DISCOVERY OF POSSIBLE METEORITIC MATTER ON SHATTER CONES – 2. CLEARWATER EAST IMPACT STRUCTURE, QUÉBEC, CANADA.

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Introduction: Within the scope of the "Shatter Cone Coatings Project", we have been investigating shatter cones from several meteorite impact structures worldwide. Schmieder et al. [1] reported brecciated schreibersite and Fe-Ni oxide flakes on a shatter cone surface from Agoudal, Morocco, interpreted as remnants of an (iron) meteorite. Likewise, rare elements on shatter cones in limestones from the Steinheim Basin [2] were interpreted as meteoritic matter, probably altered and remobilized during impact-induced hydrothermal activity. Metal (Fe-Ni-Co-rich aggregates), phosphide (schreibersite), and oxide phases on shatter cone and slickenside surfaces from the Ries crater, as well as notable enrichment of Fe, Ni, Co, and P in associated surface coatings, may also represent possible traces of the impacting projectile [3]. We here describe the finding of potentially meteoritic particles on a shatter cone in a granitoid from the Clearwater East impact structure, Quebec, Canada.

Samples, Sample Locality, and Analytical Methods: The ~26 km diameter Clearwater East impact structure is located in northern Quebec, Canada, ~125 km east of Hudson Bay. Together with the ≥36 km Clearwater West crater, Clearwater East had been regarded as a ~290 Ma-old impact crater doublet [4]. However, recent Ar-Ar dating results suggest the East crater formed at ~465 Ma (West: ~286 Ma) [5], contradicting the double impact theory. As the entire East crater is submerged, impactites and rocks that constitute the crater floor are only available from drill cores obtained in the 1960s. The shatter cone studied here (~4×3 cm surface area) stems from a depth of 1442 ft (~439 m) in drill core 1-64 that penetrated some post-impact siltstones, a sequence of impactites, and the shocked crystalline rocks of the central uplift [6]. The shatter cone surface is covered by a thin grayish to green coating, which was petrographically and geochemically analyzed using a CamScan SC44 scanning electron microscope (coupled with an EDS detector) and a CAMECA SX100 electron microprobe (WDS) at the University of Stuttgart.

Characterization of Coatings: Electron microprobe analyses indicate the shatter cone coating is generally rich in Ca, Fe, Ni, and Co. On the shatter cone surface, we detected severel Fe-Ni-Co metal and metal oxide particles in the form of brecciated aggregates, flakes, and platelets. One of these metal particles contains ~89 wt% Fe, ~7 wt% Ni, ~1 wt% Co, and some Si (~2 wt%) and Al (~1 wt%). A second metal particle contains ~75 wt% Fe, ~20 wt% Ni, ~2 wt% Co, and also minor Si and Al. These compositions are characteristic of kamacite and taenite, respectively. Locally, the metal contains ≥40 wt% Ni and up to ~3 wt% Co. One sulfide particle contains ~62 wt% Fe, ~37 wt% S, and traces of Ni, and Co, suggesting this sulfide phase may be troilite. Flakes of Fe-Cr-Ni-Co-rich oxides also occur, composed of ~70 wt% Fe_2O_3, ~16 wt% Cr_2O_3, ~9 wt% NiO, ~1 wt% CoO, and subpercent SiO_2 and Al_2O_3.

Origin of Coatings and Discussion: One can speculate whether the observed enrichment of rare elements in the Clearwater East shatter cone coating could either stem from the target rocks, or whether it could be impactor-derived matter, mobilized during impact-induced hydrothermal activity. At Clearwater East, meteorite-derived elements are thought to have reacted with the target rock-derived impact melt and to have formed neocrystallized minerals, e.g., millerite (NiS) needles in the Clearwater East impact melt sheet [7]. Similarly, Kerrigan et al. [8] recently reported impact-induced hydrothermal mineralization, including millerite formation, in suevitic breccias at Clearwater East. The newly discovered occurrence of kamacite and taenite particles associated with the granite shatter cone surface suggests at least some of these particles may be primary relics of the Clearwater East projectile, probably an ordinary chondrite [9–11]. We note that all shatter cones so far tested positive for Ni- and Co-rich particles and coatings on their surfaces represent samples from the shocked structural crater floor. If the 'meteoritic' particles found on the Clearwater East shatter cone are indeed impactor-derived, a mechanism has to be discussed that is capable of injecting particulate relics of the impactor deeply into the target rocks, e.g., the temporary opening of fractures and/or collapse-related faulting during impact crater formation. We underline that shatter cones hold a high and underexplored potential in the identification of possible projectile fingerprints in terrestrial impact structures [1].

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