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ACTIVE TECTONICS AND RESURGENCE AT ISCHIA ISLAND (SOUTHERN ITALY)

V. Acocella (1) **- R. Funiciello** (1) **- S. Lombardi** (2)
(1) Dip.to di Scienze Geologiche, Università di Roma Tre, Roma
(2) Dip.to di Scienze della Terra, Università di Roma "La Sapienza", Roma

SOMMARIO - *Tettonica attiva e risorgenza ad Ischia (Italia meridionale)* - Il Quaternario *Italian Journal of Quaternary Sciences,* **10**(2), 1997, 427-432 - Ischia é caratterizzata da un blocco risorgente sollevatosi di almeno 800 m negli ultimi 30 ka. E' stata intrapresa un'analisi strutturale, integrata con un'analisi morfologica e del contenuto in ^{4}He nei suoli dell'isola, al fine di riconoscere i caratteri strutturali principali e le deformazioni associate alla risorgenza. Sistemi di faglie orientate NW-SE e NE-SW, pre-esistenti la risorgenza, sono relazionabili alle strutture regionali responsabili dell'estensione del margine campano. Sistemi orientati N-S e E-W, presenti solamente lungo i margini del blocco risorgente, sono relazionabili al processo di risorgenza. Il blocco ha una forma ottagonale in pianta ed é basculato di 15° secondo un asse orizzontale orientato NE-SW; é inoltre delimitato da faglie ad alto angolo immergenti verso l'interno dell'isola, che hanno fortemente confinato l'ampiezza dell'area interessata dalla risorgenza.

Parole chiave: Area napoletana, risorgenza, tettonica
Key words: Neapolitan area, resurgence, tectonics

1. INTRODUCTION

Deformations associated with regional and local stresses are a common feature in volcanic areas. The emplacement of magma causes local stresses which may trigger a resurgent doming, uplifting a portion of the volcanic complex (Smith & Bailey, 1968). Resurgence is accompanied by fractures (either new and/or reactivated) connected with the regional and/or the local stress field.

The island of Ischia (Fig. 1), is characterized by a resurgent dome uplifted more than 800 meters in the last 30 ka. The structural features of the island and of the resurgent block and the influence of pre-existing regional discontinuities on resurgence have been defined on the basis of remote sensing data, field surveys and ^{4}He contents in the soil.

2. REGIONAL TECTONIC SETTING AND THE ISLAND OF ISCHIA

The plio-quaternary extension of the Tyrrhenian margin from Tuscany to Campania formed NW-SE trending normal faults and NE-SW transfer systems (Parotto & Praturlon, 1975; Faccenna *et al.*, 1994). The NW-SE graben of the Campania Plain is intersected by

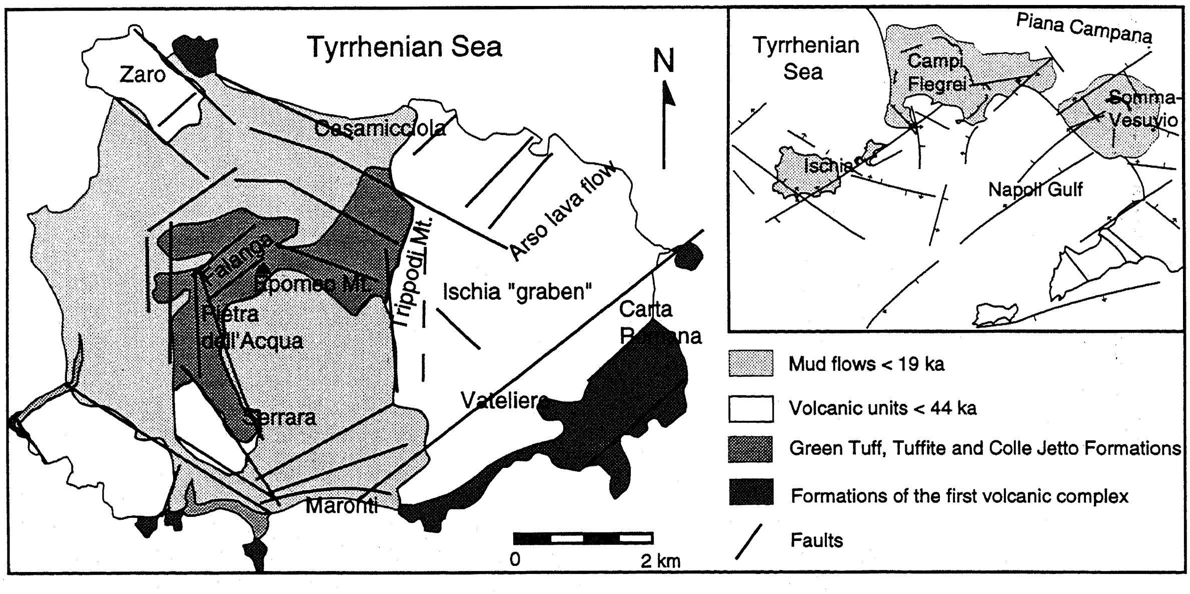


Fig. 1 - Geological sketch map of Ischia Island (modified after Gillot *et al.*, 1982). Inset: structural map of the Neapolitan volcanic area.
Schema geologico di Ischia (modificato da Gillot et al., *1982) e schema strutturale (riquadro) dell'area napoletana.*

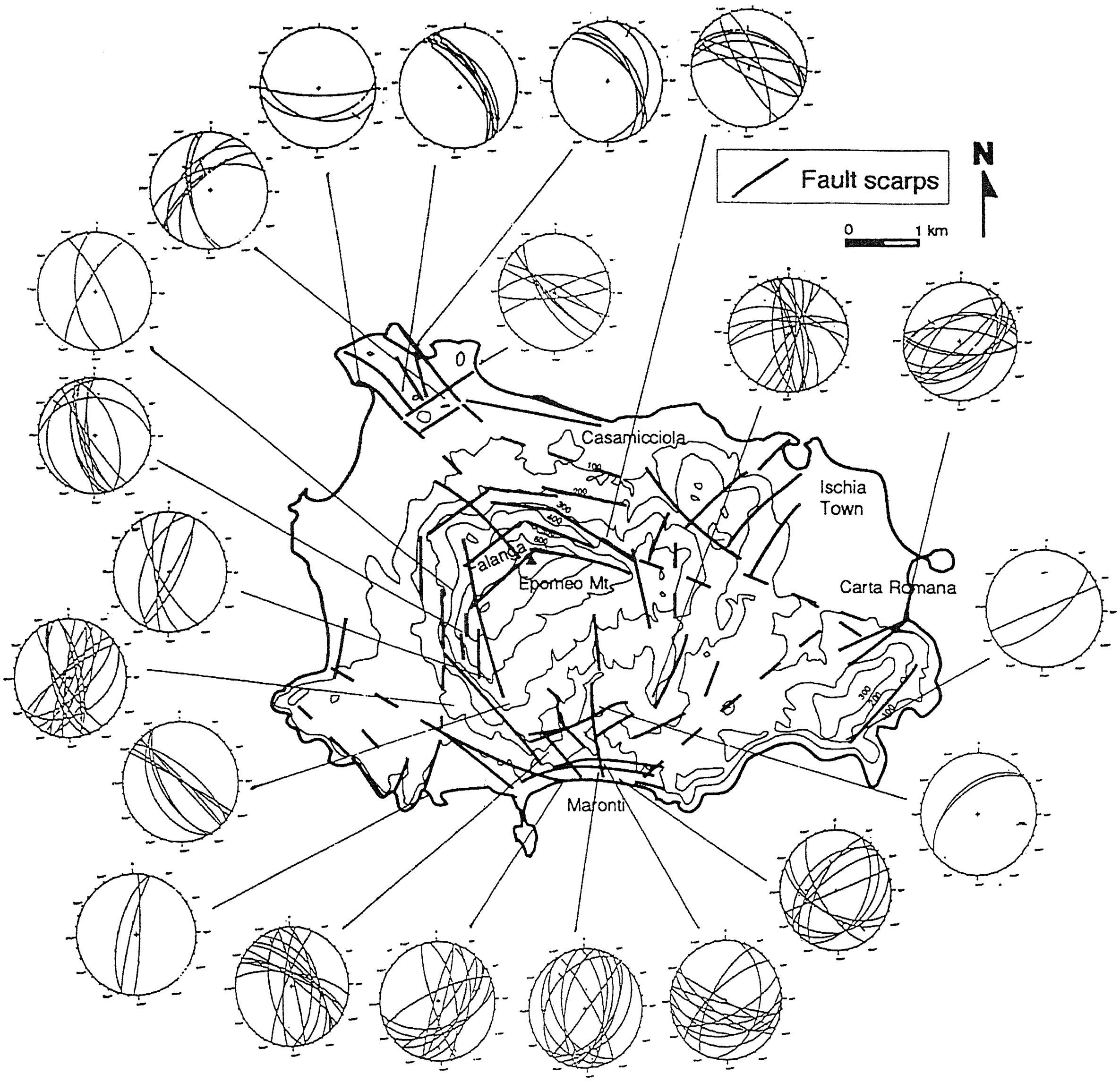


Fig. 2 - Fault scarps identified on the basis of remote sensing data. The most important structural data are subdivided into 21 stations and plotted in Schmidt lower hemisphere nets.
Scarpate riconosciute dall'analisi delle foto aeree. Sono inoltre riportati i dati strutturali più significativi, relativi a 21 stazioni di misura, proiettati sull'emisfero equiareale inferiore di Schmidt.

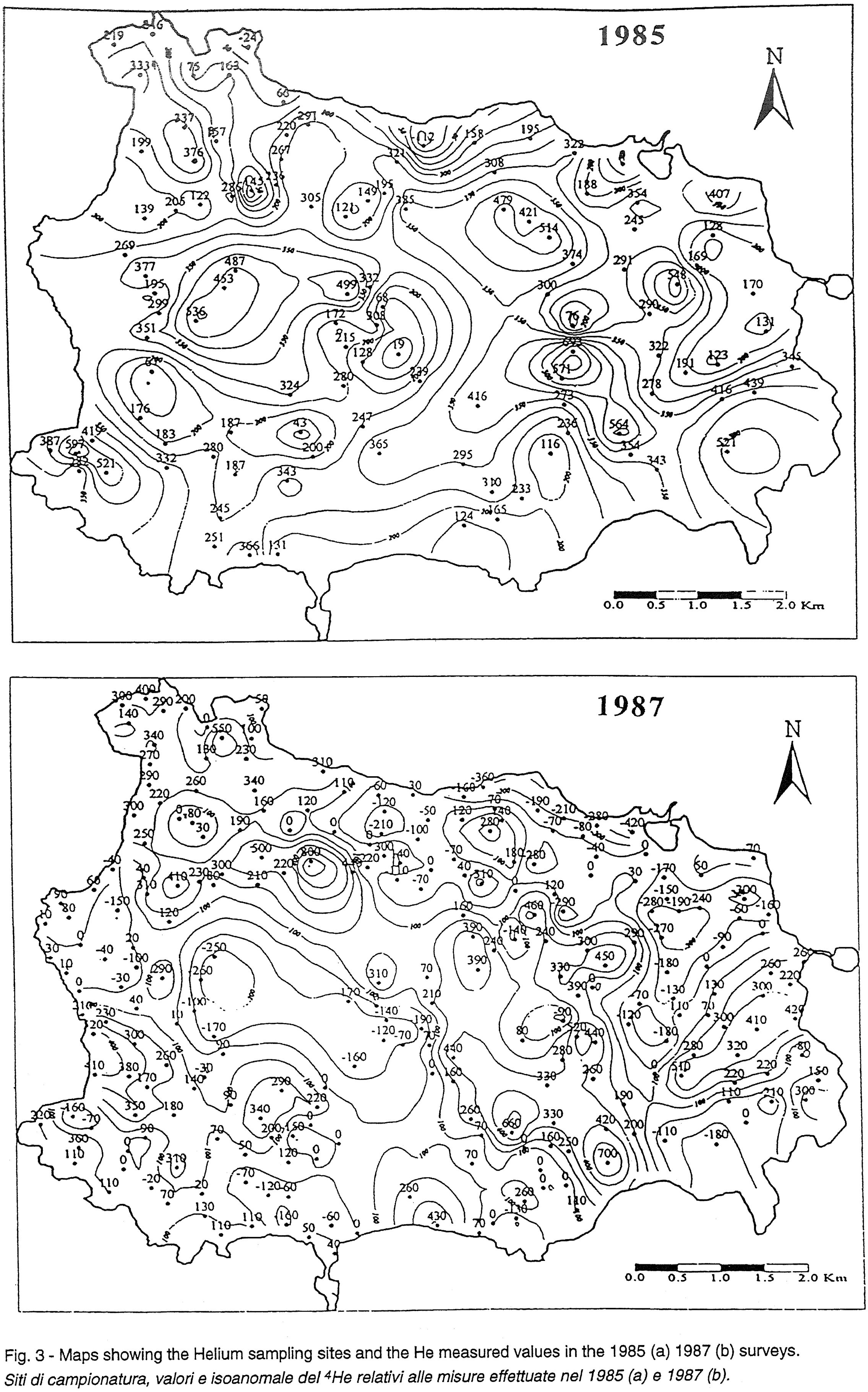
an ENE-WSW trending buried horst, crossing Campi Flegrei, Procida and Ischia (Carrara *et al.*, 1973; Finetti & Morelli, 1974; Fedi & Rapolla, 1987; Rapolla *et al.*, 1989). The NE-SW and ENE-WSW trending structures (Fig. 1) controlled the trachytic volcanic activity in the Neapolitan area (Finettyi & Morelli, 1974; Scandone *et al.*, 1991).

Ischia (Fig. 1) is mostly made of alkali-trachytes. In the time interval 150-75 ka there was a caldera-like structure along the coastline and at about 55 ka BP the Green Tuff subaerial eruption occurred (Vezzoli, 1988). Afterwards, the Green Tuff was submerged and covered by the Tuffite and Colle Jetto marine formations. In the latest 28 ka, volcanic activity occurred mainly in the "Ischia Graben" area (Fusi *et al.*, 1990); the last eruption was the Arso lava flow in 1301 A.D. At present, Green Tuff outcrops are found up to the Mt Epomeo top (787 m a.s.l.). The total amount of uplift, as evidenced by the resurgence dome, was estimated to be 800-1100 meters (Barra *et al.*, 1992). Beginning of uplift was estimated to date to 33 ka (Gillot *et al.*, 1982) or to the interval 55-19 ka (Barra *et al.*, 1992).

Two models were proposed to explain the resurgent dome structure: 1) a volcano-tectonic horst model, in which the dome is bordered by outward dipping faults (Rittmann & Gottini, 1980; Vezzoli, 1988; Fusi *et al.*, 1990) and 2) a simple-shear model, in which the resurgent block is bordered by inward dipping faults (Orsi *et al.*, 1991).

3. REMOTE SENSING, FIELD SURVEY AND ^{4}HE PROSPECTING

More than 200 faults have been studied and res-



a)

b)

Fig. 3 - Maps showing the Helium sampling sites and the He measured values in the 1985 (a) 1987 (b) surveys.
Siti di campionatura, valori e isoanomale del ^{4}He relativi alle misure effettuate nel 1985 (a) e 1987 (b).

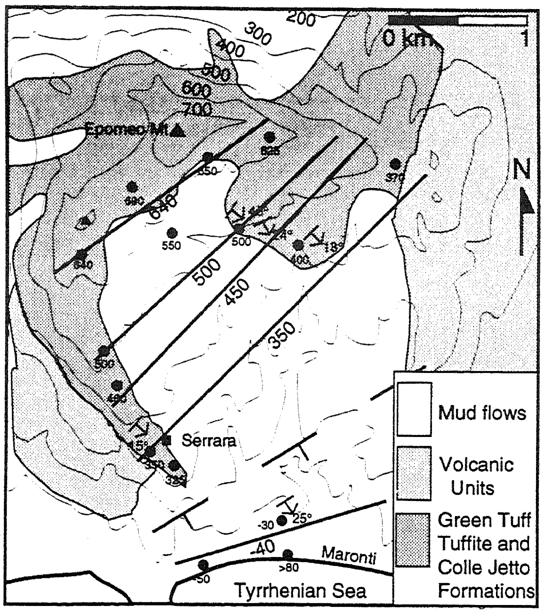


Fig. 4 - Isobaths of the Green Tuff top surface on the dome (solid lines); numbers indicate elevation in metres a.s.l. Dashed line = inferred fault. Black dots = Green Tuff outcrops.

Ricostruzione delle isobate del tetto del Tufo Verde sul blocco risorgente (linee a tratto continuo); i numeri indicano le quote s.l.m. Linea tratteggiata = faglia presunta. • = affioramenti del Tufo verde.

pective data were plotted on Schmidt lower hemisphere nets (21 nets for as many measurement stations) (Fig. 2). Normal faults are predominant. Reverse faults dip towards the centre of the island; the uplift of the dome at the southwestern margin of the island can be attributed to the activity of these faults. Two sets of stereo-pairs were studied (scales: 1:33.000 and 1:70.000) to recognize the main scarps (Fig. 2) and to correlate them, if possible, with tectonic activity.

^{4}He contents in soils were measured in the 1985 and 1987 summers and 111 and 248 soil gas samples were collected, respectively. Soil gas anomalies corresponded with main fracture systems, which are a preferential migration route for deep-seated gases (Lombardi & Reimer, 1990). Helium data are the difference between atmospheric and soil He contents. Figure 3 shows the 1985 and 1987 He iso-concentration contour lines. The sharpest anomalies trend NW-SE, NE-SW and subordinately N-S. These anomalies coincide with fault orientation and scarps (Fig. 2) and also with gravimetric and Rn anomalies, fumarolic activity and volcanic alignments (Maino & Tribalto, 1971; Nunziata & Rapolla, 1987; Vezzoli, 1988). Collected data show the predominance of NW-SE and NE-SW trending fracture systems throughout the island, both around and distant from the resurgent dome. The polygonal shape of the dome is marked also by N-S and, in a lesser extent, by E-W structures which stretch only along the dome margins.

The resurgent block is covered by massive mud and debris flow deposits (Vezzoli, 1988). The isobaths of the Green Tuff top surface have been reconstucted the dome on the basis of its maximum elevation both in outcrops and wells (see Fig. 4). Variations in elevation caused by erosion and tectonic activity have not been taken into ac-count. The Green Tuff top surface constantly dips to the SE to sink S of Serrara (see Fig. 4). According to geomorphological data (Bortoluzzi *et al.*, 1995), this may indicate the presence of an ENE-WSW trending fault zone. In general, the Green Tuff top surface and bedding are parallel. Because the emplacement surface was horizontal, as in general occurs for ignimbrites, and the present Green Tuff attitude is due to a tilting around a NE-SW trending horizontal axis. This axis is the only one compatible with the shape of the resurgent block, being orthogonal to its maximum horizontal length.

4. ISCHIA STRUCTURAL FEATURES

Structural and soil gas data show that the Ischia young morphology is controlled by tectonics. The predominant NE-SW and the NW-SE trending structures might be associated with the regional extensional systems of the Campania margin (Rapolla *et al.*, 1989; Fusi *et al.*, 1990). Although regional faults border the resurgent block, it can be assumed that they are older than resurgence, because, far from the block, they are only present in products older than the Green Tuff. The NE-SW trending fault systems stretching from the island of Procida to the "Ischia graben" are associated with the most primitive products of the Campi Flegrei-Ischia volcanic ridge.

N-S and E-W trending structures, on the contrary, are located only at the borders of the resurgent block, which indicates that they were induced by resurgence itself and are connected with local tectonic activity.

The most important structures of the southern side of the resurgent block are high-angle inward-dipping faults. No field data have been found to estimate the dipping angle of structures on the northern side of the block and only some hypotheses can be made. Outward dipping faults at the borders of the block (Fig. 5a) require the horizontal extension of 1cm/year

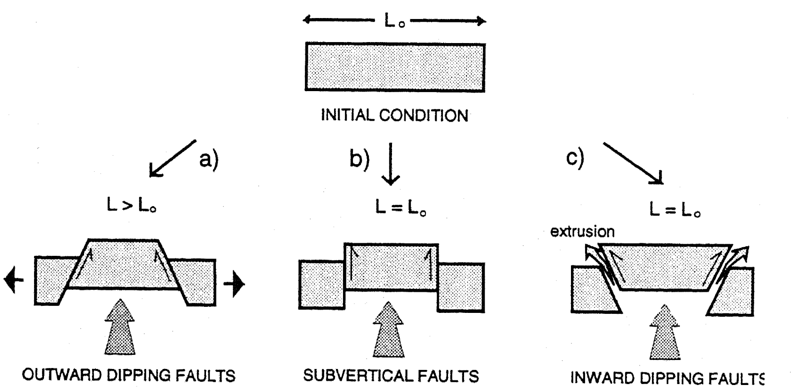
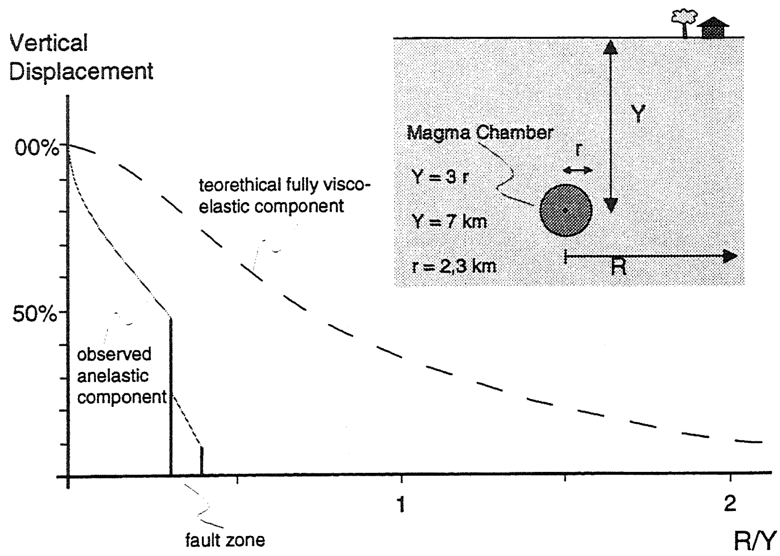


Fig. 5 - Teorethical geometrical features of resurgent blocks. a) outward dipping faults; b) subvertical faults; c) inward dipping faults.

Geometrie teoriche di blocchi risorgenti. a) Faglie immergenti verso l'esterno; b) faglie subverticali; c) faglie immergenti verso l'interno.

Fig. 6 - Anelastic and teorethical fully visco-elastic component of vertical displacement connected with resurgence at Ischia. Vertical displacement values are based on the Green Tuff height between Mt Epomeo and Maronti along a NW-SE section. Offsets near faults are marked by solid lines. The theoretical visco-elastic curve is based on Dietrich & Decker (1975) curves, where 90% of vertical displacement is reached for R/Y<2.

Componenti anelastica e visco elastica (teorica) di sollevamento relazionate alla risorgenza. Il comportamento anelastico é basato sulla quota del Tufo Verde tra l'Epomeo e i Maronti, su una sezione NW-SE. Le dislocazioni indicano la presenza di faglie, evidenziate dal tratto scuro. Il comportamento visco-elastico é basato sulle curve di Dietrich & Decker (1975), dove il 90% del sollevamento é raggiunto per R/Y<2.



at least to counterbalance an uplift of 1000 m (Orsi *et al.*, 1991). Subvertical faults (Fig. 5b) are not consistent with the observed tilting during resurgence. On the contrary, inward dipping faults (Fig. 5c) are the only ones compatible with the imposed dynamical conditions (Mandl, 1988) and, as shown by field observations, can be assumed as the ones bounding the dome as pointed out by Orsi *et al.* (1991). Tilting would prevent the formation of the voids shown in Figure 5c.

Figure 6 shows the vertical displacement of the block as a function of distance from Mt Epomeo along a NW-SE section. Uplift (light line in Fig. 6) decreases abruptly at the contact with pre-existing faults at its border, which indicates an anelastic behaviour of the crust. The dashed line is taken from theoretical elastic models of surface deformation (Dietrich & Decker, 1975). The magma chamber is assumed to be spherical at the depth Y = 7 km (Piochi, 1995), with Y = 3r, where "r" is the radius of the chamber. If the two curves are compared, it can be seen that a crust with a fully elastic behaviour would form a dome 5 times larger than the one formed by an anelastic crust (Fig. 6). Therefore, pre-existing faults bordering the dome and reaching the ground surface significantly confine vertical displacements.

5. CONCLUSIONS

Field observations integrated by remote sensing and soil gas prospecting data suggest the structural scheme of Ischia and its resurgent dome. NE-SW and NW-SE trending structures are associated with the regional systems responsible for the extension of the Campania margin. The newly formed N-S and E-W trending structures are connected with the uplift of the dome. The dome block plan is oc-tagonal, reflecting the influence of pre-existing regional faults, and is bordered by high-angle inward-dipping faults. These reactivated faults significantly confined the uplifted area width during resurgence.

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REFERENCES

Barra D., Cinque A., Italiano A. & Scorziello, R., 1992 - *Il Pleistocene superiore di Ischia: Paleoecologia e rapporti con l'evoluzione tettonica recente.* Studi Geol. Camerti, Vol. Spec., (1992/1), 231-243.

Bortoluzzi G., Donadio C., Mele R., Romano P., Russo F., Santangelo N. & Sgambati D., 1995 - *Guida all'escursione dell'Isola d'Ischia.* Gruppo Nazionale Geografia Fisica e Geomorfologia, Napoli.

Carrara E., Iacobucci F., Pinna E. & Rapolla A., 1973 - *Gravity and magnetic survey of the Campanian volcanic area, Southern Italy.* Boll. Geof. Teor. Appl., **XV**(57), 39-51.

Dietrich J.H. & Decker R.W., 1975 - *Finite element modelling of surface deformations associated with volcanism.* Journ. Geophys. Res., **80**, 4094-4102.

Faccenna C., Funiciello R., Bruni A., Mattei M. & Sagnotti L., 1994 - *Evolution of a transfer-related basin: the Ardea basin (Latium, central Italy).* Basin Res., **6**, 35-46.

Fedi M. & Rapolla A., 1987 - *The Campanian volcanic area: analysis of magnetic and gravimetric anomalies.* Boll. Soc. Geol. It., **196**, 793-805.

Finetti I. & Morelli C., 1974 - *Esplorazione sismica a riflessione dei Golfi di Napoli e Pozzuoli.* Boll. Geof. Teor. Appl., **16**, 175-222.

Fusi N., Tibaldi A. & Vezzoli L., 1990 - *Vulcanismo, risorgenza intracalderica e relazioni con la tettonica regionale nell'Isola d'Ischia.* Mem. Soc. Geol. It.,

45, 971-980.

Gillot P.Y., Chiesa S., Pasquarè G. & Vezzoli L., 1982 - *<33000yr K-Ar dating of the volcano tectonic horst of the Isle of Ischia, Gulf of Neaples.* Nature, **229**, 242-244.

Lombardi S. & Reimer G.M., 1990 - *Radon and helium in soil gases in the Phlegraean Fields, Central Italy.* Geophys. Res. Letters, **17**, 849-852.

Maino A. & Tribalto G., 1971 - *Rilevamento gravimetrico di dettaglio dell'Isola d'Ischia.* Boll. Serv. Geol. Ital., **92**, 109-123.

Mandl G., 1988 - *Mechanics of tectonic faulting: models and basic concepts.* Elsevier, Amsterdam, 401 pp.

Nunziata C. & Rapolla A., 1987 - *A gravity and magnetic study of the volcanic Island of Ischia.* J. Volcan. & Geoth Res., **31**, 333-344.

Orsi G., Gallo G. & Zanchi A., 1991 - *Simple shearing block resurgence in caldera depressions. A model from Pantelleria and Ischia.* J. Volcan. & Geotherm. Res., **47**, 1-11.

Parotto M. & Praturlon A., 1975 - *Geological summary of central Apennines.* In: Ogniben L., Parotto M. & Praturlon A. (Eds.), *Structural Model of Italy.* Quad. Ric. Scient., **90**, 257-306.

Piochi M., 1995 - *The Ischia magmatic system in the last 10 ka. Geochemical and geophysical evidence.* Plinius, **13**, 190-196.

Rapolla A., Fedi M. & Fiume G., 1989 - *Crustal structure of the Ischia-Phlegraean geothermal fields, near Naples, Italy, from gravity and aeromagnetic data.* Geophys. J., **97**, 409-419.

Rittmann A. & Gottini V., 1980 - *L'isola d'Ischia - Geologia.* Boll. Serv. Geol. It., **101**, 131-274.

Scandone R., Bellucci F., Lirer L. & Rolandi G., 1991 - *The structure of the Campanian Plain and the activity of the Neapolitan volcanoes (Italy).* J. Volcan. & Geoth. Res., **48**, 1-31.

Smith R.L., & Bailey R., 1968 - *Resurgent cauldrons.* Geol. Soc. Am. Mem., **116**, 613-662.

Vezzoli L., 1988 - *Island of Ischia.* C.N.R. Rome, 135 pp.

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