HIGHLAND AND MARE COMPONENTS IN THE CALCALONG CREEK LUNAR METEORITE;
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The Calcalong Creek meteorite is a highland regolith breccia with a glassy impact-melted matrix and mineral and lithic clasts from both highland and mare sources. The presence of highland and mare components was recognized by Hill et al. (1991a, 1991b) who calculated a bulk composition from INAA determinations consistent with a mixture of 50% anorthosite, 20% KREEP, 15% Luna 16-type low-Ti basalt, and 15% SCCRV. In the single, small, 9.3-mm² microprobe mount we have examined, we have found several varieties of highland materials admixed with Fe-rich assemblages from mare basalts along with only small traces of KREEP or of possible SCCRV-bearing minerals. Although this meteorite has been exposed to terrestrial conditions in the Australian desert, we have observed no evidence of weathered materials.

The Matrix and Fusion Crust. The microbreccia matrix consists of brownish vesicular glass with an average CIPW normative composition of 66 wt.% feldspar (An₉₀Ab₂Or₄), 26% pyroxene (En₄₄Fs₃₉Wo₁₇), 1% olivine (Fo₀₄), 1.8% ilmenite, 0.7%apatite, and <1% each of chromite and pyrite. This glass composition plots within the plagioclase field of the pseudoternary diagram of Walker et al. (1973). Much of the matrix is crowded with clasts but several relatively clast-free patches show flowbanding. One or two of these patches are, in part, concentrically banded and may represent reworked regolith agglutinates that preexisted the melting of the matrix as a whole. A thin layer of highly vesicular fusion crust borders one edge of the meteorite fragment. This glass is has an average CIPW normative composition of 46 wt.% feldspar (An₈₆Ab₁₀Or₄), 43% pyroxene (En₄₆Fs₃₉Wo₁₅), 3% olivine (Fo₅₂), 2.5% ilmenite, 1%apatite and <1% of chromite and pyrite. The average fusion crust plots in the olivine field close to the olivine-anorthite cotectic line in the pseudoternary diagram of Walker et al. (973).

Highland Clasts. Angular to rounded fragments of plagioclase (An₉₅-9₇), ranging in size from <10 to 350 μm are the most abundant clasts in our sample. Other minerals that occur in individual fragments are exsolved pyroxenes (up to 300 μm across), Mg-ilmenite, trolite, and rare grains of whitlockite, zircon, and baddeleyite. At least three types of highland rocks occur as lithic clasts: anorthosite, anorthositic gabbro, and spinel troctolite.

Anorthosites. Several lithic fragments consist mainly of plagioclase (An₉₅-9₇Ab₃-₄Or₀-₁) associated with small grains of pyroxene and/or olivine and accessory minerals. In the largest such clast, a 600-μm fragment of plagioclase contains two <80-μm grains of pyroxene (En₆₂Fs₃₂Wo₀), two 25 to 70-μm grains of olivine (Fo₆₁), and a 10-μm grain of FeS. This clast belongs to the ferroan anorthosite suite of highland rocks (Warren et al., 1983).

Gabbroic Anorthosite. A 460 x 260-μm clast consisting of plagioclase and chains of euhedral to subhedral pyroxene grains in a cumulate texture occurs along one edge of the meteorite fragment (Fig. 1a). The modal composition is about 70% plagioclase (An₇₉Ab₂Or₀-₁) and 30% pyroxene with exsolution lamellae of clinopyroxene (En₆₂Fs₃₄Wo₀) and augite (En₄₁Fs₁₆Wo₄⁴). This igneous lithology shows no evidence of shock or any other kind of alteration. It also belongs to the ferroan anorthosite suite.

Spinel Troctolite. The largest clast in the probe mount is a wedge-shaped fragment 1.5 mm long. Under the optical microscope it appears to retain a relict crystalline fabric. However, backscattered electron images show only a feathery glass with minute crystallites of olivine plus a few 200 to 750-μm patches of remnant plagioclase (An₆₂Ab₄) and olivine (Fo₀₉-9₂). This pair of minerals plots in the uppermost portion of the Mg-suite of highland rocks (e.g. Warren et al., 1983). The average composition of the glassy groundmass, measured by a broad (10-μm) electron beam, has a ternary composition of Olₒ₈ An₆₂ Si₁₀, which plots within the spinel field, close to the border with the plagioclase field, on the pseudoternary diagram of Walker et al. (1973). We conclude that the large feathery clast is a partially remelted spinel troctolite.

Mare Clasts. Fe-rich assemblages characteristic of late-stage residual components in certain mare basalts are scattered through the sample in clasts 25 to 220 μm long. They consist of any or all of the
following phases: ilmenite, ulvöspinel, fayalite, ferrohedenbergite, ferroaugite, pyroxferroite, silica, troilite, and glass. The clast with the largest number of these phases (Fig. 1b) consists of ferroaugite (En₆₆Fs₇₀Wo₂₄), ulvöspinel (with 1.8-2.2 wt.% Al₂O₃) mantling ilmenite (containing <0.3 wt.% MgO), silica, and rows of minute crystals of fayalite (Fa₉₀) in glassy borders separating ulvöspinel from ferroaugite. No KREEP-rich minerals are present, and no common minerals are attached that would indicate the composition of the basalt as a whole. In a second clast, a 34-μm grain of pyroxferroite (En₂₆Fs₈₂Wo₁₆) associated with a 2-μm grain of troilite and one of Fa₂₉ is attached to a 340 x 290-μm fragment of low-Ca pigeonite (En₆₆Fs₂₉Wo₂₄). Although the Fe-rich assemblages clearly represent late-stage mare residua, we cannot specify the type of basalt in which they formed solely on the basis of our observations. However, the INAA data of Hill et al., (1991a) suggest that VLT basalts make up 15% of the bulk meteorite. We conclude that VLT basalts, of the type collected at the Luna 24 and Apollo 17 sites, are the most likely parent materials of the mare clasts in our sample.

KREEP and SCCRV: MISSING. We have not identified any constituents that would account for the 20% KREEP and 15% SCCRV components calculated by Hill et al., (1991a). The largest K-enriched particle we found (Fig. 1c) is a 120-μm patch of glass with alternate bands of silica and silica + K-spar (An₁₄Ab₂₉Or₅₇). This glass is associated with magnesian olivine (Fo₆₇) and pyroxene (En₄₃Fs₃₈Wo₁₉). The glassy matrix of the meteorite, with 4% of normative Or, plus a few grains of apatite, whitlockite, and zircon, together with three small patches of K-enriched silica glass would contribute a KREEP component equal to no more than 1 or 2% of the bulk meteorite. With respect to SCCRV, the situation is even worse. Unlike the chromite and chromian ulvöspinel association that is found in some mare basalts, we observe ilmenite mantled by ulvöspinel containing <0.5 wt.% of Cr₂O₃. To date, we have identified only 3 scattered grains of Cr-rich spinels. We are forced to the conclusion that our small microprobe mount is grossly unrepresentative of this lunar meteorite.


Figure 1. Igneous clasts in Calcalong Creek (backscattered electron images). a. Gabbroic anorthosite consisting of plagioclase (dark gray) and pyroxenes (light gray) in a cumulate texture. b. Fe-rich residual assemblage from a mare basalt: ilmenite (i) is rimmed by ulvöspinel (U) which is separated from darker gray Fe-pyroxene (ferroaugite) by euhedral crystals of fayalite and silica (Si). c. The largest K-rich phase found, consisting of a glass showing alternate bands of SiO₂ and SiO₂ + K-spar, attached to pyroxene and olivine.