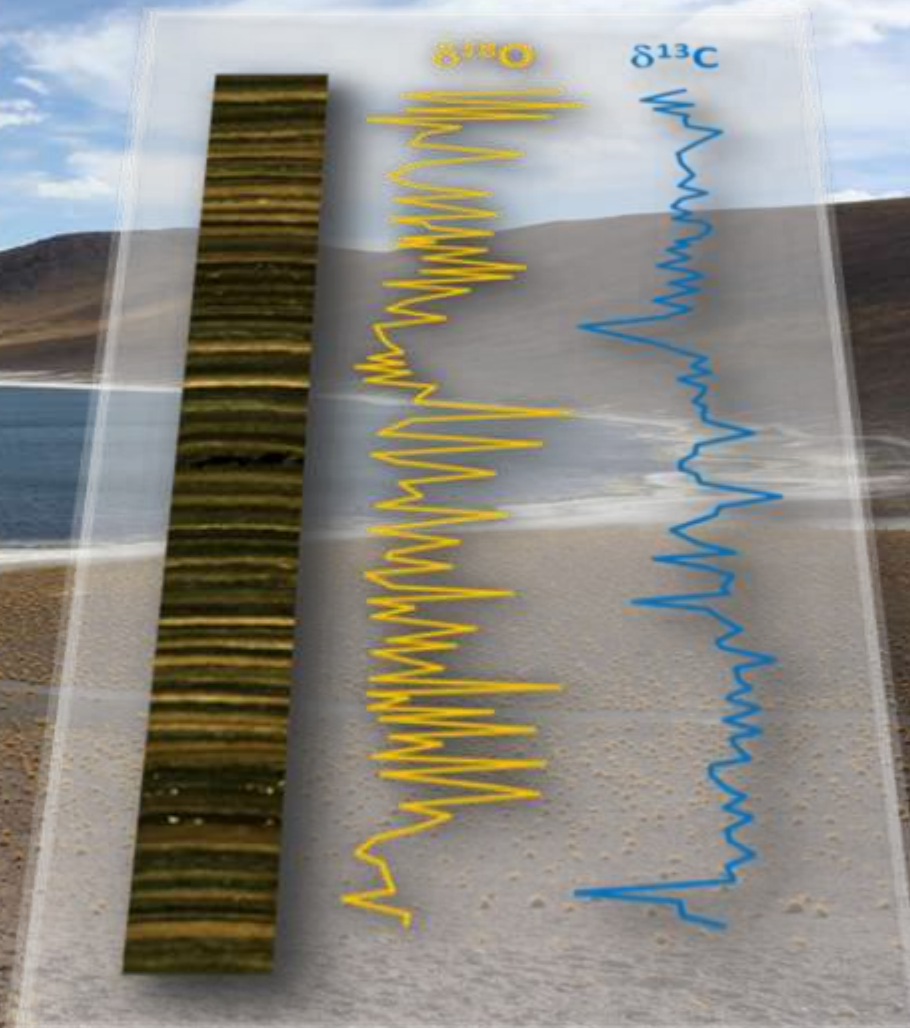
The use of stable isotopes from lake sediments in palaeonvironmental reconstructions



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February 2012

Prague, Czech Republic

1. Introduction: Lakes as climatic sensors

2. Stable isotopes in lake sediments

3. A palaeoenvironmental reconstruction using stable isotopes: Lago Chungará case

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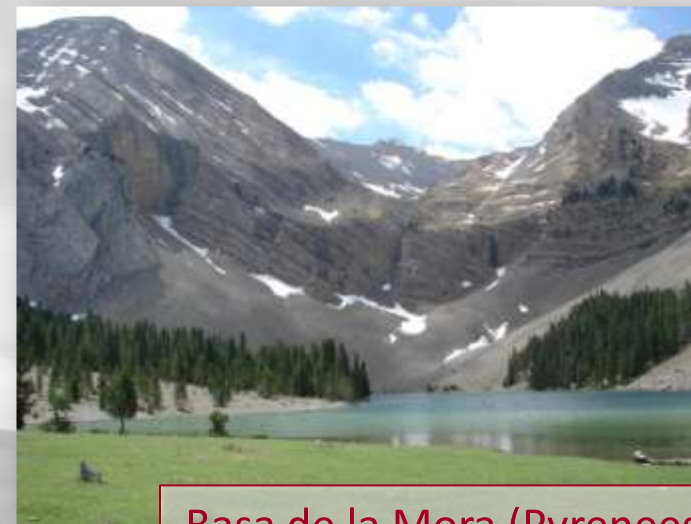
Lakes are one of the most employed natural systems as **'climatic sensors'**.

Lakes are sensitive to any **temperature** and/or **precipitation** change.



Basa de la Mora (Pyrenees)

Rano Raraku (Easter Island)

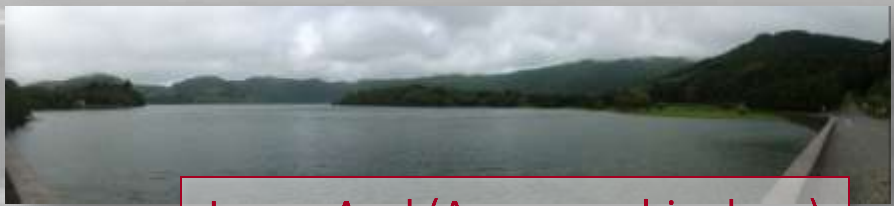
Different lakes…

- **Geographic situation**
  - **Latitude / Altitude**
    - **Climate** (External controls)
      - rainfall
      - evaporation
      - insolation
      - wind
      - weathering
    - **Seasonality**
      - productivity
      - circulation
      - Holomictic / Meromictics
- **Morphology**
  - **Tectonics**
    - **Basin morphology**
      - littoral environment
      - pelagic environment
    - **Hydrology**
      - hydrological balance
      - temperature
      - salinity
      - oxygen
      - Open / Closed
- **Geology**
  - **Basin lithology**
    - **Chemical composition**
      - nutrients
      - Oligotrophics / Eutrophics

…different type of sediments

***Climate changes** result in **lake level fluctuations**, which affect its dynamics and composition ...*

Harper Lake (USA)

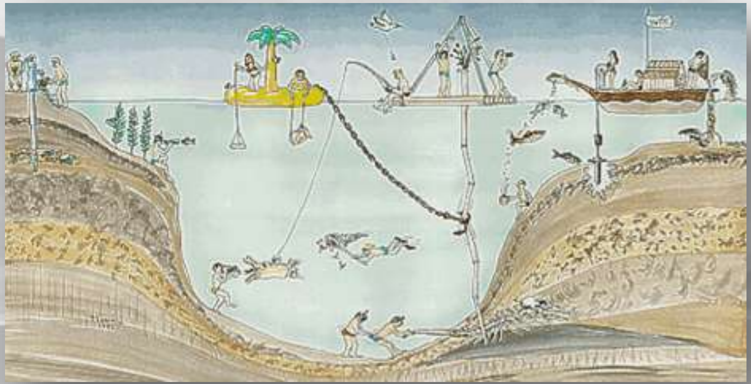


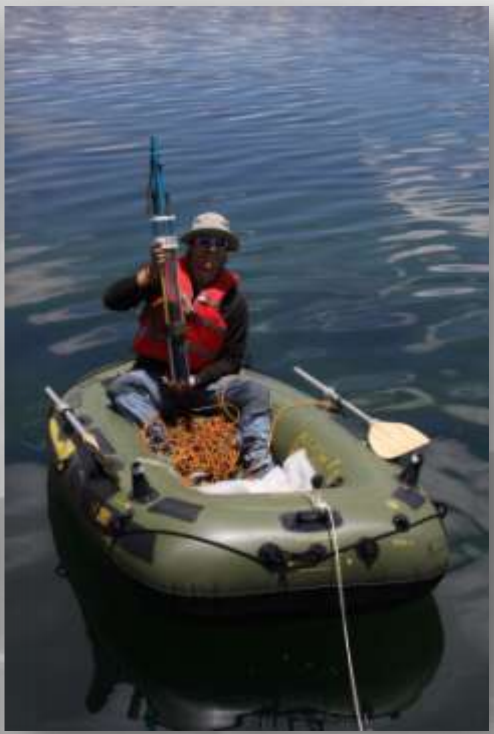
Lagoa Azul (Azores archipelago)

The lake sediments act as **'tapes'** recording most of these climate changes over time.

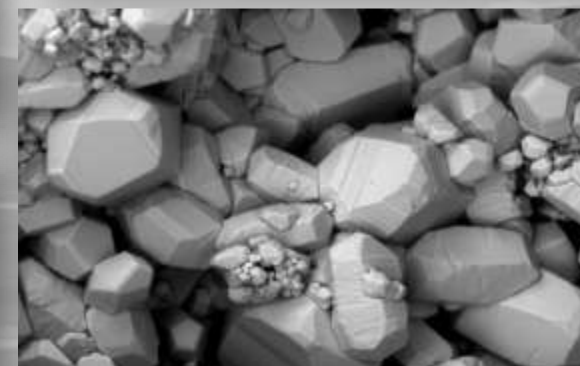
Therefore, the study of lake sediments can **'reconstruct'** past climate variations.

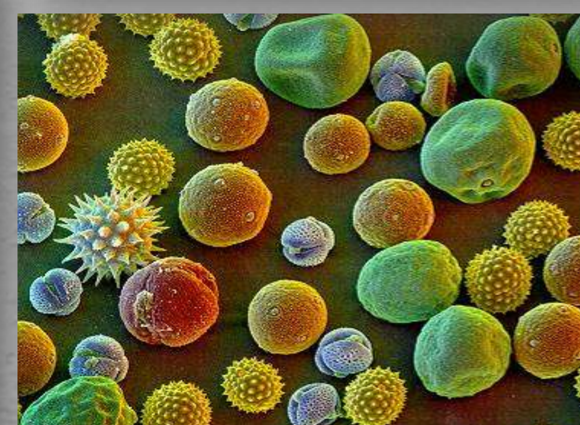
Recovery of lake sediments





Laboratory work





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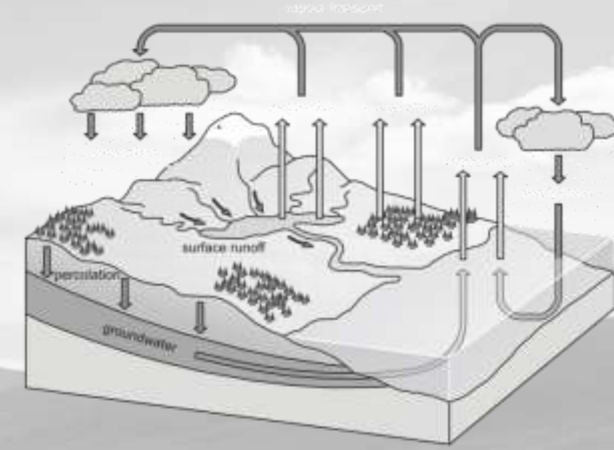
Isotopes

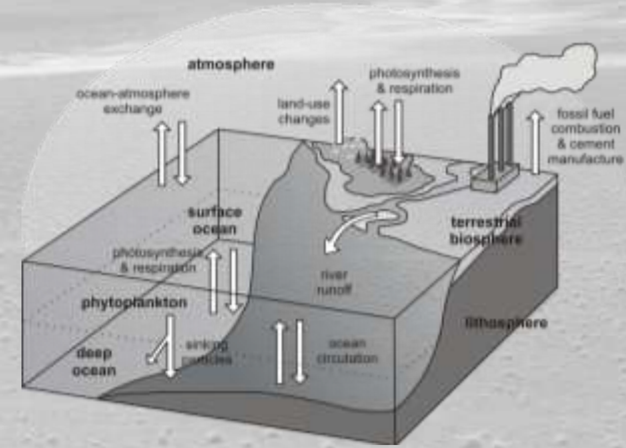
Stable isotopes in palaeoenvironmental research



δD, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{18}O$

Water, marine and lacustrine sediments, bones and teeth, speleothems and/or tree rings

Stable isotopes in palaeolimnolgy



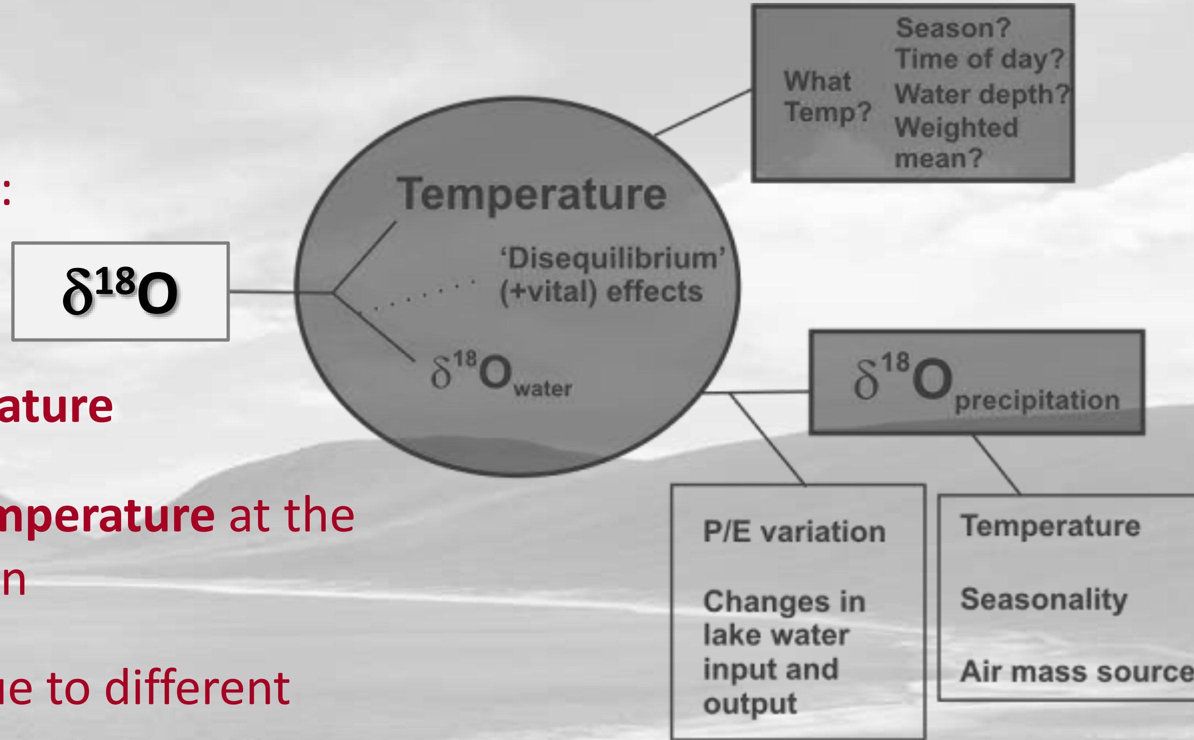
Organic matter, carbonates, biogenic silica, …

$\delta^{13}C$, $\delta^{15}N$ and $\delta^{18}O$

Oxygen isotopes

The $\delta^{18}O$ record results from:

- Changes in **P/E**
- Variations in lake **temperature**
- Oscillations in **$\delta^{18}O$** or **temperature** at the source of the precipitation
- Changes in $\delta^{18}O_{lakewater}$ due to different **sources of precipitation**



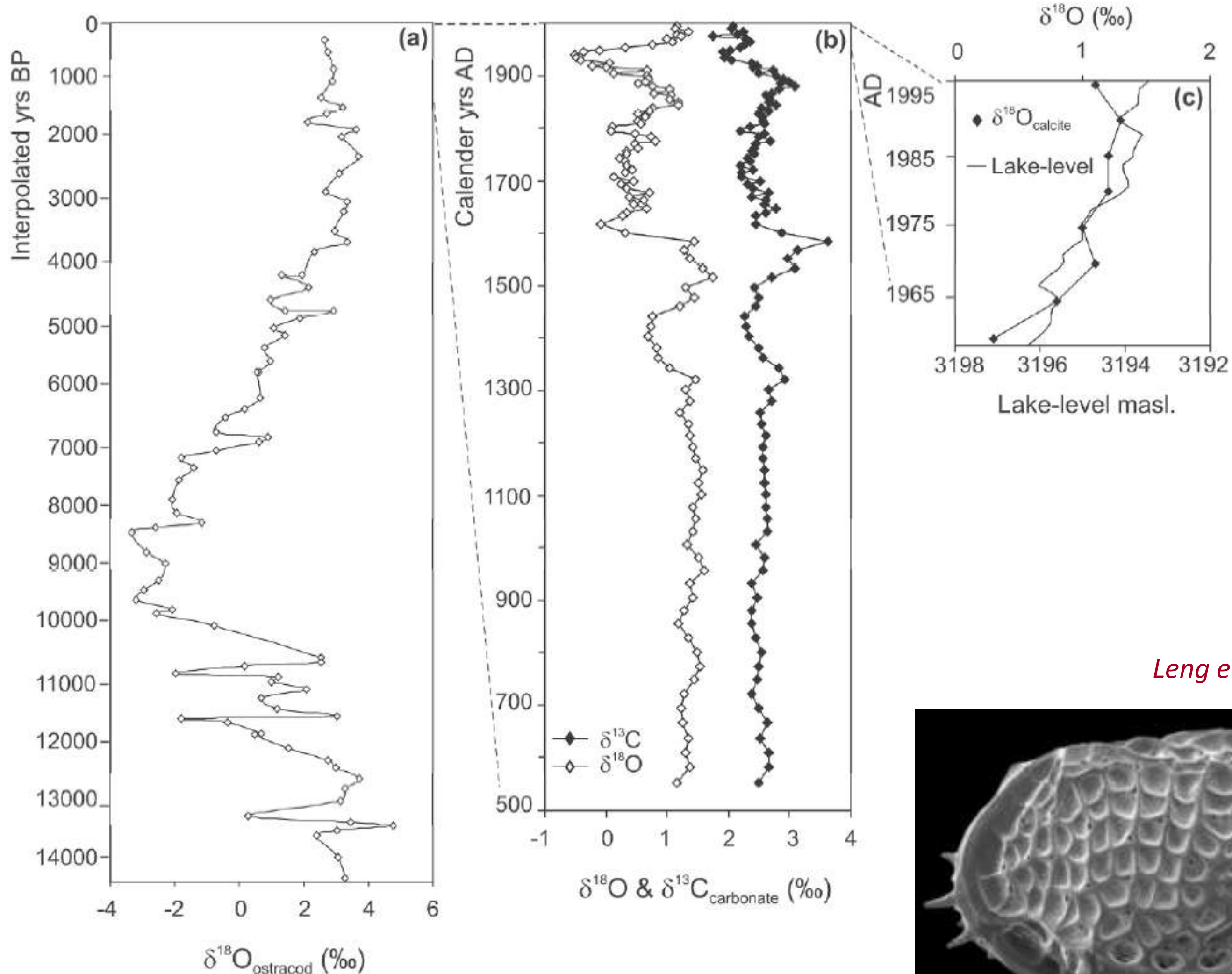
Modified from *Leng & Barker, 2006*

Lagoa das Furnas (Azores archipelago)

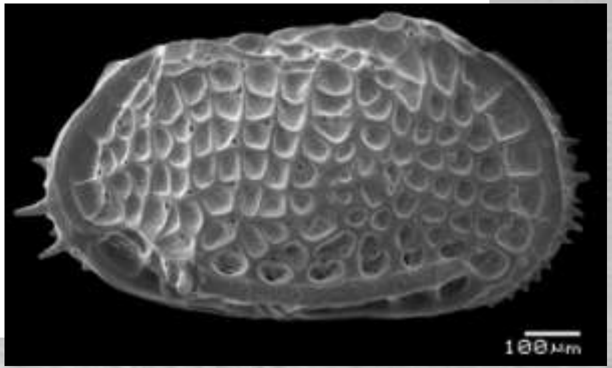
Lake-water volume	Very small	Small-medium open lakes	Small-medium closed lakes	Large
Residence time	<1 year ('open' lake)	>1 year	10's years	100's years ('closed' lake)
Predominant forcing	*S; T; δp*	*T; δp*	*P/E*	*P/E*
$\delta^{18}O$ ranges through the Holocene	Often negative values, small range of 1–2‰, possibly large range in ‰ for materials precipitated in different seasons	Often negative values, small range of 1–2‰	negative to positive values, large swings (5 to >10‰)	positive values, subdued signal homogenized by buffering of large lake volume
Example	Lake Chuma (Kola Penninsula)	Lake Ammersee (Germany)	Lago Chungará (Chile)	Lake Malawi

Modified from *Leng & Marshall, 2004*

Oxygen isotopes in carbonates



Leng et al. 2005



Lake Qinghai (Tibetan Plateau)

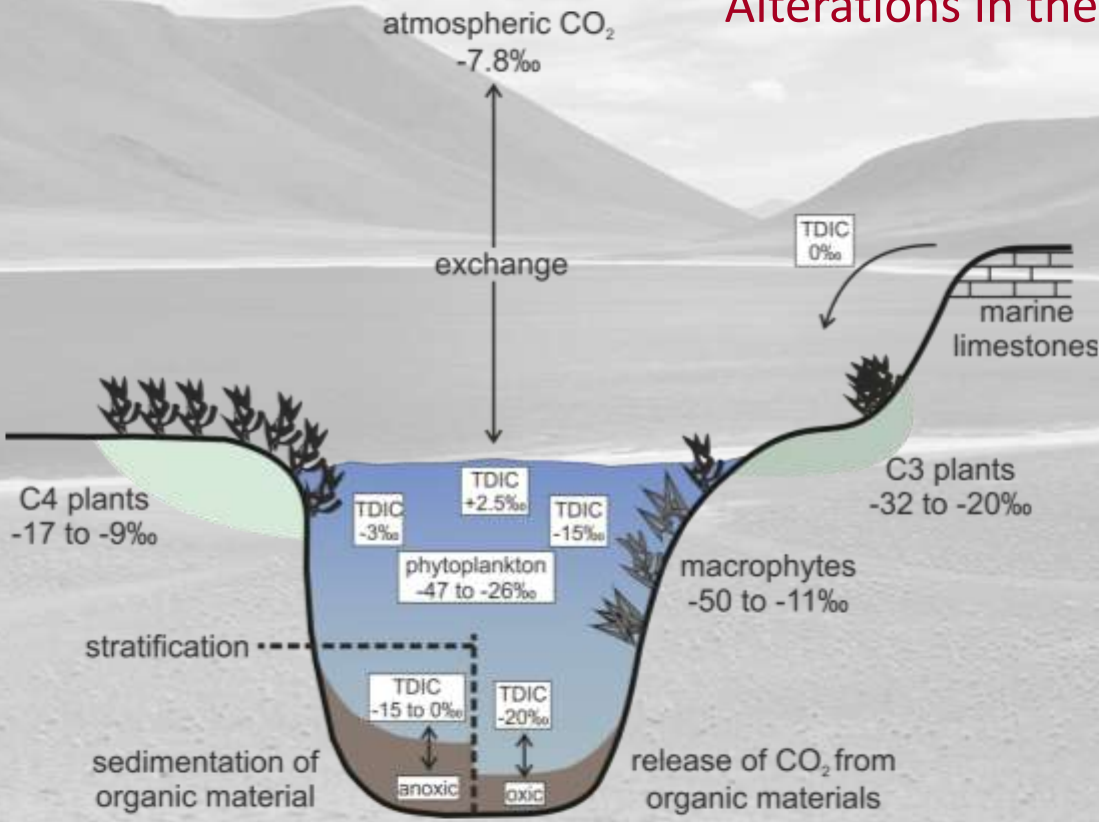
Carbon isotopes

The $\delta^{13}C$ record reveals:

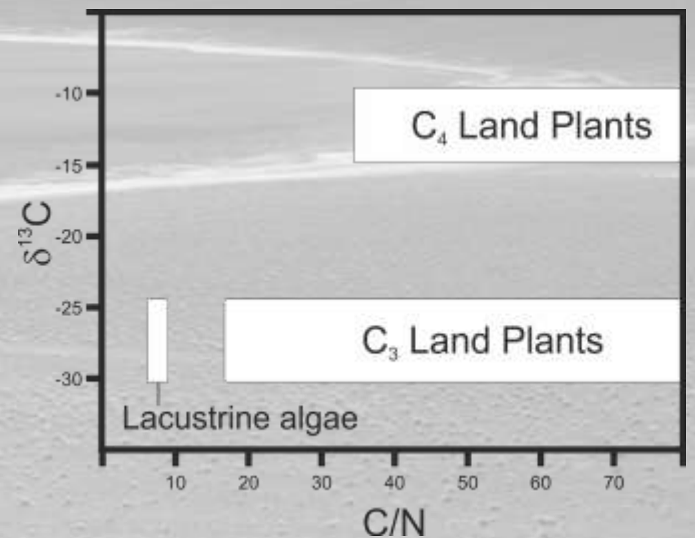
Variations in the **source** of organic matter

Changes related to **productivity** and **nutrient supply**

Alterations in the amount and **composition of CO_2**

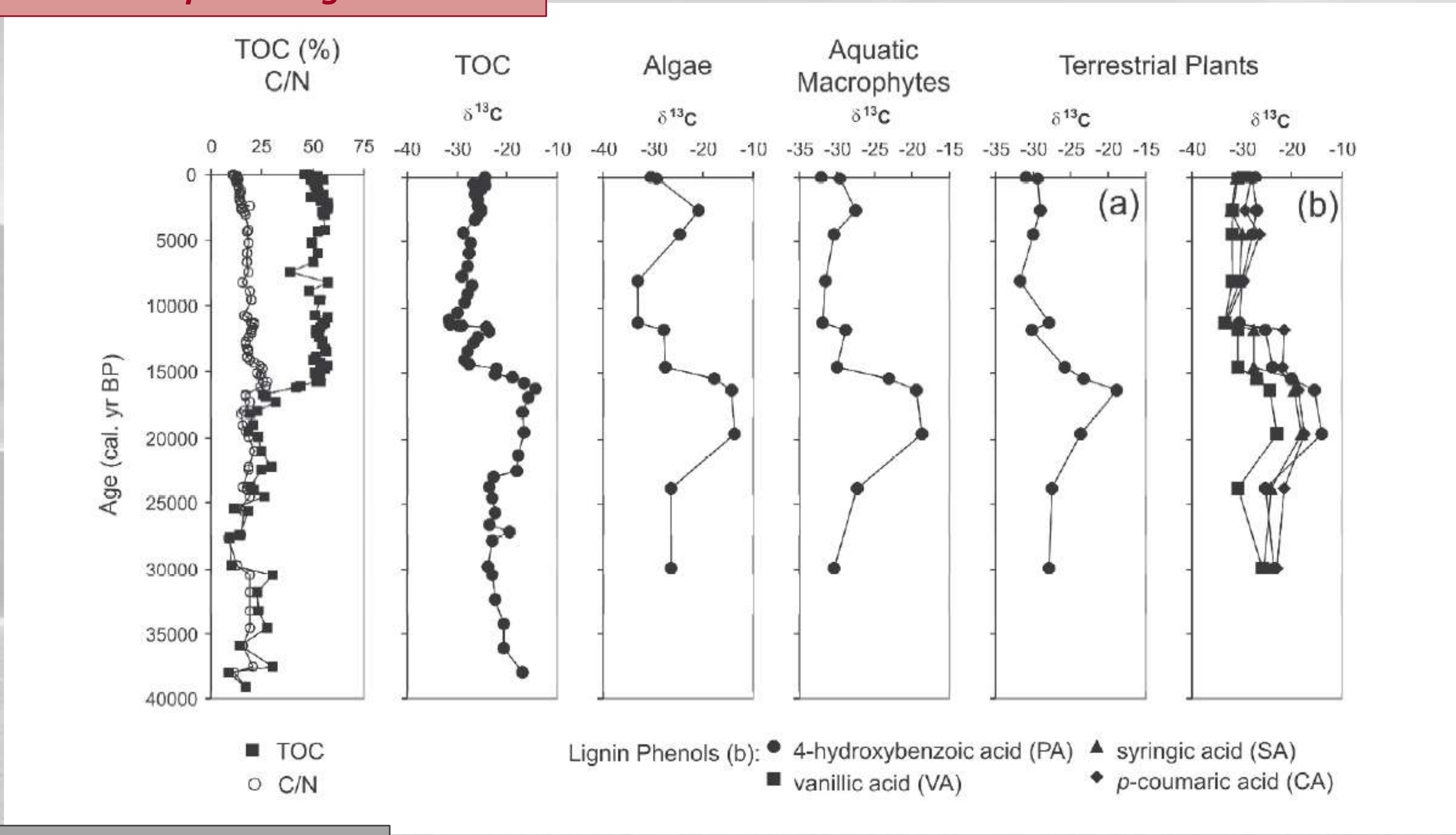


Modified from *Leng & Marshall, 2004*



Meyers & Teranes, 2001

Carbon isotopes in organic matter



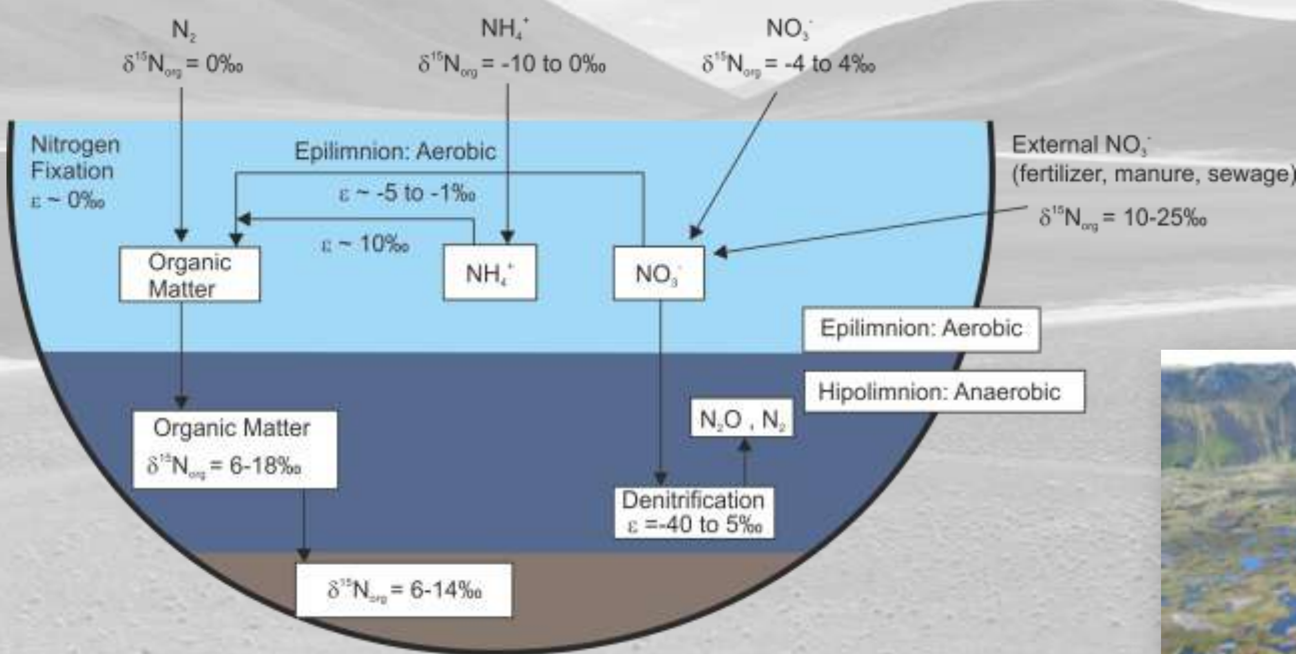
Sacred Lake (Mt. Kenya)

Street-Perrott et al. 2004

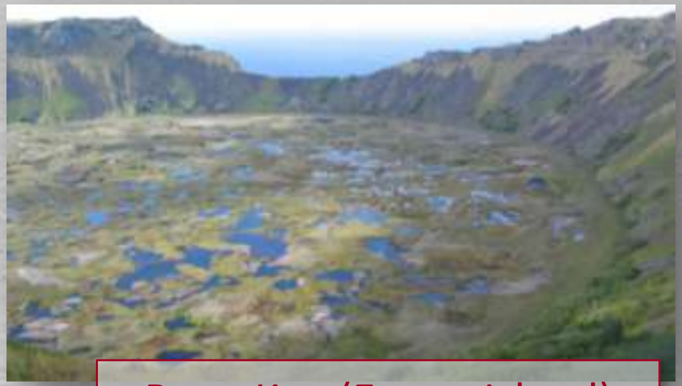
Nitrogen isotopes

The $\delta^{15}N$ record is determined by:

- **Sources** of nitrogen
- Rates of **primary production** and **respiration**
- Types of **denitrification** processes



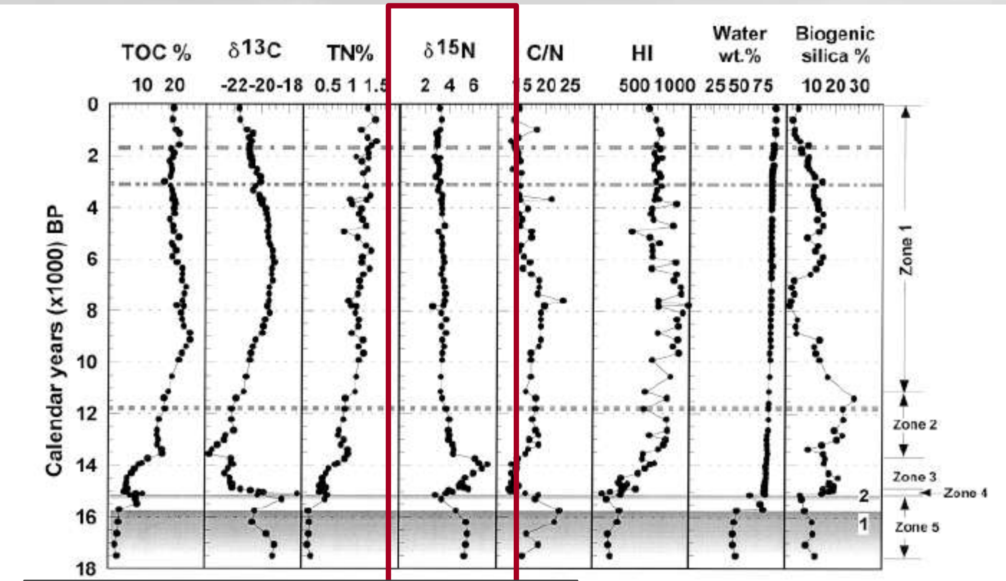
Modified from *Meyers & Teranes, 2001*



Rano Kao (Easter Island)

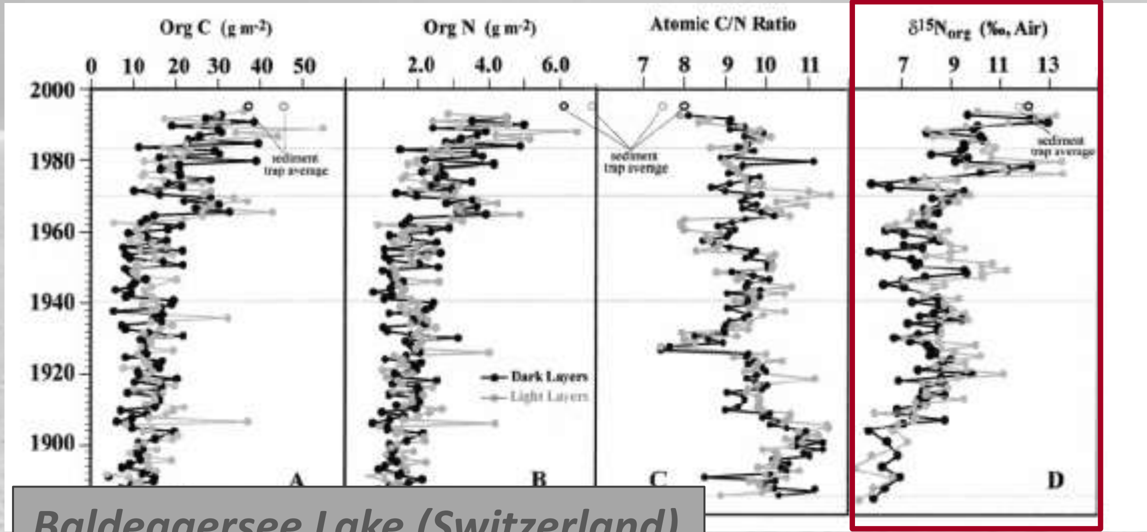
Nitrogen isotopes from Organic Matter

Lake Victoria(East Africa)



Lake Victoria (East Africa)

Talbot & Laerdal, 2000



Baldeggersee Lake (Switzerland)

Teranes & Bernasconi, 2000

Multiproxy studies allow to support our interpretations

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Lago Chungará

Subtropical lake located in the Andean Altiplano

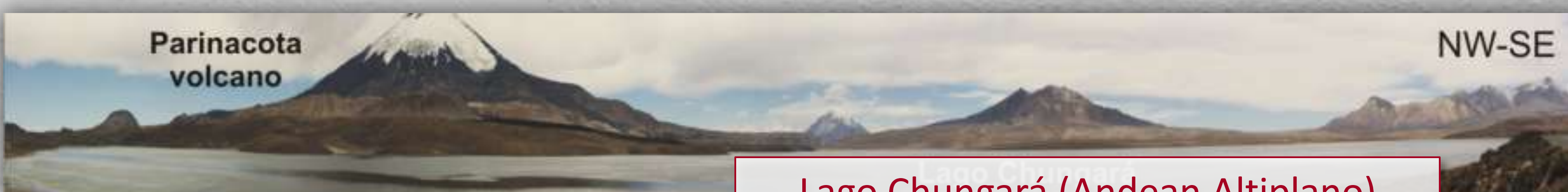
Lake altitude: 4,520 m a.s.l.

Depth: 40 m Size: 21,5 km^2

Water residence time 15 years

Closed and polimictic lake

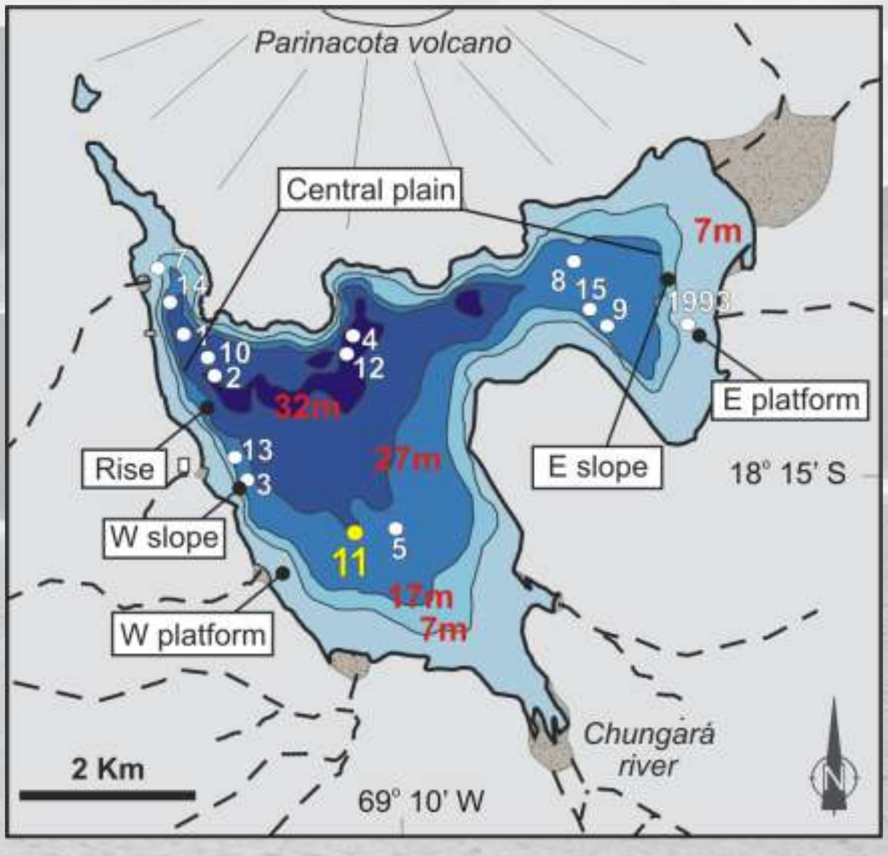
Primary productivity: diatoms and chlorophyceans



Lago Chungará (Andean Altiplano)

Coring

15 Kullenberg cores (up to 8 m long)



Modified from *Hernández et al. 2008*

<u>Litostratigraphy</u>

Unit 1

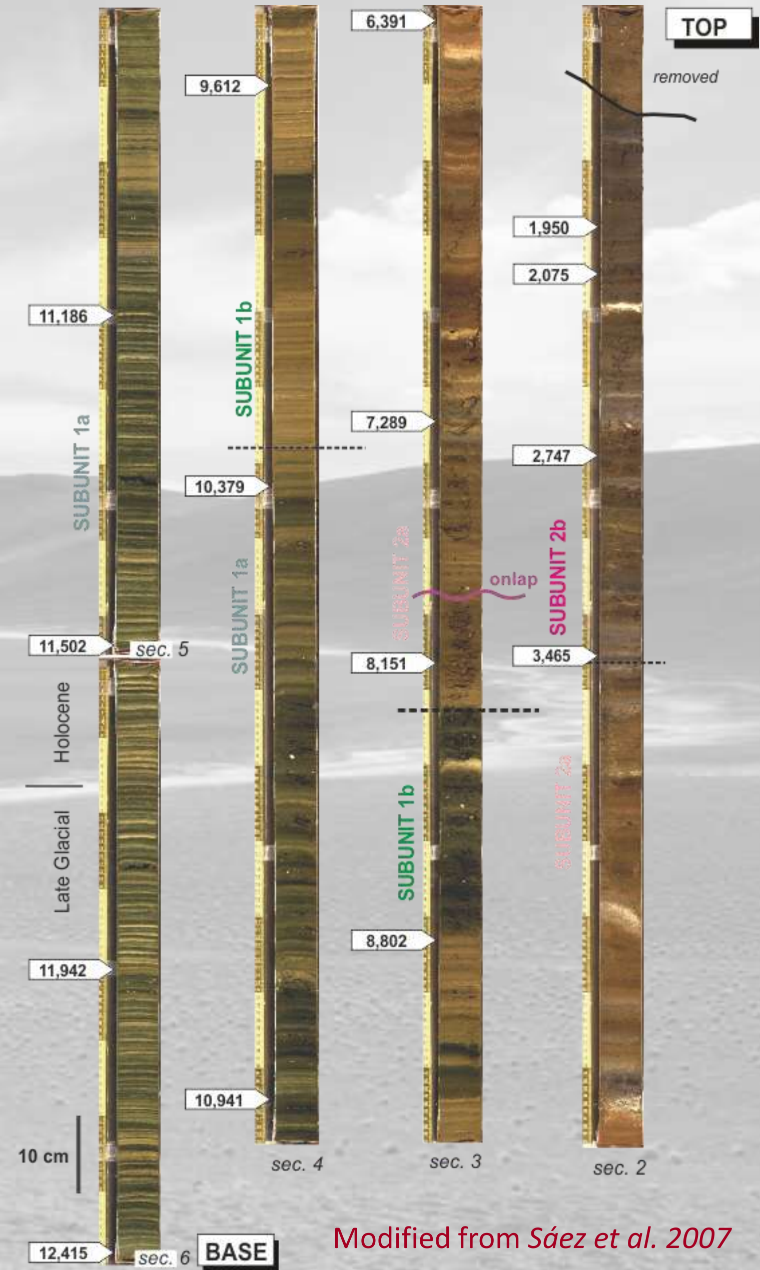
Laminated diatomaceous oozes (couplets of white and green laminae)

Unit 2

Diatomaceous muds with volcaniclastic layers

<u>Chronological model</u>

Seventeen AMS ^{14}C dates
One $^{238}U/^{230}Th$ date



Modified from *Sáez et al. 2007*

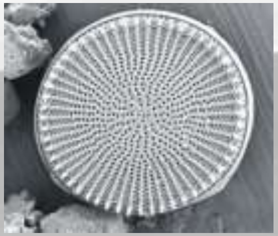
What can the study of the stable isotopes from diatom silica in Lago Chungará laminated sediments reveal?

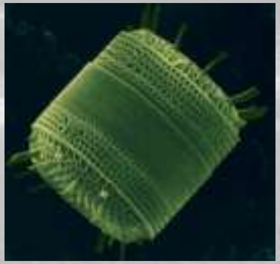
1.- Processes involved in the rhythmite formation

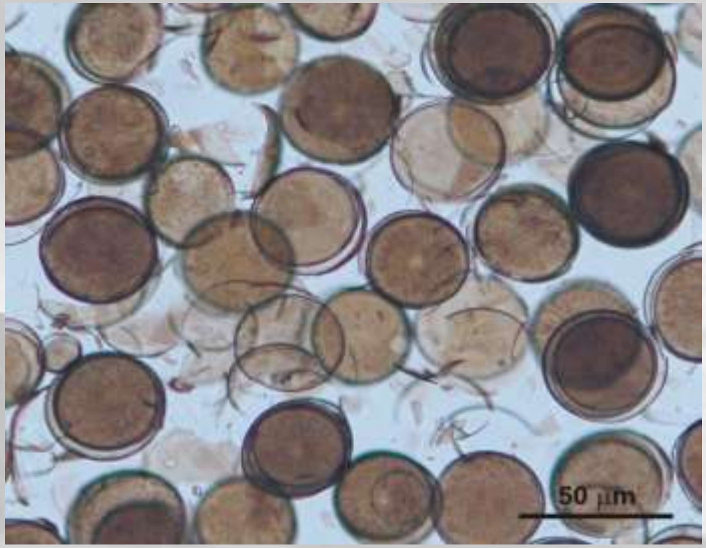
2.- The lake ontogeny

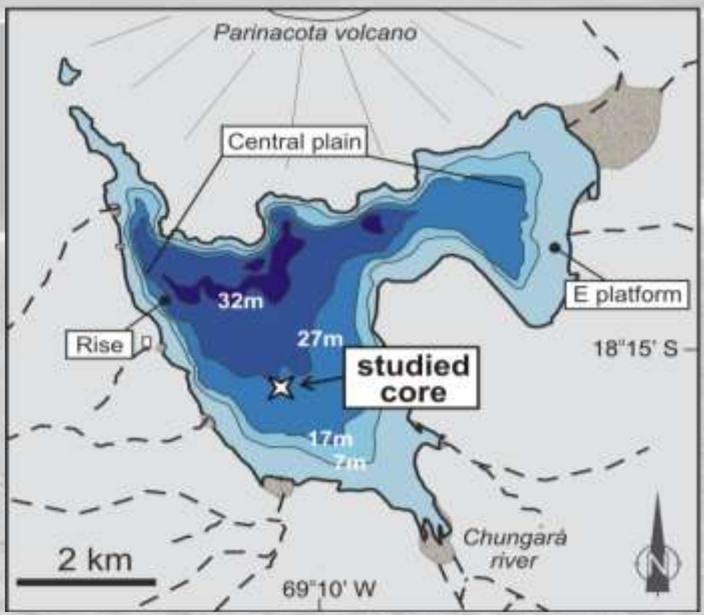
3.- The moisture balance in the region

4.- The regional environmental evolution









-Analyses in well-preserved single species therefore **biological and diagenetic factors** exert **little influence**

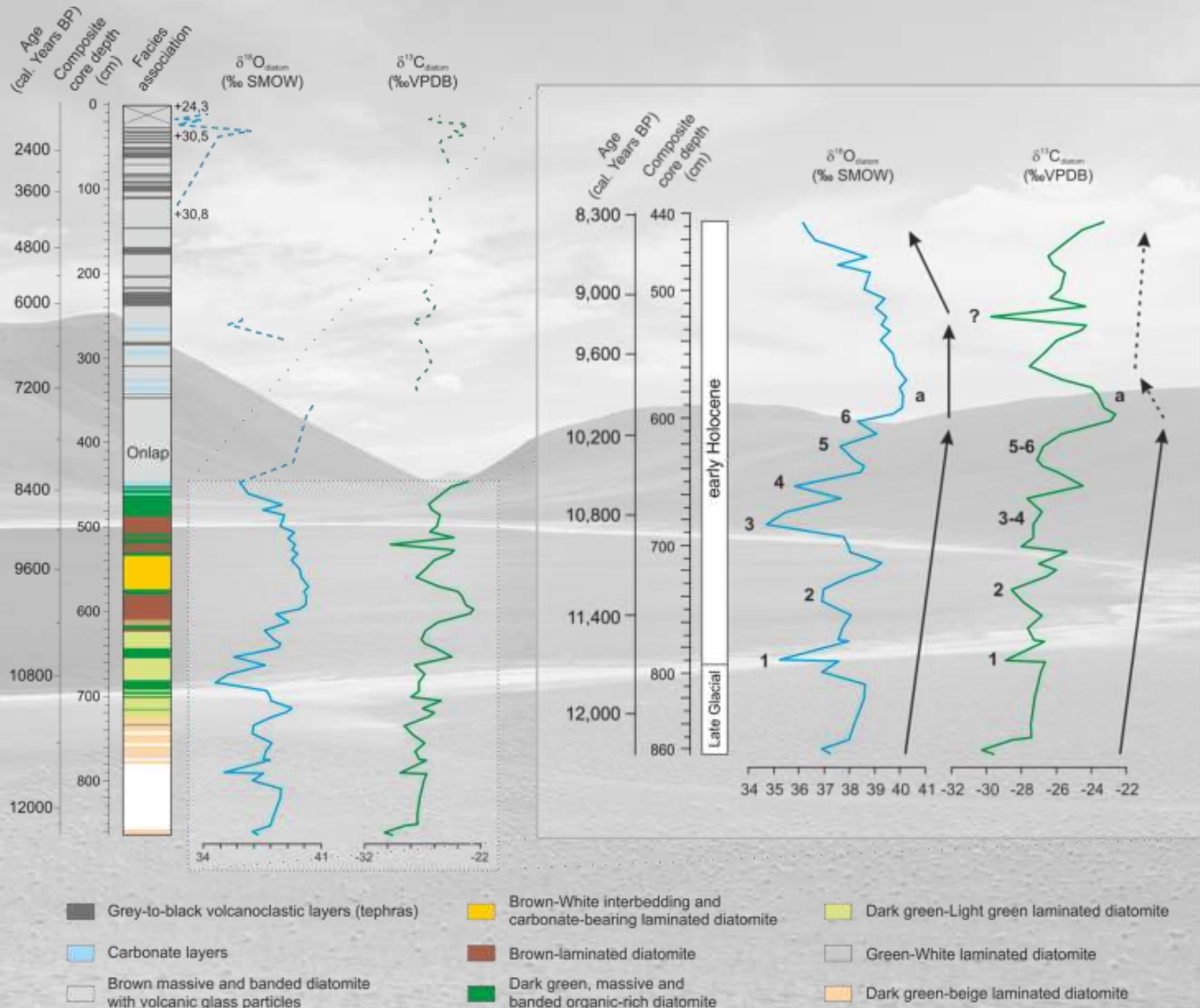
Controlling factors in $\delta^{18}O_{diatom}$

-In closed lakes, all the factors are often small in comparison to **evaporation**

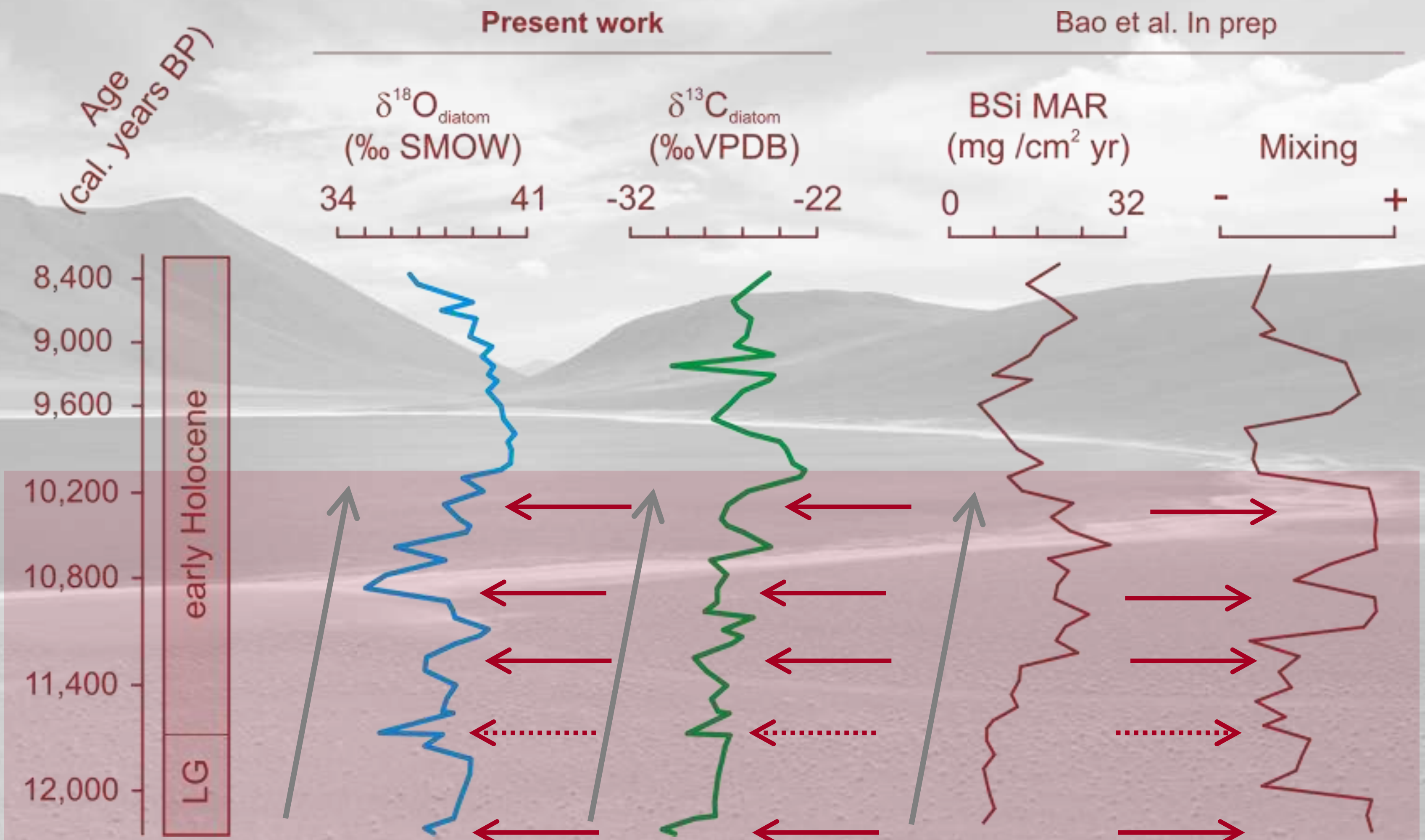
-The $\delta^{18}O_{diatom}$ record can be used as an indicator of **change in the P/E**

Controlling factors in $\delta^{13}C_{diatom}$

-$\delta^{13}C_{diatom}$ signature influenced by changes in the **carbon input** from the catchment, degree of **mixing** and/or biosiliceous **productivity**



Hernández et al. submitted



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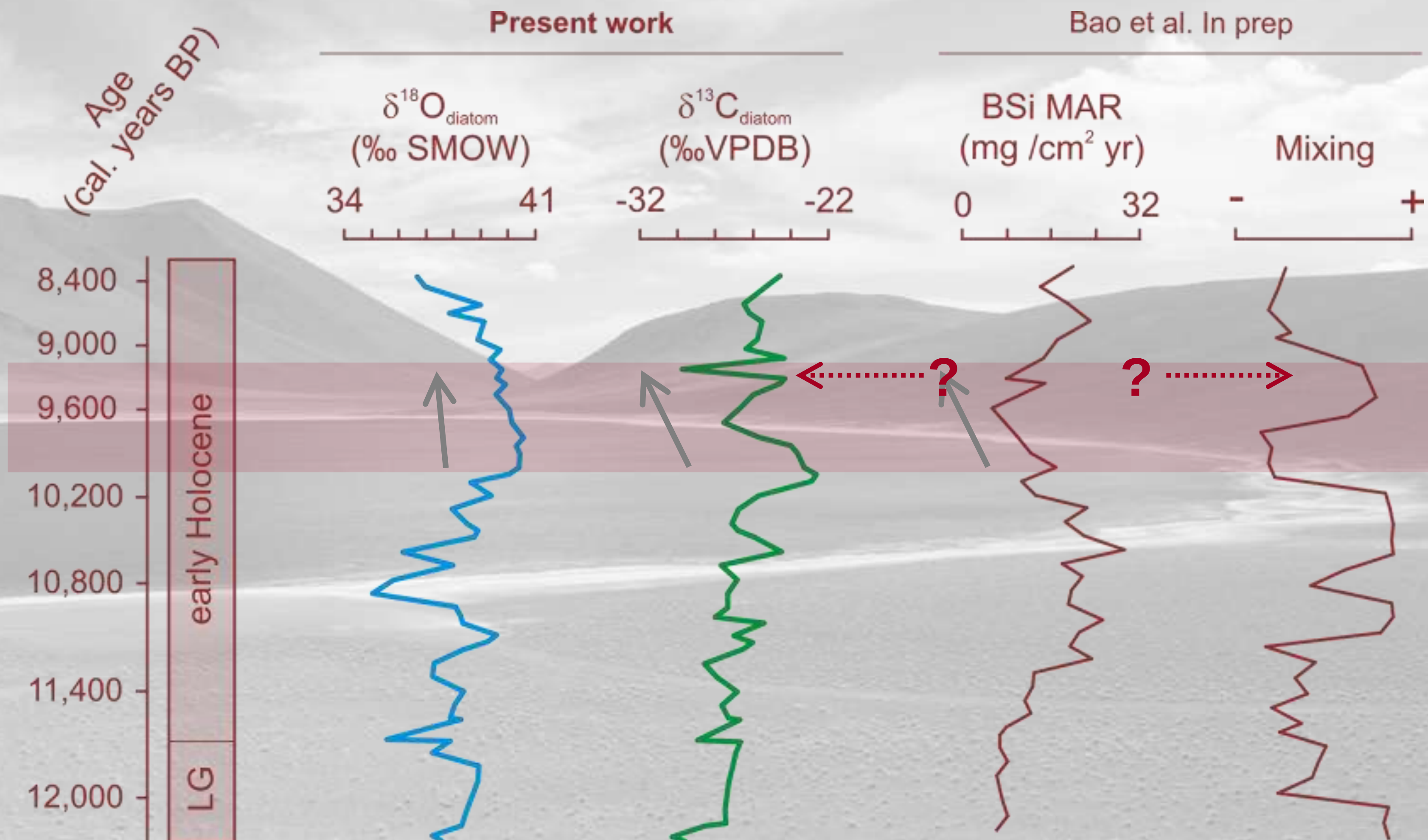

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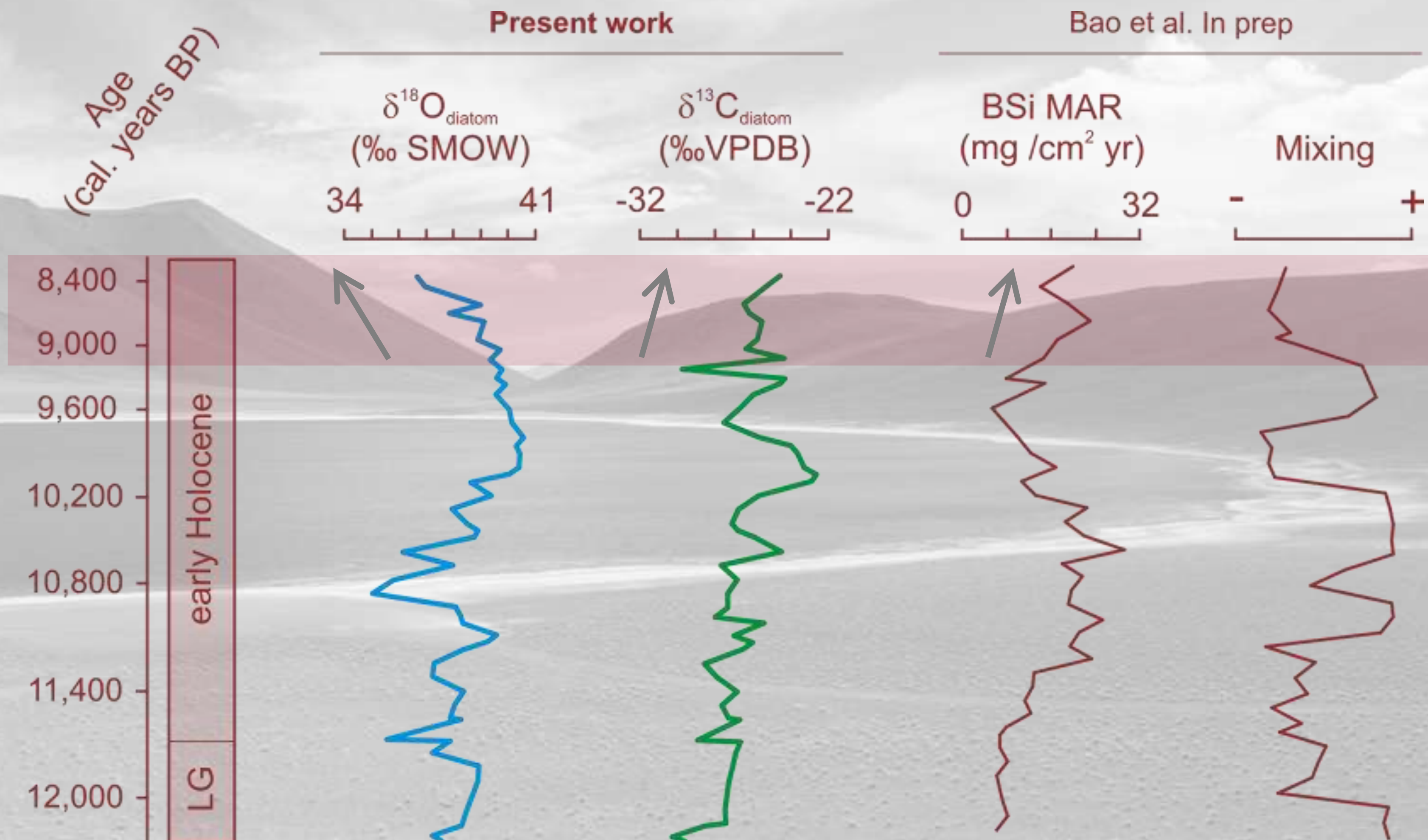

Modified from *Hernández et al. submitted*

Concluding remarks from Lago Chungará palaeoenvironmental reconstruction

-Measurements of $\delta^{18}O_{diatom}$ and $\delta^{13}C_{diatom}$ useful proxies for understanding regional climate patterns and lake-catchment processes

-Three main climate phases were identified:

a) a humid phase during the Late Glacial-Early Holocene transition

b) a dry phase in the Early Holocene

c) a dry-to-humid phase in the latter part of the Early Holocene period

-The $\delta^{13}C_{diatom}$ values show are mainly related to the paleoproductivity, however the organic matter associated to the external loadings and the CO_2 release from the hypolimnion also can influence the $\delta^{13}C_{diatom}$ varibaility

-Both $\delta^{18}O_{diatom}$ and $\delta^{13}C_{diatom}$ analyses can help us to gain a better understanding of the role of lakes in the carbon cycle in the context of global change

Laguna Meñiques (Andean Altiplano)