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Deep earthquakes and orogenic processes: toward a new global perspective?

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Earthquakes are not uniformly distributed either along mountain belts and arcs or in depth. An especially uneven distribution is present all along the Mediterranean margin between Africa and Eurasia. The zones in which the deeper earthquakes originate are shown, and their regional and global context is examined. Abandoning the traditional 2-D sections – perpendicular to the trench-arc-backarc zones –, with the help of 3-D plotting on larger scale, which can visualize the entire extent of a Wadati-Benioff zone, a characteristic inhomogeneous pattern of hypocentres along the alleged subduction zones is revealed in the Italian region as well under Mediterranean and circum-Pacific active margins. Using the recent global catalogues of relocated earthquakes, filaments of hypocenters are recognizable instead of planar or spoon-like patterns. These filaments taper downwards, resembling the shapes of trees, columns, smoke from chimneys, and leading to the idea of an origin in a narrow region of disturbance. Because very hardly a subductive process can produce similar deep hypocentral distributions, a new interpretation of the Wadati-Benioff zones and of their overimposed orogenic zones is proposed. The resulting global tectonics framework involves non-collisional orogenic processes – deriving from global expansion, rifting, isostasy, surfaceward flow of deep material, gravitational spreading, and mantle phase changes. The associated model of evolution of an orogen can be linked to the volume increase of an isostatically uprising mantle column which segments slowly overcome a solidus-solidus limit of the temperature-pressure phase diagram.

The outpouring of the exceeding material drives the gravitational nappes to overthrust the sediments of the pre-existing trough, forcing them on a burial path which emulate the subduction process, but without reaching depths greater then 50-70 km. At the boundary between uplifting material and down-pushed crust and lithosphere, phenomenon like metamorphism, mixing, migmization, upward transport of fragments of the buried lithosphere etc. are possible.

The mere existence of the earthquakes in the brittle portion of the lithosphere (first few tens of kilometres of depth) is at odd with the existence of the ‘two ways subduction channel’ – a low viscosity channel. Earthquakes are the more important circumstantial evidence of local storing and releasing of deviatoric stress, which can be cause of local overpressure. Then the possibility that lenses-like HP-UHP exhumed fragment could be mechanical product of great earthquakes occurrence at depth not exceeding few tens of kilometres should be considered.

This model of evolution of a fold belt is in agreement with the tomographically revealed P-wave and S-wave high-velocity anomalies underlying – with different slopes – most orogens and arcs, and the obtainable topographic heights are consistent with the values of volume increase that are associated to the main mineralogical phase transitions. In this view, a discontinuous upward movement of mantle materials can be linked to the observed discontinuous evolution of the orogens and to the widespread observation of uplifted coastal terraces.

Finally, the rate of rifting between two lithospheric fragments is a decisive factor in causing the evolution of the orogen toward a true fold belt (low rifting rate) or in a continuously enlarging depression (high rifting rate), leading to a true marine and oceanic sea-floor generation. Indeed, some zones like Tonga-Kermadec-New Zealand-Macquarie seems to suggest all these aligned different zones – trench and expanding ridge, mature fold belt, oceanic ridge respectively – as different moments of a unique orogenic process, which should be described in detail along a proper time-scale.