MINERALOGY AND PETROLOGY OF APOLLO 17 BASALTS.

At the Fifth Conference, data on six Apollo 17 mare basalts led to our classification (1) into Types I (olivine rich), II (olivine-free) and III (transitional). We now have mineral data on 16 basalts plus petrographic information to classify another 14 yet to be analysed. The 30 samples show surprisingly little compositional variation. It is now clear that the abundance and significance of the types require a re-grouping. Our old Type I is renamed Type IA (quenched, olivine rich); old Type III is related, abundant, and renamed Type IB (slower cooled, olivine poor); old Type II is rare but compositionally distinct from I and is still Type II.

Samples are grouped as follows, with modal olivine percent in decreasing order in parenthesis and numbers underlined where probe analyses are completed.

Type IA: 74245 (15.6), 74275 (13.8), 70275 (10.4), 70215 (10.1), 74235 (10.1), 71569 (7.8), 71155 (6.1), 76136 (5.5), 70255 (5.0), 71075 (4.4), 72155 (3.5), 72135, 71135 (trace).

Type IB: 74255 (3.2), 70135 (2.8), 78506, 71055, 71175, 71035, 75075 (2.0-1.0), 70017, 70035, 79155, 70315, 78505, 70185, 78135 (1.0-0.3), 75015 (trace).

Type II: 75035; 75055 is probably Type II.

General relations between Types. Type IA is characterised by olivine phenocrysts (often skeletal) with calcic augite rims, fine-grained groundmass, and acicular opaque oxides. There is strong positive correlation between modal olivine, forsterite of olivine, Al and Ti of early calcic pyroxene, and modal plagioclase. The extreme (74245) has 15.6% olivine (Fo80-76 zoned), augite Ca49Mg41Fe10 (9.4% Al2O3, 8.5% TiO2), and <10% plagioclase. Plagioclase is difficult to detect but no counts gave over 20%. Those Type IA (70255) with only about 5% olivine (Fo 75-68 zoned) have a coarser grained groundmass transitional to IB, and 1-2% cristobalite.

Type IB is more "gabbroic" in texture with near-equigranular pyroxene and oxides (plus small, rounded olivines) often poikilitically enclosed by plagioclase. Those with highest, about 3% olivine (Fo71-65 zoned), are transitional to IA with patches of fasciculate texture (78506). Those with traces of olivine (Fo66-59 zoned) are the other limiting extreme of IB (70185). Type IB contains 20-25% plagioclase, less opaque oxides.
than IA, and up to 4% cristobalite. The pyroxenes show strong sector-zoning, and often augite cores to pigeonite rims, with outer fringes zoned to pyroxferroite. The latter feature increases as the olivine content (and Fo value) decrease in the IB series.

Type II is compositionally distinct from Type I sub-types. Absence of olivine, abundance of cristobalite (6%), low opaque oxides (14%), high plagioclase (33%), and a pyroxene trend from Ca30Mg43Fe27 to Ca22Mg1Fe78 (near equi-alclic) suggest a lower-temperature melt from a different lava suite than Type I.

Two samples (71135, 72135) have IA textures but very low, IB olivine contents. This allows an interpretation of thermal history (below).

**Olivines.** Type IA rich in olivine show Fo80-74 zoning; those low in olivine show Fo75-68. Type IB with less olivine show Fo71-65 and, where only traces show Fo66-59. Fayalitic grains (Fo14-17) also occur in 71155. Cr2O3 is 0.52% to 0.05% with decreasing Fo.

**Pyroxenes.** Fo-rich Type IA show pyroxenes clustered around Ca46 Mg36Fe8 with high Al and Ti (above). Fo-poor IA have early augites colour-banded with brown rich in Ca, Al and Ti and colourless at about Ca34 with 2.5% Al2O3 and 2.2% TiO2, and groundmass subcalcic augites trending to Ca22Mg38Fe40. Fo-rich IB introduce pigeonite intergrown with augite, and Fo-poor IB show variable extents of a trend towards pyroxferroite. On a Ti-Al plot, all cluster near the 1:2 line indicating CaTiAl2O6 solution, the only exceptions being those very rich in Al and Ti or in Fe, which show Al/Ti < 2 indicating Ti3+.

**Fe-Ti-Cr-Al oxides.** Spinels of IA cluster along the Usp-Chr join of RO-RO2-R2O3 in a narrow field, 28% to 54% Chr. In contrast, those of IB also include chrome-spinel (82-90% Chr) and ulvöspinel (2-10% Chr). Two IB rocks (70035, 70185) contain unusual Cr-Al-rich spinels that plot midway between titanian chromites and chromian pleonastes on Haggerty's Figs. 3,4,5 (2). Grey and tan armalcolites occur in both IA and IB but grey (mantled by ilmenite) are commoner in IA. The grey are richer with maximum of 2.3% Cr2O3, 7.6% MgO (3), the tan minimum being 1.2%, 4.1%. Overlaps occur, and we could not draw a compositional boundary between the two colour varieties.

**Other minerals.** Plagioclase is An88 to An74, with An84-74 the maximum zoning range. Irons are very depleted in Ni, most being < 0.01% with 1.2% maximum, and consistent in Co (0.3-1.0%). Cristobalite is 98.5% SiO2, chiefly with Al2O3 (0.6-1.0%).

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Rutile is 97.5% TiO₂, chiefly with FeO (1.5%). Zr-rich minerals. In addition to baddeleyite and tranquillityite, analyses of three new zirkelite-type phases are presented. On the ZrO₂-TiO₂-FeO plot they add to the new phases X and Y we recorded from Apollo 14 and 15 (4). One is a Ti-Fe baddeleyite (85%ZrO₂) with 1.8% Y2O₃ but only 0.8% HfO₂. The second is similar to our Phase Y but contains 2.7% Nb₂O₅. The third plots close to terrestrial zirkelite but contains 6.8% Y₂O₃ and only 2.6% CaO. This further emphasises the extent of compositional variation within the mineral system because 8 contrasted compositions have now been recorded from lunar rocks.

Rhyolite glass. Patches analysed from 5 basalts show remarkable consistency (SiO₂ 75.1-76.0%, K₂O 7.4-9.4%, Na₂O 0.3-0.8%, FeO 1.5-2.8%, TiO₂ 0.2-0.9%). One would not expect late liquid fractions to be frozen always at similar compositions unless they were controlled by the liquid immiscibility mechanism (5).

Basalt relations. Type IA contains "primitive" olivine and pyroxene compositions and there is a series, then a transition to Type IB, and then an apparently later-fraction series of IB. However, the bulk chemistry of the rocks indicate that Types IA and IB are virtually isochemical (H.J. Rose pers.comm.). It is preferred, therefore, that Type IA is the quickly-cooled equivalent of Type IB. This means that augite very rich in Al nucleated from a low-Al₂O₃ basalt (8.5%). Slower cooling for Type IB must have caused either reaction of early Fo-rich olivine and Ca-Al-Ti-rich augite with liquid, or the establishment of different (augite-pigeonite-plagioclase) phase crystallisation. The textural and mineralogical relations indicate a gradual progression through the Types IA and IB series. Those with Type IA texture but low olivine content contain veins of basaltic glass perhaps due to shock remelting and therefore elimination of olivine by re-established IB reaction temperatures. Only one basalt magma type is implied (except for the rare Type II). Several thin flows, with slightly different cooling rates, are more likely to have been sampled than a single flow with variably chilled borders.