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

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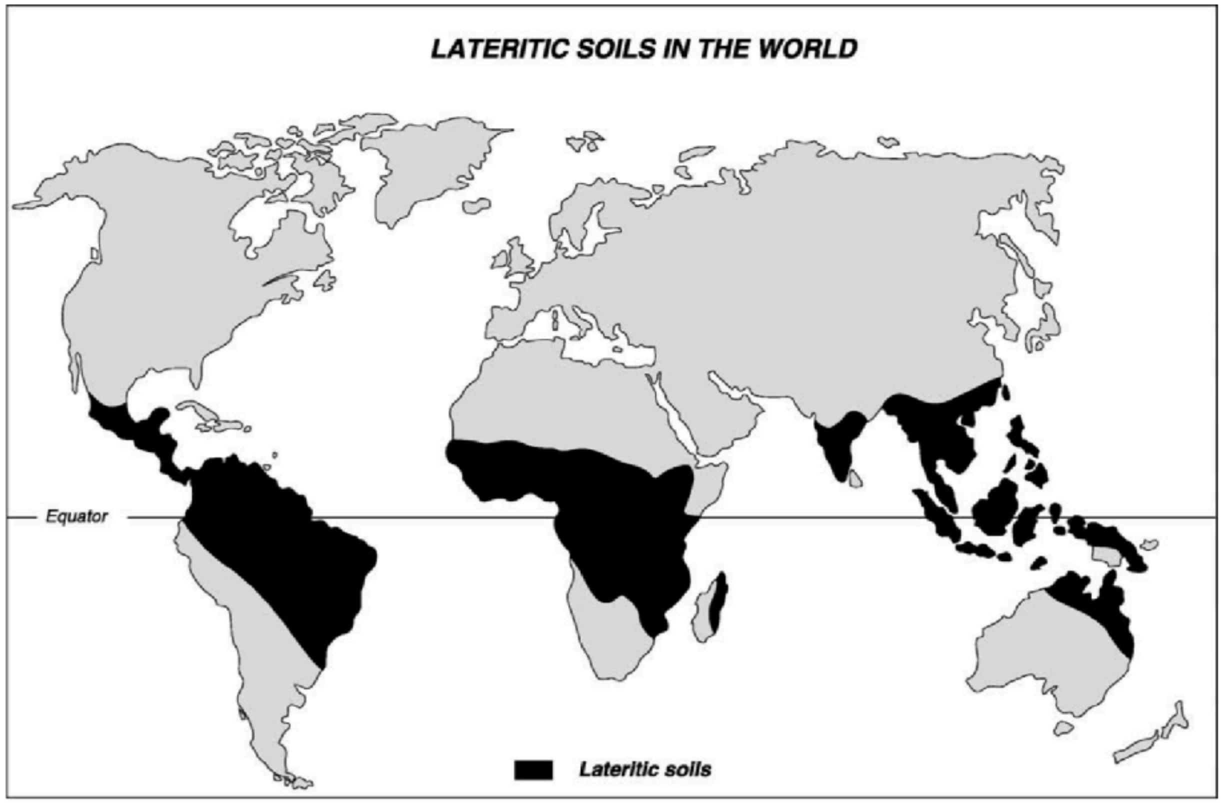
# Lateritic soils: composition and occurrence on Earth



- 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)

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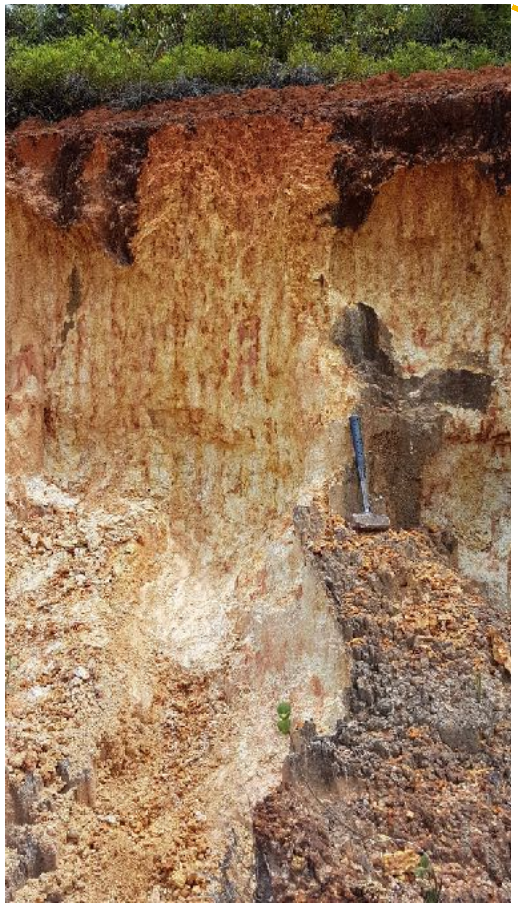

**Mottled zone**
Differentiation between whitish (kaolinite) and reddish (Fe/Al oxides) sequences

↑

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**"Iron crust" - Pisolitic horizon**

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**Red latosol**
Iron and kaolinite-rich level

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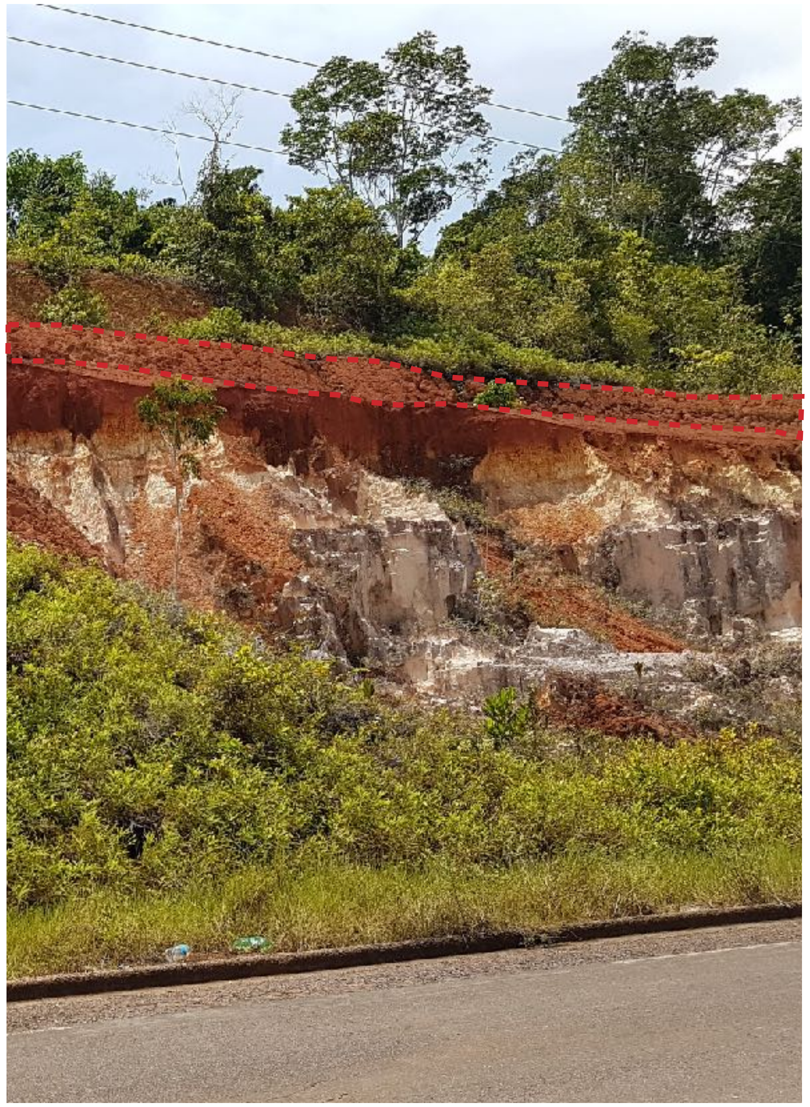

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**Yellow latosol**
Iron and kaolinite-rich level

↑

**Red latosol**
Iron and kaolinite-rich level

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**"Iron crust" - Pisolitic horizon**

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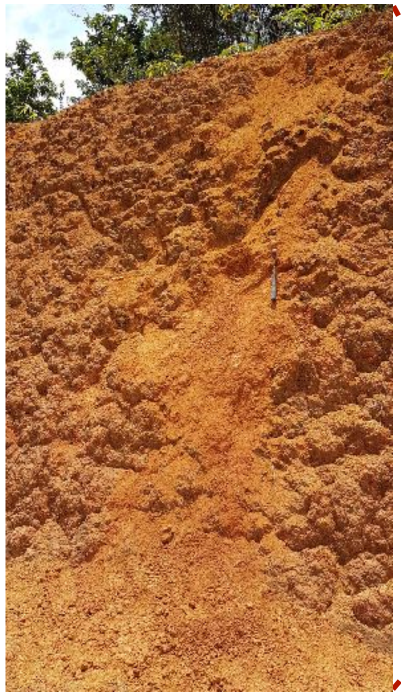

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- Composition: kaolinite clay and Fe/Al (oxi)hydroxides
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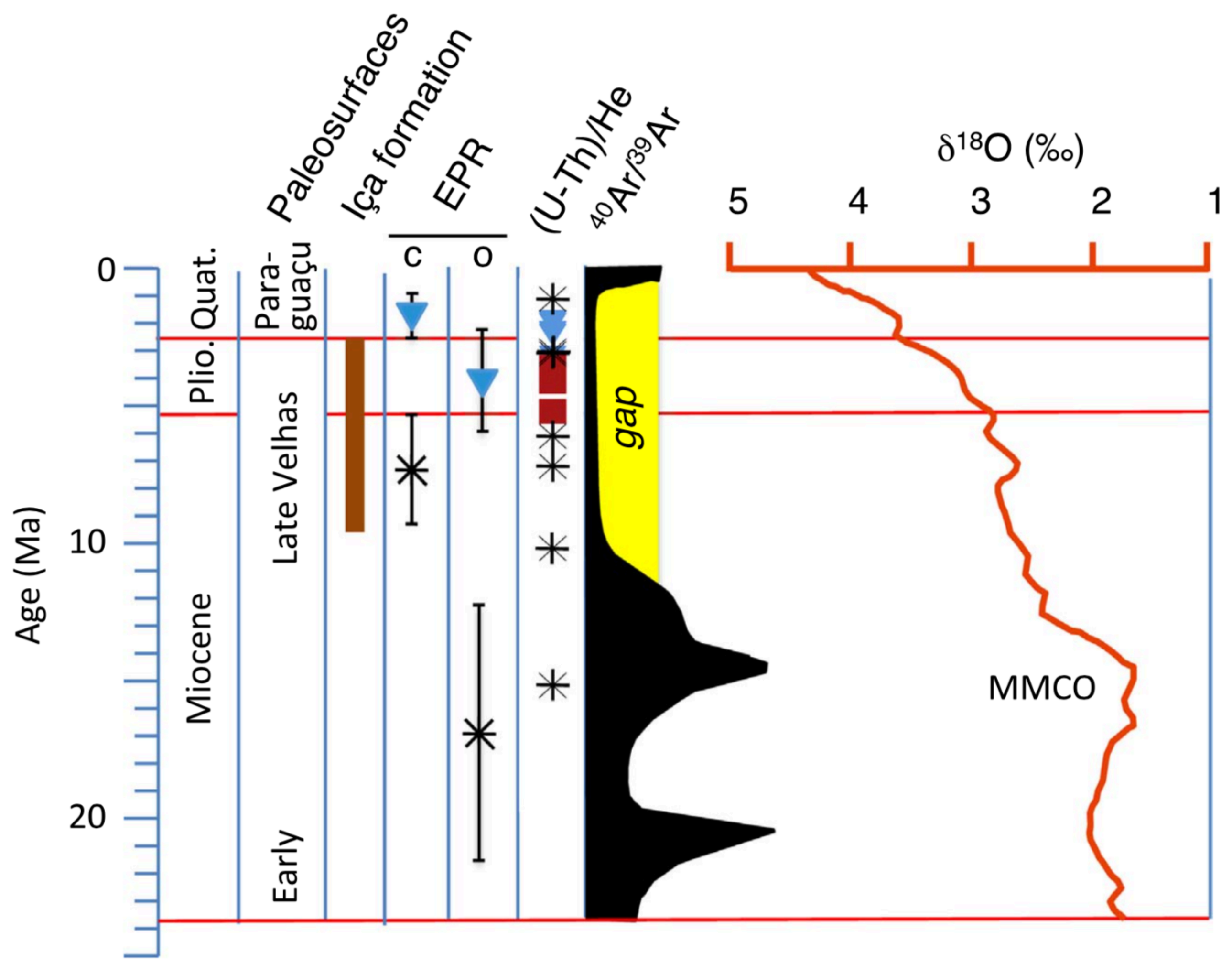
- Laterites formed by successive weathering episodes (based on dating techniques)



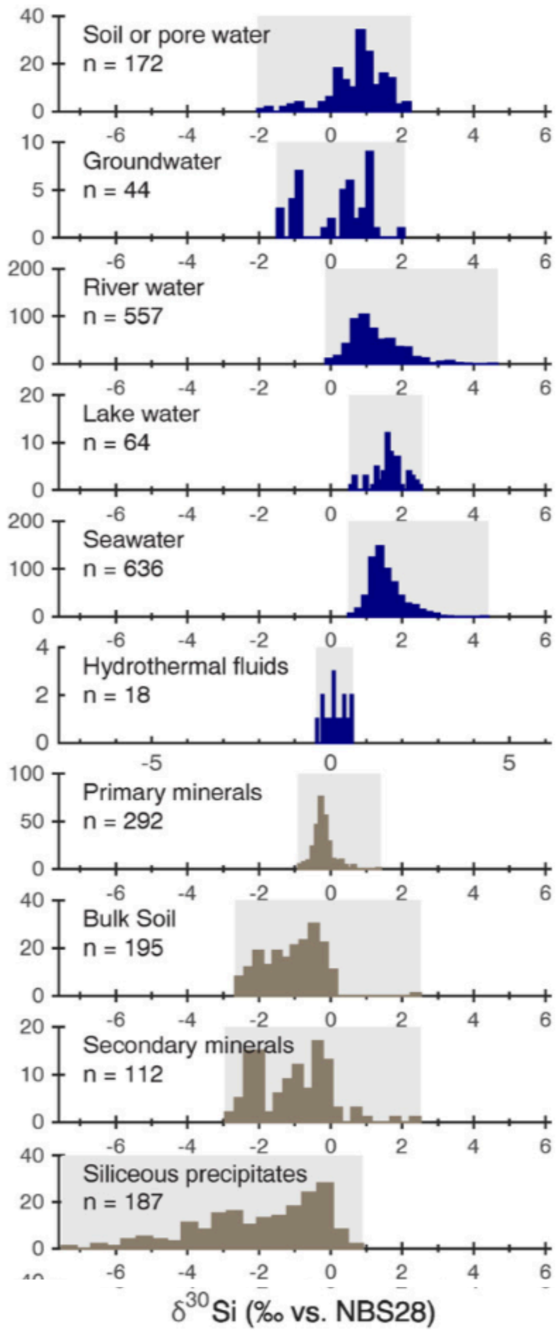

*Allard et al. 2018*

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

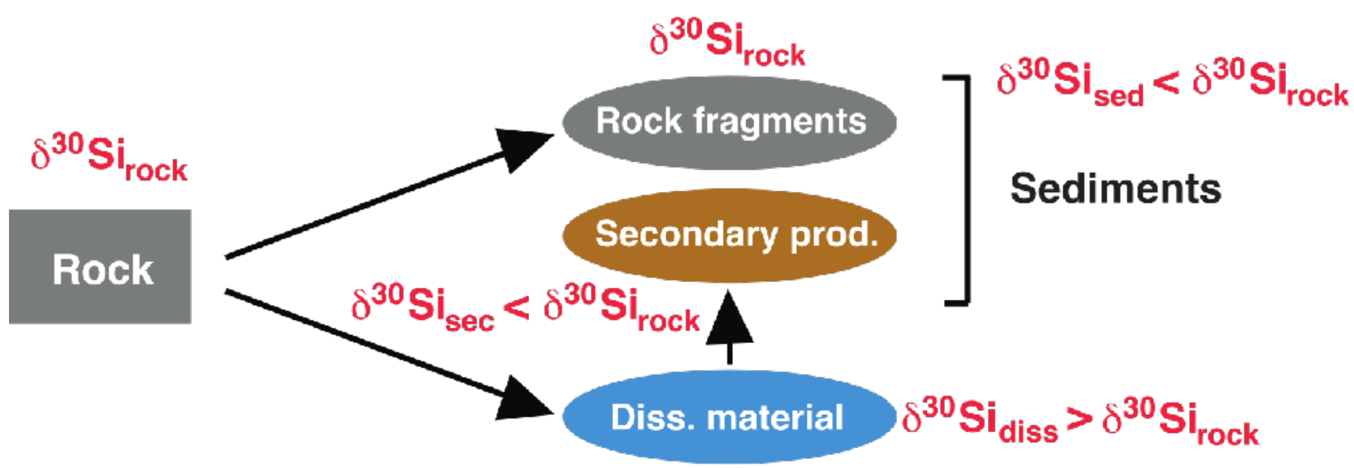
➡ Si isotopes: fractionation of kinetic origin during chemical weathering process (*Oelze et al. 2014, 2015*)

**Enrichment of solution in heavy isotopes**




*Frings et al. 2016*

**Formation of clays**



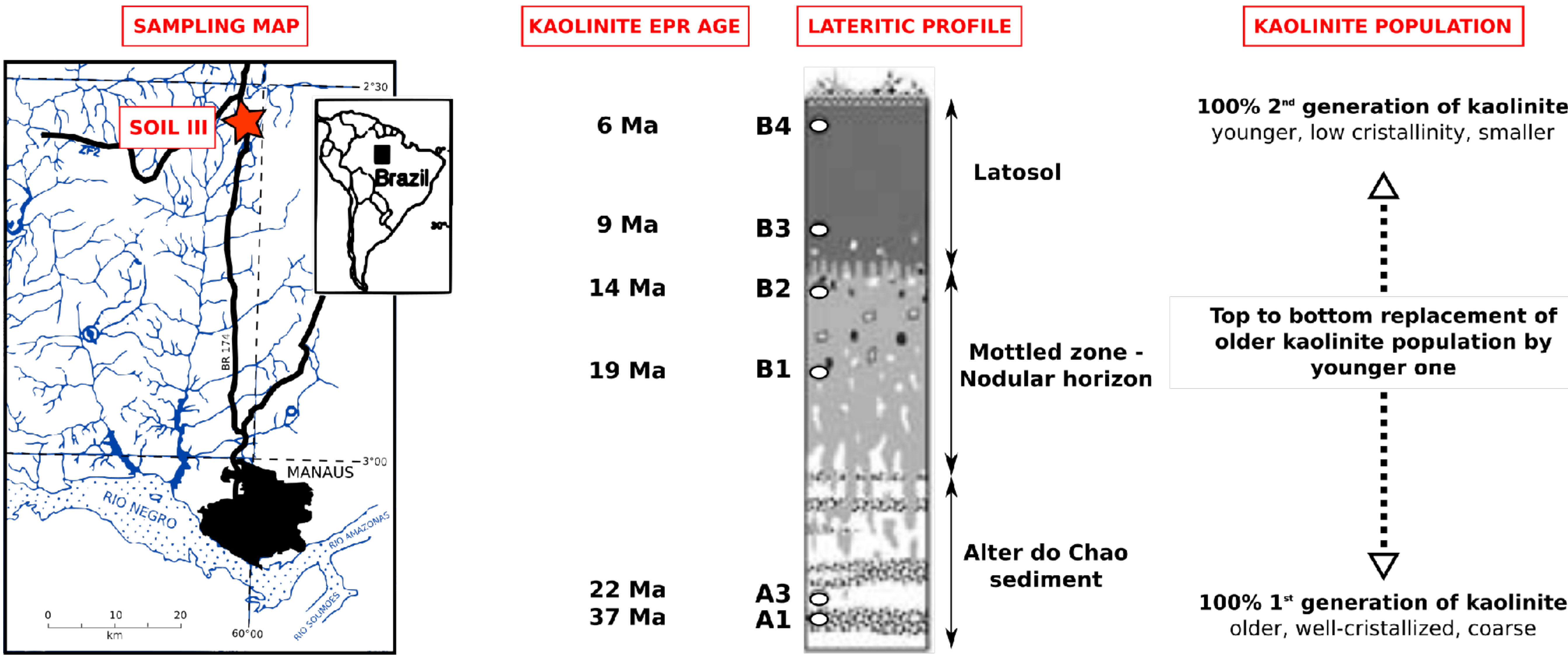

$$\delta^{30}Si = ({}^{30}Si/{}^{28}Si)_{sample} / ({}^{30}Si/{}^{28}Si)_{std} - 1) \times 1000$$

**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)*

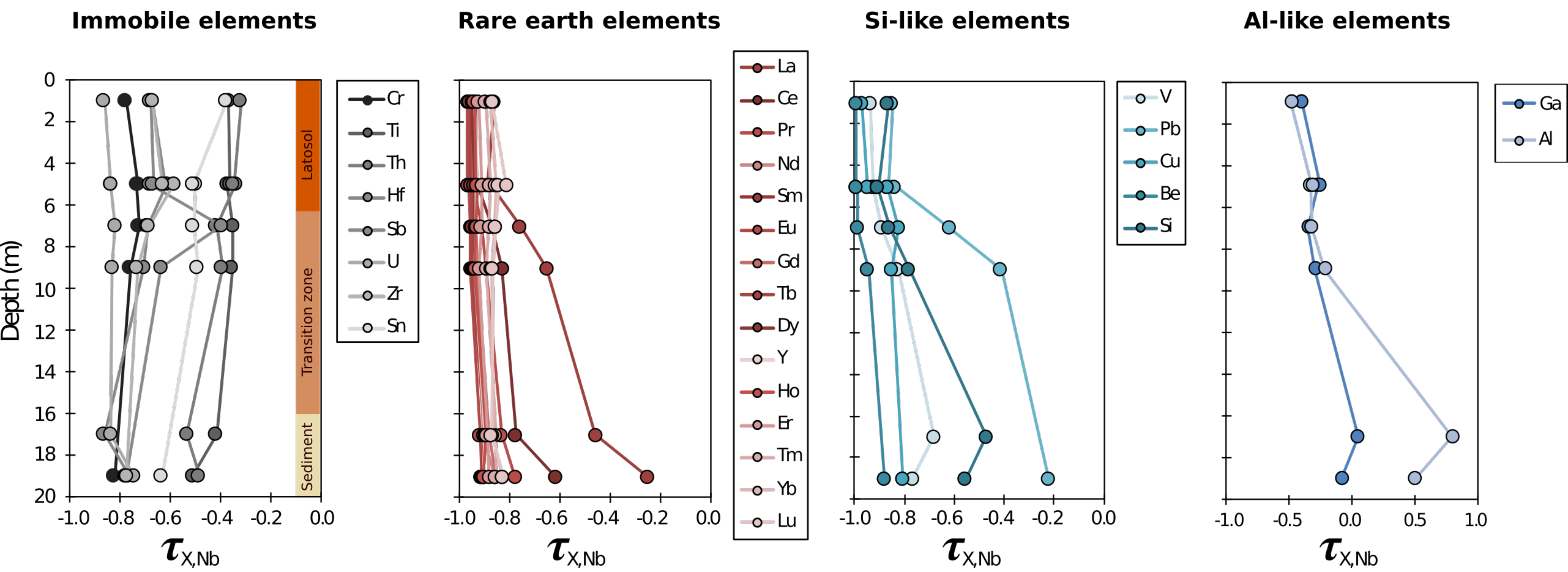



- **Do Si isotopes record a similar evolution over the lateritic profile ?**
- **Do Si isotopes record distinct conditions for the formation of the two kaolinite populations?**

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

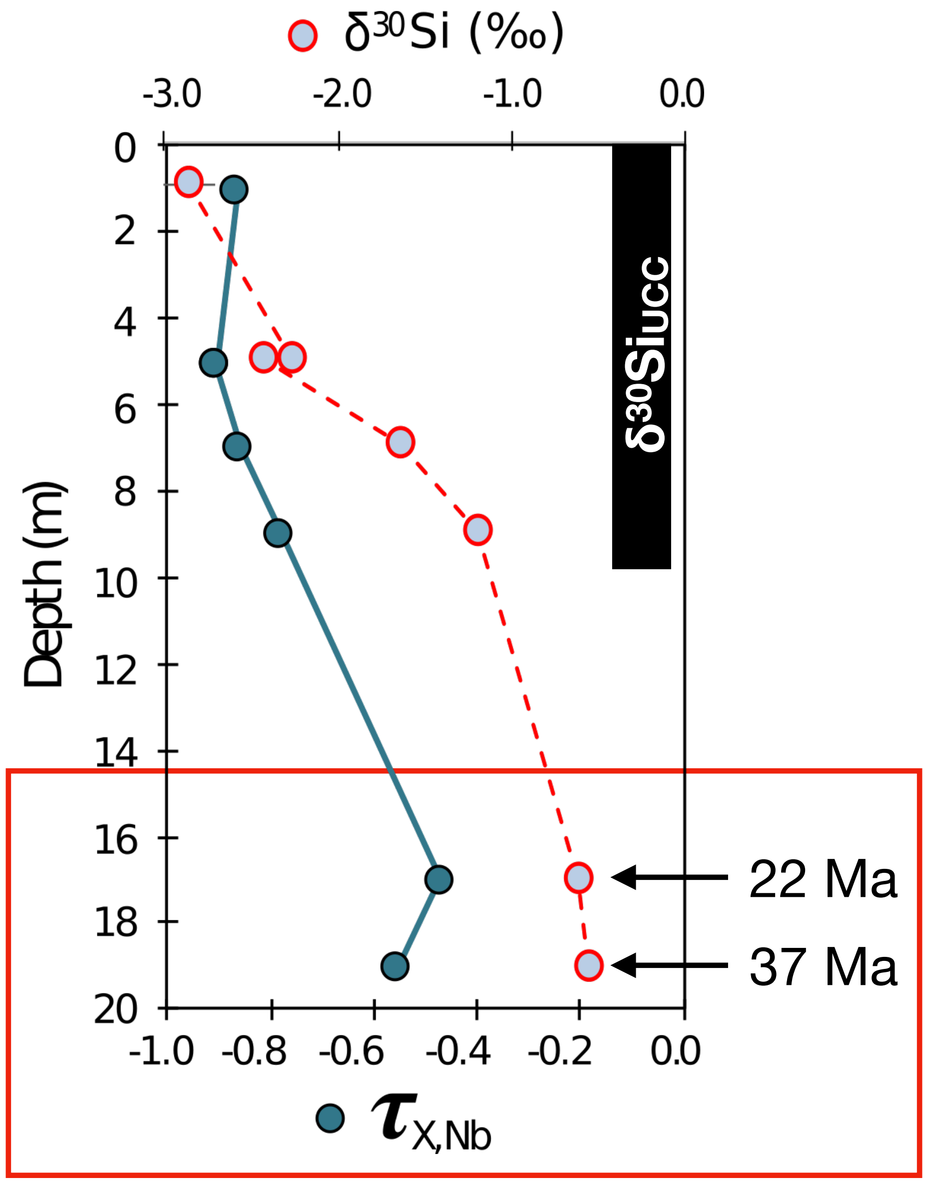
 

- **Focus on the clay fraction** (<2 µm after CBD removal of iron oxides)
- $\tau_{X,Nb} = (X_{soil} \times Nb_{UCC})/(X_{UCC} \times Nb_{soil}) - 1$



➡ 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)

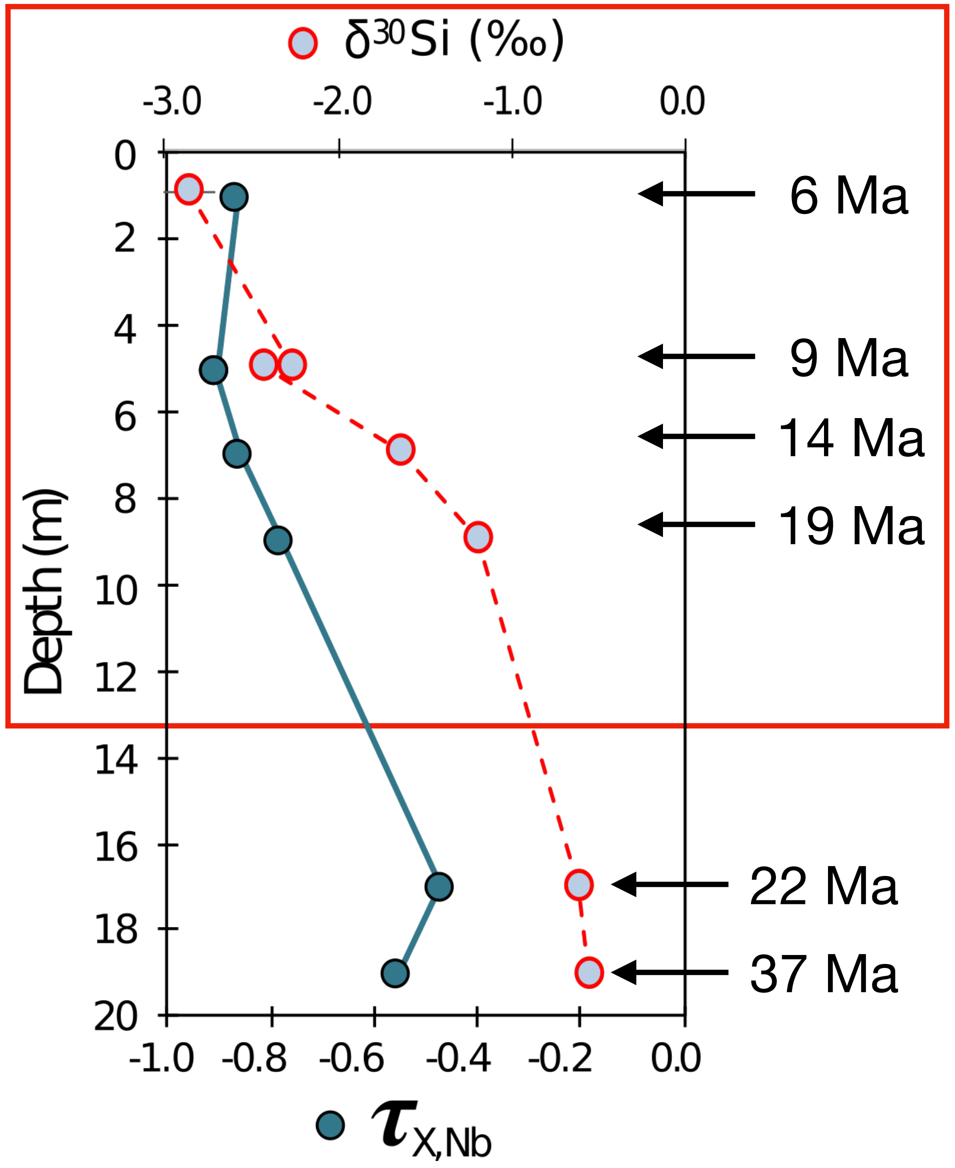
➡ Slow kaolinite precipitation

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

➡ Limited water infiltration

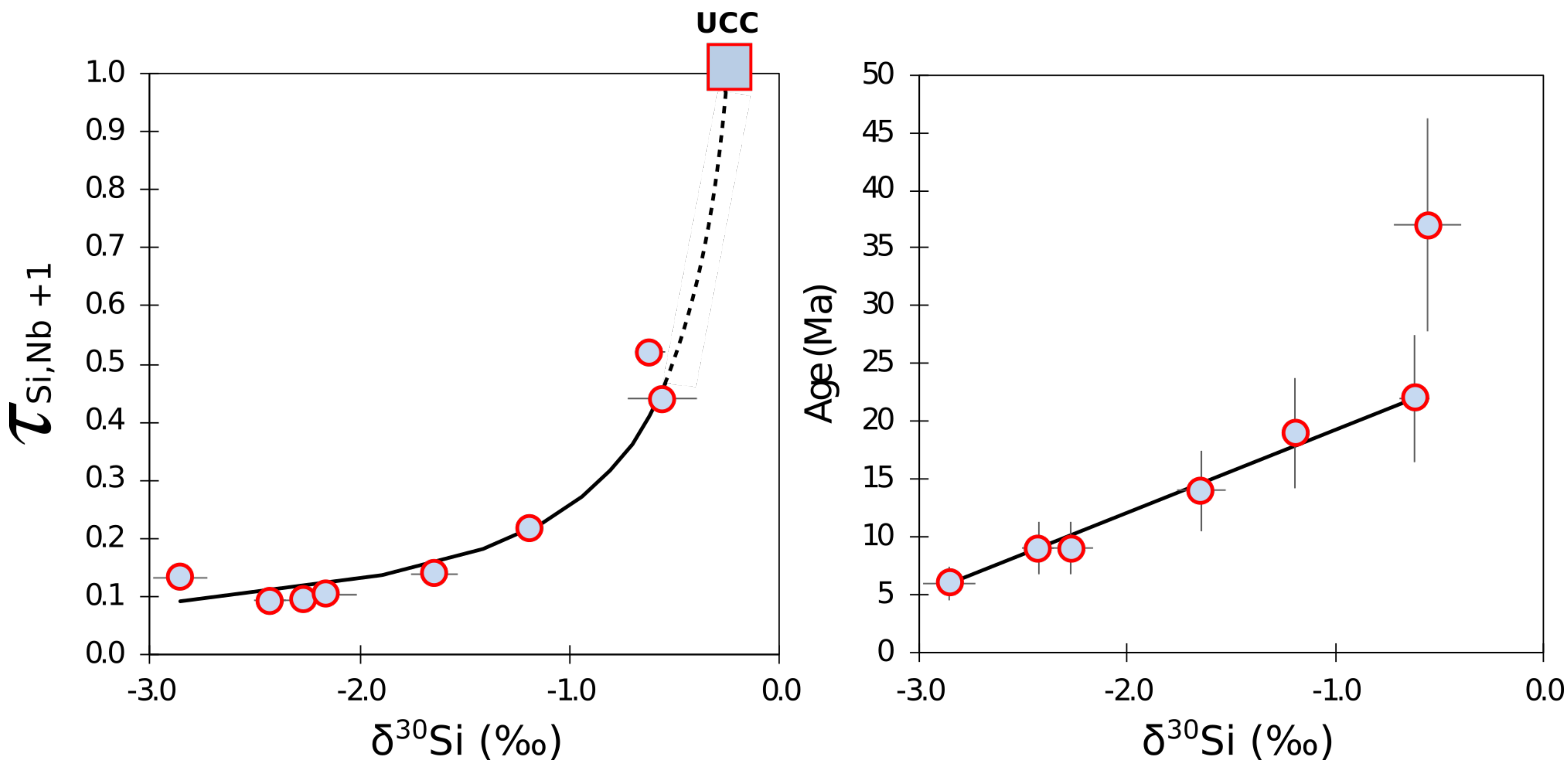
 

➡ Desilication of the clay fraction associated with strong enrichment in light Si isotopes
**fastest kaolinite formation**



- 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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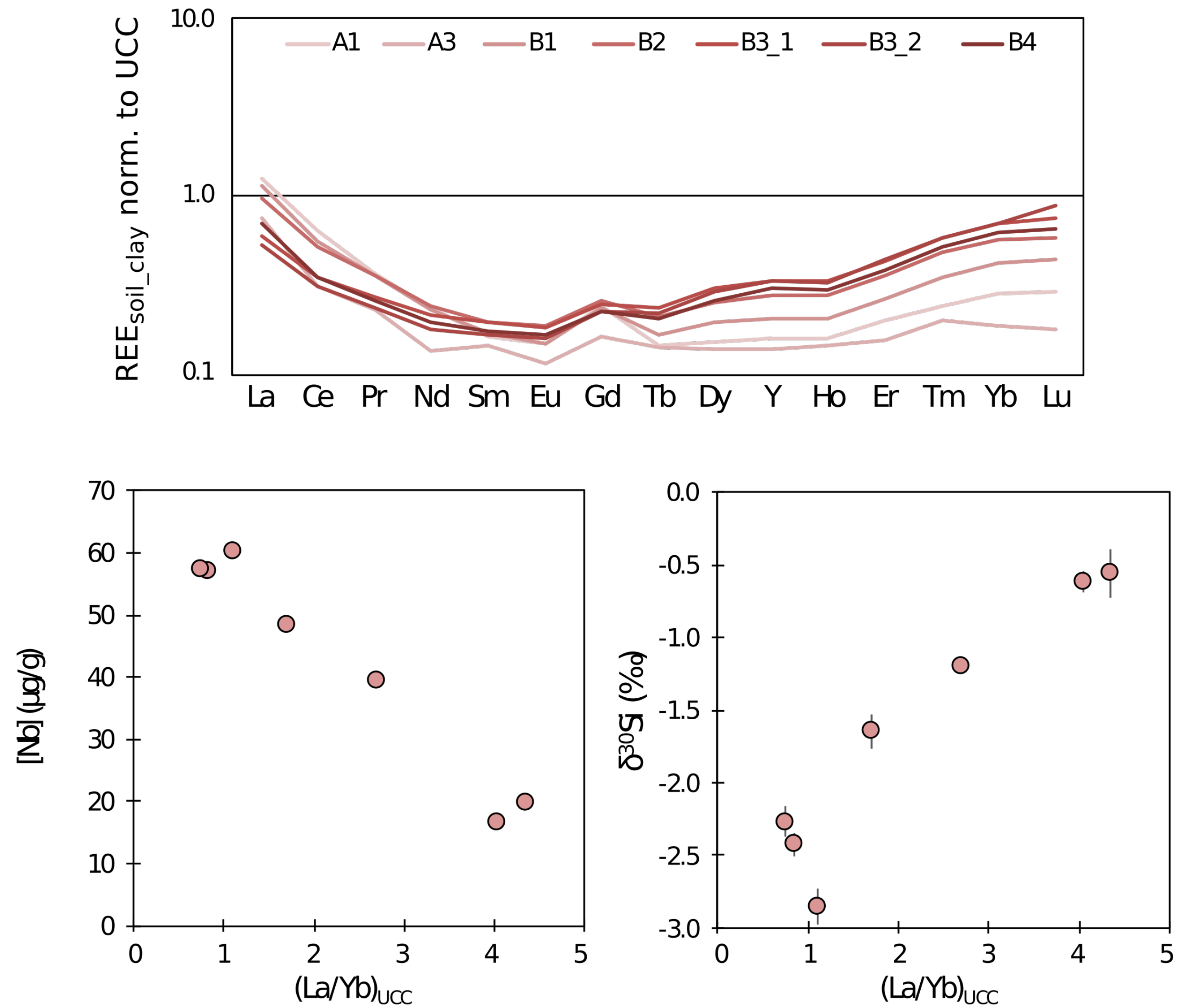


✦**Leaching of light REE: persistence of similar chemical conditions over 14 Ma unlikely**

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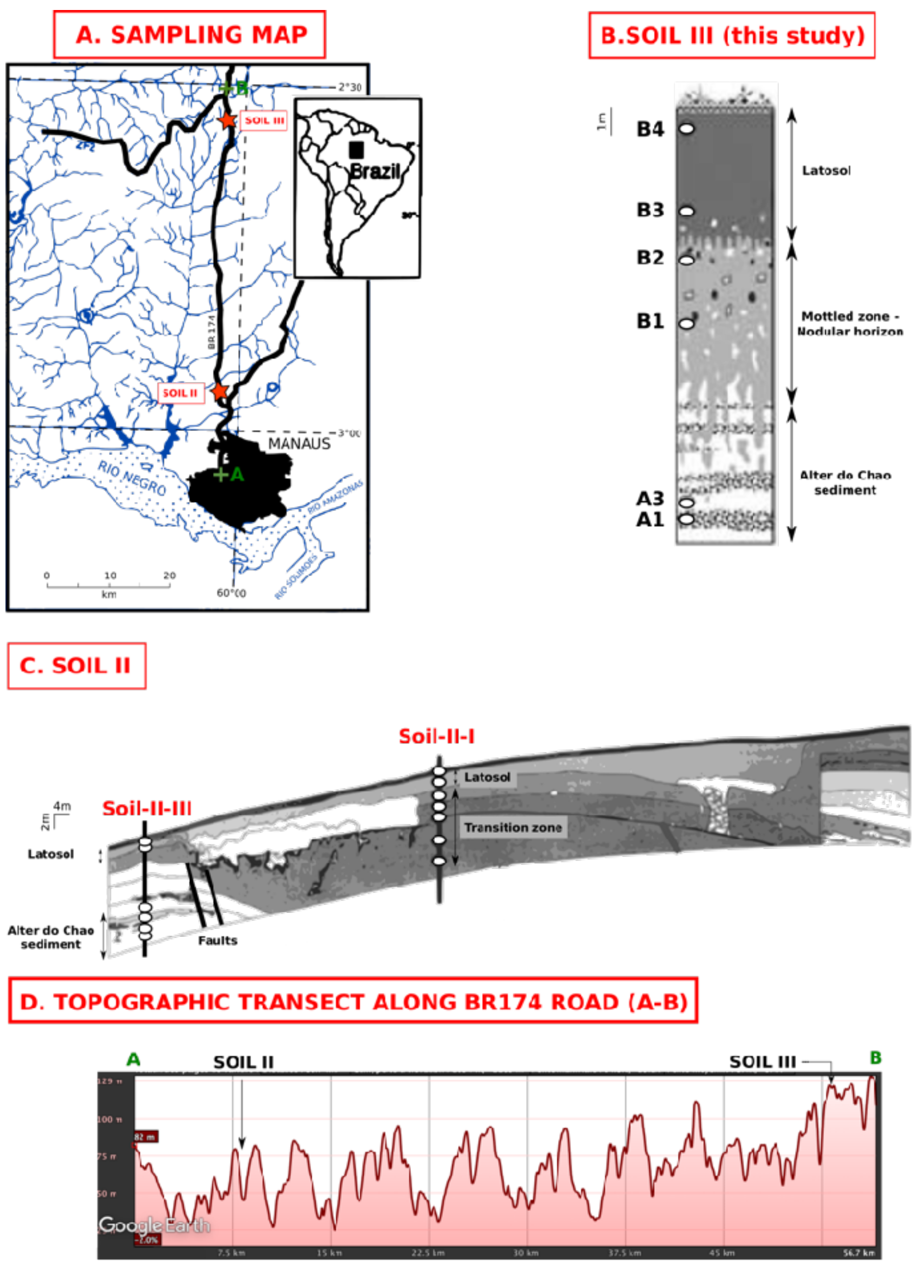
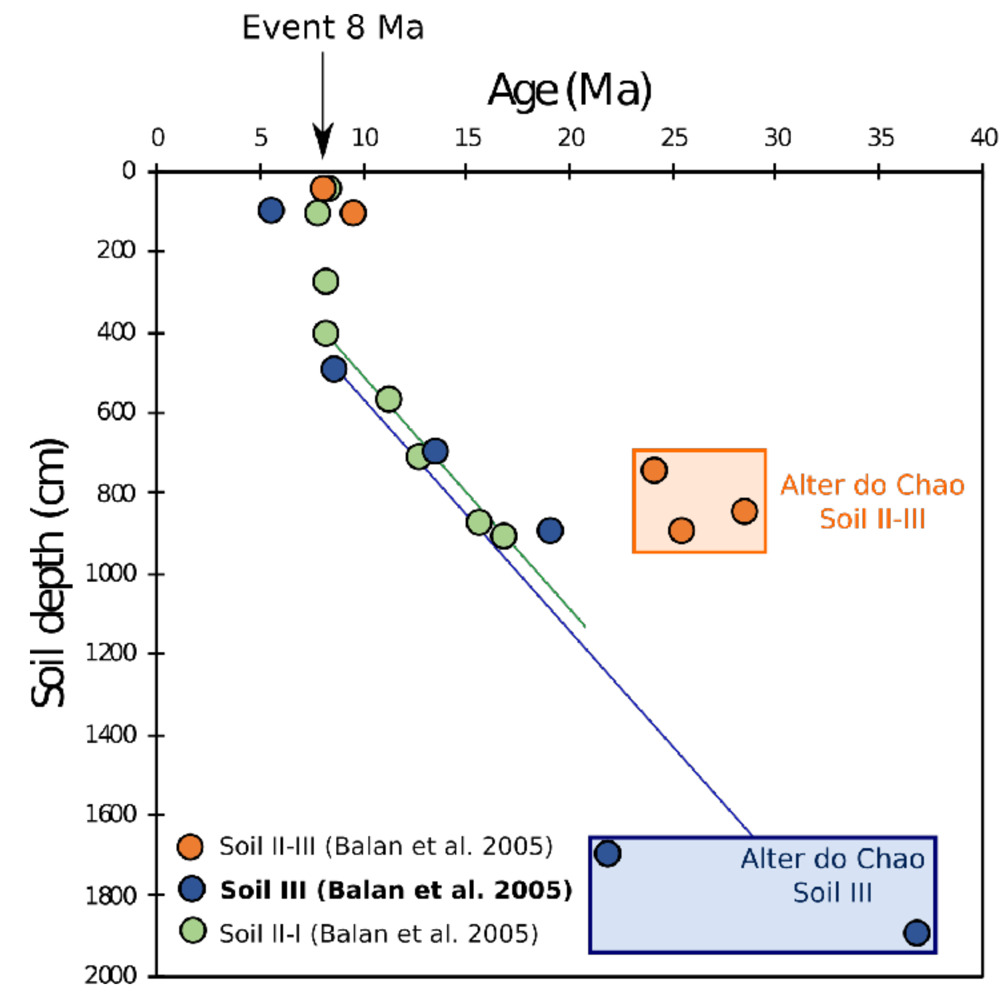


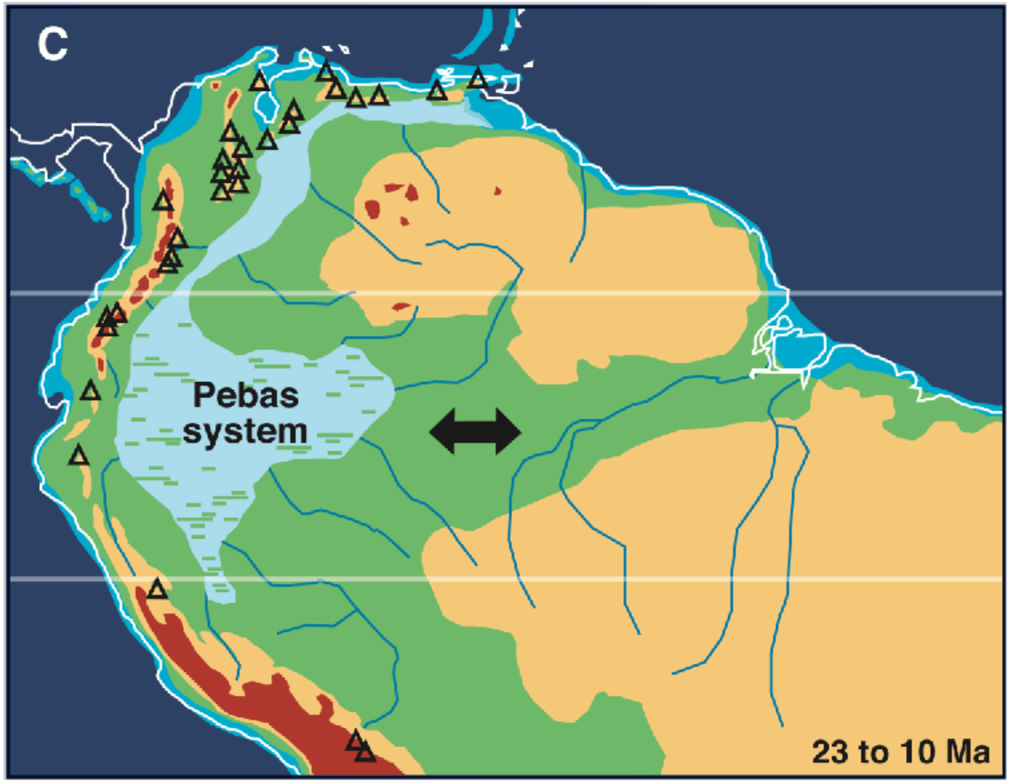



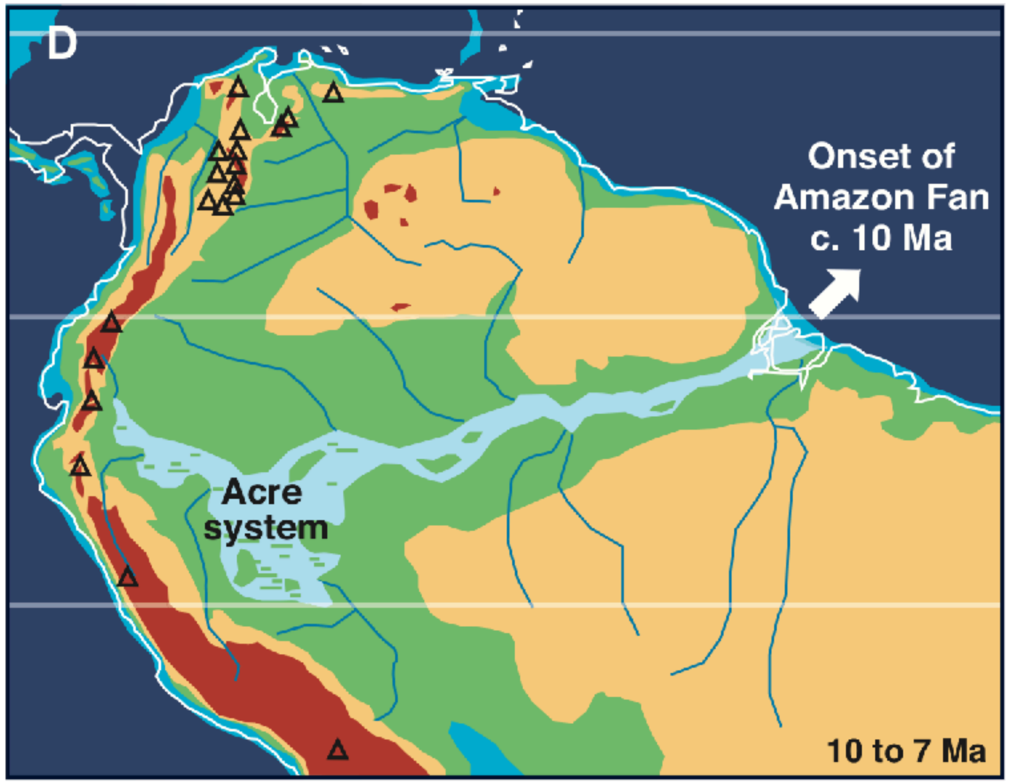

✦ **Kaolinite replacement at 8 Ma independently of altitude and thus of water dynamics**

# 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)**



## ✦ 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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- 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
- Balan et al. (2005) *Formation and evolution of lateritic profiles in the middle Amazon basin: Insights from radiation-induced defects in kaolinite*. Geochimica et Cosmochimica Acta, 69(9), 2193-2204.
- Eyrolle et al. (1996) *The distributions of colloidal and dissolved organic carbon, major elements, and trace elements in small tropical catchments*. Geochimica et Cosmochimica Acta, 60(19), 3643-3656.
- Frings et al. (2016) *The continental Si cycle and its impact on the ocean Si isotope budget*. Chemical Geology, 425, 12–36
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- Nahon (2003) *Altérations dans la zone tropicale. Signification à travers les mécanismes anciens et/ou encore actuels.* C. R. Geoscience, 335, 1109–1119



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