ASKIVAL: A SILICIFIED FELDSPATHIC CUMULATE SAMPLE IN GALE CRATER. J. C. Bridges[1], A. Cousin[2], V. Sautter[3], W. Rapin[4], S.P. Schwenzer[5], C. Bedford[5], V. Payre[6], O. Gasnault[2], O. Forni[2], P. Pinet[2], R. Wiens[6], A. Yingst[7] [1]University of Leicester, UK j.bridges@le.ac.uk [2]Institut de Recherches en Astrophysique et Planétologie, Toulouse, France, [3]Inst. de Minéralogie, de Physique des Matériaux et de Cosmochimie, Paris, France [4]JPL/Caltech, Pasadena, USA, [5]Open University, UK, [6]LANL, Los Alamos, USA. [6] EEPS, Rice University, Houston, USA,[7]Planetary Science Institute, USA.

Introduction: On sol 2016 of *Curiosity's* traverse in Gale Crater, at the Bressay locality, a group of float rocks were studied in detail. One of these – Askival – is a light toned rock with an igneous texture. Askival has a texture similar to Peacock_Hills, observed on sol 19 and Bindi (sol 544), suggesting that they represent a distinct type of Gale igneous float rocks, unique in the inventory of martian meteorites, and landing site igneous samples. ChemCam, APXS and MAHLI data gathered principally on Askival enable us to characterize these igneous rocks revealing a history of cumulate processes and subsequent alteration.

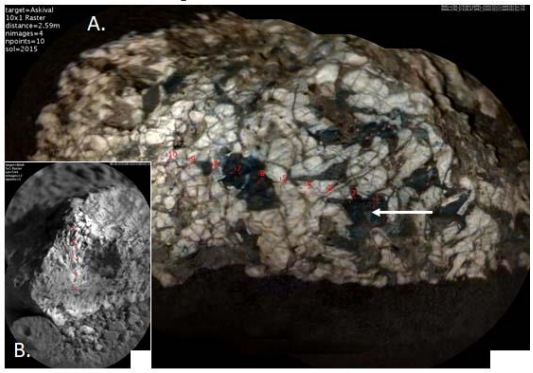

Figure 1(A). Askival Colourised RMI. 10 x 1 LIBS raster. A cumulate texture is seen with relict feldspar grains poikilitically enclosed by dark mafic phases. Possible amphibole arrowed. A network of fine veins is also seen. (B) Bindi feldspathic cumulate with 1x3 LIBS raster. 5 mm scale bars.

Methods: ChemCam contains a NIR laser and telescope within MSL's mast and 3 spectrometers inside the body unit [1,2]. It remotely analyses targets by Laser Induced Breakdown Spectroscopy LIBS, with optimal performance at ≤4 m, and also has a Remote MicroImager (RMI). Typically, there are around 30-50 laser shots on a single observation point in a raster (e.g. two 10 x 1 rasters and one 3 x 1 raster on Askival). ChemCam uses a combination of ICA and PLS to derive most major oxide compositions [3]. However, H_2O is determined with a univariate method [4]. The Alpha Particle X-ray Spectrometer (APXS) provided 3 complementary analyses on Askival [5]. This float rock was first identified during MSL operations using MastCam and MAHLI images.

Results: Askival is a 10 cm long, partially buried, float rock. It contains light-toned subhedral mineral grains (up to ±10 mm long) as well as dark and grey-toned minerals and veins (Fig. 1a). The light-toned grains (phenocrysts) comprise 65/70 % of the rock, and are in places poikilitically enclosed by the dark-toned assemblage which comprise 30/35 % of the rock. Dark veins crosscut the light toned phenocrysts. Minor sulfate veins are also present around the dark phases.

Bindi and Peacock_Hills Samples. The Gale samples most similar to Askival are the Bindi (Fig 1b) and Peacock_Hills float rocks, feldspathic cumulates, with images of Bindi in particular revealing a well-developed cumulate texture and ~80% feldspar [6,7].

Mineral Compositions. All but one of the LIBS spots on Askival show non stoichiometric compositions. Figure 2 shows that the light toned Askival compositions record a mixture of a relict intermediate plagioclase phase with SiO_2 in a 70:30 ratio. Silica-rich point analyses range up to >80 wt%. Point Askival#1 has SiO_2 34 wt%, Al_2O_3 6.8 wt%, FeO 28.4 wt% CaO 14.4 wt% and Na_2O+K_2O 2.1 wt% implying that it escaped the silica overprint, having low SiO_2 and H_2O (Figs. 1a, 2). This has similarities to ferrohastingsite [8,9], so the least altered mafic phases (Fig. 3) may contain amphibole of this or related compositions. LIBS also shows a traces of Cl, and in some of the mafic spots e.g. Askival #1 (Fig. 1, 3) fluorine is detected. Barium and Li are not elevated in Askival.

Hydration of Light Toned Phases. LIBS hydrogen analyses (Fig. 3) suggest an equivalent H_2O content in the relict feldspar grains of ~9-13 wt% H_2O. The dark toned phases show a correlation of SiO_2 with H, suggesting they have also been variably altered.

Discussion: Our compositional and textural data suggest that Askival was originally a plagioclase-mafic cumulate that has been silicified and hydrated. Identification of amphibole is not yet certain and there might be other explanations from mineral mixtures that we have not yet identified. Bindi is also a feldspathic cumulate but escaped this alteration, suggesting silicification was localised. The cumulate melt for these feldspathic cumulates is likely to be related to the trachybasalt/trachyandesite melt identified for many of the Gale igneous float rocks and clasts (Fig. 4) [6,7,10]. This in turn was formed through fractional crystallisation of an Adirondack-type melt [6].

Relatively intense alteration of the feldspar and mafic phases occurred as the Askival parent was silicified and hydrated, postdating the igneous processes. The fine network of veins (Fig. 1b) in Askival may be another sign of the mafic alteration though the exact nature of the altered mafic mineralogy is unclear. Minor sulfate veining may have occurred at the same time. Rhyolite-MELTS analysis is being performed to check our igneous with alteration model.

In situ silica remobilization has been identified in Gale sediments [11]. This is believed to have occurred under low temperature, diagenetic conditions. However, the absence of such alteration in other rocks of the Bressay locality indicates that the Askival silicification occurred prior to emplacement at its current position. Askival offers further evidence that extensive silica remobilization occurred in many parts of Gale crater and its immediate catchment. In addition to revealing plagioclase cumulate processes, possibly with a unique amphibole occurrence, Askival offers the only known example of silicification of igneous samples, adding to the diversity of known igneous samples on Mars [12-14].

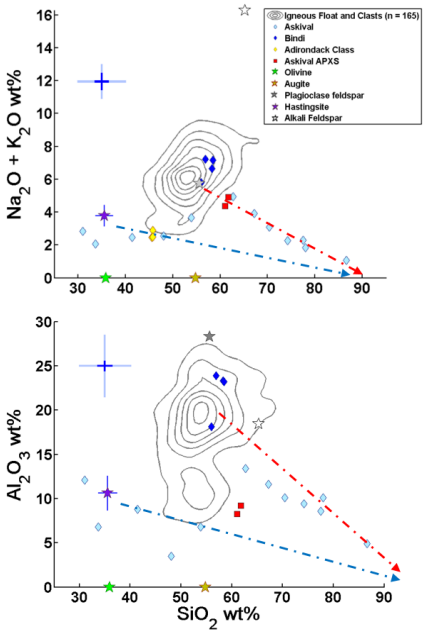

Figure 2. ChemCam, APXS analyses on Askival, and Bindi ChemCam. Density contour plots of Gale igneous basalt-trachybasalts plotted [6]. Red dashed lines show a mixing line between unaltered feldspathic cumulate represented by Bindi and hydrated silica. Blue dashed line silicification of mafic phase in Askival. The least altered mafic spot has a composition similar to nakhlite amphibole [8,9]. ChemCam 1σ precision and accuracy are shown as dark and light blue crosses.

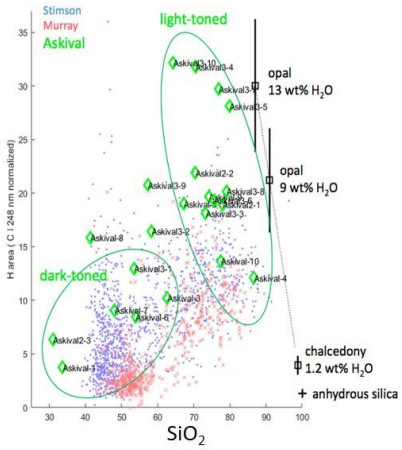

Figure 3. ChemCam hydration analyses of Askival. The least altered dark-toned phase (Askival #1) corresponds to an amphibole-like composition (Figs 1a,2). The light toned, relict feldspar grains show hydration and silicification equivalent to ≤13 wt% H_20. Stimson and Murray analyses shown for comparison. Technique described in [4].

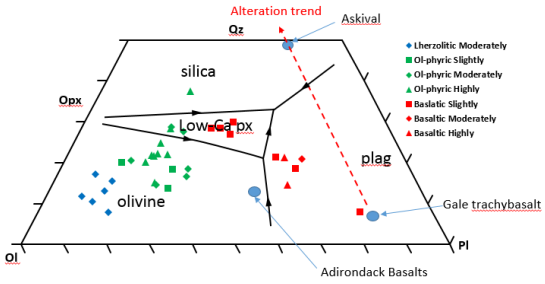

Figure 4. Ol-Pl-Qz phase diagram. Gale Trachybasalt focal compositions [4], Askival APXS, Adirondack basalts [13] and shergottite compositions. The diagram is consistent with Askival (and Bindi) forming through accumulation of feldspar from a trachybasalt type melt, followed by silicification and hydration. Oxygen molar units, adapted from [15].

References: [1] Wiens R.C. et al. (2012) *Space Sci. Rev.* 170 [2] Maurice et al. (2012) *Space Sci. Rev.* 170 [3] Clegg S.M. et al. (2017) *Spectrochimica Acta Part B*: *Atomic Spectroscopy* 129. [4] Rapin W. et al. (2017) *Spectrochimica Acta Part B*: *Atomic Spectroscopy* 130. [5] Gellert R. et al. (2009) *LPS* XXXX #2364. [6] Edwards et al. (2017) *MAPS* 52 [7] Cousin A. et al. (2017) *Icarus*, 288. [8] Sautter V. et al. (2006) *EPSL*, 252. [9] Giesting P.A. (2016) *MAPS*, 51. [10] Sautter V. et al. (2015) *Nat. GeoScience*, 8. [11] Frydenvang J. et al. (2017) *GRL* 44. [12] Schmidt M.E. et al. (2014) *JGR*, 119. [13] McSween, H. Y., et al. (2009) *Science*, 324, [14] Bedford C. et al. (2019) *GCA*, 246. [15] Bridges J.C. & Warren P.H. (2006) *J. of Geol. Soc. London*. 163.