

**CLASSIFICATION OF SHOCKED BASALT FROM VARGEÃO DOME AND VISTA ALEGRE: IMPLICATION FOR THE SEARCH FOR LIFE ON MARS** N. Posnov<sup>1</sup>, G.R. Osinski<sup>1</sup>, R.L. Flemming<sup>1</sup>, P.J.A. McCausland<sup>1</sup>, A. Pontefract<sup>2</sup> and A. Crósta<sup>3</sup>. <sup>1</sup>Centre for Planetary Science and Exploration/Dept. Earth Sciences, University of Western Ontario, London, ON, Canada ([nposnov@uwo.ca](mailto:nposnov@uwo.ca)). <sup>2</sup>Dept. of Earth, Atmospheric and Planetary Science, Massachusetts Institute of Technology, Boston, MA, USA. <sup>3</sup>Departamento de Geologia e Recursos Naturais, State University of Campinas, SP, Brazil.

**Introduction:** Impact craters have been demonstrated to present excellent targets for current (i.e. MSL) and future (i.e. ExoMars and Mars2020) life detection missions on Mars. Impact-processed crystalline targets present access to nutrients and energy and provide refugia for rock-dwelling (endolithic) microorganisms that would otherwise be exposed to extreme environmental conditions [1,2]. With over 635,000 impact craters on Mars that are one kilometer or greater in diameter, terrestrial analog studies are required to guide the selection of future life detection missions on Mars [3]. Porosity, fracturing, and differential mineral melting enhance the habitability of a host rock and its ability to support microbial life [1]. Grain mineralogy, textures and target rock porosity are heavily altered by hypervelocity impact events [4]. The relationship between the shock level and the porosity of the target rock was found to correlate strongly, with porosity increasing as a function of shock level [5].

Mars is a dominantly basalt-covered world, but terrestrial analog craters in basaltic targets are not prevalent [6]. Current classification of shock metamorphism in crystalline rocks is predominantly based on the alteration of quartz [7], which is excellent for terrestrial classifications but difficult to implement in quartz-poor basalts. As such, a new classification system is necessary in order to properly classify shocked basaltic rock, which is comprised primarily of plagioclase and pyroxene [8]. In a recent review, Stöffler et al. [7] attempts this by summarizing the diagnostic shock features of all major rock types. Quartz, however, is still heavily used as the main shock level indicator due to the paucity of data available for shocked plagioclase and pyroxenes. Through a comparison of the shock effects in plagioclase and pyroxene (i.e. planar fractures - PFs, planar deformation features - PDFs, extinction behaviour, onset of isotropization, formation of diaplectic glass, and shock melting) with known, calibrated effects in quartz, it is possible to attain a better understanding of the response of basaltic rock minerals to shock.

In this contribution, we provide the results of preliminary shock classification of basaltic rocks based on constituent minerals and their shock porosity. In addition, changes in bulk density are investigated with particular interest in samples with the greatest decrease in density (high porosity), as these samples

would theoretically have had a higher rate of microbial colonization and be good analog targets when searching for life on Mars.

**Field Sites:** Vargeão Dome (26° 49.0' S, 52° 10.0' W) and Vista Alegre (25° 57.0' S, 52° 41.5' W) are well preserved complex impact craters located ~100 km apart in the western portion of the Paraná Basin flood basalts of Brazil [9, 10]. A possible double impact origin is suggested based on the proximity and stratigraphic similarities of the two craters [11]. Both crater structures contain a central uplift, shatter cones, monomict and polymict breccias.

#### Methods:

**Shock Level Assignment:** A total of 28 samples of volcanic rock and tholeiitic basalts collected at various distances from the epicentre (recognized by the central uplift) of Vista Alegre and Vargeão Dome craters, were recognized as representative of a range of shock metamorphism and analysed in this study. Hand samples include monomict and polymict breccias, pseudotachylitic breccias and standard low shock rock samples (**Fig 1**).



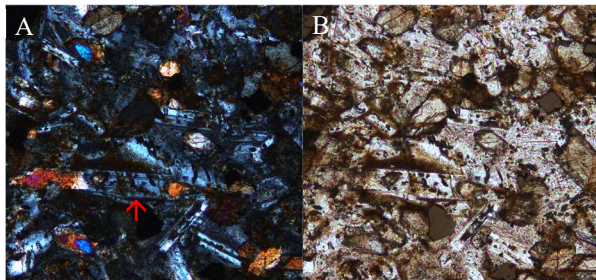
**Figure 1:** Photograph representative of the sample set. **A-** Monomict breccia. **B-** Polymict breccia. **C-** Rock with pseudotachylytes. **D-** Standard low shock rock.

Thin sections were characterized for shock metamorphism using a Nikon Eclipse LV100POL compound petrographic microscope based on Stöffler's newly updated classification system [7]. Shock features occurring in the samples were further investigated at both the mineralogical and

geochemical levels using a JXA-8350F Field Emission Electron Probe Microanalyzer (FE-EPMA) at Western University. Minerals with preliminary assigned shock levels were also examined using *in situ* micro-X-ray diffraction ( $\mu$ XRD) [12].

**Density and porosity investigation:** Grain density for samples was determined by helium pycnometry [13] using a Quantachrome Multipycnometer and bulk density was determined by the Archimedeian specific gravity method. Sample porosity, expressed as a percent value of the total (bulk) volume, was calculated from the grain and bulk densities rather than from the volumes because of slight changes in sample mass between the applications of the methods, especially for friable samples.

**Results:** Vista Alegre and Vargeão Dome basalts are dominated by plagioclase, in particular the intermediary mineral labradorite. With increased shock level, feldspar displays fracturing, a decrease in birefringence, diaplectic melting with loss of grain boundaries and flow. Few PFs are seen parallel to cleavage in K-feldspar (**Fig 2.**). No clear PDFs were observed in feldspar.



**Fig 2:** Transmitted light photomicrograph of plagioclase feldspar grains exhibiting twinning and planar features (red arrow). **A-** crossed polarized light. **B-** Plane polarized light.

The groundmass has intergranular and interstitial texture. Preliminary EPMA results show that basaltic matrix is composed of mostly labradorite (~55-70%), hornblende (25-35%) and ulvöspinel (5-10%). Quartz native to the basalts is sparse in our sample set, but when present shows the full range of shock features including fracturing, (decrease in birefringence) mosaicism, feather features, PFs, PDFs and partial diaplectic melting with loss of grain boundaries [7]. Quartz present in the Vista Alegre and Vargeão Dome craters is mainly found as a hydrothermal alteration product filling in veins and amygdulites. Secondary quartz lacks shock features suggesting the hydrothermal alteration responsible for the production of secondary quartz took place following the impact event.

This sample suite includes many samples containing garnet. Grains become more fractured with

increasing shock intensity. No PFs or diaplectic glass has been observed. Hornblende and pyroxene in these samples show fracturing, mechanical twinning, undulatory extinction and PDFs. Highly shocked biotite displays kink bands.

The shock effects identified in these samples range from level 0-5 (shock stage 0-3 IUGS 2007) which corresponds to shock pressures ranging from ~5 to ~70 GPa and post-shock temperatures ranging 0-900°C [7]. The shock effects seen in these samples include fracturing, planar fractures (PFs), planar deformation features (PDFs), and diaplectic glass.

Samples from the Vista Alegre impact show an increase in porosity with shock stage, from zero % porosity for non-shocked basalt (stage 0 [7]), 1.3% porosity for shock stage 1 basalt to 17.2% porosity for basalt with shock stage 3. These preliminary findings are in accord with results reported by [5] for the Haughton crater, where porosity ranges from negligible for unshocked target rock to 18.5% for highly shocked (stage 5) gneiss.

**Conclusion:** The present study reveals trends in porosity that support earlier conclusions observed in other shocked crystalline lithologies [e.g. 5]. Similar to Haughton impact structure (Devon Island, Canada), generally increased shock state correlates with increased porosity to the effect that shocked basalts in Vista Alegre and Vargeão Dome offer a higher porosity, high surface area environment which could likely make good habitats for endolithic microorganisms [2]. While shocked gneisses of the Haughton crater lacked evidence of microbial nutrient utilization, basalts are rapidly colonized because of the readily accessible, large source of metabolically relevant nutrients [2, 14] making shocked basalts better terrestrial analogue candidates for future Mars life detection missions.

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