TRIASSIC CRATERED COBBLES: SHOCK EFFECTS OR TECTONIC PRESSURE?

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Introduction: The Triassic age marked a global mega-monsoonal climate and large river systems that distributed gravels, mostly eroded from older metamorphosed Precambrian or Paleozoic rocks, across Pangea. Possible shock deformation fabric elements have been suggested to occur in conglomeratic deposits of the Upper Triassic Shinarump of northern Arizona [1], in the Lower Triassic Buntsandstein of northeastern Spain [2], and in the Upper Triassic Quaco Formation of the New Brunswick, Canada [3]. All 3 conglomerates contain quartzite clasts having percussion marks or brittle deformation features of millimeter- to centimeter-sized bright circular marks (halos), surrounded by radial fractures that trail away from the halo. The interpretations that Shinarump and Quaco cobble halos are shock effects were based on their similarity to those in Buntsandstein cobbles. Buntsandstein cobble marks previously had been attributed to post-depositional clast-to-clast impact deformation during proposed Azuara and Rubielos de la Cérida impact events [2]. Shinarump percussion marks were suggested as impact damage from nearby Meteor (Barringer) Crater [1] and Quaco marks were linked to the Manicouagan impact event [3]. Conglomerates of many ages worldwide show these same types of marks and there are several problems with the interpretation of shock effects in these specific conglomerates. For example, Bundsandstein conglomerates with pitted cobbles (1) occur not only in the vicinity of both proposed Spanish impact structures, but also in large areas up to 70 km away, (2) the depth of clast indentations does not vary systematically with distances from the impact structures, and (3) underneath clast indentation sites there is no confirmation of internal deformation within quartz grains [4]. Additionally, although both Azuara and Rubielos de la Cérida basins were suggested to be Late Tertiary impact structures [5], compelling impact evidence is unconfirmed [6, 7] and they no longer appear on the Earth Impact Database [8]. However, as halo marks on cobbles are continuing to be used as evidence of impact [1, 3], we decided to investigate these claims and begin our study with the Shinarump cobbles.

Cobble Studies: Percussion halos on Shinarump conglomerates occur only within clast-supported lithofacies which cap mesas near Holbrook and Winslow, Arizona [1]. The mesas are about 130m in maximum height and the conglomerate caps range from <1m to 6m thick. The marks are observed (1) at contact points between adjoining in-situ cobbles and therefore did not form by current rolling during deposition, (2) only on surfaces with no cement nor matrix between clasts, and (3) in all directions including vertical. Vertically oriented halos imply these outcrops were buried when fracturing occurred. Meteor (Barringer) Crater has been dated at 49,000 ± 3,000 years old [9]. Allowing for about 10 meters of Colorado Plateau uplift in the past 50,000 years [10], these conglomeratic caprocks would likely have been above ground at the time of impact. Seismic shock radiating horizontally from Barringer Crater would not form vertical halos on surface deposits. Impact from the 1-km-diameter crater did not even generate enough ground motion to disrupt these poorly cemented conglomerates 40 to 80 km away (distance to Winslow and Holbrook), as no faults occur within outcrops. However, there is always the possibility that the marks could be impact-related, if our logic is incorrect or if they are a result of an older unknown structure long since eroded away. To try to definitively establish the origin of the halo marks, we decided to pursue a thorough examination of these cobbles.

Shinarump cobbles are mostly reworked PreCambrian quartzites (metamorphosed sandstone and siltstone) and gneiss clasts [11, 12]. Matrix-supported cobbles differ from clast-supported conglomerates in several ways: (1) circular dissolution pits form instead of bright halos, (2) pulverized zones may occur beneath the pits, (3) clasts may be cracked, and (4) clasts often have a sugary surface texture of druzy quartz. These attributes suggest overburden pressure solution removal of quartz and surface deposition of removed material. Only a sand-grain thickness of matrix is needed to form a pit versus a halo. Thin-sections of halo marks on several quartzite clasts show no clear indication of shock features. There is no pervasive grain shattering, and incipient fracture damage seems limited to a narrow zone near points of contact between adjacent cobbles. Larger grained quartzites show "planar features" visible in optical microscopy that appear to be Bohm lamellea or healed basal plane fractures, now marked as layers of fluid inclusions. While this kind of damage certainly does occur in shocked target rocks, it is very common in rocks subjected to (1) strong tectonic/seismic forces, (2) burial and metamorphism, or (3) a combination of weak seismic force and deep burial. In order to form fluid inclusions in lamellae, the Shinarump cobbles had to be buried deeply enough to have been immersed in a surrounding fluid, had to subjected to enough pressure to crack and force the fluid into the fractures, and had to have enough time pass to allow the lamellae to heal. The healing process can take more than 100,000 years (60,000 years beyond the age of Meteor Crater). We have prepared samples for future fluid inclusion studies by Mark Evans of Pittsburgh University. These studies will determine the composition of the inclusions, burial depth, and healing time. If we can bracket a time when these marks formed and how deeply they were buried, we may be able to definitely rule out an impact origin.

This type of information may support or negate claims for the Buntsandstein and Quaco cobbles, as well. For example, although the Upper Triassic Quaco Formation cobble marks were previously attributed to percussion during fluvial transport [13], this is not likely because halos match in-situ, adjoining clast contacts. The marks were recently reinterpreted as impact-induced, but no clear indications of shock features were reported [3]. Manicouagan has been radiometrically dated at 214 ± 1 Ma [14] and rocks of the Fundy Basin are poorly age constrained. However, the Quaco conglomerate correlates to the lower Stockton Formation in the well-dated Newark Basin, which is within the 221 to 227 Ma Carnian age bracket (Paul Olsen, personnel communication 1/8/04) and a horizon that could have been affected by Manicouagan. Alternatively, outcrop photos and descriptions of the Quaco conglomerate clasts also indicate dissolution pits [15], similar to the Shinarump conglomerate, suggesting pressure and burial. If fluid inclusion work suggests a much younger age for the Quaco halo marks, then a link to Manicouagan can be ruled out. In addition, if Buntsandstein marks are older than Late Tertiary, they could not have been formed by the putative Spanish impact events. Therefore, to complement the Shinarump cobble fluid inclusion studies, we intend to collect and prepare Quaco and Buntsandstein cobbles for similar examination.

Conclusion: It is very unlikely that halo marks on Shinarump cobbles are impact damage from Meteor Crater. Halo marks on cobbles are just too problematic to definitively relate them to impact-induced causes without substantial supporting evidence. These marks could be generated by any small seismic event or enough burial pressure. Hopefully, our fluid inclusion studies will add clarity to the debate.

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