BLAST BEDS ON MARS. D. M. Burt[1], L. P. Knauth[2], and K. H. Wohletz[3] [1]School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe, AZ 85287-1404, dmburt@asu.edu, [2]same, knauth@asu.edu, [3]Los Alamos National Laboratory, Los Alamos, NM 87545, wohletz@lanl.gov.

Introduction: Ancient, salty, friable, sedimentary beds with relatively uniform grain sizes and prominent, remarkably shallow cross-bedding have now been imaged at the Martian surface by all three Mars rovers, Spirit (MER1), Opportunity (MER2), and Curiosity (MSL). Where they have been found, these beds all overlie other, older rocks. Owing to alleged analogies with terrestrial sediments deposited by wind, water, and volcanism, these beds have been variably interpreted as aeolian, fluvial, or volcanic, despite their highly uniform appearance from place to place. Except by us, they apparently have never been interpreted as having possibly resulted from meteorite impact, despite the impact-dominated early history and heavily cratered surface of Mars [1].

These beds were first encountered by the Opportunity rover in Meridiani Planum, where they cover essentially the entire plain, except where still more ancient impact breccias and altered glasses were recently encountered stratigraphically beneath (around the edge of Endeavor Crater). Although these beds were inititially interpreted to have formed in an evaporitic, semi-marine environment, published work later attributed them to wind-blown salts and sands eroded from a vanished dry lake or sea, as well as to water flows in vanished streams. The uniformly-shaped and sized, generally unclumped tiny spherules that these beds contain, left behind by wind erosion as an extremely widespread lag deposit, were interpreted as concretions formed in groundwater, despite multiple features inconsistent with textbook concretions and other features inconsistent with the presence of groundwater [2][3].

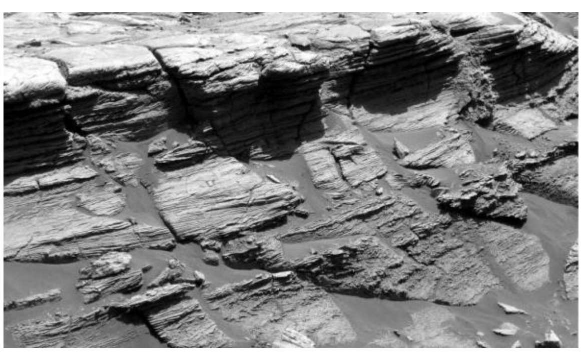

Fig. 1. Outcrop 'Payson' Meridian Planum.

Highly similar beds were later discovered by the Spirit rover at Home Plate in Gusev Crater, apparently draped over a small crater or depression. Although they contained no spherules, a spherule-rich bed did occur stratigraphically just underneath. On the basis of a single putative bomb sag, these beds were interpreted as resulting from a volcanic explosion or explosions, despite the lack of a volcanic source area in the vicinity.

Fig. 2. Outcrop 'Home Plate' Gusev Crater.

A third occurrence of these distinctive beds, somewhat coarser grained than at the other two localities (generally, although similarly coarse material does occur locally at Meridiani Planum and Home Plate), but otherwise highly similar, has recently (December, 2012) been discovered by the Curiosity rover at an outcrop named Shaler in Gale Crater. On the basis of being too coarse to attribute to wind, these beds have been interpreted as fluvial (resulting from flowing water in a stream), despite the lack any other features consistent with stream deposition (e.g., channels, beds grading vertically or laterally into shales, variable clast sizes, dewatering textures, etc.). The Shaler beds are not particularly well exposed and were were imaged merely in passing (twice) by the rover.

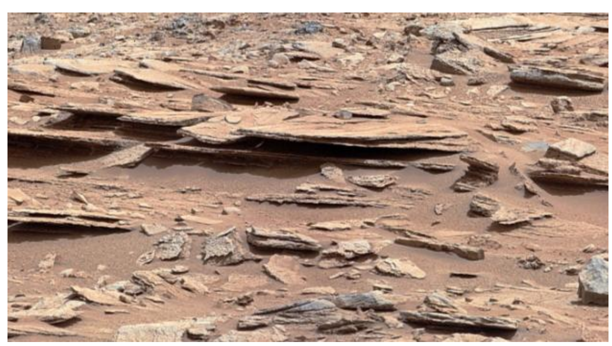

Fig. 3. Outcrop 'Shaler' Gale Crater.

Given the remarkably similar nature of these beds (see photos), it seems only logical to attribute them to a common depositional process. We have suggested [2][3][4] sedimentation by turbulent density currents resulting from impacts. For simplicity and clarity, we here suggest calling them **blast beds**. Other possible names might be impact base surge deposits or impact density current deposits. Recently, Boyce et al. [5] have suggested that similar, albeit younger, blast beds may be widespread on Mars in the form of LARLE (Low-Aspect Ratio Layered Ejecta).

Blast Beds and Spherules. Unlike the Moon and Mercury, Mars has two important features in common with Earth - the presence of an atmosphere and of abundant subsurface volatiles (mainly ice on Mars, mainly liquid water on Earth). These features imply that impact cratering on Mars should have been distinct from impact cratering on the Moon and Mercury (cf. other presentations at this meeting). Contrary to what is commonly implied, its dilute atmosphere and abundant ices do not mean that ancient Mars much resembled ancient Earth, because Mars has always been much smaller and much farther from the Sun than Earth.

On Earth, cross-bedded fine-grained sediments, locally containing various types of small spherules (glassy condensates and accretionary lapilli), are known to be deposited via explosions that vary from nuclear to volcanic to impact-derived. These explosion-deposited sediments (for volcanism called base surge or, more recently, pyroclastic density current deposits) can greatly resemble sediments deposited by flowing water or wind, a fact that has led to multiple misattributions [4]. In places, overriding of obstacles and deposition on slopes (original dip and draping over topography), can help identify such sediments. In this regard, original dip (draping over topography) appears common in deposits both in Gusev Crater (Home Plate and its immediate vicinity) and Meridiani Planum (e.g., where salty sediments appear to have overridden enormous, ancient Endeavor Crater, and then locally been eroded, exposing the brecciated, altered glassy basement). The exposure of cross-beds at Shaler in Gale Crater is too incompletely exposed to ascertain whether it also drapes over topography.

Deposits formed by explosions can vary from wet to dry, depending on the initial steam content. Spherical accretionary lapilli typically form in relatively wet deposits, via condensation of sticky steam onto particles in a turbulent, dilute density cloud. Accretionary lapilli, unlike sedimentary concretions, tend to be strictly size and shape limited and unclumped; they also can contain high temperature minerals. Uniformly small (up to about 5mm) and abundant spherules occur in cross-beds in various near-surface horizons all along the Opportunity Rover traverse in Meridiani Planum.; The most common (at least 50%) phase in these lapilli ("blueberries") appears to be the crystalline, specular, high temperature form of hematite (so-called gray hematite), with detected enrichment in Ni. Other than some doublets and a linear triplet, the spherules tend to be unclumped and uniform in size (within a given horizon or erosion area); they show no evidence of concentration or growth or clumping by moving or mixing groundwaters. Many are broken and they may have been impact reworked, in part. Millimetric spherules of unspecified composition occur in a distinctive horizon beneath Home Plate in Gusev Crater; these were assumed to be accretionary lapilli. Finally, individual spherules of unspecified types also appear to be widespread in Gale Crater, based on preliminary imaging in the landing area, but have as yet been little discussed.

Impact Glass Devitrification. Rather than forming by volcanism, palagonite (or allophane) imaged from orbit could have originated by hydration and oxidation of impact glasses in steamy impact explosion clouds. Gray or specular hematite could also have formed in this fumarole-like environment. Impact glass devitrification also provides a plausible mechanism for the formation of crystalline clays and of "newberries" (spherules [spherulites] weathering out of a clay-rich matrix at outcrop Kirkland, Cape York, Endeavor Crater, Meridiani Planum).

Terrestrial impact cratering commonly results in silica alteration and deposition by hot springs. Such alteration, followed by impact scattering, could account for the silica-rich fragmental horizon identified beneath Home Plate, Gusev Crater. This horizon occurs above the one containing the spherules.

Conclusion: Deposition by dilute impact-related density currents seems to require either a volatile-rich target or an existing atmosphere or both, and Mars certainly has both. By the end of Noachian, when the cross-bedded distal impact deposits (our interpretation [2]) and spherules at Meridiani Planum, Home Plate (Gusev Crater), and possibly Shaler (Gale Crater) presumably formed, Mars was already dry and cold. Available surface evidence at all three sites gives no unambiguous indications of flowing or standing surface or subsurface water. Mars is still an impact-dominated planet, and attributing some of its most interesting features to non-impact causes seems to be a mistake.

References (most omitted)**:** [1]. Burt, D.M. et al. (2011) 2nd P.C.C., abstr. 1108. [2] Knauth L.P. et al. (2005) *Nature, 438*, 1123. [3] Burt D.M et al. (2006) *Eos, 87*, 549. [4] Burt D.M. et al. (2008) *JVGR*, *177*, 755. [5] Boyce, J.M. et al. (2013) LPSC 44, abst. 1004.