Sediments on Mars Deposited by Impacts Instead of by Lakes, Rivers, and Oceans

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Pow! + Whoosh! => Sediments

- Early Mars **heavily cratered** and with water & atmosphere, unlike Moon.
- Resulted in **turbulent density currents and deposits** (blast beds).
- Blast beds **resemble** both wind & water deposits; **lack their diagnostic traits**.
- Mars rovers have explored **Gusev Crater, Meridiani Planum, and Gale Crater**.
- They saw up close **layered rocks** that have **all** the characteristics expected of density current deposits and **none** diagnostic of water deposits.
- **Impact spherules** (sticky accretionary lapilli, concentric growth) were confused with cemented **diagenetic concretions** (found in Gale Crater only).
- Liquid water only **after** deposition (sparse **descending acid condensates** and, inside **Gale Crater only**, variable **reaction with neutral groundwater** yielding primitive clays and concretions). Late additional impact & wind erosion.
- Impact cratering and sedimentation on Mars: **Unconventional/outrageous?**
Three Rovers Near Equator (Highland Edge)
Familiar Turbulent Density Currents on Earth

Nuclear blast (base surge)

Volcanic blast (base surge / PDC)

Dust storm (haboob)
Tempe, AZ 07/05/11
Terrestrial Blast Beds vs. Meridiani: The Same!

Wall of Kilbourne Hole Maar, NM. **Whoosh!**
(Inset: Aeolian Navajo Sandstone., Page, AZ)

Wall of Cape Verde, Victoria Crater, Meridiani Planum, Mars: **Double Whoosh!**
“Aeolian” Meridiani vs. Gusev: The Same!

“Payson” outcrop, Meridiani Planum

“Home Plate” outcrop, Gusev Crater
Meridiani vs. “Lakebeds” in Gale: The Same!

**Planar unconformity**, Burns Cliff, Meridiani. Note apparent vortex scour in center.

Low-Angle Cross-Beds Nearly Everywhere!

Low-angle cross-beds in Murray Fm. “lake beds”, Sol 1700, Gale Crater

Low-angle cross-beds in “clay-rich unit” Sol 2475, Gale Crater
Upper **young rampart crater** (suggesting subsurface ice) is **likely source** of young Peace Vallis “alluvial fan” sediments in Gale Crater (bottom left). **No feeder or distributary channels**! Rover imaged **no channels** either. **Not liquid water! Turbulent density current**! Flow of impact debris presumably cut isolated channel in Gale Crater wall.
Other Putative Water Features in Gale Cr.

Putative Gale “conglomerate” Sol 646. Note poor sorting and rounding, not in channel. Not evidence of water! Rounding indicates rolling-friction, not water! Compare cobbles, 30 km from Ries Crater., Germany.

Putative Gale mud cracks Sol 1555. Joints filled with Ca-sulfate veins, not sediment (view 40 cm wide). Not sedimentary mud cracks! Polygonal joints occur in many rock types, including blast beds. Compare actual sediment-filled mud cracks in shale, Hayden Butte, Tempe, AZ (view 2 m wide).
<table>
<thead>
<tr>
<th>Deposit Features</th>
<th>Liquid Water Deposits</th>
<th>Impact Deposits (Blast Beds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate restrictions</td>
<td>Severe: Warm and wet!</td>
<td>None: Can be frozen and icy</td>
</tr>
<tr>
<td>Compositions &amp; clays</td>
<td>Evolved; depend on slope, distance, grain size; shale should be abundant</td>
<td>Primitive, basaltic; smectites after diagenesis; no shale</td>
</tr>
<tr>
<td>Amorphous material</td>
<td>Rare to absent (crystallizes in water)</td>
<td>Expected, abundant, glassy</td>
</tr>
<tr>
<td>Salts</td>
<td>Neutral only, in evaporite beds</td>
<td>Acid sulfates persist, salts mixed in</td>
</tr>
<tr>
<td>Cross-bedding</td>
<td>Rare, small-scale, usually steep; bars &amp; ripples in channels or near shore</td>
<td>Very common, extensive, usually low-angle with planar scouring</td>
</tr>
<tr>
<td>Distinct channels</td>
<td>Typical, filled with coarser sediment; cut unconformities</td>
<td>Very rare, formed by scouring by turbulent vortices (not water)</td>
</tr>
<tr>
<td>Friction-caused rounding of clasts</td>
<td>Depends on distance from source; conglomerates usually in channels</td>
<td>Depends on distance from source; gravels not confined to channels</td>
</tr>
<tr>
<td>Dewatering textures &amp; mud cracks</td>
<td>Soft-sediment deformation &amp; sediment-filled mud cracks typical</td>
<td>None: rocks weak &amp; porous; polygonal shrinkage cracks</td>
</tr>
</tbody>
</table>
Concretions:
Unrestricted as to size, shape, or clumping; mainly cemented sand

Mars: Gale Crater concretions flattened on bedding (sol 1718)
Spherules:

Volc. accretionary lapilli (Kilbourne Hole, NM)

Archean accretionary lapilli, 3.5 Ga, S. Afr.

Meridiani spherules (incl. doublets, triplets)

Gusev hematitic spherules (Home Plate area)

Earth spherules (max. size 5 mm)

Mars spherules (max. size 5 mm)
<table>
<thead>
<tr>
<th>Spheroid Features</th>
<th>Diagenetic Concretions</th>
<th>Spherules (Accretionary Lapilli)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Any; related to permeability (e.g., flattened along bedding planes)</td>
<td>Strictly spherules, unless broken in half</td>
</tr>
<tr>
<td>Size/Mass</td>
<td>Any maximum size (supported by strength of sediment, controlled by kinetics and diffusion)</td>
<td>Severely restricted maximum size (supported by turbulent gas cloud, as are hailstones)</td>
</tr>
<tr>
<td>Clumping</td>
<td>Clumps of any number of equant spheroids growing together, up to huge masses</td>
<td>Sticky: clumping possible but rare; if doublets, spherules of 1/2 size; if triplets, of 1/3 size or smaller</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>Low T only, as cement; host rock grains are dominant component</td>
<td>High T minerals such as spinel and specular hematite are common</td>
</tr>
<tr>
<td>Bedding passes through</td>
<td>Common; feature is diagnostic</td>
<td>Absent; concentric growth only</td>
</tr>
<tr>
<td>Concentric color banding</td>
<td>Possible, if nature of diagenetic fluids changed during growth</td>
<td>Universal; visible if make-up of turbulent cloud changed</td>
</tr>
</tbody>
</table>
Summary: Pow! + Whoosh! => Sediments

- Blast beds via density currents caused by impact cratering. Early Mars was like early Earth (but colder). Early blast record uniquely preserved on Mars.
- Arguments against liquid water deposition: compositions (primitive basalt should alter), abundant amorphous materials (glassy material should crystallize), persistent acid salts (should be neutralized), unusual bedding (low-angle cross-beds), planar unconformities (no cut channels), rocks unusually weak (fragile) and porous (1.7 density calc. for Gale Crater seds.), abundant impact spherules (especially, distinctive accretionary lapilli).
- No features diagnostic of liquid water deposition (see tables). Gale Crater water-related features (neutral salt in veins, primitive clays, sparse actual concretions) indicate limited water diagenesis after deposition.
- Later: limited leaching by acid surface condensate, diagenesis by groundwater (in Gale), reworking by impacts and wind (aeolian deposits).
- Older water deposits possible beneath the studied blast beds or elsewhere on Mars; would need deep drilling or further rover studies to find out.
Dilute Density Current (Base Surge) Deposits

- Products of relatively dilute, high-velocity, particulate, turbulent, ground-hugging flows involving a gas (commonly containing steam). Flows override barriers (losing coarser material in the process) and drape topography (can have an original dip), especially if particles are wet and sticky from condensation (are plastered on).

- Are produced by explosive volcanism (especially of basaltic maar-producing type), nuclear and chemical blasts, or major extraterrestrial impacts. Deposits are rapidly eroded on Earth, but very much more slowly on Mars. Apparently missing on Moon (insufficient atmosphere or volatiles). Can travel great distances (low friction).

- Appearance of deposits (particularly bedding, sorting, rounding, and grain size) depends heavily on distance from source and also on H$_2$O content ("dry" vs. "wet" surge; wet can produce "instant rock"). Poor sorting is typical near source.

- Typical features (well-studied volcanic PDC beds) include fine layering, mainly low-angle cross-beds, wavy or trough-beds, flat-beds, massive beds, dune forms, antidunes, accretionary lapilli, polygonal shrinkage cracks, near-source bedding sags (bomb sags), and rare troughs (channels) produced by scouring vortices.

- Unfortunately, very commonly mistaken for (superficially resemble) both fluvial and eolian deposits, although features diagnostic of either environment are missing.