SHOCK DEFORMATION AT DEGRADED IMPACT CRATERS: THE SANTA FE STRUCTURE

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Introduction: Documenting diagnostic evidence to confirm hypervolcity deformation at ancient or degraded impact structures remains a challenge for recreating the terrestrial impact history. This challenge is magnified for investigations focusing on the the early Earth, but equally applies to any poorly preserved structure. Santa Fe is a confirmed impact structure located near the city of Santa Fe. Its age is likely Mesoproterozoic to Paleozoic [1-3]. Its size is also poorly known, but may be ~9-12 km in diameter based on scaling laws. The focus of this review is to summarize evidence of shock deformation reported at the Santa Fe impact structure in the broader context of considering how best to document diagnostic impact evidence at degraded impact structures.

Evidence of Impact at Santa Fe: The principle challenges in studying the Santa Fe impact structure is that it is tectonically dismembered, it may be bound by fault blocks, it is deeply eroded, and it is located in a high-relief, forested area with a complex geologic history spanning nearly two billion years. No geomorphic structural features (e.g., rim or central uplift) or geophysical anomalies suggestive of an impact structure have been reported. While regional occurrences of brecciated granite have been reported, no unequivocal impact melt rocks or breccia definitively related to impact have been described. Despite these challenges, evidence for diagnostic shock deformation have been documented in both bedrock and sediment with sufficient detail to confirm an impact origin.

Shatter Cones and Shocked Minerals: Shatter cones at Santa Fe occur in granitoid, schist, and amphibolite, and are well-exposed along Highway 475 [1-3]. Shocked quartz grains with decorated planar deformation features (PDF) in (0001) and {11-21} were documented in some shatter cones [1]. Detrital shocked quartz with decorated PDFs (**Fig. 1A**) has also been found in local drainages [4]. Shatter cones and shocked quartz have been interpreted to record conditions <10 GPa [1]. Xenotime with deformation twin lamellae in {112} (**Fig. 1B**) were documented in a shocked-quartz-bearing shatter cone in granite [5]. While formation of twin lamellae in xenotime has not been calibrated by experiment, the presence of shocked quartz with decorated PDFs and the absence of high-pressure YPO_4 phases were cited to interpret formation conditions from 5 to 20 GPa [5]. Zircon grains with {112} shock twin lamellae (**Fig. 1C**) have recently been described from Santa Fe; they occur as detrital grains, and also in shatter cones [2,3]. Shock-twins in zircon form at 20 GPa or higher [6], and thus represent the highest pressure phase thus far reported from the Santa Fe impact structure. Other putative shocked minerals have been reported from Santa Fe, including shocked apatite [7] and shocked muscovite [8], however the conditions under with impact-generated microstructures form in these minerals have not been well-calibrated.

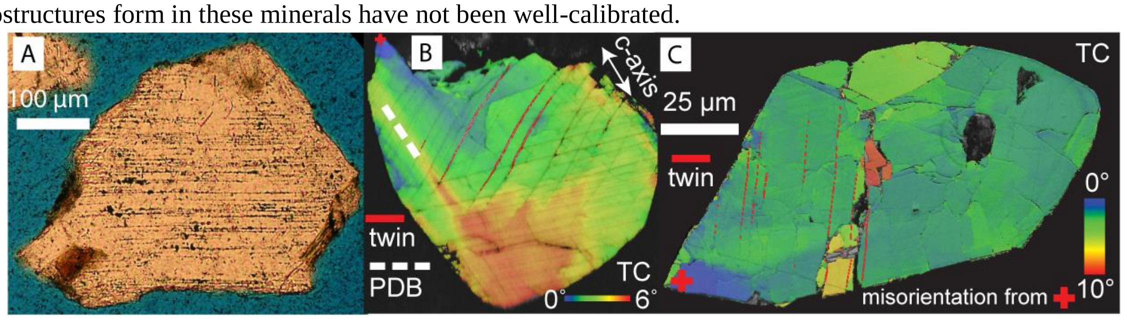

Figure 1. Examples of shocked minerals from the Santa Fe structure. **A**: Detrital shocked quartz from Little Tesuque Creek with one orientation of decorated PDFs (horizontal), transmitted light [4]. **B**: Shocked xenotime from a granite shatter cone on Highway 475 [5]. Three orientations of {112} deformation twin lamellae (red) and planar deformation bands are visible (texture component map). **C**: Detrital shocked zircon from colluvium near Chamisa Trailhead [2,3]. One orientation of {112} deformation twin lamellae (red) are visible (texture component map).

Conclusion: Santa Fe is a case study that highlights challenges to discovery of new impact structures. One can ask, in the absence of shatter cones, would the Santa Fe structure have been discovered? And what if the majority of intact impact structures that are not buried have been described- what's next? Our studies at Santa Fe and elsewhere highlight the application of new shocked accessory minerals such as xenotime [5,9], and also the ubiquitous presence of detrital shocked minerals that preserve evidence of eroded impact structures in the sedimentary record [10].

References: [1] Fackelman et al. 2008 EPSL. [2] Montalvo et al., 2017 GSA Bulletin (in review). [3] Montalvo et al., this volume. [4] Cavosie, unpublished. [5] Cavosie et al. 2016 Geology. [6] Morozova, 2015. [7] Cavosie and Lugo, 2014 LPSC. [8] Colón and Cavosie, 2014 LPSC. [9] Cavosie et al., this volume. [10] Cavosie et al. 2010 GSA Bulletin.