
Positive identification of the minerals olivine, plagioclase, and/or several types of pyroxenes were made at several locations on the lunar surface using remote measurements. For example, crater Aristarchus is found to have an average pyroxene composition of augite, and plagioclase is obviously present. The dark mantle deposit in the highland crater J. Herschel is at least partly composed of a mixture of 70% olivine and 30% pyroxene. These determinations are possible because the reflectance spectra for more than fifty 10-20 km diameter lunar areas were measured for the first time in the IR spectral region (0.65 - 2.5 μm) with sufficient spectral resolution and photometric precision to define mineral electronic absorption bands. The reflectance for all lunar regions observed continues to increase toward longer wavelengths to at least 2.5 μm and several mineral absorption bands appear. The telescopic spectra are of similar quality and contain features similar to laboratory spectra of lunar samples. The absorption features in several spectra have been quantitatively analyzed using newly developed computer processing techniques, including thermal flux removal and absorption band fitting, to produce these mineral identifications. Detection and quantitative analysis of these absorptions provide a much improved basis for remotely determining and mapping surface mineralogy quantitatively from the ground or using airborne and spacecraft platforms. A spectrometer flown on a polar orbiting spacecraft could greatly expand this information base.

Several lunar reflectance spectra were treated to a detailed computer analysis after they were calibrated and placed into a standard format. First a straight line continuum was removed. Then the remaining spectrum was fitted by several gaussian functions to determine the quantitative characteristics of the absorption bands present. The absorptions were then interpreted in terms of mineralogy, using laboratory studies of lunar and other materials. A detailed discussion of this process will be given in McCord et al. (1).

Several examples are presented here.

Aristarchus: This spectrum (Fig. 1) is dominated by deep pyroxene absorptions that indicate an immature (glass poor) surface material. Two gaussian functions fit the 1 μm region yielding a band at 0.96 μm (pyroxene) and another at 1.28 μm (plagioclase). A third gaussian function fits at 2.26 μm (pyroxene). The position of the pyroxene absorptions indicates the presence of a pyroxene component with an average composition of augite (2), somewhat more calcium-rich than the average highland basalt pyroxene, which one might expect to have been excavated from beneath relatively thin mare deposits at the Aristarchus target site.

Mare Serenitatis 2: A single gaussian function fits to the 1 μm spectral region when centered at 0.97 μm (Fig. 2). The asymmetry of this 2 μm absorption prevents a single gaussian fit, but a manual fit to the 2 μm band in this mature soil spectrum yields a position of 2.18 ± .02 μm. These two bands are indicative of a calcic pyroxene (2) such as was found at the Apollo 15 mare site. There is an apparent, very weak absorption at 1.27 μm (not shown fitted here); it is consistent with a plagioclase.

Herschel: The spectrum of the dark mantling deposit on the floor of this highland crater shows a very broad asymmetric absorption in the 1 μm region and another band in the 2 μm region. The 2 μm feature is due to pyroxene only (2), and its presence assures that at least some of the 1 μm band is due to pyroxene. The most likely candidate mineral for the remainder of the 1 μm
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band is olivine. The olivine band is known to be composed of three bands representing absorptions along three crystallographic axes\(^{(3)}\). Laboratory studies of olivine and olivine-pyroxene mixtures are underway both in Hawaii and at the University of Washington. Preliminary results of the Hawaii study\(^{(4)}\) show that the olivine band can be dissected by computer analysis into these three component bands. Further, mixtures of olivine and pyroxene show a blended set of four absorptions (3-olivine, 1-pyroxene) in the 1 \(\mu\)m region which change in relative intensity (but not wavelength positions) as the mixing ratio is changed. In Fig. 3 the telescopic spectrum of the Herschel area is shown successfully fitted by the three olivine bands and one pyroxene band in the 1 \(\mu\)m region. The pyroxene band positions (0.92 \(\mu\)m) indicates an orthopyroxene or a pigeonite. This is consistent with highland basalts found at several Apollo sites. The relative strengths of the olivine and pyroxene

Fig. 1: Part of the treatment of the spectral reflectance curves used to derive quantitative information is illustrated here for the crater Aristarchus. The straight line through the top spectrum approximate the continuum. The bottom plot is the upper spectrum with the straight line continuum removed (points) and fitted by gaussian functions (curves). The middle plot is the difference between the gaussian functions and the spectrum fitted.

Fig. 4: The reflectance spectra for two laboratory mixtures of olivine and pyroxene are shown (A - 60% olivine, 40% pyroxene; C - 80% olivine, 20% pyroxene). The Herschel spectrum (B) is shown for comparison without the portions of the spectrum affected by terrestrial water absorptions, which are incompletely removed by calibration procedures.
bands and the shape of the composite band indicate a mixing ratio for the
Herschel deposit of 70/30 ± 10/10 percent olivine to pyroxene. The range of
allowable mixing ratios is defined by measurement of a series of laboratory
mixtures (Fig. 4) and using the assumption that the particle size of the
Herschel materials is not grossly different from what is observed in Apollo
lunar samples.

Infrared and Raman Spectroscopy of Lunar and Terrestrial Minerals, 91-96, Aca-
demic Press. 3) Burns, R.G. (1970), Amer. Mineral. 55, 1608-1632. 4) Singer,

Figs. 2 & 3: The reflectance spectrum for
Mare Serenitatis
(above) and J.
Herschel (below)
are shown
recovered as was
the Aristarchus
spectrum (Fig. 1).