Mars: Correlation of Optical and Radar Observations

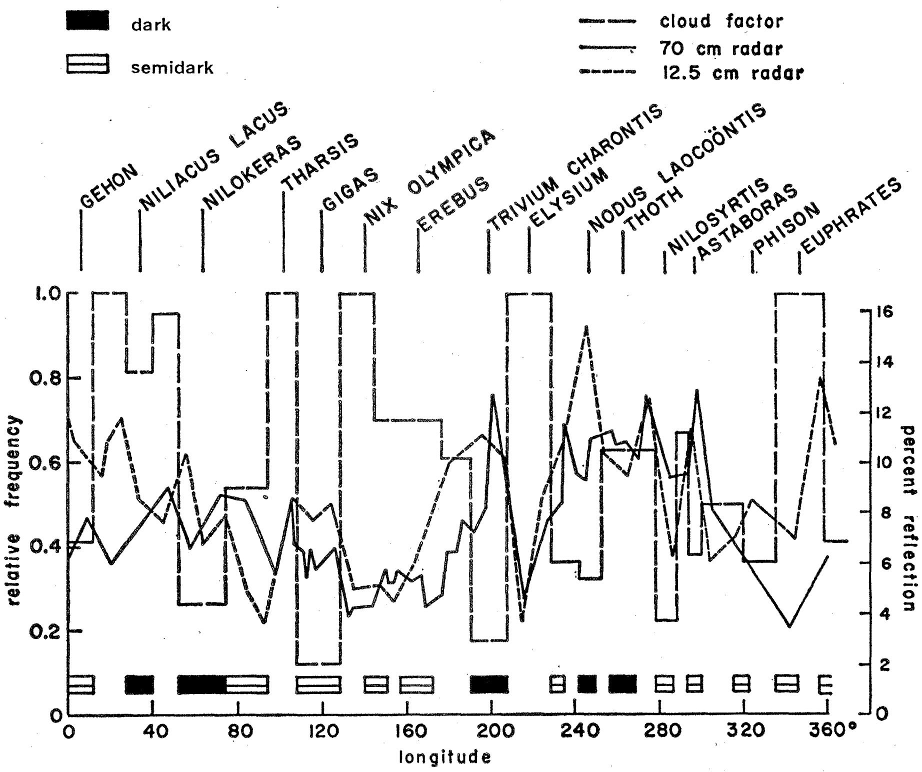
Abstract. *A comparsion of recent photographic and radar data on Mars indicates a good positive correlation between dark areas and radar reflection peaks and also between cloudy "desert" areas and radar minima. The data may be taken as evidence that dark areas are, in general, relatively smooth whereas deserts are relatively rough.*

Routine photography of Mars was undertaken at the New Mexico State University Observatory during the 1965 and 1967 apparitions of that planet. Plates were obtained with the 30-cm and 61-cm reflectors in five color regions, including ultraviolet, blue, green, red, and near-infrared (~0.80 μ). I describe a study of 157 of the better plates taken by J. Hartsell, A. S. Murrell, and T. Pope for the purpose of investigating correlations of photographic features of the planet with radar data of Goldstein and Gillmore (*1, 2*) and Dyce *et al.* (*3*).

The longitudes of boundaries between dark and light areas located at the subterrestrial latitudes (13.8°N in 1963 and 21.6°N in 1965) were measured, both on original red plates and on composite copies of original red images. The positions of white cloud areas at these latitudes were also determined, in view of their tendency to recur at the same areographic positions, which implies topographic influence.

All cloud data were taken from blue and ultraviolet plates in order to avoid the uncertainty involved in distinguishing between clouds and exceptionally bright surface areas in the visual range. Surface features are rarely (if ever) visible in the blue region; thus all bright features observed in this part of the spectrum may be unambiguously identified as clouds. For each region a quantity referred to as the "cloud factor" was determined. This was arbitrarily defined as one-fourth the sum of the relative frequencies of occurrence of clouds over a given region when near the morning limb, evening limb, and central meridian; data for the central meridian were given double weight.

The correlation between radar reflectivity peaks and dark areas and between reflectivity minima and light (desert) areas is seen in Figs. 1 and 2. A chi-square test of the data indicates compatibility exceeding the 0.90 significance level. The cloud factor esti-



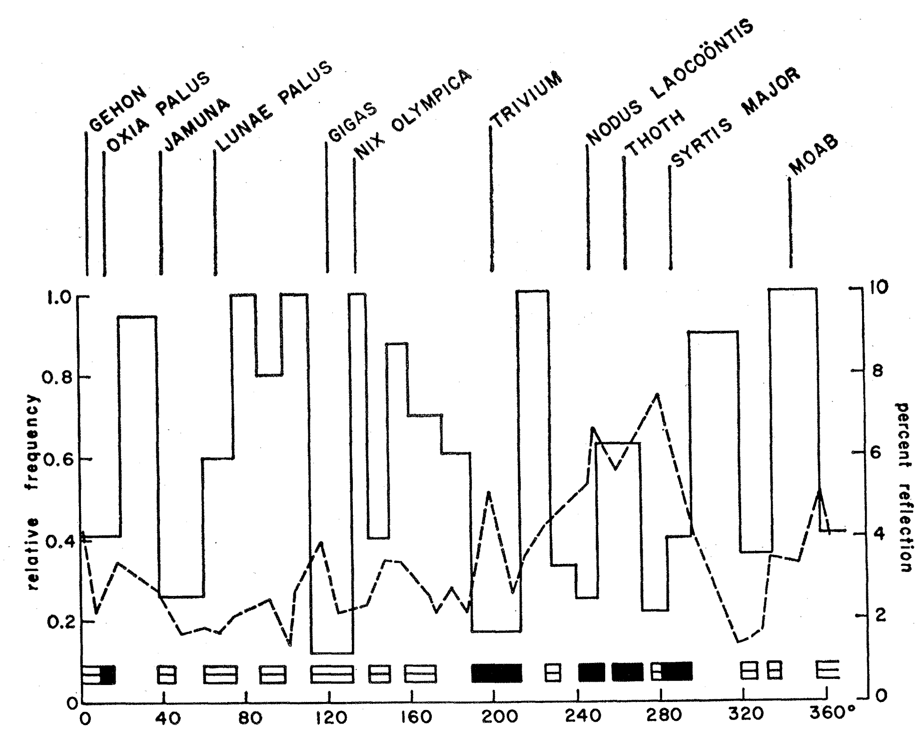


Fig. 1 (top right). Longitudes of Martian optical features at 21.5°N latitude with radar data at 12.5 cm (*2*) and 70 cm (*3*) superimposed. Cloud factor estimates are indicated by the histogram; desert areas correspond to the blank spaces between dark and semidark strips.

Fig. 2 (bottom right). Longitudes of Martian features at 14°N latitude with cloud factors and radar reflectivities (*1*) superimposed. The north tip of Cerberus I is included in the central longitudes of Trivium Charontis. The solid line represents cloud factor data; the dashed line represents radar data at 12.5 cm.

mates, showing the strong general preference of the white clouds for desert areas, are also included in the histograms.

The correlation between degree of darkness and absolute values of reflectivity is more obscure, however. The degree of darkness of each region was estimated on a scale of 1 (bright deserts) to 10 (darkest areas), and these values were then compared with reflectivity values scaled from the radar curves. The resulting correlation coefficients for the data at 12.5 cm (1963), 70 cm, and 12.5 cm (1965) were only +0.38, +0.28, and +0.22, respectively. This is due largely to the systematically higher reflectivities of all areas on one side of the planet, as seen in the figures.

A few dark or semidark longitudes did not appear to be well correlated with radar maxima (for example, Syrtis Major in Fig. 2), but in each such instance the area was also characterized by a cloud factor which was higher than average for such areas. Thus the relation between cloud areas and the radar minima appears to be somewhat stronger than the relation between dark areas and radar maxima.

The only maximum clearly occurring in a desert area was the one at longitude 275° (Fig. 1) in 1965. This is the Isidis Regio, which has the appearance of a typical desert on Mars. The existence of a radar maximum at its central longitude could be due to a mean slope of either (or both) the dark Thoth to the east or the semidark Nilosyrtis on the west side (*4*). On the other hand, if the strength of the quasi-specular radar component is assumed to be principally a function of macroscopic roughness in the subterrestrial region, the implication is that deserts are, in general, rougher than dark areas. The anomalous maximum in Isidis Regio may be interpreted as evidence of smoother terrain there than in other deserts at that latitude.

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References and Notes

1. R. M. Goldstein and W. F. Gillmore, *Science* **141**, 1171 (1963).
2. R. M. Goldstein, *ibid.* **150**, 1715 (1965).
3. R. B. Dyce, G. H. Pettengill, A. D. Sanchez, *Astron. J.* **72**, 771 (1967).
4. C. Sagan, J. B. Pollack, R. M. Goldstein, *ibid.*, p. 20.
5. Supported in part by NASA grants NsG-142-61 and NGR-32-003-027.

27 January 1969

Fauna of Çatal Hüyük: Evidence for Early Cattle Domestication in Anatolia

Abstract. *Analysis of the remains of cattle from Çatal Hüyük indicates that cattle were domesticated in Anatolia by 5800 B.C., and strongly suggests that they were probably domestic at least 500 years earlier. This is the earliest known evidence for the domestication of cattle in the Near East.*

Çatal Hüyük, on the Konya Plain in central Anatolia, is the largest known preliterate site in Asia (*1*), and it is now clear that Anatolia was an area of cultural elaboration comparable to other centers of developing civilization in the Near East. Çatal Hüyük was occupied for approximately 1000 years, from the middle of the 7th millennium B.C. This was a critical period in the development and spread of animal husbandry elsewhere in the Near East, but this phase is heretofore unknown from excavations in Turkey. Although the site has yielded a rich collection of artifacts, shrines, and murals, faunal remains were surprisingly scarce, possibly because the excavation seems to have been done in the priestly quarter of the town, and domestic debris was meager (*2*). However, with the completion of the 1965 season, adequate faunal collections were available from level VI (5800 B.C.) and levels X to XII (6400 B.C.) (*3*), the greater part of which was not from the shrines themselves. The data indicate that domestic cattle were present at Çatal Hüyük early in the 6th millennium B.C., and probably were present there more than 500 years earlier. This is the earliest known evidence for domestic cattle in Asia.

In addition to cattle, the following species were represented in both samples from Çatal Hüyük—Anatolian moufflon (*Ovis orientalis anatolica*), Asian wild goat (*Capra hircus aegagrus*), red deer (*Cervus elaphus*), wild boar (*Sus scrofa*), onager (*Equus hemionus*), and the domestic dog (*Canis familiaris*) (*4*). A small collection of remains from small mammals, birds, and fish has not been identified.

In assessing the fauna's contribution to the economy, the relative frequency of each species important in the diet must be determined. Often this has been done by listing the number of identifiable specimens from each species and giving their percentages of the whole sample. An apparently more sophisticated method is to determine the "minimum number of individuals," a calculation based on a count of the most frequent diagnostic skeletal part. Both methods are predicated on several questionable or unwarranted assumptions. (i) The pattern of bone survival is the same for all species; (ii) the number of identifiable skeletal elements is the same for all species; (iii) each species is exploited in the same manner; and (iv) butchering techniques are the same for each species.

I developed a technique that attempts to take these factors into account. (i) The number of diagnostic elements in the skeleton of each species is determined. This does not correspond to the number of bones in the skeleton, for bones are seldom found intact in an archeological context, and, in any case, not all bones are assignable to species. For the cattle and sheep at Çatal Hüyük there appears to be a standard pattern of bone survival for the limb and foot bones, comprising 30 diagnostic elements. For the equid remains, on the other hand, there were only 16 diagnostic elements (*5*, *6*). (ii) The identifiable bone fragments from each species are counted. (iii) The relative frequency (*F*) of occurrence of each species is calculated (*7*) by multiplying the number of specimens per species by the reciprocal of the number of diagnostic elements per species. The calculated frequency is a quantity similar to the calculation of minimum number of individuals because it is also based on a fixed number of identifiable elements in the skeleton of a given species. Its advantage is that it enables one to use a far larger proportion of the collection, and is less affected by chance distortion.

After *F* has been determined for each species, the differences in average size for individual species are considered. This is done by multiplying the relative frequency of each species by the average edible meat weight per individual (50 percent of the average live weight) (*8*), the result being the total meat weight per species. The live weights for each species at Çatal Hüyük are based on figures given for Old World mammals by Walker (*9*). I assumed that the cattle from level VI were approximately the size of medium-size modern domestic cattle. Certainly they were smaller than the wild ox (*Bos primigenius*) and comparable in size to the earliest known domestic cattle in Asia. The cattle from layers X through