Eberswalde Talks

1. Deltas, Lakes, Megabreccia, and Giant Veins: Interrogating Geologic Diversity for a NASA 2020 Mission to Eberswalde Crater (20 min) - M. Rice

2. Chronostratigraphy, Provenance, and Geologic Context of the Eberswalde System (20 min) - N. Warner

3. Deltaic Evolution in the Large Closed Basin Eberswalde Crater Lake: Sedimentary Archives of Lake Level History, Habitability, and Biosignature Preservation (15 min) - S. Gupta

4. Summary of a Potential Mars2020 Investigation at Eberswalde (5 min) – M. Rice
Deltas, Lakes, Megabreccia, and Giant Veins: Interrogating Geologic Diversity for a NASA 2020 Mission to Eberswalde Crater

Delta

Delta Bottomsets

Megabreccia

Giant Veins

Melissa Rice, Western Washington University
Nicholas Warner, State University of New York at Geneseo
Sanjeev Gupta, Imperial College London
Main Points:

- Eberswalde crater contains a spectacularly-preserved delta with easily-accessible bottomset deposits (which have a high potential for concentrating and preserving organic biosignatures).

- An opportunity to examine how potentially long-lived lacustrine systems were able to survive under changing global climate conditions in the early to mid Hesperian.

- Megabreccias from the Holden crater impact and giant veins are also located in the center of the ellipse.

- The “compact diversity” in the center of the Eberswalde ellipse, and the clear geologic context, would make for an efficient sampling mission with the potential for fundamental scientific discoveries.
Eberswalde Crater predates the formation of Holden Crater to the south, and lies entirely within Holden’s continuous ejecta blanket.
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Spectacularly-preserved delta in western Eberswalde crater

Consensus in literature for a delta:

Defining deltaic features summarized by Irwin et al. (2015):
- Meander migration and cutoff
- Transition from sinuous to straight distal ridges
- Interfingering of sedimentary strata
- Gradient of deposit surface
- Steep margins of deposit
The presence of meanders requires cohesion from ice, clays, or cements (or, on Earth, vegetation).

Songhua River, China (Google)

Irwin et al., 2020 1st Workshop presentation
Development of the Eberswalde delta occurred AFTER the Holden-forming impact, because delta sediments onlap impact megabreccia deposits on crater floor.
Paleohydrology of Eberswalde system suggests $10^4$ - $10^6$ years of deposition to form the delta (Irwin et al., 2015)

**Width-wavelength relationships in two inverted paleochannels**
- Consistent with meandering rivers on Earth
- Inverted channels are well-preserved here

**Bank-full flow for inverted paleochannels**
- From width: 450 m$^3$/s (north), 140 m$^3$/s (south)
- From wavelength: 400 m$^3$/s (north), 180 m$^3$/s (south)

**Annual runoff (lake levels of –1350 and –1400 m, 5,000 km$^2$ watershed)**
- For evaporation of 1 m/y: 8–16 cm/y
- For evaporation of 0.1 m/y: 0.8–1.6 cm/y

**Deposition timescale (deposit volume of 6 km$^3$)**
- For water/sediment volume ratio of 1,000: tens to hundreds of thousands of years
- For water/sediment volume ratio of 10,000: hundreds of thousands to millions of yrs

*Irwin et al., 2020 1st Workshop presentation*
Delta development may have occurred towards the end of the Late Noachian – Early Hesperian “optimum” of valley network formation

Mangold et al. 2012

Warner et al. (next talk)

Outflow Channels
Holden late fans?
Uzboï second stage (overflow to Holden)

Revised crater statistics put maximum age at LN/EH boundary

Valley Networks
Holden fans and lake
Eberswalde fluvial valleys and fans

Valley Networks
Eberswalde impact crater
Holden-Ladon basin

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<tr>
<th>Era</th>
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<td>Late Hesperian</td>
<td>Holden fans and lake</td>
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A total of six fluvio-deltaic systems present around crater margins. Crater topography suggests 2 or 3 sub-basins within Eberswalde.
Possible “spillover” feature could indicate that western basin overflowed into eastern basin, constraining lake depth up to 200m.
Eberswalde crater floor has been modified by a system of faults with a strong NNE-SSW trend
Crater topography appears to be controlled by the NNE-SSW trending faults.
Delta front and other crater floor units have undergone extensive erosion and exhumation (see next talk by N. Warner)
Erosion of delta front into bays and headlands may indicate a dominant direction of ongoing erosion (see talk by J. Williams)
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- “Erosion bays” are where the delta sediments have been most recently-exposed
- Outcrop exposures at these locations may have the highest potential for organic preservation
Overhanging ledges and variations in polygonal fracture patterns indicate variations in grain size and differences in cementation.
A variety of sedimentary facies to sample at the delta, likely including coarse sandstones higher in the stratigraphy.
Overhanging ledges shedding boulders indicates that erosion may be ongoing at the delta front.
Delta bottomsets are easily accessible and may have been recently-exposed via scarp retreat
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CRISM indicates hydration associated with delta sediments, megabreccia, and crater floor units.

Milliken, MSL 4th Workshop Presentation
Fe/Mg phyllosilicate signatures in delta front also vary with stratigraphy. Megabreccias also contain Fe-rich clays.
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There are at least 3 distinct units:

- Clay-bearing unit with pyroxene
- Pyroxene unit with clays
- Fe-rich clay unit
Opaline silica detected in the delta sediments and other crater floor units (Poulet et al., 2014)

Opaline silica in deltaic sediments is consistent with an authigenic origin (Poulet et al., 2014)
A diversity of geologic units mapped across the crater floor

Rice et al. (2013) Mars
A large subset of crater’s geologic diversity is sampled in the ellipse.
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Brecciated unit interpreted as megabreccias from the Holden crater impact and may include blocks of Noachian materials.

Rice et al. (2013) Mars
Veins in Holden megabreccia proposed to have formed by circulation of hydrothermal fluids (Rice et al., 2013), but widths up to 5m could also be consistent with igneous intrusions (e.g., dike swarms).
Mars2020 rover for scale
Largest megabreccia outcrop contains veins with a predominant WNW-ESE orientation

n = 280
Max value = 245°
Orientation appears to be unrelated to other trends within crater (e.g., faults, other fracture-fill deposits), suggesting the possibility that veins either formed due to localized stresses and hydrothermal activity, or they pre-date the emplacement of the megabreccia (were carried into Eberswalde as an intact ejecta block).
A diversity of other geologic units within the landing ellipse

Rice et al. (2013) Mars
A diversity of other geologic units within the landing ellipse

**Rice et al. (2013) Mars**

**Pitted unit**
Origin unknown, possibly another expression of the Holden ejecta deposits
A diversity of other geologic units within the landing ellipse

**Knobby unit**
Contains light-toned, polygonally-fractured hills and mesas that may be remnants of more extensive lacustrine deposits (Pruiett et al., GSA2016)
A diversity of other geologic units within the landing ellipse

**Mantling unit**
Observed regionally and interpreted as an airfall deposit. Retention of small craters and scarps suggests some degree of induration.
A diversity of other geologic units within the landing ellipse

Rice et al. (2013) Mars
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• The “**compact diversity**” in the center of the Eberswalde ellipse, and the clear geologic context, would make for an **efficient sampling mission** with the potential for **fundamental scientific discoveries**