Catena 171 (2018) 299–315

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Role of weathering of pillow basalt, pyroclastic input and geomorphic processes on the genesis of the Monte Cerviero upland soils (Calabria, Italy)

Anna Chiara Tangari[a,*], Fabio Scarciglia[b], Eugenio Piluso[b], Lucia Marinangeli[a], Loredana Pompilio[a]

[a] Dipartimento di Scienze Psicologiche, della Salute e del Territorio (DiSPUTer), Università di Chieti-Pescara, 66013 Chieti, Italy
[b] Dipartimento di Biologia, Ecologia e Scienze della Terra (DiBEST), Università della Calabria, Via P. Bucci – Cubo 15B, 87036 Arcavacata di Rende, CS, Italy

ARTICLE INFO

Keywords:
Pillow basalts
Weathering
Soil genesis
Pyroclastic input
Erosion
Central Mediterranean

ABSTRACT

In this paper we present new data on weathering and soil formation processes affecting alkaline pillow basalts on the summit of Mt. Cerviero (Calabria, southern Italy). We investigated two representative soil profiles using an integrated approach, including pedological, petrographic, mineralogical and geochemical investigations. We distinguished the main features inherited from the hydrothermal alteration of the pillow basalts in a submarine environment from the chemical weathering processes under meteoric conditions. Irregular geochemical patterns and chemical index of alteration values across the soil profiles indicate a lithological discontinuity between the bedrock and the upper soil horizons, as a response to soil rejuvenation, in turn controlled by erosive processes and an allochthonous pyroclastic input. The soil profiles display poor horizonation and an incipient to intermediate degree of weathering, in line with the clay mineralogy (chlorite or hydroxy-interlayered vermiculite, illite, kaolinite and varying mixed-layers). The degeneration microtextures of clay and iron-manganese coatings in one soil profile suggest their relict genesis, with an emplacement under warm-humid conditions during the last interglacial. A Late Pleistocene to Holocene age of soil development is supported by the trachytic composition of volcanic micropumices, correlated to explosive eruptions from the Campania Province or the Aeolian Islands, in both soil profiles. Geochemical indices obtained from selective extractions of pedogenetic Al, Fe and Si pools point to poor andic properties with humus-Al-complexes prevailing over short-range order minerals. Nonetheless, the latter are consistent with the presence of volcanic glass, an optically isotropic pedogenic matrix and the Andosol-like field features of the soil profiles, even if they developed in a non-volcanic area. This should lead to a partial reassessment of the volcanic versus non-volcanic origin of certain Andosols worldwide and claims a good field work as a basis for choosing the best-suited laboratory methods to fill the gap between ordinary lab and field results.

1. Introduction

Studies of weathering and soil-forming processes on basaltic rocks have been approached with a large variety of investigation methods, at different scales and in several environments, as documented in the current literature. The published studies provide information on the morphological textures produced by chemical and physical weathering processes, weathering of primary minerals, mineralogy of neoformed products, rock and soil geochemistry, including isotopes. Other topics are the degree and rates of the weathering processes and soil development, relationships with relief features and landscape evolution, paleoweathering and climatic signature (e.g., Prudêncio et al., 2002; Sayyed, 2014; Conceição et al., 2015; Taboada et al., 2016).

Previous studies focused on basalt soils in the peri-Mediterranean area are mainly localized to the southeastern (Singer, 2007; Lucke et al., 2014), southwestern (Hamidi et al., 1999; Dekayir and El Maâtaoui, 2000) regions, and insular Italy (Egli et al., 2008; Vacca et al., 2009; Vingiani et al., 2010). The knowledge of weathering and pedogenetic processes occurring on basaltic parent rocks in mountainous environments of the central Mediterranean area is quite poor. These sites are characterized by significantly more humid climate compared to the Mediterranean coastal areas. In addition, only few papers focus on the weathering and soil formation processes affecting pillow basalts (e.g., Polat et al., 2012; Žigová and Štastný, 2014), which are very peculiar rocks in terms of genesis and corresponding primary features.

* Corresponding author.
E-mail address: a.tangari@unich.it (A.C. Tangari).

https://doi.org/10.1016/j.catena.2018.07.015
Received 23 November 2017; Received in revised form 12 July 2018; Accepted 13 July 2018

In this paper, we present new data on the weathering and soil formation processes involving basaltic pillow lavas which outcrop in the Monte Cerviero area (Calabria, southern Italy). Although pillow basalts have a tholeiitic geochemical affinity and form in mid-oceanic ridge settings, the pillow basalts of the study area show an alkaline geochemical affinity and were intruded in a submarine environment within Meso-Cenozoic carbonatic sequences. These features represent an intriguing case study in order to assess soil formation processes on alkaline basalts.

We analyzed the weathering products which formed on the basalts which were emplaced in a submarine environment and subsequently emerged and exposed to subaerial, meteoric conditions. We tried to distinguish the main features inherited from hydrothermal alteration from those diagnostic of weathering processes under environmental conditions. We also explored the potential contribution of fine volcanic ash (not easily visible, either to naked eyes or under the optical microscope) on soil formation processes, which is usually poorly investigated in basalt-derived soils (Rasmussen et al., 2010; Taboada et al., 2016). Since in recent years soils with andic properties were largely described worldwide in non-volcanic ecosystems, spanning a wide range of parent materials and climatic conditions (Bäumler et al., 2005; Dümig et al., 2008; Mileti et al., 2013), our work is relevant to test the hypothesis that the Andosol-like field appearance of the pedons, along with corresponding andic properties estimated in the lab, could be considered as proxies of cryptotephras even in non-volcanic areas. This would have important implications on tephrostratigraphy, geochronology and reconstruction of Quaternary landscape evolution (Scarciglia et al., 2008; Pelle et al., 2013; Vingiani et al., 2014), as well as help the assessment of fertility and susceptibility to land degradation of andic soils, which are particularly fragile ecosystems subject to soil erosion and landslides (Terribile et al., 2007; Arnalds, 2013; Henry et al., 2013).

2. Geology, geomorphology and climate of the study area

Mount Cerviero is part of the mountainous group of the Pollino Massif, located at the Calabria-Lucania boundary of the southern Apennine fold-and-thrust belt (southern Italy). It consists of an isolated relief, reaching an altitude of 1443 m a.s.l. (Fig. 1A). Mt. Cerviero emerges from a flat to gently rolling landscape, which consists of old planation surfaces (paleosurfaces), shaped during the Late Pliocene-Early Pleistocene and uplifted at different elevations above 1100 m a.s.l. (Schiattarella et al., 2013, 2017). The whole area is dominated by a wide exposure of the Middle Trias to Early Miocene limestone-dolostone sequence (Amodio Morelli et al., 1976; Grandjaquet and Grandjaquet, 1962; Iannace et al., 2005), exhumed during Miocene age (Iannace et al., 2007) and strongly affected by typical karst processes. Sheet wash, soil creep and colluvial dynamics also occur, especially on bare to sparsely vegetated surfaces, with local gravity-driven phenomena, such as falls, topples, translational slides and debris flows/avalanches along steeper slopes. Alkaline basalt intrusions within the carbonatic rocks outcrop at places (Pierattini et al., 1975; Macciotta et al., 1986; Matrangolo, 2013).

From bottom to top, the calcareous-dolomitic sequence includes (Fig. 1A): Late Triassic black and white dolomite; Jurassic-Cretaceous limestone and metalimestone with cherts; Paleocene to Early Miocene (?) calcirudites and calcarenites with nummulites, and limestone breccias (Ghisetti and Vezzani, 1983; Iannace et al., 2004).

The mafic rocks consist of pillow lava basalts cross-cutting the Triassic-Paleocene sequence. The age of the basalts is still debated. Proposed emplacement ages vary between Middle Eocene (Quitzow, 1935) to Early Miocene (Grandjaquet and Grandjaquet, 1962), although more recently Iannace et al. (2007) placed the basaltic magmatism in the Cerviero area within the Jurassic period. K/Ar geochronological dating of the basaltic intrusions yields an Early Miocene age, which was also attributed to the greenschist metamorphism, well documented in the carbonatic rocks (Pierattini et al., 1975).

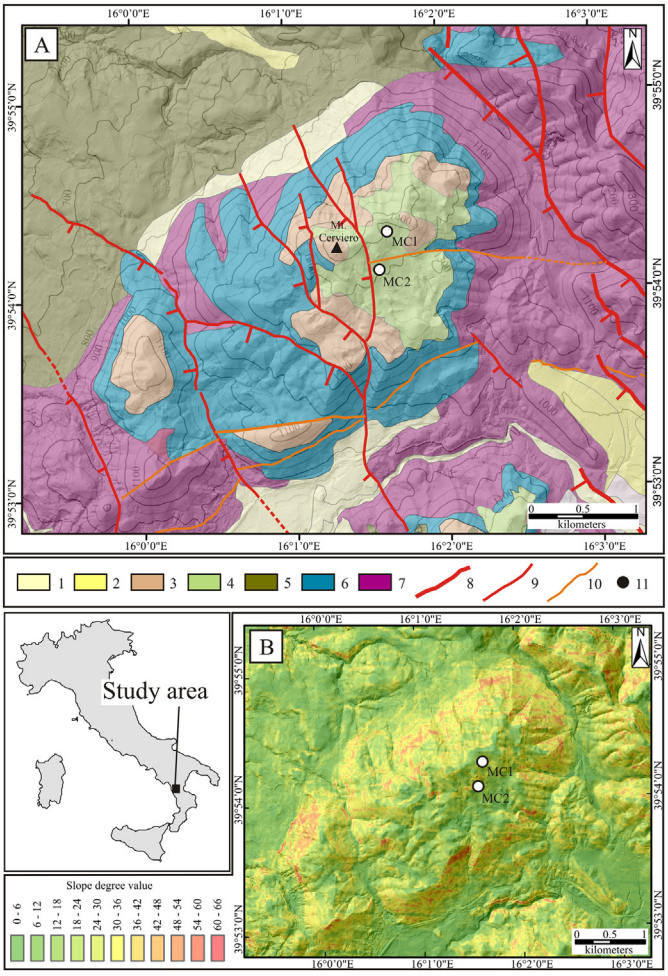

Fig. 1. (A) Geological-structural sketch of the sampling area (modified after CASMEZ, 1954; Servizio Geologico d'Italia, 1971; Ghisetti and Vezzani, 1983; Iannace et al., 2004; Brozzetti et al., 2017): 1 = Late Pleistocene-Holocene alluvial fans, colluvium and slope debris; 2 = Middle to Late Pleistocene fill of the basin (mainly lacustrine); 3 = Paleocene to Early Miocene(?) calcirudites and calcarenites with nummulites, and limestone breccias; 4 = pillow basalts; 5 = Upper Jurassic to Early Cretaceous weakly schistose argillites and slates with intercalations of quartzites and calc-schists; 6 = Jurassic-Cretaceous limestone and metalimestone with cherts; 7 = Late Triassic black and white metadolomite; 8 = Late Pleistocene to Holocene west-dipping normal fault; 9 = Early-Middle Pleistocene west-dipping normal fault; 10 = Early to Middle Pleistocene south-dipping normal fault; 11 = sample site. (B) Slope map of the study area. The circles indicate the location of the soil profiles.

Mt. Cerviero is characterized by temperate humid climatic conditions typical of Mediterranean upland climate, with mean annual precipitation around 1600 mm and mean annual temperature around 8 °C, with udic and mesic moisture and temperature regimes (ARSSA, 2003).

3. Materials and methods

Based on the major soil types described in the summit landscape of Mt. Cerviero, where shallow to moderately deep Cambisols, Regosols and Phaeozems or Umbrisols (cf. ARSSA, 2003) occur, and basaltic rocks outcrop for only 1 km^2, we accomplished a field soil survey and selected two representative soil profiles (MC1 and MC2) developed on top of the pillow basalts. Both the soil profiles were sampled on gentle slopes of the Plio-Pleistocene planation surfaces at an elevation of about 1330 m a.s.l. (Fig. 1B). The field study focused on a detailed morphological description of the major soil features, such as depth, color,