Steady state thermal regime of subduction zones : effects of sediment thickening and fluid expulsion in the accretionary prism

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In subduction zones, consolidation of accreted sediment section and the associated decrease in average porosity induces fluid expulsion and sediment thickening. The thermal modelling, presented here, investigates the effects of the resulting sediment and fluid flows within the accretionary prism.

In this approach, the steady state simple two-dimensional analytical solutions given by Bekins and Dreiss (1992) are used to calculate the rate of fluid expulsion in the thickening accretionary prism and the resultant spatial distribution of dewatering rate. In their model, the porosity function is known a priori. They assume that the sediment thickens uniformly landward, and that the porosity within the prism varies vertically as an exponential function of depth and laterally with distance from the deformation front. The hydrological and thermal regimes are calculated using two-dimensional finite element models.

The thermal effects of fluid expulsion and sediment thickening have already been investigated by previous studies (e.g. Wang et al., 1993) restricted to the accretionary prism (without taking into account the presence of a subducting plate). In that case, a fixed heat flow is imposed at the base of the accretionary prism and the heat flow at the surface is normalized by the basal one. This approach enables to calculate the perturbation of the surface heat flow relative to the lithospheric one. Their results indicate that upward advective heat transport due to fluid expulsion is at least one order of magnitude smaller than the downward oriented effect of sediment thickening.

Here, the subducting plate is added and the normalization of the surface heat flow is used to quantify the perturbation due to fluid expulsion and sediment thickening processes within the accretionary prism. The normalized heat flow is calculated by dividing the surface heat flow calculated when computed fluid and sediment velocities are introduced by the one calculated at the surface when these velocities equal zero (i.e. usual subduction models).

Compared to the results of previous studies, our results show that the subduction of the slab modifies the perturbation. The difference between the results of the two approaches is related to the fact that previous models impose a fixed heat flow at the base of the prism. Actually, in real subduction zones, the heat flow entering the base of the prism has a variable value.

As a result, the simple approach which does not take into account the subducting slab is not sufficient to estimate the heat flow perturbation associated with the effects of fluid and sediment flows within the accretionary prism. Indeed, as the perturbation depends on the lateral temperature gradient, a normalization of the vertical surface heat flow by the basal heat flow does not give the same results when the basal heat flow varies laterally. Complete subduction models are thus necessary to properly correct the surface heat flow for the effects of fluid expulsion and sediment thickening. Thus, models have to include the presence of the subducting slab to calculate the perturbation of the heat flow in order not to overestimate the effect of sediment thickening in particular. In addition, the models which include the subducting plate show that fluid flow does not only increase the heat flow within the accretionary prism. Indeed, it increases the heat flow at shallow depths but reduces it at the base of the prism, because fluid is traveling together downward with sediments.