Silicon isotopes as tracers of paleoenvironmental conditions during laterite formation in the Amazon Basin

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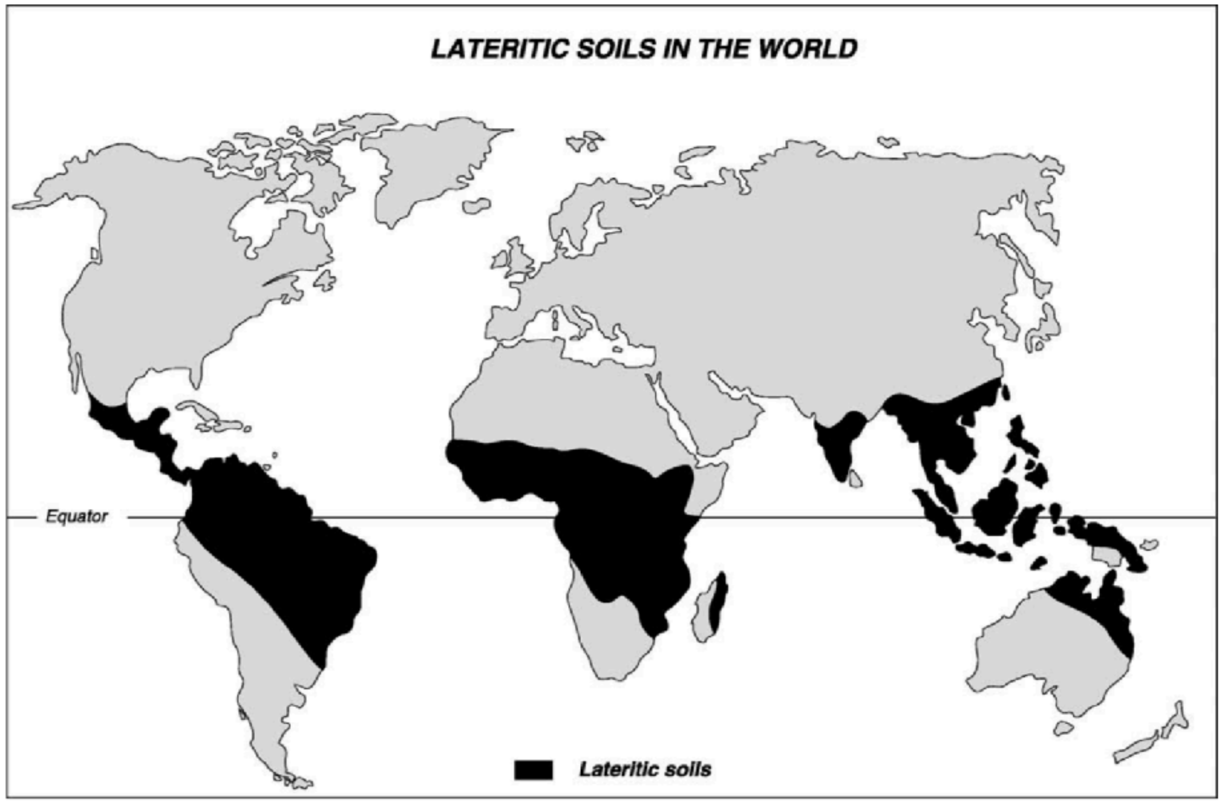
Lateritic soils: composition and occurrence on Earth

- 1/3 of emerged land but 85 % of soil volume on Earth
- Composition: kaolinite clay and Fe/Al (oxi)hydroxides
- Formation under tropical rainy climate



Nahon 2003

Laterite developed on sedimentary Alter do Chão Formation

Credit: Z. Fekiacova

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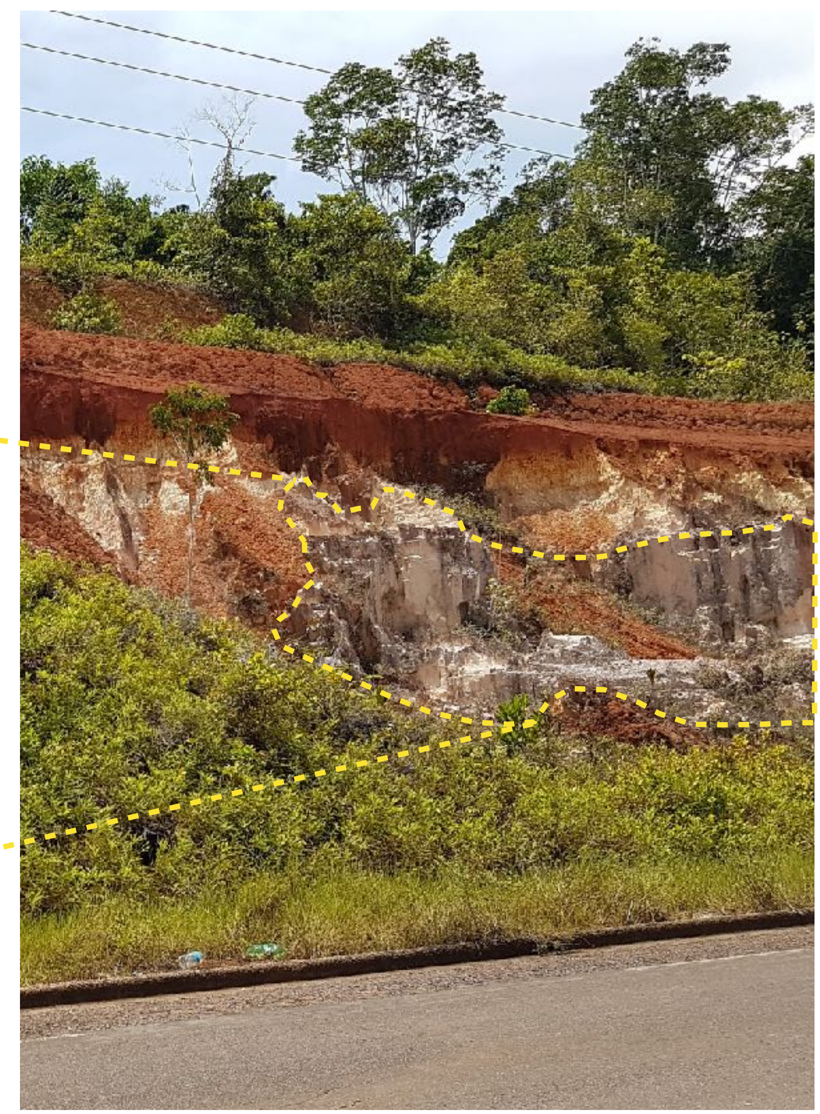

Parent rock or sediment
Here: sedimentary Alter do Chão formation
(Sandy and kaolinite-rich sediment)

Credit: Z. Fekiacova

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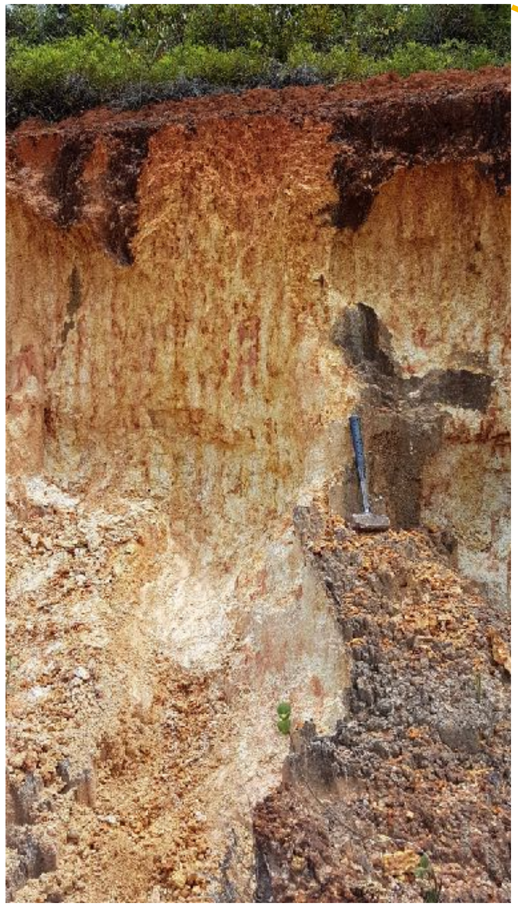

Mottled zone
Differentiation between whitish (kaolinite) and reddish (Fe/Al oxides) sequences

↑

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"Iron crust" - Pisolitic horizon

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Red latosol
Iron and kaolinite-rich level

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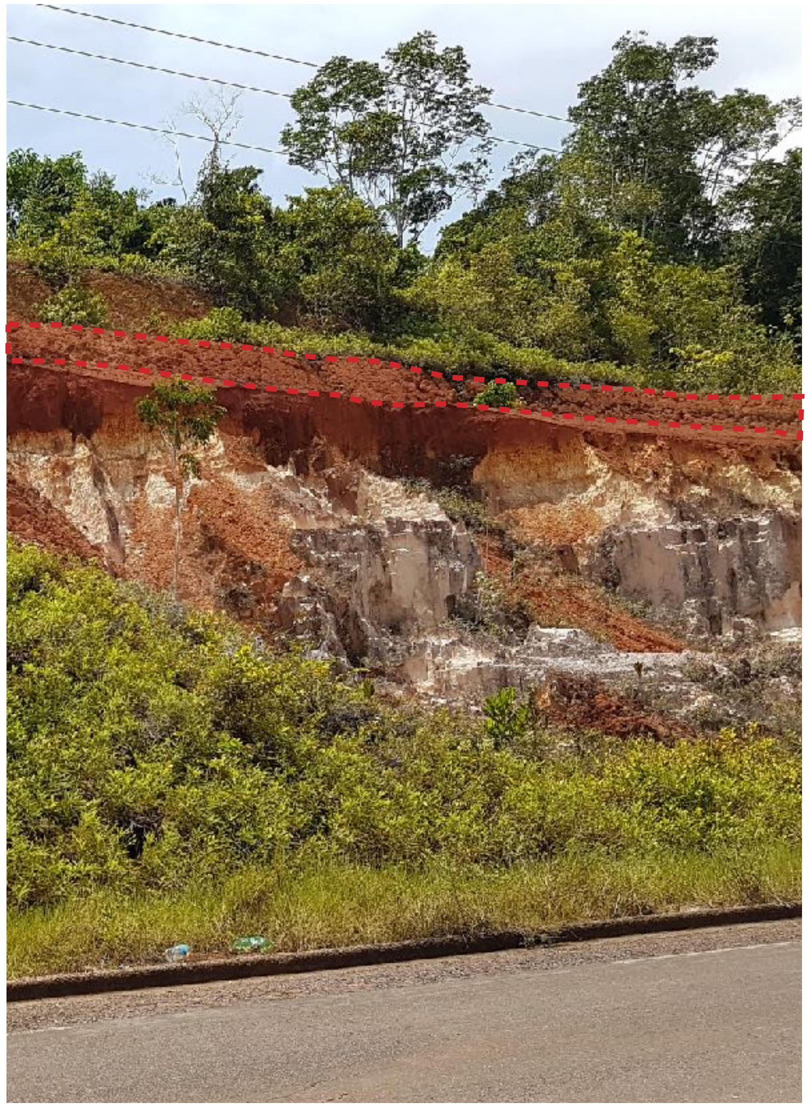

Credit: Z. Fekiacova

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Yellow latosol
Iron and kaolinite-rich level

↑

Red latosol
Iron and kaolinite-rich level

↑

"Iron crust" - Pisolitic horizon

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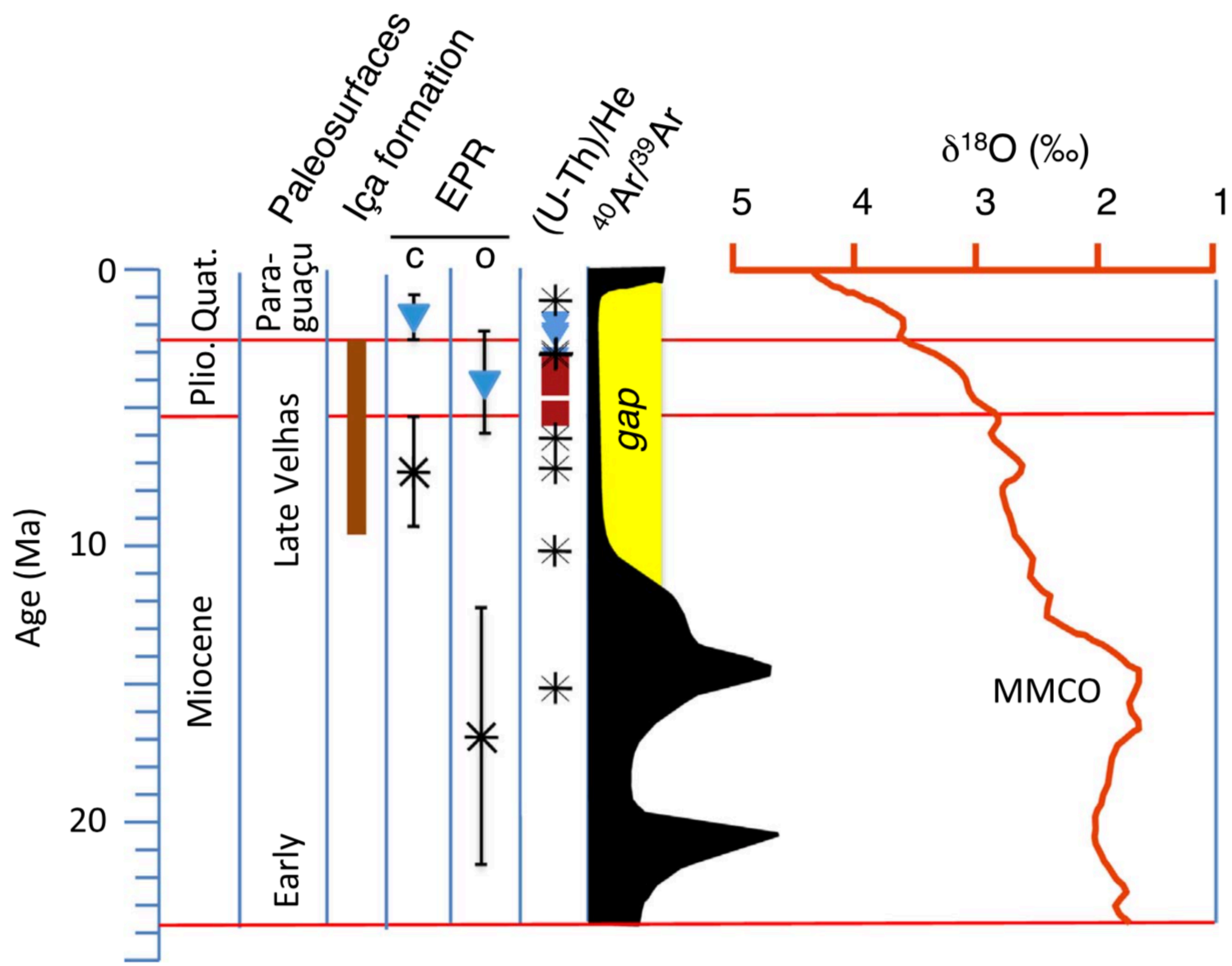
- Laterites formed by successive weathering episodes (based on dating techniques)

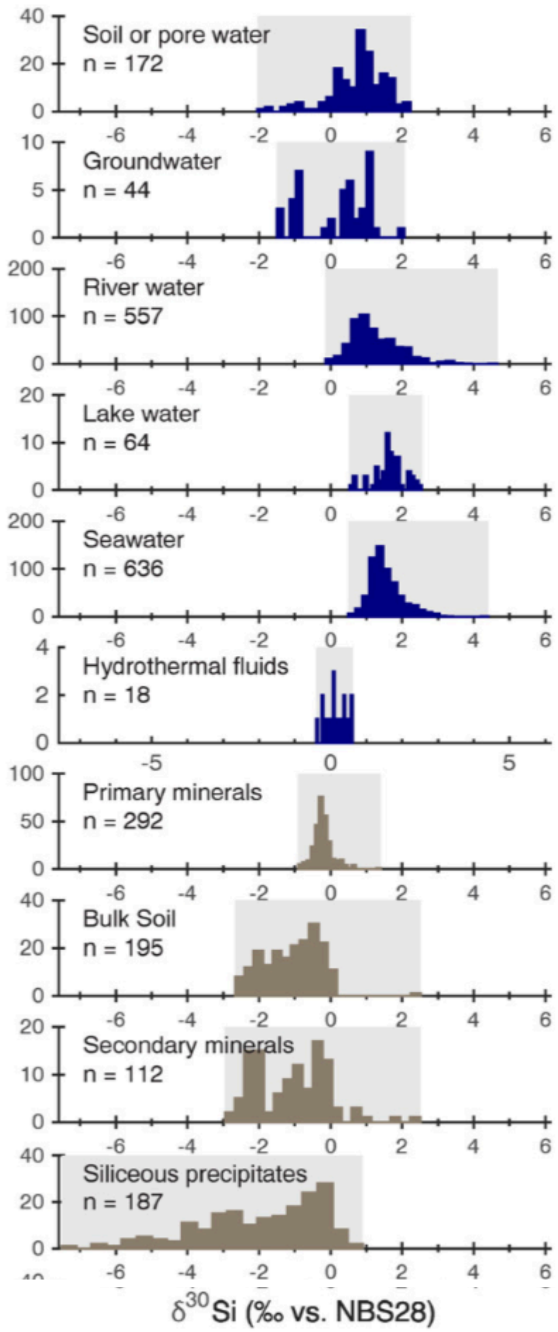


Allard et al. 2018

Does a geochemical tracer exist to identify the paleoenvironmental conditions during these successive episodes of formation?

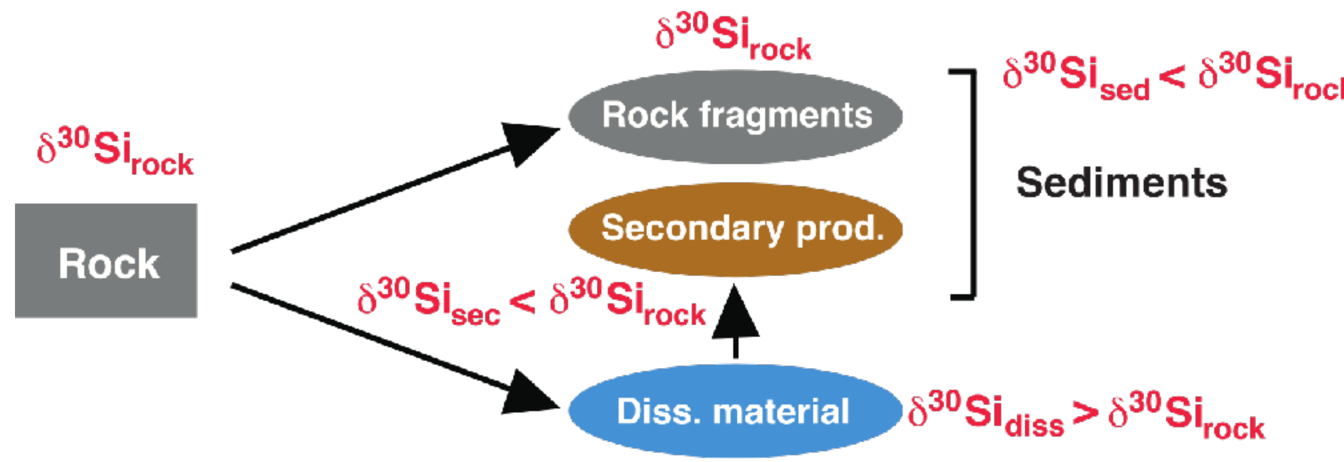
➡ Si isotopes: fractionation of kinetic origin during chemical weathering process (*Oelze et al. 2014, 2015*)

Enrichment of solution in heavy isotopes



Frings et al. 2016

Formation of clays



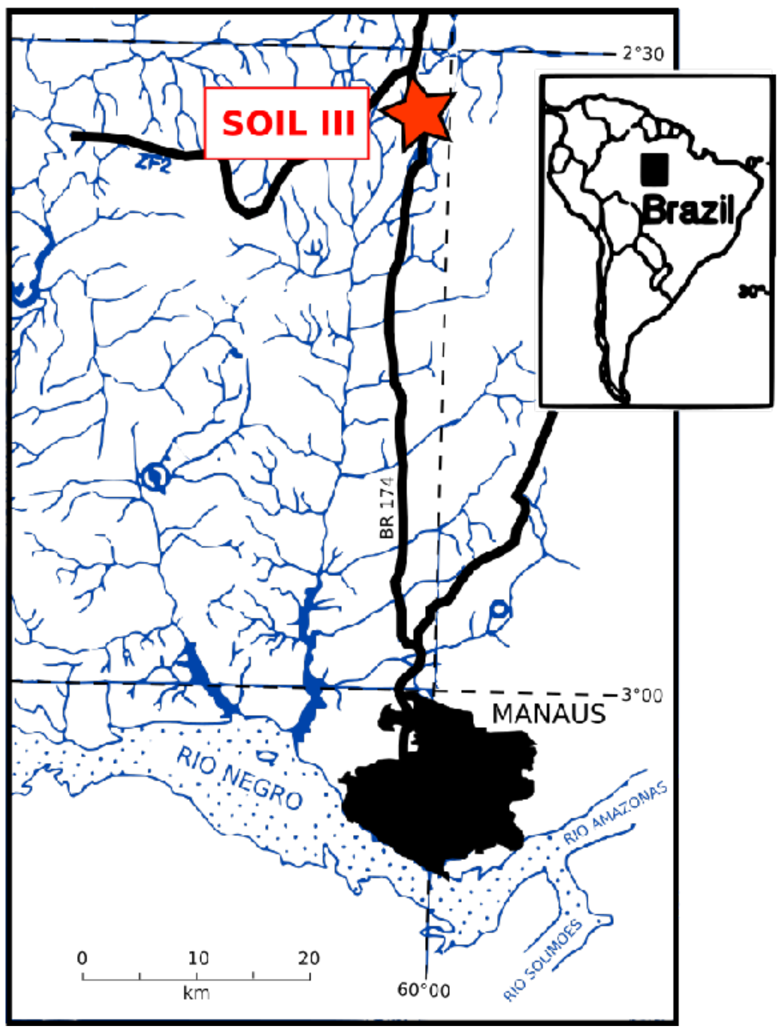
$$\delta^{30}Si = ({}^{30}Si/{}^{28}Si)_{sample} / ({}^{30}Si/{}^{28}Si)_{std} - 1) \times 1000$$

Si isotope fractionation expected during lateritization
Control of climatic conditions on recorded Si isotope signal

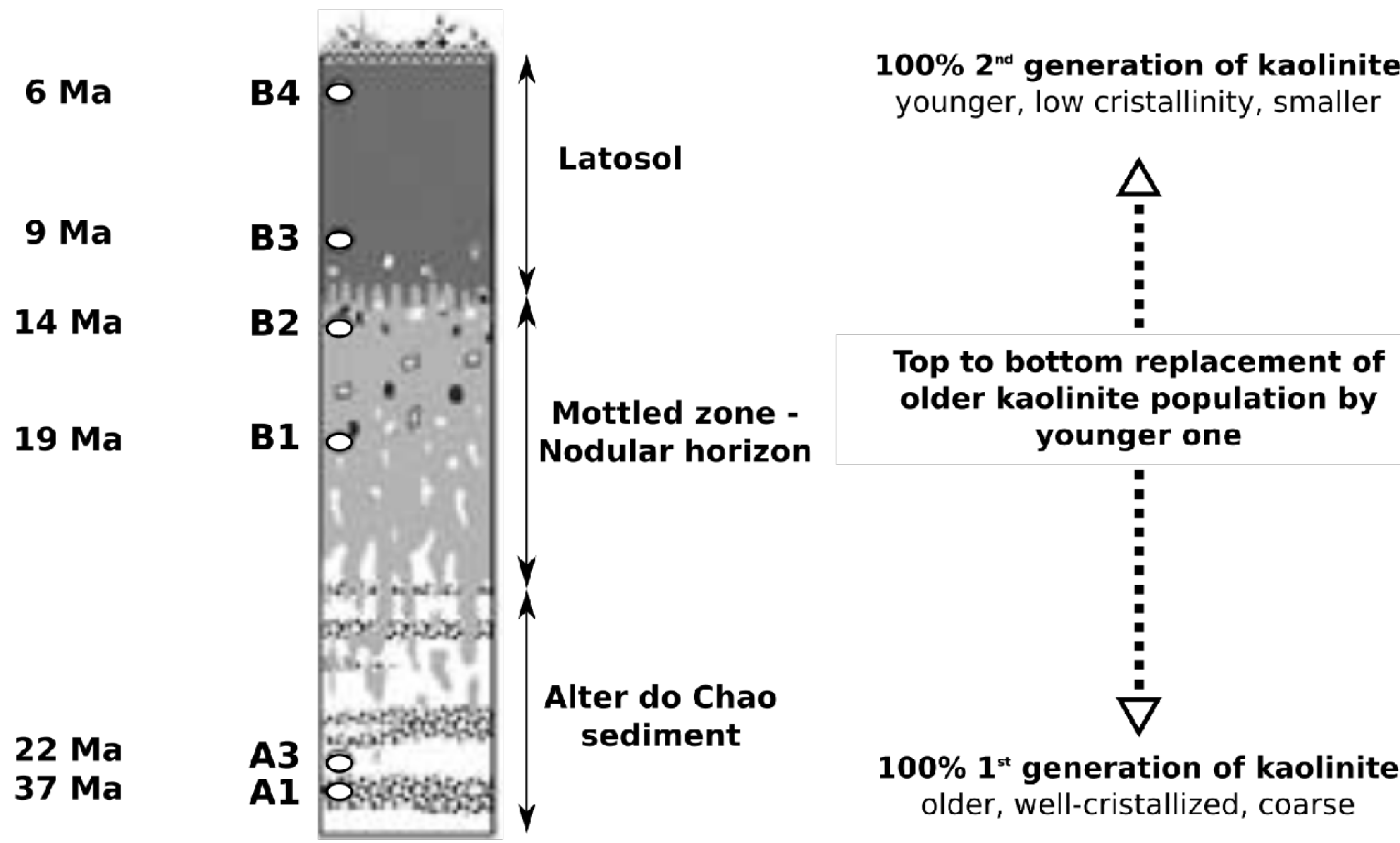
“Test" lateritic profile: soil III North of Manaus *(Lucas et al. 1996)*

- Lateritic profile developed on Alter do Chão (65-45 Ma) sedimentary formation
- Already studied for dating and kaolinite crystallinity *(Balan et al. 2005)*

SAMPLING MAP



KAOLINITE EPR AGE | **LATERITIC PROFILE** | **KAOLINITE POPULATION**

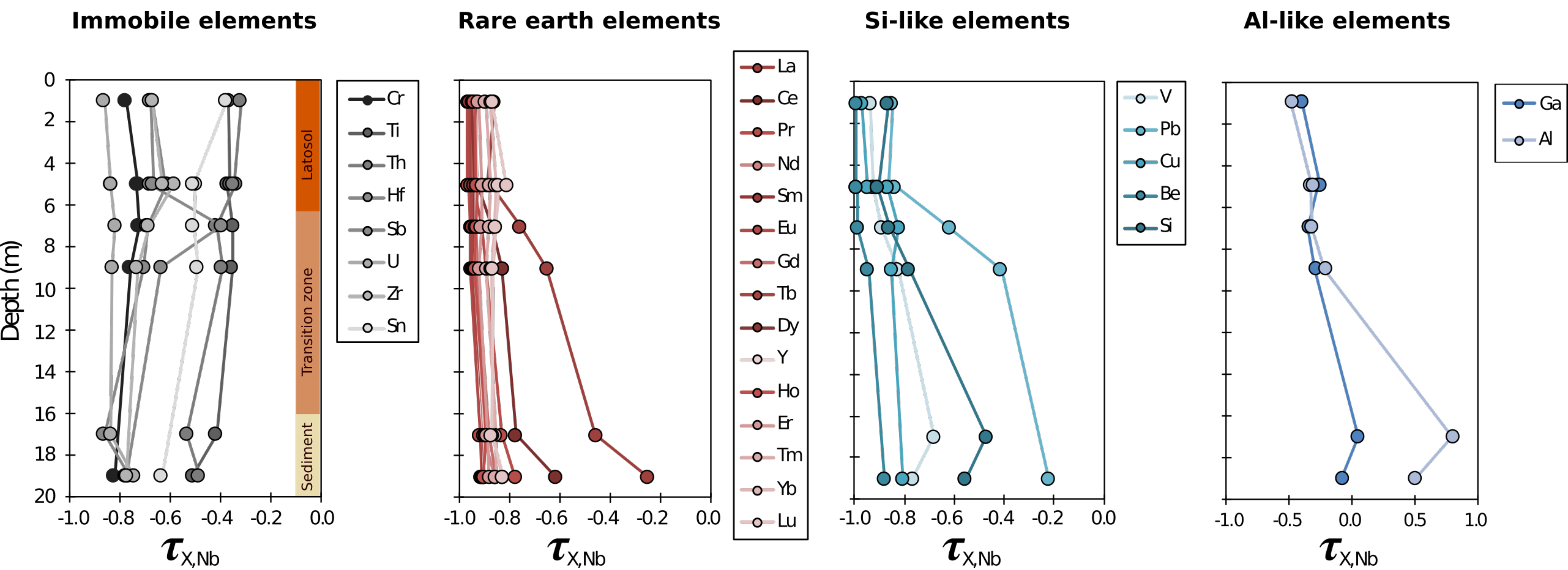


- **Do Si isotopes record a similar evolution over the lateritic profile ?**
- **Do Si isotopes record distinct conditions for the formation of the two kaolinite populations?**

Modified from Eyrolle et al. 1996 and Balan et al. 2005

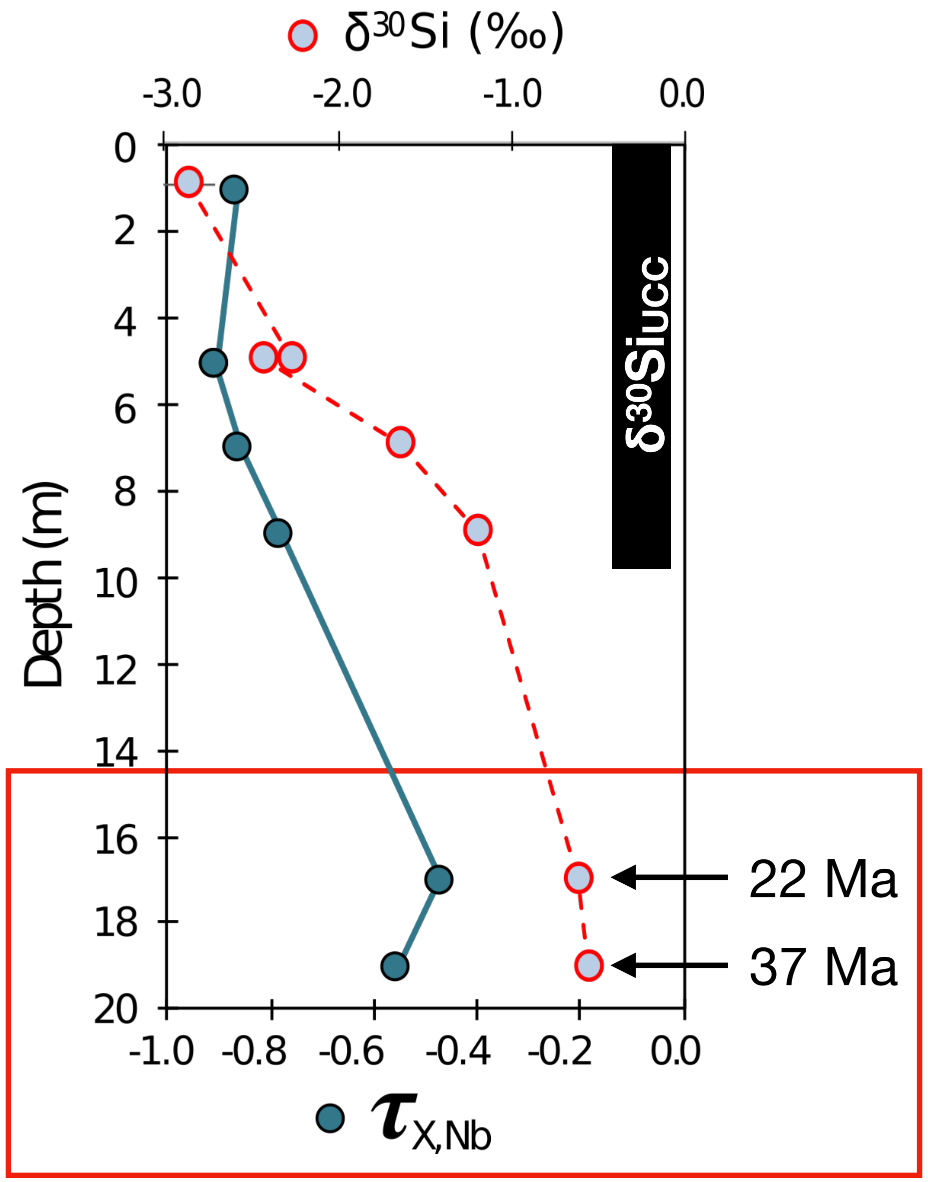
Elemental transfer through the profile

- **Focus on the clay fraction** (<2 µm after CBD removal of iron oxides)
- $\tau_{X,Nb} = (X_{soil} \times Nb_{UCC})/(X_{UCC} \times Nb_{soil}) - 1$



1st episode: weathering of Alter do Chão sediment

➡ Alter do Chão sediment experienced *in situ* pedogenetic weathering before laterization (Fritsch et al. 2002, Lucas et al. 1989, Balan et al. 2005)



1/ Limited Si isotope fractionation ($\Delta^{30}Si_{sediment-UCC}$= -0.40 ‰) compared with fractionation reported in literature for kaolinite formation (ca. $\Delta^{30}Si_{clay-parent\ rock}$ = -2 ‰)

2/ Silicon isotope recording kinetic fractionation (Oelze et al. 2014)

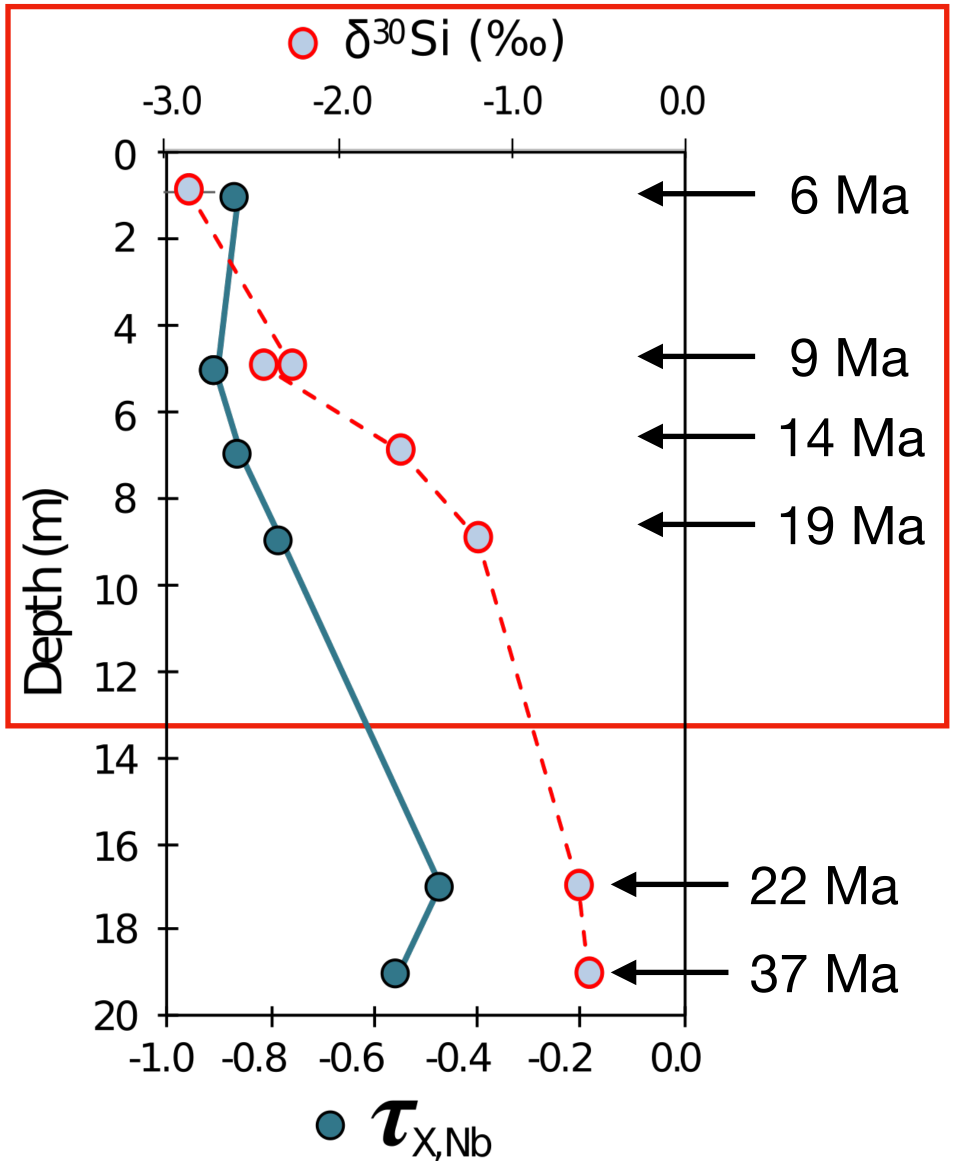
➡ Slow kaolinite precipitation

3/ Post-Oligocene weathering phase (25-30 Ma) under climatic conditions enabling the slow precipitation of kaolinite mineral

➡ Limited water infiltration

2nd episode: lateritization process

➡ Desilication of the clay fraction associated with strong enrichment in light Si isotopes
fastest kaolinite formation

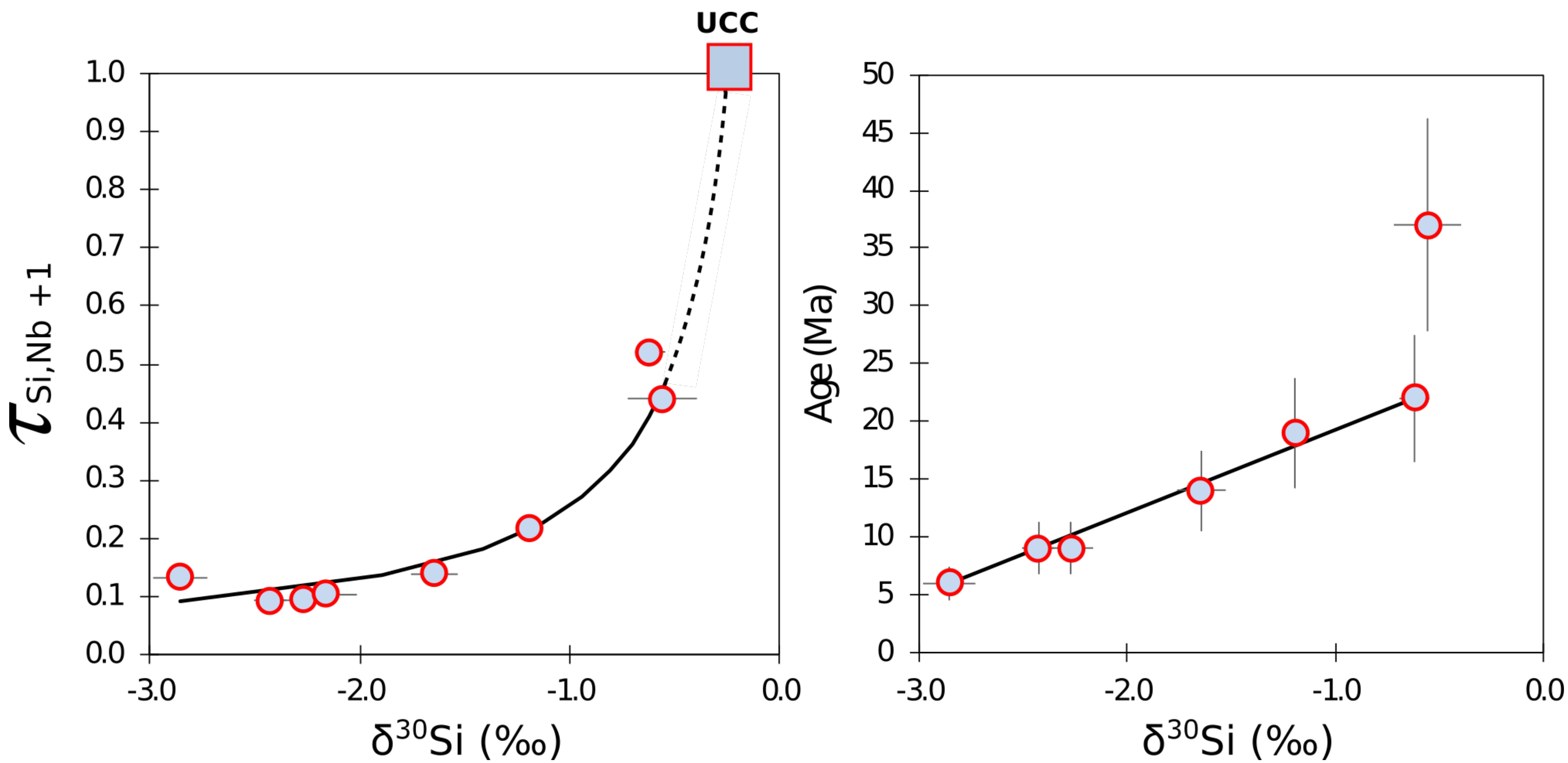


2nd episode: lateritization process

- Desilication of the clay fraction associated with strong enrichment in light Si isotopes **fastest kaolinite formation**

- Two possible scenarios to explain Si isotope evolution during laterite formation

  - ❖ Progressive lateritization process between 22 Ma and 6 Ma
  - ❖ Binary mixing with a short-term episode around 6-8 Ma



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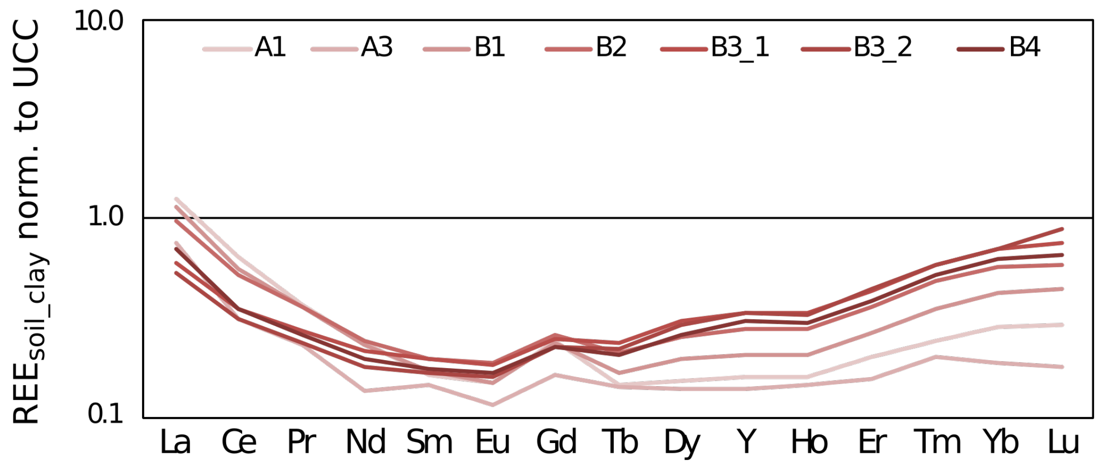

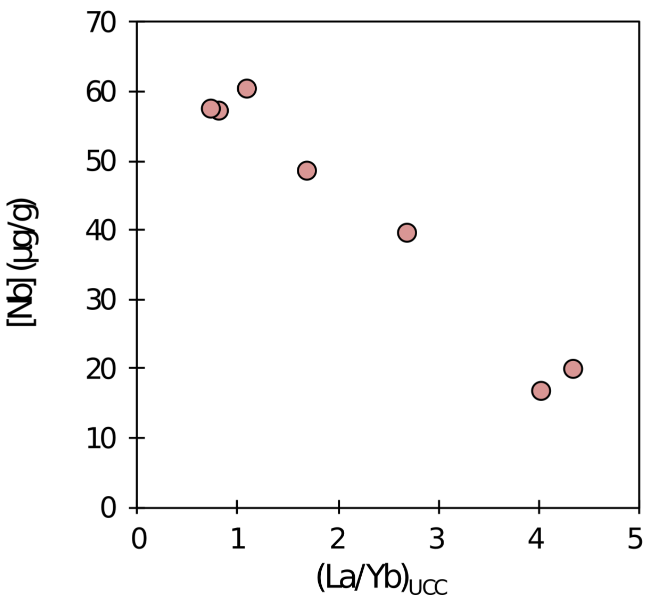

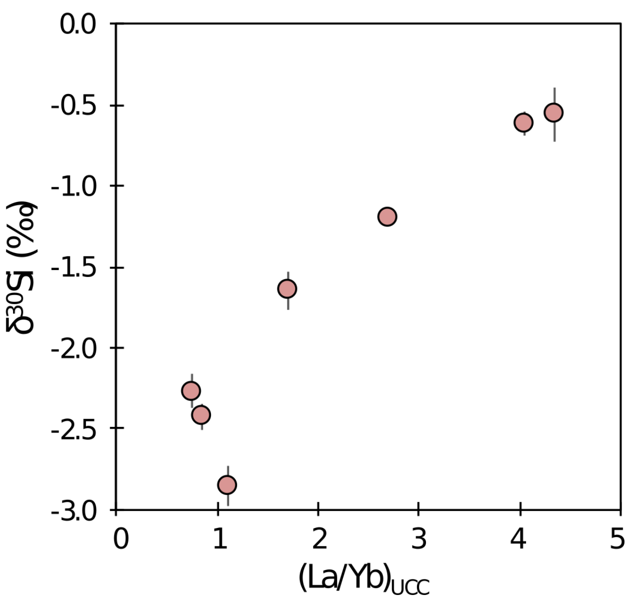

✦**Leaching of light REE: persistence of similar chemical conditions over 14 Ma unlikely**

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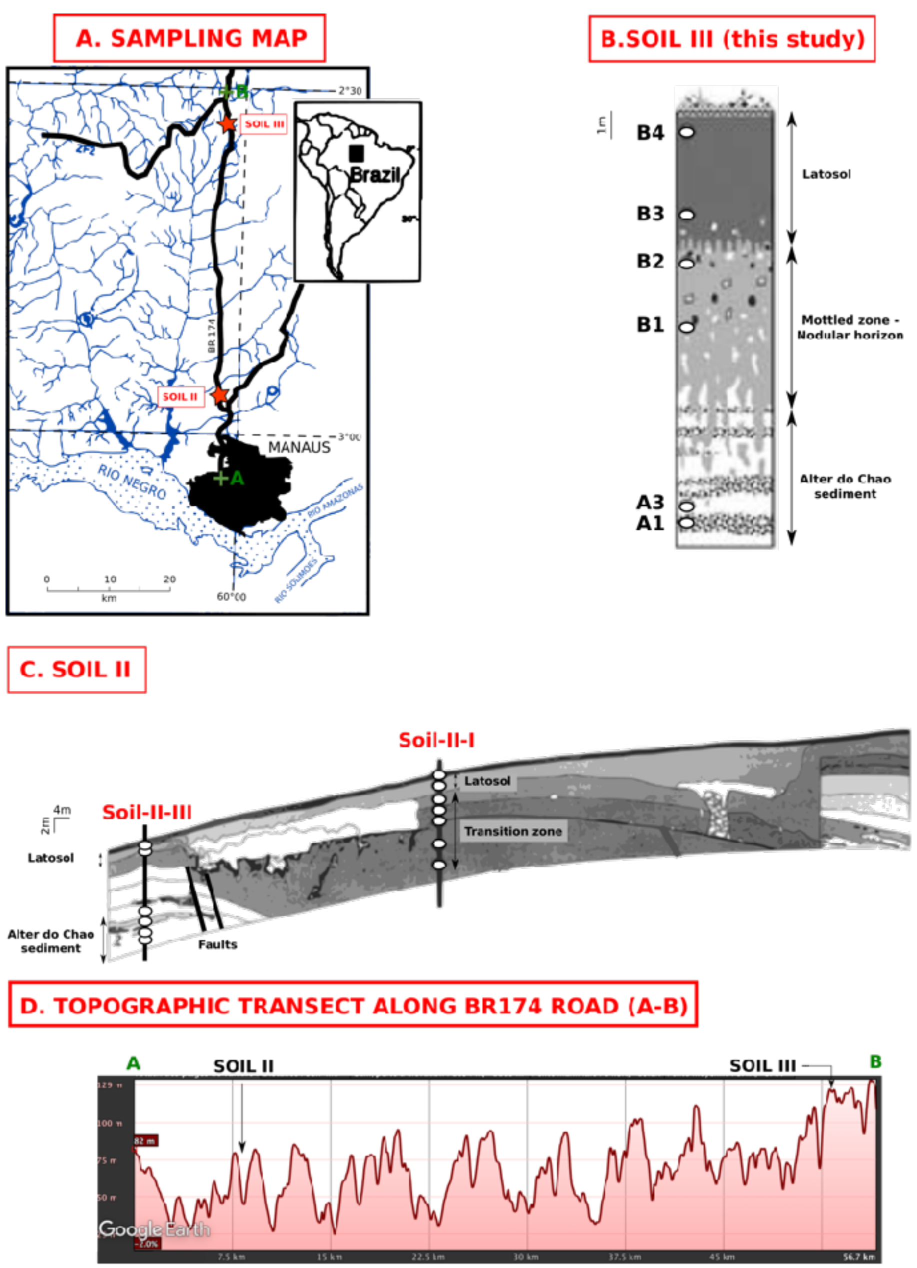
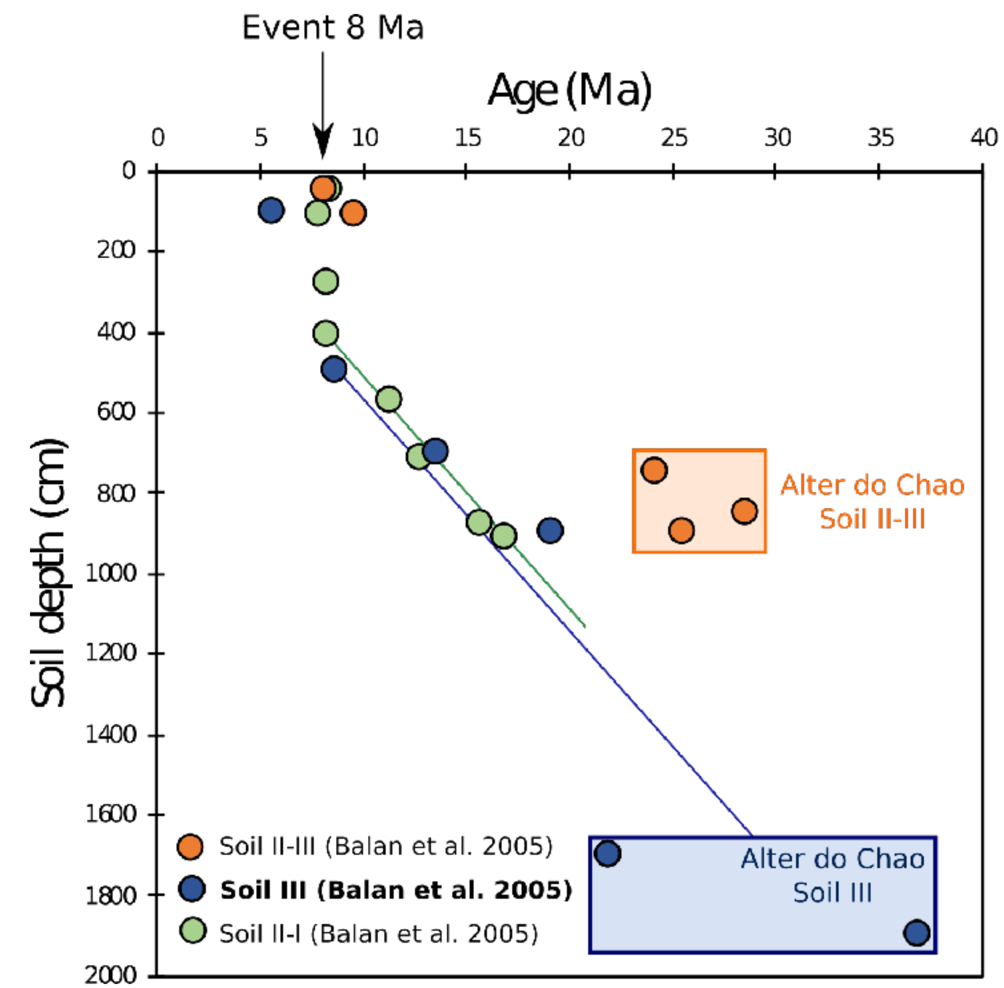


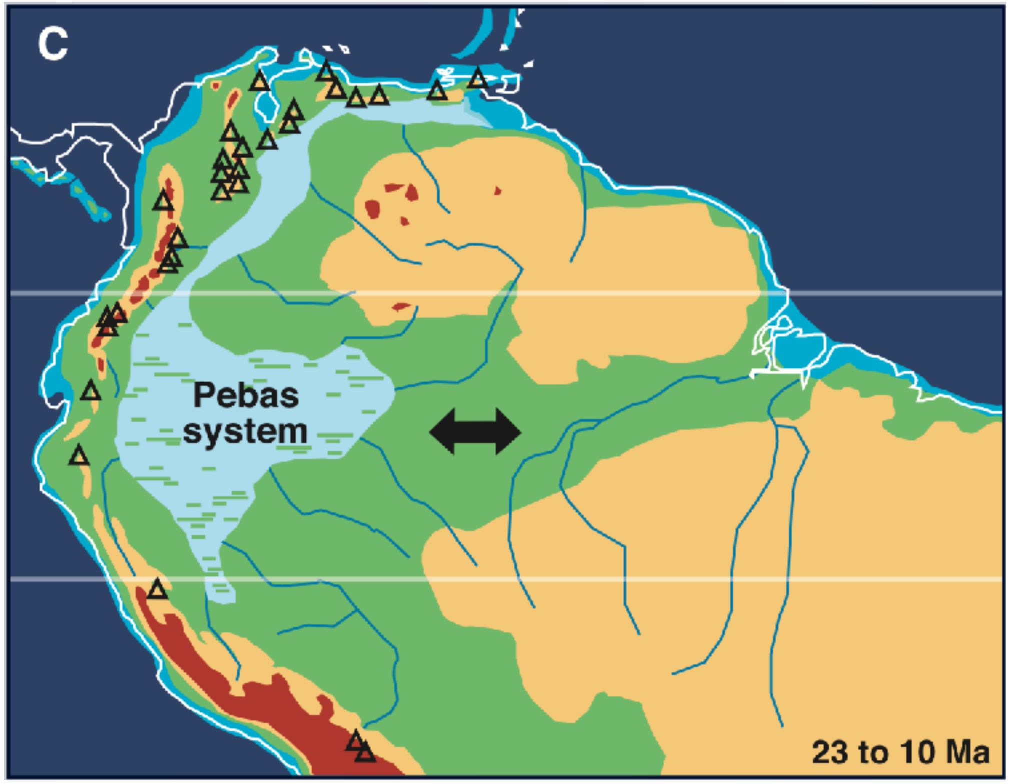


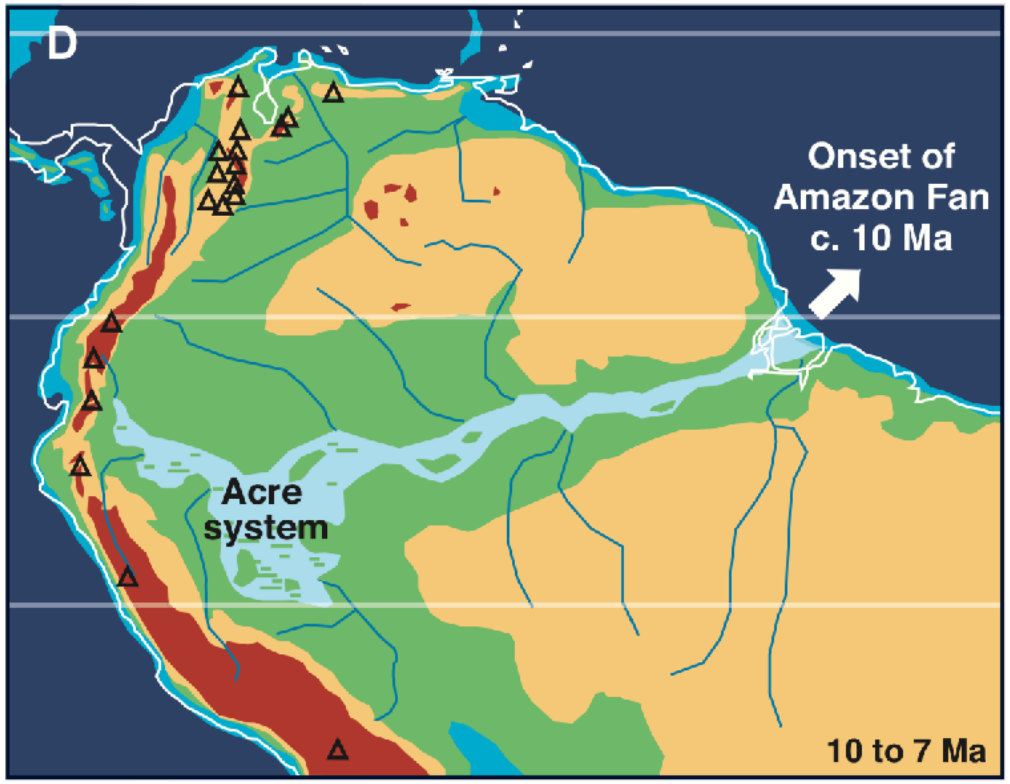
✦ **Kaolinite replacement at 8 Ma independently of altitude and thus of water dynamics**

Environmental conditions during the lateritization process? How to explain it?

- Desilication of the clay fraction associated with strong enrichment in light Si isotopes
  fastest kaolinite formation than during the first weathering episode
- Lateritization prone to occur with a persistent rainy season (Beauvais et al. 1999)
- Massive changes in paleogeography and water drainage during early Miocene (8-10 Ma) may have cause important changes in seasonality and water drainage in the Amazon Basin

✦ **Onset of transcontinental Amazon River between 8 and 10 Ma (Hoorn et al.. 2010)**





Conclusions and future steps

✦ **Si isotopes: a powerful tool to identify weathering episodes**

- Two distinct weathering periods with distinct climatic conditions
- Current development: use of a transport reactive model
  - Constraints on water flow dynamics during Alter do Chão weathering and lateritization process

✦ **Use of Si isotopes at a larger scale**

- On lateritic soils with various ages
- On lateritic soils developed on crystalline rocks

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Cited references in the presentation

- Allard et al. (2018) *Combined dating of goethites and kaolinites from ferruginous duricrusts. Deciphering the Late Neogene erosion history of Central Amazonia.* Chemical Geology, 479, 136–150
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