

FIELD GEOLOGIC CONTEXT OF GYPSUM VEINS AND IMPACTITES ON THE RIM OF ENDEAVOUR CRATER, CAPE YORK, MER OPPORTUNITY ROVER. L. Crumpler¹ and Athena Science Team. ¹New Mexico Museum of Natural History & Science, 1801 Mountain Rd NW Albuquerque, NM, 87104,USA, larry_crumpler@state.nm.us.

Introduction. The unconformable contact between the plains and the hill “Cape York” is the site of scattered occurrences of hydrated CaSO_4 (gypsum) [1,6] veins. Merging orbital data and field mapping of contacts, we can determine the stratigraphic and structural context for Opportunity’s results in this new terrain [Fig. 1] and place bounds on conditions following erosion of the crater rim and prior to the emplacement of Meridian Plains that led to gypsum vein formation.

Cape York Traverse. The Mars Exploration Rover Opportunity crossed a significant geologic unconformity when it arrived at the rim of Endeavour crater. Previously it had traversed within a single lithology, the sulfate- and hematite-rich sandstones of the Meridiani Plains (“Burns Formation”) [2]. The rim of Endeavour crater currently being explored by Opportunity [1,3,4] is a significant additional lithology and provides records via their textures, structures, stratigraphy, mineralogy, and chemistry of conditions extant during earlier, likely Noachian times. An assessment of the conditions under which the rocks of Endeavour crater were formed, altered, eroded, and subsequently overlain by later materials supports the over-arching mission goal to assess the rock record for information about environmental and climatic conditions on past Mars.

Cape York is the site of Opportunity’s initial investigations of Endeavour crater and is a low oblong-shaped, 760 m by 200 m, asymmetric ridge and east-facing scarp developed from an isolated remnant of the 22 km-diameter Endeavour crater rim. It is surrounded and on-lapped by Meridiani Plains type sandstones. Opportunity traversed a total of 875 m along the west side of the crest, “Shoemaker Ridge”, to a site near the north end after its arrival near the southern end of Cape York. *In situ* outcrop localities at the south end (“Chester Lake”) and near the current location at the north end (“Transvaal”/“Greeley Haven”) are interpreted to be impactite, including suevite, formed at the time of the original Endeavour crater impact, but subsequently altered chemically. The craterward slopes of Cape York have not yet been traversed.

The margin of Cape York slopes less than a few meters down to the unconformable contact with overlying plains sandstone on the west. On the east, Cape York slopes more steeply with relief in excess of 10 m towards the upper wall and interior of Endeavour crater. The eastern margins are also unconformably overlain farther down slope by the plains sandstones similar to those elsewhere in Meridiani [5] but here the sandstone floods the crater floor, including a distinct elevated mound-like crater interior deposit.

Outcrop Units. Four bedrock units and two late, mobile fines units are identified (Fig 1). In order of descending stratigraphic order:

Aeolian ripple bedforms, (a_2). Interpretation: Currently stable, oriented accumulations of sand-sized materials transported through saltation.

Drifted mobile (aeolian) fines (a_1). Silt-size and finer mobile materials, locally mixed with *in situ*-derived fines.

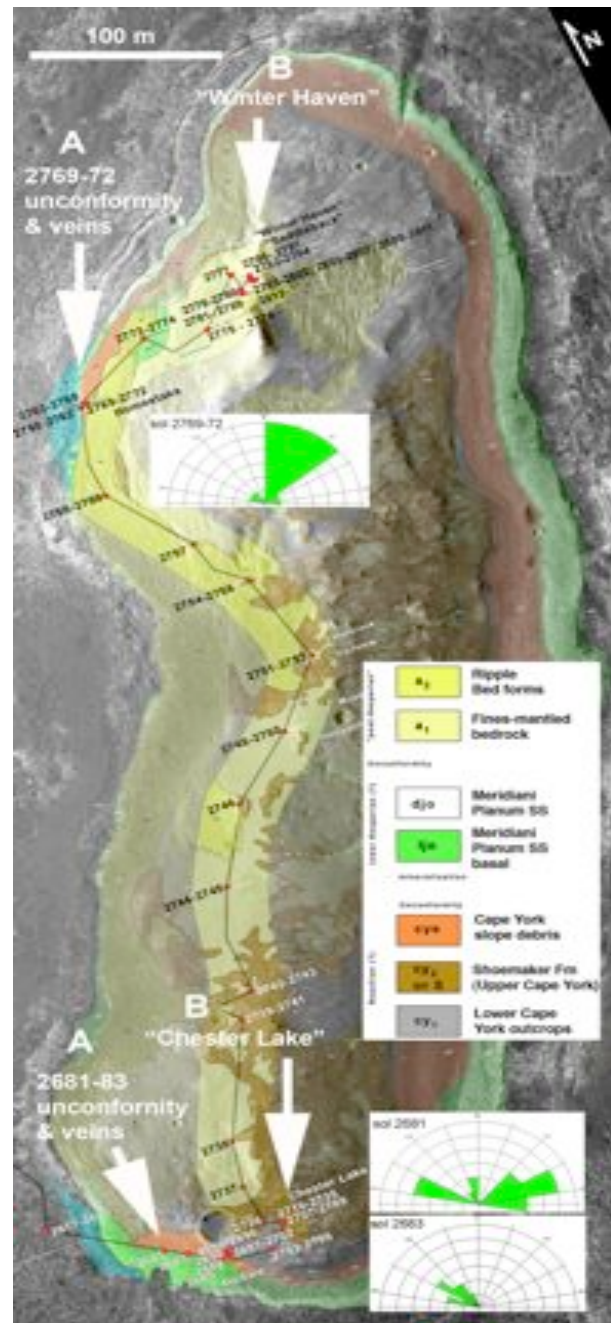


Figure 1. Field-based context transect geologic map based on observations within 20 m of Opportunity’s traverse (transect with saturated colors). Far-field mapping based on correlation of *in situ* results with surroundings using stereo MRO/HiRISE image stereo pairs (PSP_010341_1775 and PSP_010486_1775). **A.** Visited sites of gypsum veins and unconformity. Rose plots show orientations of veins. **B.** Sites of *in situ* analysis of Shoemaker Formation impact breccias.

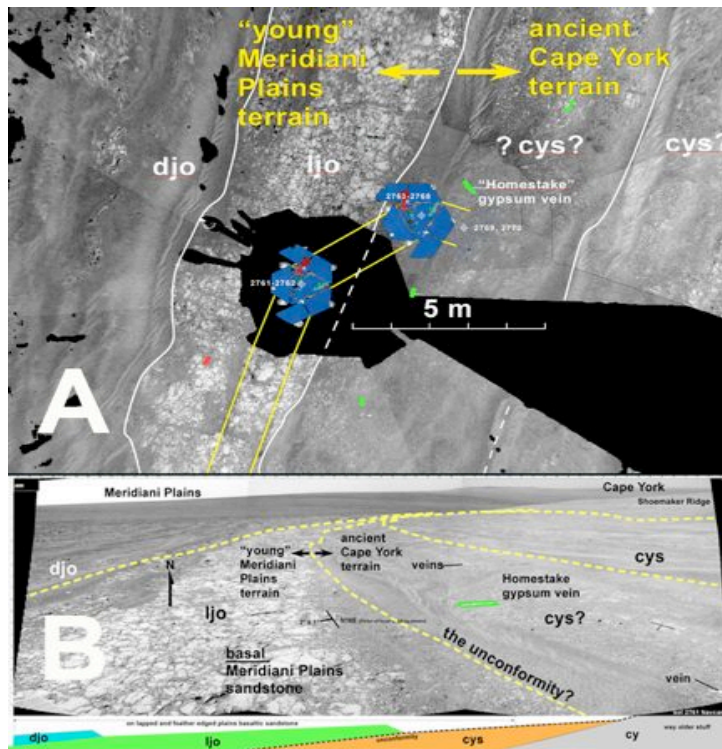


Figure 2. *A.* Navcam overhead projection showing the unconformity and the distribution of veins (short green lines) at the sol 2761-72 “Homestake” site. Note the sharply defined contact between Cape York and the Meridiani Plains. *B.* View north along the strike of the unconformable contact. Note that the westward-dipping light-toned jointed (ljo) outcrops of the plains feather edge and on lap the older Cape York unit (cys) bearing the veins. Bottom: schematic section across the unconformity.

Interpretation: Mix of Aeolian fines and local outcrop erosion products.

Dark, jointed outcrops (djo). Well-sorted sulfate-rich sandstone. Dark tone arises from abundant mobile dark sand filling irregularities. *Interpretation:* Typical sandstone of the Meridiani Plains documented at multiple localities.

Light, jointed outcrops (ljo). Well-sorted sulfate-rich sandstone occurring as a narrow (5-6m) band of light, finely jointed or fractured outcrop on the west margin of Cape York. Directly overlies the angular unconformity. *Interpretation:* Basal Meridiani Planum sulfate sands.

Cape York slope debris (cys). A somewhat bland unit, characterized by few outcrops and smooth fines-covered slopes of Cape York. *Interpretation:* Ancient surface and materials from time of the unconformity; formed prior to the Meridiani sandstones.

Shoemaker Formation (S). Outcrops bearing agglomeratic textures and slabs of a mixed dark clast-rich breccia in a indurated (welded? glassy?) matrix. Dips less than 1 degree craterward. *Interpretation:* Endeavour crater impact breccias and melts.

Basal Cape York outcrops (cy). Coarse, clastic outcrop forming slopes beneath upper beach of Shoemaker Ridge. Few exposures. Not examined in situ. *Interpretation:* Lower Cape York bedrock of unknown character.

Significant Unconformity. The contact between the Meridiani Planum sulfate-rich sandstones and the residual hills

of Endeavour crater is sharply delineated at centimeter scales by a change in the surface outcrops [Fig. 2]. Observations made at the contact on sols 2681-83 on the south and sols 2760-72 on the northwest show an on lap of the Meridiani plains sandstone onto a low basal apron, or bench, encircling Cape York. The contact is sharply defined in MRO/HiRISE images as a prominent light band encircling Cape York, narrow on the west side (5 to 6 m) and wider on the east side (up to 20 m).

Gypsum Veins. Light-toned veins were encountered on sols 2681-83 and 2769-72 as Opportunity was adjacent to or astride the unconformity. Using Navcam and Hazcam images, we determined dimensions and orientations of 37 veins visible at these localities. The mean width is 2 cm and the mean length 33 cm, commonly segmented every 5 cm and offset and axially separated a few millimeters. Veins appear prominent in the fine, darker, poorly exposed slope materials on the Cape York side of the contact, but clearly occur within the basal Meridiani sandstone (ljo) as well. Orientations are varied, but axial trends align approximately with the marginal contact between Cape York and the plains (Fig. 1 insets). This orientation implies that the veins are filling tension fractures tangential to the margins of Cape York. Compaction and settling of the Meridiani sandstones is one possible origin of the tensile stress necessary. The vein “Homestake” appears to be a typical example, although the northwesterly axial strike is unusual locally.

Discussion. Rocks on both sides of the geologic unconformity at the rim of Endeavour crater are separated significantly within the global stratigraphic sequence. From *in situ* examination of these rocks, we now have direct evidence bearing on the conditions existing across a significant fraction of martian geologic time, including epochs when aqueous conditions were pervasive. The unconformable contact between the plains and the hill “Cape York”, an erosion remnant from the rim of Endeavour crater, are also revealing regarding (1) the intense character of erosion following the formation of Endeavour crater, (2) the subsurface transport of aqueous solutions during and after the emplacement of the evaporates and sulfate sands of the plains, and (3) the transport and character of fluids at the interface of rocks of differing permeabilities responsible for deposition of hydrated CaSO_4 (gypsum) [1] in scattered veins near the contact between the plains and the rim of Endeavour crater. *Careful documentation of the character of chemical modifications, the manifestation of fluids and mechanical erosion at the surface of the unconformity, and the geometry of fractures and attitude of bedding are future observations at Cape York and Endeavour crater that will have important implications for understanding the early climatic history of Mars.*

References: [1] Squyres & Arvidson., 2011. *AGU, Abstract P34C-04*; [2] Grotzinger et al., 2005. *EPSL*; [3] R. Arvidson, 2011. *AGU, Abstract P31D-1720*; [4] J. Johnson et al, 2011. *AGU, Abstract P22A-01*; [5] Squyres, S.W. et al., 2006. *JGR*, 111, E12S12; [6] Squyres et al., 2012. Manuscript in pep.