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Linking tephrochronology and soil characteristics in the Sila and Nebrodi mountains, Italy

Gerald Raab[a], Dieter Halpern[a], Fabio Scarciglia[b], Salvatore Raimondi[c], Kevin Norton[d], Thomas Pettke[e], Jörg Hermann[e], Raquel de Castro Portes[a], Asel Maria Aguilar Sanchez[f], Markus Egli[a,*]

[a] Department of Geography, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland
[b] Department of Biology, Ecology and Earth Sciences (DiBEST), University of Calabria, Via P. Bucci – Cubo 15B, 87036 Arcavacata di Rende, CS, Italy
[c] Dipartimento dei Sistemi Agro-Ambientali, Universitá degli Studi di Palermo, Viale delle Scienze, 90128 Palermo, Italy
[d] School of Earth and Environment, Victoria University of Wellington, PO Box 600, 6140 Wellington, New Zealand
[e] Institute of Geological Sciences, University of Bern, Baltzerstrasse 1 + 3, 3012 Bern, Switzerland
[f] Institute for Building Materials, ETH Zurich, 8093 Zurich, Switzerland

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ABSTRACT

Recent studies have demonstrated that soils formed on pyroclastic ash deposits are much more common in the Mediterranean area than previously assumed. These soils are an important key to understanding past volcanic events and landscape evolution. Chronological information in soils of Quaternary volcanic events, however, remains still poorly understood in southern Italy. Using a multi-method forensic approach, we explore the origin and age of volcanic deposits (soils) in Sicily and Calabria. The geochemical signature of the soil was compared to the chemical fingerprint of the magmas of potential source areas of southern Italian volcanoes. The results indicate that the investigated soils on the Nebrodi (Sicily) and Sila (Calabria) mountains were both impacted by materials having a high-K calc-alkaline series volcanism. The Aeolian Islands (in particular Lipari and Vulcano) are the most likely source of origin, but contributions also from the Etna (particularly the Biancavilla ignimbrites and Plinian eruptions) occurred. Weathering and leaching processes, along with a potential contribution from the underlying non-volcanic bedrock, has altered the main chemical composition of soils, often precluding direct relation to potential source areas. Immobile elements and their ratios (e.g. the Nb/Y vs Zr/Ti plot) or trace elements (Co, Th) and rare earth elements (laser ablation ICP-MS analyses of glass particles, volcanic clasts and pumice-like materials) gave precious hints of the origin of the volcanic deposits. Radiocarbon dating of the H_2O_2 resistant soil organic fraction indicates a minimum age of 8–10 ka of the soils. The weathering index WIP (weathering index according to Parker) and the chemical composition of volcanic glasses and clasts were tested as proxies for the age of the volcanic deposits and time for soil formation. The soils and landscape are characterised by multiple volcanic depositional phases for the last about 50 ka in the Sila mountains and about 70 ka or more in the Nebrodi mountains. Chemical-mineralogical analyses enabled the detection of deposition phases during the Pleistocene and also Holocene. The multi-method approach enabled the identification of potential source areas, provided a tentative age estimate of the start (and in part duration) of ash deposits and therefore improved our understanding of volcanic landscape evolution.

1. Introduction

Volcanic eruptions are spectacular natural events (Giaccio et al., 2008) that have captured man's curiosity since prehistoric times. On the one hand, they can be of great benefit to man (e.g. increased soil fertility), but on the other hand they can also cause great harm (Fisher and Schmincke, 1984; Sulpizio et al., 2014; Sandri et al., 2016). In a large part of the world, today's landscape has been predominately formed since the late Quaternary period. In those last two and half million years, the Mediterranean region was marked by numerous spectacular natural and highly explosive volcanic events (Paterne et al., 2008; Scarciglia et al., 2008; Bourne et al., 2015). These events have clearly left their marks on the landscapes. Fine volcanic material generally affects large areas around volcanic centers (Giaccio et al., 2008).

* Corresponding author.
E-mail address: markus.egli@geo.uzh.ch (M. Egli).

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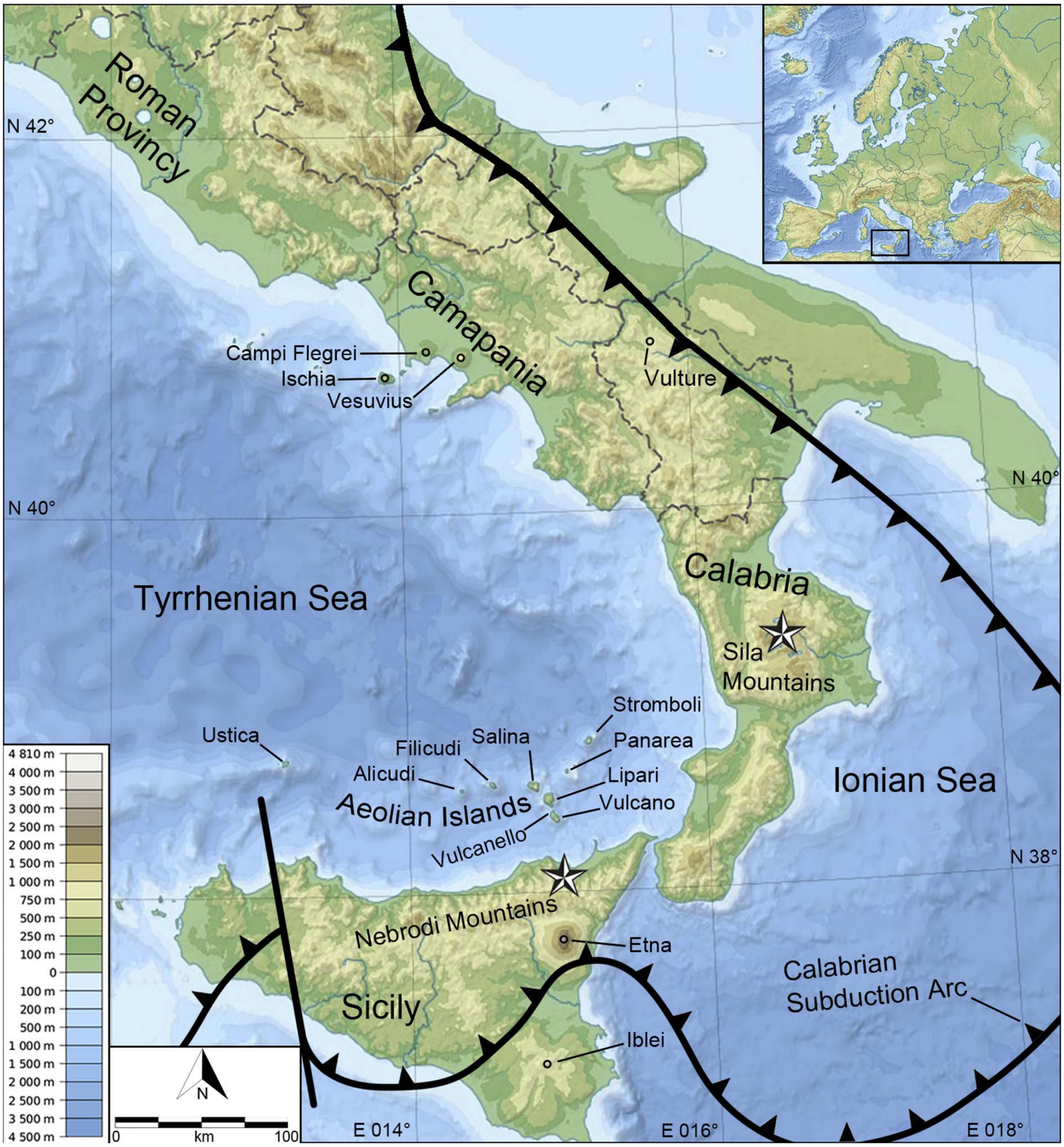

Fig. 1. Location of the study areas. The two stars mark the investigation sites in the Nebrodi and Sila mountains.

Chemical evaluation of this fine grained material is a powerful tool for Quaternary studies, providing not only a target for dating, but also a means to correlate specific deposits to a specific source, sometimes located at a great distance (Giaccio et al., 2008). According to Zimmerer et al. (2016), information about timescales of magmatism and ages of eruptions is crucial to understanding the history as well as the hazards of active and dormant volcanic areas. These authors also claim that knowledge of eruption ages can be further used to calculate hazard parameters such as recurrence intervals and repose periods, as well as to identify vent migration patterns that are crucial to eruption forecasting. In spite of their social and geological importance, chronologies for Quaternary volcanic events remain poorly understood (Zimmerer et al., 2016). To date, several numerical methods have been used for dating volcanic sediments, such as radiocarbon (^{14}C), potassium-argon decay ($^{40}K/^{39}Ar$), fission-track geochronology, uranium-lead decay ($^{235}U/^{207}Pb$) or cosmogenic nuclides (^{10}Be). However, the necessary conditions for successful application of these numerical methods are often not fulfilled and hence relative dating techniques remain an essential tool (Favilli et al., 2009a, 2009b). A multi-method approach, i.e. a combination of numerical analyses and relative dating methods, can possibly yield more accurate results (Giaccio et al., 2008). The Italian Mediterranean Basin is a complex and volcanically active zone in Europe (Pichler, 1984) with abundant ash fall. Despite their wide spread occurrence (about 7% of the soil area has volcanic deposits as parent material; Costantini and Dazzi, 2013), the source of volcanic sediments is still unknown in many areas. Throughout Sicily and mid- to southern-Italy, the large physical presence of volcanic materials is a constant reminder of the intense volcanic activity of the area. The origin of much of this volcanic material is unknown due to the abundance and activity of different volcanoes in close proximity (Giaccio et al., 2008). Here we attempted to trace the origin of volcanic sediments in southern Italy (Sicily/Calabria) and to