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Mantle-derived helium in sedimentary basins of Central Mediterranean: Geologic and tectonic constrains on fluids accumulation and migration.

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The geodynamics of the central Mediterranean is characterized by the interaction between the European plate and the African one. In this setting Sicily is a sector of the Appenine-Maghrebide accretionary prism, which is located between two areas affected by extensional tectonics (Sicily Channel to the south and the Thyrrenian back arc basin to the north).

In the present study we present the first dataset of helium isotopic composition measured in fluids released from the central-western Sicily. With the aim to constrain the transfer system of fluids in this area we relate the results of geochemical investigations with the stratigraphy and structural setting, derived from field geology, deep boreholes and new seismic reflection, gravimetry and magnetometry data.

Significant mantle-derived helium (0.4<R/Ra<2.8; R=3He/4He in the sample, Ra in atmosphere) is found in the CH4 and N2-CO_2 rich fluids released in central western Sicily. CH4-dominated gases are released from mud volcanoes and feed everlasting fires mainly located in the central region, where upper Oligocene-Miocene terrigenous cover Mesozoic carbonatic units. The abundance of CH4, usually linked to the presence of hydrocarbons- and/or organic matter-rich layers, is almost exclusively linked to the Messinian evaporitic and pre-evaporitic levels (containing diatomites).

On the other hand, CO_2 is mainly associated to the thermal groundwaters circulating mainly in Mesozoic limestone and dolomite, which here constitute the bulk of the deformed wedge of the Sicilian chain (up to 15 km thick). In thermal waters, we found a positive correlation between water temperature, ranging between 22.1°C and 59°C, and helium isotopic ratio. Taking into consideration that helium rises from the mantle coupled to CO_2 and others components, we discussed CO_2 and CH4 coupled to helium. Our samples did no show any correlation between C/3He vs. R/Ra and only samples of the Sciacca thermal basin show C/3He in the typical ranges of the mantle fluids. CH4-dominated fluids shows a CH4/3He vs. R/Ra correlation that underlies a mixing between a 3He rich and CH4-poor term and a CH4-rich and 3He-poor one typical of crustal reservoir of gases. Our previous investigations showed up an heat excess coupled to the presence of mantle-derived helium in western Sicily, which was linked to the occurrence of melts rising from the mantle below the continental crust or intruding through lithospheric faults. This study shows that degassing of mantle derived fluids cover entirely the central-western Sicily and the transfer of mantle helium rich fluids through the crust is mainly regulated by fault-controlled advective flux. In particular: a) in the central-northern Sicily recent data from deep seismic reflection investigations (SiRiPro project), evidenced a dense network of faults that develops between the area of Caltanissetta and the central portion of the Madonie, involving both the deformed sedimentary units of the fold and thrust belt and the underlying crust and upper mantle; b) in the Sciacca area multichannel seismic profiles highlighted the occurrence of deep-seated faults (correlated with the N-S lineaments well known offshore in the Sicily Straits), also characterized by strike-slip component (as evidenced by the seismicity of the Belice valley), which involves the deeper portions of the chain; in addition gravimetry and magnetic data displayed a shallow crustal basement, whose involvement in the deformation suggests a link with the fault systems recognized in the overlying tectonic wedge.