Geophysical Research Abstracts
Vol. 18, EGU2016-15454, 2016
EGU General Assembly 2016

A review of the heat flow data of NE Morocco

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The Atlas chain is characterised by a SW-NE trending volcanic belt roughly extending from the Atlantic to the Mediterranean Sea and showing activity that spans in age mainly from Middle Miocene to Quaternary (14.6-0.3 Ma). The geochemical features of volcanism are mostly intraplate and alkaline with the exception of the northeastern termination of the belt where calc-alkaline series crop out. Lithospheric thermal and density models so far proposed, constrained by heat flow, gravity anomalies, geoid, and topography data, show that the Atlas chain is not supported isostatically by a thickened crust and a thin, hot and low-density lithosphere explains the high topography. One of the possible explanations for lithospheric mantle thinning, possibly in relation with the observed alkaline volcanism, is thermal erosion produced by either small-scale convection or activation of a small mantle plume, forming part of a hot and deep mantle reservoir system extending from the Canary Islands. This paper focuses on the several geothermal data available in the northeastern sector of the volcanic belt. The occurrence of an extensive, often artesian, carbonatic reservoir hosting moderately hot groundwater might boost the temperature gradient in the overlying impermeable cover, and consequently mask the deep thermal regime. We therefore revised the available dataset and investigated the contribution of advection. Temperature data available from water and oil wells were reprocessed and analysed in combination with thermal conductivity measurements on a wide set of lithotypes. Data were filtered according to rigid selection criteria, and, in the deeper boreholes, the heat flow was inferred by taking into account the porosity variation with depth and the temperature effect on the matrix and pore-filling fluid conductivity. Moreover, the possible effect of advection was evaluated with simple analytical models which envisage the carbonatic layers as confined aquifers heated by the background terrestrial heat flow and loosing heat by conduction through the overlying cover. The results slightly modify the heat-flow picture proposed in previous investigations and point to negligible effects of advection. The heat flow ranges from 64 to 112 mW m^{-2}, showing a variation in relation to the different tectonic units, and increases with the decrease of crustal thickness. Heat-flow data do not satisfactorily track the volcanism of the northeastern sector. The largest values (86-112 mW m^{-2}) are found in the Oujda region, at the easternmost edge of the investigated area. The mantle origin of this thermal anomaly can be neither ruled out nor proved using only heat flow data, because $\sim$15 Ma or less is a too short time to enhance the surface heat flow for pure conduction through a $\sim$ 100 km-thick lithosphere. We speculate that the heat flow in the Oujda region might be related to subduction and rifting processes that occurred during the opening of the western Mediterranean basins.