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Tephra layers along the southern Tyrrhenian coast of Italy: Links to the X-5 & X-6 using volcanic glass geochemistry

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ABSTRACT

We present the geochemistry of glass fragments from three visible tephra layers outcropping in Southern Italy. Two tephra deposits (LeS1 and LeS2), outcropping in the Palinuro area (Cilento, Southern Italy), correspond stratigraphically to the CIL1 and CIL2 tephra units (Giaccio et al., 2012), respectively; in turn these are correlated with the X-5 (ca. 105 ka) and X-6 (ca. 108 ka) marine tephra markers on the basis of their major element glass compositions. In order to reinforce these tephra correlations we examine both their major and trace element glass compositions. LeS1 compositions were compared with other correlatives of the X-5 tephra layer (POP3 [Sulmona basin], TM-25 [Lago Grande di Monticchio (LGdM)], CIL1 [Palinuro]) from the central Mediterranean. Our data validate a correlation of the Palinuro tephra layer, LeS1, to the X-5 correlatives. The Palinuro tephra deposit, LeS2, has glass compositions which correspond precisely with correlatives of the X-6 marker tephra (CIL2 [Palinuro], TM-27 [LGdM], I-9 [Ionian Sea] and PRAD 2812 [PRAD1-2, Adriatic Sea]). A tephra in the Valle del Crati (Calabria) appears to overlap in composition with the LeS2 tephra, indicating a probable correlation with the X-6 marker. These new data provide a detailed geochemical characterisation of two widespread marker horizons and are crucial for establishing precise correlations of sedimentary archives across the central Mediterranean region.
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1. Introduction

Explosive volcanic eruptions are responsible for the widespread dispersal of ash (particle diameter < 2 mm) or tephra, and its near instantaneous deposition provides important stratigraphic markers recorded in a range of sedimentary records. Over the past few decades tephrostratigraphic investigations of marine and terrestrial sedimentary archives have played a fundamental role in stratigraphically constraining and synchronising Quaternary successions in the Mediterranean region. The central Mediterranean is particularly well placed to utilise tephra markers owing to an abundance of volcanoes, with differing geochemical signatures, that have been repeatedly active during the last 200 ka (e.g. Keller et al., 1978; Paterne et al., 1986, 1988, 2008; Sulpizio et al., 2003; Giaccio et al., 2008a, 2008b, 2009, 2012; Wulf et al., 2004, 2012; Siani et al., 2004; Lowe et al., 2007; Zanchetta et al., 2008). Key tephrostratigraphic markers rely upon (1) a widespread dispersal from a volcanic source and; (2) their chemical and petrographic fingerprints being well characterised, enabling the identification of diagnostic features unique to individual eruptions. Where a tephra can be attributed to a specific eruption of known age it can provide an important chronological marker. Linking distal tephra deposits to dated (i.e., $^{40}Ar/^{39}Ar$; ^{14}C) proximal tephra units is not always possible, with resurgent explosive activities often destroying the volcanic stratigraphy of older eruptive events (Di Vito et al., 2008; Zanchetta et al., 2008; Albert et al., 2015). In these instances the dating of an eruption must be determined in the distal realm through direct dating (e.g., $^{40}Ar/^{39}Ar$; Smith et al., 2011a; Giaccio et al., 2012) or indirect dating (e.g., varve chronologies; Wulf et al., 2004, 2008, 2012). Through rigorous geochemical correlations the age of distal tephra markers can then be exported between sedimentary archives.

Both proximal–distal and distal–distal tephra correlations are increasingly underpinned by volcanic glass geochemistry. Furthermore it is widely accepted that distal tephra layers should be correlated to proximal glass chemistries rather than whole rock compositions because proximal tephra deposits are often richer in phenocryst phases. In contrast during wind transport, density sorting means that the distal ash deposits are enriched in the light, glassy components, and depleted in the heavier, crystalline or lithic fractions. As a consequence the composition of a distal tephra is not directly comparable to proximal, crystal rich, whole rock compositional data as this can lead to erroneous correlations (see E. Tomlinson et al., 2012; E.L. Tomlinson et al., 2012). It is also recognised that major element compositions of volcanic glass cannot always be sufficient for precise correlations, this is because the products of the same magmatic source can produce indistinguishable major element compositions through successive eruptions (Allan et al., 2008;

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Giaccio et al., 2008a; E. Tomlinson et al., 2012). Moreover, as the tephra layers can often show a certain degree of alteration, their content in mobile elements, e.g. alkalis, can be modified by the weathering process. More recently some authors have proposed that tephra correlations can be strengthened by assessing the trace element concentrations in the glass shards and minerals (De Rosa et al., 2008; Smith et al., 2011a, 2011b; E. Tomlinson et al., 2012; E.L. Tomlinson et al., 2012; Albert et al., 2012). The advantage in using trace elements is that their concentrations are generally more variable between eruptions from the same volcanic source owing to their greater sensitivity to fractionation processes (i.e., Allan et al., 2008; Albert et al., 2015); in addition, some trace element concentrations (i.e. immobile High Field Strength Elements) are less susceptible to modification by weathering processes.

The X-5 and X-6 tephras represent two key Late Quaternary central Mediterranean tephrostratigraphic markers within the post Interglacial MIS 5e period (MIS 5a-d or Early Weichselian) owing to their widespread distribution across the region (Fig. 1). These tephra layers were first identified within Ionian Sea marine cores (Keller et al., 1978), below sapropel 4, their trachytic compositions linking them to Campanian volcanic activity. The Ionian Sea X-6 and X-5 tephras have been successively recognised in many Mediterranean marine, lacustrine and terrestrial sequences. Paterne et al. (2008) recognised the two levels in the Tyrrhenian and Ionian Sea cores; the C-27 is correlated with X-5, whilst C-31 corresponds to X-6. X-5 and X-6 are also thought to occur interbedded within the proximal pyroclastics of Salina and Panarea (Aeolian Islands, Lucchi et al., 2013). The X-6 has also been reported in central Adriatic Sea (Bourne et al., 2015), in the Ionian Sea (Insinga et al., 2014) and in the Balkan region (Sulpizio et al., 2010).

The X-6 and X-5 tephras are also recorded in the annually laminated lacustrine sequence of Lago Grande di Monticchio (LGdM; Monte Vulture, Southern Italy). TM-27 is the recognised correlative of X-6 tephra at LGdM (Wulf et al., 2012), and following a recent re-appraisal TM-25 is considered the LGdM equivalent of the X-5 tephra (Wulf et al., 2012). The X-5 had been previously assigned to the slightly younger LGdM tephra layers TM-24a and b. The varve chronology of LGdM means that these eruptions can be independently dated (Table 1). In a recent paper the two tephra markers have been found in the subaerial environments of southern and central Italy, both the Sulmona basin and along the Cilento coast (Giaccio et al., 2012; Regattieri et al., 2015). Direct and indirect age determinations presented for the proposed distal equivalents of these two tephra markers are consistent with their stratigraphic positions within sediments deposited immediately following the termination of the Last Interglacial (MIS 5e) (Table 1).

The composition of X-5 tephra is trachytic (Wulf et al., 2012; Giaccio et al., 2012), while the X-6 has been reported as a trachy-phonolite (e.g. Wulf et al., 2012; Iorio et al., 2014) to trachyte (Giaccio et al., 2012; Regattieri et al., 2015). Tephra correlations associated with the X-5 and X-6 tephras are predominantly underpinned by stratigraphy and major element glass chemistry (EDX or EMP), indeed only limited trace element data is currently available for X-5 and X-6 correlatives. Such trace element data is crucial in helping to prevent erroneous tephra correlations, particularly if we consider the significant major element

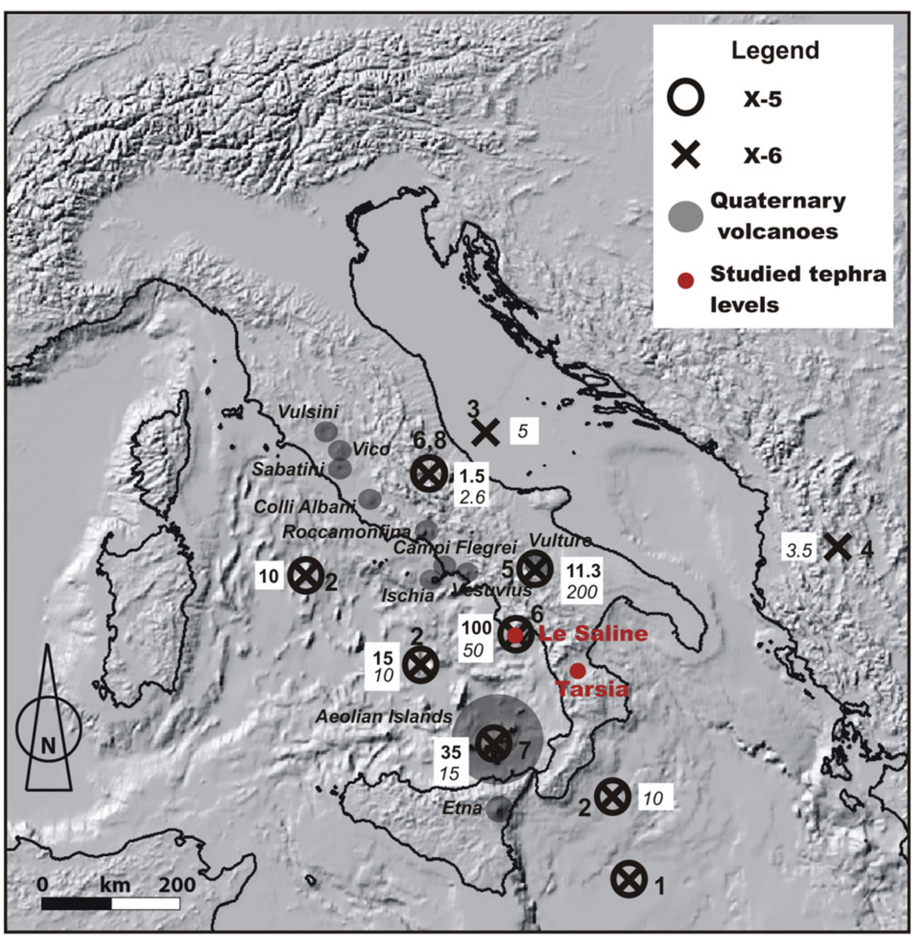

Fig. 1. Distribution of X-5 and X-6-related tephra layers in the central Mediterranean region. 1: Keller et al. (1978); 2: Paterne et al. (2008) and refs. therein; 3: Bourne et al. (2015); 4: Sulpizio et al. (2010); 5: Wulf et al. (2007); 6: Giaccio et al. (2012); 7: Lucchi et al. (2013); 8: Regattieri et al. (2015). Numbers in white squares indicate the thickness of tephra layers in centimeters; numbers in italics are referred to X-6-related tephras, bold numbers to X-5-related tephras. Red dots indicate the location of the tephra layers studied in this paper. The major Italian volcanic centers active during the Late Quaternary are also shown.

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