SHORT COMMUNICATIONS

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A carbon dioxide-rich volatile phase in Mount Etna volcanism

THE collection and analysis of high temperature volcanic gases has often been used to provide data on the nature of the magmatic volatile phase at Mount Etna (Chaigneau, 1962; Huntingdon, 1973). However, such gas collections are limited to eruptions where collection close to degassing lava is possible, which considerably restricts the range of available data. Solidified lavas represent a far wider spectrum of magma compositions and eruptive conditions, but to obtain data on the volatile phase coexisting with the magmas at the time of eruption it is necessary to use the evidence preserved in the rocks themselves.

Trapped igneous gases can be released from rocks by heating small samples of lava in a vacuum, and the resulting gases can be analysed by a variety of methods (Shepherd, 1925; Muenow, 1973). This note compares the compositions of gases released from a whole-rock sample of rapidly cooled Etna lava, and the gases evolved from the major crystalline phase in that rock, namely plagioclase. The lava studied was collected from a small flow on the flanks of the north-east crater of Mount Etna in September 1975. No erupted gas could be collected at this time. The sample, which was red hot at the time of collection, was air cooled, and has the composition of hawaiite. The rock consists of 50-60% pale-brown glass, with plagioclase dominating the crystalline phases (clinopyroxene, olivine, and magnetite). The plagioclase phenocrysts contain large numbers of glass inclusions (fig. 1*a*). These inclusions, characteristic of Mount Etna lavas, are often concentrated in concentric growth bands within the mineral grain. Closer examination of these inclusions (fig. 1*b*), shows the presence of vapour bubbles within them, suggesting that volatiles have been trapped during the crystallization of the early-formed phases. Plagioclase is the primary liquidus phase in Mount Etna lavas under most conditions (Downes, 1973). The trapped gases in the phenocrysts thus represent the composition of the magmatic volatile phase at an earlier stage than it is possible to sample at the surface through volcanic gas collection.

The method of gas extraction and analysis used in this study is based on heating the sample *in vacuo*, followed by mass spectrometric analysis. To prevent the problems associated with the use of powdered samples for gas extraction (Price, *et al.*, 1977), the whole rock sample is broken into small (5 mm) fragments before use. The sample weight used was between 1 and 2 g and consisted of 5-10 rock chips.

Separated plagioclase crystals (0.5-1 mm in size)

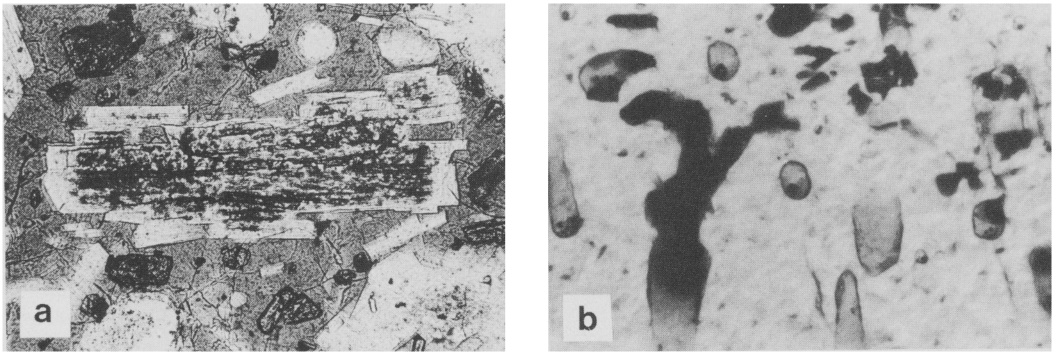

FIG. 1. (*a*) Typical plagioclase phenocryst, length 1 mm, showing glassy inclusions (plane polarized light). (*b*) Glass inclusions in plagioclase showing trapped vapour bubbles, width of plate = 100 μm (plane polarized light).

were hand-sorted to ensure that no particles of matrix glass or other crystalline phases were included. Plagioclase itself makes up 25% of the modal composition of the whole rock, and a 1–2 g sample of separated crystals was used for gas extraction. After drying overnight at 200 °C under vacuum, samples are heated at 1100 °C for two hours. Evolved water and carbon dioxide are condensed in a liquid-nitrogen-cooled trap, to prevent gas reactions in the furnace hot zone. The pyrex extraction and analysis line (including the mass spectrometer) is maintained at 110 °C, to prevent the adsorption of water on to the internal surfaces of the system during analysis. After the heating period is complete the trap is warmed to match the temperature of the remainder of the line, and the gas mixture is analysed using a calibrated Vacuum Generators Micromass 2 mass spectrometer. The results from blank runs under identical conditions are subtracted before presentation of gas extraction analyses. Gas compositions are presented (Table I) both in terms of percentage partial pressures of molecular species as determined at the time of analysis by mass spectrometry, and the proportions of the major atomic constituents, carbon (C), hydrogen (H), and oxygen (O). Atomic proportions enable real compositional differences, which may otherwise be obscured by apparent differences caused by equilibrium shifts, to be observed.

Table I shows the composition of gases released from the whole rock sample, and the gases evolved from the phenocrysts under identical extraction and analysis conditions. Delaney *et al.* (1978) have shown that non inclusion-bearing plagioclase crystals do not release gases during vacuum heating, and thus the gases released from the Etna plagioclase phenocrysts can be assumed to originate solely in the glass inclusions. The same species are present in both analyses, water and carbon dioxide being the most abundant. The major difference is that the gases released from the glass inclusions in the plagioclase phenocrysts are much richer in carbon than the whole rock gases. This is reflected in the high carbon dioxide and methane contents (although the methane may itself result from reaction of evolved water and carbon dioxide). The proportion of water, which normally accounts for more than 70% of the constituents of an extracted gas mixture, is considerably lowered in the inclusion gases. When the compositions are plotted on a C, H, O diagram (fig. 2), the enrichment of the whole rock gases in water is clearly seen, together with the carbon dioxide depletion.

TABLE I. *Composition of gases extracted from whole rock sample of Etna lava (I), and separated plagioclase phenocrysts (II), in terms of percentage partial pressures at 110 °C and 10^{-5} torr, and atomic proportions of C, H, and O. Both samples analysed in duplicate.*

	I	II
H_2O	90.03	47.91
CO_2	5.30	41.06
CH_4	3.99	10.31
SO_2	0.45	0.31
HCl	0.39	0.07
H_2S	0.06	0.15
Ar	0.05	0.16
C	3.14	16.02
H	63.61	42.89
O	33.25	41.08

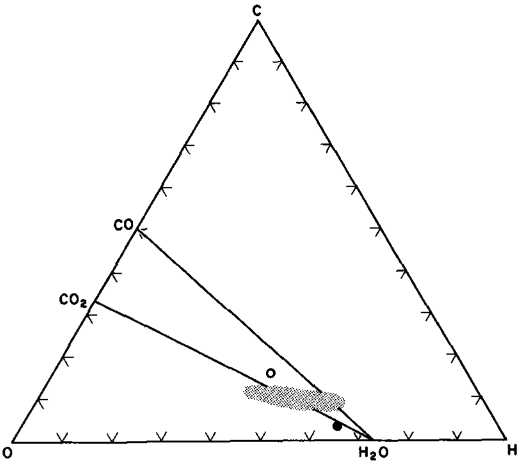

FIG. 2. C, H, O plot for gases extracted from whole-rock sample of Etna lava (closed circle), and separated plagioclase phenocryst (open circle). Stippled area encloses 1970, 1971 volcanic gas samples (Huntingdon, 1973).

Since the whole rock samples contain plagioclase phenocrysts, which evolve more carbon dioxide, and no inclusions were observed in the other crystalline phases, the matrix glass itself must be water-enriched and carbon-dioxide depleted. The proportion of carbon in the gases released by the phenocrysts is also higher than that observed in recent volcanic gases from Mount Etna (fig. 2) (Huntingdon, 1973). This evidence suggests that the role of carbon (probably in the form of carbon dioxide) in the volatile phase of Mount Etna volcanism is more important than is generally supposed. The volatile phase coexisting with the magma at the time of phenocryst formation (i.e. near liquidus conditions), has a higher carbon dioxide content than is apparent from study of the vent gases, where water is the dominant volatile species.

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Department of Geology, University of Reading
Whiteknights, Reading RG6 2AB

W. F. PRICE
D. K. BAILEY

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Thermal decomposition of okenite from India

AMIDST a wide variety of fibrous zeolites occurring in druses and cavities of basaltic lava flows referable to the Deccan Traps of India, okenite is widespread in all the three zeolite zones, namely the laumontite, scolecite, and heulandite zones identified by Sukheswala *et al.* (1974) in the western region of this volcanic province. In spite of its wide occurrence in India and other parts of the world, including Disko Island (Greenland), Crestmore (California), Scawt Hill (Northern Ireland), literature relating to the dehydration and thermal decomposition of okenite is lacking. The present study was undertaken on Indian material from Bombay, Nasik, and Poona in order to fill this lacuna and supply basic DTA curves for the mineral. In this attempt the effects were recorded by continuous heating up to 1000 °C using a Mom Derivatograph OD Type 102 (System Paulik, Paulik and Erdey) in which DTA, DTG, and TG curves are simultaneously recorded.

Okenite commonly occurs as delicate fibres aggregating into spherical globules ranging from a few mm to 4 cm in diameter, in association with other cavity minerals (fig. 1). In the Poona region it is commonly associated with quartz, chalcedony, apophyllite, stilbite, and heulandite; in the Nasik region it occurs with scolecite, laumontite, stilbite, and apophyllite; and in the Bombay region it is accompanied by laumontite, quartz, calcite, prehnite, mordenite, apophyllite, and rare babingtonite, At times it is seen to grow over gyrolite. Chemical analyses are given in Table I.

In hand specimen okenite closely resembles mordenite, but it may be easily distinguished microscopically by its higher refractive indices ($\alpha = 1.540$, $\gamma = 1.542$). However, in the present studies the identity of the study material was confirmed from the X-ray powder diffraction patterns using Cu K_α radiations and Ni filter.

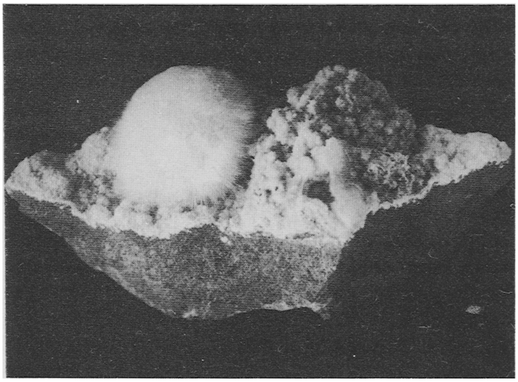

FIG. 1. Fibrous aggregate of okenite from Bombay (2/3 natural size).