SEDIMENT-ATMOSPHERE WATER EXCHANGE AND POLYGONAL CRACKS: LESSONS FROM WHITE SANDS NATIONAL MONUMENT, NM. D. Y. Sumner[1] and G. V. Chavdarian[2], [1]Geology Department, University of California, Davis, CA 95616, dysumner@ucdavis.edu.

Introduction: Water loss from cohesive sediments results in contraction [1-4]. When volume shrinks sufficiently that stresses exceed the tensile strength of the material, cracks form. The geometry of the cracks and resulting polygons reflects material properties and the history of water exchange between the sediment and the atmosphere [1-3,5]. Water content, transport, and exchange with the atmosphere affect the nucleation and propagation of cracks in hydrous sulfate dunes at White Sands National Monument, New Mexico [4].

Cohesion and Mineralogy: In White Sands dunes, capillary forces and gypsum cements give the sand sufficient cohesiveness to act as a uniform material with moderate tensile strength. With water loss, cracks form, defining dominantly five-sided polygons. Cracks extend to variable depths on the order of centimeters to more than half a meter.

Water Loss: Water loss is interpreted as the dominant cause for crack formation. Our measurements show that 5-10 cm below dune surfaces, the relative humidity remains 100% due to the evaporation and condensation of water in thin films on damaged grain boundaries. The amplitudes of daily temperature fluctuations, and thus absolute humidity fluctuations, decrease with depth, implying less evaporation/condensation cycling with depth in the dunes. Humidity contrasts between pores and the overlying atmosphere result in significant water loss from the dunes except during precipitation and frost/dew condensation. This water loss induces crack nucleation and propagation similar to that in some soils, where water evaporates producing negative pore pressures that increases effective stress, causing the soil volume to decrease and inducing cracking [3]. The volume decrease initially equals moisture loss. Later, capillary tension from moisture decreases sufficiently that air moves into pores and moisture loss is greater than the volume decrease [3]. We interpret upper surfaces of White Sands dunes to be in the second stage, whereas dunes are in the first stage at depth, and crack propagate downward.

Geometry: Geometry of crack triple junctions records the history of fracturing processes [1-3,6-7]. Cracks propagate perpendicular to the maximum tensile stress, and they release stress, changing the local stress field with maximum stress parallel to the crack [8]. Thus, when a crack terminates against an older one, triple junction angles tend to be 90°, 90°, and 180°. In contrast, ideal cracks propagating from a point show three 120° angles. Propagation of cracks with depth or repeated cracking and healing causes evolution of angles toward 120° [9]. At White Sands, polygonal crack networks have average triple junction angles of 92°, 117°, and 142° (N=165). This angular distribution can not be due to propagation of cracks with depth because these distributions are observed at the tops of dunes as well as slopes. Similarly, cracks at tops of dunes are unlikely to heal and reopen frequently enough for crack angles to evolve. Thus, we interpret crack angles as reflecting nucleation from points with inhomogeneities in stress causing variations in crack geometry..

Martian Sediments: Similar analysis of cracks in hydrous sulfate-rich sediments or sedimentary rocks on Mars [10-11] can provide insights into contraction and water loss processes. Fracture patterns range from dominated by 90° to dominated by 120° angles. These variations may reflect evolution of cracking patterns through repeated wetting and drying or variable contraction properties, either of which can provide insights into water cycling between sediments and the martian atmosphere.

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Fig. 1: Polygonal cracks in gypsum sand, White Sands National Monument, showing dominantly 120° triple junction angles. Image is about 50 cm across.