SO MANY IMPACT CRATERS IN SOUTHEASTERN WYOMING: SECONDARY CRATERING ON EARTH

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A large number of small impact structures have recently been discovered in southeastern Wyoming, USA [1, 2]. The crater field in its current extent is situated within a triangular region between Casper, Douglas and Laramie in Wyoming´s Converse and Albany Counties. Thirty-one crater structures ranging in size from 10 to 70 m diameter with corresponding shock features, but missing meteorite relics have been documented. More than 60 possible additional craters have been identified. All craters occur along the outcrops of the uppermost Permo-Pennsylvanian Casper Sandstone Formation in immediate contact to the Opeche shales of the Goose Egg Formation, and are approximately 280 Myr old. Due to their stratiform occurrence we infer that all craters were formed at the same time in a single event.

The craters partly overlap and form clusters and ray-like alignments. The degree of preservation of the craters varies considerably from almost pristine morphologies with preserved crater rim and proximal ejecta blanket to strongly degraded structures. Several craters have elliptical morphologies that allow the reconstruction of impact trajectories. The trajectories project to an area in the Northern Denver Basin at a distance of 150-200 km from the observed craters.

Secondary cratering appears to be the most plausible mechanism to explain the spatial distribution and characteristics of the craters. Observations that support the secondary cratering model are: (i) The wide area of occurrence of the craters (90 x 40 km) is incompatible with a formation by the break-up of a single meteoroid during passage through the atmosphere. (ii) The elliptical crater morphologies and aligned crater chains allow the reconstruction of trajectories that meet in a single area. (iii) The relative abundance of elliptical crater morphologies and the partly irregular crater shapes suggest relatively low impact velocities, which is compatible with secondary crater formation. (iv) The presence of radial crater chains and irregular crater clusters is also known from secondary craters formed on the Moon or Mars. (v) Commonly, small craters a few decameters in size are associated with relics of iron meteorites. The absence of iron meteorites in the Wyoming crater field is compatible with an ejection process from a primary crater as the cause of crater formation. As we did not observe any foreign rock types in the craters, we assume that the ejecta are also mainly composed of quartz-dominated rocks such as sandstones or other felsic rocks. (vi) We found linear ejecta accumulations close to crater SM-1 that are reminiscent to herringbone patterns formed by the interaction of ejecta of the primary and secondary cratering process. (vii) We found massive chert beds that contain spherules at the event horizon that may represent accretionary lapilli. Such spherules cannot form in small craters because the shock level is not sufficient to either form melt of a significant volume or to develop a hot plume above the small craters. The presence of possible accretionary lapilli mixed with the ejecta of the small craters indicates that a presumably hot ejecta plume existed and interacted with the local ejecta distribution. (viii) Calculations of ballistic paths of hypothetical ejecta boulders showed that 2 m radius ejecta, launched at 3 km/s or 4 km/s and 4 m radius ejecta launched at 2 km/s reached the distance where the craters are observed. (We calculated 1, 2 and 4 m radius ejecta, leaving the primary crater at speeds of 1, 2 and 4 km/s and launch angles of 30 to 60°.) The impact velocities of these ejecta range from 500 to 1000 m/s. We used such impact conditions to simulate the crater formation process with the i-SALE shock-physics code and suitable equation of state for porous and non-porous quartzitic rocks [2]. Modeled secondary craters form with diameters ranging from 10 m to 55 m at 150-200 km distance from the proposed primary crater, which represents a good matching to the measured crater sizes. (ix) Crater simulations also allowed to determine the volume of shock in the small craters: Impacts at 500 m/s generate no material shocked to pressures greater than 3 GPa. Impacts between 500 m/s and 1000 m/s generate between 0 and 10% of shocked material of the impactor's mass. These findings are also qualitatively fitting to the overall sparse shock overprinting of the craters.

This is ongoing research with many open questions to be addressed. We conducted a new field campaign in April 2022, at which we investigated and sampled known and additional possible craters. Some of the craters were mapped by a drone at high resolution. With this new endeavor we hope to better constrain the dimensions of the secondary crater field and to narrow down the location of the hypothetical primary crater. We also obtained drilling chips from a deep borehole in the northern Denver Basin (I-35 Hawk Fee). These chips are from near the area of the suspected buried primary impact structure and will be screened for shock and impact deformation.

References:

[1] Kenkmann, T., et al. (2018) *Scientific Reports* 8, 13246. doi: 10.1038/s41598-018-31655-4. [2] Kenkmann, T. et al. (2022) *GSA Bulletin*. doi.org/10.1130/B36196.1.