Mt. Etna is located on the easter coast of the island of Sicily (Italy) and with a height of about 3350 m a.s.l. is the highest volcano in Europe. Several parasitic pyroclastic cones affect its flanks, concentrated along three main rifts converging at the summit (Rasà et al., 1992). The rift of the northern flank matches with a narrow deformed zone trending NE, known as the NE Rift. The southern flank rift is coincident with a NNW-SSE zone of normal right-lateral faults mainly dipping eastward. The western flank rift is characterized by a ENE-WSW striking strike-slip faults system (Fig. 1).
The parasitic pyroclastic cones provide a great amount of information that can help in distinguishing the geometry of buried magma-feeding fractures (e.g. Corazzato and Tibaldi, 2006 and reference therein). Parasitic pyroclastic cones are usually studied through the reconstruction of their stratigraphic position, the geological and morphometric characteristics, and growing process evolution in relation to the underlying magma-feeding fracture and subsurface morphology. Three main kinds of parasitic pyroclastic cones (right panel in Fig. 1) can be distinguished: i) simple cones characterized by a unique vent, having a plan from perfectly circular to markedly elliptical, ii) multiple superimposed cones represented by overlapping cones related to the same eruption where craters are aligned but do not interfere with each other and iii) multiple rifted cones represented by strongly elongated monogenetic edifices which usually have large dimensions (hundreds of metres).

The present study aims to provide, through a ambient vibrations survey, useful information to increase the knowledge on subsurface structure of Mt. Vetore pyroclastic cone which is located in the upper S rift zone. It is a simple cone with a unique elliptical shape vent having a maximum and minimum axis in the range 170-240 m (Fig. 2).

In this first survey we deployed, in the vent area, 6 single station ambient vibrations recording sites and a L shape geometry array, having two branches with length of 85 m (N-S direction) and 40 m (E-W direction) (Fig. 2).

Methodology. A quick estimate of the surface geology influence on seismic motion is provided by the horizontal to vertical noise spectral ratio technique (HVSR). This technique firstly introduced by Nogoshi and Igarashi (1971), was put into practice by Nakamura (1989) and became in recent years widely used since it provides a reliable estimate of the fundamental frequency of soft soil deposits. The good agreement observed between results obtained using earthquake records and ambient noise has pointed out that microtremors are a valid tool to investigate ground motion polarization properties (Rigano et al., 2008; Di Giulio et al., 2009; Panzera et al., 2017).
Ambient noise recordings were performed randomly in the Mt. Vetore cone area, sampling time series of 20 minutes length through a short period velocimeter, using a sampling rate of 128 Hz and processing data through the HVNR technique. According to common assumptions (Bard, 1998; Parolai et al., 2001), to compute HVSR, we subdivided the recorded signal taking care that at least 10 cycles of the lowest frequency analysed were included. Then, time windows of 20 s were considered and the most stationary part of the signal was selected excluding transients associated to very close sources. In this way the Fourier spectra were calculated in the frequency range 0.5-20.0 Hz and smoothed using a proportional 20% triangular window. Finally the resulting HVSR were computed estimating the logarithmic average of the spectral ratio obtained for each time window. The experimental spectral ratios were also calculated after rotating the horizontal components of motion by steps of 10 degrees starting from 0° (north) to 180° (south) in order to investigate about the possible presence of directional effects (left and right panels in Fig. 2). However, in presence of lateral and vertical heterogeneities or velocity inversion, the HVSRs can be “not-informative” due to the occurrence of amplification on the vertical component of motion (Panzera et al., 2015).

In this study we also applied the time-frequency (TF) polarization analysis proposed by Vidale (1986) and exploited by Burjánek et al. (2012 and reference therein). Following Burjánek et al. (2012), the continuous wavelet transform (CWT) was applied to signals in order to select time windows whose length matches the dominant period: signals were thus decomposed in the time-frequency domain and the polarization analysis was applied. For each time-frequency pair, polarization is characterized by an ellipsoid and is defined by two angles: the strike (azimuth of the major axis projected on the horizontal plane from North) and the dip (angle of the major axis, starting from the vertical axis). Another important parameter is the ellipticity that is defined, according to Vidale (1986), as the ratio between the length of the minor and major axes. This
parameter approaches 0 when ground motion is linearly polarized. Polarization strike and dip, obtained all over the time series analyzed, are cumulated and represented using polar plots where the contour scale represents the relative frequency of occurrence of each value, and the distance to the center represents the signal frequency in Hz (Fig. 3a). In order to assess whether ground motion is linearly polarized, the ellipticity is also plotted versus frequency.

The shear wave velocity of Mt. Vetore deposits (Fig. 3b) were investigated through non-invasive techniques such as $f_k$ analysis (Capon, 1969). A “L” array configuration (red lines in Fig. 2) was used for the ambient vibration measurements, recording 20 minutes of noise. The array was settled using a 26-channel seismograph and 4.5 Hz geophones. Time windows of 20 s were considered to calculate dispersion curves of the fundamental mode and the average of the dispersion curves was computed, excluding those not showing a clear dispersion or in which higher modes were dominant. In present study, the Rayleigh wave dispersion curves, obtained from the experimental setup, were inverted using the DINVER software (www.geopsy.org) which provide a set of dispersion curve models compatible with the experimental dispersion curve (Fig. 3b). The inversion process needs a rough definition of the free parameters. Since in our case, this information was not available, the input parameters were directly deduced from the fundamental mode of the Rayleigh wave dispersion curves. To invert the dispersion curve, a set of 3 uniform layers with homogeneous properties were considered, taking into account five parameters: shear waves velocity ($V_S$), thickness (H), compressional waves velocity ($V_P$), Poisson’s ratio (ν) and density (ρ).

**Results and discussions.** The present study shows preliminary results obtained through ambient vibrations measurements on the top of Mt. Vetore pyroclastic cone. The HVSR measurements (see Fig. 2, for locations) point out a clear seismic site effect, quite noticeable in the frequency range 1.0–4.0 Hz, showing a preferential resonance direction highlighted through rotated spectral ratios (Fig. 2). In particular, such effect occurs at angles of about N80°-90°. The
results obtained through TF method allowed us to better quantify the horizontal polarization of the ground motion, giving a clear indication which corroborate findings pointing out that the recorded ambient noise is polarized in a narrow frequency band (1.0-4.0 Hz) and follows a trend roughly oriented ENE (see example in Fig. 3a). Moreover the TF polarization analysis revealed the existence of low values of the ellipticity in a wide frequency band (1.0-4.0 Hz) as well as dip values showing an horizontal trend in the same frequency band. It appears therefore clear that the maxima of the horizontal ground motion polarization take place almost perpendicularly to the main buried magma-feeding fractures, which are trending North-North-West.

The inversion of the dispersion curve data, obtained by recording ambient vibrations using a “L shape array, allowed us to build a shear wave profile up to 50 m depth. The main observed velocity contrast is between a low velocity layer, having \( V_s \) in the range 200-400 m/s, and an higher velocity layer with \( V_s \) of about 1200 m/s.

Although results are preliminary, it is possible to hypothesize the existence in the investigated area of at least 50 m thick pyroclastic deposits overlaying the lava rock cooled within the eruptive fracture NNW oriented. A more detailed geophysical survey is planned in the next future to better constrain the thickness of pyroclastic deposits around the cone and to outline the geometry of the eruptive fracture.

References
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