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Unravelling the terrestrial heat flow from deep thermal data

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The terrestrial heat flow is the only observable geophysical quantity that in principle can reflect the thermal effects of deep-seated geodynamic processes. On the other hand, this parameter is particularly difficult to measure. Most of the available heat flow information derives from thermal measurements in the uppermost layers of the crust and thus may include both transient components, related to the tectonic history, and geological noise. Especially in young and active deformation areas, processes such as basin formation and sedimentation, groundwater circulation and thrusting may drastically change the temperature distribution in the shallow crust and hide the deep conductive thermal regime of the lithosphere. Temperature and petrophysical data obtained in hydrocarbon and geothermal exploratory wells, as well as scientific drillings, may help to unravel the deep undisturbed thermal regime. However, temperature measurements must be treated with appropriate techniques to remove the thermal perturbation due to the drilling operations, and the thermophysical properties of rocks must be evaluated by taking into account the effects of the overburden pressure, temperature, anisotropy and fluids filling the pores. Moreover, the radiogenic heat production, which in shallow boreholes can be neglected, should be taken into account when processing data from several kilometres deep wells. In this paper, we analyse deep thermal data to unravel the lithosphere thermal regime in the central-northern Apennines chain and the surrounding sedimentary basins. Besides groundwater flow, the several kilometres thick sedimentary formations are still affected by thermo-tectonic perturbations (sedimentation and overthrusting), whereas the underlying crystalline basement should be in an undisturbed, conductive thermal regime. Unfortunately, few thermal data were recorded in the metamorphic basement and most of the available temperature values were measured in the permeable carbonate Palaeogene-Mesozoic formations, which represent the major and widespread tectono-stratigraphic unit of the study area. First, we corrected for the drilling disturbance the available temperatures from hydrocarbon and geothermal wells by means of a technique specifically calibrated for the Apennines foreland basins. Subsequently, we estimated the thermal conductivity profiles on the basis of detailed litho-stratigraphic information derived from deep wells and by taking into account the pressure and temperature effects. Finally, the thermal resistance approach, including also the effect of radiogenic heat production, was used to determine the terrestrial heat flow. In each well, an optimum surface heat-flow value was found by minimising the differences between the calculated and corrected temperatures. We noticed that only a few boreholes close to recharge areas show a mismatch between calculated and observed temperatures, thus arguing for deep groundwater flow in the permeable carbonate unit, whereas most of the obtained heat-flow data may reflect the deep thermal regime.