Poster # EGU2020-3306
EGU General Assembly 2020, 3 – 8 May 2020, Vienna, Austria

TS.14.2 - Multi-disciplinary & multi-scale approaches to investigating tectonic and geodynamic events in Earth history

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

PALEOC4 PERMO-TRIASSIC CLIMATE CHANGE & CARBON CYCLE

888 – 444 Ma global plate tectonic reconstruction with emphasis on the formation of Gondwana

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Abstract

The formation of Gondwana results from a complex history, which can be linked to many orogenic sutures. Those sutures have often been gathered in the literature under broad orogenies — in particular the Eastern and Western Pan-African Orogenies — although their ages may vary a lot within those wide belts.
The PANALESIS model is a plate tectonic model, which aims at reconstructing 100% of the Earth's surface, and proposes a geologically, geometrically, kinematically, and geodynamically coherent solution for the evolution of the Earth from 888 Ma to 444 Ma. Although the model confirms that the assembly of Gondwana can be considered complete after the Damara and Kuunga orogenies, it shows above all that the detachment and amalgamation of "terranes" is a roughly continuous process, which even persisted after the Early Cambrian.
By using the wealth of Plate Tectonics, the PANALESIS model makes it possible to derive numerous additional data and maps, such as the age of the sea-floor everywhere on the planet at every time slices, for instance. The evolution of accretion rates at mid-oceanic ridges and subduction rates at trenches are shown here, and yields results consistent with previous estimates. Understanding the variation of the global tectonic activity of our planet through time is key to link plate tectonic modelling with other disciplines of Earth sciences.

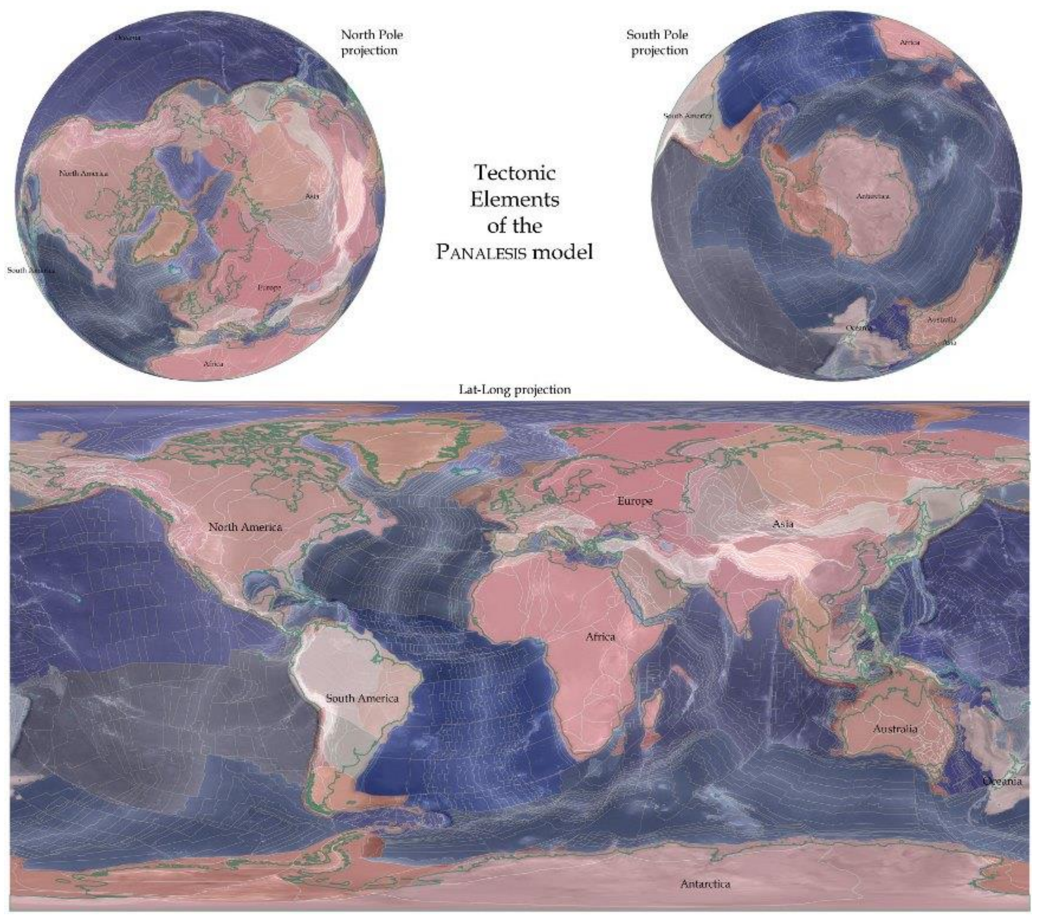


Figure.1 — 'Tectonic elements' ('TEs') of the PANALESIS model.

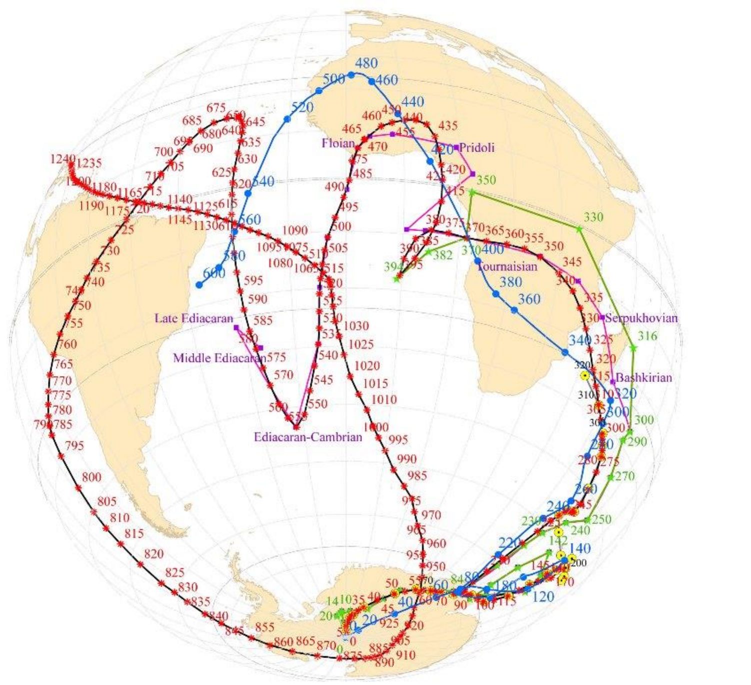


Figure.2 — Apparent polar wander (APW) path for central Africa (Congo TE) after the PANALESIS model (black curve with red stars). Also shown for comparison, the APW paths after Scotese & Elling (2017; blue line and dots), after Hochard (2008; purple line and squares), after Stampfli et al. (2013; green line and stars), after Torsvik et al. (2012; grey line and yellow circles).
Orthogonal projection centered at 010°W/30°S.

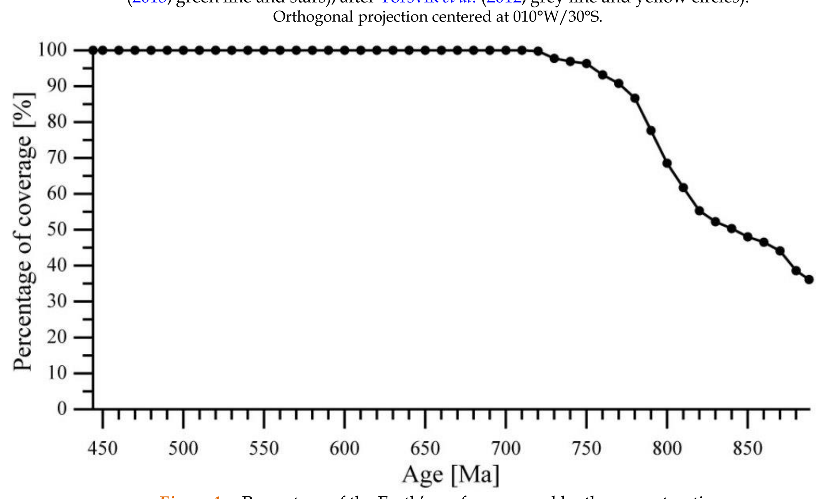


Figure.4 — Percentage of the Earth's surface covered by the reconstructions.

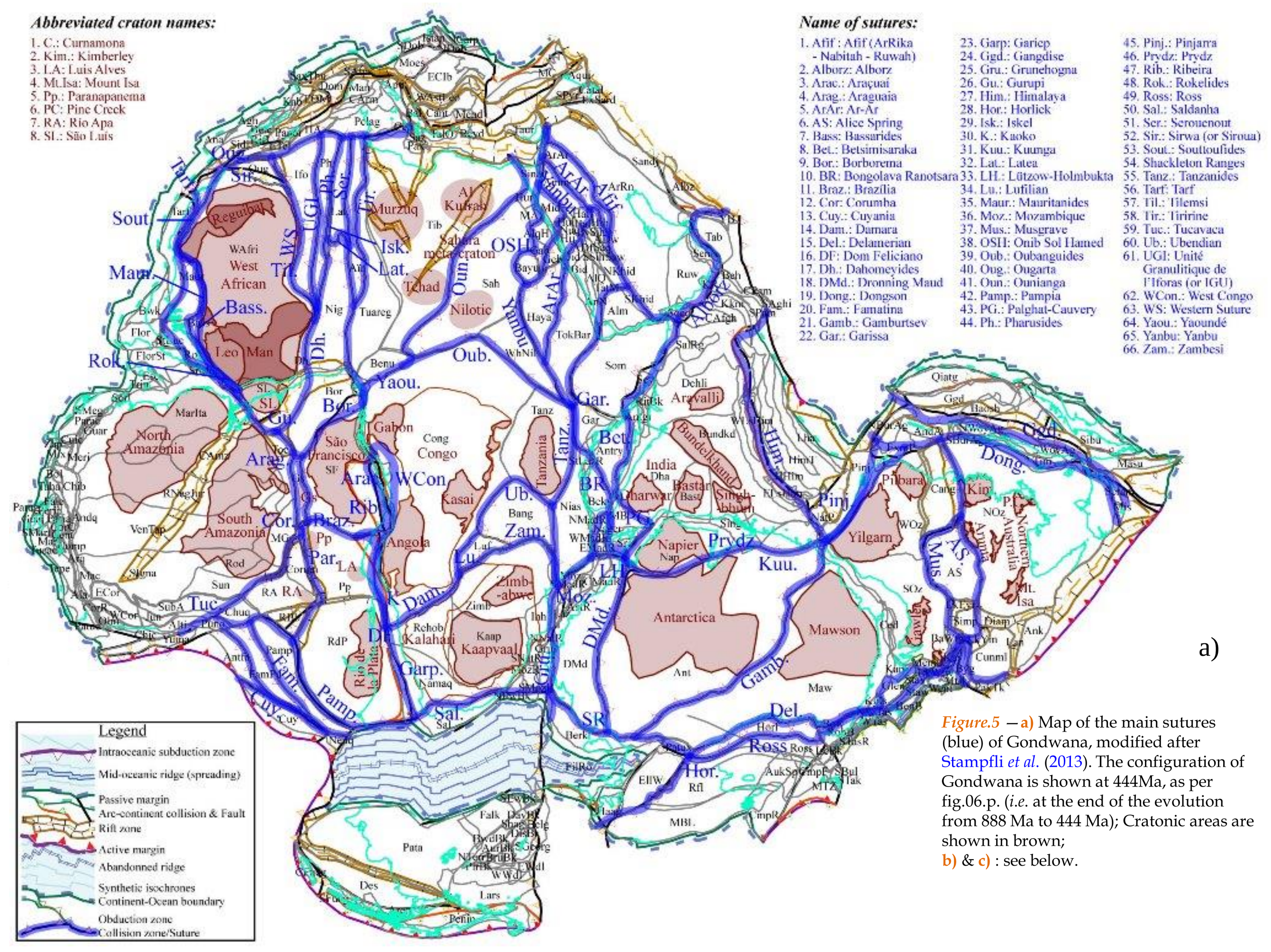


Figure.5 — a) Map of the main sutures (blue) of Gondwana, modified after Stampfli et al. (2013). The configuration of Gondwana is shown at 444Ma, as per fig.06.p. (i.e. at the end of the evolution from 888 Ma to 444 Ma); Cratonic areas are shown in brown;
b) & c) : see below.

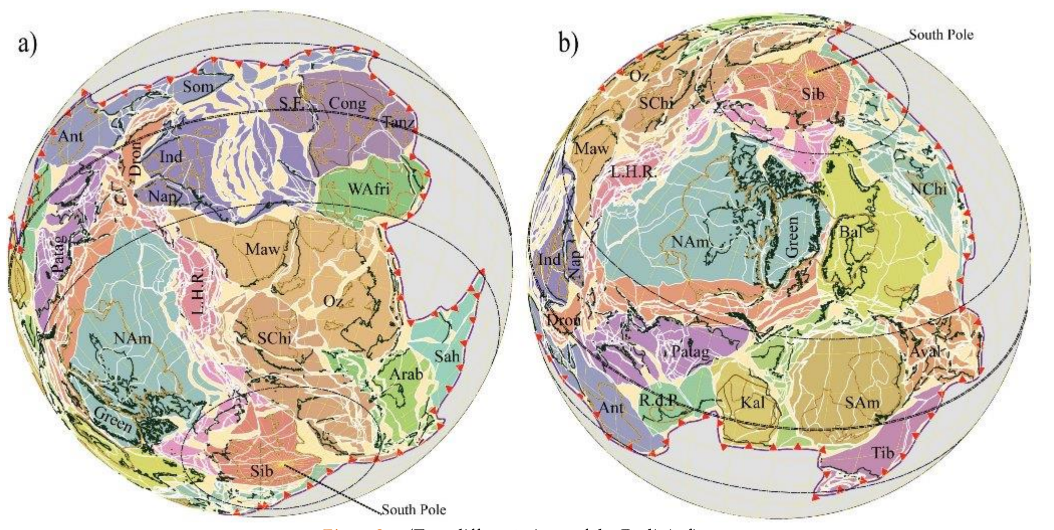
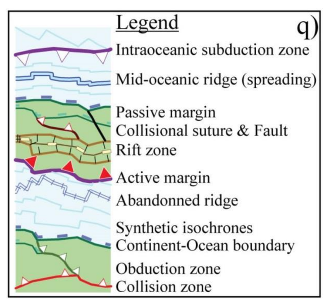


Figure.3 — 'Two different views of the Rodinia fit.
Coulours are random and merely highlight different domains discussed in the text (Ant: Antarctica; NAm; North America; SAm: South America; WAfri; West Africa; Cong: Congo/Central Africa; Arab: Arabia; Oz: Australia; Bal: Baltica; NChi: North China; SChi: South China; Dron: Dronning Maud; Green: Greenland; Ind: India; Kal: Kalahari; LHR: Lord Howe Rise; Maw: Mawson; Nap: Napier; Patag: Patagonia; RdP: Río de la Plata; SF: São Fancisco; Sah: Sahara; Sib: Siberia; Som: Somalia; Tanz: Tanzania; Tib: Tibesti).



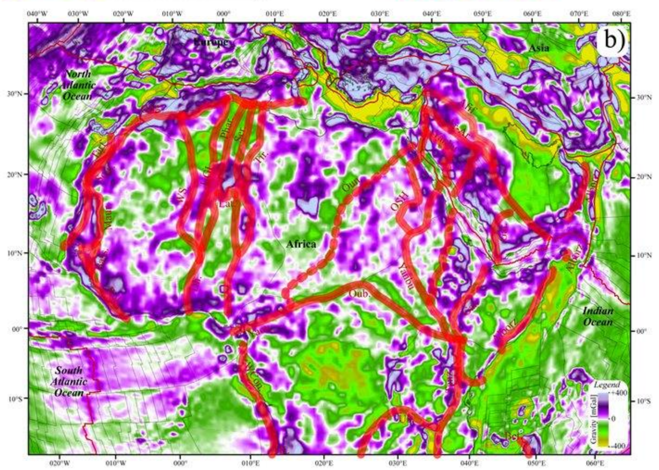


Figure.5 — b) Sutures(red lines) in the Africa – Arabia area associated with the formation of Gondwana superimposed onto the gravity map (Tapley et al., 2005), used in particular for the determination of the Ounianga suture (dashed red line).

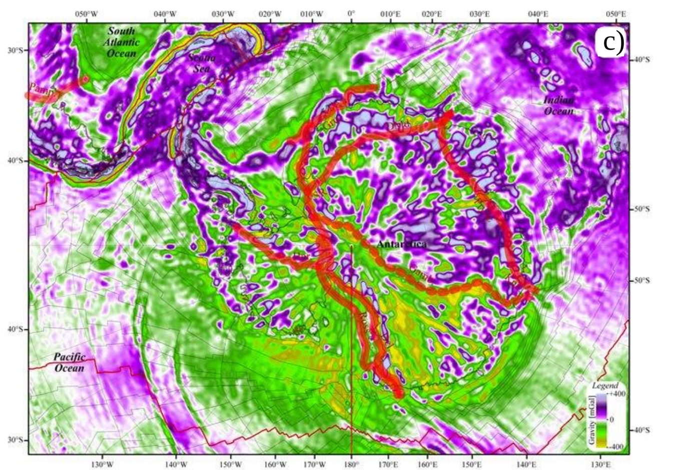


Figure.5 — c) Sutures(red lines) in the Antarctica area associated with the formation of Gondwana superimposed onto the gravity map (Tapley et al., 2005), used in particular for the determination of the Gamburtsev suture (dashed red line).

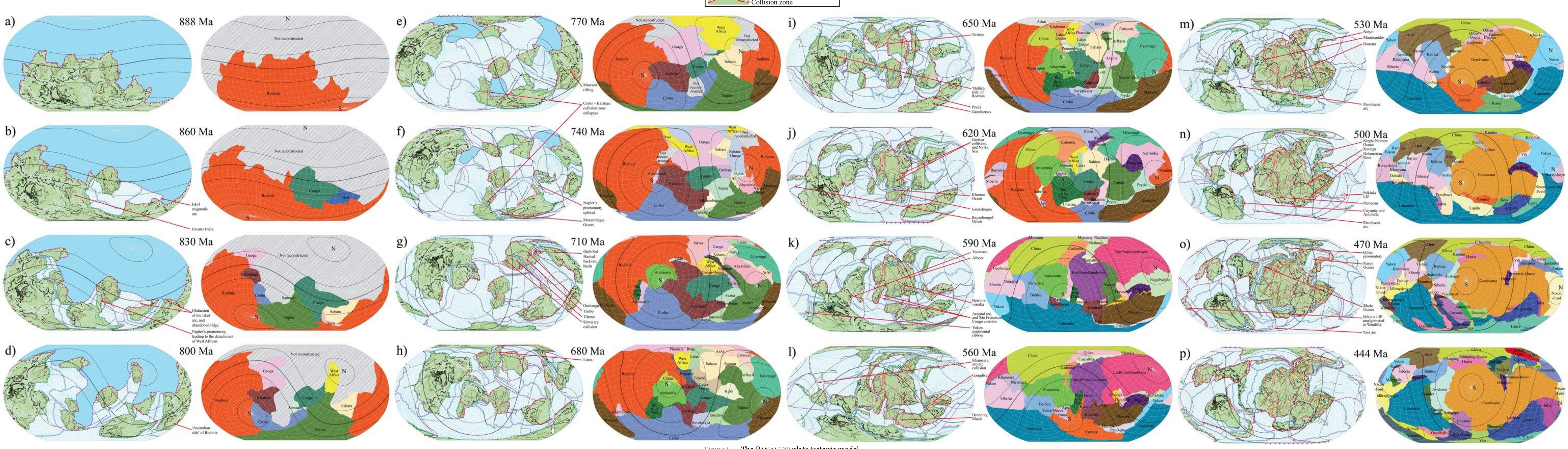


Figure.6 — The PANALESIS plate tectonic model.
left: reconstruction maps (see legend in fig.6.q); right: tectonic plates (random colours).

Because the PANALESIS plate tectonic model reconstructs 100% of the Earth's surface (but see Fig.4), it means that not only continental areas but also oceanic realms are reconstructed. It implies it is possible to compute many derivative maps and data (e.g. Vérard et al., 2015.a, -.b; Vérard, 2019.a, -.b). For example, it is possible to compute the age of the sea-floor at every time slice at any point of the entire planet. One example of such map is shown here for the reconstruction at 444 Ma (Fig.7.a).
Given the sea-floor age distribution (Fig.7.b) for this map, the mean age (and associated two-sigma uncertainty, $\mu \pm 2\sigma$) of 466.6 ± 41.7 Ma has probably little meaning (skewness γs = 2.497; kurtosis γk = 10.056; normal distribution shown in blue for comparison). Although more statistical analysis should be done to properly characterize this Poisson-like distribution, it seems to be more appropriate to consider, to first order, the median value (and associated absolute median deviation, $m \pm \varepsilon_{am}$) of 460.9 ± 10.5 Ma. Such kind of consideration is true for all reconstructions, so that the absolute values given for the mean ocean age over time (Vérard et al., 2015.a, -.b) must be considered with caution, although the general trend is certainly more robust

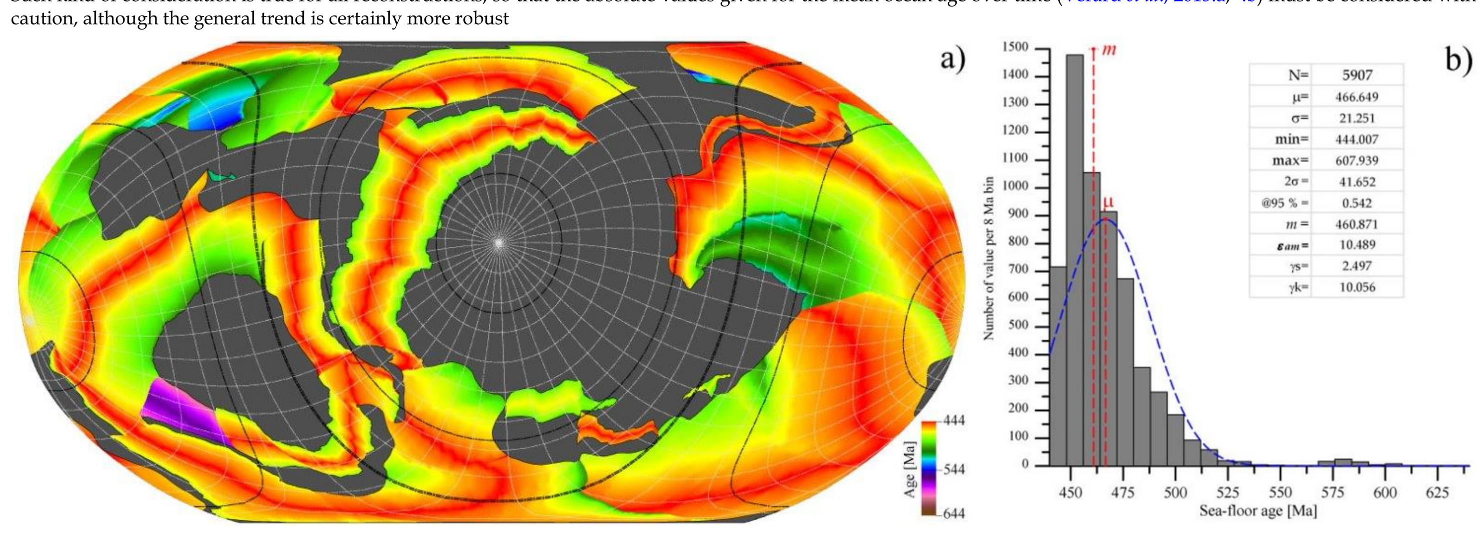


Figure.7 — Sea-floor age for the reconstruction at 444 Ma; a) Color-coded global map (continental area in grey); b) Age distribution and statistics (see text).

Poster derived from the submitted paper:

Vérard C. (2020). 888 – 444 Ma global plate tectonic reconstruction with emphasis on the formation of Gondwana. Tectonophysics, *submitted*.

Vérard et al. (2015.a) have proposed a "combined tectonic rate" — or "tectonic activity" (TA) index (Vérard & Veizer, 2019) — derived from the UNIL plate tectonic model throughout the Phanerozoic. It is indeed considered that the mean global tectonic activity of the planet is primarily reflected by the mean value, in km²/yr, between the accretion rates and subduction rates.
It is reassuring to note that the curves (black: PANALESIS *versus* grey: UNIL ; Fig.8) are relatively similar over the period in which they overlap, even though the values from the PANALESIS model are slightly higher. It implies that the increase in TA index from 888 Ma to 444 Ma (black curve in Fig.8) is most likely apparent. Ignoring values from 888 Ma to ca. 750 Ma (dashed black curve in Fig.8) for which plate tectonic coverage in significantly inferior to 100%, therefore, the general trend of the plate tectonic activity of our planet is decreasing, in agreement with general cooling of the Earth (Vérard et al., 2015.a, -.b; see also Vérard & Veizer, 2019).

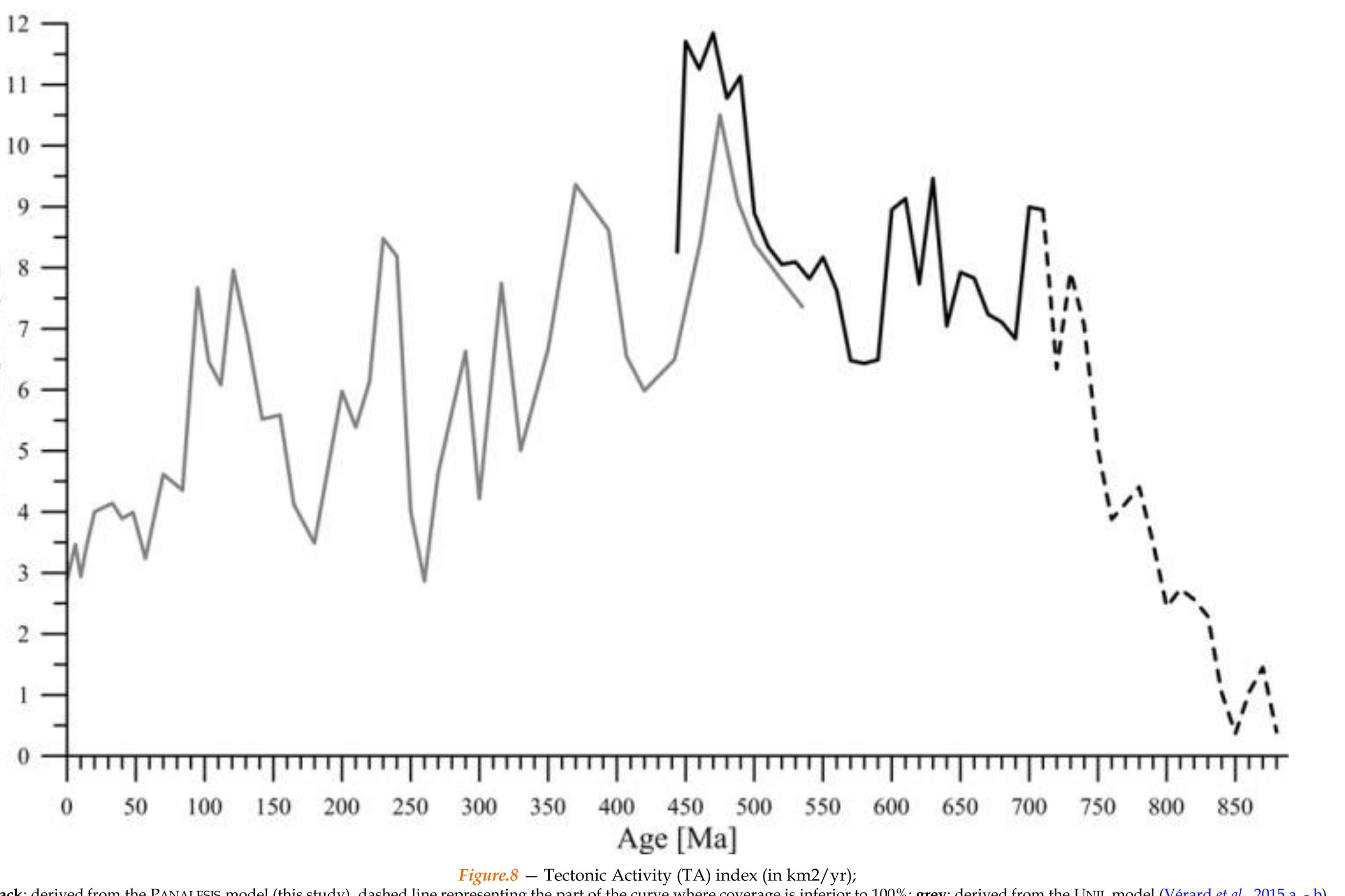


Figure.8 — Tectonic Activity (TA) index (in km2/yr);
black: derived from the PANALESIS model (this study), dashed line representing the part of the curve where coverage is inferior to 100%; **grey**: derived from the UNIL model (Vérard et al., 2015.a, -.b).

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