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Sr and Nd isotopes as tracers in pedogenic studies: Evidence for Saharan dust contribution to the soils of Muravera (Sardinia, Italy)

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ABSTRACT

Sr and Nd isotopes were applied to 5 soil profiles from the Muravera area, in south-eastern Sardinia.

All the soils, which have developed during the Quaternary on the Lower Paleozoic metamorphic basement except for one on Eocene carbonates, are located far from major sources of pollution. Therefore, they are suitable for testing pedogenic processes and geochemical evolution to benefit for environmental studies.

The Sr isotopic ratios range largely ($\delta^{87}Sr = 1.7–65.9‰$), even in each soil profile. In particular, the observed increase of $\delta^{87}Sr$ with depth in the most of the metamorphic rock-based soils can be accounted for by the downward decrease of Sr contributions from organic matter and Saharan dust, both displaying lower isotopic ratios than the soil bedrocks. The carbonate rock-based soil exhibits $\delta^{87}Sr$ higher (1.7–18.1‰) than the bedrock, indicating a significant contribution of radiogenic Sr from the siliciclastic fraction of the soil, and probably from dust input. The Nd isotopic ratios are slightly variable through the profiles (ε_{Nd} from −7.8 to −14.5), confirming little mobility of Nd and Sm during the pedogenesis. Among the minerals present in the soils, phosphates, albite, and calcite are those important in providing low radiogenic Sr and Nd to organic matter of the soils.

Lastly, this isotopic study has in particular allowed for evaluating the potential proportion of contribution of Saharan dust to south-eastern Sardinia, thus corroborating the findings of other studies related to soils from the central-western Mediterranean.

1. Introduction

Unlike in other Countries (e.g. Borg and Banner, 1996; Steinmann and Stille, 1997; Martin and McCulloch, 1999; Kurtz et al., 2001; Aubert et al., 2002; Pett-Ridge et al., 2009; Stille et al., 2009), the coupled application of Sr and Nd isotopes to the study of soils is still a novelty in Italy (Castorina and Masi, 2007, 2008). In particular, Sr isotopes have been applied to soil sciences since the late 1980s (e.g. Åberg et al., 1989; Blum and Erel, 1997; Bullen et al., 1997; Capo et al., 1998; Stewart et al., 1998; Vitousek et al., 1999; Green et al., 2004; Poszwa et al., 2004; Drouet et al., 2005), showing that they can be important tracers applicable not only to large-scale ecosystem studies, but also to short-scale to describe chemical weathering, pedogenesis, cation provenance, and mobility. The application of Nd isotopes as tracers of rock weathering processes and mobilization of rare earth elements (REE) in soils is more recent, probably because REE have long been considered immobile in the most of supergenic processes. It has been emphasized that the Nd isotopic composition dominantly reflects the provenance of soil components (e.g. Borg and Banner, 1996; Steinmann and Stille, 1997; Öhlander et al., 2000; Viers and Wasserburg, 2004; Roig et al., 2006). In particular, Öhlander et al. (2000) showed that Nd is preferentially released from minerals with a lower Sm/Nd ratio than the bulk soil, leading to lower $^{143}Nd/^{144}Nd$ ratio in the initial stages of weathering. Viers and Wasserburg (2004) demonstrated that the soil evolution involves the differential dissolution of primary phases of the parent rock, surface waters, and the atmospheric REE input via dust from even far regions, as well as the formation of diagenetic phases, particularly phosphates, indicating contributions from different reservoirs to soils. Nevertheless, the mechanisms controlling the REE fractionation and mobility in soils are still not fairly understood.

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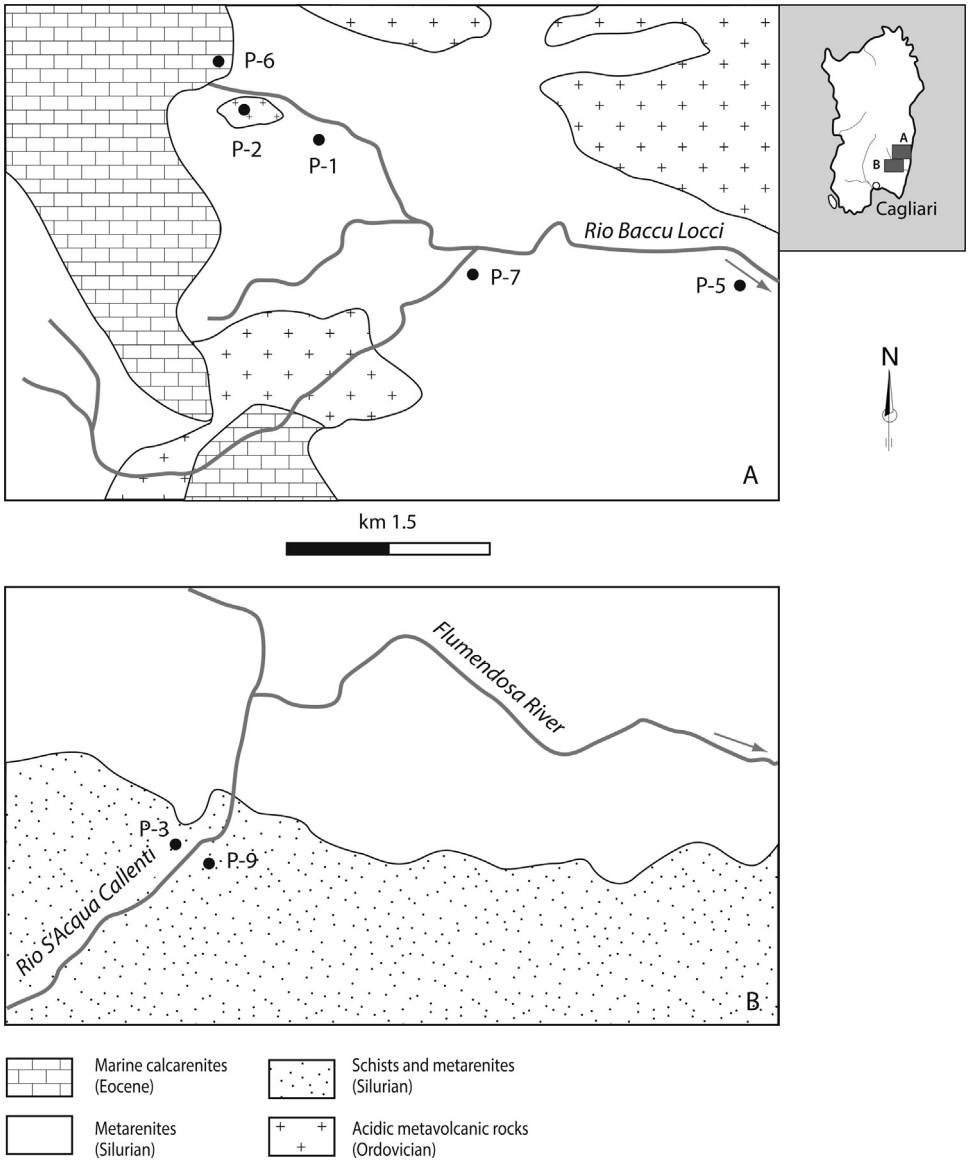

Fig. 1. Geological sketchy map of the study areas near Muravera (modified after Carmignani et al., 2001) showing the locations of the studied soils. The area depicted in (A) lay about 15 km NE of the area shown in (B). The locations of the P-3 and P-5 soils from the same territories (Castorina and Masi, 2007, 2008) are also shown (see text). The inset map shows the location of the study areas in Sardinia.

This paper presents a study conducted on 23 samples collected from 5 profiles located in the Muravera area, south-eastern Sardinia (Fig. 1), aimed at defining the bearing of Sr and Nd isotopes on the pedogenic and geochemical evolution of those soils. As the study area is remote from major sources of pollution such as industries, traffic, animal husbandry, agriculture, and towns, it provides a good test for studying natural processes. Moreover, as almost all the soils, although displaying different stages of pedogenesis, have developed on the same bedrock represented by the Lower Paleozoic metarenites known as *Arenarie di san Vito* (Scarciglia et al., 2013), this can be useful for tracing the soil evolution through time.

Another major goal of this paper is the estimation of the potential aeolian deposition of dust on the soils. In this context, a number of papers unveiled that deserts provide significant material to the most of soils throughout the world (e.g. Spencer et al., 1995; Kurtz et al., 2001; Aubert et al., 2002; Nakano et al., 2004; Lahd Geagea et al., 2008b; Lawrence et al., 2011), including the Mediterranean area (e.g. Moulin et al., 1997; Yaalon, 1997; Nicolás et al., 2008; Erel and Torrent, 2010). In particular, Nicolás et al. (2008) found that Saharan dust makes up to 5–40% of the total concentration of PM_{10} deposited on southern Spain, and Erel and Torrent (2010) were the first researchers to have applied Sr isotopes to recognize the significant (33–86% in Al–silicates of the fine soil fraction) contribution to two soils from such area. In the Mediterranean, Sardinia is a favorable land for ascertaining the potential aeolian deposition, laying on storm trajectories from the Sahara to central Europe. The first study on aeolian deposits (from unknown sources) on Sardinian soils was carried out by Sevink and Kummel (1984). Later, Le-Bolloch et al. (1996) estimated that the present-day dust deposition on southern Sardinia ranges between 6 and 13 g/m^2. The Saharan contribution, although of modest magnitude, was also documented in paleosoils from the island by Genova et al. (2001) and Andreucci et al. (2012).

Lastly, the Sr isotopic data of the studied soils have been merged with those of two other profiles from the same area, developed on the same bedrocks (Castorina and Masi, 2007, 2008), thus obtaining a more representative set of data to corroborate the conclusions of this paper. We have also compared the Sr–Nd isotopic characteristics of the Sardinian soils with those of soils from other areas,