BACKSTAY AND IRVINE: ALKALINE VOLCANIC ROCKS FROM GUSEV CRATER, MARS. H. Y. McSween[1], S. W. Ruff[2], R. V. Morris[3], J. F. Bell[4], K. E. Herkenhoff[5], R. Gellert[6], and the ATHENA Science Team. [1]Department of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN 37996, mcsween@utk.edu, [2]Arizona State University, [3]NASA Johnson Space Center, [4]Cornell University, [5]Astrogeology Branch, U.S. Geological Survey, [6]University of Guelph.

Introduction: Study of the Martian crust by orbital spectroscopy and SNC meteorites has so far only recognized subalkaline volcanic rocks. However, Spirit rover measured high alkalis and low silica in picritic basalts on the Gusev plains [1,2], allowing the possibility that alkaline differentiates might occur. Isolated rocks having mildly alkaline compositions and distinctive spectra have now been discovered in the Columbia Hills. Backstay and Irvine are the type specimens for these classes of rock. Both rocks have been characterized by the Athena instruments. They appear to be related to the Gusev plains (Adirondack-class [3]) basalts through fractional crystallization.

Field Occurrence: Backstay and other rocks of this class was encountered as float on top of the Cumberland Ridge at elevations >50m above the plains [3]. Irvine-class rocks occurred as aligned rocks on the summit of Husband Hill, suggesting that they might be a dike or sill, although imaging from several vantage points could not confirm that they were actually parts of an outcrop. Although all Backstay- and Irvine-class rocks could be ejecta blocks, their close spatial association and restriction to high elevations in the Hills may suggest a local magmatic source.

Both rocks are very dark and featureless except for small surface pits, and microscopic images (Fig. 1) reveal that they are aphanitic without the discernable megacrysts seen in plains basalts [1,2]. Backstay was brushed with the RAT, but Irvine was analyzed only as-is. Mini-TES observations suggest only minor dust cover. Backstay has the lowest albedo of any rock seen in Gusev. Both rocks are apparently unweathered, unlike the Hills outcrops [3].

Spectroscopy and Mineralogy: Pancam spectra of both rocks suggest the presence of significant amounts of orthopyroxene or pigeonite, with less olivine than in plains basalts. Opaque minerals are indicated in brushed Backstay but not in unbrushed Irvine.

Mini-TES spectra for these rocks classes are distinctive (Fig. 2) and serve to identify them in the field. However, thermal emission spectra cannot yet be deconvolved because of a dust coating on the pointing mirror. Synthetic spectra were produced from the normative mineralogy (see below), but they are a poor fit to the measured Mini-TES spectra. This may suggest an incorrectly modeled component, perhaps glass, in these rocks.

Mössbauer spectra indicate the presence of olivine, pyroxene, and Fe oxides (magnetite, hematite, nanophase oxides, and, in the case of Irvine, ilmenite). The relative proportions of these minerals, when adjusted for normative feldspar and apatite not detected by Mössbauer, generally agree with the calculated normative mineralogy (see below).

Chemistry: APXS analyses of alkalis and silica (Fig. 3) allow the classification of Irvine as basalt (with higher alkali contents than plains basalts) and Backstay as trachybasalt (hawaiite, with Na_2O-2.0 $\geq$ K_2O). These rocks are clearly alkaline and unlike any other rocks seen on Mars [4]. Normative calculations suggest Backstay and Irvine are composed of 55/36 wt. % sodic plagioclase (An_{24-27}, with high K_2O), 5/12% high-Ca and 16/33% low-Ca pyroxenes, 13/2% ferroan olivine (Fo_{64-55}), 13/16% Fe-Ti-Cr oxides (magnetite, ilmenite, chromite), and 3/2% apatite, respectively.

Petrogenesis: The compositions of Backstay and Irvine resemble those of some terrestrial alkaline volcanoes, such as Nandewar [5] (Fig. 4). The magmatic evolution of these mildly alkaline centers is characterized by strong increase in alkalis relative to silica in basaltic members and its moderation at intermediate compositions. Also shown in Fig. 4 is a liquid line of descent for a magma having the composition of Humphrey (the least altered Gusev plains basalt [1]), calculated using MELTS at 1 atm and QFM, an appropriate oxidation state for the measured Humphrey Fe^{2+}/Fe(total) [2]. A similar liquid line of descent, shown as a dashed line in Fig. 4, was calculated for fractional crystallization of the Nakhla (SNC) intercumulus liquid composition [6] at 1 atm and QFM. All of these magma trends approach the compositions of Irvine and Backstay, and the Humphrey melt calculation actually intersects both rocks (Fig. 4). Humphrey liquid lines of descent for other elements also intersect the Irvine and Backstay compositions.

We hypothesize that Irvine- and Backstay-class rocks formed by fractional crystallization of picritic basalt (Adirondack-class) magmas. These mildly alkaline magmas formed at low pressure, presumably in a near-surface reservoir, and may have been emplaced as dikes or sills, coevally with basaltic flows on the plains. The source of the plains basalts

has been suggested to be Apollinaris volcano or other proximal volcanic centers, although none of their flows have been traced into the crater [2,7]. However, it is doubtful that flows overtopped the Columbia Hills, so the occurrence of these alkaline rocks in the Hills and their inferred relationship to plains basalts may favor a local magma source under Gusev crater itself.

References: [1] McSween H. Y. et al. (2004) *Science, 305*, 842-845. [2] McSween H. Y. et al. (2006) *J. Geophys. Res., 110(E12S39)*. [3] Squyres S. W. et al. (2006) *J. Geophys. Res., in press*. [4] McSween et al. (2003) *J. Geophys. Res., 108(E12)*, 5135. [5] Nekvasil H. et al. (2004) *J. Petrol., 45*, 693-721. [6] Stockstill K. A. et al. (2005) *Meteorit. Planet. Sci., 40*, 377-396. [7] Martinez-Alonso S. et al. (2005) *J. Geophys. Res., 110(E1)*.

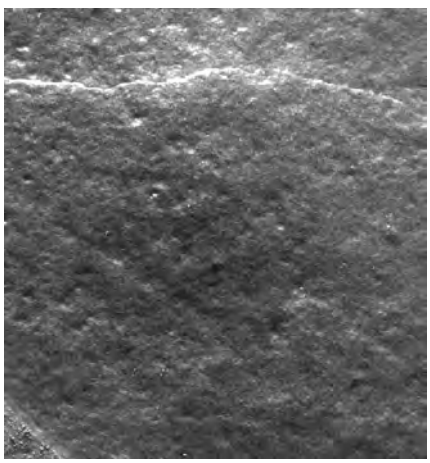

Fig. 1. Microscopic image (19 mm high) of brushed Backstay, which appears fine-grained and featureless.

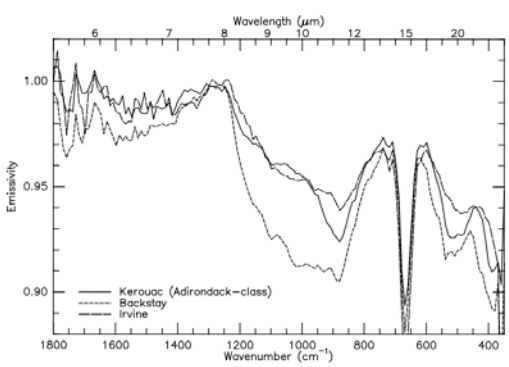

Fig. 2. Distinctive Mini-TES spectra of Backstay and Irvine allow them to be distinguished from Adirondack-class basalts (Kerouac) and other rocks in Gusev.

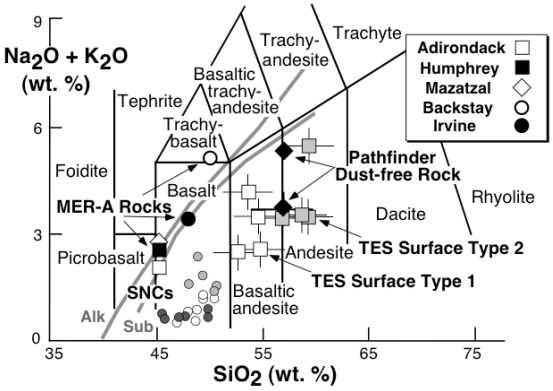

Fig. 3. Alkalis-silica classification diagram for volcanic rocks, showing distinction between alkaline and subalkaline rocks (diagonal gray lines). Spirit (MER-A) plains basalts and Irvine plot on this boundary, whereas Backstay is clearly alkaline. Subalkaline compositions of SNC meteorites, the Mars Pathfinder dust-free rock, and TES surface types from [4].

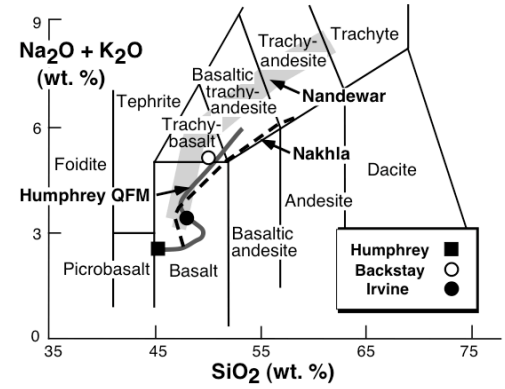

Fig. 4. Alkalis-silica diagram illustrating that the compositions of Irvine and Backstay plot along the calculated QFM liquid line of descent for Humphrey. This path is similar to the fractionation paths for rocks from the Nadewar alkaline volcano [5] and the Nakhla (SNC) intercumulus liquid [6].