RECENT RESULTS FROM THE MARS EXPLORATION ROVER OPPORTUNITY AT VICTORIA CRATER. S. W. Squyres[1] and the Athena Science Team, 1. Department of Astronomy, Cornell University, Ithaca, NY.

Victoria crater is an impact crater about 800 meters in diameter that lies roughly 5 km south of the landing site of the Opportunity rover. Opportunity reached the rim of Victoria crater on Sol 952, and has spent its time since then traversing along the crater's rim. After arriving at a broad alcove in the crater wall named Duck Bay, Opportunity acquired a Pancam panorama of the crater that set the stage for further exploration. Opportunity then spent superior conjunction near the tip of a nearby promontory named Cape Verde, acquiring atmospheric science observations, in situ data on rock, and another panorama of the crater. Analysis of the Duck Bay panorama, plus the acquisition at about the same time of a high-resolution orbital image by HiRISE, led to the decision to traverse around the crater in a clockwise direction.

Our strategy in conducting this traverse has been to use the unusual promontory-and-alcove structure of Victoria's rim to enable high-resolution stereo and color imaging of stratigraphy in the crater walls. At many points along the crater rim we have driven to an overlook that affords a good view of nearby stratigraphy. We then acquire Pancam images of the crater wall that constitute one "eye" of a long-baseline stereo pair. A drive of a few meters along an axis perpendicular to the line of sight then places the rover in position to acquire the second eye of the pair. These images are complemented by Mini-TES observations and Pancam 13-filter images aimed at investigating compositional variations.

While the primary focus of the traverse has been this textural and compositional remote sensing of the crater walls, the traverse has also afforded access to materials in the crater's ejecta blanket. Opportunity performed in-situ observations of an eroded ejecta block at Cape Verde during superior conjunction, and spent sols 1045-1055 investigating a field of cobbles near Cabo Anonimo that included a rock named Santa Catarina.

As of this writing, Opportunity is poised above an alcove in the crater wall named the Valley Without Peril, with views of Cabo Corrientes to the west and Cape St. Vincent to the east. The rover has driven more than a kilometer since its arrival at Duck Bay. Promontories that have been imaged at high resolution to date include (in order of clockwise progression) Cabo Frio, Cape Verde, Cape St. Mary, Cabo Anonimo, Cape Desire, Cabo Corrientes, and Cape St. Vincent. All except Cabo Frio and Cape St. Vincent have had both their visible faces imaged.

With a diameter of about 800 meters, Victoria crater is the largest impact crater examined to date by either rover; indeed, it is likely to be the largest deep crater that ever will be examined. It provides an unprecedented window into the martian subsurface.

The shape of Victoria crater is unusual. The rim is characterized by a number of prominent alcoves that are U-shaped in plan view, separated by sharp promontories that project toward the crater interior. The alcoves are clearly sites of mass wasting, and this distinctive shape indicates that the crater has been enlarged significantly by mass wasting processes. The enlargement by mass wasting is important, as it means that the bedrock exposed in the promontory walls is relatively undisturbed by impact fracturing, preserving intact, undeformed stratigraphy.

Orbital images obtained by MOC and HiRISE show that the crater is surrounded by a dark annulus about half a kilometer in width that has few of the prominent eolian ripples that characterized and often complicated much of Opportunity's southward traverse.

A surprising finding upon reaching the annulus was that the soil there is rich in large (~4-6 mm) hematite-rich concretions. Concretions in this size range had been abundant at Opportunity's landing site at Eagle crater, and also at Endurance crater. However, as the rover had progressed southward, the concretions in the bedrock along the route had become smaller, and in some areas were absent completely. Concretions and concretion fragments in the soil were also conspicuously smaller along much of the route than they were at Eagle and Endurance craters, implying that the concretions in the soil are largely locally derived.

Victoria's annulus extends to a distance of several hundred meters from the crater rim, and the edge of the annulus corresponds well with the expected limit of continuous ejecta. This observation leads to the obvious conclusion that the large concretions in the annulus originated in ejecta blocks excavated from the crater. We therefore suggest that the sudden increase the size of concretions in the soil upon entering Victoria's

annulus may be a consequence of the following sequence of events: (1) A sequence of flat-lying sulfate-rich sedimentary rocks is deposited. (2) There is an influx of groundwater to some level within the sequence, and hematite-rich concretions are precipitated from this groundwater. (3) The groundwater recedes, leaving the concretions within the rock. (4) Eolian erosion strips away surface materials, creating a surface that rises gently to the south. (There is evidence that Opportunity gained elevation during its southward traverse, moving slightly up-section from concretion-rich materials into concretion-poor materials.) (5) Victoria crater forms, excavating through concretion-poor materials into underlying concretion-rich materials, and depositing these concretion-rich materials into its ejecta blanket. (6) Continued eolian erosion strips away the highly friable sulfate-rich sedimentary materials in the ejecta blanket, leaving behind a lag deposit of concretions excavated from depth.

This scenario can be tested in the future when Opportunity enters Victoria crater, since it predicts that a traverse down the crater wall will move from upper concretion-poor bedrock into deeper concretion-rich bedrock.

Large eolian ripples dominated the surface along the portions of Opportunity's traverse where concretions were small, but are generally absent in the concretion-rich annulus, as they were at the concretion-rich landing site. We suspect that the absence of ripples in the annulus is due to the inhibiting effect that the surface roughness produced by large concretions has on sand saltation trajectories.

Since arriving at the crater's rim, Opportunity has been traversing along the rim imaging the stratigraphy exposed on the promontories. The promontories are quite steep, and most of them expose several to many meters of intact bedrock on near-vertical faces. Because Victoria crater is so large, by imaging these faces we can for the first time study lateral sedimentary facies variations at Meridiani over horizontal length scales of hundreds of meters. The objective of the traverse and the associated imaging has been to create a "circumferential fence diagram" along the crater's perimeter that characterizes lateral facies variations in the exposed bedrock.

On most of the promontories, the uppermost unit is crater ejecta consisting a jumbled breccia of blocks up to a meter or more in size. The ejecta blanket is dominated by blocks of sulfate-rich sandstone; no other material is evident in anything other than trace quantities.

The ejecta blanket overlies a zone in which sulfate-rich bedrock is extensively fractured in place, with an abrupt contact that is clearly visible around most of the crater rim. We interpret this contact to represent the pre-impact surface. The fracturing below it may have occurred before the crater formed, created by the substantial volume loss that can be associated with dehydration of sulfate minerals. Alternatively, it may have taken place as a consequence of the impact itself, as the shock wave generated by the impact impinged on the free surface, loading the rock there in tension.

Beneath the fractured zone lies intact bedrock. Mini-TES observations reveal this bedrock to be sulfate-rich over all depths observed to date.

Pancam observations of the bedrock show all the promontories on the north side of Victoria crater to be dominated by eolian facies. No clasts are visible in Pancam images; evidently the grain size is too small everywhere to be revealed by Pancam, as is the case everywhere else at Meridiani. Bedding, however, is prominent. In several locations, most notably at the promontories named Cape St. Mary, Cabo Corrientes, and Cape St. Vincent, there is spectacular eolian cross-stratification exposed on the cliff faces, with bed sets up to a meter thick and high-angle truncations indicative of former dune deposits. Elsewhere we see the subparallel bedding and low-angle truncations expected for eolian sand sheets. Generally, then, the stratigraphy at Victoria is consistent with what was observed in the lower portions of Endurance crater, although much better exposed over significantly larger vertical and horizontal scales.

Scattered in small numbers within the ejecta blanket are small rocks that are markedly different in composition from the sulfate-rich sandstone that is otherwise so dominant at Victoria. These rocks lie well within the crater's annulus, and so may represent a minor fraction of the crater ejecta that is more resistant to wind erosion than the very friable sulfate-rich material, and hence better preserved. Opportunity has carefully investigated one small cluster of these rocks to date. All of them had very similar Pancam and Mini-TES spectral properties, suggesting a common origin. One, named Santa Catarina, was investigated in detail using the IDD. Its chemistry was similar to that of Barberton, a 3-cm pebble found near Endurance crater that we concluded was probably a meteorite because it contained kamacite, a nickel-iron alloy. Santa Catarina

does not contain detectable kamacite, but it does contain troilite, another mineral common in meteorites. We suspect, then, that the first group of such materials in Victoria's ejecta investigated by Opportunity were of meteoritic origin.

We cannot say yet whether or not Santa Catarina and the related objects are part of the impactor that formed Victoria crater, but it is a testable hypothesis. If they are, then other objects with similar composition should be found throughout Victoria's ejecta. If, however, they are meteoritic material unrelated to the Victoria impact, then other such objects in the ejecta can be expected to have a range of compositions, representative of the broad range of compositions expected for a random collection of meteorites.

As of this writing, Opportunity is wrapping up the investigation of Victoria crater from its rim. One key activity will be investigating the prominent dark wind streaks that emanate from the alcoves on the northern rim of Victoria crater. Another will be completing the rim traverse and the associated remote sensing of stratigraphy in the crater walls.

The next phase will be to enter Victoria crater and begin the exploration of its interior. Within the crater, we will use Opportunity to conduct a number of scientific investigations, including (a) High-resolution imaging and (if possible) in-situ investigation of the spectacular high-angle eolian cross-stratification at Cape St. Mary, Cabo Corrientes, Cape St. Vincent, and perhaps elsewhere. (b) In-situ investigation of chemical and textural evidence for diagenetic processes, for comparison with the chemostratigraphy observed at Endurance crater. This includes investigation of concretion size as a function of stratigraphic position. (c) Remote sensing investigation of crater wall morphology and mass wasting processes. (d) Remote sensing investigation of intracrater dunes.

While Opportunity's mobility system is currently performing well, the failure of Spirit's right front wheel is a reminder that this will not be the case indefinitely. Our near-term focus on the interior of Victoria is planned with this in mind. Successful operation on the rugged and steep terrain within Victoria will require a rover with six functional wheels, which is what we have today. Once the work within Victoria has been completed, however, a wheel failure like the one on Spirit would not prevent Opportunity from conducting extensive further operations on the Meridiani plains.