DOUGLAS IMPACT CRATER STREWN FIELD, WY, USA: A PROGRESS REPORT.

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Introduction: Douglas is a collective term for a recently discovered strewn field of small impact craters found on the Sheep Mountain anticlinal range of the eastern Rocky Mountains in Wyoming.

Five circular depressions on Sheep Mountain were first recognized in a master thesis by A. Spelman in 1959 [1], who did not interpret their origin. In an undergraduate fellowship report by H. Kastning and P. Huntoon in 1996 [2] these depressions were interpreted as small impact craters – however, without providing proof for the validity of this hypothesis. This report stimulated a survey of these craters in 2017, in which shock metamorphism could be demonstrated and the size of the strewn field [3-5] was enlarged. The current state of knowledge is given in [5] and is briefly summarized below. The present investigation focuses on the microstructural proof of the impact origin of further crater depressions of this strewn field that were not yet analyzed. This is a progress report and includes implications concerning the formation of this large crater strewn field.

The Douglas crater strewn field: More than 40 circular to ellipsoidal possible impact structures have been identified on the northeast flank of the Sheep Mountain anticline near Douglas, WY, USA, centered on 42°40'38"N, 105°28'00"W [5]. The crater structures are exposed in the uppermost sandstone of the Permo-Carboniferous Casper Formation. The diameters of the crater pits range from 16 to 100 m. The previously reported strewn field size had a minimum length of 7.5 km in southeast-northwest direction and a width of 1.5 km. Many of the "craterlings" have the geomorphology of a simple, bowl-shaped impact crater with a raised rim and overturned flap, apparently continuous ejecta blankets, and ovoid shapes oriented SE to NW coincident with the strike of the strewn field. Based on crater structure and ejecta distribution, an impact from the southeast towards the northwest has been inferred [5]. Other craters exhibit lesser quality of the described features and are variably rated "possible" to "probable". Prior to this study, shock metamorphism had been demonstrated in seven of the crater pits by the documentation of indexed planar deformation features (PDFs) and planar fractures (PFs) of various crystallographic orientations in quartz [5]. It was documented that the deformation affected rounded quartz grains but not quartzitic overgrowths on them. This implied that the impact occurred in unconsolidated sand prior to diagenesis. Fractures and PDFs are massively decorated with fluid inclusions suggesting that pore space was filled with water during impact. The craters have been exhumed from beneath the red-colored shales of the Permo-Triassic Goose Egg Formation and are formed in very resistant Casper sandstone. Strata were tilted by 15° east-northeast during the Laramide Orogeny during the Upper Cretaceous and Paleogene. The craters occur only in a narrow stratigraphic band along strike at the top of the Casper Formation. The impact age was inferred from the age limits placed by regional stratigraphy as 280 Myr [5].

Methods: Polished thin sections of rock samples were prepared and examined with a LEICA DMR polarizing microscope. Shock lamellae were investigated at 500x magnification. Orientations of planar microstructures in quartz grains, including PFs and PDFs were measured with a four-circle LEITZ U-stage mounted onto a LEITZ polarizing microscope. Measurements were then indexed using a template for crystallographic orientations in quartz. The accuracy of U-stage measurements is estimated at ±5°.

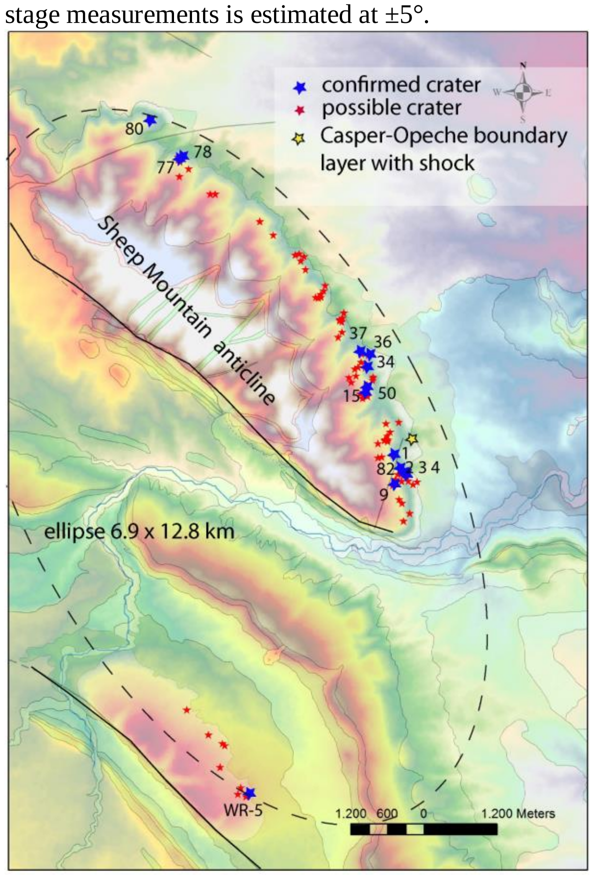

Fig.1. Douglas crater strewn field ellipse constrained by 14 confirmed craters and the inferred impact direction

New results: Meanwhile we have inspected 98 thin sections of Casper sandstone samples of 29 possible impact craters of the crater strewn field. We found PDFs and PFs in quartz grains in 14 of the crater pits (Tab. 1) and additionally in a nearby stratigraphic profile that comprise a continuous section from the Casper Formation to the Opeche Member of the Goose Egg Formation. In total we found so far 55 quartz grains that contain either PDFs or PFs or both in 40 thin sections. Some grains show crosscutting sets of PDFs. Various crystallographic orientations of the lamellae were measured for both PDF and PF lamellae (Tab.1). Feather features have not been observed in any of the samples. With a mean grain size of the Casper sandstone of 200-300 µm and approximately 1.5 shocked grains per thin section, one out of 6000-7000 quartz grains exhibits a shock metamorphic overprint. The vast majority of quartz grains show intense brittle deformation. Among the new confirmed craters is one that lies not on the Sheep Mountain anticline but further south on a the Sage Hen Anticline within the same exposure of the uppermost Casper sandstone in transition to the Opeche Member of the Goose Egg Formation (Crater WR-5; Table 1). This crater outlier of about 50 m diameter is situated about 9 km south of the center of the previously determined strewn field ellipse [5] and expands the inferred crater strewn field ellipse to a minimum of 6.9 km by 12.8 km (Fig.1).

With increasing size and width of the crater strewn field a classical atmospheric break-up scenario of a single bolide becomes more unlikely [6]. Alternative scenarios to explain the wide extent of the strewn field may include: (i) Multiple airbursts of a single or paired meteoroids at high altitude, (ii) an asteroid break-up prior to atmospheric entry, (iii) an asteroid shower. Alternatively (iv), the craters may represent a section of a secondary crater field around a large, yet unknown crater that should be located several hundreds of kilometers SE of the current exposure somewhere buried near the Colorado-Nebraska-Kansas boundary. Likewise, a possible connection to the 7 km diameter Cloud Creek crater [7], situated 120 km NW of the strewn field along the trajectory downrange needs to be investigated further.

References: [1] Spelman, A.R. (1959). University of Wyoming, unpublished Master thesis, 89 pp. [2] Kastning H., Huntoon P. W. (1996). NASA's Wyoming Space Grant Fellowship Program 1995-6, p. 57-64. [3] Kenkmann, T. et al. (2018). *LPSC 49*, Abstract, #1469. [4] Sundell, K. A. et al. (2018) *M&PS 81*, Abstract, #6149 [5] Kenkmann, T. et al. (2018). *Scientific Reports, 8*, pp. 13,246. [6] Artemieva, N. A. & Shuvalov, V. V. (2001) *J. Geophys. Res. 106*, 3297–3309. [7] Stone, D. S. & Therriault, A. M. (2003) *M&PS 38*, 445-455.

Sampling point	Latitude	Longitude	Crater major axis (m)	Sample position	Shock features	
					PDF	PF
Crater 1	42°39'7.30" N	105°26'58.73"W	60	ejecta, crater rim, crossrange & uprange	{10-10}*; (10-11); (15-61); {51-61}	(0001); (10-13); (10-11); {10-12}; (11-22); {10-13}
Crater 2	42°28'56.45"N	105°26'51.53"W	31	overturned flap downrange	{10-14}, (0001)	{15-61}
Crater 3/ 4	42°38'59.32"N	150°26'52.65"W	17 & 12	ejecta flap downrange	(0001); {01-14}; {01-12}; {51-61}	
Crater 9	42°38'52.29"N	105°26'57.03"W	20	dike, crater center	(0001)	(0001)
Crater 15	42°39'14.77"N	105°27'5.12"W	26	center of crater	{01-13}	(0001)
Crater 34	42°39'47.45"N	105°27'13.67"W	73	breccia, crest	{51-61}; {10-14}; {21-31}	{10-14}; {10-13}
Crater 36	42°40'0.37"N	105°27'17.02"W	21	dike, uprange	{10-13}; {01-11}; (0001)	
Crater 37	42°40'1.26"N	105°27'22.04"W	65	breccia	{10-13}	
Crater 50	42°39'15.32"N	105°27'4.90"W	102	degraded	{10-12}; {10-14}	
Crater 77	42°41'42.67"N	105°29'33.81"W	33	degraded	{10-14}	
Crater 78	42°41'43.71"N	105°29'35.14"W	14	ejecta down-crossrange	(0001)	{01-12}
Crater 80	42°42'8.98"N	105°29'56.98"W	62	ejecta crossrange	{10-10}*; {15-61}	
Crater 82	42°39'3"N	105°27'0"W		degraded	{10-13}	{01-13}
Crater WR-5	42°36'7.50"N	105°28'42.82"W	50		{51-61}	
Casper-Opeche boundary	42°39'21.65"N	105°26'46,12"W	-	transition zone	{51-61}	{01-12}

Table 1: Location of samples containing shock features. {10-10}* is not unambiguous, could also be {11-20} or {51-60}.