

REGOLITH IN THE SOLAR SYSTEM

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The regolith at the surface of celestial bodies is the superficial layer of finely divided particulate material resulting from the pulverization of the solid surface by meteoritic and micrometeoritic impacts.

A regolithic structure is recognizable at the surface of distant celestial objects from remote telescopic observations. Several criteria in the optical properties of the light are specific :

a)- Retro-reflection of light towards the incident beam's direction is enhanced, as the mutual shadowing between the grains of the complex texture of mutually supporting grains drastically reduces the light returned toward the observer when the observing direction departs from the exact direction of the incident beam. The result is a spike in the photometric curve near 0° phase angle (B. HAPKE)(T. GEHRELS).

b)- Multiple scattering between the surfaces of the opaque grains in a complex structure generate a certain amount of polarized light with an enhanced electric vector parallel to the plane containing the incident and emergent beams (negative polarization) for observation azimuths near the direction of incidence. The result is a very specific and characteristic negative branch in the polarization curve for phase angles smaller than 24° (A. DOLLFUS).

c)- The dark glasses generated by impact melting (J. ADAMS and T. McCORD) and possibly solar wind irradiation processes (T. GOLD and B. HAPKE) (M. MAURETTE) produce an overall change of colour and darkening of the surface. The result is a low albedo and a specific type of spectrophotometric reflectivity curve (T. McCORD); another result is that the opacity of the grains produces an inversely proportional relationship between the geometric Albedo A and the maximum amount of polarization P_{\max} for all wavelengths in the optical range. (E. BOWELL and A. DOLLFUS).

We shall discuss these optical criteria for a large number of celestial bodies on the basis of lunar results, and with emphasis on the polarization criteria.

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For the Moon, the spike effect on the photometric curve at 0° phase angle, the negative branch of polarization, the spectrophotometric curve and the albedo-polarization relationship observed telescopically are fully reproduced on the returned lunar fines samples.

For Mercury, all these criteria are also noted with relevant observational accuracies; the similarity with the Moon is striking in all aspects, the departures being too marginal to deserve physical interpretations. Thus, Mercury must be covered by a regolithic layer of lunar type, impact-generated on a material of approximately the same nature.

For Mars, the negative branch of polarization is of the lunar type and indicates the creation of a layer of finely divided particles, most probably impact-generated. The spike effect is small and the photometric curve is flat, indicating a smoothing out of the micro-texture & small impact craters by wind transportation of the grains. The spectrophotometric reflection curve is characteristic of hydrated ferrous oxides and implies a superficial oxidization of the grains by the atmosphere.

For Jupiter's satellites, Callisto has a contrast between its surface markings, a global albedo (0.14) and a spike effect of the lunar type. On the leading hemisphere in its orbital motion, the negative branch of polarization gives a minimum of $-9 \cdot 10^{-3}$ against $-12 \cdot 10^{-3}$ for the Moon indicating a regolithic structure of the lunar type covering most, if not all, of the surface - although perhaps slightly tighter packed. But on the trailing hemisphere, the polarization curve shows a minimum of $-6 \cdot 10^{-3}$ and a change of the sign of polarization at phase angle 13° . These properties are not characteristic of a regolith at all, but rather of consolidated rocks. This surprising result represents the unique exception among all the Solar System bodies already polarimetrically investigated. Explanations could involve impact mechanisms on orbit around Jupiter, or perhaps the recent disappearance of a frost deposit.

The surface of Europa resembles an almost uniform water-frost deposit in all its investigated properties. Observations of Io indicate a volatile deposit of a different nature.

Ganymede resembles a lunar or Callisto-type surface partly covered with large areas of water-frost deposits.

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The asteroids for which photometric curves have been measured sometimes show spike effects at 0° phase angle (T. GEHRELS and co-workers). Their albedo measurements are based on infrared observations (T. MATSON) and on the slopes of polarization curves at the inversion angle (E. BOWELL and B. ZELLNER)(J. VEVERKA). The albedo range covered is very large, and extends from 0.04 to 0.23; this rules out the possibility of a uniform surface caused by irradiation or impact melting; the reason is the very low escape velocity (0.1 km/sec. for asteroids of 130 km diameter); the powder ejected at impact is lost into space, and the surface is continually rejuvenated by micro-impacting. The range of Albedoes also rules out a mantling of the surface by cosmic dust slowly accreted at low velocity. It implies, and the variety of spectrophotometric reflection curves confirm (T. McCORD, C. CHAPMAN), that the asteroids are made from varieties of material of different compositions.

The negative branch of polarization however, already determined for about 20 asteroids (T. GEHRELS and al., B. ZELLNER, J. VEVERKA) always shows inversion angles between 18° and 25° , and minimum polarization between $-6 \cdot 10^{-3}$ and $-15 \cdot 10^{-3}$. This minimum is roughly inversely correlated with the logarithm of albedo, in a way that rules out freshly chipped solid rocks, and suggests textures consistent with regolithic structures. This polarimetric behaviour is also consistent with brecciated surfaces coated with adhesive dust (A. DOLLFUS); this last structure may be preferred because of the impossibility of generating pure regolith with such a low escape velocity. The four darkest asteroids measured (1 Ceres, 2 Pallas, 324 Bamberga and 511 Davida) have albedo and negative branches of polarization of the type observed in the laboratory on the Orgueil carbonaceous chondrite.