Meteoritic material, though very subordinate, is enriched within the finest fractions of the regolith in which the metallic iron and troilite content is high enough to be detected by X-ray diffraction.

The modal composition of the 1–2 mm fraction of soil 12033,74, collected at the north rim of Head Crater, is 70 vol. % maroon-brown glass, 15 vol. % breccias, 14 vol. % basalts, and 1 vol. % pyroxene. Although neither the coarse fines of 12070 and 12001 nor the fine fines of 12033 could be investigated, it is obvious that the light-colored soil near Head Crater has a composition quite different from that of the dark soil near the LM (Table 8). We assume that the maroon-brown glasses which are the main constituents of 12033,74 are products of one single impact, possibly within the Fra Mauro formation (see next section).

In conclusion, the soil at Apollo 11 and Apollo 12 landing sites is the product of repeated impacts on the lunar surface which mixed disintegrated rocks and fractured minerals of a dominantly local origin together with shock-fused glasses from local and farther distant sources. In Apollo 11 and Apollo 12 soil components which obviously do not originate from mare rocks are anorthositic rock and glass fragments, probably derived from impacts in terra areas, and in Apollo 12 soils rock fragments and maroon-brown glasses which may be derived from rocks underlying the mare basalts (Fra Mauro formation).

Unlike terrestrial impact formations like the Ries suevite, the lunar regolith contains a large amount of shock-induced fusion products but only very few rock and mineral fragments with clear indications of shock. Two reasons may be responsible for this difference between regolith and terrestrial suevites: (1) Impacts into loose and porous material produce more irreversible heat and consequently more molten material than impacts on solid rocks (see below). (2) In contrast to terrestrial suevites which are products of one single event, the lunar regolith was formed by multiple impacts. Each of them produced a certain amount of vapor, melt, and shock-deformed minerals and rocks, diluted by a much larger mass of fractured material. From an estimate by GAULT (1970), less than 1% of the displaced mass of each impact is vaporized and fused. Later impacts into older impact debris would increase the ratio of shock fused glass. Hence, the glass content of the regolith should have kept growing through its long history of several billion of years. The unlimited continuation of this process, without later addition of undamaged primary rocks, should finally result in the conversion of the whole detritus into glass, the final product of shock metamorphism.

BRECCIAS

Modal compositions of 4 breccias from Apollo 11 and of two breccias from Apollo 12 have been determined by point counting of thin sections. The results are given in Table 10. Matrix includes all material not resolvable with the microscope, i.e., glassy cement and very fine fragments. To some extent variable section thicknesses may influence the measured amounts of matrix.

Modal compositions of breccias and soils from the same localities are similar (Tables 8 and 10) if allowance is made for the fact that the determinations of modal compositions of soils refer to smaller grain sizes than those of breccias. The higher

Contrary to the agglomerate forming melt splashes, regular glass bodies were embedded as solid bodies into the soil. Most likely, most of them were formed by the breakup of impact-induced liquid jets. Some of the angular glass fragments are disintegrated agglomerates. Others are fragments of quenched shock melts transported from distant localities and reworked by repeated impacts.

It has been shown by chemical analyses that the glassy components of the soils are substantially different from the local basaltic rocks at both landing sites. This is also confirmed by a comparison between modal and normative compositions of the soils (Tables 8 and 9). In both soils the normative (pyroxene + olivine)/plagioclase ratio is lower than the modal ratio as determined from the mineral frequencies. We conclude that the glass components of both soils are richer in normative plagioclase than the fragmental mineral components.

Table 8. Modal composition of Apollo 11 and Apollo 12 soils.

	Apollo 11 10084,106 10–250 μm (70% of the total soil < 1 mm)	Apollo 12 Average of 12001,84 and 12070,139 20–1000 μm (75% of the total soil < 1 mm)
Basalt	4	9
Anorthosite	0.3	1
Breccia	~ 7	~ 8
Agglomerates / Glass fragments	39	46
Regular glass bodies	1.5	0.7
Pyroxene + olivine	29	25
Plagioclase	14	7
Opaques	4	3
Pyroxene/plagioclase	2.0	3.6

Table 9. Normative composition of Apollo 11 and Apollo 12 soils (CIPW—norms).

	Apollo 11 10084*	Apollo 12 12070**
Q	0.00	0.00
Or	0.83	1.31
Ab	3.81	3.91
An	35.33	33.15
Di	19.31	13.85
En	12.69	14.70
Fs	10.97	14.87
Ol	2.47	11.70
Il	14.24	5.47
Ap	0.23	0.75
$\frac{\text{Pyroxene + Olivine}}{\text{Plagioclase}}$	1.13	1.44

* Average chemical composition compiled by COMPSTON *et al.* (1970).

** Average of chemical analyses by LSPET (1970), ANNELL *et al.* (1971), and ROSE *et al.* (1971).