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Research paper

Luminescence dating of scoria fall and lahar deposits from Somma–Vesuvius, Italy

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ABSTRACT

Luminescence dating has been applied to scoria and lahar deposits from Somma–Vesuvius, Italy. Samples include scoria from the AD472 and 512 (or 536) eruptions and lahar deposits. In order to find a stable luminescence signal which is less affected by anomalous fading, infrared stimulated luminescence (IRSL) signals at elevated temperatures after bleaching with IR at 50 °C (termed post-IR IRSL; pIRIR) were tested at different preheat and elevated stimulation temperatures. The fading rates of both IRSL and pIRIR signals reduced dramatically with increasing preheat and pIRIR stimulation temperatures. A pIRIR signal measured at 290 °C after a preheat at 320 °C (60 s) and an IR stimulation at 50 °C (100 s) was selected to calculate the equivalent dose (D_e). The gamma spectrometry results indicate that the U-series nuclides are not in equilibrium and there is a large ^{226}Ra excess. The dose rates and ages were calculated by assuming a ^{226}Ra excess (over its parent ^{230}Th) at deposition, and that this unsupported excess then decayed to the present level. The resulting luminescence ages of the two scoria samples agreed with the expected ages, and the ages of the lahar deposits indicate that they are associated with the AD1631 eruption.

1. Introduction

Luminescence dating has been successfully applied to various Quaternary sediments using quartz and K-feldspar minerals (e.g. Murray and Olley, 2002; Buylaert et al., 2012). Basaltic lava samples were tested for thermoluminescence (TL) dating by Wintle (1973), however, she found that TL signals from various types of feldspars in the lava show a large athermal signal loss (i.e. anomalous fading) of up to 40% within a day after an artificial irradiation, leading to an underestimated age. Since then attempts to date basaltic samples using luminescence have been limited, although more recently the luminescence characteristics of basalts have been discussed in the context of using luminescence methods for the dating of Martian basaltic sediments (e.g. McKeever et al., 2003; Jain et al., 2006; Kalchgruber et al., 2007). Tsukamoto and Duller (2008) found that among various luminescence signals from Martian analogue samples, infrared stimulated luminescence (IRSL) signals measured at 200 °C showed the lowest and relatively uniform fading rate at ~5–7%/decade. Based on this result, Tsukamoto et al. (2011) successfully dated two young basaltic lavas from the Cima Volcanic Field, USA (Cima-4, 13.5 ± 2.2 ka and Cima-6, 10.3 ± 1.2 ka) which have an independent age control of ~12 ka.

Thomsen et al. (2008) proposed the use of elevated temperature post-IR IRSL (pIRIR) measurements which minimises the anomalous fading of luminescence signals from feldspar. They showed that when feldspar samples are first bleached with IR at a lower temperature, and then measured again with IR stimulation at an elevated temperature, the latter signal is much more stable (fades less). This method has been tested by many researchers using both K-feldspar and polymineral fine grains (e.g. Buylaert et al., 2009, 2012; Li and Li, 2011; Thiel et al., 2011a,b,c; Thomsen et al., 2011), and most of these studies have found that there is no need to correct anomalous fading when a high preheat and pIRIR stimulation temperatures (e.g. preheat at 320 °C, pIRIR at 290 °C) or multiple-step elevated temperature measurements are used.

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In this study, we use scoria fall and lahar sediments derived from historical eruption events of Somma–Vesuvius, Italy to test the potential of pIRIR signals to the dating of volcanic materials. These samples contain abundant leucite ($KAlSi_2O_6$) phenocrysts, a feldspathoid with much lower SiO_2 content than feldspars, and also minor sanidine, $(K,Na)(Si,Al)_4O_8$. To our knowledge, neither feldspathoids nor sediments of basaltic origin have been successfully dated previously by luminescence methods.

2. Study sites and samples

Somma–Vesuvius is a volcanic complex located about 15 km east of Naples, Italy (Fig. 1) and is composed of an older summit caldera, Somma (1131 m a.s.l.) and a more recent cone, Vesuvius (1281 m a.s.l.); the latter formed after the AD79 "Pompei" eruption. There are four known caldera-forming plinian-type eruptions from this complex, at 18.3 ka, 8.0 ka, 3.4 ka and AD79 (e.g. Cioni et al., 1999). After the AD79 eruption, two sub-plinian eruptions occurred in AD472 and 1631 as well as many small scale eruptions in AD512, 536, 685, 787, 968, 991, 999, 1006 or 1007, 1037, 1139, and 1944 (Principe et al., 2004). The volcanic products from Somma–Vesuvius have high alkali contents and are classified in most cases as tephriphonolite to phonolite. The majority of phenocrysts are clinopyroxene and leucite; sanidine and garnet are also observed (Santacroce et al., 2008).

2.1. Somma Vesuviana

Two scoria samples (SMV7 and SMV9) were collected in 2005 from an excavation of a Roman building complex in Somma-Vesuviana, at the northern foot of Somma–Vesuvius (Fig. 1). The site was first excavated in the 1930s and was then considered to be a villa of Emperor Augustus (Della Corte, 1932), but its true identity remains unknown. Since 2002 the site has been extensively re-excavated by a joint Japanese–Italian group of archaeologists and geoscientists (Aoyagi et al., 2005–6). Based on the whole rock chemical composition of the tephra in comparison with its type locality and radiocarbon dating of carbonised woods it has been confirmed that the site was first buried by the AD472 eruption of Somma–Vesuvius (Kaneko et al., 2005). Volcanic successions and the sequence of events burying the site have been extensively studied (Perotta et al., 2006; Niihori et al., 2007; Maeno et al., 2009).

SMV7 was collected from a ~30 cm thick scoria bed exposed in the south wall (Fig. 2a) containing 1–3 cm diameter scoria lapilli, lithic fragments of lava and other basement rocks (Niihori et al., 2007). The scoria bed was derived from the AD472 eruption (Kaneko et al., 2005). SMV9 was taken from a 35 cm thick scoria bed overlying lahar and/or fluvial deposits associated with the AD472 eruption and a palaeosol (Niihori et al., 2007, Fig. 2a). This scoria bed contains scoria lapilli (0.5–1 cm in diameter) and lithic fragments of lava and carbonates (Niihori et al., 2007), and is correlated with one of the eruptions in the 6th century (AD512 or 536; Perotta et al., 2006; Niihori et al., 2007).

2.2. Plunge-pool area

Three samples (SMV1, SMV2, and SMV3) were collected between the vent and the excavation site from a relict plunge-pool in a valley approximately 530 m a.s.l. in a northern flank of Somma–Vesuvius, approximately 3 km upstream of the excavation site. The 37–18 ka Cognoll lava (Santacroce and Sbrana, 2003) forms the bedrock of the plunge-pool, with columnar and tabular joints contributing to the formation of the vertical alcove morphology. According to Santacroce and Sbrana (2003) the 4 ka Avellino and AD 472 Pollena eruptives cover the surrounding ridgelines and the latter is also distributed in the mouth of the valley.

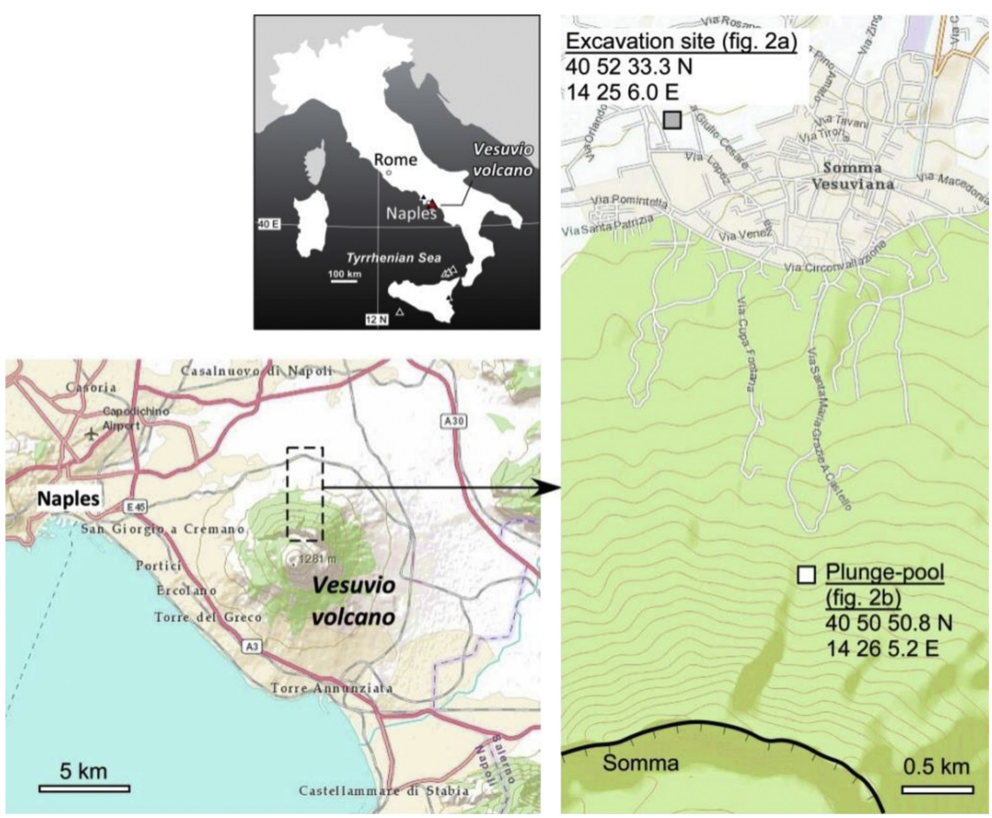

Fig. 1. Map showing the location of Somma–Vesuvius and the study sites.