**SHOCK METAMORPHISM AT THE RED WING CREEK STRUCTURE, NORTH DAKOTA: CONFIRMATION OF IMPACT ORIGIN.** Christian Koeberl[1] and Wolf Uwe Reimold[2]. *[1]Institute of Geochemistry, University of Vienna, UZA II, A-1090 Vienna, Austria (a8631dab@vm.univie.ac.at); [2]Department of Geology, University of the Witwatersrand, P.O. Wits, Johannesburg 2050, South Africa (065wur@cosmos.wits.ac.za).*

**Introduction and Summary.** The 9-km-diameter Red Wing Creek structure is located in North Dakota at 47° 36' N and 103° 33' W. Similar to Newporte and Ames, Red Wing Creek is a buried structure. As Newporte, it is located within the oil-rich Williston Basin. The crater obviously serves as a structural trap for oil and, indeed, hosts several commercial oil producing wells. Geophysical studies related to the oil exploration showed that Red Wing Creek has a central uplift, surrounded by an annular crater moat, and a raised rim [1,2]. Breccias were encountered during the drilling between about 2000 and 2800 m depth in the central uplift area. Brenan et al. [1] reported the discovery of shatter cone fragments from the drill core samples. These authors suggested that the occurrence of shatter cones and fractured quartz grains is indicative of an impact origin of the Red Wing Creek structure. However, no evidence of shock metamorphism, such as planar deformation features (PDFs) in rock-forming minerals, was found [1]. Thus, an impact origin of Red Wing Creek could not be confirmed. No further investigations have been done using drill core samples from Red Wing Creek until now. For the present study, we performed detailed petrographic and geochemical studies of samples of well cuttings from two boreholes. We found several quartz grains with PDFs, providing unambiguous evidence for shock metamorphism at Red Wing Creek. An impact origin of Red Wing Creek seems the most likely explanation for the structure.

**Geological Setting.** The Red Wing Creek structure is a disturbed zone of circa 9 km in diameter, located about 36 km east of the Montana-North Dakota border. In 1972, the True Oil company drilled a hole (22-27 Burlington Northern) in the area and found an oil column about 870 m thick, which was viewed as being highly unusual, as oil columns in the area are generally only about 30 m thick. This discovery led to intense geological and geophysical (seismic) studies of the Red Wing Creek area. The structure has a central gravity high (1.5 mGal), but no distinct magnetic anomaly. Seismic exploration and drill core logging indicated the existence of a central uplift with a maximum diameter of about 6 km (including the flanks) [1]. Mississippian units (ranging from the Bakken to the Tyler-Heath Formations), which are composed predominantly of carbonates and evaporates (intercalated with sandstone, siltstone, and shale subunits), are uplifted about 1 km above the normal stratigraphic position in the region [1]. Brenan et al. [1] subsequently identified shatter cone-like fragments in Mississippian carbonates from the True Oil 13-27 core and suggested that these findings provided evidence for an impact origin of the Red Wing Creek structure, but noted the absence of any other evidence for shock metamorphism. The age of the Red Wing Creek structure was estimated from stratigraphic data at about 200 Ma [1].

**Petrography of Red Wing Creek samples.** We obtained 81 samples of drill cuttings from two drill holes, True Oil 22-27 Burlington Northern (North Dakota Geological Survey #5182), and True Oil 11-27 Burlington Northern (#5212). Borehole #5182 (True Oil 22-27) is situated exactly at the center of the central uplift, while borehole #5212 (True Oil 11-27) is located about 750 m to the NW of #5182, close to the center of the structure. The samples were usually less than 0.5 cm in size, and most commonly about <1 - 2 mm in size. 48 samples were obtained from #5182 and 41 samples from #5212. These samples were screened for quartz and feldspar fragments and lithic fragments containing these minerals. Such clasts were separated by handpicking, and grain mounts were prepared for 15 samples from True Oil 22-29 and 27 samples from True Oil 11-27. Besides relatively rare quartz and feldspar fragments, the most important lithologies in the True Oil 22-27 samples are carbonate lithologies (70-100 vol%), as well as some sandstone and quartzite (generally < 1 vol%) and siltstone (1 - 30 vol%) particles. In contrast, the True Oil 11-29 samples contain more sandstone and quartzite (generally 10 - 30 vol%; rarely exceeding 40 vol%) and limestone (mostly < 25 vol%, but in a few cases comprising 80-95 vol%). The majority of the quartz grains in our samples are undeformed. Non-diagnostic, probably tectonic deformation in the form of fracturing, kinkbanding, or deformation bands was observed in a number of quartz and feldspar grains, and occasional kinkbanding of biotite was recorded. Annealing is insignificant for all these samples. No unequivocal shock effects were found for the feldspar fragments. However, several quartz grains with one or more sets of PDFs were recognized. Figs. 2-4 show examples of quartz grains with one and two sets of PDFs. Preliminary U-stage measurements of the crystallographic orientations of the PDFs indicate the presence of c, $\omega$, and $\pi$ orientations, which are indicative of shock. In addition, sample 6980-6990 (2128 m depth) from hole #5182 contains a partially diaplectic quartz grain, and in sample 8040 (2450 m depth) from core #5212 two melt breccia fragments were found. No PDFs were seen in quartz from #5182 samples. In the #5212 hole, almost all quartz grains with PDFs were found in the depth interval 7460 - 7620 ft (2274 - 2323 m), within the Kibbey Formation. Our observations confirm an impact origin of the Red Wing Creek structure.

# RED WING CREEK IMPACT STRUCTURE, NORTH DAKOTA: Koeberl and Reimold

**Acknowledgements:** We are grateful to Julie LeFever and her staff at the North Dakota Geological Survey Core Library in Grand Forks, North Dakota, for invaluable help with obtaining the samples for this study, and background information. We are also indebted to Dion Brandt (Univ. of the Witwatersrand) for U-stage work. Supported by Austrian FWF Project P08794-GEO.

**References:** [1] Brenan, R.L., Peterson, B.L., and Smith, H.J. (1975) Wyoming Geol. Assoc. Earth Sci. Bull. **8**, 11-41; [2] Sawatzky, H.B. (1977), in Roddy et al., Impact and Explosion Cratering, Pergamon Press, 461-480.

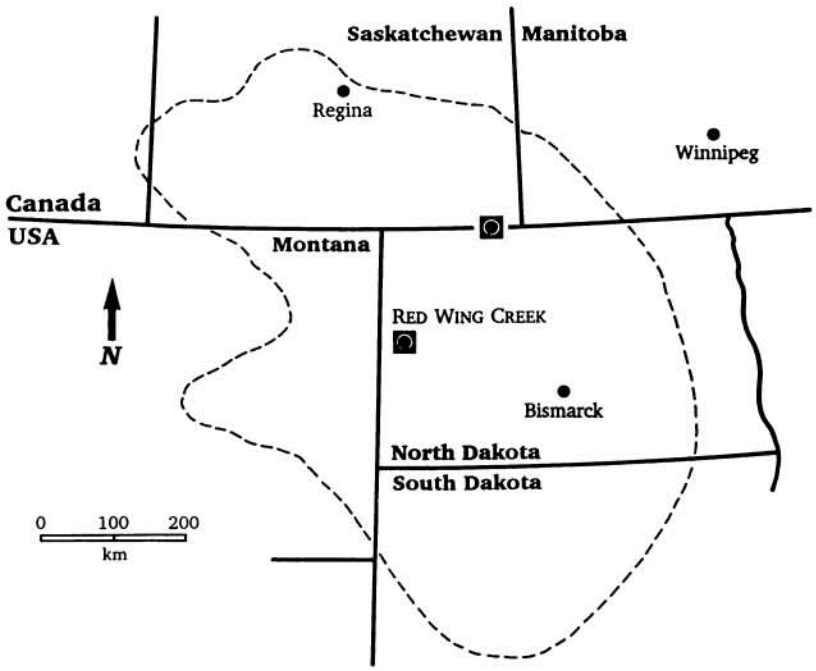


**Fig. 1.** Location of the Red Wing Creek structure. The second square symbol marks the Newporte structure. The dashed line indicates the extension of the Williston Basin.

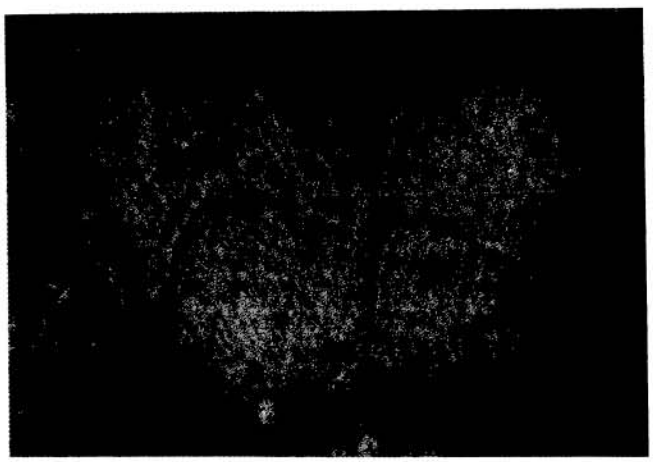

**Fig. 2 (left).** PDFs in quartz from hole #5212 (sample 7070); depth 2155 m; width: 150 μm, crossed nicols.

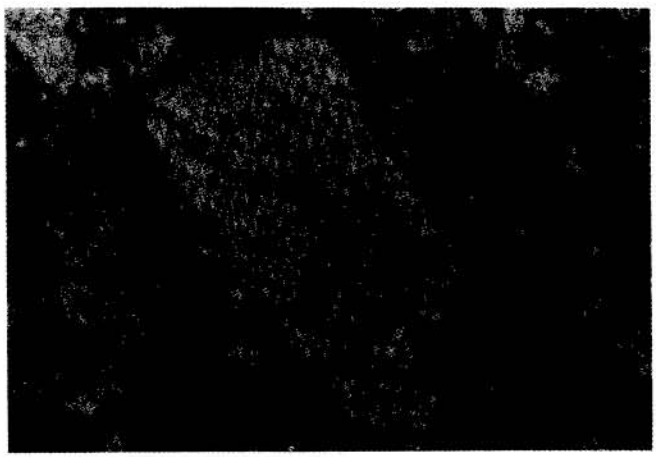

**Fig. 3 (left, bottom).** Two sets of PDFs in quartz from hole 5212 (sample 7550); depth 2301.2 m; width: 550 μm, crossed nicols.

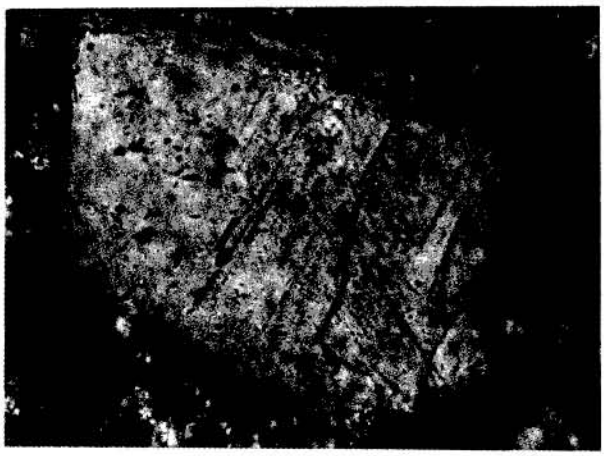

**Fig. 4 (below).** Two sets of PDFs in quartz from hole 5212 (sample 7590); depth 2313.4 m; width: 300 μm, crossed nicols.