BIMBE AND RELATED BLOCKY GEOMORPHIC UNITS IN GALE CRATER: HETEROGENEOUS COMPOSITIONAL UNITS OVERLYING MURRAY AND STIMSON FORMATIONS

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Overview: On Sol 1400 the *Curiosity* rover encountered the third of three examples of "blocky units" investigated by the team. This one, named Bimbe, overlies Murray formation bedrock just north of Murray Buttes (Figs. 1 and 2). The predominant surface expression ever since Sol ~750 has been the Murray formation, which consists of finely laminated mudstones to fine-grained sandstones extending ~200 meters in vertical elevation [1]. Overlying the sloping and apparently eroded Murray is a cross-bedded aeolian sandstone unit, Stimson, which comprises the cap rock of the Murray Buttes and surface expressions encountered sporadically since the rover reached Murray formation rocks at Pahrump Hills.

Fig. 1. Overhead image showing the three blocky units. The rover path is shown in white. (MRO/HiRISE image: NASA/JPL-Caltech/ASU)

Relationship to Other Units: Bimbe appears to belong to a family of 'blocky units' that superpose Murray formation rocks on the lowermost northern slopes of Mt. Sharp; some of these are also superimposed on the much younger Stimson formation. Camera observations indicate that these are not lithified units; they are not interbedded with the Stimson or the Murray but superpose their erosional surfaces.

Curiosity drove across one such unit (Blackfoot, Sols 1094-1104) near Bridger Basin, and past another named Brandberg (Sols 1158-1160). Relatively few compositions were measured from these units and they have not yet been studied in depth. Dark-toned blocky outcrops were also seen earlier along the rover traverse at high points within Bradbury Rise, such as at Twin Cairns Island (TCI; sol 343). At least one instance of a cm-size circular void is seen in a dark blocky float rock in a blocky unit at Bridger Basin, similar to voids characteristic of dark-toned rocks at TCI and Point Lake [2].

Textures and Expressions: As seen in Fig. 2, the geomorphic surface of Bimbe has many dark-toned cobbles and small boulders, but float rocks of several other textures were also found. They included faintly layered textures (but unlike the distinct Stimson and Murray layered expressions) and conglomerates (Fig. 3). One conglomerate observed by MAHLI contained a sandstone clast (cut by a vein-filled fracture), which is one of the first examples of the recycling of sedimentary rock (a sandstone clast within a younger conglomerate, the conglomerate itself being a boulder clast of the Bimbe deposit). ChemCam observed 8 blocky targets, 6 conglomerates, and 2 layered targets with a total of 125 observations. One blocky target (Sonneblom) was observed by both APXS [3] and ChemCam.

Compositions: Fig. 4 presents the mean compositions of 4 major oxides based on 5-10 ChemCam observations of each Bimbe float rock.

Results: The two layered float rocks (Fig. 4, yellow) are relatively mafic and cluster together, coinciding with a layered group observed near Yellowknife Bay (YKB), typified by Bathurst Inlet, and clearly distinct from Stimson, Murray, blocky rocks, or conglomerates. Fig. 4 represents the 8 YKB layered floats [4] by their mean ± std. dev (Fig. 4, "Bradbury Layered"). One of the two Bimbe layered targets, Chinchimane (Fig. 3), bears a striking textural resemblance to these YKB rocks, located 15 km away.

Bimbe blocks are divided compositionally into two groups (Fig. 4), one of which (Group 2) coincides with local Stimson sandstones except for slightly lower Al. Blocky Group 1 has higher Si, Na, and K, but lower Al, Mg, and Fe. A suggestion was made earlier [3] that this group may be similar to rough-textured, ventifacted stones on Bradbury Rise, such as Jake_M [5], so a comparison is made in Fig. 4 with the mean ± std. dev. of Jake_M plus three similar-textured floats observed near TCI. The Bimbe blocky Group 1 rocks are distinctly lower in Al compared to the Bradbury blocky rocks; they are also nominally higher in Si and lower in Ca (not shown), despite the similar textural appearance.

The 6 Bimbe conglomerates have diverse compositions as sampled by ChemCam (Fig. 4, blue circles) and do not appear to coincide with the mean compositions of conglomerates from Bradbury Rise or the Kimberley (Fig. 4; [6]). However, in this case where clast sizes are large, whole-rock compositions are less accurate.

Discussion and Conclusions: Several aspects of the Bimbe unit are not yet understood. The observation of faintly layered float rocks of unique composition found 15 km apart in distance and > 150 m in elevation may indicate that the cobbles and boulders of Bimbe are remnants of bedrock from higher stratigraphic positions that have been all but eroded away; these rocks would have once occupied space some meters to many

tens of meters above the present-day surface near Bimbe. Or these blocks, and the Bimbe unit as a whole, could be the product of lateral transport from further up the slopes of Mt. Sharp, but the sedimentological and geomorphic evidence for transport mechanisms are not clear. The presence of conglomerates and blocky float rocks overlying an erosional surface of the Murray formation is interesting. Conglomerates and cumulate float-rock clasts found on Bradbury Rise were interpreted to be composed of clasts that were transported fluvially from the crater walls. However, the Bimbe unit appears to lie well within otherwise undisturbed strata of the Murray formation.

Based on orbital maps, no new blocky units are expected to be encountered along the next several km of *Curiosity's* traverse. Sampling of the Siccar Point channel deposits and fan, located well above the Hematite Ridge, might provide additional information.

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References: [1] Fedo C. et al. (2017) this meeting; [2] Wiens R.C. et al. (2017) Cm to dm hollow concretions and voids…, subm. to Icarus; [3] Gellert R. et al. (2016) Fall AGU; [4] Mangold N. et al. (2015) JGR 120, 452; [5] Stolper E.M. et al. (2014) Science 341, doi: 10.1126/ science.1239463; [6] Mangold N. et al. (2016) JGR 121, 353.

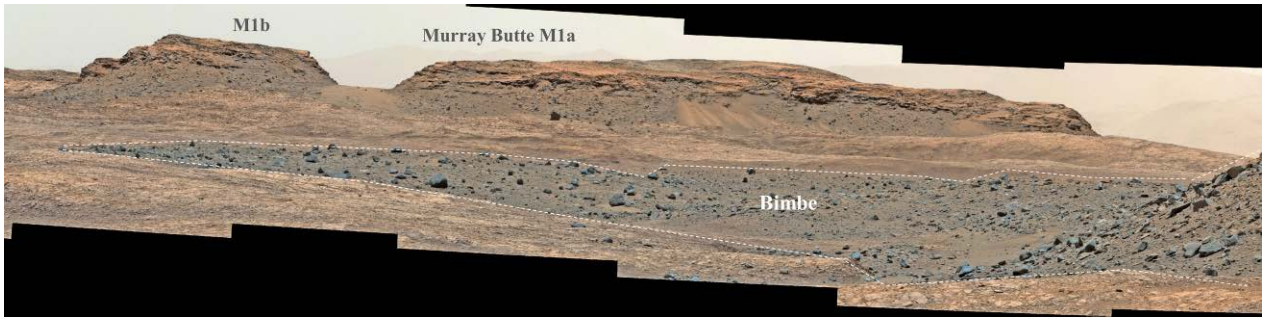

Fig. 2. Bimbe unit in Mastcam mosaic from sol 1387. In front of and behind Bimbe is Murray bedrock; the first Murray Buttes encountered by the rover are in the background, and consist of aeolian Stimson material.

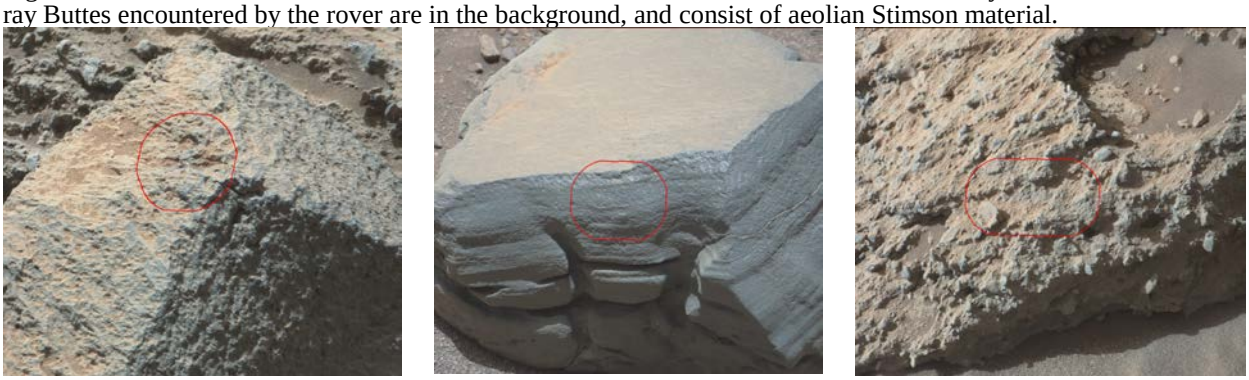

Fig. 3. Textures of float rocks observed in Bimbe. Left: Sonneblom (blocky), center: Chinchimane (faintly layered), and right: Balombo (conglomerate). Red outlines on the Mastcam images indicate locations and spatial extent of the ChemCam Remote Micro-Imager mosaics, ~5 cm across.

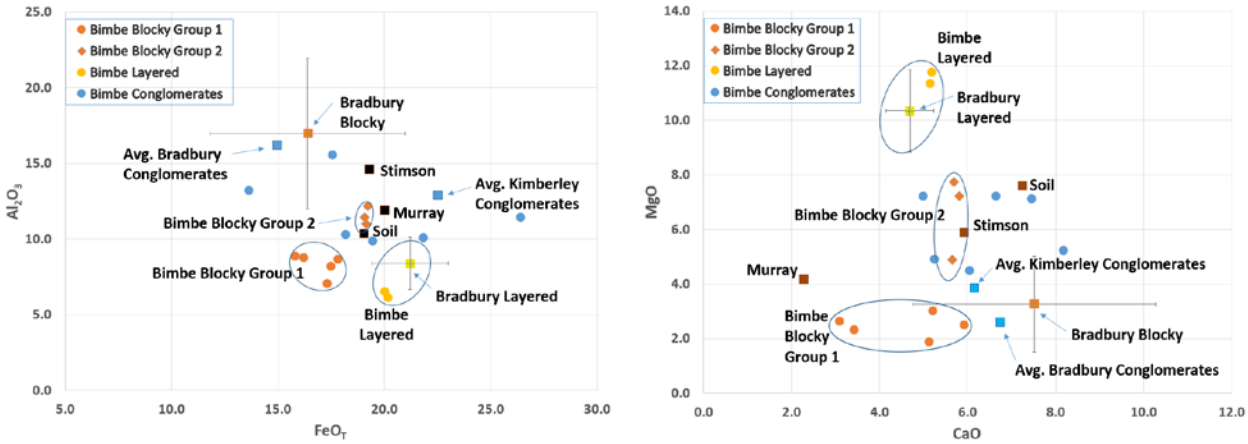

Fig. 4. Compositions of the 16 Bimbe targets, in wt. %, and mean compositions from other Gale units.