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In his comment, *Pujol* [2000] proposes to integrate the information furnished by the sonic logs, made in the San Vito and Mofete wells, in the three-dimendional (3-D) velocity model used to relocate the seismic events in the central zone of Campi Flegrei caldera. We show here that the tectonic and lithologic context are different in the zone covered by *Aster and Meyer* [1988] seismic data and Mofete and San Vito 3 well zones. Consequetly, the information contained in these wells can not be used to construct the 3-D velocity model.

The Campi Flegrei volcanic complex was formed by a succession of volcanic eruptions, beginning probably earlier than 50,000 years B.P., whose last manifestation is the Monte Nuovo eruption of 1538. The most important structural element of Campi Flegrei is the 12-km-wide caldera attributed to the collapse following the emplacement of the Campanian Ignimbrite 35,000 years ago [*Rosi et al.*, 1983; *Barberi et al.*, 1991]. The postcaldera activity is a succession of episodes, first submarine and then subaerial, during which the volcano-tectonic depression is progressively filled by volcanoclastic deposits interbedded with lava bodies and covered by yellow tuffs. The depression was affected further by postcaldera collapses. In particular, geological and geophysical observations indicate the existence of a roughly circular tectonic collapse, centered around the town of Pozzuoli, affecting the inner part of the caldera. This collapse has been related to the eruption of the Napolitan Yellow Tuffs that occurred ~ 12,000 years ago. The limits of the collapse region are well evidenced by gravity anomalies. A very well-defined subcircular negative anomaly, situated around the town of Pozzuoli and surrounded by a series of positive anomalies, is observed in the Bouguer anomalies map [*AGIP*, 1987]. The transition from the positive to the negative anomaly is made by a series of steps with varying gradients between. These nonuniform gradients have been interpreted by *Cassano and La Torre* [1987] as the consequence of successive subsidence steps of higher-density rocks toward the center of the gulf of Pozzuoli. In addition, Cassano and La Torre interpreted the large gravimetric minimum as being associated with the deepest area of the collapse, which was subsequently filled by at least 2000 m of light volcanic products.

The study carried out by *De Natale et al.* [1995] of composite focal mechanisms from groups of earthquakes, located in different zones of the ring structure, from a dense swarm on April 1, 1984, indicates the presence of a ring fracture system dipping toward the center of the caldera and marking the borders of the inner collapse. The work of De Natale et al. strongly supports the hypothesis that the seismic activity during the 1982-1984 unrest episode at Campi Flegrei was generated by a local stress field associated with ground deformation which occurred along weakness zones of the ring fracture system. The existence of this ring fracture system was previously hypothesized by *Aster and Meyer* [1988], who attributed the central seismic anomaly of their 3-D seismic velocities model (low V_P and V_S associated with high V_P/V_S ratio) to a relatively incompetent, highly-fractured zone of liquid-water-filled cracks.

Geochemical observations (see *De Natale et al.* [1991] for a complete review) suggest a rapid fluid transfer between deep levels and the surface in the central part of the inner caldera during the 1982-1984 unrest episode. Because of the low permeability of the Campi Flegrei formations [*Chelini and Sbrana*, 1987], this vertical transfer is only possible if the central part of the caldera is fractured.

These observations indicate that the central part of the Campi Flegrei caldera, a roughly circular zone with a radius of 3 or 4 km, centered on the town of Pozzuoli, is the zone of the Campi Flegrei where the collapse was maximum. This area is filled with low-density postcaldera pyroclastites that are highly fractured. It is inside this area, delimited by the zero Bouguer anomaly, that the ground deformation and the majority of the

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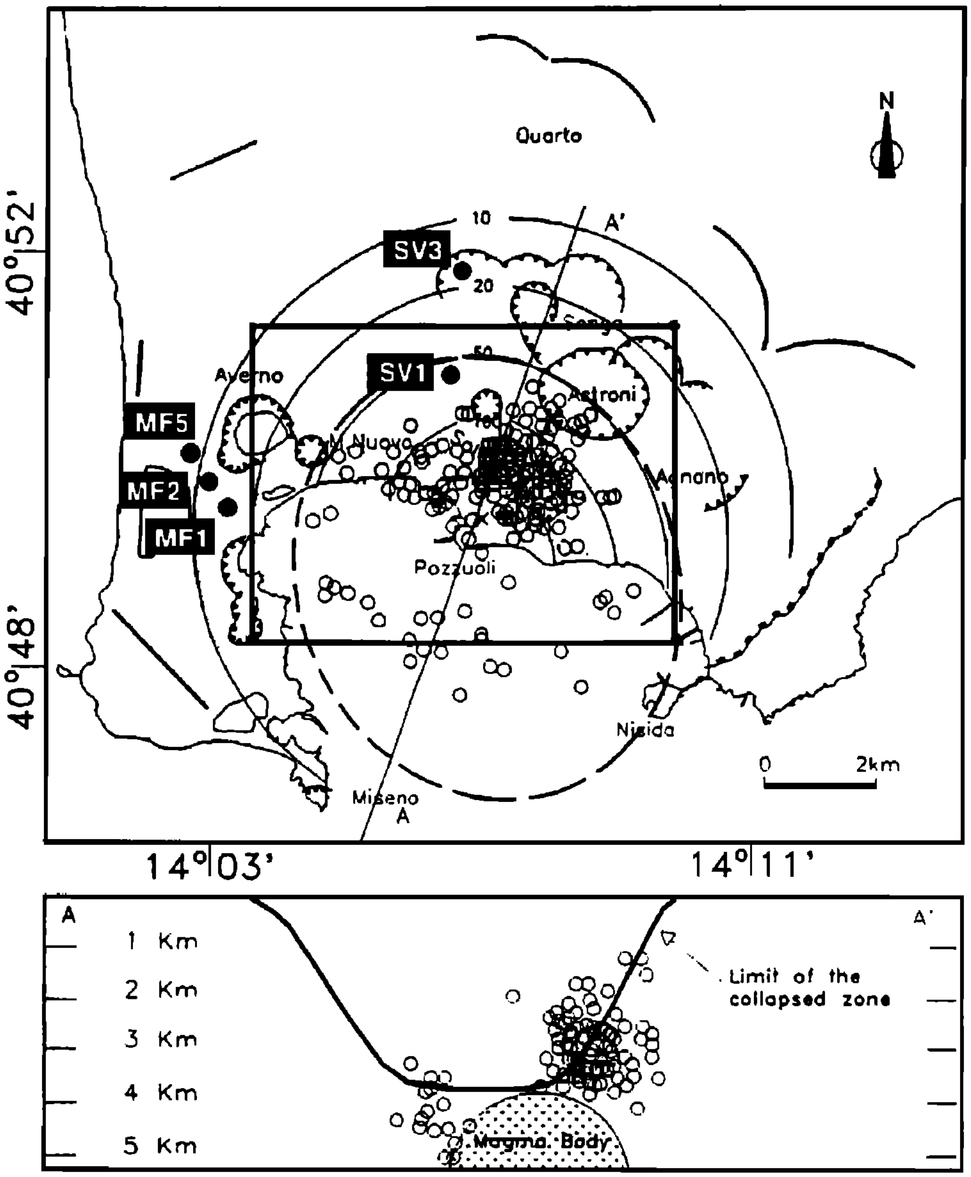

Figure 1. (top) Position of the zero contour line of the Bouguer anomaly (dashed line), contours of vertical elevation, positions of the earthquake hypocentres studied by *De Natale et al.* [1995], the position of the zone covered by the *Aster and Meyer* [1988] 3-D seismic model (rectangle), and the locations of the San Vito (SV1 and SV2) and Mofete (MF1, MF2, and MF5) AGIP wells. (bottom) Crossection through A-A' showing limit of collapsed zone and hypocenter locations (modified from *De Natale et al.* [1995]).

seismic activity were concentrated during the 1982-1984 crisis.

Figure 1 shows the position of the zero contour line of the Bouguer anomaly together with the positions of the earthquake hypocentres studied by *De Natale et al.* [1995], the position of the zone covered by the *Aster and Meyer* [1988] 3-D seismic model and the locations of the San Vito and Mofete AGIP wells. We can see that, excepting the San Vito 1 well (SV1), all the wells are situated outside of the inner collapsed zone. The three Mofete wells (MF1, MF2, and MF3) and San Vito 3 well (SV3) were drilled on the surrounding positive gravity anomalies belt. These anomalies are explained by the presence of dense lava bodies and hydrothermalized rocks. The similarity of the lithologies observed in these four wells is a consequence of the circular symmetry of the inner caldera zone and the equidistant positions of the wells from the center of the caldera.

Pujol [2000] has pointed out the existence of vertical and lateral variations of sonic log and seismic wave velocities. These variations are the result of precaldera and postcaldera activity which created a heterogeneous region situated inside the caldera. The vertical crosssections of Mofete and San Vito wells [*Zamora et al.*, 1994, Figure 1] show this heterogeneity. If the main lithological formations (yellow tuffs, chaotic tuffs, tuffites, lavas, and volcano sedimentary complex) are all present in the five wells, their thicknesses and their positions in depth vary from well to well. As a consequence of this lithological heterogeneity, vertical as well as lateral variations may be observed in different physical properties and, in particular, in the elastic properties.

A tectonic collapse is observed [*Zamora et al.*, 1994, Figure 1] between the San Vito 3 and the San Vito 1 wells, shifting down by almost 700 m the different formations of San Vito 1. The strong difference observed by Pujol between the SV1 V_P sonic log velocities and those measured in the other four wells (at a given depth) is a consequence of the break down of the different lithologies of San Vito 1 provoked by this collapse.

Figure 1 shows that the zone covered by the 3-D seismic model of *Aster and Meyer* [1988] is situated in the central and lowest area of the inner collapse, where the gravity data suggest the presence of weakly consolidated pyroclastites down to ~2000 m. This explains why the lateral and vertical variations in velocity of the Aster and Meyer model are less important than those obtained by the sonic logs in the San Vito 3 and Mofete wells: while the lithology is relatively uniform (weakly consolidated pyroclastites) in the first 2 km of depth in the area covered by the 3-D model, it is most heterogeneous in the Mofete and San Vito 3 zones because of the presence of interbedded lava bodies. Likewise, if the vertical increase of the sonic log velocities (which is the consequence of differences in lithology, and hydrothermal and thermometamorphic reactions) is not observed in the 3-D model, that is due to (1) the weak variation of lithology with depth in the inner part of the collapse zone and (2) to the fact that because of the collapse, the different hydrothermal parageneses and the top of the metamorphic zone have been lowered in this zone. For instance, the top of the metamorphic zone is situated below 2500 m in SV1 (that is the well the closest to the center of the inner collapse), while it is situated above 2000 m in the other wells [*Chelini and Sbrana*, 1987]. On the other hand, the low velocities obtained at 3 km in the Aster and Meyer model are probably due to the fact that this zone is highlyfractured, as has been said previously, but at this depth the velocity resolution is not very good [*Aster and Meyer*, 1988, Figure 13].

The proposal of Pujol to establish a layered velocity model founded in the sonic log velocities obtained in the San Vito 3 and Mofete zone, in order to relocate the seismic events of the inner collapse zone, may be questioned, as the tectonic and lithologic context are different in these two zones.

Moreover, the 3-D velocities furnished by the Aster and Meyer inversion are in quite good agreement with the lithological, geophysical, and geochemical observations obtained in the zone covered by this model. It certainly represents the actual velocities of the inner collapsed zone, contrary to the suggestion of Pujol. This is confirmed by the good agreement between the seismic velocities of Aster and Meyer ($V_P = 2.81$ km s^{-1}) and the sonic log velocities ($V_P = 2.70$ km s^{-1}) of SV1, in the first kilometer of depth, where the lithologies of both zones are similar. The difference (4%) may be explained by the difference of wavelengths: 0.3 m for sonic log and 30-300 m for seismic data.

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