Subduction obliquity as a prime indicator for the geotherm in subduction zones

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Introduction

Subduction zones represent today 55 00 km of converging plate boundary on Earth. They are associated with arc magmatism and seismic activity in response to their thermal structures. The geotherm of a subduction zone is thought to vary as a function of subduction rate and the age of the subducting lithosphere [1]. Along a single subduction the rate of burial can strongly vary due to changes in the angle between the trench and the plate convergence vector, *i.e* the subduction obliquity.

Numerous studies have been conducted on the effect of temperature and its link with seismicity, fluid release, coupling of the interface, and melting using 2D high resolution models [2, 3, 4]. In contrast, no study investigated the effect of obliquity on the geotherm of subduction zone despite the preponderance of oblique subduction trenches on Earth (Fig 3) and their possible expression in the geological records of Turkey [5].

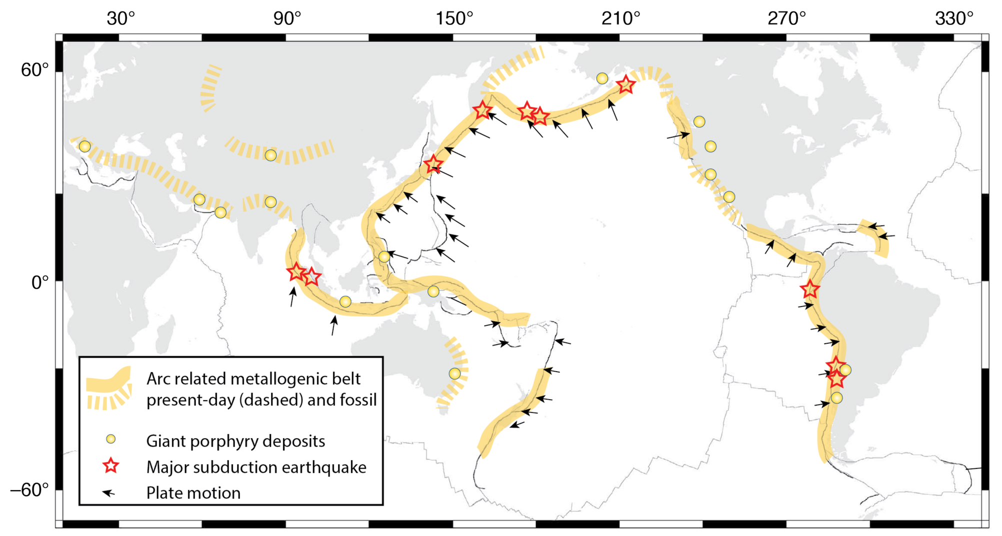

Figure 3: Plate motion at trenches. Modified from [6, 7]

Setup and strategy

- Finite element model computed with ELEFANT [8]
- 3 km spatial resolution
- Trench geometry described by arctangent function
- Velocity (4 cm/yr) prescribed with a analytical "corner flow" solution in 2D [9]
- Temperature profile of a *ca.* 70 My old oceanic lithosphere
- Computed to steady state (*i.e* 10 My; Fig. 2)

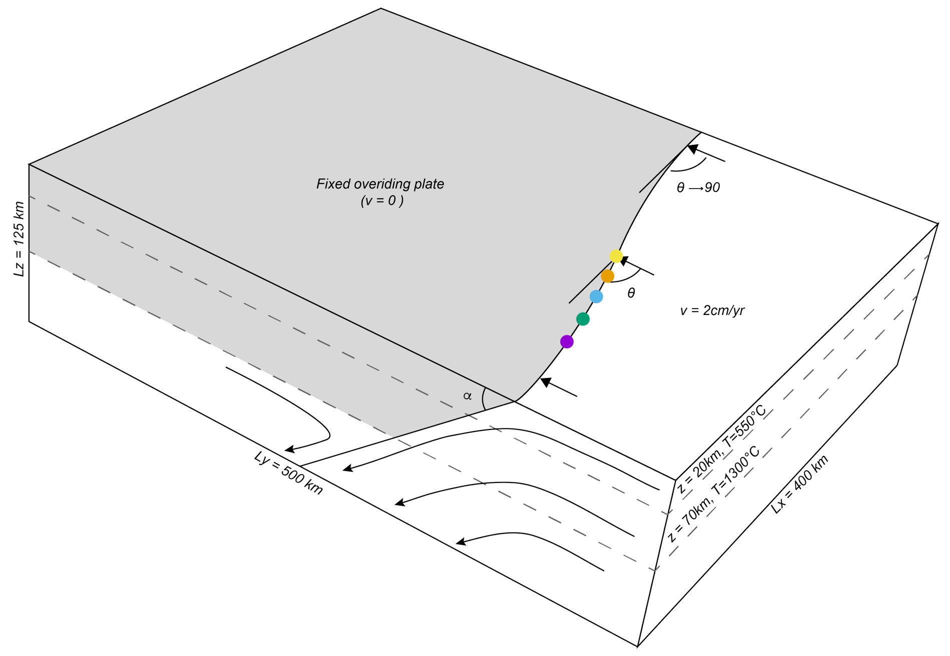

Figure 1: Setup of the numerical model with location of PT path (Fig. 4)

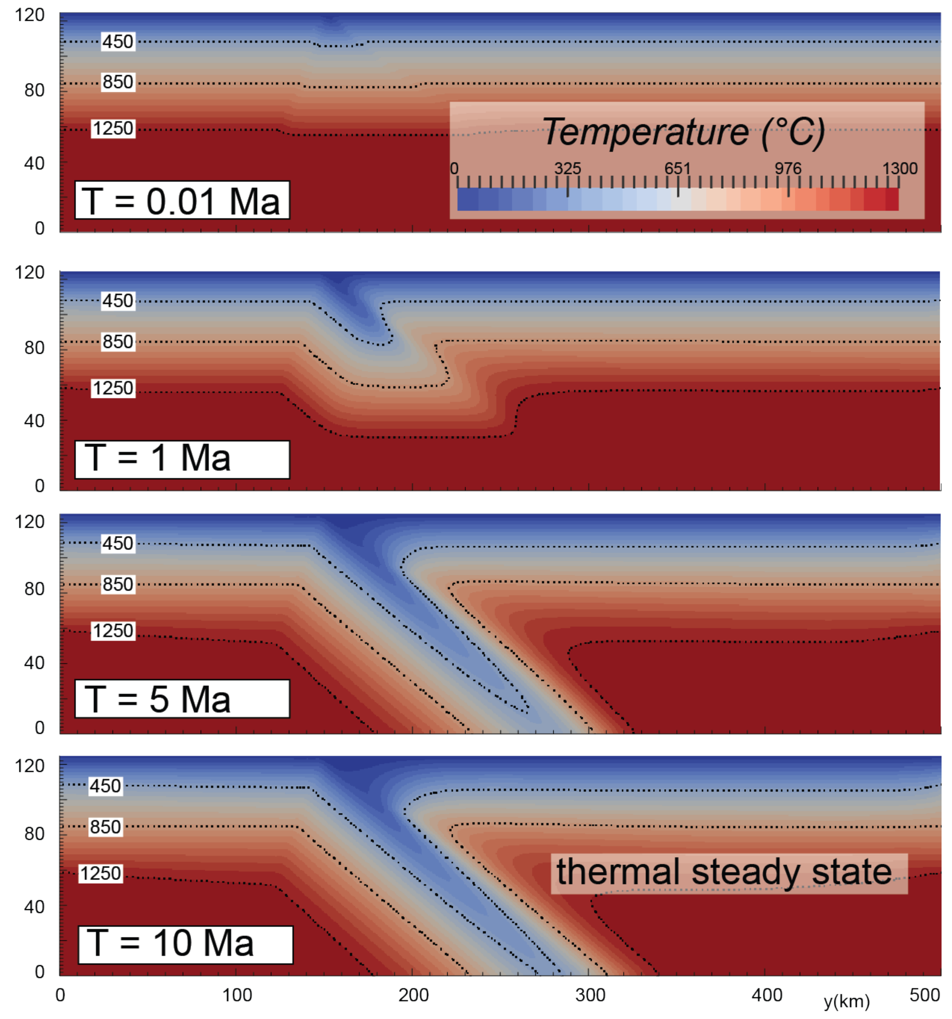

Figure 2: Thermal evolution to steady state for the side of the model. After 10 Ma of computation only the diffusion term is effective and thermal steady state can be considered.

The energy equation $\left\{ \rho C_p \left(\frac{\partial T}{\partial t} + \mathbf{v} \cdot \nabla T \right) = \nabla \cdot (k \nabla T) \right\}$ is solved in 3D allowing a systematic parametric study and to constrain first order effects of obliquity on the thermal behaviour of the subduction zone. We first investigate the geometry of the trench (Fig. 4), then the velocity and the dip of the slab.

Significance for subduction zones

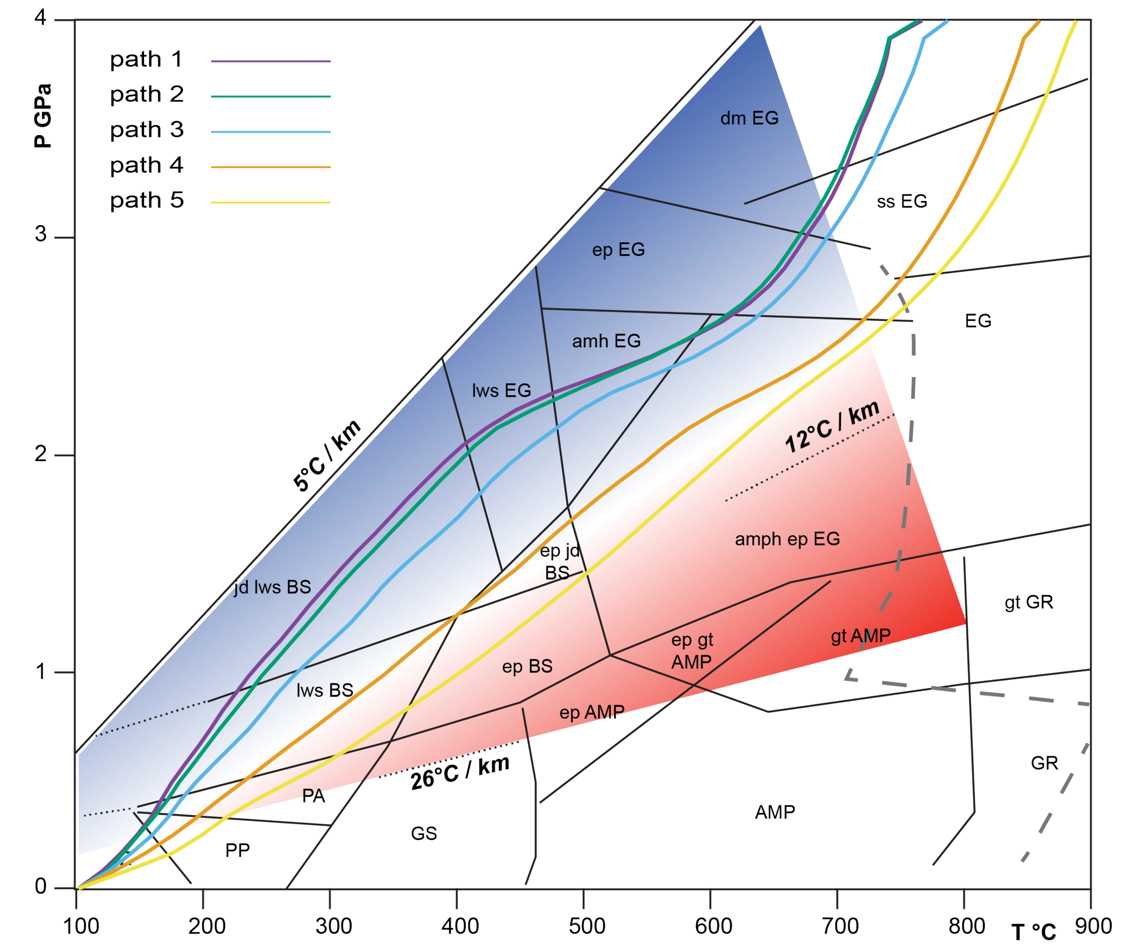

Figure 5: PT path of the model 75-7 (highly oblique) plotted on a phase diagram for a MORB composition after [10].

The temperature in the model can be very different (with geotherm from 5 to 12°C/km) according to the prescribed geometry, with $\Delta T = 200°C$ at 30 km depth (Fig. 5). It seems critical for segmented slab systems (Fig. 4, model M_M-75-7). Such configurations might represent the nascent period of subduction zone. These important effect might also be linked to the differences of magmatism (and amount of partial melting in the mantle wedge) along trenches, for example in south America. The effect of obliquity is more important than previously appreciated as showed by our first order models. Tests performed with different velocity and/or slab dip show similar effects.

Future work:

- Test with different dip along the subduction zone
- More complex material (*i.e* crust and mantle)
- Real geometry (South America or Marianna)
- Non-linear rheologies
- Link with mantle tomography and implication for segmented slabs
- Continental subduction

Next we will perform calculation with **velocity computed in 3D** to consider **lateral** advection of heat through **toroidal flow**. It appears that obliquity has an effect inducing **asymmetric mantle wedge flow** [11] also inducing differences in the temperature predicted either at the subduction interface, in the subducting slab or in the overriding plate

Results

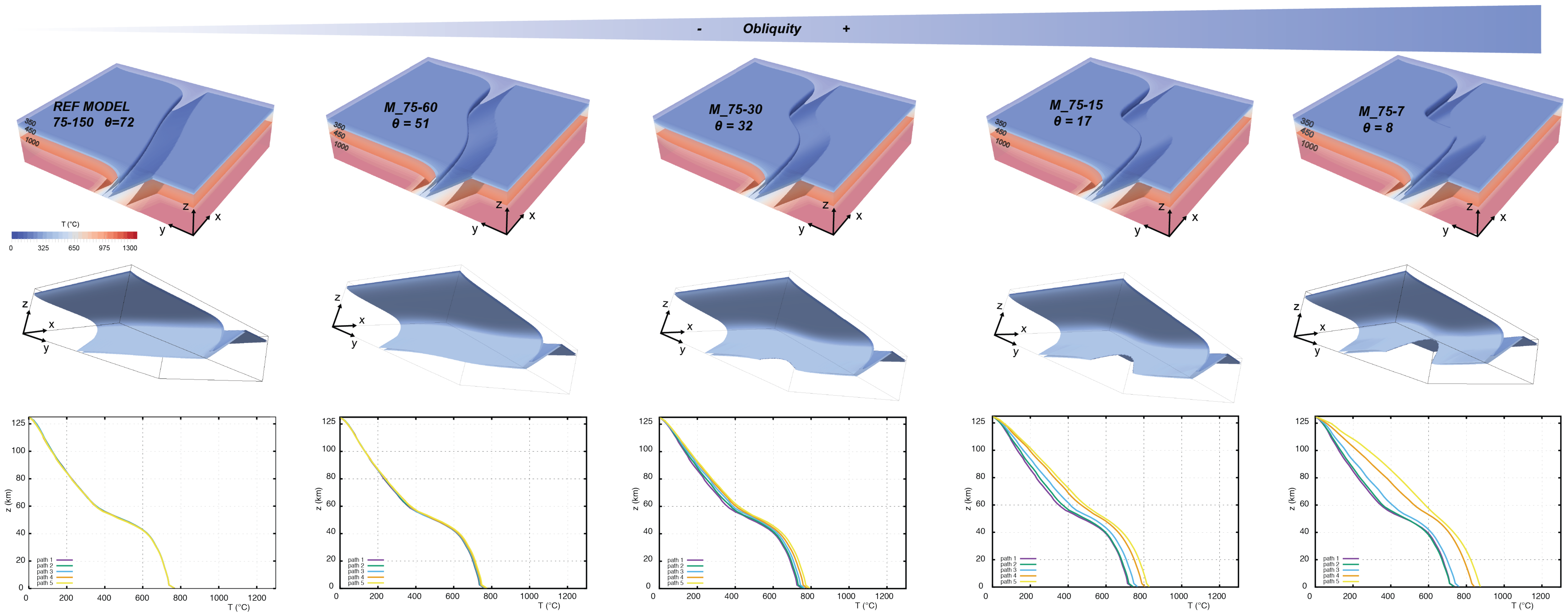

Figure 4: Panel top: top view of the model, evolution of the thermal regime with increasing obliquity. Middle panel: bottom view of the 450°C isotherm. Bottom panel: PT path at the subduction interface as a function of the obliquity. Location of each PT path is indicated on Fig. 1.

Acknowledgements & references

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