Impact-induced magmatism on early Earth

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At the JpGU Meeting 2017, we reported the discovery of numerous fragments (<~3 mm in size) of stony meteorites and impact spherules of basalt in the lowest (i.e., the earliest) ~70 m section of the submarine Apex Basalt that overlies the ~110 m-thick Marble Bar Chert Member (MBCM; ca. 3.46 Ga in age) in the ABDP #1 drill core, which was recovered in 2003 at Marble Bar, Pilbara, Western Australia. We suggested that the asteroid body that produced the meteorite fragments was >10 km in diameter, impacted at ~40 km E of Marble Bar, terminated the deposition of the MBCM, and created a crater (“The Apex Impact Crater”) more than ~100 km in diameter. To test this hypothesis, in the summer of 2018 we conducted a geological survey of the proposed “Apex Impact Crater” utilizing a drone equipped with a high-resolution (4K) camera.

Our survey has revealed the presence of “impact tsunami deposits” at the boundary of the MBCM and the Apex Basalt. They are ~1-40 m thick, extending at least 20 km along the strike in the Marble Bar area. They contain numerous fragments (<5 mm size) of stony meteorites, together with various-sized (<1 mm to ~10 m), generally angular-shaped, fragments and blocks of the MBCM. We have also discovered ~15-40 m thick “impact tsunami deposits” underlying the Apex Basalt at ~80 km SE of Marble Bar. Numerous fractures (mostly perpendicular to the bedding planes, and many extending to 100s of meter into the underlying Duffer Formation), the dislocations and rotations of the MBCM in ~cm to ~100 m scales, as well as the “impact tsunami deposits”, were most likely created by an asteroid impact. Our survey has provided evidence that the ~3km-thick Apex Basalt represents the crater-filing komatiite/basalt lavas that were generated by the sudden decompression-melting of the mantle peridotites, triggered by a giant impact, and that the Mt. Edgar Batholiths (~3.46-3.43 Ga in ages), which intruded in the crater, probably represent the rebound of the older continental crust and the products of partial melting of the mantle peridotite and oceanic crust.

Our investigations suggest that the greenstone-granite complexes (“granite dome complexes”) that characterize the geology of the East Pilbara district may represent 8 or more craters created by impacts of asteroid bodies 10-30 km in diameter during the Archean. Consequently, the magmatism and tectonics of early Earth may have been dictated by gigantic asteroid impacts, rather than by the plume- and/or plate tectonics.

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