PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Structural Implications of the 1971 Mount Etna Eruption

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Structural implications of the 1971 Mount Etna eruption

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The author believes the 1971 eruption has been triggered by an uprise of the magma column which had for several decades fed the persistent activity located in both the NE crater and in the central crater's chasm. This uprise split open a set of *en-echelon* fissures first on the southern, then on the eastern upper slopes of Mt Etna. Degassing occurred at the uppermost part of the successive fissure systems, while the degassed lava flows poured out at the lowermost end. When the ENE tectonic fault-system came into operation and controlled the second half of the eruption, it led to the engulfment of the degassing vent and subsequently acted as an undergound channel through which the degassed lavas could flow freely until they poured out at the lower end of the fault zone.

This fault zone follows one of the main tectonic trends which intersect below Mt Etna, the main other ones being oriented SW–NE and WSW–ENE.

1. Mount Etna and related tectonics

Everyone is aware that any volcano or volcanic range is closely related to its tectonic environment. These close relations between volcanism and tectonics are now far better understood, since volcanism is considered to be genetically included in global tectonic reconstructions.

Every volcano is located on at least one fracture of the Earth's crust. Even the most perfectly circular volcanic cones were born as fissure volcanoes. Their evolution from the linear stage to the eventual circular one may have taken a comparatively long time, say centuries, or have been quite short: a matter of a few days. This fissure origin is usually easily detectable for any experienced geological eye; and the usual arrangement of volcanoes into narrow elongated systems marked by more or less obvious tensional faults clearly demonstrates their tectonic dependences.

Mt Etna however stands by itself, 100 km away from the closest active volcano and absolutely no connexion appears between Mt Etna and the Aeolian volcanic range nor the Monti Iblei (figure 1). Neither Mt Etna itself, a roughly oval base, about 60×40 km across, nor the eastern Sicily tectonics, clearly exhibit any conspicuous tectonic features which would account for the loneliness – or even for the very existence of this mighty volcano. It appears to be still more isolated than Mt Erebus is in the Antarctic. This peculiarity, which is seldom, if ever, pointed out, should stimulate more detailed and careful investigations of its tectonics and their relations with its eruptive activity. This eruptive activity also is exceptional: first, it has been practically continuous for 3000 years at least; secondly, Mt Etna has delivered one of the longest eruptions ever observed, the last northeast crater eruption lasted more than 17 years. The quite uncommon persistent activity shown by Mt Etna for scores of centuries (only about half a dozen volcanoes amid the thousands presently active existing ones display some type of permanent eruptive activity) is presumably linked with deep-seated tectonic phenomena.

However isolated it appears, Mt Etna is by no means a simple volcanic cone; in reality it is a pile of volcanoes, built up by successive activity in Pleistocene times when volcanic centres migrated from east to west; and present-day so-called eccentric eruptions represent outbursts of smaller but distinct volcanoes pertaining to that curiously concentrated range.

The only published tectonic sketch of Mt Etna by Rittmann shows that the volcano has been built at the intersection of four different fault zones, which (figure 2) trend respectively SW–NE, SE–NW, WSW–ENE, and WNW–ESE. During the period extending from 1949 when the present author first visited Etna, there have been many opportunities to observe that the two

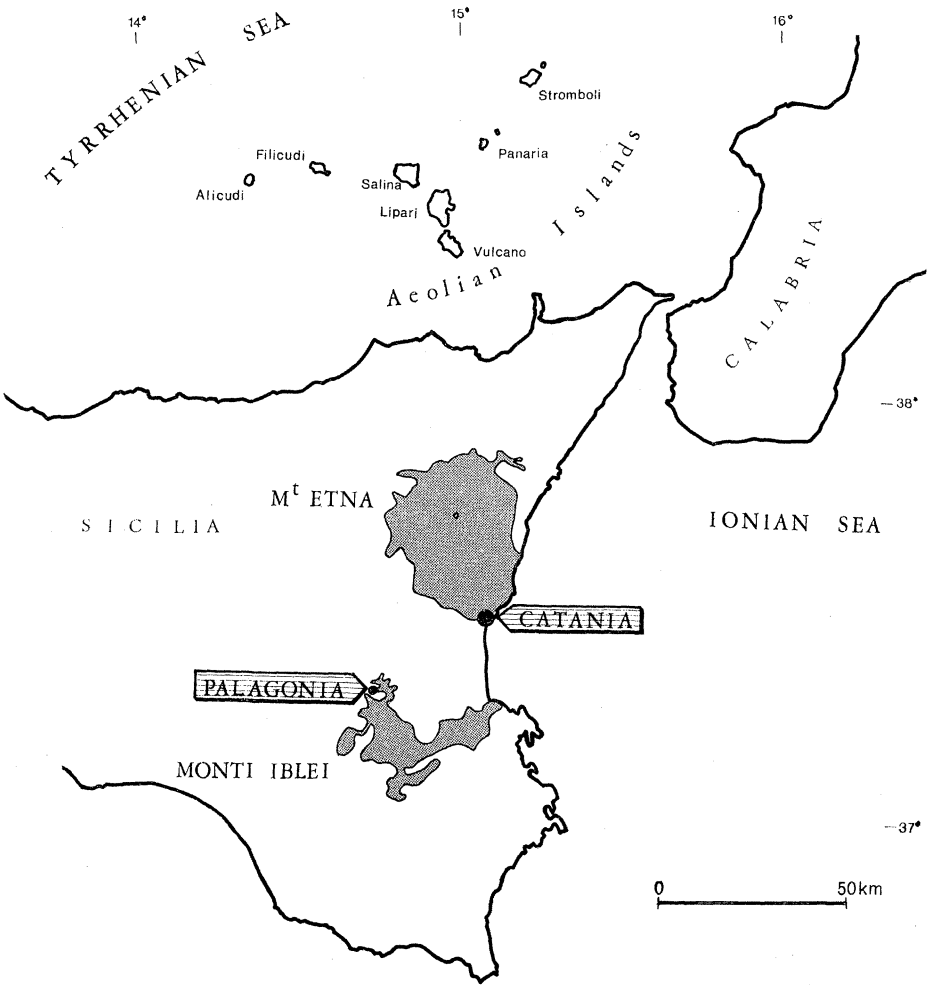

FIGURE 1. Map showing the location of Mt Etna.

most actively erupting zones were the SW–NE one and that oriented WNW–ESE. The first had controlled the 1949 and 1964 terminal outbursts as well as the persistent activity of the northeast crater. The latter was, on the other hand, also controlled by WNW–ENE fractures which, during the last ten years, delivered lava flows with a total volume of about 10^6 m^3. The exceptional duration of the northeast crater effusive activity may be related to the intersection of these two fracture zones.

The SW–NE fracture zone is parallel to the rifted northeastern coast of Sicily, which marks the limit of the Ionian graben. Mt Etna's ancestors – Mte Calanna and possible former volcanoes – were probably engendered on this tensional structure and the westward migration of the main eruptive centre, through the successive Mte Trifoglietto to present-day Mongibello, was possibly due to further block-collapse processes of the western margins of this Ionian rift system.

The WNW–ESE fracture trend, almost orthogonal to the former, pertains to another tectonic category. Whereas the first appears as one of subsidence and collapse, this one is due to an uprise. An anticline extends west from Mt Etna (Cristofolini, this volume) which is supposed to be continued eastward underneath the mountain either as the broad-arched structure it is in central Sicily (Cristofolini, this volume) or as a faulted block, i.e. a horst (Rittmann, this volume).

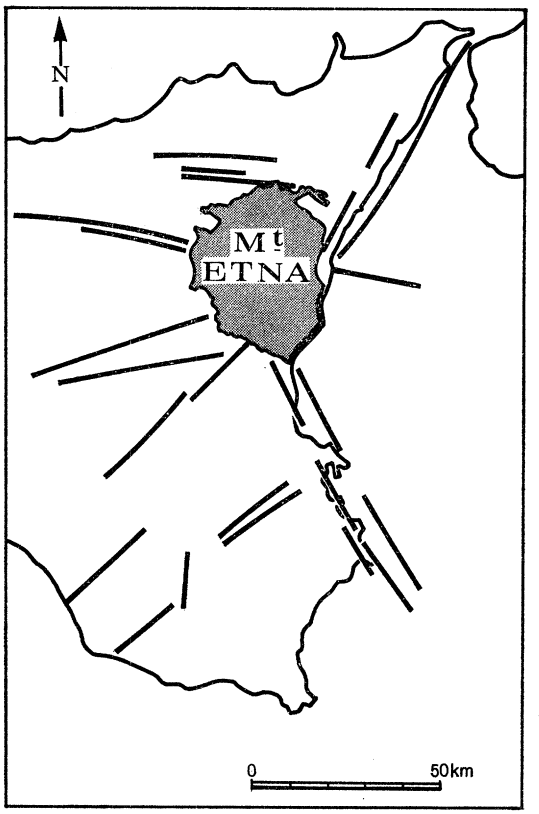

FIGURE 2. Map showing the relationships between the main fault zones and Mt Etna (after Rittmann 1964).

2. THE 1971 ERUPTION AND ITS STRUCTURAL RELATIONSHIPS

The April to June 1971 outburst has shown the influence of a third tectonic trend, the WSW–ENE one, which also appears as one of the main persistent active fault zones of Mt Etna. In fact, this event's first stage, which lasted from 4 April to 5 May, was but a mere lateral eruption delivered through a set of radial fissures split open under the hydrostatic pressure of the magma. These fissures were oriented a few degrees east of south. The second stage was initiated on 5 May by the splitting open of another radial fissure, oriented approximately east to west. For 3 days this new fracture delivered a lateral eruption similar to the former one which had been exhausted by then. Then something less common happened.

A new set of *en-echelon* fissures split open, starting from the upper termination of the 5 May fracture and extending E 27° N. At the upper end of this new set, a circle about 8000 m² of the surface ground and subsurface firn collapsed into a chasm through which the degassing of

the magma occurred while the degassed lava was poured out at the lowest point of the *en-echelon* fissures. From 7 May to 11 May, these fissures extended intermittently over a distance of 6 km, from an altitude of about 3000 to 1800 m. This extension operated by a series of approximately daily steps and the splitting of *en-echelon* fissures. Each further opening allowed the lava flows a lower escape point; this explains the rather unusual way the lavas were poured out during this phase of the eruption, by small daily flows escaping through fissure vents located at successively lower altitudes. This was due to the extension of the fracture which acted as a deep underground channel through which the lavas, continuously degassed at the upper end of the fractured zone, were canalized to the latter's lower point where they eventually came out.

These new fissures were not radial as were the two first sets, but followed a trend (E 27°N) exhibited by numerous dykes outcropping in the northern scarp of the Valle del Bove. The famous 1928 outbreak which annihilated the city of Mascali was triggered by the opening of a fissure along this trend. The persistence of this direction as an actively erupting one over many scores of milennia shows it is tectonic. It has, moreover, been recognized SW from Mt Etna, as attested on Rittmann's sketch map. However, the author thinks that the last 4 weeks of the 1971 outburst, during which the lavas flowed out at the lower end of these tectonic fissures, were of a similar type to the lateral eruptions characteristic of the first half of the event. In reality, although the appearance was different owing to the steam explosions generated by the engulfed snow and firn in the newly collapsed chasm, the degassing was confined to the upper end of the fissures, on the foot of the terminal cone of Mt Etna. The magma column ascended through a channel which was located below the SE part of the summit cone of Mongibello. No magma came up through the newly opened ENE tectonic fissures, as is ascertained by the total absence of any primary degassing or lava fountaining anywhere along their whole length.

The degassed magmas drained through these new fractures, but the fractures acted in a passive way only, as a system of pipes which insulated the magmas during their passage to the vents located 6 km away. The stupendous – more than 1000 m – welling up of the lava level in the great central crater's chasm (La Voragine) 15 weeks after the end of the eruption in a very short time appears as a confirmation that the lava column had not shifted from the axis of Mongibello.

3. Concluding remarks

The tectonic significance of Mt Etna should not be underestimated. As with any volcanic edifice, it is in close connexion with the deep structures of the lower crust and upper mantle. Its magmatological history is an important clue to the understanding of the regional structures, and cannot be overlooked in any tectonic hypothesis of value.

Study of the tectonophysics of the Mediterranean is currently in fashion. It should be borne in mind that simplified models such as those usually used in oceanic plate-tectonics are insufficient here if they do not account for the tectonic features and the magmatology of the volcano.

Conseqently, the still quite schematic knowledge presently available for Mt Etna should be widely enlarged by *coordinated* studies involving all possible fields and techniques of the Earth sciences and carried on over both the submerged and emerged Thyrrhenian and Ionian areas.

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