IN THE EYES OF A ROVER: AN EDUCATIONAL GAME EXPLORING UBEHEBE CRATERS, DEATH VALLEY CALIFORNIA FOR iOS A.C. Williams[1], M.E. Schmidt[1], F. Amad[2], P.L. Bork[2], [1]Dept. Earth Sci, Brock University, St. Catharines, ON, Canada L2S 3A1, [2] Dept. Comp. Sci, Brock University, St. Catharines, ON, Canada L2S 3A1, aw16lt@brocku.ca

Introduction: A pedagogical tool was developed for secondary school students to explore Earth science concepts through an interactive game that simulates a robotic geologic traverse. The goal of the game is to solve a geologic problem that is relevant to planetary exploration: namely, *how to distinguish between a volcano and an impact crater?* By introducing students to a problem and providing the techniques to solve them, they will appreciate the options as well as the the limitations of using a rover to adequately describe a remote location.

Ubehebe Volcanic Field, Death Valley National Park, California was selected because the maar volcanoes appearing as cicular holes from orbit resemble the geology identified on Mars [1][2]. The Ubehebe Crater Volcanic Cluster formed during a sequence of late Holocene phreatomagmatic eruption and produced craters [3]. The game investigates two of the volcanic craters, including the largest Ubehebe Crater and Little Hebe, a smaller crater south of Ubehebe (Fig 1).

Fig. 1. Ariel photo of Ubebehe Crater and Little Hebe. Red-spots represent sites examined in the game. The red line represents the traverse.(GoogleEarth,2013)

Geologic description: Ubehebe Crater is the largest of the volcanic field (700–800 m across and up to 235 m deep). Base surge and air fall deposits ~50 m thick occur at the crater rim and thin radially outward over an area of >15 km^2 . There is evidence of a succession of lower Miocene red-brown and yellow conglomerate, sandstone and siltstone exposed in the crater walls (Fig 2). All Ubebehebe volcanic conduits cross-cut Miocene fanglomerate and sandstone, which are now distributed as comminuted matrix and rounded lithic clasts in all Ubehebe deposits [4]. The phreatomagmatic eruptions ejected both fragmental basalt and appreciable quantities of silt, sand, and quartz-bearing larger clasts (>10 cm. The ejecta provides evidence that up 50 individual eruptions formed the Ubehebe Crater [4].

The Little Hebe Crater (100 m across and 20 m deep) is located due south of Ubehebe Crater. The eruption was completely magmatic as indicated by a (4-5 m) high ledge of well vesiculated, oxidized scoria bombs and lapilli. Covering the surface of the crater are fragments of vesiculated pieces of basaltic scoria, and fined grained quartzite (Figs 3; 4a,b). In and around Little Hebe are thinly stratified Ubehebe Crater surge and airfall deposits, which suggests that it is older than Ubehebe Crater [4].

Methods: Data was collected at six sites. At four sites, a suite of images were collected, including an infinite panorama, a near field panorama, and microscopic images for select rocks within the near field panorama. Microscropic images are meant to be at a similar scale to those collected by the Mars Hands Lens Imager (MAHLI) onboard the Mars Science Laboratory (MSL) rover Curiosity. After imaging at the MAHLI-scale, these select samples were collected for laboratory analysis. At two sites, only infinite panoramas were conducted. A hand-held GPS was used to find the position of each site.

Image data collected include infinite panorama views, near field panaramas, and color microscopic images of select rock samples. A Gigapan EPIC Pro is a robotic camera mount that allows capture of gigapixel panoramic images at high resolution, depth and clarity. It was used to capture stunning gigapixel images of infinite and near field panoramas [5]. An image stitching software called PT Gui was used to stitch photographs into panoramic images and supports jpeg, tiff, png and bmp source images [6].

Whole rock geochemical analysis by X-ray Flurescence (XRF), was conducted on bulk powders at the Hamilton Analytical Laboratory. Mineralogical analysis, X-ray Diffraction is scheduled to be conducted at Brock University.

The iOS game application was built, compiled and written using Code IDE and Swift Programming language. The Site Explorer app was designed for iPad, iPhone devices, but can be installed and run on any iOS device running iOS version 9.0 devices.

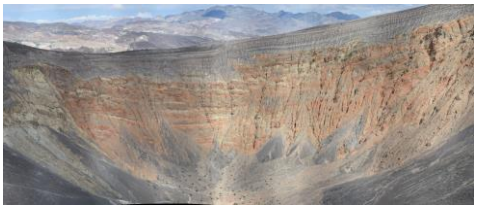

Fig. 2. Infinite Gigapan panorama compilation of 53 images spanning the north-east, south- east view of Ubehebe Crater (Site 6).

Fig. 3. Section of near field Gigapan panorama at Little Hebe Crater site 1 (56 images) showing upper surface of black, bedded tuff exposed on rim

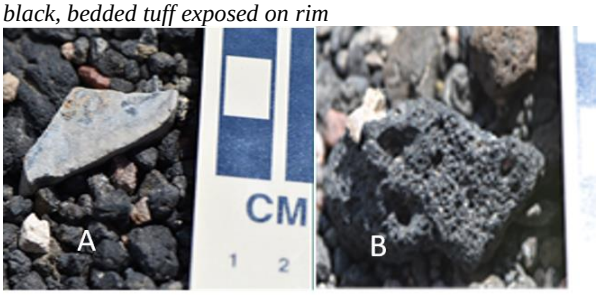

Fig. 4. A. MAHLI-scale image of angular accidencal quartzite clast (Little Hebe, Site 1). B: site 1: MAHLI-scale image of juvenile black scoria lapilli (Little Hebe, Site 1).

The Game: The premise of the game is the student plays the role of an explorer, controlling a rover on a Martian traverse. The job is to solve the question whether the craters were volcanic or impact. This can be solved by going through 6 sites collecting clues.

The game flow shows the repeated flow of the game: the map screen, explore site (panorama), pick up a rock (hints), choose what to analyse, view results, options to move to the next site, view log and solve the problem (Fig. 5).

The application is presented in high quality panoramic shots of the Ubehebe Craters, that the user uses touch gestures to navigate and collect clues. The clues are stored in a log. The clues include image, mineralogical and geochemical data for select the rocks. Example clues include: aphyric rocks with vesicles and black angular rock (Fig. 4). The log is used to keep track of clues and must be reviewed after each expedition. There are hints at each site to help analyse the rocks. There are two important resources in effect: Time and Energy. The user must play the role of an explorer, while he has limited time and energy at each site. The user has the option to move on to the next site or continue at the particular site.

Near the end of the game, the quiz screen will ask for the evidence at each site whether it is impact or volcanic. The final screen will show the final score of the breakdown of the number of clues, hints, remaining energy and time.

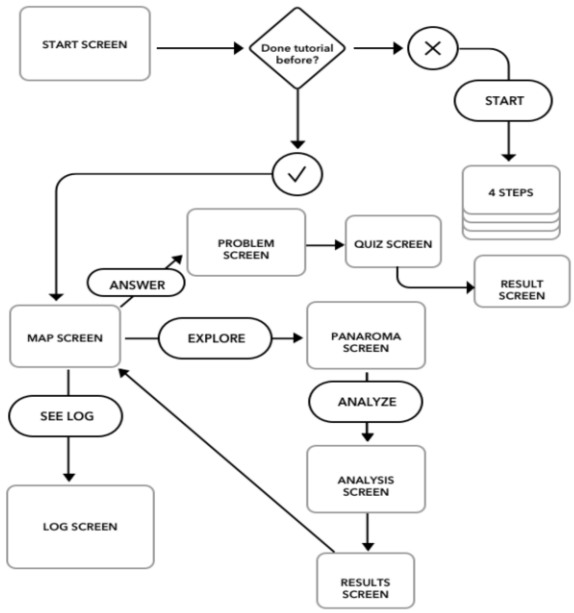

Fig. 5: Screen-action diagram of the Game Flow. The 4 steps described in the game flow are screens explaining the following concepts: Map, Log, Time and Energy and Problem.

Solving the geologic problem: To determine whether Little Hebe and Ubebehebe were created by impact or volcanic events, the user will need to identify several key findings in order to determine that the Ubehebe Volcanic Field was created by phreatomagmatic volcanic eruptions: 1. rock textures, including vesicles in basaltic scoria are the characterisitc of a volcanic eruption; and 2. The circular crater rims may be true for both impact and volcanic craters but volcanic craters have tephra rings and ejecta material. Solving these problems should be achievable for a student who understands the rock cycle and the formation and location of igneous rocks in volcanic setting.

References: [1] Squyres, S. W. et al (2007) *Sci* 316, 738. [2] Broz, P & Hauber, E. (2013) *J. Geophys. Res. Planets*, 118, 1656–1675. [3] Klinger, R. E. (2001). *FPP*, 21. [4] Fierstein J. & Hildreth W. (2017). *JVGR, 335, 128-146.* [5] B&HFoto & Elec. Corp. (2018). [6] PTGui software, ptgui.com.