Subduction obliquity as a prime indicator for geotherm in subduction zone

Alexis Plunder, Cédric Thieulot and Douwe van Hinsbergen
Utrecht University, Department of Earth Sciences

Introduction

Subduction zone represent today 55 00 km of converging plate boundary on Earth. They are associated with arc magmatism and seismic activities in response with 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, namely the subduction obliquity. Numerous studies have been conducted on the effect of temperature and its link with seismicity, fluid release, coupling of the interface, 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 1) and their possible expression in the geological records of Turkey [5].

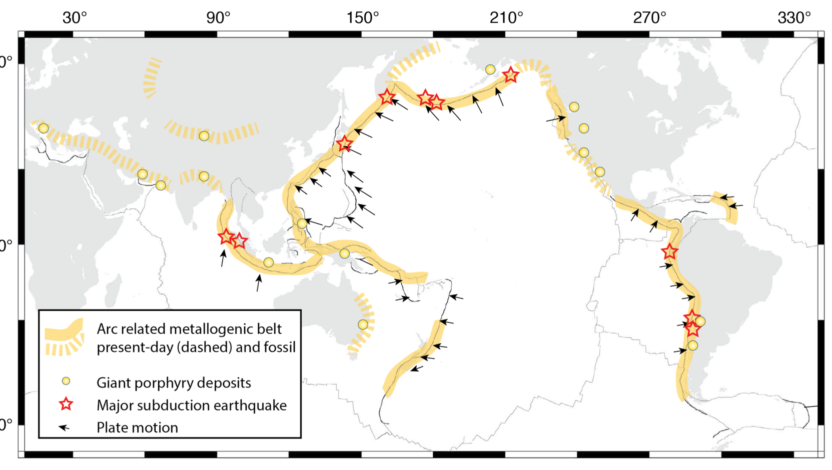

Figure 1: Plate motion at trenches. Modified from [6, 7]

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 lithosphere
- Computed to steady state (*i.e* 10 My; Fig. 3)

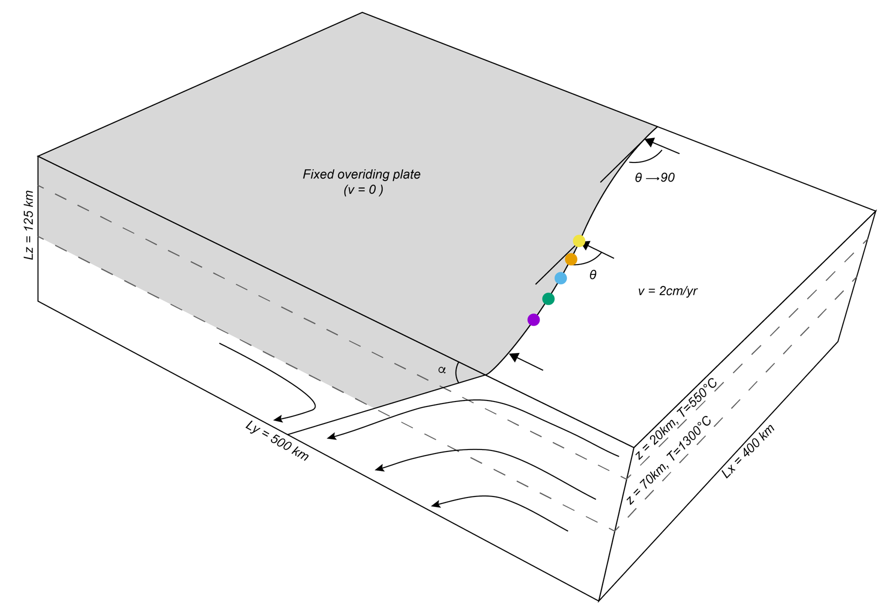

Figure 2: Setup of the numerical model

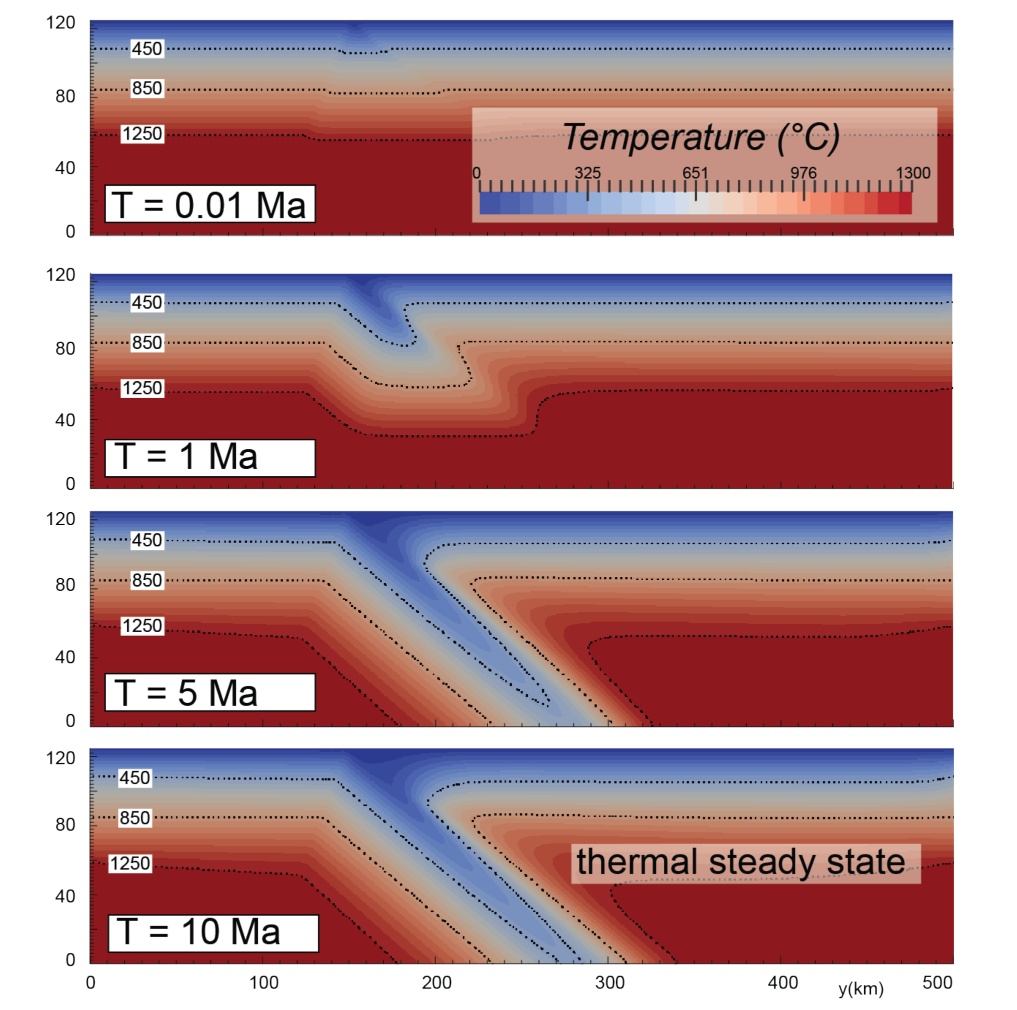

Figure 3: Thermal evolution to steady state for the side of the model. After 10 Ma of computation only the diffusion term is effective and thermal steady state can be considered.

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

Results

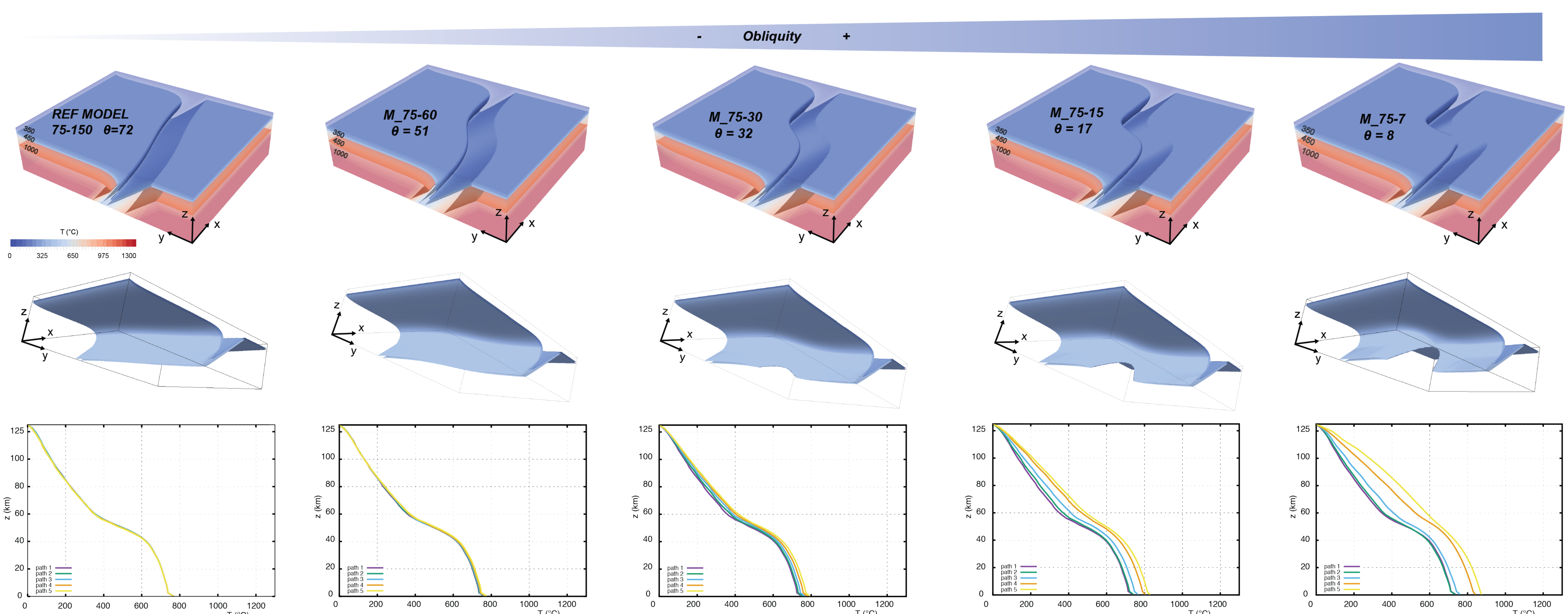

Figure 4: Evolution of the thermal regime with increasing obliquity. Top view of the model. Bottom view of the 450°C isotherm. PT path at the subduction interface as a function of the obliquity. Location of each PT path is indicated on Fig. 2.

Significance for subduction zones and future research

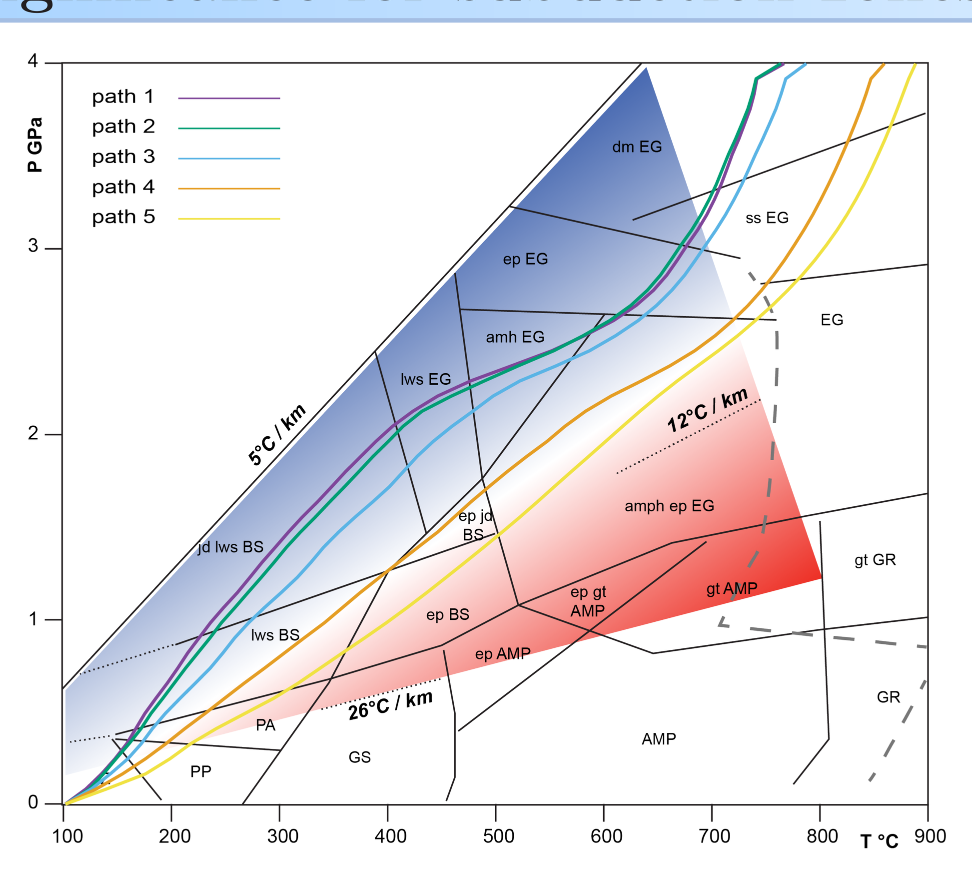

Figure 5: PT path of the model 75-7 (highly oblique) plotted on a phase diagram for a MORB composition after [10].

The thermal regime 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 that admitted 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

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

Contact Information

Email a.v.plunder@uu.nl
Address Dept. of Earth sciences. Heidelberglaan 2, 3584CS Utrecht, The Netherlands

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