MARTIAN "STEALTH(s)"; B. J. Butler, National Radio Astronomy Observatory

During a series of radar experiments with Mars as the target in 1988, 1992, and 1993, a huge region was discovered which reflected no measureable echo power which was distinguishable from the noise. The region extends west from the region of the Tharsis volcanoes for over 2000 km, and its total areal extent is $\gtrsim 10^6$ km (1,2). For obvious reasons, this region was dubbed "Stealth". Figure 1 shows an estimate of the boundary of Stealth (2). Also shown in that figure is the original estimate of its extent (1). The reason for the difference is a slightly different selection criterion, and the fact that the original boundary only used the 1988 data. Elsewhere, it has been shown that the most likely explanation for Stealth is that it is a very underdense region with a lack of subsurface scatterers to significant depth, with that depth being $\gtrsim 5$ m (1,2,3). So, the question is, what is this thing geologically?

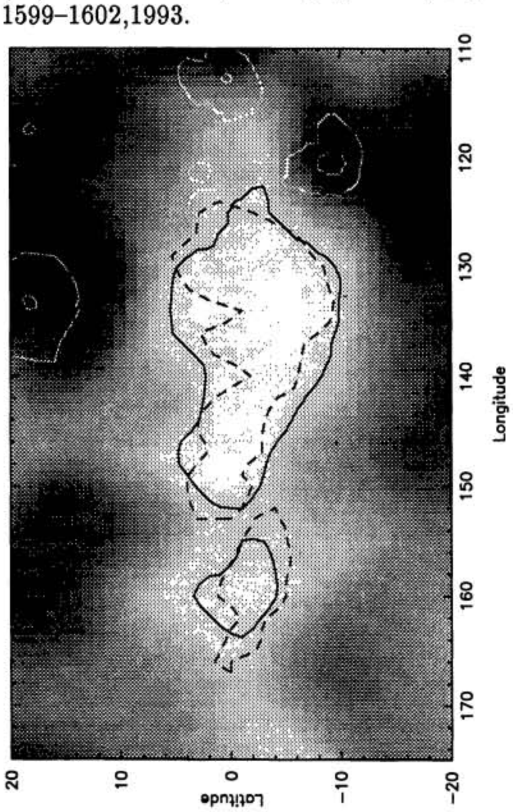
The Stealth region is between the provinces of Amazonis and Memnonia, in the eastern part of what has been called Mesogaea. It has portions in what have been mapped geologically as the Memnonia, Amazonis, Tharsis and Phoenicis Lacus quadrangles. The western half of the southern boundary of Stealth coincides very well with the boundary between the northern lowlands and the southern highlands. The break between the east and west sections of Stealth is caused by the Mangala Valles region, a proposed large outflow channel caused by catastrophic flooding (4). The geology of the region where Stealth is has been studied by many investigators (see e.g., 5,6,7). The region appears to contain a very thick deposit of loosely consolidated (very friable) material which has undergone extensive wind erosion (see 8,9, and 10, in addition to the just mentioned references). There is no distinct geologic, topographic, or albedo region which corresponds with Stealth. In fact, it seems to contain portions of very different geological terrains, and covers a topographic range of ~ 7 km above the datum in the east, to near the datum level in the west (slopes in the region are generally less than $1°$, in a northwest direction). From the geologic map of Scott and Tanaka (11), much of the eastern and northern portion of Stealth lies in their upper and middle Medusae Fossae units (Amu and Amm). They interpret the upper portion of this formation to be a nonwelded ash–fall or ash–flow tuff (ignimbrite) or thick accumulation of eolian debris. There is some argument against this (7,12), but we agree in principle with this interpretation, since this would be a good candidate for the material comprising Stealth. It has been shown that a terrestrial ignimbrite is relatively radar bright (13), indicating that the material is more likely an ash fall or tephra. Radar sounding of ash fields on Kilauea (14) and the Galapagos (recent X–SAR results) have indicated that they have very low cross sections, which provides confirmation of this interpretation. Scott and Tanaka further suggest that the source of the material (ash) was probably a series of fissures and vents now covered up by the material itself (5). We suggest that while this may be the case, it may also be that the source of at least part of the materials is the Tharsis shield volcanoes Pavonis and Arsia Montes. We make this suggestion based upon the eastern extent of Stealth, which almost abuts the Arsia Mons caldera, and the smaller volcanoes of Biblis and Ulysses Paterae. In fact, the entire southeastern portion of Stealth lies directly on top of what has been mapped as undivided Tharsis lava flows (11). It is hard to understand how lava flows could have such low cross sections, particularly considering that much of the rest of the Tharsis (and Elysium) flows have very high cross sections (1,2). It must be that these flows are covered by at least a thin layer of material similar to that described above, which has not been recognized previously, probably due to resolution constraints. Indications are that the current wind direction is east to west in this region (10,15,16). The development of yardangs in the region also indicate that that has been the primary direction of wind for some time (10). Wind streaks also indicate significant downslope winds from all of the Tharsis volcanoes, but especially Arsia Mons (16,17). Thus, any material ejected from Pavonis and Arsia Montes would make its way into Stealth. A less likely explanation is that the material comprising Stealth is a very low porosity volcanic material other than ash, e.g., reticulite. The problem with this is that the material must have sufficient strength to support several meters of overlying material for long periods of time.

While Stealth is the most noticeable large region of low cross section on the planet, there are other regions which have low cross sections (2). It should be stressed here that there are no other locations of low cross section which have been imaged by us in near as good a geometry as Stealth, and none which have cross sections as low as Stealth. There is one other large region on the planet which satisfies the requirements for being "stealthy", however, which is shown in Figure 2. Note that the region is much smaller in extent than Stealth ($\sim 2 \times 10^5\,\mathrm{km}^2$, as opposed to Stealth, which is $\sim 10^6\,\mathrm{km}^2$). The region is contained mostly in the northwest portion of the Argyre basin, in Argyre Planitia. On the map of Scott and Tanaka (11), Martian "Stealth(s)"; B. J. Butler

the stealthy area lies almost exclusively in the etched unit of Argyre Planitia (Nple). This is a unit which, similar to the Medusae Fossae units discussed above, has been heavily degraded by wind erosion, indicating a very loosely consolidated surface (6,11). In this respect, it is similar to the region of Stealth. This may be an indication that all surfaces which are heavily eroded by wind on Mars are stealthy.

It is unfortunate that the Hellas basin was imaged with such poor geometry during the radar experiments. Since it is the other major region of highly eroded southern plains (6), we expect that it will be stealthy, similar to the Argyre region. The preliminary result is that the region of Hellas indeed has low cross section, but the best incidence angles for most of the region are $\gtrsim 60°$. Because of this, we cannot make any definitive statement about it. If future measurements allow us to make a statement about the materials in the Hellas basin, it will help in the geologic interpretation of that region. It has been proposed lately (18) that the Hellas basin is an area of net dust erosion, and that there should be very few rocks and boulders there. Again, this seems like the perfect setting for another stealthy region. The other region of heavy wind erosion on Mars is in the high latitude plains. Without a drastic increase in transmitter power, we can never hope to determine whether that region has similar backscatter characteristics from ground based radar experiments (because of the poorer geometry).

References: (1) Muhleman *et al.*, *Science, 253*, 1508–1513, 1990; (2) Butler, PhD thesis, 1994; (3) Muhleman *et al.*, in press: *Ann. Rev. Earth and Plan. Sci.*, 1994; (4) Tanaka and Chapman, *J. Geophys. Res., 95*, 14315–14323,1990; (5) Scott and Tanaka, *J. Geophys. Res., 87*, 1179–1190, 1982; (6) Carr, in *The Geology of the Terrestrial Planets*, NASA SP–469, 1984; (7) Schultz and Lutz, *Icarus, 73*, 91–141, 1988; (8) Cutts and Smith, *J. Geophys. Res., 78*, 4139–4154, 1973; (9) McCauley, *J. Geophys. Res., 78*, 4123–4137, 1973; (10) Ward, *J. Geophys. Res., 84*, 81147–8166, 1979; (11) Scott and Tanaka *USGS map I–1802–A*, 1986; (12) Francis and Wood, *J. Geophys. Res., 87*, 9881–9889, 1982; (13) Fielding *et al.*, *IEEE Geosci. Remote Sens., 24*, 582–589,1986; (14) Gaddis *et al.*, *Geol. Soc. Am. Bull., 101*, 317–332, 1989; (15) Thomas and Veverka, *J. Geophys. Res., 84*, 8131–8146, 1979; (16) Lee *et al.*, *J. Geophys. Res., 87*, 10025–10041, 1982; (17) Veverka *et al.*, *J. Geophys. Res., 82*, 4167–4187, 1977; (18) Moore and Edgett, *Geophys. Res. Lett., 20*, 1599–1602,1993.



← Figure 1. Cylindrical projection showing the best estimates of the boundary of "Stealth". Solid line is the new estimate (2), dashed line is the old (1). Gray scale is radar cross section at normal incidence, with darker shades being higher values, range is -.4% to 24.2%. White outlines denote the geological boundaries of the calderas and shields of the Tharsis volcanoes (11).

↓ Figure 2. Mercator projection showing the other "stealthy" region on Mars (in the Argyre basin). Gray scales as in figure 1, with range: .4% to 1.8%. White outline is a very rough approximation of the basin rim.