HOW MUCH OF THE SEDIMENT IN GALE CRATER'S CENTRAL MOUND WAS FLUVIALLY TRANSPORTED? B. J. Thomson[1], C. I. Fassett[2], D. L. Buczkowski[3], and K. D. Seelos[3], [1]Center for Remote Sensing, Boston University, Boston, MA (bjt@bu.edu), [2]Dept. of Astronomy, Mount Holyoke College, South Hadley, MA, [3]Johns Hopkins University Applied Physics Lab, Laurel, MD.

Introduction: While there is a broad consensus that the central mound in Gale crater is sedimentary in origin, there remains stark disagreement about the nature of the medium that transported and deposited those sediments, particularly if the dominant agent was wind or water. Results from the Curiosity rover indicate evidence for fluvial deposition of sediments on the crater floor [1-3]. But how much of the central mound is attributable to fluvial and/or lacustrine processes? Here, we address this question by conducting a simple mass-balance approach to compare the volume of the mound with the transportation capacity of the contributing fluvial network.

Mound volume: The mound volume was obtained using gridded altimetry data from the MOLA instrument and stereo-image derived topography from HRSC. We determined the difference in elevation between the mound surface and inferred basal level (approx. –4.5 km elevation). The average mound height is 2.2 km, and the resulting mound volume is ~9 × 10^3 km^3. No account has been made to correct for the effects of porosity, compaction due to overburden, or the presence of a buried central peak or peak complex. For context, this volume of sediment is significantly larger than the volume of Eberswalde fan deposit (6–30 km^3 [4]) though smaller than the 1.5 × 10^4 km^3 layered mesa within the comparably-sized Henry crater [5].

Fluvial transport capacity: There are three components to consider in estimating the fluvial transport capacity: the network of small inward-draining channels, a larger entrance breach in the south rim of Gale, and the eroded volume due to overland (i.e., non-channelized) flow.

Small channels: Gale crater exhibits numerous inward draining channels but no outlet; if it once hosted a lake, it remained topographically closed. More than 100 small inward-draining channels have been recognized in high-resolution images from the MOC, HiRISE, CTX, and HRSC instruments [e.g., 6, 7-10]. These channels originate in approximately 25 separate catchment zones around the crater's rim. Individual channels are typically 100–300 m in width and extend 10s to 100 km in length from the rim region down to on or near the crater floor. The lower portions of some of these channels stand in positive relief, indicating that a cementing agent has armored the floor of the these former watercourses to form linear mesa-tops due to later differential erosion [e.g., 11]. Summing up the total volume of missing material in small negative-relief channels and valleys and adding the volume of the positive-relief inverted channels (assuming a rough equivalence of their positive and negative volumes for simplicity), we obtain a volume of roughly 30 km^3 of sediment. For reference, the estimated volume of material removed due to channel incision in Peace Vallis is 0.8 km^3, which is roughly equivalent to the volume of the Peace Vallis fan (0.9 km^3) [12].

Large input channel: One large channel (IAU recognized name: Farah Vallis) incises the crater's southwest rim and is visible in Viking images [13, 14]. Farah Vallis stretches over 500 km to the edge of Herschel crater along the northern rim of the Hellas Basin. It has a morphology consistent with other V-shaped martian valley networks [15] and is a few km wide and ~100 m deep (although the incision is deeper in some places). Assuming an average width and depth of 1.5 km and 100 m, respectively, yields an approximate eroded volume of 75 km^3. Two separate terminal deposits are found at the mouth of this channel; collectively they occupy a volume less than half of the channel erosive volume (32 km^3).

Overland flow: Totaling up the volume of channels provides only part of the picture; widespread landscape denudation in overland (i.e., non-channelized) flow must also be factored in. Given its location on the dichotomy boundary, there is minimal terrain north of Gale from which sediment may have been derived. To the south, in contrast, the Gale watershed terminates against northern rim of the Herschel crater, encompassing an area of roughly 270,000 km^2 [16]. Average landscape denudation of 33 m throughout the watershed would yield a volume of sediment that matches the mound volume. However, while such a high value might be plausible during more intense erosive periods in the Early Noachian [e.g., 17], it is unreasonably high after this time (at least for most places on Mars). Estimates of post-Early to Middle Noachian erosion rates are more than an order of magnitude lower (e.g., ~2 m of denudation in Milna crater watershed [18]), yielding ~5 × 10^2 km^3 of material.

Even this value is likely an overestimate as indicated by the minimal contribution of non-channelized erosion to the Peace Vallis fan (~12% of the channelized eroded volume) estimated by [12]. Additionally, since the Gale impact appears to have disrupted Farah Vallis while it was active [19], only part of this sediment budget that occurred during late-stage activity in this valley network should be included.

Table 1. Mass balance components

Volume [km^3]	Source
30	Small channels
75	Farah Vallis
500	Overland flow
9000	Mound volume

Mass-balance comparison: Taking the least conservative (largest, in this case) approach, the total volume of material capable of being moved by flowing water into Gale is at most $\sim 6 \times 10^2$ km^3 (**Table 1**). It is readily apparent that the volume of the mound exceeds the carrying capacity of the contributory fluvial network by more than a factor of 10. Thus, mechanisms other than fluvial transport are needed to explain more than 90% of the mound's sedimentary budget.

We can also place some constraints on the maximum elevation where one would expect fluvially transported material to be found *within* the mound. Dividing the volume of fluvially transported material ($\sim 6 \times 10^2$ km^3) by the mound area (6×10^3 km^2) yields a height on the order of 100 m above the base elevation. However, fluvio-lacustrine deposits could be found superposed *on* the mound at higher elevations if a lake was present in Gale after the mound was emplaced [e.g., 20]. Such deposits would be bounded by basal unconformities over the pre-existing mound strata.

Additional geometric considerations: As pointed out numerous times previously [e.g., 5, 9, 21], the mound of Gale rises to an elevation that is >2.5 km higher than the lowest point of the northern rim. Thus, formation of the entire mound by lacustrine processes would necessitate filling of the entire catchment area, an area that includes the northern plains. There is no evidence of any scour or incision of commensurate scale with this volume of water either into or out of the northern rim of Gale. In this case, we interpret an absence of evidence as evidence of absence, i.e., the lack of inlets or outlets as most consistent with them not ever having formed.

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