Electric discharge evidence found in Pook’s Pebbles, new class of Chicxulub ejecta

G. Kletetschka, A. Ocampo, V. Zila, T. Elbra

1Faculty of Science, Charles University, Prague, Czech Republic (gk@natur.cuni.cz), 2Institute of Geology, Czech Academy of Sciences, Czech Republic, 3Geophysical Institute, University of Alaska Fairbanks, AK, USA, 4NASA Headquarters, Washington DC 20546, USA, 5Department of Infectious Diseases, Virology, University of Heidelberg, Germany

Introduction: Chicxulub impact (66 Ma) event resulted in deposition of spherules, melt glass, diamicrite and carbonate ejecta e.g. large polished, striated rounded pebbles and cobbles called Albion Formation [1] Pook’s Pebbles, named after first site identified in Cayo District, central Belize.

Methods and Results: We collected hundreds of samples from three distinct carbonate sections (Spheroid Bed, Diamicrite Bed, and Pook’s Pebble Bed) from the Albion Formation unit. The lowest unit is 1 to 2 m thick spheroid bed that lays on the preexisting karst topography and is rich in accretionary lapilli. The next deposited unit is 8-15 m thick Diamicrite bed. This material includes matrix supported clasts of angular to sub-rounded shape, some of them with well-preserved striated surfaces, and contains clasts over 5 m in size with accretionary rims. In central Belize, the Diamicrite Bed is absent and instead, directly overlaying the Spheroid Bed is ~ 4 m thick Pook’s Pebble bed [2]. The Albion Formation Pook’s Pebble Bed is a matrix- and clast-supported with sub-to well-rounded pebbles and cobbles. Over half of these carbonaceous pebbles have distinctive pits ranging from 1 mm to 1-2 cm in size. Portions of these pebbles have smooth polish with defined lineation that grade into striations. The Pook’s Pebbles are made of pink to white microcrystalline limestone sometimes with microfossils, and often contain cherty veins and nodules of microspherulitic nature. These nodules have high relief and a rough bleached surface that is surrounded by polished and striated surface. The Pook’s Pebble carbonate originates from early Maastrichtian as seen by common occurrence of fossil foraminifera [2,3]. The microfossils found in these pebbles are similar to the microfossils of the Yucatan platform target rocks [4].

The Albion Formation Spheroid Bed sampling site was located over three Chicxulub crater’s radii from the crater center. The Spheroid Bed contains clay spheroids (palagonite) which represent devitrification products from the impact glass that formed during the K-Pg Chicxulub impact structure formation [5]. Dolomite-containing spheroids are altered impact-derived accretionary lapilli [6] from the same event. We analyzed 19 oriented spheroids (1-3 cm in diameter) from the Spheroid Bed in Albion Island Quarry for directional magnetic analyses. One of the consolidated Spheroid Bed fragments was cut clean, and revealed devitrified glass, white spheroids, pink spheroids, and limestone/dolomite fragments. These were extracted and exposed to 2T magnetic field while measuring their magnetic moment with VSM magnetometer (LakeShore model 7300, at GSFC/NASA). Measurements of magnetic remanence and demagnetization by alternating magnetic field were done using vertical rock superconducting magnetometer system (SRM, Superconducting Technology, 2G Inc).

The Albion Formation Pook’s Pebble Bed is composed of sub- and well-rounded, polished, plastically deformed and striated, white and pink pebbles and cobbles in a clay rich matrix with degraded impact glass green spherules. Some of the Pook’s Pebbles carbonates comprise microfossils. 20 pebbles with polish and/or striations, with clast diameters ranging from 4 to 25 cm were analyzed. Nearly all (90%) Pook’s Pebbles were fine (~5 µm) grained pink recrystallized limestones with annealed carbonate crust shown by its polish. The pink color was not uniform and in thin sections appear patchy due to halos around small (~100 µm) hematite grains, indicating reduction/oxidation processes. Both hematite and goethite have been identified in spherule bed and likely contribute to the magnetization of this carbonaceous material. Oxygen-deficient water moving through the pores dissolved and re-precipitated nano-sized iron oxides around the preexisting iron oxide grains. These pebbles were abundant near the type locality Pook’s Hill Lodge in central Belize. Pook’s Pebbles are mostly flattened ellipsoids (68%), but also rod (15%) and spheroidal (18%) shapes are common [7]. All faceted. These facets, contain both interior and exterior rounded corners. While majority (80%) samples have pits, several (35%) have pitting that covers half of the clast [7]. Pits are elliptical to circular depressions with abrupt rims. The plastically deformed larger pits look like thumb impressions made in soft clay [7]. Typical pits are 0.3-2.0 cm in diameter and are about half as deep as they are wide. In a few examples the pits are much deeper, forming 0.5-2 cm deep holes that are 0.1-0.5 cm in diameter [7]. All Pook’s Pebbles have patches of a white, chalky calcite crust that covers on average 24% of the clast. The chalky crust is a few mm thick and composed of mostly 40-µm sized calcite crystals [7].
The crust contains about 1% sand and few larger clasts, which are abundant in a few (8%) samples. Patches of the crust form a gray, translucent, coarse (100 µm-sized) material from calcite recrystallization [7]. A few examples of this denser crust (8%) contain indentations 1-3 mm in diameter and striations abruptly truncated. 43% of the clasts have just one facet, mostly covered with crust. 42% of clasts with crust on one side have abundant pitting on the back side. Where the crust material is missing, the surface is often polished and/or striated and it seems that the crust has been stripped away by an energetic process. A fine polish occurs in patches along the surface. 15% with the harder gray translucent crust is also polished, including the small fragments that appear embedded in the crust. Parallel lines are common, occurring in sets of striations and in multiple directions, typically within marked 2-10 mm wide gouges.

Several thin sections from of the Pook’s Pebble carbonate clasts were made for microscopy examinations.

We used a non-magnetic saw to cut ~15 cm in length; 1.5 kg, Pook’s Pebble into three segments where the middle segment was ~1 cm thick slab. During the cutting, the oriented pebble was such that the long cut was in vertical plane, 11 degrees East from North so that the cut fragments were similar oriented in respect to the original pebble orientation mark. The arrow on the pebble indicated the strike and dip of the specific surface (N11E,90) and the resulting sub-fragments contain the same orientation direction. The slab from the pebble was then sliced into 52 individual cubes, each of them ~1 cm in size. Measurements resulted in a paleomagnetic direction for each sample along with the NRM intensity, and magnetization of saturation remanence (Msr).

Discussion and Conclusion: It appears that the Pook’s Pebble’s surface features are combined with the ablation features, as they were formed by particle interactions and collisions when the pebbles passed through a near-surface debris cloud and struck the regolith-covered Cretaceous land surface. Required ejection velocities of 1-2km/s to reach Belize produce trajectories that reach altitudes of ~100 km. Metamorphism along the Pook’s Pebbles’ surfaces suggests that some of the them may have experienced shock pressure up to 500 MPa along with the surface heating. Impact glass (devitrified) shows a distinct paramagnetic signature. Anomalous paramagnetism can provide with identification of impact glass fragments on the planetary surfaces. Note that the pink spheroids distinguishes this material from being diamagnetic or tending to become magnetized in a direction at 180 degrees to the existing magnetic field. This may be due to nanominalization of hematite. The overall magnetic remanent vector is parallel with the paleomagnetic direction at the time of the Chicxulub impact. There is some directional spread of magnetization. This may be either the evidence from the time of aerodynamic landing and/or the result of the sum of a magnetic vector acquired after the landing and the combination of the magnetization vector of the hot exterior with the cold interior containing a preexisting magnetization direction. Pebbles seem to vary in magnetic intensity due to larger amount of hematite. This shows as reddening of the Pook’s Pebble’s surfaces. Such color change is associated with larger magnetizations. Due to larger temperatures along the surfaces, the iron hydroxide (goethite)-containing dust reduced to hematite with large magnetization potential. In addition, the magnetic characteriztion of the Albion Formation Pook’s Pebble revealed that the directional and magnitude changes in magnetization of sub-fragments of Pook’s Pebbles is indicative of the exposure to electric currents that magnetized/demagnetized portions of the material with a non-homogeneous magnetic field. Such data may provide insights into the debris cloud environment during the initial phases of debris excavation. Furthermore, the magnetization remanence of the Albion Formation Spheroid Bed, show potential to be used as a signature for impact ejecta deposits during the detection by planetary rovers. Magnetometer on board of the rover would be capable to detect various types of ejecta and thus enhance the payload for future planetary missions. This work was just accepted for publication [8].
