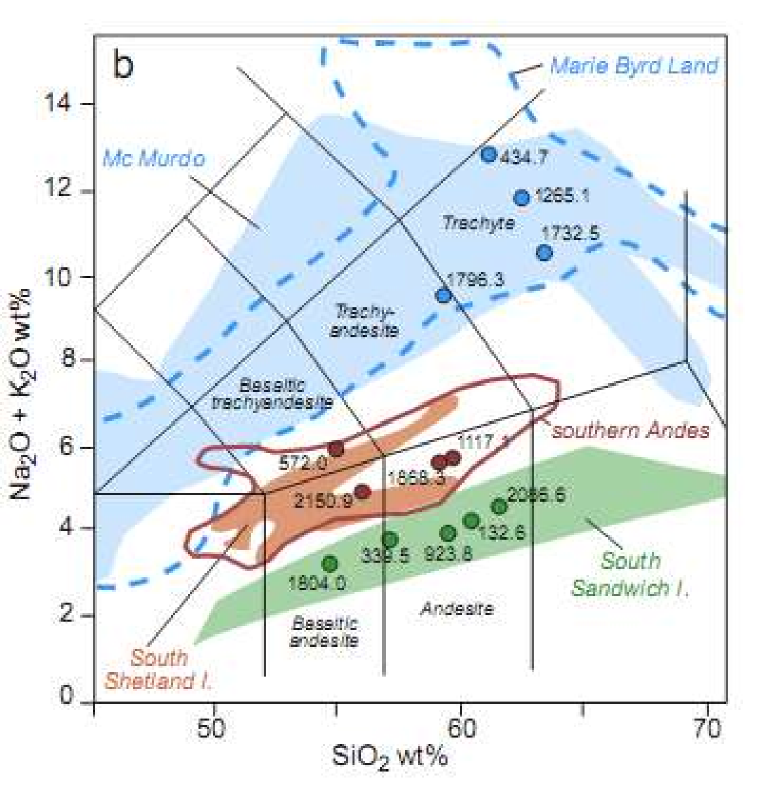
..other insoluble impurities in polar ice cores

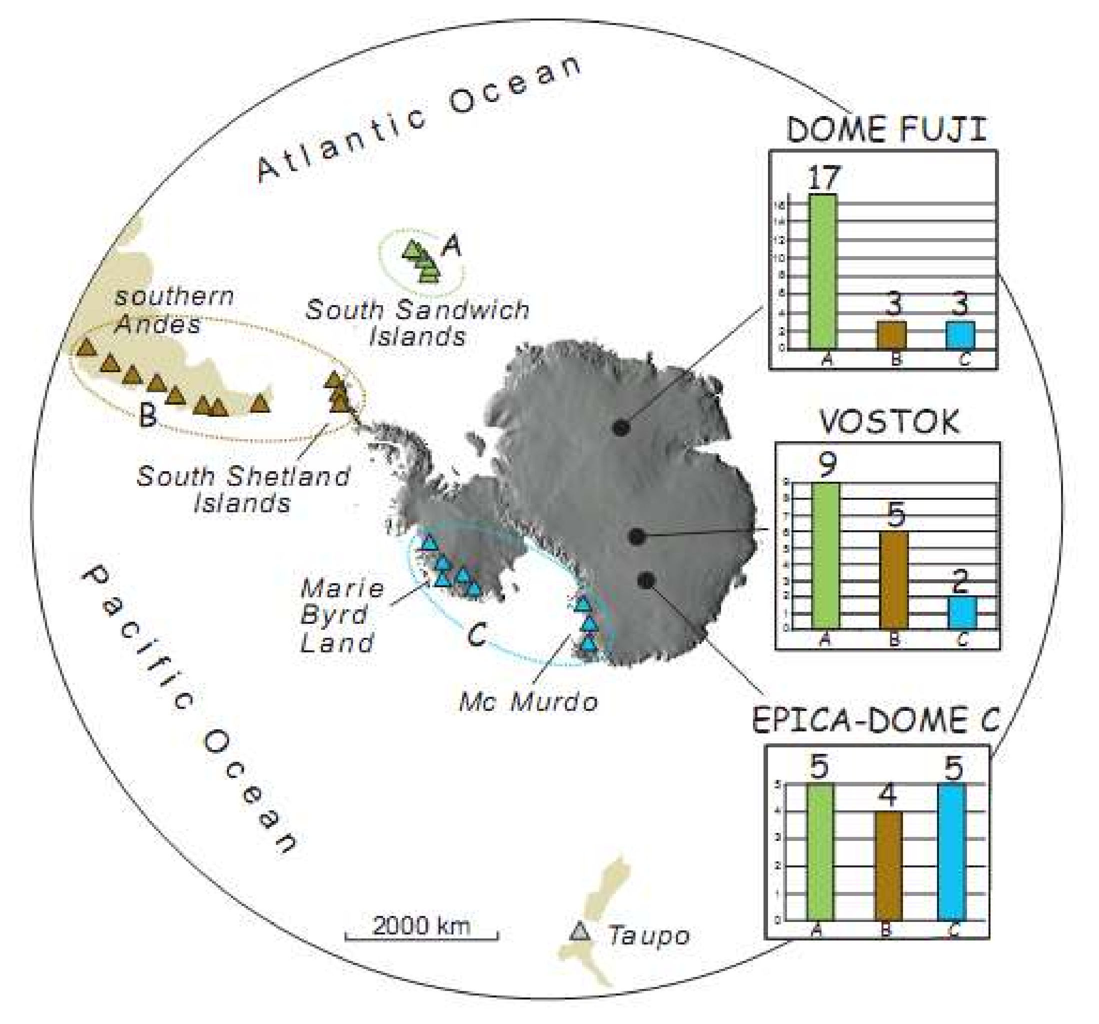
INSOLUBLE PARTICLES IN ICE CORES:



Mainly dust from continents, but also….

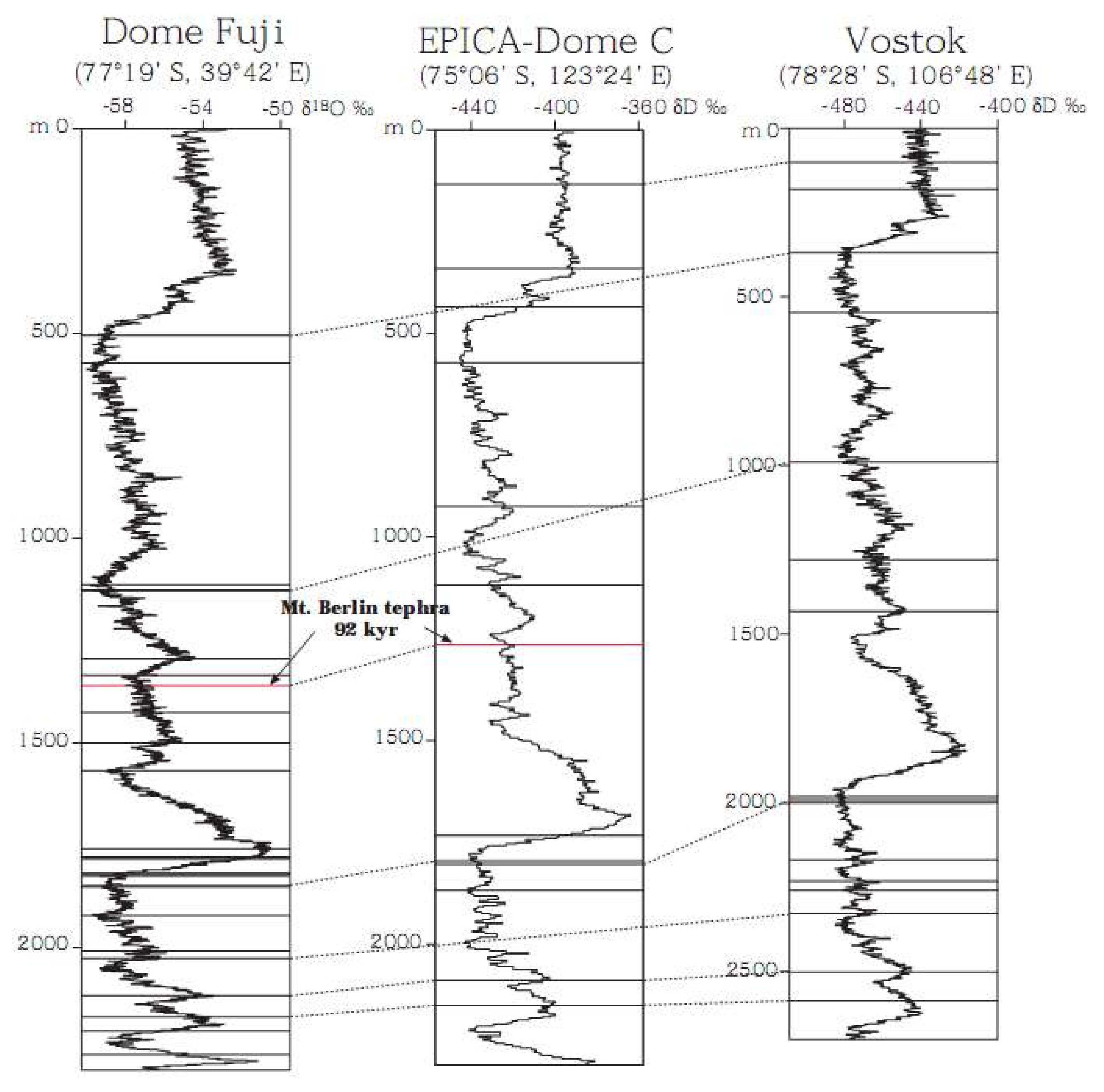
- Tephra layers



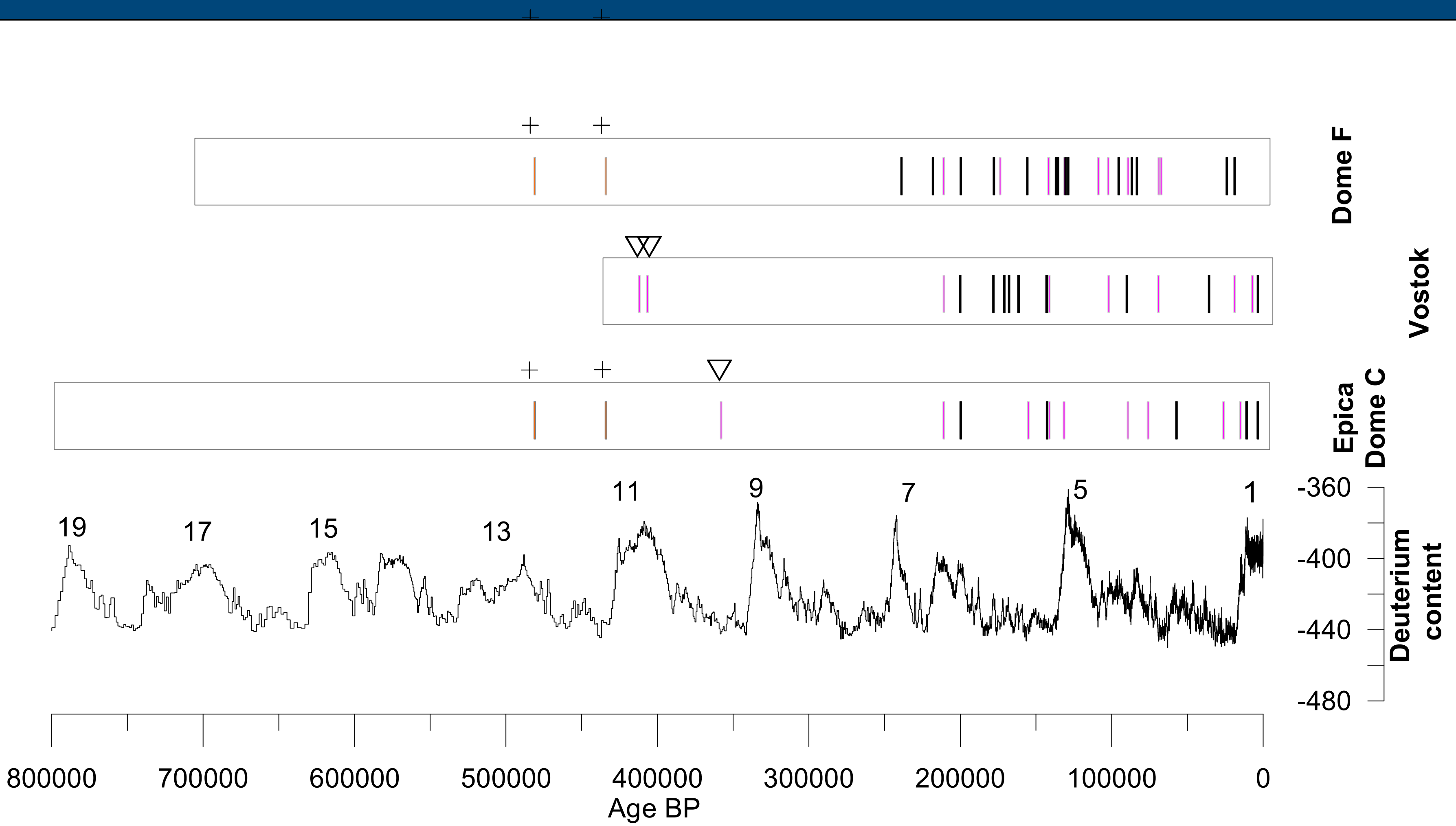


Narcisi et al, 2005, 2009

Tephra layer study in Antarctic ice cores: a contribution to the chrono-stratigraphic link among different ice cores



Narcisi et al, 2006

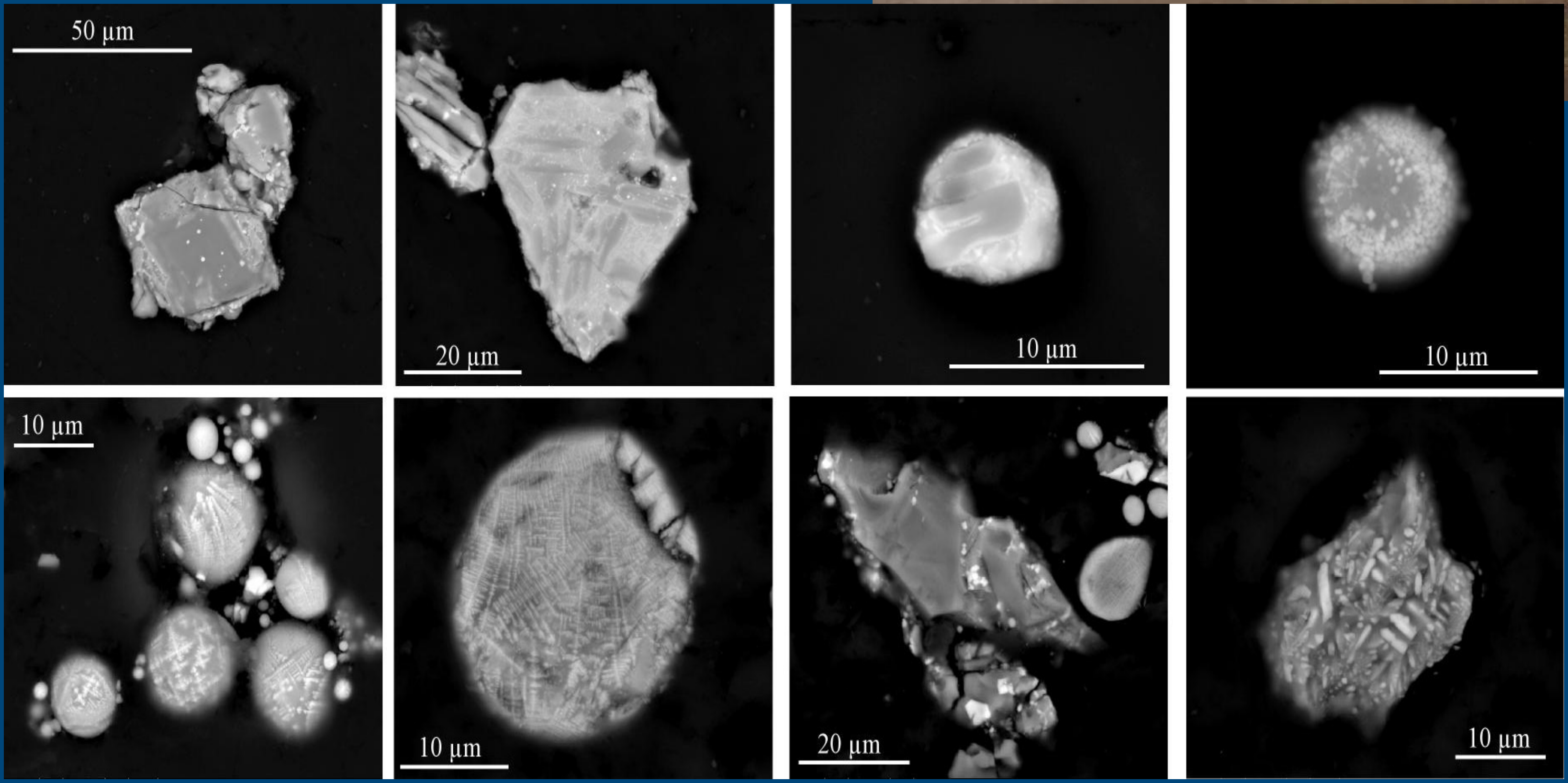


Most visible volcanic layers originate from eruptives centers surrounding Antarctica, and were likely subjected to favorable rapid atmospheric transport through the low troposphere (Narcisi et al., 2005).

INSOLUBLE PARTICLES IN ICE CORES:

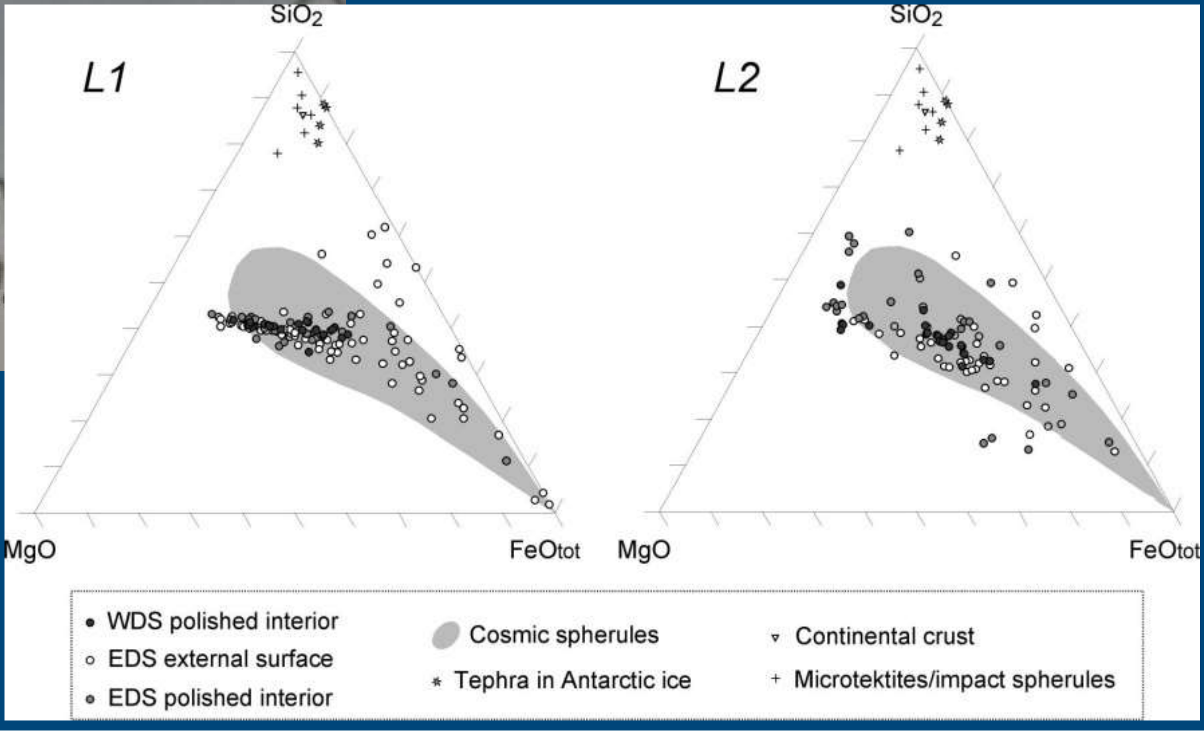
- Micrometeorites

(Narcisi et al., 2008)



Two meteoritic events have been found in the EPICA-Dome C ice core (440 ky and 480 ky BP) and also in the Dome Fuji core

Narcisi et al, 2007

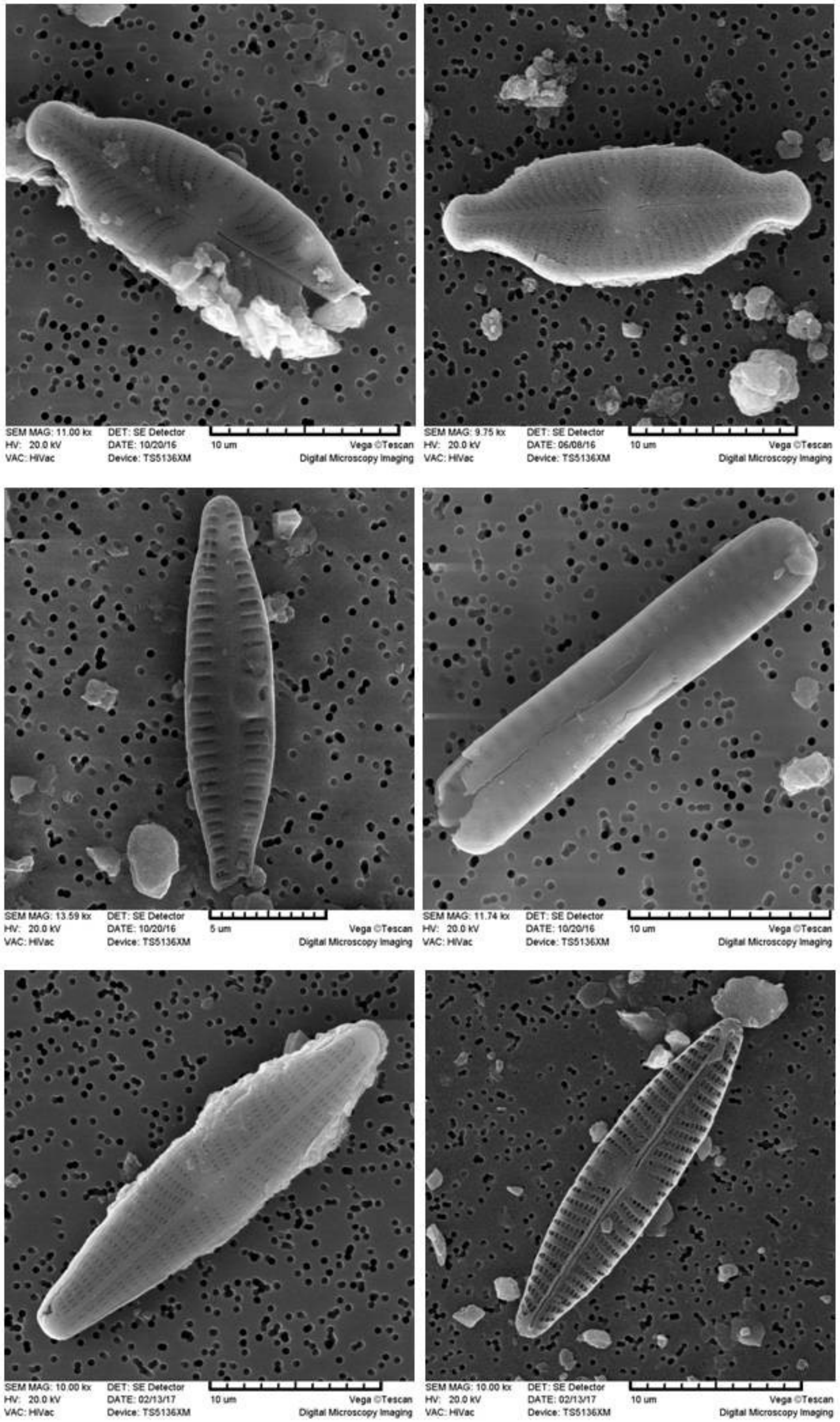


INSOLUBLE PARTICLES IN ICE CORES:

- Diatoms

These can be diagnostic for paleo-environmental reconstruction

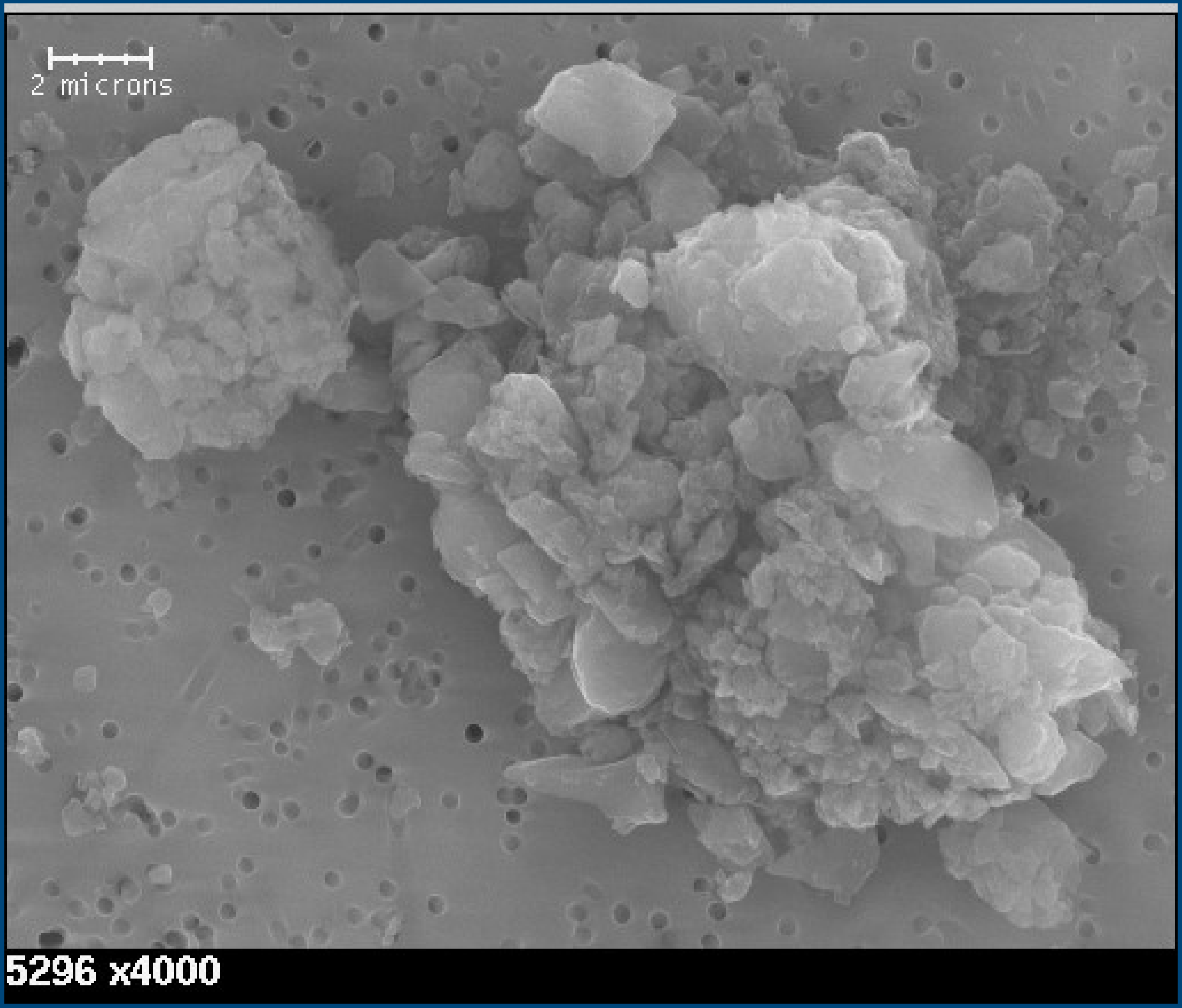
example> some freshwater diatom species (together with dust) allowed identifying the Patagonian outwash plains as major dust source region during the last glacial period




45°S
South Georgia
60°S
Falckland Is.

A final remark….

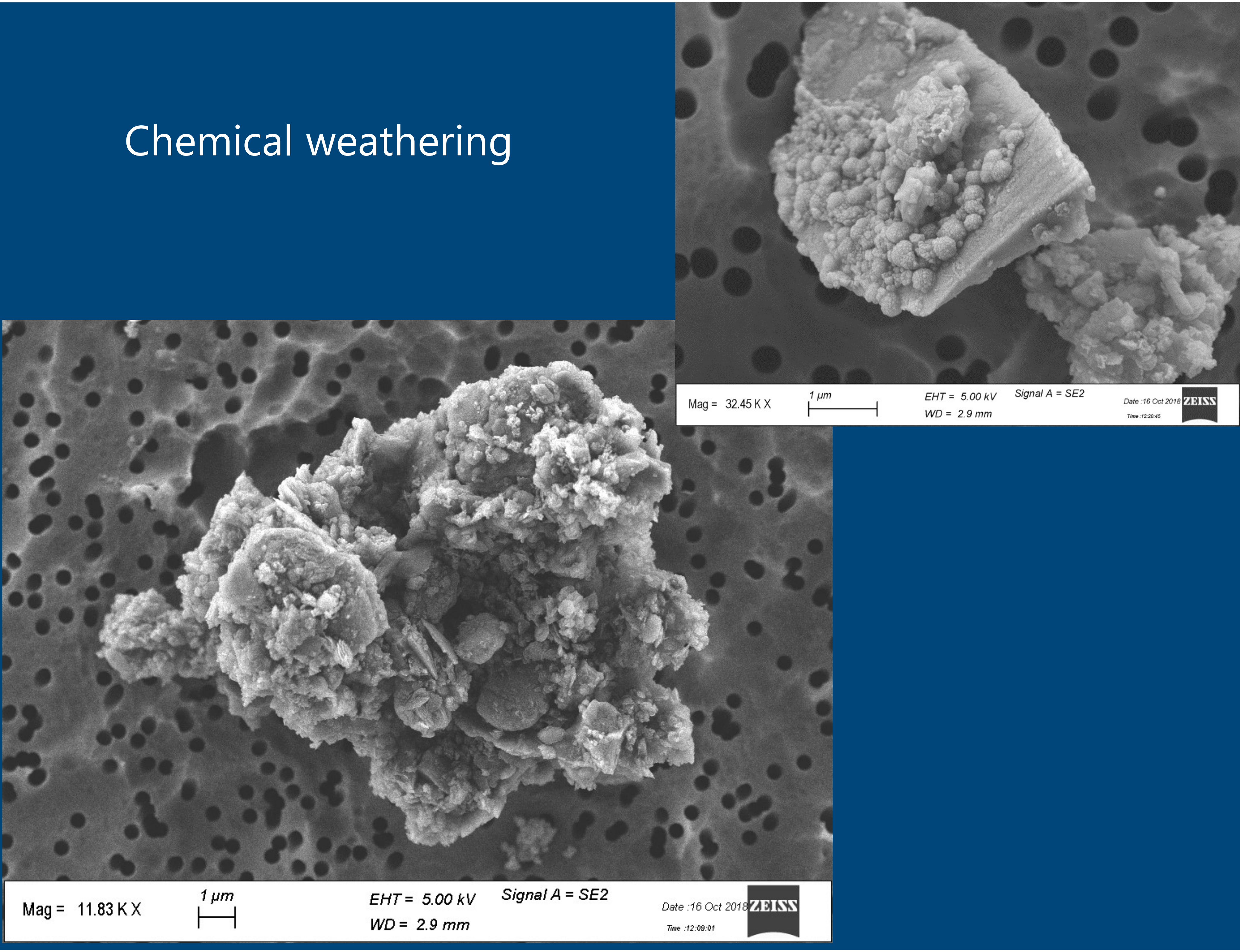
At great depth, where re-crystallization processes can be important, some post-depositional processes occur:

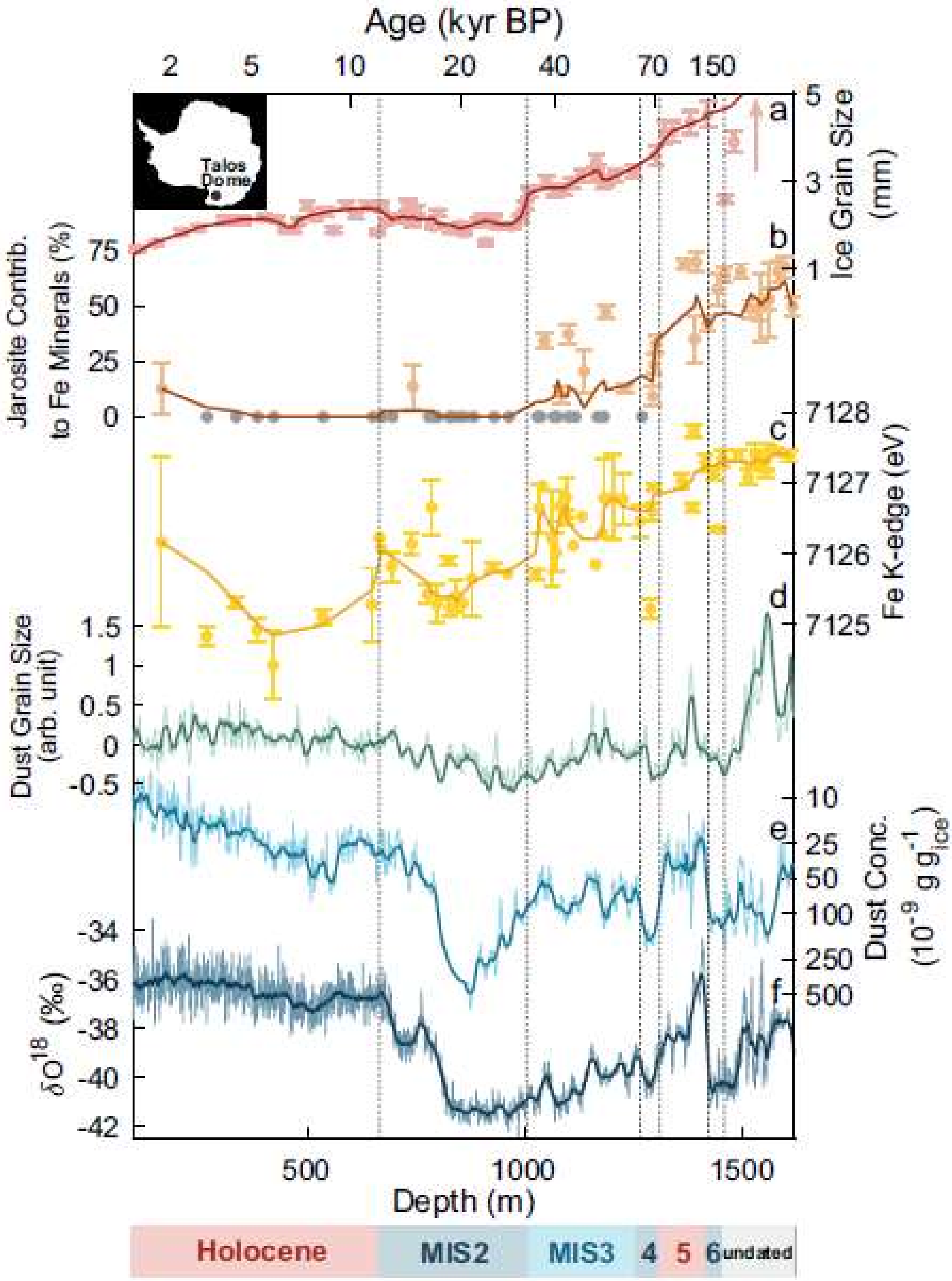


Physical aggregation

←

Chemical weathering



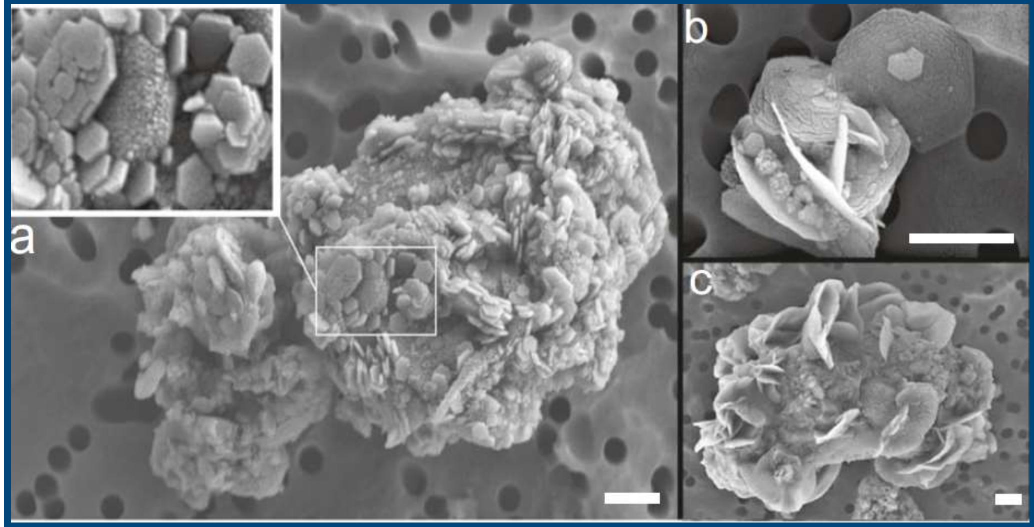



ARTICLE

https://doi.org/10.1038/s41467-020-20705-z OPEN

Jarosite formation in deep Antarctic ice provides a window into acidic, water-limited weathering on Mars

Giovanni Baccolo[1,2], Barbara Delmonte[1], P. B. Niles[3], Giannantonio Cibin[4], Elena Di Stefano[1,2,5], Dariush Hampai[6], Lindsay Keller[3], Valter Maggi[1,2], Augusto Marcelli[6,7], Joseph Michalski[8], Christopher Snead[9] & Massimo Frezzotti[10]



In Milan..

Prof. Giuseppe Orombelli, *Emeritus*

Prof. Valter Maggi
full Professor

Claudio Artoni
technician

Samuel Albani
Professor

...and myself