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Seismicity and rheological modelling in an extensional-compressional tectonic realm

P. Chiozzi, V. Pasquale, M. Verdoya

Dipart. per lo Studio del Territorio e delle sue Risorse, Settore di Geofisica, Università di Genova, Viale Benedetto XV 5, I-16132 Genoa, Italy (pasquale@dipteris.unige.it)

The mechanical behaviour of the lithosphere is a function of composition, thermal state and crustal structure, which in turn depend on its evolution and geological age. In young lithosphere, large lateral variation of rheological layering may occur as a result of different tectonic processes leaving their signature especially in geotherm and crustal thickness. To this regard the northern sector of the Tyrrhenian-Apennines system represents an outstanding example showing evidence of both extensional and compressional tectonics which have left a clear thermal signature. The present-day setting of this tectonic realm can be interpreted as a result of an evolutionary process, which has started with stretching and ocean spreading in the Ligurian-Provençal basin. Extension has occurred prior to or contemporaneously to the Apennines subduction and then proceeded eastwards in the Tyrrhenian area, previously affected by compression. These dynamic processes are mirrored by the surface heat-flux pattern, whose lateral variation can be considered as both a piece of evidence and an interpretive key. The lithosphere thermal state is in many sectors still far from equilibrium and at different stages of relaxation. Thus a transient thermal approach has to be adopted and, consequently, the rheological behaviour will be a function of time and position.

We formulate thermo-mechanical models to infer the rheological behaviour with particular reference to the crust. The most up-to-date information on the thermal pattern, local earthquake data and magmatism are taken into account, together with geophysical evidence of the lithosphere structure. The inferred present-day rheological stratification is discussed in relation to seismicity.

Variscan Corsica appears as the only thermally stable fragment of lithosphere in the study area. The crustal and thermal structure of the Northern Tyrrhenian and peri-

Tyrrhenian zone is the result of three eastward-migrating extensional events which have taken place within relatively small space and time intervals. The oldest tectono-thermal occurred 14 m.y. ago in eastern Corsica. It was followed by a second event 7 m.y. ago in the central part of the Northern Tyrrhenian. The third and youngest rift episode, dated 3 m.y. ago, affected a wider area including most of the peri-Tyrrhenian zone. Uniform stretching cannot account for the high heat flux in the zone affected by the youngest tectono-thermal event. For this zone we apply a thermal model which incorporates the removal of 15 km of mantle lithosphere, due to asthenosphere flow induced by subduction. In the external zone of the northern Apennines arc, the recent thrust-faulting phase (about 2 m.y.) is modelled by isolating the effects of the heat supplied from below the lower thrust plate, the radiogenic heating within the crust of both the upper and lower plates, and frictional heating along faults. In general the surface heat-flux values agree well with the proposed thermal models.

The modelled strength profiles predict a lateral variation in the crust mechanical strength from the Variscan block to the Apennines external arc. The thickness of the upper crustal brittle layer is thinner where rifting age is more recent. It decreases from 20 km in Corsica to 10-15 km in the Northern Tyrrhenian and peri-Tyrrhenian sector, both characterized by ductile rheology in the lower crust and upper mantle. A brittle layer is expected in the lower beneath eastern Corsica. Ductile flow may occur at about 30 km beneath the external zone of the Apennines. Under the assumption of thrust faulting, in this area and in the Variscan block brittle layers of thickness about 5 and 10 km are expected in the lower crust and in the upper mantle, respectively.

Generally, the observed seismic activity is consistent with the rheological structure predicted by our models. There is no seismic activity in Corsica and at its eastern margin, whereas the Northern Tyrrhenian and the peri-Tyrrhenian zone are characterized by low seismicity with major occurrence in the uppermost 10 km and consistent with the expected brittle-ductile transition. In particular in the peri-Tyrrhenian zone the brittle layer is very thin and follows the regional pattern of the high reflectivity horizon inferred from seismics. Seismicity is mainly concentrated beneath the Apennines chain at the zone of crustal overlapping. Crustal earthquakes tend to become deeper below the external zone of the northern Apennines. Some low magnitude events occurring in the lower crust and in the uppermost mantle can be accounted for by our rheological models.