

Two millennia A millennium of anthropogenic impact: Sedimentary biomarker evidence from Lake San Pablo, Ecuador

Lake San Pablo: introduction

Located in the Ecuadorian Andes (Fig. 1) and surrounded by the city of Otavalo, settlements, and agricultural land, Lake San Pablo experiences declining water quality and eutrophication.

The lake's longer-term environmental history remains poorly constrained. We adopt a **paleolimnological approach** based on multi-proxy analyses of a 1.16 m long **sediment core** retrieved at a water depth of 21 m, which spans approximately the last two millennia. A **multi-proxy approach** integrates geochemical proxies and palynology.

Objective:

To understand long-term **natural** and **anthropogenic environmental change** of Lake San Pablo.

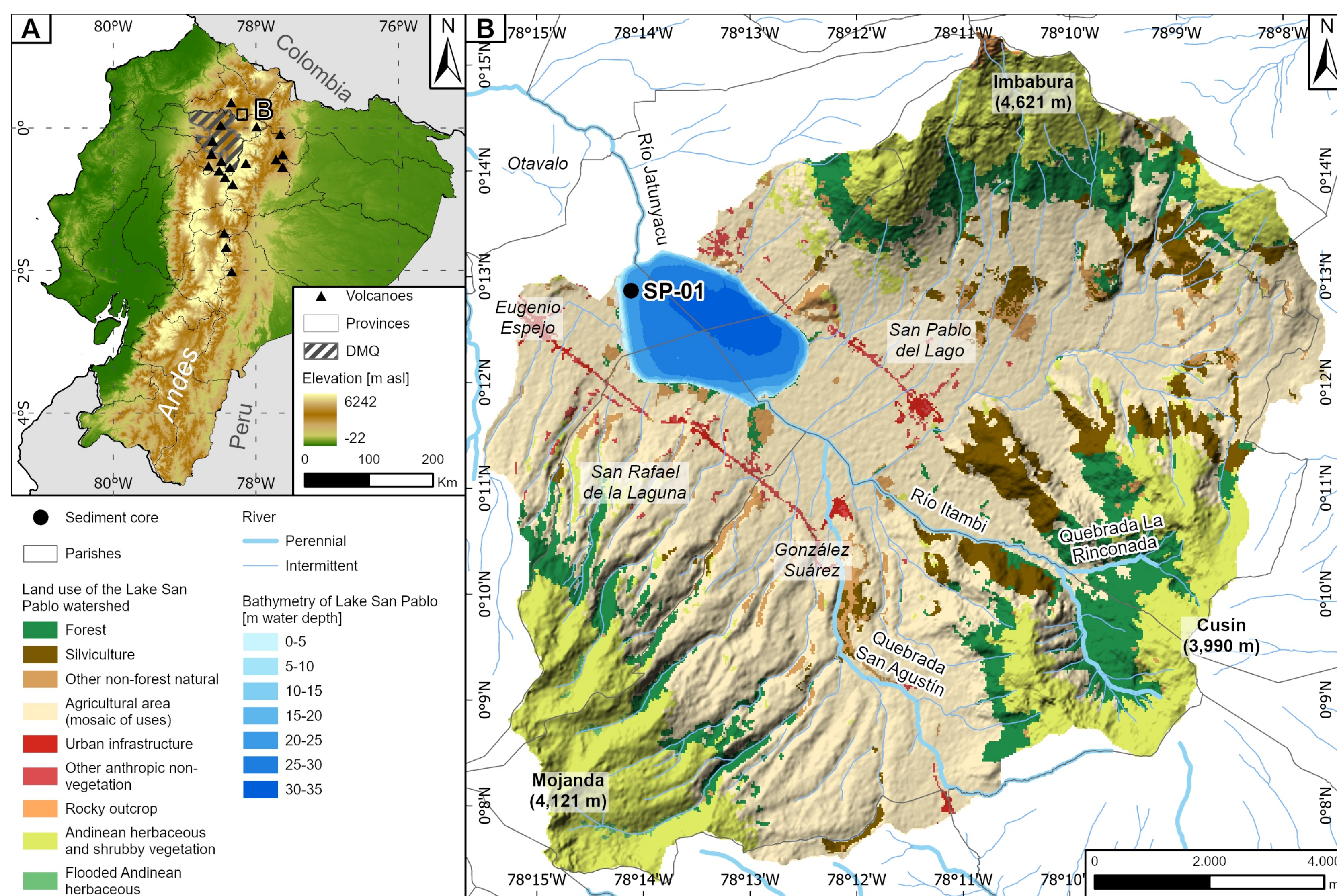


Fig. 1: Overview maps of Ecuador and the study area around Lake San Pablo. DEM from: ASF DAAC. (2011). ALOS PALSAR High Resolution Radiometric Terrain Corrected Product. NASA Alaska Satellite Facility Distributed Active Archive Center. <https://doi.org/10.5067/Z97HFCNKR6VA>. Topographic information (volcanoes, province/parish/DMQ boundaries, rivers) from Instituto Geográfico Militar Ecuador: <https://www.geoportaligm.gob.ec/portal/>. Land use information from MapBiomias 3.0: <https://ecuador.mapbiomas.org/en/home-english/>.

Methods

Biomarker analysis:



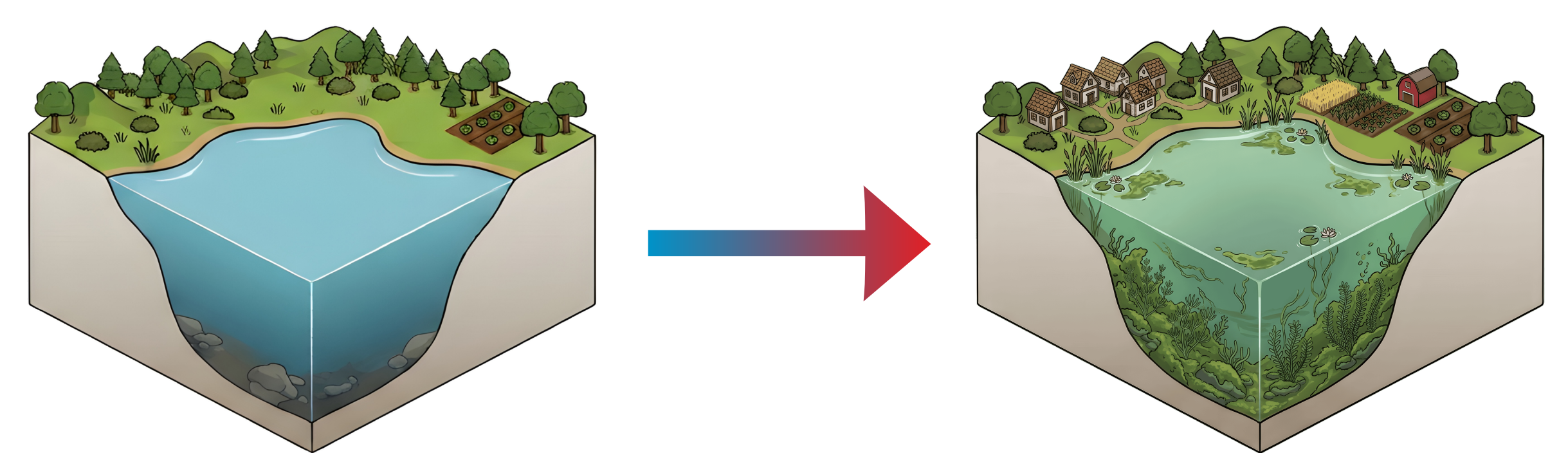
→ Pollen analysis by Prof. Hermann Behling (UGöttingen)

Anthropogenic pressures in the catchment



Fig. 2: Potential pollution sources around Lake San Pablo: agriculture (left), land clearing by fire (center), urbanization (right). Photos: E. Velarde, A. Horsch, L. Feist.

Environmental change

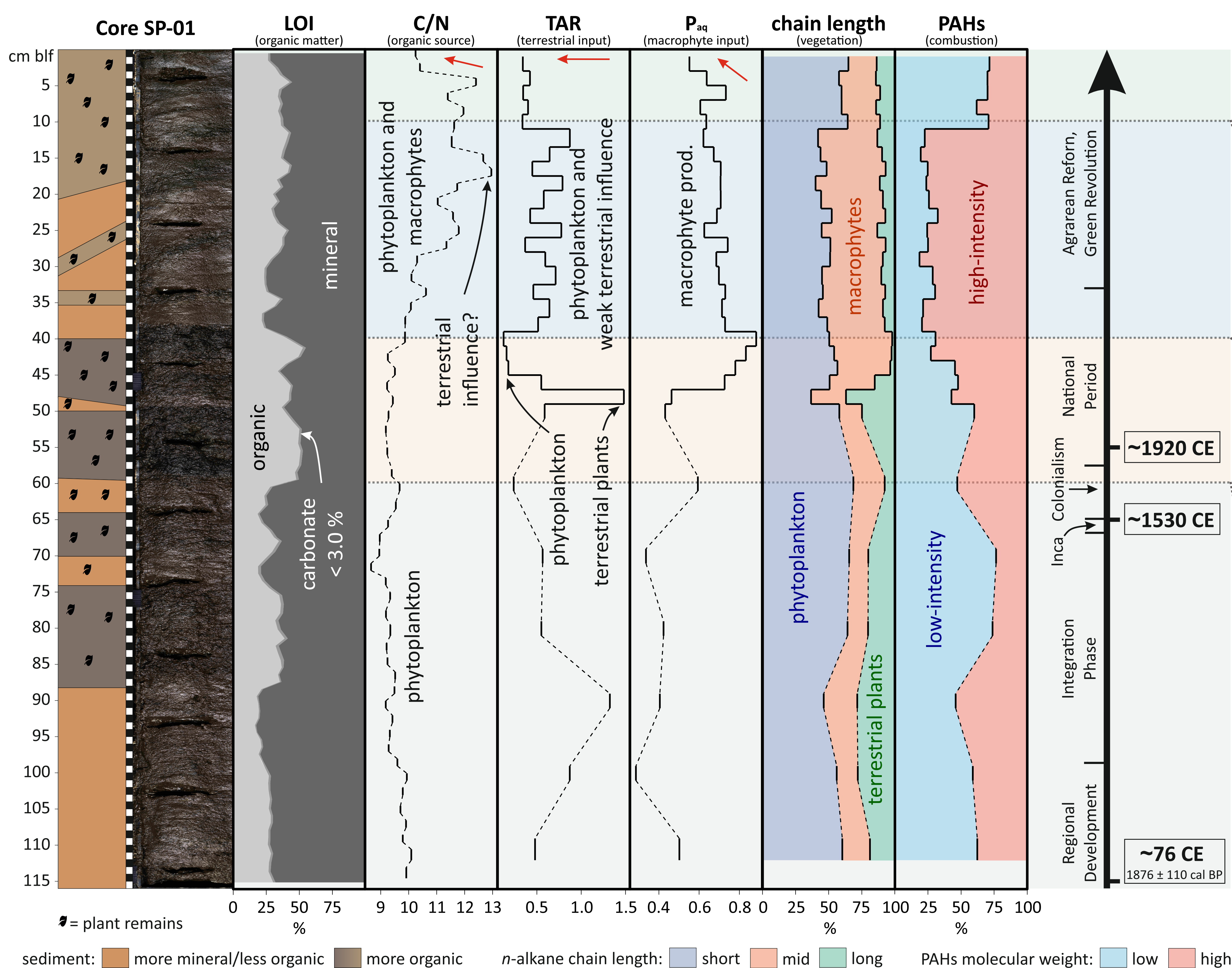


oligotrophic lake until ~1920 CE

eutrophic lake from ~1920 CE

Fig. 3: Shift in lake trophic state from oligotrophic conditions (until ~1920 CE) to eutrophic conditions. Images generated by Gemini.

Two millennia of land-use intensification and lake ecosystem change



Unit C2: Recent eutrophication

Interpretation: Eutrophic state, high human impact
Biomarkers: Increase in phytoplankton, veg. fires
Pollen: Mix of Andean forest, exotic trees, herbs, cultivated crops and ferns; **low Botryococcus**

Unit C1: Anthropogenic

Interpretation: Intensive agricultural activity, high population density, **high nutrient input**
Biomarkers: High macrophyte production, forest fires
Pollen: Mix of Andean forest, exotic trees, herbs, cultivated crops and ferns; **low Botryococcus**

Unit B: Transition

Interpretation: Intensification of agriculture, population growth, **beginning eutrophication?**
Biomarkers: Increase in terrestrial plants?, macrophytes, and forest fires
Pollen: Mix of Andean forest, exotic trees (increasing), herbs, cultivated crops and ferns; first occurrence of *Pinus*, *Eucalyptus* and Cupressaceae; decreasing **Botryococcus**

Unit A: Natural

Interpretation: Oligotrophic state, natural conditions, low human impact
Biomarkers: Phytoplankton dominated, mixed vegetation and forest fires
Pollen: Mix of Andean forest (increasing), herbs (decreasing), cultivated crops and ferns; abundant **Botryococcus**

Take-home message

The sediment record demonstrates that the modern eutrophication of Lake San Pablo is the culmination of centuries of increasing anthropogenic pressure.