REVIEW OF FAULTS ASSOCIATED WITH COMPLEX IMPACT STRUCTURES IN SEDIMENTARY ROCK TARGETS, WITH REFERENCE TO THE UPHEAVAL DOME IMPACT STRUCTURE, UTAH, U.S.A.

W. R. Orr[1] and R. A. Schultz, Geomechanics-Rock Fracture Group, Department of Geological Sciences and Engineering/172, Mackay School of Earth Sciences and Engineering, University of Nevada, Reno, NV 89557-0138, [1]orrw@unr.nevada.edu.

Summary: We present a compliation of the literature on known terrestrial impact structures and focus on complex impact structures within sedimentary rock targets. Bedding-parallel or low-angle faults are observed in the field, but not geophysically, within impact structures may affect the shape of the crater profile, therefore the identification of stratigraphically confined faults in terrestrial impact structures is a potentially important observation.

Introduction: Impact cratering is among the most fundamental geologic processes in the solar system and is characterized by very high strain rates that generate extreme shock pressure and temperature conditions [1,2]. There are currently 174 confirmed terrestrial impact craters, and of those, 69 are in sedimentary targets, 55 are in mixed sedimentary and crystalline targets, 49 are in crystalline targets, and one is of undetermined target type [3] (Figure 1). The majority of terrestrial impact research has been focused on crater morphology [4], geochemical characteristics such as the presence of high temperature and high pressure minerals and planar deformation features (PDFs) in quartz and feldspars [2,5,6], and shatter cones [2,6]. While studies have been conducted regarding faulting and deformation associated with impact structures [7,8], the amount of information available on this is limited in comparison to studies previously discussed.

Several computer and numerical models have been developed in order to further evaluate and understand complex cratering mechanics; however these models have been limited to targets of homogeneous compositions and do not account for differences in lithologies which are typical of sedimentary targets [9]. At the Upheaval Dome impact structure located in southeastern Utah on the Colorado Plateau, normal and thrust faulting associated with the formation of this complex crater is stratigraphically bounded within weaker shale units between stronger sandstone units such as the Wingate and Navajo sandstones [9,10]. The field relations suggest that computer simulations of its development and eventual shape would be improved with the inclusion of targets rocks having comparable contrasts in rheology.

Results and Implications: In this abstract we synthesize results of impact structures from the literature in sedimentary, crystalline, and mixed rock targets and subdivide them by crater morphologies: simple, complex, and unclassified. As shown in Figure 2a, there are 69 impact in sedimentary targets, 55 in mixed targets, 49 in crystalline targets, and one of undetermined target type; therefore 40% of impact structures are located within sedimentary rock targets (Figure 2b) [3]. Furthermore, 37 impacts display a simple crater morphology, 116 impacts are complex, and 21 are not classified (Figure 3a); therefore 67% known impacts display complex crater morphology (Figure 3b).First results show that of the 67 impact structures in sedimentary targets, 46 display complex morphologies and therefore provide suitable locations for investigating faults similar to those identified at Upheaval Dome.

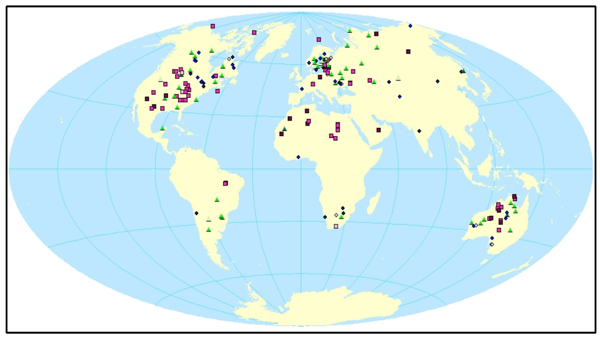

Figure 1. Locations of known terrestrial impact structuress [3]. Pink squares represent structures in sedimentary targets, blue circles represent structures in crystalline targets, and green trianges represent structures in mixed rock targets.

We find that in the ring synclines of complex impact structures within sedimentary targets, fault patterns reflect two general fault types: high-angle faults (concentric and radial faults) that cut across target stratigraphy, and low-angle faults (detachment faults) that are confined to layers apparently in response to some contrast in stratigraphic properties. Faults exposed at impact structures including Gosses Bluff, Australia [11], Araguainha, Brazil [12], Haughton, Canada [1], Kentland, Indiana [13], and Upheaval Dome, Utah, USA [9,10] have been evaluated primarily by field investigations and results have occasionally been compared to geophysical data collected within and/or adjacent to the structures. Numerous additional impact sites have been evaluated with geophysical methods and with borehole technologies (i.e. Flynn Creek, Tennessee, USA [14]; Cloud Creek, Wyoming, USA [15]; Montagnais, Canada [16]), however, at each of these structures only high-angle faulting has been reported. Therefore, we infer that stratigraphically confined faults are not easily identified by seismic or borehole technologies, but instead require detailed field examination.

At impact sites in which faults are reported as stratigraphically confined, the faults are located within weaker units, such as shales and silts, sandwiched between stronger, more competent units such as sandstones and limestones (i.e. Upheaval Dome and Kentland, USA). In each of the structures in which low-angle faulting has been identified, it is thought by various authors that the stratigraphically controlled faults were initially developed early, during the excavation stage of the cratering process. However, it is interesting that while these faults were reactivated and behaved as thrust faults during crater collapse in the Upheaval Dome structure [10], they are not believed to have played a significant part in the modification stage in the similar Haughton structure [1]. Instead, high-angle faults were reportedly developed to accommodate the Haughton crater collapse [1]. It has been suggested that low-angle faults experience interference during the late stages of their formation from normal and reverse fault motion along high-angle faults during modification stages [17, 18]. Why this sequence happens at some impact structures (i.e. Haughton, Canada) and not at others (i.e. Upheaval Dome, USA) is currently under study.

References: [1] Osinski, G.R. and Spray, J.G. (2005) *Meteoritics and Planetary Science*, v. 40, p. 1,813-1,834. [2] Pati, J.K. and Reimold, W.U. (2007) *Journal of Earth System Science,* v. 116, no. 2, p. 81-98. [3] Earth Impact Database (2007) and references therein. [4] Melosh, H.J. (1989) *Impact cratering: A geologic process*. [5] Therriault, A.M. and Grantz, A. (1995) *LPSC XXVI, abstract*. [6] Milam, K.A. et al. (2004) *LPSC XXXV, abstract*. [7] Spray, J.G. (1997) *Geology*, v. 25, no. 7, p. 579-582. [8] O'Keefe, J.D., and Arhens, T.J. (1999) *LPSC XXX, abstract*. [9] Kenkmann, T. et al. (2005) *GSA Special Paper 384*, p. 85-115. [10] Kriens, B.J. et al. (1999) *JGR*, v. 104, p. 18,867-18,897. [11] Milton, D.J. et al. (1972) *Science*, v. 175, no. 4027, p. 1,199-1,207. [12] Lana, C. et al. (2006) *Geology*, v. 34, no. 1, p. 9-12. [13] Laney, R.T., and Van Schmus, W.R. [1978] *LPSC, abstract*. [14] Roddy, D.J. (1979) *LPSC Proceedings 10th*, p. 2,519-2,534. [15] Stone, D.S. and Therriault, A.M. (2003) *Meteoritics and Planetary Science*, v. 38, p. 445-455. [16] Plinkington, M. et al. (1995) *Meteoritics*, v. 30, p. 446-450. [17] Kenkmann, T., and Ivanov, B.A. (2005) *LPSC XXXVI, abstract*. [18] Kenkmann, T., and Ivanov, B.A. (2006) *Earth and Planetary Science Letters*, v. 252, p. 15-29.

Abstract published in: Lunar and Planetary Science XXXIX, CD-ROM, Lunar and Planetary Institute, Houston (2008).

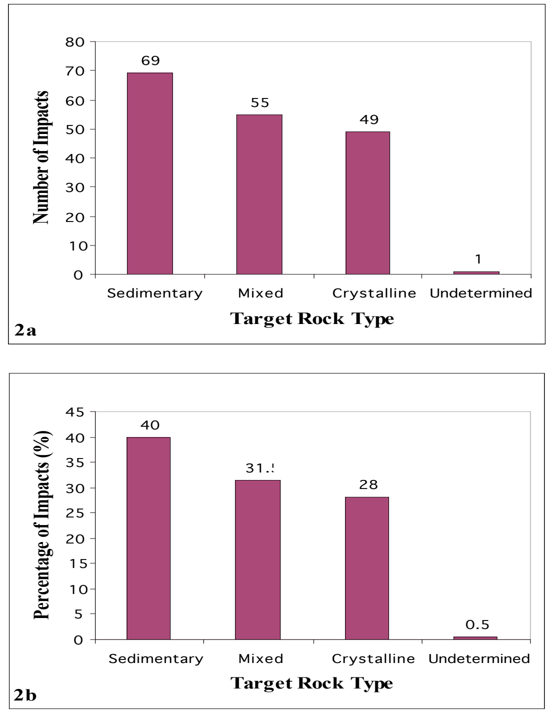

Figure 2. a) Histogram synthesizing the number of known impacts in relation to their target rock types; **b)** Histogram synthesizing the percentage of known impacts in relation to their target rock types.

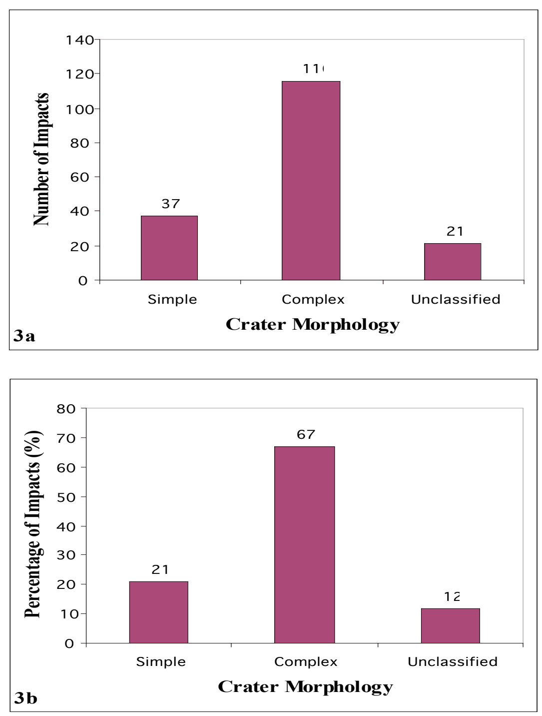

Figure 3. a) Histogram synthesizing the number of known impacts in relation to their crater morphologies; **b)** Histogram synthesizing the percentage of known impacts in relation to their crater morphologies.