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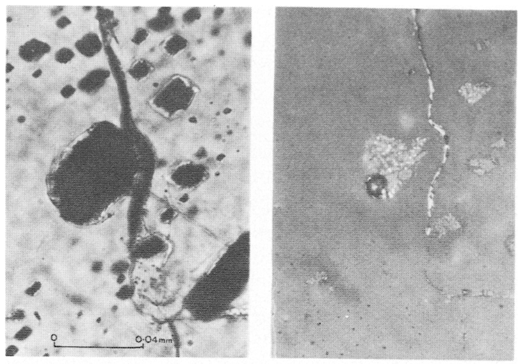
Electron-microprobe investigation of melt inclusions in plagioclase phenocrysts from Mount Etna

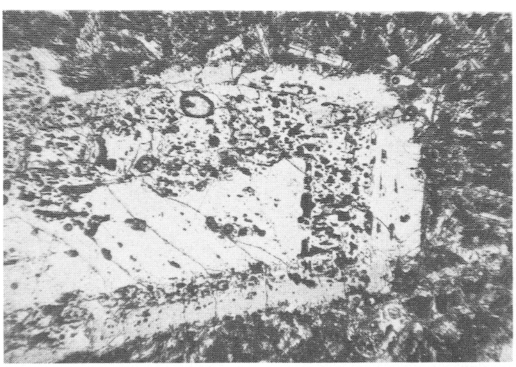
IN the course of a petrological study of the trachybasaltic lavas from the Adrano area of Mount Etna, Sicily, plagioclase phenocrysts rich in glass inclusions were noted (Duncan, 1976). The small inclusions (usually less than 0.10 mm) were considered to represent trapped magmatic liquid, but a detailed study was not carried out at the time. The present note is a record of preliminary qualitative microprobe analyses of inclusions in a plagioclase phenocryst from one of the samples: a porphyritic lava of hawaiite composition. This lava is of prehistoric age (probably less than 30 000 years) and crops out at the south-western periphery of the Etnean volcanics near the village of Schettino.

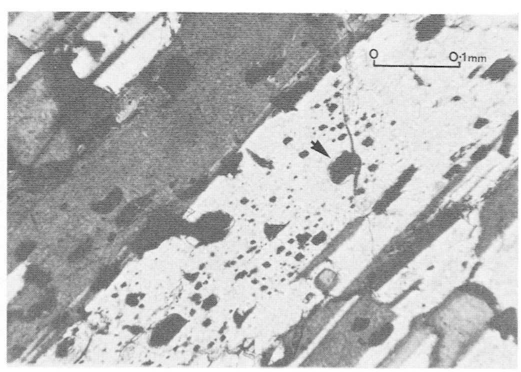
The inclusions occur concentrated in the core of phenocrysts or are associated with distinct growth bands parallel to the oscillatory zoning (fig. 1). They are therefore considered to be primary. The inclusions are subangular, showing an approach to a rectangular outline, although some are square or triangular. The more elongate inclusions show a pronounced alignment parallel to the cleavage directions of the plagioclase lattice (fig. 2). Viewed in transmitted light the glass inclusions are opaque (fig. 3*a*). This opaque character is considered to be due to minute inclusions of chalcosine. Under incident light two distinct parts can be seen in most inclusions: a spherical cavity lined with an opaque substance of low reflectivity and a flat, polished part, which comprises areas of three different reflectivities (fig. 3*a*, *b*). The areas of highest reflectivity are chalcosine and the other two types of area



A B

FIG. 3. Inclusion in (*a*) transmitted light, (*b*) reflected light.





FIGS. 1 and 2: FIG. 1 (*left*). Plagioclase phenocryst in transmitted light showing typical arrangement of inclusions. (Width of phenocryst about 1 mm.) FIG. 2 (*right*). Close-up view of inclusions in transmitted light with partially crossed polars. (The inclusion illustrated in fig. 3*a*, *b* is indicated with an arrow.)

of differing reflectivity are both composed of Si-rich material. The spherical cavity is usually situated at one corner of the inclusion, but a few inclusions lack a cavity and some have a cavity associated with them that has become almost completely separated. This feature suggests there has been differential movement between the cavity and the rest of the inclusion.

X-ray photomicrographs of several randomly selected inclusions showed the cavities to be lined with a S- and As-rich substance that lacked Si and the flat, polished parts to be predominantly silicate with very little S and no detectable As. Taken as a whole, the inclusions are enriched in Fe, Mg, Na, Ti, Cu, S, and As relative to the plagioclase, have comparable amounts of Ca and Si, and are slightly depleted in Al. The S- and As-rich part of each inclusion (the cavity) is enriched in Cu relative to the Si-rich part and very much depleted in the other elements except for Fe and Mg. X-ray photomicrographs show these elements to be fairly evenly distributed between the two parts. This is unexpected in the case of Mg and suggests that the material lining the cavity is not a single mineral species. Fig. 4*a–d* illustrate the distribution of selected elements. The cavity is only slightly enriched in Cu because most of it is concentrated in a single small area which optical examination showed to be a grain of chalcosine. (Discrete grains of well-polished chalcosine occur in the silicate parts of the inclusions and as isolated grains in the plagioclase phenocrysts. This shows there was a separate liquid-sulphide phase present in the melt and also that the spherical cavities are real features and not caused by plucking of sulphides during polishing.) Scan traces across the Si-rich part of the inclusions show that Cu, Fe, and S vary sympathetically with one another and antipathetically with Si (fig. 5).

The inclusions described here are considered to represent trapped portions of homogeneous magmatic liquid from which an immiscible volatile-rich liquid separated on cooling. By analogy with aqueous-fluid inclusions (Roedder, 1967) the liquids may have been subcritical silicate and supercritical H_2O, CO_2, SO_2, etc. The sphericity of the cavities suggests the separation occurred while both were fluid. It is possible that two phases were

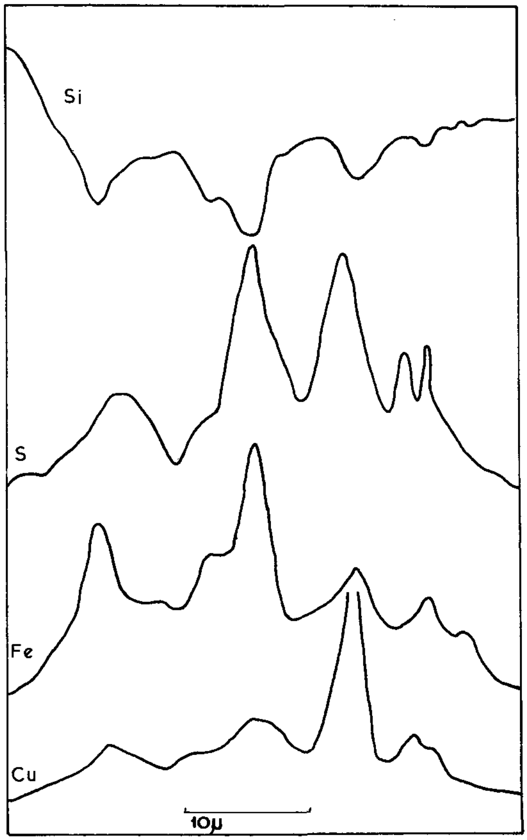


FIG. 5. Distribution of Cu, Fe, S, and Si along a scan across the Si-rich part of the inclusion.

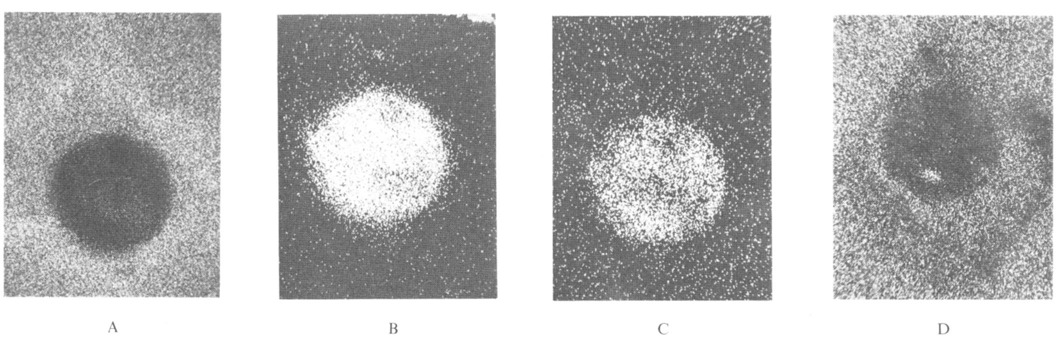


FIG. 4. Distribution of Si (*a*), S (*b*), As (*c*), and Ca (*d*) in and around the inclusion figured in fig. 3*a*, *b*.

originally trapped, but this is unlikely because of the rarity of single-phase inclusions. Partition of elements between the Si-rich phase and the volatile-rich phase would lead to the presently observed distribution of elements. The composition of the material coating the cavities will not be the same as that of the non-fugitive elements in the original volatile-rich phase as some of these elements would not have been precipitated. When the solvent was lost by leakage through or along cleavage planes or during sectioning the remaining dissolved material would also have been lost.

Immediately adjacent to each inclusion there is an albite-rich aureole. The presence of this zone indicates that there was exchange of ions between inclusion and feldspar. This reaction may have led to the angular shape of the silicate inclusions because movement of ions would be facilitated by the plagioclase cleavage, which would thus control the shape of the inclusion.

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Cleavage in pyrite from Tasmania

DURING an investigation of Tasmanian mining areas late in 1971, specimens of pyrite crystals associated with muscovite and crystallized quartz were shown to the author by employees of the Hydro-Electric Commission of Tasmania who were engaged in the construction of the Mersey-Forth power development scheme at Wilmot, in the central-northern part of the state. The specimens came from a large fissure-like cavity in granite intersected by the hydro tunnel near Moina, which now supplies water to the Wilmot power station.

Unfortunately, at the time of the author's visit the tunnel had been completed so that verification of the occurrence and the determination of its associated mineral paragenesis was not possible. However, several interesting specimens were obtained from local mineral collectors.

These specimens showed pyrite crystals, predominantly as striated cube-pyritohedron combinations, directly associated with crystallized muscovite, kaolinite, and/or crystallized quartz. The crystals range in size from 4 mm to over 4 cm in diameter. Complete single crystals, free from any matrix, showing various combinations of cube and octahedron forms up to 2 cm were also seen but their genetic relationship to the cube-pyritohedron crystals is not known.

Crystals with the cube-pyritohedron morphology removed from kaolinite matrix showed what appeared to be small perfectly developed octahedral faces. However, on close examination these faces displayed irregular surface features uncharacteristic of a crystal face. Further investigation indicated that they were due to a very easily produced and very pronounced octahedral cleavage in the pyrite crystals. Only crystals associated with the pyrite-muscovite-kaolinite assemblage showed this phenomenon.

The presence of octahedral cleavage was positively demonstrated by cutting and polishing crystal sections parallel to the (001) and (110) directions. The (001) section showed incipient cleavage cracks meeting at 90° and arranged at 45° to the cube faces (fig. 1). A section parallel to (110)