

CHARACTERIZATION OF HYDROTHERMAL MINERALIZATION AT THE PRINCE ALBERT IMPACT STRUCTURE, VICTORIA ISLAND, CANADA. C. L. Marion¹, G. R. Osinski¹ and R.L. Linnen¹,

¹Dept. of Earth Science, Western University, London, Ontario, N6A 5B7 (cmarion3@uwo.ca).

Introduction: Evidence for impact-generated hydrothermal alteration has been identified at over 70 impact structures worldwide [1]. The heat generated from an impact is capable of inducing a hydrothermal system. Near-surface water is heated and circulates through the shocked, brecciated and melted target rocks. Evidence of this process is preserved in the form of precipitated and altered minerals as the fluids cool. For a detailed overview of impact-related hydrothermal systems see [1, 2].

A deeper understanding of hydrothermal systems on Earth is essential to develop understanding of these systems on other planetary bodies such as Mars. In this setting, liquid water, heat and dissolved nutrients may have been obtainable for a considerable amount of time making hydrothermal systems a suitable location to search for life beyond Earth [1]. In addition, hydrothermal deposits in impact structures can be economically viable natural resources [3, 4].

Objective: The goal of this study is to characterize the hydrothermal alteration products observed at the newly-discovered Prince Albert impact structure. Field studies consisted of systematic mapping and sampling in July 2012 followed by a series of laboratory investigations. In this summary, preliminary findings are presented.

Geological Setting: The Prince Albert structure is located on Victoria Island, NWT, in the Canadian High Arctic [5, 6]. The approximately 30 km-diameter structure is situated adjacent to Collinson Inlet on the Prince Albert peninsula. The target rocks consist of flat lying Cambrian to Devonian age carbonates, siltstones and shales. From oldest to youngest, the strata presently exposed include the Shaler Supergroup, the Cambrian-age clastic, tan dolostone and stripy units, the Victoria Island Formation and the Ordovician to Silurian Thumb Mountain and Allen Bay Formations. Based on target stratigraphy, the impact event is estimated to be younger than 350 Ma [5]. The structure has undergone considerable glacial erosion including the removal of all crater fill and ejecta. Shocked and uplifted basement rocks are preserved and covered by Quaternary glacial deposits. Topographic evidence of the crater is subtle and is overprinted by regional faulting.

Mineralization: Hydrothermal deposits at Prince Albert occur primarily in the form of vugs and veins.

Central Uplift: Carbonate vugs are abundant in thrust-faulted blocks in the central uplift, particularly as long (>1 m) narrow (< 25 cm) vugs. These occur parallel to steeply dipping dolostone beds and along

displacement planes. Cloudy quartz-rich vugs also occur in this setting, predominantly in the mudstones of the Shaler Supergroup. Finally, a fine-grained yet-unidentified red alteration occurs, both in the dolostone and mudstones, in cm-scale vugs and lining of carbonate vugs. This is likely from iron oxidation of sulfide minerals but is yet to be confirmed.

Central uplift periphery: The focus of the laboratory studies to date have been on a network of quartz-carbonate-sulfide veins in the southern periphery of the central uplift (Fig.1). The veins intrude a fine-grained dolostone host rock, of the Victoria Island formation and have a relatively consistent vein thickness of ~1.5 cm. The network is pervasive throughout the outcrop but has not been observed elsewhere in the impact structure. The orientation is generally subhorizontal but veins run both parallel to and cross-cut bedding as well as shattercones.



Fig. 1. Quartz-dolomite-sulfide hydrothermal vein in dolostone host rock of the Victoria Island Formation. Thumb (1.8 cm wide) for scale.

Vein mineralogy, as confirmed by Raman spectroscopy and scanning electron microscopy – energy dispersive x-ray spectrometry (SEM-EDX), consists of dolomite, quartz and marcasite with accessory amounts of sphalerite, pyrite and an iron oxide or hydroxide, possibly goethite.

The order of crystallization in the vein was ascertained through petrography. A thin layer of medium-grained dolomite crystallized, lining the contact with the fine-grained dolostone host rock. This was followed by the crystallization of coarse-grained quartz and finally marcasite-dolomite. Euhedral dolomite fills the majority of the central region of the main vein, and entirely fills thinner, quartz-poor veins. Corroded quartz grains and eroded quartz fragments within the marcasite-dolomite region suggest deposition from boiling fluids [7]. Marcasite-only vugs also occur in this outcrop.

Framboidal Pyrite: Pyrite occurs as $<5\ \mu\text{m}$ inclusions in growth zones, in clusters, and as framboids hosted by quartz. The latter are microscopic, 3-dimensional spheres (1–45 μm diameter) which consist of aggregates of sub-micron, euhedral pyrite crystals (Fig. 2). They occur within hydrothermal quartz and often along sealed fractures, alone or in clusters. Hypotheses for the formation of these structures are controversial and include direct bacterial, organic and inorganic processes [8]. In this case, the prospect of sulfate-reducing bacteria to form H_2S or HS^- to react with iron-rich fluids is intriguing. The astrobiological implications of thermophilic bacteria living within an impact-generated hydrothermal system on Earth are far-reaching. Isotopic analysis of sulfur in the pyrite should confirm a biogenic origin [9].

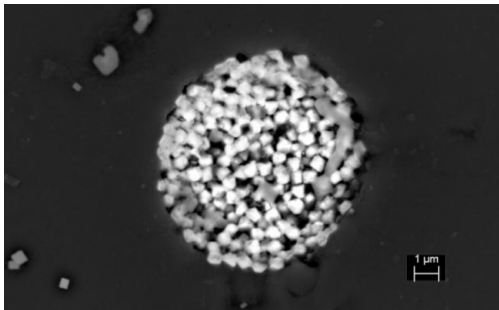


Fig. 2. SEM-BSE photomicrograph of framboidal pyrite (bright) in quartz (dark grey), from sample VI28C2.

Fluid Inclusion Studies: Fluid inclusion studies include petrographic analysis of the host rock and mineral, as well as analysis of fluid inclusion assemblages (FIAs). This is followed by fluid inclusion microthermometry through which pressure, temperature and fluid composition conditions at the time of entrapment are determined.

Primary and secondary FIAs have been identified in quartz in a preliminary study. Primary inclusions include liquid-vapour with $<10\%$ vapour and liquid-only inclusions. Secondary FIAs consist of vapour-only, liquid-only and vapour-liquid inclusions. Solid mineral inclusions are present and make up most of the prominent growth zones in the quartz. Complex cross-cutting relationships of fluid inclusions are present but not yet understood.

To date, freezing and ice melting of single-phase inclusions have not been observed and on cooling these inclusions do not nucleate vapour bubbles. Most liquid-vapour inclusions were too small to analyze ($<5\ \mu\text{m}$), however results have been obtained for two of the larger inclusions. The first inclusion (Fig 3A) was isolated and may be associated with the adjacent framboidal pyrite in that it occurs along the same growth zone in the quartz. Because the inclusion was trapped in the

near surface environment (low pressure) the trapping temperature is approximated by the homogenization temperature (T_h). The T_h of the inclusion is $83.6\ ^\circ\text{C} \pm 0.3$; freezing and melting temperatures were inconclusive. The second inclusion (Fig. 3B) had a T_h of $95^\circ\text{C} \pm 10$, a freezing temperature of $-34.1^\circ\text{C} \pm 0.2$, and final melting temperature (T_m) of $-4.1^\circ\text{C} \pm 0.1$. These values are representative of aqueous inclusions containing primarily H_2O and NaCl . Using the method described in [10], the salinity of the above mentioned inclusion is $6.5\ \text{wt}\% \text{ NaCl} \pm 0.2$. The moderate salinity indicates that the circulating fluids were not pure meteoric waters.

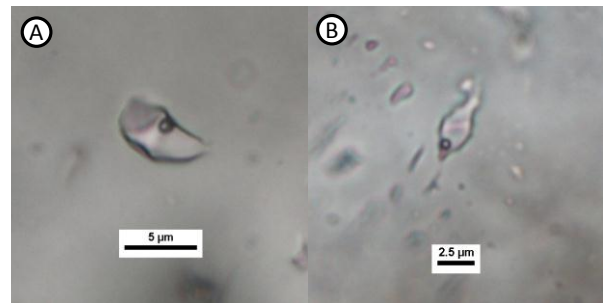


Fig. 3. Aqueous two-phase fluid inclusions in quartz from sample VI28C2, vein in Fig. 1.

Conclusions: Evidence to support the formation of the quartz-carbonate-sulfide vein as a product of the Prince Albert hydrothermal system is illustrated by: 1) establishment of syn- to post-impact timing by cross-cutting relationship with a shattercone; and 2) lack of a regional heating event post-impact to produce temperatures of $>80^\circ\text{C}$. A hydrothermal model has been suggested for the Houghton impact structure on Devon Island, NT of similar size and target lithology as Prince Albert [11, 12]. Continued study will include a comparison with this model.

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