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Seismic hazard assessment at Mt. Vesuvius: Maximum expected magnitude

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Abstract

This paper deals with the problem of seismicity at Mt. Vesuvius with a view to providing an estimation of the maximum expected earthquake. Integrated analysis of both historical and current seismicity as well as the geological conditions of Vesuvius and the surrounding areas show that seismogenetic structures may fall within the crater axis and at the boundaries of the volcanic complex. While activation of the whole seismogenetic volume detected by seismicity in the past 30 years would indicate a total seismic moment of Mo = 7.1E+ 15 Nm for a magnitude M = 4.5, knowledge of the area's geological structure suggests faulting surfaces of about 32 km^2 with an associated magnitude of M = 5.4. The areas of maximum expected damage differ according to the orientation of the hypothesized structure. Analysis of geological and geophysical data and the damage associated to the AD 62 earthquake shows that the prevailing directions in the faulting planes are NE–SW in the eastern sector of the volcanic complex, and roughly WNW–ESE in the southern part of the volcano along the coast.

Comparison of instrumental seismicity and historical data reveals two significantly different energy levels: a lower earthquake level with Mmax = 4.5, corresponding to current seismicity and that which accompanied volcanic activity in the eruptive period from 1631–1944; an upper level with Mmax = 5.4, represented by the AD 62 earthquake. The two levels correspond to two stress states and different seismogenetic structures.

Keywords: Mt. Vesuvius; seismic hazard; historical seismicity

1. Introduction

To evaluate the maximum earthquake expected at Vesuvius, data are required on the location, source mechanism and damage levels of historical earthquakes, in addition to understanding how the volcano works. From the historical data there is no clear evidence for events with magnitudes greater than 4.0–4.5 except the earthquake which occurred in 62 AD, 17 years before the 79 AD plinian eruption which completely buried the towns of Pompeii, Herculaneum, Oplontis and Stabiae. It is, however, not yet clear whether this event was located in the magma feeding shallow structure or rather along an active fault at the boundary of the volcano (Sigurdsson et al., 1985; AA.VV., 1995; Marturano and Rinaldis, 1998).

At Vesuvius the risk associated to a large eruption is very high since 600,000 people live on the volcano and a further 2,000,000 are located around it, but complete assessment means including the potential damage due to earthquakes accompanying the largest eruptions.

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Moreover low-moderate energy earthquakes are also observed in volcanically active areas during quiescent periods. Generally such events are shallow and produce high intensities in the epicentral area. Today at Vesuvius the high housing density and economic value exposed make the area of considerable importance for mitigating seismic risk (Cherubini et al., 2001).

In volcanoes the stress field generating seismicity is made even more complex than in tectonic areas because, in addition to the regional stress field, there is that generated by the migration of magmatic masses towards the surface, as well as the rheological properties of the rocks conditioned by the high geothermal gradient.

In the present paper the data set of historical seismicity is built up using reliable sources from classical and medieval times and instrumental seismicity which has been available since the 1944 eruption. During this last time span the most reliable data have been available since 1970 when a modern seismic network was installed for monitoring the seismicity of Vesuvius. Such data will be correlated to the structural framework of the volcano basement to define the suspected seismogenetic sources and evaluate the maximum earthquake expected at Mt. Vesuvius.

2. Volcanic history and seismicity

Eruptive activity in the Vesuvius area dates back about 400 ka although the volcano edifice formed only in the last 25 ka. The recent crater was built inside an older stratovolcano, Monte Somma, and since 1944 has been quiescent (Santacroce, 1987; Brocchini et al., 2001; Santacroce and Sbrana, 2003). The earliest eruptive history of Mt. Vesuvius has been reconstructed on the basis of stratigraphic and radiometric studies of volcanic products and palaeosoils, whereas its later history, which begins with the eruption of 79 AD, has been reconstructed from the direct descriptions of eruptive events as well. The volcano produced at least five large-scale plinian eruptions (18,300 ±180 years BP, 16,130 ±110 years BP, 8010 ± 35 years BP, 3760 ±70 years BP, and 79 AD) and smaller-scale subplinian eruptions (Santacroce and Sbrana, 2003). After the Avellino eruption (3760 ±70 years BP) the volcano continued with subplinian and strombolian eruptions for a few centuries (Rolandi et al., 1998; Santacroce and Sbrana, 2003), and then became quiescent for several hundred years until the eruption in AD 79 (Sigurdsson et al., 1985; AA.VV., 1995; Marturano and Rinaldis, 1998; Luongo et al., 2003; Marturano, 2006).

The activity of Mt. Vesuvius during the early centuries of the first millennium and Middle Ages is not very well known. After the subplinian eruption of 472 Vesuvius was active until the twelfth century (Arnò et al., 1987; Figliuolo and Marturano, 1995; Mastrolorenzo et al., 2002; Rolandi et al., 2004). There then followed a long period during which no significant eruptive events took place until 1631 when the volcano resumed its activity with a subplinian eruption (Rolandi et al., 1993; Rosi et al., 1993). From 1631 to 1944 the volcano produced 18 eruptive periods of small and medium-sized eruptions from both terminal and side vents (Santacroce and Sbrana, 2003) (Fig. 1).

The oldest seismic events recorded by Suetonius (Tiberius 74,2) in the Vesuvian area occurred in AD 37 when, a few days before the death of the emperor Tiberius, an earthquake brought down the lighthouse on Capri. On 5 February in AD 62 a strong earthquake hit Campania, causing considerable damage to Pompeii and Herculaneum and relatively minor damage to Naples and Nuceria (Tacitus, Ann. XV.22.1; Seneca, NQ VI. 1.1–3), with maximum intensity of IX MCS degree and a magnitude of about $M=5$ (Fig. 2). In light of recent archaeological and epigraphic evidence, this earthquake and subsequent low-moderate energy seismic swarms have been considered as precursors of the AD 79 eruption (AA.VV., 1995; Marturano and Rinaldis, 1998; Cubellis and Marturano, 2002a ; Luongo et al., 2003; Cubellis and Marturano, 2006).

In AD 64 a seismic event occurred during a representation in the theatre in Naples when Nero was present

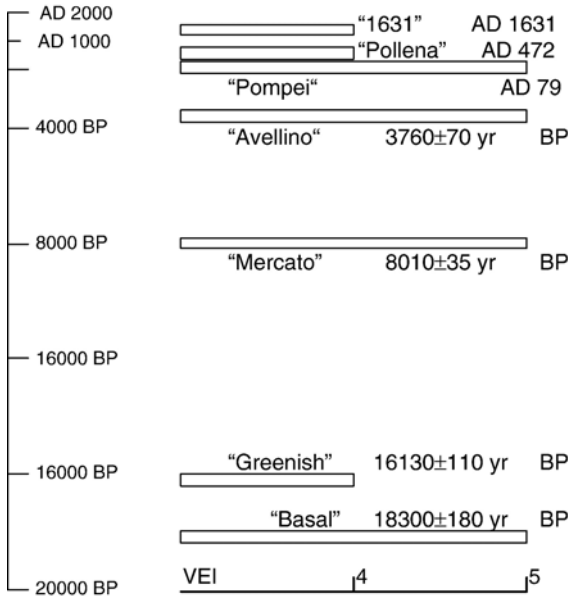

Fig. 1. Chronogram of Vesuvian activity in the last 18 ka (modified by Andronico et al., 1998). Plinian and subplinian eruptions (VEI 4–5) are reported.