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The Source Characteristics of Mt. Etna Magmas Erupted During the Last 60 ka

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During the last decades, Mt. Etna volcano attracted the attention of the scientific community due to its odd geodynamic location and geochemical signature of the erupted lavas. Indeed, they have OIB-like compositions although the edifice is placed above the front of a compressive regional tectonic setting. During the 500 ka of life, Mt. Etna has shown a complex geochemical variability, with sub-alkaline products erupted during the first stage of activity followed since ~220 ka by an alkaline stage. The various phases of the alkaline stage exhibit long-term geochemical variations, which chiefly derive from the superimposition of several evolutionary processes that magma underwent at various levels of the plumbing system during ascent to the surface. However, Mt. Etna lavas also display short-term changes in specific eruptive periods. Since the 1971 eruption, as an example, an increase in some LILEs and volatiles coupled with marked changes in Sr-Nd-Pb-Hf isotope ratios was observed [e.g., Clocchiatti et al., 1988; Michaud, 1995; Métrich et al., 2004; Viccaro and Cristofolini, 2008; Viccaro et al., 2011]. The evolution of a volcano studied in terms of long vs. short-term geochemical variations is one of the best ways to get important responses on: 1) the geodynamic significance; 2) the mechanism of partial melting; 3) the processes able to modify the pristine compositions of magmas and their eventual repetition through time; 4) the link with possible changes of the eruptive behavior.

Although Mount Etna can certainly be regarded as one among the most studied volcanoes on Earth, the main characteristics of the mantle source and of partial melting processes are still debated. This is primarily due to the lack of mantle xenoliths brought to the surface by magmas, which are efficiently fractionated in the deepest levels of the plumbing system. Only indirect information can be therefore obtained from the compositions of the erupted volcanics. In order to achieve these goals, we have focused the attention on some Ellittico and Recent Mongibello lavas (RM).

The behavior of incompatible trace elements for mantle-equilibrated magma compositions of the Ellittico and RM, and in particular of their Enrichment ratio [Ei, as defined by Class and Goldstein (1997)] reveal that the Etnean magmas are produced by a variable, low degrees of partial melting. Furthermore, the Ei provides information on the mantle mineralogy of the Etnean source: magmas can be produced from a classic garnet peridotite (i.e., constituted by various proportions of olivine, orthopyroxene, clinopyroxene and garnet) enriched by metasomatic mineral phases such as amphibole and/or phlogopite (Fig.1). The enriched signature of the Etnean mantle source is confirmed by the Zr/Nb vs. Ce/Y and Ba/Th vs. Lu/Hf diagrams (Fig. 2a-b), which are sensitive of the partial melting degree. The Zr/Nb vs. Ce/Y diagram shows that the contribution of metasomatic phases increased through time from the Ellittico to present-day magmas. The Ba/Th vs. Lu/Hf diagram, which is a blow-up for some pre-1971 and post-1971 magmas, shows the short-term coupled increase of the

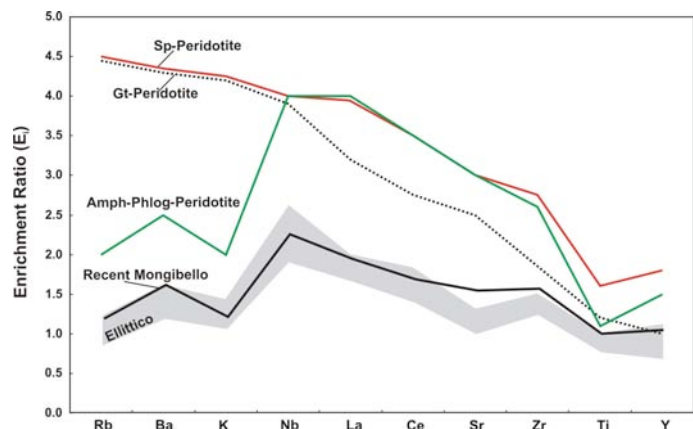


Figure 1. Enrichment ratio (Ei) patterns calculated by partial melting of spinel (sp), garnet (grt) and hydrous-phase bearing peridotites (amphibole and phlogopite). Best fit for Etna volcanic rocks is obtained by melting of anhydrous-phase-bearing peridotite.

contribution by metasomatic agents and partial melting degree.

Several authors also debated on the mantle components involved in the process of partial melting generating the Etnean magmas. The integration of Sr-Nd-Pb-Hf isotopic ratios suggested that FOZO [FOcus ZOne; cf. Stracke et al. 2005] is the dominant component in the Etnean source [cf. Cadoux et al., 2007; Viccaro et al., 2011]. The origin of the FOZO mantle source has been attributed to recycling of oceanic lithosphere little affected by sub-arc alteration, with composition and age different than the recycled crust producing the HIMU signature. The sole FOZO component is, however, not enough to explain the observed isotopic variations from the Ellittico to RM. The involvement of an enriched material should be therefore considered. The isotopic compositions of the Ellittico and RM magmas can be justified by addition of variable proportions (up to 10%) of an EM1-type component to a dominant FOZO source. The origin of the EM-1 component in literature has been ascribed to the presence of: 1) pelagic sediments; 2) recycled lower continental crust or 3) sub-continental lithosphere metasomatized by fluids and/or melts. The coupled analysis of Sm/Hf and Th/Hf ratios, along with Hf isotope compositions, provided evidence that the enriched component in the Etnean source could be metasomatizing silicate melts. Long- vs. short-term compositional variations of Mt. Etna magmas could be therefore related to partial melting of a recycled, altered oceanic lithosphere, infiltrated by metasomatizing silicate melts. Variable amounts of the enriched component participating to partial melting are able to affect its degree and the geochemical signature of the produced magmas.

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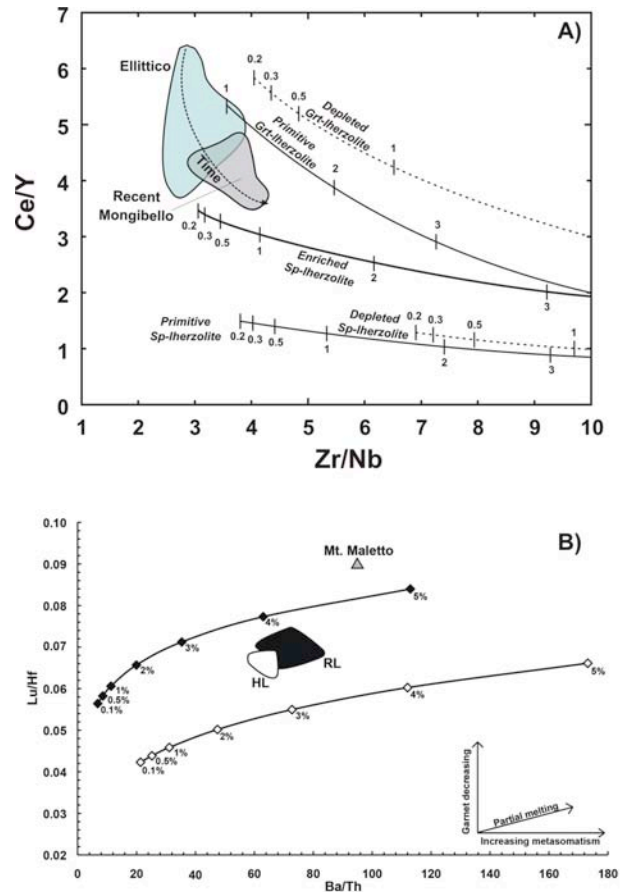


Figure 2. A) Zr/Nb vs. Ce/Y diagram for some mantle-equilibrated Etna volcanic rocks. Dashed arrow indicates the evolution with time for Etnean products. B) Ba/Th vs. Lu/Hf ratios resulting from modal fractional melting modelling of two different mantle sources: white diamonds are calculations for a peridotite source with a FOZO isotopic signature, black diamonds for a source resulting by mixing FOZO composition with 10% of an EM-1 source.

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