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SOME TEXTURES IN LUNAR IGNEOUS ROCKS AND TERRESTRIAL ANALOGS

by

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One of the most distinctive textural characteristics of lunar igneous rocks of basaltic type is the crystallisation of olivine, pyroxene and plagioclase in immature forms. The immaturity extends, also characteristically but not invariably, to phenocrysts in porphyritic basalts. It is with this immature crystallisation and the textures it characterises that our investigation is principally concerned. Many igneous rock samples from the Apollo 12 and Apollo 15 Missions come into this category.

The approach is a selective and comparative one, particular attention being paid to textures in Procellarum samples 12002, 12009, 12021 and 12065, together with those textures which, falling within our direct experience, represent the closest terrestrial analogs. The validity of this approach depends on the relatively much greater degree to which the geological context of the terrestrial rocks is known and the better basis we have for petrogenetic interpretation. Some compositional differences, in both the bulk chemistry and the mineral components, must be borne in mind, although they do not invalidate this approach. The analogs selected are mainly from two remarkably similar Tertiary minor intrusions of ultrabasic affinity and rich, relatively to more common terrestrial igneous rocks, in Mg and Ca (Drever and Johnston 1967). The chemistry of the terrestrial samples with analogical textures is upgraded, and the following elements determined by thermal neutron activation: Na, Mg, Al, Ca, Sc, V, Cr, Mn, Fe, Co, Rb, Sr, La, Ce?, Sm, Eu, Yb, Lu?, Hf, Ta. Chemical analyses by electron probe should be indivisibly linked with textural analyses.

Analogous lunar and terrestrial textures are subjected to rigorous optical analysis and the results consolidated on equal area projections, particular attention being paid to a comparison of radiating and fascicular (or plumose) associations of plagioclase and pyroxene and to the development of pyroxene cores within the plagioclase. A new textural term, intrafasciculate is introduced to denote a characteristic tendency of the pyroxene to develop in elongated shape within hollow plagioclase.

Of all igneous textures, porphyritic texture is the one with which the interpretation of the major differentiation of lunar basalts is mainly concerned. Many lunar rocks have this texture, particularly those from the Apollo 12 and Apollo 15 Missions, the most typical phenocrysts being lime-

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poor pyroxene; less common are forsteritic olivine and anorthitic plagioclase still less. That the pyroxene phenocrysts have developed very commonly as immature hollow crystals has been stressed by Hollister et al. (1971). Conspicuously plagioclase-phyric rocks appear to be lacking on the moon although well represented on earth. The Fra Mauro high alumina basalt 14310 is more seriate than porphyritic.

(a) Fig. 1 (b)

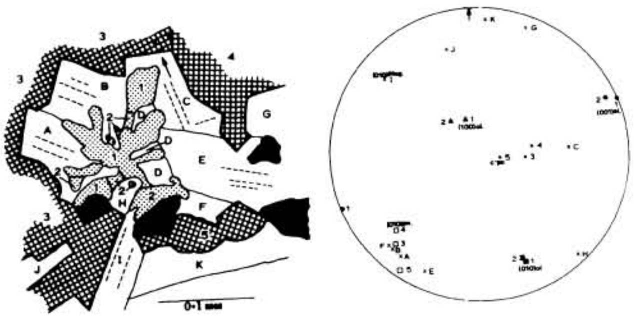

Fig. 2

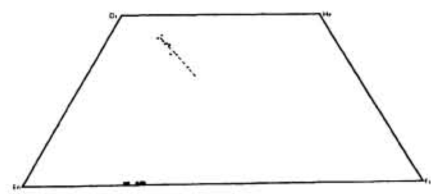

Fig.1 (a). Drawing of a cross-section of an elongated skeletal olivine and its associated plagioclase and augite. (b) Crystallographic orientations of the minerals in (a) on an equal area projection. The rock sample was obtained from the top contact facies of the Gars-bheinn picritic intrusion, Skye, Scotland.

Fig. 2. Electron probe analysis of augites (slightly zoned) and olivine in the same sample (Fig. 1). The indicated fractionation trend is similar to certain other terrestrial augite trends (Evans and Moore 1968; Smith and Lindsley 1971) and to the initial fractionation trend of augites in lunar basalts.

In assessing the value of the methods adopted in this comparative approach reference is here made to one of a number of terrestrial analogs. This analog is found at the top contact of a picritic intrusion in which olivine, plagioclase and augite are intergrown in immature, elongated, plumose forms. In superficial terms this rock might be regarded as an aphyric association of these minerals in subophitic to subvariolitic textural relationship, suggesting rapid cotectic crystallisation of all three. On the basis of a more detailed analysis it can be discerned that there are: (1) an order of nucleation (olivine, plagioclase, augite), (2) a crystallographic radiate relationship between the feldspars and the olivine (Figs. 1a, 1b), and (3) a metastable fractionation trend in the augites (Fig. 2).

Immature or skeletal crystals that attain pegmatitic dimensions cannot be regarded as the result of 'quenching'. If such crystals occur as phenocrysts they could have been formed by rapid, early-stage crystallisation from well-dispersed nuclei. The size of a crystal may be less critical than its form: even the huge olivine crystals in the Rhum harrisite are of immature type (Drever and Johnston (1972)). Lunar liquids appear to be reluctant to nucleate before attaining a higher degree of supersaturation than terrestrial liquids, the rapid growth rate after nucleation being due to this, to the relatively low viscosity (Weill et al. 1971) and relatively high

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thermal conductivity. Volatilisation of alkalis at any stage would result in viscosity reduction to which there should be a textural response.

The textures investigated provide reliable information on the nucleation density, on a sequence of crystallisation, and on relative rates of crystallisation. But it is unjustifiable to infer, from the textural evidence presented, either a rapid cooling rate or the relative depth at which any mineral phase was precipitated. The supersaturation principally responsible for rapid crystallisation does not necessarily imply rapid cooling. Supersaturation, undercooling and 'quenching' are not synonymous, and a small degree of undercooling can yield a high degree of supersaturation (Wyllie 1963). The remarkable range in the immature forms of olivine in 12009 is probably a response to micro-scale environmental differences in the degree of supersaturation corresponding to different chemical diffusion gradients around each growing crystal (Drever and Johnston 1957; Chernov 1963). Associated with a rapid vectorial growth at one point there may be some cessation of growth, or even dissolution, at another. In many lunar basalts it is evident that the rate of crystallisation exceeded the rate of diffusion.

Interpretative igneous petrology requires a more rigorous approach to textural analysis, a standardisation of textural types and a rejection of antiquated terminology applied too loosely. In addition, comparatively new terms such as cumulate, which has a genetic connotation, should not be used in descriptive petrography. The occurrence of phenocrysts, even with preferred orientation, does not necessarily imply accumulation.

In applying the results of experimental phase petrology either to magmatic differentiation on a major lunar scale, or to lunar fractionation in a micro-environment, petrologists have recognised the need for reliable textural observations. But these observations are rarely rigorous enough, and attempts to correlate them with the sequence and composition of the liquidus phases may have limited validity.

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