Table 1 lists the number and total areas of different types of fragments (> 0.1mm) in 14306, 14321, 14270 thin sections. Dark polymict basaltic metabreccia predominates. Among monomict fragments, light-basaltic material (i.e. noritic) predominates over anorthosite + large plagioclase crystals, with minor granitic + rhyolitic, feldspathic basalt and others. These rock types and proportions are generally similar to the 1-2mm rock fragments (Steele and Smith) from 14002, 14258.

The textures and compositions of rock and mineral fragments in 14306 imply various thermal histories with possible implications for models of thermal accretion. Breccia 14306 is polymict with a poorly-sorted, light-gray matrix that is non-porous (<5% porosity). The matrix is probably holocrystalline but distinction between fragments and matrix is arbitrary. Many tiny and some large fragments are partly glass. Fractures cut equally across fragments and matrix indicating equal coherency; however glass does not appear to pervade and bind the matrix. Hence the matrix probably cohered below the temperature of partial melting (900 ± 100°C).

Dark-gray polymict metabreccias have a non-porous matrix comprising finely-crystalline (≤50µm) plagioclase and pyroxene with minor ilmenite, metal, sulfide, zircon and phosphates. Noteworthy fragments include light-gray, partly-glassy, basaltic metabreccias; pyroxenes with 5µm exsolution; partly glassy granite; deformed glassy rhyolite and irregular grains of metal-sulfide. These metabreccias cooled quickly (mins. to hrs.) from an initial temperature near 900°C as indicated by deformation of rhyolite and lack of melting in sulfide-metal grains. Marginal sodium enrichment of rhyolite suggests presence of vapor during compaction and initial cooling. Grains with concentric shells of texturally-distinct material are rare in the darker-gray metabreccias, and contain a central kernel of rhyolite or granophyre, or rarely a light-gray metabreccia. Probably stickiness of nearly molten rhyolite and partly-liquid metabreccia resulted in attachment of solid matrix during transport or in cohesion of adhering matrix immediately upon deposition.

Round fragments of crystals and rocks occur sporadically in the darker-gray metabreccias. Evidence of melting is absent, and rounding presumably occurred by abrasion in a turbulent dust jet.

The coarser texture and mineral compositions of the light-gray, partly-glassy basaltic metabreccias suggests a higher temperature of recrystallization than attained in the matrix of darker-gray metabreccia. The Mg-distribution between ilmenite and pyroxene in the basaltic metabreccias suggests by analogy with terrestrial specimens a temperature near 1000 ± 100°C. Possibly the light-gray basaltic metabreccias were
were undergoing metamorphism near 1000°C immediately prior to disruption and incorporation into their present matrix. This is consistent with the hypothesis of a hot outer Moon at the time of formation of the Imbrium basin, as previously suggested by Öpik (1969) on the basis of geometrical relations of the impact features.

Coordination of these mineralogic and petrologic data with geological maps of the Imbrium and Apollo 14 regions, together with extrapolations from terrestrial and laboratory data, suggests that these Apollo 14 breccias derived from the upper 5 to 10Kms of the pre-Imbrium "crust" during impact, and were transported in a hot, turbulent jet (~900°C) containing dust and vapor. The depth estimate assumes that the Apollo 14 material derives mainly from the initial impact with high-velocity jetting between the circumference of the incoming body and the disintegrating crust.

We attempt now to face the problem of how much material derives from the impacting body, and whether such material can be identified. We tentatively accept various arguments for the body impacting at low velocity (2-4Kms/sec) consistent with capture from Earth orbit. We expect that several percent of Apollo 14 breccias derive from the incoming body. They should result predominantly from the impacting surface and not represent the mean body if it is chemically zoned. The Apollo 14 breccias yield no positive evidence for the incoming body being an iron meteorite, and we consider possible stony meteorites. Rounded bodies are present, but are relatively rare and could be accounted for by (a) formation of droplets with later recrystallization, and (b) abrasion of existing crystals and rock fragments. We see no evidence for hydrous minerals in the breccias, or for thermal breakdown products, but recognize that both impact and thermal metamorphism might destroy any evidence. Rare fragments of dunite (olivine near Fo 90) might result from deep-seated rocks in the Moon, but could be ascribed to the incoming body. We see no evidence that conflicts seriously with existing ideas that the impacting body was a moonlet of Earth, with a composition not far removed from that of the Moon. If indeed the impacting body has a similar composition to the Moon, distinction between materials from the Moon's surface and the Imbrium moonlet may require very subtle techniques.

Turning now to the pre-Imbrium "crust", we envisage further problems. Let us assume that the dominant material in the Apollo 14 breccias is indeed from this source. From stratigraphic data we can anticipate that the pre-Imbrium surface was complex, containing debris from earlier impacts. However such material should have similar composition to pre-Imbrium "bedrock". If the Moon is only moderately inhomogeneous laterally. Assuming that the dominant populations in the breccias actually derive from the pre-Imbrium "crust", we can use the chemical data of Steele and Smith for Imbrium fragments since they resemble breccia populations. These suggest that the upper 5-10Kms of pre-Imbrium crust are dominated by light-colored basalts (i.e. noritic), dark-colored basalts, and feldspar-rich rocks (anorthosites and rhyolites). The chemical relations are consistent with crystal fractionation together with some liquid immiscibility, as shown or implied by Apollo 11 and 12 data of many workers. The high proportion of noritic material suggests that this is a major differentiate of the Moon implying extensive melting to a depth depending on one's estimate of the Imbrium
impact mechanics but not inconsistent with complete melting with formation of a metal-sulfide core. Anorthosites could derive by cumulation of plagioclase and would be expected near the surface. Cumulates of pyroxene and olivine would be expected at greater depths, and be sampled less efficiently by the Apollo 14 breccias: small amounts of pyroxene- and olivine-rich rocks do indeed occur and have characteristics of deep seated crystallization.

Thus we reaffirm the viability as a working model for the Moon of the concept of extensive early melting forming a crust composed of feldspar-rich rocks and basalts: various data (e.g. Rb/Sr evolution) indicate that this was an early process (~4.5 b.y.). The subsequent roles of residual liquid, of remelting, and of impact-generated melt are unclear to us, but we envisage extensive permeation and disruption of the early crust plus a long history of cooling and volcanism in debris produced in mare basins.

The breccia populations are consistent with mare-type basalts forming after the noritic material, as expected from evidence that the former enter basins excavated in the former. However the origin and depth of formation of the mare basalts remains controversial because of conflict in the interpretation of crystallization sequences and chemical contents of minerals, and of uncertainty in heat sources (radioactivity, tidal heating, impact heating). Furthermore the mare basalts of Apollo 11 and 12 may represent thin surface flows unrepresentative of the deeper mare fill. The extent and nature of later melting episodes on the Moon remains equivocal, but evidence for an early major episode seems good from the Apollo 14 breccias and other information.

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