Trace element concentrations in lunar samples have for the most part hitherto been determined for whole rock or average soil samples. Our present technique allows us to determine with moderate accuracy a very wide range of trace element contents in an individual mineral grain or glassy fragment obtained from lunar rock, breccia or soil.

Some glasses may show trace element contents related closely to those of mineral grains from which they were derived by direct melting, some may correspond primary glasses, and some may be of hybrid character through mixing while in the molten state. Effects of selective volatilisation and its variation with degree of impact melting can be looked for, and contrasts might be expected between fused glasses, condensation glasses and diaplectic glasses.

A study of the above possibilities, many of which interact, is being undertaken with the Apollo 12 and 14 samples made available to us, but only very few specimens have so far been examined.

Method of analysis

Mineral grains (< 0.01 mg) from rocks and glass particles hand-picked from soils have been analysed using spark source mass spectrography (Nicholls et al., 1967) with the modification that tipped electrodes were used instead of bar electrodes, and no internal standard was used. Individual grains were made the pointed tips of compressed silver rod electrodes and the spark was struck between a sample electrode and a counter-pointed silver rod electrode. To obtain maximum sensitivity exposures were continued until the sample had been completely consumed. Sparking parameters used previously on deep sea basalts were found to be suitable for lunar material.
Results

So far only two minerals, olivine and pyroxene, have been examined from Apollo 12 igneous rocks and five glass particles from Apollo 14 soils. In the five glasses the contents of B, F, Ni, Cu, Ga, Br, Sr, Zr and Ba generally exceed their contents in the two minerals. Ga, Sr and Ba may have higher concentrations in plagioclase, so far not examined, and Ni might derive from nickel-iron or ilmenite. Cu and Zr might derive from other minerals but B, F and Br require some other explanation.

Of the two fragments from soil sample 14257, 11, (both dark grey) one was highly vesicular while the other was virtually free from gas bubbles. The former is, as expected, depleted in B, F and Br relative to the latter, but it is also depleted in Sc, Ba, Hf and Th, none of which would be expected to be lost readily on volatilization. Ga shows a particularly high depletion. Some elements are enriched by factors of two or more in the highly vesicular glass, (e.g. Co, Sr and Y). The relation between these two fragments is thus not a simple one of differing degree of melting, though this process may well have contributed.

Similar difficulties are encountered in comparing honey colored vesicular and non-vesicular particles from sample 14258, 37. Elements depleted in the vesicular particle are not only B, F and Br, but Zn, Ga, Ge, Se, Zr, Te, Hf, Th and U. Of these neither Zr nor Hf would be expected to be lost in a volatile phase. Elements enriched in the vesicular particle include Sc, Co, Ni, Cu, Sr and Ba. The relative enrichment (or depletions) of Rb and Cs, and of Sr and Ba, are contrary to those expected for a simple hypothesis of differential loss of volatiles.

A yellow-green non-vesicular glass from the same soil sample 14, 258, 37 shows more affinities with the non-vesicular honey colored glass, but also significant differences (e.g., Ni, Cu, Ga, Sr and Ba). It is not immediately apparent how such differences could be related to mineralogical variation in the parent material modified by subsequent differential loss of volatiles.
It is apparent that the results so far raise more problems than they solve. Clarification may emerge when analyses are acquired from a greater variety of mineral grains and perhaps from some assemblages of glasses and minerals which are physically more closely related. It is felt that the technique is one which can be usefully applied to study various problems of lunar particle origin and lunar surface processes.