C-28 SURFACE CONTROLS ON THE THERMAL REGIME OF EXTERNAL ZONES OF OROGENIC BELTS

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Abstract

In extensional settings, the thermal evolution is closely linked to the global geodynamic development (lithospheric and crustal thinning). In collision areas, numerous processes acting on the thermal field are superimposed and the evolution through time is subsequently more complex. The surface heat flow density (HFD) distribution across active orogenic belts show large variations and illustrates that no standard profile can be proposed (fig.1).

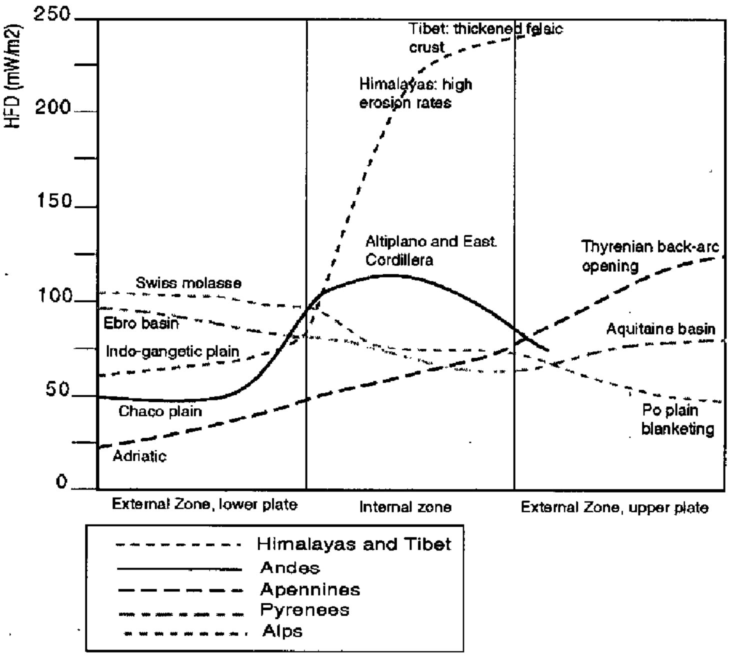

Figure 1: Heat flow density profiles across active orogenic belts showing significant variations in similar morphotectonic units.

Not only deep processes (increasing heat production due to crustal thickening, lithospheric thickening and potential delamination, strain heating...) but surface phenomena control the heat flow. Although they can be very local processes, their magnitude can be high and even mask the deeper signal in the first kilometers of the crust, i.e. where hydrocarbon maturation and migration occur. Hence, the assessment of these parameters is necessary for oil and gas exploration. They include sedimentation which induces the well-known blanketing effect, erosion which on the contrary generates positive anomalies, fluids circulation, and terrain effect (topography, climate, microclimatic effects...). In areas where geodynamic processes are fast, such as the Mediterranean Sea and surroundings, large amounts of heat flow density variations are due to near-surface transient effects (although certainly not only).

In the Circum Mediterranean basins, heat flow density values range from 10 to more than 500 mW/m^2 (fig.2).

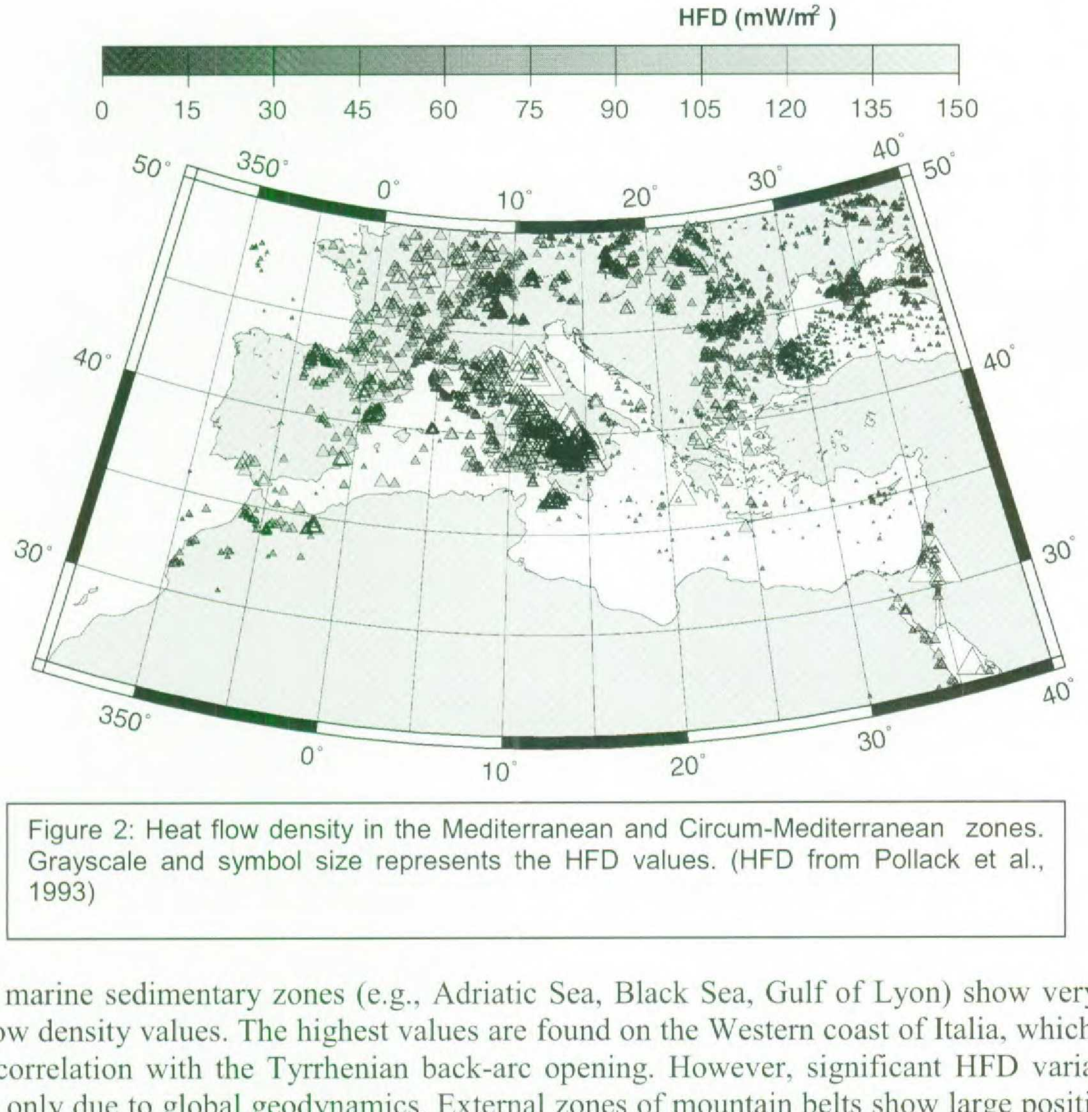

Figure 2: Heat flow density in the Mediterranean and Circum-Mediterranean zones. Grayscale and symbol size represents the HFD values. (HFD from Pollack et al., 1993)

Active marine sedimentary zones (e.g., Adriatic Sea, Black Sea, Gulf of Lyon) show very low heat flow density values. The highest values are found on the Western coast of Italia, which is in direct correlation with the Tyrrhenian back-arc opening. However, significant HFD variations are not only due to global geodynamics. External zones of mountain belts show large positive or negative discrepancies with regard to the 50 mW/m^2 average for continental areas. The Po plain or the Adriatic Sea are very cool (about 30 mW/m^2), and the Swiss molasse basin or the Aquitaine and Ebro basins are rather warm (more than 80 mW/m^2).

In collision areas, the various geological constraints can significantly hide the deep signal. In internal zones of orogenic belts, where the crust is thickened, the elevated thermal regime is mainly associated to bulk processes (increased crustal radiogenic production, strain heating..., and lithospheric mantle behavior during orogenesis. The principal deformation in these areas is vertical due to the isostatic response to crustal thickening. Subsequent uplift generates deep erosion, globally acting homogeneously over large geographic areas. Hence the thermal field is in a maintained transient state, and the heat flow is high. In foreland basins, sedimentation can be rapid and generate a global cooling effect.

Between the foreland basins and the heavily eroding internal zones are the folded belts. They constitute series of ramp-folds striking parallel to the main orogenic trend, forming a broad periodic system. Numerous processes acting on the thermal field are cumulated in these zones (fig.3). These phenomena either induce positive or negative anomalies. The magnitude and polarity of these anomalies depends on the geomorphologic structure, i.e. the anticline/syncline alternation controls the distribution of the surface processes acting on the thermal regime. In order to stress the thermal field through time and space during orogenesis, the perturbations from surface processes are evaluated.

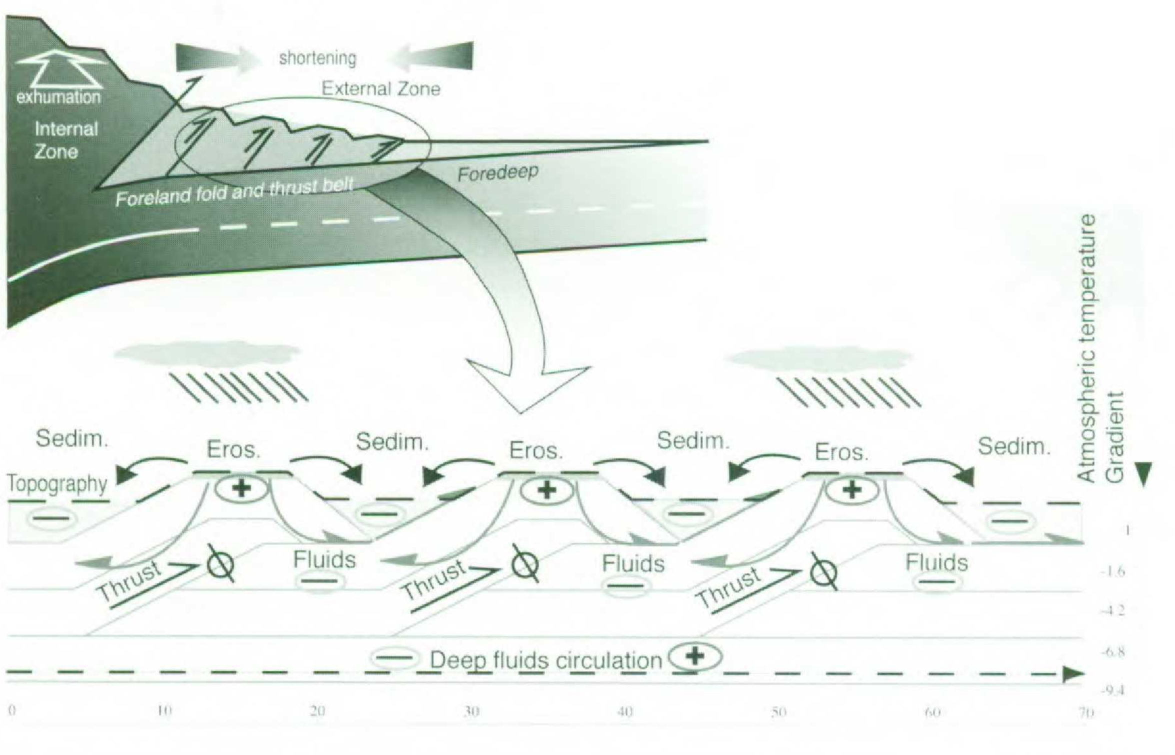

Figure 3: Surface processes and potential associated thermal anomaly in fold and thrust belt. Minuses and pluses are negative and positive thermal anomalies, respectively.

A quantitative analysis by numerical modeling of the surface phenomena (Husson & Moretti, 2000) shows that erosion and sedimentation are first order controls on the thermal regime. Fluid circulation can generate local negative anomalies.

Thin-skinned thrusting have a negligible influence as conduction is faster than advection for most geological settings. 2D numerical modeling (THRUSPACK) allows to quantify the parameters for which no distortion of the thermal field occurs.

Erosion corresponds to an advection of heat towards the surface (e.g. Lucazeau & Le Douaran, 1985, Pasquale & Verdoya, 1990), and sedimentation is the opposite (see for instance, Stüwe et al., 1994, Mancktelow & Grasemann, 1997). If the rates are faster than conduction, the thermal regime increases or decreases, respectively. Numerical modeling of these surface processes using GENEX program shows that for realistic rates and thicknesses, the transient effects on the heat flow can achieve as much as 50 % of the steady state HFD. They are rather penetrative, and the even if most of the anomalies vanishes few Ma after sedimentation or erosion ceased, little remains for more than 10 Ma.

Topographically-driven fluids circulation can induce local cooling below recharge areas, if the permeability is high enough; however, it is not likely to show major regional cooling around discharge areas (essentially the foreland) as circulation is seldom fast enough. Assessment of the impact of fluid flow is performed using TEMISPACK program, and it is shown that local variations on the permeability field lead to significant changes on its thermal impact.

Terrain effects can influence the near-surface thermal regime but are not penetrative at all. It is evidenced that surface morphology should induce rather important anomalies, but the atmospheric temperature gradient and adjacent relieves significantly lower the topography-induced perturbations.

Although erosion and sedimentation are the main controls on the near-surface thermal regime –in addition to the deep crust and mantle heat sources-, other parameters such as fluid circulation can generate local anomalies. In external zones of mountain belts, all the parameters are cumulated; the impact of each of them depends on the geological setting, and their respective influences lead to a large range of HFD measured in the various external zones of orogenic belts.

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