

Eruptive chronology of Tungurahua volcano (Ecuador) revisited from new K-Ar ages and geomorphological reconstructions

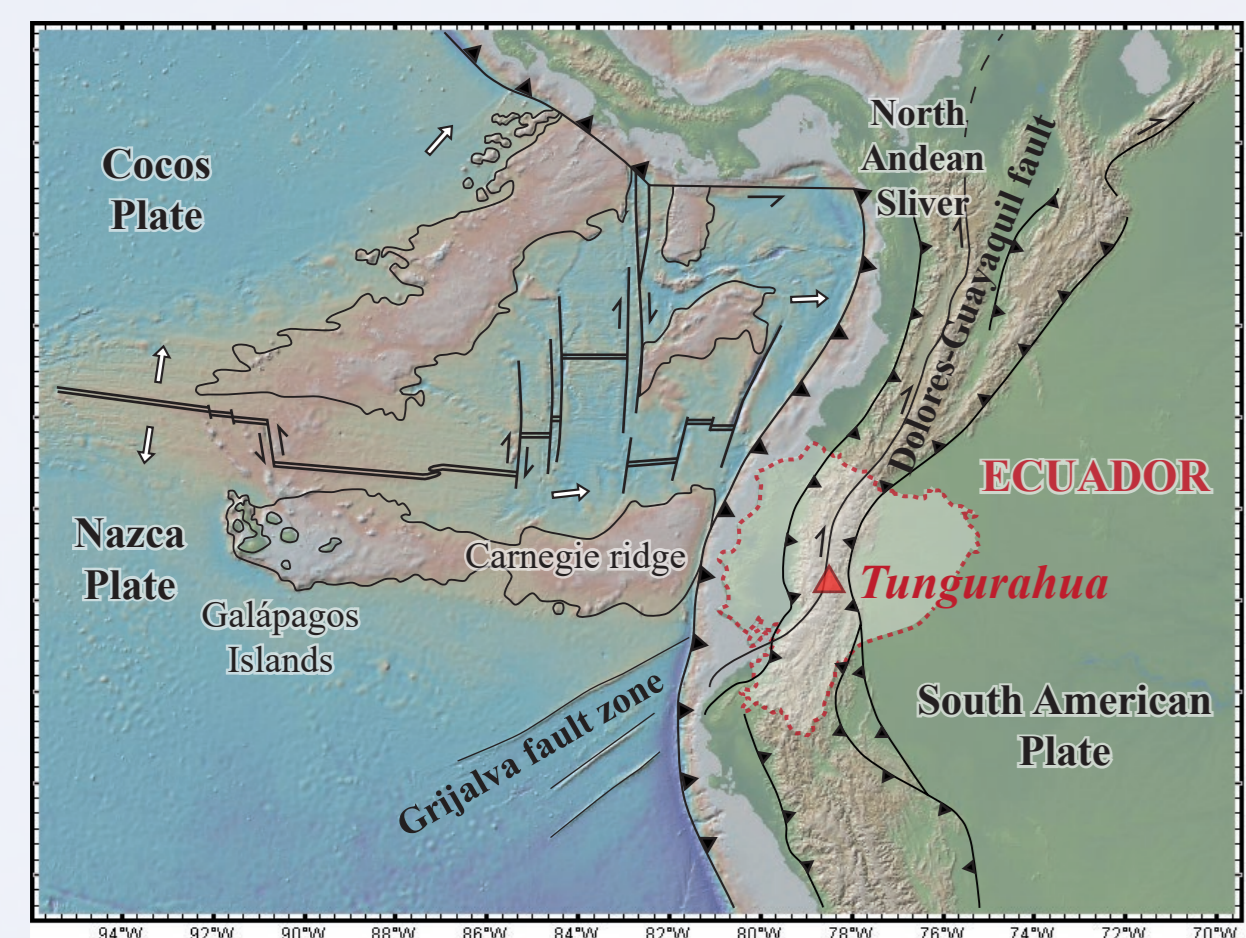
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Introduction

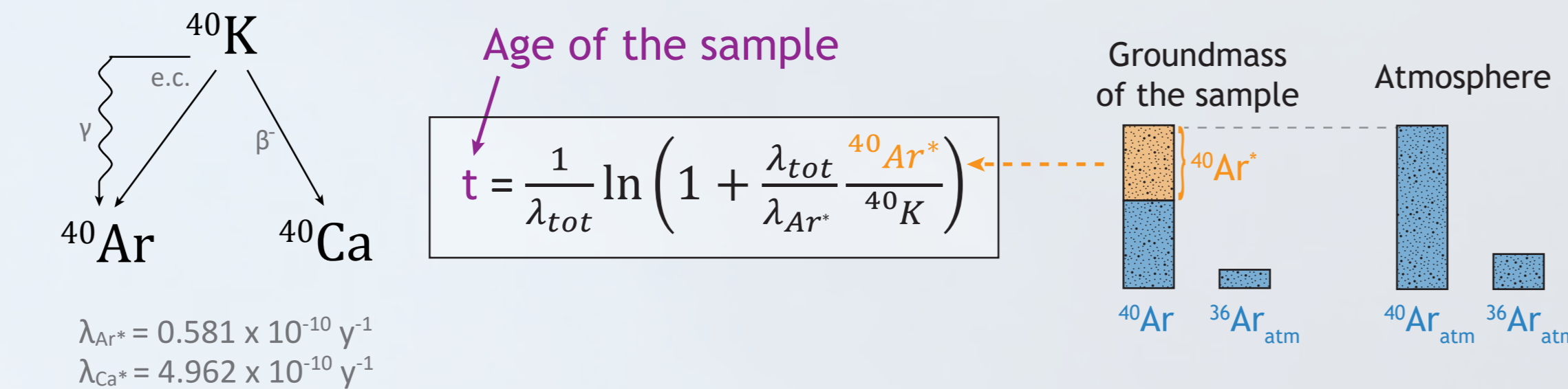
The northern part of the Andean arc presents a very active volcanism since about 2 Ma¹. Our study focuses on the **Tungurahua volcano**, one of the most active edifices of Ecuador. Currently erupting since 1999, it threatened the surrounding villages and infrastructures. The Holocene activity of Tungurahua has been well studied previously, but the older history is poorly documented.

We combined **K-Ar ages**, **geomorphological reconstructions** and **geochemical analyzes** to provide new knowledge on the past activity and the paleomorphology of the volcano, to constrain through time its three construction stages, and to quantify their magmatic productivity and erosion rates.



K-Ar dating

The lava samples were dated with the **K-Ar dating method**, using the unspiked Cassinot-Gillot technique². The Ar* of the sample is measured with a mass spectrometer, and the K with a flame spectrometer. The measurements were carry out on the **groundmass**, in order to avoid inherited argon, which may be present in the phenocrysts.

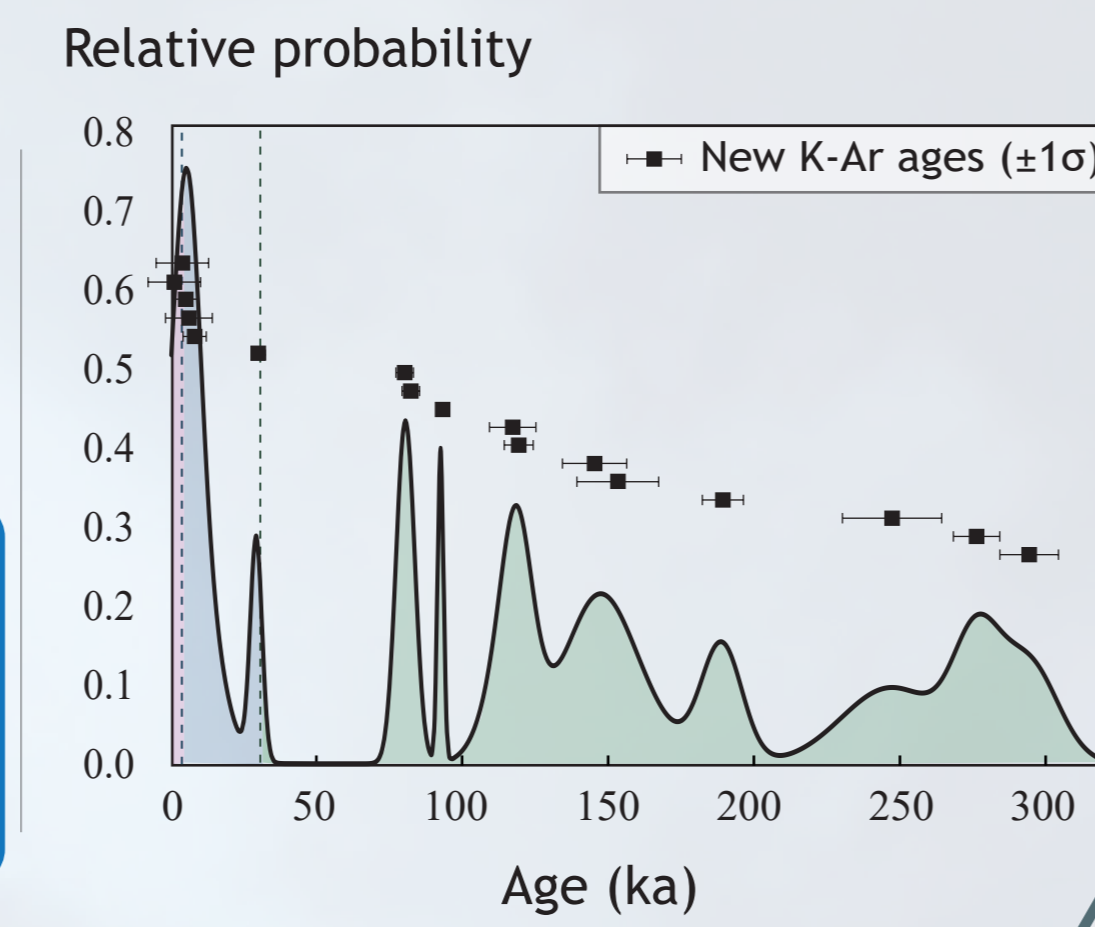


Previous studies :

- 3 edifices: Tungurahua I, II and III³.
- 2 whole-rock ages at 770 ± 50 and 350 ± 40 ka⁴.
- Tungurahua III: < 3 ka BP (¹⁴C)^{3,5}.

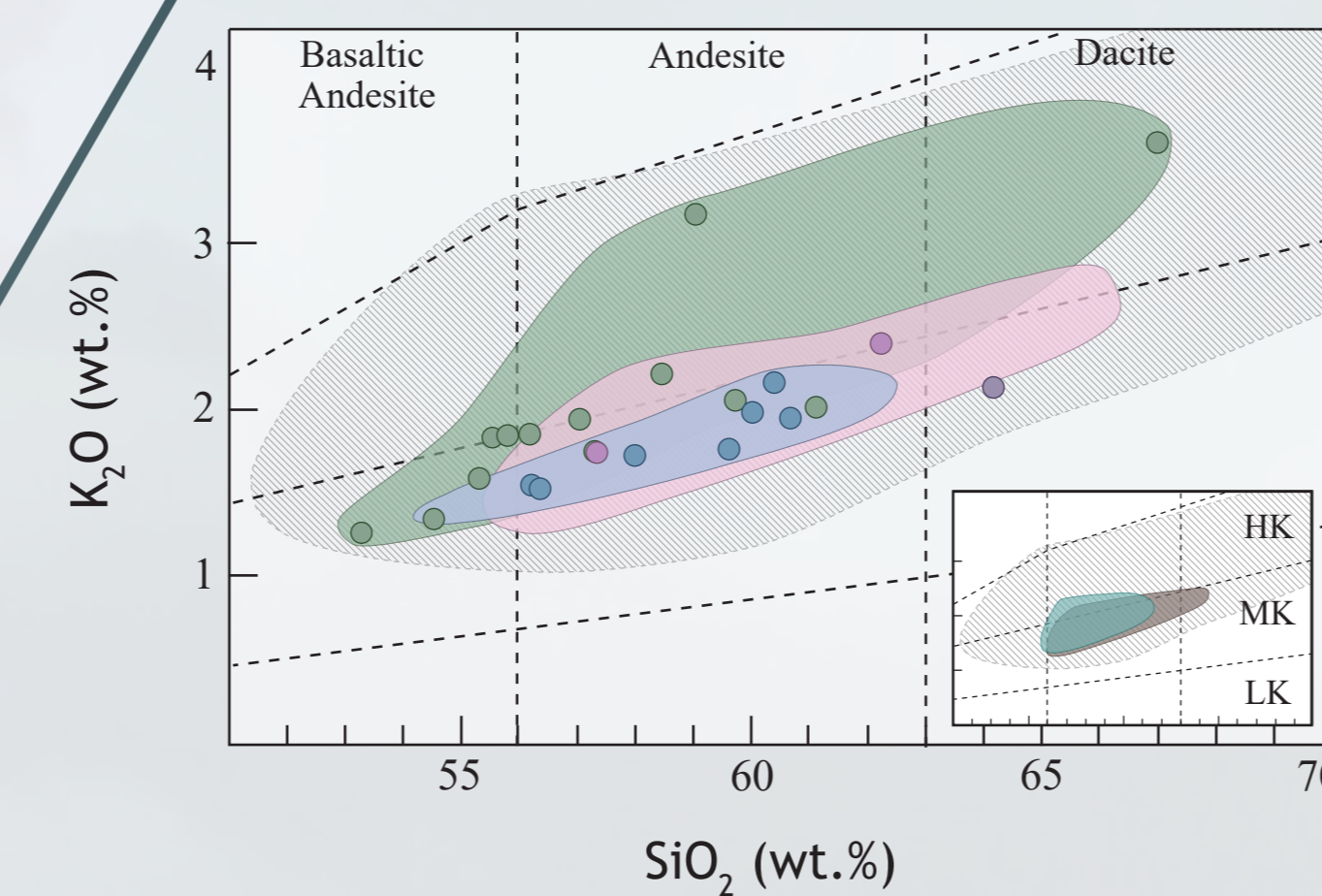
New K-Ar ages on groundmass:

- Tungurahua I: 300-80 ka.
- Tungurahua II: 30-3 ka.
- Gap of activity between 80 and 30 ka.

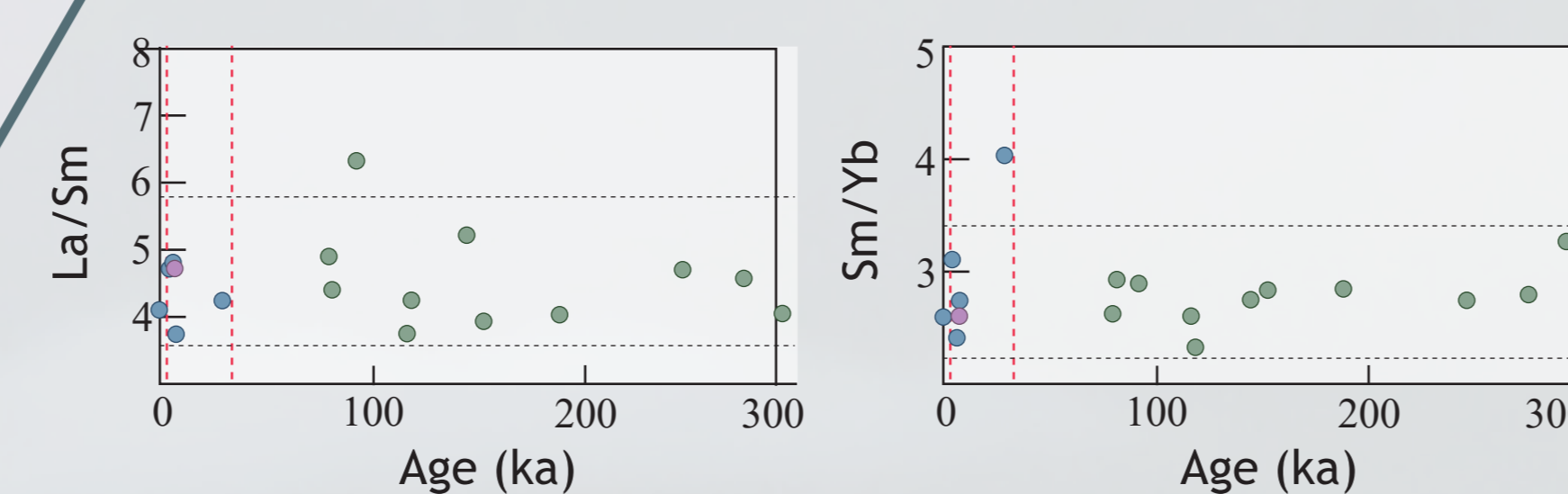


Geochemistry

Major and trace element whole-rock contents of all samples were measured by ICP-AES.

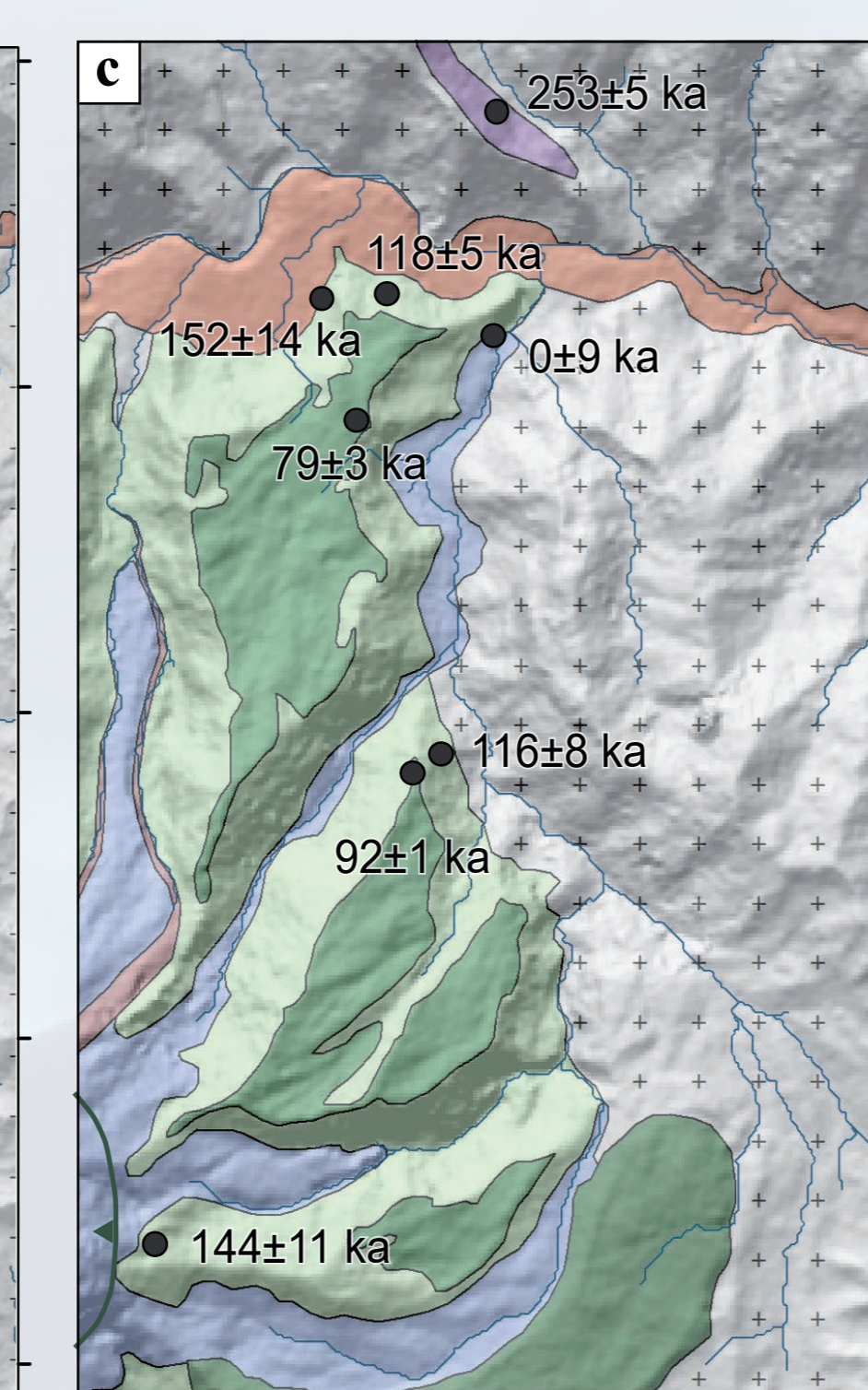
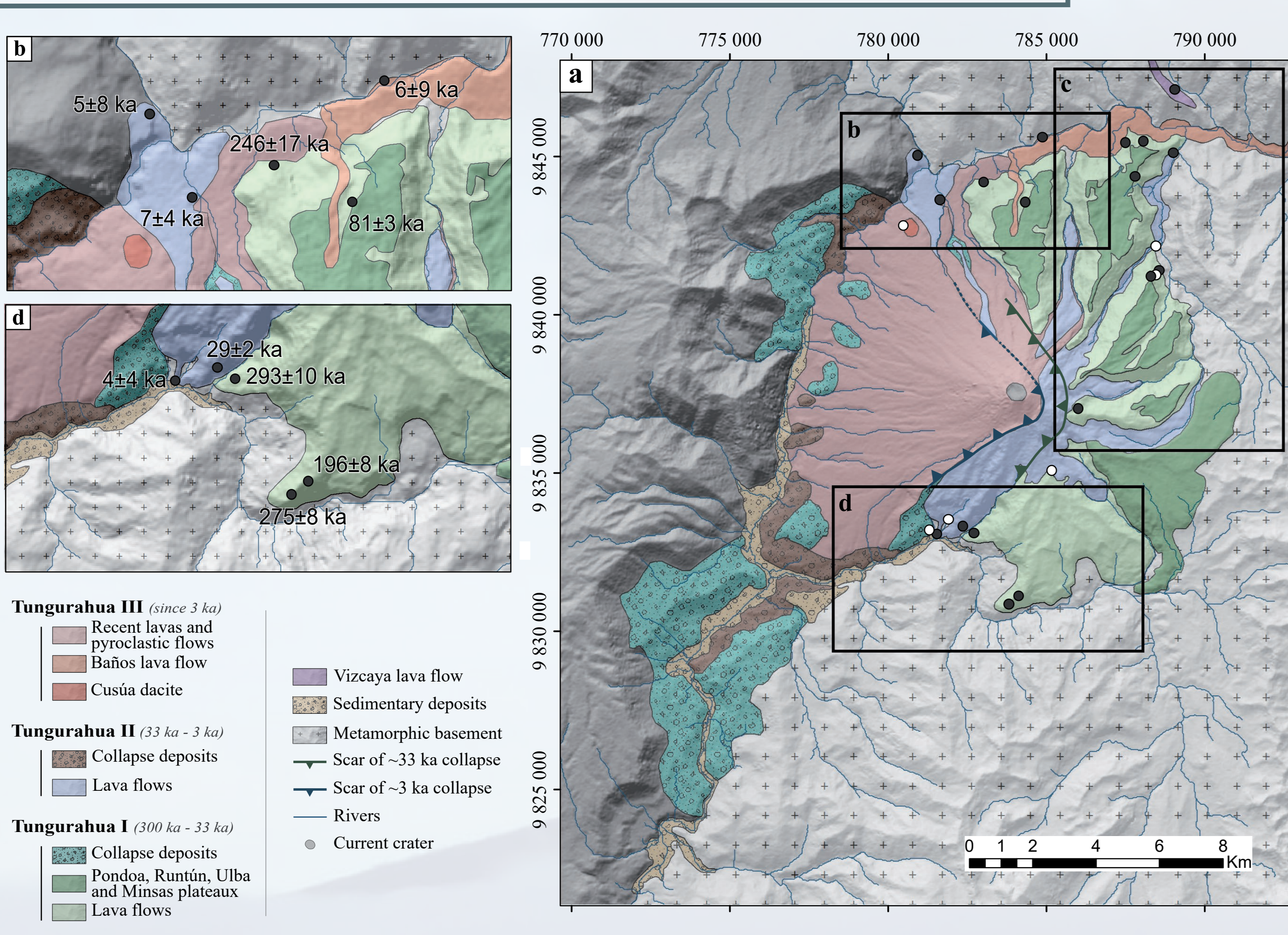
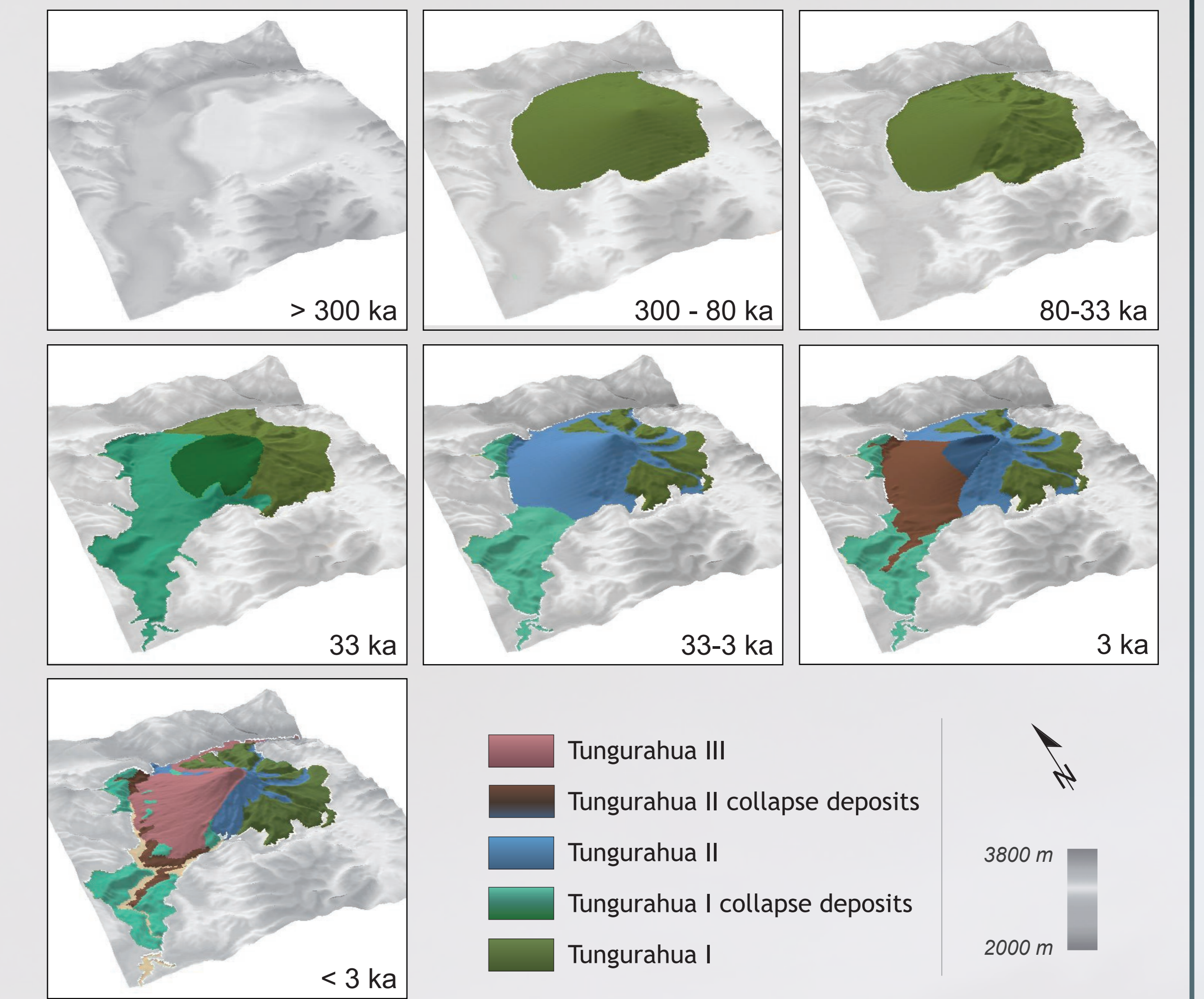
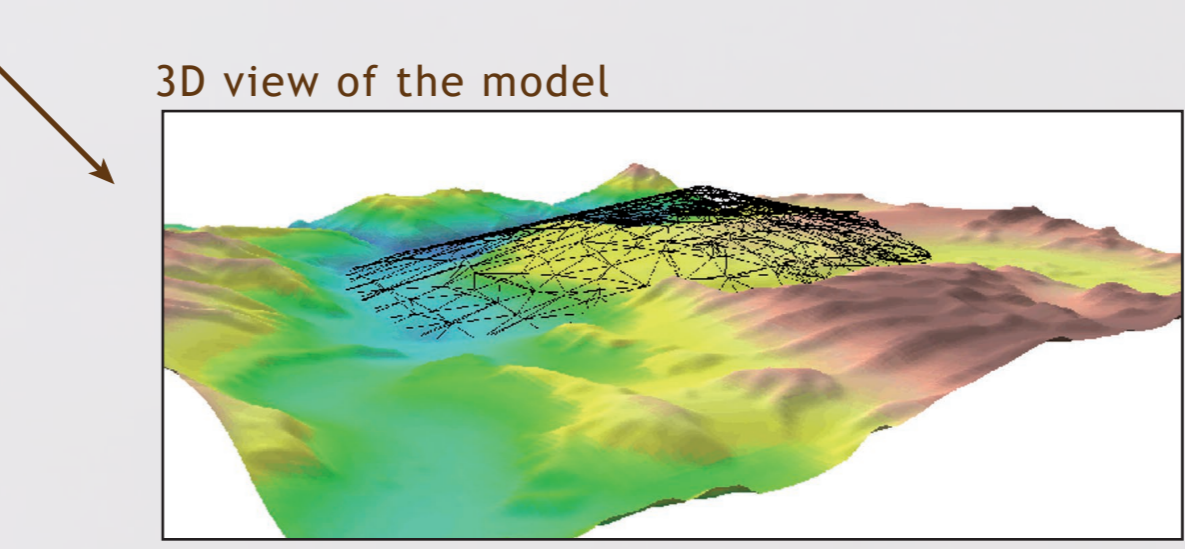
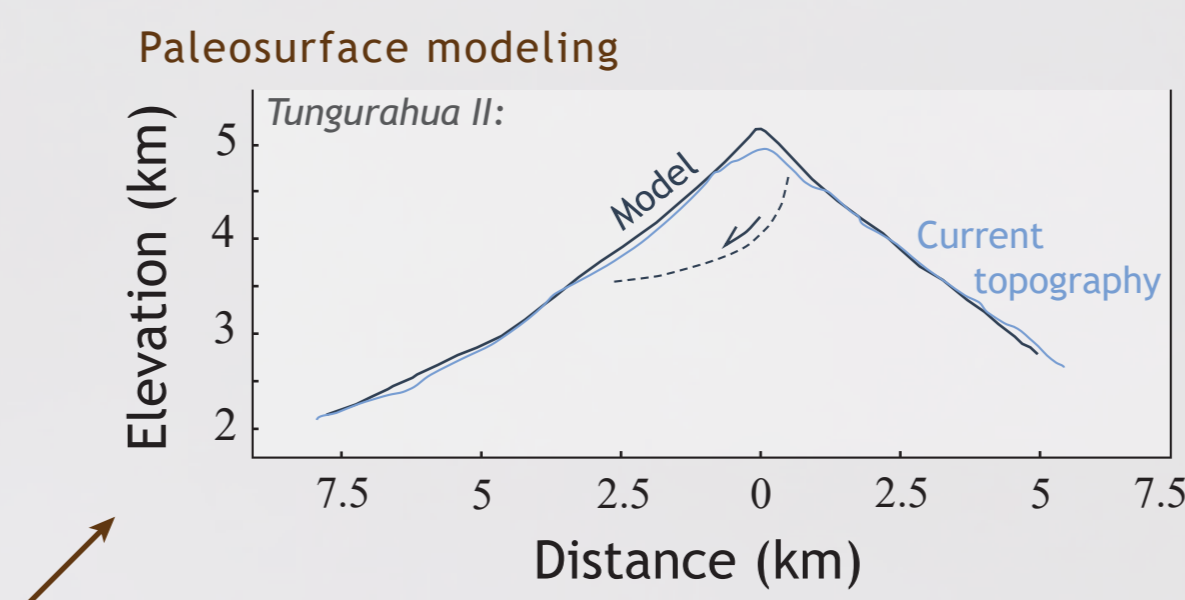
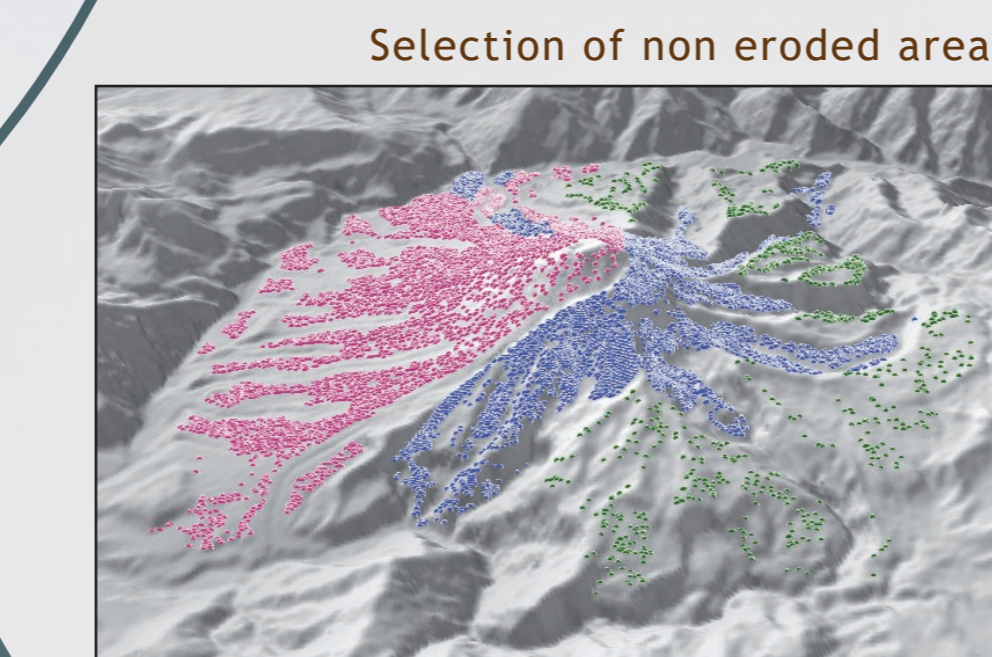


- Typical trends of subduction rocks.
- Composition of the lavas rather **homogeneous** and **not affected** by the collapses.
- **No change** in the deep magmatic source.



Geomorphological reconstructions

Numerical reconstructions of Tungurahua paleotopographies were used to **model the morphology** of the volcano during its main phases of construction, erosion and collapse. The models are constrained from **points selected** from the present day topography, as belonging to **non eroded surfaces**, which are extrapolated in order to obtain a paleosurface. The **volume** constructed or eroded then corresponds to the difference between the upper and the lower surface, over the area of the edifice considered^{7,8}. Together with our new ages, we can calculate the **magmatic productivity** and **erosion rates**.



New geological map based on the new ages and previous studies^{3,6}.

- Eruptive rate of Tungurahua I and II **similar to other Ecuadorian volcanoes**^{9,10}.
- **High eruptive rate** for Tungurahua III: due to the **absence of a large period of quiescence** since the onset of its activity, there is 3 ka.

Tungurahua I: (300 - 30 ka)
V = 56 km³
Eruptive rate = 0.6 km³/ky
Erosion rate = 0.2 km³/ky

Tungurahua II: (30 - 3 ka)
V = 24 km³
Eruptive rate = 0.8 km³/ky

Tungurahua III: (<3 ka)
V = 7 km³
Eruptive rate = 2.5 km³/ky

Conclusions

- **K-Ar dating method** performed on groundmass can be **successfully applied** to volcanoes from the Andean arc.
- Tungurahua I activity is **younger** than expected, based on published whole-rock ages, and began at **300 ka**, whereas Tungurahua II began at **30 ka**.
- The **magmatic productivity rate** is similar to other Ecuadorian volcanoes except for Tungurahua III, which is growing since 3 ka and **did not experience period of quiescence**.
- The magma composition is rather **homogeneous** for the three edifices, and is not affected by the collapses or by changes in the deep magma source.

References :

¹Hall et al. (2008), Journal of Volcanology and Geothermal Research, vol.176, 1-6.
²Gillot et al. (2006), Acta Vulcanologica, vol.18, 55-66.
³Hall et al. (1999), Journal of Volcanology and Geothermal Research, vol.91, 1-21.
⁴Barberi et al. (1988), Geochemical Magazine, vol.123, 1-14.
⁵Le Pennec et al. (2013), Radiocarbon, vol.55, 1199-1214.
⁶Bustillos (2008), Las avalanchas de escombros en el sector del volcán Tungurahua (MSC, EPN-Quito).
⁷Lahitte et al. (2012), Geomorphology, vol.136, 148-164.
⁸Germa et al. (2015), Journal of Geophysical Research: Earth Surface, vol.120, 1206-1226.
⁹Samaniego et al. (2012), Journal of Volcanology and Geothermal Research, vol.221-222, 33-51.
¹⁰Robin et al. (2010), Bulletin of Volcanology, vol.72, 1109-1129.