MARS RADAR MAPPING: STRONG DEPOLARIZED ECHOES FROM THE ELYSIUM/AMAZONIS OUTFLOW CHANNEL COMPLEX; J. K. Harmon, M. P. Sulzer, and P. Perillat, National Astronomy and Ionosphere Center, Arecibo, PR 00613.

A new technique has been used to make radar maps of Mars with the Arecibo radiotelescope. The observations were made during the 1990 opposition (close approach) of Mars. Among the most interesting of the preliminary results is the discovery of strong depolarized echoes from the enormous Elysium/Amazonis outflow channel complex. These strong echoes may represent rough-surface scattering off the youngest lava flows on Mars.

Measurement of the strength and angular dispersion of radar scattering from a planet's surface can provide information on the hardness and roughness of the surface. The typical echo from a planet can be broken down into two components: (1) a highly polarized "quasispecular" echo representing mirror-like reflections from the center of the apparent disk of the planet, and (2) a partially depolarized "diffuse" echo which arises from the entire visible disk and which is assumed to represent high-angle scattering off of very small (wavelength-scale) surface roughness elements. Two-dimensional mapping of the diffuse echo strength across the apparent disk ("reflectivity mapping") is normally done using the so-called "delay-Doppler" technique; here each element of the echo is identified by its characteristic time delay and Doppler frequency and then assigned to that spot on the planet which corresponds to that particular delay-Doppler combination. The delay-Doppler technique has been used very successfully for Venus, although in this case the interest has not been so much in the radar scattering properties *per se* as in the fact that radar reflectivity features reveal large-scale morphological structures such as volcanoes and impact craters which otherwise would be unobservable through Venus' cloud cover. In the case of Mars, whose features are already well known from orbiter images, the objective of radar mapping is to study properties (such as wavelength-scale roughness) which are not provided by the optical images and to correlate those with known surface features. Unfortunately, the standard delay-Doppler technique used to map Venus cannot be applied to Mars because of that planet's rapid rotation. The problem arises from the fact that in order to recover the entire breadth of Mars' broad Doppler spectrum one has to sample the echo at intervals which are shorter than the delay depth of the planet, which results in a foldover or delay-confusion of the echo if one uses a standard pulse train or cyclic phase code for transmission. This limitation (called "overspreading") has discouraged Mars radar mapping efforts and it is only within the last two years that any progress in radar mapping of this planet has been made.

Radar observations made at Arecibo about a decade ago showed that the diffuse radar echo from Mars shows very strong spatial variations in strength and degree of depolarization (1,2). These were simple CW observations (Doppler only) which could not be used to make two-dimensional radar maps. However, tracking of Doppler features in these data as the planet rotated suggested that the strongest diffuse/depolarized echoes (and, by inference, the roughest surfaces) were located in the northern volcanic regions of Tharsis, Amazonis, and Elysium. By contrast, the heavily-cratered uplands terrain which covers most of the southern hemisphere of Mars was found to have a diffuse echo component which is relatively weak and featureless. In reporting those results we speculated that much of the enhanced diffuse scatter arose from rough-textured volcanic constructs and lava flows (2). This is certainly a plausible hypothesis since lava flows on Earth can be extremely rough and often show strong radar depolarization.

The first true radar maps of Mars were made by Muhleman and coworkers (3) during the 1988 opposition. They avoided the overspreading problem completely by transmitting with the Goldstone antenna in California and mapping the received echo with the Very Large Array interferometer in New Mexico. Their maps confirmed the strong Tharsis feature as well as the relative radar blandness of the heavily cratered uplands. Their data did not include a full planet rotation and only the eastern edge of Elysium was mapped. During the 1990 Mars opposition we made the first attempt to make the first delay-Doppler reflectivity maps of Mars using the "random code" or "coded long pulse" technique, a method developed to overcome the overspreading problem in ionospheric radar measurements (4,5). In this technique a random (non-repeating) code is transmitted. The resultant echo contains a delay clutter which reduces the sensitivity of the measurement but, because the code is random, does not add delay confusion. We have made about 20 observations using this technique with the S-band (12.6-cm wavelength) radar at Arecibo from September 1990 to January 1991. Although the mapping analysis is not yet complete, some interesting results have already been obtained. Of these, perhaps the most interesting is the mapping of the radar-bright features which together make up the depolarized enhancement which we had previously seen from the general region of Elysium (2). One of the maps from this region is shown in Fig. 1; this is a radar reflectivity map of the depolarized echo component, with brighter shades corresponding to stronger echoes. Superimposed on this map is a latitude-longitude grid with 10° spacing. Although this map shows the north-south ambiguity about the Doppler equator which is inherent to the delay-Doppler method, we have established from maps obtained 6° farther north that all of the prominent features in Fig. 1 actually come from north of the Doppler equator. The northernmost feature which can be discerned is a faint patch near 210°W, 25°N which coincides with the eastern flank of the volcano Elysium Mons. The brightest features on the map are concentrated between 180°W and 215°W at latitudes from 5°S to 10°N. This breaks down into three separate bright patches which we will denote Features "A" (near 210°W, 7°N), "B" (near 196°W, 2°S), and "C" (a large bow-shaped structure extending from 180°W to 200°W). These three features lie within (and, taken together, roughly delineate) the boundaries of the vast Elysium/Amazonis outflow channel complex as mapped by Tanaka (6). Tanaka argues that this province is the erosional remnant of catastrophic flooding (presumably by water) which occurred during a recent epoch. He describes the flood plains as consisting of "low-albedo material marked by light, wispy streaks." A study of the Viking photomosaic maps of this region shows that radar features "A" and "B" correspond to well-defined regions for which Tanaka's description is particularly apt. Feature "C" coincides precisely with what may be the outflow channel-proper, a continuous flow of dark streaks which the photomosaics show as starting near 195°W, 5°N, dipping down toward the equator, and then trending NE to about 175°W, 25°N.

Upon identifying the Elysium radar features with the outflow channel our first impression was that this was an interesting, if unexpected, example of enhanced radar backscatter from a non-volcanic surface. We speculated in our LPSC abstract that the scattering might be off gravels deposited by the floods. Since then a paper by Plescia (7) has appeared in the December 1990 issue of *Icarus* in which a strong case is made that the low-albedo features which dominate this region are in fact low-viscosity flood lavas which filled the pre-existing channels and flood plains. Plescia also points out that some of the identifications of lava flows in this region had been made a decade ago by Schaber (8); our radar feature "B" coincides with one of the lava flow features identified by Schaber. Plescia points out that these lavas are very young by Martian standards and therefore are of considerable interest for studies of the thermal and volcanic history of the planet. The identification of lava flows in the Elysium/Amazonis outflow channels would explain why we see enhanced radar backscatter from this region and not from the other large outflow channel complex in Chryse Planitia (which is not lava filled). It also offers support for our speculation of a few years ago that many of the strong features in the diffuse/depolarized radar echo from Mars are associated with rough volcanic surfaces such as lava flows.

References

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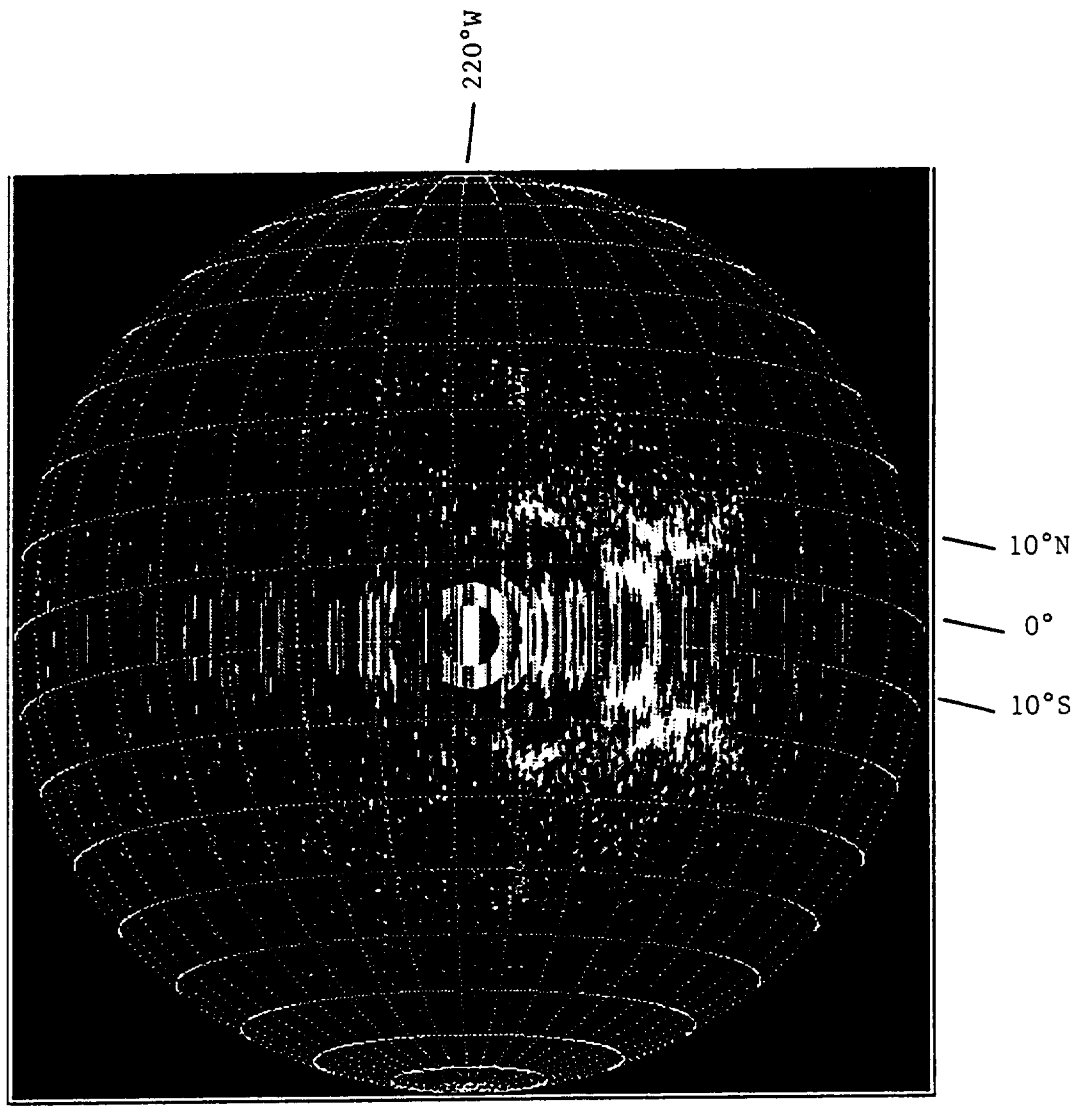

Fig. 1