Briefing Topic:
Black Point Lava Flow, Arizona
Preliminary Traverse Plan (N section)
Science Traverse Team
# Black Point Lava Flow, Arizona

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Black Point Lava Flow, Arizona

Briefing constraints:

• Limited to the types of data available from orbit (i.e., no robotic precursor surface data)

• Resolution of data is comparable to best Lunar Orbiter data and approaching that expected from LRO LROC NAC

• Geologic mapping is based on black and white images only

• Geologic mapping is based on a limited number of properties
  • albedo
  • distribution of albedo-defined patterns in plan view
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Briefing constraints (continued):

- No spectral information was utilized (either from orbit, any other remote sensing platform, or from a robotic precursor)

- No chemical information was utilized (either from orbit, any other remote sensing platform, or from a robotic precursor)

- Geologic mapping is crude; sufficient funds were not available to provide the type of pre-mission detail that accompanies actual missions

- Shadow lengths were not utilized to quantify topography

- DEM was only used to characterize the regional context; it was not utilized to map the geology in the test area
Black Point Lava Flow Area

Introduction to the

Black Point Lava Flow Area
Regional Geologic Context

Black Point Lava Flow 2009 Test Site

BPLF occurs along the NE margin of a large volcanic field
Regional Geologic Context

Morphology of an eroded stratovolcano
Regional Geologic Context

Morphologies of cinder cones
Regional Geologic Context

Morphologies of lava flows
Black Point Lava Flow Area

Black Point Lava Flow
Compared to LROC NAC Image Strip

5 km width comparable to LROC NAC image strip

19 of 25 km length of an LROC NAC image strip
Boundary Conditions

Navajo Indian Reservation

Black Point Lava Flow

Wupatki National Monument

(Checkerboard Country)
Approximate Test Region (2008)

1-day-long UPR and SPR traverses
3-day-long SPR traverse
Approximate Test Region (2009)

2-day-long LER traverse
14-day-long LER traverse
Black Point Lava Flow Area

Introduction
to geologic features on the
north side of the 2009 test area
Geologic Units

• Volcanics
  – Black Point Lava Flow
  – Neighboring lava flows (up to seven within QuickBird frame)
  – Potential vents (with cinder cones abundant beyond the limits of the QuickBird frame)

• Layered Terrain
  – Strata with a wide range of albedos
  – Surfaces with distinctly different knobby, lineated, & smooth surfaces
  – Structurally modified (potential faults and fold)

• Cross-cutting Channels

• Localized High-albedo Terrain
Approximate Test Region (2009)

Black Point Lava Flow
Scale of Test Site
Distances Relevant to N Traverse

- 7.5 km
- 8.0 km
- 4.8 km
Black Point Lava Flow Area

What types of geologic features are evident in this area?
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Regional Slope Drains Towards River
Black Point Lava Flow, Arizona
Black Point Lava Flow, Arizona

Are the ages, mineralogy, & chemistry of these lavas the same?

What were the physical properties (e.g., viscosity) of these magmas?
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Black Point Lava Flow
- Age?
- Morphology?
- Structure?
- Petrology/Mineralogy
- Chemical Composition?
- Spatial & Temporal Variations?
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Are these lobes similar?
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Flow Structures
- Pahoehoe?
- Low viscosity, low shear flow?
Does lava flow cap and protect any strata that have been lost to erosion elsewhere?

Because of regional slope to NE, does eastern lobe of flow sit on top of different bedrock unit than western edge of flow?

What is the slope beneath the flow?

What type of topography was buried by the flow?
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The eastern and northeastern portions of the lava flow have lots of fresh rock faces, which may enhance opportunities to detect internal flow structure and content.
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Is this feature:
- a kipuka in the original lava flow?
- the collapse of the flow margin due to secondary erosion?
- or ..................?
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NW-SE Oriented Structural Elements
Layered Terrain
- strata in mesas
- strata in ravines
- strata parallel to structural element

Layered Terrain (continued)
Layered Terrain
- strata in mesas
- strata in ravines
- strata parallel to structural element

Layered Terrain (continued)
Black Point Lava Flow, Arizona

Layered Terrain
Black Point Lava Flow, Arizona

Erosion exposes dipping strata

Requires a structural element - some type of anticlinal fold

Layered Terrain

Erosion exposes approximately horizontal strata
Layered Terrain
- strata in mesas
- strata in ravines
- strata parallel to structural element

Layered Terrain that is being dissected by channels
- strata in mesas
- cross-cutting channels
Black Point Lava Flow, Arizona

Layered Terrain
- strata in mesas
- strata in ravines
- strata parallel to structural element

Layered Terrain that is being dissected by channels
- strata in mesas
- cross-cutting channels

Layered Terrain (continued)
Black Point Lava Flow, Arizona

Stratified Mesas

Layered Terrain cross-cut by washes
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Layered Terrain
- strata in mesas
- strata in ravines
- strata parallel to structural element

Layered Terrain that is being dissected by channels
- strata in mesas
- cross-cutting channels

Layered Terrain (continued)
Black Point Lava Flow, Arizona

- Dunes?
- Bedrock?
- Flow direction
- Smaller channels
- Channel
- Bedrock?
- Lava
What are layered units?
- Volcaniclastic units?
- Sedimentary units?

Do they extend the:
- volcanic history of region?
- or provide clues about past climates and environmental conditions?
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- Lava Flow Lobe Collapse?
- Landslide?
- Undercut by River?

Inverted Topography?

Channel cut after lava solidified; Similarly, the main river channel (out of view to E) cut lower after lava solidified
Does alluvium contain cobbles, pebbles, sand, and silt from lithologies far to the south of traverse region? Can sediment be used to determine the geology of those distant sites?
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What are lineations?
- exposed strata?
- joints?
- dissolution fissures?
Black Point Lava Flow, Arizona

Lineations
- exposed strata?
- joints?
- dissolution fissures?
Black Point Lava Flow, Arizona

Structural element:

Offset stream channel
Black Point Lava Flow, Arizona

Structural element:

Offset stream channel

Scale of feature is 0.5 to 1 km

~1 km

~0.5 km
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Stream incision controlled by joints?
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Shear fault?
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Preferred model
- consistent with extension in area
- consistent with distinct lithological “window”
Preliminary Traverse Plans

North Side of Black Point Lava Flow

21 May 2009
Preliminary Traverse Plans

Traverse Schedule & Limitations
Traverse Schedule

- 1-day-long K-10 traverse, west side of flow
- 1-day-long K-10 traverse, north side of flow
- 1-day-long Crew B traverse, west side of flow w/ K-10 overlap
- 1-day-long Crew B traverse, north side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, west side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, north side of flow w/ K-10 overlap
- 2-day-long Crew A traverse, north side of flow
- 2-(or 3?)-day-long Crew A traverse, on top of flow
- 2-day-long Crew A traverse, south side of flow
Traverse Schedule

- 1-day-long K-10 traverse, west side of flow
- 1-day-long K-10 traverse, north side of flow
- 1-day-long Crew B traverse, west side of flow w/ K-10 overlap
- 1-day-long Crew B traverse, north side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, west side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, north side of flow w/ K-10 overlap
- 2-day-long Crew A traverse, north side of flow
- 2-(or 3?)-day-long Crew A traverse, on top of flow
- 2-day-long Crew A traverse, south side of flow

The first day of the traverse on the north side will be conducted by K-10, Crew B, and Crew A.

The second and third days of the traverse on the north side will only be conducted by Crew A.
Traverse Schedule

- 1-day-long K-10 traverse, west side of flow
- 1-day-long K-10 traverse, north side of flow
- 1-day-long Crew B traverse, west side of flow w/ K-10 overlap
- 1-day-long Crew B traverse, north side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, west side of flow w/o K-10 overlap
- 1-day-long Crew A traverse, north side of flow w/ K-10 overlap
- 2-day-long Crew A traverse, north side of flow
- 2-(or 3?)-day-long Crew A traverse, on top of flow
- 2-day-long Crew A traverse, south side of flow

The traverse on the west side includes the pit, so the traverse on the north side begins north/east of pit.

The traverse on the north side should end on top of the flow, where the next traverse segment can begin.
Traverse Limitations

- **K-10 limitations**
  - Deployed from base camp
  - 
- **Crew A and B limitations**
  - LER limited to 8 – 12 km/day distance
  - LER average speed is ~4 km/hr
  - Crew A and B can have ~5 hrs suit time in days 1-2
  - Crew A can have ~5 hrs suit time in days 3-4
  - Crew A can have ~4 – 5 hrs suit time in days 5-7
  - Crew A limited to a total of 23 hrs EVA for days 3-7
  - Crew A can have ~ 5 hrs suit time in days 8-10
  - We currently estimate 3 to 3.5 hrs/day “boots on the ground” at 4 to 5 stations/day.
Black Point Lava Flow Area

Science Objectives
Science Objectives

Top-level objectives
• Determine the origin (nature) and relative ages of geologic units to determine the geologic history of the site
• Locate and collect suitable samples that will further elucidate these issues when analyzed in a terrestrial laboratory

Specific test site objectives
• Characterize the Black Point Lava Flow (age, morphology, flow structure, petrology, chemistry, and any spatial or temporal variations)
• Determine the relationship of BPLF with other volcanic features in the area
• Characterize other geologic units in the area
• Characterize the structural evolution of the area
Science Objectives

BPLF and other volcanic rocks
- Provide precise ages that are calibration points for the geologic history of a planet
- Provide information about the thermal evolution and interior chemistry of a planet
- Ideal targets for sample return missions, because a lot of additional information can be gleaned from them using terrestrial laboratories
- Thus, the highest priority sequence of rocks

Layered, channel, and high-albedo units
- Layered rocks may be either volcaniclastic (in which case they might extend story gleaned from BPLF) or sedimentary (in which case they might provide information about past environments and climate)
- Channel deposits may provide mobilized debris from far-away terrains (although of limited value in this particular setting)
- High-albedo units are likely tertiary and unconsolidated sediments
- Although geologic important units, they are of lower science priority (particularly when viewed in a lunar analogue context)

Structural elements
- Features that were not evident within the 2008 test area
- Rely more heavily on observational techniques rather than sample collection
- Provides an anologue to structural elements on the Moon (e.g., fault bounded blocks around the peripheries of impact craters or the folding that occurs in crater peaks and rims)
Science Objectives

BPLF and other volcanic rocks
• Special Note: Although there are multiple flows in the test area, the only bedrock samples available on the north traverse will be from the BPLF. Samples of other flows will be limited to alluvial and eolian sedimentary deposits. Other volcanic rocks will, however, be accessible to traverses on the south and west sides of BPLF and should be a primary target during those traverses.

Layered, channel, and high-albedo units
• Special Note: These units are well-exposed on the north side of BPLF. Some overlapping observations and collecting of these units may also be possible by traverses on the south and west sides of BPLF.

Structural elements
• Special Note: Structural elements may be best exposed and accessible on a traverse along the north side of BPLF. A smaller number of features will be accessible on top of the flow (and all of them visible in the distance from the top of the flow). A subset of the structural elements may also be accessible on a traverse on the south side of the flow, if crew is able to reach the far southeastern corner of the test area.
Black Point Lava Flow Area

Preliminary Traverse Stations

North Side of Flow
Black Point Lava Flow Area

- K-10 robotic precursor traverse
  - Provide ground-level views that are distinct from orbital views, which may change the planning team’s perspective and/or help define crew station activities (from both an operational perspective, like trafficability, and from a science perspective, like sampling strategies)
  - Provide in situ data that is not available from an orbital platform
  - Potentially provide data for station where crew observations are not needed
  - Range should be w/i 5 km of base camp
Preliminary K-10 Traverse Plan

Approximate area within range of K-10 reconnaissance
Preliminary K-10 Traverse Plan

If K-10 does not need to return to base camp, then traverse can end in knobby, moderately light albedo unit.

What units are exposed on floor and in walls of this basin?

What is the best navigation route from basin to north edge of this dark albedo lobe?

What are relatively dark layered units?

What is high-albedo material?

Are these two lobes part of the same lava flow?

What is light-colored layered unit at base of lava flow?

Will cross-sections of lava flows be accessible to crew?
Preliminary K-10 Traverse Plan

Stations 1-5: Characterize the basin, its irregular floor, and exposures in its steep walls.

Station 6: Characterize layered unit in small mesa. Also, characterize nearby high-albedo unit.

Determine best route for crew between Station 1 and 7.

Station 7: Characterize several patches of dark to moderately bright albedo surfaces (sediments?). Also, image the dark lobe.
Station 8: Characterize bright-albedo sediment in wash.

Station 9: Characterize bright-albedo layered unit at base of lava flow.

Station 10: Image cross-section through flow (in cliff face) and determine if it will be accessible to crew for sampling.

Station 11: Same.
If K-10 must return to base camp, then Station 11 is final station; otherwise:

Station 12: Characterize layered units near NE edge of dark albedo unit.

Station 13: Characterize bright, knobby unit.
Preliminary K-10 Traverse Plan

<table>
<thead>
<tr>
<th>Station</th>
<th>Objective</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>Characterize basin walls</td>
<td>1</td>
</tr>
<tr>
<td>1-5</td>
<td>Characterize basin floor</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Characterize layered units in mesa</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Characterize nearby high-albedo units</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Characterize variations in dark to moderate-albedo sediments</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Image lobe of dark-albedo material in cliff</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Characterize bright-albedo channel sediment</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Characterize bright-albedo layered unit</td>
<td>1</td>
</tr>
</tbody>
</table>
## Preliminary K-10 Traverse Plan

<table>
<thead>
<tr>
<th>Station</th>
<th>Objective</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Image cross-section through flow</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Image cross-section through flow</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Characterize layered units near the north-east edge of dark-albedo layered unit</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Enroute from Station 12 to Station 13, evaluate geologic boundary between dark-albedo layered unit and bright-albedo knobby unit</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Characterize bright-albedo knobby unit</td>
<td>1</td>
</tr>
</tbody>
</table>
Preliminary K-10 Traverse Plan

• K-10 traverse summary
  • Stations 1-5 are designed to assist crew with their Station 1 location.
  • Area between Stations 1 and 7 needs to be investigated to assist crew with route between their Station 1 and 2.
  • Stations 10 and 11 are designed to determine if outcrops can be accessed by crew.
  • Stations 6, 7, 8, and 12 will not be visited by crew.
  • Stations are numbered in order of priority.

• Crew traverse (in following slides)
  • Will not duplicate K-10 Stations 6-8, because they should provide sufficient data to answer science questions.
  • Will assume Station 10 and/or 11 of K-10 traverses will be accessible to crew for sampling.
Total traverse distance is ~25 km (~8 km/day)
Primary objective (without K-10 input):
- Characterize the lava flow and collect a vertical section of samples through the flow

Station 1a-c: Sample basin floor and units exposed in walls. Crew selects station (a, b, or c).

Station 2: Sample bedrock layer below flow and bottom of flow

Station 3: Sample cross-section of flow; top of flow well-exposed

Station 4: Same as Station 2

Station 5: Sample relatively dark-albedo unit in layered mesa

Station 6: Similar to Station 1; continue sampling to top of flow if possible
LER is driven back to base camp, either by Crew B or by support staff, so that it is ready for Crew A traverse.

Distance from starting point to Station 6a = 7.6 km
Distance from starting point to Station 7 = 9.8 km
Preliminary Crew A North Traverse Plan

Primary objective (with K-10 input):
- Characterize the lava flow and collect a vertical section of samples through the flow

Station 1a-c: Sample basin floor and units exposed in walls.

Station 2: Sample bedrock layer below flow and bottom of flow

Station 3: Sample cross-section of flow; top of flow well-exposed

Station 4: Same as Station 2

Station 5: Sample relatively dark-albedo unit in layered mesa

Station 6: Similar to Station 1; continue sampling to top of flow if possible

Distance from starting point to Station 6a = 7.6 km
Distance from starting point to Station 7 = 9.8 km
Set up camp at Station 7 or enroute to Station 7.

The open circle is a location adjacent to a road, which will facilitate access by support vehicles.
Preliminary Crew A North Traverse Plan

Primary objective:
- Characterize the knobby and light-albedo layered unit; evaluate structural elements

Station 7: Describe transition between dark and lighter albedo units; sample knobby unit and any nearby high-albedo patch; evaluate lineations

Station 8: Sample smooth layered unit; evaluate structure that influenced stream flow

Station 9: Describe layered units in ravine walls; sample top of ravine; describe and sample dipping dark-albedo unit

Set up camp at Station 10 or enroute to Station 10
Primary objective:
- Evaluate margin of flow where it reaches and pours over structural element; sample vertical section of flow

Station 10: Sample lineated bright-albedo bedrock; describe wall of flow, including peculiar unit along wall

Station 11: If possible, collect material from peculiar unit along flow margin; is it the underlying layered unit or part of the flow? Describe if not accessible.

Station 12: Sample cross-section of flow; top of flow well-exposed

Station 13: Ascend to top of flow; collect suitable samples and camp
Potential Trafficability Issues

Do washes have impassible banks?
Do washes have too-soft sediments?
Is slope too steep?
Are any of the lineations open fissures that might block planned route?
Must avoid ravines
Ravine along this portion of flow is probably impassable.
Black Point Lava Flow, Arizona

Additional Information
Geology Map for 2008 Test

Desert Rats Traverse Planning - Black Point Lava Flow
Geologic Sites of Interest (so far)
* discussed by Science Team on 7-17-08

2 km

- Dissected Unit
- 'Non-dissected' Transitional Unit
- 'Knobby' Unit
- 'Marbled' Albedo Unit
- Light Albedo Unit 'channel'
- Lava flows capping Layered Unit
- 'Marbled' Albedo Unit
- Mounds
- Points of interest based on albedo
- White Albedo surface unit and 'sag' in lava flow
- Outcrops of Black Point Flow Margin