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The Collection and Analysis of Volcanic Gases

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The collection and analysis of volcanic gases

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Introduction

A French team, with workers from Centre d'Etudes Nucleaire, Fontenay, Commissariat à l'Energie Atomique, and Centre National des Recherche Scientifique, have conducted numerous missions to Etna in recent years and these will be briefly reviewed (Tazieff, Boulay, Garrand & Maulard 1968; Boutry & Jatteau 1968; Elskens 1969; Tazieff *et al.* 1969).

Pre-1971 missions

In 1969, the central crater had many deep explosions (figure 1). Of particular interest was the Bocca Nuova, a small vent, 6 to 7 m in diameter, which displayed vigorous high temperature gas emission. The gases were emitted in gusts with a regular period, and their physical and

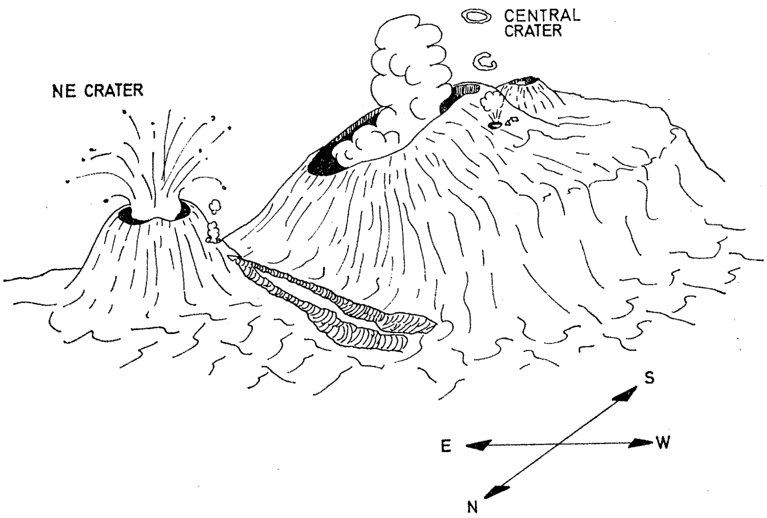

Figure 1. A drawing of the north face of Mt Etna in 1969.

chemical characteristics were studied. The maximum water content was of the order of 30 to 40 %. The periodic explosions could be correlated with carbon dioxide contents of 40 to 60 %. All the gas samples taken from the Bocca Nuova were heavily contaminated with air, this could be due to either air percolating through the porous superstructure of the volcano into the vent throat, or by air being sucked into the vent via the orifice in between gusts. The latter is supported by measurements of velocity and a film taken of the phenomenon.

In 1970, Le Guern & Le Bronec noted that the central crater was in the same state as 1969. Many explosions were taking place at the bottom of the chasm, which at the surface had dimensions of 200 m by 300 m. The ejectamenta accompanying the explosions rarely reached the top lip due to the great depth. The crater was filled with dense volcanic fumes which occasionally cleared, allowing a glimpse of the vertical walls, and by night, to see the explosive activity at the bottom. During this mission, an automatic gas sampling device was lowered 400 m into the crater. Unfortunately this proved an insufficient depth to sample the active gases. The samples collected were found to contain small amounts of carbon dioxide and no sulphur dioxide. This suggests that the sampler was still in the fog zone, i.e. the gas was below its dew point. Gas in this form cannot pass through the needles of the sampling device.

The Bocca Nuova had enlarged by collapse at the beginning of 1970 to form a crater 150 m across, the violent gas activity had ceased, probably owing to the fact that the vent was blocked by material which had collapsed from the walls. The gas was sampled using the automatic sampler, and the samples showed that apart from the acid fog, the gaseous phase in the crater was air.

From these experiments it can be concluded that the sampler did not go deep enough into the craters, and that the gases emitted at the base mix with the air and cool rapidly.

Northeast cone

The NE cone (figure 2) was continually being built up by the fall of pyroclastics, from the strong explosive activity taking place at its summit crater. Because of this, work could not be carried out on the cone itself. However, at its eastern foot lava was being extruded and gases

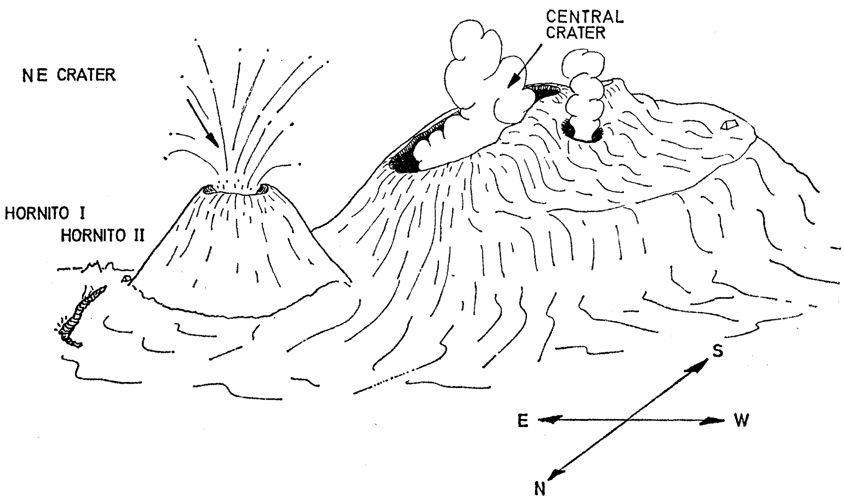

FIGURE 2. A drawing of the north face of Mt Etna in 1970.

emitted through a recent lava crust were at several points building up small spatter cones or hornitos. Gas samples were collected at these points by two different methods, in simple Pyrex containers and also in glass tubes specially designed for use with the gas chromatograph. The presence of a mobile laboratory, equipped with vacuum pump and a gas chromatograph, permitted *in situ* analysis. The samples were re-analysed in Paris, on return, using a gas chromatograph and a mass spectrometer.

From previous work (Tazieff *et al.* 1968), it is known that the physical parameters of the gas phase fluctuate rapidly and that it is important to identify accurately the location of the sample both in time and space, and to ensure that the sampling interval is of the same order as the period of fluctuation. Results are as shown in figure 3.

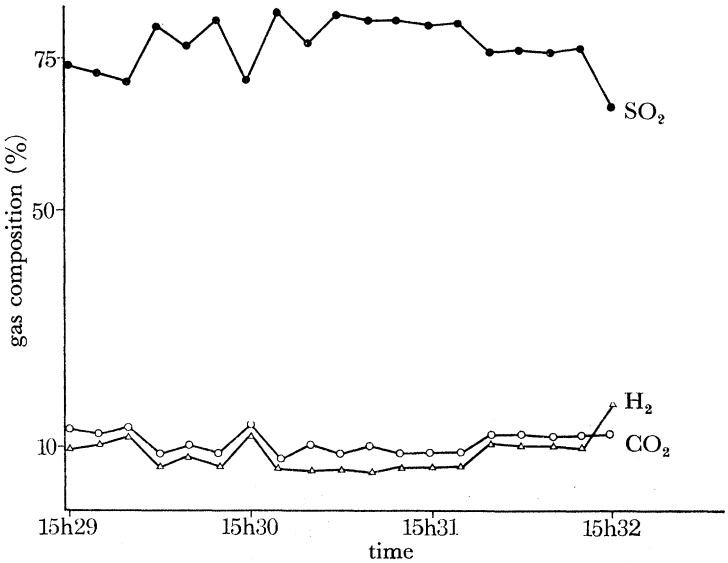

FIGURE 3. Composition of gas plotted against time, from a hornito on 11 July 1970.

Winter 1970–1971

During the winter of 1970–1, a considerable volume of lava had spread from the col between the central crater and the NE cone (figure 4). Near its source the lava had a thickness of 30 to 40 m; it flowed to the NW and to the SE with a flow thickness of about 10 m. The shape of the flows was difficult to determine as they had subsequently been covered with ash. The fissures at the source of these flows were orientated SSW to NNE and were visited in the summer of 1971. Although the lavas were cold, from one of these fissures gases at a temperature of 500 to 580 °C were being emitted, but proved on analysis to be air. The gas from this fissure showed no change in activity during the major activity of 1971.

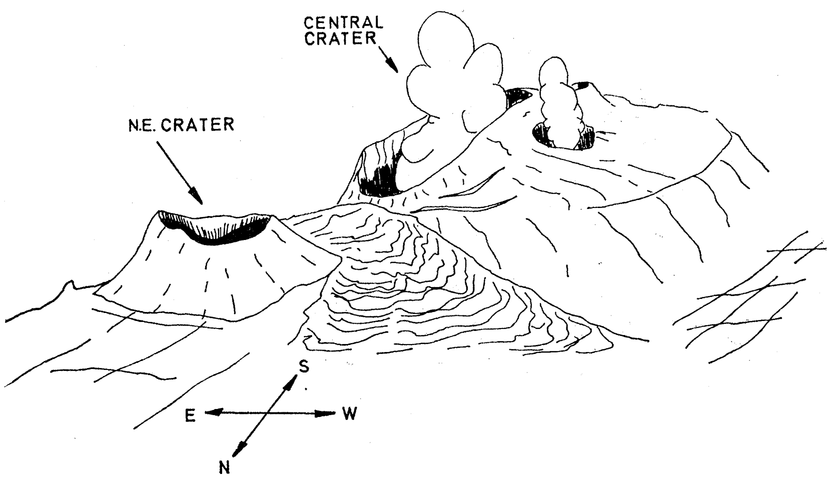

FIGURE 4. A drawing of the central crater and the NE cone in April 1971.

1971 MISSIONS

In 1971 Etna increased its normal activity both in the volume of lava involved and in the sites of activity, indeed the eruption was notable for the widespread nature of the activity (figure 5). On 5 April at the very start of the eruption cones built up on the radial N–S fissures (figure 6).

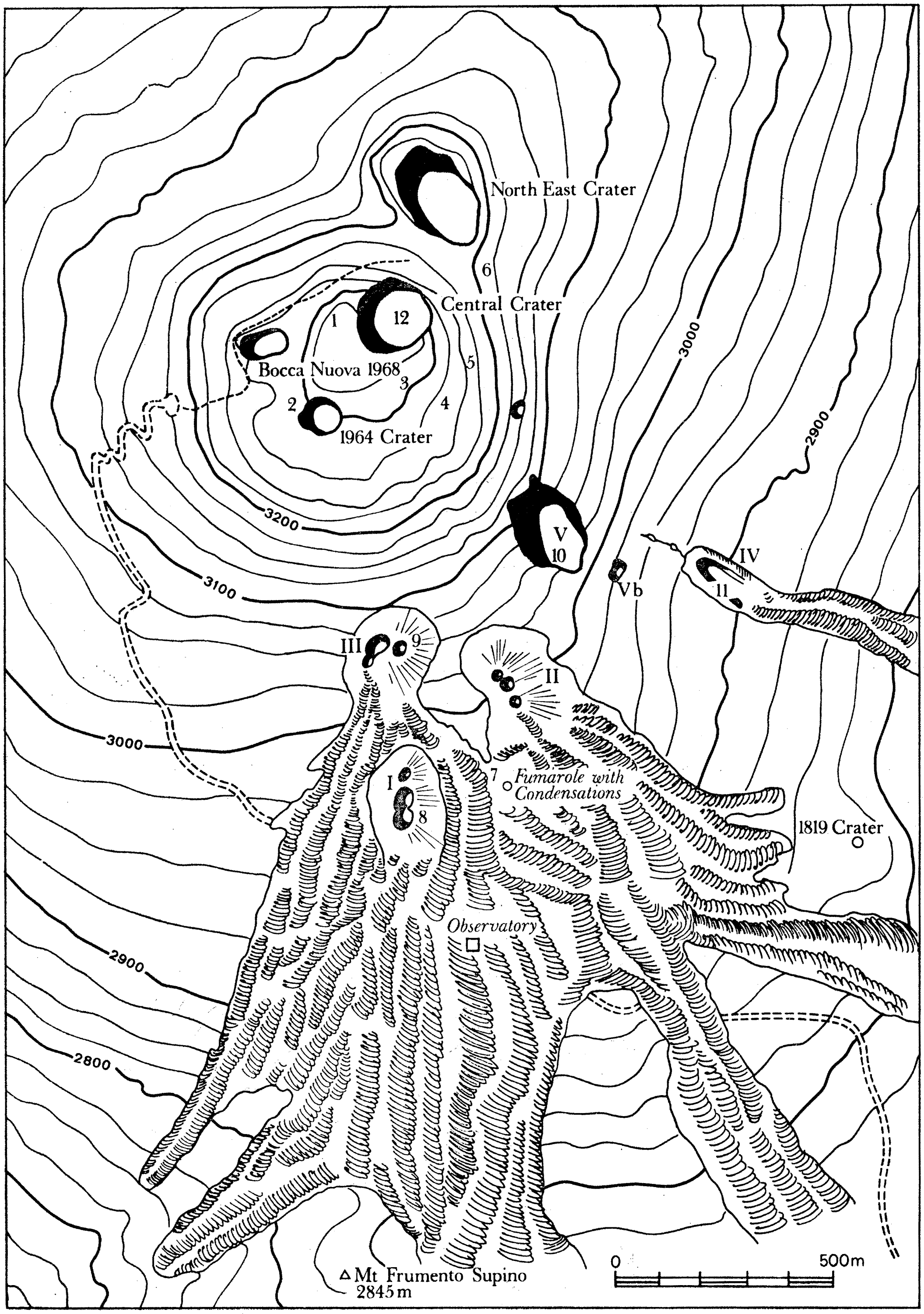

Figure 5. Map showing the first stage of the 1971 eruption.

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Sampling was extremely difficult owing to the violence of activity. Gas from the cones immediately to the north of the Volcano Observatory were sampled on 25 April. The samples were taken right inside the crater. Sulphur dioxide was less than 1 % and the speed of this gas was greater than Mach 0.25 (> 85 m/s). The abundance of projectiles prevented extensive

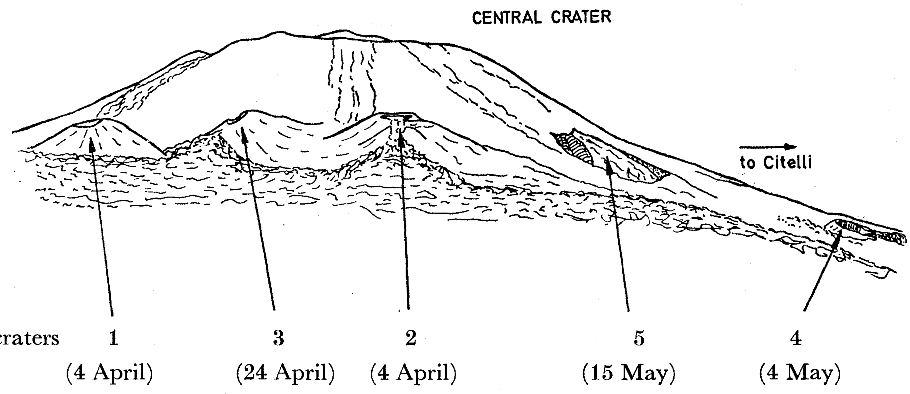

FIGURE 6. Drawing showing the position of the craters 1–5.

collection! On 26 April samples were obtained from crater III. On 28 April samples were taken from crater I, and the temperature of the gas was measured at 550 °C. These cones were situated on a crust beneath which lava was circulating. In this type of phenomenon contamination by air appears to be considerable.

During the night of 4 May, a new crater formed SE of the central crater at an altitude of 2930 m. The activity in this area was the initiation of a series of eruptive vents all related to a SW–NE fissure system. The evolution of this phenomenon was marked by the appearance of hornitos and lava flows at progressively lower altitudes. Measurements of physical parameters were made at the highest vent.

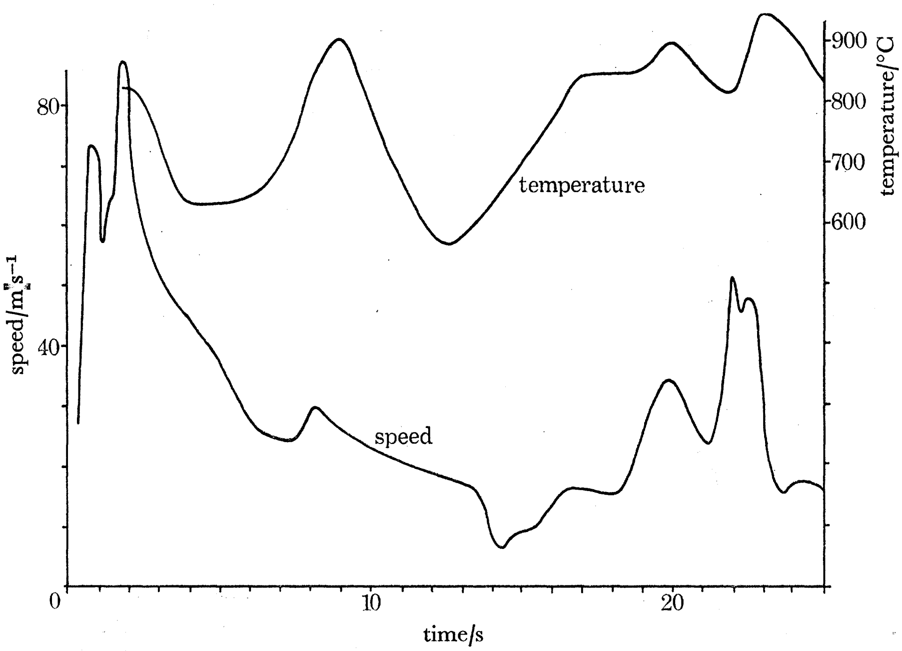

FIGURE 7. Diagram showing the variation of temperature and speed with time as determined for crater 4.

The gas speed fluctuated from 6 to 92 m/s, the temperature from 600 to 975 °C (figure 7). Analyses of the gas showed substantial air contamination. This contamination could be due to local subsurface permeation of air, e.g. along the fissure, or a fault in the collecting apparatus. As the activity migrated northeastwards other gas samples were taken at the hornitos of the Valle del Leone, at an altitude of 2600 m, these samples were also air contaminated.

At Citelli, samples were taken using a combination of Huntingdon's apparatus (Huntingdon, this volume) and the author's sampling bottles and apparatus. Different results were obtained, the principal differences were that using Huntingdon's apparatus the sample had less air contamination and increased hydrogen contents. These differences are being actively studied.

Post-eruption mission, August 1971

The eruption terminated in early June, a further mission was organized in August 1971 during which time new techniques were tested. These were the study of the aerosol form of gas, the radioactivity of the gas (figures 9 and 10), and the detection of gaseous compounds of

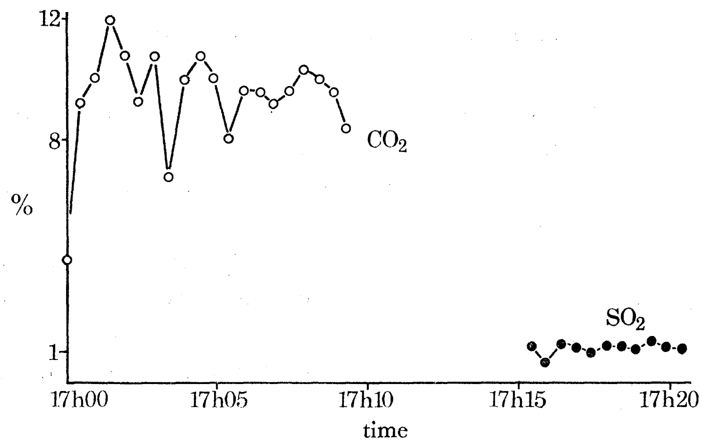

FIGURE 8. Diagram showing the variation of CO_2 and SO_2 with time on 27 August 1971 for crater 5.

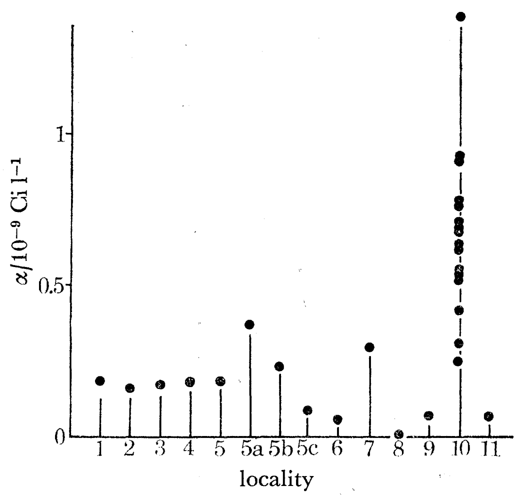

FIGURE 9. Radioactive (α) determinations for various places. Localities shown in figure 5.

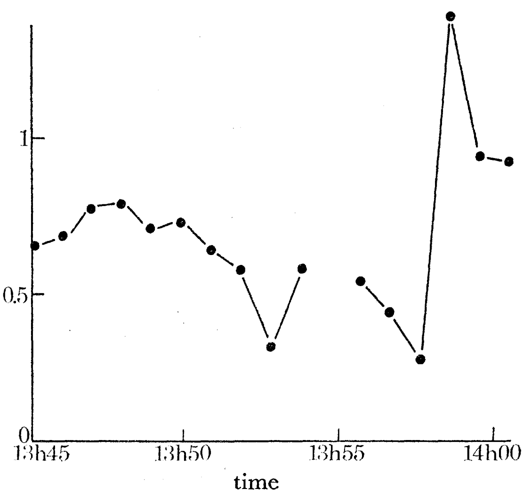

FIGURE 10. Diagram showing the variation of radioactivity (α) with time during part of 27 August 1971 for crater 4. $T = 601$ °C.

fluorine and chlorine. These measurements, together with temperature and analysis of the gas, were synchronized so as to be able to correlate the phenomena (figure 8). Samples were taken at sites 1 to 12 as shown in figure 5. All the measured temperatures were low exceptat no. 6 where it was 558 °C.

Finally, in September the central crater displayed the following post-eruptive activity. The deep lava lake rose until it had filled the chasm to near the rim, emitting incandescent gases; however, no lava flows formed and the magma receded into the throat of the central crater. Only craters 3 and 5 of the first formed cones showed any signs of activity in September. Sulphur dioxide was detected at crater 5.

During this expedition the automatic module was lowered into the central crater, this time to a depth of 1000 m. The gas collected consisted of air and small amounts of carbon dioxide. At night from the edge of the crater, a large red E–W fissure could be seen at the bottom. Unfortunately, the distance involved made it impossible to land the module on the fissure.

Conclusions

There has been much discussion about the eruption of 1971. The author considers it as being simply an extension of the normal activity of Etna. Two main trends can be seen in the evolution of the gas phase. The concentration of sulphur dioxide was much lower during the eruption than previously, and the water content was highly variable. The water content is influenced by the nature of the material through which the new conduits pass. These may traverse snow layers interstratified with ashes and lavas. The problems of these local effects and the difficulties of collecting and analysing under these conditions are being vigorously pursued.

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