Sediments on Mars Deposited by <u>Impacts</u> Instead of by Lakes, Rivers, and Oceans

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Impact Spherules (Mars)

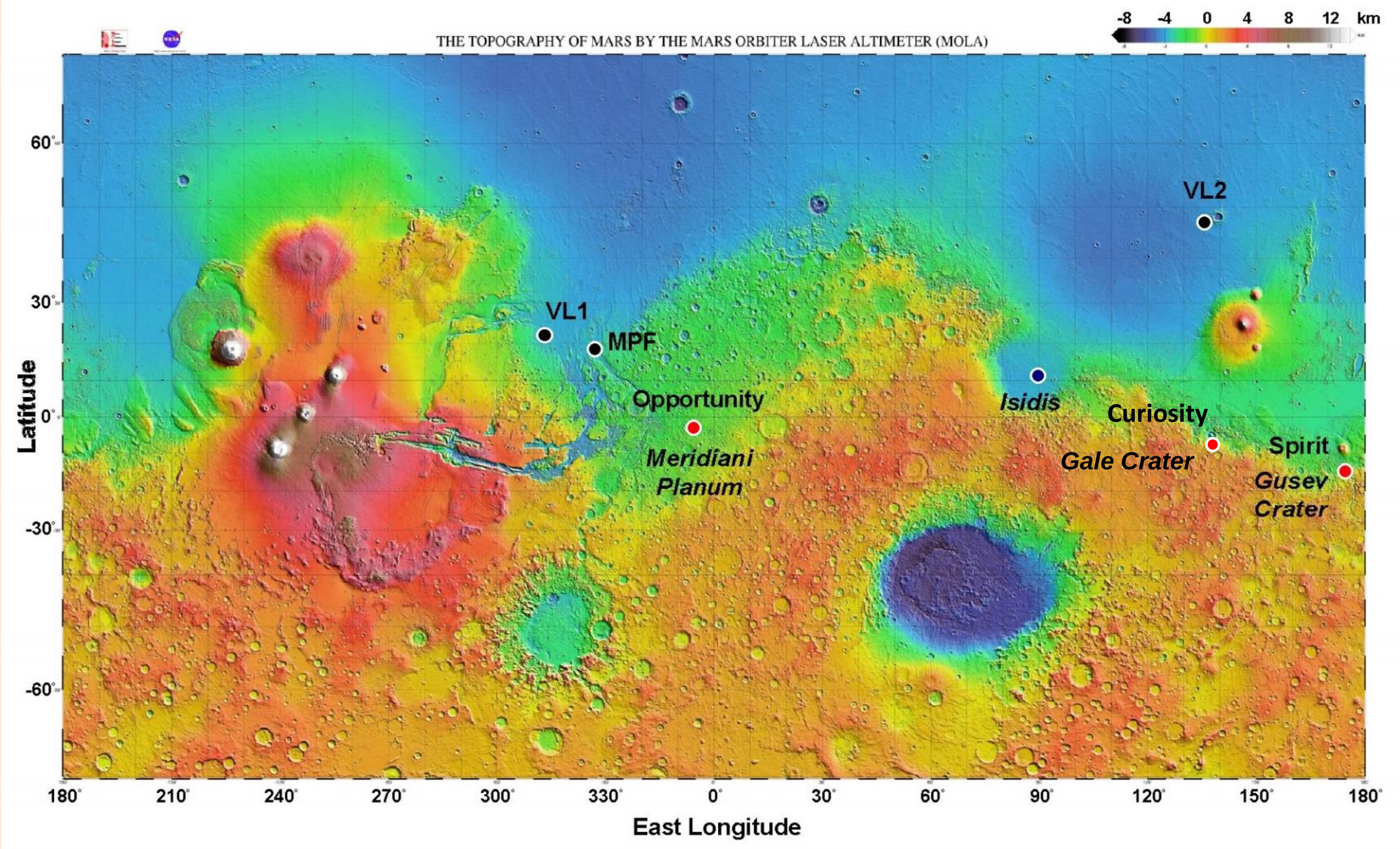
Concretions (Page, AZ)

2019 GSA Annual Meeting, Phoenix, AZ, Session T48, Unconventional Ideas III

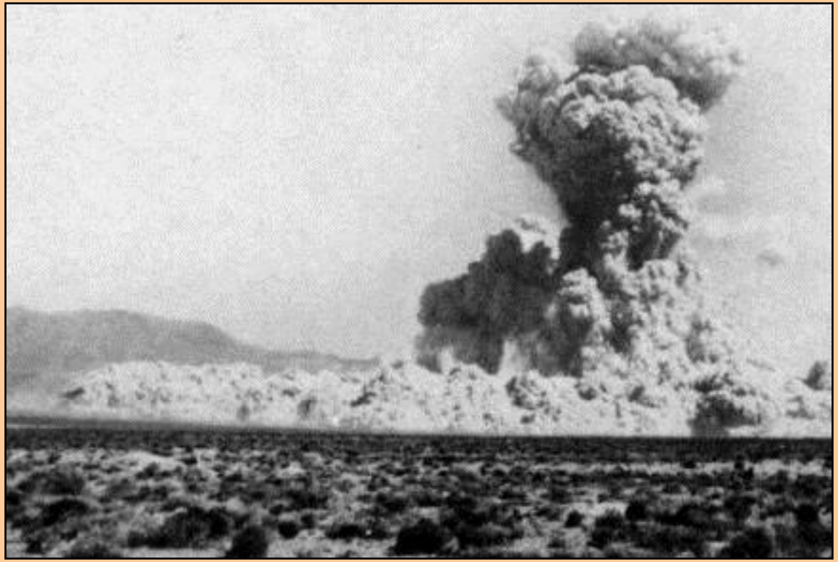
Pow! + Whoosh! => Sediments

- 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

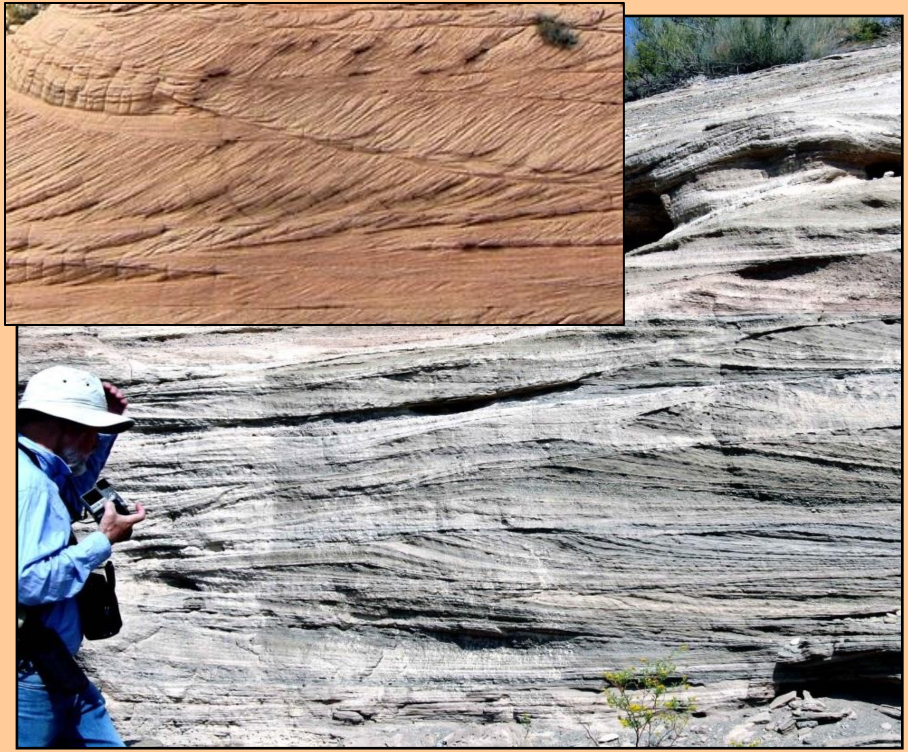


Nuclear blast (base surge)

Volcanic blast (base surge / PDC)

Dust storm (haboob)
Tempe, AZ 07/05/11

Terrestrial Blast Beds vs. Meridiani: The Same!

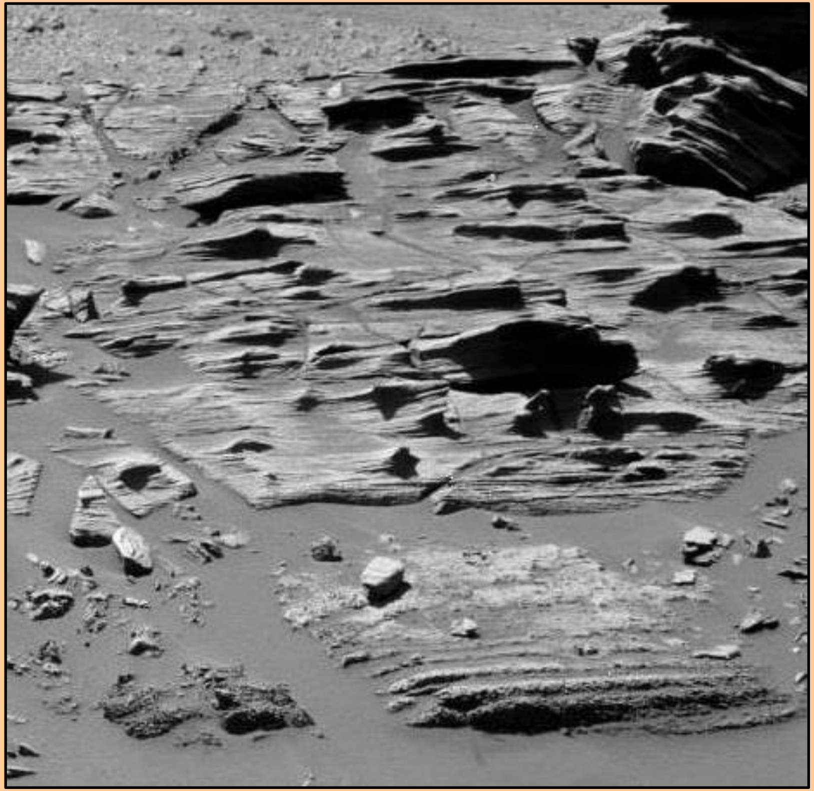


Wall of Kilbourne Hole Maar, NM. **Whoosh!**
(Inset: Aeolian Navajo Sandstone., Page, AZ)

Wall of Cape Verde, Victoria Crater, Meridiani Planum, Mars: **Double Whoosh!**

“Aeolian” Meridiani vs. Gusev: The Same!

“Payson” outcrop, Meridiani Planum



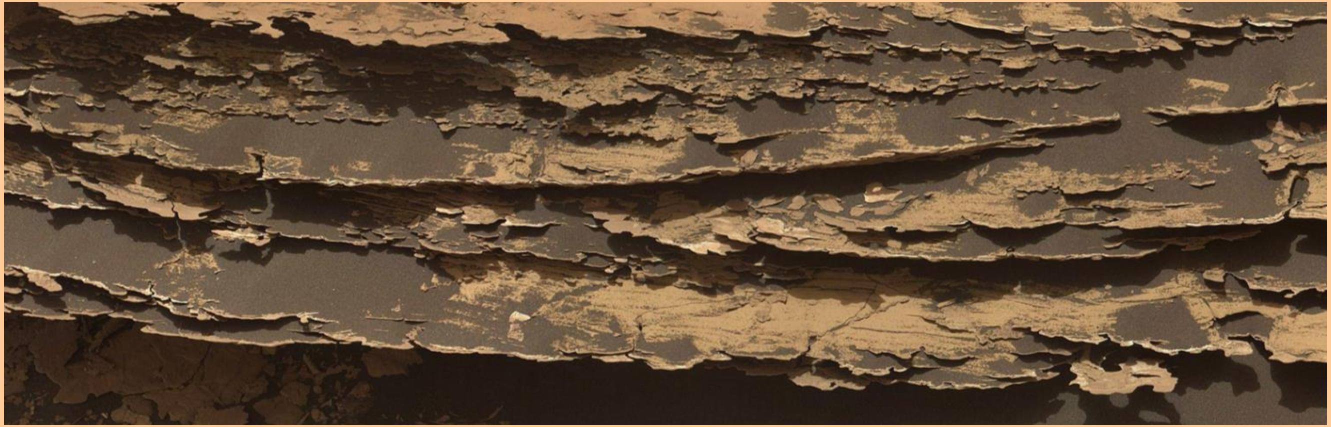
“Home Plate” outcrop, Gusev Crater

Meridiani vs. "Lakebeds" in Gale: The Same!

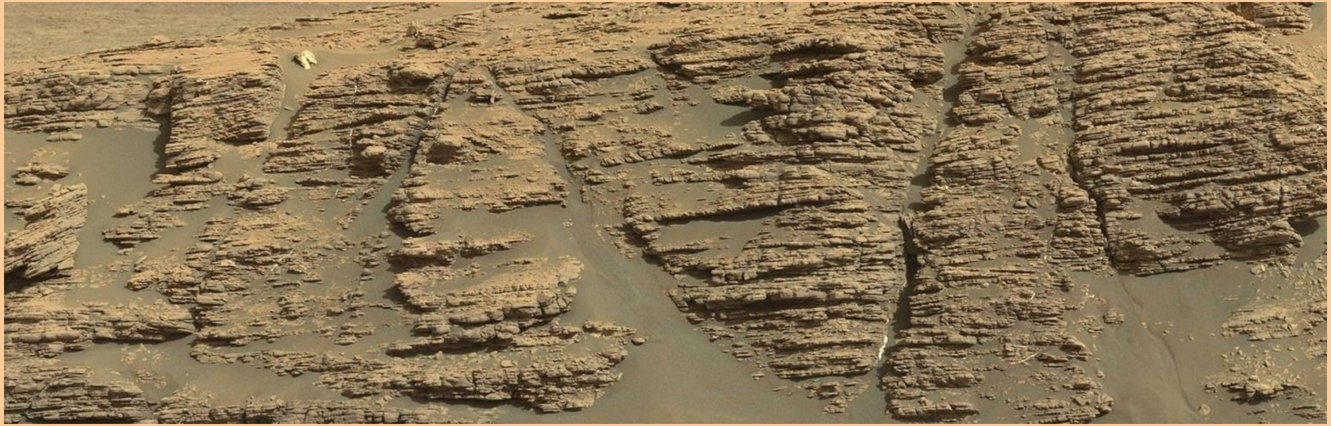
Planar unconformity, Burns Cliff, Meridiani.
Note apparent vortex scour in center.

Planar unconformity, Sol 631, Gale Crater.
Clay-altered by neutral groundwater.

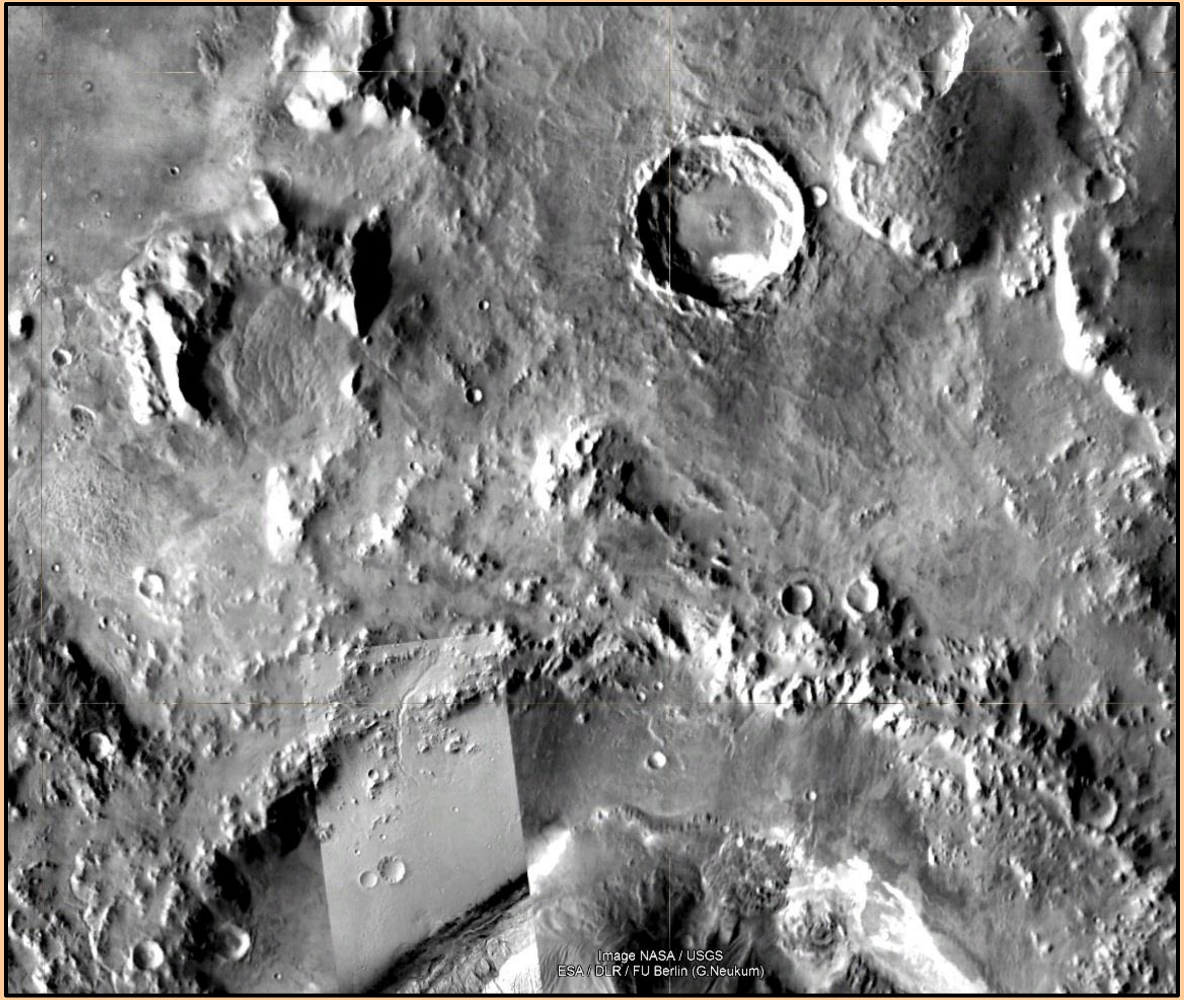
Low-Angle Cross-Beds Nearly Everywhere!



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



Putative Gale Alluvial Fan

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.

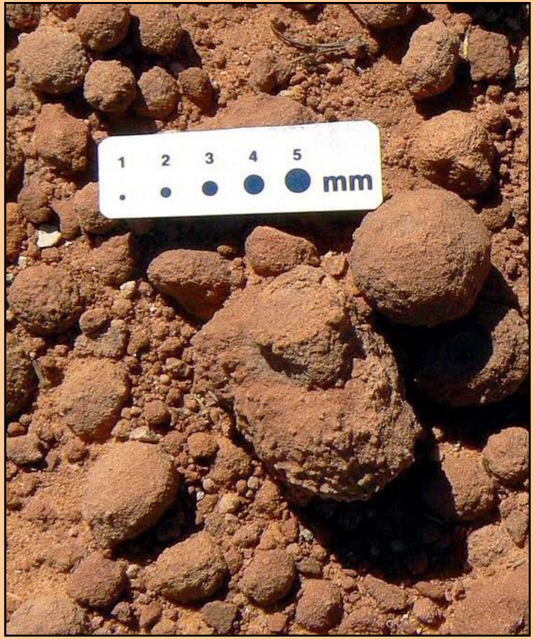
Putative Gale **"conglomerate"** Sol 646. Note poor sorting and rounding, **not in channel**. Not evidence of water! Rounding indicates **rolling-friction, not water**! Compare cobbles, 30 km from Ries Crater., Germany.

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).

Deposit Features :	Liquid Water Deposits	Impact Deposits (Blast Beds)
Climate restrictions	Severe: Warm and wet!	None: Can be frozen and icy
Compositions & clays	Evolved; depend on slope, distance, grain size; shale should be abundant	Primitive, basaltic; smectites after diagenesis; no shale
Amorphous material	Rare to absent (crystallizes in water)	Expected, abundant, glassy
Salts	Neutral only, in evaporite beds	Acid sulfates persist, salts mixed in
Cross-bedding	Rare, small-scale, usually steep; bars & ripples in channels or near shore	Very common, extensive, usually low-angle with planar scouring
Distinct channels	Typical, filled with coarser sediment; cut unconformities	Very rare, formed by scouring by turbulent vortices (not water)
Friction-caused rounding of clasts	Depends on distance from source; conglomerates usually in channels	Depends on distance from source; gravels not confined to channels
Dewatering textures & mud cracks	Soft-sediment deformation & sediment-filled mud cracks typical	None: rocks weak & porous; polygonal shrinkage cracks

Concretions:

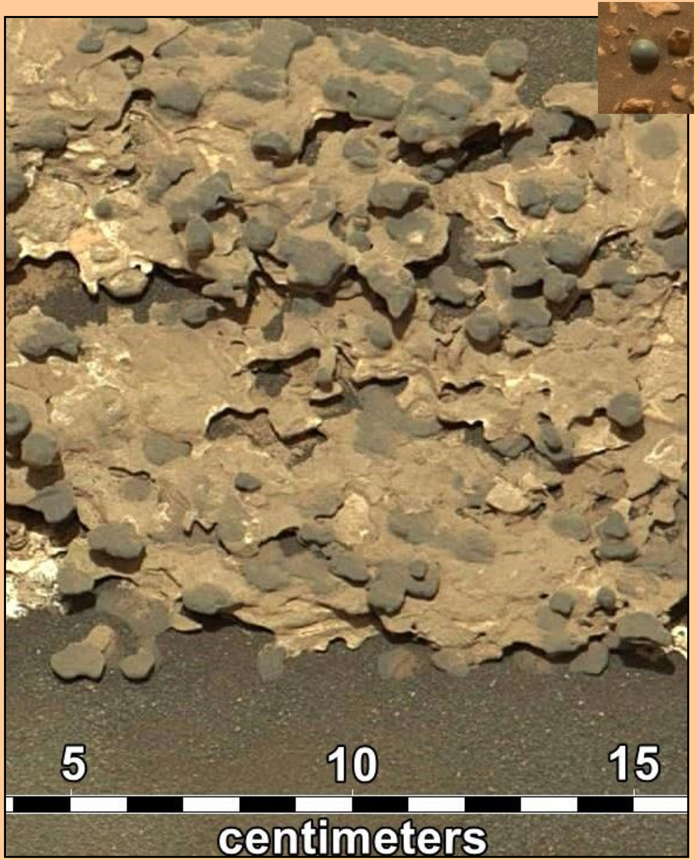
Unrestricted as to size, shape, or clumping; mainly cemented sand



Page, AZ

Textbook

Page, AZ



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

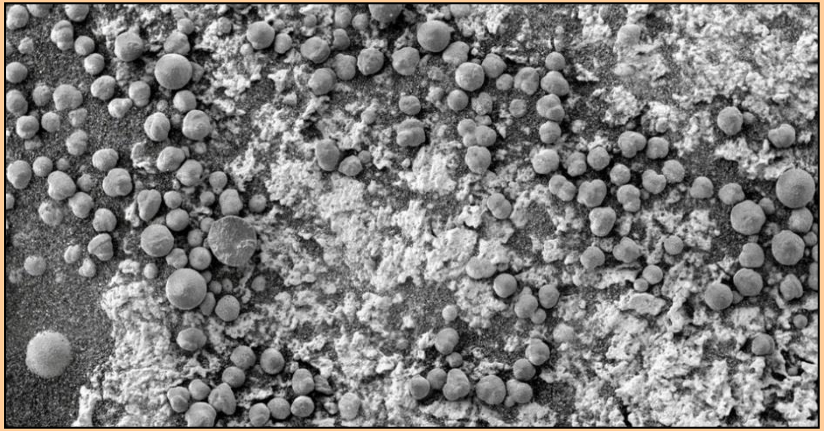
Spherules:

<u>Earth</u>
spherules (max. size 5 mm)

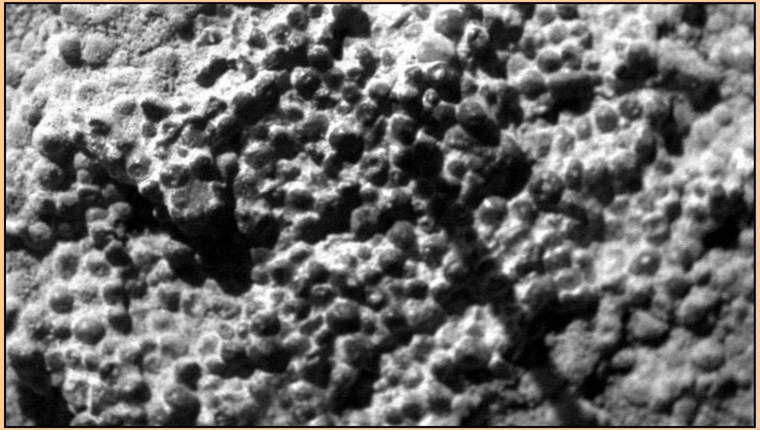
Volc. accretionary lapilli (Kilbourne Hole, NM)

Archean accretionary lapilli, 3.5 Ga, S. Afr.

<u>Mars</u>
spherules (max. size 5 mm)



Meridiani spherules (incl. doublets, triplets)



Gusev hematitic spherules (Home Plate area)

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

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 <u>against</u> 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 (**friable**) and **porous** (1.7 density calc. for Gale Crater seds.), abundant **impact spherules** (especially, distinctive **accretionary lapilli)**.
- **<u>No</u> 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 **<u>after</u>** 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_2O 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**.