"WATER-LAID TUFF" OF THE UTAH DESERT AND SIMILAR SURGE DEPOSIT MISINTERPRETATIONS: A POSSIBLE LESSON FOR MARS?

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Introduction: The cross-bedded, finely layered, altered, salty sediments observed at the Opportunity landing site on Mars were first interpreted as having been deposited by flowing and standing water in an evaporating acid lake environment [1] and, more recently [2], as having been deposited by the wind, in a near-playa setting similar to that at White Sands, NM, but complicated by an episode of flowing (but not standing) water [3], and multiple episodes of rising and falling near-surface groundwater with a remarkably variable chemistry [4]. This second interpretation, like the first, appears complex and contradictory and could, like the first, represent a misinterpretation [5], because a much simpler explanation, impact surge followed by simple weathering, seems to account for all features observed to date by the Opportunity rover [6,7].

Layered, cross-bedded, altered rocks somewhat similar to those at the Opportunity landing site on Mars occur in the Spor Mountain mining district, west central Utah. These altered rocks host the largest beryllium deposit in the USA, actively mined since the 1960's. They also are genetically related to older uranium and fluorite mines. At Meridiani on Mars, hematite mineralization is contained in disseminated perfectly spherical nodules initially called "blueberries" [1]; their origin (and the origin of the hematite itself) is enigmatic. At Spor Mt., beryllium (in the mineral bertrandite) is dissemined in scattered purple nodules of fluorite and silica replacing dolomite clasts [e.g., 8]. The origin of this mineralization likewise is enigmatic [8].

For nearly 15 years these bedded, mineralized rocks of Spor Mt., and similar unmineralized rocks in the nearby Thomas Range and adjacent ranges, were interpreted as alluvial "water-laid tuff" in numerous publications by U.S. Geological Survey (USGS) authors. In fact, they mainly appear to be base surge deposits resulting from explosive rhyolitic volcanism [e.g., 8]. Of various ages, they underlie associated lava flows of F-rich topaz rhyolite. It might appear that the geologists who initially misinterpreted them as water-laid lacked adequate training and preparation in volcanology. Nevertheless, their mistake was natural and common, because the differences between surge deposits and normal sedimentary deposits can indeed be subtle, and the unique characteristics of surge deposits (e.g., impact sags, present at Spor Mt.) were not recognized until about 1970 [e.g., 9].

Spor Mt. interpretations: In the early 1960's, the first USGS geologist to study the Spor Mt. Be deposits made no specific genetic interpretation and simply referred to the layered tuffaceous rocks as "vitric tuff" [10]. At this early stage of investigation, it wasn't realized that the district had experienced two episodes of topaz rhyolite volcanism, at 22-21 ma and 7-6 ma. Except for gem topaz in miarolitic cavities in young lava at Topaz Mountain, and minor radioactive opal along fractures, only the older volcanic episode caused economic Be-, F-, and U-mineralization (perhaps because only the older rhyolitic volcanoes erupted through reactive Paleozoic carbonate rocks and their associated aquifer). In the next study (by a distinguished Be expert who was mainly familiar with intrusive pegmatites) the layered, cross-bedded rocks were interpreted as water-reworked alluvium ("water-laid tuff") [11] and this interpretation was shortly incorporated as a chapter in the much-cited book "Ore Deposits in the United States" [12]. A young sedimentologist-statigrapher (apparently also untrained in volcanology) was next assigned to the district. He stuck with the "water-laid" interpretation, and, over the following 10 years or so he (with various USGS coauthors) published numerous scientific articles and Professional Papers on mineralization related to the "water-laid tuffs" of Utah [e.g., 13,14,15]. Needless to say, these studies were not particularly useful in prospecting for new deposits, inasmuch as they were based on a fundamental misinterpretation of the observations and data.

All of this changed in March, 1979, when the three of us first met with that young sedimentologist (we were young then too, and one was still a student) on our first joint field trip to Spor Mountain. The first outcrop of "water laid tuff" that he proudly took us to (Fig. 1) was an excellent, Burns Cliff-like exposure with giant cross-beds, low-angle cross-beds, and laminar bedding at a near-vent locality called Antelope Ridge, right next to world-famous Topaz Mountain. One of us (the volcanologist) immediately blurted out "Why, those are surge deposits!" and that utterance marked an instant end to any further "water-laid tuff" publications. In print, the young sedimentologist never specifically admitted error or acknowledged us, but simply started referring to "stratified tuff" instead of "water-laid tuff" [e.g., 16,17].

Fig. 1. Base surge deposits (initially called "water laid tuff") exposed in cliff at Antelope Ridge, Thomas Range, UT. Note steep cross-beds, shallow cross-beds, and laminar bedding. This exposure is proximal to the vent, explaining the relatively coarse grain size and poor sorting.

Lesson: In addition to some aspects of human nature, this example illustrates just how much volcanic surge deposits can resemble normal sedimentary deposits (both alluvial and eolian), and vice versa. Careful mapping and observation (along with adequate training) may be required to discern the difference. Several other examples of misinterpretations of surge deposits (mainly from older literature, not specifically referenced here) are listed below. (This list, based on personal experience, is far from exhaustive.)

Mt. St. Helens, WA: Old blast deposits were originally misinterpreted as glacial or fluvial by the USGS.

Zuni Salt Lake maar, NM: Fine-grained, cross-bedded basaltic surge deposits were initially mistaken for eolian dune deposits, until careful mapping revealed a radial distribution of presumed wind directions away from the vent.

Sugarloaf Mt. Tephra, San Francisco Peaks, AZ: Rhyolitic base surge deposit misidentified as glacial outwash until 1975.

Surge beds above the AD 79 eruption deposits of Vesuvius, Italy: Misinterpreted as "reworked sedimentary" until 1981. Similar surge deposits at Lipari and Vulcano in Italy were likewise not correctly interpreted until 1981.

These examples largely reflect misinterpretations of volcanic surge deposition in recognized volcanic areas. Overlying lava flows preserved many of the cited surge beds from erosion, allowing for modern examination.

What about impact surge deposits, radial to a major impact crater? No one really knows what they might look like, because on Earth, water and wind erosion starts to remove them almost as soon as they form (there typically is no overlying depositional layer to protect them). Allowing for compositional differences (target and impactor variability) and scale, presumably they could look rather similar to volcanic surge deposits.

What if the major impact occurred on Mars, with its icy, salty regolith, thin atmosphere, and weak gravity? Again, no one really knows, but the finely-laminated cross-beds exposed in "Burns Cliff" in Meridiani Planum might well represent an example of a distal surge deposit formed under such conditions [5,6]. Water erosion on Mars is almost non-existent, glacial erosion is likely to be very localized, and wind erosion is extremely slow, so that chances of preserving an impact deposit on Mars are much better than on Earth. In fact, some or all of the sequences of laminar strata exposed around the edge of the heavily-cratered Martian highlands (as observed from orbit [18]) could represent preserved older impact deposits [6], just as the ramparts of relatively young and small "rampart craters" (a crater form that is unique to Mars) could represent younger impact surge deposits [19].

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