Influence of the thermal state of the overriding plate on the slab dip.

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RIASSUNTO

Influenza dello stato termico della placca superiore sull'angolo di subduzione

Al fine di valutare l'influenza operata dalla variazione dello stato termico della placca superiore sull'angolo di subduzione in un sistema convergente oceano-continente, si è sviluppato un codice termo-meccanico 2D agli elementi finiti. Lo stato termico della litosfera è stato espresso in termini di profondità variabile dell'isoterma 1600 K. Per 4 differenti spessori della litosfera oceanica (60 km, 80 km, 95 km e 110 km) si sono considerate 5 possibili variazioni della litosfera continentale (100%, 120%, 140%, 160% e 200% dello spessore della litosfera oceanica). I risultati mostrano come vi sia una elevata variabilità deli profili della placca in subduzione al variare dello spessore della litosfera continentale, in particolar modo per spessori della placca subdotta compresi tra 60 km e 80 km. Tale variabilità tende ad esaurirsi per elevati spessori di litosfera oceanica (95 km e 110 km). L'angolo dello slab è fortemente influenzato dallo stato termico della litosfera continentale e, in particolare, esso diminuisce all'aumentare dello spessore della placca superiore. Un buon accordo è stato riscontrato tra i risultati del modello numerico e i dati naturali ottenuti per un elevato numero di subduzioni attuali, confermando l'elevate influenza dello spessore della litosfera continentale sull'angolo di subduzione. Sebbene ulteriori prove siano necessarie per ottenere una significativa correlazione incrociata tra i vari parametri che identificano il sistema, questi risultati preliminari evidenziano l'elevato impatto dello stato termico della placca superiore nei confronti della geometria della subduzione.

Key words*: Lithospheric thermal model, Numerical models, Slab dip, Subduction zones).*

INTRODUCTION

In the recent years several statistical analysis of subduction zones pointed out that a direct correlation between the slab dip and the age of the oceanic lithosphere does not exist (e.g. JARRARD *et alii,* 2005). and other parameters may have much more impact on slab dip variation such as: (1) back-arc stress variation; (2) absolute motion of the overriding plate; (3) convergence rate; (4) nature of the overriding plate (oceanic or continental) (CRUCIANI *et alii,* 2005; LALLEMAND *et alii,* 2005). Nevertheless, although the mutual interaction between these parameters controls the slab dip variations, the low cross-correlations coefficients obtained suggests the influence of other parameters and the development of supplementary effects.

In order to add a contribution on this subject, we analyzed the effect of the thermal state of ocean-continent convergent system on the slab dip variations by using a 2D finite element numerical model to obtain a preliminary quantitative analysis of the impact of a single parameter on the convergent system geometry: this could be a very difficult or impossible analysis to perform on exclusively natural data. Furthermore, we make a preliminary comparison between the results of numerical modelling and data from natural systems to evaluate the robustness and the fidelity of the model.

NUMERICAL MODELLING AND DISCUSSION

We used a 2D thermodynamic code (SubMar, MAROTTA *et alii,* 2006), in which the equations of continuity, momentum and energy conservation are solved by finite element method. The model represents a strongly coupled ocean-continent convergent system, affected by slab dehydration and progressive mantle wedge serpentinization; erosion and sedimentation processes are also accounted; shear heating is not taken into account (MAROTTA & SPALLA, 2007; MEDA *et alii,* 2010; RODA *et alii,* 2010). We fixed a constant convergent velocity of 3 cm/yr below the oceanic plate (10 km depth from the surface) and up to 50 km depth in the trench zone, along a 45° dip plane in order to force the subduction. We identify the thermal states of the plates in terms of 1600 K isotherm depth. We considered 4 different thicknesses of the oceanic lithosphere (60 km, 80 km, 95 km and 110 km) and 5 different thermal states for the continental lithosphere for each oceanic plate thickness (100%, 120%, 140% 160% 200% of the thickness of the oceanic lithosphere). We fixed the continental lithospheric base (1600 K isotherm) at the distance of 800 km from the trench, linearly decreasing to the trench reaching the fixed depth of oceanic lithosphere.

We evaluate the influence of the lithospheric thickness variation on subduction geometry by plotting the slab profiles (Fig. 1) starting from 50 km depth, that is the lower limit of fixed velocity vectors. Generally the slab profiles change with the changing of the lithospheric thickness of the overriding plates and this variability increases with oceanic thickness decrease.

For an oceanic lithosphere thick ranging from 60 km to 80 km

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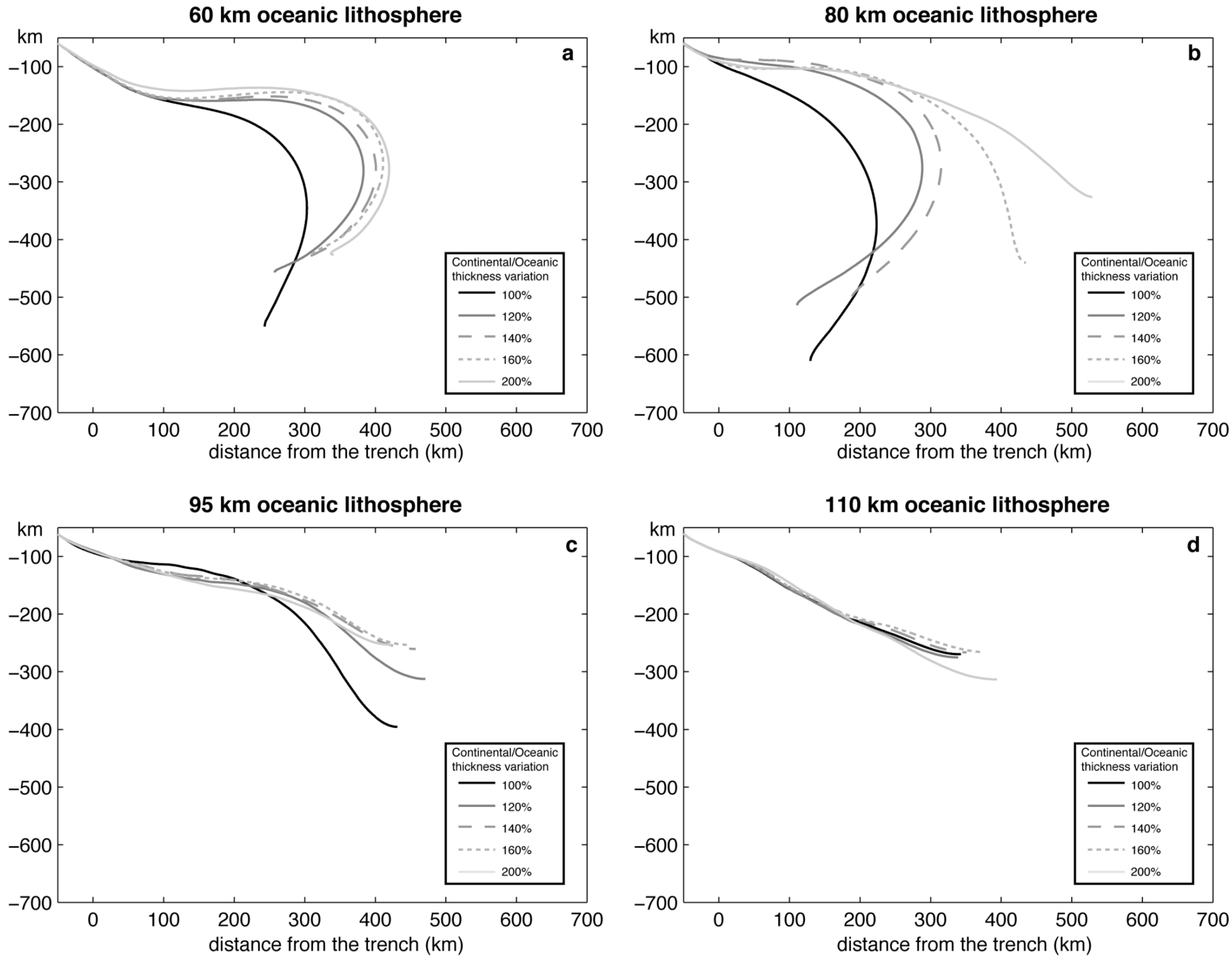

Fig. 1 – Slab profiles for different thickness of the oceanic lithosphere and for different thickness of the overriding lithosphere. The profiles start from 50 km depth (y-axis), that is the limit of the fixed velocity vectors.

a decrease of slab dip (until 250-300 km depth) occurs associated with the increase of the thickness of the continental lithosphere (Fig. 1, panels a and b). Below 300 km depth a gradual increase of slab dip is predicted until to reach a near vertical setting, followed, in same cases, by a change of the subduction polarity. For the oceanic lithosphere thicker then 80 km a lower dip variability is observed increasing the continental thickness (Fig. 1, panels c and d).

The statistical analysis on dip distribution, obtained by linear interpolation of profiles from 50 km to 300 km depth, shows the strong relationship between slab dip and thickness of the continental lithosphere (Fig. 2) with a rapid decrease of the dip with the continental thickness increase, for the oceanic thickness of 60 km, 80 km and 95 km. Same as shown in Figure 1, for higher oceanic thickness, a low correlation between the dip and the continental thickness is observed, with a near constant slab dip distributed around 30°.

These preliminarily results suggest that, in the colder overriding configuration, which is represented by a high lithospheric thickness, the viscosity gradients between subducting and upper plate increase, decreasing the efficiency of the right-side convective cell with a consequent decrease of the flow active at the top of slab surface (Fig. 3, panel b); moreover the suction force in the mantle wedge increase. The result is a shallower slab dip setting. On the contrary, in a hot upper plate configuration the viscosity of the mantle wedge decrease and a high efficient convective flow can develop in the right-side, driving the subduction of a steeper slab dip (Fig. 3, panel a).

Finally a preliminarily comparison between model results and natural data is done. We considered the dips obtained for several worldwide actual ocean-continent subduction zones from CRUCIANI *et alii,* (2005) and LALLEMAND *et alii,* (2005) databases. Furthermore we calculated the thickness of the continental lithosphere at a distance of 800 km from the trench for each subduction system, using the global thermal model of the continental lithosphere of ARTEMIEVA (2006) except for the data with the lowest resolution of the thermal model (e.g. Japan, Aleutins and Indonesia subductions) (Fig. 4).

Although we have not discriminated the convergent velocities of the subduction systems, we obtained a good agreement between the natural samples and the model predictions, with a

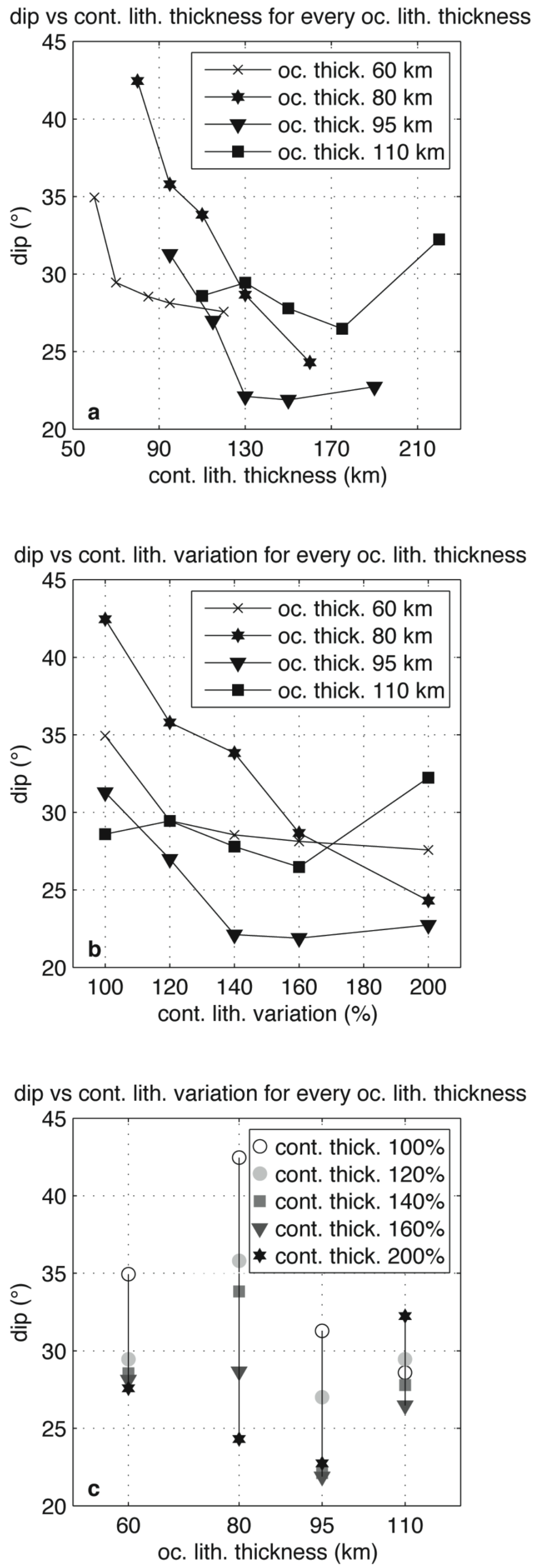

Fig. 2 – Statistical analysis of slab dip variation for different oceanic and continental thickness: the dips are obtained from the slab profiles using a linear intepolation between 50 km and 300 km depth.

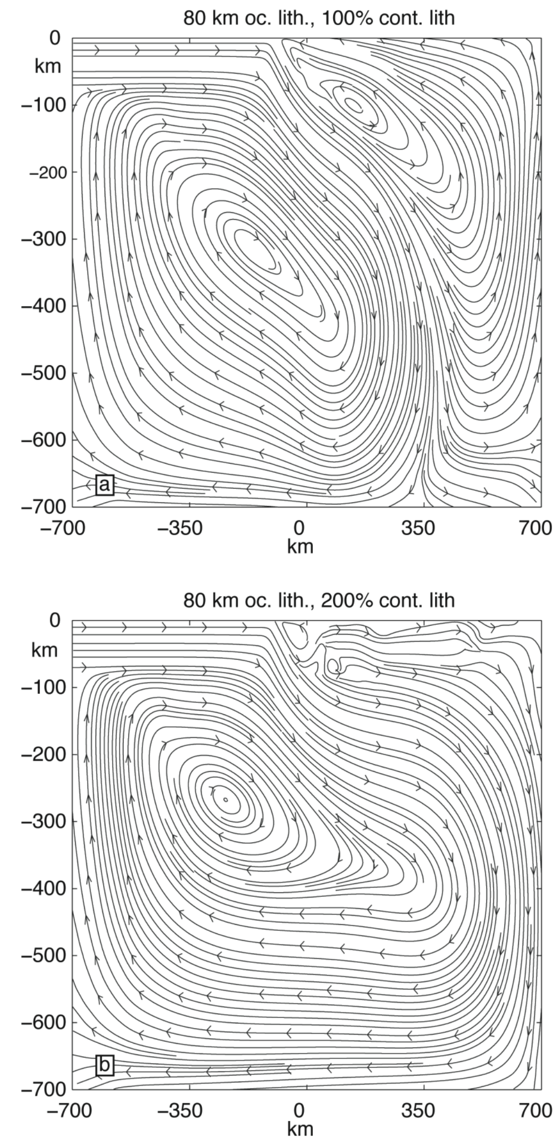

Fig. 3 – Comparison between two different configurations of convective cells (shown as stream-lines) obtained for models with thickness of oceanic lithosphere of 80 km: panel (a) is the flow setting for 100% of continental lithosphere variation and panel (b) for variation of 200%.

similar trend of dip related to the thickness of the continental lithosphere: high slab dip seem to characterize the subduction systems with lower overriding plate thickness and the dip decreases with the increase of the lithospheric.

The results of this preliminary study indicate that a factor not yet taken into account, that is the thermal state of the overriding plate, exerts a relevant influence on the subduction geometry although other simulation with different convergent rate are needed to obtained a robust cross-correlation between the different impacting factor and to quantify the single action of each one.

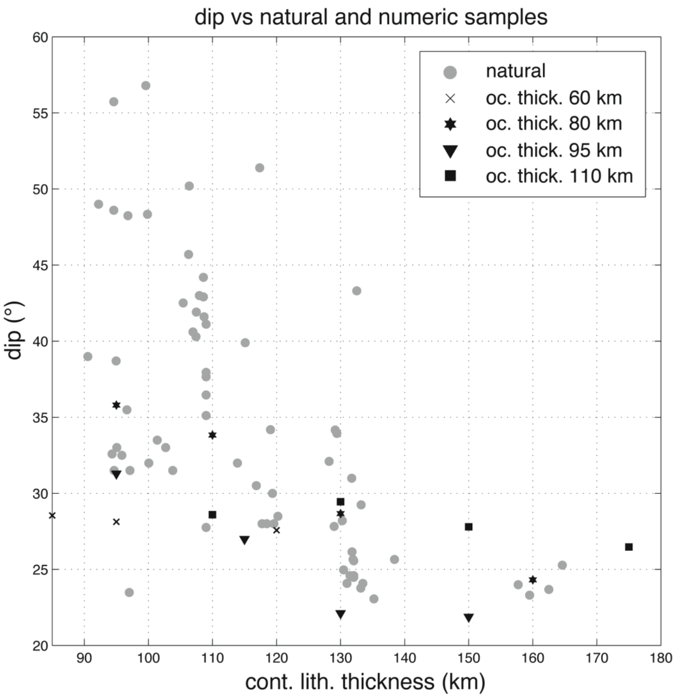

Fig. 4 – Comparison between numerical prediction and natural data obtained for several worldwide actual ocean-continent subduction zones.

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