AVCO
ELECTRONICS DIVISION
TULSA OPERATION
10700 EAST INDEPENDENCE ST. TULSA, OKLA. 74115
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FINAL REPORT

ANALYSIS OF MARINER 6 AND 7 DATA FOR GEOCHEMICAL IMPLICATIONS

By Benton C. Clark

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TABLE OF CONTENTS

ABSTRACT

The results of the Mariner 6 and 7 experimental investigations have been analyzed for information relative to the problem of assessing the likely geochemistry of the surface of Mars. Studies of the television pictures reveal areas of the planet apparently very old and of a probable igneous-meteoritic composition. Other areas of the planet show evidence of extensive active processes which change surface features and in these areas surface composition may be of a sedimentary nature. Infrared spectrometer data point to a silicate composition with some evidence for limonite or other iron oxides. However, no technique is presently available for unambiguous determination of even semi-quantitative geochemical relationships on Mars without accomplishing a landing on the planet's surface.

Rock and mineral composition data have been collected for earth rocks, meteorites, and lunar samples. Combining this information with present information on chemical abundances in the sun and stars, it has been possible to derive the following list of elements in their most likely order of abundance by weight for an arbitrary body in the solar system: O, Si, Fe, Mg, Ca, Al, Na, S, Ti, Cr, Mn, K, and Ni. These elements are discussed individually in terms of their geo- and cosmo-chemistry. A geochemical analysis of the surface of Mars would have many very significant scientific benefits: (1) complement life-detection experiments, (2) obtain data essential to the understanding of the geological history of Mars, and (3) provide indispensable information relative to the origin and history of the solar system. An x-ray fluorescence spectrometer could provide the desired analysis of the abundant elements as part of the Viking mission to Mars.

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1.0 INTRODUCTION

The recent accomplishments of Mariners 6 and 7 in collecting data on the atmospheric and surface characteristics of Mars have added immensely to our knowledge of this planet. Many advances have also been made in ground-based measurements of the properties of Mars during the past two years. Analysis of lunar samples has provided a wealth of new information concerning the surface composition of an extraterrestrial object. It is therefore timely that a systematic study be performed to make preliminary estimates of the surface composition* and surface properties of the planet Mars.

* In this report, we have elected to give all concentrations in terms of weight per cent of the pure element.

2.0 RESULTS OF MARINER 6 AND 7 EXPERIMENTS

2.1 Television Experiment

Analysis of the Mariner 6 and Mariner 7 photographs of Mars has conclusively demonstrated that the planet has surface features different from both the Earth and the Moon. The finding that there are no features relatable to Earth-like tectonism on Mars, and the corollary that large areas have remained unchanged for billions of years, is probably the most important result of this experiment. Implications of this major finding are the greatly reduced chances of existence of life on the planet and a renewed interest in the body as an exhibit of planetary evolution different from anything so far known in the solar system.

2.1.1 Earth/Moon/Mars Comparisons

2.1.1.1 Early Stages of Development

Mars appears to conform to the concept of an accretionary origin by comparisons of lunar uplands with martian cratered terrains. The early histories of these bodies are, therefore, probably similar. Subsequent events (see below) have modified the cratered regions on both, but to a different extent on Mars. Despite these changes both planets are totally different from Earth where accretion (if the formational process) was followed by differentiation into compositional shells. Most lunar information supports a concept of a homogeneous interior. Murray, et al, (Mu-71) point out that the structural properties of lunar and martian crusts must be similar to account for the corresponding development of polygonization of large craters on both. All evidences for such a developmental stage on Earth have been obliterated by differentiation, tectonic and erosional processes continuing for billions of years.

An additional feature apparently belonging to an early stage of Mars history is its "featureless terrain", best exemplified to date by pictures of Helas. This topographically low basin has been marginally altered by craters indicating its ancient age, but the featurelessness of its interior must be ascribed to some form of subsequent modification (see below). These martian areas of exceptional smoothness, whatever their mode(s) of origin, are apparently unique with no analogues on Earth or the Moon.

2.1.1.2 Subsequent Stages of Development

With a sample of three (Earth, Moon, Mars) the solar system so far exhibits very contrasting sets of planetary evolution. Only the Earth has passed through stages of crustal differentiation, tectonism and formation of oceans and a dense atmosphere, with its concomitant surface erosion and recycling of rock material.

In contrast, all lunar evidence suggests a present day development unchanged from the late accretionary stage except for extensive and continued surface modification by impact from without and the development of a thick regolith of shatter-debris. On Mars, however, large craters representative of the late accretionary stage are still present and no "young" large craters (analogous to the lunar Copernicus) have been found. In contrast, Mars exhibits a relatively young set of surface structures, termed "chaotic terrain", not found on either the Moon or the Earth. These features have developed at the expense of cratered terrain, taking the form of slump and collapse structure with little internal order. The origin of the chaotic terrain is unknown. Speculation involves dune material, volcanic ejecta sheets and collapse due to withdrawal of lava. If the latter idea is correct, this might suggest that Mars is now entering a stage of development reached millions or billions of years ago by Earth in which internal processes are coming into play; the Moon never attained this stage.

2.1.1.3 Latest Stages of Development

The Earth and the Moon can be thought of as in two stages, continuing for the past several hundreds of millions of years in each, of relative constancy. On the former planet tectonism and atmospheric processes are dominant; on the latter, impact processes. Mars, however, may be in a transitory state as evidenced by the possible origins for the chaotic terrain through internal geothermal processes. Perhaps this feature of Mars and its primitive CO_2 atmosphere are related. Certainly the latter does provide the means for aeolian processes to be operative to some degree on the Martian surface. Mariner 6 and 7 results do indicate substantial horizontal re-distribution of material on the floors of large craters. Photos also indicate that, compared to lunar terrain, Martian topography is greatly subdued. Appeal to aeolian processes, however, is complicated by the apparent total lack of physical or chemical means to break up Martian bedrock in a fashion to prepare it for transport. As Murray, et al, (Mu-71) point out, the mechanism of effective weathering on Mars remains unknown.

2.2 Infrared Spectrometer Experiment

From ground-based observations of the spectral reflectivity of the Martian surface, it was early concluded that the surface may be composed of limonite. The spectra have also been likened to finely divided basalt and to the polymer carbon sub-oxide (Pl-69) which is a possible photochemical product of the Martian atmosphere. The Mariner 6 and 7 IR data does not allow one to draw unambiguous conclusions concerning the surface composition, although it does provide the basis for excluding certain possibilities (Oc-70). Thus, the spectra show no evidence of absorption by carbonates, ruling out an extensive carbonate surface layer. Likewise, all spectra exhibit a strong silicate band, thus ruling out an extensive non-silicate covering such as carbon sub-oxide. The spectra are not inconsistent with a limonite-basalt mixture, although they are not sufficiently definitive to allow one to <u>deduce</u> such a composition. On the other hand, the experimenters (Oc-70) conclude that there definitely is indication of <u>some ferrous iron</u> on the Martian surface.

3.0 PROBABLE CONCENTRATIONS OF MAJOR AND MINOR ELEMENTS

3.1 Geo- and Cosmo-chemistry of Major and Minor Elements

The first attempt to estimate the relative abundance of the elements in the universe was made at the turn of the century. Since then a number of investigators have worked to refine our knowledge of this important distribution function. Its importance lies, of course, in its usefulness in testing various theories of the genesis of the solar system and the universe. Such data are generated in two ways: First, by careful spectrographic analysis of the sun, certain stars, and the Orion nebula; Second, by chemical analysis of meteorites. In the latter case, chondritic meteorites are usually the preferred variety since their metal content distribution closely matches that deduced from the spectroscopic observations of the sun. Also, isotopic dating of chondrites infers a very great age, strengthening the belief that they represent fragments of primordial matter.

The most recent compilation of elemental abundances using a combination of both approaches was made by Suess and Urey (Su-56). However, more recent and probably more accurate compilations have been made by Aller (Al-61) who relies very heavily upon spectroscopic data and by Cameron (Ca-67) who chooses to base his results mainly upon analyses of Type I carbanaceous chondrites. In general, the work of the latter two authors agrees quite satisfactorily, with the most notable exception being the inferred abundance of iron. Whereas Cameron believes iron to be more abundant than silicon by a factor of 1.8, Aller deduces from observations of the sun that the abundance of iron is only one-fourth that of silicon by weight.

The two most striking characteristics of all cosmic abundance schemes are: (1) the extremely high abundances of elements of low atomic number compared to those of high atomic number, and (2) the seesaw effect, sometimes known as the Oddo-Harkins rule, whereby elements of even atomic number are present in much greater abundance than their neighboring odd atomic number elements. This latter effect is very striking and very apparent, since ratios between adjacent elements are often of the order of 10 to 100.

The materials which may be considered as possible models for Martian surface work include rocks found on the earth's surface (igneous, sedimentary, and metamorphic) and extraterrestrial rocks of which there are now two important categories for consideration: (1) meteorites and (2) lunar samples. Regardless of origin, all rocks in these categories exhibit the general property that 99.9% of their weight is made up by about a dozen elements.

The distinct types of chemical assemblages found in these rocks consist of (1) crystals, (2) pure metallic phase (mostly iron), and (3) sulfide phase. Based upon this generality, Goldschmidt long ago introduced the concept of a geochemical classification of the elements as determined by the tendency of each element to partition itself chiefly in one of these three phases. This classification was derived from extensive mineralogical analyses of meteorites. It probably should be stressed that the crystal phase is chiefly one involving silicates and aluminosilicates. At any rate, the terminology invented by Goldschmidt is as follows:

A. Those elements preferentially entering the silicate crystalline phase are termed lithophilic.

B. Those entering the iron phase, siderophilic.

C. Those preferring the sulfide phase, chalcophilic.

D. Extremely volatile elements (gases at room temperature), atmophilic.

In the earth's crust, the lithophilic elements are found at higher abundance than would be expected from the cosmic abundance data. The siderophilic elements are greatly depleted. This general result is part of the evidence from which it is inferred that the earth consists of several concentric shells, each having a distinct geochemical and mineralogical makeup.

In comparing abundances between cosmic predictions and actual rock samples, it is necessary to make certain assumptions about the atmophilic constituents, since rocks do not normally contain appreciable quantities of gas. An important empirical fact is that in the crystalline phase of all rock types, oxygen is by far the important anion. There are no other anions present at high levels. Thus, a meaningful comparison between the cosmic abundance patterns and rock analyses can be conveniently made by summing the abundances of all the major cations (principally Na through Ni in the periodic table) and recomputing the abundance of each element as a percentage of this cation total. When this is done for data on the earth's crust (Ma-66) and compared with the cosmic data (Al-61, Ca-67) one can conclude that the earth's crust is highly enriched in K, Al, Ti, Na and Ca; slightly enriched in Si, Fe; slightly depleted in P, Mn; significantly depleted in Mg, Cl, Cu, Zn; and very strongly depleted in S, Ni, Co and Cr. Similarly, in comparing a Type A crystalline sample obtained on the Apollo 11 flight with cosmic abundance shows the lunar sample to be highly enriched in Ti, Al, Ca and Fe; only slightly enriched in Mn and Cr; about equal to cosmic levels for Si and K; slightly depleted in Mg and Na; and very strongly depleted in P, S, Cl, Co, Ni, Cu and Zn.

Comparing the lunar sample with the earth's crust, there are many differences and similarities, perhaps the most striking of which are that the lunar sample is 50-fold enriched in Cr, 10-fold enriched in Ti, about equal in S, about 50-fold depleted in K and Cl, and 8-fold depleted in Na. From this brief discussion, it is seen that the "expected" concentrations of several key elements can vary by significant factors. Nonetheless, the overriding consideration that should be made is that all rock samples, whether terrestrial or extraterrestrial, tend to consist mainly of oxygen and of elements between sodium and nickel in the periodic table. Almost all elements are present, of course, at extremely low levels, but as far as the major and minor analysis is concerned, the original statement that approximately a dozen elements are to be considered remains valid.

A survey of available data on chemical analyses of major terrestrial and extraterrestrial rock types has been performed for this report. For data on the earth's crust, we have used the extensive compilations by Poldervaart (Po-55) of igneous, sedimentary, and metamorphic rocks. To this has been added data on various average rock types by Ahrens (Ah-65), Mason (Ma-66), and Ernst (Er-69). Estimates of the composition of the interior of the earth have also been made by Mason (Ma-66). Data on analyses of various meteorites have been extracted from the works of Mason (Ma-62), Watson (Wa-56), and Wood (Wo-63). Data on the Apollo 11 and 12 samples were taken from a variety of excellent papers on this subject (LSPET-69, LSPET-70, En-70, Ma-70, Wi-70, Ro-70, Wo-70). The results of Surveyor 7 were also included (Pa-70). Data on tektite compositions were obtained from Schnetzler and Pinson (Sc-63) and O'Keefe (Ok-70). In Appendix I these compilations are presented giving the percent by weight of 10 elements. Also, ratios of various elements have been calculated for a number of interesting cases for each rock type. These data are presented in Appendix II.

A computer program was written to analyze these data in various ways. One method consisted of calculating various element ratios and then plotting these ratios against single element concentrations and also against other element ratios to search for significant trends. A number of interesting correlations were found. One of the most striking was an extremely strong correlation between the ratio Mg/Si and the absolute Mg concentration, with virtually all data from earth, meteorite and lunar rocks grouped tightly around a straight line. This indicates that by simply measuring the Mg/Si ratio one may deduce with a high degree of confidence the absolute value of the Mg concentration in the sample.

One ratio apparently having strong significance is the ratio K/Ca. It has been pointed out quite often that this ratio alone varies by more orders of magnitude than the ratio of nearly any other pair of major or minor elements in terrestrial rock samples. The computer studies showed that K/Ca is an excellent indicator of overall chemical composition of a sample, e.g., low K/Ca implies low Al/Mg and high Mg/Si, Mg/Na, and Ti/Si. Many other patterns were found in the computer plots, including several cases which allowed a rather "clean" separation of sedimentary rock samples from igneous samples. In general, the results obtained demonstrate that the lunar rocks, although of distinctly unearthlike composition, show many of the same trends among elements and element ratios as do earth and meteorite samples. The success of this preliminary work suggests that this line of investigation should be pursued further.

Another computer study which was performed consisted of an n-dimensional mapping of each sample where the n-axes in the n-dimensional space are the concentrations of n selected elements.

Two arbitrary geologic samples may be compared for the extent to which their composition is the same by calculating the distance between the two loci in n-dimensional space. This distance is a numerical measure of the similarity of two samples. The computer program takes one rock as the reference material and then calculates its distance in this space from all other rocks listed in the computer memory. This approach shows very promising results for establishing an objective method of comparing an unknown sample with known samples. For example, the results of this study clearly show that the lunar samples are more closely akin to basic igneous rocks (esp. basalts) than any other type of rock sample, although they do show fairly good correlation with certain meteorites (esp. eucrites). This method was also used to test the hypothesis that tektites and lunar surface material have a common origin. It was found that the distance between tektites and lunar material was much greater than the distance between tektites and earth sandstones.

3.2 Element-by-Element Summary

The following are brief discussions of 15 important constituents in rocks: O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Cr, Mn, Fe, and Ni. These discussions are intended to bring out some of the more significant facts and derived rules concerning the occurrence of these elements. As elsewhere in this report, all figures are given in terms of percent by weight of the pure element (i.e., not in terms of oxides).

3.2.1 Oxygen

Oxygen is a decidedly lithophilic element. It is probable that the earth's core is totally devoid of oxygen. It is the only important anion in the earth's crust. All other major elements are present as cations. The same is true of meteorite and the lunar samples. Of great significance in considering the origin of atmospheric oxygen is the fact that volcanic gases contain little or no oxygen in the form O_2. Igneous rocks typically contain from 42% (basic) to 49% (acidic) oxygen by weight. Pure quartz contains 53%. Pure limestone contains 48% oxygen. Sedimentary rocks seldom contain less than 48% oxygen. The Apollo 11 and 12 samples contain from 40 to 43% oxygen. In meteorites the range is much broader due to the presence of the iron and sulfide phases, allowing the concentrations to go as low as 24% and as high as 52%. In the common silicate and aluminosilicate minerals, oxygen is present at levels of 31 - 51%. FeO is 22% and Fe_2O_3 is 30% oxygen by weight.

3.2.2 Sodium

Sodium is a major element in the earth's crust, although it is in the minor category in cosmic abundance and in lunar and chondrite samples. In igneous rocks the concentration range is 1.5 to 3% with the exception of early crystallates such as peridotites and dunites where it is highly depleted. It covers a similar range in metamorphic and sedimentary rocks except that it is very low in highly refined products such as orthoquartzite and limestone. Its average concentration is 0.4% in Apollo 11 samples and 0.3% in Apollo 12 samples. The typical range for meteorites is 0.3 to 1%, although some meteorites contain much lower quantities. Sodium is a product of main stage magmatic crystallization where it is found mostly in the form of sodic feldspar (up to 8.8% in albite). In other minerals it is also sometimes found at high concentrations, viz., up to 11% in pyroxenes (acmite, jadeite), 6% in amphiboles (horn blende, riebeckite, glaucophane), 5% in micas (paragonite) and 18% in feldspathoids. It is classified as a strongly lithophilic element due to its concentration in the earth's crust.

3.2.3 Magnesium

Magnesium is a very common element found in nearly all mineral silicates and aluminosilicates with the notable exceptions of the feldspars and feldspathoids. It is a strongly lithophilic element and in the opinion of Rankama (Ra-61) is probably wholly contained in the earth's mantle and crust, with the concentration in the mantle much greater than that in the crust. Mg^{2+} substitutes for Fe^{2+} in all minerals, but magnesium is normally found in higher concentrations in earlier crystallates than Fe. Hence, the Fe/Mg ratio steadily increases in the intermediate products. In igneous rocks magnesium steadily increases from a low of about 0.2% in acidic material to about 5% in basic material. It reaches highs of 13 - 30% in certain very early crystallates (peridotite and dunite). The range is much more restricted in sedimentary materials for which nearly all common types fall within 0.5 to 2%. It is found at a level of approximately 4 to 6% in the lunar samples. In meteorites it is typically present at very high concentrations, but is never found in the iron or sulfide phases. Rather, it is found in the olivines and in the hypersthene pyroxenes. Most meteorites contain from 10 to 15% magnesium by weight, but values as low as 4 and as high as 21% are not uncommon. In the common minerals, it is found at concentrations up to 34% in olivine (forsterite), 24% in pyroxene (diopside, enstatite), 22% in amphibole, and 18% in biotite mica.

3.2.4 Aluminum

In terms of cosmic abundance and average chondritic composition, aluminum must be classified as a minor element. However, in terms of its abundance in the earth's crust and on the lunar surface, it is a major element. In the case of the earth this has been taken as proof of the origin of the earth's lithosphere by a process involving extensive chemical differentiation. Aluminum is indeed probably almost quantitatively concentrated in the earth's upper lithosphere, since its enrichment over cosmic levels is about a factor of 10. In magmatic differentiation almost no aluminum is present in the early products, but in all other crystallates it is very common, chiefly because of its key structural role in the aluminosilicates. (Note: Although many types of aluminosilicates exist, other metals are nearly always found to be present in the crystal structure.) In igneous rocks the aluminum concentration is rather uniform and non-varying between the limits of 7 - 9% except that much lower concentrations are present in peridotites and dunites. Sedimentary and metamorphic rocks cover a slightly broader range, 3 - 10%. All lunar specimens contain aluminum in the range of 4 - 8%. Only in meteorites is aluminum commonly found at lower values, usually at a level of the order of 1%, but sometimes at other levels between 0.5 and 7%. Among the common minerals aluminum is especially prominent in the feldspars and feldspathoids where it may be present at concentrations as high as 19%. It is also present in some amphiboles (up to 10%) and in all micas (up to 21%). Jadeite pyroxene contains 13% aluminum. It is, however, absent from olivines. It is found in the form of its oxide, alumina, only in rare occurrences when it is present in great excess over the elements Ca, Na and K.

3.2.5 Silicon

Silicon is a lithophilic element with only small quantities found in the iron phase in meteorites. If one compares the composition of the earth's crust to the cosmic abundance schemes of Cameron and Aller, by neglecting all atmophilic elements and other elements below sodium in the periodic table, then the enrichment of silicon is 1.5 to 2.5. The lunar abundance of silicon is lower, but agrees quite well with the cosmic abundance according to Cameron and is enriched at a factor of 1.4 in comparison to the cosmic abundance of Aller. In igneous rocks it is present in concentrations from 21 to 35% with a very strong trend toward higher silicon contents for the later products of magmatic crystallization. Indeed the silicon content is often taken as an index of the course of differentiation and evolution of rock types, although in many special cases the index is not totally reliable. Pure quartz contains 47% silicon by weight. Consequently, certain sedimentary rocks approach this limit, although silicon content in sediments may approach zero. The Apollo 11 and 12 lunar samples contain 17 to 23% silicon. As mentioned above, this is considerably below values typical of the earth's crust except for the most basic rocks, but not in strong disagreement with cosmic abundance predictions. In meteorites the silicon content ranges from a high of about 25% all the way down to about 8%.

3.2.6 Phosphorus

This element is both siderophilic and lithophilic. It is present in the important non-silicate mineral apatite which is one of the most common accessory minerals of igneous rocks. Indeed Rankama (Ra-50) estimates that typically 95% of the phosphorus in igneous rocks is in the form of apatite. In magmatic crystallization both phosphorus and titanium appear in the early formed rocks. This is not because of substitution for one another in a common system, but because they both form minerals (ilmenite and sphene for Ti and apatite for P) having high melting points. The concentration of phosphorus in igneous and sedimentary rocks is typically about 0.1%, which agrees roughly with cosmic abundance indications. However, it is depleted in material from the lunar surface by a factor of approximately 25. Phosphorus can reach concentrations of 0.3% in iron meteorites. Mason (Ma-66), from a consideration of the probable composition of the mantle, states that phosphorus shows no marked fractionation between mantle and crust.

3.2.7 Sulfur

Although sulfur is present at only trace levels in the earth's crust, it is a major element in chondritic meteorites and in terms of the cosmic abundance schemes. It is often found at concentrations of 2 - 3% in meteorites and may be as high as 6% in the Type I carbonaceous chondrites. Indeed the spectroscopic data as reviewed by Aller shows sulfur to be more abundant in the solar system than any element above sodium in the periodic table with the exception of silicon. Its presence at low concentration in the earth's crust is presumably due to an increasingly high concentration of the mineral troilite deep within the earth. When it does occur in igneous rocks, it is usually one of the earliest rocks of magmatic crystallization and occurs in the form of several independent minerals: pyrite, pyrrhotite, calcopyrite, pentlandite and bornite. Also in the very late pegmatitic stages sulfur is considerably enriched in the residual melt.

3.2.8 Chlorine

Chlorine and the other halogens are classified as lithophilic. However, if the cosmic abundance observations by Aller (Al-61) are correct, chlorine is significantly depleted from the earth's crust. The compound $FeCl_2$ has been found in the iron phase in meteorites, which indicates that chlorine could be present in the earth's core. The halogens and their compounds are quite volatile. The fact that chlorine is depleted in the lunar samples by a factor of 10 to 100 compared to the earth's crust has been taken as evidence that the moon went through a heating and degassing phase. Even in the earth's crust, chlorine is present at a concentration of only about 0.01%. Aller's data (Al-61) indicates a concentration of over 1% is to be expected if stellar abundances were preserved in the earth's crust.

3.2.9 Potassium

The cosmic, meteoritic, and lunar abundances of potassium place it as a trace element. However, because of extensive differentiation it is a relatively abundant constituent in the earth's crust, reaching levels as high as 4.5% in acidic igneous rocks and decreasing to about 0.5% in basic rocks. Much lower concentrations are found in dunites and peridotites. Likewise, it is found at levels of 0.5 to 3.5% in sedimentary rocks. In lunar samples it is present at levels of 0.1 to 0.2% and is at even lower concentrations in meteorites. Pure minerals may contain high concentrations of potassium, up to 14% in feldspar (anorthite), 18% in feldspathoids (leucite) and 10% in micas. The low concentration of potassium and other volatile elements in the lunar surface has often been taken as evidence of extreme heating and degassing.* The ratio of potassium to calcium varies strikingly in rocks of the earth's crust and has been considered as a diagnostic ratio of major importance.

* Note, however, that from the discussion on page 8 above, the lunar sample is probably not depleted at all in potassium content in terms of estimated cosmic abundances.

3.2.10 Calcium

Calcium is a strongly lithophilic element enriched by a factor of approximately 3 in the earth's crust over cosmic abundances. In addition to being an important cation in several silicate minerals, it is also found in many important non-silicate minerals including limestone, dolomite, gypsum, anhydrite, and fluorite. The most important igneous mineral containing calcium is anorthite feldspar (14% Ca). It is also present at up to 18.5% in pyroxene (diopside, hedenhergite), 10% in amphiboles and sometimes as a substitution cation in feldspathoids (sodalite). During magmatic crystallization calcium is an early product appearing mainly in the anorthite form. In igneous rocks its concentration is a strong function of silicon content. Thus, calcium is present at 0.8% in very acidic rocks, but as silicon content decreases the calcium level steadily rises to as high as 8% in very basic forms (although it is very low in peridotites and dunites). The concentration in typical sedimentary rocks is 1 - 5%, but in limestone it is in the order of 30%. The Apollo 11 and 12 samples contained 7 - 9% calcium and the Surveyor 7 data (Pa-70) indicate even higher concentrations in the highlands. In meteorites it is usually present at a level of 1 - 2%, although the range of 0.5 to 10% is representative. Angrite meteorites contain 18% calcium.

3.2.11 Titanium

This element is in the trace category in terms of cosmic abundances and levels in chondrites. However, it is found at much higher levels in the earth's crust and in the lunar surface. Indeed the Apollo 11 values show enrichment over cosmic levels by a factor of about 100. Although titanium can replace aluminum in sixfold coordination and is accordingly found in pyroxenes, amphiboles, and biotite micas, it is mainly present in the earth's crust and in the lunar surface as the iron-titanium oxide, ilmenite. Other important titanium compounds are rutile, sphene, and titanium magnetite. It crystallizes early from magmas mainly as ilmenite. Consequently, its concentration is low in acidic rocks (about 0.2%), rising to a maximum of about 1.5% in basic rocks. In sedimentary rocks it covers the range 0.1 to 0.5%. Apollo 11 samples contained 4.5 to 7.5% titanium, while Apollo 12 samples contained 1.5 to 3%. The unusually high concentration in lunar samples is considered a major experimental result that has not been adequately explained to date. In meteorites, the level of titanium is usually quite low, of the order of 0.05%, although it reaches levels of 1.5% in angrites and 0.3% in eucrites.

3.2.12 Chromium

Although chromium is classified as a lithophilic element, its abundance is very low in the earth's crust. Mason (Ma-66) states that chromium depletion in the crust is one of the significant cases of strong fractionation of an element between the crust and the mantle. Rankama (Ra-61) states that the low Cr content of the crust is another important experimental fact which verifies that the crust is the product of extreme geochemical differentiation. Although Cr^{3+} has an ionic radius very close to Fe^{3+} it seems to be preferentially removed from an igneous melt very early in crystallization, where it comes out in a form of the iron-chromium oxide, chromite. The average crustal content of chromium is only 0.01%, but Apollo 11 samples contain of the order of 0.5% chromium.

3.2.13 Manganese

Considerable data on the manganese content of earth rocks is available because of the existence of a simple, sensitive, colormetric method of determination. In igneous rocks manganese is present almost exclusively in the form Mn^{2+} where it substitutes extensively for Fe^{2+}. The Mn/Fe ratio is quite constant for rocks found during the main stage of crystallization. However, it is enriched in very late crystallates and consequently the Mn/Fe ratio is much higher in pegmatites. It is a lithophilic element and hence would not be expected to be found in significant quantities in the earth's core. On the other hand, Mason (Ma-66) concludes that Mn is one of the elements which shows little fractionation between the mantle and the crust. Its typical concentration in igneous rocks is 0.1%. Lunar samples contain as much as 0.5% manganese.

3.2.14 Iron

Iron, together with silicon, sulfur and oxygen, are the key elements in discussing the geochemical evolution of planetary matter. It is extremely abundant from the cosmic standpoint, being even more abundant than silicon according to Cameron's scheme, and only slightly behind silicon, sulfur and magnesium according to Aller's scheme. The siderophilic elements (Co, Ni, Ru, Rh, Pd, Os, Ir, Pt, Au and several others to a lesser extent) concentrate in the pure iron phase when such a phase is present and in equilibrium with silicate and sulfur phases. Thus, the presumed iron core of the earth also probably contains significant quantities of these siderophilic elements. Likewise, the presence of an iron phase during formation of any other solar system bodies would result in significant geochemical differentiation. On earth, among the earliest products of magmatic differentiation are the iron oxide minerals and FeS. The Fe^{3+} content varies rather slowly as crystallization proceeds, but Fe^{2+} comes out early. Thus the Fe^{3+}/Fe^{2+} ratio increases in later differentiates. The iron content in very acidic rocks is about 1.5% and increases as the silicon content decreases to a maximum of about 10% in basalts. The same concentration range is covered in sedimentary and metamorphic rocks. Apollo 11 and 12 samples contain from 12 to 18% iron. Most meteorites contain more than 20% iron and levels can easily reach 55%. In common minerals the concentration by weight of iron can also be quite high, up to 55% in olivine (fayalite), 42% in pyroxenes, 39% in amphiboles, and 33% in micas.

3.2.15 Nickel

Nickel is a very strongly siderophilic element and therefore it is probably concentrated in the earth's iron core. Indeed, it is found only at very low levels on the earth's crust and in the lunar samples analyzed to date. In contrast, it is an important constituent in chondrites and is considered to have a high cosmic abundance since its concentration in the sun is likewise high. Therefore, an important theoretical consideration in planetary evolution is to explain the strong depletion in nickel in both the earth and lunar surfaces. Indeed, O'Keefe (Ok-70) has argued that its very low concentration on the moon is strong evidence that the moon was formed by fission of material from the earth's crust and mantle. In common minerals nickel is mainly found in the hypersthene pyroxenes, although some is also found in the augite pyroxenes, the amphiboles and the biotite micas. It is not found in the feldspars or feldspathoids. Its general tendency is to become enriched in the early crystallized ferro-magnesian minerals and it forms no significant minerals of its own. The average crustal concentration of Ni is only 0.008%, but it reaches concentrations as high as 2% in chondrite meteorites and even 20% in irons.

3.3 Estimated Rank-Order of Elements on Mars

Table I is a tabulation of a large amount of data on various rock samples, with all elements ranked in decreasing abundance by weight. (Note: Oxygen has been purposely omitted and H and He have been dropped from the cosmic abundance lists.) The abundances are categorized in terms of major, minor, trace, and ultra-trace on a relative weight scale where silicon has been assigned the value of 100. It is of special interest that the "major" category is made up by no more than seven elements for every rock type. The same statement holds for the "minor" category. At the trace level, a significantly larger number of elements may or may not be involved. To compare the frequency at which each element occurs at a given level in different samples, Table II has been prepared. In this table all elements normally found in the earth's crust at levels above 0.01% are included. From this table it is possible to easily determine which elements are consistently present in high abundance and those which exhibit strong fluctuations. For example, Fe and Si are always in the major category. Ca is either major or minor, but not less. On the other hand, Sc is never found above the ultra-trace level. Elements like Ni, Cl, S, Ti and Cr exhibit strong and highly significant variations.

A semi-objective list of the elements most likely to be found on an unknown planetary body has been compiled by mathematically averaging the rankings in Table II for the five sets of data. By this procedure, it was possible to assign a classification to each element. The results are presented in Table III which gives the ranking of each element in order, decreasing from silicon at the highest level. The procedure followed tends to emphasize, of course, the cosmic abundance results. However, it has the special advantage of emphasizing those elements which are not normally found at high levels in the earth's crust, but

Table I. Rank Order of the Elements by Weight Abundance

Abundances (Si = 100)	Cosmic (Aller)	Cosmic (Cameron)	Ave. Chondrites (Ahrens)	Bulk Earth	Earth's Crust	Apollo 11 (LSPET-50)	Apollo 12 (LSPET-12009)	Average Igneous	Average Shale	Average Sandstone
Major (10-1000)	C Si S Mg Fe	C Fe Si Mg S Ca	Fe Si Mg S	Fe Si Mg Ni S	Si Al Fe Ca Na	Si Fe Ca Mg Al Ti	Si Fe Mg Ca Al Ti	Si Al Fe Ca Na	Al, Si Fe K Ca Mg Na	Si Ca
Minor (1-10)	Cl Ca Ni Na Al F Cr	Ni Al Na Cr Mn P	Ca Ni Al Na Co Cr Mn	Ca Al Na Cr Mn	K Mg Ti	Cr Mn Na	Cr Na	K Mg Ti	Ti S Mn F	Al K Fe Mg
Trace (0.1-1)	P Mn Ti Co K Cu Zn	Co K Ti Zn Cl F Cu, V	P K Ti	Co P K Ti	P Mn F Ba Sr	S Zr K P	Mn K	P Mn F Ba Sr	P Ba Sr Cl Zr, Rb, V B, Zn, La Cr	Na Ti
Ultra-Trace (0.01-0.1)	V		Cl Cu V Zn		S Zr V Cl Cr Rb Ni Zn Cu	Sc Sr Y V Ba Ni F Cl	Zr Sr V Ni Ba Y Co Sc	S Zr V Cl Cr Rb Ni Zn Ce, Cu	Ni Li Ce Cu	F S Zr P Ce Rb
References	Al-61	Ca-67	Ah-65	Ma-66	Ma-66	LSPET-69	LSPET-70	Ma-66	Ma-66	Ma-66

Table II. Relative Abundances of the Elements*

Z	Element	Cosmic (1)	Cosmic (2)	Ave. Chondrites (3)	Earth's Crust (4)	Apollo 11 (5)
6	C	Major	Major			UT
9	F	Minor	T	UT	T	UT
11	Na	Minor	Minor	Minor	Major	Minor
12	Mg	Major	Major	Major	Minor	Major
13	Al	Minor	Minor	Minor	Major	Major
14	Si	Major	Major	Major	Major	Major
15	P	T	Minor	T	T	T
16	S	Major	Major	Major	T, UT	T
17	Cl	Minor	T	UT	UT	UT
19	K	T	T	T	Minor	T
20	Ca	Minor	Major	Minor	Major	Major
21	Sc	UUT	UUT	UUT	UUT	UT
22	Ti	T	T	T	Minor	Major
23	V	UT	T	UT	UT	UT
24	Cr	Minor	Minor	Minor	UT	Minor
25	Mn	T	Minor	Minor	T	Minor
26	Fe	Major	Major	Major	Major	Major
27	Co	T	T	Minor	UUT	UUT
28	Ni	Minor	Minor	Minor	UT	UT
29	Cu	T	T	UT	UT	UUT
30	Zn	T	T	UT	UT	UUT
38	Sr	UUT	UUT	UUT	T	UT
39	Y	UUUT	UUT	UUT	UUT	UT
40	Zr	UUT	UUT	UUT	UT	T
56	Ba	UUUT	UUUT	UUT	T	UT

*Relative to Si = 100. Based upon weight.

References: (1) is Al-61
(2) is Ca-67
(3) is Ah-65
(4) is Ma-66
(5) is LSPET-69

Table III. Most Likely Rank-Order Abundance*

Major Elements

Si
Fe
Mg
Ca
Al

Minor Elements

Na
S
Ti
Cr
Mn

Trace Elements

K
Ni
P
C
Co
F
Cl

Ultra-Trace Elements

Cu
Zn
V

* Based upon the assumption that the rank-order can be determined from an average of the five rank-orders given previously.

Oxygen is purposely omitted from this list.

which could well be present at high levels on other planetary surfaces. Thus, in the list of Table III, chromium and manganese appear as minor elements, whereas they are ultra-trace and trace, respectively, in the earth's crust. The utility of this classification is apparent when it is realized that these two elements turned out to be in the minor range in the lunar analyses. This list also gives special importance to elements like sulphur and nickel, compared to what one would expect simply by using the earth's rocks as a basis for predicting elemental compositions. In Table IV the elements likely to account for 99% of any arbitrary rock are presented, along with their expected minimum and maximum concentration levels as compiled from a survey of the data presented in Appendix I and in section 3.2.

Table IV. Probable Concentration Range for Abundant Elements

Element	Percent by Weight Lower Limit	Upper Limit
O	20	53
Si	8	47
Fe	1.5	55
Mg	0.2	30
Ca	0.2	20
Al	0.5	10
Na	0	3
S	0	6
Ti	0.05	8
Cr	0.01	0.5
Mn	0.1	0.5
K	0.05	4.5
Ni	0	5
P	0	0.3

4.0 SPECIALIZED COMPOSITIONS IN LOCALIZED REGIONS

4.1 Large Scale Terrain Types

Present information suggests a three-fold sub-division of Martian terrain into (1) cratered, (2) chaotic, and (3) featureless. The cratered terrain appears closely similar to lunar uplands and the expectation is that the two planetoid areas will be compositionally similar. By analogy to Apollo 11 and 12 results we may expect basic volcanic-type rocks admixed with a very small quantity of meteoritic materials. The compositions of areas of chaotic and featureless terrain, however, remain totally speculative, but are of extreme interest in deducing the history of the planet. Some limiting possibilities are:

(1) Chaotic terrain

- (a) If of collapse origin perhaps of the same composition as cratered terrain.
- (b) If of an ejecta origin perhaps of a different volcanic composition.
- (c) If of a dune origin perhaps the "weathered" and transported products of a Martian erosion.

(2) Featureless terrain

- (a) If of impact origin perhaps composed of finely divided Martian basement rock and admixed meteoritic material.
- (b) If of volcanic origin perhaps composed of sheetlike tuffaceous volcanics.
- (c) If of subsidence origin perhaps filled with Martian "erosional" debris.

4.2 Specialized Landing Sites

Prior to landing on Mars, the Viking spacecraft will orbit the planet for an extended reconnaissance period. At this time, based upon information obtained from television pictures and numerous other sensors, decisions will be made as to the most likely locations for the presence of life forms. Green and Larmore (Gr-70) point out that the ideal landing point in the search for life on such a cold, arid planet as Mars would be at sites exhibiting volcanological activity. Such areas of defluidization are warmer and wetter than adjacent areas, thus favoring biological activity. As the authors state, "In short, the geology may determine the biologically significant sites." On Earth, defluidization centers are commonly marked by sulfur-rich and highly hydrated minerals.

5.0 EXPERIMENTAL PLANETARY GEOCHEMISTRY

5.1 Meteorites

The considerable interest of geologists and other scientists in the geochemistry of meteorites has in recent years been given added impetus by the availability of new, improved, non-destructive methods of analysis and by the great interest generated in planetary chemistry through the availability of lunar samples. Much additional work can be done in this area and it is expected that ever more sensitive investigational techniques will reveal important new data on this class of rock samples.

5.2 The Lunar Surface

Our knowledge of the geochemistry of the surface of the moon has increased enormously during the past few years through the data obtained remotely by the Surveyor spacecraft and from laboratory analyses of the Apollo 11 and 12 samples. More Apollo samples are expected in the near future and, in addition, a gross geological survey of the moon will be attempted using x-ray fluorescence spectrometers orbiting the moon. Ground-based efforts include spectral reflectance (Mc-70) and emissivity (Fu-70) mapping of the lunar surface to reveal areas of different composition. Russian achievements in this area have included the successful landing and takeoff of a spacecraft whose mission was to obtain soil and rock samples and return them to earth for analysis. They have also landed an automated lunar roving vehicle, Lunokhod I, which includes an x-ray fluorescence analyzer for measuring surface composition.

5.3 The Asteroids

Remote minerological analysis of the asteroids now has begun with the spectral reflectance studies of McCord, Adams, and Johnson (Mc-70a). These authors conclude that asteroid Vesta contains abundant Mg-rich orthopyroxene, at least on the surface, and that its composition is much more similar to certain basaltic achondrites than to other types of meteorites or to the Apollo 11 samples.

5.4 Mars

Spectral reflectivity measurements of Mars have been interpreted by different observers to infer the presence of limonite (Po-69, Po-70), oxidized basalt (Mc-69), and carbon suboxide (Pl-69). At any rate, such data is not necessarily sufficient to define surface composition on a planet like Mars where atmospheric or specialized erosional processes may give rise to superficial surface coatings not at all indicative of average surface composition (e.g., an earth analog would be the iron oxide stains found on certain desert sands). No practical technique for unambiguous analysis of surface composition of Mars from other than the Earth or Mars orbit is available at this time. For further data, we must await a surface landing of appropriate instrumentation.

6.0 AN X-RAY FLUORESCENCE SPECTROMETER FOR ANALYSIS OF PLANETARY SURFACES

As part of this investigation, methods for remote analysis of the chemical composition of planetary surfaces were surveyed. Particular attention was given to the possible use of such an instrument on the Viking spacecraft being designed for a soft landing on Mars. Among the techniques that have been successfully used to measure the element composition of rocks are: (1) wet chemistry, (2) atomic absorption, (3) neutron and gamma activation analysis, (4) spark source mass spectrometry, (5) alpha particle scattering spectrometry, and (6) x-ray fluorescence spectrometry. From the standpoint of mission constraints, and the requirement for high performance by a small, lightweight unit, the x-ray fluorescence method has been determined to be a quite practical and satisfactory approach. Among the investigations performed for this report were improved computer modeling of instrument response, estimates of performance capabilities of an instrument, laboratory verification of the theoretical calculations, and development of critical electronic circuits.

6.1 Computer Modeling

A computer model previously developed for a spaceborne x-ray spectrometer (Cl-69) has been expanded and updated to include nearly all pertinent parameters affecting the performance of such an instrument. The new version of this computer program includes the following factors: energy and source strength of two independent radioisotope excitation sources, source to sample distance, sample to detector distance, sample size, detector window diameter, detector window composition and thickness, detector gas filling composition and pressure, angle of incidence of excitation radiation, exit angle of fluorescent radiation, measurement time, thickness and composition of two independent filters, filter absorption, fluorescent radiation produced in each filter, amount of radiation coherently scattered by sample from sources, detector resolution, detector gain, drift in system gain, low and high energy discriminator settings, the sample matrix effects of (1) internal absorption of fluorescent emissions and (2) secondary fluorescent excitation of one element by another element in the sample, background gamma radiation spectrum from the radioisotope thermo-electric generators, fluorescent yields of the elements, mass absorption coefficients of the elements, and sample composition. The program is capable of two distinct output modes. The first of these plots and prints out the pulse height spectrum predicted for a given set of conditions. The second is used to calculate the standard deviation and minimum detection limit for each element under the prescribed instrument setup conditions.

6.2 Predicted Performance Capabilities

Table V shows the results of computer calculations based upon realistic levels of excitation source strength and practical proportional counter performance capabilities. It is seen that the minimum detection limit will be excellent for all elements above aluminum and that even for a difficult element like magnesium the minimum detection limit will be of the order of 1%. Sodium was not included since the minimum limit for this system would be in the neighborhood of a few percent and sodium very rarely achieves this level of concentration in any type of rock. With special techniques such as ultra-thin counter windows and perhaps gas flow mode of operation, it would be possible to considerably

Table V. Preliminary Predicted Performance Capabilities*

Element	Minimum Detection Limit (Weight)	Precision**
Mg	1.0%	8%
Al	0.4%	2%
Si	< 0.1%	1%
S	< 0.1%	0.5%
K	< 0.05%	0.2%
Ca	< 0.05%	0.2%
Ti	< 0.05%	0.1%
Cr, Mn, Fe, Ni	< 0.1%	< 1%

* Based upon a 50 mCi source strength and presumed RTG background radiation levels. Number given is average for 30 rocks analyzed.

** Relative standard deviation due to counting statistics at the 10% weight level. For other weights, use Rel. Std. Dev. = (10 x Precision)/(Weight)

NOTE: All counting times assumed to be 100 seconds.

reduce the minimum detection limit for magnesium and to achieve a satisfactory limit for detection of sodium. However, such techniques, although they could be employed for a space mission, would very seriously reduce the reliability of the device. Therefore, this possibility is not considered in detail at this time.

6.3 Laboratory Experimentation

Considerable data has been taken with various rock specimens in pressed powdered form, using Fe-55 and Cd-109 isotope x-ray sources. The proportional counter employed was fabricated from solid brass stock, is cylindrical in shape, with an inside diameter of 0.5", a 1-mil diameter stainless steel anode wire, and a 1-mil thick beryllium entrance window. Data for four USGS standard rock specimens is presented in Figures 1 through 4. The dots are experimental data obtained with the sources, counter, and rock specimens inside a helium-filled tent. The solid lines are the results as predicted by computer calculations using the program described in section 6.1 above. In general, the experimental results confirm quite satisfactorily the computer predictions. The most serious discrepancy is the presence of more counts between 2.5 and 3 keV than predicted by theory. This was determined to be due to fluorescence of residual argon gas in the helium tent by measurement of background spectrum with no sample present. Figures 5 and 6 show the theoretical curves for these four samples normalized in two different ways to demonstrate the differences in spectra which result from differences in sample composition. From this one can see that the potassium-calcium ratio can be estimated with fair accuracy from the shape of the peak in the energy region 3.5 - 4 keV. By employing energy filters to alter the spectrum, the K/Ca ratio can be determined very accurately.

OCT 21 1970

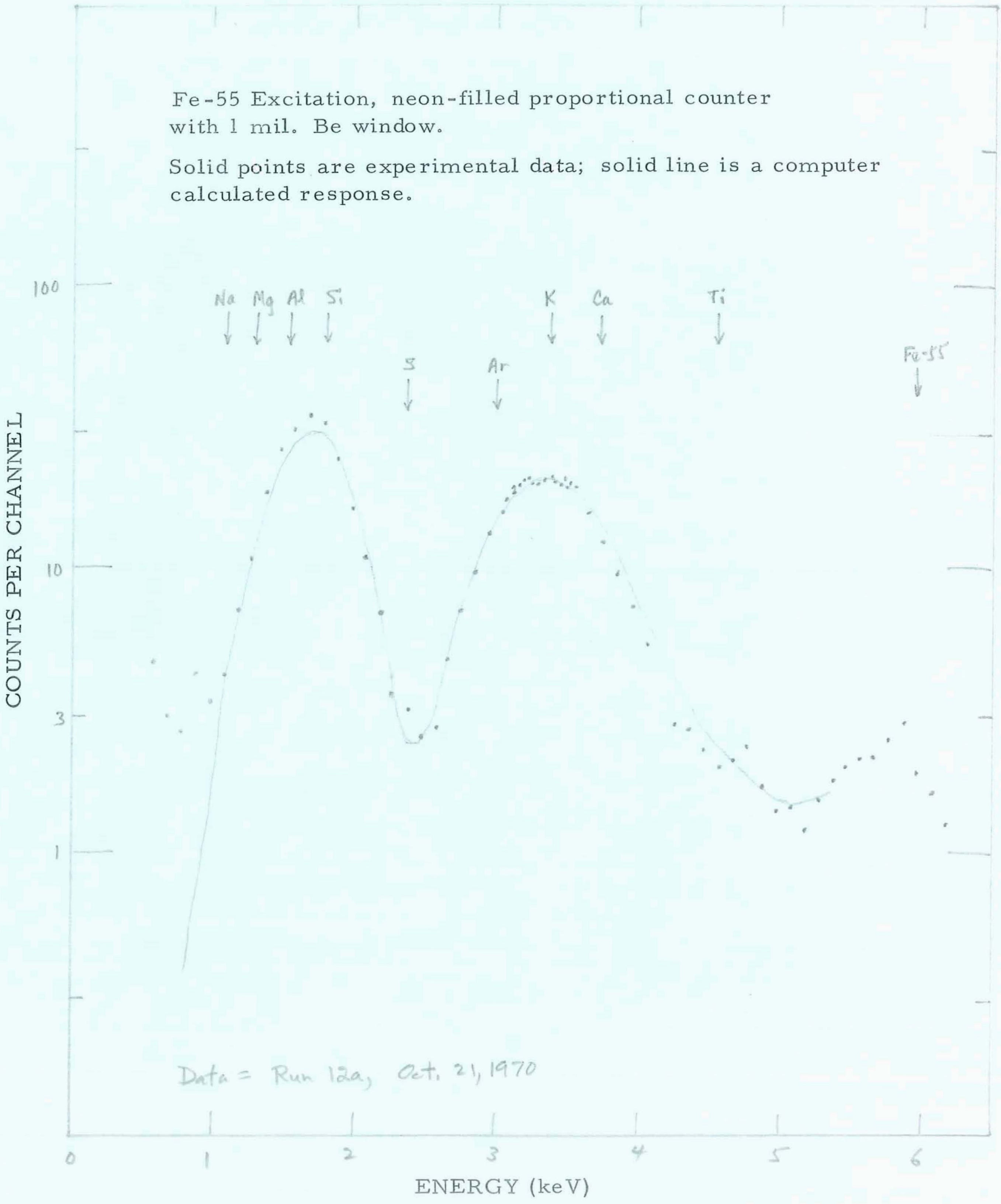


Fig. 1. Pulse height spectrum of fluorescent emissions from USGS standard GSP-1.

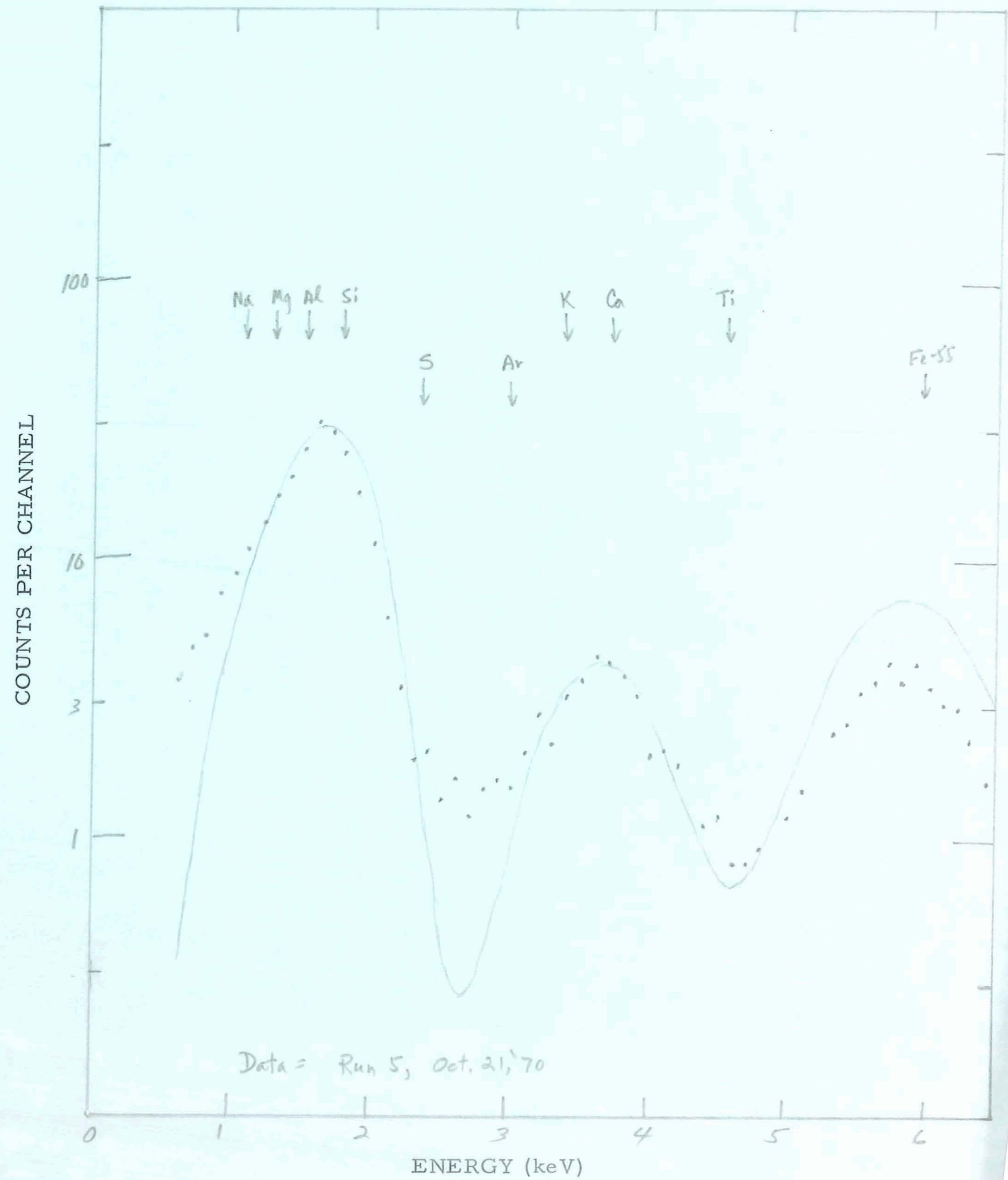


Fig. 2. Same as Fig. 1, but for USGS standard PCC-1.

OCT 2 1 1970

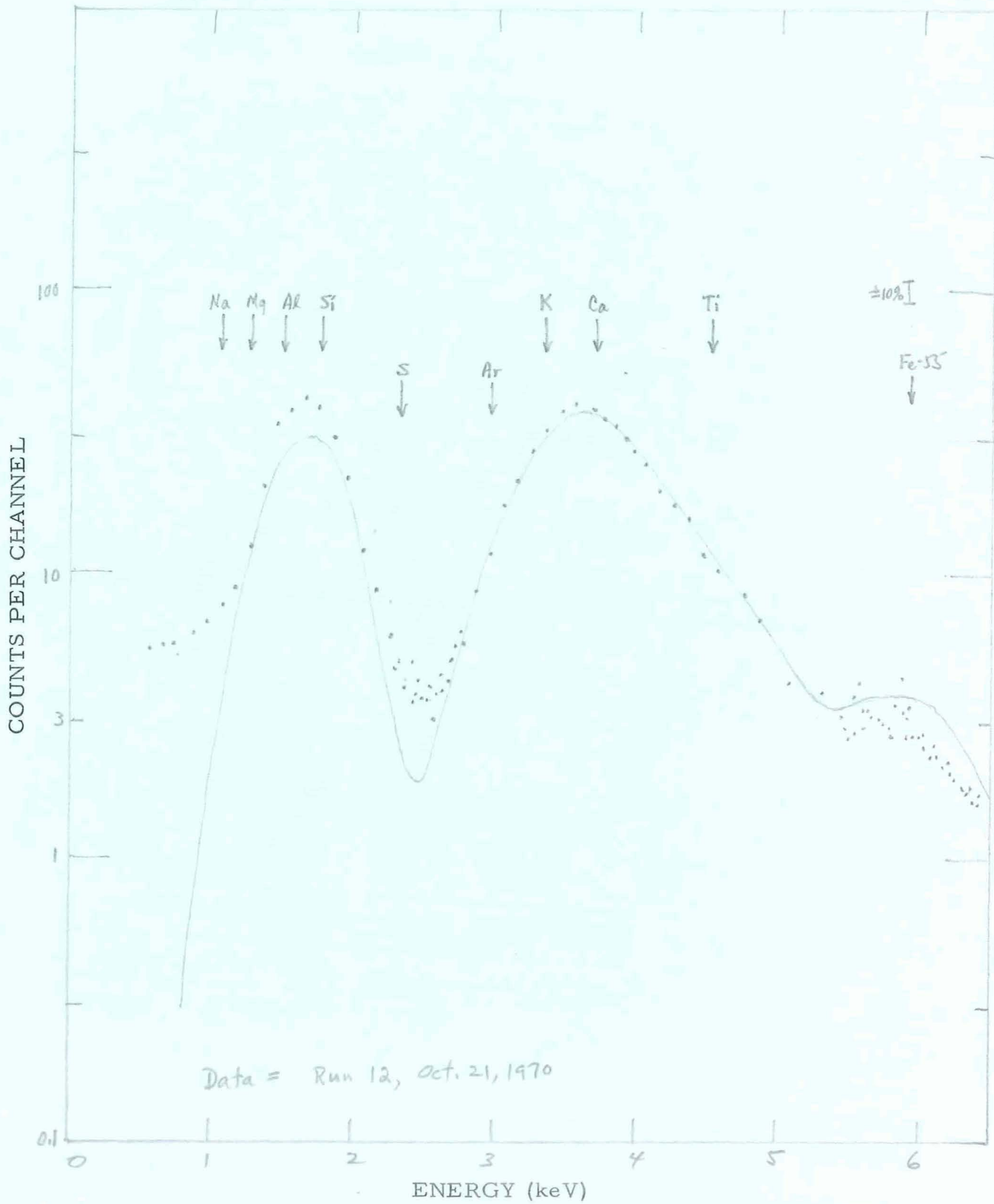


Fig. 3. Same as Fig. 1, but for USGS standard BCR-1.

OCT 2 1 1970

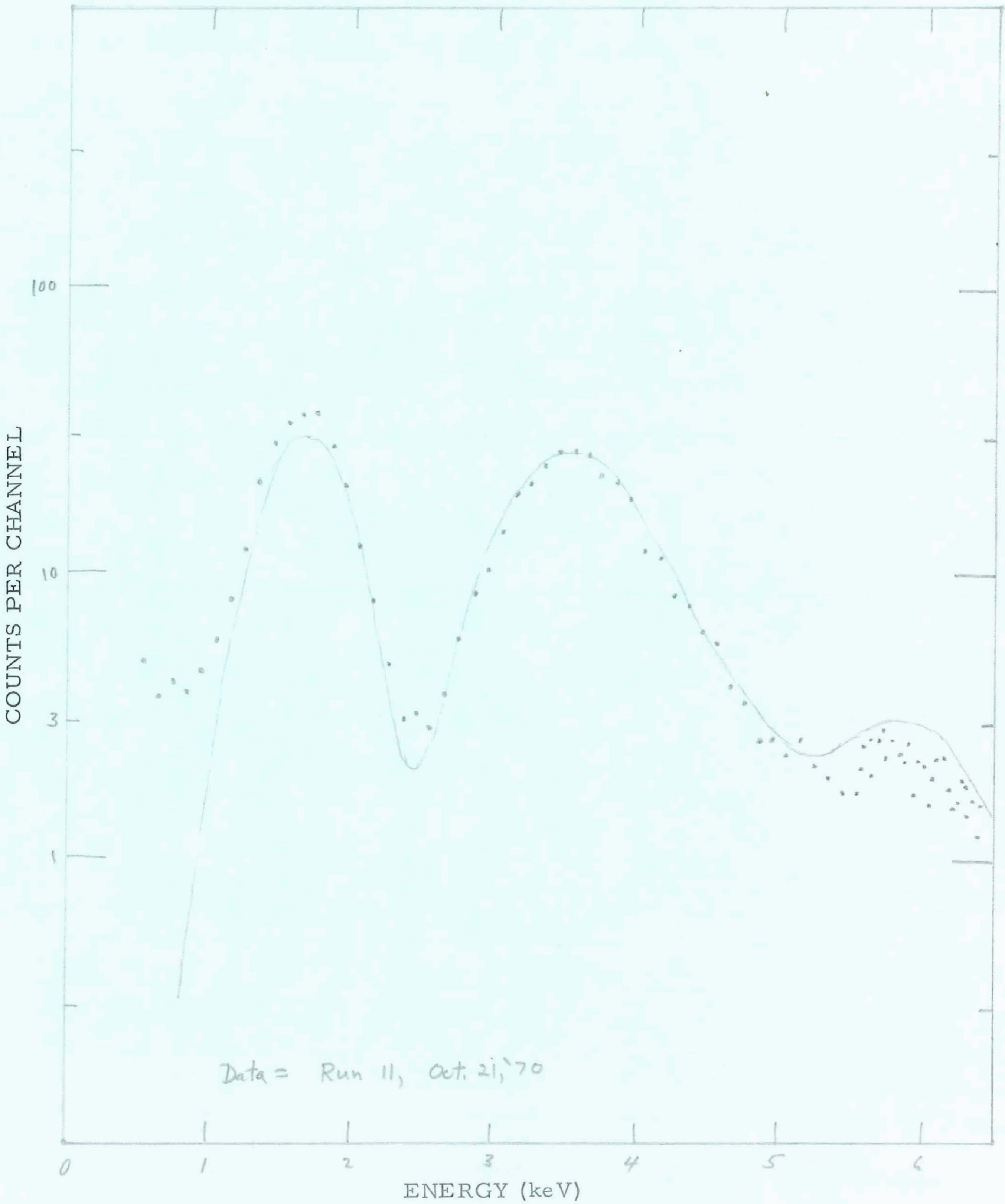
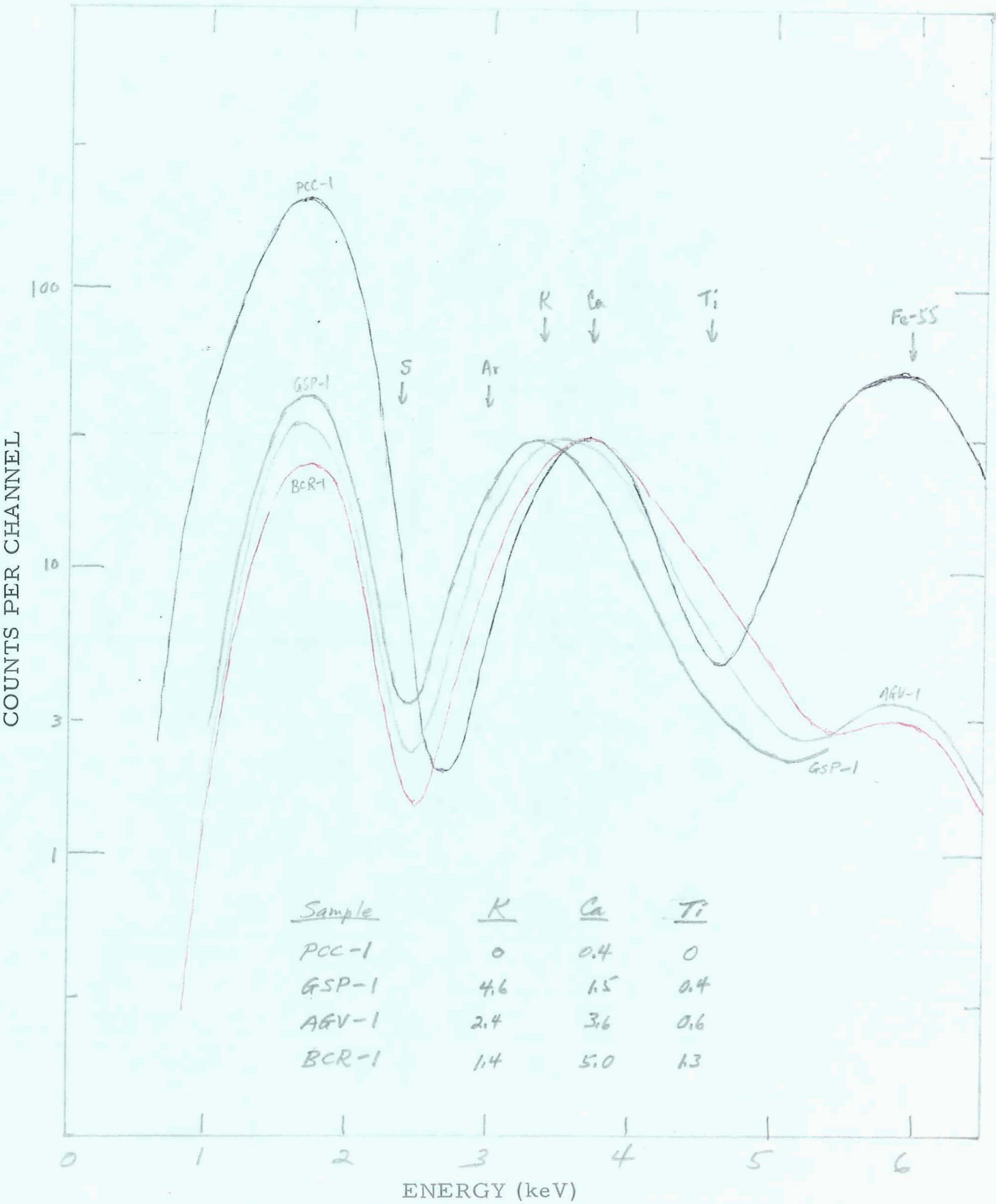


Fig. 4. Same as Fig. 1, but for USGS standard AGV-1.



Sample	K	Ca	Ti
PCC-1	0	0.4	0
GSP-1	4.6	1.5	0.4
AGV-1	2.4	3.6	0.6
BCR-1	1.4	5.0	1.3

Fig. 5. The spectra of Figs. 1-4 normalized to the same peak count rate at the K, Ca peak. Note the systematic shift of this peak as the K/Ca ratio changes.

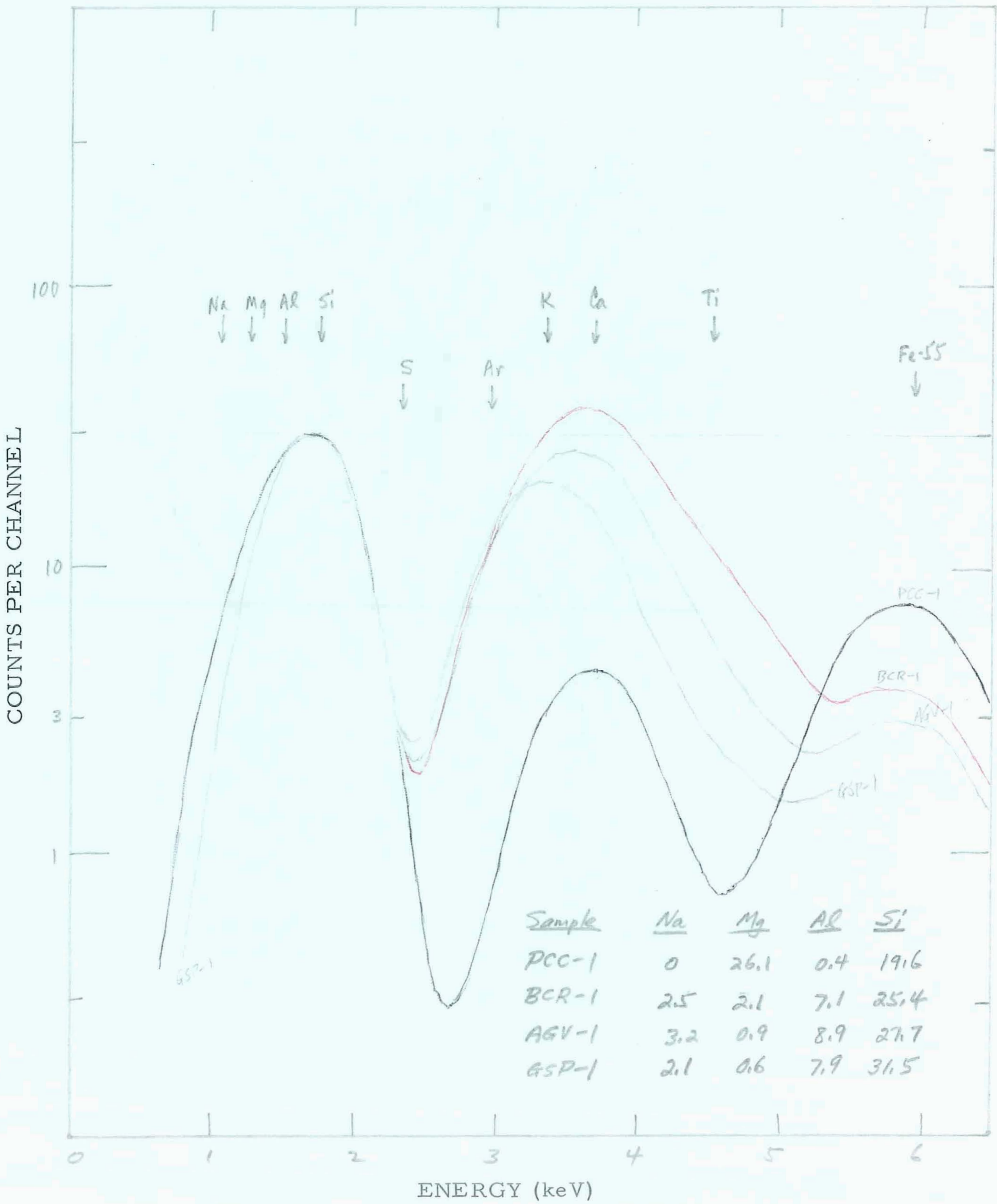


Fig. 6. Same as Fig. 5, except curves normalized at the Si peak.

6.4 Electronic Circuitry Developments

The key circuits requiring specific development for a Mars x-ray fluorescent spectrometer are the preamplifier, amplifier, and energy threshold discriminator. Figures 7 and 8 show two circuits that were breadboarded and tested for performance and temperature stability. The first circuit employs operational amplifiers where possible and can be fabricated at a smaller volume than the second circuit. However, it draws more power and is not as satisfactory at high counting rates since it produces pulses with a much greater width than the second circuit. Both circuits are reasonably well compensated for temperature effects, although further work is required in this area.

P.C. Preamp

OCT 25 1970

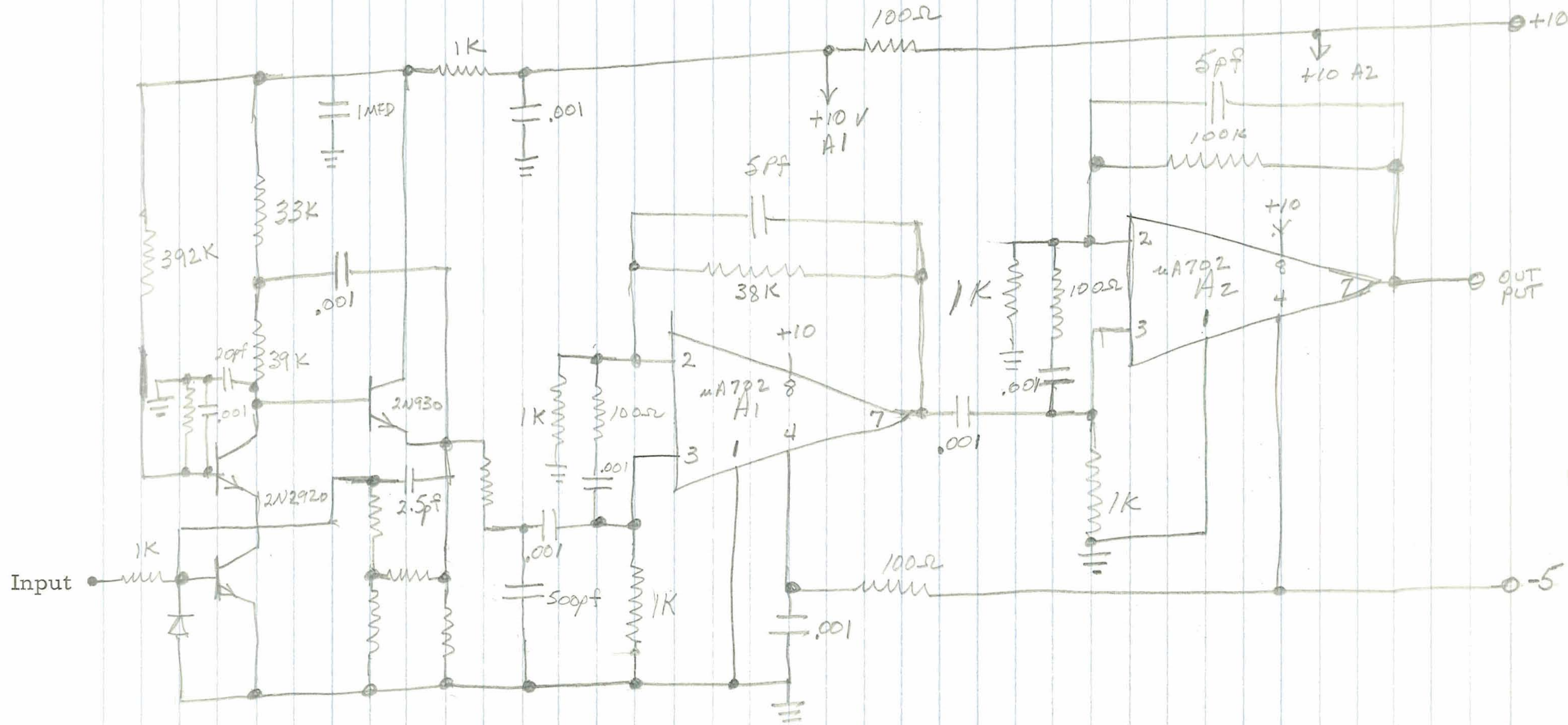


Fig. 7. Preamplifier, amplifier circuitry for soft x-ray proportional counter. This circuit maximizes the use of operational amplifiers (A1, A2).

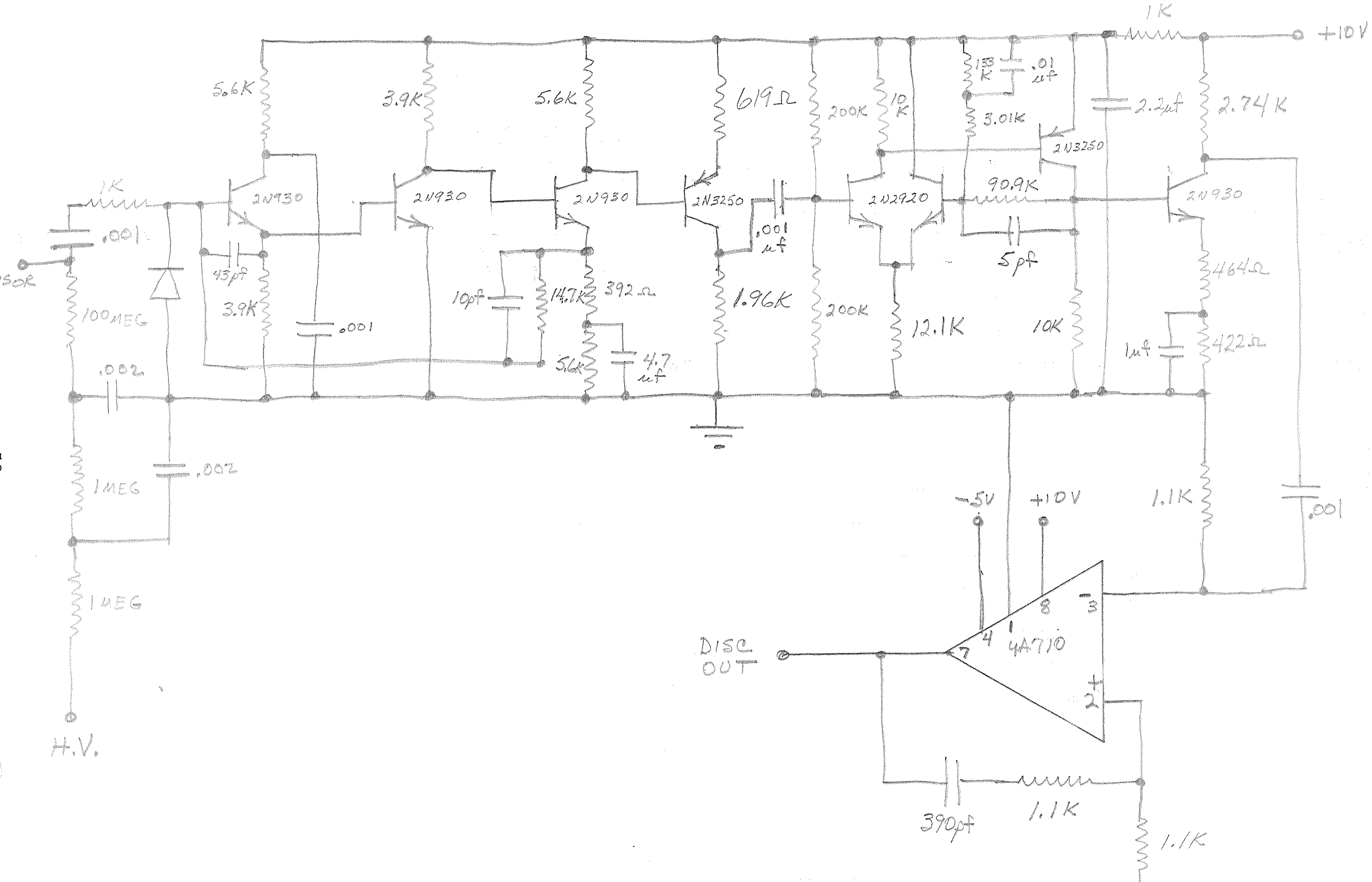


Fig. 8. Preamplifier, Amplifier, Discriminator circuitry for same application as circuit in Fig. 7, but employing mostly discrete components.

7.0 SCIENTIFIC BENEFITS OF A GEOCHEMICAL ANALYSIS PERFORMED BY THE VIKING LANDER

7.1 Life on Mars

The Viking '75 mission to Mars will search for the presence of life and organic compounds in surface soil. Any information, such as elemental analysis, on the nature of this soil will greatly complement these investigations. Indeed, the selection of landing sites for the Viking spacecraft may correlate strongly with certain apparent geological features. Green and Larmore (Gr-70) state,

> "To determine the possibility of life on the planets we must find out if the planet has been differentiated. If it has been differentiated, it had to defluidize. If it defluidized, it would release warmth and moisture to the surface at discrete places determined by planetary tectonics. Warmth and moisture would favor the generation of life forms......Such centers may be the fountainhead of possible life forms on an arid planet such as Mars."

7.2 Geological History of Mars

Although the primary mission of Viking '75 remains the search for extraterrestrial life, the results of the Mariner 6 and 7 Mars fly-bys and the finding of no appreciable organic carbon in the Apollo 11 and 12 samples have led many to suggest a reappraisal of goals. Wetherill (We-70) has argued for inclusion of soil elemental analysis on the Viking payload. Murray, Soderblom, Sharp, and Cutts (Mu-71) conclude their important analysis of the television pictures of Mars with the following comments:

> "The basis for emphasis on Mars as the prime target in the search for extra-terrestrial life seems to be weakened by the strong resemblance of its surface to the uplands of the moon. Rather, Mars should be accorded priority geologically

as exhibiting important aspects of planetary evolution unknown elsewhere in this Solar System, such as the replacement of cratered terrains by younger uncratered terrains....... Only on Mars can there be found a carbon dioxide frost cap with all its associated phenomena. There are erosional processes and modification episodes recorded on the martian surface unlike those yet known on any other body. The unravelling of these characteristically martian processes and the associated surface history provides a compelling and rewarding intellectual focus for exploration of that planet."

Analysis of the abundant elements in the Martian surface, especially if accomplished at different sites, will be of inestimable value in unravelling the geological story of Mars. Indeed, the geochemical analyses of lunar samples have already disproved certain models of the moon, and have laid the framework for more sophisticated and complete models (e.g., Wo-70, An-70, Ri-70, etc.).

7.3 Origin and History of the Solar System

A very thorough and objective analysis of current models of the evolution of the solar system has been made by Adams, Conel, Dunne, Fanale, Holstrom, and Loomis (Ad-69). In considering several possible evolutionary models, they concluded that the master strategy for scientific exploration of the planets should be to obtain as much data as possible to answer five key questions:

(1) Were there elemental and isotopic nonuniformities in the primordial nebula?

(2) What was the state of the sun-cloud system when it first appeared as a recognizable unit?

(3) Was the sun-cloud chemically homogenous?

(4) Did accretion into planets result in the present array of planets, or was the array subsequently altered?

(5) Are the individual planets chemically uniform or nonuniform?

The authors go further to define the experiments which should be performed to gather the data required to answer these questions and recommend the following "essential investigations" for planetary surfaces:

(a) Elemental abundances

(b) Mineral phases and assemblages

(c) Heat flow

(d) Isotopic abundances of certain elements

Experiment (a), the quantitative measurement of the key chemical elements, would provide data which could make a large contribution toward answering questions (3) through (5) above.

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APPENDIX I

ROCK AND MINERAL COMPOSITION DATA

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(3),NUMER	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(4),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		Na	Mg	Al	Si	P
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	.30	22.31	1.06	20.36	.00
107	CRUST	2.40	1.95	8.20	28.20	.11
104	CRUST	2.30	2.95	7.93	27.47	.00
127	HCP AVE IGNEOUS	2.85	2.10	8.09	27.66	.13
211	CONTINENTAL CRUST	2.89	2.17	8.25	28.13	.13
212	OCEANIC CRUST	2.08	4.40	9.15	23.35	.09
108	BASALTIC ACHONDRITE	.37	4.75	6.88	22.70	.08
109	OCEANIC THOLEIITE BASALT	2.07	4.65	8.57	23.40	.06
110	ALKALI OLIVINE BASALT	2.77	3.17	8.46	22.46	.18
111	AVERAGE CHONDRITE	.70	14.50	1.10	17.90	.10
112	AVERAGE ACHONDRITE	.15	12.10	2.10	18.90	.10
101	BASALTIC ROCK (BASIC ROCK)	1.71	5.19	8.20	22.70	.00
102	INTERMEDIATE ROCK	3.12	2.29	8.68	25.51	.00
103	GRANITIC ROCK	2.89	.66	7.67	32.34	.00
105	SHALE	.96	1.45	8.15	27.19	.00
128	HCP AVE SHALE	.96	1.47	8.15	27.19	.07
129	HCP AVE SANDSTONE	.33	.70	2.52	36.64	.03
131	HCP AVE SEDIMENT	.84	1.60	7.09	27.10	.06
106	CHONDRITES	.68	14.40	1.30	17.80	.11
135	COSMIC ABUNDANCE	.90	20.00	2.31	25.40	.27
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	2.23	.18	7.19	34.73	.04
2	RHYOLITES	2.52	.24	7.14	34.59	.04
3	CALC ALKALI GRANITES	2.30	.30	7.35	33.93	.09
4	GRANITES	2.60	.54	7.72	33.13	.09
5	SILICIS IGNEOUS ROCKS	2.89	.66	7.78	32.39	.09
6	GRANDIORITES(1)	2.89	.96	8.36	31.45	.09
7	GRANDIORITES(2)	2.75	1.15	8.52	30.75	.09
8	PLUTONIC IGNEOUS	2.60	1.51	8.25	30.47	.09
9	CORD APP IGNEOUS	2.52	1.81	8.41	29.20	.13
10	ANDESITES(1)	2.67	1.69	9.26	28.22	.13
11	AVE IGNEOUS	2.89	2.11	8.25	28.13	.13
12	DIORITES	2.52	2.53	8.94	26.96	.13
13	INTERMEDIATE IGNEOUS	3.12	2.29	8.83	25.69	.17
14	ANDESITES(2)	2.75	2.65	9.20	25.55	.13
15	PARENTAL CALC ALK MAGMAS	2.52	3.32	9.57	25.32	.09

AUG 14 1970

		Na	Mg	Al	Si	P
16	DIORITES(2)	2.52	3.68	8.73	24.52	.17
17	NORMAL THOLEIITES	1.71	3.86	7.51	24.01	.09
18	AVE THOLEITE	1.63	4.22	8.25	23.87	.09
19	BASALTS	2.37	3.80	8.46	23.35	.17
20	PLATEAU BASALTS	1.93	4.10	7.51	23.26	.13
21	MAFIC IGNEOUS	1.71	5.25	8.31	22.74	.13
22	AVE OLIVINE BASALT PACIFIC	2.00	4.76	7.99	22.00	.13
23	NORMAL ALK BASALTS	2.00	5.67	7.83	21.57	.17
24	PERIDOTITE NODULES IN BASA	.07	24.96	1.53	20.87	.00
25	ULTRAMAFIC IGNEOUS	.59	13.69	3.23	20.59	.13
26	PERIDOTITES	.45	20.68	2.12	20.55	.04
27	DUNITES(DALY)	.07	28.76	.48	19.52	.04
28	DUNITES (NOCKOLDS)	.22	26.17	.42	18.91	.00
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	.07	.06	.74	43.29	.00
30	AVE QUARTZITE FINLAND	.59	.42	3.39	39.08	.26
31	AVE SANDSTONE	.37	.72	2.54	37.30	.04
32	AVE SUBGRAYWACKE	1.56	.96	5.08	36.93	.09
33	AVE DIATOM OOZE	.07	1.09	2.70	36.32	.04
34	AVE ARKOSE	1.48	.06	6.08	35.61	.00
35	AVE MISSISSIPPI SILT	1.19	.90	5.98	34.96	.09
36	AVE GRAYWACKE	2.60	1.81	7.62	30.79	.04
37	AVE RADIOLARIAN OOZE	.74	1.99	7.25	29.86	.13
38	PALEZOIC SHALES	.82	1.51	9.26	29.81	.09
39	AVE BLUE MUD	1.78	1.33	8.57	29.62	.09
40	AVE SHALE	1.04	1.57	8.73	29.11	.09
41	GLACIAL CLAYS	1.63	2.11	8.78	29.06	.09
42	AVE TERRIGENOUS MUD	1.78	1.39	9.84	28.78	.09
43	CLAYS AND SOILS	.96	1.99	8.41	27.89	.04
44	MESO AND CENOZOIC SHALES	1.41	1.75	7.83	27.75	.09
45	AVE RED CLAY	1.04	1.21	8.94	25.04	.09
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	1.41	.60	5.08	37.53	.00
49	LEPTITES AND HAELLEFLINTAS	2.37	.60	7.04	34.54	.04
50	QUARTZOFELDSPATHIC GNEISSE	2.37	.72	7.67	33.09	.09
51	PLUTONIC GNEISSES	2.60	.72	7.83	32.90	.00
52	AVE MICA SCHIST FINLAND	2.00	1.09	8.73	32.10	.04
53	AVE PRECAMBRIAN FINLAND	2.30	1.03	7.83	32.01	.04
54	MICA SCHISTS NORWAY	.96	2.05	8.09	31.87	.00
55	TWO-MICA GNEISSES	2.30	1.09	8.78	31.68	.00
56	MICA SCHISTS (1)	1.34	1.21	9.47	31.59	.04
57	KINZIGITES FINLAND	1.85	1.75	8.41	31.08	.04
58	SLATES (1)	2.00	1.87	9.15	30.37	.00
59	ROOFING SLATES	.96	.96	10.21	30.33	.00
60	MICA SCHISTS (2)	1.19	1.63	10.16	30.23	.00
61	MICA SCHISTS (3)	1.41	1.63	9.26	30.09	.09
62	PHYLLITES NORWAY	1.11	1.33	10.69	29.95	.00
63	AVE PRECAMBRIAN CANADA	2.75	1.09	8.99	29.91	.00
64	SLATES AND PHYLLITES	.96	1.75	10.84	28.97	.00
65	SLATES (2)	1.26	1.75	10.10	28.92	.04
66	PRECAMBRIAN SLATES	.96	1.63	9.79	28.27	.09
67	PHYLLITES	1.48	1.75	10.95	28.08	.09
68	AMPHIBOLITES (1)	2.15	4.22	8.31	23.54	.13
69	AMPHIBOLITES (2)	2.15	4.16	8.78	23.54	.00
70	ECLOGITES	1.85	5.37	7.67	22.93	.00
	***** METEORITES *****					
712	AUBRITES	.98	21.65	.35	25.27	.01

		Na	Mg	Al	Si	P
713	DIOGENITES	.00	15.62	.62	24.38	.01
710	SHERGOTTITE	.94	6.00	3.11	23.40	.01
711	HOWARDITES	.79	7.12	5.26	23.07	.01
716	NAKHLITES	.30	7.24	.92	22.84	.01
709	EUCRITES	.32	5.10	6.88	22.28	.01
715	ANGRITES	.19	6.03	4.61	20.55	.01
708	AMPHOIERITES	.77	15.98	.96	19.09	.01
703	HYPERSTHENE CHONDRITES	.70	14.83	1.49	18.58	.01
714	UREILITES	.32	21.53	.20	18.21	.01
707	ENSTATITE CHONDRITES	.74	12.66	.99	18.06	.01
701	ORDINARY CHRONDITES	.67	14.41	1.44	17.92	.01
721	MANTLE (AVE STONY METEORIT	.74	14.47	1.32	17.92	.01
702	BRONZITE CHRONDITES	.69	13.93	1.38	17.04	.01
718	SIDEROPHYRES	.01	6.09	.01	16.19	.01
706	CARBONAC. CHRONDITES, TYPE	.41	14.41	1.40	15.82	.01
719	LODRANITES	.01	14.05	.10	13.53	.01
705	CARBONAC. CHONDRITES, TYPE	.40	11.46	1.22	12.78	.01
704	CARBONAC. CHONDRITES, TYPE	.56	9.41	.94	10.81	.01
720	MESOSIDERITES	.13	3.84	2.17	9.13	.01
717	PALLASITES	.05	11.94	.20	8.00	.01
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	.70	7.00	22.30	46.10	.01
601	LSPET A 72	.44	4.80	4.80	21.00	.01
600	LSPET A 22	.30	3.90	4.10	20.00	.01
605	LSPET B 58	.41	3.90	6.90	20.00	.01
608	LSPET C 21	.15	4.50	5.80	20.00	.01
610	LSPET D 37	.40	4.80	6.90	20.00	.01
606	LSPET B 45	.38	4.20	6.90	19.60	.01
611	LSPET 54 (BULK SAMPLE)	.38	4.60	6.90	19.60	.01
612	10044 GABBRO	.36	3.77	6.19	19.66	.03
614	10084=28 REGOLITH (DUST)	.36	4.79	7.56	19.42	.04
615	10017 29	.38	4.61	4.30	19.09	.06
637	10047	.48	3.68	5.18	19.33	.00
638	10049	.53	4.24	5.03	19.19	.00
639	10050	.49	4.84	4.71	19.14	.00
640	10058 (WHOLE ROCK)	.59	3.77	5.66	19.38	.00
642	10019	.69	4.74	7.25	19.23	.00
643	10048	.39	4.55	6.82	19.75	.00
644	10060	.58	4.53	6.24	19.42	.00
645	311079	.40	4.79	7.46	19.75	.00
641	10062	.51	4.35	6.40	18.16	.00
604	LSPET B 17	.48	5.10	5.30	18.70	.01
609	LSPET C 61	.37	5.40	5.80	18.70	.01
613	10057 VESICULAR DIABASE	.40	4.61	5.71	18.63	.07
616	10020 30	.27	4.71	5.29	18.67	.03
617	10072	.39	4.86	4.12	18.81	.08
635	10022	.68	4.67	4.55	18.77	.00
636	10024	.59	4.89	5.03	18.25	.00
634	10003	.63	4.34	5.82	17.69	.00
603	LSPET A 20	.44	4.80	5.80	17.80	.01
607	LSPET B 50	.38	6.00	5.80	17.80	.01
602	LSPET A 57	.40	5.70	5.80	16.80	.01
	***** APOLLO 12 *****					
633	LSPET 12013	.51	3.62	6.35	28.55	.00
627	LSPET 12038,CRYS	.45	3.92	6.35	22.93	.00
631	LSPET 12010 BRECCIA	.39	6.63	6.08	20.12	.00
625	LSPET 12052,CRYS	.33	6.03	5.82	19.66	.00
623	LSPET 12009,CRYS	.38	7.54	5.82	19.19	.00

		Na	Mg	Al	Si	P
629	LSPET 12070 FINES	.30	7.24	7.41	19.66	.00
630	LSPET 12073 BRECCIA	.37	6.63	7.93	19.19	.00
632	LSPET 12033 LIGHT FINES	.40	6.63	8.46	19.19	.00
624	LSPET 12065,CRYS	.29	5.43	6.35	18.25	.00
626	LSPET 12064,CRYS	.31	4.82	6.35	18.72	.00
628	LSPET CRYS ROCKS,AVE	.33	7.06	5.92	18.72	.00
620	LSPET 12004,CRYS	.36	9.04	5.55	17.32	.00
621	LSPET 12015,CRYS	.27	8.44	5.82	17.78	.00
619	LSPET 12012,CRYS	.39	10.55	5.82	16.38	.00
622	LSPET 12022,CRYS	.27	7.84	5.82	16.85	.00
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	.59	4.82	6.45	30.00	.00
300	J-87 JAVANITE TEKTITE	.52	4.10	6.67	29.72	.00
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	2.35	.27	7.19	34.59	.02
113	USGS STAND G-1	2.55	.22	7.46	33.93	.04
121	P-17 BIOTITE QUARTZ MONZON	2.90	.30	7.72	33.70	.03
115	USGS STAND G-2	3.08	.46	8.09	32.43	.07
122	P-4 BIOTITE QUARTZ MONZON	3.20	.62	8.20	31.59	.07
116	USGS STAND GSP-1	2.12	.57	7.88	31.50	.13
123	P-19 BIOTITE GRANDIORITE	3.15	.75	9.05	30.79	.06
126	P-26 TONALITE (2)	3.40	1.20	10.05	28.08	.08
117	USGS STAND AGV-1	3.21	.92	8.94	27.66	.21
125	P-25 TONALITE (1)	2.34	2.17	9.31	27.24	.06
118	USGS STAND BCR-1	2.46	2.09	7.09	25.37	.17
114	USGS STAND W-1	1.67	3.99	7.88	24.62	.06
119	USGS STAND PCC-1	.00	26.11	.38	19.56	.00
120	USGS STAND DTS-1	.00	30.03	.16	18.95	.00
281	AVE OLIVINE	.00	14.10	.00	16.30	.00
285	AVE PYROXENE	3.40	5.30	2.00	24.70	.00
286	AVE AMPHIBOLE (W/O HORNBLE	1.70	6.90	1.00	25.50	.00
287	AVE HORNBLENDE	2.40	5.00	7.00	23.20	.00
288	AVE BIOTITE	.00	8.30	.00	19.30	.00
274	MUSCOVITE (MICA)	.00	.00	20.30	21.20	.00
278	ORTHOCLASE (FELDSPAR)	.00	.00	9.70	30.30	.00
280	ANORTHITE (FELDSPAR)	.00	.00	19.40	20.20	.00
279	ALBITE (FELDSPAR)	8.80	.00	10.30	32.10	.00
		1.20	5.12	6.07	23.50	.04

AUG 14 1970

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(3),NUMER	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(4),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		Na	Mg	Al	Si	P
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	-4.03	4.36	-5.73	-1.15	-.00
107	CRUST	2.01	-2.63	1.35	1.20	2.49
104	CRUST	1.92	-1.73	1.31	1.17	-.00
127	HCP AVE IGNEOUS	2.38	-2.43	1.33	1.18	2.97
211	CONTINENTAL CRUST	2.42	-2.36	1.36	1.20	2.97
212	OCEANIC CRUST	1.74	-1.16	1.51	-1.01	1.98
108	BASALTIC ACHONDRITE	-3.22	-1.08	1.13	-1.04	1.88
109	OCEANIC THOLEIITE BASALT	1.73	-1.10	1.41	-1.00	1.29
110	ALKALI OLIVINE BASALT	2.31	-1.61	1.40	-1.05	4.16
111	AVERAGE CHONDRITE	-1.71	2.83	-5.52	-1.31	2.27
112	AVERAGE ACHONDRITE	-7.98	2.36	-2.89	-1.24	2.27
101	BASALTIC ROCK (BASIC ROCK)	1.43	1.01	1.35	-1.04	-.00
102	INTERMEDIATE ROCK	2.60	-2.24	1.43	1.09	-.00
103	GRANITIC ROCK	2.42	-7.72	1.26	1.38	-.00
105	SHALE	-1.24	-3.54	1.34	1.16	-.00
128	HCP AVE SHALE	-1.24	-3.48	1.34	1.16	1.68
129	HCP AVE SANDSTONE	-3.58	-7.32	-2.40	1.56	-1.26
131	HCP AVE SEDIMENT	-1.43	-3.21	1.17	1.15	1.29
106	CHONDRITES	-1.76	2.81	-4.67	-1.32	2.49
135	COSMIC ABUNDANCE	-1.33	3.90	-2.63	1.08	6.12
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	1.86	-28.31	1.19	1.48	-1.01
2	RHYOLITES	2.11	-21.24	1.18	1.47	-1.01
3	CALC ALKALI GRANITES	1.92	-16.99	1.21	1.44	1.98
4	GRANITES	2.17	-9.44	1.27	1.41	1.98
5	SILICIS IGNEOUS ROCKS	2.42	-7.72	1.28	1.38	1.98
6	GRANDIORITES(1)	2.42	-5.31	1.38	1.34	1.98
7	GRANDIORITES(2)	2.29	-4.47	1.40	1.31	1.98
8	PLUTONIC IGNEOUS	2.17	-3.40	1.36	1.30	1.98
9	CORD APP IGNEOUS	2.11	-2.83	1.39	1.24	2.97
10	ANDESITES(1)	2.23	-3.03	1.53	1.20	2.97
11	AVE IGNEOUS	2.42	-2.43	1.36	1.20	2.97
12	DIORITES	2.11	-2.02	1.47	1.15	2.97
13	INTERMEDIATE IGNEOUS	2.60	-2.24	1.46	1.09	3.96
14	ANDESITES(2)	2.29	-1.93	1.52	1.09	2.97
15	PARENTAL CALC ALK MAGMAS	2.11	-1.54	1.58	1.08	1.98

AUG 14 1970

		Na	Mg	Al	Si	P
16	DIORITES(2)	2.11	-1.39	1.44	1.04	3.96
17	NORMAL THOLEITES	1.43	-1.33	1.24	1.02	1.98
18	AVE THOLEITE	1.36	-1.21	1.36	1.02	1.98
19	BASALTS	1.98	-1.35	1.40	-1.01	3.96
20	PLATEAU BASALTS	1.61	-1.25	1.24	-1.01	2.97
21	MAFIC IGNEOUS	1.43	1.02	1.37	-1.03	2.97
22	AVE OLIVINE BASALT PACIFIC	1.67	-1.08	1.32	-1.07	2.97
23	NORMAL ALK BASALTS	1.67	1.11	1.29	-1.09	3.96
24	PERIDOTITE NODULES IN BASA	-16.12	4.87	-3.95	-1.13	-10.10
25	ULTRAMAFIC IGNEOUS	-2.02	2.67	-1.88	-1.14	2.97
26	PERIDOTITES	-2.69	4.04	-2.87	-1.14	-1.01
27	DUNITES(DALY)	-16.12	5.62	-12.74	-1.20	-1.01
28	DUNITES (NOCKOLDS)	-5.37	5.11	-14.34	-1.24	-10.10
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	-16.12	-84.94	-8.19	1.84	-10.10
30	AVE QUARTZITE FINLAND	-2.02	-12.13	-1.79	1.66	5.94
31	AVE SANDSTONE	-3.22	-7.08	-2.39	1.59	-1.01
32	AVE SUBGRAYWACKE	1.30	-5.31	-1.19	1.57	1.98
33	AVE DIATOM OOZE	-16.12	-4.72	-2.25	1.55	-1.01
34	AVE ARKOSE	1.24	-84.94	1.00	1.52	-10.10
35	AVE MISSISSIPPI SILT	-1.01	-5.66	-1.01	1.49	1.98
36	AVE GRAYWACKE	2.17	-2.83	1.26	1.31	-1.01
37	AVE RADIOLARIAN OOZE	-1.61	-2.57	1.19	1.27	2.97
38	PALEZOIC SHALES	-1.47	-3.40	1.53	1.27	1.98
39	AVE BLUE MUD	1.49	-3.86	1.41	1.26	1.98
40	AVE SHALE	-1.15	-3.27	1.44	1.24	1.98
41	GLACIAL CLAYS	1.36	-2.43	1.45	1.24	1.98
42	AVE TERRIGENOUS MUD	1.49	-3.69	1.62	1.22	1.98
43	CLAYS AND SOILS	-1.24	-2.57	1.39	1.19	-1.01
44	MESO AND CENOZOIC SHALES	1.18	-2.93	1.29	1.18	1.98
45	AVE RED CLAY	-1.15	-4.25	1.47	1.07	1.98
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	1.18	-8.49	-1.19	1.60	-10.10
49	LEPTITES AND HAELLEFLINTAS	1.98	-8.49	1.16	1.47	-1.01
50	QUARTZOFELDSPATHIC GNEISSE	1.98	-7.08	1.26	1.41	1.98
51	PLUTONIC GNEISSES	2.17	-7.08	1.29	1.40	-10.10
52	AVE MICA SCHIST FINLAND	1.67	-4.72	1.44	1.37	-1.01
53	AVE PRECAMBRIAN FINLAND	1.92	-5.00	1.29	1.36	-1.01
54	MICA SCHISTS NORWAY	-1.24	-2.50	1.33	1.36	-10.10
55	TWO-MICA GNEISSES	1.92	-4.72	1.45	1.35	-10.10
56	MICA SCHISTS (1)	1.12	-4.25	1.56	1.34	-1.01
57	KINZIGITES FINLAND	1.55	-2.93	1.39	1.32	-1.01
58	SLATES (1)	1.67	-2.74	1.51	1.29	-10.10
59	ROOFING SLATES	-1.24	-5.31	1.68	1.29	-10.10
60	MICA SCHISTS (2)	-1.01	-3.15	1.67	1.29	-10.10
61	MICA SCHISTS (3)	1.18	-3.15	1.53	1.28	1.98
62	PHYLLITES NORWAY	-1.07	-3.86	1.76	1.27	-10.10
63	AVE PRECAMBRIAN CANADA	2.29	-4.72	1.48	1.27	-10.10
64	SLATES AND PHYLLITES	-1.24	-2.93	1.79	1.23	-10.10
65	SLATES (2)	1.05	-2.93	1.67	1.23	-1.01
66	PRECAMBRIAN SLATES	-1.24	-3.15	1.61	1.20	1.98
67	PHYLLITES	1.24	-2.93	1.80	1.19	1.98
68	AMPHIBOLITES (1)	1.80	-1.21	1.37	1.00	2.97
69	AMPHIBOLITES (2)	1.80	-1.23	1.45	1.00	-10.10
70	ECLOGITES	1.55	1.05	1.26	-1.02	-10.10
	***** METEORITES *****					
712	AUBRITES	-1.22	4.23	-17.12	1.08	-4.41

		Na	Mg	Al	Si	P
713	DIOGENITES	-403.08	3.05	-9.72	1.04	-4.41
710	SHERGOTTITE	-1.27	1.17	-1.95	-1.00	-4.41
711	HOWARDITES	-1.52	1.39	-1.15	-1.02	-4.41
716	NAKHLITES	-3.93	1.41	-6.63	-1.03	-4.41
709	EUCRITES	-3.75	-1.00	1.13	-1.05	-4.41
715	ANGRITES	-6.20	1.18	-1.32	-1.14	-4.41
708	AMPHOTERITES	-1.55	3.12	-6.34	-1.23	-4.41
703	HYPERSTHENE CHONDRITES	-1.72	2.90	-4.08	-1.26	-4.41
714	UREILITES	-3.75	4.20	-30.18	-1.29	-4.41
707	ENSTATITE CHONDRITES	-1.61	2.47	-6.13	-1.30	-4.41
701	ORDINARY CHRONDITES	-1.79	2.81	-4.22	-1.31	-4.41
721	MANTLE (AVE STONY METEORIT	-1.61	2.83	-4.59	-1.31	-4.41
702	BRONZITE CHRONDITES	-1.73	2.72	-4.41	-1.38	-4.41
718	SIDEROPHYRES	-161.23	1.19	*******	-1.45	-4.41
706	CARBONAC. CHRONDITES, TYPE	-2.93	2.81	-4.33	-1.49	-4.41
719	LODRANITES	-161.23	2.74	-60.36	-1.74	-4.41
705	CARBONAC. CHONDRITES, TYPE	-2.99	2.24	-4.96	-1.84	-4.41
704	CARBONAC. CHONDRITES, TYPE	-2.12	1.84	-6.48	-2.17	-4.41
720	MESOSIDERITES	-9.48	-1.34	-2.80	-2.58	-4.41
717	PALLASITES	-23.03	2.33	-30.18	-2.94	-4.41
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	-1.71	1.37	3.68	1.96	-4.41
601	LSPET A 72	-2.72	-1.07	-1.26	-1.12	-4.41
600	LSPET A 22	-3.99	-1.31	-1.48	-1.18	-4.41
605	LSPET B 58	-2.92	-1.31	1.14	-1.18	-4.41
608	LSPET C 21	-7.98	-1.14	-1.05	-1.18	-4.41
610	LSPET D 37	-2.99	-1.07	1.14	-1.18	-4.41
606	LSPET B 45	-3.15	-1.22	1.14	-1.20	-4.41
611	LSPET 54 (BULK SAMPLE)	-3.15	-1.11	1.14	-1.20	-4.41
612	10044 GABBRO	-3.36	-1.36	1.02	-1.20	-1.26
614	10084-28 REGOLITH (DUST)	-3.36	-1.07	1.25	-1.21	-1.01
615	10017 29	-3.16	-1.11	-1.41	-1.23	1.29
637	10047	-2.48	-1.39	-1.17	-1.22	-10.10
638	10049	-2.27	-1.21	-1.21	-1.22	-10.10
639	10050	-2.44	-1.06	-1.29	-1.23	-10.10
640	10058 (WHOLE ROCK)	-2.04	-1.36	-1.07	-1.21	-10.10
642	10019	-1.73	-1.08	1.19	-1.22	-10.10
643	10048	-3.10	-1.13	1.12	-1.19	-10.10
644	10060	-2.07	-1.13	1.03	-1.21	-10.10
645	311079	-2.99	-1.07	1.23	-1.19	-10.10
641	10062	-2.34	-1.18	1.06	-1.29	-10.10
604	LSPET B 17	-2.49	-1.00	-1.14	-1.26	-4.41
609	LSPET C 61	-3.23	1.05	-1.05	-1.26	-4.41
613	10057 VESICULAR DIABASE	-2.99	-1.11	-1.06	-1.26	1.68
616	10020 30	-4.36	-1.09	-1.15	-1.26	-1.26
617	10072	-3.10	-1.05	-1.47	-1.25	1.78
635	10022	-1.77	-1.10	-1.33	-1.25	-10.10
636	10024	-2.02	-1.05	-1.21	-1.29	-10.10
634	10003	-1.90	-1.18	-1.04	-1.33	-10.10
603	LSPET A 20	-2.72	-1.07	-1.05	-1.32	-4.41
607	LSPET B 50	-3.15	1.17	-1.05	-1.32	-4.41
602	LSPET A 57	-2.99	1.11	-1.05	-1.40	-4.41
	***** APOLLO 12 *****					
633	LSPET 12013	-2.34	-1.42	1.05	1.21	-10.10
627	LSPET 12038, CRYS	-2.69	-1.31	1.05	-1.02	-10.10
631	LSPET 12010 BRECCIA	-3.04	1.29	1.00	-1.17	-10.10
625	LSPET 12052, CRYS	-3.58	1.18	-1.04	-1.20	-10.10
623	LSPET 12009, CRYS	-3.16	1.47	-1.04	-1.22	-10.10

		Na	Mg	Al	Si	P
629	LSPET 12070 FINES	-4.03	1.41	1.22	-1.20	-10.10
630	LSPET 12073 BRECCIA	-3.22	1.29	1.31	-1.22	-10.10
632	LSPET 12033 LIGHT FINES	-2.99	1.29	1.40	-1.22	-10.10
624	LSPET 12065,CRYS	-4.13	1.06	1.05	-1.29	-10.10
626	LSPET 12064,CRYS	-3.84	-1.06	1.05	-1.26	-10.10
628	LSPET CRYS ROCKS,AVE	-3.58	1.38	-1.02	-1.26	-10.10
620	LSPET 12004,CRYS	-3.36	1.77	-1.09	-1.36	-10.10
621	LSPET 12015,CRYS	-4.36	1.65	-1.04	-1.32	-10.10
619	LSPET 12012,CRYS	-3.04	2.06	-1.04	-1.43	-10.10
622	LSPET 12022,CRYS	-4.48	1.53	-1.04	-1.39	-10.10
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	-2.02	-1.06	1.06	1.28	-10.10
300	J-87 JAVANITE TEKTITE	-2.30	-1.25	1.10	1.26	-10.10
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	1.97	-18.88	1.19	1.47	-2.02
113	USGS STAND G-1	2.13	-22.96	1.23	1.44	-1.01
121	P-17 BIOTITE QUARTZ MONZON	2.43	-16.99	1.27	1.43	-1.44
115	USGS STAND G-2	2.57	-11.03	1.33	1.38	1.49
122	P-4 BIOTITE QUARTZ MONZON	2.67	-8.25	1.35	1.34	1.58
116	USGS STAND GSP-1	1.77	-8.94	1.30	1.34	2.97
123	P-19 BIOTITE GRANDIORITE	2.64	-6.85	1.49	1.31	1.39
126	P-26 TONALITE (2)	2.84	-4.27	1.66	1.19	1.78
117	USGS STAND AGV-1	2.68	-5.55	1.47	1.18	4.85
125	P-25 TONALITE (1)	1.95	-2.36	1.53	1.16	1.39
118	USGS STAND BCR-1	2.06	-2.45	1.17	1.08	3.76
114	USGS STAND W-1	1.40	-1.28	1.30	1.05	1.39
119	USGS STAND PCC-1	-268.72	5.10	-15.93	-1.20	-10.10
120	USGS STAND DTS-1	-268.72	5.86	-38.23	-1.24	-10.10
281	AVE OLIVINE	-.00	2.75	-.00	-1.44	-.00
285	AVE PYROXENE	2.84	1.03	-3.03	1.05	-.00
286	AVE AMPHIBOLE (W/O HORNBLE	1.42	1.35	-6.07	1.09	-.00
287	AVE HORNBLENDE	2.01	-1.02	1.15	-1.01	-.00
288	AVE BIOTITE	-.00	1.62	-.00	-1.22	-.00
274	MUSCOVITE (MICA)	-.00	-.00	3.35	-1.11	-.00
278	ORTHOCLASE (FELDSPAR)	-.00	-.00	1.60	1.29	-.00
280	ANORTHITE (FELDSPAR)	-.00	-.00	3.20	-1.16	-.00
279	ALBITE (FELDSPAR)	7.36	-.00	1.70	1.37	-.00
		1.20	5.12	6.07	23.50	.04

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(3),NUMER	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
RATIO(4),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
RATIO(5),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		S	K	Ca	Ti	Fe
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	.01	.08	2.15	.48	9.44
107	CRUST	.03	2.10	4.20	.57	5.60
104	CRUST	.01	1.91	4.79	.72	5.65
127	HCP AVE IGNEOUS	.01	2.60	3.63	.63	5.11
211	CONTINENTAL CRUST	.01	2.66	3.72	.66	5.20
212	OCEANIC CRUST	.01	.17	8.51	.90	6.76
108	BASALTIC ACHONDRITE	.01	.07	7.86	.29	13.13
109	OCEANIC THOLEIITE BASALT	.01	.18	8.08	.82	7.12
110	ALKALI OLIVINE BASALT	.01	1.57	6.46	1.75	8.58
111	AVERAGE CHONDRITE	1.80	.20	1.40	.10	25.00
112	AVERAGE ACHONDRITE	2.10	.01	2.90	.01	31.00
101	BASALTIC ROCK (BASIC ROCK)	.01	.58	7.65	1.08	8.25
102	INTERMEDIATE ROCK	.01	2.66	4.65	.90	6.35
103	GRANITIC ROCK	.01	3.15	1.86	.30	2.90
105	SHALE	.01	2.66	2.22	.42	4.74
128	HCP AVE SHALE	.01	2.69	2.22	.39	4.72
129	HCP AVE SANDSTONE	.01	1.09	3.93	.15	.98
131	HCP AVE SEDIMENT	.01	2.37	4.21	.34	4.05
106	CHONDRITES	2.30	.09	1.40	.08	25.10
135	COSMIC ABUNDANCE	10.90	.11	1.77	.10	30.30
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	.01	4.48	.79	.12	1.53
2	RHYOLITES	.01	3.90	.86	.18	1.76
3	CALC ALKALI GRANITES	.01	4.48	.93	.24	1.95
4	GRANITES	.01	3.40	1.43	.24	2.52
5	SILICIS IGNEOUS ROCKS	.01	3.15	1.86	.30	2.90
6	GRANDIORITES(1)	.01	2.57	2.57	.36	2.93
7	GRANDIORITES(2)	.01	2.32	3.22	.36	3.29
8	PLUTONIC IGNEOUS	.01	3.07	3.07	.30	3.41
9	CORD APP IGNEOUS	.01	2.24	3.65	.42	4.66
10	ANDESITES(1)	.01	1.74	4.22	.48	4.79
11	AVE IGNEOUS	.01	2.66	3.72	.66	5.20
12	DIORITES	.01	1.83	4.86	.48	5.74
13	INTERMEDIATE IGNEOUS	.01	2.66	4.72	.90	6.35
14	ANDESITES(2)	.01	.91	5.72	.78	6.72
15	PARENTAL CALC ALK MAGMAS	.01	.83	6.01	.54	6.26

		S	K	Ca	Ti	Fe
16	DIORITES(2)	.01	1.08	6.08	.90	7.33
17	NORMAL THOLEIITES	.01	.75	7.51	1.20	9.10
18	AVE THOLEITE	.01	.83	7.51	.84	8.38
19	BASALTS	.01	1.24	6.51	.84	8.83
20	PLATEAU BASALTS	.01	.58	6.86	1.32	10.36
21	MAFIC IGNEOUS	.01	.58	7.72	1.08	8.25
22	AVE OLIVINE BASALT PACIFIC	.01	.83	7.79	1.80	8.88
23	NORMAL ALK BASALTS	.01	.83	7.72	1.56	9.08
24	PERIDOTITE NODULES IN BASA	.01	.01	1.79	.12	6.31
25	ULTRAMAFIC IGNEOUS	.01	.58	7.29	1.02	9.99
26	PERIDOTITES	.01	.17	2.50	.48	9.44
27	DUNITES(DALY)	.01	.01	.50	.01	6.46
28	DUNITES (NOCKOLDS)	.01	.08	.57	.12	10.58
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	.01	.08	2.15	.01	.37
30	AVE QUARTZITE FINLAND	.01	1.49	1.22	.01	2.46
31	AVE SANDSTONE	.01	1.08	4.00	.18	1.00
32	AVE SUBGRAYWACKE	.01	1.24	.86	.36	2.73
33	AVE DIATOM OOZE	.01	.08	5.15	.18	1.62
34	AVE ARKOSE	.01	4.73	1.14	.01	1.69
35	AVE MISSISSIPPI SILT	.01	2.08	1.64	.36	2.60
36	AVE GRAYWACKE	.01	1.74	2.57	.30	4.04
37	AVE RADIOLARIAN OOZE	.01	1.41	2.22	.36	6.66
38	PALEZOIC SHALES	.01	3.15	1.07	.48	5.42
39	AVE BLUE MUD	.01	1.41	1.86	.48	5.82
40	AVE SHALE	.01	2.91	2.36	.42	5.03
41	GLACIAL CLAYS	.01	3.40	2.29	.48	5.12
42	AVE TERRIGENOUS MUD	.01	.91	1.57	.84	5.79
43	CLAYS AND SOILS	.01	1.91	3.86	.30	5.38
44	MESO AND CENOZOIC SHALES	.01	2.41	4.58	.30	4.49
45	AVE RED CLAY	.01	1.66	4.29	.48	9.11
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	.01	2.16	.79	.01	2.62
49	LEPTITES AND HAELLEFLINTAS	.01	3.07	1.14	.12	2.22
50	QUARTZOFELDSPATHIC GNEISSE	.01	3.15	1.57	.30	2.67
51	PLUTONIC GNEISSES	.01	3.57	1.36	.01	2.95
52	AVE MICA SCHIST FINLAND	.01	3.15	1.79	.18	2.80
53	AVE PRECAMBRIAN FINLAND	.01	2.99	2.43	.24	3.40
54	MICA SCHISTS NORWAY	.01	3.15	.93	.01	5.29
55	TWO-MICA GNEISSES	.01	2.91	1.43	.01	3.97
56	MICA SCHISTS (1)	.01	2.82	.93	.36	4.04
57	KINZIGITES FINLAND	.01	2.66	1.00	.36	5.18
58	SLATES (1)	.01	2.74	.79	.54	4.98
59	ROOFING SLATES	.01	3.24	2.00	.01	4.59
60	MICA SCHISTS (2)	.01	3.49	1.14	.01	4.53
61	MICA SCHISTS (3)	.01	3.07	1.36	.60	5.04
62	PHYLLITES NORWAY	.01	3.90	.29	.01	5.45
63	AVE PRECAMBRIAN CANADA	.01	2.57	2.93	.48	4.01
64	SLATES AND PHYLLITES	.01	2.99	1.00	.01	6.22
65	SLATES (2)	.01	3.15	.71	.42	6.51
66	PRECAMBRIAN SLATES	.01	3.40	.79	.48	8.08
67	PHYLLITES	.01	3.32	.86	.66	5.83
68	AMPHIBOLITES (1)	.01	.91	6.79	.96	8.58
69	AMPHIBOLITES (2)	.01	.58	7.15	.01	9.51
70	ECLOGITES	.01	.58	8.22	.01	9.73
	***** METEORITES *****					
712	AUBRITES	.46	.08	.65	.04	3.84

		S	K	Ca	Ti	Fe
713	DIOGENITES	.41	.00	1.01	.11	14.01
710	SHERGOTTITE	.00	.15	7.44	.01	17.19
711	HOWARDITES	.22	.30	5.51	.06	14.10
716	NAKHLITES	.06	.12	10.80	.23	16.20
709	EUCRITES	.20	.05	7.29	.26	14.43
715	ANGRITES	.46	.16	17.52	1.43	7.48
708	AMPHOTERITES	1.46	.20	1.20	.01	20.21
703	HYPERSTHENE CHONDRITES	2.21	.09	1.37	.07	22.09
714	UREILITES	.00	.01	.56	.05	18.00
707	ENSTATITE CHONDRITES	3.91	.09	.69	.04	27.91
701	ORDINARY CHRONDITES	2.15	.08	1.36	.07	24.76
721	MANTLE (AVE STONY METEORIT	2.12	.17	1.43	.06	25.30
702	BRONZITE CHRONDITES	2.07	.08	1.34	.07	27.99
718	SIDEROPHYRES	.00	.01	.01	.01	49.43
706	CARBONAC. CHRONDITES, TYPE	2.22	.04	1.66	.07	25.08
719	LODRANITES	2.70	.01	.13	.01	38.49
705	CARBONAC. CHONDRITES, TYPE	3.13	.04	1.45	.06	21.08
704	CARBONAC. CHONDRITES, TYPE	6.17	.06	1.08	.05	18.84
720	MESOSIDERITES	1.03	.01	2.07	.01	53.80
717	PALLASITES	.19	.02	.20	.01	54.50
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	.01	.01	18.30	.01	5.50
601	LSPET A 72	.01	.17	6.80	6.00	13.00
600	LSPET A 22	.01	.17	6.40	6.60	16.00
605	LSPET B 58	.01	.09	7.50	5.40	13.00
608	LSPET C 21	.01	.12	7.90	5.20	14.80
610	LSPET D 37	.01	.10	8.60	4.20	12.40
606	LSPET B 45	.01	.08	7.10	4.80	14.00
611	LSPET 54 (BULK SAMPLE)	.01	.11	8.30	4.20	12.10
612	10044 GABBRO	.01	.09	8.72	5.28	13.99
614	10084=28 REGOLITH (DUST)	.01	.13	8.44	4.49	12.13
615	10017 29	.01	.25	7.58	7.01	15.39
637	10047	.01	.09	8.72	6.11	14.76
638	10049	.01	.30	7.86	6.77	14.53
639	10050	.01	.04	8.08	7.55	13.44
640	10058 (WHOLE ROCK)	.01	.06	8.65	6.65	13.44
642	10019	.01	.12	8.51	4.94	12.20
643	10048	.01	.14	8.15	5.36	12.20
644	10060	.01	.15	8.29	5.48	13.21
645	311079	.01	.12	8.65	4.55	11.89
641	10062	.01	.06	8.58	6.17	14.22
604	LSPET B 17	.01	.18	7.10	6.60	14.70
609	LSPET C 61	.01	.15	7.90	5.40	12.40
613	10057 VESICULAR DIABASE	.01	.27	7.22	6.83	15.08
616	10020 30	.01	.04	8.01	6.41	15.08
617	10072	.01	.24	7.36	7.37	15.39
635	10022	.01	.25	7.65	7.31	14.69
636	10024	.01	.23	7.15	7.91	14.37
634	10003	.01	.04	7.86	7.19	15.38
603	LSPET A 20	.01	.05	7.10	7.20	14.00
607	LSPET B 50	.01	.05	7.10	5.40	15.50
602	LSPET A 57	.01	.15	7.10	7.50	15.50
	***** APOLLO 12 *****					
633	LSPET 12013	.01	1.66	4.50	.72	7.78
627	LSPET 12038,CRYS	.01	.05	7.86	1.92	13.22
631	LSPET 12010 BRECCIA	.01	.13	7.15	2.22	15.16
625	LSPET 12052,CRYS	.01	.06	7.86	2.16	16.32
623	LSPET 12009,CRYS	.01	.05	7.15	1.98	15.55

		S	K	Ca	Ti	Fe
629	LSPET 12070 FINES	.01	.15	7.15	1.86	13.22
630	LSPET 12073 BRECCIA	.01	.21	8.22	1.86	13.22
632	LSPET 12033 LIGHT FINES	.01	.32	8.22	1.56	12.44
624	LSPET 12065,CRYS	.01	.06	9.01	2.28	17.10
626	LSPET 12064,CRYS	.01	.07	8.58	2.94	17.10
628	LSPET CRYS ROCKS,AVE	.01	.05	7.65	2.22	16.56
620	LSPET 12004,CRYS	.01	.05	7.15	2.04	17.88
621	LSPET 12015,CRYS	.01	.05	7.01	1.92	17.10
619	LSPET 12012,CRYS	.01	.05	6.65	1.86	17.88
622	LSPET 12022,CRYS	.01	.06	7.86	3.05	17.10
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	.01	1.24	2.29	.48	7.00
300	J-87 JAVANITE TEKTITE	.01	1.24	2.72	.48	6.61
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	.01	3.84	1.35	.12	1.26
113	USGS STAND G-1	.01	4.63	.98	.16	1.32
121	P-17 BIOTITE QUARTZ MONZON	.01	3.45	1.35	.21	1.34
115	USGS STAND G-2	.01	3.74	1.43	.29	1.84
122	P-4 BIOTITE QUARTZ MONZON	.01	3.34	1.68	.35	2.73
116	USGS STAND GSP-1	.01	4.58	1.47	.40	2.97
123	P-19 BIOTITE GRANDIORITE	.01	1.63	3.22	.35	2.52
126	P-26 TONALITE (2)	.01	1.14	4.25	.43	4.06
117	USGS STAND AGV-1	.01	2.42	3.56	.63	4.70
125	P-25 TONALITE (1)	.01	1.36	5.06	.47	5.16
118	USGS STAND BCR-1	.01	1.41	5.00	1.33	9.38
114	USGS STAND W-1	.01	.53	7.79	.65	7.73
119	USGS STAND PCC-1	.01	.00	.39	.01	5.70
120	USGS STAND DTS-1	.01	.00	.02	.01	6.05
281	AVE OLIVINE	.00	.00	.00	.00	32.40
285	AVE PYROXENE	.00	.00	5.90	.00	16.40
286	AVE AMPHIBOLE (W/O HORNBLE	.00	.00	3.00	.00	18.00
287	AVE HORNBLENDE	.00	.00	8.30	.00	14.40
288	AVE BIOTITE	.00	8.90	.00	.00	19.20
274	MUSCOVITE (MICA)	.00	9.80	.00	.00	.00
278	ORTHOCLASE (FELDSPAR)	.00	14.00	.00	.00	.00
280	ANORTHITE (FELDSPAR)	.00	.00	14.40	.00	.00
279	ALBITE (FELDSPAR)	.00	.00	.00	.00	.00
		.26	1.30	4.21	1.38	10.09

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	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(3),NUMER	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
RATIO(4),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
RATIO(5),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		S	K	Ca	Ti	Fe
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	-26.33	-15.69	-1.96	-2.88	-1.07
107	CRUST	-10.13	1.61	-1.00	-2.42	-1.80
104	CRUST	-26.33	1.47	1.14	-1.92	-1.79
127	HCP AVE IGNEOUS	-26.33	1.99	-1.16	-2.20	-1.98
211	CONTINENTAL CRUST	-26.33	2.04	-1.13	-2.10	-1.94
212	OCEANIC CRUST	-26.33	-7.85	2.02	-1.54	-1.49
108	BASALTIC ACHONDRITE	-26.33	-19.61	1.87	-4.80	1.30
109	OCEANIC THOLEIITE BASALT	-26.33	-7.13	1.92	-1.68	-1.42
110	ALKALI OLIVINE BASALT	-26.33	1.20	1.54	1.27	-1.18
111	AVERAGE CHONDRITE	6.84	-6.51	-3.01	-13.81	2.48
112	AVERAGE ACHONDRITE	7.98	-130.24	-1.45	-138.11	3.07
101	BASALTIC ROCK (BASIC ROCK)	-26.33	-2.24	1.82	-1.28	-1.22
102	INTERMEDIATE ROCK	-26.33	2.04	1.10	-1.54	-1.59
103	GRANITIC ROCK	-26.33	2.42	-2.26	-4.61	-3.48
105	SHALE	-26.33	2.04	-1.90	-3.29	-2.13
128	HCP AVE SHALE	-26.33	2.06	-1.89	-3.55	-2.14
129	HCP AVE SANDSTONE	-26.33	-1.20	-1.07	-9.22	-10.28
131	HCP AVE SEDIMENT	-26.33	1.82	1.00	-4.05	-2.50
106	CHONDRITES	8.74	-14.47	-3.01	-16.25	2.49
135	COSMIC ABUNDANCE	41.40	-11.84	-2.38	-13.81	3.00
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	-26.33	3.44	-5.35	-11.53	-6.59
2	RHYOLITES	-26.33	3.00	-4.91	-7.69	-5.75
3	CALC ALKALI GRANITES	-26.33	3.44	-4.53	-5.76	-5.17
4	GRANITES	-26.33	2.61	-2.94	-5.76	-4.01
5	SILICIS IGNEOUS ROCKS	-26.33	2.42	-2.26	-4.61	-3.48
6	GRANDIORITES(1)	-26.33	1.98	-1.64	-3.84	-3.45
7	GRANDIORITES(2)	-26.33	1.78	-1.31	-3.84	-3.07
8	PLUTONIC IGNEOUS	-26.33	2.36	-1.37	-4.61	-2.96
9	CORD APP IGNEOUS	-26.33	1.72	-1.15	-3.29	-2.16
10	ANDESITES(1)	-26.33	1.34	1.00	-2.88	-2.11
11	AVE IGNEOUS	-26.33	2.04	-1.13	-2.10	-1.94
12	DIORITES	-26.33	1.40	1.16	-2.88	-1.76
13	INTERMEDIATE IGNEOUS	-26.33	2.04	1.12	-1.54	-1.59
14	ANDESITES(2)	-26.33	-1.43	1.36	-1.77	-1.50
15	PARENTAL CALC ALK MAGMAS	-26.33	-1.57	1.43	-2.56	-1.61

		S	K	Ca	Ti	Fe
16	DIORITES(2)	-26.33	-1.21	1.44	-1.54	-1.38
17	NORMAL THOLEITES	-26.33	-1.74	1.78	-1.15	-1.11
18	AVE THOLEITE	-26.33	-1.57	1.78	-1.65	-1.20
19	BASALTS	-26.33	-1.05	1.55	-1.65	-1.14
20	PLATEAU BASALTS	-26.33	-2.24	1.63	-1.05	1.03
21	MAFIC IGNEOUS	-26.33	-2.24	1.83	-1.28	-1.22
22	AVE OLIVINE BASALT PACIFIC	-26.33	-1.57	1.85	1.30	-1.14
23	NORMAL ALK BASALTS	-26.33	-1.57	1.83	1.13	-1.11
24	PERIDOTITE NODULES IN BASA	-26.33	-156.92	-2.35	-11.53	-1.60
25	ULTRAMAFIC IGNEOUS	-26.33	-2.24	1.73	-1.36	-1.01
26	PERIDOTITES	-26.33	-7.85	-1.68	-2.88	-1.07
27	DUNITES(DALY)	-26.33	-156.92	-8.41	-230.58	-1.56
28	DUNITES (NOCKOLDS)	-26.33	-15.69	-7.36	-11.53	1.05
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	-26.33	-15.69	-1.96	-230.58	-27.06
30	AVE QUARTZITE FINLAND	-26.33	1.15	-3.46	-230.58	-4.10
31	AVE SANDSTONE	-26.33	-1.21	-1.05	-7.69	-10.06
32	AVE SUBGRAYWACKE	-26.33	-1.05	-4.91	-3.84	-3.70
33	AVE DIATOM OOZE	-26.33	-15.69	1.22	-7.69	-6.24
34	AVE ARKOSE	-26.33	3.63	-3.68	-230.58	-5.98
35	AVE MISSISSIPPI SILT	-26.33	1.59	-2.56	-3.84	-3.89
36	AVE GRAYWACKE	-26.33	1.34	-1.64	-4.61	-2.50
37	AVE RADIOLARIAN OOZE	-26.33	1.08	-1.90	-3.84	-1.52
38	PALEZOIC SHALES	-26.33	2.42	-3.92	-2.88	-1.86
39	AVE BLUE MUD	-26.33	1.08	-2.26	-2.88	-1.74
40	AVE SHALE	-26.33	2.23	-1.78	-3.29	-2.01
41	GLACIAL CLAYS	-26.33	2.61	-1.84	-2.88	-1.97
42	AVE TERRIGENOUS MUD	-26.33	-1.43	-2.68	-1.65	-1.74
43	CLAYS AND SOILS	-26.33	1.47	-1.09	-4.61	-1.88
44	MESO AND CENOZOIC SHALES	-26.33	1.85	1.09	-4.61	-2.25
45	AVE RED CLAY	-26.33	1.27	1.02	-2.88	-1.11
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	-26.33	1.66	-5.35	-230.58	-3.85
49	LEPTITES AND HAELLEFLINTAS	-26.33	2.36	-3.68	-11.53	-4.54
50	QUARTZOFELDSPATHIC GNEISSE	-26.33	2.42	-2.68	-4.61	-3.78
51	PLUTONIC GNEISSES	-26.33	2.74	-3.10	-230.58	-3.42
52	AVE MICA SCHIST FINLAND	-26.33	2.42	-2.35	-7.69	-3.60
53	AVE PRECAMBRIAN FINLAND	-26.33	2.29	-1.73	-5.76	-2.97
54	MICA SCHISTS NORWAY	-26.33	2.42	-4.53	-230.58	-1.91
55	TWO-MICA GNEISSES	-26.33	2.23	-2.94	-230.58	-2.54
56	MICA SCHISTS (1)	-26.33	2.17	-4.53	-3.84	-2.50
57	KINZIGITES FINLAND	-26.33	2.04	-4.20	-3.84	-1.95
58	SLATES (1)	-26.33	2.10	-5.35	-2.56	-2.03
59	ROOFING SLATES	-26.33	2.49	-2.10	-230.58	-2.20
60	MICA SCHISTS (2)	-26.33	2.68	-3.68	-230.58	-2.23
61	MICA SCHISTS (3)	-26.33	2.36	-3.10	-2.31	-2.00
62	PHYLLITES NORWAY	-26.33	3.00	-14.72	-230.58	-1.85
63	AVE PRECAMBRIAN CANADA	-26.33	1.98	-1.44	-2.88	-2.52
64	SLATES AND PHYLLITES	-26.33	2.29	-4.20	-230.58	-1.62
65	SLATES (2)	-26.33	2.42	-5.89	-3.29	-1.55
66	PRECAMBRIAN SLATES	-26.33	2.61	-5.35	-2.88	-1.25
67	PHYLLITES	-26.33	2.55	-4.91	-2.10	-1.73
68	AMPHIBOLITES (1)	-26.33	-1.43	1.61	-1.44	-1.18
69	AMPHIBOLITES (2)	-26.33	-2.24	1.70	-230.58	-1.06
70	ECLOGITES	-26.33	-2.24	1.95	-230.58	-1.04
	***** METEORITES *****					
712	AUBRITES	1.73	-15.69	-6.47	-38.43	-2.63

		S	K	Ca	Ti	Fe
713	DIOGENITES	1.55	*******	-4.17	-12.14	1.39
710	SHERGOTTITE	-72.13	-8.72	1.77	-230.58	1.70
711	HOWARDITES	-1.20	-4.36	1.31	-23.06	1.40
716	NAKHLITES	-4.51	-11.21	2.57	-6.07	1.60
709	EUCRITES	-1.29	-26.15	1.73	-5.36	1.43
715	ANGRITES	1.75	-8.26	4.16	1.04	-1.35
708	AMPHOTERITES	5.56	-6.54	-3.50	-230.58	2.00
703	HYPERSTHENE CHONDRITES	8.40	-14.27	-3.07	-20.96	2.19
714	UREILITES	-72.13	-156.92	-7.45	-25.62	1.78
707	ENSTATITE CHONDRITES	14.83	-14.27	-6.07	-38.43	2.76
701	ORDINARY CHRONDITES	8.17	-15.69	-3.10	-20.96	2.45
721	MANTLE (AVE STONY METEORIT	8.04	-7.85	-2.94	-23.06	2.51
702	BRONZITE CHRONDITES	7.86	-15.69	-3.15	-20.96	2.77
718	SIDEROPHYRES	-72.13	-156.92	-588.67	-230.58	4.90
706	CARBONAC. CHRONDITES, TYPE	8.43	-31.38	-2.54	-19.21	2.48
719	LODRANITES	10.26	-156.92	-32.70	-230.58	3.81
705	CARBONAC. CHONDRITES, TYPE	11.90	-31.38	-2.90	-23.06	2.09
704	CARBONAC. CHONDRITES, TYPE	23.43	-22.42	-3.90	-28.82	1.87
720	MESOSIDERITES	3.92	-156.92	-2.04	-230.58	5.33
717	PALLASITES	-1.36	-52.31	-21.02	-230.58	5.40
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	-26.33	-130.24	4.35	-138.11	-1.84
601	LSPET A 72	-26.33	-7.66	1.62	4.34	1.29
600	LSPET A 22	-26.33	-7.66	1.52	4.78	1.58
605	LSPET B 58	-26.33	-14.47	1.78	3.91	1.29
608	LSPET C 21	-26.33	-10.85	1.88	3.76	1.47
610	LSPET D 37	-26.33	-13.02	2.04	3.04	1.23
606	LSPET B 45	-26.33	-15.50	1.69	3.48	1.39
611	LSPET 54 (BULK SAMPLE)	-26.33	-11.84	1.97	3.04	1.20
612	10044 GABBRO	-26.33	-14.27	2.07	3.82	1.39
614	10084=28 REGOLITH (DUST)	-26.33	-9.81	2.00	3.25	1.20
615	10017 29	-26.33	-5.23	1.80	5.07	1.52
637	10047	-26.33	-14.27	2.07	4.42	1.46
638	10049	-26.33	-4.36	1.87	4.90	1.44
639	10050	-26.33	-31.38	1.92	5.46	1.33
640	10058 (WHOLE ROCK)	-26.33	-22.42	2.06	4.81	1.33
642	10019	-26.33	-11.21	2.02	3.58	1.21
643	10048	-26.33	-9.23	1.94	3.88	1.21
644	10060	-26.33	-8.72	1.97	3.97	1.31
645	311079	-26.33	-11.21	2.06	3.30	1.18
641	10062	-26.33	-22.42	2.04	4.47	1.41
604	LSPET B 17	-26.33	-7.24	1.69	4.78	1.46
609	LSPET C 61	-26.33	-8.68	1.88	3.91	1.23
613	10057 VESICULAR DIABASE	-26.33	-4.90	1.72	4.94	1.49
616	10020 30	-26.33	-31.38	1.90	4.64	1.49
617	10072	-26.33	-5.41	1.75	5.33	1.52
635	10022	-26.33	-5.23	1.82	5.29	1.45
636	10024	-26.33	-5.60	1.70	5.72	1.42
634	10003	-26.33	-31.38	1.87	5.20	1.52
603	LSPET A 20	-26.33	-24.57	1.69	5.21	1.39
607	LSPET B 50	-26.33	-24.57	1.69	3.91	1.54
602	LSPET A 57	-26.33	-8.68	1.69	5.43	1.54
	***** APOLLO 12 *****					
633	LSPET 12013	-26.33	1.27	1.07	-1.92	-1.30
627	LSPET 12038, CRYS	-26.33	-27.53	1.87	1.39	1.31
631	LSPET 12010 BRECCIA	-26.33	-9.81	1.70	1.60	1.50
625	LSPET 12052, CRYS	-26.33	-22.74	1.87	1.56	1.62
623	LSPET 12009, CRYS	-26.33	-24.91	1.70	1.43	1.54

		S	K	Ca	Ti	Fe
629	LSPET 12070 FINES	-26.33	-8.72	1.70	1.34	1.31
630	LSPET 12073 BRECCIA	-26.33	-6.28	1.95	1.34	1.31
632	LSPET 12033 LIGHT FINES	-26.33	-4.02	1.95	1.13	1.23
624	LSPET 12065,CRYS	-26.33	-21.79	2.14	1.65	1.69
626	LSPET 12064,CRYS	-26.33	-18.68	2.04	2.13	1.69
628	LSPET CRYS ROCKS,AVE	-26.33	-24.14	1.82	1.60	1.64
620	LSPET 12004,CRYS	-26.33	-27.05	1.70	1.47	1.77
621	LSPET 12015,CRYS	-26.33	-25.31	1.66	1.39	1.69
619	LSPET 12012,CRYS	-26.33	-28.53	1.58	1.34	1.77
622	LSPET 12022,CRYS	-26.33	-23.08	1.87	2.21	1.69
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	-26.33	-1.05	-1.84	-2.88	-1.44
300	J-87 JAVANITE TEKTITE	-26.33	-1.05	-1.55	-2.88	-1.53
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	-26.33	2.95	-3.11	-11.53	-8.01
113	USGS STAND G-1	-26.33	3.56	-4.30	-8.54	-7.65
121	P-17 BIOTITE QUARTZ MONZON	-26.33	2.65	-3.11	-6.59	-7.55
115	USGS STAND G-2	-26.33	2.87	-2.94	-4.80	-5.47
122	P-4 BIOTITE QUARTZ MONZON	-26.33	2.56	-2.50	-3.98	-3.70
116	USGS STAND GSP-1	-26.33	3.52	-2.86	-3.49	-3.40
123	P-19 BIOTITE GRANDIORITE	-26.33	1.25	-1.31	-3.98	-4.00
126	P-26 TONALITE (2)	-26.33	-1.15	1.01	-3.20	-2.49
117	USGS STAND AGV-1	-26.33	1.86	-1.18	-2.20	-2.15
125	P-25 TONALITE (1)	-26.33	1.05	1.20	-2.96	-1.96
118	USGS STAND BCR-1	-26.33	1.08	1.19	-1.04	-1.08
114	USGS STAND W-1	-26.33	-2.45	1.85	-2.13	-1.31
119	USGS STAND PCC-1	-26.33	*******	-10.90	-230.58	-1.77
120	USGS STAND DTS-1	-26.33	*******	-196.22	-230.58	-1.67
281	AVE OLIVINE	-.00	-.00	-.00	-.00	3.21
285	AVE PYROXENE	-.00	-.00	1.40	-.00	1.62
286	AVE AMPHIBOLE (W/O HORNBLE	-.00	-.00	-1.40	-.00	1.78
287	AVE HORNBLENDE	-.00	-.00	1.97	-.00	1.43
288	AVE BIOTITE	-.00	6.83	-.00	-.00	1.90
274	MUSCOVITE (MICA)	-.00	7.52	-.00	-.00	-.00
278	ORTHOCLASE (FELDSPAR)	-.00	10.75	-.00	-.00	-.00
280	ANORTHITE (FELDSPAR)	-.00	-.00	3.42	-.00	-.00
279	ALBITE (FELDSPAR)	-.00	-.00	-.00	-.00	-.00
		.26	1.30	4.21	1.38	10.09

APPENDIX II

ELEMENT RATIOS IN VARIOUS ROCKS

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	10.	0.
RATIO(2),DENOM	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
RATIO(3),NUMER	0.	0.	0.	0.	0.	0.	10.	0.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
RATIO(4),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
RATIO(4),DENOM	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.
RATIO(5),DENOM	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.

		(1)	(2)	(3)	(4)	(5)
		$10\left(\frac{Na}{Ca}\right)$	$10\left(\frac{Ti}{Ca}\right)$	$10\left(\frac{K}{Ca}\right)$	$\frac{Fe}{Mg}$	$100\left(\frac{Ti}{Fe}\right)$
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	1.38	2.23	.39	.42	5.08
107	CRUST	5.71	1.36	5.00	2.87	10.18
104	CRUST	4.80	1.50	3.98	1.91	12.72
127	HCP AVE IGNEOUS	7.84	1.73	7.15	2.43	12.31
211	CONTINENTAL CRUST	7.78	1.77	7.14	2.40	12.67
212	OCEANIC CRUST	2.44	1.06	.20	1.54	13.29
108	BASALTIC ACHONDRITE	.47	.37	.08	2.77	2.19
109	OCEANIC THOLEIITE BASALT	2.56	1.02	.23	1.53	11.53
110	ALKALI OLIVINE BASALT	4.28	2.71	2.43	2.71	20.38
111	AVERAGE CHONDRITE	5.00	.71	1.43	1.72	.40
112	AVERAGE ACHONDRITE	.52	.03	.03	2.56	.03
101	BASALTIC ROCK (BASIC ROCK)	2.23	1.41	.76	1.59	13.06
102	INTERMEDIATE ROCK	6.71	1.93	5.71	2.77	14.15
103	GRANITIC ROCK	15.57	1.61	16.97	4.37	10.33
105	SHALE	4.35	1.89	11.98	3.28	8.84
128	HCP AVE SHALE	4.34	1.75	12.09	3.21	8.25
129	HCP AVE SANDSTONE	.85	.38	2.76	1.40	15.25
131	HCP AVE SEDIMENT	1.99	.81	5.64	2.53	8.44
106	CHONDRITES	4.86	.61	.64	1.74	.34
135	COSMIC ABUNDANCE	5.08	.56	.62	1.51	.33
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	28.30	1.52	56.99	8.47	7.82
2	RHYOLITES	29.40	2.09	45.47	7.28	10.23
3	CALC ALKALI GRANITES	24.75	2.58	48.22	6.47	12.28
4	GRANITES	18.16	1.68	23.80	4.64	9.51
5	SILICIS IGNEOUS ROCKS	15.57	1.61	16.97	4.37	10.33
6	GRANDIORITES(1)	11.24	1.40	10.00	3.04	12.27
7	GRANDIORITES(2)	8.53	1.12	7.22	2.87	10.93
8	PLUTONIC IGNEOUS	8.45	.97	9.99	2.26	8.78
9	CORD APP IGNEOUS	6.92	1.15	6.15	2.58	8.99
10	ANDESITES(1)	6.33	1.14	4.13	2.84	10.01
11	AVE IGNEOUS	7.78	1.77	7.14	2.46	12.67
12	DIORITES	5.19	.99	3.76	2.27	8.35
13	INTERMEDIATE IGNEOUS	6.60	1.90	5.63	2.77	14.15
14	ANDESITES(2)	4.80	1.36	1.60	2.53	11.58
15	PARENTAL CALC ALK MAGMAS	4.20	.90	1.38	1.89	8.62

		$10\left(\frac{Na}{Ca}\right)$	$10\left(\frac{Ti}{Ca}\right)$	$10\left(\frac{K}{Ca}\right)$	$\frac{Fe}{Mg}$	$100\left(\frac{Ti}{Fe}\right)$
16	DIORITES(2)	4.15	1.48	1.78	1.99	12.26
17	NORMAL THOLEITES	2.27	1.60	1.00	2.36	13.16
18	AVE THOLEITE	2.17	1.12	1.11	1.99	10.00
19	BASALTS	3.65	1.29	1.91	2.32	9.50
20	PLATEAU BASALTS	2.81	1.92	.85	2.53	12.72
21	MAFIC IGNEOUS	2.21	1.40	.75	1.57	13.06
22	AVE OLIVINE BASALT PACIFIC	2.57	2.31	1.06	1.86	20.23
23	NORMAL ALK BASALTS	2.59	2.02	1.07	1.60	17.16
24	PERIDOTITE NODULES IN BASA	.42	.67	.05	.25	1.90
25	ULTRAMAFIC IGNEOUS	.81	1.40	.80	.73	10.20
26	PERIDOTITES	1.78	1.91	.66	.46	5.08
27	DUNITES(DALY)	1.48	.12	.17	.22	.09
28	DUNITES (NOCKOLDS)	3.89	2.09	1.45	.40	1.13
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	.35	.03	.39	6.19	1.61
30	AVE QUARTZITE FINLAND	4.88	.05	12.29	5.84	.24
31	AVE SANDSTONE	.93	.45	2.69	1.39	17.91
32	AVE SUBGRAYWACKE	18.16	4.19	14.51	2.83	13.17
33	AVE DIATOM OOZE	.14	.35	.16	1.49	11.11
34	AVE ARKOSE	12.97	.05	41.35	27.99	.35
35	AVE MISSISSIPPI SILT	7.22	2.19	12.62	2.87	13.83
36	AVE GRAYWACKE	10.09	1.16	6.77	2.23	7.41
37	AVE RADIOLARIAN OOZE	3.35	1.62	6.37	3.35	5.40
38	PALEZOIC SHALES	7.61	4.47	29.41	3.59	8.84
39	AVE BLUE MUD	9.58	2.58	7.59	4.39	8.24
40	AVE SHALE	4.40	1.78	12.31	3.21	8.34
41	GLACIAL CLAYS	7.13	2.09	14.87	2.42	9.36
42	AVE TERRIGENOUS MUD	11.32	5.33	5.80	4.18	14.48
43	CLAYS AND SOILS	2.50	.78	4.94	2.70	5.57
44	MESO AND CENOZOIC SHALES	3.08	.65	5.26	2.57	6.68
45	AVE RED CLAY	2.42	1.12	3.87	7.55	5.26
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	17.92	.08	27.44	4.35	.23
49	LEPTITES AND HAELLEFLINTAS	20.76	1.05	26.84	3.69	5.39
50	QUARTZOFELDSPATHIC GNEISSE	15.09	1.90	20.05	3.70	11.20
51	PLUTONIC GNEISSES	19.12	.04	26.27	4.08	.20
52	AVE MICA SCHIST FINLAND	11.21	1.01	17.64	2.58	6.41
53	AVE PRECAMBRIAN FINLAND	9.46	.99	12.29	3.31	7.05
54	MICA SCHISTS NORWAY	10.38	.06	33.93	2.58	.11
55	TWO-MICA GNEISSES	16.09	.04	20.31	3.66	.15
56	MICA SCHISTS (1)	14.37	3.87	30.36	3.35	8.89
57	KINZIGITES FINLAND	18.53	3.59	26.53	2.96	6.93
58	SLATES (1)	25.47	6.85	34.83	2.67	10.82
59	ROOFING SLATES	4.82	.03	16.17	4.76	.13
60	MICA SCHISTS (2)	10.38	.05	30.47	2.78	.13
61	MICA SCHISTS (3)	10.38	4.41	22.61	3.10	11.88
62	PHYLLITES NORWAY	38.92	.21	136.40	4.11	.11
63	AVE PRECAMBRIAN CANADA	9.37	1.63	8.78	3.70	11.95
64	SLATES AND PHYLLITES	9.64	.06	29.85	3.56	.10
65	SLATES (2)	17.64	5.86	44.11	3.72	6.45
66	PRECAMBRIAN SLATES	12.26	6.09	43.27	4.96	5.93
67	PHYLLITES	17.30	7.68	38.69	3.33	11.30
68	AMPHIBOLITES (1)	3.17	1.41	1.34	2.03	11.17
69	AMPHIBOLITES (2)	3.01	.01	.81	2.28	.06
70	ECLOGITES	2.26	.01	.71	1.81	.06
	***** METEORITES *****					
712	AUBRITES	15.05	.55	1.28	.18	.94

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		$10\left(\frac{Na}{Ca}\right)$	$10\left(\frac{Ti}{Ca}\right)$	$10\left(\frac{K}{Ca}\right)$	$\frac{Fe}{Mg}$	$100\left(\frac{Ti}{Fe}\right)$
713	DIOGENITES	.03	1.13	.01	.90	.81
710	SHERGOTTITE	1.27	.01	.20	2.86	.03
711	HOWARDITES	1.43	.11	.54	1.98	.42
716	NAKHLITES	.28	.21	.11	2.24	1.41
709	EUCRITES	.44	.35	.07	2.83	1.78
715	ANGRITES	.11	.82	.09	1.24	19.15
708	AMPHOTERITES	6.42	.05	1.66	1.26	.03
703	HYPERSTHENE CHONDRITES	5.08	.48	.67	1.49	.30
714	UREILITES	5.65	.95	.15	.84	.30
707	ENSTATITE CHONDRITES	10.70	.52	1.32	2.20	.13
701	ORDINARY CHRONDITES	4.92	.49	.61	1.72	.27
721	MANTLE (AVE STONY METEORIT	5.19	.42	1.16	1.75	.24
702	BRONZITE CHRONDITES	5.16	.49	.62	2.01	.24
718	SIDEROPHYRES	10.38	8.38	11.61	8.12	.01
706	CARBONAC. CHRONDITES, TYPE	2.46	.43	.25	1.74	.29
719	LODRANITES	.58	.47	.64	2.74	.02
705	CARBONAC. CHONDRITES, TYPE	2.76	.41	.29	1.84	.28
704	CARBONAC. CHONDRITES, TYPE	5.22	.44	.54	2.00	.25
720	MESOSIDERITES	.61	.03	.04	14.03	.01
717	PALLASITES	2.59	.30	1.24	4.57	.01
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	.38	.01	.01	.79	.18
601	LSPET A 72	.65	8.82	.25	2.71	46.15
600	LSPET A 22	.47	10.31	.27	4.10	41.25
605	LSPET B 58	.55	7.20	.12	3.33	41.54
608	LSPET C 21	.19	6.58	.15	3.29	35.14
610	LSPET D 37	.47	4.88	.12	2.58	33.87
606	LSPET B 45	.54	6.76	.12	3.33	34.29
611	LSPET 54 (BULK SAMPLE)	.46	5.06	.13	2.63	34.71
612	10044 GABBRO	.41	6.05	.10	3.71	37.71
614	10084=28 REGOLITH (DUST)	.42	5.32	.16	2.53	37.04
615	10017 29	.50	9.25	.33	3.34	45.53
637	10047	.55	7.00	.10	4.01	41.39
638	10049	.67	8.61	.38	3.43	46.58
639	10050	.61	9.34	.05	2.78	56.15
640	10058 (WHOLE ROCK)	.68	7.69	.07	3.57	49.46
642	10019	.81	5.81	.14	2.57	40.51
643	10048	.47	6.58	.17	2.68	43.95
644	10060	.70	6.61	.18	2.91	41.49
645	311079	.46	5.26	.13	2.48	38.29
641	10062	.60	7.19	.07	3.27	43.39
604	LSPET B 17	.68	9.30	.25	2.88	44.90
609	LSPET C 61	.47	6.84	.19	2.30	43.55
613	10057 VESICULAR DIABASE	.55	9.46	.37	3.27	45.28
616	10020 30	.34	8.00	.05	3.20	42.50
617	10072	.52	10.00	.33	3.17	47.87
635	10022	.88	9.55	.33	3.15	49.76
636	10024	.83	11.06	.33	2.94	55.01
634	10003	.80	9.14	.05	3.54	46.72
603	LSPET A 20	.62	10.14	.07	2.92	51.43
607	LSPET B 50	.54	7.61	.07	2.58	34.84
602	LSPET A 57	.56	10.56	.21	2.72	48.39
	***** APOLLO 12 *****					
633	LSPET 12013	1.14	1.60	3.69	2.15	9.24
627	LSPET 12038,CRYS	.57	2.44	.06	3.37	14.50
631	LSPET 12010 BRECCIA	.55	3.10	.19	2.29	14.62
625	LSPET 12052,CRYS	.42	2.74	.07	2.71	13.21
623	LSPET 12009,CRYS	.53	2.76	.07	2.06	12.71

		$10\left(\frac{Na}{Ca}\right)$	$10\left(\frac{Ti}{Ca}\right)$	$10\left(\frac{K}{Ca}\right)$	$\frac{Fe}{Mg}$	$100\left(\frac{Ti}{Fe}\right)$
629	LSPET 12070 FINES	.42	2.60	.21	1.83	14.05
630	LSPET 12073 BRECCIA	.45	2.26	.25	1.99	14.05
632	LSPET 12033 LIGHT FINES	.49	1.89	.39	1.88	12.52
624	LSPET 12065,CRYS	.32	2.53	.07	3.15	13.31
626	LSPET 12064,CRYS	.36	3.42	.08	3.54	17.16
628	LSPET CRYS ROCKS,AVE	.44	2.90	.07	2.35	13.39
620	LSPET 12004,CRYS	.50	2.85	.07	1.98	11.39
621	LSPET 12015,CRYS	.39	2.74	.07	2.03	11.21
619	LSPET 12012,CRYS	.59	2.79	.07	1.69	10.39
622	LSPET 12022,CRYS	.34	3.88	.07	2.18	17.86
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	2.59	2.09	5.44	1.45	6.85
300	J-87 JAVANITE TEKTITE	1.91	1.76	4.58	1.61	7.25
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	17.41	.89	28.44	4.65	9.50
113	USGS STAND G-1	25.98	1.65	47.28	5.92	12.25
121	P-17 BIOTITE QUARTZ MONZON	21.47	1.55	25.55	4.44	15.67
115	USGS STAND G-2	21.53	2.01	26.18	3.97	15.59
122	P-4 BIOTITE QUARTZ MONZON	19.03	2.07	19.86	4.40	12.72
116	USGS STAND GSP-1	14.41	2.68	31.11	5.18	13.32
123	P-19 BIOTITE GRANDIORITE	9.80	1.08	5.06	3.37	13.78
126	P-26 TONALITE (2)	7.99	1.01	2.67	3.38	10.62
117	USGS STAND AGV-1	9.00	1.77	6.81	5.09	13.40
125	P-25 TONALITE (1)	4.62	.92	2.69	2.38	9.06
118	USGS STAND BCR-1	4.92	2.66	2.82	4.50	14.17
114	USGS STAND W-1	2.14	.83	.68	1.94	8.37
119	USGS STAND PCC-1	.12	.16	.02	.22	.11
120	USGS STAND DTS-1	2.08	2.79	.39	.20	.10
		5.59	2.57	7.89	2.90	13.36

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	0.	0.	0.	0.	0.	0.	0.	10.	0.	0.
RATIO(1),DENOM	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.
RATIO(2),DENOM	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
RATIO(3),NUMER	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
RATIO(3),DENOM	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
RATIO(4),NUMER	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.
RATIO(4),DENOM	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	0.	0.	0.	0.	0.	10.	0.	0.
RATIO(5),DENOM	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.

		(1)	(2)	(3)	(4)	(5)
		$10\left(\frac{Ca}{Mg}\right)$	$100\left(\frac{K}{Al}\right)$	$\frac{Al}{Fe}$	$\frac{Al}{Mg}$	$10\left(\frac{Ca}{Fe}\right)$
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	.96	7.84	.11	.05	2.27
107	CRUST	21.54	25.61	1.46	4.21	7.50
104	CRUST	16.21	24.06	1.40	2.69	8.48
127	HCP AVE IGNEOUS	17.26	32.10	1.58	3.85	7.11
211	CONTINENTAL CRUST	17.13	32.18	1.59	3.80	7.15
212	OCEANIC CRUST	19.33	1.81	1.35	2.08	12.58
108	BASALTIC ACHONDRITE	16.57	.97	.52	1.45	5.99
109	OCEANIC THOLEIITE BASALT	17.38	2.13	1.20	1.84	11.35
110	ALKALI OLIVINE BASALT	20.38	18.53	.99	2.67	7.53
111	AVERAGE CHONDRITE	.97	18.18	.04	.08	.56
112	AVERAGE ACHONDRITE	2.40	.48	.07	.17	.94
101	BASALTIC ROCK (BASIC ROCK)	14.75	7.09	.99	1.58	9.27
102	INTERMEDIATE ROCK	20.28	30.61	1.37	3.79	7.32
103	GRANITIC ROCK	28.03	41.12	2.65	11.56	6.41
105	SHALE	15.32	32.60	1.72	5.63	4.67
128	HCP AVE SHALE	15.11	33.01	1.73	5.54	4.71
129	HCP AVE SANDSTONE	56.22	43.09	2.57	3.61	40.04
131	HCP AVE SEDIMENT	26.35	33.49	1.75	4.44	10.41
106	CHONDRITES	.97	6.92	.05	.09	.56
135	COSMIC ABUNDANCE	.88	4.76	.08	.12	.58
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	43.48	62.30	4.70	39.77	5.14
2	RHYOLITES	35.57	54.62	4.06	29.61	4.88
3	CALC ALKALI GRANITES	30.83	60.95	3.77	24.39	4.76
4	GRANITES	26.35	44.06	3.07	14.23	5.68
5	SILICIS IGNEOUS ROCKS	28.03	40.56	2.68	11.72	6.41
6	GRANDIORITES(1)	26.68	30.78	2.85	8.66	8.78
7	GRANDIORITES(2)	28.08	27.29	2.59	7.43	9.79
8	PLUTONIC IGNEOUS	20.39	37.21	2.42	5.47	9.01
9	CORD APP IGNEOUS	20.16	26.64	1.80	4.65	7.82
10	ANDESITES(1)	24.99	18.83	1.93	5.48	8.81
11	AVE IGNEOUS	17.62	32.18	1.59	3.91	7.15
12	DIORITES	19.20	20.42	1.56	3.53	8.48
13	INTERMEDIATE IGNEOUS	20.59	30.06	1.39	3.86	7.43
14	ANDESITES(2)	21.56	9.92	1.37	3.47	8.51
15	PARENTAL CALC ALK MAGMAS	18.11	8.67	1.53	2.89	9.60

AUG 14 1970

		$10\left(\frac{Ca}{Mg}\right)$	$100\left(\frac{K}{Al}\right)$	$\frac{Al}{Fe}$	$\frac{Al}{Mg}$	$10\left(\frac{Ca}{Fe}\right)$
16	DIORITES(2)	16.52	12.36	1.19	2.37	8.29
17	NORMAL THOLEITES	19.45	9.94	.83	1.95	8.25
18	AVE THOLEITE	17.79	10.06	.98	1.96	8.95
19	BASALTS	17.13	14.71	.96	2.23	7.37
20	PLATEAU BASALTS	16.74	7.73	.73	1.83	6.63
21	MAFIC IGNEOUS	14.72	7.00	1.01	1.58	9.36
22	AVE OLIVINE BASALT PACIFIC	16.36	10.39	.90	1.68	8.77
23	NORMAL ALK BASALTS	13.62	10.60	.86	1.38	8.51
24	PERIDOTITE NODULES IN BASA	.72	.54	.24	.06	2.83
25	ULTRAMAFIC IGNEOUS	5.33	18.00	.32	.24	7.30
26	PERIDOTITES	1.21	7.84	.22	.10	2.65
27	DUNITES(DALY)	.17	1.74	.07	.02	.77
28	DUNITES (NOCKOLDS)	.22	19.61	.04	.02	.54
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	355.72	11.21	1.98	12.28	57.49
30	AVE QUARTZITE FINLAND	28.80	44.13	1.37	8.02	4.93
31	AVE SANDSTONE	55.33	42.49	2.53	3.51	39.92
32	AVE SUBGRAYWACKE	8.89	24.52	1.86	5.26	3.15
33	AVE DIATOM OOZE	47.43	3.08	1.67	2.49	31.82
34	AVE ARKOSE	189.72	77.77	3.60	100.89	6.78
35	AVE MISSISSIPPI SILT	18.18	34.71	2.30	6.61	6.33
36	AVE GRAYWACKE	14.23	22.88	1.89	4.21	6.37
37	AVE RADIOLARIAN OOZE	11.14	19.47	1.09	3.64	3.33
38	PALEZOIC SHALES	7.11	34.07	1.71	6.14	1.98
39	AVE BLUE MUD	14.01	16.46	1.47	6.46	3.20
40	AVE SHALE	15.05	33.28	1.74	5.57	4.69
41	GLACIAL CLAYS	10.84	38.75	1.72	4.16	4.47
42	AVE TERRIGENOUS MUD	11.34	9.28	1.70	7.09	2.72
43	CLAYS AND SOILS	19.40	22.70	1.56	4.23	7.17
44	MESO AND CENOZOIC SHALES	26.17	30.74	1.75	4.48	10.20
45	AVE RED CLAY	35.57	18.57	.98	7.41	4.71
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	13.04	42.49	1.94	8.42	3.00
49	LEPTITES AND HAELLEFLINTAS	18.97	43.65	3.16	11.67	5.15
50	QUARTZOFELDSPATHIC GNEISSE	21.74	41.12	2.87	10.60	5.88
51	PLUTONIC GNEISSES	18.77	45.59	2.65	10.82	4.60
52	AVE MICA SCHIST FINLAND	16.47	36.13	3.11	8.04	6.37
53	AVE PRECAMBRIAN FINLAND	23.71	38.16	2.31	7.64	7.16
54	MICA SCHISTS NORWAY	4.53	38.97	1.53	3.95	1.76
55	TWO-MICA GNEISSES	13.17	33.08	2.21	8.09	3.60
56	MICA SCHISTS (1)	7.71	29.80	2.34	7.85	2.30
57	KINZIGITES FINLAND	5.72	31.58	1.62	4.81	1.93
58	SLATES (1)	4.21	29.93	1.84	4.90	1.58
59	ROOFING SLATES	20.75	31.71	2.22	10.58	4.36
60	MICA SCHISTS (2)	7.03	34.32	2.24	6.24	2.52
61	MICA SCHISTS (3)	8.34	33.17	1.84	5.69	2.69
62	PHYLLITES NORWAY	2.16	36.51	1.96	8.06	.53
63	AVE PRECAMBRIAN CANADA	27.01	28.61	2.24	8.29	7.31
64	SLATES AND PHYLLITES	5.72	27.55	1.74	6.20	1.61
65	SLATES (2)	4.09	31.22	1.55	5.78	1.10
66	PRECAMBRIAN SLATES	4.83	34.77	1.21	6.01	.97
67	PHYLLITES	4.91	30.32	1.88	6.26	1.47
68	AMPHIBOLITES (1)	16.09	10.99	.97	1.97	7.92
69	AMPHIBOLITES (2)	17.18	6.62	.92	2.11	7.52
70	ECLOGITES	15.32	7.57	.79	1.43	8.45
	***** METEORITES *****					
712	AUBRITES	.30	23.42	.09	.02	1.70

		$10\left(\frac{Ca}{Mg}\right)$	$100\left(\frac{K}{Al}\right)$	$\frac{Al}{Fe}$	$\frac{Al}{Mg}$	$10\left(\frac{Ca}{Fe}\right)$
713	DIOGENITES	.65	.13	.04	.04	.72
710	SHERGOTTITE	12.39	4.81	.18	.52	4.33
711	HOWARDITES	7.75	5.68	.37	.74	3.91
716	NAKHLITES	14.92	12.70	.06	.13	6.67
709	EUCRITES	14.30	.72	.48	1.35	5.05
715	ANGRITES	29.05	3.42	.62	.76	23.43
708	AMPHOTERITES	.75	20.80	.05	.06	.59
703	HYPERSTHENE CHONDRITES	.93	6.14	.07	.10	.62
714	UREILITES	.26	4.13	.01	.01	.31
707	ENSTATITE CHONDRITES	.55	9.23	.04	.08	.25
701	ORDINARY CHRONDITES	.94	5.77	.06	.10	.55
721	MANTLE (AVE STONY METEORIT	.99	12.55	.05	.09	.57
702	BRONZITE CHRONDITES	.96	6.03	.05	.10	.48
718	SIDEROPHYRES	.01	156.90	.00	.00	.00
706	CARBONAC. CHRONDITES, TYPE	1.15	2.96	.06	.10	.66
719	LODRANITES	.09	8.26	.00	.01	.03
705	CARBONAC. CHONDRITES, TYPE	1.27	3.40	.06	.11	.69
704	CARBONAC. CHONDRITES, TYPE	1.15	6.21	.05	.10	.57
720	MESOSIDERITES	5.39	.38	.04	.57	.38
717	PALLASITES	.17	12.39	.00	.02	.04
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	26.14	.04	4.05	3.19	33.27
601	LSPET A 72	14.17	3.54	.37	1.00	5.23
600	LSPET A 22	16.41	4.15	.26	1.05	4.00
605	LSPET B 58	19.23	1.30	.53	1.77	5.77
608	LSPET C 21	17.56	2.07	.39	1.29	5.34
610	LSPET D 37	17.92	1.45	.56	1.44	6.94
606	LSPET B 45	16.90	1.22	.49	1.64	5.07
611	LSPET 54 (BULK SAMPLE)	18.04	1.59	.57	1.50	6.86
612	10044 GABBRO	23.15	1.48	.44	1.64	6.23
614	10084=28 REGOLITH (DUST)	17.60	1.76	.62	1.58	6.96
615	10017 29	16.43	5.80	.28	.93	4.92
637	10047	23.71	1.76	.35	1.41	5.91
638	10049	18.55	5.95	.35	1.19	5.41
639	10050	16.69	.88	.35	.97	6.01
640	10058 (WHOLE ROCK)	22.96	1.03	.42	1.50	6.44
642	10019	17.95	1.60	.59	1.53	6.97
643	10048	17.93	2.07	.56	1.50	6.68
644	10060	18.29	2.39	.47	1.38	6.28
645	311079	18.07	1.56	.63	1.56	7.28
641	10062	19.73	.91	.45	1.47	6.03
604	LSPET B 17	13.92	3.40	.36	1.04	4.83
609	LSPET C 61	14.63	2.59	.47	1.07	6.37
613	10057 VESICULAR DIABASE	15.65	4.65	.38	1.24	4.79
616	10020 30	17.00	.78	.35	1.12	5.31
617	10072	15.15	5.85	.27	.85	4.78
635	10022	16.39	5.47	.31	.97	5.21
636	10024	14.62	4.62	.35	1.03	4.97
634	10003	18.12	.71	.38	1.34	5.11
603	LSPET A 20	14.79	.91	.41	1.21	5.07
607	LSPET B 50	11.83	.91	.37	.97	4.58
602	LSPET A 57	12.46	2.59	.37	1.02	4.58
	***** APOLLO 12 *****					
633	LSPET 12013	12.45	26.15	.82	1.75	5.79
627	LSPET 12038, CRYS	20.07	.75	.48	1.62	5.95
631	LSPET 12010 BRECCIA	10.78	2.18	.40	.92	4.72
625	LSPET 12052, CRYS	13.04	.98	.36	.97	4.82
623	LSPET 12009, CRYS	9.49	.90	.37	.77	4.60

		$10\left(\frac{Ca}{Mg}\right)$	$100\left(\frac{K}{Al}\right)$	$\frac{Al}{Fe}$	$\frac{Al}{Mg}$	$10\left(\frac{Ca}{Fe}\right)$
629	LSPET 12070 FINES	9.88	2.02	.56	1.02	5.41
630	LSPET 12073 BRECCIA	12.40	2.61	.60	1.20	6.22
632	LSPET 12033 LIGHT FINES	12.40	3.82	.68	1.28	6.61
624	LSPET 12065,CRYS	16.60	.94	.37	1.17	5.27
626	LSPET 12064,CRYS	17.79	1.10	.37	1.32	5.02
628	LSPET CRYS ROCKS,AVE	10.84	.91	.36	.84	4.62
620	LSPET 12004,CRYS	7.90	.87	.31	.61	4.00
621	LSPET 12015,CRYS	8.30	.88	.34	.69	4.10
619	LSPET 12012,CRYS	6.30	.78	.33	.55	3.72
622	LSPET 12022,CRYS	10.03	.97	.34	.74	4.60
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	4.74	19.29	.92	1.34	3.27
300	J-87 JAVANITE TEKTITE	6.63	18.68	1.01	1.63	4.11
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	49.80	53.42	5.71	26.51	10.72
113	USGS STAND G-1	43.90	62.09	5.65	33.43	7.42
121	P-17 BIOTITE QUARTZ MONZON	44.82	44.71	5.77	25.62	10.10
115	USGS STAND G-2	30.80	46.25	4.39	17.43	7.75
122	P-4 BIOTITE QUARTZ MONZON	27.05	40.69	3.00	13.20	6.15
116	USGS STAND GSP-1	25.71	58.13	2.66	13.76	4.96
123	P-19 BIOTITE GRANDIORITE	43.03	17.98	3.59	12.10	12.76
126	P-26 TONALITE (2)	35.45	11.31	2.48	8.38	10.48
117	USGS STAND AGV-1	38.59	27.11	1.90	9.69	7.58
125	P-25 TONALITE (1)	23.32	14.62	1.80	4.29	9.81
118	USGS STAND BCR-1	23.99	19.91	.76	3.40	5.33
114	USGS STAND W-1	19.52	6.74	1.02	1.97	10.09
119	USGS STAND PCC-1	.15	.22	.07	.01	.68
120	USGS STAND DTS-1	.01	.52	.03	.01	.04
		17.95	17.27	1.18	4.59	5.99

AUG 14 1970

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(3),NUMER	100.	0.	0.	0.	0.	0.	100.	0.	0.	0.
RATIO(3),DENOM	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
RATIO(4),DENOM	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(5),NUMER	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
RATIO(5),DENOM	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		$100\left(\frac{Na}{Si}\right)$	$100\left(\frac{K}{Si}\right)$	(1)+(2)	$100\left(\frac{Ca}{Si}\right)$	$100\left(\frac{Al}{Si}\right)$
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	1.46	.41	1.87	10.54	5.20
107	CRUST	8.51	7.45	15.96	14.89	29.08
104	CRUST	8.37	6.95	15.32	17.44	28.88
127	HCP AVE IGNEOUS	10.30	9.39	19.69	13.13	29.26
211	CONTINENTAL CRUST	10.29	9.44	19.73	13.22	29.34
212	OCEANIC CRUST	8.90	.71	9.61	36.43	39.19
108	BASALTIC ACHONDRITE	1.63	.29	1.93	34.65	30.30
109	OCEANIC THOLEIITE BASALT	8.85	.78	9.63	34.53	36.62
110	ALKALI OLIVINE BASALT	12.32	6.98	19.30	28.77	37.68
111	AVERAGE CHONDRITE	3.91	1.12	5.03	7.82	6.15
112	AVERAGE ACHONDRITE	.79	.05	.85	15.34	11.11
101	BASALTIC ROCK (BASIC ROCK)	7.52	2.56	10.08	33.71	36.12
102	INTERMEDIATE ROCK	12.22	10.41	22.63	18.22	34.01
103	GRANITIC ROCK	8.95	9.75	18.70	5.75	23.72
105	SHALE	3.55	9.77	13.32	8.15	29.96
128	HCP AVE SHALE	3.55	9.89	13.44	8.18	29.96
129	HCP AVE SANDSTONE	.91	2.97	3.88	10.73	6.89
131	HCP AVE SEDIMENT	3.09	8.76	11.85	15.54	26.16
106	CHONDRITES	3.82	.51	4.33	7.87	7.30
135	COSMIC ABUNDANCE	3.54	.43	3.98	6.97	9.09
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	6.41	12.91	19.32	2.26	20.72
2	RHYOLITES	7.29	11.28	18.57	2.48	20.65
3	CALC ALKALI GRANITES	6.78	13.21	19.99	2.74	21.67
4	GRANITES	7.84	10.27	18.11	4.32	23.31
5	SILICIS IGNEOUS ROCKS	8.94	9.74	18.67	5.74	24.01
6	GRANDIORITES(1)	9.20	8.18	17.38	8.18	26.58
7	GRANDIORITES(2)	8.93	7.56	16.49	10.46	27.70
8	PLUTONIC IGNEOUS	8.52	10.08	18.60	10.09	27.09
9	CORD APP IGNEOUS	8.64	7.67	16.31	12.49	28.80
10	ANDESITES(1)	9.47	6.18	15.64	14.95	32.80
11	AVE IGNEOUS	10.29	9.44	19.73	13.22	29.34
12	DIORITES	9.36	6.77	16.13	18.04	33.16
13	INTERMEDIATE IGNEOUS	12.13	10.34	22.47	18.37	34.38
14	ANDESITES(2)	10.74	3.57	14.32	22.39	36.02
15	PARENTAL CALC ALK MAGMAS	9.96	3.28	13.24	23.72	37.82

AUG 12 1970

		$100\left(\frac{Na}{Si}\right)$	$100\left(\frac{K}{Si}\right)$	(1)+(2)	$100\left(\frac{Ca}{Si}\right)$	$100\left(\frac{Al}{Si}\right)$
16	DIORITES(2)	10.29	4.40	14.69	24.78	35.59
17	NORMAL THOLEITES	7.11	3.11	10.22	31.27	31.29
18	AVE THOLEITE	6.84	3.48	10.32	31.45	34.58
19	BASALTS	10.17	5.33	15.50	27.86	36.24
20	PLATEAU BASALTS	8.29	2.50	10.79	29.51	32.30
21	MAFIC IGNEOUS	7.50	2.55	10.06	33.95	36.52
22	AVE OLIVINE BASALT PACIFIC	9.11	3.77	12.88	35.43	36.32
23	NORMAL ALK BASALTS	9.29	3.85	13.13	35.79	36.29
24	PERIDOTITE NODULES IN BASA	.36	.04	.40	8.56	7.35
25	ULTRAMAFIC IGNEOUS	2.88	2.82	5.70	35.42	15.67
26	PERIDOTITES	2.17	.81	2.97	12.18	10.30
27	DUNITES(DALY)	.38	.04	.42	2.56	2.44
28	DUNITES (NOCKOLDS)	1.18	.44	1.62	3.03	2.24
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	.17	.19	.36	4.95	1.71
30	AVE QUARTZITE FINLAND	1.52	3.82	5.34	3.11	8.66
31	AVE SANDSTONE	.99	2.89	3.89	10.73	6.81
32	AVE SUBGRAYWACKE	4.22	3.37	7.59	2.32	13.75
33	AVE DIATOM OOZE	.20	.23	.43	14.18	7.43
34	AVE ARKOSE	4.17	13.28	17.45	3.21	17.08
35	AVE MISSISSIPPI SILT	3.40	5.94	9.33	4.70	17.10
36	AVE GRAYWACKE	8.43	5.66	14.09	8.36	24.74
37	AVE RADIOLARIAN OOZE	2.49	4.73	7.21	7.42	24.27
38	PALEZOIC SHALES	2.74	10.58	13.32	3.60	31.05
39	AVE BLUE MUD	6.01	4.76	10.77	6.28	28.93
40	AVE SHALE	3.57	9.98	13.55	8.11	29.98
41	GLACIAL CLAYS	5.62	11.71	17.33	7.87	30.22
42	AVE TERRIGENOUS MUD	6.19	3.17	9.36	5.47	34.19
43	CLAYS AND SOILS	3.46	6.84	10.30	13.84	30.16
44	MESO AND CENOZOIC SHALES	5.08	8.67	13.75	16.49	28.21
45	AVE RED CLAY	4.15	6.63	10.78	17.13	35.71
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	3.76	5.75	9.51	2.10	13.53
49	LEPTITES AND HAELLEFLINTAS	6.87	8.89	15.77	3.31	20.37
50	QUARTZOFELDSPATHIC GNEISSE	7.18	9.53	16.71	4.75	23.18
51	PLUTONIC GNEISSES	7.89	10.85	18.74	4.13	23.80
52	AVE MICA SCHIST FINLAND	6.24	9.82	16.06	5.57	27.19
53	AVE PRECAMBRIAN FINLAND	7.19	9.33	16.52	7.59	24.46
54	MICA SCHISTS NORWAY	3.03	9.90	12.92	2.92	25.40
55	TWO-MICA GNEISSES	7.26	9.17	16.43	4.51	27.72
56	MICA SCHISTS (1)	4.23	8.93	13.16	2.94	29.97
57	KINZIGITES FINLAND	5.97	8.55	14.52	3.22	27.07
58	SLATES (1)	6.60	9.02	15.61	2.59	30.13
59	ROOFING SLATES	3.18	10.67	13.85	6.60	33.67
60	MICA SCHISTS (2)	3.93	11.53	15.46	3.78	33.60
61	MICA SCHISTS (3)	4.68	10.21	14.89	4.51	30.76
62	PHYLLITES NORWAY	3.72	13.02	16.74	.95	35.68
63	AVE PRECAMBRIAN CANADA	9.18	8.60	17.78	9.80	30.07
64	SLATES AND PHYLLITES	3.33	10.31	13.64	3.46	37.43
65	SLATES (2)	4.36	10.91	15.27	2.47	34.93
66	PRECAMBRIAN SLATES	3.41	12.04	15.45	2.78	34.62
67	PHYLLITES	5.28	11.82	17.11	3.06	39.00
68	AMPHIBOLITES (1)	9.14	3.88	13.02	28.85	35.28
69	AMPHIBOLITES (2)	9.14	2.47	11.61	30.37	37.30
70	ECLOGITES	8.09	2.53	10.62	35.86	33.45
	***** METEORITES *****					
712	AUBRITES	3.88	.33	4.20	2.57	1.40

		$100\left(\frac{Na}{Si}\right)$	$100\left(\frac{K}{Si}\right)$	(1)+(2)	$100\left(\frac{Ca}{Si}\right)$	$100\left(\frac{Al}{Si}\right)$
713	DIOGENITES	.01	.00	.02	4.13	2.56
710	SHERGOTTITE	4.03	.64	4.67	31.78	13.27
711	HOWARDITES	3.41	1.30	4.70	23.89	22.81
716	NAKHLITES	1.33	.51	1.84	47.27	4.01
709	EUCRITES	1.43	.22	1.66	32.74	30.87
715	ANGRITES	.94	.77	1.71	85.26	22.45
708	AMPHOTERITES	4.04	1.04	5.08	6.29	5.01
703	HYPERSTHENE CHONDRITES	3.75	.49	4.25	7.39	8.00
714	UREILITES	1.75	.05	1.80	3.10	1.10
707	ENSTATITE CHONDRITES	4.11	.51	4.61	3.84	5.48
701	ORDINARY CHRONDITES	3.73	.46	4.19	7.58	8.03
721	MANTLE (AVE STONY METEORIT	4.14	.93	5.07	7.98	7.38
702	BRONZITE CHRONDITES	4.05	.49	4.54	7.85	8.07
718	SIDEROPHYRES	.05	.05	.10	.04	.03
706	CARBONAC. CHRONDITES, TYPE	2.58	.26	2.84	10.49	8.86
719	LODRANITES	.05	.06	.12	.95	.74
705	CARBONAC. CHONDRITES, TYPE	3.14	.32	3.46	11.36	9.56
704	CARBONAC. CHONDRITES, TYPE	5.22	.54	5.75	9.99	8.66
720	MESOSIDERITES	1.38	.09	1.47	22.64	23.77
717	PALLASITES	.65	.31	.96	2.50	2.51
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	1.52	.02	1.54	39.70	48.37
601	LSPET A 72	2.10	.81	2.90	32.38	22.86
600	LSPET A 22	1.50	.85	2.35	32.00	20.50
605	LSPET B 58	2.05	.45	2.50	37.50	34.50
608	LSPET C 21	.75	.60	1.35	39.50	29.00
610	LSPET D 37	2.00	.50	2.50	43.00	34.50
606	LSPET B 45	1.94	.43	2.37	36.22	35.20
611	LSPET 54 (BULK SAMPLE)	1.94	.56	2.50	42.35	35.20
612	10044 GABBRO	1.81	.46	2.28	44.38	31.49
614	10084=28 REGOLITH (DUST)	1.83	.68	2.52	43.44	38.95
615	10017 29	1.98	1.30	3.29	39.69	22.50
637	10047	2.50	.47	2.97	45.13	26.82
638	10049	2.75	1.56	4.30	40.99	26.19
639	10050	2.56	.22	2.78	42.21	24.60
640	10058 (WHOLE ROCK)	3.03	.30	3.33	44.65	29.21
642	10019	3.59	.60	4.19	44.23	37.68
643	10048	1.95	.71	2.67	41.27	34.55
644	10060	2.98	.77	3.75	42.70	32.14
645	311079	2.03	.59	2.62	43.81	37.77
641	10062	2.82	.32	3.14	47.25	35.25
604	LSPET B 17	2.57	.96	3.53	37.97	28.34
609	LSPET C 61	1.98	.80	2.78	42.25	31.02
613	10057 VESICULAR DIABASE	2.15	1.43	3.58	38.77	30.67
616	10020 30	1.47	.22	1.69	42.88	28.33
617	10072	2.05	1.28	3.33	39.14	21.88
635	10022	3.60	1.33	4.92	40.77	24.24
636	10024	3.25	1.27	4.53	39.17	27.53
634	10003	3.57	.23	3.80	44.46	32.89
603	LSPET A 20	2.47	.30	2.77	39.89	32.58
607	LSPET B 50	2.13	.30	2.43	39.89	32.58
602	LSPET A 57	2.38	.89	3.27	42.26	34.52
	***** APOLLO 12 *****					
633	LSPET 12013	1.79	5.81	7.61	15.78	22.24
627	LSPET 12038,CRYS	1.94	.21	2.15	34.30	27.68
631	LSPET 12010 BRECCIA	1.95	.66	2.61	35.53	30.23
625	LSPET 12052,CRYS	1.70	.29	1.99	40.01	29.60
623	LSPET 12009,CRYS	1.97	.27	2.24	37.26	30.33

AUG 12 1970

		$100\left(\frac{Na}{Si}\right)$	$100\left(\frac{K}{Si}\right)$	(1)+(2)	$100\left(\frac{Ca}{Si}\right)$	$100\left(\frac{Al}{Si}\right)$
629	LSPET 12070 FINES	1.51	.76	2.27	36.38	37.68
630	LSPET 12073 BRECCIA	1.93	1.08	3.01	42.85	41.35
632	LSPET 12033 LIGHT FINES	2.09	1.69	3.78	42.85	44.11
624	LSPET 12065,CRYS	1.59	.33	1.91	49.36	34.78
626	LSPET 12064,CRYS	1.66	.37	2.04	45.83	33.91
628	LSPET CRYS ROCKS,AVE	1.78	.29	2.07	40.87	31.65
620	LSPET 12004,CRYS	2.06	.28	2.33	41.29	32.08
621	LSPET 12015,CRYS	1.54	.29	1.83	39.40	32.72
619	LSPET 12012,CRYS	2.40	.28	2.68	40.60	35.53
622	LSPET 12022,CRYS	1.59	.33	1.92	46.68	34.54
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	1.98	4.15	6.13	7.63	21.51
300	J-87 JAVANITE TEKTITE	1.75	4.19	5.94	9.14	22.43
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	6.80	11.11	17.91	3.91	20.80
113	USGS STAND G-1	7.50	13.65	21.15	2.89	21.98
121	P-17 BIOTITE QUARTZ MONZON	8.61	10.25	18.86	4.01	22.92
115	USGS STAND G-2	9.49	11.54	21.04	4.41	24.96
122	P-4 BIOTITE QUARTZ MONZON	10.12	10.56	20.69	5.32	25.96
116	USGS STAND GSP-1	6.74	14.55	21.28	4.68	25.03
123	P-19 BIOTITE GRANDIORITE	10.24	5.28	15.52	10.45	29.38
126	P-26 TONALITE (2)	12.10	4.05	16.15	15.15	35.79
117	USGS STAND AGV-1	11.59	8.76	20.35	12.87	32.32
125	P-25 TONALITE (1)	8.58	5.00	13.58	18.59	34.18
118	USGS STAND BCR-1	9.71	5.56	15.27	19.73	27.95
114	USGS STAND W-1	6.78	2.16	8.94	31.66	32.02
119	USGS STAND PCC-1	.02	.00	.03	1.97	1.95
120	USGS STAND DTS-1	.02	.00	.03	.11	.84
		4.41	4.04	8.44	19.32	24.00

	NA	MG	AL	SI	P	S	K	CA	TI	FE
RATIO(1),NUMER	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.
RATIO(1),DENOM	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.
RATIO(2),NUMER	0.	0.	0.	0.	0.	0.	10.	0.	0.	0.
RATIO(2),DENOM	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.
RATIO(3),NUMER	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.
RATIO(3),DENOM	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(4),NUMER	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.
RATIO(4),DENOM	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
RATIO(5),NUMER	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RATIO(5),DENOM	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.

		(1)	(2)	(3)	(4)	(5)
		Si	$10\left(\frac{K}{Ti}\right)$	$100\left(\frac{K}{Mg}\right)$	$100\left(\frac{K}{Fe}\right)$	$10\left(\frac{Na}{K}\right)$
	***** GENERAL *****					
100	PERIDOTITE(ULTRA-BASIC ROC	20.36	1.73	.37	.88	35.76
107	CRUST	28.20	36.84	107.69	37.50	11.43
104	CRUST	27.47	26.56	64.61	33.79	12.05
127	HCP AVE IGNEOUS	27.66	41.31	123.45	50.85	10.97
211	CONTINENTAL CRUST	28.13	40.31	122.35	51.07	10.90
212	OCEANIC CRUST	23.35	1.85	3.77	2.46	125.16
108	BASALTIC ACHONDRITE	22.70	2.31	1.40	.51	55.87
109	OCEANIC THOLEIITE BASALT	23.40	2.23	3.93	2.57	113.37
110	ALKALI OLIVINE BASALT	22.46	8.97	49.46	18.28	17.64
111	AVERAGE CHONDRITE	17.90	20.00	1.38	.80	35.00
112	AVERAGE ACHONDRITE	18.90	10.00	.08	.03	150.00
101	BASALTIC ROCK (BASIC ROCK)	22.70	5.39	11.20	7.04	29.37
102	INTERMEDIATE ROCK	25.51	29.56	115.91	41.82	11.73
103	GRANITIC ROCK	32.34	105.31	475.50	108.78	9.18
105	SHALE	27.19	63.34	183.53	56.00	3.63
128	HCP AVE SHALE	27.19	69.07	182.77	57.00	3.59
129	HCP AVE SANDSTONE	36.64	72.61	155.44	110.71	3.07
131	HCP AVE SEDIMENT	27.10	69.53	148.55	58.68	3.53
106	CHONDRITES	17.80	10.59	.62	.36	75.56
135	COSMIC ABUNDANCE	25.40	11.00	.55	.36	81.82
	***** EARTH IGNEOUS *****					
1	CALC ALKALI RHYOLITES	34.73	374.12	2477.61	292.64	4.97
2	RHYOLITES	34.59	217.08	1617.33	222.03	6.47
3	CALC ALKALI GRANITES	33.93	187.06	1486.57	229.74	5.13
4	GRANITES	33.13	142.03	627.05	135.11	7.63
5	SILICIS IGNEOUS ROCKS	32.39	105.31	475.50	108.78	9.18
6	GRANDIORITES(1)	31.45	71.59	266.69	87.81	11.25
7	GRANDIORITES(2)	30.75	64.66	202.85	70.68	11.81
8	PLUTONIC IGNEOUS	30.47	102.54	203.71	89.99	8.46
9	CORD APP IGNEOUS	29.20	53.45	123.88	48.05	11.26
10	ANDESITES(1)	28.22	36.37	103.23	36.40	15.33
11	AVE IGNEOUS	28.13	40.31	125.85	51.07	10.90
12	DIORITES	26.96	38.11	72.10	31.83	13.82
13	INTERMEDIATE IGNEOUS	25.69	29.56	115.91	41.82	11.73
14	ANDESITES(2)	25.55	11.72	34.41	13.58	30.07
15	PARENTAL CALC ALK MAGMAS	25.32	15.40	25.03	13.27	30.40

		Si	$10\left(\frac{K}{Ti}\right)$	$100\left(\frac{K}{Mg}\right)$	$100\left(\frac{K}{Fe}\right)$	$10\left(\frac{Na}{K}\right)$
16	DIORITES(2)	24.52	12.01	29.33	14.72	23.38
17	NORMAL THOLEITES	24.01	6.24	19.36	8.21	22.85
18	AVE THOLEITE	23.87	9.90	19.66	9.90	19.67
19	BASALTS	23.35	14.85	32.77	14.10	19.07
20	PLATEAU BASALTS	23.26	4.41	14.17	5.61	33.20
21	MAFIC IGNEOUS	22.74	5.39	11.07	7.04	29.37
22	AVE OLIVINE BASALT PACIFIC	22.00	4.62	17.42	9.34	24.14
23	NORMAL ALK BASALTS	21.57	5.33	14.64	9.14	24.14
24	PERIDOTITE NODULES IN BASA	20.87	.69	.03	.13	89.40
25	ULTRAMAFIC IGNEOUS	20.59	5.71	4.24	5.82	10.22
26	PERIDOTITES	20.55	3.46	.80	1.76	26.82
27	DUNITES(DALY)	19.52	13.86	.03	.13	89.40
28	DUNITES (NOCKOLDS)	18.91	6.93	.32	.78	26.82
	***** EARTH SEDIMENTARY *****					
29	AVE ORTHOQUARTZITE	43.29	138.56	137.65	22.25	8.94
30	AVE QUARTZITE FINLAND	39.08	2494.16	353.94	60.62	3.97
31	AVE SANDSTONE	37.30	60.04	149.12	107.57	3.44
32	AVE SUBGRAYWACKE	36.93	34.64	129.04	45.64	12.52
33	AVE DIATOM OOZE	36.32	4.62	7.65	5.13	8.94
34	AVE ARKOSE	35.61	7898.16	7845.77	280.31	3.14
35	AVE MISSISSIPPI SILT	34.96	57.74	229.41	79.88	5.72
36	AVE GRAYWACKE	30.79	58.20	96.35	43.13	14.90
37	AVE RADIOLARIAN OOZE	29.86	39.26	70.91	21.19	5.26
38	PALEZOIC SHALES	29.81	65.82	209.22	58.21	2.59
39	AVE BLUE MUD	29.62	29.44	106.36	24.25	12.62
40	AVE SHALE	29.11	69.28	185.29	57.75	3.58
41	GLACIAL CLAYS	29.06	71.01	161.24	66.49	4.80
42	AVE TERRIGENOUS MUD	28.78	10.89	65.83	15.76	19.50
43	CLAYS AND SOILS	27.89	63.74	95.93	35.47	5.05
44	MESO AND CENOZOIC SHALES	27.75	80.37	137.65	53.65	5.86
45	AVE RED CLAY	25.04	34.64	137.65	18.23	6.26
	***** EARTH METAMORPHIC *****					
48	METAQUARTZITES	37.53	3602.67	357.88	82.36	6.53
49	LEPTITES AND HAELLEFLINTAS	34.54	256.34	509.29	138.13	7.73
50	QUARTZOFELDSPATHIC GNEISSE	33.09	105.31	435.88	117.95	7.53
51	PLUTONIC GNEISSES	32.90	5958.26	493.23	120.82	7.28
52	AVE MICA SCHIST FINLAND	32.10	175.51	290.58	112.47	6.35
53	AVE PRECAMBRIAN FINLAND	32.01	124.71	291.48	87.98	7.70
54	MICA SCHISTS NORWAY	31.87	5265.44	153.84	59.62	3.06
55	TWO-MICA GNEISSES	31.68	4849.75	267.64	73.14	7.92
56	MICA SCHISTS (1)	31.59	78.52	234.00	69.82	4.73
57	KINZIGITES FINLAND	31.08	73.90	151.88	51.23	6.98
58	SLATES (1)	30.37	50.81	146.53	54.97	7.31
59	ROOFING SLATES	30.33	5404.01	335.51	70.45	2.98
60	MICA SCHISTS (2)	30.23	5819.70	214.11	76.92	3.41
61	MICA SCHISTS (3)	30.09	51.27	188.62	60.88	4.59
62	PHYLLITES NORWAY	29.95	6512.52	294.06	71.63	2.85
63	AVE PRECAMBRIAN CANADA	29.91	53.69	237.06	64.15	10.67
64	SLATES AND PHYLLITES	28.97	4988.31	170.87	48.05	3.23
65	SLATES (2)	28.92	75.22	180.36	48.48	4.00
66	PRECAMBRIAN SLATES	28.27	71.01	209.02	42.14	2.83
67	PHYLLITES	28.08	50.39	189.86	56.95	4.47
68	AMPHIBOLITES (1)	23.54	9.53	21.63	10.64	23.57
69	AMPHIBOLITES (2)	23.54	969.95	13.96	6.11	37.04
70	ECLOGITES	22.93	969.95	10.83	5.97	31.93
	***** METEORITES *****					
712	AUBRITES	25.27	23.09	.38	2.16	118.00

		Si	$10\left(\frac{K}{Ti}\right)$	$100\left(\frac{K}{Mg}\right)$	$100\left(\frac{K}{Fe}\right)$	$10\left(\frac{Na}{K}\right)$
713	DIOGENITES	24.38	.07	.01	.01	35.76
710	SHERGOTTITE	23.40	249.42	2.49	.87	63.07
711	HOWARDITES	23.07	49.88	4.20	2.12	26.32
716	NAKHLITES	22.84	5.10	1.61	.72	26.18
709	EUCRITES	22.28	1.93	.98	.35	64.07
715	ANGRITES	20.55	1.10	2.62	2.11	12.23
708	AMPHOTERITES	19.09	332.55	1.25	.99	38.74
703	HYPERSTHENE CHONDRITES	18.58	13.86	.62	.41	76.39
714	UREILITES	18.21	1.54	.04	.05	384.41
707	ENSTATITE CHONDRITES	18.06	25.40	.72	.33	81.27
701	ORDINARY CHRONDITES	17.92	12.60	.58	.34	80.46
721	MANTLE (AVE STONY METEORIT	17.92	27.71	1.15	.66	44.70
702	BRONZITE CHRONDITES	17.04	12.60	.60	.30	83.14
718	SIDEROPHYRES	16.19	13.86	.14	.02	8.94
706	CARBONAC. CHRONDITES, TYPE	15.82	5.77	.29	.17	98.34
719	LODRANITES	13.53	13.86	.06	.02	8.94
705	CARBONAC. CHONDRITES, TYPE	12.78	6.93	.36	.20	96.55
704	CARBONAC. CHONDRITES, TYPE	10.81	12.12	.62	.31	97.06
720	MESOSIDERITES	9.13	13.86	.22	.02	151.98
717	PALLASITES	8.00	41.57	.21	.05	20.86
	***** APOLLO 11 *****					
618	SURVEYOR 7 (TURKEVICH)	46.10	10.00	.14	.18	700.00
601	LSPET A 72	21.00	.28	3.54	1.31	25.88
600	LSPET A 22	20.00	.26	4.36	1.06	17.65
605	LSPET B 58	20.00	.17	2.31	.69	45.56
608	LSPET C 21	20.00	.23	2.67	.81	12.50
610	LSPET D 37	20.00	.24	2.08	.81	40.00
606	LSPET B 45	19.60	.18	2.00	.60	45.24
611	LSPET 54 (BULK SAMPLE)	19.60	.26	2.39	.91	34.55
612	10044 GABBRO	19.66	.17	2.42	.65	39.01
614	10084=28 REGOLITH (DUST)	19.42	.30	2.77	1.09	26.82
615	10017 29	19.09	.36	5.40	1.62	15.20
637	10047	19.33	.15	2.48	.62	52.83
638	10049	19.19	.44	7.05	2.06	17.63
639	10050	19.14	.05	.86	.31	118.00
640	10058 (WHOLE ROCK)	19.38	.09	1.54	.43	100.89
642	10019	19.23	.24	2.45	.95	59.39
643	10048	19.75	.26	3.10	1.16	27.35
644	10060	19.42	.27	3.29	1.13	38.74
645	311079	19.75	.26	2.43	.98	34.48
641	10062	18.16	.09	1.34	.41	88.12
604	LSPET B 17	18.70	.27	3.53	1.22	26.67
609	LSPET C 61	18.70	.28	2.78	1.21	24.67
613	10057 VESICULAR DIABASE	18.63	.39	5.76	1.76	15.09
616	10020 30	18.67	.06	.88	.28	66.15
617	10072	18.81	.33	4.95	1.56	16.03
635	10022	18.77	.34	5.34	1.70	27.12
636	10024	18.25	.29	4.75	1.62	25.54
634	10003	17.69	.06	.96	.27	151.98
603	LSPET A 20	17.80	.07	1.10	.38	83.02
607	LSPET B 50	17.80	.10	.88	.34	71.70
602	LSPET A 57	16.80	.20	2.63	.97	26.67
	***** APOLLO 12 *****					
633	LSPET 12013	28.55	23.09	45.88	21.34	3.08
627	LSPET 12038,CRYS	22.93	.25	1.21	.36	94.10
631	LSPET 12010 BRECCIA	20.12	.60	2.00	.88	29.61
625	LSPET 12052,CRYS	19.66	.27	.95	.35	58.30
623	LSPET 12009,CRYS	19.19	.26	.69	.34	72.37

AUG 14 1970

		Si	$10\left(\frac{K}{Ti}\right)$	$100\left(\frac{K}{Mg}\right)$	$100\left(\frac{K}{Fe}\right)$	$10\left(\frac{Na}{K}\right)$
629	LSPET 12070 FINES	19.66	.80	2.06	1.13	19.87
630	LSPET 12073 BRECCIA	19.19	1.12	3.13	1.57	17.88
632	LSPET 12033 LIGHT FINES	19.19	2.08	4.88	2.60	12.38
624	LSPET 12065,CRYS	18.25	.26	1.10	.35	48.42
626	LSPET 12064,CRYS	18.72	.24	1.45	.41	44.70
628	LSPET CRYS ROCKS,AVE	18.72	.24	.76	.33	61.89
620	LSPET 12004,CRYS	17.32	.24	.53	.27	73.98
621	LSPET 12015,CRYS	17.78	.27	.61	.30	53.35
619	LSPET 12012,CRYS	16.38	.25	.43	.26	86.15
622	LSPET 12022,CRYS	16.85	.18	.72	.33	47.33
	***** TEKTITES *****					
301	J-86 JAVANITE TEKTITE	30.00	25.98	25.81	17.79	4.77
300	J-87 JAVANITE TEKTITE	29.72	25.98	30.36	18.83	4.17
	***** SAMPLES AND STANDARDS *****					
124	P-23 GRANDIORITE	34.59	320.78	1416.22	304.81	6.12
113	USGS STAND G-1	33.93	286.37	2075.84	350.88	5.50
121	P-17 BIOTITE QUARTZ MONZON	33.70	164.69	1145.21	258.10	8.40
115	USGS STAND G-2	32.43	130.19	806.21	202.94	8.23
122	P-4 BIOTITE QUARTZ MONZON	31.59	96.04	537.22	122.19	9.58
116	USGS STAND GSP-1	31.50	115.89	799.79	154.34	4.63
123	P-19 BIOTITE GRANDIORITE	30.79	46.83	217.57	64.54	19.38
126	P-26 TONALITE (2)	28.08	26.37	94.76	28.00	29.89
117	USGS STAND AGV-1	27.66	38.53	262.70	51.62	13.23
125	P-25 TONALITE (1)	27.24	29.13	62.70	26.38	17.17
118	USGS STAND BCR-1	25.37	10.61	67.63	15.04	17.46
114	USGS STAND W-1	24.62	8.21	13.31	6.87	31.43
119	USGS STAND PCC-1	19.56	1.39	.00	.01	53.64
120	USGS STAND DTS-1	18.95	1.39	.00	.01	53.64
		23.49	339.88	184.00	35.67	35.89

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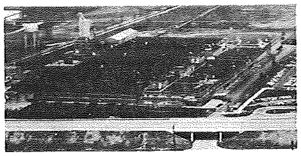
THE AVCO DEFENSE AND INDUSTRIAL PRODUCTS GROUP

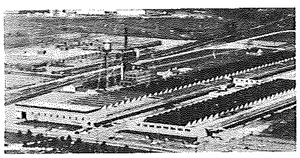
The Avco Defense and Industrial Products Group, of which the Electronics Division is a key member, is comprised of the five Divisions illustrated on this page. The combined effort of this Group offers a wide degree of flexibility and overall capability for advanced research, design, development, and production of defense and industrial products.



ELECTRONICS DIVISION

Avco Electronics plays a vital role in National Defense and Industrial Progress. This Division possesses the technical capability and modern facilities to volume produce complex electronic systems and components.

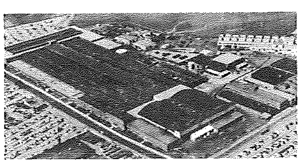
In the fields of Advanced Technology, Systems Engineering, Tactical Communications, and Field Engineering, the Avco Electronics Division has a history of successful defense programs including radar, bomber defense, ground and airborne communications, data handling, air traffic control, infrared detection, electro-optical surveillance, missile and satellite command control systems, and missile range support operations.



ORDNANCE DIVISION

The Ordnance Division has a complete facility for electrical, mechanical and materials research development engineering, an up-to-date high volume production facility and a field test site for static and dynamic testing of certain weapons, explosives and ammunition. Ordnance devices and systems include arming and fuzing systems, ammunition and warheads, tactical weapons, and ordnance instruments.

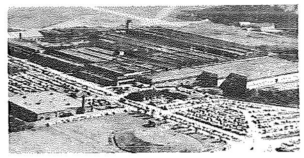
Some of these product areas include the Polaris nuclear adaption kit, the Titan radiation fuzing system, mortar, and impact fuzes, Tactical Atomic Demolition Munitions and armor piercing rounds. The Ordnance Engineering Group has extensive background in fuzing, lethality studies, ballistic matching, fragmentation, penetration, velocity and stability, static and dynamic balancing.



LYCOMING DIVISION

This Division produces reciprocating aircraft engines, gas turbine engines, missile components, rocket chambers, engine components, ground support equipment, constant speed drives, gears and machined parts, heat treating and plating, hardened and ground precision parts, and hydrofoil vehicles.

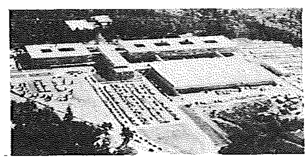
Production of aircraft engines and missile components has been accelerating at the Lycoming Division. Lycoming's growth in the missile field includes production of re-entry vehicles for the Titan, Atlas, and Minuteman ICBM's, as well as components for the Polaris, Talos, and Nike-Hercules missiles.



AEROSTRUCTURES DIVISION

This Division directs major effort in the design, development, and manufacture of large light-weight structures such as radar antennas, airframe components, missile and space vehicle components, and ground support equipment. The plant houses complete laboratories, environmental facilities, manufacturing test equipment, and large production areas. It is located adjacent to the Nashville Airport, providing ready accessibility to aircraft flown in for complete overhaul or repair.

The Division provides the U.S. Air Force with tail assemblies for the C-130 turboprop transport and wing box beam assemblies for the C-141 turbofan jet transport, produces structures for the Saturn rocket booster, manufactures rocket nozzles and chambers for missiles and space boosters, and builds a number of components for classified defense and space projects.



RESEARCH & ADVANCED DEVELOPMENT DIVISION

RAD specializes in research and development of missiles, satellites and space probes, high temperature materials, advanced propulsion systems, rocket nozzle development, environmental test systems and equipment, re-entry telemetry systems, electric arc plasma generators, and medical science technology.

Work on advanced ICBM and space vehicle re-entry problems continues at RAD accompanied by increasing diversification into other areas of interest. Technical progress has been made in the many fields associated with re-entry and the division is doing advanced work on the Titan and Minuteman re-entry vehicles under Air Force contracts.

Scientific advancements through basic research is the keynote at Avco's ADVANCED RESEARCH LABORATORY in Everett, Massachusetts. A team of highly skilled Scientists is enhancing our knowledge of space technology, high temperature gas dynamics, aerodynamics, re-entry physics, satellite recovery methods and electric propulsion for space vehicles. Avco's BAY STATE ABRASIVES DIVISION has precision abrasive and ceramic manufacturing capabilities. MEREDITH-AVCO, INC. is engaged in the rapidly growing community antenna television business. Avco's NEW IDEA DIVISION has made outstanding contributions in the development of modern farm equipment. Avco has two wholly owned subsidiaries —— the AVCO BROADCASTING CORPORATION and MOFFATS LIMITED in Canada, a leading supplier of electric home appliances.