Mid-Infrared (2.5 to 13.5 μm) Spectra of Igneous Rocks

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1.0 ABSTRACT

Directional hemispherical reflectance spectra are presented from 2.5 to 13.5 μm of a suite of well-characterized solid and powdered igneous rocks. Igneous rock types in this suite range in composition from felsic to ultramafic, and include coarse-grained, fine-grained, and glassy varieties. Spectral features and their variation with rock type and rock chemistry are described. The use of thermal infrared spectra in remote sensing applications is also discussed.

2.0 INTRODUCTION

Libraries of igneous rock spectra have been published by Lyon (1964), Hunt and Salisbury (1974), and Vincent et al. (1975). However, these libraries lack the potentially useful 3- to 5-μm region of the spectrum, do not document the effects of particle size for each sample, generally lack full chemical and petographic characterization, and are not available in digital form. Thus, these works are of limited use for both laboratory studies and remote sensing applications. The present work seeks to remedy all of these defects.

3.0 EXPERIMENTAL METHOD

3.1. Sample Acquisition and Preparation. Most samples were either purchased from Ward's Natural Science Establishment or borrowed from the National Museum of Natural History. A few basalt and picrite samples were supplied by Rosalind Helz of the U.S. Geological Survey.

After spectral measurements were made, typically on fresh rough surfaces of solid samples unless otherwise noted, a representative, portion of each sample was passed through a jaw crusher, the jaws of which were lined with alumina tiles; then passed several times through a disk grinder using alumina disks; and the remaining coarse particles finally ground in a sintered saphire mortar until all of the ground sample passed through a 74-μm sieve. The resulting powder samples presumably have a particle size distribution that follows the lognormal grinding law (Rowan and Becker, 1971). That is, they are dominated numerically by fine (<5 μm) particles.

3.2. Sample Characterization. Rocks were first examined and described as hand samples. Typically, thin sections were then cut for petrographic and microprobe analysis and a portion of each sample set aside for chemical analysis, unless petrographic descriptions and/or microprobe and chemical analyses were available from the donor.

Petrographic descriptions and modal analyses of the Wards samples were made by D. D'Aria. Modal analyses reported are the average of two analyses of 500 points on a circular 3.3 cm. diameter polished thin section.

Microprobe analyses were performed by L. Walter, unless otherwise noted in the text, on the same polished thin sections used for modal analyses. In general, the grains and areas within grains to be microprobed were first located using the petrographic microscope in transmitted or reflected light for transparent and opaque minerals respectively. Photomicrographs in reflected light were used to relocate the sample areas in the microprobe.

Through kind permission, the Applied Research Laboratory instrument at the Smithsonian Institution Division of Mineral Sciences was used. Six fixed wavelength dispersive detectors were used to analyze for Si, Al, Fe, Mg, Ca and K. Three movable, wavelength-dispersive detectors were used to analyze for Na, Ti and Mn. Quartz was used as a background standard for Al; alumina was used as a background standard for all other elements.

Standards employed were selected from those offered generally by the Smithsonian: Rhodonite for Mn and Kakaui Hornblende for all other elements. The Bence-Albee correction procedure was used to convert intensity ratios to element/oxide abundances. As usual, Fe is reported as FeO; ferric and ferrous iron were not distinguished.

In analyzing a mineral, points were accumulated for ten-second integration times. Particular attention was paid to assessing the degree of grain-to-grain and within-grain homogeneity. To do this for a mineral species in a rock where grain sizes permitted, about five analyses were made in each of two or three grains and up to ten different grains would be analyzed.

Estimated errors (as determined by replicate analyses) are:

Oxide	Coefficient of Variation (Rel. %)
SiO_2	1.7
Al_2O_3	2
FeO	2
MgO	2
CaO	2
K_2O	3
Na_2O	5
TiO_2	2
MnO_2	1

These estimates apply to cases in which the oxide abundance is greater than 3%. The limit of reliable detection is generally about 0.5%.

Analytical results, originally interpreted in terms of weight percent, were also cast in terms of oxide mole percent and as mole proportions of the oxides relative to silica (all Fe was initially calculated as Fe^{2+}). This facilitated assignments of cation substitutions and mineral identification where this was necessary.

Chemical analyses of the Ward's samples were performed by S. A. Mertzman of Franklin and Marshall College using X-ray flourescence, except for the ferric/ferrous ratio which he determined by wet chemical analysis. Analyses of the samples donated by Rosalind Helz were classical wet chemical analyses. The National Museum of Natural History samples, on the other hand, had their chemistry measured by various analysts and techniques described in the references given on the sample description sheets.

3.3. Spectral Measurements. Spectra were recorded using a Nicolet 5DXB FTIR* spectrophotometer at 4 cm^{-1} spectral resolution from 2.17 to 13.5 μm. This instrument has both a sample compartment, in which the infrared beam is brought to a focus, and an external port to which the beam may be switched and through which the beam exits in collimated form. A gold-coated integrating sphere was attached to the instrument at this external port. The sphere is 12.7 cm in diameter and has a 2.5-cm illumination port in the top of the sphere at 10 degrees off the vertical, through which the beam passes to fall on a 2.5-cm sample/reference port in the bottom of the sphere. Beam size on the sample in that bottom port is 1.54 cm. In view of this relatively small beam size, multiple measurements were made of different areas of coarse-grained igneous rocks surfaces and the resulting spectra averaged to yield a representative solid rock spectrum. Solid samples of fine-grained homogeneous (compared to the beam size) rocks were measured only once.

A 2.5-cm detector port is in the side of the sphere and the liquid nitrogen-cooled, mercury-cadmium-telluride (MCT) detector chip is baffled to eliminate direct viewing of either the sample or the specular "hot spot" on the sphere wall. A port at the specular angle was filled during these measurements with a plug having a surface curved to match the interior curvature of the sphere.

Integrating sphere performance was carefully calibrated by comparing known reflectances of Halon, a diffuse gold surface, a front-surface aluminum mirror, water, and a black body cone. Figure 1 documents the reproducibility of powdered rock spectra measured with this sphere.

3.4. Data Storage and Retrieval. Data are initially stored in digital form on 8-inch floppy disks in Nicolet format. They are also transferred to a VAX 11/780 where they are stored as x, y values in ASCII format (VMS operating system). These data can be obtained by writing or calling the senior author at (703) 648-6382 (commercial) or FTS 959-6482.

Graphic plots of the spectral data are presented in Appendix 1 with the X-axis plotted in micrometers, which is the format most requested by users. However, the digital data are recorded and stored in reciprocal centimeters, with a constant spectral resolution of 4 cm^{-1} (data points every 2 cm^{-1}) throughout the range. The range recorded extends from 192.90 cm^{-1} (51.84 μm) to 4808.88 cm^{-1} (2.08 μm). However, the combination of beam splitter and detector used for these measurements results in unacceptably noisy data at wavelengths longer than 14 μm, so that digital files distributed to users are usually edited to delete data beyond 713.71 cm^{-1} (14.01 μm). Graphic plots are further confined to the 2.5- to 13.5-μm range for plotting convenience.

4.0 DISCUSSION OF SPECTRA

4.1. Solid Rock Spectra. Reflectance spectra of solid igneous rocks typically display two kinds of spectral features: reflectance minima associated with OH, CH, and CO_3 and reflectance maxima associated with SiO. The SiO features in the 8- to 14-μm region are expressed as peaks because the

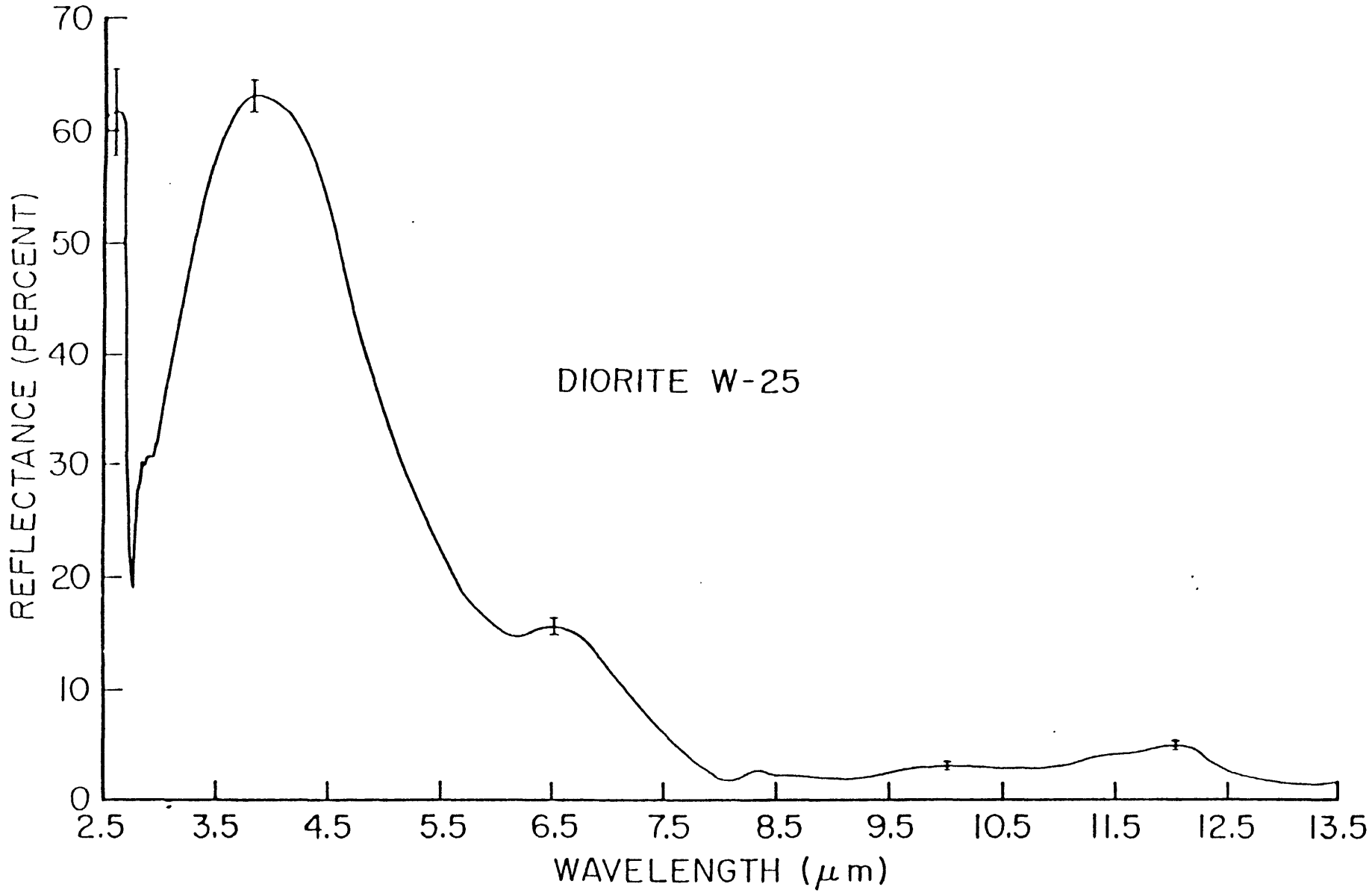

Figure 1. Directional hemispherical reflectance spectrum of diorite.1 with vertical bars showing standard deviation of individual spectra of 10 separately sifted samples at five different wavelengths.

reflectance dominates the scattering process. The OH, CH, and CO_3 features in the 2.5- to 6.0-μm region, on the other hand, are expressed as troughs because the absorption coefficient is low enough in these bands that volume scattering dominates the reflectance (See Salisbury et al., 1987a & b). These spectral features will be briefly discussed in order of increasing wavelength.

4.1.1. Water and Hydroxyl bands are prominent in spectra of most igneous rocks, as illustrated in Figure 2. Here a strong, sharp hydroxyl band near 2.75 μm is accompanied by a broader molecular water band at 2.9 μm, with barely discernable fine structure between them due to hydroxyls at different sites in the mineral structure lattice. All of these features are due to fundamental O-H stretching vibrations. The differences in wavelength are caused by different bond strengths (and hence different vibrational frequencies) associated with different structural sites for OH or, in the case of the water, with a different molecular configuration.

Water and hydroxyl bands are usually prominent in spectra of igneous rocks, even when hydrated or hydroxylated minerals are nominally absent, because the ubiquity of water in the terrestrial environment causes incipient alteration of all vulnerable silicates (Salisbury et al., 1987b). Moreover, anhydrous silicates are otherwise spectrally featureless with relatively low absorption coefficients in the 2.5 to 4.0 um region, while OH bands typically have absorption coefficients that produce intense bands when volume scattering takes place (Salisbury et al., 1987b). The roughness of the broken surfaces of these rocks that were measured is sufficient to induce considerable scattering. Thus, a little water or hydroxyl goes a long way (see chemical analyses), and the same can be said for the hydrocarbons and carbonates discussed below.

The detailed structure of OH bands may reveal the presence of specific hydrated or hydroxylated minerals in igneous rocks. Comparison with mineral spectra (Salisbury et al., 1987b) suggests, for example, that tonalite W-24, granodiorite W-7, diorite W-25, and norite W-125 all contain hornblende, although the diagnostic fine structure is not well-displayed at the scale of the X-axis used here.

Molecular water also displays a weaker H-O-H fundamental bending vibration band near 6.0 μm in addition to the O-H stretching fundamental. This feature is seen in the solid sample spectra of a few rocks, such as basalt.1 and lamprophyre.1.

4.1.2. Hydrocarbon bands are also seen in the 3 μm region due to a triplet of C-H fundamental stretching vibrations near 3.35, 3.40, and 3.50 μm, as illustrated in Figure 3. Figure 3 is a biconical reflectance spectrum of KBr powder wetted with alcohol and then dried in a 100-degree centigrade oven. KBr is spectrally featureless in this region and thus all of the weak bands in Figure 3 are due to a film of hydrocarbon remaining on the KBr grains. Of all these bands, the C-H stretching triplet is the most prominent and sharply defined feature. The same feature is displayed on the margin of the OH band due to water in Figure 2. These features are marked with an arrow where they appear in igneous rock spectra because they are artifacts due to contamination of the sample surface with hydrocarbon. Even when care is taken in handling samples not to leave fingerprint oils on the surfaces measured, hydrocarbons are absorbed on these surfaces out of laboratory air (Salisbury et al., 1987b). Unfortunately, the solid samples were not sufficiently

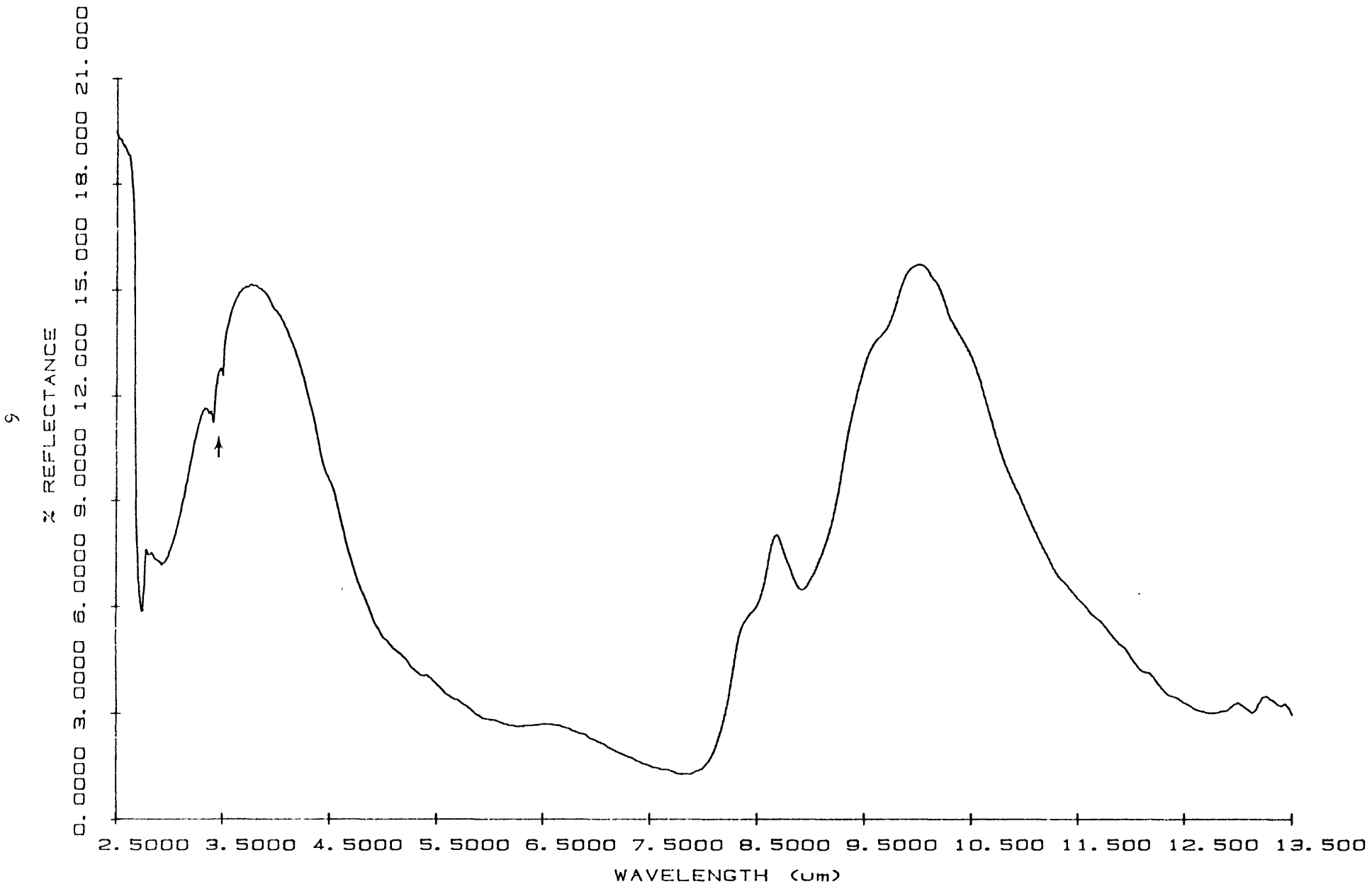

Figure 2. Directional hemispherical reflectance spectrum of a solid sample of norite.1. The arrow points to CH bands that are spectral artifacts due to hydrocarbon contamination.

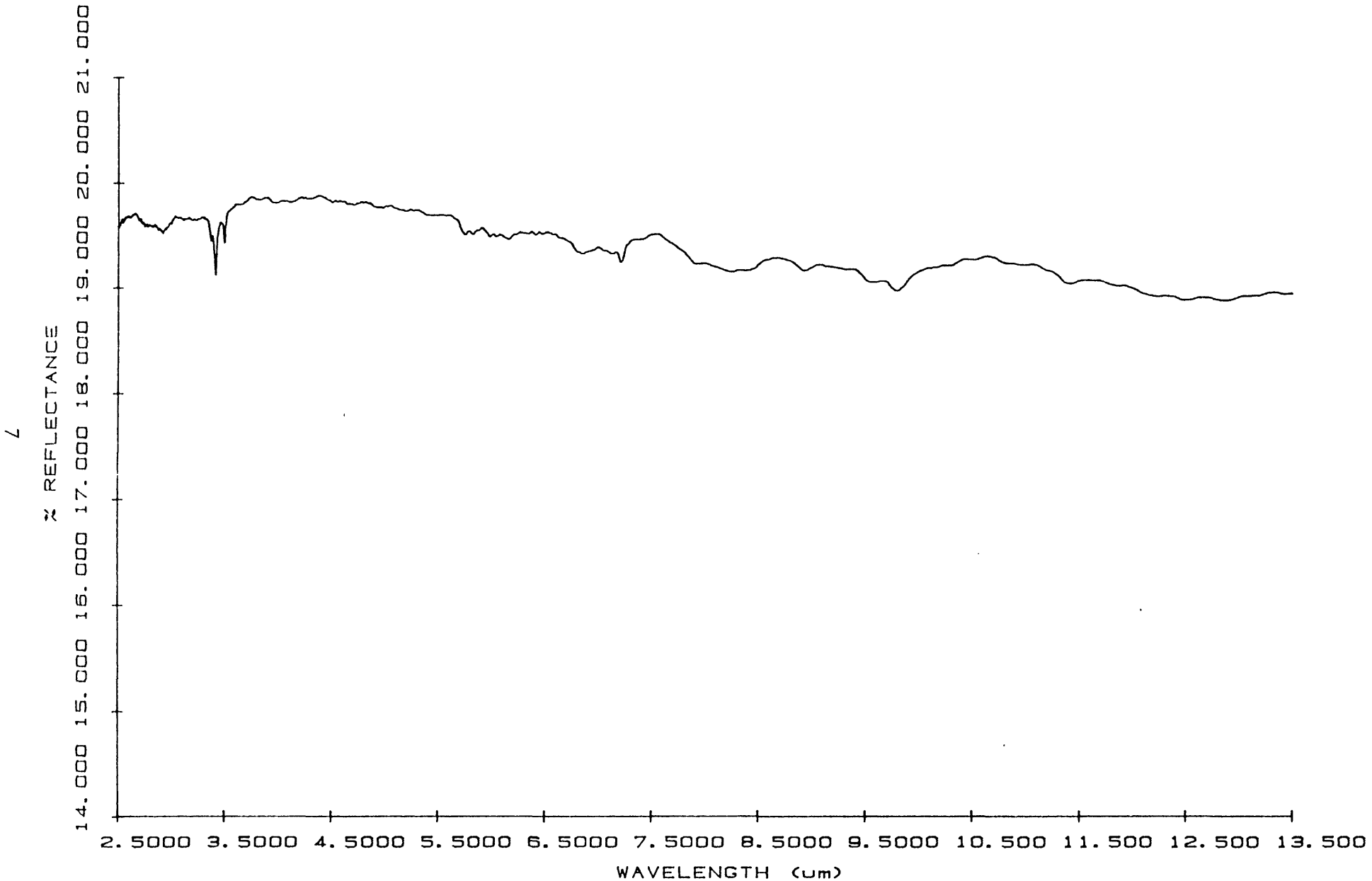

Figure 3. Biconical reflectance spectrum of KBr powder wetted with alcohol and then dried, showing CH triplet resulting from the remaining film of hydrocarbon (from Salisbury et al., 1987b).

protected from such contamination by the plastic bags in which they were kept before measurement.

4.1.3. Carbonate bands are common in igneous rocks due to small amounts of calcite that are often present as a result of alteration of plagioclose (Winchell and Winchell, 1927). A biconical reflectance spectrum of fine particulate calcite is shown in Figure 4 to illustrate the location of bands that might result. The strongest CO_3 overtone occurs as a doublet near 4.0 μm where silicates typically are spectrally featureless, making it quite apparent, even when little calcite is present (e.g., see chemical analysis and spectrum of andesite.2). Some rocks were not analyzed for CO_2, but clearly have carbonate present (e.g. ijolite.1 and anorthosite.1). In each case, the 4.0 μm doublet is the most prominent feature, but the single 5.6 μm feature also can sometimes be seen. The doublet near 3.5 μm is usually weakly expressed, but it is notable that it overlaps, and may obscure or be mistaken for, any hydrocarbon features that may be present.

4.1.4. SiO bands produce prominent peaks in reflectance spectra of solid igneous rocks in the 8.0 to 14.0 μm region. These features, commonly referred to as "reststrahlen" bands, are due to the fundamental Si-O stretching vibration bands of the component minerals.

It has been known for a long time that spectra of individual minerals in a rock are usually linearly additive in the region of the reststrahlen bands (Lyon, 1964). Consequently, deconvolution of mineralogy from a rock spectrum should, in principle, be possible. To date, however, the more modest goal has been to use igneous rock spectra to identify the nature of the mineral mixture--i.e., to identify rock type.

Past efforts have shown a systematic shift of reststrahlen bands to longer wavelength as rock type changes from felsic to ultramafic (Lyon, 1964; Hunt and Salisbury, 1974; Vincent et al., 1975), and this shift has been used in remote sensing of rock type (Kahle and Goetz, 1983). The solid rock spectra presented here offer three advantages that make possible a more refined analysis of the crystallo-chemical basis for variations in spectral behavior with changing rock type. First, the spectra are available as digital data. Second, the rock samples are more fully characterized chemically and mineralogically than in previous collections. Third, the directional hemispherical spectra measured here yield a more realistic representation of the spectral behavior of igneous rocks for remote sensing applications. For example, both Lyon (1964) and Hunt and Salisbury (1974) measured biconical reflectance from polished rock surfaces. Under these circumstances, not only does the prominence of the spectral features of component minerals depend upon the degree to which each one takes a polish, but also this reflectance geometry does not allow quantitative prediction of emittance (Nicodemus, 1965). Thus, Lyon's reflectance and emittance spectra often are dissimilar, and it is the emittance spectra that have the greater value for understanding spectral behavior, despite their limited wavelength range and low spectral resolution.

Vincent et al (1975), measured directional hemispherical reflectance, which is the appropriate geometry for prediction of emittance (Nicodemus, 1965). However, 11 of their 26 specimens were noted by the authors as being weathered or coated with silt, and spectra of their coarse-grained samples show sampling errors due to the small area (15 by 0.5 mm) measured.

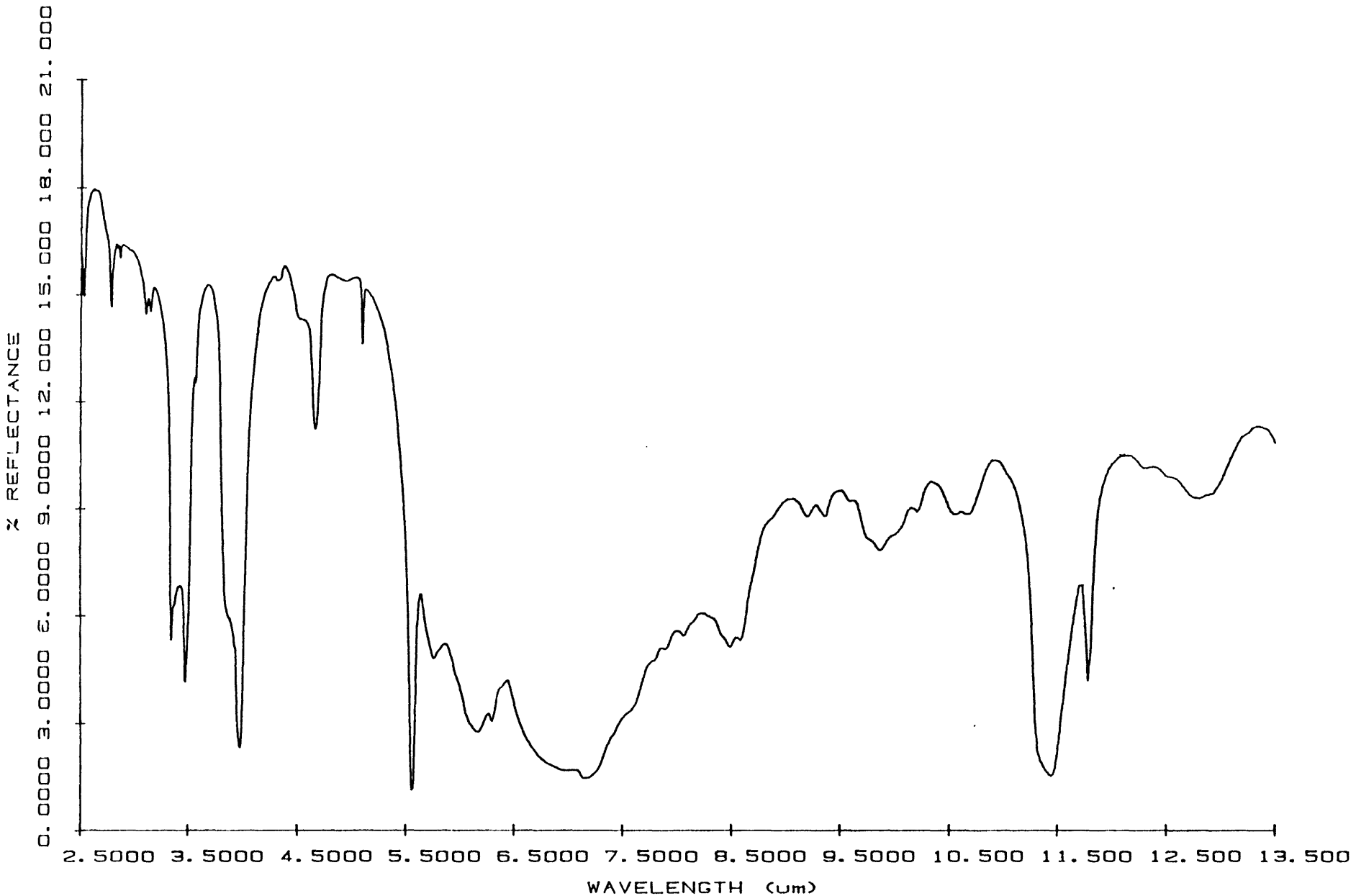

Figure 4. Biconical reflectance spectrum of 0 to 74 μm calcite powder (from Salisbury et al. 1987b).

In view of the limitations of earlier spectral libraries, the data presented here represent a significant opportunity to reevaluate the spectral behavior of fresh and unweathered igneous rocks. An initial such reevaluation has been accomplished in a separate study (Walter and Salisbury, 1988), which is summarized briefly below.

The key to a quantitative assessment of the spectral behavior of igneous rocks is the development of a numerical descriptor of igneous rock composition that also correlates with spectral behavior. The spectral behavior of silicates in the 8.0 to 14.0 μm region is a result of selective absorption at frequencies which match the stretching vibrations of the Si-O bonds. As these bonds become generally longer and weaker, the absorption occurs at lower frequencies or longer wavelengths. The principal cause of changing bond length in silicates is the progressive deploymerization of the SiO_4 silicate ion due to a decrease in the number of Si-O-Si disiloxy groups, which is associated with structural changes from framework silicates to isolated tetrahedra (Smith and Bailey, 1963). A dominant factor in deploymerization of the major rock-forming minerals is the presence of divalent cations, chiefly Ca, Fe, and Mg. Thus, Walter and Salisbury (1988) defined a parameter to characterize polymerization called the SCFM index, which is the ratio of silica to silica plus the oxide abundances of Ca, Fe, and Mg (in weight percent).

Walter and Salisbury (1988) showed that SCFM correlated systematically with mineralogy and with igneous rock composition as defined by the Thorton-Tuttle Differentiation Index (Thorton and Tuttle, 1960). They also showed that it correlated well with the spectral changes associated with changes in igneous rock type. Thus, SCFM was used as a dependent variable against which to calculate the effectiveness of variations in location, number, and width of spectral bandpasses for discriminating rock composition. They found that, when spectral bandpasses are not permitted to overlap, coefficients of determination (R^2) with SCFM ranged from 0.96 for seven 0.2 μm-wide bands to 0.88 for two 1.2 μm-wide bandpasses. This relatively small decrease in R^2 indicates that it is the broad spectral envelope of the aggregate mineral bands, rather than the fine spectral structure, which contains most of the information diagnostic of igneous rock composition (although the fine structure may yield information on individual mineral constituents). Thus, relatively little is gained for rock type discrimination by achieving high spectral resolution in a remote sensing measurement. Consequently, thermal infrared remote sensing systems can be designed with relatively broad bandpasses and correspondingly higher signal-to-noise, which can be traded off against the important requirement for higher spatial resolution.

4.2 Powdered Rock Spectra. Spectra of powdered (0-74 um) igneous rocks display many spectral features in common with solid samples, but with a few important changes. First and foremost of these changes is the decrease in spectral contrast of the reststrahlen bands, as initially pointed out by Lyon (1964). Thus, other spectral features have been sought which are diagnostic of composition. As in the case of the solid rock spectra, the data presented here offer a significant opportunity to advance this search, and a preliminary analysis has been made (Salisbury and Walter, 1988). The results of this analysis are summarized below, again with spectral features discussed in order of increasing wavelength.

4.2.1. Water, hydroxyl, hydrocarbon, and carbonate bands were described above in section 4.1 and the origins and wavelengths of these features will not be repeated here. It is noteworthy that the strong OH and CO_3 bands are more prominent in spectra of powdered rocks than they are in spectra of the solid equivalents. As pointed out by Salisbury et al. (1987b), the absorption coefficients of these bands typically are such that the band centers remain saturated or near-saturated as particle size is reduced, while reflectance in the band wings increases due to increased scattering. The result is that smaller amounts of water or carbonate are more detectable in spectra of powdered igneous rocks than in spectra of solid ones. This can be illustrated with basalt.5 for water and with granite.2 for carbonate. Hydrocarbon bands, on the other hand, are less apparent in spectra of powdered rocks. This is due, not to the spectral character of the hydrocarbon bands, but rather to the better protection against contamination offered by the glass vials in which the rock powders were stored before measurement. As a result, only the rhyolite sample was significantly contaminated.

Salisbury and Walter (1988) documented the correlation between band depth of the water/hydroxyl features in powder spectra and the amount of water present as measured by chemical analyses. Despite the limited accuracy of loss on ignition measurements of water content, they obtained a correlation coefficient (R^2) of 0.64.

In addition to more sensitive detection of water and hydroxyl, spectra of powdered rocks also typically reveal more fine structure associated with hydroxyls at different structural sites. This fine structure makes possible a more certain identification of the hydroxylated minerals present. Unfortunately, a much larger library of mineral reflectance spectra than that assembled so far (Salisbury et al., 1987b) is required to make the most of this opportunity.

4.2.2. Silicate overtone and combination tone bands of silicate minerals are seen in powdered rock spectra between 3.5 and 7.0 μm. These bands result from overtones of the fundamental molecular vibrations, or from combination tones due to combinations of these frequencies with each other or with lattice modes. These bands, which we will refer to collectively as overtones for simplicity, result in relatively weak features to shorter wavelength than the fundamentals. Because they are weak (i.e., their absorption coefficients are low compared to the fundamentals), volume scattering dominates the reflectance, and they are expressed as troughs instead of peaks (Salisbury et al., 1987a). Like the carbonate overtone bands and the water/hydroxyl OH fundamentals discussed above, silicate overtone bands initially become more prominent with decreasing particle size. As particle size continues to decrease, these bands will ultimately begin to lose intensity. The point at which this reversal takes place depends primarily on individual band absorption coefficients. However, the fact that these features initially increase in intensity with decreasing particle size is in sharp contrast to the behavior of the still weaker overtone and electronic transition bands in the visible/near-infrared, which steadily diminish in intensity as particle size decreases. The result is that overtone bands are well displayed in our powder spectra.

Some silicate minerals display a large number of overtone bands (Salisbury et al., 1987b), and chief among these is quartz. As illustrated in Figure 5, quartz has a series of such bands between 3.5 and 7.0 μm [(the features in the 2.6- to 3.5-μm range are OH bands associated with hydroxylated alkali metals serving to balance charges when aluminum substitutes for silicon (Aines and Rossman, 1984)]. Quartz overtone bands are clearly visible and quite distinctive in reflectance spectra of powdered felsic rocks, as well as in spectra of quartz-bearing intermediate rocks.

Olivine also displays distinctive overtone bands at 5.7 and 6.0 μm that are best seen in the spectrum of powdered dunite. These features are clearly expressed in picrite spectra as well.

Unfortunately, many minerals have overlapping bands and, in addition, these overtone bands are not lineraly additive in their expression in a mineral mixture spectrum. Thus, a great deal more work must be done to make possible the deconvolution of mineral abundances from such spectral features.

4.2.3. The Christiansen frequency feature is a minimum in reflectance or a maximum in emittance that occurs in a wavelength region where the real part of the refractive index undergoes rapid change just prior to a fundamental molecular vibration. During this change, the refractive index of the mineral grains may approach that of the surrounding medium (air or vacuum), resulting in minimal scattering (Conel, 1969). Because this takes place at a wavelength slightly shorter than that of the fundamental molecular vibration, absorption is still relatively low. With little backscattering and little absorption, infrared radiation can pass through a sample with relative ease, resulting in a minimum in reflectance (see Fig. 5) or a maximum in emittance. The "principal" Christiansen frequency is associated with the strongest (hence, principal) molecular vibration band, and thus falls between 7.0 and 9.0 μm for silicates. When we use the term "Christiansen frequency" here, we refer to the wavelength of the spectral feature, rather than to some fixed frequency or wavelength. As will be discussed below (Section 5.2), environmental factors may cause a wavelength shift of this spectral feature while, of course, the optical constants remain unchanged.

As discussed in detail by Salisbury and Walter (1988), the wavelength of the Christiansen frequency feature seen in powdered igneous rock spectra correlates well (R^2 = 0.86) with rock type as represented by the SCFM index. Thus, it can be used as a laboratory or remote sensing tool in rock type identification of fine particulate material.

4.2.4. SiO bands are greatly diminished and distorted in reflectance spectra of powdered rocks. However, some minerals have particularly strong and persistent reststrahlen bands that can be readily identified in powdered rock spectra. Chief among these is quartz, the distinctive reststrahlen bands of which can be seen in spectra of many powdered felsic and intermediate rocks (compare fig. 5 with rock spectra). This persistence is also seen in the spectral behavior of olivine (compare powdered dunite spectrum with two picrites). Otherwise, unfortunately, reststrahlen bands appear to be of relatively little use in analysis of finely powdered (ie. 0-74 um) rock spectra.

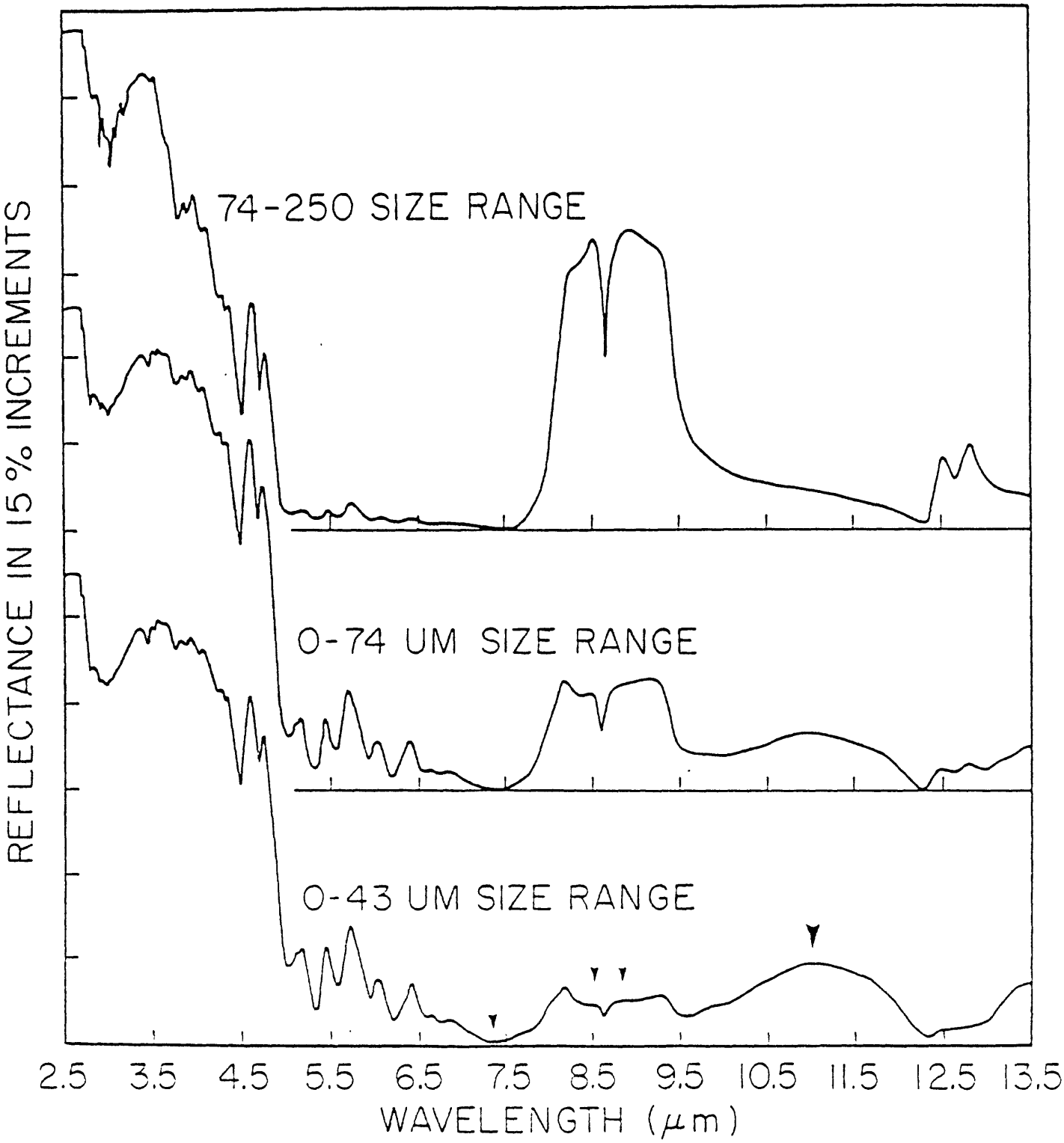

Figure 5. Directional hemispherical reflectance spectra of three different particle size ranges of quartz powder. Spectra are offset vertically with partial X axes showing each zero level. The Christiansen frequency minimum is shown by a single narrow arrow. A double arrow marks the reststrahlen bands and a broad arrow the transparency peak.

4.2.5. Transparency peaks have only recently been recognized as spectral features that may be indicative of composition (Salisbury et al., 1987b; Salisbury and Walter, 1988). These spectral features are associated with a wavelength region of relative transparency between the Si-O stretching and bending vibrational bands. The absorption coefficient is low enough in this region that silicate grains become optically thin and volume scattering comes to dominate the scattering process as the particle size is reduced. The particle size at which volume scattering begins to dominate depends upon the absorption coefficient of the individual mineral, but reflectance measurements of a wide variety of minerals (Salisbury, et al., 1987b) show that this usually has occurred by the time a mineral has been ground sufficiently to pass through a 74-μm sieve screen. Such a sample is dominated numerically by fine particles, because the grinding process results in a lognormal particle size distribution. Because the reststrahlen bands are greatly diminished in intensity at such fine particle size, this volume scattering results in a reflectance peak or emittance minimum. This is illustrated in Figure 5, although quartz spectra are not dominated by the transparency peak until a relatively small particle size is reached because of the great intensity of the quartz reststrahlen bands.

Again, Salisbury and Walter (1988) have shown the good correlation (R^2 = 0.85) between transparency peak and igneous rock type as represented by the SCFM index. They also showed that when Christiansen frequency and transparency peak are used together, the correlation rises to an R^2 of 0.90.

5.0 USE OF REFLECTANCE SPECTRA IN REMOTE SENSING

5.1 Kirchhoff's Law. According to Kirchhoff's Law (E = 1-R), directional hemispherical reflectance can be used to calculate directional emittance (Nicodemus, 1965). That is, the hemispherical reflectance of a sample illuminated with infrared radiation from a given direction can be used to predict emittance in that direction. Thus, our reflectance measurements at 10 degrees off of vertical should be interpretable in terms of near-vertical emittance.

5.2. Effects of Environmental Factors. A calculated spectral emittance may be affected by many environmental factors, the more significant of which are summarized below.

5.2.1. Background radiance falling on the target surface is probably the largest environmental factor affecting spectral emittance in the terrestrial environment, where most remote sensing targets are outcrops of solid rock. Infrared radiance may emanate from the atmosphere due to atmospheric emission or due to backscattered terrestrial emission, or it may emanate from the surrounding solid surfaces of trees, hillsides, or buildings. Whatever the source of background radiance, its reflection from the surface of a rock dilutes the emitted spectral signature, because the rock reflects most where it emits least and vice versa. Cooperative measurements with Gordon Hoover of the Jet Propulsion Laboratory, in which he measured spectral emittance of the same sample for which we had measured reflectance, showed that background radiance may reduce spectral contrast on the order of 50 percent in the vicinity of buildings and trees, even under clear sky conditions.

5.2.2. Particle size has a very strong effect on spectral behavior, as demonstrated long ago by Lyon (1964). We have chosen to present spectra of rough broken surfaces of rocks and 0 - 74 μm powders as two states having broad remote sensing applications. For example, experiments show that spectra of rough broken surfaces are essentially the same as spectra of coarse particulate materials down to sand size (74 to 250 μm). Likewise, spectra of 0 - 74 μm powders are little affected by changes in average grain size, as long as they are dominated by fines or by agglutinates composed of fine particles (Salisbury and Walter, 1988). Thus, we believe that they are good analogues of unsorted or poorly sorted regoliths found on many planetary surfaces. However, spectral features do change with changing particle size (note, for example, the shift of the Christiansen frequency minimum to longer wavelengths in powder spectra compared to those of solid samples, due to the lower intensity of the reststrahlen peaks). Thus, some care must be taken in applying these spectra to targets having quite different particle size or surface roughness characteristics.

5.2.3. Ambient pressure has been shown to affect the wavelength of the Christiansen frequency, the spectral contrast of the reststrahlen bands and the importance of the transparency peak (Logan et al., 1974; Salisbury and Walter, 1988). These effects become very significant in a vacuum environment, thus strongly influencing emittance spectra of some lunar and planetary targets. Fortunately, spectral measurements in air of the same samples that were measured in vacuum show that there is a simple correction for the effect of vacuum on the Christiansen frequency (Salisbury and Walter, 1988).

5.2.4. Other factors, such as micrometeorological conditions, time of day, or insolation angle may have some effect on spectral emittance, but are yet to be evaluated. We think, however, that the most important factors have been outlined above, with the exception of alteration and obscuration. It should be obvious that alteration of rock minerals by hydrothermal fluids or (space or terrestrial) weathering will change the spectrum to reflect the presence of the alteration minerals. Likewise, a rock may be partially obscured by coatings, such as desert varnish, or by vegetation. Again, the spectral signature of the rock will be diluted by that of the obscuring material. Thus, the spectra of relatively fresh unaltered rocks presented here represent optimum remote sensing targets.

6.0. ACKNOWLEDGEMENTS

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7.0 REFERENCES

Aines, R.D. and Rossman, G.R., 1984, Water in minerals? A peak in the infrared: Journal of Geophysical Research, v. 89, p. 4059-4071.

Conel, J. E., 1969, Infrared emissivities of silicates: Experimental results and a cloudy atmosphere model of spectral emission from condensed particulate mediums: Jour. of Geophysical Research, v. 74, p. 1614-1634.

Hunt, G. R., and Salisbury, J. W., 1974, Mid-infrared Spectral Behavior of Igneous Rocks: Air Force Cambridge Research Laboratories Technical Report, TR-74-0625, 142 p.

Kahle, A.B. and Goetz, A.F.H., 1983, Mineralogic information from a new thermal infrared multispectral scanner: Science, v. 222, p. 24-27.

Logan, L. M., Hunt, G. R., and Salisbury, J. W., 1974, The use of mid-infrared spectroscopy in remote sensing of space targets: in Infrared and Raman Spectroscopy of Lunar and Terrestrial Minerals, Chap. 9, edited by C, Karr, Academic Press, Orlando, Fla., p. 117-142.

Lyon, R. J. P., 1964, Evaluation of Infrared Spectrophotometry for Compositional Analysis of Lunar and Planetary Soils. Part II: Rough and Powdered Surfaces: NASA-CF-100, Washington, DC, 262 p.

Nicodemus, F. E., 1965, Directional reflectance and emissivity of an opaque surface: Applied Optics, v. 4, p. 767-773.

Rowan, R. J., and Becker, G. W., 1971, Batch Grinding Model: New Mexico Bureau of Mines and Mineral Resources Circular 117, 7p.

Salisbury, J. W., Hapke, Bruce, and Eastes, J. W., 1987a, Usefulness of weak bands in mid-infrared remote sensing of particulate planetary surfaces: Jour. of Geophysical Research, v. 92, p. 702-710.

Salisbury, J. W., Walter, L. S., and Vergo, Norma, 1987b, Mid-Infrared (2.1 to 25 μm) Spectra of Minerals: First Edition: U.S. Geological Survey Open-File Report 87-263, 356p.

Salisbury, J. W., and Walter, L. S., 1988, Thermal infrared (2.5 to 13.5 μm) spectroscopic remote sensing of igneous rock types on particulate planetary surfaces: submitted to the Jour. of Geophysical Research.

Smith, J. V., and Bailey, S. W., 1963, A second review of Al-O and Si-O tetrahedral distances: Acta Crystall., v. 16, p. 801-811.

Thorton, C. P., and Tuttle, O. F., 1960, Chemistry of igneous rocks: I. Differentiation index: American Jour. of Sciences, v. 259, p. 664-684.

Vincent, R. K., Rowan, L. C., Gillespie, R. E., and Knapp, Charles, 1975, Thermal-infrared spectra and chemical analyses of twenty-six igneous rock samples: Remote Sensing of Environment, v. 4, p. 199-209.

Walter, L. S., and Salisbury, J. W., 1988, Spectral characterization of igneous rocks in the 8 to 12 μm region: submitted to Jour. of Geophysical Research.

Winchell, N.H., and Winchell, A.N., 1927, Optical Elements of Mineralogy: Part II. Descriptions of Minerals: John Wiley and Sons, Inc., p. 295.

8.0 APPENDIX 1

Spectra and description sheets of solid and particulate igneous rocks are grouped according to rock type and presented alphabetically within each group.

Rock Type	Rock Name	Sample No.	Digital File Name	Page No.
Mafic Rocks				
	Anorthosite	W-32	Anorthosite.H1	A57
	Basalt	W-36	Basalt.H1	A60
	Basalt	NMNH 111276	Basalt.H2	A63
	Basalt	KI 79-3-100	Basalt.H5	A67
	Basalt	KI 75-1-50.8	Basalt.H7	A70
	Basalt	KI 67-3-84	Basalt.H9	A73
	Basalt	KI 81-1-273.6	Basalt.H10	A76
	Diabase	W-127	Diabase.H1	A79
	Diabase	W-33	Diabase.H2	A82
	Gabbro	W-28	Gabbro.H1	A85
	Ijolite	W-19	Ijolite.H1	A88
	Lamprophyre	W-39	Lamprophyre.H1	A91
	Norite	W-125	Norite.H1	A94
	Norite	W-40	Norite.H2	A97
Ultramafic Rocks				
	Dunite	W-41	Dunite.H1	A100
	Picrite	KI 81-1-210.0	Picrite.H1	A103
	Picrite	KI 79-5-180.8	Picrite.H2	A106

Rock Name: Aplite

Locality: Boulder County, Colorado

Donor: Ward's Scientific

Catalogue Number: W-101

Hand Sample Description: A fine-grained to medium-grained leucocratic rock composed of quartz, feldspar, micas and opaques.

Petrographic Description: The sample is a holocrystalline, allotriomorphic rock consisting of undulose quartz (34%), coarsely twinned microcline (27%), and plagioclase showing albite twinning (36%); the latter are often subhedral and frequently have sericitized cores. Sympletic texture was observed in a few areas of the sample. Minor amounts of biotite are present (1.3%) which has often been altered to muscovite plus hematite. Opaques comprise <1% of the rock sample. There was no sign of calcite in thin section, nor was the rock analyzed for CO_2, but the spectrum shows weak carbonate bands indicating a small amount of calcite (<1%).

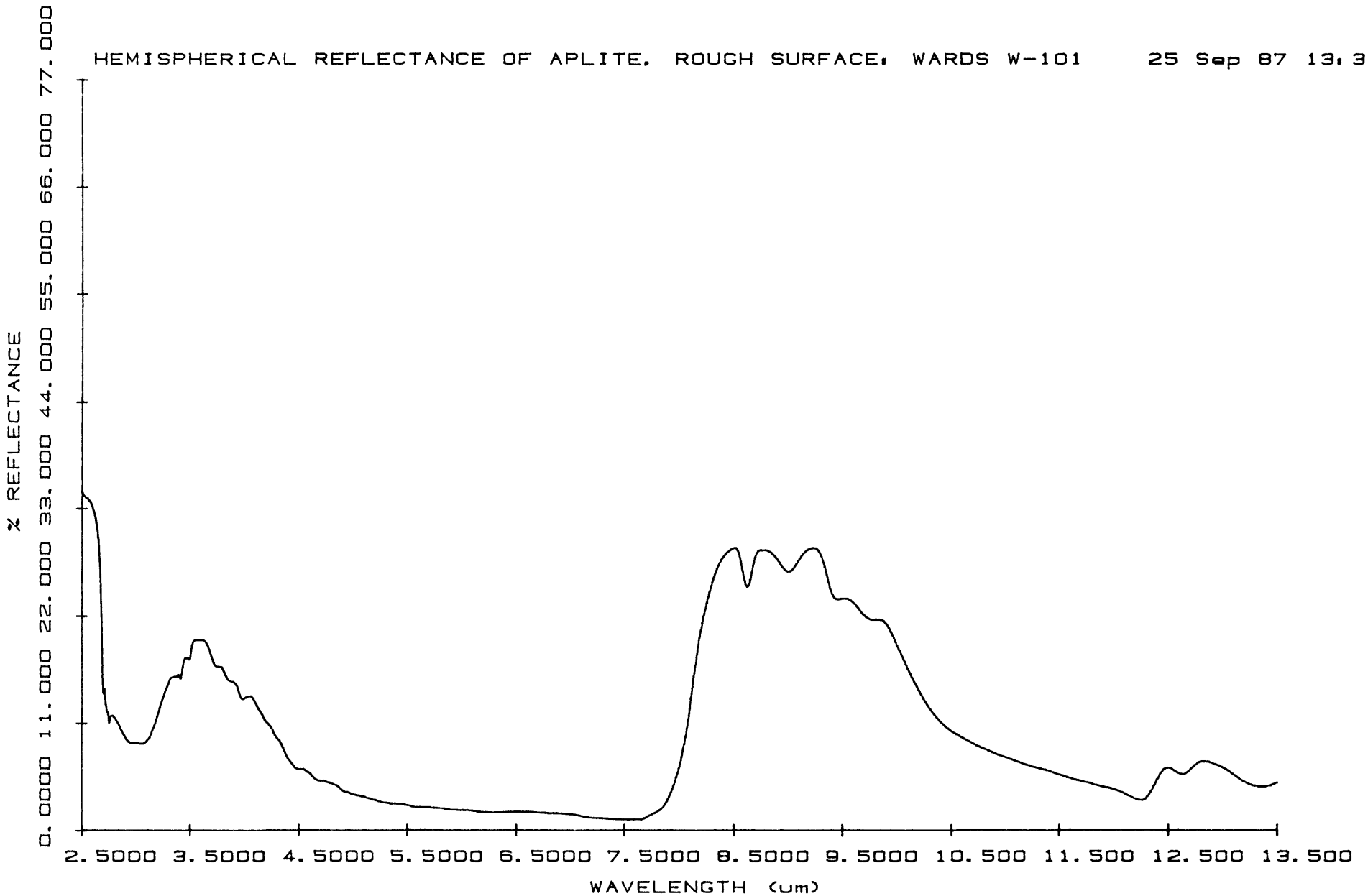
Microprobe Analysis: Microprobe analysis revealed that the alkali feldspar contained very little sodium (~1% by weight), while the plagioclase composition was nearly constant at about An_{15} (oligoclase).

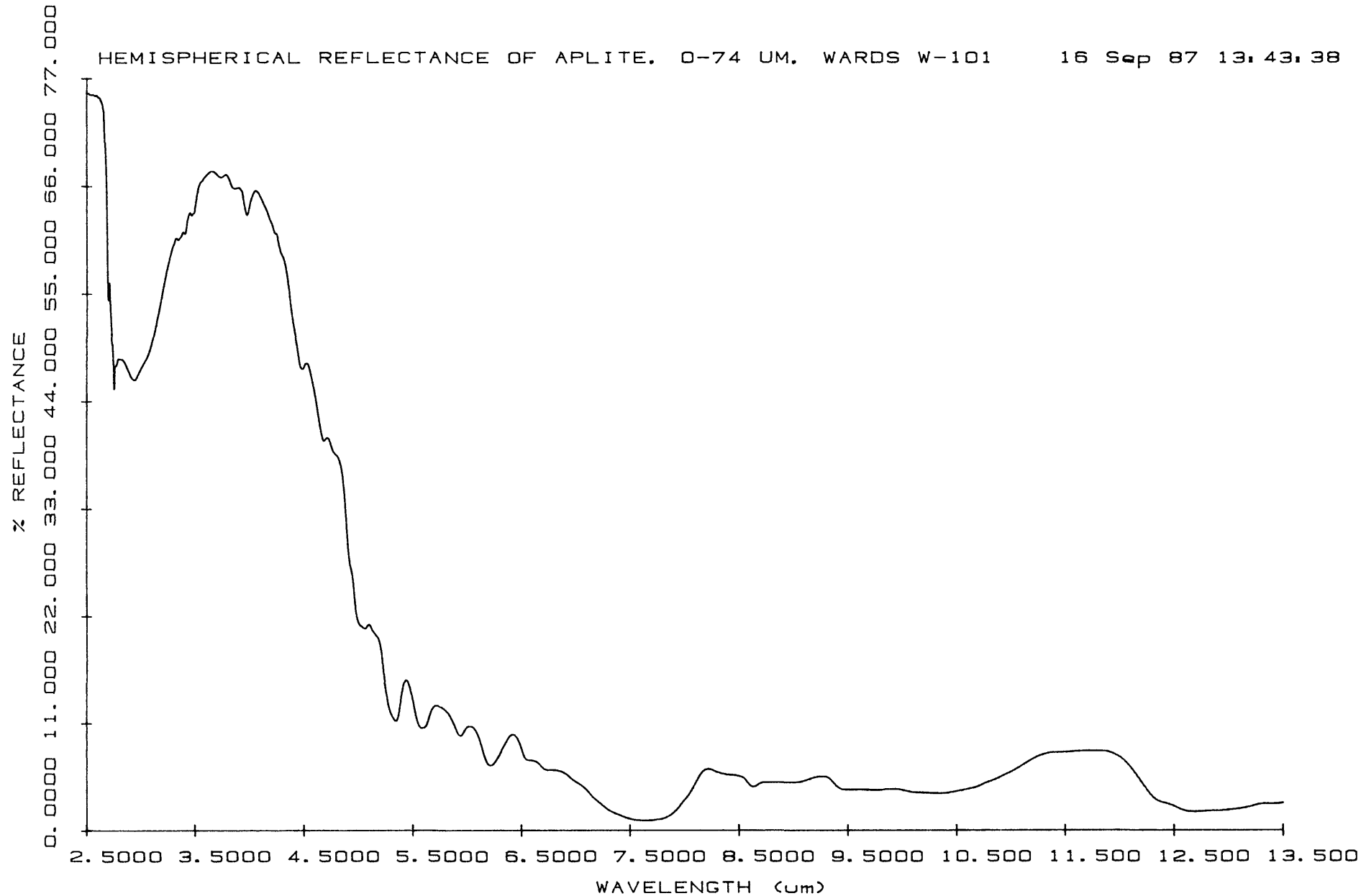
Chemical Analysis:

SiO_2	75.8	CaO	1.39
TiO_2	0.03	Na_2O	4.31
Al_2O_3	13.99	K_2O	3.55
Fe_2O_3	0.04	H_2O	0.38
FeO	0.30	P_2O_5	0.0
MnO	0.01		
MgO	0.14		
	TOTAL	99.94	

Spectra on File:

Aplite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Aplite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Aplite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF APLITE, ROUGH SURFACE; WARDS W-101 25 Sep 87 13:37:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF APLITE. 0-74 UM. WARDS W-101
16 Sep 87 13:43:38
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Granite.1

Rock Name: Alkalic Granite

Locality: Quincy, Norfolk, Massachusetts

Donor: Ward's Scientific

Catalogue Number: W-4

Hand Sample Description: A gray, medium- to coarse-grained rock composed of quartz, feldspar, and a mafic mineral.

Petrographic Description: A granular hypidiomorphic rock composed of 65% orthoclase, 30% quartz, 3% pyroxene, 1.5% riebekite, and 0.9% albite. The turbid orthoclase subhedra are highly albitized perthite frequently showing Carlsbad twinning, while interstital to these are a few albite anhedra. The anhedral quartz is somewhat undulose. A bright green, slightly pleochroic pyroxene has been largely replaced by dark blue to brown pleochroic riebekite. In addition, there are minute blue riebikite needles disseminated throughout the sample. The spectrum shows extremely weak carbonate features, but no calcite was seen in thin section nor was the rock analyzed for CO_2.

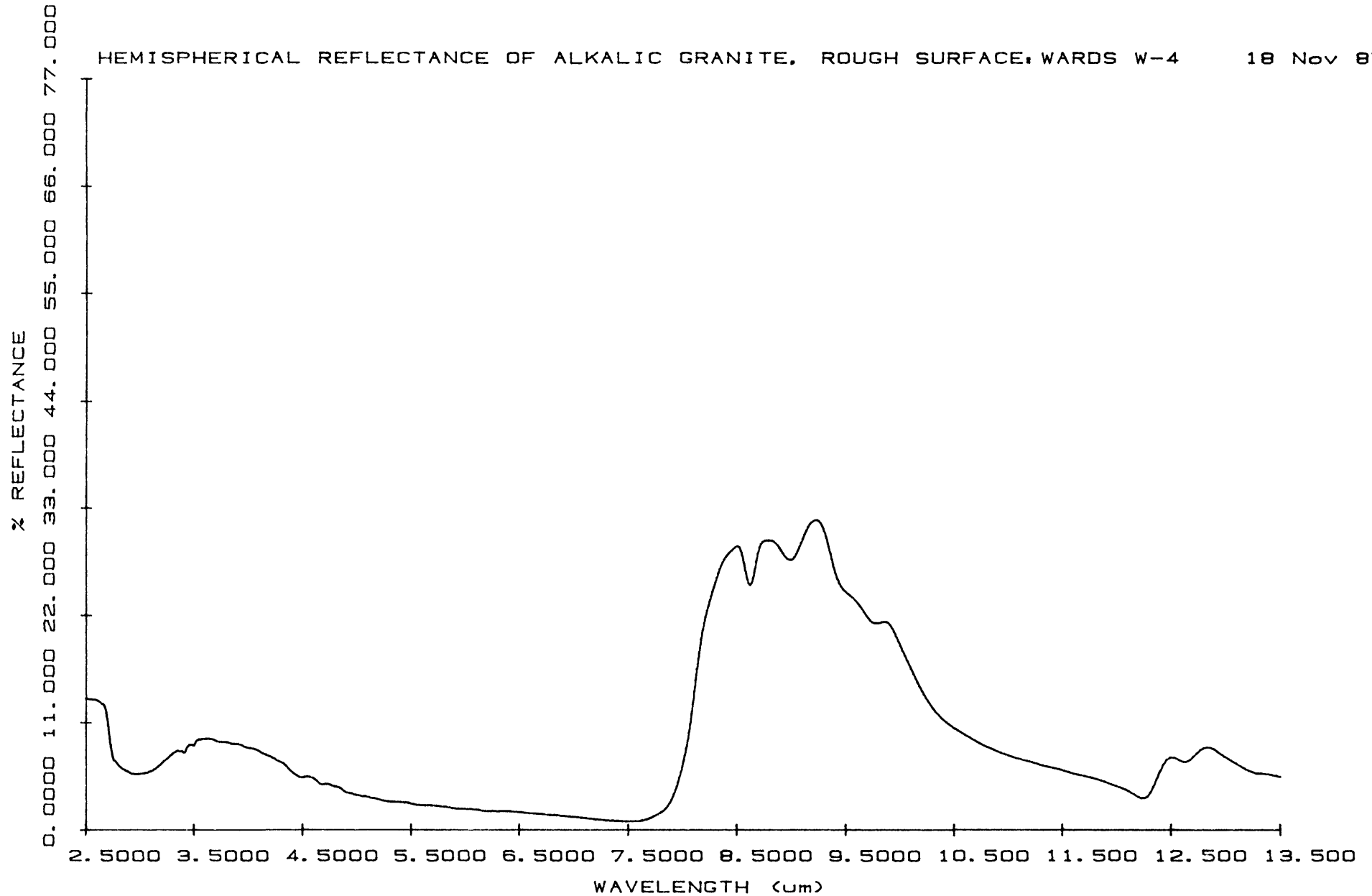
Microprobe Analysis: The microprobe analysis revealed an orthoclase-rich compsition (Or_{97}) with perthitic exsolution. The sodic pyroxene (aegerine) proved to be homogeneous in composition, as was the riebekite.

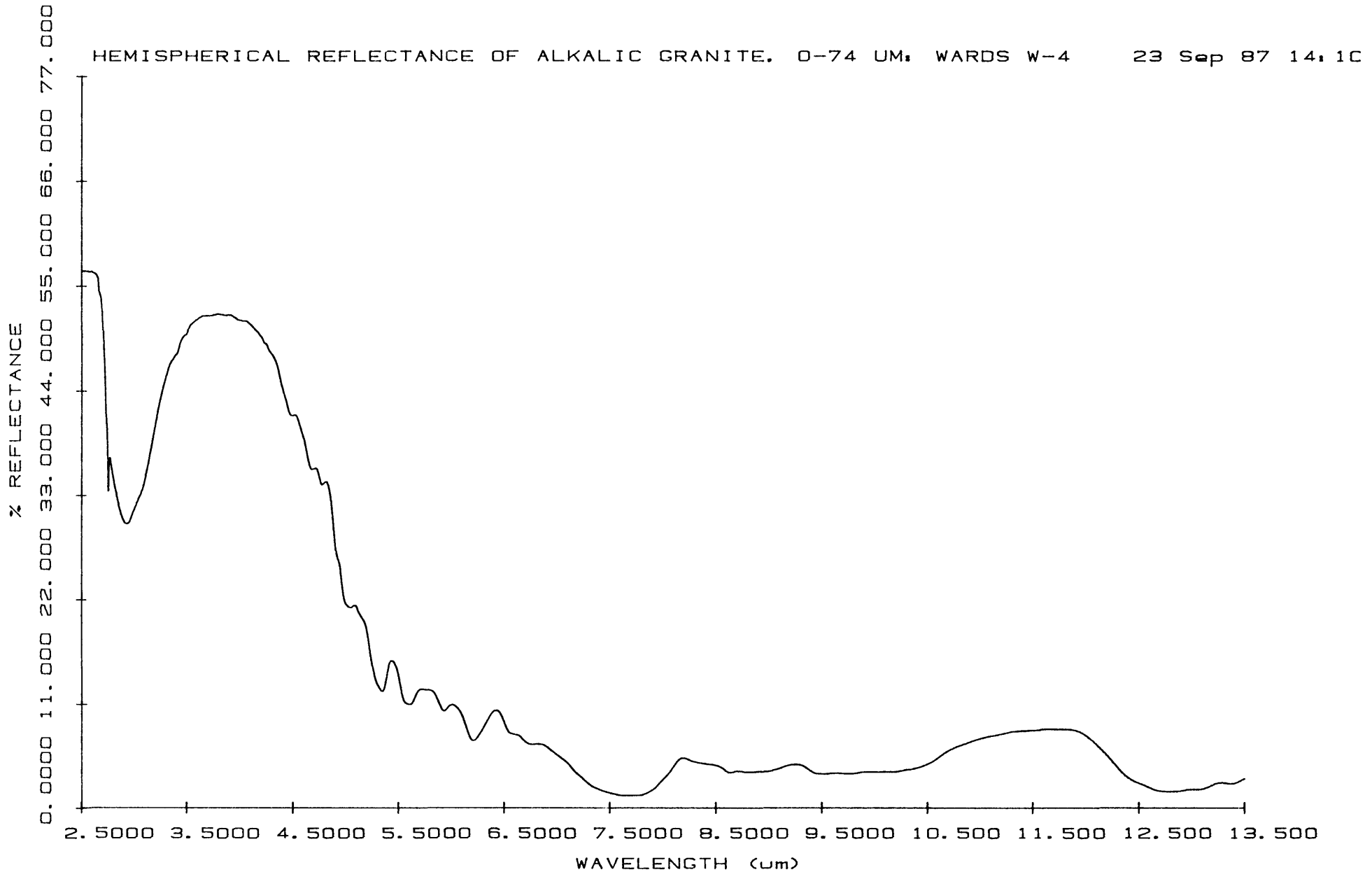
Chemical Analysis:

SiO_2	73.44	CaO	0.39
TiO_2	0.21	Na_2O	4.96
Al_2O_3	12.29	K_2O	4.94
Fe_2O_3	2.11	H_2O	0.56
FeO	1.6	P_2O_5	0.0
MnO	0.08		
MgO	0.02		
	TOTAL		100.6

Spectra on File:

Granite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Granite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Granite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF ALKALIC GRANITE, ROUGH SURFACE: WARDS W-4
18 Nov 87
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF ALKALIC GRANITE. 0-74 UM: WARDS W-4 23 Sep 87 14:10
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Granite

Locality: Santa Rita Mountains, Arizona

Donor: Smithsonian

Catalogue Number: NMNH 113640-17

Hand Sample Description: A gray, medium-grained rock consisting of white feldspar grains, some of which contain red or pinkish cores, quartz, and minor biotite. Some of the feldspar appears to be perthitic.

Petrographic Description: Typically these rocks are hypidiomorphic with granular texture. Quartz, orthoclase, and plagioclase make up at least 93% of the rocks. Quartz anhedra possess moderate to strong undulatory extinction, the orthoclase anhedra are slightly kaolinitized. Perthite is common in the orthoclase with the amount of albite in the orthoclase ~8%. The plagioclase is often sericitized, while the biotite is largely altered to chlorite. The modes for this sample were; 40.4% orthoclase, 38.5% quartz, 19.7% plagioclase, 1.1% biotite, and 0.3% magnetite. There was no sign of carbonate in thin section, but spectrum and chemical analysis both indicate presence of a small amount.

Microprobe Analysis: The analysis revealed the plagioclase composition to be albite, with no more than 5% anorthite.

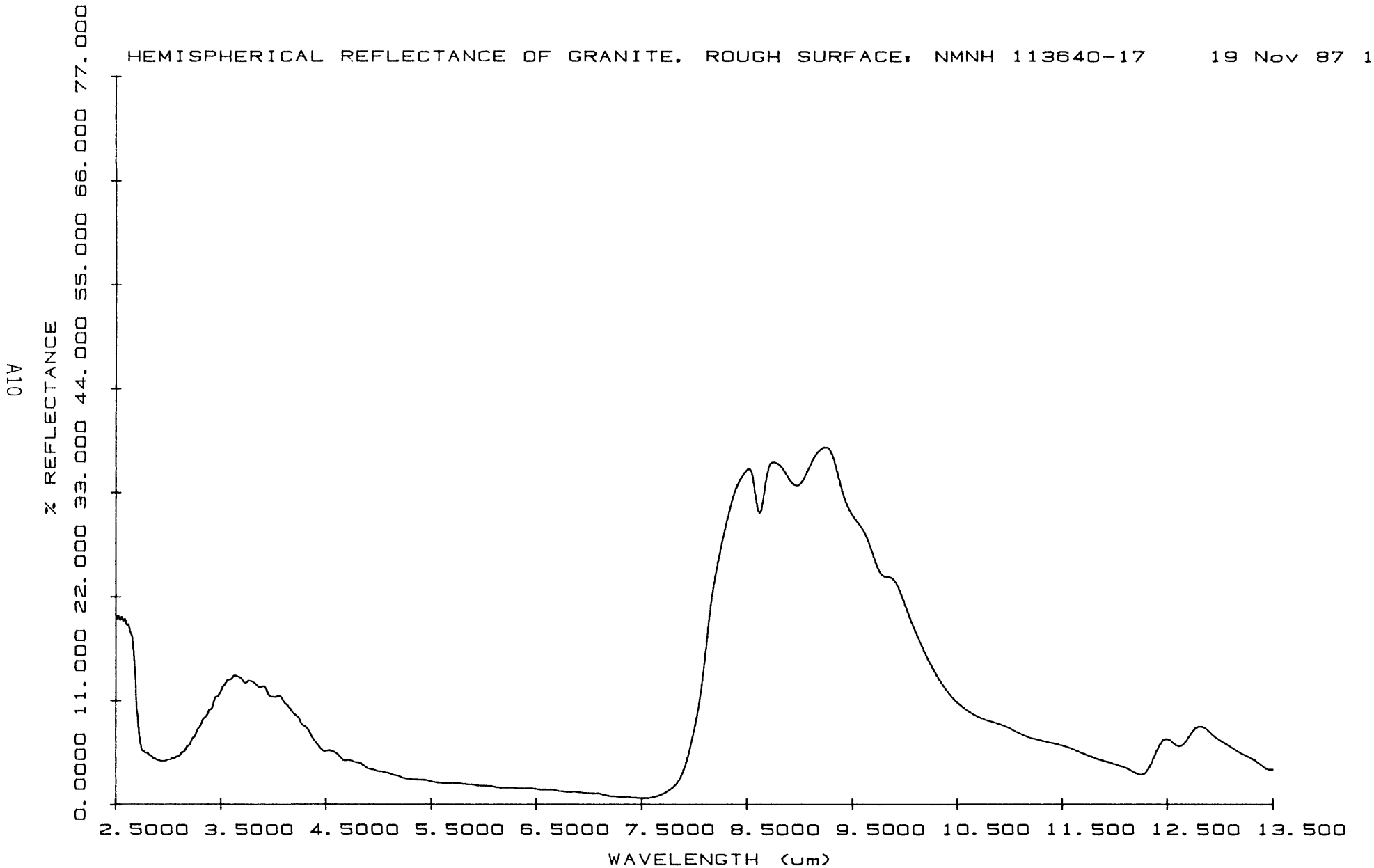
Chemical Analysis:

SiO_2	75.50	CaO	0.35
TiO_2	0.21	Na_2O	3.5
Al_2O_3	12.6	K_2O	4.7
Fe_2O_3	1.0	H_2O	1.04
FeO	0.24	P_2O_5	0.02
MnO	0.02	CO_2	0.15
MgO	0.23		
	TOTAL	99.56	

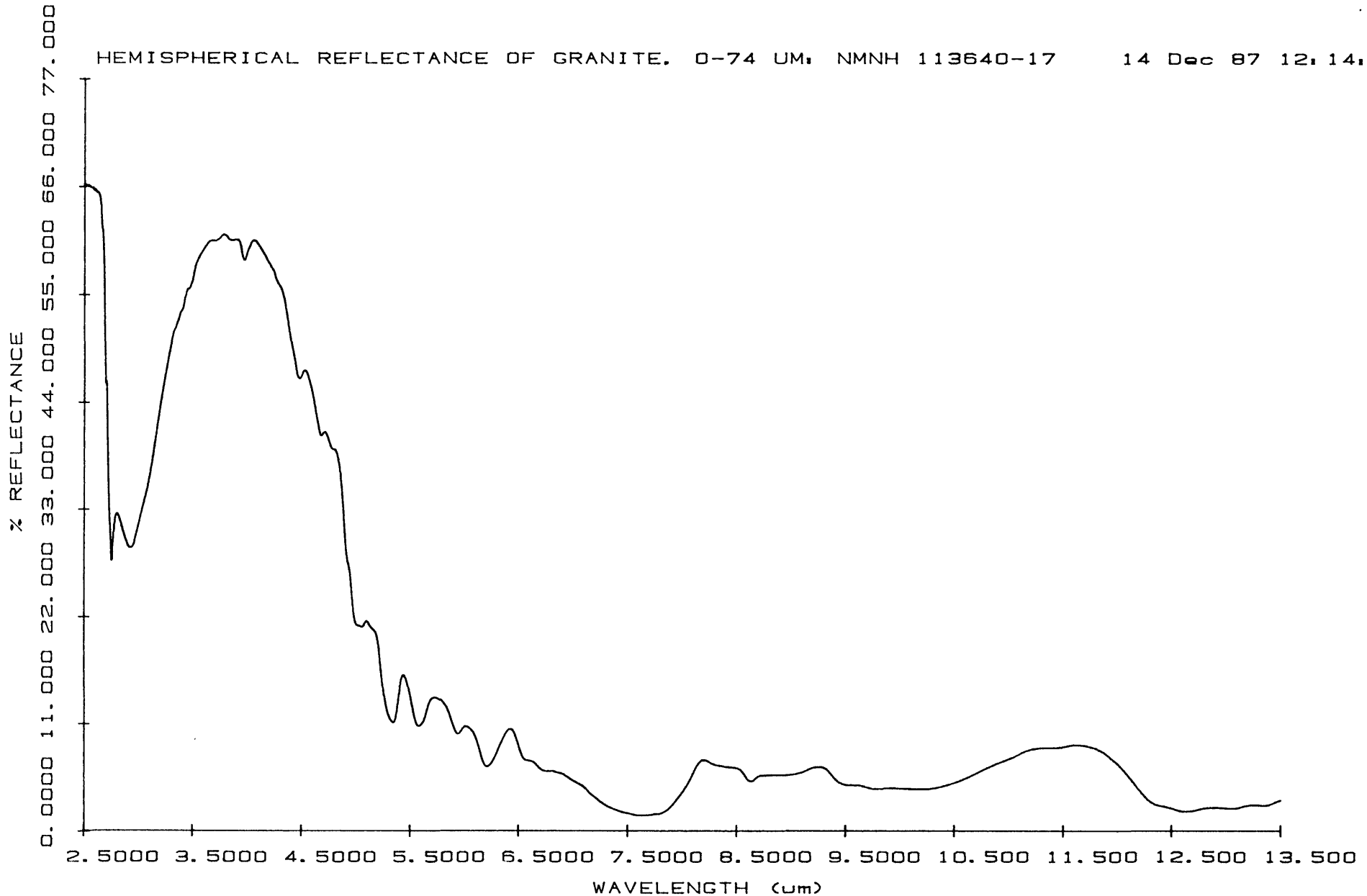
Reference: Harold Drewes, 1976, Plutonic Rocks of the Santa Rita Mountains, Southeast of Tuscon, Arizona, USGS Prof. Paper 915.

Spectra on File:

Granite.H2 Hemispherical reflectance of rough surface on Solid Rock disk #1
Granite.H2 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF GRANITE. ROUGH SURFACE: NMNH 113640-17 19 Nov 87 15
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A10


HEMISPHERICAL REFLECTANCE OF GRANITE. 0-74 UM; NMNH 113640-17 14 Dec 87 12:14:07
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Name: Granite

Locality: Santa Rita Mountains, Arizona

Donor: Smithsonian

Catalogue Number: NMNH 113640-13

Hand Sample Description: A light gray, medium- to coarse-grained rock consisting of gray plagioclase, white feldspar, quartz, and chloritized biotite.

Petrographic Description: The sample consists of 37.6% orthoclase, 36.1% plagioclase (of which 11.3% is perthitic), 23.2% quartz, 1.9% biotite, and 0.9% magnetite. The quartz in these samples is typically undulatory, the orthoclase is frequently perthitic and slightly kaolinitized, while the plagioclase is often sericitized. There was no sign of carbonate in thin section, but spectrum and chemical analysis both indicate presence of a small amount.

Microprobe Analysis: The plagioclase phases proved to be pure albite.

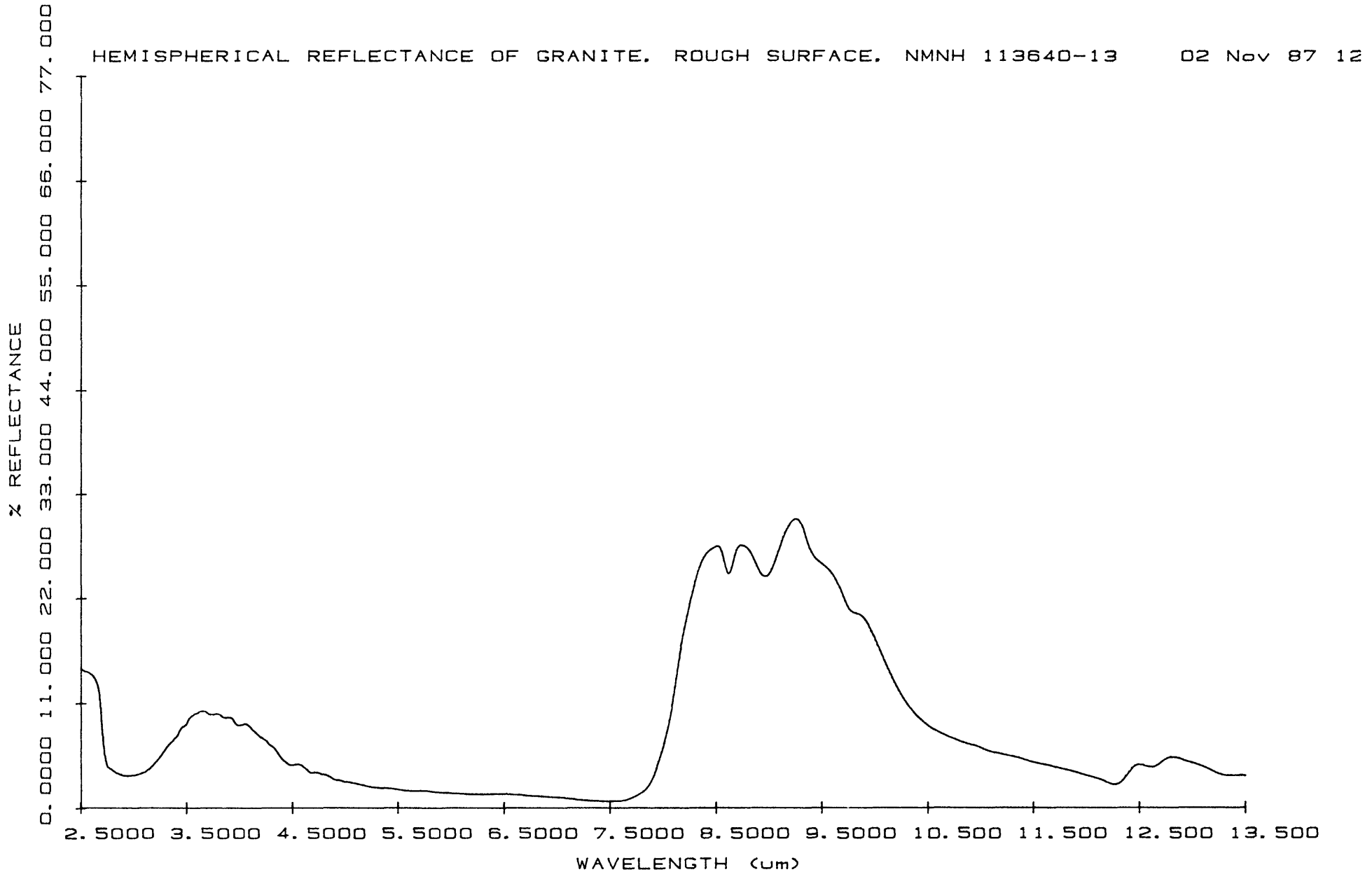
Chemical Analysis:

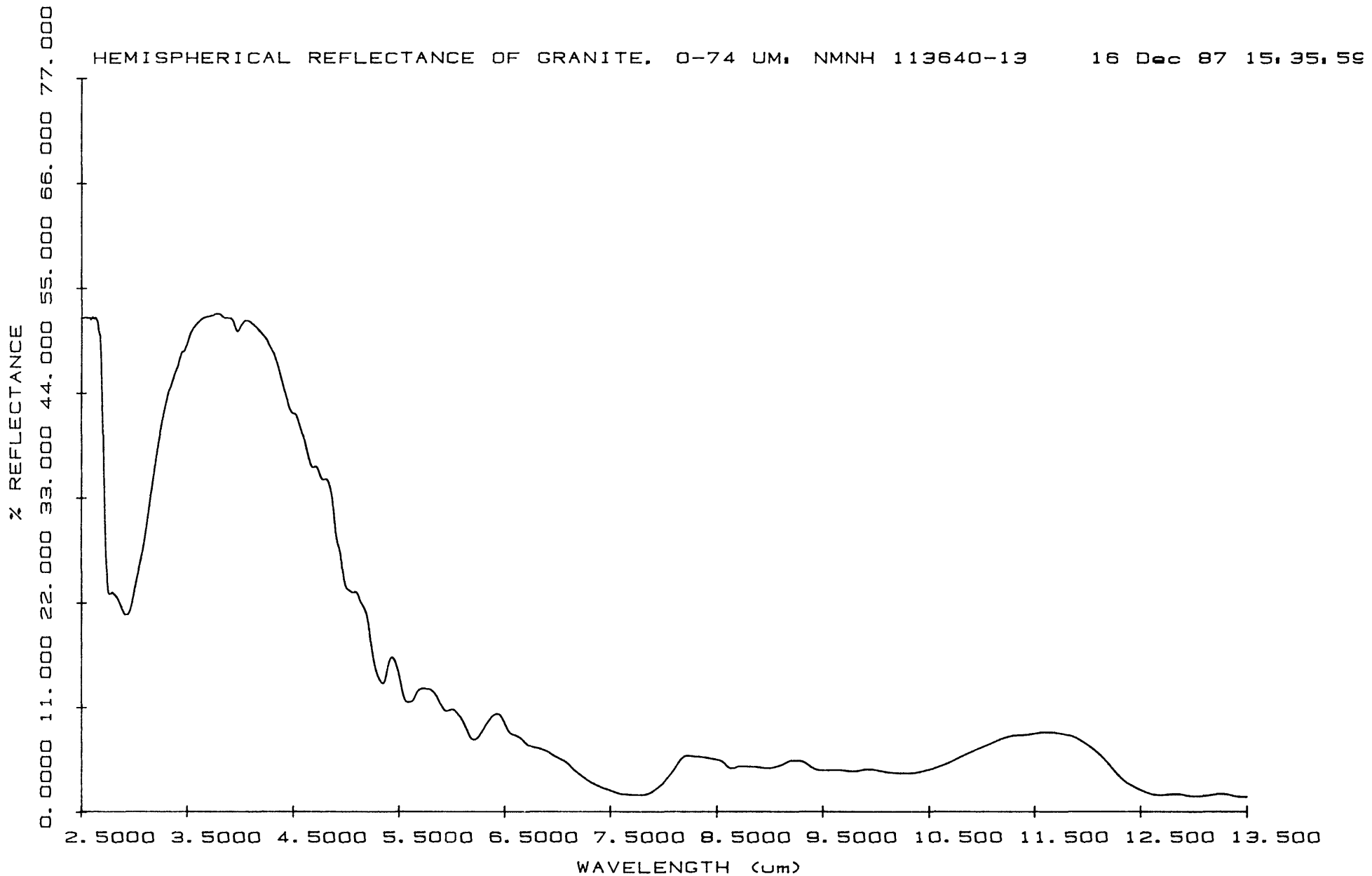
SiO_2	69.1	CaO	1.1
TiO_2	0.42	Na_2O	4.0
Al_2O_3	15.2	K_2O	5.2
Fe_2O_3	1.9	H_2O	1.27
FeO	1.0	P_2O_5	0.16
MnO	0.03	CO_2	0.19
MgO	0.55		
	TOTAL		100.10

Reference: Harold Drewes, 1976, Plutonic Rocks of the Santa Rita Mountains, Southeast of Tuscon, Arizona, USGS Prof. Paper 915.

Spectra on File:

Granite.H3 Hemispherical reflectance of rough surface on Solid Rock disk #1
Granite.H3 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF GRANITE. ROUGH SURFACE. NMNH 113640-13 02 Nov 87 12
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF GRANITE, 0-74 UM; NMNH 113640-13
16 Dec 87 15:35:59
% REFLECTANCE
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2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Granite.5

Rock Name: Granite

Locality: Santa Rita Mountains, Arizona

Donor: Smithsonian

Catalogue Number: NMNH 113640-15

Hand Sample Description: A pinkish medium-grained sample consisting of feldspar and quartz with minor biotite. Some areas of the sample show granophyric texture and a few vugs are present.

Petrographic Description: The sample consists of 47.9% orthoclase, 35.2% quartz, 14.6% plagioclase (of which 6.6% is perthitic), 1.4% biotite and 0.8% magnetite. In these rocks the quartz anhedra show moderate to strong undulatory extinction, the orthoclase anhedra are often finely perthitic and slightly kaolinitized. The plagioclase often show sericitic alteration while the biotite may be altered to chlorite. The thin section did not show any carbonate, but the spectrum and chemical analysis both indicate a trace is present.

Microprobe Analysis: In this sample all the plagioclase probed was pure albite.

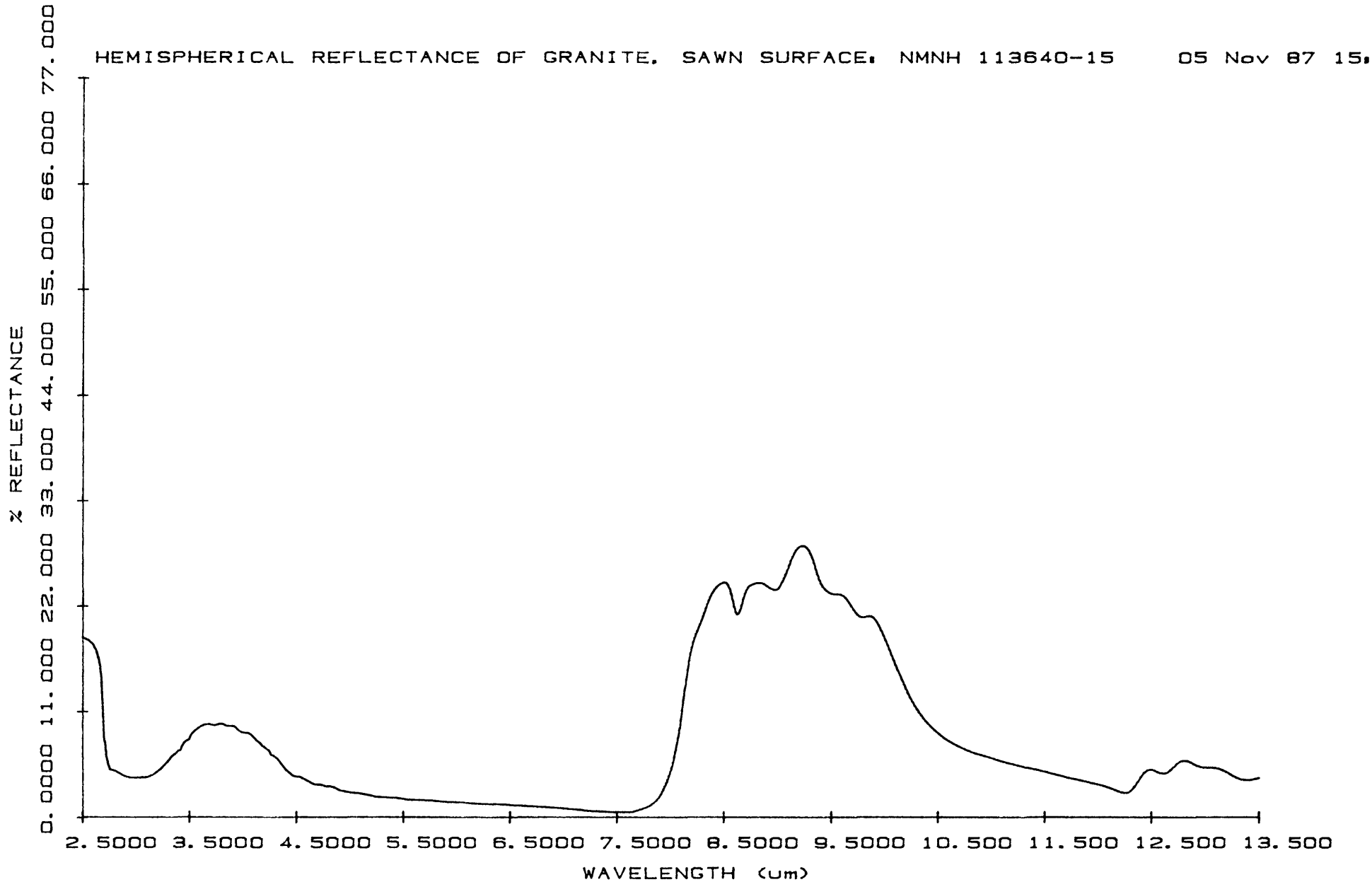
Chemical Analysis:

SiO_2	75.10	CaO	0.19
TiO_2	0.18	Na_2O	3.6
Al_2O_3	13.0	K_2O	5.5
Fe_2O_3	1.3	H_2O	0.73
FeO	0.18	P_2O_5	0.01
MnO	0.02	CO_2	0.05
MgO	0.05		
	TOTAL 99.91		

Reference: Harold Drewes, 1976, Plutonic Rocks of the Santa Rita Mountains, Southeast of Tuscon, Arizona, USGS Prof. Paper 915.

Spectra on File:

Granite.H5 Hemispherical reflectance of rough surface on Solid Rock disk #1
Granite.H5 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF GRANITE. SAWN SURFACE: NMNH 113640-15 05 Nov 87 15:
% REFLECTANCE
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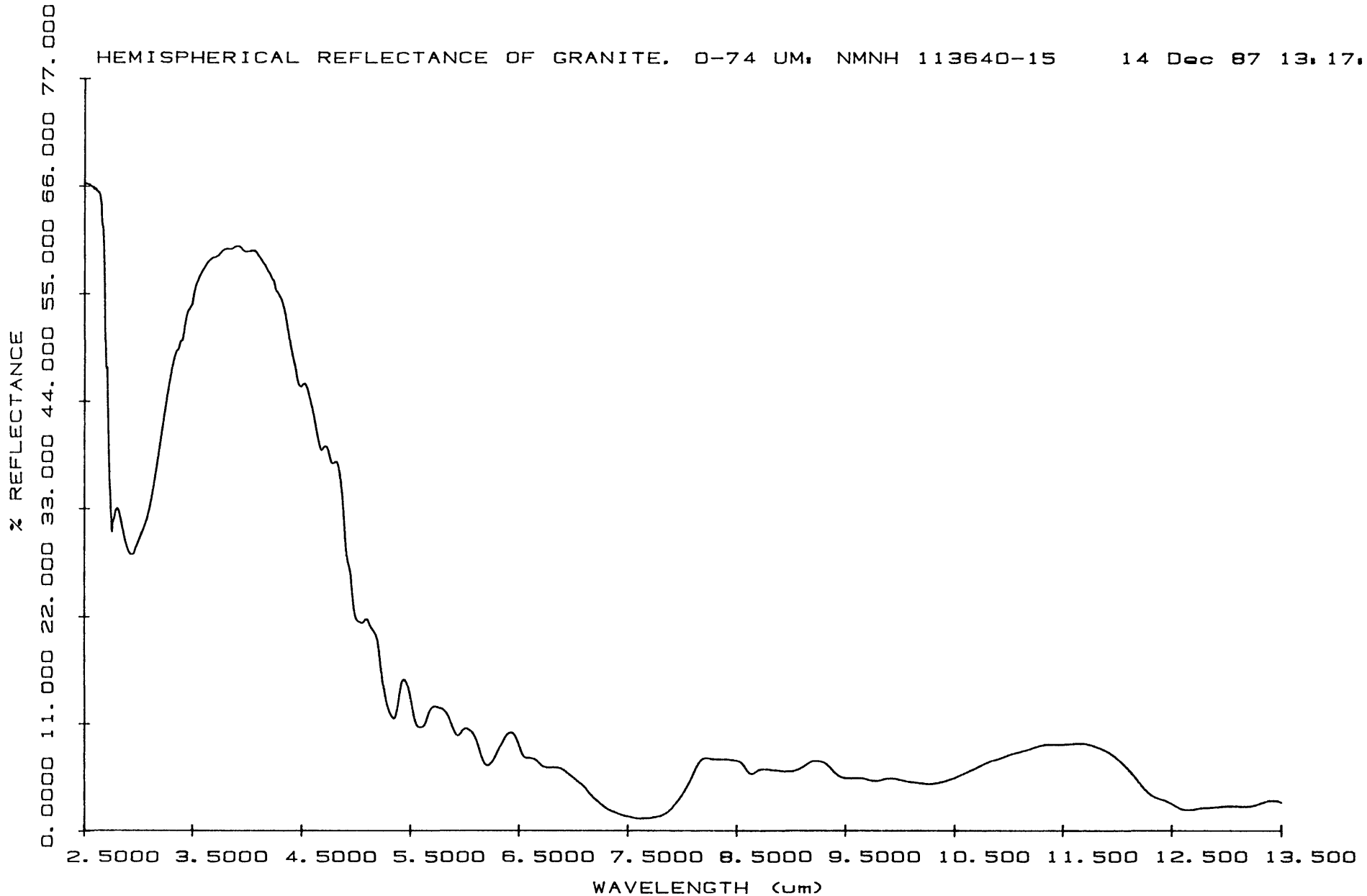
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF GRANITE. 0-74 UM: NMNH 113640-15
14 Dec 87 13:17:54
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Obsidian.1

Rock Name: Rhyolitic obsidian

Locality: Mono Lake, California

Donor: Smithsonian

Catalogue Number: NMNH 111123-60

Hand Sample Description: This sample appears to be a black homogenous glass with good conchoidal fracture.

Petrographic Description: The sample is chiefly a structurless glass which is isotropic and colorless in this section. There are fluidal arrangements of gas inclusions and microlites of biotite, augite, probably feldspars and other unidentified phases. High magnification shows trichites. This appearance is not constant throughout the mass.

Microprobe Analysis: None.

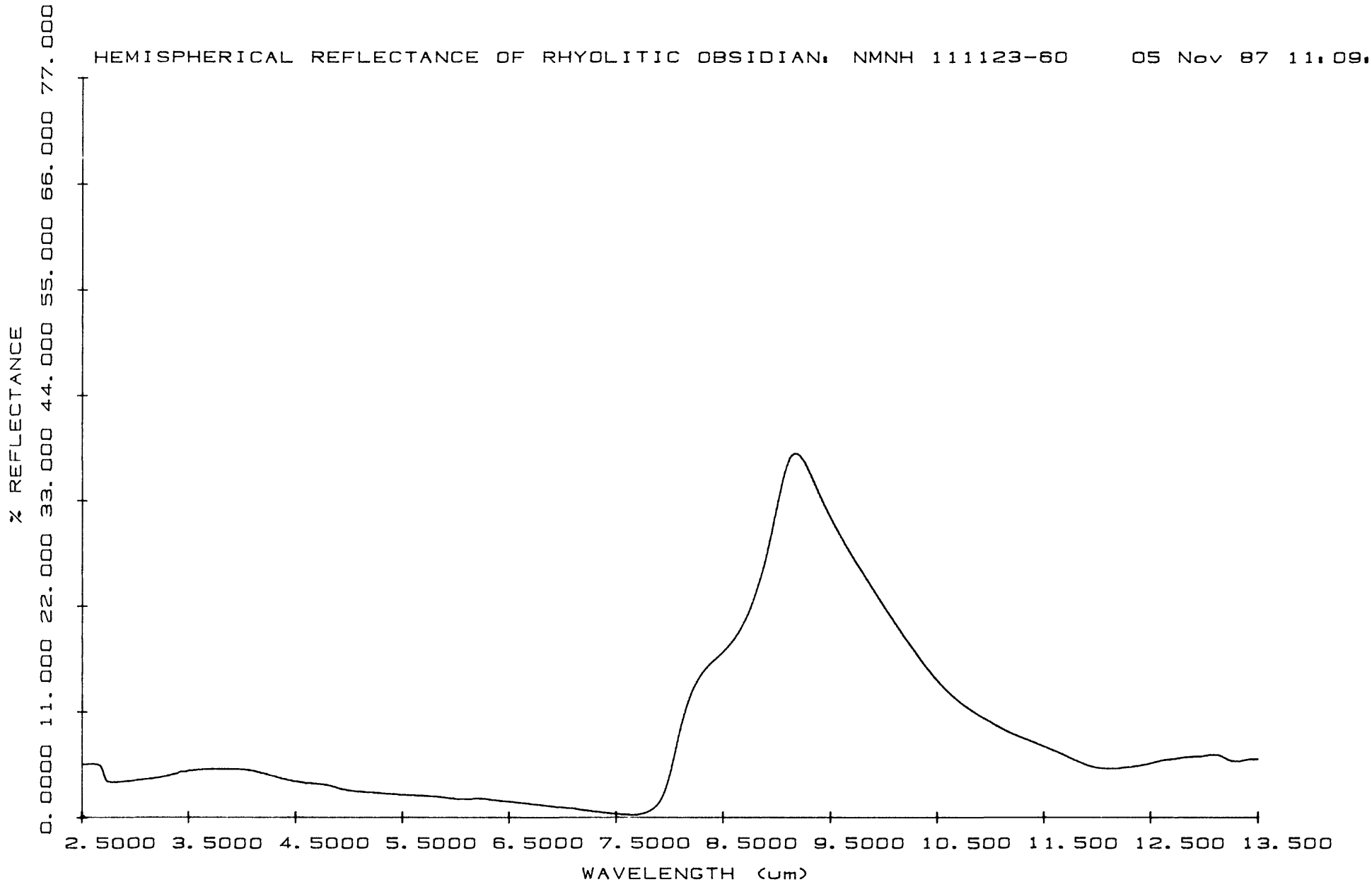
Chemical Analysis:

SiO_2	- 75.78	CaO	- 0.81
Al_2O_3	- 12.39	Na_2O	- 4.00
Fe_2O_3	- 0.22	K_2O	- 4.64
FeO	- 1.25		
MgO	- 0.31		
	TOTAL 99.4		

Reference: Diller, J.S., 1898, The Educational Series of Rock Specimens Collected and Distributed by the United States Geological Survey, USGS Bulletin 150, p. 149-151.

Spectra on File:

Obsidian.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Obsidian.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1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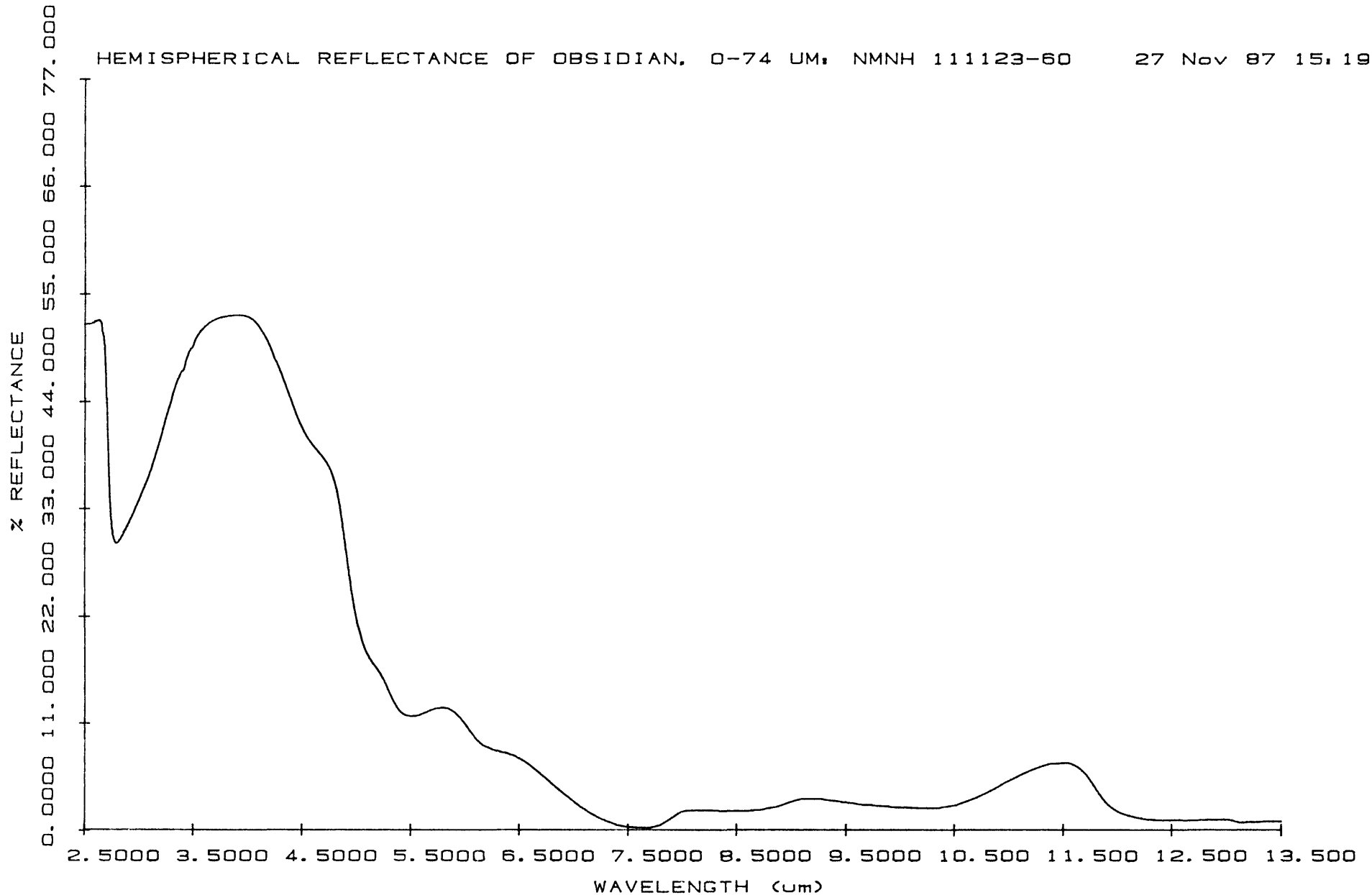
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF OBSIDIAN, 0-74 UM; NMNH 111123-60 27 Nov 87 15:19:1
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A20

Rock Name: Rhyolite

Locality: Pennsylvania Hill near Rosita, Custer County, Colorado

Donor: Smithsonian

Catalogue Number: NMNH 111123-525

Hand Sample Description: A reddish, banded, porphyritic rock with the phenocrysts small (< 1 mm) and variable in size.

Petrographic Description: The groundmass is glassy, microlitic and spherulitic. The phenocrysts consist of sanidine > plagioclase (oligoclase in part) > biotite > quartz. Accessories are apatite and magnetite.

Microprobe Analysis: None.

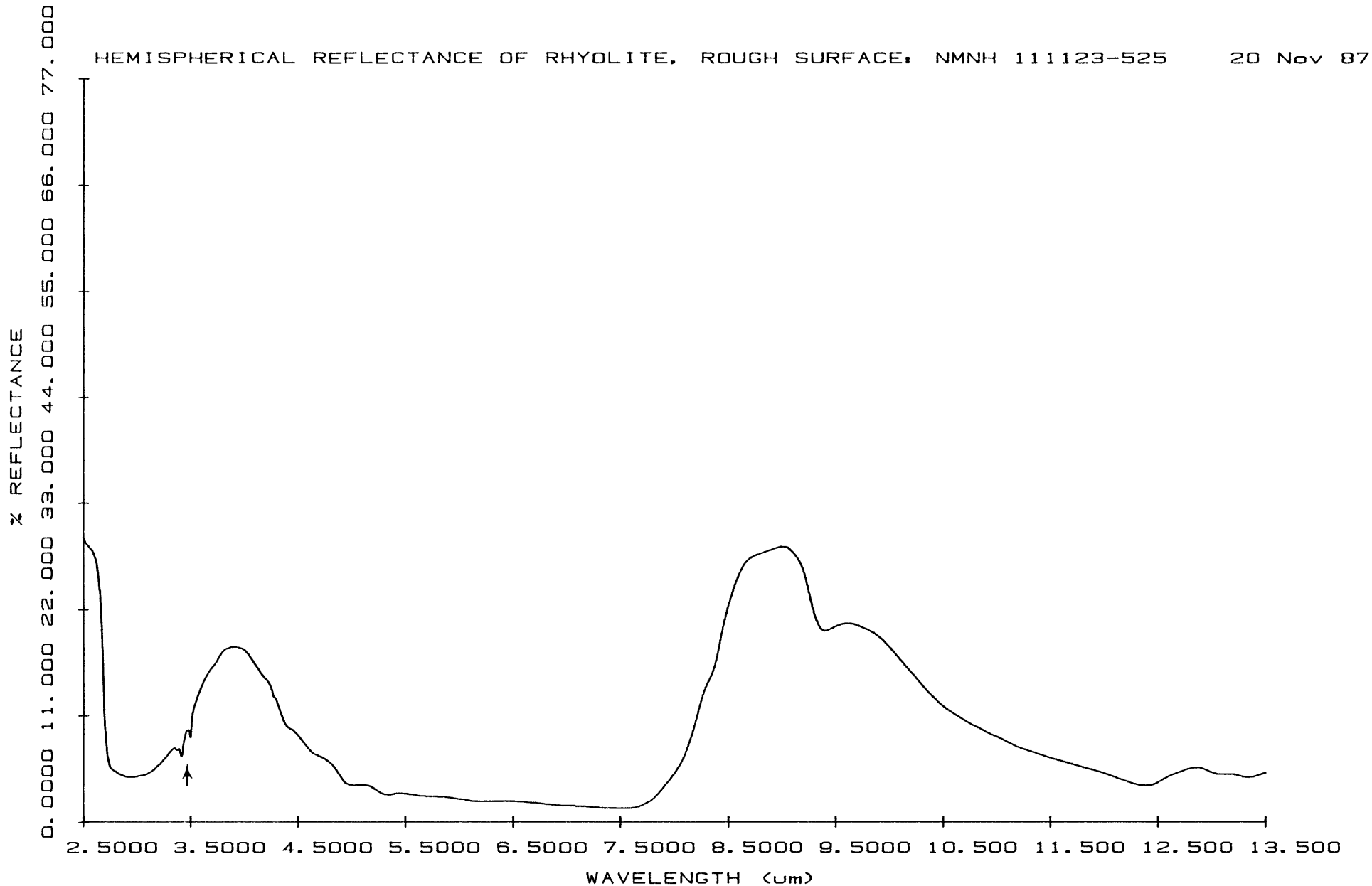
Chemical Analysis:

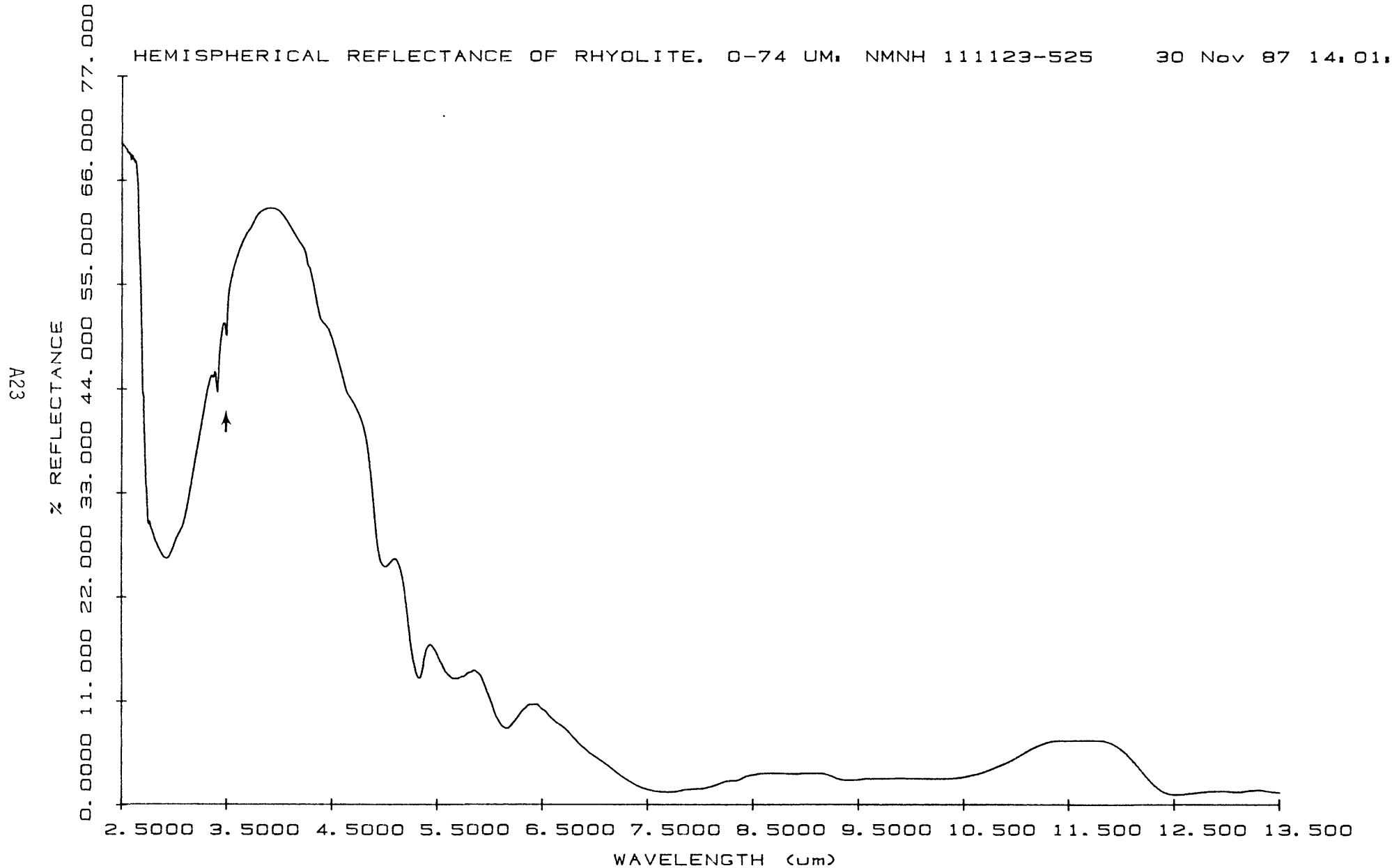
SiO_2	70.87	CaO	1.58
TiO_2	trace	Na_2O	3.47
Al_2O_3	15.18	K_2O	5.04
Fe_2O_3	2.18	H_2O	1.08
FeO	0.12	P_2O_5	trace
MnO	trace		
MgO	0.6		
	TOTAL		100.12

Reference: W. Cross, 1896, Geology of Silver Cliff and the Rosita Hills in 17th Ann. Rept. USGS, pt. II, p. 296-297, 324, 349.

Spectra on File:

Rhyolite.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Rhyolite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF RHYOLITE. ROUGH SURFACE: NMNH 111123-525 20 Nov 87
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF RHYOLITE. 0-74 UM. NMNH 111123-525 30 Nov 87 14:01:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Augite-hypersthene Andesite

Locality: Saipan

Donor: Smithsonian

Catalogue Number: NMNH 108982-135

Hand Sample Description: The sample is about 4 x 3 cm, brown on the weathered surface and dark gray on fresh surfaces. It is porphyritic with the phenocrysts making up about 25-30% of the rock. The groundmass is gray and microcrystalline. The phenocrysts are ~≤ 1mm and consist of plagioclase laths, pyroxene and opaques, in that order of abundance, with pyroxenes nearly as abundant as the feldspars.

Petrographic Description: The modes for phenocrysts for this sample gave 26.75% plagioclase, 8.5% augite, 1.05% magnetite, 0.95% hypersthene, and 62.75% groundmass. The groundmass for these samples consists of labradorite, augite, hypersthene, magnetite, ilmenite, trydimite as isolated grains and aggregates of small wedge-shaped crystals closely associated with small patches of intergrown granular quartz and chalcedony, anorthoclase, and partly devitrified glass.

Microprobe Analysis: The composition of the plagioclase phenocrysts was found to range from An_{59} to An_{62} (labradorite), while the composition in the groundmass ranged from An_{50} to An_{55}. The augite phenocryst composition was Wo 34%, En 43%, Fs 23%, that of the hypersthene phenocrysts was En 67%, Fs 33%. Augite in the groundmass was WO 24%, En 45%, Fs 31%.

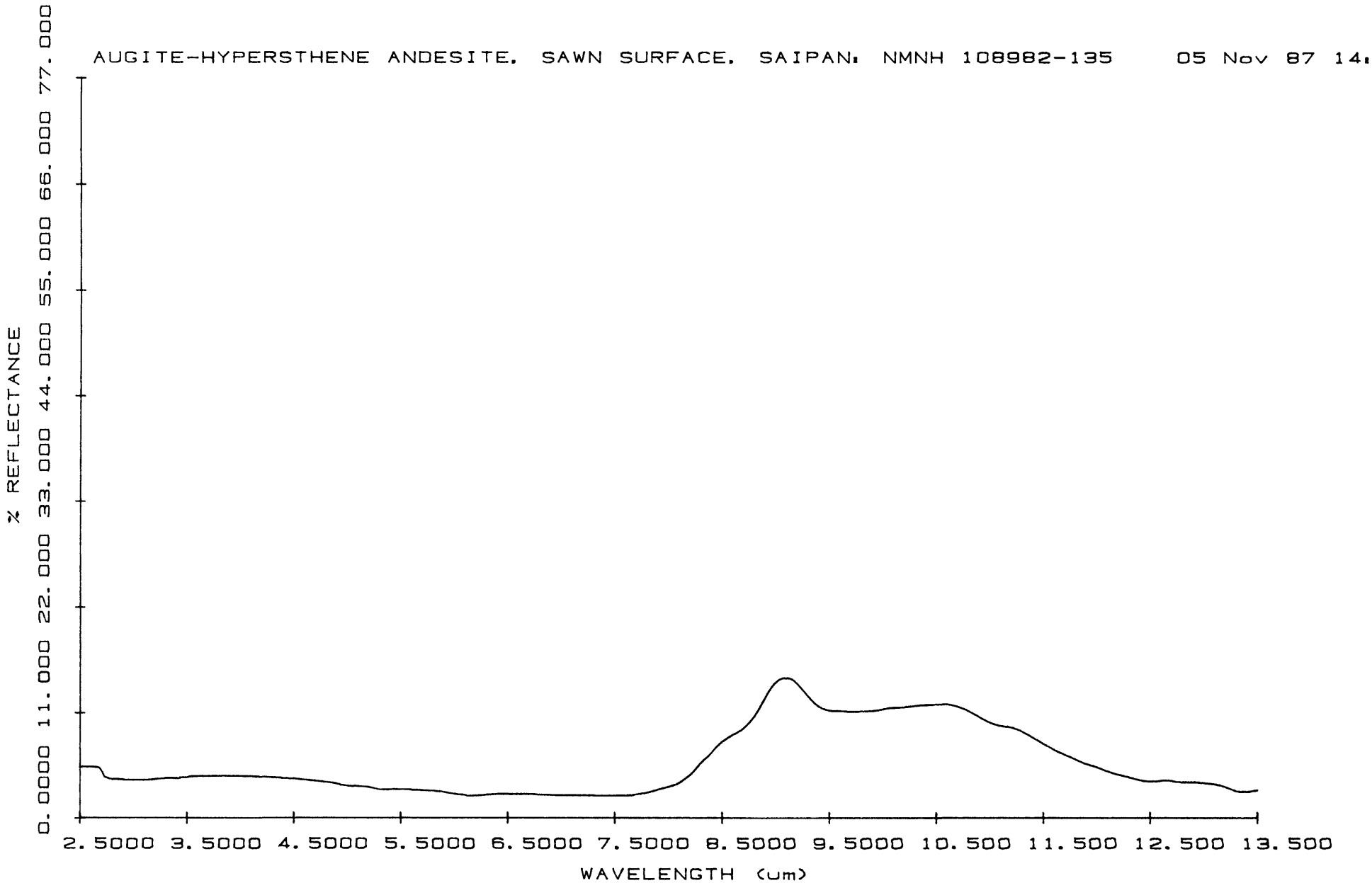
Chemical Analysis:

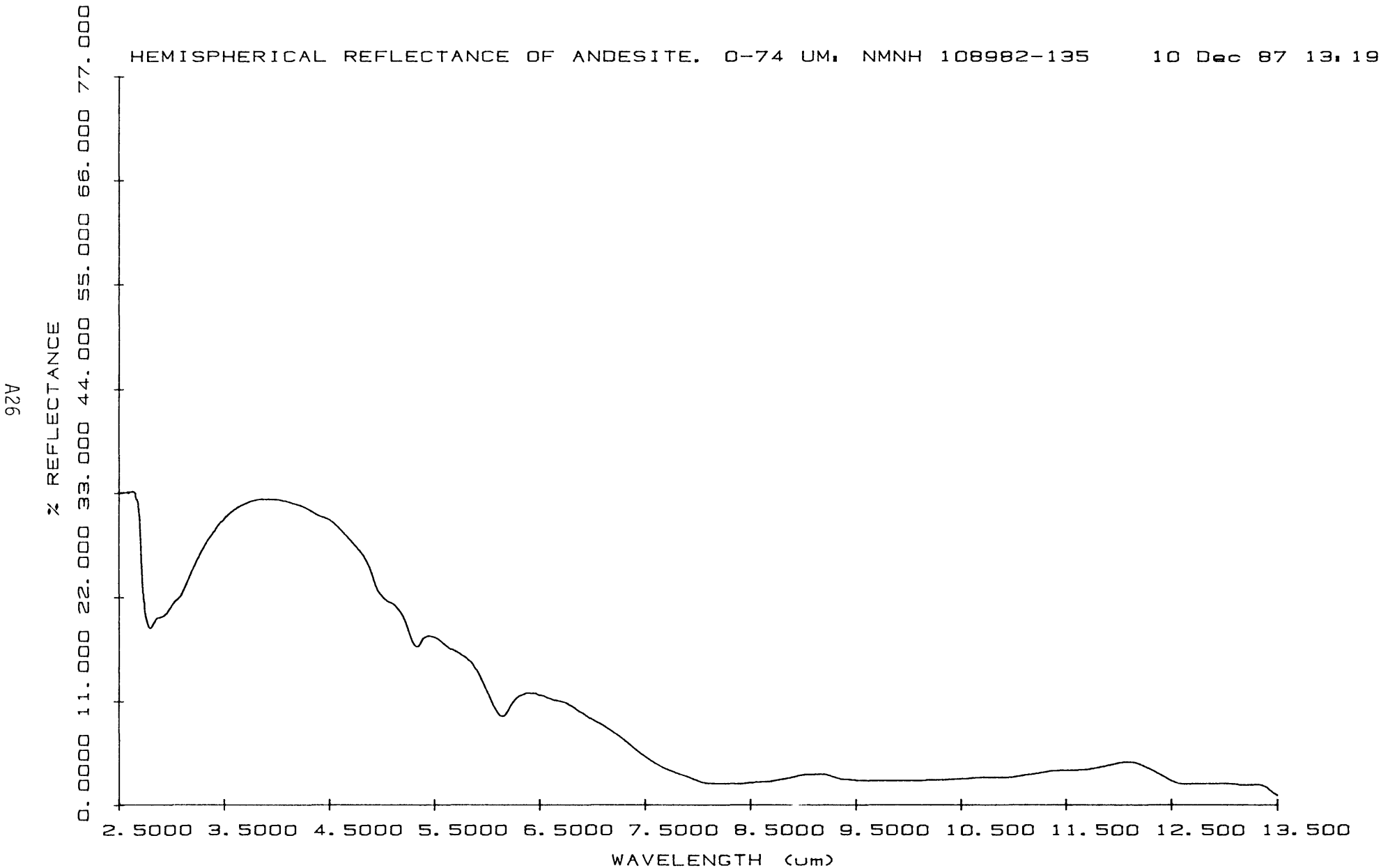
SiO_2	57.20	CaO	8.85
TiO_2	0.54	Na_2O	2.50
Al_2O_3	16.35	K_2O	0.68
Fe_2O_3	2.23	H_2O	0.90
FeO	5.93	P_2O_5	0.36
MnO	0.14		
MgO	4.65		
	TOTAL		100.3

Reference: Robert George Smith, 1957, Petrology of the Volcanic Rocks in Geology of Saipan, Mariana Islands, USGS Prof. Paper 280-B.

Spectra on File:

Andesite.H1 Hemispherical reflectance of sawn surface on Solid Rock disk #1
Andesite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


AUGITE-HYPERSTHENE ANDESITE. SAWN SURFACE. SAIPAN. NMNH 108982-135 05 Nov 87 14:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF ANDESITE. 0-74 UM: NMNH 108982-135 10 Dec 87 13:19:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Augite-hypersthene Andesite

Locality: Saipan

Donor: Smithsonian

Catalogue Number: NMNH 108982-15

Hand Sample Description: The sample consists of a dark gray, fine-grained groundmass, with yellow (hypersthene?), dark green (augite?) and white (plagioclase) phenocrysts. The sample is also slightly vuggy.

Petrographic Description: The modes of phenocrysts gave 30.05% plagioclase, 9.8% hypersthene, 3.10% augite, 1.65% magnetite, and 56.30% groundmass. There was no sign of carbonate in thin section, but chemical analysis showed CO_2 (see below) and the spectrum also shows weak carbonate bands.

Microprobe Analysis: The composition of the augite phenocrysts was WO 38%, En 38%, Fs 24%, that for hypersthene gave En 64%, Fs 36%. The average composition of plagioclase phenocrysts ranged from An_{55} to An_{58} (labradorite).

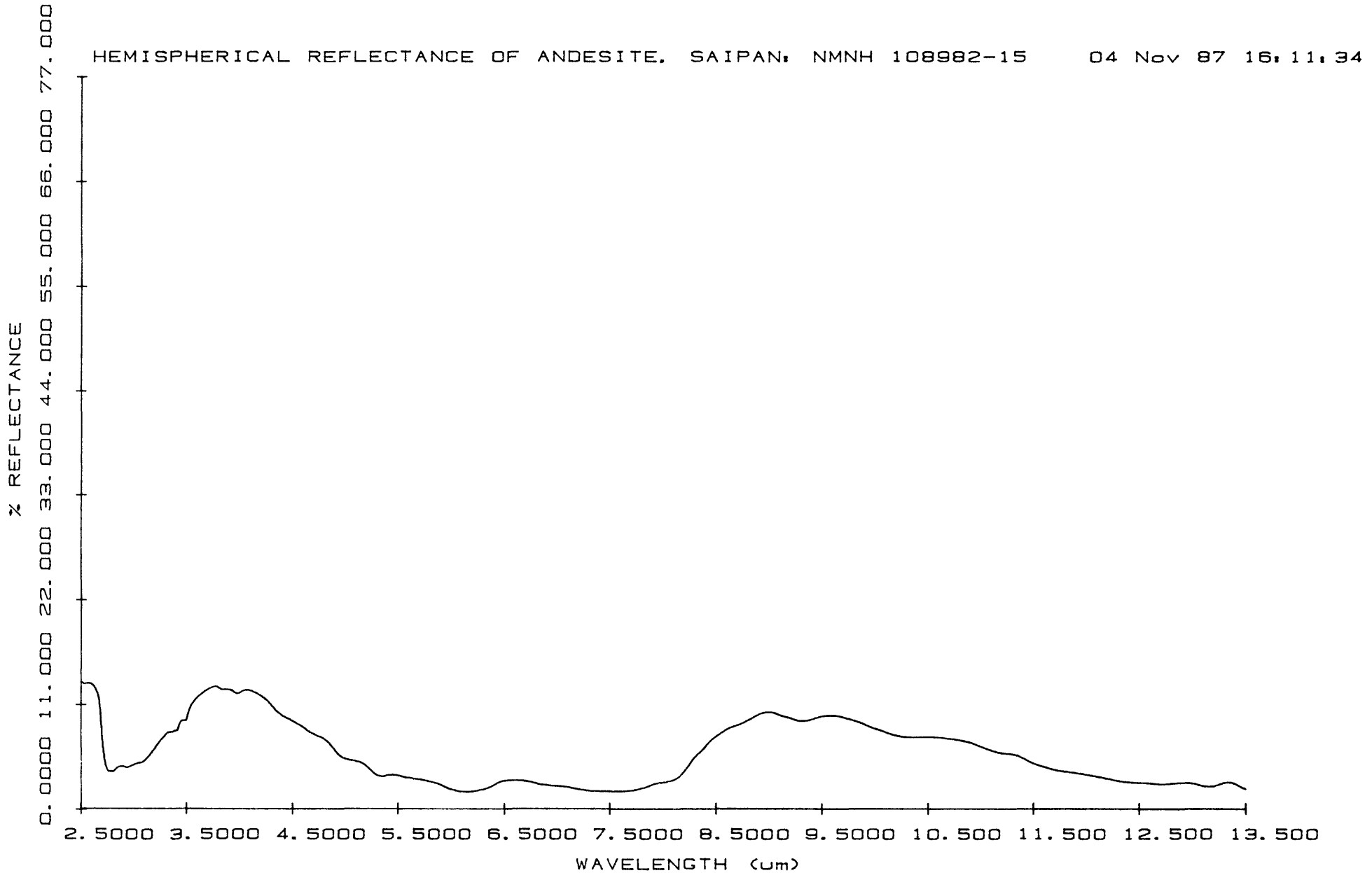
Chemical Analysis:

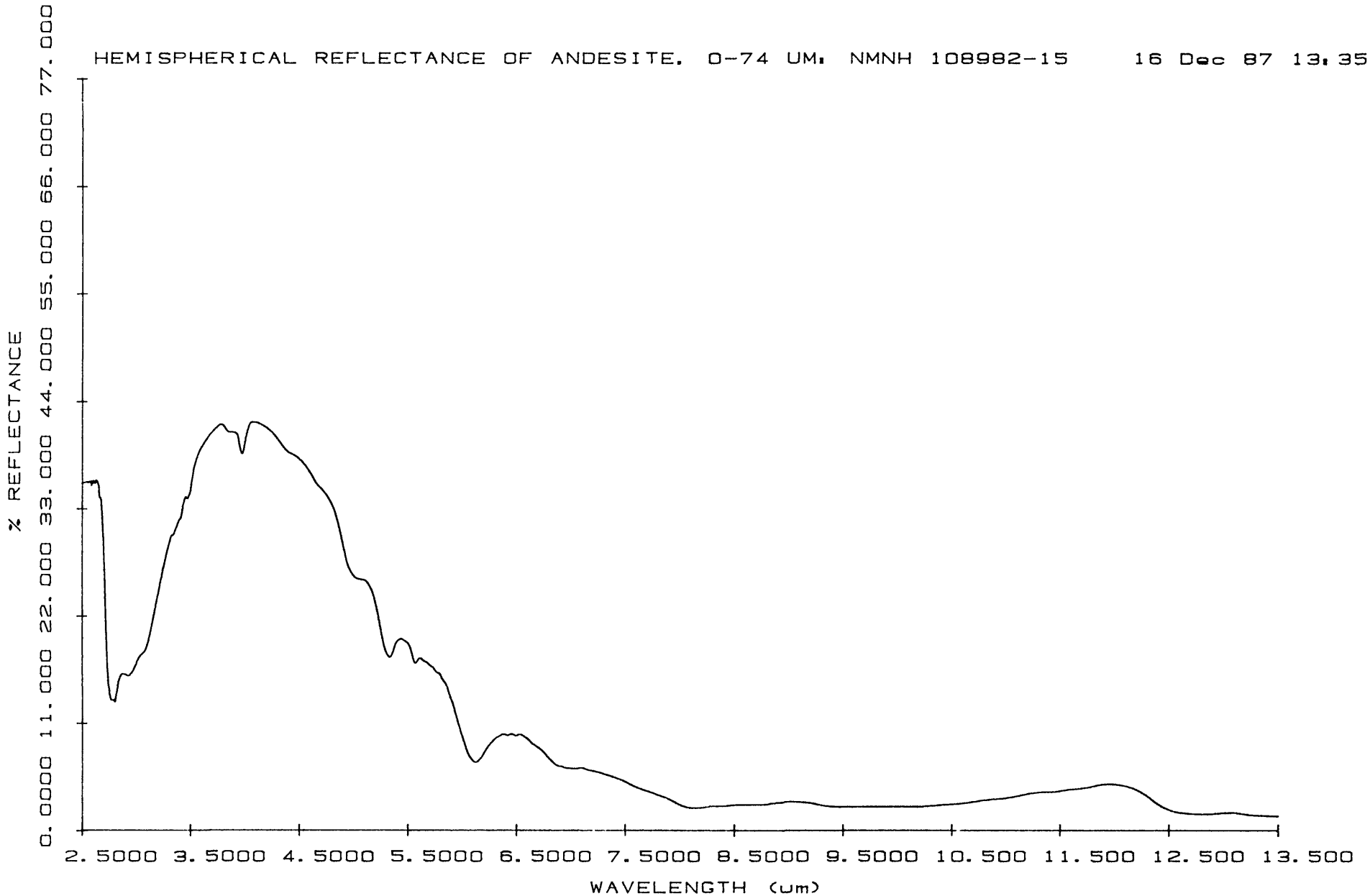
SiO_2	57.38	CaO	8.48
TiO_2	0.62	Na_2O	2.76
Al_2O_3	18.36	K_2O	0.74
Fe_2O_3	4.88	H_2O	1.30
FeO	2.26	P_2O_5	0.02
MnO	0.07	CO_2	0.57
MgO	2.40		
	TOTAL 99.84		

Reference: Robert George Smith, 1957, Petrology of the Volcanic Rocks in Geology of Saipan, Mariana Islands, USGS Prof. Paper 280-B.

Spectra on File:

Andesite.H2 Hemispherical reflectance of rough surface on Solid Rock disk #1
Andesite.H2 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF ANDESITE, SAIPAN: NMNH 108982-15 04 Nov 87 16:11:34
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF ANDESITE, 0-74 UM; NMNH 108982-15 16 Dec 87 13:35:2
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Andesite.4

Rock Name: Basaltic Andesite

Locality: Agrigan Volcano, Mariana Is.

Donor: Smithsonian

Catalogue Number: NMNH 115263-19

Hand Sample Description: A dark gray, porphyritic and vuggy rock. The phenocrysts are plagioclase laths, orangish-yellow olivine and opaques.

Petrographic Description: None.

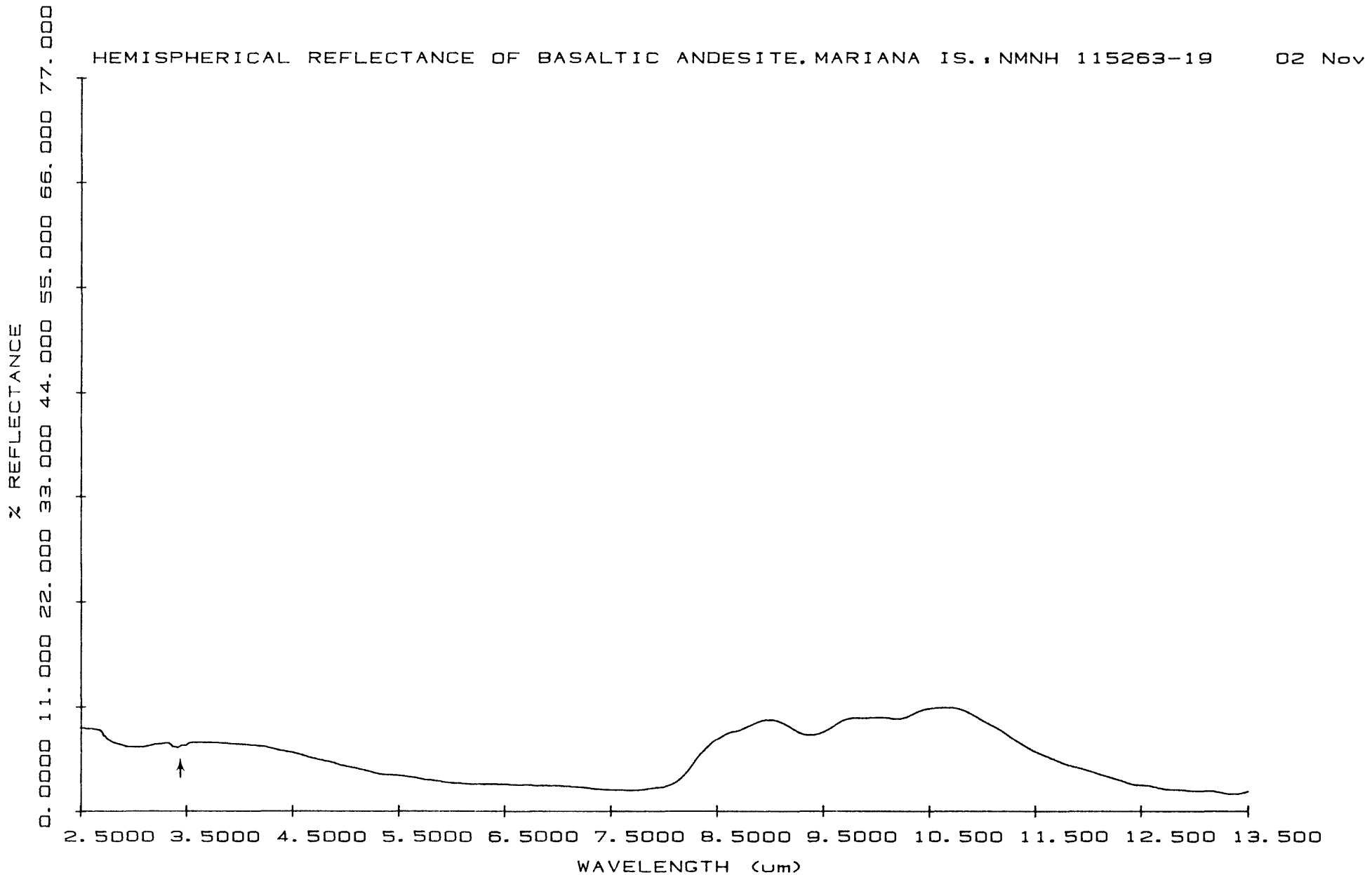
Microprobe Analysis: None.

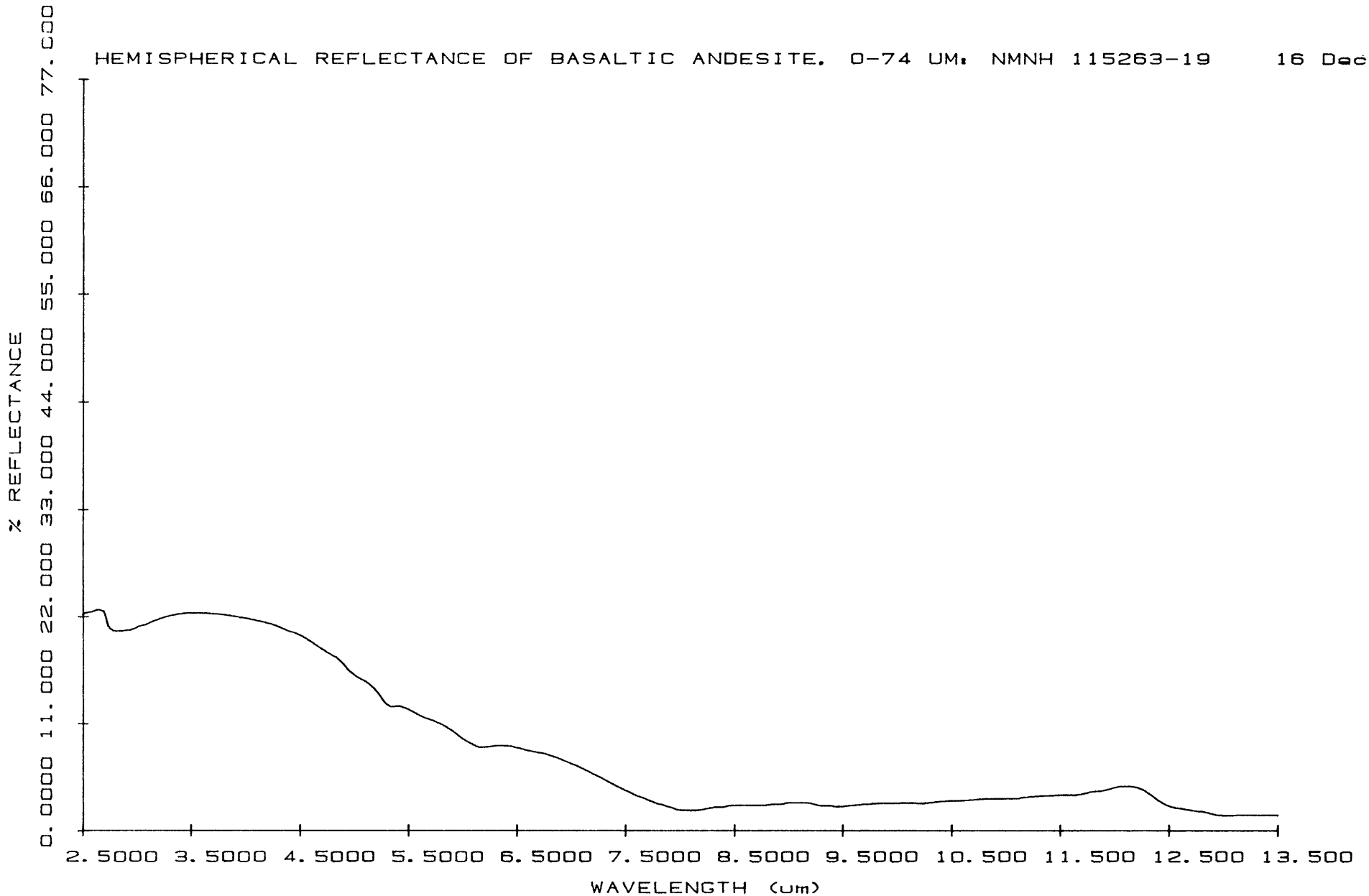
Chemical Analysis: (analyzed by Robert J. Stern, Carnegie Geophysical Laboratory)

SiO_2	53.3	CaO	10.05
TiO_2	0.73	Na_2O	3.04
Al_2O_3	19.5	K_2O	1.18
Fe_2O_3	3.5	P_2O_5	0.20
FeO	6.07		
MnO	0.18		
MgO	2.87		
	TOTAL		100.62

Spectra on File:

Andesite.H4 Hemispherical reflectance of rough surface on Solid Rock disk #1
Andesite.H4 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALTIC ANDESITE. MARIANA IS. : NMNH 115263-19
02 Nov
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALTIC ANDESITE. 0-74 UM: NMNH 115263-19 16 Dec 8
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Diorite

Locality: Near Azusa, Los Angeles County, California

Donor: Ward's Scientific

Catalogue Number: W-25

Hand Sample Description: A dark gray, medium-grained rock composed of plagioclase, a dark mafic phase and minor biotite.

Petrographic Description: A hypidiomorphic rock with moderately well-developed gneissoid foliation due to the subparallel alignment of subhedral green hornblende, which is partly replaced by biotite. The anhedral plagioclase is frequently zoned gradationally and often shows either Carlsbad or albite twinning. The cores of most of the feldspars are slightly sericitized and in a few regions of the sample are heavily sericitized. Epidote was a common accessory mineral, much less commonly apatite. The modal analyses gave: 51% plagioclase, 39% hornblende, 3.4% biotite, 0.8% epidote, with the remaining percentages composed of sericite and apatite.

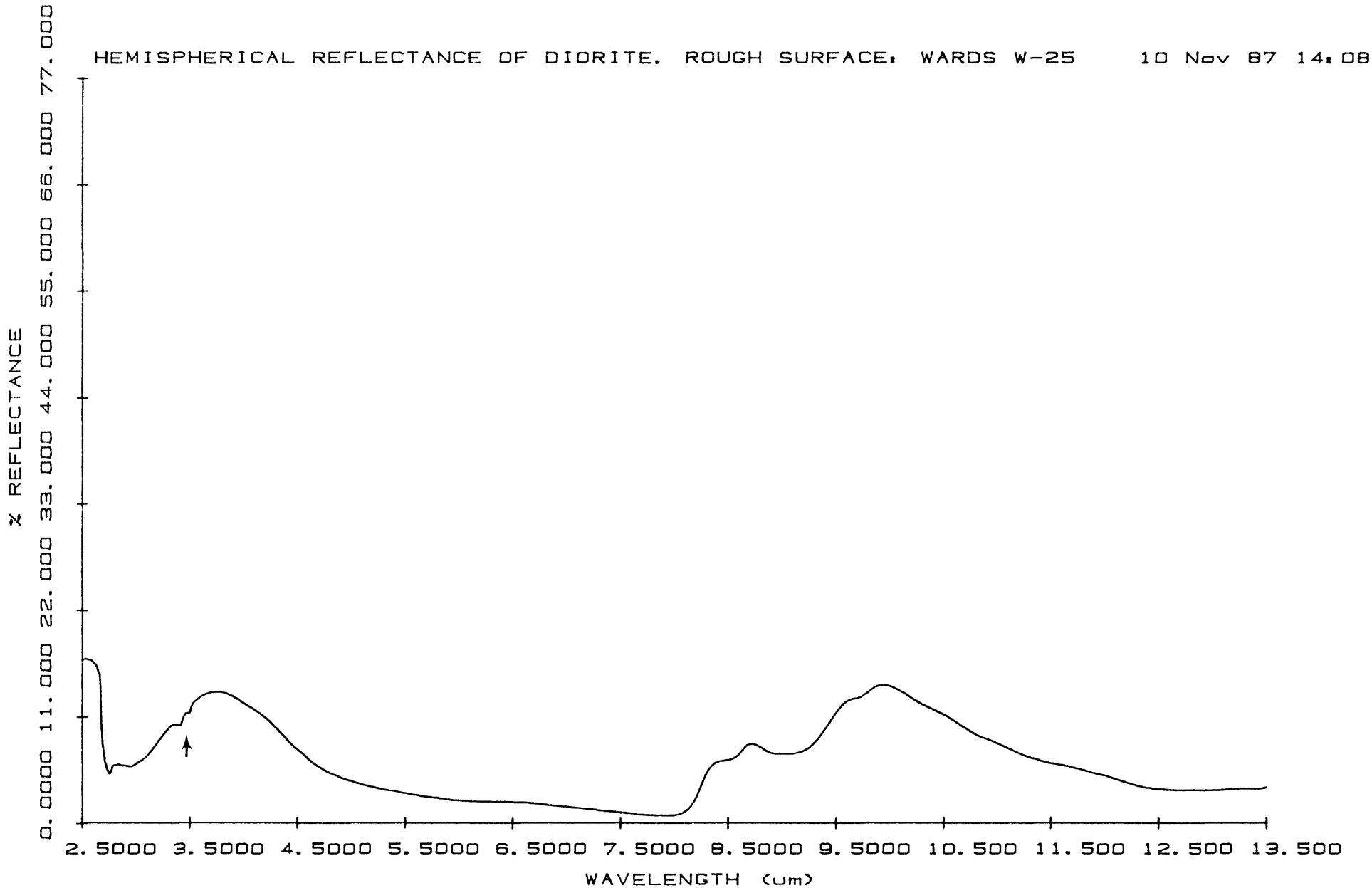
Microprobe Analysis: The plagioclase composition was rather homogeneous, ranging from An_{40} to An_{48} (andesine). However, some grains were quite heterogeneous. One grain had a composition of Or_{62} at the border where Ab dropped to about 10%; another feldspar (An_{16}) was heterogeneous as well, with a composition ranging from 0.5% to 12% CaO. The hornblende analysis revealed a homogeneous composition equivalent to pargasite.

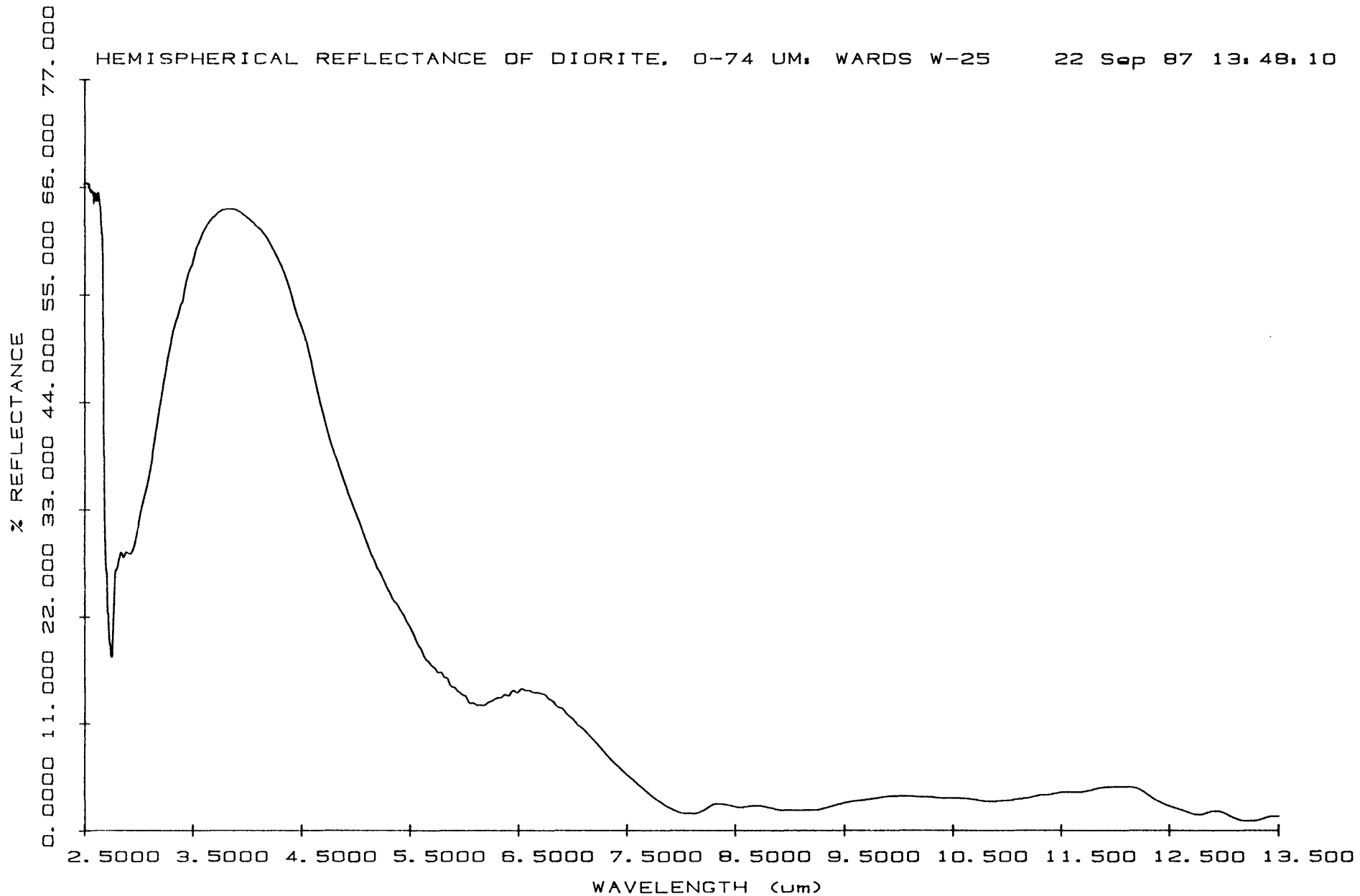
Chemical Analysis:

SiO_2	49.81	CaO	9.48
TiO_2	1.27	Na_2O	3.86
Al_2O_3	19.35	K_2O	1.18
Fe_2O_3	2.38	H_2O	1.41
FeO	5.34	P_2O_5	0.08
MnO	0.08		
MgO	6.16		
	TOTAL		100.4

Spectra on File:

Diorite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Diorite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Diorite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF DIORITE. ROUGH SURFACE: WARDS W-25 10 Nov 87 14:08:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF DIORITE, 0-74 UM: WARDS W-25 22 Sep 87 13:48:10
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Granodiorite

Locality: St. Cloud, Stearns County, Minnesota

Donor: Ward's Scientific

Catalogue Number: W-7

Hand Sample Description: A dark gray medium-grained rock consisting of gray plagioclase, pinkish potash feldspar, quartz, biotite, scattered sulfides, and a black mafic phase.

Petrographic Description: A hypidiomorphic granular rock composed of 47% alkali feldspar, 20% plagioclase, 19.7% quartz, 6.3% biotite, 3.3% green hornblende, 1.7% colorless augite, and <1% opaque anhedra. The euhedral plagioclase is often complexely zoned and selectively sericitized, occasionally showing both albite and Carlsbad twinning. The alkali feldspar anhedra are microcline perthite which also show selective sericitization. Brown biotite frequently replaces hornblende marginally; the latter are occasionally twinned and commonly contain remnants of colorless augite. Minor accessories are coarse sphene, zircon (in biotite), and apatite. No carbonate was seen in thin section, but very weak bands in the spectrum indicate a trace amount.

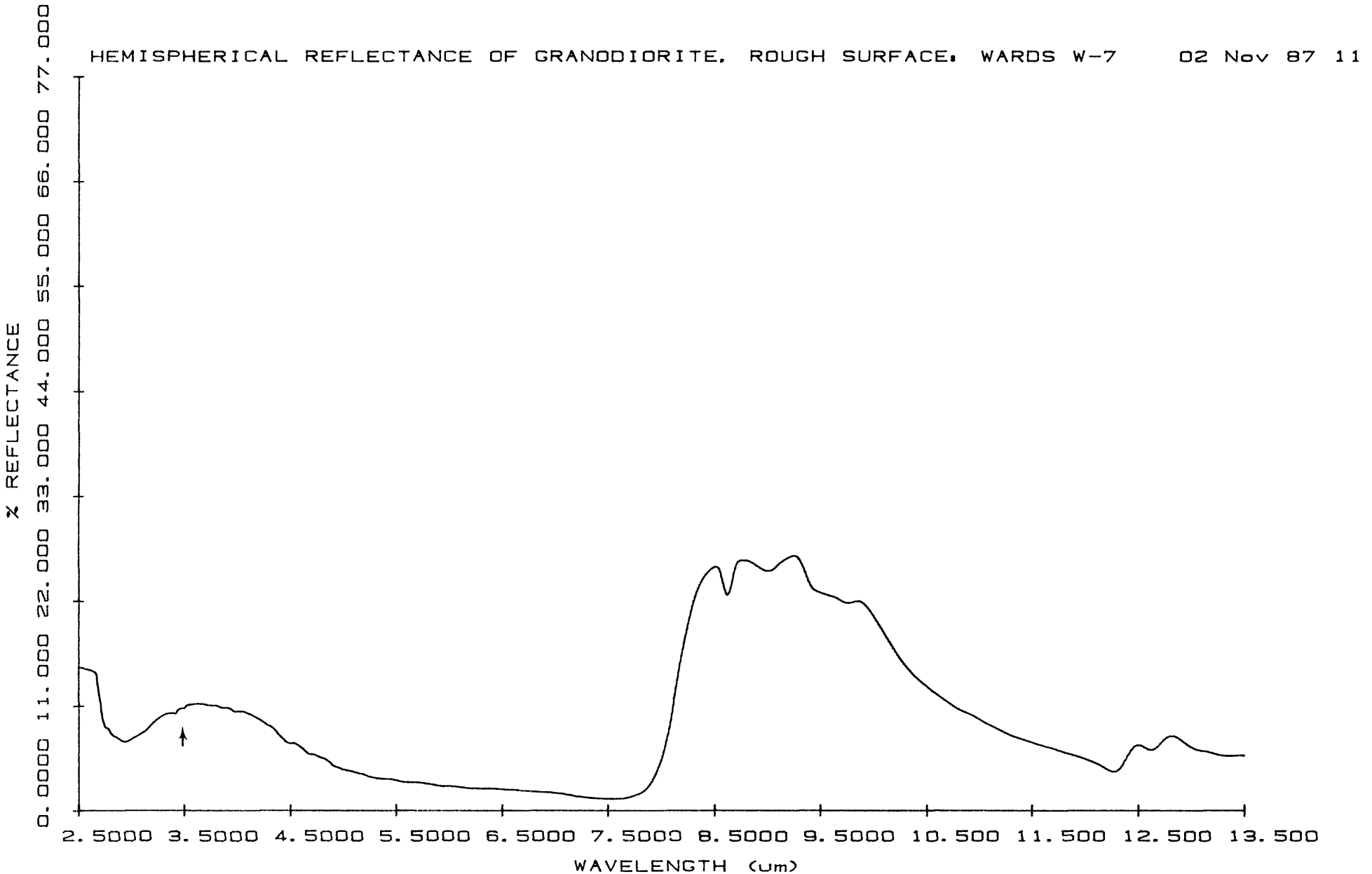
Microprobe Analysis: The analysis revealed a homogeneous composition for the biotite which was titanium and magnesium-rich. An ilmenite-magnetite analysis gave 2% ilmenite by weight. A small amount of substitution (~1%) of MgO by FeO was detected in the pyroxene while the hornblende analysis showed an equal amount of substitution of FeO for MgO. This analysis shows both augite and hornblende which is unusual. However, the "augite" has very low alumina (~2%) and a 98% sum, the "hornblende" has over 1% soda and a 97% sum.

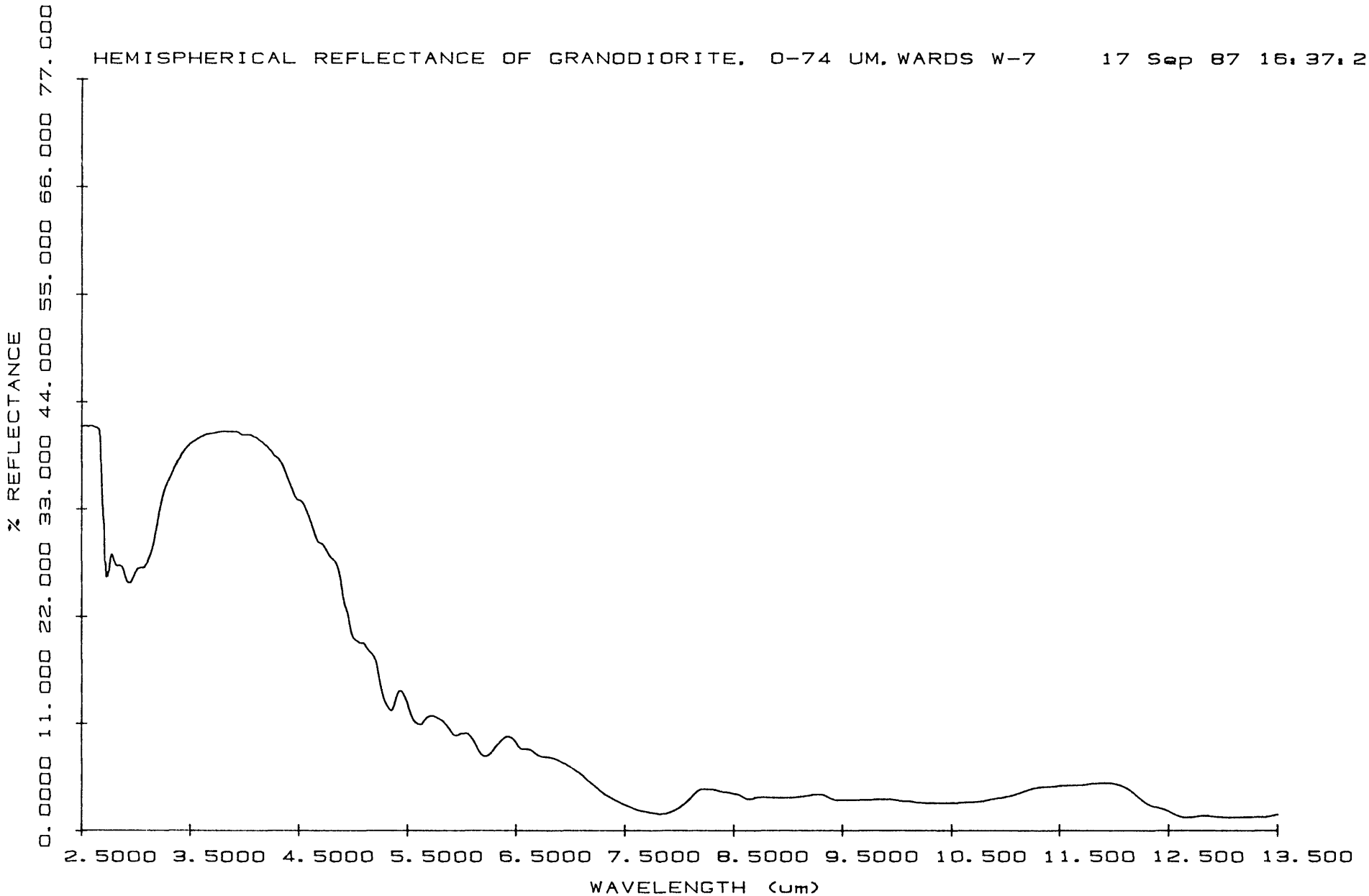
Chemical Analysis:

SiO_2	64.20	CaO	4.19
TiO_2	0.62	Na_2O	3.78
Al_2O_3	15.44	K_2O	3.91
Fe_2O_3	1.38	H_2O	0.70
FeO	3.22	P_2O_5	0.23
MnO	0.07		
MgO	2.25		
	TOTAL 99.99		

Spectra on File:

Granodior.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Granodior.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Granodior.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF GRANODIORITE, ROUGH SURFACE. WARDS W-7 02 Nov 87 11
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF GRANODIORITE, 0-74 UM, WARDS W-7
17 Sep 87 16:37:22
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Granodiorite

Locality: Santa Rita Mountains, Arizona

Donor: Smithsonian

Catalogue Number: NMNH 113640-10

Hand Sample Description: A dark gray medium-grained rock consisting of light gray plagioclase grains, white to pinkish feldspar (plagioclase >> alkali feldspar), green epidote or apatite, a black mafic phase and quartz.

Petrographic Description: Modally the sample contains 57.8% plagioclase, 14.5% orthoclase, 14.4% hornblende, 8.6% quartz, 4% magnetite, and 0.7% apatite. The plagioclase generally forms large subhedral grains moderately to strongly altered to clay minerals and sericite. The orthoclase and quartz are anhedral and interstitial, with orthoclase often altered to kaolinite, and finely perthitic. Quartz shows little or no undulatory extinction. The amphibole forms subhedral to anhedral crystals which are usually pleochroic pale yellowish green to greenish gray, and commonly uralitized. The slightly low quartz content of this rock for a granodiorite makes it more properly a syenodiorite. No carbonate was seen in thin section, but both the spectrum and chemical analysis indicate the presence of a small amount.

Microprobe Analysis: These feldspars range in composition from calcic oligoclase to labradorite (An_{40} to An_{60}).

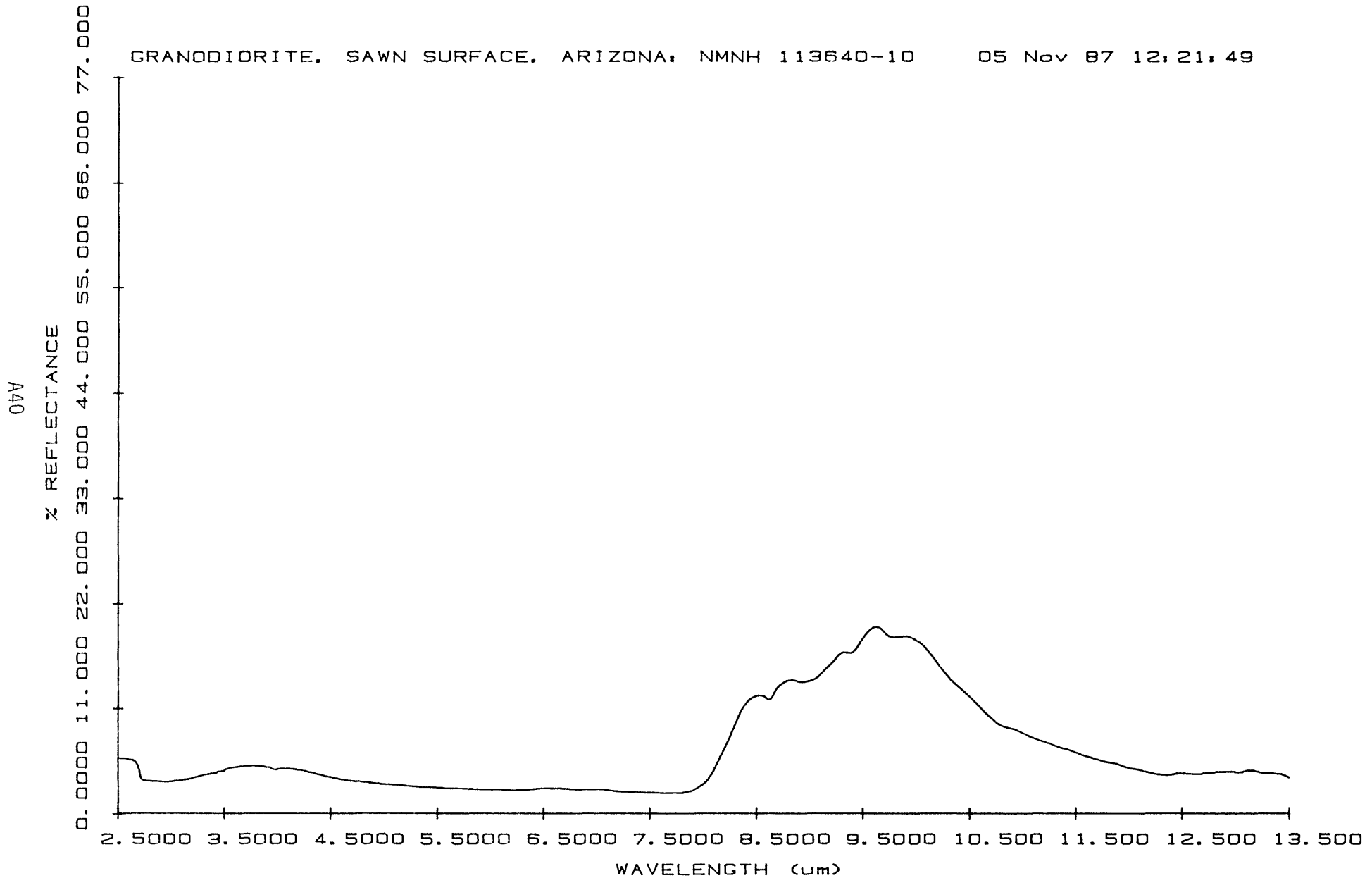
Chemical Analysis:

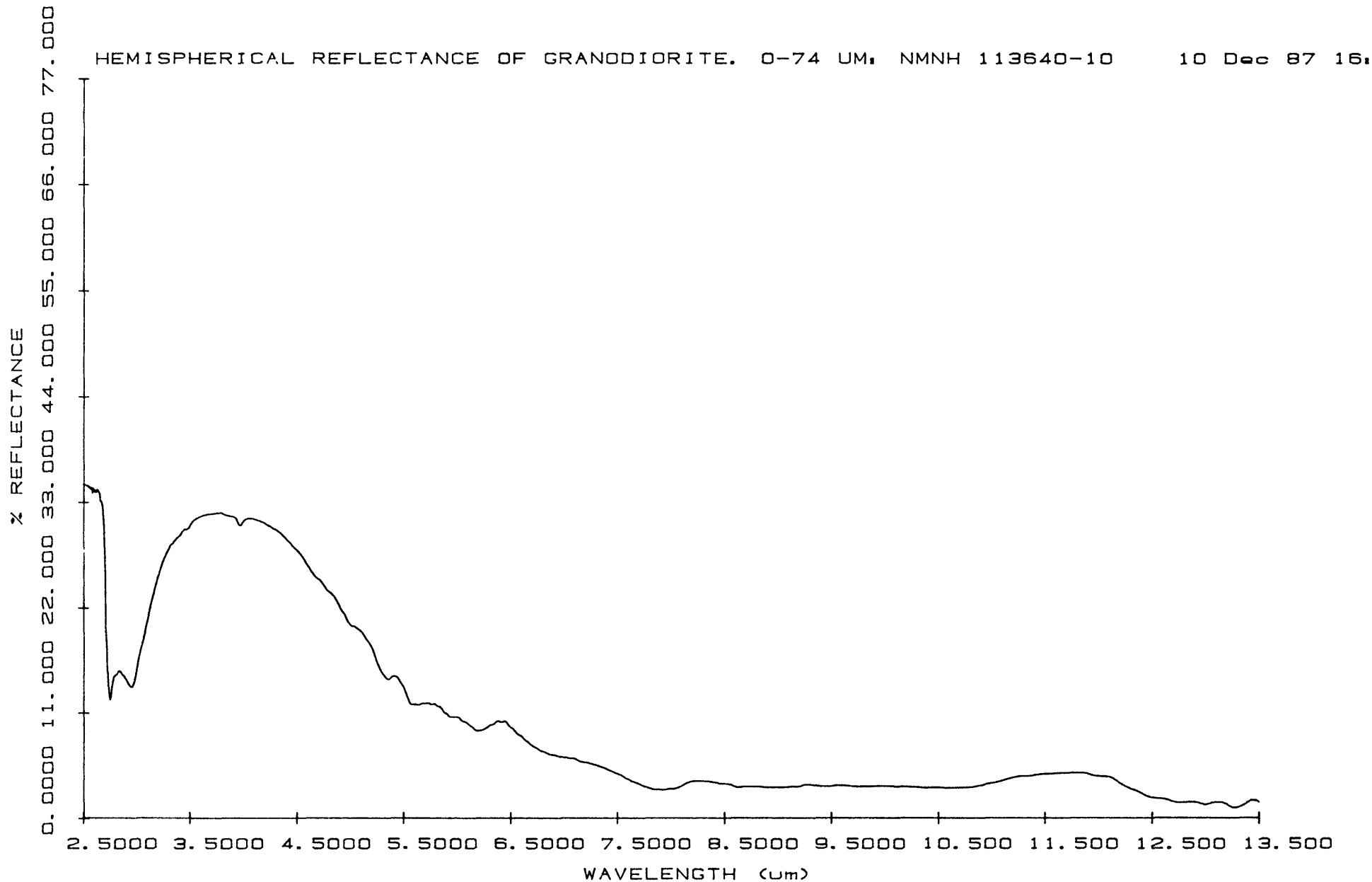
SiO_2	56.0	CaO	5.3
TiO_2	1.23	Na_2O	3.0
Al_2O_3	15.8	K_2O	4.2
Fe_2O_3	5.0	H_2O	1.59
FeO	3.8	P_2O_5	0.53
MnO	0.33	CO_2	0.16
MgO	2.7		
	TOTAL	99.61	

Reference: Harold Drewes, 1976, Plutonic Rocks of the Santa Rita Mountains, Southeast of Tuscon, Arizona, USGS Prof. Paper 915.

Spectra on File:

Granodior.H2 Hemispherical reflectance of rough surface on Solid Rock disk #1
Granodior.H2 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


GRANODIORITE. SAWN SURFACE. ARIZONA: NMNH 113640-10 05 Nov 87 12:21:49
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF GRANODIORITE. 0-74 UM: NMNH 113640-10 10 Dec 87 16:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Monzonite

Locality: Near Silverton, San Juan County, Colorado

Donor: Ward's Scientific

Catalogue Number: W-22

Hand Sample Description: A purplish-gray, medium-grained granular rock composed of feldspar, a greenish to black mafic mineral and opaques.

Petrographic Description: An inequigranular hypidiomorphic rock consisting of larger plagioclase euhedra, smaller interstitial alkali feldspar and quartz, colorless to pale green pyroxene anhedra which may be partly uralitized, and scattered biotite and opaques. The feldspar is often sericitized, and the plagioclase occasionally shows both albite and Carlsbad twinning, as well as oscillatory (less commonly gradational) zoning. The average modes are: 70% feldspar, 18% quartz, 8.2% pyroxene, 2% opaques and 1.2% biotite. No carbonate was seen in thin section, but a weak carbonate feature near 4.0 μm indicates the presence of a very small (< 1%) amount.

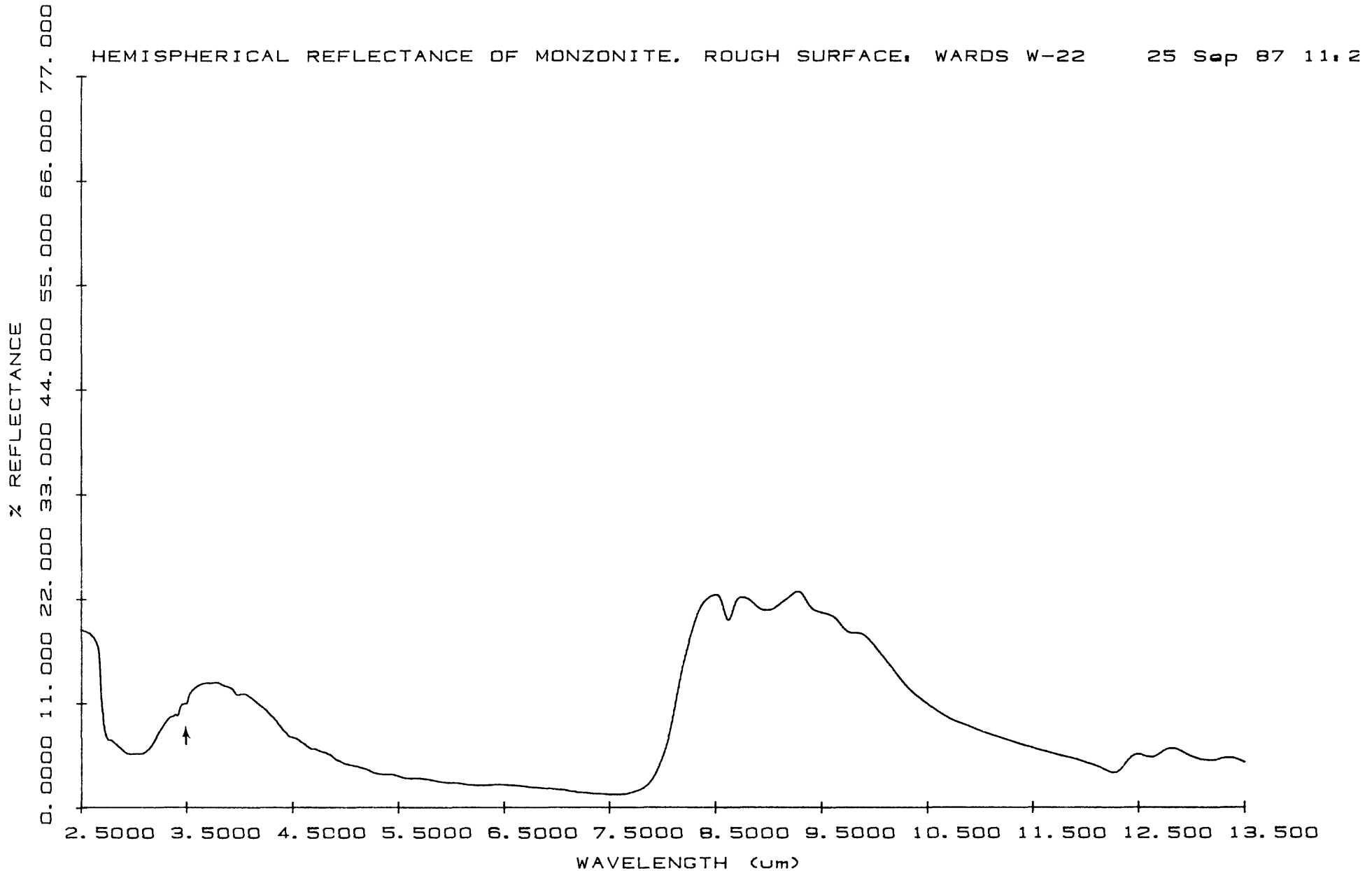
Microprobe Analysis: The plagioclase phases proved to be either andesine ($\sim An_{47}$), or a mixture of alkali feldspar (Or_{55}) and plagioclase ($\sim An_{39}$); one feldspar probed was orthoclase ($\sim Or_{97}$). The pyroxene was augite, or possibly augite with uralite. Magnetite had from 0.5 to 1.5 % variation in titania.

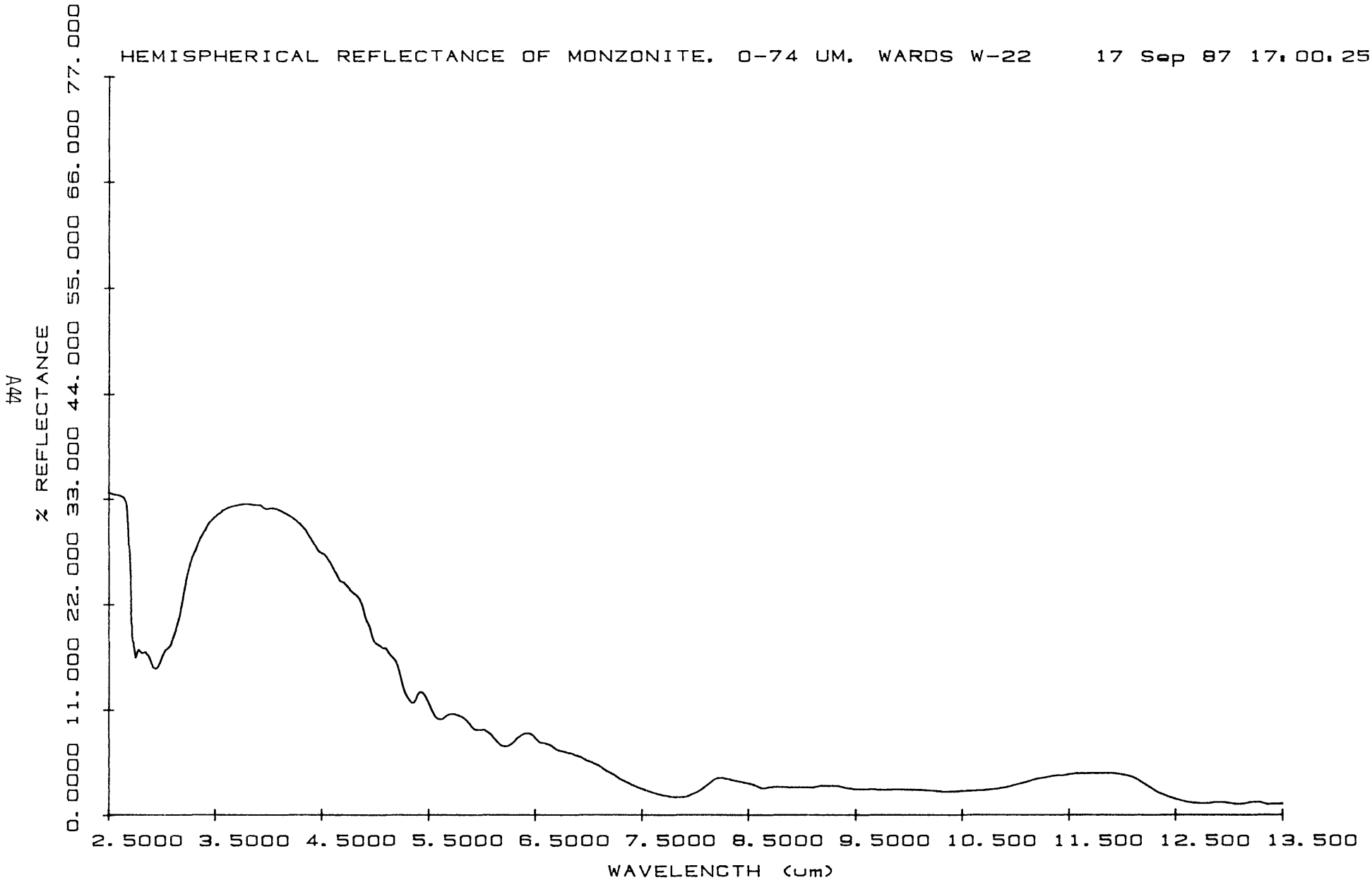
Chemical Analysis:

SiO_2	61.42	CaO	4.13
TiO_2	0.77	Na_2O	3.48
Al_2O_3	15.95	K_2O	4.17
Fe_2O_3	3.6	H_2O	1.37
FeO	2.84	P_2O_5	0.25
MnO	0.11		
MgO	2.32		
	TOTAL		100.41

Spectra on File:

Monzonite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Monzonite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Monzonite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF MONZONITE, ROUGH SURFACE: WARDS W-22 25 Sep 87 11:2
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF MONZONITE. 0-74 UM. WARDS W-22
17 Sep 87 17:00:25
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Quartz Monzonite

Locality: Santa Rita Mountains, Arizona

Donor: Smithsonian

Catalogue Number: NMNH 113640-18

Hand Sample Description: A light gray medium-grained rock composed of pink feldspar, grayish plagioclase, quartz and biotite.

Petrographic Description: The granitoid rocks of the Corona stock are typically hypidiomorphic granular. The quartz is anhedral with moderate to strong undulose extinction, plagioclase forms subhedra with strong normal compositional zoning, the orthoclase is perthitic and the biotite is partly chloritized. The modes for this sample are: 34.8% plagioclase, 34.3% potassium feldspar, 28.1% quartz, and 2.4% biotite. No carbonate was seen in thin section, but very weak carbonate features in the powder spectrum indicate a trace amount, as does the chemical analysis.

Microprobe Analysis: Compositionally these zoned plagioclases contained 15% anorthite (oligoclase) in the rims of the feldspars.

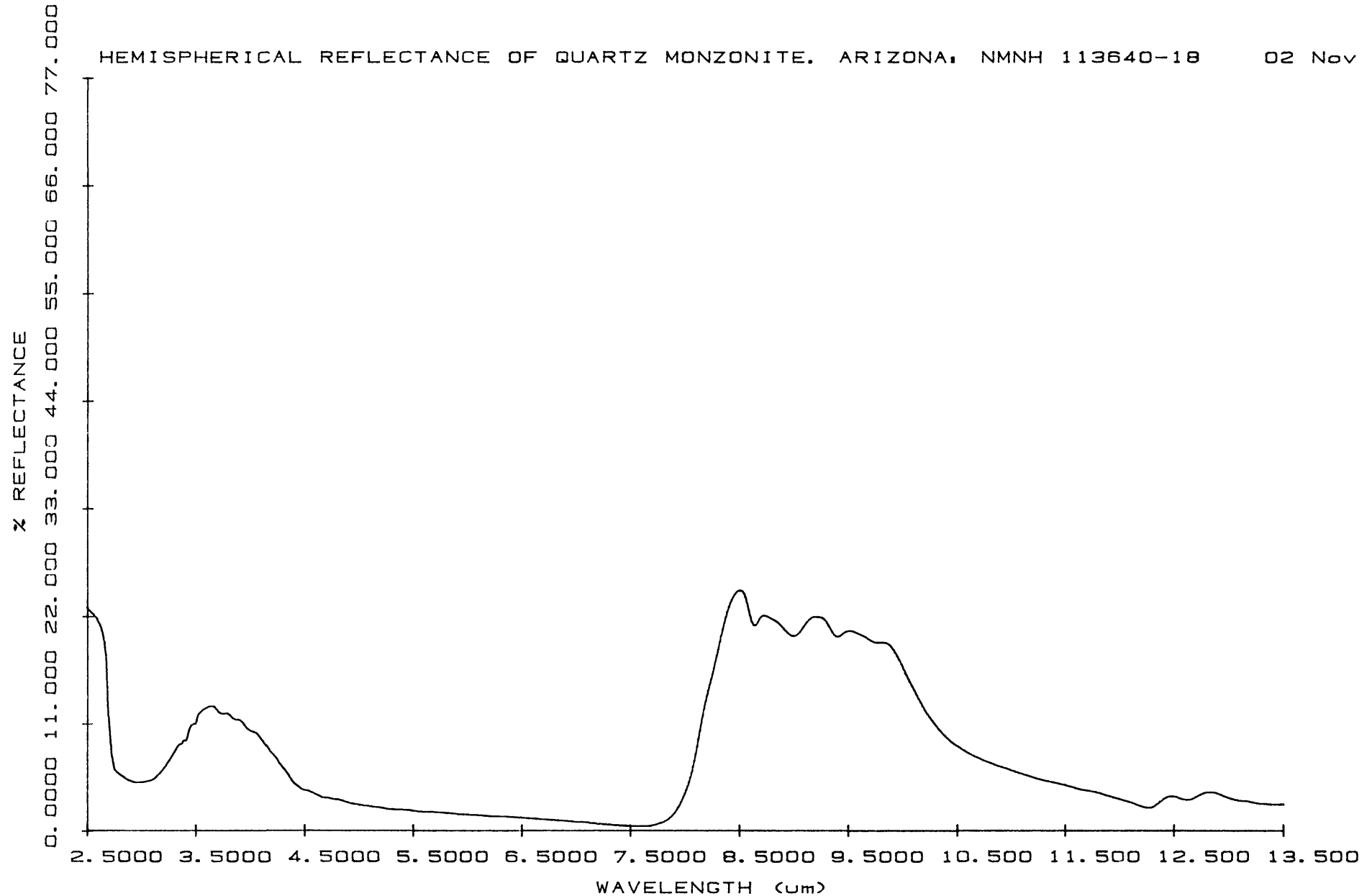
Chemical Analysis:

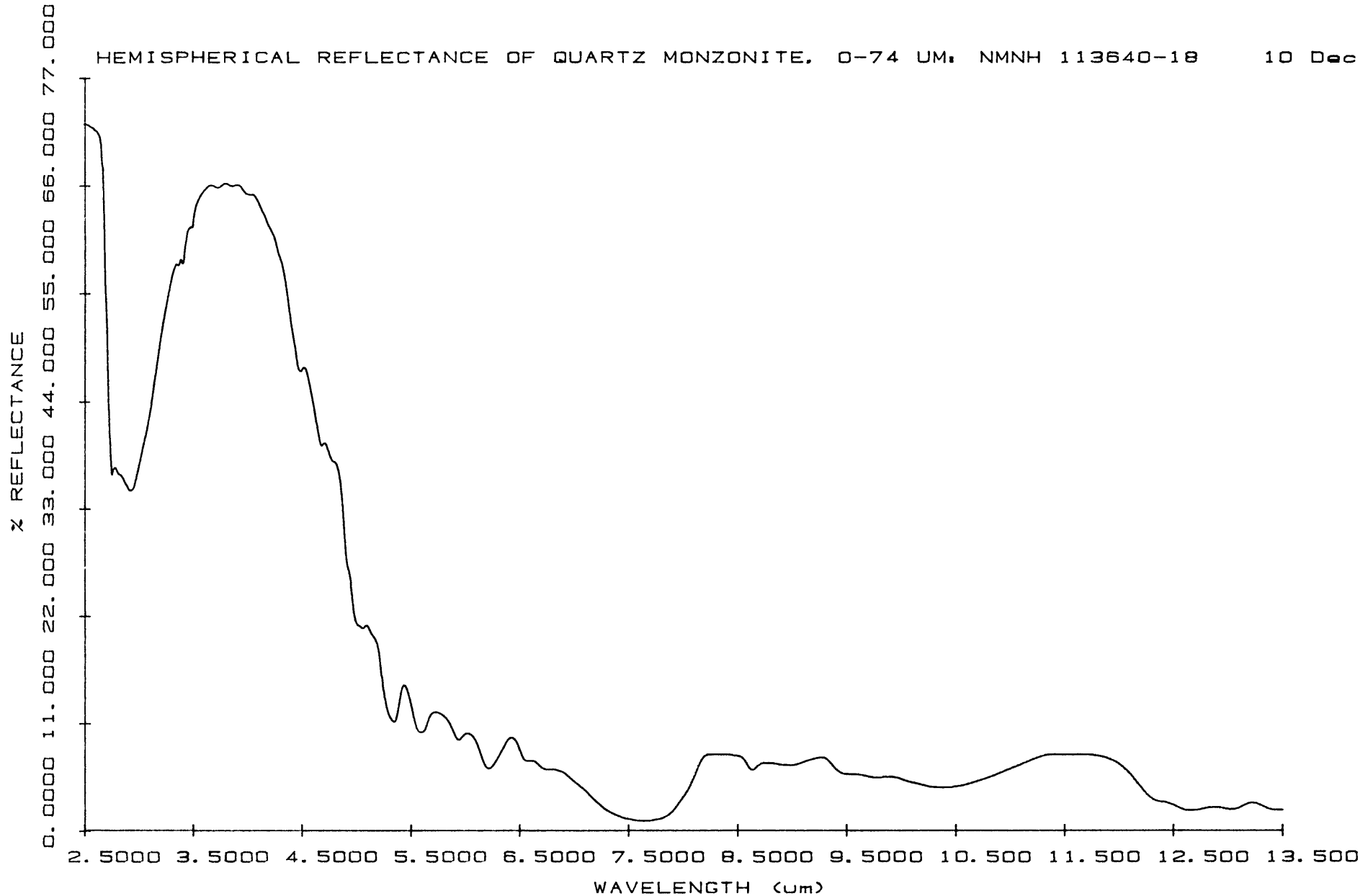
SiO_2	73.9	CaO	1.0
TiO_2	1.1	Na_2O	3.9
Al_2O_3	13.3	K_2O	4.5
Fe_2O_3	0.58	H_2O	0.31
FeO	0.56	P_2O_5	0.04
MnO	0.04	CO_2	<0.05
MgO	0.33		
	TOTAL	99.46	

Reference: Harold Drewes, 1976, Plutonic Rocks of the Santa Rita Mountains, Southeast of Tuscon, Arizona, USGS Prof. Paper 915.

Spectra on File:

Qmonzonite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Qmonzonite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF QUARTZ MONZONITE. ARIZONA. NMNH 113640-18 02 Nov 87
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF QUARTZ MONZONITE, 0-74 UM, NMNH 113640-18 10 Dec 87
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Alkalic Syenite

Locality: Golden Cycle Mine, near Victor, Teller County, Colorado

Donor: Ward's Scientific

Catalogue Number: W-14

Hand Sample Description: A dark gray fine-grained rock spotted with white feldspar grains in a dark gray groundmass with scattered mafics, opaques, and sulfides.

Petrographic Description: The sample possesses a moderately to strongly developed flow texture from the subparallel orientation of slender feldspar laths; clear sodic orthoclase (Carlsbad twinning), turbid sodic plagioclase (fine albite twinning) amd more highly turbid alkali feldspar. Pale green pyroxene euhedra are frequently rimmed with pleochroic brown amphibole, while the opaques tend to cluster around the pyroxenes. Apatite is a common accessory mineral. Both nepheline and sphene occur as scarce, rather minute grains. Modes were 90% feldspar, 5% pyroxene, 4% opaques, and about 1% amphibole. No carbonate was seen in thin section, but the weak spectral feature near 4.0 μm indicates that a small amount is present.

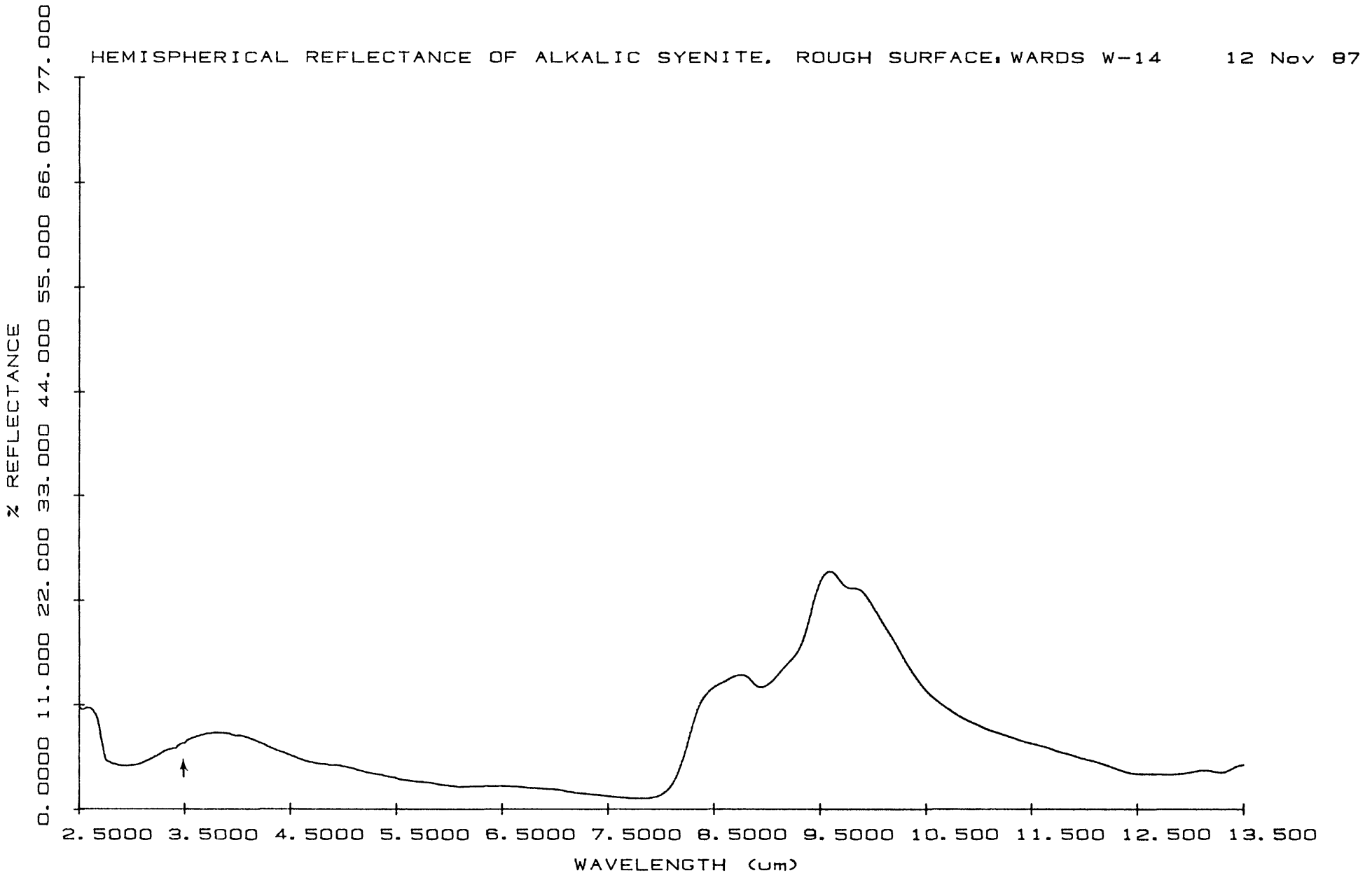
Microprobe Analysis: According to the analysis, the pyroxene phase was diopside (salite), the amphibole composition was equivalent to hastingsite, while opaques probed were ilmenite and magnetite (with titanomagnetite).

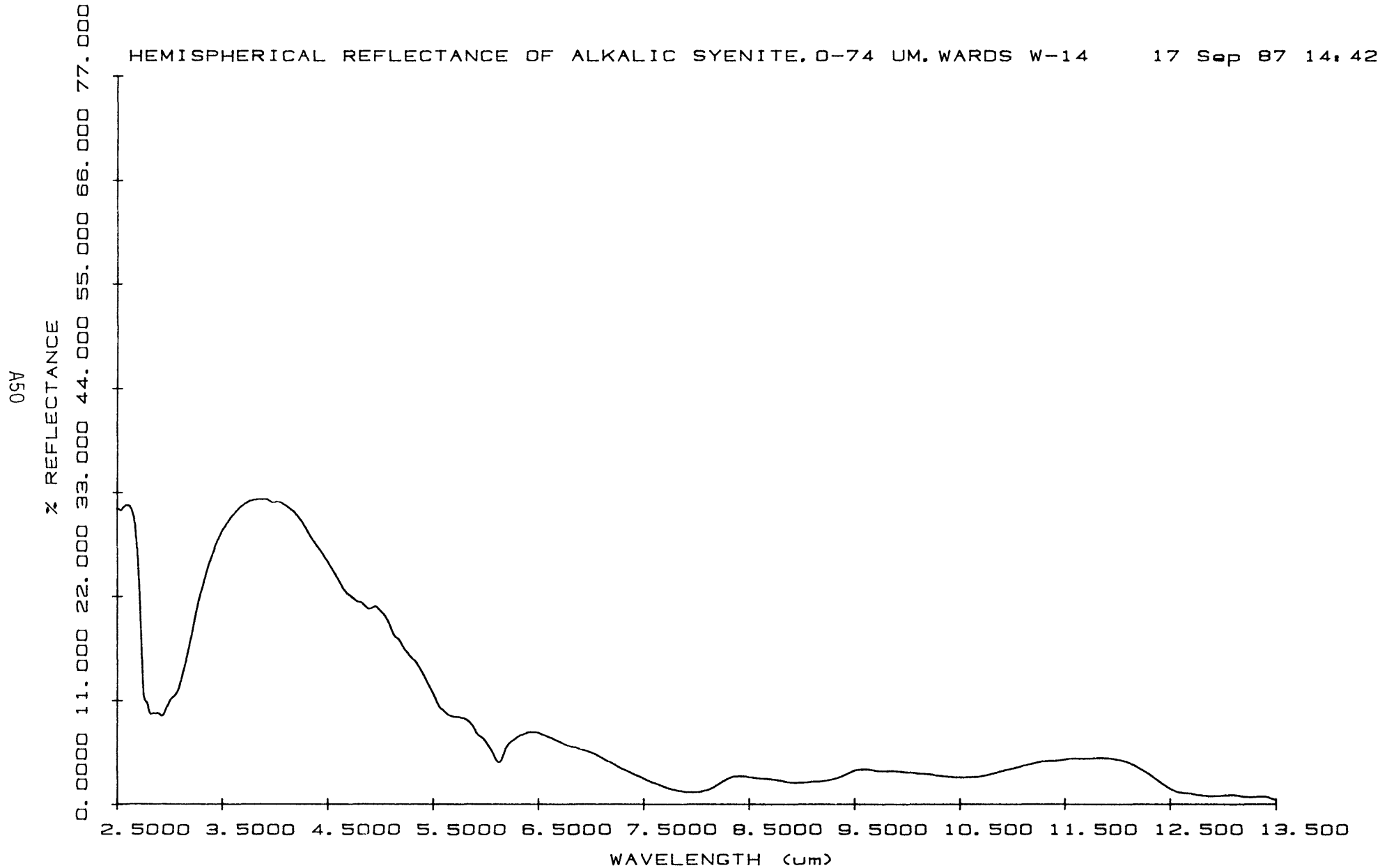
Chemical Analysis:

SiO_2	55.28	CaO	3.08
TiO_2	0.68	Na_2O	7.46
Al_2O_3	19.93	K_2O	5.72
Fe_2O_3	2.54	H_2O	2.11
FeO	1.63	P_2O_5	0.19
MnO	0.14		
MgO	0.84		
	TOTAL 99.6	(CO_2 not analyzed)	

Spectra on File:

Syenite.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Syenite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF ALKALIC SYENITE, ROUGH SURFACE: WARDS W-14
12 Nov 87
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF ALKALIC SYENITE, 0-74 UM. WARDS W-14
17 Sep 87 14: 42:
A50
% REFLECTANCE
0. 0000 11. 000 22. 000 33. 000 44. 000 55. 000 66. 000 77. 000
2. 5000 3. 5000 4. 5000 5. 5000 6. 5000 7. 5000 8. 5000 9. 5000 10. 500 11. 500 12. 500 13. 500
WAVELENGTH (um)

Rock Name: Nepheline Syenite

Locality: Blue Mountain, Methuen Twp., Ontario

Donor: Ward's Scientific

Catalogue Number: W-17

Hand Sample Description: A medium-grained leucocratic rock showing some foliation, consisting of plagioclase, nepheline and biotite.

Petrographic Description: An inequigranular rock with some foliation due to the subparallel alignment of the long axes of feldspars and mica. The plagioclase is subhedral with albite and ocasionally Carlsbad twinning as well. The alkali feldspar anhedra can show grid-iron or Carlsbad twinning. The nepheline anhedra often contain rounded inclusions of microcline, are slightly turbid and frequently contain sericitic alteration along fractures. Some of the nepheline contain abundant grains of a clear mica (muscovite) as an alteration product; in some cases the nepheline is almost completely replaced by mica grains. In addition, there are scattered subhedra of brown biotite and less abundant anhedra of dark green (Fe-rich) biotite. The average modes were 45% plagioclase, 26% alkali feldspar, 3% muscovite (including sericite) and 1.5% biotite. No carbonate was seen in thin section, but very weak spectral features indicate that some is present.

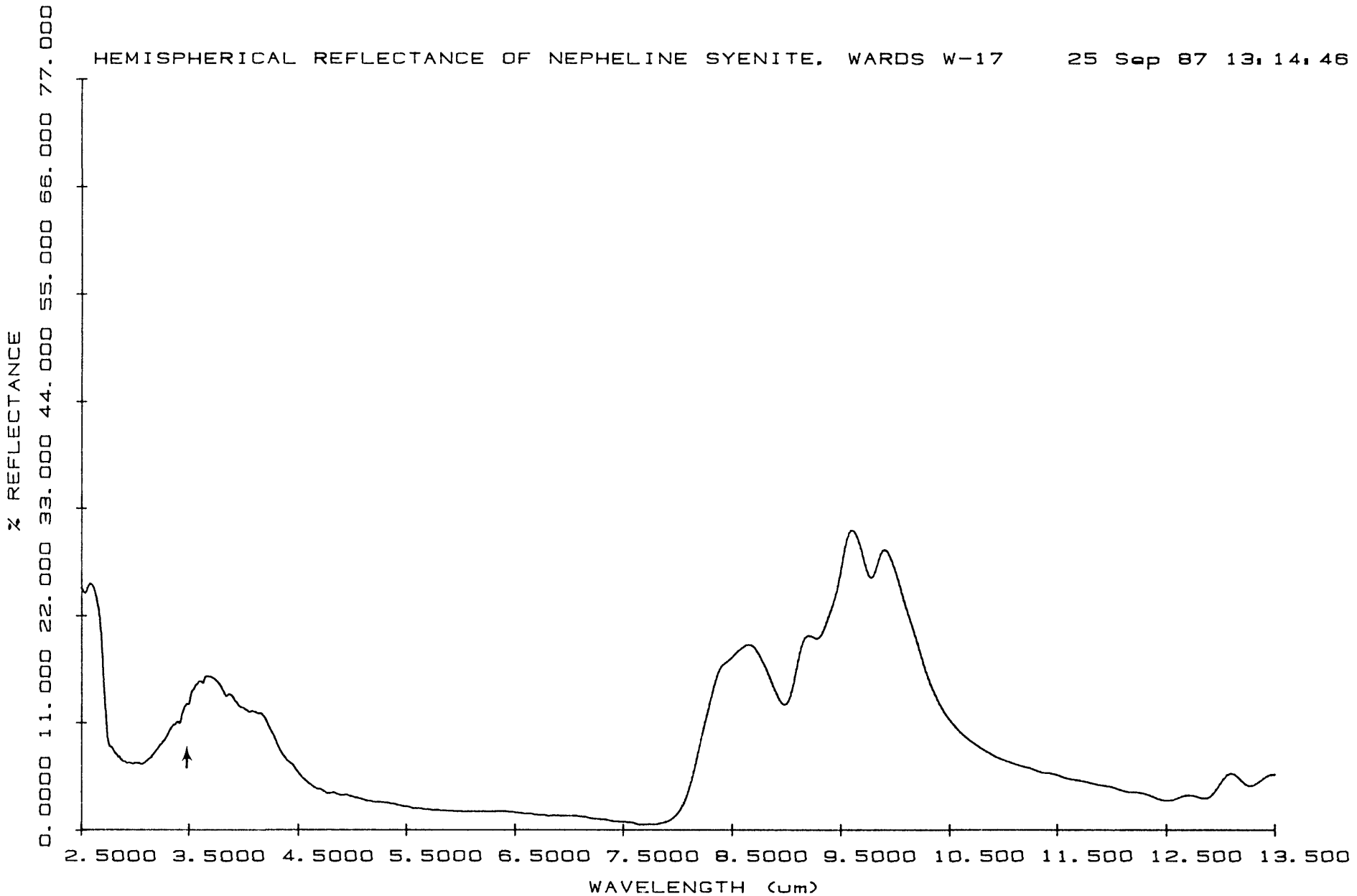
Microprobe Analysis: The microprobe analysis revealed two modes of feldspar composition; Or_{94} and pure albite. The nepheline analyses were consistent and indicated a composition equivalent to 17% kalsilite.

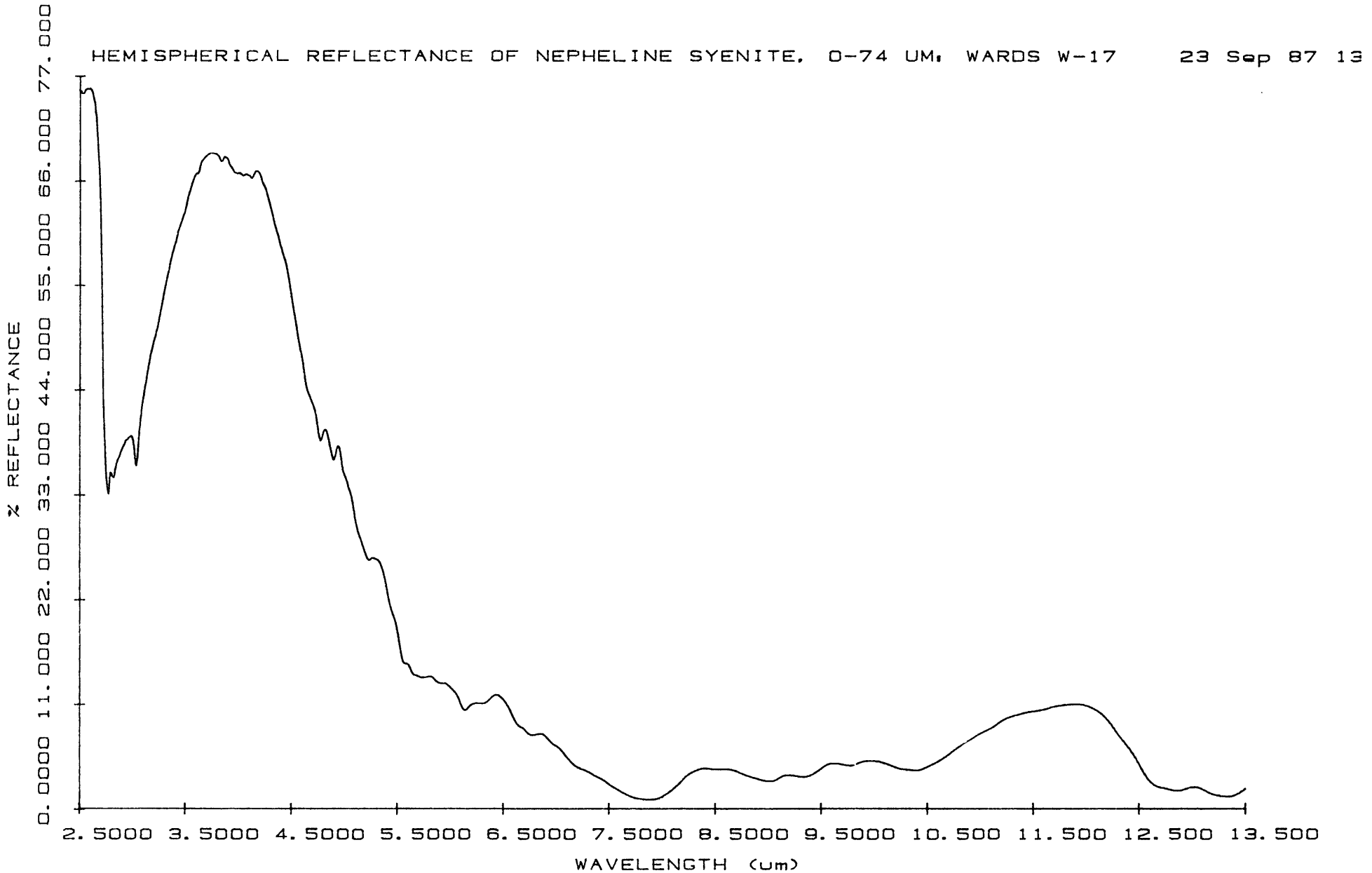
Chemical Analysis:

SiO_2	59.85	CaO	0.16
TiO_2	0.03	Na_2O	9.69
Al_2O_3	22.07	K_2O	5.18
Fe_2O_3	0.23	H_2O	0.93
FeO	1.06	P_2O_5	0.0
MnO	0.02		
MgO	0.04		
TOTAL	99.26	(CO_2 not analyzed)	

Spectra on File:

Syenite.H2	Hemispherical reflectance of rough surface on Solid Rock disk #1
Syenite.H2	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Syenite.2	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF NEPHELINE SYENITE, WARDS W-17
25 Sep 87 13:14:46
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF NEPHELINE SYENITE, 0-74 UM, WARDS W-17 23 Sep 87 13
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Tonalite (Bonsall Tonalite)

Locality: San Diego County, California

Donor: Ward's Scientific

Catalogue Number: W-24

Hand Sample Description: A medium-grained gray rock composed of whitish plagioclase, quartz, biotite, and a black mafic mineral.

Petrographic Description: In this sample the sodic plagioclase and hornblende are subhedral, the quartz, biotite, and opaques are anhedral. Some of the basal sections of hornblende shown twinning while the biotite is partly chloritized. Some of the plagioclase show sericitization in the cores, and occasionally normal zoning. The quartz often show undulose extinction. Apatite occurs as a minor accessory mineral, and much less zircon (in biotite) and epidote. The modes are 53% plagioclase, 21% quartz, 15% biotite, 9% hornblende, 1.4% miscellaneous (apatite, epidote, sericite), and 0.6% opaques. Very weak spectral features indicate the presence of a trace of carbonate.

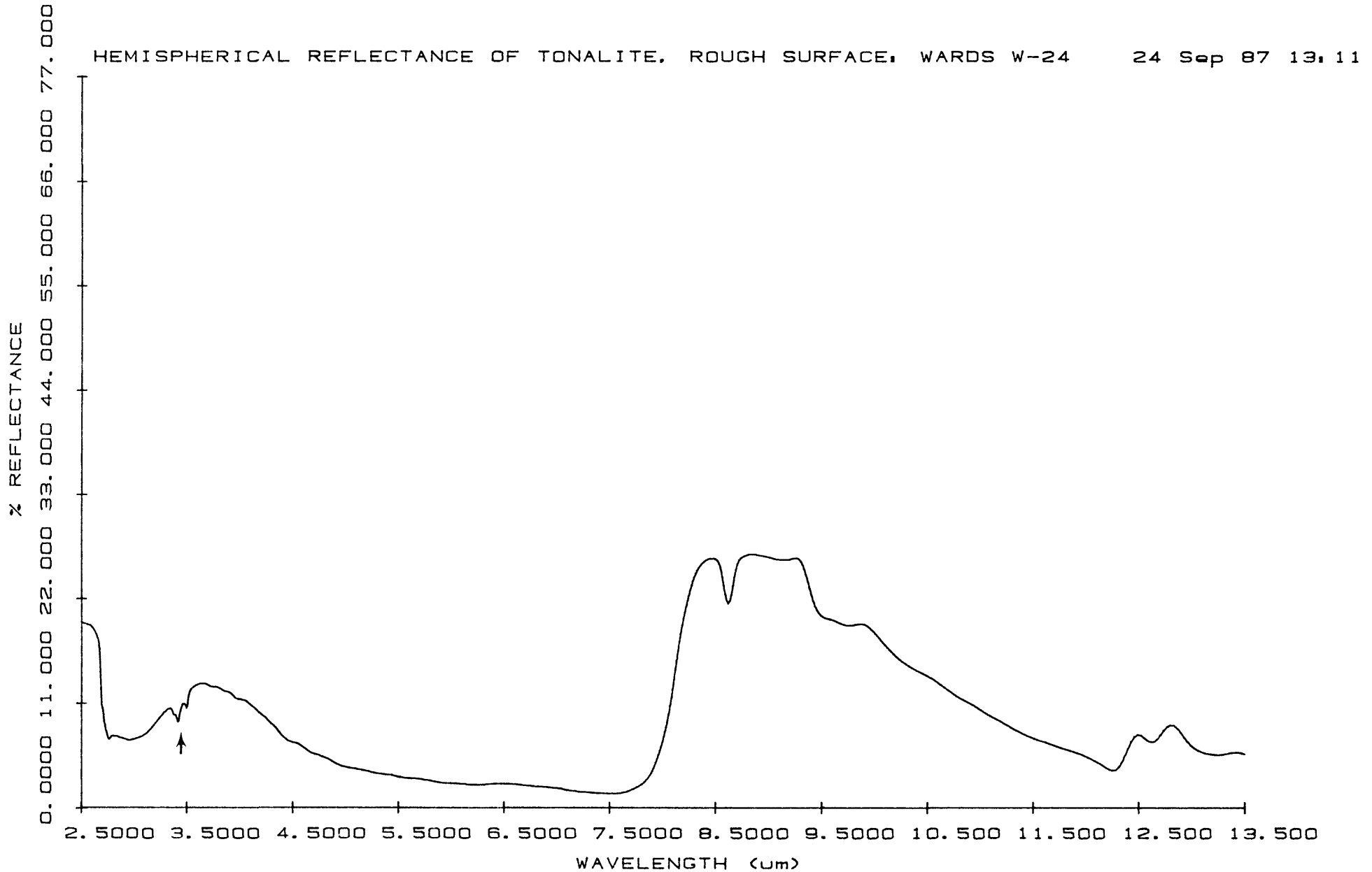
Microprobe Analysis: The plagioclase composition ranged from An_{38} to An_{50} (andesine-labradorite). The hornblende composition was relatively homogeneous, with a composition equivalent to hastingsite.

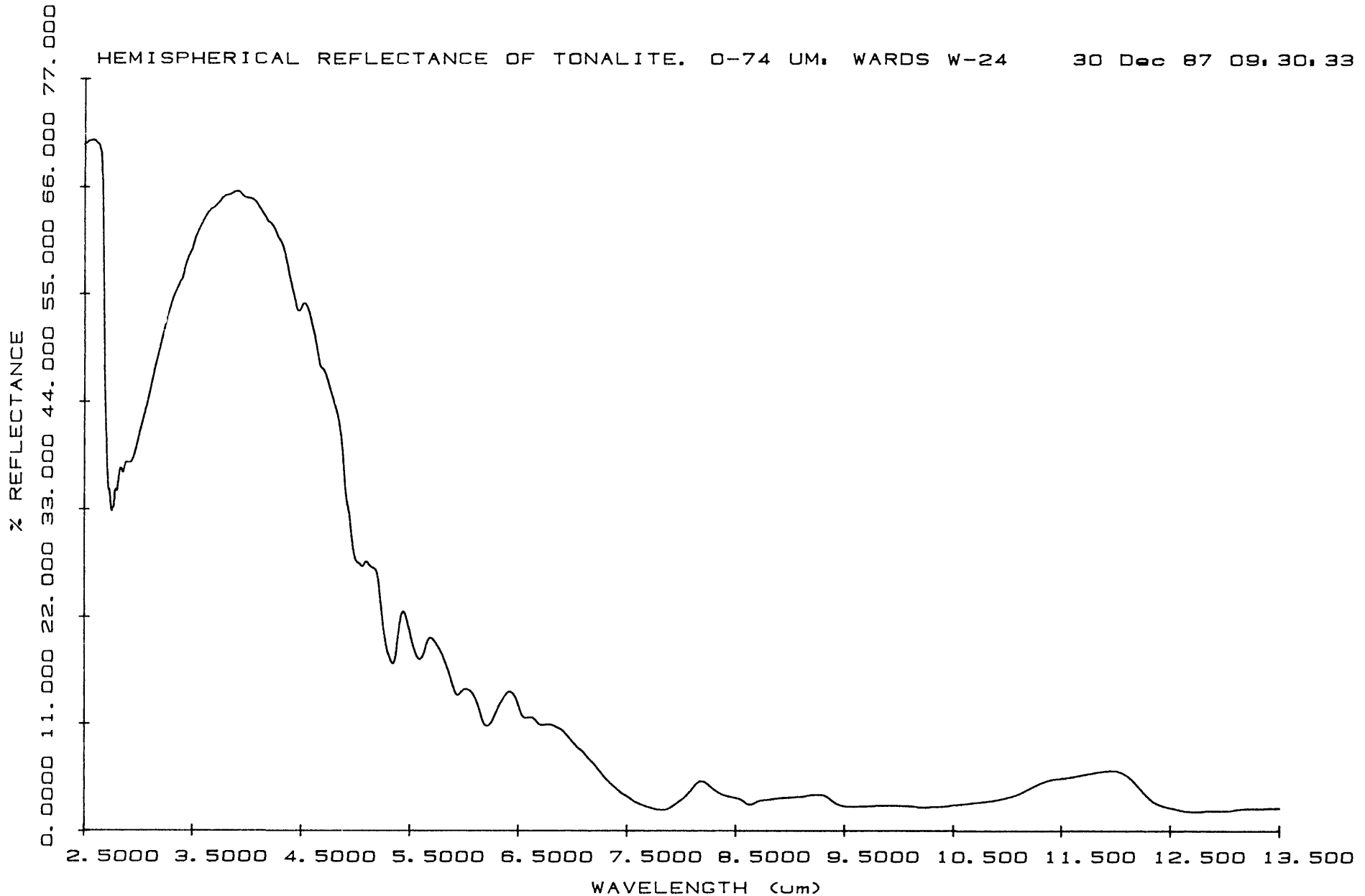
Chemical Analysis:

SiO_2	63.08	CaO	2.39
TiO_2	0.67	Na_2O	3.56
Al_2O_3	16.88	K_2O	1.3
Fe_2O_3	1.41	H_2O	1.06
FeO	4.08	P_2O_5	0.1
MnO	0.09		
MgO	5.98		
	TOTAL	100.6	(CO_2 not analyzed)

Spectra on File:

Tonalite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Tonalite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Tonalite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF TONALITE, ROUGH SURFACE: WARDS W-24 24 Sep 87 13:11
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF TONALITE. 0-74 UM. WARDS W-24
30 Dec 87 09:30:33
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Anorthosite

Locality: Near Elizabethtown, Essex County, New York

Donor: Ward's Scientific

Catalogue Number: W-32

Hand Sample Description: The hand sample consists of very dark gray large tabular plagioclase with interstitial bluish-green granulated feldspar groundmass, with some opaque areas ~1-3 mm in size scattered through the sample. The Marcy anorthosite from which this sample was taken is described in: Buddington, A. F., 1938, Adirondack igneous rocks and their metamorphism: Geological Society of America Memoir No. 7, p. 19-33 and 258-259.

Petrographic Description: Very coarse-grained sample consisting of subhedral plagioclase (96%) with some areas showing mortar texture. The plagioclase groundmass apparently is cryptocrystalline due to granulation. There are minute scattered amphibole anhedra (0.6%) and 0.7% opaques. There was no sign of calcite in thin section, nor was the rock analyzed for CO_2, but the spectrum clearly indicates the presence of a small amount of carbonate.

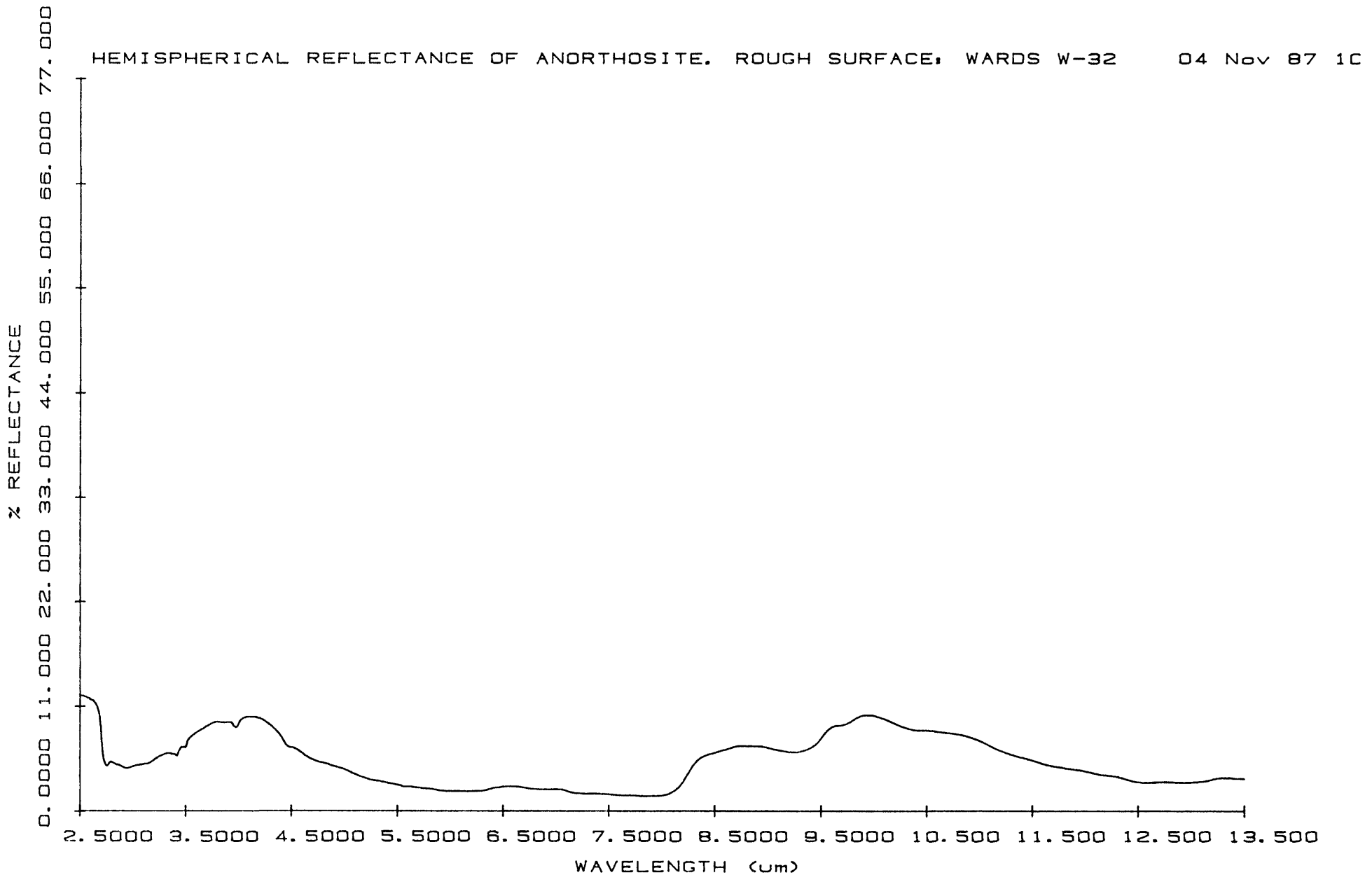
Microprobe Analysis: Microprobe analysis indicated a range of feldspar grains and groundmass composition from ~ An_{10}-An_{50} (oligoclase-andesine); various cryptocrystalline amphiboles (either Tschermakite or hastingsite), opaques high in titanium but also high in silica and lime (a mixture), and possibly some zoisite. Like most "anorthosites" of the Adirondacks, average plagioclase composition is andesine. Hence, these rocks are sometimes classed with lime diorites instead of gabbros and referred to as "andesinites."

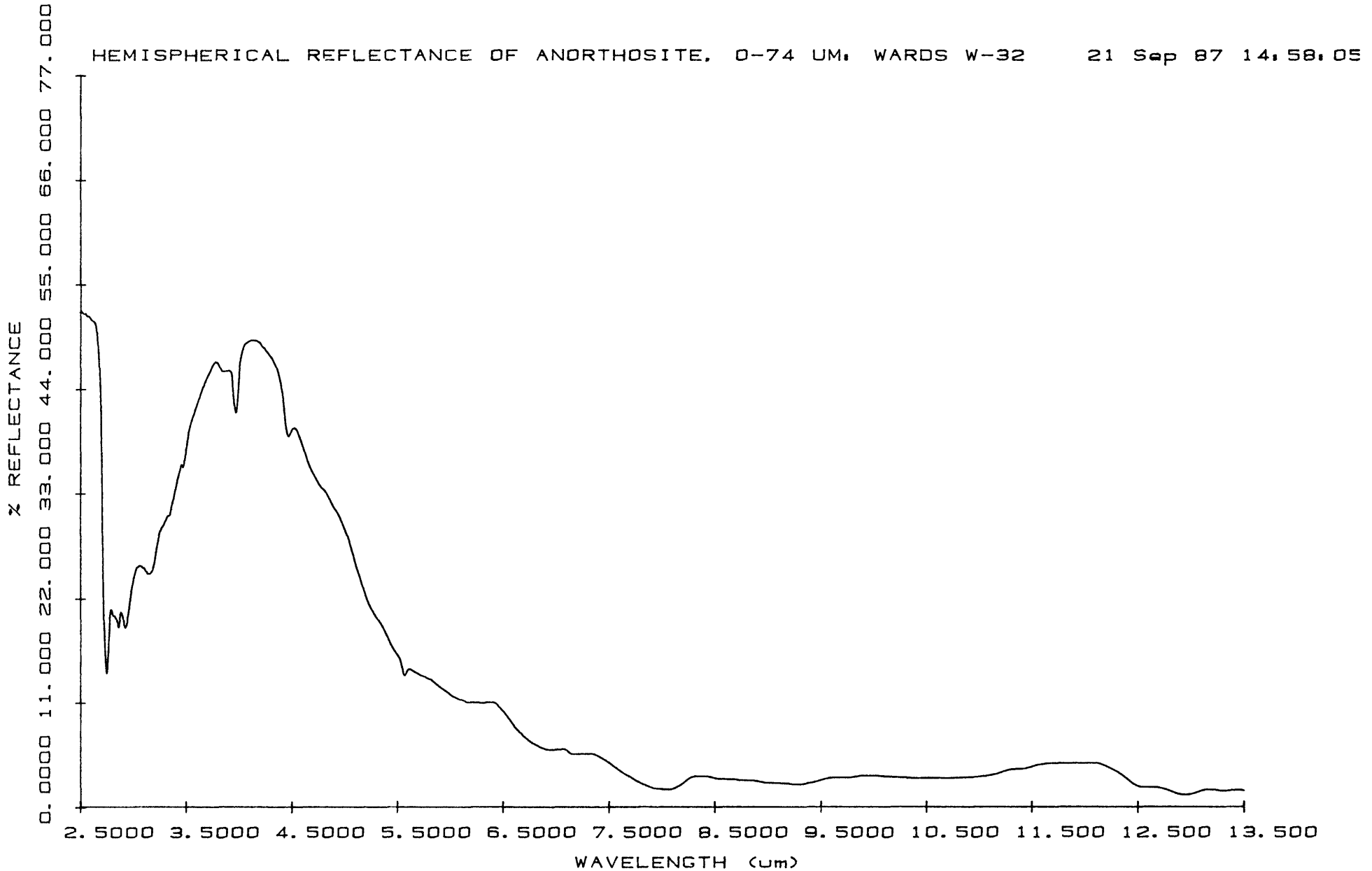
Chemical Analysis:

SiO_2	53.41	CaO	9.65
TiO_2	0.73	Na_2O	5.31
Al_2O_3	25.79	K_2O	1.16
Fe_2O_3	1.15	H_2O	2.25
FeO	1.08	P_2O_5	0.04
MnO	0.02		
MgO	0.25		
	TOTAL	100.84	(CO_2 not analyzed)

Spectra on File:

Anorthosite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Anorthosite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Anorthosite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF ANORTHOSITE. ROUGH SURFACE; WARDS W-32 04 Nov 87 1C
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF ANORTHOSITE, 0-74 UM, WARDS W-32 21 Sep 87 14:58:05
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Basalt

Locality: Chimney Rock, Somerset County, New Jersey

Donor: Ward's Scientific

Catalogue Number: W-36

Hand Sample Description: A greenish-black aphanitic rock.

Petrographic Description: Microphenocrysts of augite (some glomeroporphyritic) are set in a matrix of thin laths of labradorite, granular clinopyroxene and dark, essentially opaque glass which is subordinate and interstitial. Some of the glass has been altered to a brown iron-rich chlorite. The modes gave 31% feldspar, 30% pyroxene, 31% groundmass, 0.2% opaque and 7.8% miscellaneous (alteration products mostly).

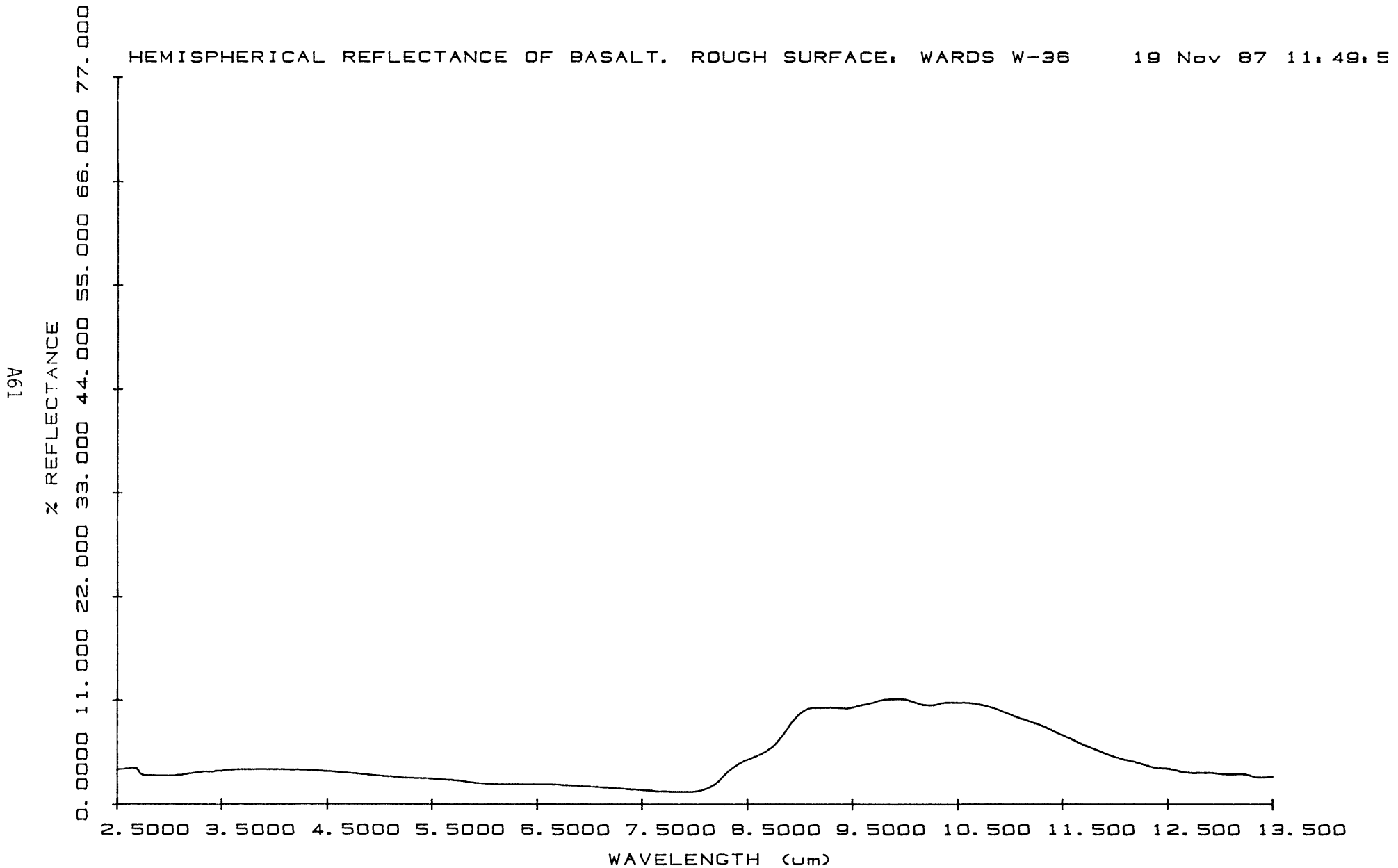
Microprobe Analysis: The feldspar composition ranged from An_{67} to An_{74} (labradorite-bytownite); pyroxene phases probed were augite and pigeonite.

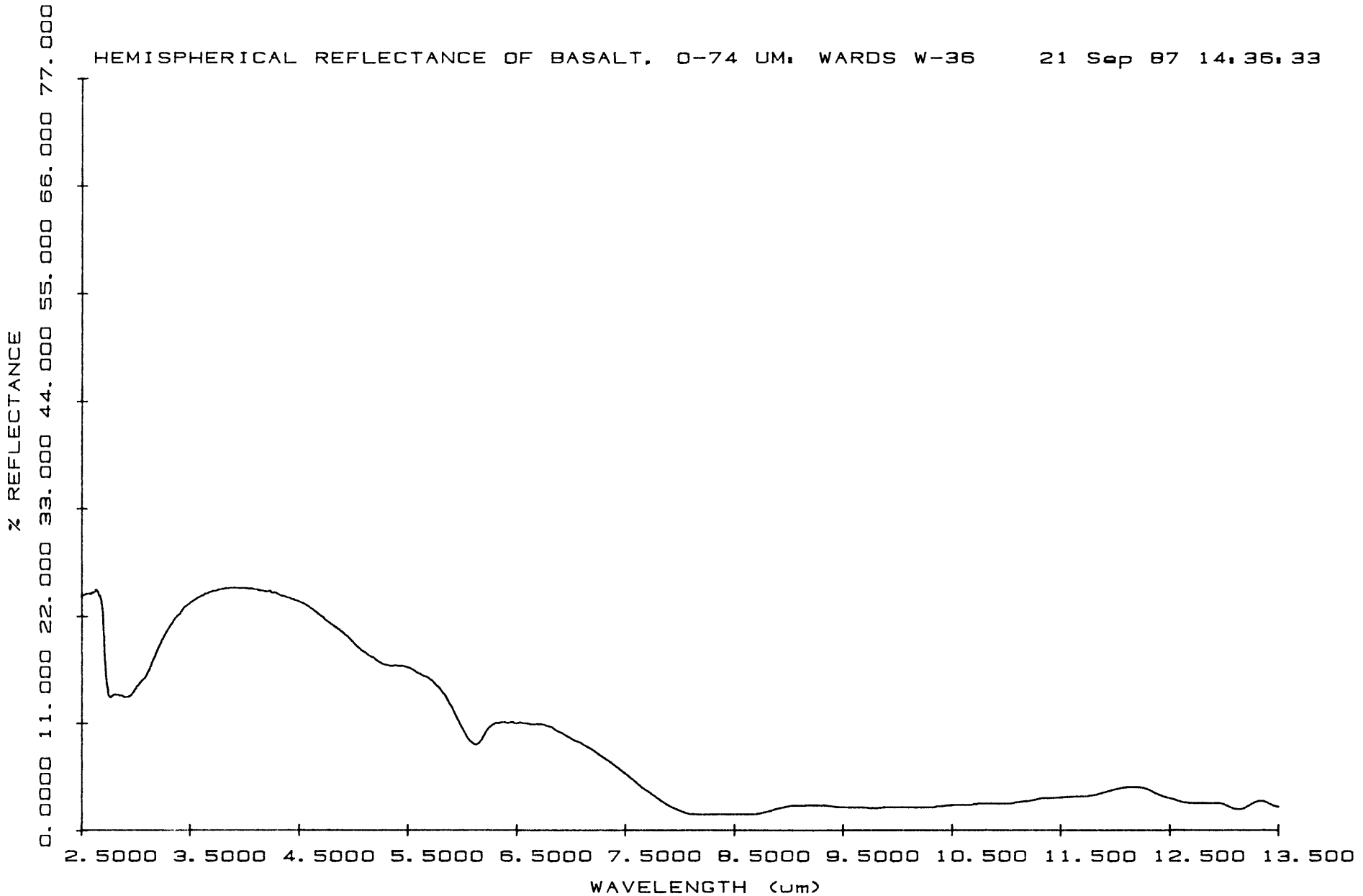
Chemical Analysis:

SiO_2	51.02	CaO	11.26
TiO_2	1.07	Na_2O	1.77
Al_2O_3	14.02	K_2O	0.40
Fe_2O_3	2.59	H_2O	2.55
FeO	7.94	P_2O_5	0.12
MnO	0.17		
MgO	7.86		
	TOTAL	100.77	(CO_2 not analyzed)

Spectra on File:

Basalt.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Basalt.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Basalt.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT, ROUGH SURFACE, WARDS W-36 19 Nov 87 11:49:5
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT, 0-74 UM: WARDS W-36 21 Sep 87 14:36:33
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Basalt.2

Rock Name: Basalt

Locality: Juan de Fuca Ridge

Donor: Smithsonian

Catalogue Number: NMNH 111276

Hand Sample Description: The sample has a glassey rind over a more crystalline interior. It is approximately 4 x 2 cm, light gray on "weathered" surfaces and dark gray on fresh surfaces. This vesicular sample possesses small phenocrysts $\leq$ 1 mm which make up about 10% of the rock. The phenocrysts consist of plagioclase laths and olivine, with plagioclase much more abundant than olivine.

Petrographic Description: The glassy rind portions are almost apheric, with rare plagioclase and olivine microphenocrysts (in that order of abundance). The core of the sample consists of plagioclase and augite (?) in a 1:1 ratio with interstitial glass.

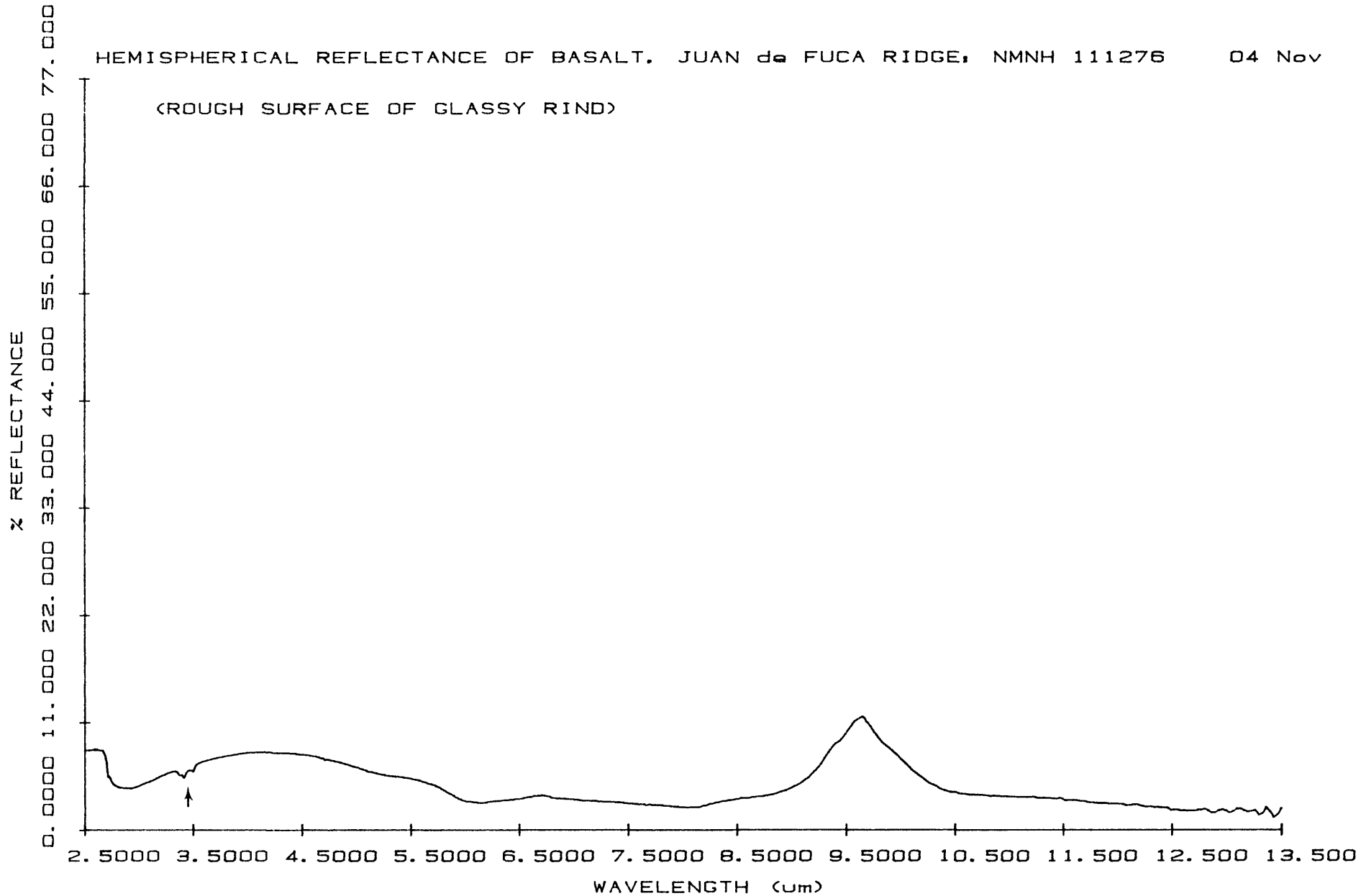
Microprobe Analysis: None.

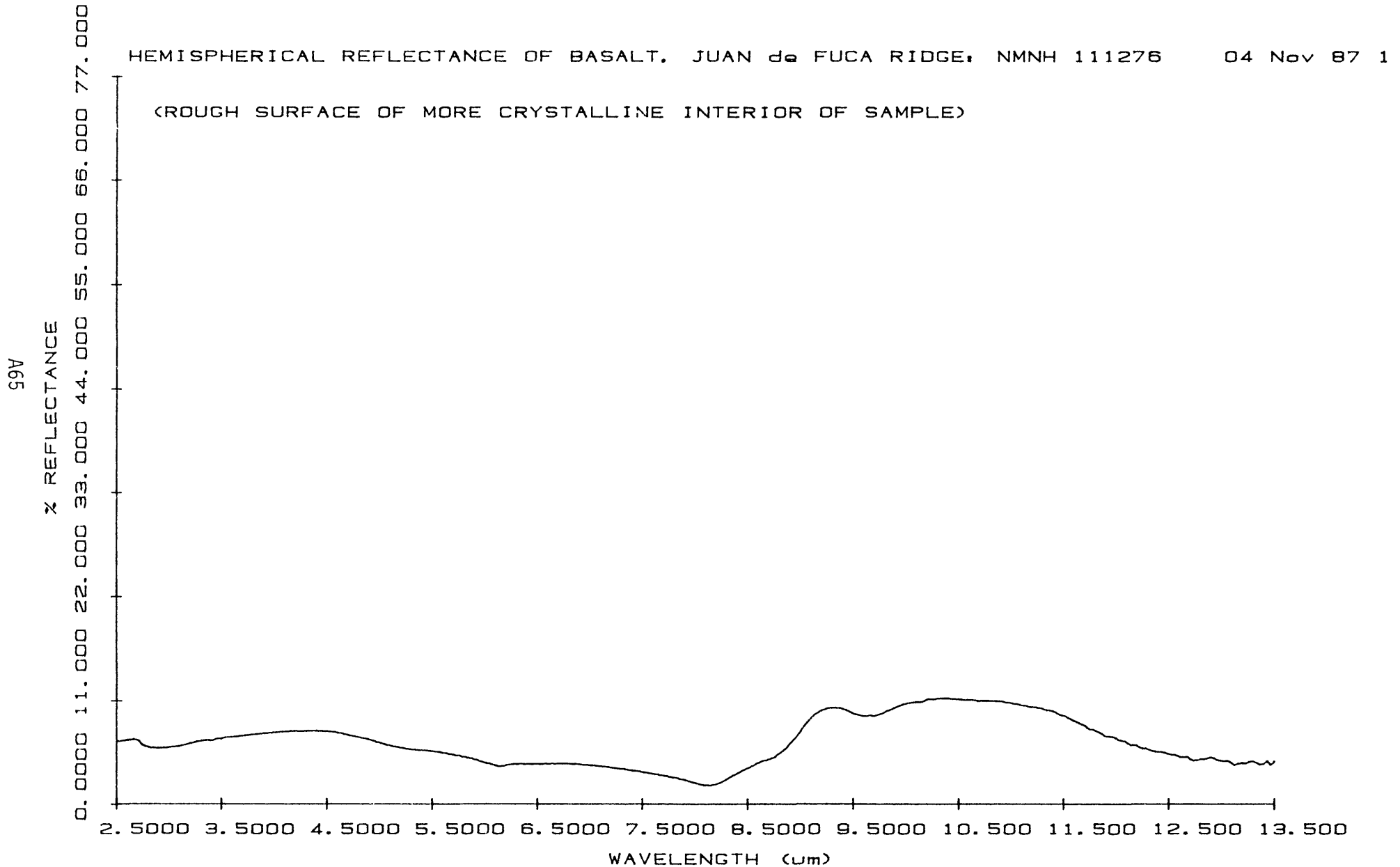
Chemical Analysis: (by William Melson, NMNH, Wash., DC)

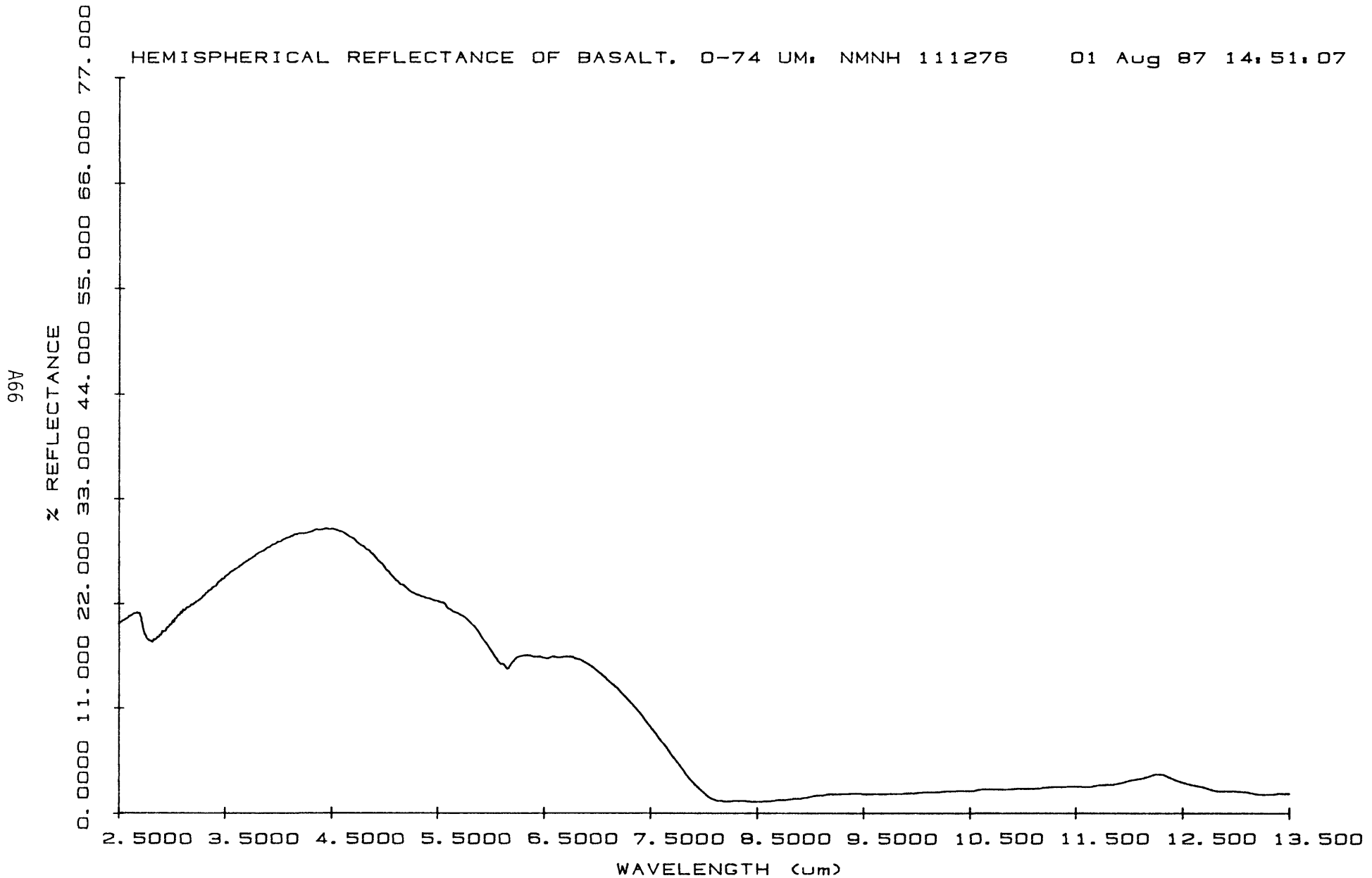
SiO_2	49.95	CaO	12.04
TiO_2	1.48	Na_2O	2.48
Al_2O_3	14.8	K_2O	0.100
Fe_2O_3	1.74	H_2O	0.180
FeO	9.15	P_2O_5	0.12
MnO	0.190		
MgO	7.75		
	TOTAL 99.98		

Spectra on File:

Basalt.H2	Hemispherical reflectance of glassy rind on Solid Rock disk #1
Basalt.H2B	Hemispherical reflectance of core of basalt on Solid Rock disk #1
Basalt.H2	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT. JUAN de FUCA RIDGE: NMNH 111276 04 Nov
(ROUGH SURFACE OF GLASSY RIND)
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT. JUAN de FUCA RIDGE: NMNH 111276 04 Nov 87 1
(ROUGH SURFACE OF MORE CRYSTALLINE INTERIOR OF SAMPLE)
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT, 0-74 UM; NMNH 111276 01 Aug 87 14:51:07
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A66

Rock Name: Basalt

Locality: Kilauea Iki Drill core

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 79-3-100

Hand Sample Description: A gray, medium-grained, slightly vesicular rock with plagioclase laths $\leq$3 mm, opaques and a green phase ~1-2 mm in size, set in a grayish groundmass.

Petrographic Description: A medium-grained basaltic rock with a subophitic texture. Subhedral plagioclase laths are partially enclosed in anhedral clinopyroxene (augite?). There are also scattered opaque anhedra and dark brownish interstitial glass.

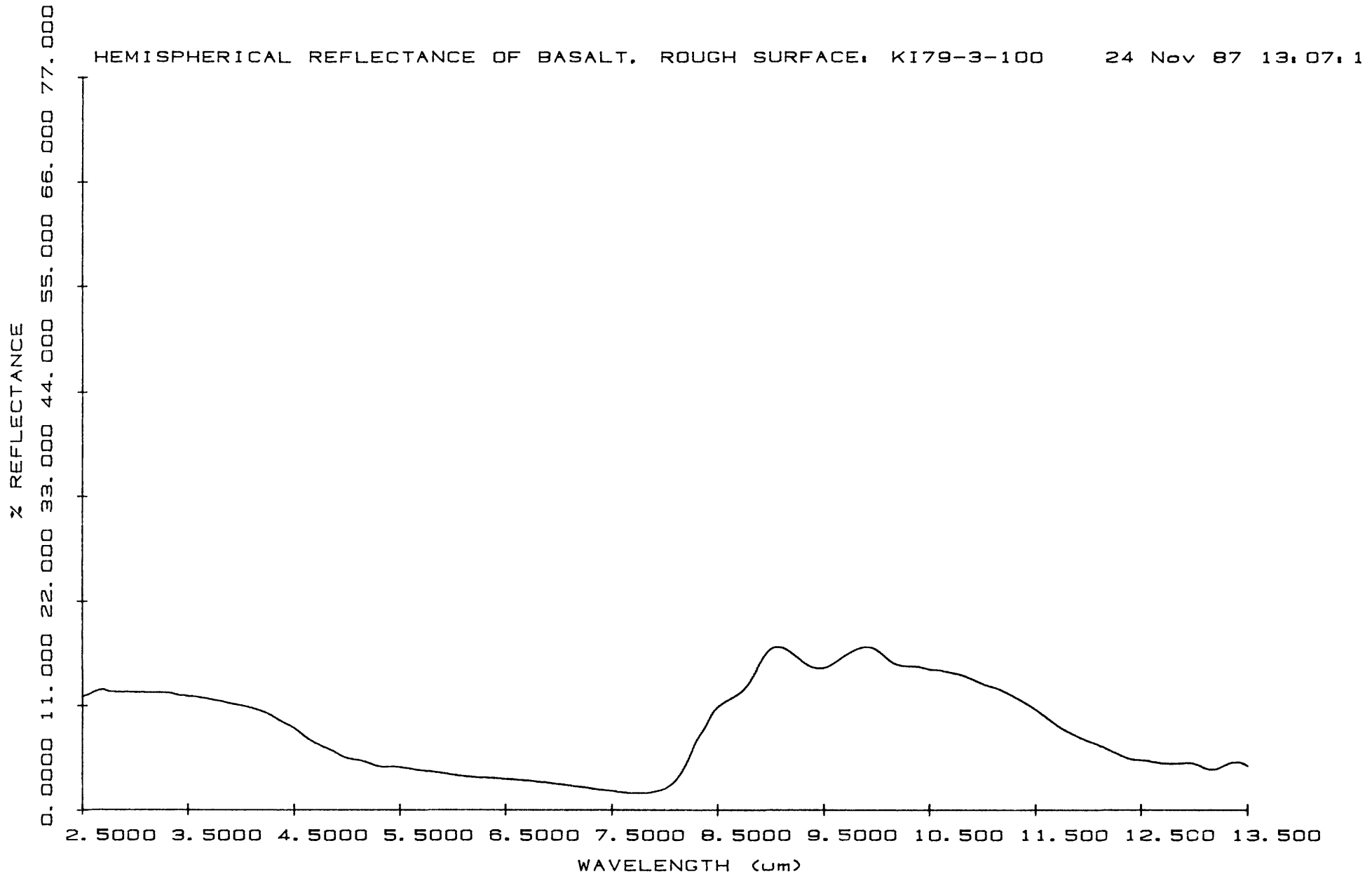
Microprobe Analysis: None.

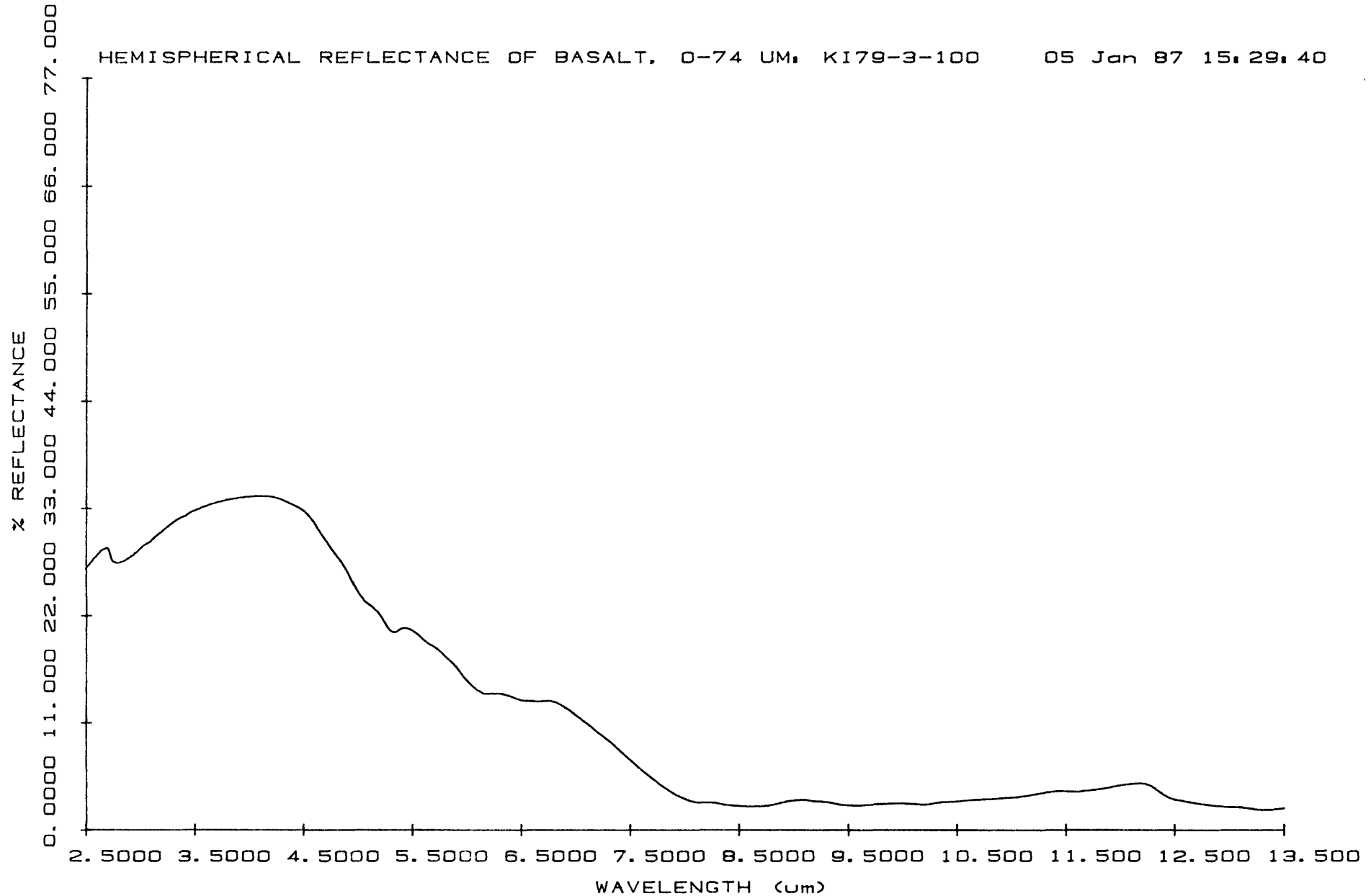
Chemical Analysis: (by John Marinenko, USGS, Reston, VA.)

SiO_2	51.03	CaO	10.75
TiO_2	3.36	Na_2O	2.84
Al_2O_3	14.28	K_2O	0.71
Fe_2O_3	1.74	H_2O	0.1
FeO	8.69	P_2O_5	0.32
MnO	0.16	Cr_2O_3	0.02
MgO	5.91		
	TOTAL 99.91		

Spectra on File:

Basalt.H5 Hemispherical reflectance of rough surface on Solid Rock disk #1
Basalt.H5 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT, ROUGH SURFACE: KI79-3-100 24 Nov 87 13:07:1
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT, 0-74 UM, KI79-3-100 05 Jan 87 15:29:40
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Basalt

Locality: Kilauea

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 75-1-50.8

Hand Sample Description: A gray, porphyritic, vuggy or vesicular rock with green phenocrysts ranging in size from < 1 mm to 2 mm and making up ≤ 5% of the whole rock.

Petrographic Description: A medium- to fine-grained porphyritic rock with a felty texture. Phenocrysts of olivine, some with probable reaction rims, are set in a groundmass of plagioclase laths, olivine, clinopyroxene (augite?), opaques, and interstitial glass.

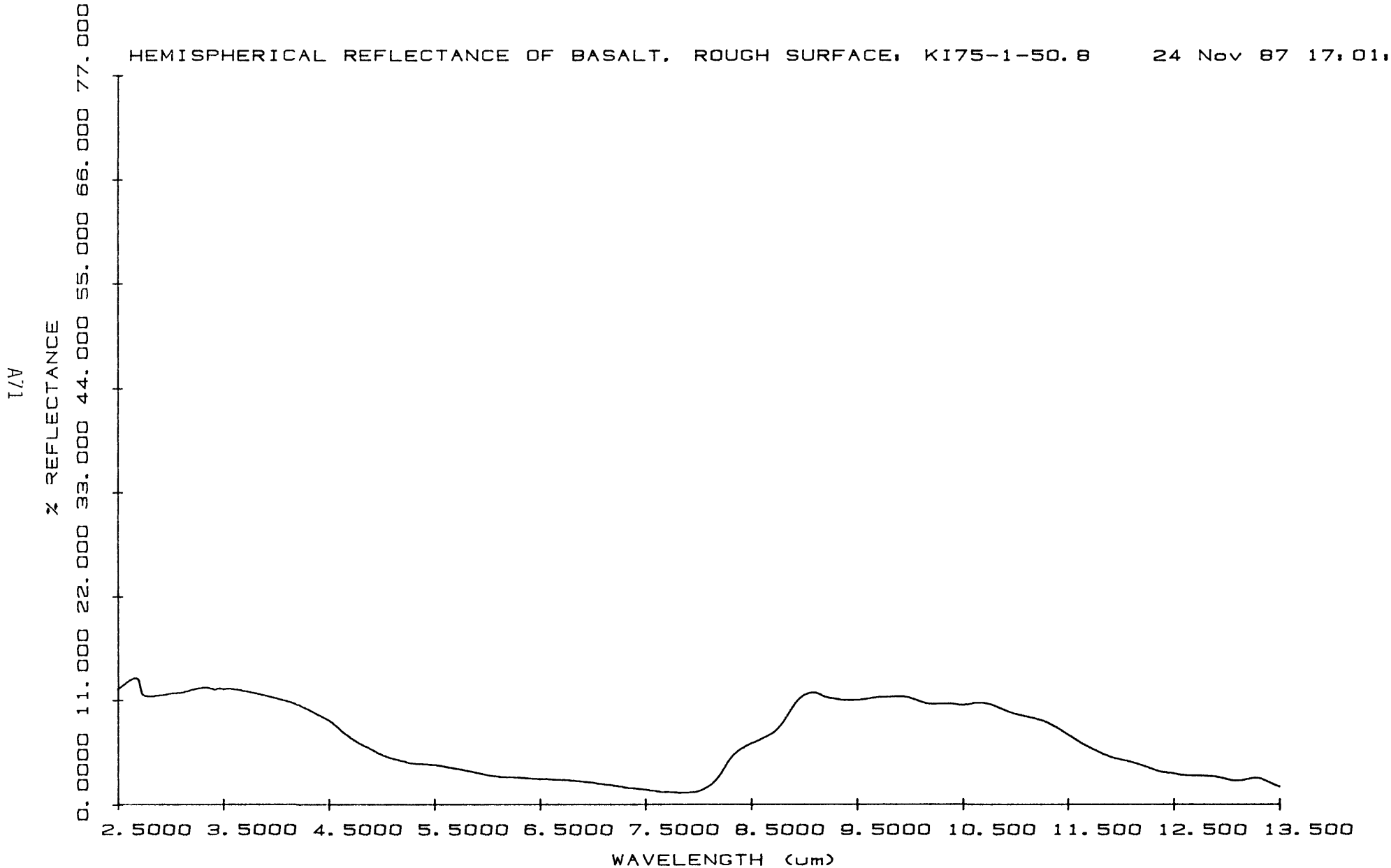
Microprobe Analysis: None.

Chemical Analysis: (by John Marinenko, USGS, Reston, VA.)

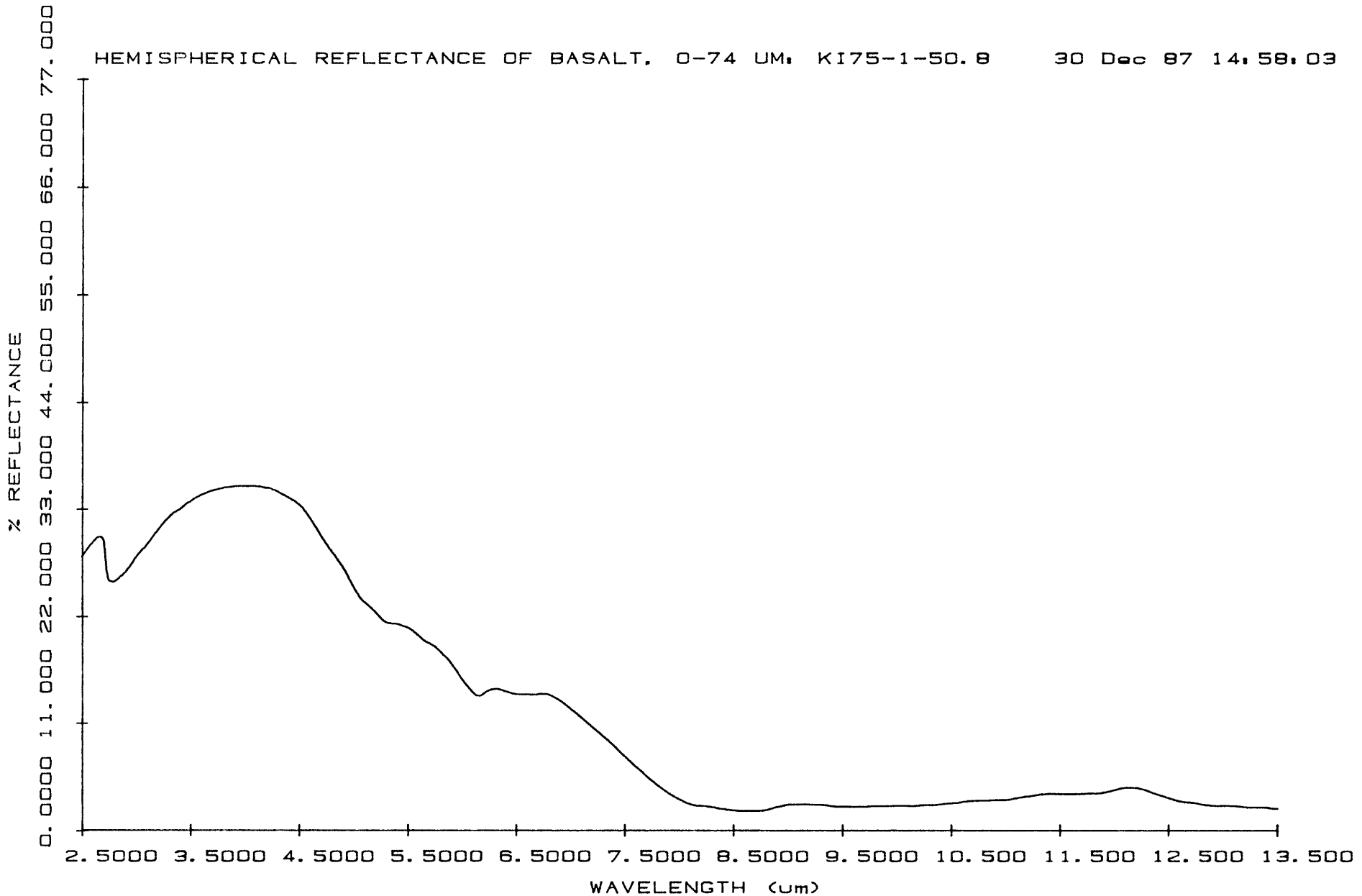
SiO_2	49.52	CaO	10.54
TiO_2	3.11	Na_2O	2.33
Al_2O_3	12.91	K_2O	0.62
Fe_2O_3	1.78	H_2O	0.19
FeO	9.45	P_2O_5	0.30
MnO	0.17	Cr_2O_3	0.06
MgO	9.07		
	TOTAL	100.05	

Spectra on File:

Basalt.H7 Hemispherical reflectance of rough surface on Solid Rock disk #1
Basalt.H7 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT, ROUGH SURFACE; KI75-1-50.8 24 Nov 87 17:01:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A71


HEMISPHERICAL REFLECTANCE OF BASALT, 0-74 UM: KI75-1-50.8 30 Dec 87 14:58:03
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Basalt

Locality: Kilauea

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 67-3-84

Hand Sample Description: A dark gray, slightly vesicular rock, consisting of black and light green phenocrysts ~0.5-1 mm in size making up about 40% of the rock.

Petrographic Description: A medium-grained porphyritic rock with olivine and pyroxene phenocrysts. The groundmass consists of plagioclase, abundant interstitial brownish glass, olivine, pyroxene, opaques, and apatite. The glass analysis is given below.

Microprobe Analysis: (by Rosalind Helz). The average composition of the olivine was Fo_{62}, that of the feldspar An_{78} (bytownite). Two pyroxene phases were probed; a high Mg low Ca pigeonite and titanaugite. Opaque phases probed were ilmenite and magnetite. Glass composition was:

SiO_2	55.02	Cr_2O_3	0.00
TiO_2	2.83	CaO	6.46
Al_2O_3	12.50	Na_2	3.50
FeO	12.58	K_2O	1.82
MnO	0.14	P_2O_5	0.82
MgO	2.74		

TOTAL 98.41

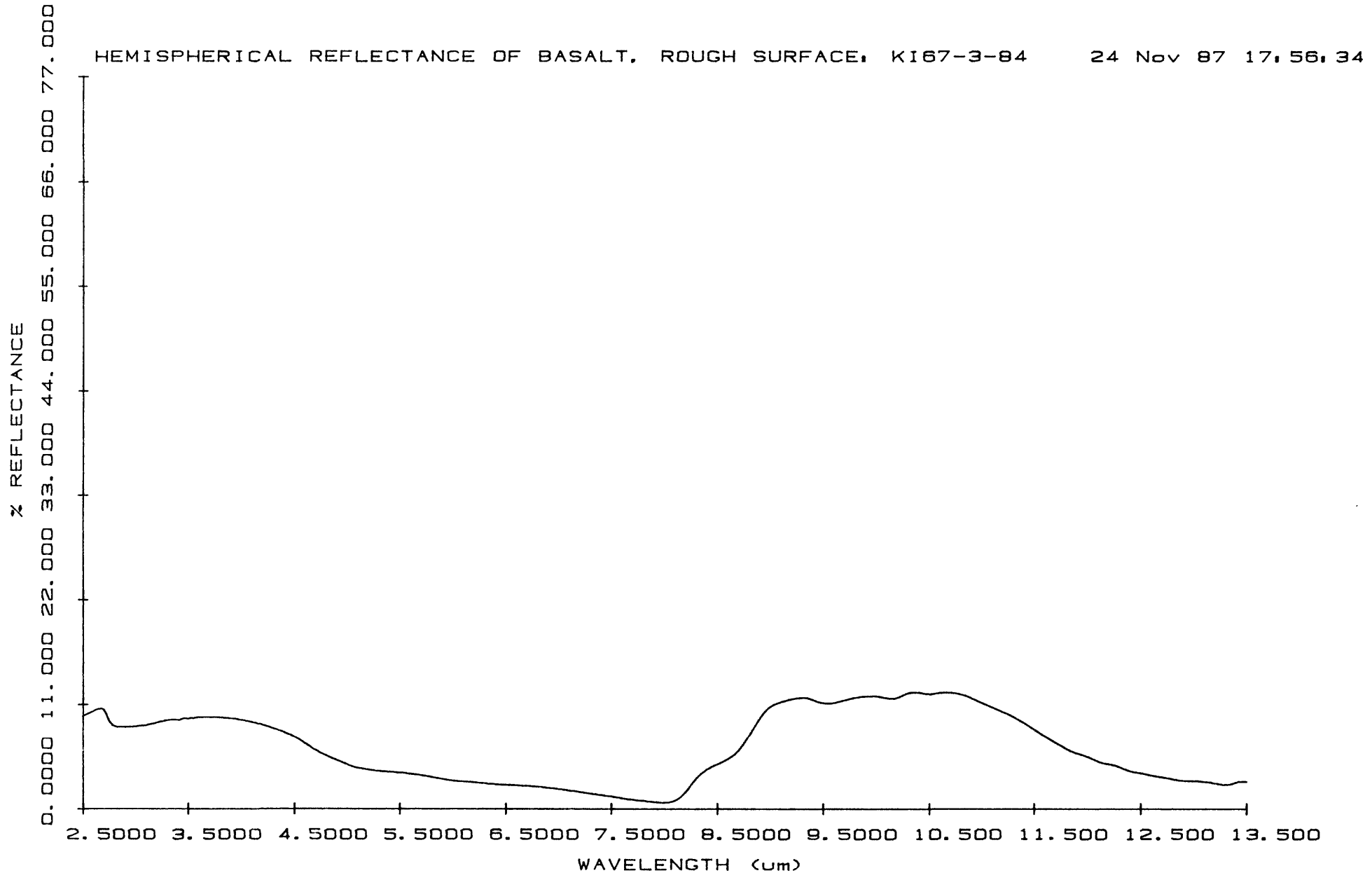
Chemical Analysis: (by Herb Kirschenbaum, USGS, Reston, VA.)

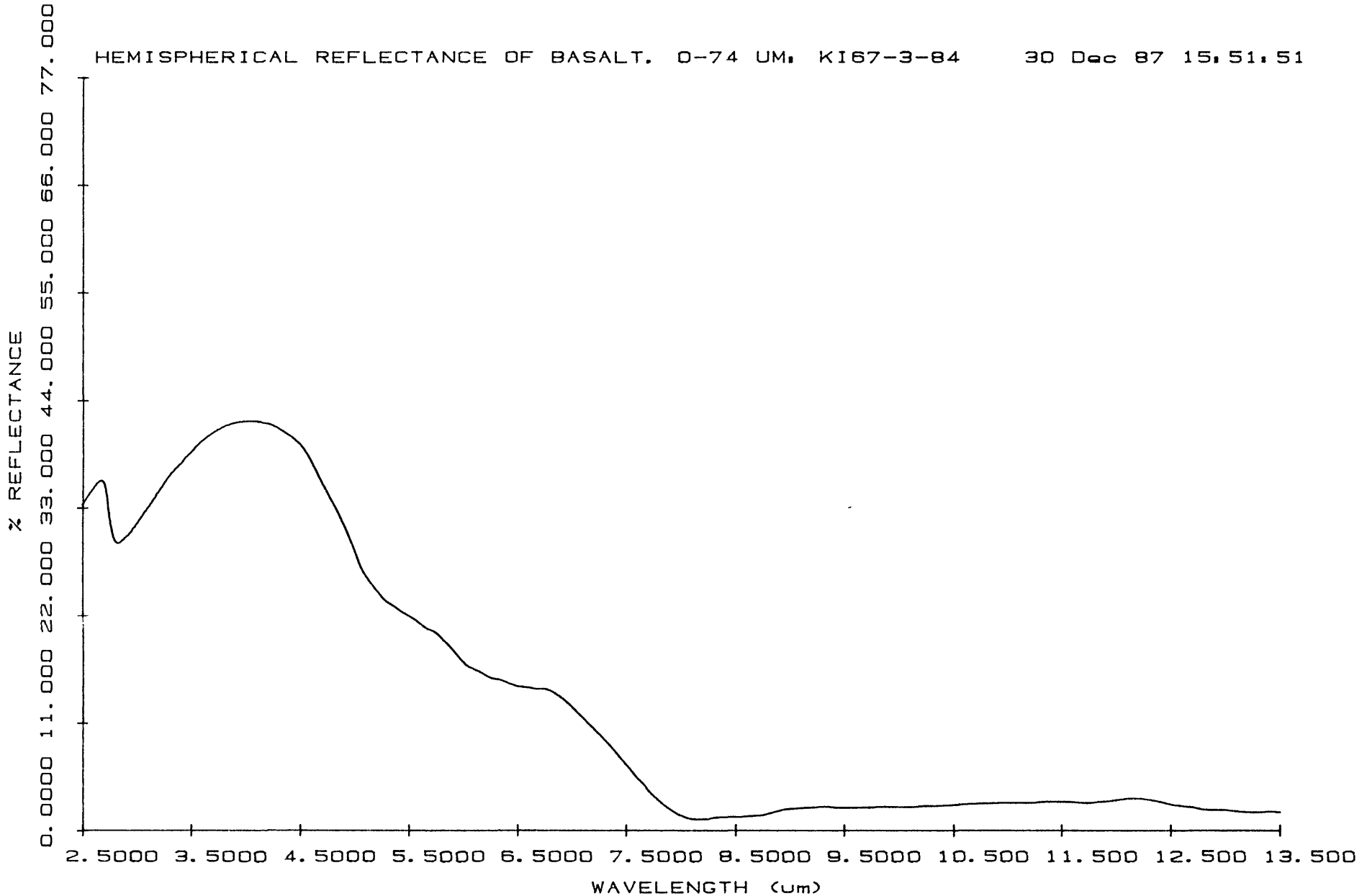
SiO_2	49.93	CaO	10.88
TiO_2	2.99	Na_2O	2.51
Al_2O_3	13.81	K_2O	0.65
Fe_2O_3	1.73	H_2O	0.15
FeO	9.13	P_2O_5	0.31
MnO	0.16	Cr_2O_3	0.2
MgO	7.69		

TOTAL 99.95

Spectra on File:

Basalt.H9 Hemispherical reflectance of rough surface on Solid Rock disk #1
Basalt.H9 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT, ROUGH SURFACE: KI67-3-84 24 Nov 87 17:56:34
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT. 0-74 UM, KI67-3-84 30 Dec 87 15:51:51
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Basalt

Locality: Kilauea

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 81-1-273.6

Hand Sample Description: A light gray porphyritic rock with green olivine phenocrysts 1 to 2 mm in size making up about 3% of the rock; set in a gray, very fine-grained groundmass.

Petrographic Description: A fine-grained porphyritic rock with a felty texture, bearing olivine phenocrysts. The groundmass consists of plagioclase, olivine, augite, and chromite with interstitial brownish glass; results of the glass analysis are given below.

Microprob Analysis: (by Rosalind Helz). The olivine composition was Fo_{80}, that of the feldspar An_{85} (bytownite). Titanaugite was also probed. Glass composition was:

SiO_2	50.54	Cr_2O_3	0.00
TiO_2	4.25	CaO	9.64
Al_2O_3	12.83	Na_2	2.83
FeO	12.60	K_2O	0.86
MnO	0.14	P_2O_5	0.36
MgO	5.58		

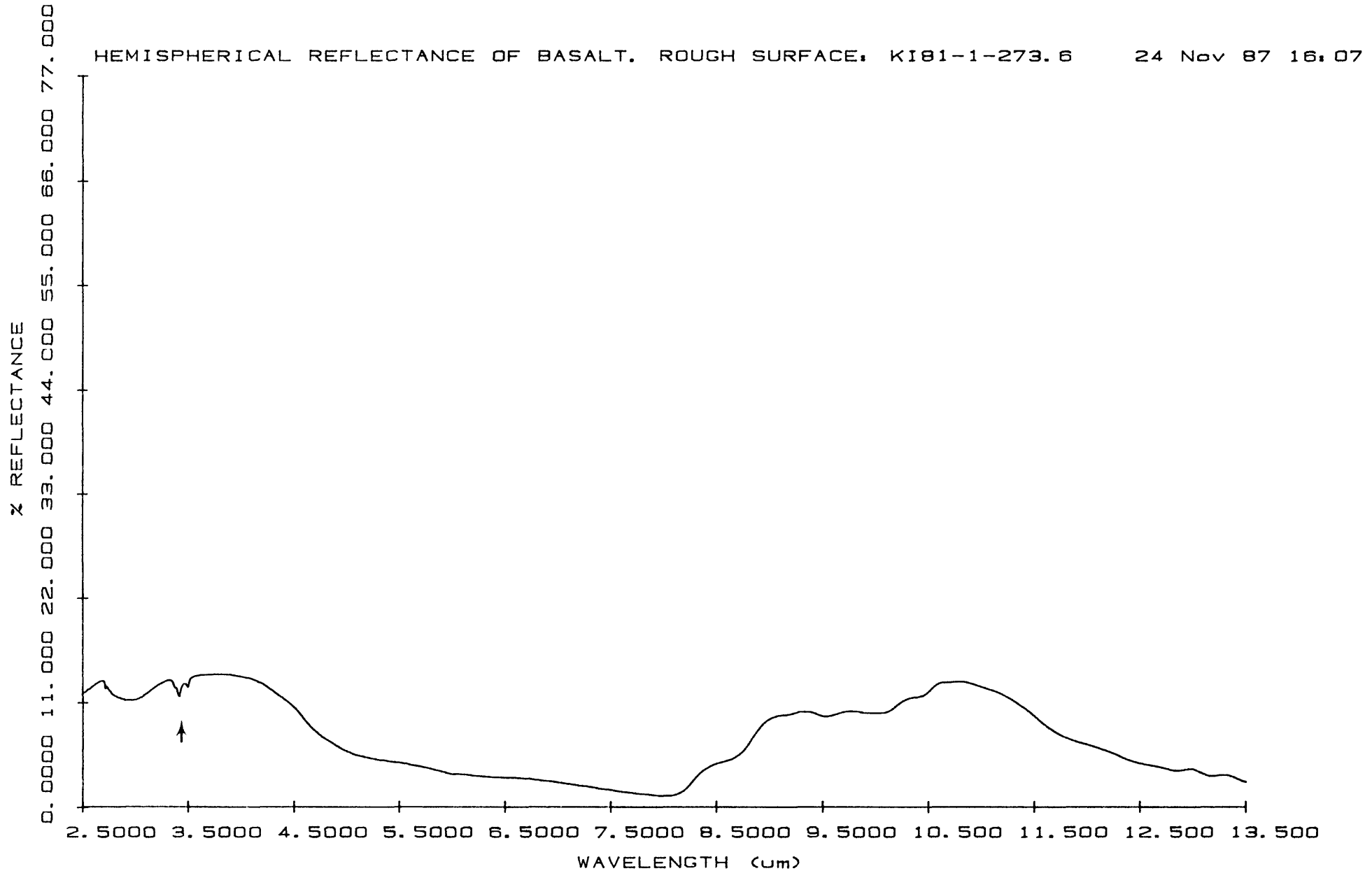
TOTAL 99.49

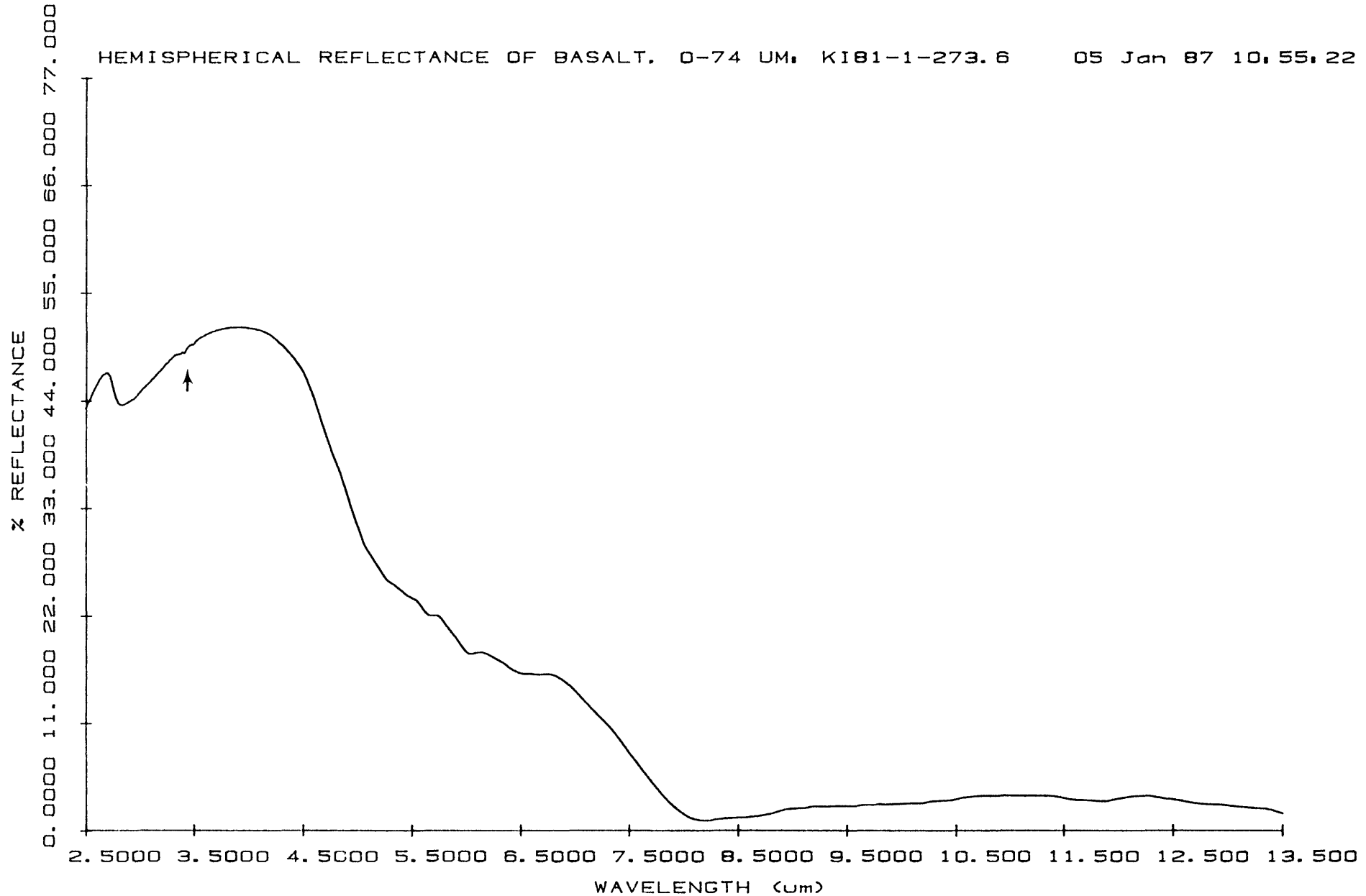
Chemical Analysis: (by John Marinenko, USGS, Reston, VA.)

SiO_2	49.11	CaO	12.22
TiO_2	1.56	Na_2O	1.84
Al_2O_3	12.96	K_2O	0.32
Fe_2O_3	1.47	H_2O	0.04
FeO	8.26	P_2O_5	0.18
MnO	0.15	Cr_2O_3	0.13
MgO	11.95		
TOTAL	100.13		

Spectra on File:

Basalt.H10 Hemispherical reflectance of rough surface on Solid Rock disk #1
Basalt.H10 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF BASALT. ROUGH SURFACE: KI81-1-273.6 24 Nov 87 16:07
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF BASALT. 0-74 UM. KI81-1-273.6 05 Jan 87 10:55:22
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Diabase

Locality: St. Peters, Pennsylvania

Donor: Ward's Scientific

Catalogue Number: W-127

Hand Sample Description: A medium-grained dark gray rock consisting of feldspar and pyroxene.

Petrographic Description: A sample of typical diabasic texture, with euhedral to subhedral plagioclase laths showing albite twinning and zoning (normal and oscillatory). The plagioclase makes up about 48% of the rock. The anhedral pyroxenes (26% orthopyroxene, 22% clinopyroxene) commonly show exsolution lamellae, and the clinopyroxenes are occasionally twinned and frequently show "herringbone" exsolution. Minor biotite (0.5%) replaces some pyroxene marginally, while opaque phases constitute about 2% of the sample.

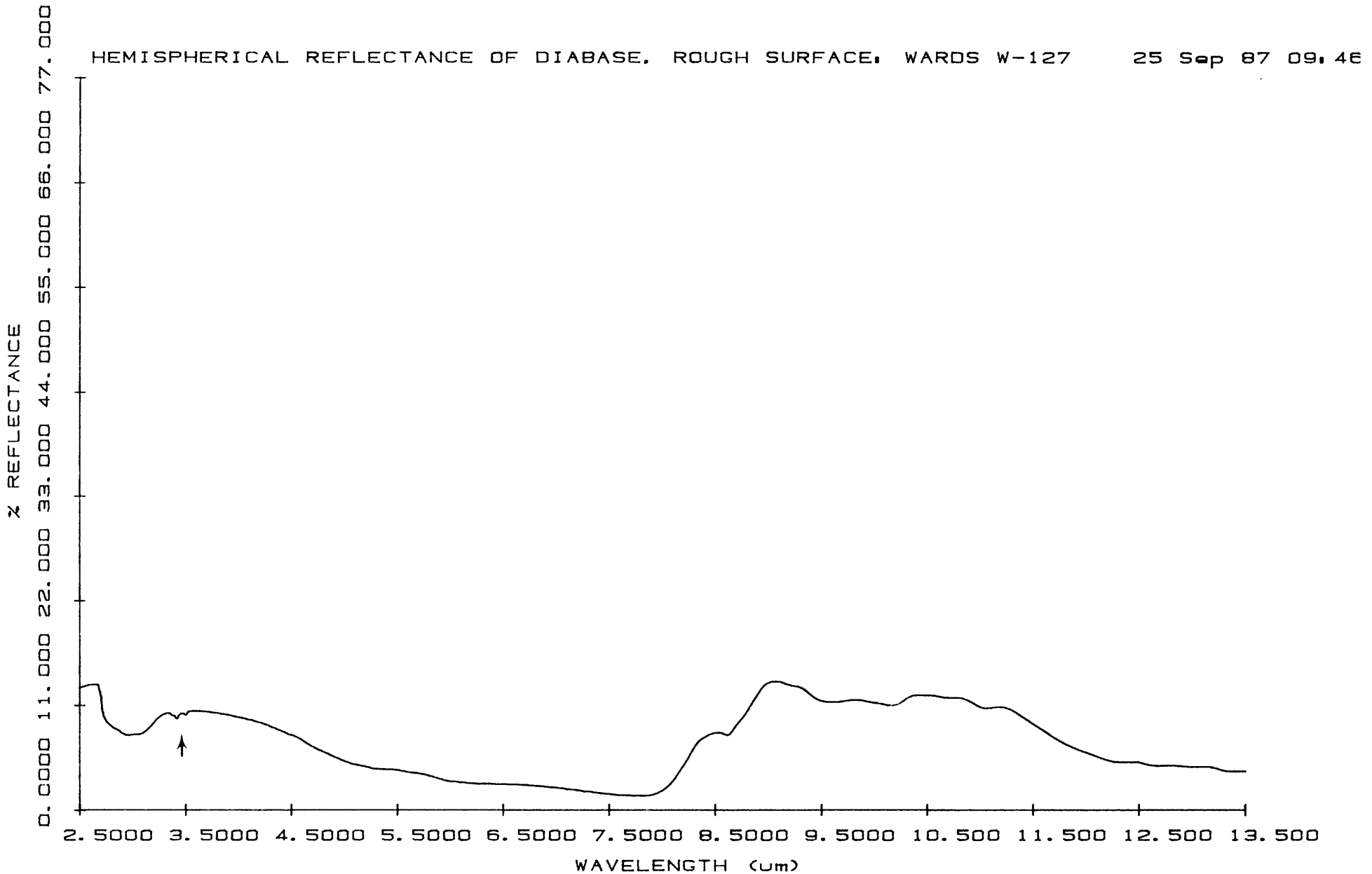
Microprobe Analysis: The feldspar composition was that of labradorite, ranging from An_{65} to An_{69}. The hypersthene, according to one analysis, had 40 mol % ferrosilite. The augite was homogeneous with about 20% FeO, 40% MgO, and 40% CaO. An analysis of ilmenite indicated about 1% MgO.

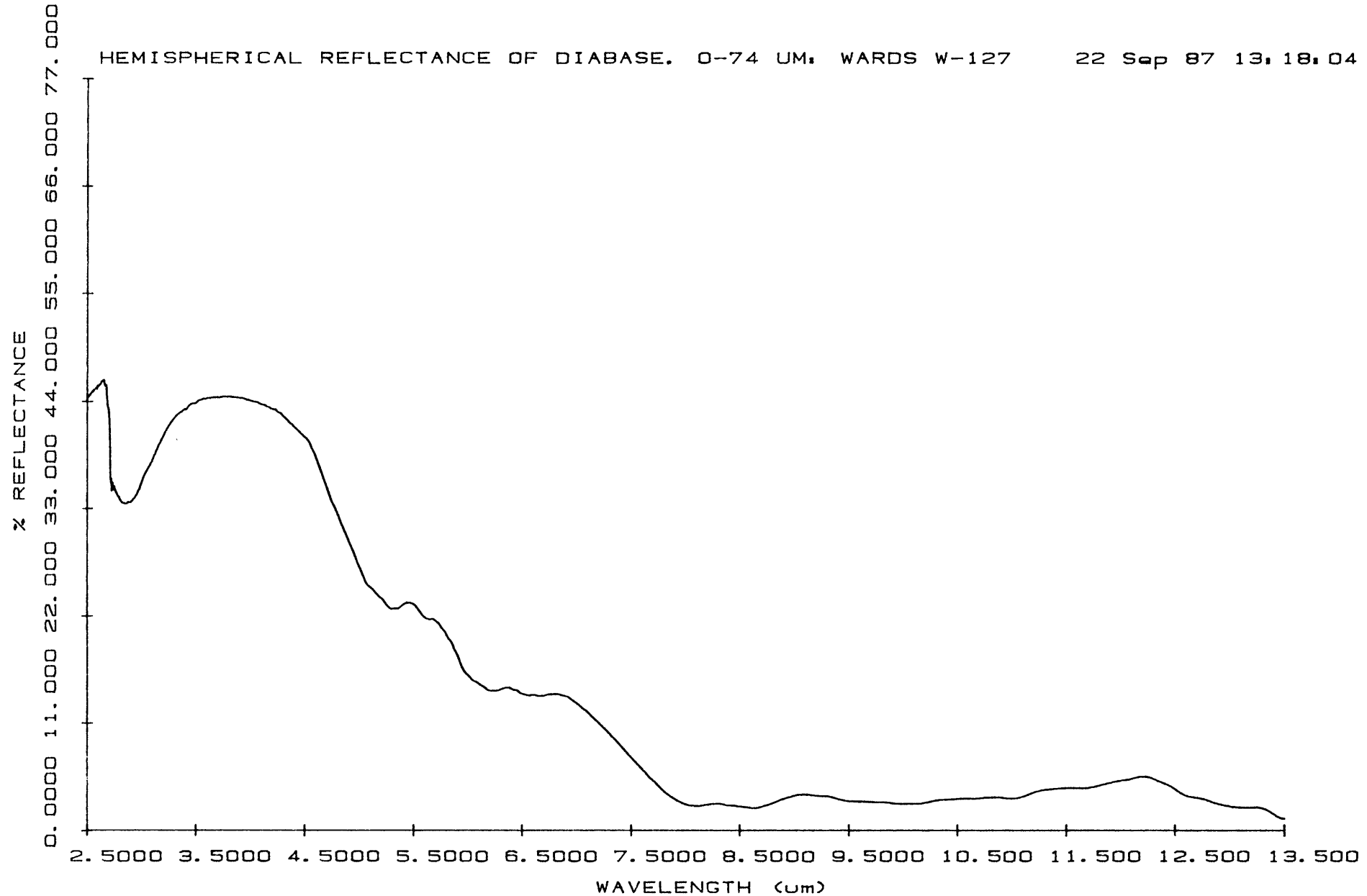
Chemical Analysis:

SiO_2	52.41	CaO	11.70
TiO_2	0.94	Na_2O	1.64
Al_2O_3	13.11	K_2O	0.47
Fe_2O_3	1.35	H_2O	0.80
FeO	8.34	P_2O_5	0.07
MnO	0.17		
MgO	9.36		
	TOTAL	100.3	

Spectra on File:

Diabase.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Diabase.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Diabase.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF DIABASE, ROUGH SURFACE: WARDS W-127 25 Sep 87 09:46
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF DIABASE. 0-74 UM: WARDS W-127 22 Sep 87 13:18:04
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Diabase

Locality: Jersey City, Hudson County, New Jersey

Donor: Ward's Scientific

Catalogue Number: W-33

Hand Sample Description: A medium-grained gray rock consisting of plagioclase, pyroxenes and opaques.

Petrographic Description: A uniformly-grained aggregate of chiefly euhedral to subhedral plagioclase laths and anhedral pyroxenes in a classic diabasic texture. The plagioclase frequently shows oscillatory zoning, less commonly normal zoning. The augite usually contains exsolution phases and is occasionally twinned. Minor biotite replaces some pyroxenes marginally. Modal analysis gave: 46% feldspar, 35% clinopyroxene, 14% orthopyroxene, 2% opaques and 1.2% biotite.

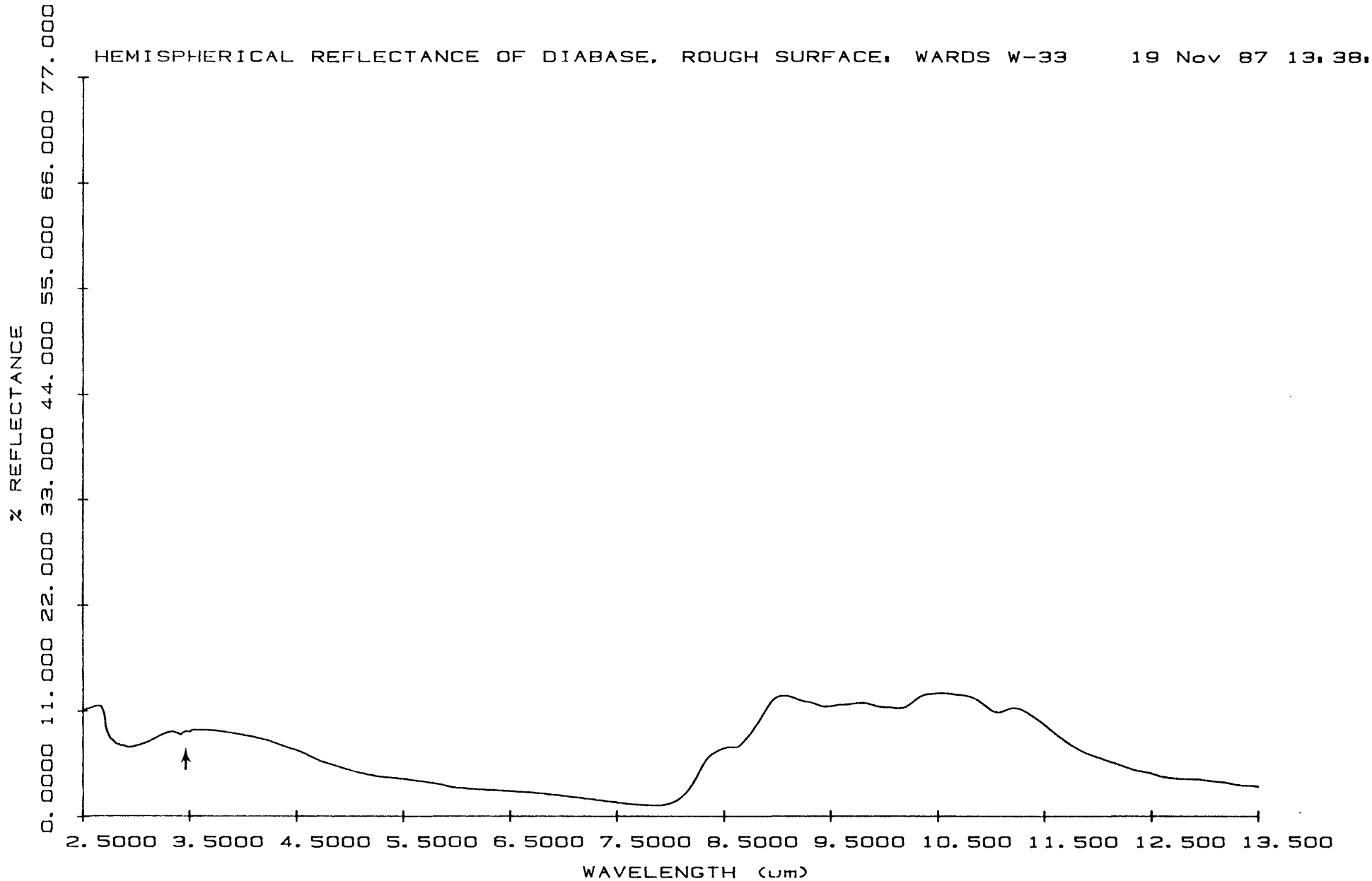
Microprobe Analysis: The analysis revealed the feldspar composition to range from labradorite to bytownite (An_{56} to An_{72}). Individual grains often varied in composition between labradorite and that of bytownite due to zoning. The augite frequently showed complex substitutional relationships among the divalent cations FeO, MgO, and CaO, probably a result of exsolution. One augite grain probed showed hypersthene exsolved from salite, while another grain gave a mixture of magnesian pigeonite and salite. The orthopyroxene grains (not the exsolved phases) proved to be hypersthene, one of which was 33 mol % ferrosilite. Other phases probed were ilmenite and phlogopite.

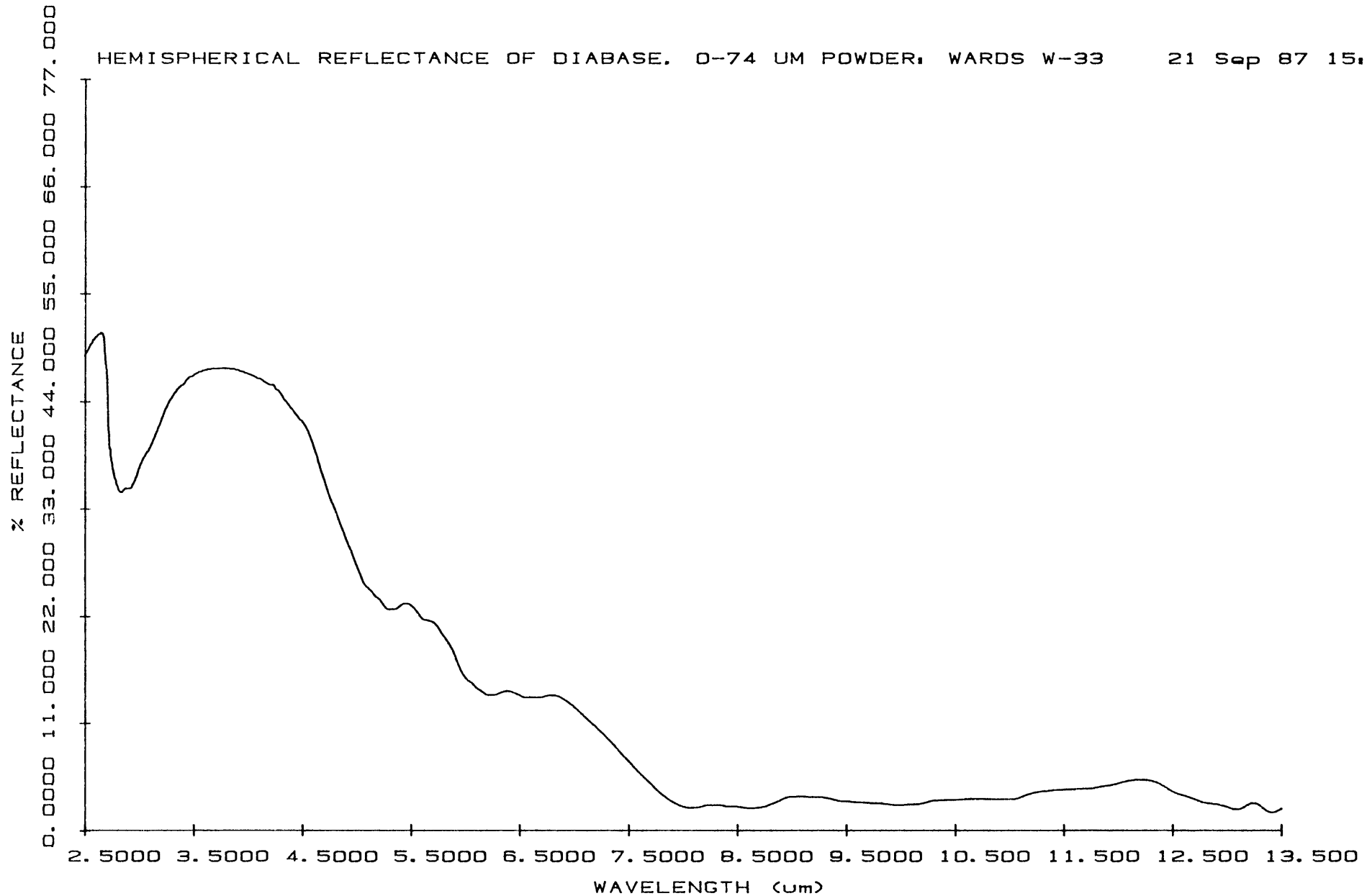
Chemical Analysis:

SiO_2	52.54	CaO	11.74
TiO_2	0.86	Na_2O	1.61
Al_2O_3	12.82	K_2O	0.45
Fe_2O_3	1.16	H_2O	0.98
FeO	8.44	P_2O_5	0.09
MnO	0.17		
MgO	9.81		
	TOTAL	100.6	

Spectra on File:

Diabase.H2	Hemispherical reflectance of rough surface on Solid Rock disk #1
Diabase.H2	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Diabase.2	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF DIABASE, ROUGH SURFACE: WARDS W-33 19 Nov 87 13:38:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF DIABASE. 0-74 UM POWDER: WARDS W-33 21 Sep 87 15:16
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Gabbro

Locality: Escondido, San Diego County, California

Donor: Ward's Scientific

Catalogue Number: W-28

Hand Sample Description: A dark gray medium-grained rock composed of plagioclase, a mafic mineral and minor opaques.

Petrographic Description: An equigranular, hypidiomorphic rock composed of subhedral plagioclase laths showing albite twinning,sometimes Carlsbad twinning, and frequently gradational zonation. There are anhedra of green pyroxene and colorless pyroxene (as exsolution), minor green hornblende and abundant opaque anhedra. Modes were: 66% plagioclase, 28% pyroxene and 6% opaque.

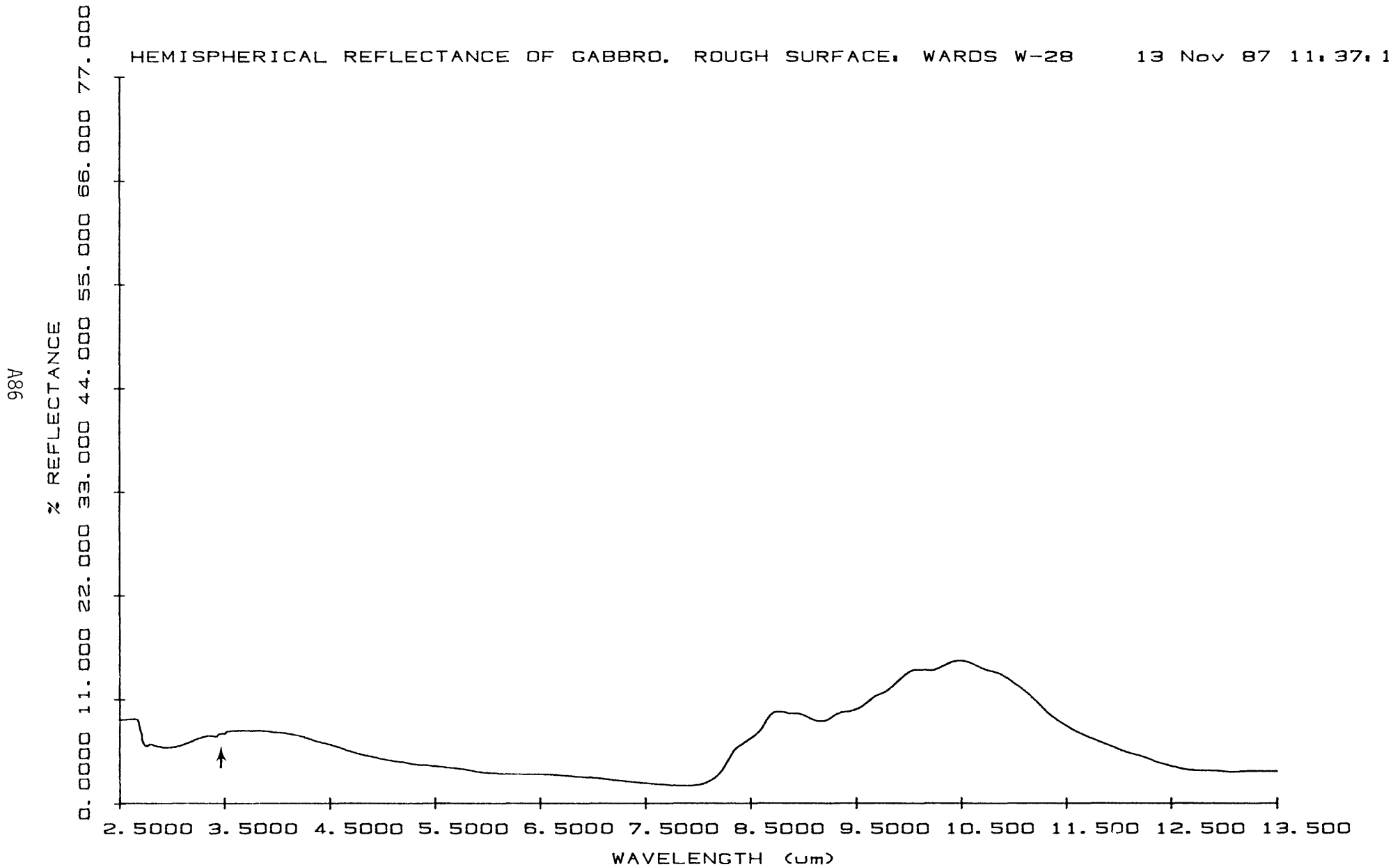
Microprobe Analysis: Bytownite was the predominant feldspar composition, ranging from An_{80} to An_{84}. One plagioclase analysed proved to be andesitic (An_{42}). The pyroxene phases proved to be green, subcalcic augite and exsolved (colorless) salite. Opaque phases were either magnetite or a mixture of ilmenite and magnetite.

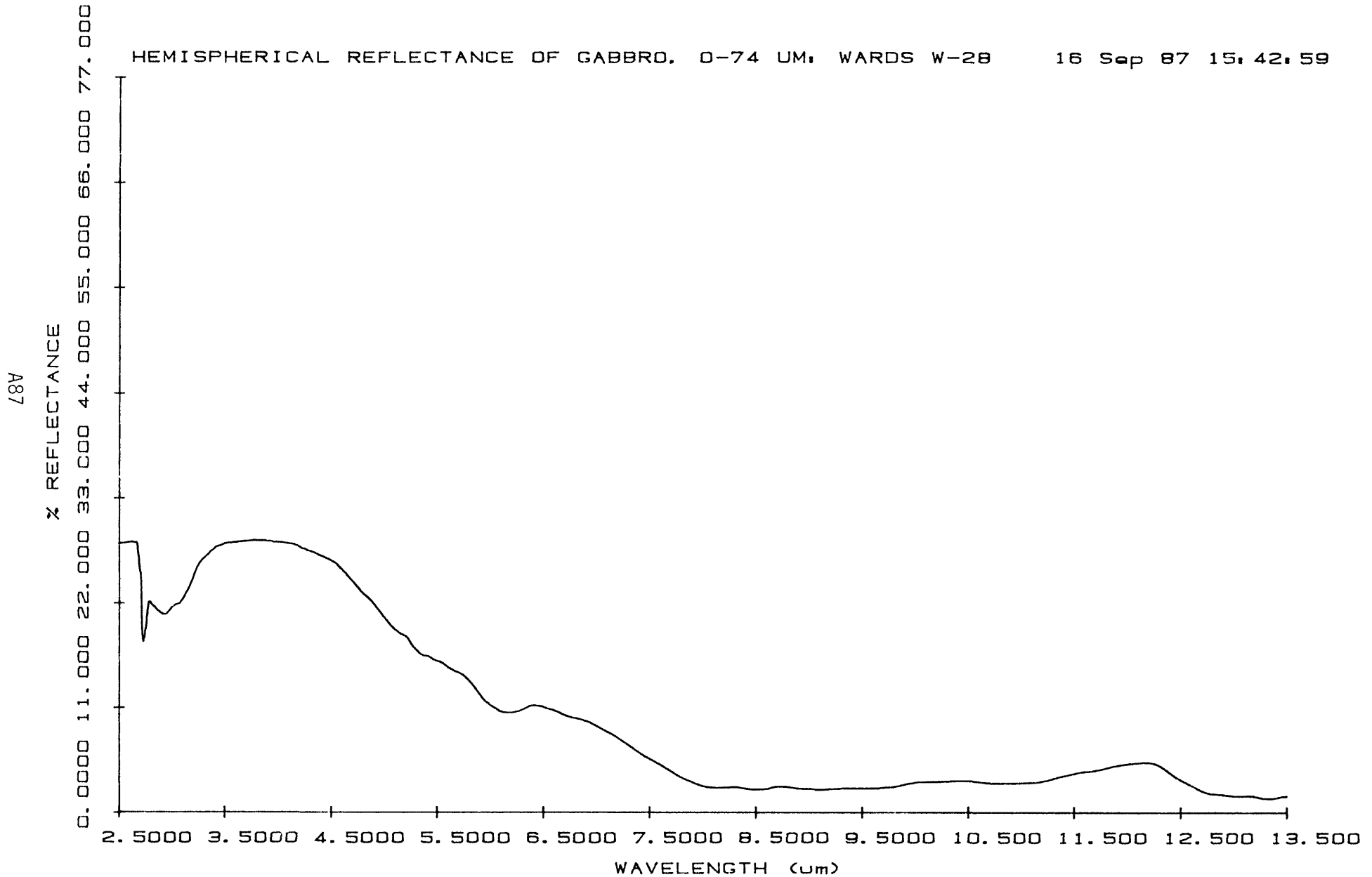
Chemical Analysis:

SiO_2	44.20	CaO	12.61
TiO_2	1.49	Na_2O	1.80
Al_2O_3	17.82	K_2O	0.16
Fe_2O_3	6.26	H_2O	1.11
FeO	8.34	P_2O_5	0.04
MnO	0.16		
MgO	5.30		
	TOTAL 99.29		

Spectra on File:

Gabbro.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Gabbro.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Gabbro.1 Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF GABBRO, ROUGH SURFACE: WARDS W-28 13 Nov 87 11:37:1
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF GABBRO, 0-74 UM; WARDS W-28 16 Sep 87 15:42:59
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Ijolite

Locality: McClure Mountains, Colorado

Donor: Ward's Scientific

Catalogue Number: W-19

Hand Sample Description: A dark gray to black, medium- to coarse-grained rock composed of nepheline, biotite, a black mafic mineral and opaques.

Petrographic Description: An allotriomorphic rock composed of 40% pale greenish pyroxene, 30% nepheline anhedra, 22% pleochroic brown biotite, 7% brown amphibole and less than 1% each of opaque anhedra and apatite euhedra. In addition, there was minor sphene and one large grain of feldspar observed in thin section. The biotite and amphibole tended to be intimately associated. A brownish clay (?) mineral has formed as an alteration product of the feldspar. Some of the pyroxenes showed twinning along 100. No carbonate was seen in thin section, but spectral features area 4.0 and 5.6 μm indicate its presence in small amount.

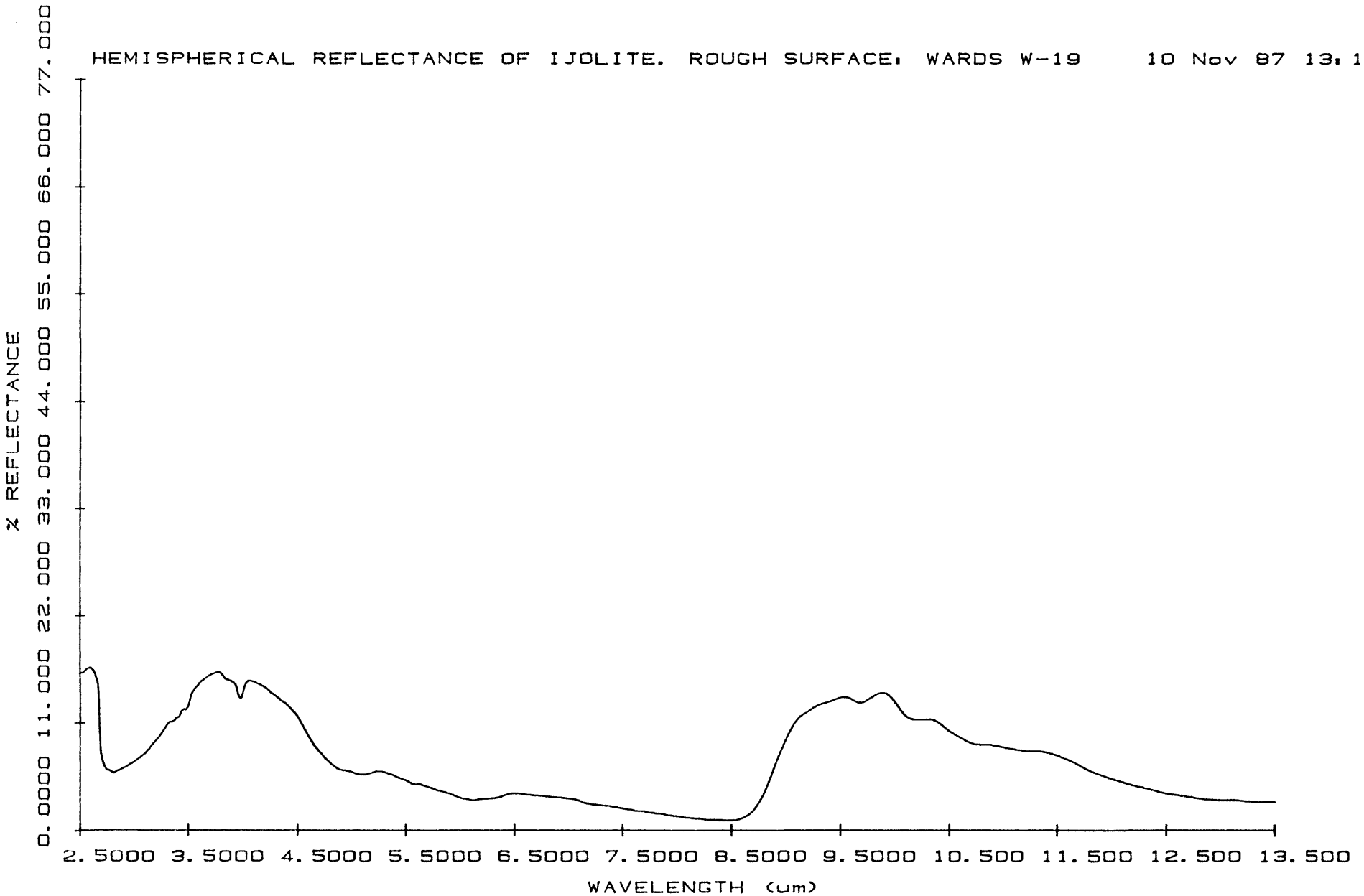
Microprobe Analysis: The microprobe analysis revealed the pyroxene phase to be augite, with a rather homogeneous composition high in both soda (1%) and titania (1%). The biotite composition was homogeneous, as was that of the amphibole, the latter approximating kaersutite in composition (high in alkalis, ~2.3%, and high titania, ~3.9%, by weight). An opaque phase analyzed was high in iron (74%) but contained silicon ~3%; the balance may be made up of chromium (chromite?) but this seems unlikely because of the chemical nature of the rock.

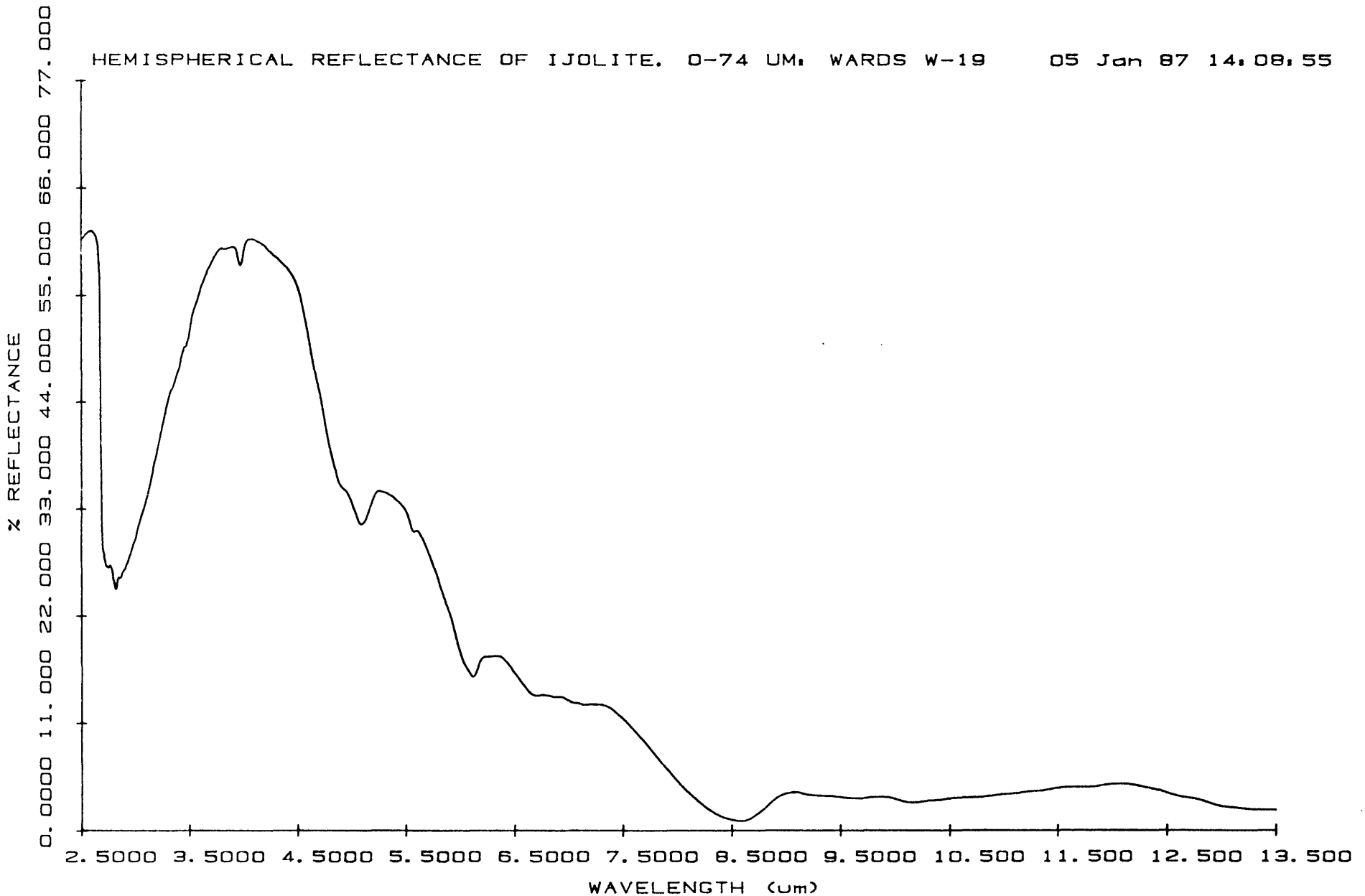
Chemical Analysis:

SiO_2	43.08	CaO	12.13
TiO_2	2.6	Na_2O	3.49
Al_2O_3	13.1	K_2O	3.39
Fe_2O_3	2.6	H_2O	1.87
FeO	7.32	P_2O_5	0.54
MnO	0.20		
MgO	9.66		
	TOTAL	100.5	(CO_2 not analyzed)

Spectra on File:

Ijolite.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Ijolite.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Ijolite.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF IJOLITE. ROUGH SURFACE: WARDS W-19 10 Nov 87 13: 13:
% REFLECTANCE
0. 0000 11. 000 22. 000 33. 000 44. 000 55. 000 66. 000 77. 000
2. 5000 3. 5000 4. 5000 5. 5000 6. 5000 7. 5000 8. 5000 9. 5000 10. 500 11. 500 12. 500 13. 500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF IJOLITE. 0-74 UM: WARDS W-19 05 Jan 87 14:08:55
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Lamprophyre

Locality: Spanish Peaks, Colorado

Donor: Ward's Scientific

Catalogue Number: W-39

Hand Sample Description: A very dark gray aphanitic rock weathering to a tan color.

Petrographic Description: A partially altered, inequigranular rock with a felty fabric consisting of 58% sanidine, 28% pale green pyroxene,7.6% opaques and 6.3% olivine anhedra. Large pyroxene grains are occasionally twinned and most basal sections show oscillatory zoning. The olivine grains are generally much smaller than the large pyroxenes and show iddingsite alteration along fractures. Many olivines are completely altered to a yellowish- or reddish-brown mineral (iddingsite?). The sanidine laths show Carlsbad twinning, and often oscillatory zoning as well. Small opaque anhedra are scattered throughout the sample. In addition a yellowish brown alteration product (limonite?) occurs throughout the section

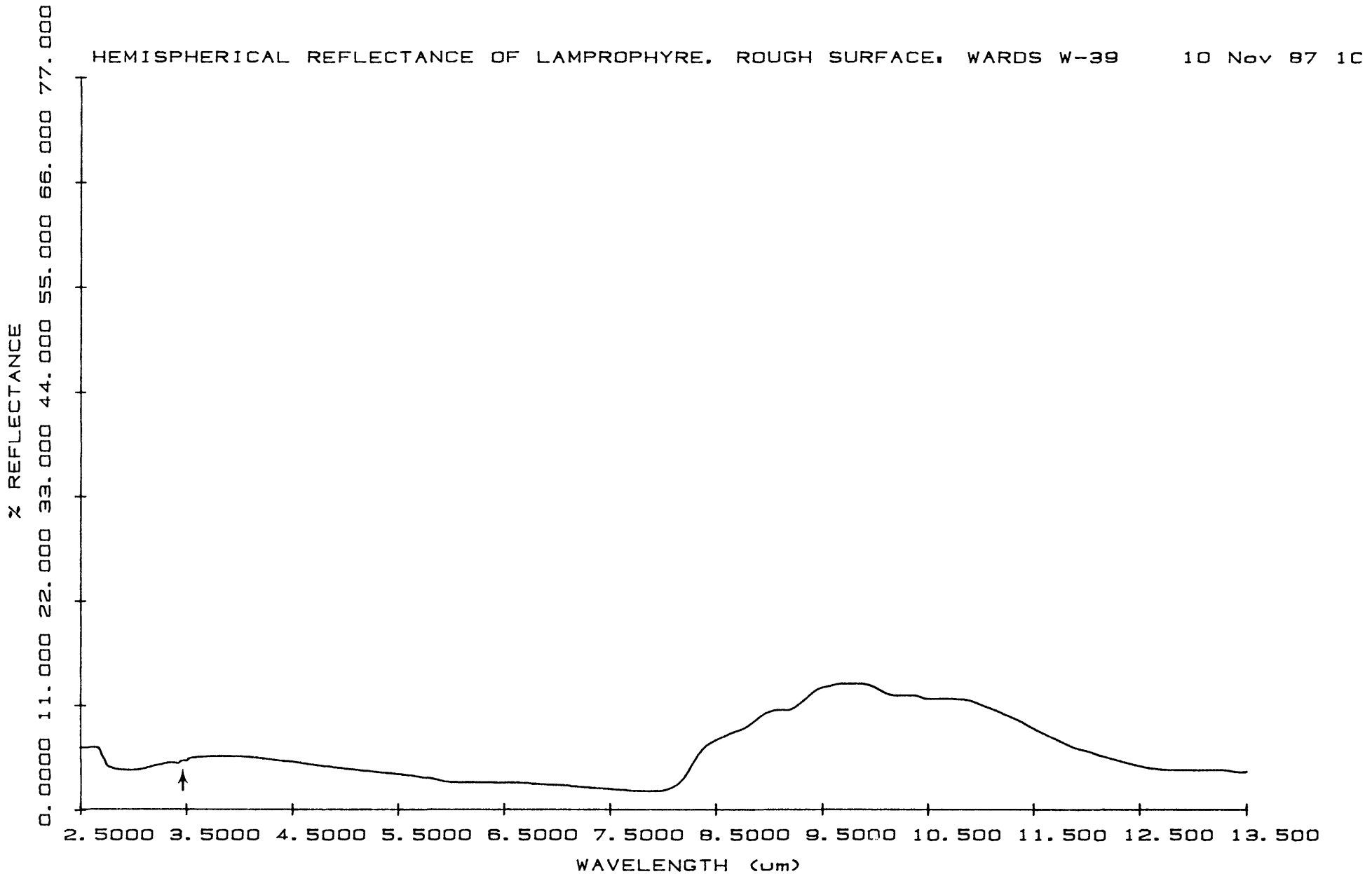
Microprobe Analysis: The pyroxene phase proved to be ferrian augite. Compositionally the olivine was Fo_{55} while opaques probed were all titanomagnetite. Some sericite was indicated in the analysis.

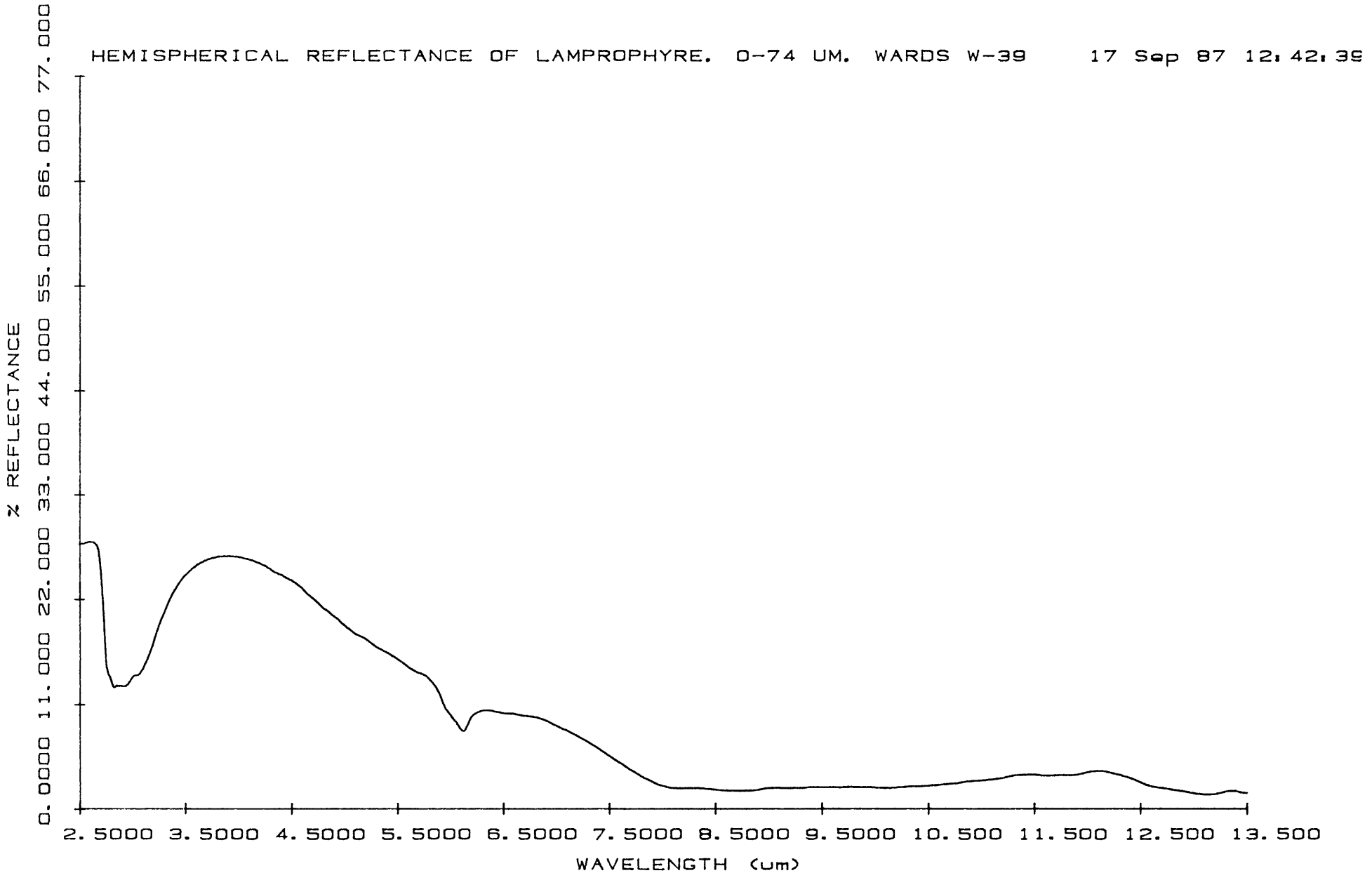
Chemical Analysis:

SiO_2	45.94	CaO	12.06
TiO_2	1.57	Na_2O	3.04
Al_2O_3	16.09	K_2O	1.49
Fe_2O_3	4.21	H_2O	1.47
FeO	7.34	P_2O_5	0.62
MnO	0.19		
MgO	6.53		
	TOTAL		100.55

Spectra on File:

Lamprophyre.H1	Hemispherical reflectance of rough surface on Solid Rock disk #1
Lamprophyre.H1	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Lamprophyre.1	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF LAMPROPHYRE. ROUGH SURFACE: WARDS W-39 10 Nov 87 1C
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF LAMPROPHYRE. 0-74 UM. WARDS W-39 17 Sep 87 12:42:39
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Norite

Locality: Wollaston Twp., Ontario, Canada

Donor: Ward's Scientific

Catalogue Number: W-125

Hand Sample Description: A dark green to black, coarse-grained rock composed of gray 0.5 to 1.0 cm plagioclase laths, opaque areas of about the same size in a dark green groundmass.

Petrographic Description: A slightly deformed metamorphosed norite consisting of large plagioclase anhedra (30%), occasionally showing undulatory extinction, bent twin lamellae and granulation. The mafic phase (originally pyroxene) has been altered to a pleochroic green, prismatic amphibole (60%). The opaque anhedra (~4.6%) are frequently aligned along former crystallographic axes of this pyroxene phase. Minor quartz (2%) was also noted.

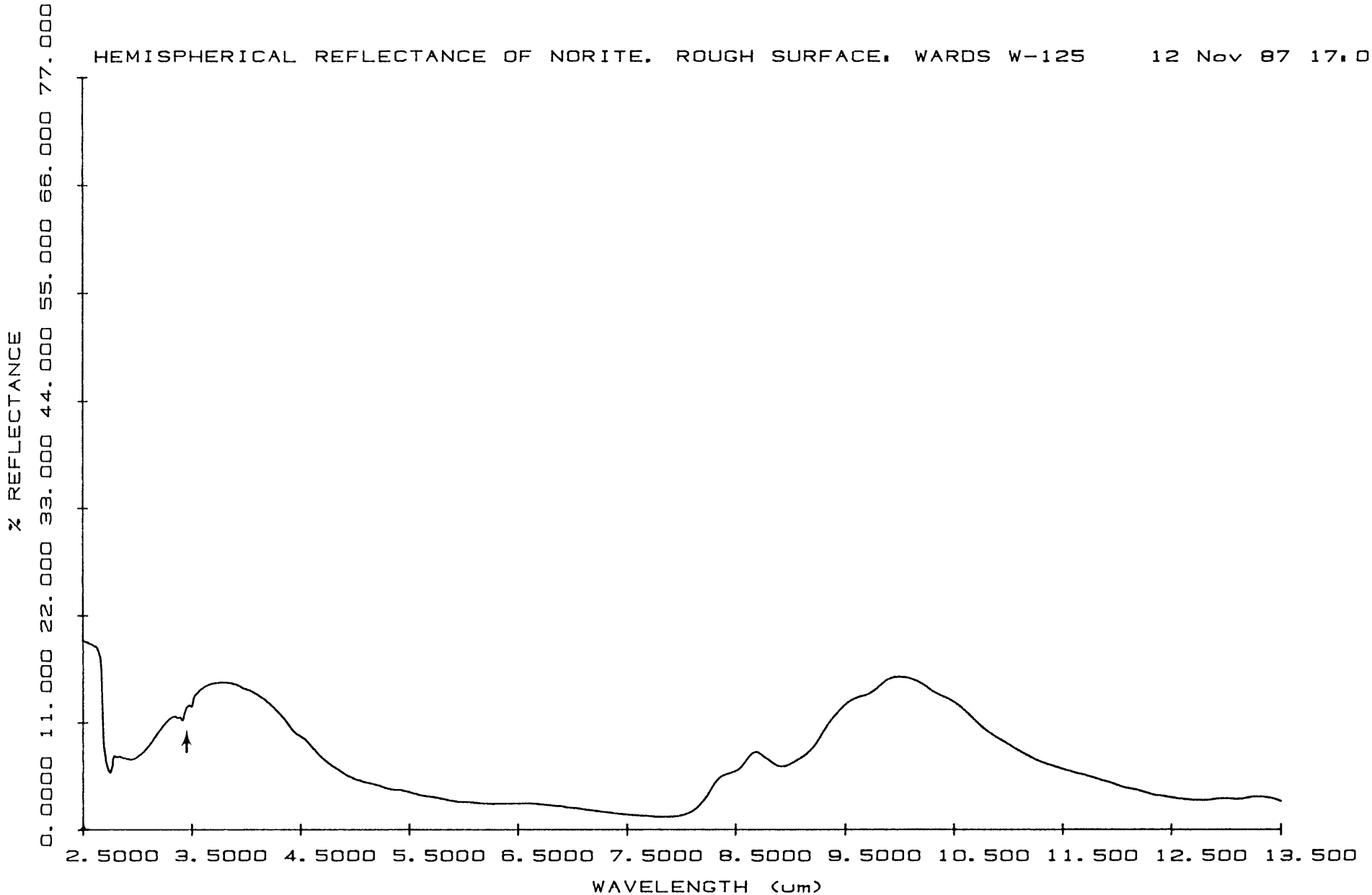
Microprobe Analysis: Microprobe analysis revealed the amphibole to be a hornblende, probably tschermakite or hastingsite, with relatively low soda (1.5% by weight). The plagioclase ranged from andesine to bytownite (An_{45} to An_{72}), with the groundmass more calcic than the coarse plagioclase grains, which is unusual. An opaque phase probed proved to be ilmenite summing to 92%, with the balance probably made up of chromium.

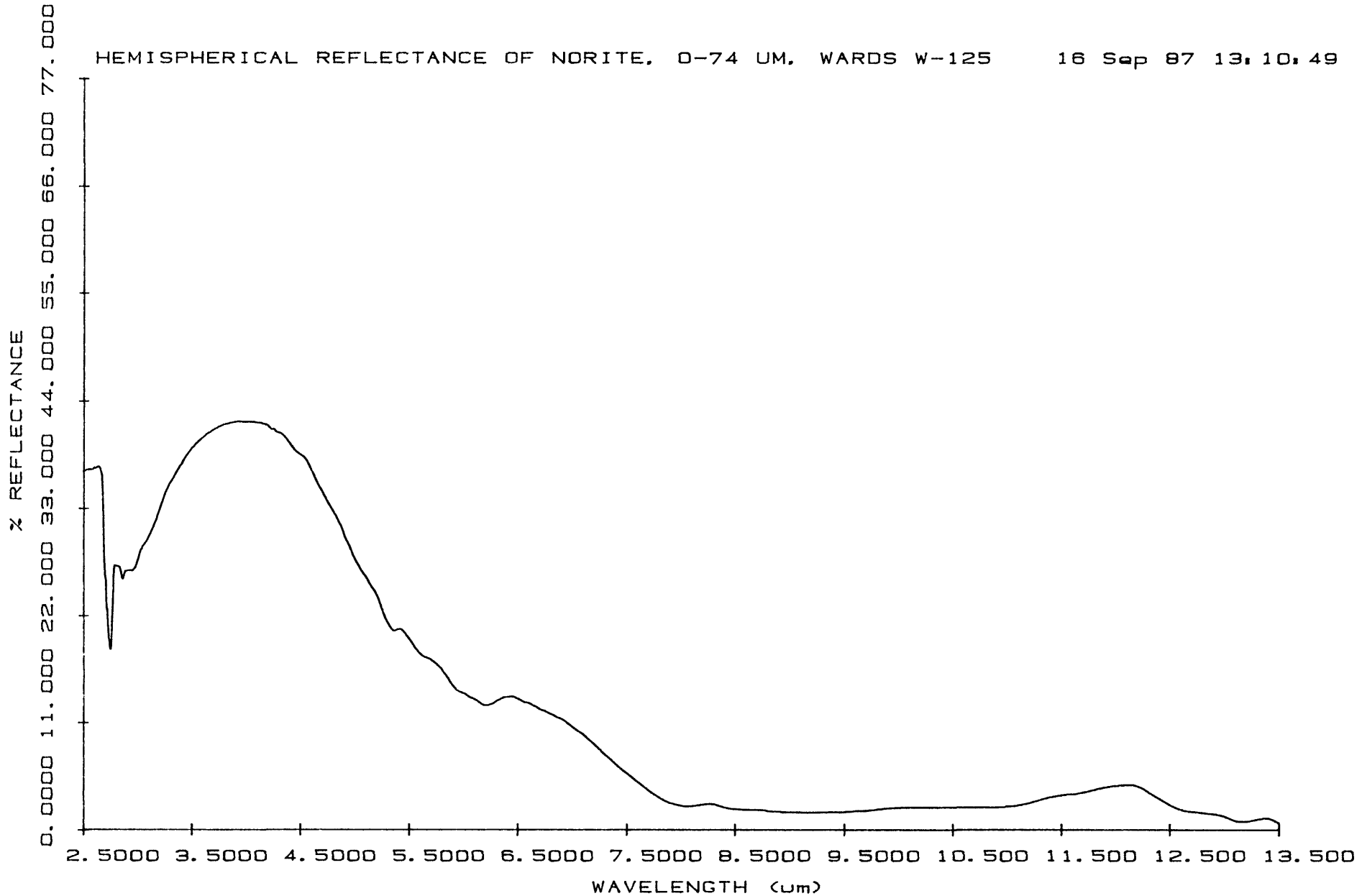
Chemical Analysis:

SiO_2	48.42	CaO	4.96
TiO_2	2.52	Na_2O	2.87
Al_2O_3	19.66	K_2O	0.27
Fe_2O_3	2.63	H_2O	1.15
FeO	7.09	P_2O_5	0.03
MnO	0.09		
MgO	10.83		
	TOTAL		100.52

Spectra on File:

Norite.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Norite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Norite.1 Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF NORITE. ROUGH SURFACE: WARDS W-125 12 Nov 87 17:04:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF NORITE, 0-74 UM, WARDS W-125 16 Sep 87 13:10:49
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Norite

Locality: Nye, Montana

Donor: Ward's Scientific

Catalogue Number: W-40

Hand Sample Description: A dark greenish-gray, medium-grained granular rock composed of olivine, pyroxene, plagioclase laths ($\leq$ 3 mm), opaques, and a few bronze colored mica grains (phlogopite?).

Petrographic Description: An equigranular rock with subophitic texture consisting of subhedral plagioclase laths (38%), occasionally showing either oscillatory or normal zoning, partially enclosed in orthopyroxene (~27%) or clinopyroxene (11%) anhedra. There are scattered olivine grains (~4%) which are crisscrossed with brownish serpentine veinlets. Some areas of the sample are heavily sericitized. Very minor amounts ($\leq$ 1%) of biotite are also present. Called a "pryoxenite" by Ward's, but contains too much plagioclase.

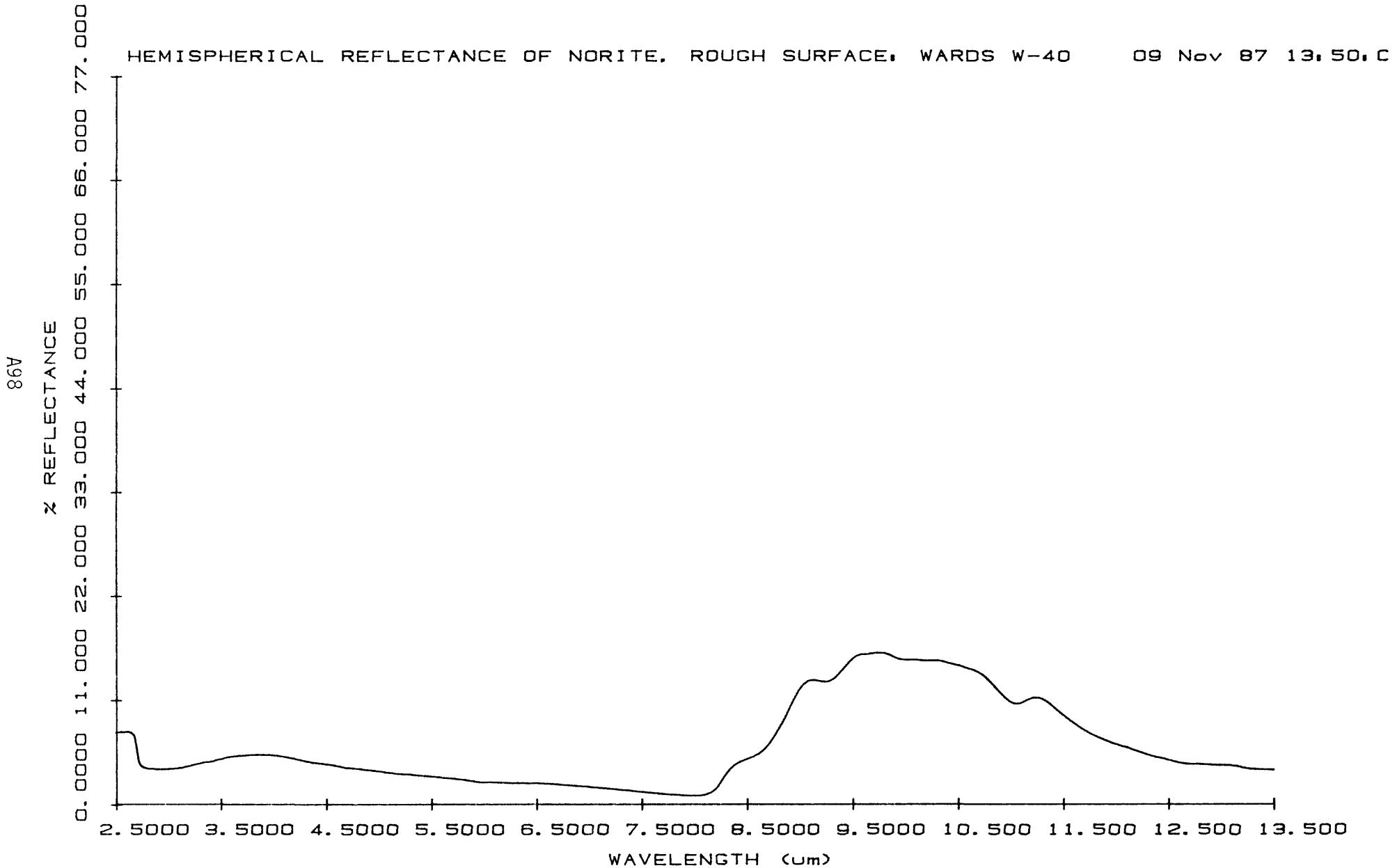
Microprobe Analysis: Microprobe analysis shows that the orthopyroxene phase was hypersthene, while that of the clinopyroxene was iron-rich diopside (salite). The feldspars probed were labradorite, the mica was phlogopite and an opaque proved to be ilmenite with about 0.6% each of MgO and MnO.

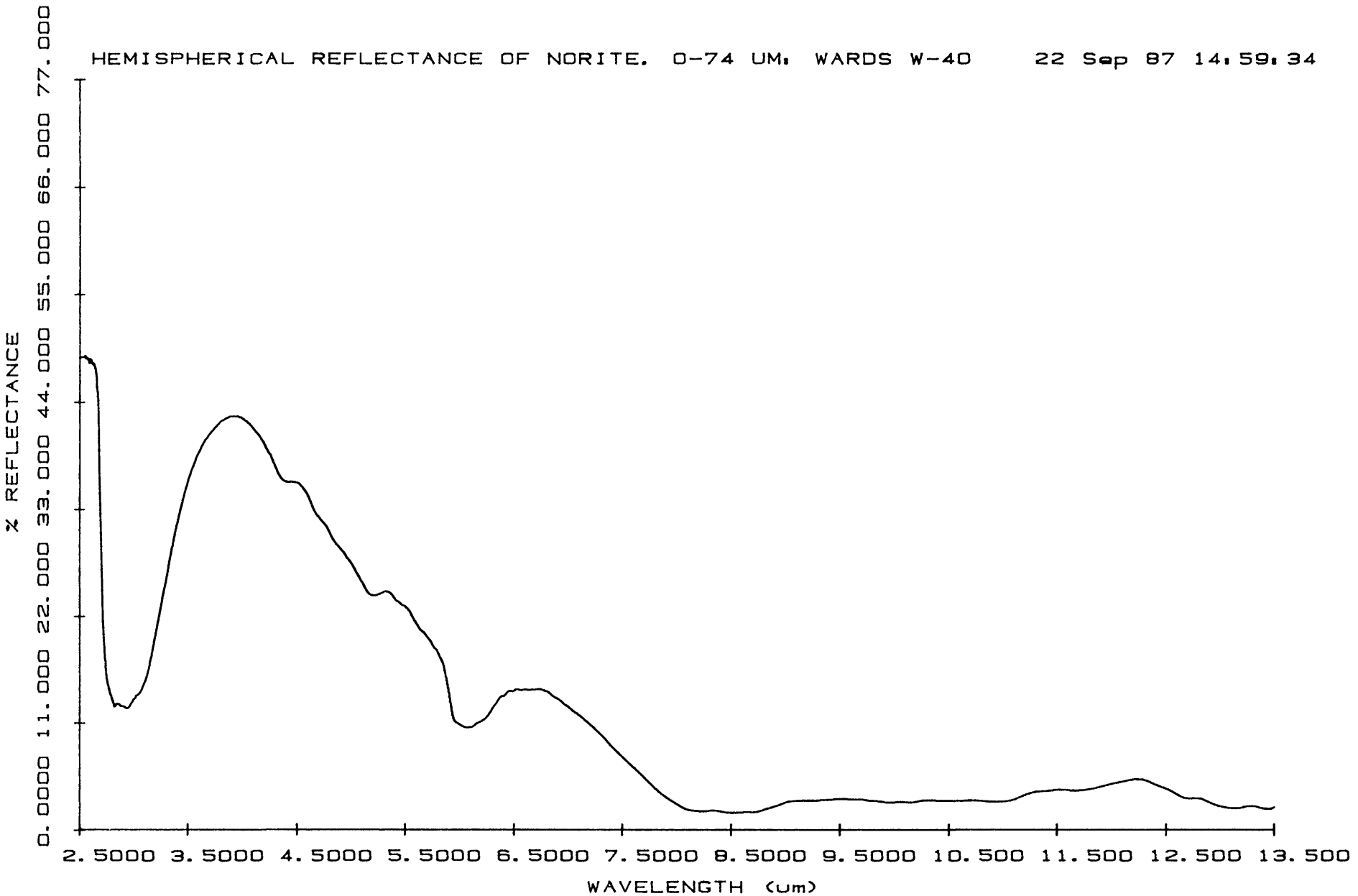
Chemical Analysis:

SiO_2	48.23	CaO	6.43
TiO_2	1.1	Na_2O	1.85
Al_2O_3	12.31	K_2O	0.74
Fe_2O_3	2.36	H_2O	3.16
FeO	10.78	P_2O_5	0.06
MnO	0.22		
MgO	12.95		
	TOTAL	100.19	

Spectra on File:

Norite.H2	Hemispherical reflectance of rough surface on Solid Rock disk #1
Norite.H2	Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Norite.2	Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF NORITE, ROUGH SURFACE; WARDS W-40 09 Nov 87 13:50:C
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF NORITE. 0-74 UM: WARDS W-40 22 Sep 87 14:59:34
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Dunite

Locality: Near Balsam, Jackson County, North Carolina

Donor: Ward's Scientific

Catalogue Number: W-41

Hand Sample Description: A green, medium- to fine-grained granular rock composed almost entirely of olivine, with some scattered opaques (chromite?). There is a brown weathering stain on one surface.

Petrographic Description: A mosaically-textured aggregate of anhedral olivine with serpentine alteration along some of the fractures. Chromite (?) occurs as scattered subhedra. The modal analysis gave: 89% olivine, 8% serpentine, and 3% opaque.

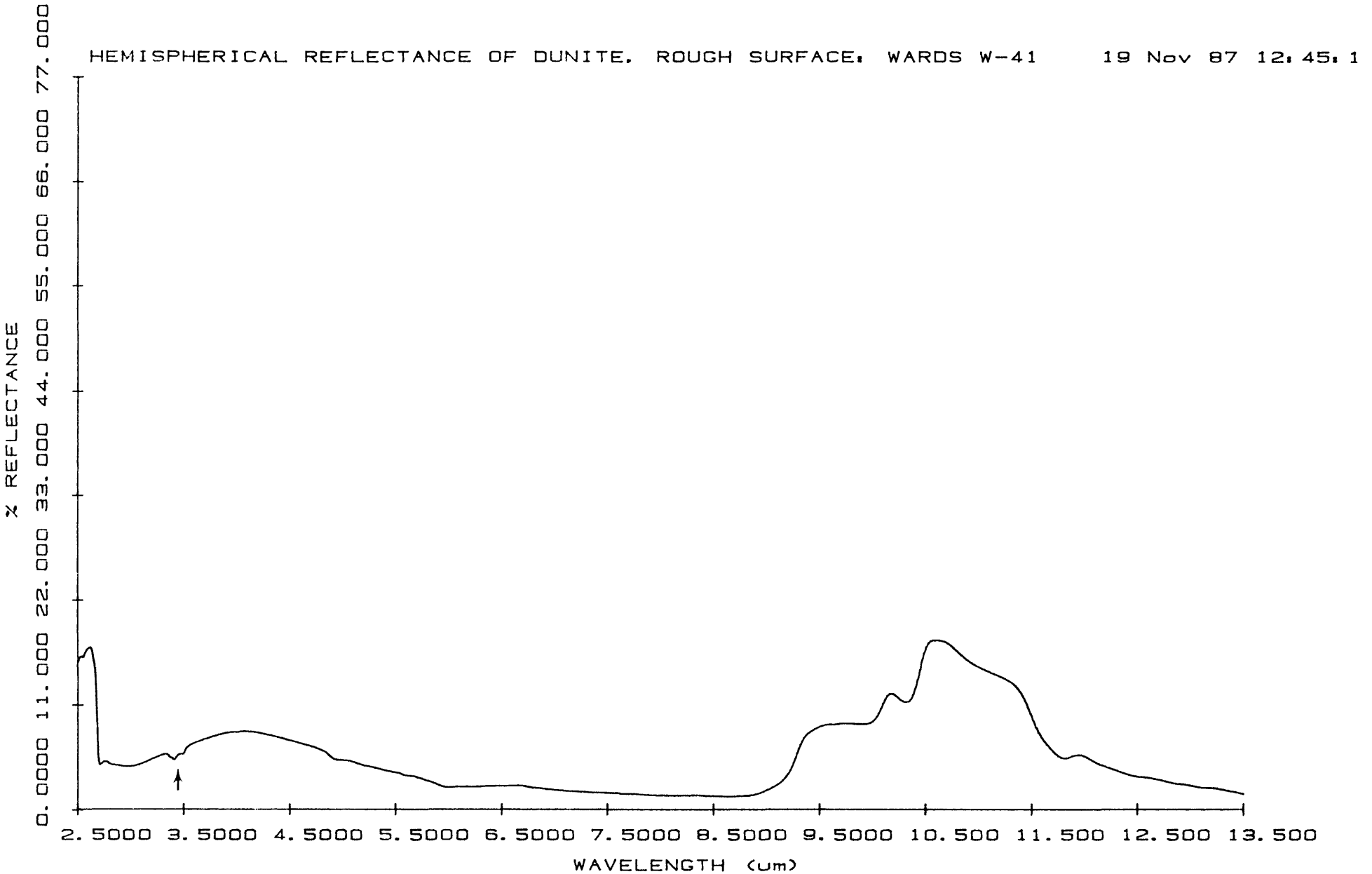
Microprobe Analysis: Microprobe analysis revealed an olivine composition of FO_{91}. The opaque phase showed Fe >AL >Mg with little titanium, and is probably chromite. Serpentine (antigorite) had 4% substitution of FeO for MgO. Minor chlorite approximated clinochlore in composition.

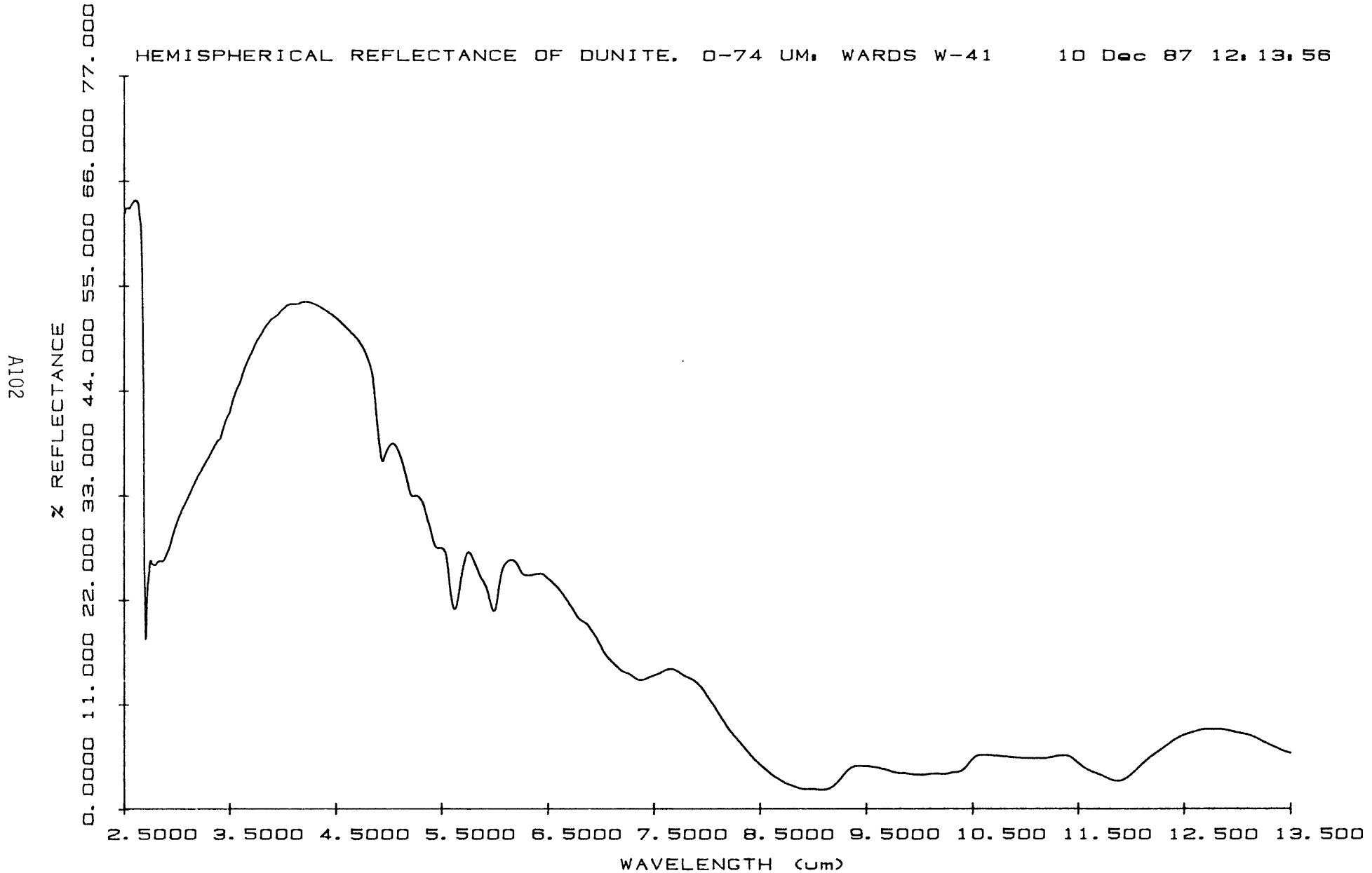
Chemical Analysis:

SiO_2	39.57	CaO	0.05
TiO_2	0.004	Na_2O	0.0
Al_2O_3	0.44	K_2O	0.004
Fe_2O_3	1.62	H_2O	2.85
FeO	7.47	P_2O_5	0.0
MnO	0.16		
MgO	47.6		
	TOTAL 99.76		

Spectra on File:

Dunite.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Dunite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1
Dunite.1 Biconical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF DUNITE, ROUGH SURFACE: WARDS W-41 19 Nov 87 12:45:1
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF DUNITE. 0-74 UM: WARDS W-41 10 Dec 87 12:13:56
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A102

Rock Name: Picrite

Locality: Kilauea

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 81-1-210.0

Hand Sample Description: A dark gray porphyritic rock. Green olivine phenocrysts 1-8 mm in size make up about 8% of the rock. There are also opaque grains $\leq$ 1 mm in size. The groundmass is dark gray and very fine-grained.

Petrographic Description: A porphyritic sample with a slightly trachytic texture. The phenocrysts are all olivine. The groundmass is fine-grained and consists of olivine, plagioclase laths, opaques, augite, and brownish interstitial glass; the analysis for the glass is given below.

Microprobe Analysis: (by Rosalind Helz). The olivine analysis gave a composition of Fo_{80}, while the feldspar was bytownite (An_{78}). Titanaugite was also probed. Glass composition was:

SiO_2	51.00	Cr_2O_3	0.03
TiO_2	3.92	CaO	9.82
Al_2O_3	13.44	Na_2	3.14
FeO	10.88	K_2O	0.90
MnO	0.13	P_2O_5	0.36
MgO	6.01		

TOTAL 99.63

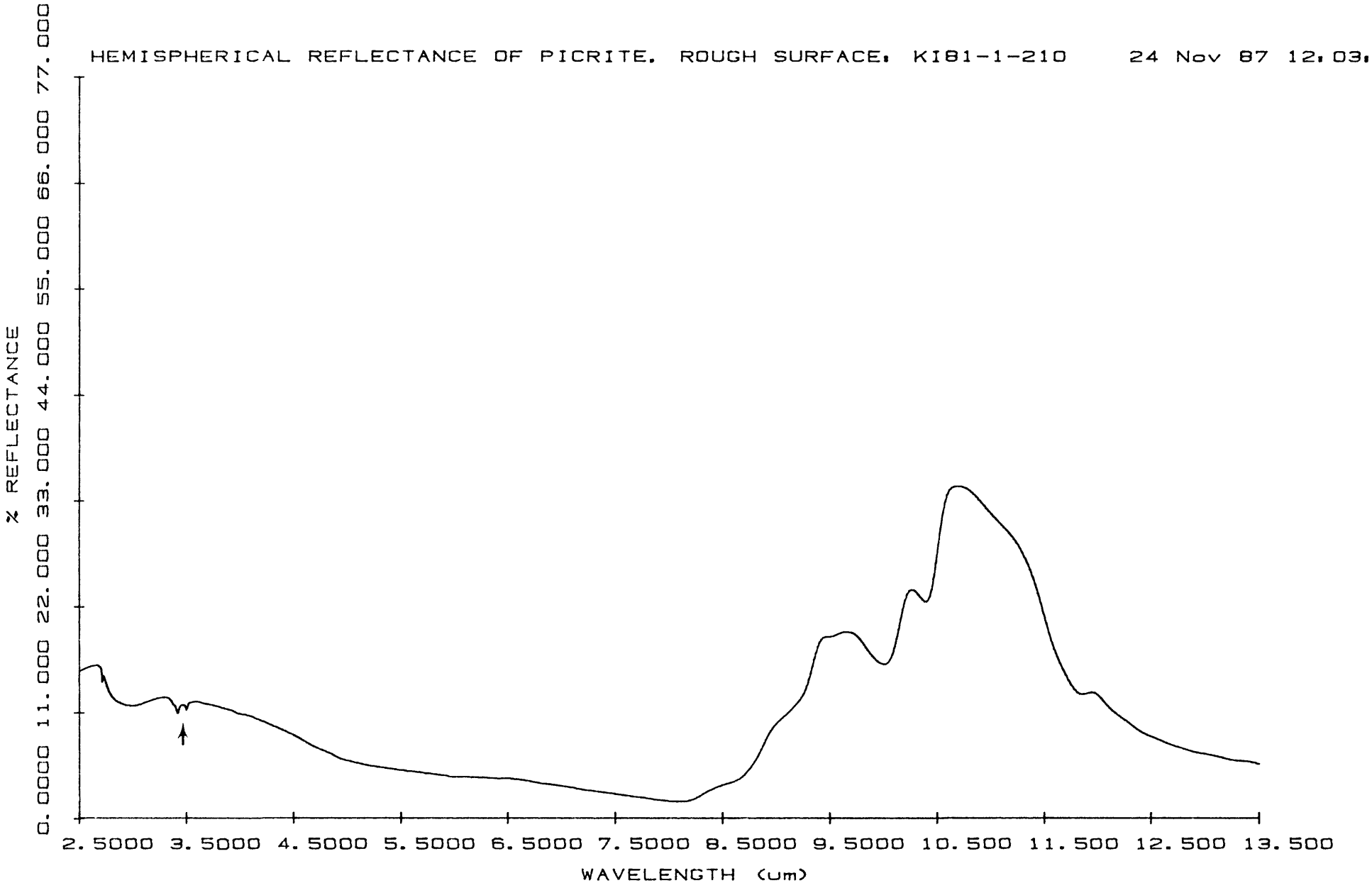
Chemical Analysis: (by Herb Kirschenbaum, USGS, Reston, VA.)

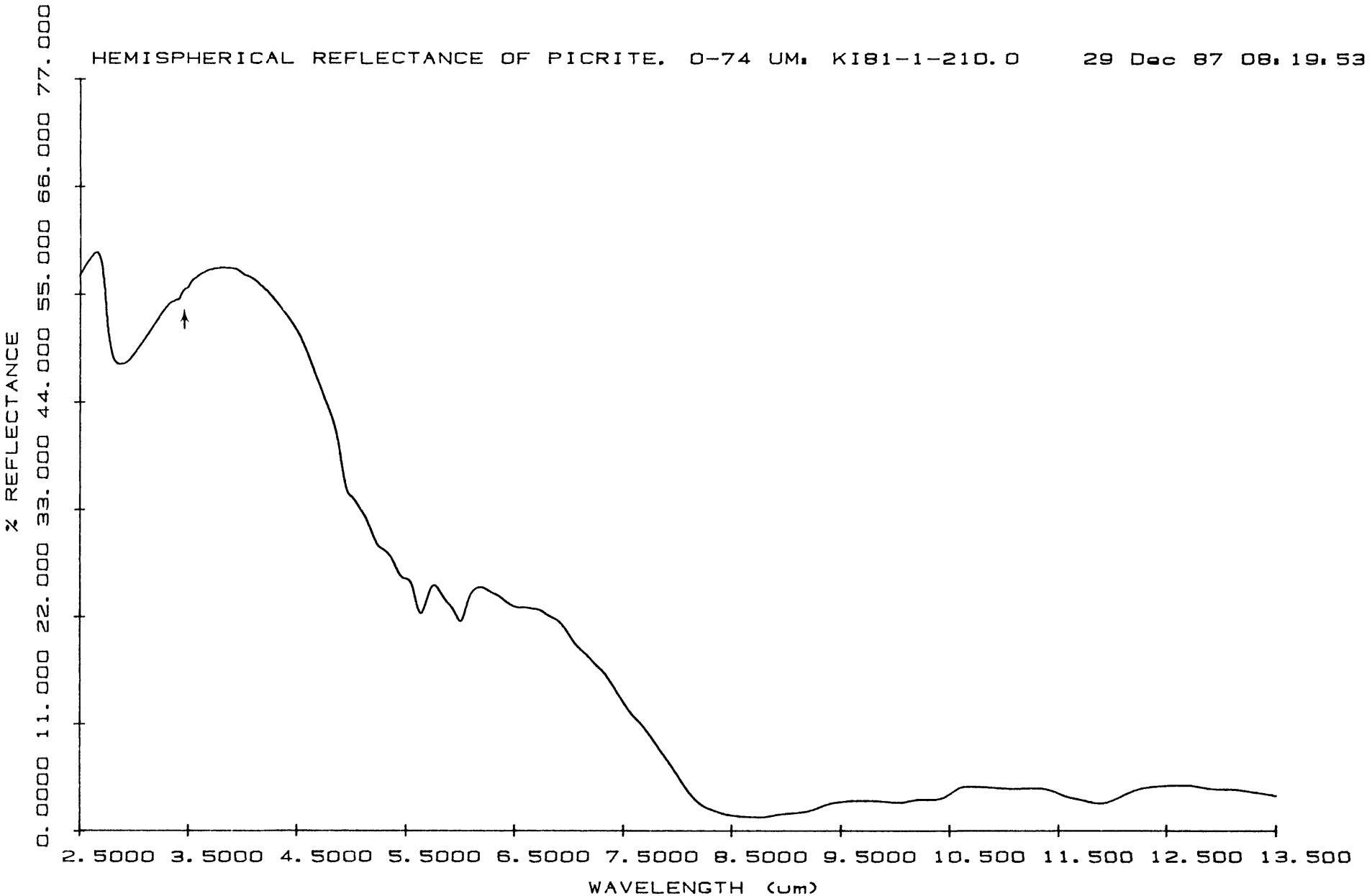
SiO_2	44.87	CaO	7.66
TiO_2	1.09	Na_2O	0.98
Al_2O_3	7.64	K_2O	0.21
Fe_2O_3	1.1	H_2O	0.05
FeO	11.24	P_2O_5	0.10
MnO	0.18	Cr_2O_3	0.20
MgO	24.53		

TOTAL 99.85

Spectra on File:

Picrite.H1 Hemispherical reflectance of rough surface on Solid Rock disk #1
Picrite.H1 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF PICRITE, ROUGH SURFACE, KI81-1-210 24 Nov 87 12:03:
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF PICRITE, 0-74 UM: KI81-1-210.0 29 Dec 87 08:19:53
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

Rock Name: Picrite

Locality: Kilauea

Donor: Rosalind Helz, USGS, Reston, VA

Catalogue Number: KI 79-5-180.8

Hand Sample Description: A light gray porphyritic, slightly vesicular rock. Green olivine phenocrysts range in size from ~0.5 mm to 4.0 mm and make up about 2-3% of the rock. The grayish groundmass is very fine-grained.

Petrographic Description: A porphyritic, fine grained rock with a felty texture consisting of olivine phenocrysts and groundmass phases of olivine, augite, plagioclase, an orthopyroxene, opaques, some pseudo-brookite and apatite, along with minor interstitial glass. The glass analysis is given below.

Microprobe Analysis: (by Rosalind Helz). Probe analysis indicated the presence of two opaque phases; chromite and ilmenite. The latter phase contained 6% MgO by weight, as did the pseudobrookite, which is typical for high-MgO bulk composition basalts. Glass composition was:

SiO_2	68.90	Cr_2O_3	0.00
TiO_2	1.70	CaO	1.17
Al_2O_3	14.81	Na_2	3.40
FeO	2.72	K_2O	4.79
MnO	0.02	P_2O_5	0.33
MgO	0.70		

TOTAL 98.54

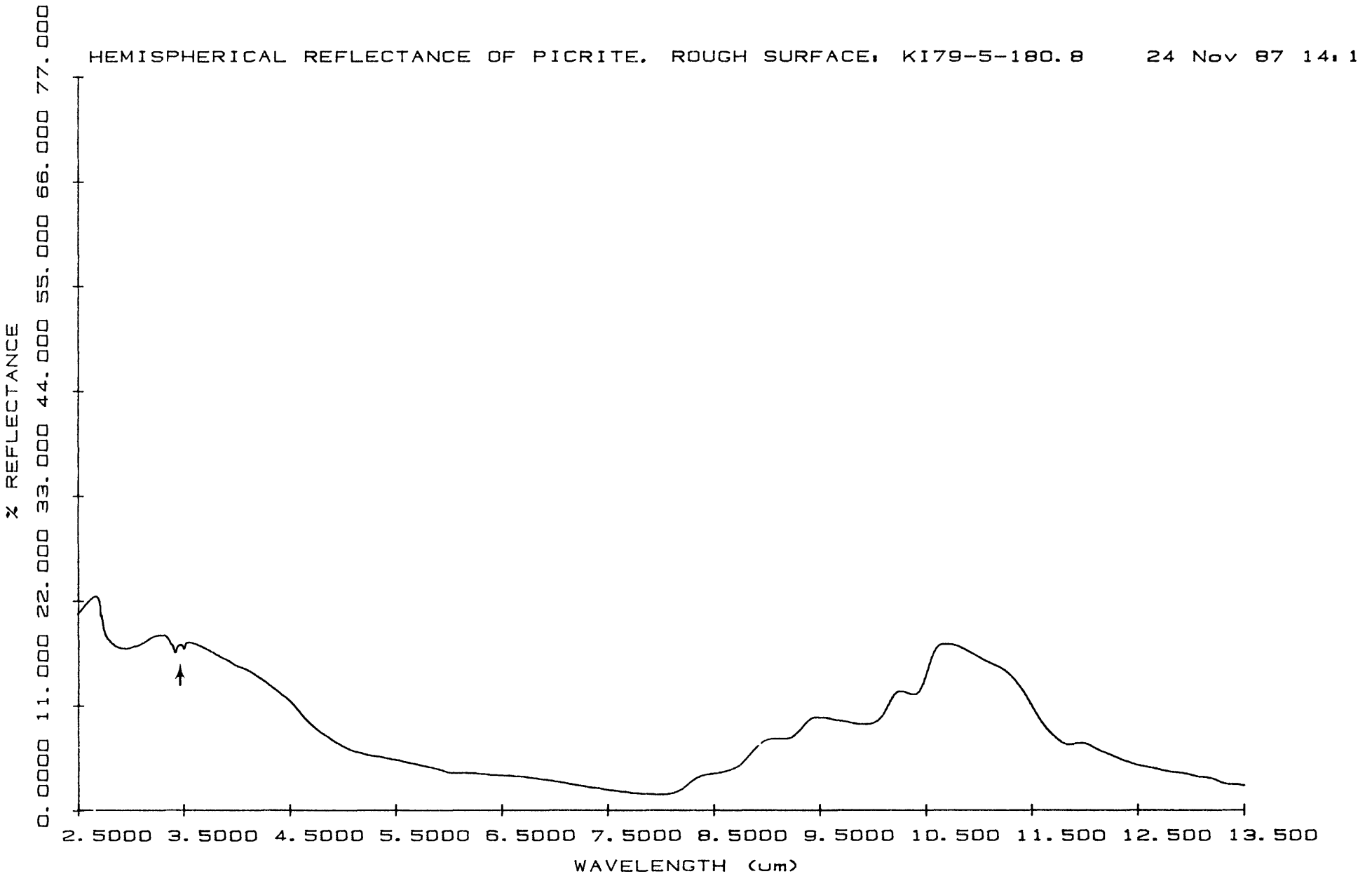
Chemical Analysis: (by John Marinenko, USGS, Reston, VA.)

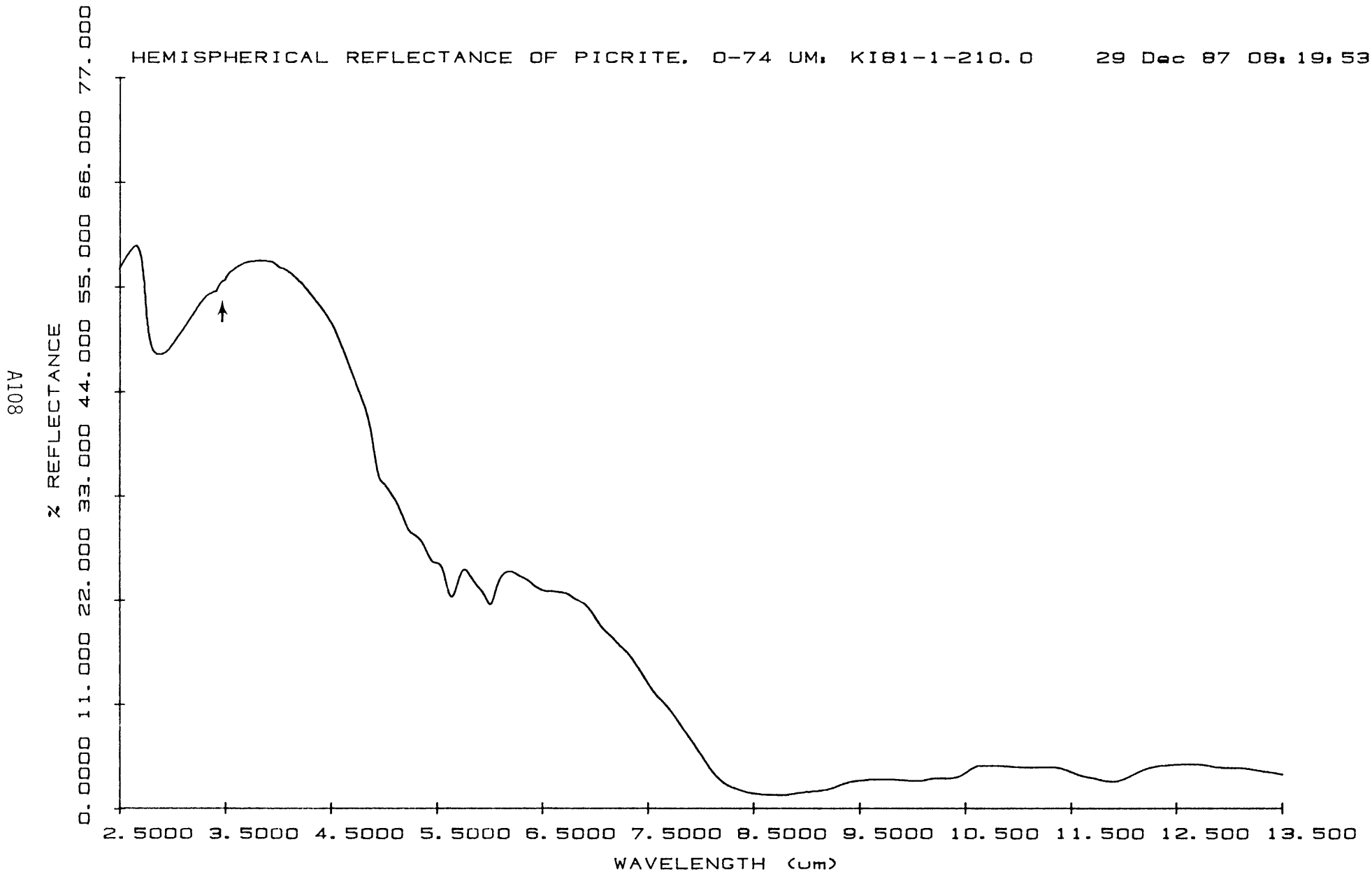
SiO_2	46.23	CaO	8.68
TiO_2	1.47	Na_2O	1.37
Al_2O_3	9.83	K_2O	0.30
Fe_2O_3	0.53	H_2O	0.04
FeO	10.49	P_2O_5	0.15
MnO	0.17	Cr_2O_3	0.23
MgO	20.65		

TOTAL 100.14

Spectra on File:

Picrite.H2 Hemispherical reflectance of rough surface on Solid Rock disk #1
Picrite.H2 Hemispherical reflectance of 0-74 μm size range on Powdered Rock disk #1


HEMISPHERICAL REFLECTANCE OF PICRITE, ROUGH SURFACE; KI79-5-180.8 24 Nov 87 14:1
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)


HEMISPHERICAL REFLECTANCE OF PICRITE, 0-74 UM; KI81-1-210.0 29 Dec 87 08:19:53
% REFLECTANCE
0.0000 11.000 22.000 33.000 44.000 55.000 66.000 77.000
2.5000 3.5000 4.5000 5.5000 6.5000 7.5000 8.5000 9.5000 10.500 11.500 12.500 13.500
WAVELENGTH (um)

A108

APPENDIX 2 - Mineral Analyses

Rock	Mineral	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-4	Acmite	50.62	0.30	29.51	0.03	3.95	0.03	10.94	1.76	0.46	97.6
PW-4	Acmite	50.75	0.21	29.42	0.04	4.28	0.03	10.61	1.51	0.34	97.19
PW-4	Acmite	51.21	0.49	30.31	0.04	4.02	0.02	11.16	0.27	0.59	98.11
PW-4	Orthoclase	64.22	19.22	0.22	0.01	0.00	17.17	0.33	0.02	0.01	101.2
PW-4	Quartz	98.30	0.00	0.03	0.01	0.00	0.01	0.01	0.03	0.00	98.39
PW-4	Perthite	66.70	19.31	0.22	0.02	0.00	13.27	2.30	0.00	0.02	101.84
PW-4	Quartz	101.51	0.00	0.06	0.00	0.00	0.01	0.03	0.00	0.00	101.61
PW-4	Riebeckite	50.42	0.32	36.62	0.26	0.66	0.53	6.34	0.39	1.17	96.71
PW-4	Perthite	63.23	19.84	0.25	0.02	0.20	11.65	3.23	0.00	0.03	98.45
PW-4	Albite	51.30	0.22	30.03	0.06	0.26	0.02	13.18	2.78	0.70	98.55
PW-36	Augite	52.23	2.16	8.09	19.15	17.99	0.02	0.20	0.36	0.25	100.45
PW-36	Bytownite	49.33	32.09	0.65	0.39	14.86	0.15	2.69	0.02	0.02	100.2
PW-36	Bytownite	49.44	32.78	0.71	0.28	14.91	0.15	2.52	0.04	0.04	100.87
PW-36	Bytownite	52.87	29.28	1.27	0.18	12.24	0.22	4.13	0.07	0.02	102.09
PW-36	Augite	51.66	1.66	14.14	20.65	11.29	0.00	0.13	0.55	0.39	100.47
PW-36	Pigeonite	53.82	0.70	15.59	23.70	5.21	0.01	0.07	0.21	0.44	99.75
PW-36	Bytownite	49.44	32.20	0.74	0.29	15.24	0.22	2.71	0.04	0.01	100.89
PW-36	Groundmass	50.53	17.72	6.13	9.81	14.37	0.07	1.65	0.25	0.21	100.74
PW-36	Labradorite	54.16	29.81	1.16	0.34	12.01	0.34	4.01	0.09	0.01	101.93
PW-36	Groundmass	73.02	12.70	3.36	0.11	2.58	1.41	1.78	0.66	0.04	106.66
PW-22	Magnetite	0.12	0.01	91.86	0.12	0.10	0.06	0.05	0.63	0.32	93.27
PW-22	Quartz	100.52	0.00	0.03	0.03	0.01	0.03	0.04	0.04	0.00	100.7
PW-22	Feldspar	61.68	23.80	0.28	0.05	4.54	5.23	5.56	0.01	0.02	101.17
PW-22	Biotite	38.43	13.62	11.62	18.51	0.11	9.30	0.13	3.99	0.19	95.9
PW-22	Augite	52.84	2.54	10.77	17.51	12.54	0.25	0.54	0.33	0.48	97.8
PW-22	Andesine	56.74	28.05	0.32	0.03	9.50	0.24	5.97	0.04	0.01	100.9
PW-22	Orthoclase	64.64	19.01	0.16	0.03	0.05	16.47	0.43	0.00	0.03	100.82
PW-22	Andesine	55.84	28.83	0.38	0.00	9.82	0.24	5.98	0.07	0.08	101.24
PW-22	Biotite	39.00	13.24	10.35	18.56	0.02	10.13	0.17	4.41	0.20	96.08
PW-22	Magnetite	0.11	0.00	88.93	0.13	0.01	0.04	0.05	0.37	0.19	89.83
PW-22	Augite	53.68	1.52	9.02	18.49	5.67	0.25	0.52	0.30	0.50	89.95
PW-22	Augite	54.05	1.06	11.51	16.74	12.86	0.11	0.23	0.07	0.52	97.15
PW-22	Andesine	57.85	28.18	0.47	0.02	9.47	0.46	6.01	0.02	0.01	102.49

APPENDIX 2 - Mineral Analyses Continued

Rock	Mineral	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-17	Orthoclase	64.28	19.94	0.07	0.07	0.00	16.55	0.75	0.03	0.02	101.71
PW-17	Albite	68.01	20.78	0.03	0.01	0.15	0.12	10.50	0.02	0.01	99.63
PW-17	Nepheline	41.97	36.63	0.06	0.01	0.00	7.31	15.38	0.01	0.00	101.37
PW-17	Muscovite	44.55	37.08	1.50	0.02	0.01	10.53	0.22	0.01	0.00	93.92
PW-17	Albite	68.15	20.31	0.06	0.03	0.11	0.12	10.63	0.00	0.00	99.41
PW-17	Orthoclase	63.97	19.37	0.07	0.04	0.01	16.70	0.58	0.00	0.03	100.77
PW-17	Albite	68.70	20.88	0.03	0.03	0.15	0.13	11.01	0.00	0.01	100.94
PW-17	Unidentified	49.45	28.54	0.02	0.02	0.00	0.06	9.02	0.00	0.01	87.12
PW-17	Nepheline	42.15	36.17	0.09	0.01	0.00	7.48	15.64	0.01	0.00	101.55
PW-17	Sodalite (?)	54.80	24.11	0.01	0.01	0.00	0.13	9.79	0.01	0.00	88.86
PW-17	Orthoclase	65.08	19.09	0.05	0.06	0.01	16.19	0.57	0.00	0.02	101.07
PW-17	Albite	67.76	21.07	0.05	0.05	0.21	0.12	10.40	0.00	0.01	99.67
PW-17	Biotite	31.34	20.99	30.77	0.08	0.02	9.42	0.25	0.19	0.80	93.86
PW-17	Orthoclase	64.20	19.26	0.04	0.04	0.01	16.14	0.59	0.02	0.01	100.31
PW-17	Albite	67.43	20.85	0.07	0.00	0.14	0.08	11.13	0.00	0.00	99.7
PW-7	Biotite	36.33	13.55	17.62	12.71	0.02	9.69	0.08	2.92	0.25	93.17
PW-7	Biotite	36.12	14.01	17.91	12.06	0.00	9.87	0.06	3.76	0.26	94.05
PW-7	Microcline	64.06	19.48	0.12	0.04	0.13	15.08	1.22	0.03	0.02	100.18
PW-7	Quartz	98.36	0.00	0.03	0.01	0.00	0.00	0.02	0.01	0.00	98.43
PW-7	Perthite	65.66	20.40	0.06	0.03	0.37	5.83	7.06	0.01	0.01	99.43
PW-7	Perthite	65.35	20.07	0.08	0.01	0.13	9.03	4.76	0.02	0.01	99.46
PW-7	Augite	52.30	2.32	13.16	16.05	12.37	0.29	0.55	0.21	0.49	97.74
PW-7	Hornblende	46.06	6.36	16.44	12.53	11.77	0.79	1.37	1.05	0.46	96.83
PW-7	Quartz	101.36	0.00	0.01	0.00	0.00	0.05	0.01	0.00	0.02	101.45
PW-7	Microcline	64.08	19.64	0.16	0.01	0.07	13.89	2.10	0.00	0.05	100
PW-7	Ilmenite	0.04	0.01	50.41	0.20	0.02	0.09	0.02	43.56	2.19	96.54
PW-7	Biotite	36.51	13.15	18.67	13.09	0.04	9.61	0.14	3.21	0.30	94.72
PW-41	Opaque	0.12	8.89	31.42	5.44	0.04	0.06	0.01	0.22	0.75	46.95
PW-41	Olivine	40.05	0.00	8.81	49.26	0.00	0.00	0.04	0.00	0.16	98.32
PW-41	Serpentine	39.37	0.05	4.16	39.45	0.02	0.01	0.01	0.02	0.02	83.11
PW-41	Olivine	40.03	0.00	8.83	49.67	0.01	0.02	0.04	0.03	0.15	98.78
PW-41	Serpentine	36.54	0.05	5.12	38.31	0.00	0.01	0.02	0.00	0.05	80.1
PW-41	Opaque	0.04	8.73	29.86	5.23	0.02	0.03	0.06	0.23	0.74	44.94
PW-41	Olivine	40.29	0.00	8.90	48.77	0.00	0.02	0.02	0.00	0.18	98.18
PW-41	Olivine	39.68	0.00	9.26	49.26	0.00	0.00	0.02	0.08	0.09	98.39
PW-41	Chlorite	32.03	12.46	2.41	32.82	0.01	0.07	0.02	0.00	0.02	79.84
PW-41	Chlorite	39.90	0.00	9.02	49.91	0.00	0.03	0.02	0.01	0.15	99.04

APPENDIX 2 - Mineral Analyses Continued

Spec.	Min	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-33	Augite	51.15	2.19	11.23	16.27	18.74	0.23	0.53	0.79	0.43	101.56
PW-33	Bytownite	50.89	32.66	0.62	0.04	14.37	0.19	3.39	0.01	0.00	102.17
PW-33	Labradorite	52.28	31.28	0.69	0.04	13.00	0.26	4.39	0.10	0.00	102.04
PW-33	Ilmenite	0.07	0.06	50.82	0.55	0.07	0.07	0.02	43.12	0.69	95.47
PW-33	Augite	51.08	1.87	10.86	14.95	19.36	0.01	0.27	0.63	0.28	99.31
PW-33	Hypersthene	52.03	0.95	22.85	21.32	1.78	0.01	0.04	0.52	0.50	100.00
PW-33	Labradorite	53.29	30.96	0.49	0.03	12.70	0.30	4.48	0.10	0.00	102.35
PW-33	Labradorite	52.26	31.71	0.48	0.03	13.01	0.25	4.29	0.04	0.00	102.07
PW-33	Augite	50.66	2.26	12.22	16.32	17.58	0.10	0.29	0.43	0.28	100.14
PW-33	Phlogopite	38.13	13.85	17.76	15.15	0.16	8.61	0.04	2.38	0.09	96.17
PW-33	Bytownite	50.46	32.17	0.57	0.08	14.71	0.20	3.25	0.04	0.01	101.49
PW-33	Augite	50.80	1.74	14.86	16.39	14.98	0.03	0.22	0.72	0.30	100.04
PW-33	Ilmenite	0.07	0.09	50.75	1.52	0.05	0.03	0.00	42.60	0.56	95.67
PW-33	Augite	50.55	1.85	13.63	15.30	16.84	0.00	0.26	0.73	0.31	99.47
PW-33	Labradorite	53.81	30.29	0.46	0.07	12.22	0.20	4.79	0.03	0.00	101.87
PW-33	Hypersthene	52.31	1.02	21.53	23.66	1.99	0.01	0.10	0.43	0.44	101.49
PW-33	Labradorite	53.07	30.80	0.85	0.09	12.20	0.27	5.15	0.52	0.10	103.05
PW-33	Augite	51.42	1.07	23.30	22.22	1.99	0.02	0.06	0.38	0.48	100.94
PW-39	Titanomagnetite	0.21	6.51	73.01	3.12	0.07	0.02	0.03	9.29	0.62	92.88
PW-39	Ferrian augite	48.81	5.00	10.23	12.65	21.85	0.01	0.49	1.18	0.37	100.59
PW-39	Sanidine	64.36	20.84	0.29	0.05	0.96	9.17	4.74	0.05	0.02	100.48
PW-39	Sanidine	63.70	21.02	0.23	0.02	1.01	8.58	4.91	0.08	0.00	99.55
PW-39	Augite	49.64	3.78	9.90	13.58	22.18	0.05	0.42	0.67	0.30	100.52
PW-39	Sanidine	63.99	20.24	0.29	0.05	0.74	9.29	4.76	0.09	0.01	99.46
PW-39	Augite	51.02	4.61	9.79	12.69	22.68	0.02	0.43	0.93	0.31	102.47
PW-39	Sanidine	66.70	20.34	0.19	0.03	0.68	10.57	3.88	0.06	0.03	102.48
PW-39	Augite	51.83	3.31	11.18	11.49	22.43	0.00	0.75	0.72	0.49	102.20
PW-39	Sanidine	67.47	20.46	0.23	0.05	1.00	10.38	3.98	0.04	0.02	103.63
PW-39	Titanomagnetite	0.82	2.87	76.76	0.58	0.26	0.09	0.00	13.00	0.00	94.38
PW-39	Sericite	63.84	19.68	0.41	0.11	1.25	8.24	0.00	0.90	0.00	94.43
PW-39	Olivine	35.58	0.10	38.83	25.73	0.14	0.04	0.00	0.13	0.00	100.55
PW-39	Titanomagnetite	0.24	4.03	72.73	1.49	0.00	0.05	0.00	12.96	0.00	91.50

APPENDIX 2 - Mineral Analyses Continued

Spec.	Min	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-40	Diopside	52.67	1.40	9.69	16.23	18.11	0.01	0.34	0.80	0.31	99.56
PW-40	Biotite	39.83	14.16	12.59	18.11	0.09	8.15	0.60	2.41	0.05	95.99
PW-40	Ilmenite	0.03	0.07	50.04	0.90	0.06	0.02	0.04	44.99	0.60	96.75
PW-40	Hypersthene	54.39	0.60	18.93	23.10	1.87	0.01	0.08	0.44	0.45	99.87
PW-40	Labradorite	54.51	30.55	0.49	0.02	12.75	0.11	4.73	0.10	0.02	103.28
PW-40	Labradorite	53.58	30.62	0.64	0.06	12.99	0.04	4.69	0.08	0.00	102.70
PW-40	Sericite	45.34	30.38	0.24	0.03	11.38	0.07	3.66	0.03	0.02	91.15
PW-40	Labradorite	54.79	29.52	0.58	0.10	11.90	0.09	4.75	0.10	0.00	101.83
PW-40	Labradorite	55.33	30.08	0.62	0.15	12.17	0.09	4.92	0.14	0.01	103.51
PW-40	Diopside	49.88	1.69	9.68	14.56	17.38	0.00	0.38	1.05	0.25	94.87
PW-40	Hypersthene	41.63	0.01	25.46	13.22	0.00	0.07	0.03	0.08	0.55	81.05
PW-40	Hypersthene	53.42	0.00	20.13	22.41	0.16	0.01	0.04	0.22	0.46	96.85
PW-101	Orthoclase	67.20	19.03	0.02	0.03	0.05	15.70	0.49	0.02	0.00	102.54
PW-101	Biotite	35.83	16.19	23.35	5.49	0.06	9.49	0.07	3.05	1.14	94.67
PW-101	Quartz	103.92	0.00	0.04	0.01	0.00	0.01	0.03	0.04	0.01	104.06
PW-101	Oligoclase	66.45	23.11	0.02	0.01	3.35	0.24	10.15	0.02	0.00	103.35
PW-101	Orthoclase	66.26	18.97	0.05	0.02	0.04	15.87	0.94	0.05	0.01	102.21
PW-101	Biotite	34.92	18.86	24.39	5.87	0.09	5.98	0.06	2.20	1.27	93.64
PW-101	Oligoclase	66.19	23.04	0.07	0.02	3.16	0.26	9.94	0.01	0.02	102.71
PW-101	Orthoclase	66.63	19.20	0.05	0.02	0.04	15.76	1.15	0.04	0.01	102.90
PW-101	Quartz	104.18	0.02	0.01	0.01	0.02	0.00	0.02	0.04	0.00	104.30
PW-101	Oligoclase	68.19	23.58	0.02	0.01	3.04	0.29	9.76	0.00	0.02	104.91
PW-127	Labradorite	52.85	31.36	0.61	0.07	13.37	0.29	3.90	0.10	0.01	102.56
PW-127	Biotite	38.43	13.76	14.86	15.30	0.09	9.38	0.16	1.72	0.09	93.79
PW-127	Ilmenite	0.04	0.32	49.06	1.88	0.06	0.03	0.06	44.64	0.46	96.55
PW-127	Hypersthene	54.27	0.88	23.05	21.08	1.24	0.01	0.03	0.36	0.53	101.45
PW-127	Augite	51.53	1.93	12.19	14.87	18.27	0.02	0.31	0.53	0.29	99.94
PW-127	Labradorite	53.07	31.48	0.51	0.09	14.05	0.23	3.84	0.06	0.01	103.34
PW-127	Labradorite	56.98	30.21	0.15	0.03	11.58	0.23	4.98	0.16	0.02	104.34

APPENDIX 2 - Mineral Analyses Continued

Spec.	Min	SiO2	Al203	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-30	Biotite	36.81	15.37	15.41	12.08	0.03	9.92	0.23	8.19	0.05	98.09
PW-30	Ilmenite	0.05	1.24	46.72	0.16	0.01	0.03	0.00	49.89	0.77	98.87
PW-30	Amphibole	39.93	13.42	18.45	8.21	9.25	1.89	1.79	3.96	0.07	96.97
PW-30	Oligoclase	64.93	24.80	0.46	0.12	4.93	0.73	8.27	0.03	0.02	104.29
PW-30	Ferroaugite	52.23	2.33	11.95	10.62	20.36	0.01	1.04	0.32	0.28	99.14
PW-30	Ferroaugite	48.42	3.64	14.03	10.37	17.67	0.03	1.13	0.28	0.23	95.8
PW-30	Almandine	39.45	20.08	26.16	4.04	7.13	0.04	0.07	0.12	1.17	98.26
PW-30	Oligoclase	61.74	24.44	2.81	1.15	5.35	0.70	7.64	0.02	0.00	103.85
PW-30	Oligoclase	63.06	25.03	0.24	0.03	5.97	0.70	7.58	0.03	0.01	102.65
PW-30	Biotite	37.43	14.49	16.18	11.16	0.04	9.92	0.18	8.23	0.07	97.7
PW-30	Ferroaugite	51.13	3.50	12.28	9.92	20.22	0.01	1.27	0.52	0.25	99.1
PW-30	Andesine	60.33	26.46	0.06	0.01	8.08	0.57	7.04	0.04	0.00	102.59
PW-125	Ilmenite	0.04	0.01	44.43	0.18	0.07	0.04	0.03	46.81	0.65	92.26
PW-125	Hornblende	41.18	16.00	15.81	8.04	11.89	0.55	1.64	0.64	0.16	95.91
PW-125	Andesine	58.29	29.04	0.18	0.01	9.91	0.04	6.25	0.14	0.01	103.87
PW-125	Bytownite	51.60	33.32	0.08	0.02	15.40	0.02	3.29	0.05	0.02	103.8
PW-125	Hornblende	43.92	13.34	15.66	10.08	11.81	0.32	1.55	0.64	0.13	97.45
PW-25	Sanidine	58.25	27.77	0.30	0.51	0.98	5.02	5.45	0.01	0.03	98.323
PW-25	Andesine	56.69	28.48	0.07	0.04	9.08	0.09	6.03	0.03	0.03	100.54
PW-25	Epidote	37.35	26.35	9.48	0.08	23.40	0.02	0.04	0.16	0.12	97
PW-25	Hornblende	41.78	14.23	15.17	11.30	12.22	0.94	1.43	1.13	0.24	98.44
PW-25	Epidote	37.63	26.65	9.62	0.15	23.58	0.02	0.06	0.18	0.12	98.01
PW-25	Andesine	55.34	28.51	0.12	0.03	9.45	0.12	5.80	0.00	0.02	99.39
PW-25	Hornblende	42.00	13.92	15.55	11.64	11.83	0.88	1.45	1.04	0.23	98.54
PW-25	Andesine	56.71	28.37	0.12	0.03	9.24	0.16	5.73	0.01	0.00	100.37
PW-25	Biotite	34.07	17.37	14.41	15.66	0.31	7.32	0.18	2.00	0.16	7
PW-25	Andesine	48.39	24.98	0.09	0.01	6.83	0.09	5.72	0.00	0.00	86.11
PW-25	Andesine	57.78	28.44	0.07	0.00	8.70	0.09	6.46	0.00	0.02	101.56
PW-25	Oligoclase	62.52	24.15	0.11	0.07	2.84	0.95	8.56	0.01	0.02	99.23
PW-25	Biotite	36.40	17.19	14.86	15.38	0.38	8.31	0.22	2.01	0.12	94.864
PW-25	Biotite	36.45	17.34	14.49	14.96	0.00	9.16	0.19	2.03	0.13	94.75
PW-25	Hornblende	42.99	13.63	15.06	11.70	11.74	0.92	1.48	1.47	0.27	99.26
PW-25	Epidote	37.84	26.90	9.84	0.11	23.42	0.01	0.04	0.16	0.16	98
PW-25	Hornblende	41.69	14.04	15.30	11.62	12.12	0.94	1.46	1.09	0.19	98.45
PW-25	Andesine	58.03	27.67	0.09	0.06	8.23	0.09	6.56	0.00	0.02	100.75

APPENDIX 2 - Mineral Analyses Continued

Rock	Mineral	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-24	Hornblende	44.33	9.00	19.64	10.74	11.58	0.60	1.04	1.10	0.50	98.53
PW-24	Biotite	36.20	16.61	21.88	10.29	0.03	9.32	0.16	3.69	0.28	98.46
PW-24	Hornblende	45.64	7.92	18.68	10.82	11.57	0.46	0.95	1.13	0.55	97.72
PW-24	Quartz	98.55	0.00	0.05	0.01	0.00	0.00	0.01	0.02	0.00	98.64
PW-24	Andesine	58.00	27.54	0.11	0.03	8.59	0.16	6.28	0.01	0.02	100.74
PW-24	Labradorite	55.25	29.32	0.12	0.02	10.19	0.12	5.57	0.01	0.03	100.63
PW-24	Andesine	58.36	26.89	0.17	0.02	7.49	0.18	6.54	0.02	0.02	99.69
PW-24	Hornblende	44.84	8.59	19.89	10.73	11.60	0.56	1.02	1.06	0.57	98.86
PW-24	Hornblende	45.15	8.49	19.51	11.05	11.72	0.67	0.88	1.12	0.57	99.16
PW-24	Hornblende	45.30	7.74	19.62	11.28	11.82	0.49	0.90	1.21	0.50	98.86
PW-24	Biotite	35.33	13.15	21.78	10.27	0.02	8.95	0.15	3.48	0.17	93.3
PW-24	Quartz	99.94	0.00	0.08	0.00	0.00	0.00	0.00	0.05	0.02	100.09
PW-24	Andesine	56.86	27.91	0.16	0.02	8.66	0.14	6.10	0.03	0.01	99.89
PW-28	Andesine	56.72	28.22	0.20	0.01	8.73	0.13	5.97	0.00	0.00	99.98
PW-28	Iron diopside	50.85	1.30	8.99	14.00	22.94	0.01	0.29	0.29	0.43	99.1
PW-28	Magnetite	0.09	0.23	93.01	0.03	0.05	0.03	0.01	0.31	0.17	93.93
PW-28	Sub-calcic augite	51.67	2.71	14.23	15.04	13.45	0.14	0.23	0.31	0.31	98.09
PW-28	Bytownite	47.87	34.17	0.34	0.03	15.98	0.07	2.33	0.01	0.01	100
PW-28	Sub-calcic Al augite	48.47	6.35	13.98	15.10	11.44	0.22	0.81	1.31	0.34	98.02
PW-28	Sub-calcic Al augite	48.26	6.50	14.04	15.15	11.97	0.25	0.93	1.32	0.33	98.73
PW-28	Iron diopside	52.31	1.96	9.88	15.31	20.56	0.04	0.31	0.45	0.41	101.23
PW-28	Sub-calcic Al augite	49.05	6.10	15.75	15.36	10.96	0.14	0.77	1.13	0.36	99.62
PW-28	Salite + augite	52.70	2.39	15.25	15.83	13.39	0.11	0.23	0.11	0.23	100.24
PW-28	Ilmenite + magnetite	0.11	0.14	74.42	0.04	0.07	0.02	0.07	23.19	1.55	99.61
PW-28	Bytownite	47.65	34.37	0.34	0.02	15.66	0.03	2.24	0.02	0.05	100.38
PW-28	Bytownite	47.83	35.25	0.46	0.02	17.03	0.02	1.83	0.03	0.01	102.48
PW-32	Unidentified	31.07	12.07	2.40	0.43	20.76	1.12	0.07	27.44	0.07	95.43
PW-32	Amphibole	36.07	24.51	7.34	1.51	23.22	0.01	0.05	0.06	0.07	92.84
PW-32	Amphibole	36.01	24.40	5.89	2.09	23.24	0.02	0.04	0.02	0.10	91.81
PW-32	Oligoclase	63.97	23.55	0.20	0.08	2.03	0.84	8.83	0.02	0.00	99.52
PW-32	Zoisite (?)	48.33	22.82	1.25	0.41	20.02	0.38	1.65	0.03	0.05	94.94
PW-32	Zoisite (?)	41.94	24.58	1.03	0.21	25.96	0.20	0.06	0.04	0.03	94.05
PW-32	Andesine	56.05	28.58	0.13	0.01	9.88	0.23	5.51	0.02	0.01	100.42
PW-32	Andesine	55.55	28.16	0.08	0.05	9.48	0.31	5.86	0.00	0.00	99.49
PW-32	Andesine	56.47	28.53	0.14	0.04	9.09	0.47	5.54	0.01	0.06	100.35

APPENDIX 2 - Mineral Analyses Continued

Rock	Mineral	SiO2	Al2O3	FeO	MgO	CaO	K2O	Na2O	TiO2	MnO	Total
PW-14	Diopside	49.27	4.83	7.71	12.94	22.41	0.02	1.36	1.37	0.44	100.35
PW-14	Albite	69.09	20.31	0.14	0.05	0.47	0.24	10.60	0.01	0.01	100.92
PW-14	Orthoclase	63.69	18.98	0.10	0.01	0.05	11.57	1.31	0.01	0.03	95.75
PW-14	Perthite	64.59	20.48	0.20	0.03	0.43	8.06	5.40	0.04	0.02	99.25
PW-14	Groundmass	37.23	31.20	0.11	0.10	12.30	0.05	2.86	0.00	0.00	83.85
PW-14	Groundmass	56.46	26.26	0.37	0.03	0.90	6.66	7.25	0.04	0.02	97.99
PW-14	Diopside	48.73	6.07	9.80	10.49	20.94	0.03	1.16	1.38	0.54	99.14
PW-14	Diposide	48.72	4.38	10.73	11.24	22.31	0.03	1.12	1.42	0.59	100.54
PW-14	Apatite	0.85	0.00	0.29	0.08	51.21	0.05	0.21	0.04	0.12	52.85
PW-14	Amphibole	39.46	11.56	18.96	9.55	11.24	1.76	2.77	2.48	1.22	99
PW-14	Anorthoclase	63.95	20.58	0.37	0.02	0.70	6.75	6.09	0.18	0.02	98.66
PW-14	Groundmass	42.34	33.33	0.49	0.11	0.78	3.48	20.92	0.02	0.04	101.51
PW-14	Groundmass	66.31	19.58	0.08	0.02	0.27	5.22	7.07	0.03	0.03	98.596
PW-19	Biotite	35.48	15.91	15.57	14.54	0.01	9.81	0.30	3.57	0.28	95.47
PW-19	Apatite	0.57	0.08	0.10	0.05	50.70	0.02	0.10	0.07	0.10	51.79
PW-19	Augite	47.26	5.97	8.31	11.65	23.52	0.03	1.09	1.69	0.30	99.82
PW-19	Augite	47.28	6.14	8.12	11.52	22.97	0.11	1.14	1.85	0.25	99.38
PW-19	Alk. feldspar	42.96	35.40	0.39	0.03	0.90	6.55	15.29	0.02	0.00	101.54
PW-19	Amphibole	38.30	13.73	12.41	12.60	12.06	2.16	2.42	3.90	0.25	97.83
PW-19	Biotite	35.57	16.26	15.51	15.14	0.03	9.48	0.33	2.73	0.34	95.39
PW-19	Opaque	3.17	0.04	73.58	0.18	0.39	0.07	0.04	0.17	0.12	77.76
PW-19	Biotite	35.80	15.34	17.65	14.43	0.00	9.50	0.38	3.90	0.33	97.33
PW-19	Augite	47.31	5.59	8.96	11.79	23.22	0.03	1.12	1.52	0.28	99.82
PW-19	Augite	48.68	4.98	8.90	11.93	23.37	0.04	1.12	1.54	0.32	100.88
PW-19	Apatite	0.41	0.00	0.15	0.11	49.30	0.00	0.09	0.05	0.06	50.17
PW-19	Apatite	0.48	0.00	0.20	0.10	51.05	0.02	0.08	0.04	0.14	52.11
PW-19	Alk. feldspar	42.97	36.15	0.37	0.07	0.69	6.67	15.26	0.02	0.01	102.21