CONSTRAINING THE RELATIVE TIMING AND DURATION OF AN ANCIENT FLUVIO-LACUSTRINE SYSTEM IN GALE CRATER USING MSL CURIOSITY ROVER OBSERVATIONS. K. M. Stack[1], J. P. Grotzinger[2], and the MSL Science Team, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109 (kathryn.m.stack@jpl.nasa.gov), [2]California Institute of Technology, Pasadena, CA 91125.

Introduction: Since arriving in Gale Crater in August 2012, the Mars Science Laboratory Curiosity rover has driven ~9.5 km from the Bradbury landing site to the base of Mount Sharp (Fig. 1). At several key waypoints along this traverse (Yellowknife Bay, Darwin, Cooperstown, Kimberley, and Pahrump Hills), the MSL team observed evidence in the rock record for past fluvial, fluvio-deltaic, and lacustrine deposition in Gale crater. However, determining the stratigraphic relationships between the major waypoints is not always a straightforward task. In particular, major questions persist about the relative age relationships between the Peace Vallis fan system, the plains north of Mount Sharp (Aeolis Palus), and lower Mount Sharp. This study presents a summary and overview of the ancient sedimentary depositional environments observed during the primary phase of the MSL mission and discusses stratigraphic constraints on the relative timing of major depositional and erosional events in Gale crater.

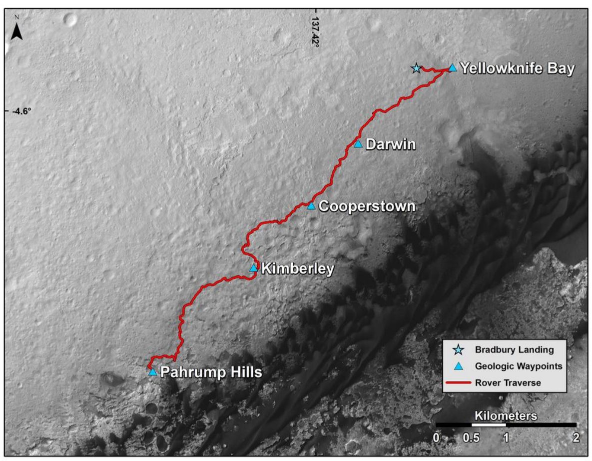

Figure 1. Curiosity's traverse from Bradbury Landing to lower Mount Sharp Image credit: NASA/JPL-Caltech/UofA.

Fluvio-lacustrine sedimentary rocks observed by Curiosity in Gale crater:

Yellowknife Bay. Approximately 500 m east of the Bradbury landing site, Curiosity examined the Yellowknife Bay formation, a 5 meter-thick siliciclastic assemblage representing deposition in a fluvio-lacustrine environment [1]. The clay-bearing, very fine-grained, basal Sheepbed member suggests suspension settling in a distal alluvial or proximal lacustrine setting and is thought to represent an ancient habitable environment [1]. The overlying cross-bedded sandstones and pebble beds of the Gillespie and Glenelg members are consistent with a fluvial environment dominated by bedload and suspended load transport [1].

Aeolis Palus. The rover encountered isolated outcrops of fine to coarse-grained cross-bedded sandstones and pebble conglomerates consistent with fluvial deposition at the Darwin, Cooperstown, and Kimberley waypoints [2-5]. In situ observations at the Kimberley waypoint also revealed the presence of generally southward-dipping, decimeter-thick sandstone beds [3,6,7] interpreted to represent a transition from fluvial to a fluvio-deltaic deposition at Kimberley consistent with transport from the northern Gale crater rim [3,6].

Lower Mount Sharp. The Curiosity rover encountered the first exposure of strata thought to represent lower Mount Sharp at the Pahrump Hills outcrop. The very fine grain size of sedimentary rocks within the Pahrump Hills outcrop implies that the primary mode of deposition occurred from suspension [8] in a proposed lacustrine environment [6].

Stratigraphic Relationship Between Peace Vallis, Aeolis Palus, and lower Mount Sharp: Four general models are considered [6,7] (Fig. 2):

Model 1. In this model, sediments exposed at Yellowknife Bay, Darwin, Cooperstown, and Kimberly onlap lower Mount Sharp (Fig. 2a), and the basal Sheepbed and Gillespie members of the Yellowknife Bay formation are considered to be part of a more recent episode of Peace Vallis fan deposition and are shown in a schematic onlap relationship with Aeolis Palus [9]. This model implies at least 3 episodes of fluvio-lacustrine deposition in Gale crater and 2 significant unconformities. In this model, lower Mount Sharp strata were both deposited and significantly eroded prior to the deposition of Aeolis Palus sediments. Sediments of Aeolis Palus were then eroded prior to the deposition of fluvio-lacustrine sediments of the Peace Vallis fan, including in this case the Sheepbed and Gillespie members of Yellowknife Bay. Although this model is most consistent with orbital geologic mapping studies [9-11], it is difficult to reconcile with: 1) the lack of a recognizable unconformity observed in situ within the Yellowknife Bay section, and 2) in situ observations of a lateral facies transition between Aeolis Palus fluvio-deltaic clinoforms and potential lacustrine deposits at Pahrump Hills.

Model 2. Model 2 (Fig. 2b) is similar to Model 1 in that the sediments of Aeolis Palus onlap lower Mount Sharp, but here the Sheepbed and Gillespie members of Yellowknife Bay are considered to be conformable with, and older than, overlying fluvial sediments of Aeolis Palus. This model still requires a significant unconformity between lower Mount Sharp and Aeolis Palus and does not account for the most recent deposition of the Peace Vallis fan.

Model 3. In Fig. 2c, the fluvial, fluvio-deltaic, and lacustrine sediments of Aeolis Palus (including the entire Yellowknife Bay section) inter-finger and are time equivalent with the hypothesized lacustrine deposits of lower Mount Sharp [6]. In constrast to Models 1 and 2, the lacustrine sediments of lower Mount Sharp exposed at Pahrump Hills are younger, although perhaps not significantly so, than the rocks exposed at Yellowknife Bay and throughout Aeolis Palus. This model implies relatively continuous fluvio-lacustrine deposition early in the formation of the Gale crater mound, prior to the period of erosion that shaped the mound to its present morphology.

Model 4. In Fig. 2d, the sediments of Aeolis Palus and lower Mount Sharp inter-finger as in Model 3, but the Sheepbed and Gillespie members of Yellowknife Bay are in onlap relationship with both Aeolis Palus and Mount Sharp, as in Model 1. In both Models 1 and 4, the lacustrine Sheepbed sediments are the youngest interval examined thus far, and are perhaps much younger, than both Aeolis Palus and lower Mount Sharp.

Implications: Each model has unique implications for the history of erosion and aqueous deposition in Gale Crater, particularly concerning the duration and timing of lacustrine depositional environments observed at Yellowknife Bay and Pahrump Hills. Given the current understanding of stratigraphic relationships at Gale crater, Model 3 (Fig. 2c) is most consistent with in situ rover observations, but continuing investigations at Mount Sharp, coordinated with geologic orbital mapping, will help refine the regional stratigraphic framework of ancient depositional environments in Gale crater.

References: [1] Grotzinger et al. (2014) *Science*, [2] Vasavada et al. (2014) *JGR-Planets*, [3] Rice et al. (2014) *GSA* Abstract #202-7, [4] Edgar et al. (2014) *AGU* Abstract #P42C-05, [5] Williams et al. (2014) *AGU* Abstract #P42C-06, [6] Grotzinger et al. (2014) *AGU* Abstract #P42C-01, [7] Stack et al. (2014) *GSA* Abstract #202-4, [8] Stack et al. (2015) *LPS XLVI* this volume, [9] Palucis et al. (2014), *JGR-Planets,* [10] Anderson and Bell (2010), *Mars*, [11] LeDeit et al. (2013), *JGR-Planets.*

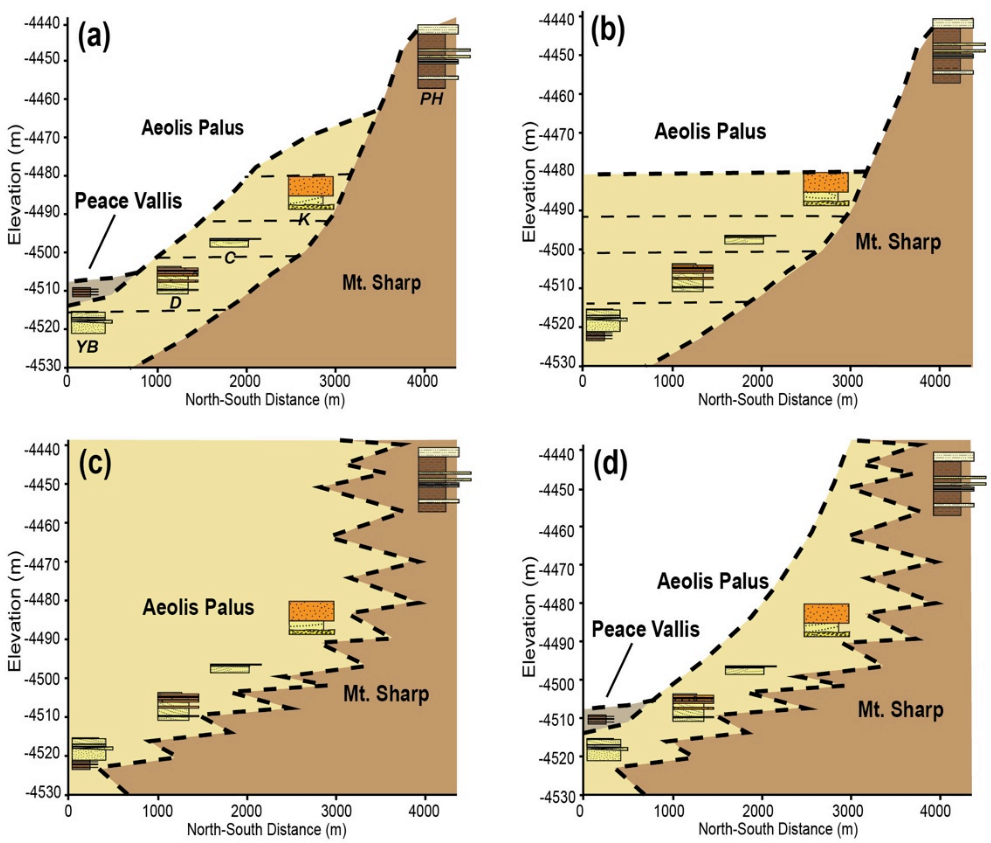

Figure 2. Stratigraphic models describing the relative age relationship between key stratigraphic sections examined by the Curiosity rover. YB = Yellowknife Bay; D = Darwin; C = Cooperstown; K = Kimberley; PH = Pahrump Hills