RELATIVE AGES OF GEOMORPHIC FEATURES VISITED BY THE OPPORTUNITY ROVER. T. J. Parker[1] and J. P. Grotzinger[2], and the Athena Science Team, [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, timothy.j.parker@jpl.nasa.gov, [2]California Institute of Technology, Pasadena, CA, grotz@gps.caltech.edu.

Introduction: The Opportunity Rover is currently investigating the largest contiguous expanse of in situ outcrop that has ever been visited by a landed spacecraft on Mars. The outcrop lies just inside the degraded west rim of Erebus Crater in Meridiani Planum – 4 kilometers from where the exploratory mission began in Eagle Crater. Our first encounter of outcrop in this area on sol 542 (~215 meters from Terra Nova Crater) gave us our first exposure of outcrop not obviously disrupted by impact since leaving the Anatolia fracture area east of Eagle Crater.

Field Geology 101: The first requirement for conducting a detailed geologic investigation is knowing, as accurately as possible, your local and regional context. To accomplish this, we used the MER project's activity planning tools, which enable rapid projection of ground panoramas into overhead views. We then scale these to equal that of the MOC orbiter view, and place them by matching features common to both data sets and by triangulating to features visible on the horizon, but not included in the terrain model overhead view (Fig 1).

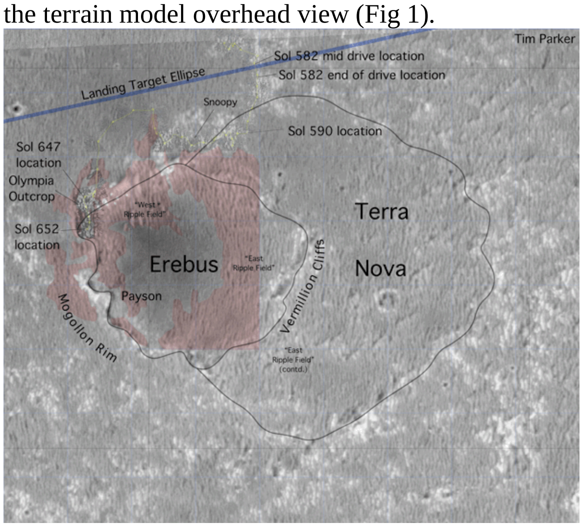

Figure 1: Erebus and Terra Nova Craters. Opportunity location from sols 582-652 (= 698 current, as of this writing). Scene width, 900 m. Background image: S1100471, courtesy Malin Space Science Systems.

Principal Features of the Meridiani Planum Landscape: A number of familiar landforms and lithologies can be investigated in detail with these maps:

Meridiani Planum outcrops. Morphologically, the sulfate-rich outcrop material in the Erebus Crater region is essentially identical to that observed at Eagle Crater, at the Anatolia Fracture area, and at Endurance Crater [1,2]. Fine, millimeter-scale laminations are present at all these locations, as are ripple festoons and hematite "blueberries." Low-angle cross laminations and truncations of laminae are also present.

The surface of the Meridiani Planum outcrops are late Noachian in age, based on crater counts across the region [3]. Most of these craters are highly degraded, like Terra Nova and Erebus. But because most of them are hundreds of meters and less in diameter and the deposits are a few hundred meters thick (~300-500m locally), they must have formed within the deposits rather than being visible from beneath them.

Ripples. Eolian ripple bedforms are present at two (possibly 3) scales – several centimeter wavelength ripples that appear to conform with the current predominant wind direction (NW-SE), and meter-scale ripples with crests oriented N-S. The cm-scale ripple forms appear to be presently active, whereas the larger forms appear to be either currently inactive, or active over much longer time-spans than the smaller forms. Though these larger forms were present around Eagle crater, they were much smaller in amplitude than at Erebus. The Athena team began to first notice their gradual increase in amplitude and wavelength south of the heatshield impact site, as Opportunity began the transition from the "smooth plains" around Eagle and Endurance, to the so-called "etched terrain" to the south. These ripples often exhibit banding on their east flanks, suggesting incorporation of varying percentages of fines as they form, with prior stratigraphy being exposed as the crest migrates westward.

Craters of all sizes. Terra Nova (~550m) and Erebus (~300m) are the largest craters visited to date by Opportunity. They are also among the most degraded craters in the region.

Terra Nova and Erebus likely formed "near" the end of deposition of the outcrop material. These craters clearly predate the upper surface exposures of the outcrop, because the fine laminations are present all the way up to and within the rims of both craters. Erebus crater is only 5 meters deep, and effectively rimless, and Terra Nova doesn't exhibit any obvious depression at all. Outcrop can be seen within both craters from orbit and on the ground, so the two craters must have either been nearly completely filled in by outcrop depostion, or their primary topography has been destroyed by eolian erosion, or both.

The smallest craters (meter- to centimeter-scale) are perhaps not surprisingly also the best preserved and likely indicate relatively recent secondary impacts. The very smallest, centimeter-scale craters are defined by rimmed pits in the dark sand sheet and larger ripple forms on the plains. As Opportunity approached the Erebus rim, the frequency of very small craters increased, likely indicating a local swarm of secondary craters. In nearly all observed cases, these craters lie on the east flanks of the large ripple forms, suggesting that the east flanks of the ripples are less active at present than the west flanks.

From orbit, most several-meter craters appear fresh, with bright patches suggesting outcrop ejecta on the surface. But nearly all those visited by Opportunity appear degraded to some degree, such that ejecta blocks seldom appear perched, but rather appear to have been planed off by eolian abrasion (as was observed at Endurance Crater). One notable exception is Fram Crater (~9m), with prominent perched blocks of ejecta.

Rimless pits. Initially, these features were easily confused with small crater forms, which weren't identified in large numbers until the approach to Erebus. They were first identified in the vicinity of the Anatolia fracture feature, and likely indicate sloughing of the mobile sand into large ground cracks like Anatolia. The persistence of these pits into modern times raises interesting questions about the rates and timing of crack growth and sand transport across them.

Cobbles. Cobble-size rocks have been seen since Eagle Crater, and often occur in clusters on the plains. Prior to reaching the Erebus Highway, however, their relationship to the outcrop could not be assessed with much confidence. The appeared to be either a lag remnant of some horizon within the outcrop for which we have yet to find a contiguous exposure, or they represent secondary or primary meteoritic material. Indeed, in the Olympia Outcrop area, clusters of cobbles often appear associated with small patches of highly-fragmented outcrop, possibly indicating secondary craters that have been largely destroyed by eolian abrasion and ripple migration.

Volume-loss cracking (desiccation polygons). Polygonal cracks have been observed whenever Opportunity has traversed across outcrop. In Eagle and Endurance Craters, the simplest assumption regarding the origin of the fractures is that they're due to impact disruption of the target material. Away from crater forms, however, volume loss due to desiccation or diagenetic volume loss (or both) is indicated. Anatolia Fracture was the first site where polygonal cracks were studied away from craters. Not until Opportunity reached the Erebus Highway did we again have the chance to study them, and detailed examination of the fractures began.

The cracking and associated polygons occur at multiple scales in the region – from the smallest, centimeter-scale polygons, through a few "intermediate" size polygons (several cm, tens of cm, a few to several meters) to the largest, "Anatolia-class" polygons that are several tens to a hundred meters or more across. From Anatolia northward, these larger fractures are readily discernable from orbit, and are identifiable on the ground as open cracks, or continuous aligned "sand pits" where the plains sand sheet material appears to slough into the cracks. In the Erebus region, they are not recognizable from orbit, but they can be identified on the ground by the presence of rimless pits and pit chains across the larger ripple forms. The wide range of scales represented by the cracks and polygons suggests that the outcrop material has undergone desiccation or diagenetic volume-loss to depths of perhaps hundreds of meters beneath the modern surface. This, in turn, implies that the Merdiani Planum deposits, as a whole, may be rheologically homogenous to great depth.

References: [1] Squyres, S. W. et al. (2005) Science 306, 1709-1714. [2] Grotzinger J. P. et al. (2005) EPSL 240, 11-72. [3] Lane M. D. et al. (2003) GRL 30, 1770.