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INFRARED REFLECTIVITY OF SOME COMMON MINERALS

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ABSTRACT

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Infrared reflectivities of minerals of the carbonate, sulfate, nitrate and silicate families exhibit spectral features that can be detected in reflection from surface minerals. These features could be used to identify such minerals from infrared reflection spectra of the moon and some planets and could also be a source of confusion in interpretation of atmospheric spectra.

INDRODUCTION

The infrared reflection spectrum of minerals has been investigated by a number of people though the work was mainly concerned with materials of optical interest. The recent bibliography by McCarthy(1) contains references to a large number of these measurements. More recently Rea et al (2) investigated the infrared reflectivity of both organic and inorganic materials in an attempt to explain features in the reflection of Mars. The availability of the infrared total reflectance attachment described by White (3) for the Cary 90 double beam spectrometer has made total reflectance measurements beyond 2.5 microns more readily available and has stimulated the measurements reported here.

EXPERIMENTAL PROCEDURE

The total reflectivity for all specimens was measured with a Beckman DK 2A double beam spectrometer equipped with a total reflectance attachment from 0.5 to 2.5 microns. From 2.5 to 6 microns measurements were made with the Cary 90 mentioned previously. Specimens identified by their chemical name were reagent grade chemicals, natural specimens were collected as described in the discussion of each specimen.

PURE MATERIALS

Carbonates: Carbonates are abundant in the surface mineral cover of Earth. Calcite or $CaCO_3$ is the most abundant occurring as limestone, chalk, as cementing material in sedimentary rocks and in the shells of

[redacted]

the hard shelled marine organisms. Figure 1 shows the reflectivity of granular calcium carbonate and Fig. 2 the reflectivity of sodium carbonate. A number of strong spectral features are seen particularly near 3.5 and 4.0 microns.

Sulfates: Hydrous calcium sulfate or gypsum is found extensively in sedimentary deposits and is normally the first salt deposited in the evaporation of sea water. Figure 3 shows the reflectivity of $Ca\ SO_4 \cdot 2\ H_2O$. As with the carbonates numerous strong features are seen. The feature at 2.7 to 3 microns is due to water of hydration.

Nitrates: Nitrates are normally found in arid regions of the Earth, the only significant deposits occurring in Chile. The reflectivities of sodium and potassium nitrate are shown in Figures 4 and 5. Again a number of strong features are observed especially in the 3 to 4 micron region.

Salt: Sodium chloride is widely distributed occurring in extensive beds following evaporation by enclosed bodies of water. The reflectivity of granular sodium chloride is shown in Figure 6. The features at 1.46, 1.96 and 2.9 microns are due to water of hydration.

Silica: Figure 7 shows the reflectivity of a silica sand of high purity gotten by washing and sizing natural sand. Some water of hydration is present as evidenced by the feature at 2.9 microns. The features from 3.7 to 5 microns are characteristic of natural crystal quartz. While synthetic quartz has features at the same wavelengths they are not as detailed and the double features such as the one centered around 4.7 microns are blended into one. The restrahlen or residual ray features of synthetic quartz at longer wavelengths also show this effect since natual quartz is birefringent and synthetic quartz is not. This indicates a relationship between the well known residual ray features at longer wavelengths and the features found from 3.7 to 5 microns.

NATURAL MINERALS

The reflectivity of Rosamond Dry Lake in California and the Pawnee Grassland area in Colorado is of interest since these areas are used for comparison of radiometric measurements from satellites with known surface conditions. Figures 8 and 9 show the reflectivities of soil from these areas. The soil was taken from the surface and preserved in its original form as well as possible. Both samples show features due to water of hydration near 1.4, 1.9 and 2.9 microns. Since most natural surface minerals are hydrated these features will be found in their reflection spectrum.

The Rosamond Dry Lake soil has features at 3.96 and 3.48 microns due to carbonates, mainly calcium carbonate. The feature at 4.68 microns found in pure calcium carbonate is not seen and may be obscured by features such as those seen in silica sand due to quartz in the soil. The Pawnee Grassland soil shows the carbonate feature at 3.96 microns weakly and the quartz features from 4.4 to 4.8 microns.

Gypsum is common in much of the soil of Western United States particularly in the sand of the White Sands National Monument. Figure 10 shows the reflectivity of a sample of this sand in its natural state and partially dehydrated to enhance the features. Agreement is good between the sand features and those of calcium sulfate.

Beach sand from ocean beaches is largely silica and the sands from Atlantic City, N.J. and Daytona Beach, Fla. whose reflectivities are shown in Figs. 11 and 12 exhibit the features seen in the purer silica sand. The Daytona beach sand was sized by sieves into two parts one with particles from 0.105 to .250 mm. and the other from .250 to .5 mm. as shown in Fig. 12.

The reflectivity of a sample of the Salt Pool of Death Valley, Calif. is shown in Figure 13. This salt occurs in cakes with a rough, granular surface and the cakes were preserved intact during measurement. The roughness of the surface and impurities present account for the generally lower reflectivity than that of pure sodium chloride.

Figure 14 shows the reflectivity of two samples of nitrate soil from Chile. The soil from Pampa Nebraska is approximately 15% $NaNO_3$, 15% NaCI and 5% Na_2SO_4. That from Oficina Victoria is 10 to 12% NaNO3 with some NaCl and Na_2SO_4. This Pampa Nebraska specimen shows a stong carbonate feature overlapping one of the nitrate features. The Oficina, Victoria specimen shows a strong feature at 4.12 microns probably due to KNO3.

DISCUSSION:

The infrared reflectivities of a number of common minerals have strong spectral features. These features could be used for remote identification of minerals on the surfaces of the moon or other planets, whose surface is accessible to infrared. These features may also be a serious complication in the interpretation of low resolution infrared spectra of planets with an atmosphere, such as Mars since they, in may cases, overlap absorption features of various common atmospheric gases.

Since restrahlen or residual ray features that would be seen in thermal emission spectra from the moon or a planetary surface are reduced in intensity by decreasing particle size a dusty surface such as might be expected on Mars or the lunar surface might be better be examined for mineral constituents by reflected rather than emitted radiation. As shown in a previous work, (Hovis (4)) on reflectivity of iron oxides, reflection features are enhanced by reduced particle size.

The large number of inorganic features possible from minerals will seriously complicate detection of organic material by remote spectroscopic investigation. It would be difficult to identify any particular spectral feature seen in reflected spectra as positively organic in origin when such a large number of inorganic features exist.

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CAPTIONS OF FIGURES

Fig. 1)	Reflectivity of Calcium Carbonate
Fig. 2)	Reflectivity of Sodium Carbonate
Fig. 3)	Reflectivity of Hydrous Calcium Sulfate
Fig. 4)	Reflectivity of Sodium Nitrate
Fig. 5)	Reflectivity of Potassium Nitrate
Fig. 6)	Reflectivity of Sodium Chloride
Fig. 7)	Reflectivity of Silica Sand
Fig. 8)	Reflectivity of Rosamond Dry Lake Soil
Fig. 9)	Reflectivity of Pawnee Grassland Soil
Fig.10)	Reflectivity of Gypsum Sand
Fig.11)	Reflectivity of Atlantic City, N.J. Beach Sand
Fig.12)	Reflectivity of Daytona Beach, Fla. Beach Sand
Fig.13)	Reflectivity of Salt Pool, Death Valley
Fig.14)	Reflectivity of Chilean Nitrate Soil

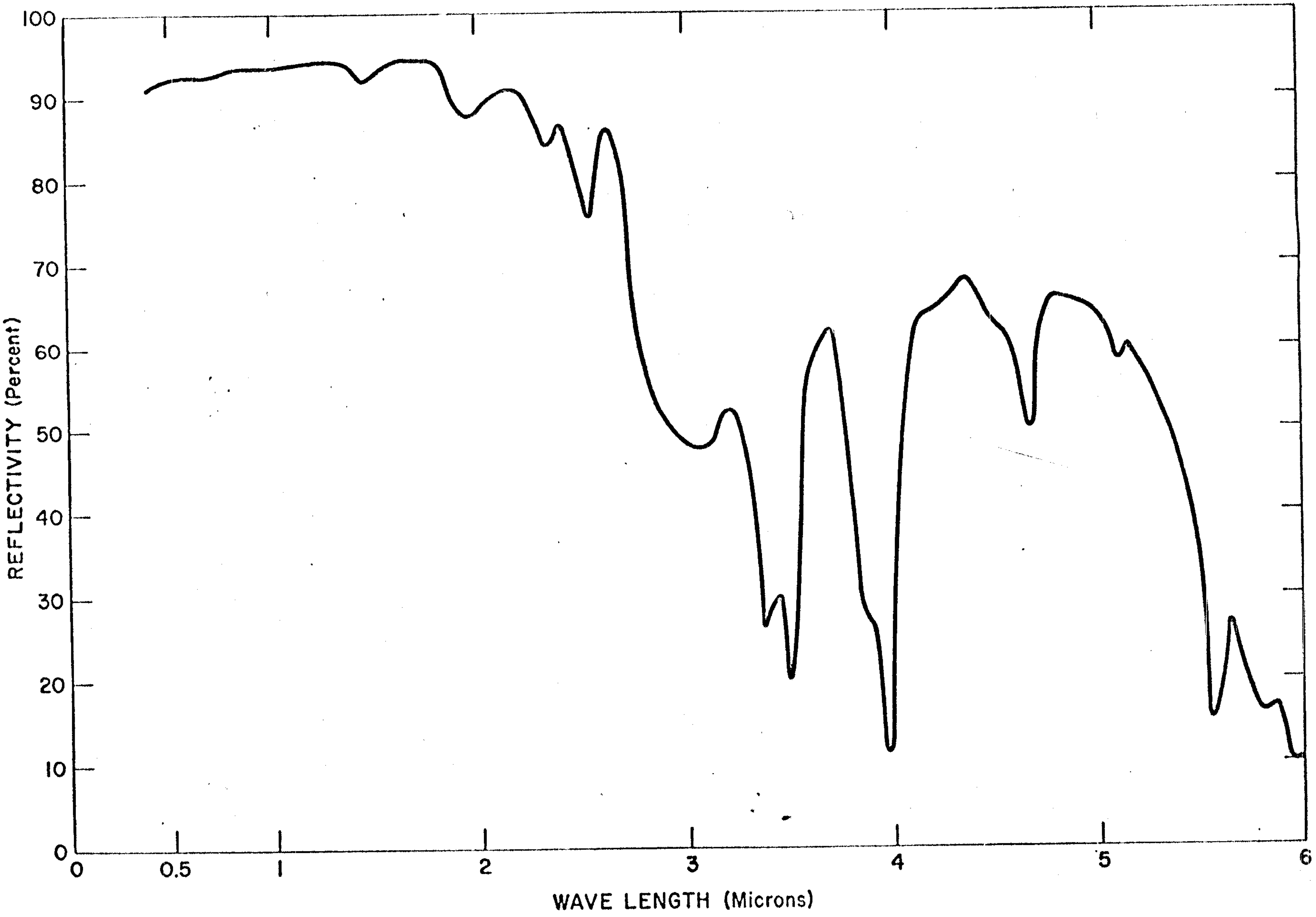
REFERENCES:

(1) Donald E. McCarthy, Applied Optics, 4 , 507 (1965)

(2) D. G. Rea, T. Belsky and M. Calvin, Science, 141, 923 (1963)

(3) John U. White, J.O.S.A., 54, 1332 (1965)

(4) W. A. Hovis, Icarus, in press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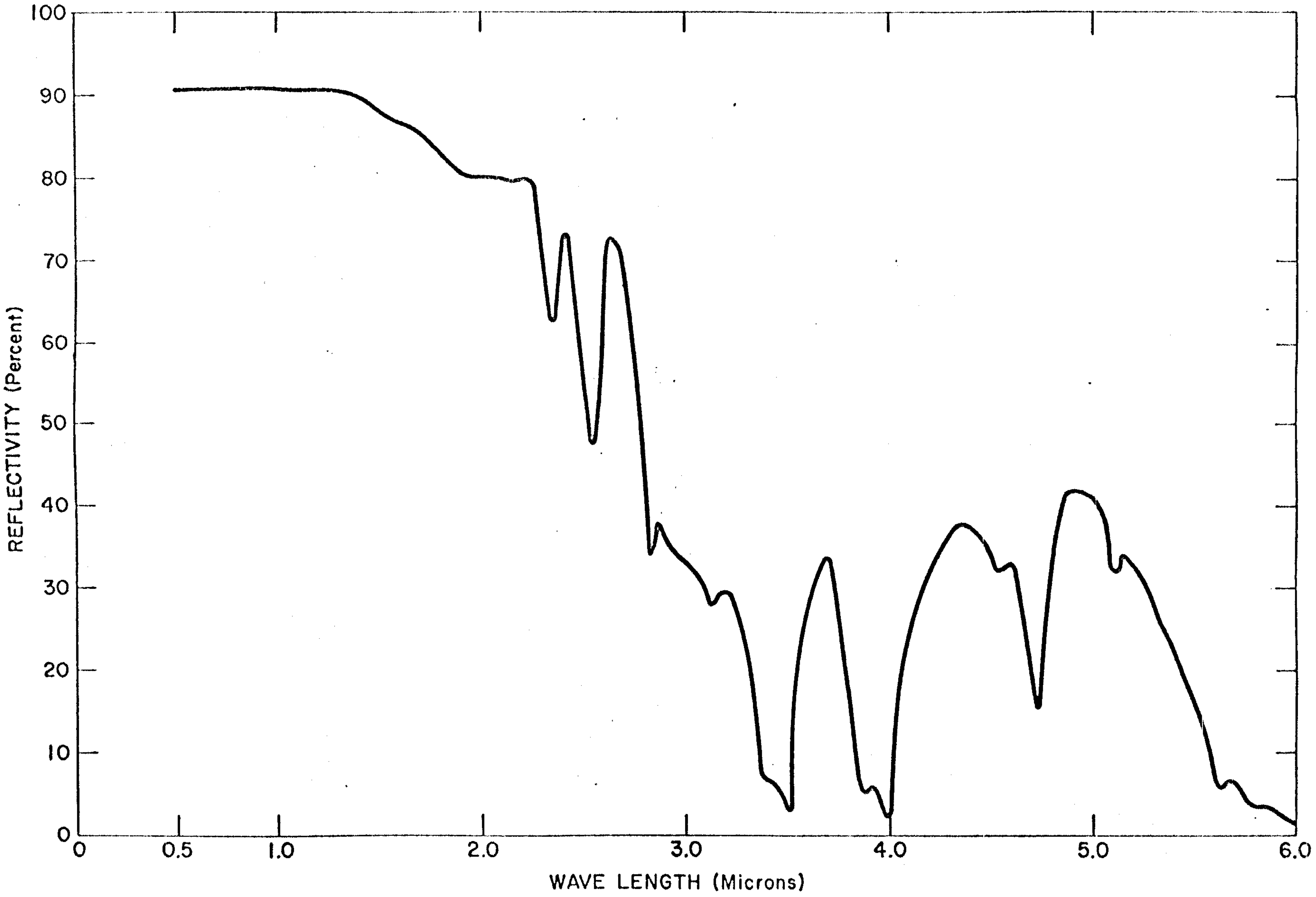
6
WAVE LENGTH (Microns)

Fig. 1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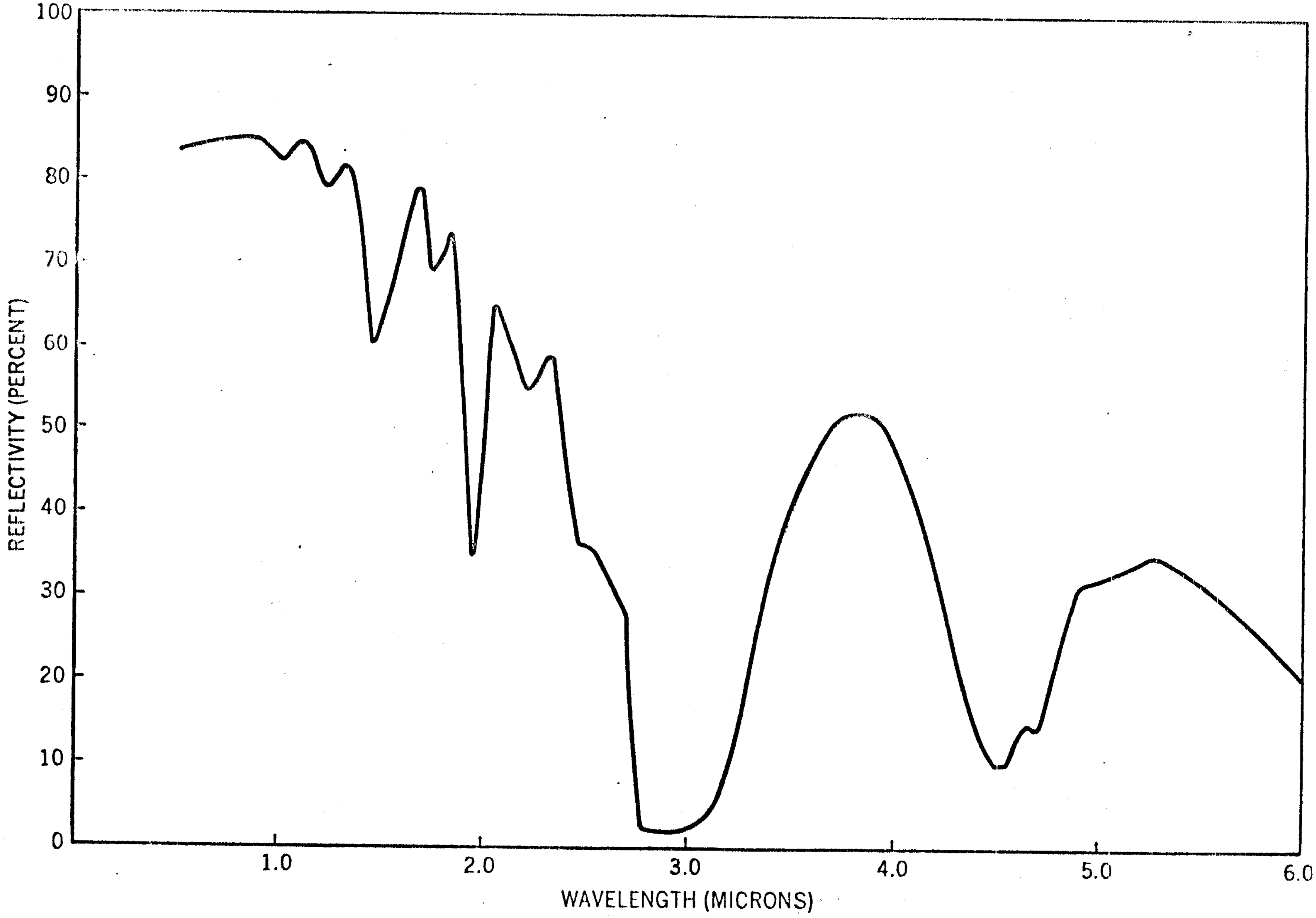
WAVE LENGTH (Microns)

Fig. 2



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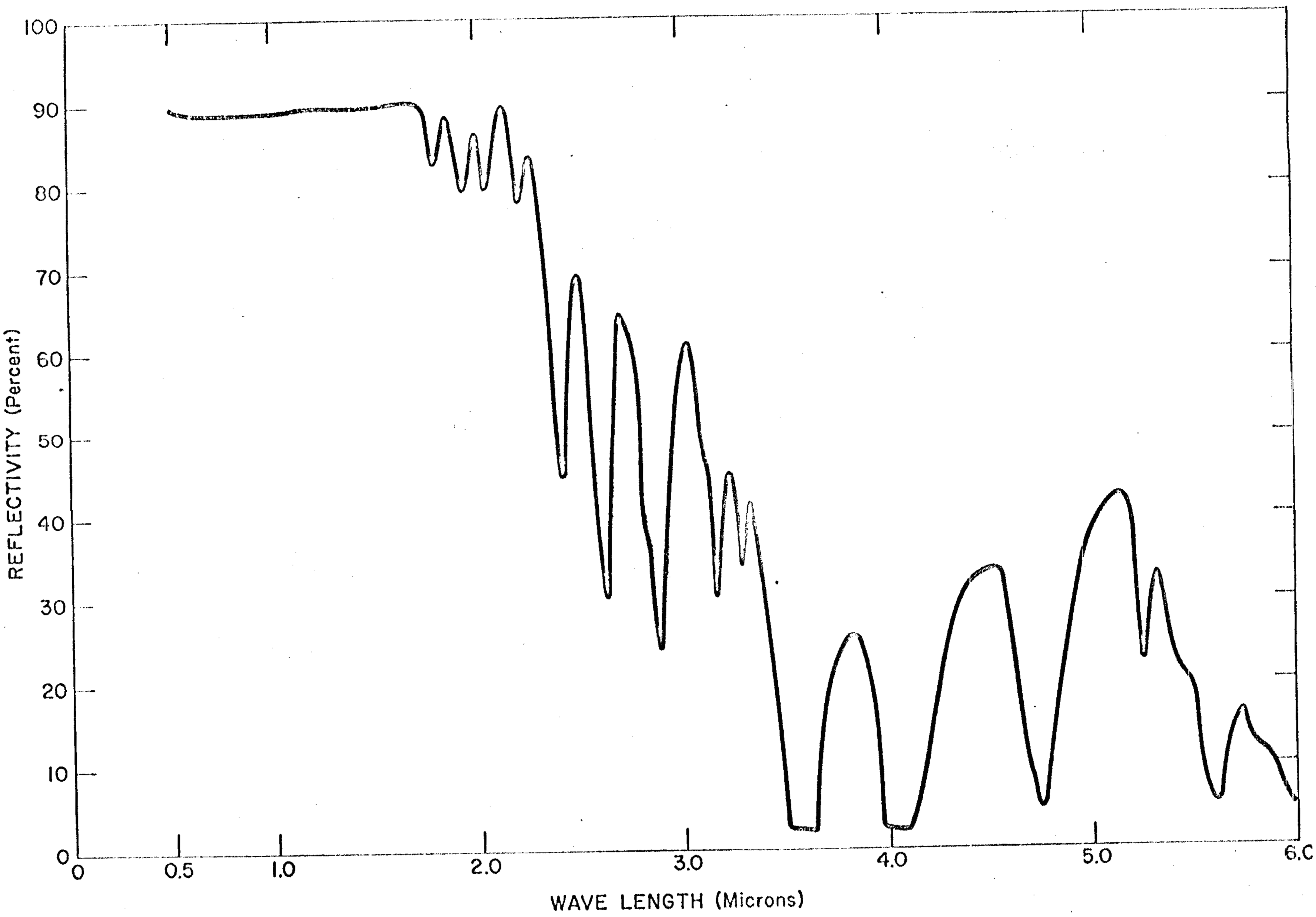
WAVELENGTH (MICRONS)

Fig 3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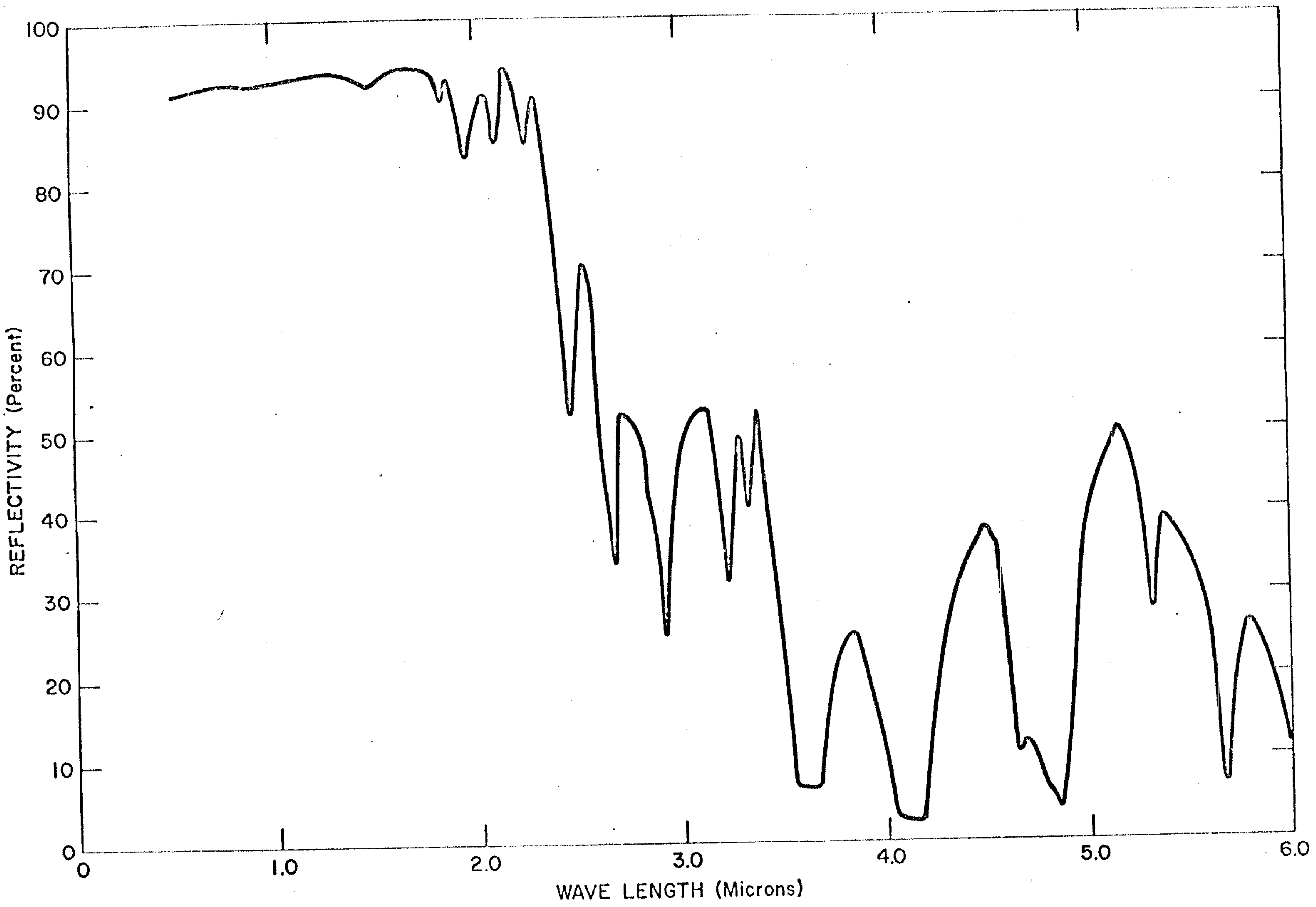
WAVE LENGTH (Microns)

Fig 4.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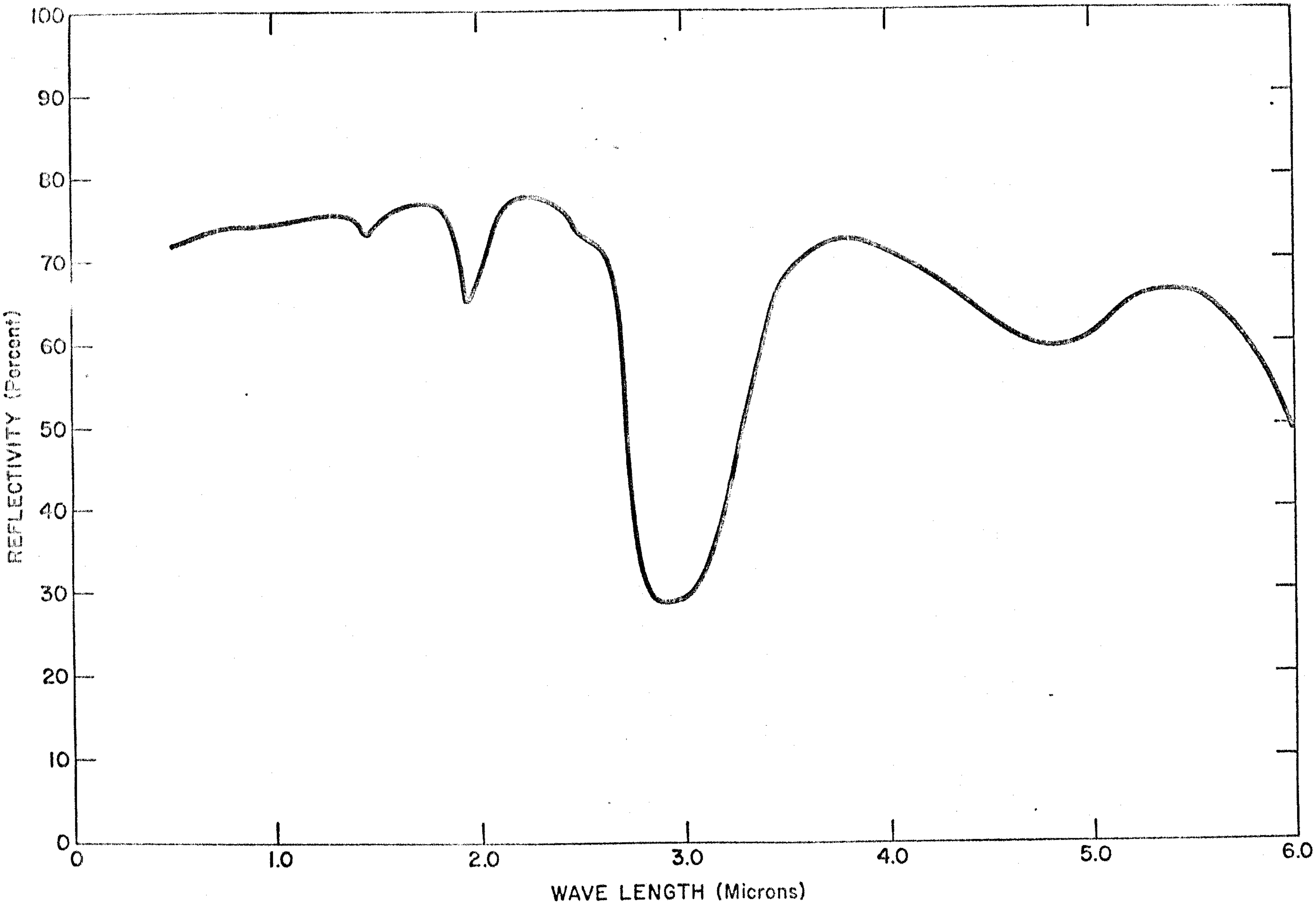
WAVE LENGTH (Microns)

Fig 5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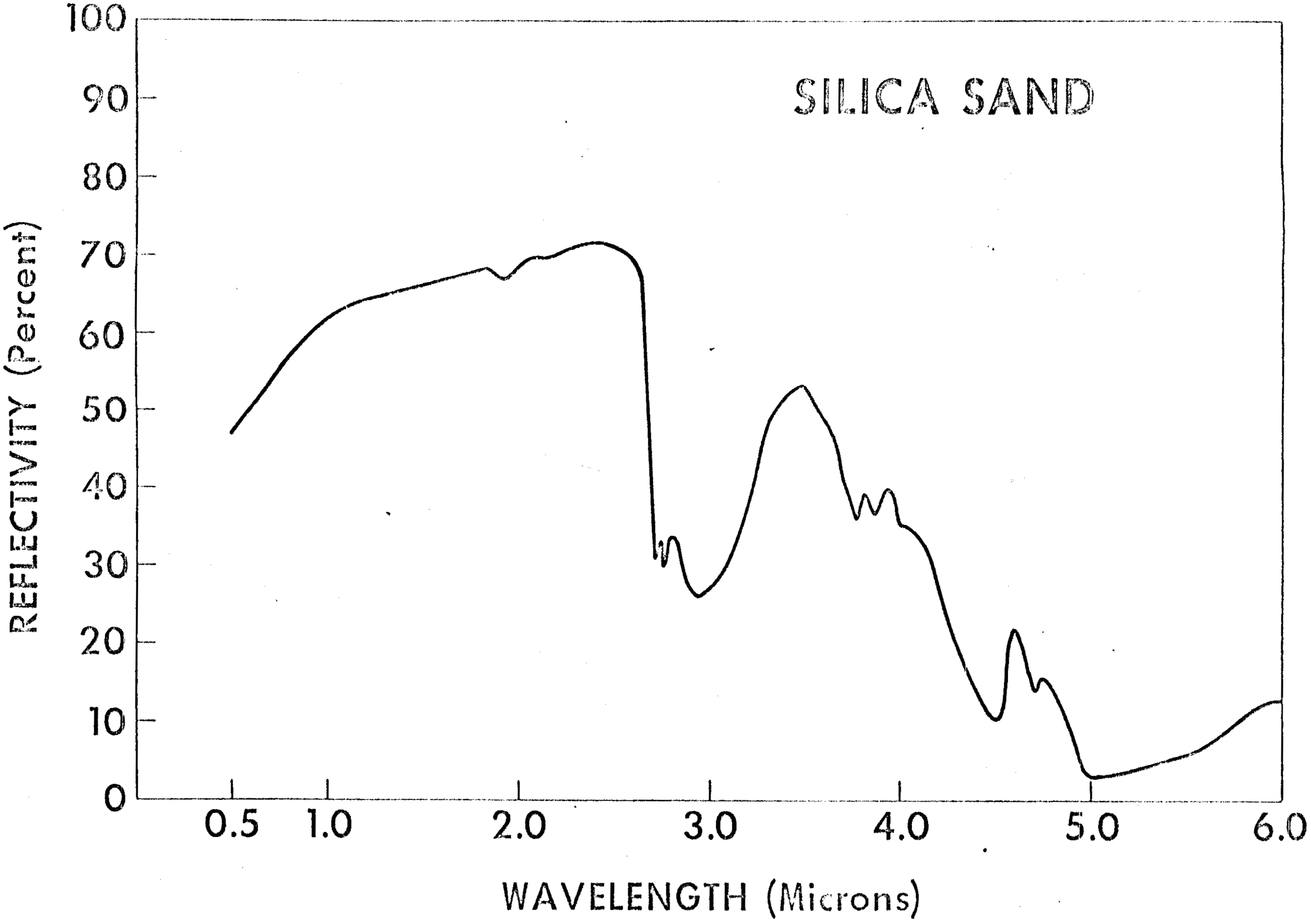
WAVE LENGTH (Microns)

Fig.6


SILICA SAND
REFLECTIVITY (Percent)
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30
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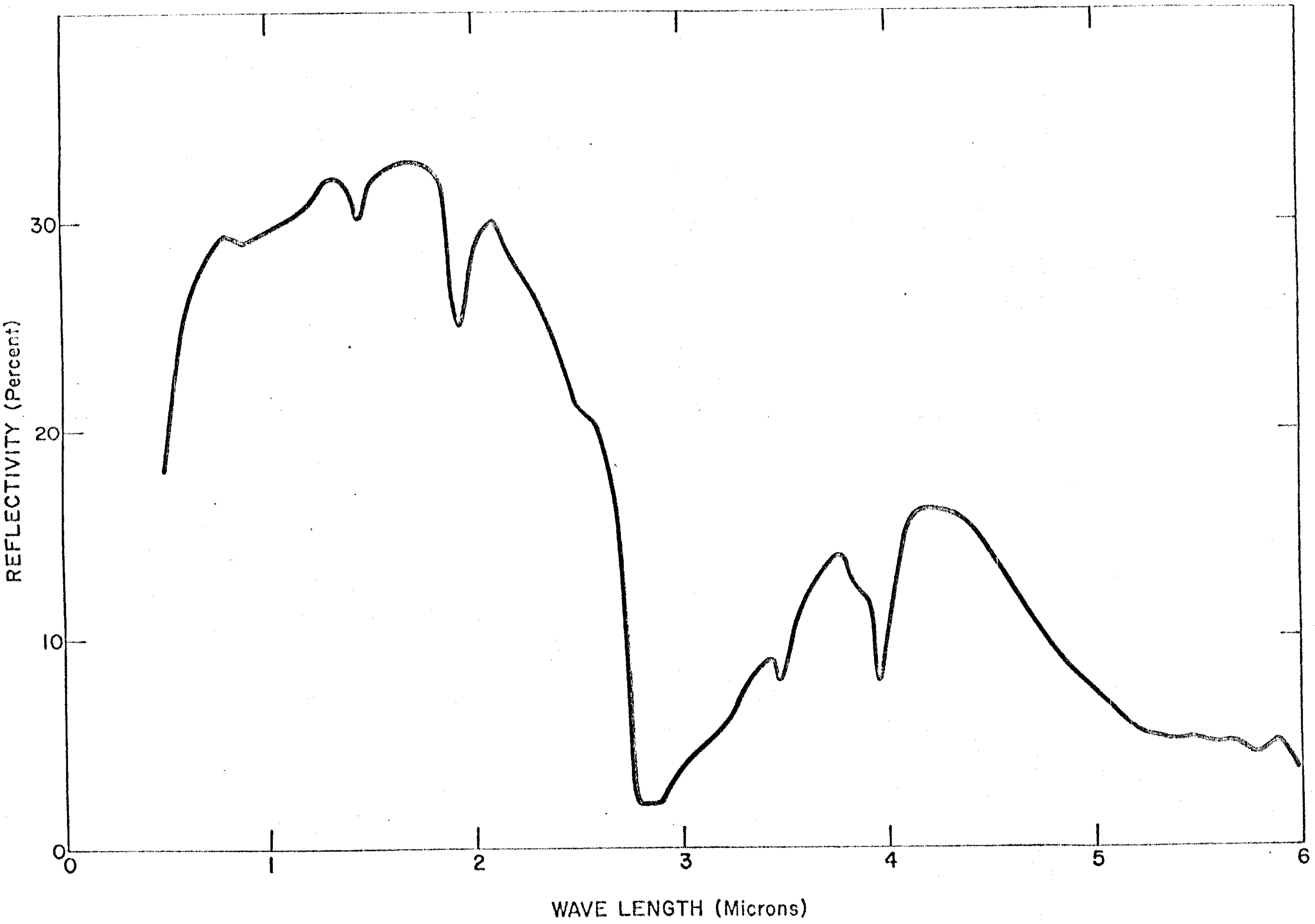
6.0
WAVELENGTH (Microns)

Fig 7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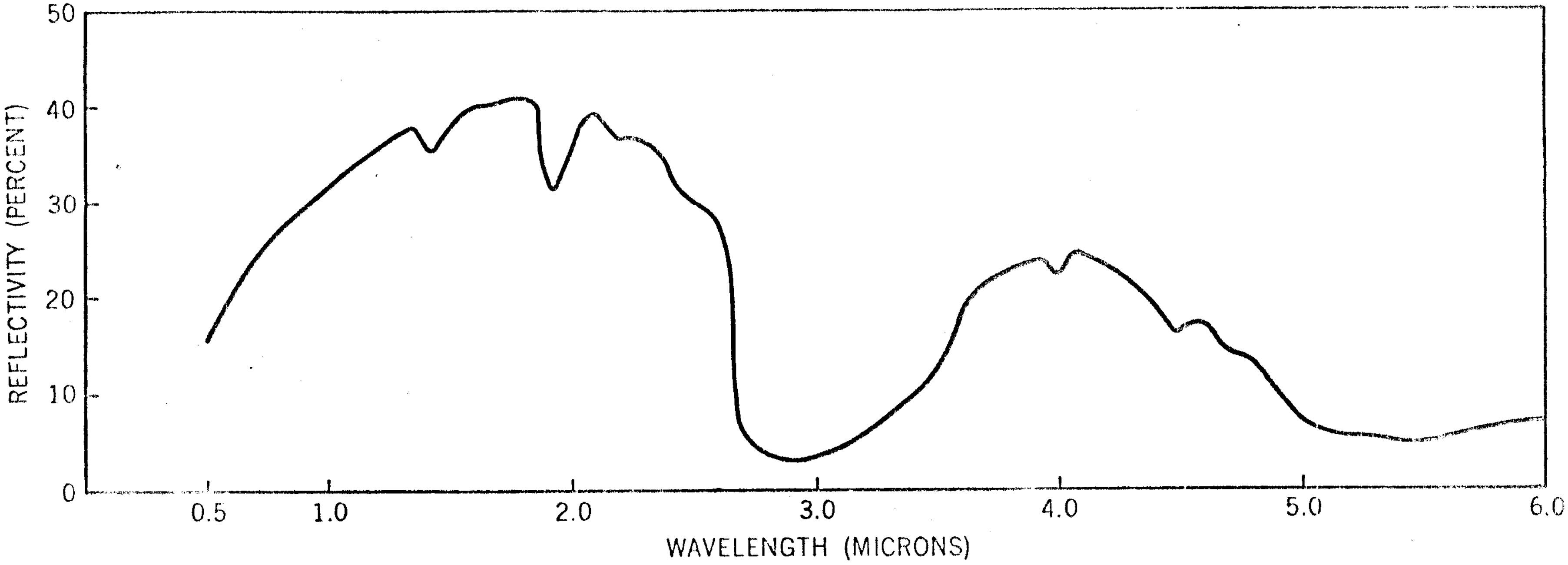
WAVE LENGTH (Microns)

Fig. 8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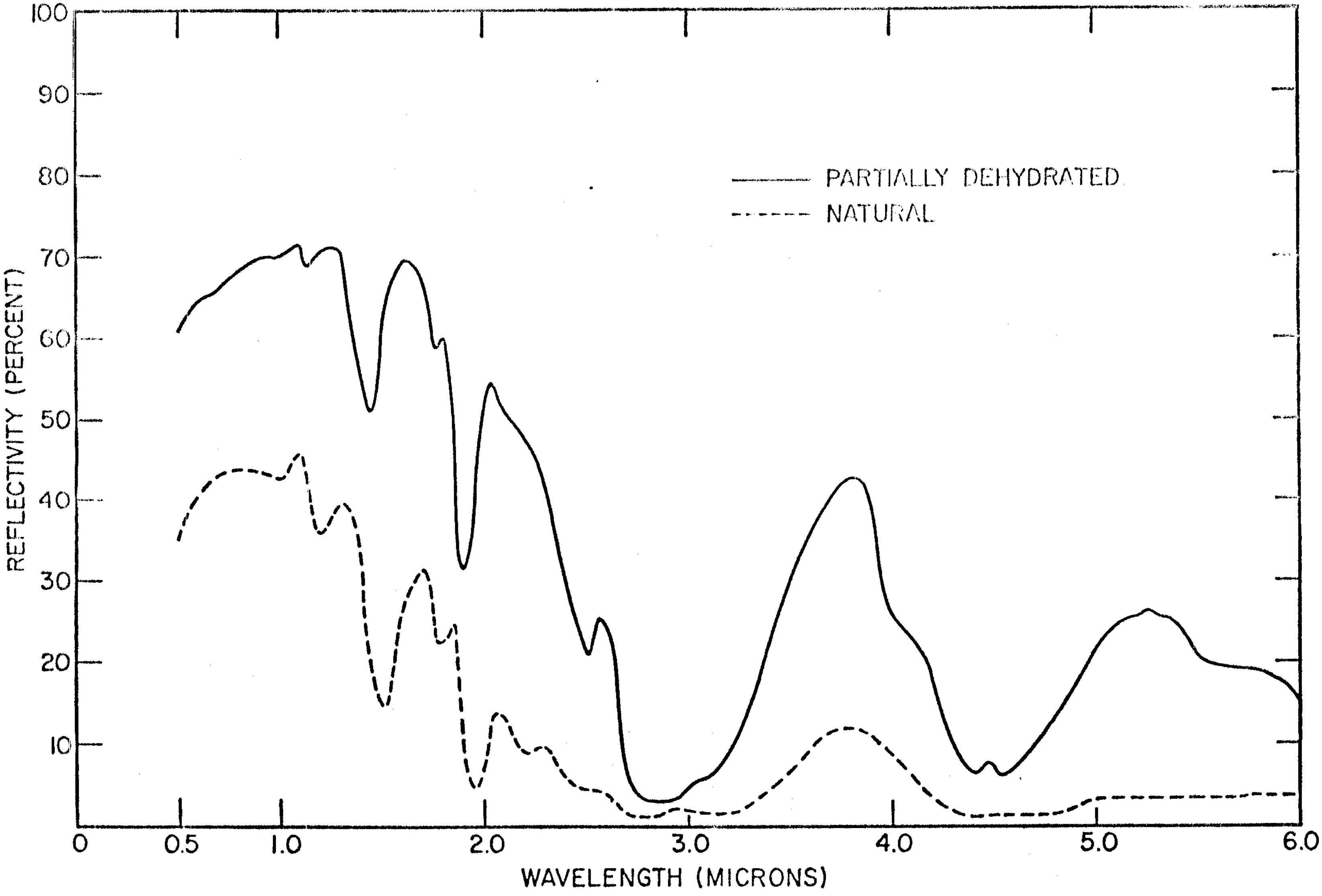
WAVELENGTH (MICRONS)

Fig 9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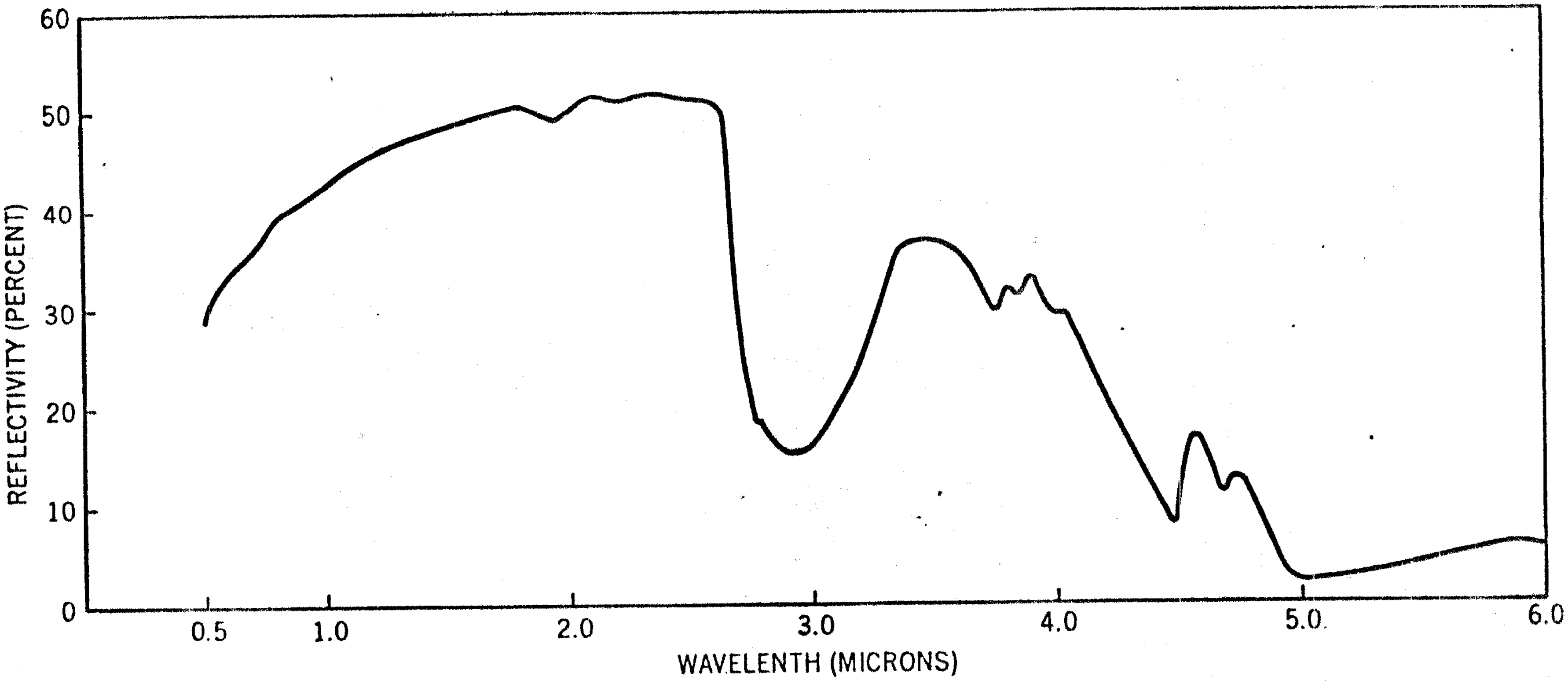
REFLECTIVITY (PERCENT)
WAVELENGTH (MICRONS)
PARTIALLY DEHYDRATED
NATURAL

Fig. 10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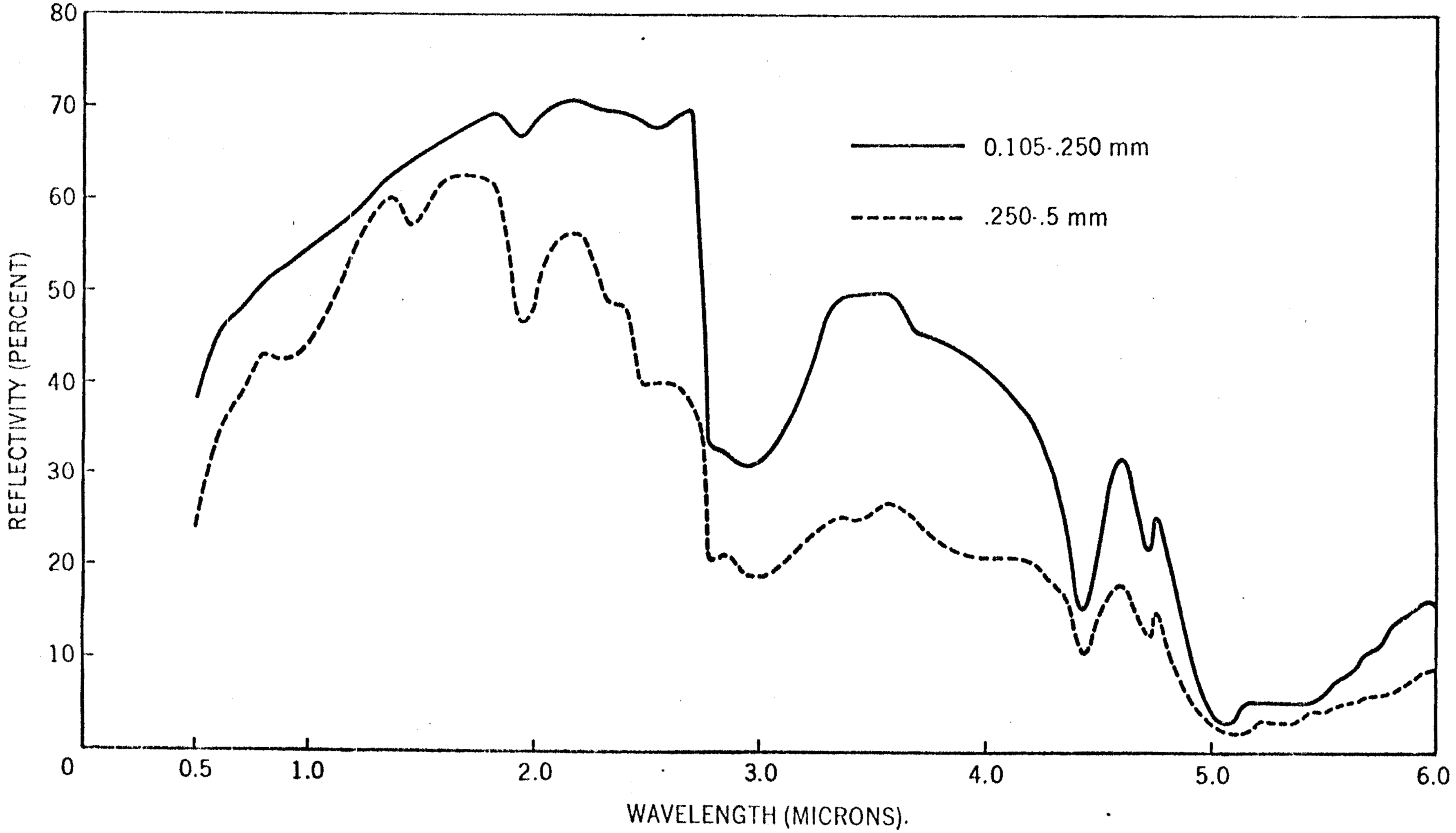
WAVELENTH (MICRONS)

Fig 11.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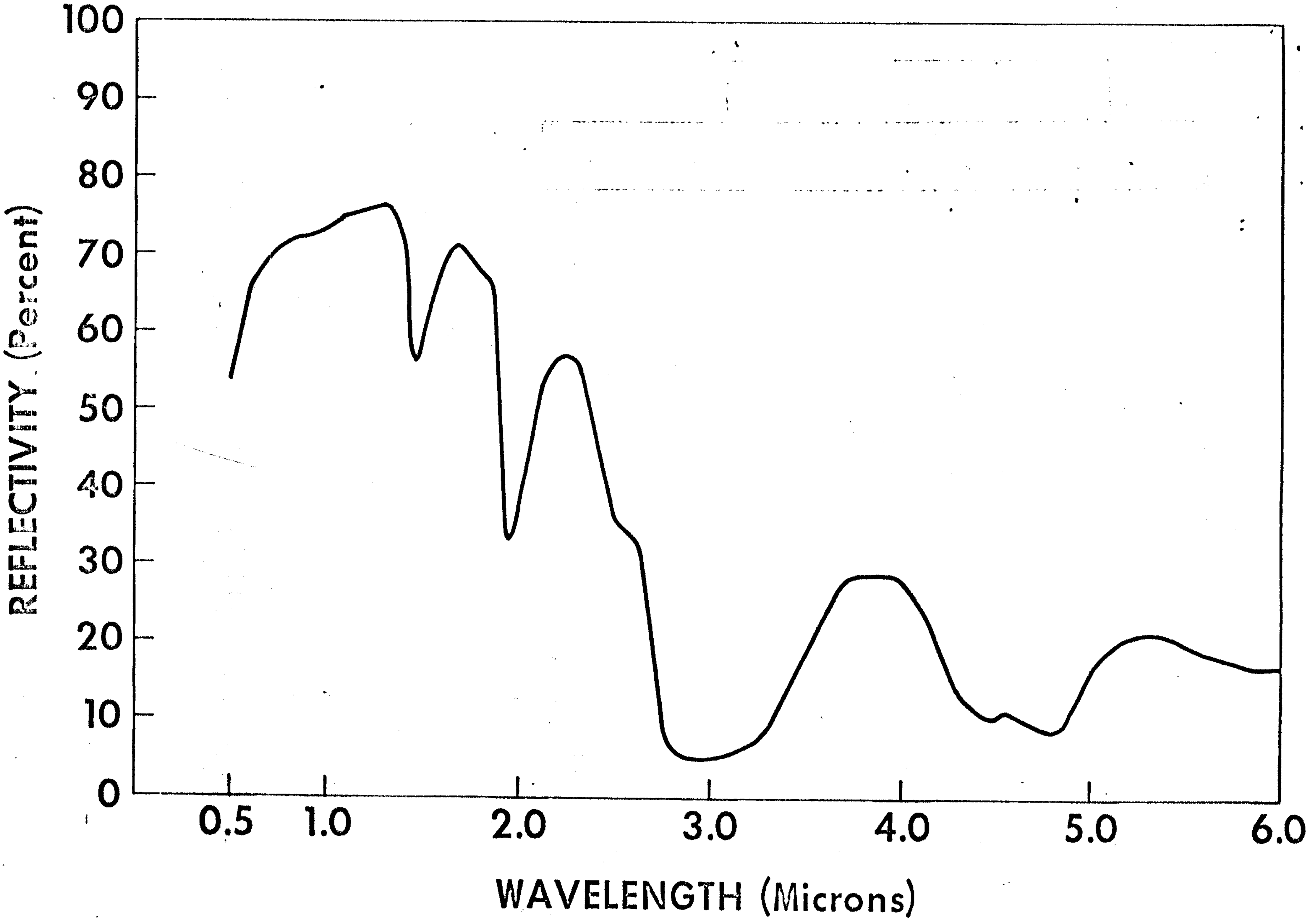
WAVELENGTH (MICRONS).
0.105-.250 mm
.250-.5 mm

Fig 12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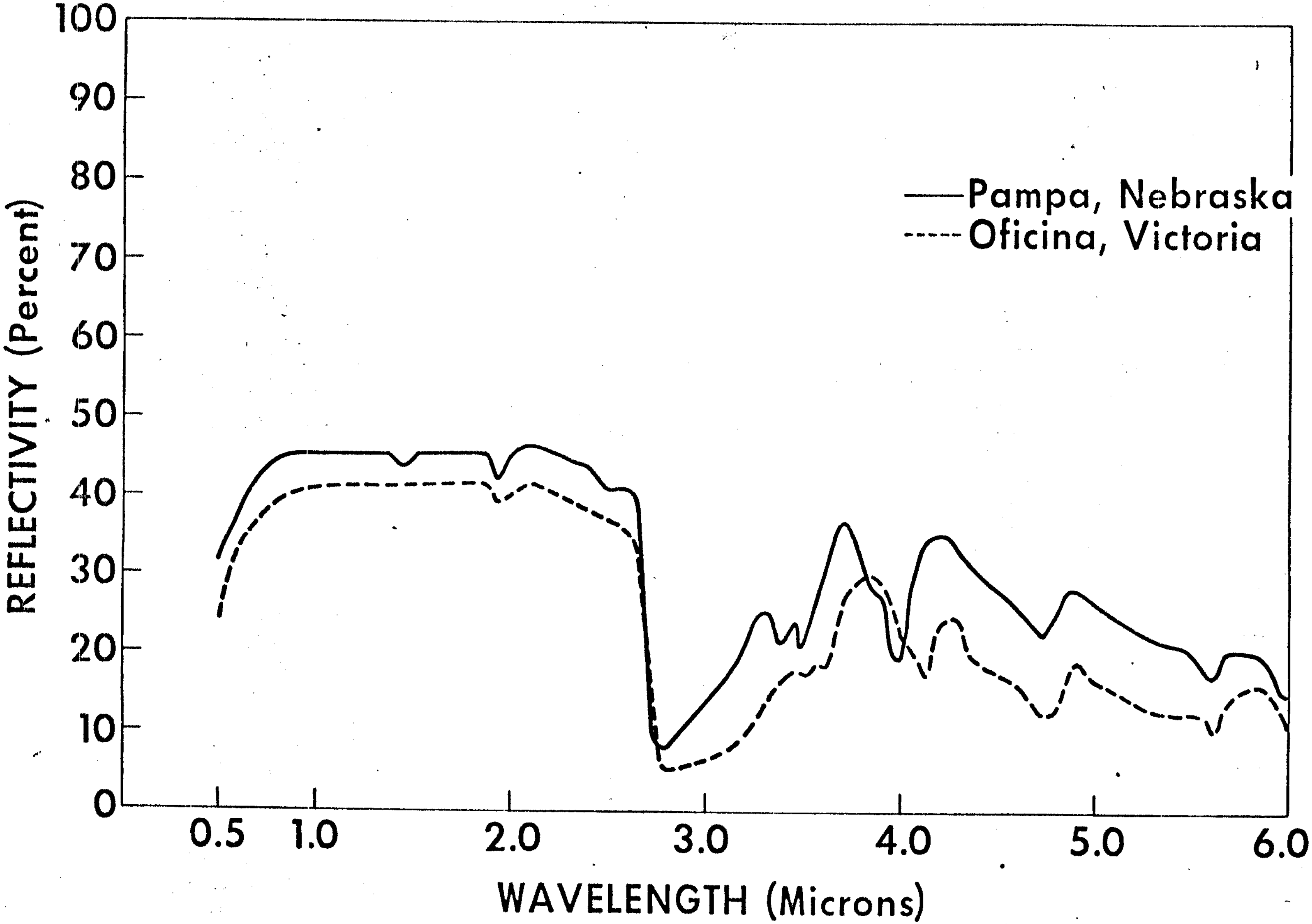
WAVELENGTH (Microns)

Fig 13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WAVELENGTH (Microns)
—Pampa, Nebraska
----Oficina, Victoria

Fig 14.