MARTIAN SOUTH POLAR DEFORMATION AND SUBLIMATION PROCESSES S. N. Brightwell[1], J. S. Kargel[2], and T. N. Titus[2], [1]Northern Arizona University Department of Geology, PO Box 4099, Flagstaff, AZ, 86011, [2]U.S.Geological Survey, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (snb9@dana.ucc.nau.edu, jkargel@usgs.gov, ttitus@usgs.gov)

Introduction: The first glacial deformations of an extraterrestrial ice sheet have been discovered and documented at the Martian south polar cap in Mars Orbital Camera (MOC) images *[1-4]*. Within the south polar cap various structural deformational features have been found, including boudinage, folds, and faults *[1-2]* (Fig. 1). These features are also found in terrestrial glaciers *[5-7]*.

Mars presents a unique environment where there is a known existence of dry ice (CO_2) and water ice and, possibly, either a metastable coexistence of these two ices or stable CO_2 clathrate hydrate. The south polar cap is laterally heterogeneous in these ices (at least the first two) and vertically structured with a layered sequence of what may be interbedded ices. This is a form of glacier that is not known on Earth.

In addition to boudinage, folds, and faults, distinctive forms of ice and dry-ice sublimation features exist. A comparison of these features with terrestrial glacial features and thermokarst will be particularly interesting, as they were formed under different gravitational conditions, different climatic environments, and in a variety of ice compositions.

Sublimation erosion of the layered sequence of ices (H_2O, CO_2, and possibly CO_2 clathrate hydrate) *[8]* allows us to observe the internal structure of an active polar cap. Kargel and Tanaka *[1-2]* note that some of these layered ices are deformed. Faults, folds, boudinage, thrust faults, and elastic flexural bulges are common features of deformation in the south polar ice cap. Ice also undergoes brittle failure under certain temperature and stress conditions, as indicated by ice deformation experiments in the lab and by formation of leads in arctic sea ice and crevasses in glaciers *[9]*. Martian polar caps also exhibit faults, fractures, and rarely crevasses that are indicative of brittle failure *[2]*.

Each ice type has unique properties that cause different stress responses and thus result in differing deformation behavior *[10-14]*. CO_2 clathrate hydrate is the strongest of the three ices and is suspected to be the unit which forms boudins, water ice is moderate in strength, but will form boudins if it is the strongest ice present during deformation, and CO_2 ice is the weakest of the three and does not form boudins.

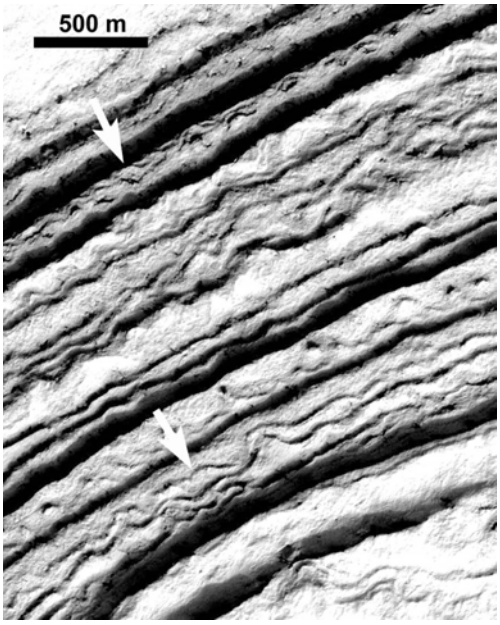
MOC 09 Observations: Images of MGS orbit sequence 09 that are located between -83.16º and -87.17º Lat. and all longitudes were selected; from these images those with a resolution of 11.39 m/pixel or better were used, resulting in 496 images to examine. Features noted include; layers, folds, boudins, scarps, chevrons, angular unconformities, faulting, polygons, "spiders", "swiss cheese", and other types of sublimation features (Fig. 2). We also identified those clearly lacking these features at observed resolution. To these results we added observations of deformation features found previously in images from other orbit sequences.

Conclusions and Next Steps: Each of the mapped classes of features has a distribution related to geologic units, material properties, and topographic features within the South Polar deposits. We are investigating the specific relationships, which are being explored with a combination of MOC, MOLA, TES, and THEMIS data. We expect this study to yield clues to polar processes and the origins of these features and their relationships to ice composition.

References: [1] Kargel, J. S. and Tanaka, K. L. (2002 a) *LPS XXXIII*, Abstract #1799. [2] Kargel, J.S. and Tanaka, K.L. (2002 b) Martian south polar cap: Flowing, folding, faulting glaciers of multiple interbedded ices. Submitted to Nature. [3] Clifford, S. M. et al. (2000) Icarus, v. 144, p. 210-242. [4] Head, J. W. (2001) JGR, v. 106, p. 10075-10085. [5] Hambrey, M. J. and Lawson, W. (2000) Structural styles and deformation fields in glaciers: a review: London, The Geological Society, p. 59-83. [6] Marmo, B. A. and Wilson, J. L. (2000) The stress distribution related to the boudinage of a visco-elastic material: examples from a polar outlet glacier: London, The Geologic Society, p. 115-134. [7] Ximenis, L., et al. (2000) Folding in the Johnsons Glacier, Livingston Island, Antarctica: London, The Geologic Society, p. 147-157. [8] Kargel, J. S. and Lunine, J. I. (1998) Clathrate hydrates on Earth and in the solar system: Netherlands, Kluwer Academic Publishers, p. 97-117. [9] Renshaw, C. E. and Schulson, E. M. (2001) Nature, v. 412, p. 897-900. [10] Alley, R. B. (1992) Journal of Hydrology, v. 38, p. 245-256. [11] Stern, L. A., et al. (1996) Science, v. 273, p. 1843-1848. [12] Durham, W. B. et al., (1997) JGR, v. 102, p. 293-302. [13] Durham, W. B., et al. (1998) Rheology of planetary ices: Kluwer Academic Publishers, p. 63-78. [14] Durham, W. B., et al. (1999) Geophysical Research Letters, v. 26, p. 3493-3496.

Figure 1. (A) Crop of MOC image M0904866 displays several probable deformation features such as folds, boudinage, and an angular unconformity. Arrows indicate outcrop of possible boudin layers. Image center Lat. -84.37º, Long. 27.72º; resolution 2.84 m/pixel. (B) Crop of MOC image M090308 shows "spider"-like features of unknown origin but likely related to volatile venting. Here, and many other places, they are structurally controlled and commonly exist just beneath the bases of scarps. Image center Lat. -85.62º, Long. 263.61º; resolution 2.83 m/pixel.

1A



1B

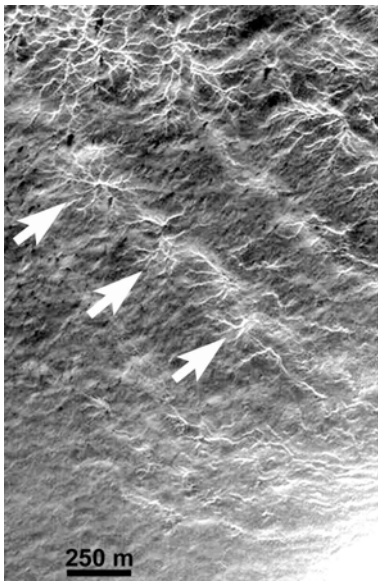
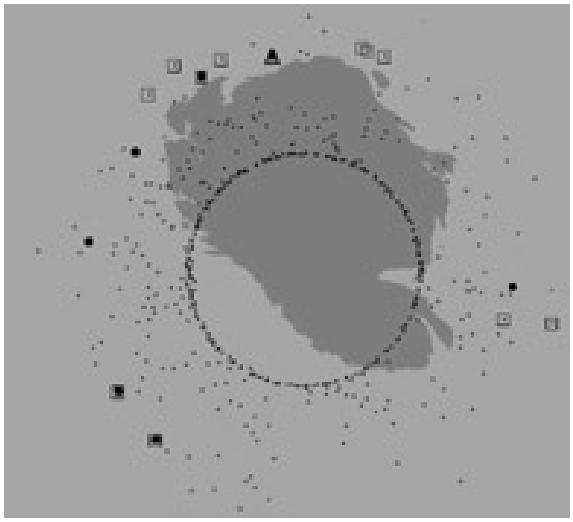


Figure 2. Distribution of selected features in the South Polar Cap. (A) Deformation related features. Open squares, open triangles, and large closed circles represent boudins, faults, and folds respectively. (B) Sublimation related features. Open polygons, open circles, and "X"s represent polygons, "spiders", and "swiss cheese" respectively. The small dots on both represent MOC sequential orbit 09 images.

2A



2B