Geothermal 3D model of the shallow crustal structure in the Val d'Agri oil field (Basilicata region)

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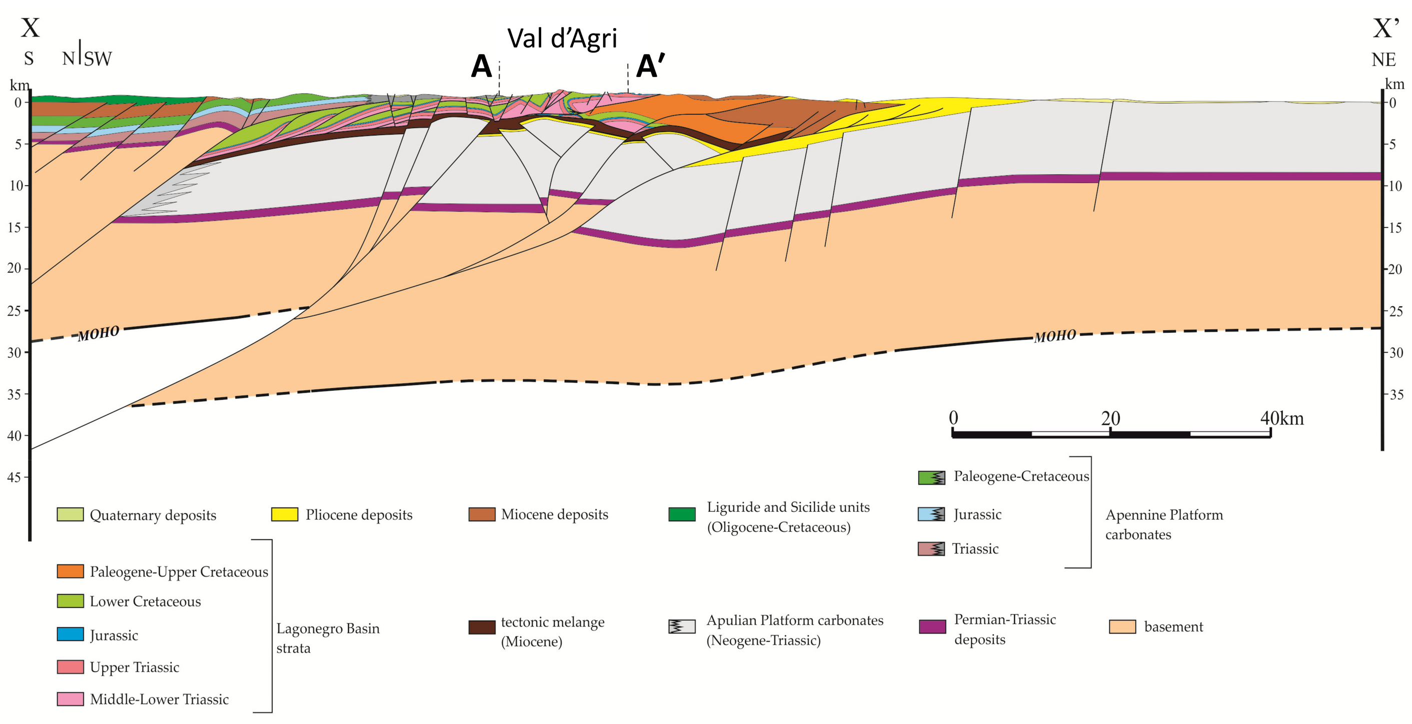
Abstract

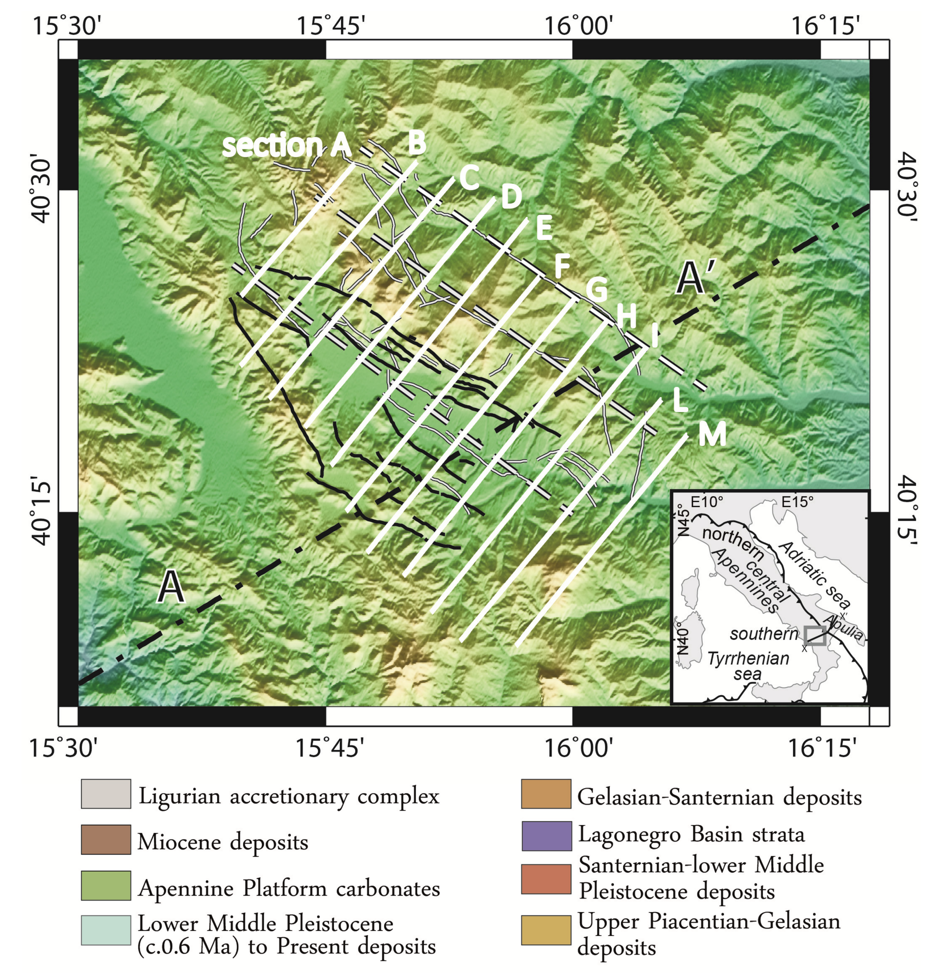
A good understanding of the geothermal gradient in any region is of primary importance for hydrocarbon/geothermal reservoir management and further applications in the fields of (e.g.) subsurface *CO2* storage and nuclear waste disposal. In the particular case of the Basilicata oil fields area, the analytical definition of the geotherms carried out in this study is particularly relevant, both for industrial applications and for seismotectonic modelling in a region characterized by a magnitude 7 historical earthquake. In fact, the thermal state plays a fundamental role in controlling the modes of strain accommodation in the crust, which in turn controls the partitioning and distribution of seismic vs. aseismic strain. A geothermal model for the area of the Val d'Agri oil fields has been obtained by an analytical procedure. The model takes into account both the temperature variation due to the re-equilibrated conductive state after thrusting and frictional heating. Input parameters include heat flow density data and a series of geologically derived constraints – thrust depth, timing of thrusting, slip rate – obtained by the integration of surface and subsurface datasets. This work, representing a first attempt to reconstruct a geothermal 3D model for the Val d'Agri seismic zone of the Basilicata region, provides thermal constraints that could constitute a basis for future studies in the area.

Tectonic framework

The southern Apennines accretionary wedge is composed of both ocean-derived (Ciarcia et al., 2012; Vitale et al., 2013) and continental margin-derived tectonic units. The latter include Mesozoic-Tertiary carbonate platform/slope successions (Apennine Platform - thickness of 6 to 8 km) and pelagic basin successions (Lagonegro), stratigraphically covered by Neogene foredeep and wedge-top basin sediments (e.g. Mazzoli et al., 2012). The detachment between the allochthonous units and the buried Apulian Platform unit is marked by a mélange zone of variable thickness, locally reaching ca. 1500 m (Mazzoli et al., 2001). The structure at surface is characterized by low-angle tectonic contacts separating the Apennine Platform carbonates, in the hanging wall, and the Lagonegro Basin successions in the footwall (Mazzoli et al., 2008). These tectonic contacts consist of both thrusts – in part reactivated during extensional stages – and newly formed low-angle normal faults (Mazzoli et al., 2014). The buried Apulian Platform is characterized by reverse-fault-related, open, long-wavelength folds that form the hydrocarbon traps for the significant oil discoveries in southern Italy (Shiner et al., 2004).



Crustal geological section (after Mazzoli et al., 2013, modified; Santini et al., 2013). The AA' cross-section through the Basilicata oil fields of Alta Val d'Agri has been constructed by the interpretation of available high-quality seismic data (Shiner *et al.*, 2004).

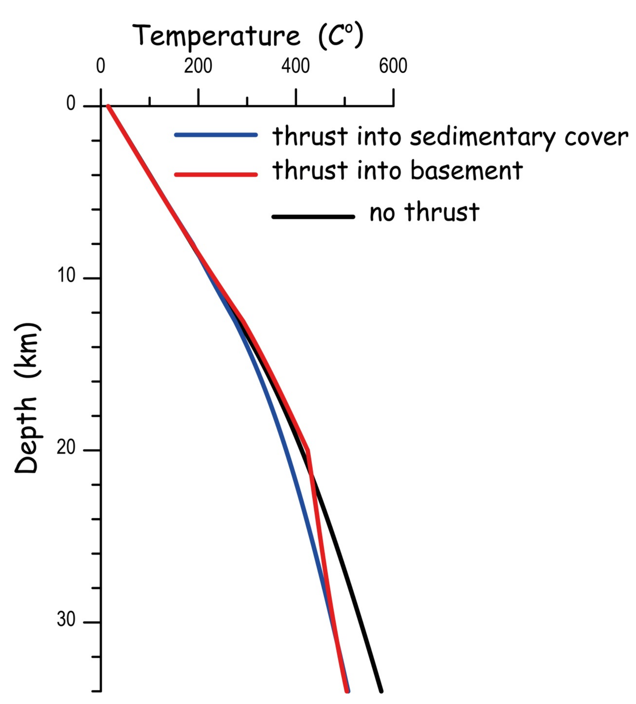


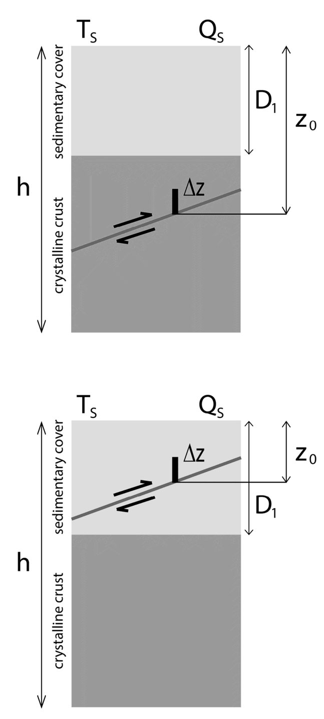
Geological map (after Mazzoli et al., 2014); black lines are surface faults, dashed white lines show the generic alignment of sub-surface structures, dashed black line is the trace of the crustal cross-section X X', and white lines are the eleven traces of the crustal cross-sections in which the thermal field has been computed.

Thermal structure

To allow the calculation of the tectonic contribution to frictional heating (Molnar et al., 1983), we simplified this structural setting considering two layers, one for the sedimentary cover ($z \leq D_1$) and the other for the basement ($D_1 < z \leq h$), and only one major SW dipping thrust fault at depth. We considered the different thrusting depths (z_o) and thickness along the sections, and we took into account that the major thrust offset the basement along a vertical profile for each of these sites. Furthermore, taking into account the estimated slip rate (v = 2.0 mm/a), the overthrusting time span (ca. 1.9 Ma; Butler et al., 2004; Mazzoli et al., 2000; Patacca and Scandone, 2001) and the angle of dip of the thrust fault, we define a superimposed thrust thickness (Δz).

We used the map of the heat flow density in Italy by Scrocca et al. (2003) to constrain surface heat flow in the study area. The Val d'Agri, similarly to the whole axial zone of the southern Apennines, sits in a zone characterized by a low value of surface heat flow density (Q_s average of 45 mW m^{-2}).





$$T(z,t) = T_s + T_{DH}(z,t) + T_{FH}(z,t) \qquad z \leq D_1$$

$$T(z,t) = T_s + T_{DH}(D_1,t) + T_{MH}(z,t) + T_{RH}(z,t) + T_{FH}(z,t) \qquad D_1 < z \leq h$$

$$T(z,t) = T_s + T_{SH}(z,t) + T_{FH}(z,t) \qquad z \leq D_1$$

$$T(z,t) = T_s + T_{SH}(D_1,t) + T_{BH}(z) + T_{FH}(z,t) \qquad D_1 < z \leq h$$

The consequences of overthrusting are a different distribution of the temperature due to new perturbed state and an increase of temperature due to friction.

If the overthrusting occurs in the basement, the new thermal status is computed in two parts. In the lower layer we considered the new perturbed conductive status associated with two principal heat sources – i.e. mantle heat flow (T_{MH}) and radiogenic heat (T_{RH}) – and the additional heat source due to friction on the fault (T_{FH}). For the sedimentary cover, we estimated the radiogenic heat increment at the bottom of this layer as a consequence of basement overthrusting in addition to the previous equilibrium status (T_{DH}). For this upper layer we also added the temperature increase due to friction (T_{FH}) (Candela et al., 2015).

If the overthrusting occurs in the sedimentary cover, the temperature is the sum of the temperatures due the new structural configuration produced by overthrusting (T_{SH}) and frictional heating (T_{FH}). Whereas, in lower layer the temperature is increased by the frictional heating (Megna et al., 2014).

T_S is the surface temperature.

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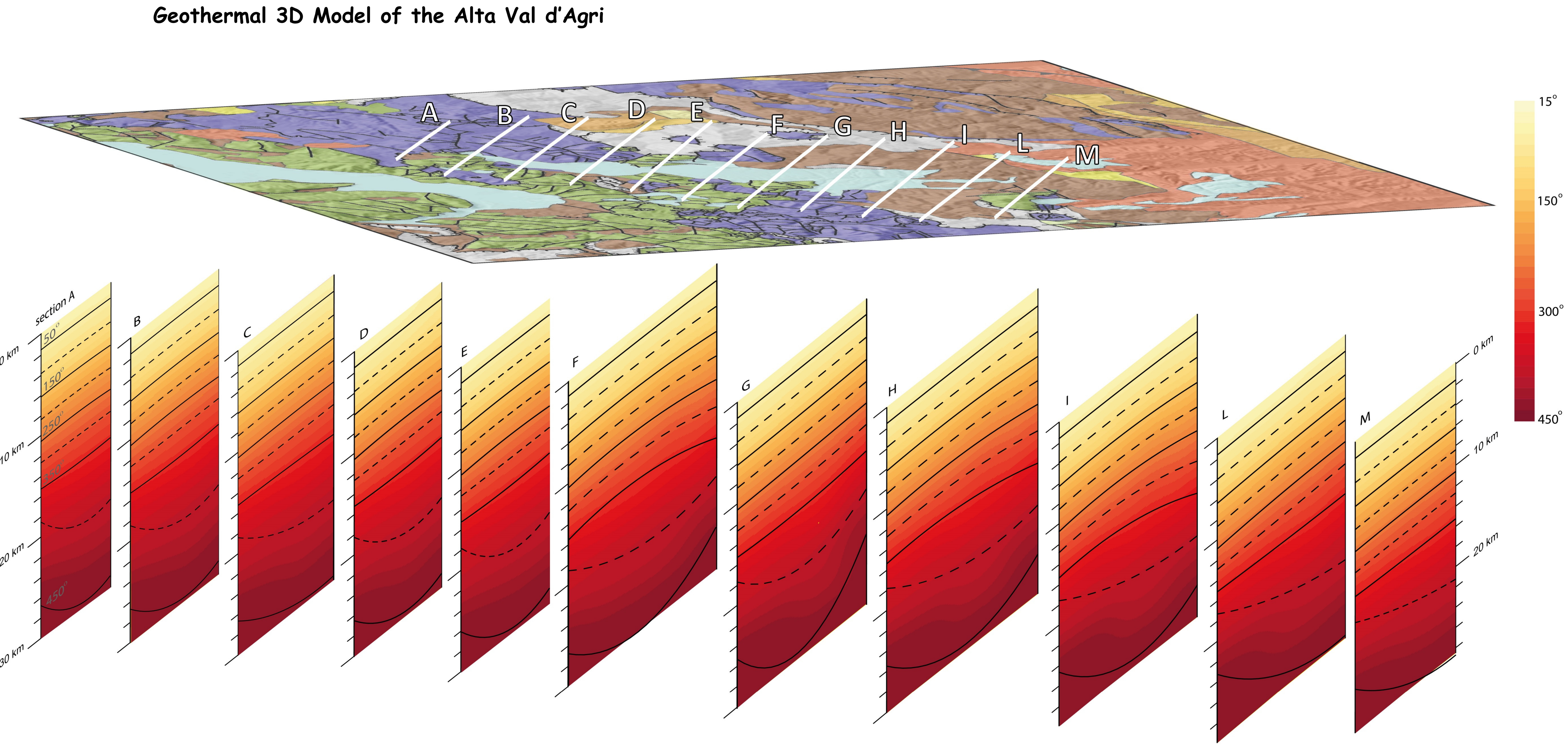

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