side (30°N to −10°S; 30°W to 60°E). Three sampled areas were entirely within highland terrain (Apollo 14, Apollo 16, and Luna 20) and two were on a mare-highland boundary at the mare-filled edge of two large impact basins (Apollo 15 and Apollo 17). The location of the landing sites are indicated on the lunar near-side image shown in Figure 1. The hemisphere of the lunar far side has not been sampled nor is it accessible to earth-based remote sensing techniques.

The most appropriate classification of returned lunar highland rocks was not immediately apparent to all lunar chemists, petrologists, and geologists and resulted in an expanding profusion of partially synonymous terms. The complex brecciated form of the majority of returned highland rocks required a classification that could convey the normally multicomponent nature of these samples. An Apollo 16 breccia which exhibits typical mineralogic diversity from multiple impact events is shown in Figure 2. An extensive literature exists on the details of breccia types, although usage in the literature has not been uniform until recently. A good summary of the common terms used to describe the structure and texture of highland breccias has been compiled by *Taylor* [1982].

Currently, terms preferred by most lunar geochemists to describe the bulk mineralogy of highland rocks and breccias are those summarized by *Stoffler et al.* [1980], which are defined by the amount of the major mafic mineral present in a mixture with plagioclase. In this classification the less dominant species is used as an adjective to describe the rock type: >90% plagioclase (anorthosite); between 10% and 22.5% mafic (orthopyroxene, clinopyroxene, or olivine), with the remainder plagioclase (noritic anorthosite, gabbroic anorthosite, and troctolitic anorthosite, respectively); between 22.5% and 40% mafic, with the remainder plagioclase (anorthositic norite, anorthositic gabbro, and anorthositic troctolite, respectively); more than 40% mafic (norite, gabbro, and troctolite, respectively). Additional adjectives may be used to describe the relative proportions of important incompatible elements (for example, enrichment or depletion of potassium and rare earth elements.

Many current characterizations of the composition of the lunar crust discuss more idealized suites of rock types that are presumed to represent the primary constituents of the lunar crust independent of the effects of the intense early bombardment and brecciation. A number of such "pristine" lunar samples have been identified as fragments within the collection, providing important constraints on the nature of the lunar crust. Three components of this primordial lunar crust, each with a different possible origin, are summarized by *Taylor* [1982], largely from the detailed sample work of P. H. Warren et al., O. B. James et al., and others: First are the anorthosites (or ferroan anorthosites), composed almost entirely of high-Ca plagioclase feldspar (>90%). These rocks would "float" in the hypothesized cooling magma ocean and could represent the earlier crust [*Warren and Wasson*, 1980, 1977]. Second is the Mg-rich suite, including significant components of norites, troctolites, dunite, and anorthositic gabbros. These more mafic rocks exhibit a range of plagioclase content, generally <75%. They are often referred to as plutonic in nature and described as originally occurring as layered plutons within the anorthositic crust [*James*, 1980; *Warren and Wasson*, 1980]. Alternatively, both the ferroan anorthosites and the Mg-rich suite could have been produced by massive amounts of serial magmatism during early crustal formation [*Walker*, 1983]. Third is KREEP (or Fra Mauro Basalt), evidenced by high REE, Th,
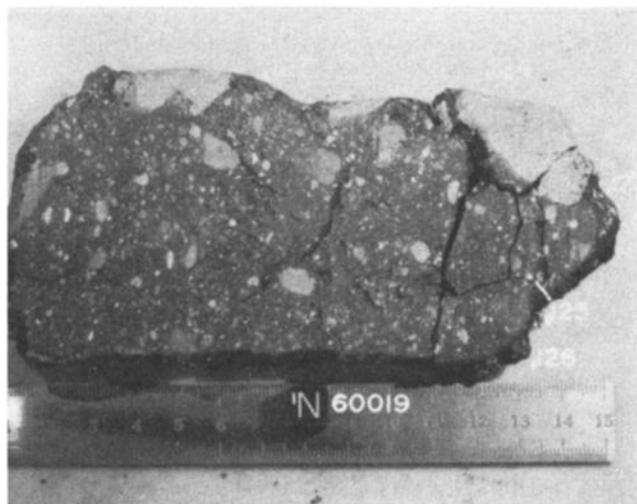

Fig. 2. Apollo 16 breccia 60019. This 14-cm cut surface exhibits a variety of clasts several centimeters in size down to the scale of the minerals in the darker matrix.

U, K, etc., a widespread but elusive component that occurs in varing amounts in many rocks, although few plutonic fragments exist to define a rock type. This component is commonly thought to be a (premare) residual liquid of crustal/mantle differentiation.

At the close of the Apollo program in 1972 some direct information about the global distribution for these components was provided by the Apollo 15 and 16 X-ray and gamma ray spectrometers which measured bulk elemental compositions (Al/Si, Mg/Si, Th, U, K, and Fe + Ti) from orbit for the 10-20% of the lunar surface along the Apollo ground tracks. A recent compilation and summary of these orbital geochemical data can be found in *Basaltic Volcanism* [*Basaltic Volcanism Study Project*, 1981, chap. 2]. Two very important results were immediately apparent: (1) The distinct chemical difference between the basaltic maria (Fe and Mg rich) and the feldspathic highland crust (Al rich) was observed regionally for the 10% of the lunar surface measured by the X ray spectrometer. The basaltic nature of the mare and the feldspathic nature of the highland crust were thus confirmed beyond the areas actually sampled. (2) The distribution of radiogenic elements (Th, U, and K) was distinctly asymmetric and apparently not associated with the distribution of mantle-derived basaltic units. Of the 20% of the lunar surface measured with the gamma ray spectrometer, the least radiogenic was the highland crust on the far side, and localized regions on the western near side exhibited the highest concentration of radiogenic elements. If these variations are largely due to a KREEP component, ubiquitous throughout the sampled sites, KREEP clearly occurs in local concentrations, none of which have been sampled.

Since there are strong correlations between many chemical elements for returned highland rocks, *Taylor* [1975; 1982, chap. 5] has used the results from the orbital geochemical experiments, however limited in coverage, and constraints from geophysical observations to estimate an average crustal composition and ultimately an average composition for the moon. Such estimates require broad assumptions about representative lateral sampling and vertical homogeneity, neither of which are well constrained. Thus as additional compositional information becomes available about the global distribution