TRANSIENT AND DISRUPTION CAVITY DIMENSIONS OF COMPLEX TERRESTRIAL IMPACT STRUCTURES DERIVED FROM MAGNETIC DATA. M. Pilkington[1] and A.R. Hildebrand[2], [1]Geological Survey of Canada, 615 Booth Street, Ottawa, ON, Canada K1A 0E9 mpilking@nrcan.gc.ca [2]Department of Geology and Geophysics, University of Calgary, 2500 University Drive NW, Calgary, AB, Canada T2N 1N4 hildebra@geo.ucalgary.ca

Introduction: Transient and disruption cavity sizes are fundamental parameters in the study of impact structures [1]. They are governed by the velocity, size and density of the impacting body, the target density and ambient gravitational acceleration. Hence, knowledge of transient and disruption cavity dimensions allows the calculation of energy release associated with impact. Since the recognition of the devastating environmental effects related to the Chicxulub crater it has been underscored that accurate estimates of transient and disruption cavity dimensions are crucial in evaluating potential environmental degradation from an impact.

Cavity dimensions: For simple craters, the transient and disruption cavities are closely related to the final crater shape, both being well-described by paraboloids of revolution. The transient cavity is the melt- and breccia-lined cavity that collapses to form the final observed simple crater form. The final observed crater diameter in a simple crater corresponds to that of the disruption cavity; the limit of disruption of the impacted rocks by brecciation. The transient cavity diameter $D_t = 0.84D$ [2], where D is the final crater diameter (and equals disruption cavity diameter D_d).

For complex craters, the difference between D_t, D_d, and D is greater because of the extensive collapse and slumping of the disruption cavity walls and rim. The resulting craterform is highly modified compared to smaller, simple craters and obscures the direct observation of disruption cavity size based on either geological or geophysical data. Nevertheless, bounds on the collapsed disruption cavity (CDC) can be established by determining the size of certain morphological elements of the complex crater form [3]. If the disruption cavity size can be established, the diameter of the transient cavity follows by calculation. The diameter of the central uplift, D_{CU}, provides a lower bound on the diameter of the CDC. D_{CU} gives only a weak bound on CDC because crater floor rebound does not extend outward as far as the CDC edge. Estimates of D_{CU} are also strongly influenced by erosion level. A stronger bound comes from D_M, the diameter of the thick coherent melt sheet or suevite deposits that occupy the crater floor out to the inner edge of the zone of slumped blocks. This definition of D_M does not include melt/suevite that may be present as much thinner deposits on the tops of the slumped blocks. The collapse of the disruption cavity walls involves movement downwards and inwards to the cavity center, therefore D_M will always be smaller than D_d. In a similar fashion, we can use the diameter at which the innermost slump block occurs (D_S) to define a better estimate of D_d [1,3]. This value does not provide a direct observation of D_d because the inward slumping along faults always results in an observed D_S less than that value before wall collapse begins. However, this effect is small compared with the final rim diameter, and reconstruction of the slump deformation allows reconstruction of D_d. No discernible trace of the melt/breccia lined transient cavity (which defines D_t) remains after crater collapse. However, by analogy with simple craters, $D_{at} = 0.84D_{ad}$ [1]. The values of the cavity diameters as measured at the level of the pre-impact surface are believed the relevant parameters to be used in energy, impactor size, and melt production calculations [2].

Magnetic data: Direct observation of D_M and D_S through surface geologic mapping is hampered by the varying levels of erosion at terrestrial impact structures. At well-preserved craters, slump faults and melt/suevite units are obscured by impact ejecta and breccia. As erosion levels deepen, these features are revealed but are often modified by later erosion and subsequent reburial resulting in limited exposure. Once erosion has reached down through the CDC floor, little evidence of these elements remain. Consequently, estimates of transient cavity size based on geologic evidence are limited [3,4]. Geophysical data can provide useful estimates of both D_M and D_S even when structures are partially or wholly buried. Geophysical methods also have the advantage of being able to achieve systematic areal coverage of a given structure, thus avoiding the problems of limited exposure. By far the most useful are magnetic data, since both D_M and D_S are often associated with observable changes in magnetic anomaly character.

The dominant magnetic signature associated with impact structures is a magnetic low or subdued zone, which is commonly manifest as a truncation of the regional magnetic fabric. At larger structures, the magnetic low can be modified by the presence of shorter wavelength, large amplitude, localized anomalies, which usually occur at or near the center of the structure. These anomalies are often caused by increased magnetizations (usually thermoremanent) in impact melt rocks and/or suevite deposits [5,6]. They may also be caused by uplifted magnetic lithologies (usually crystalline basement rocks) within the central uplift. In the former case, mapping the outer extent of the melt sheet gives an estimate of its diameter, D_M, while for the latter, the outer extent of the anomalous area gives an estimate of the central uplift diameter, D_{CU}. Within the disruption cavity, we expect to see complete removal or moderate suppression of the regional magnetic fabric. Within the slump zone, the pre-impact magnetic fabric is only slightly modified, since the slump blocks are relatively undeformed and are unshocked. Downward movement of blocks may lead to diminished and broadened anomalies but trends can be preserved and mapped. Therefore determining the innermost occurrence of regional (pre-impact) magnetic trends provides an estimate of the inner limit of D_S.

Estimates of either D_{CU}, D_M or D_S from magnetic data at 19 terrestrial complex impact structures are shown in Figure 1. The magnetization levels of igneous and metamorphic rocks are generally much greater than those of sedimentary lithologies, hence magnetic anomalies associated with the latter may not be significant enough to detect the morphological elements discussed above. Consequently, most of the structures used here occur in crystalline target rocks. Values of crater diameter are largely from [7]. The dashed line shows our estimate of the best description of the data which gives D_{CDC} = 0.49D or D_t = 0.41D. Our D_{CDC} relation is similar to the 0.5-0.65D of [4] based on limited terrestrial data, but is at odds with the scaling relation of $D_{TC} = D_Q^{0.15}D^{0.85}$ of [3] based mostly on lunar craters (D_Q is the simple to complex transition diameter). The observation of cover rocks preserved in the annular trough at 0.5-0.6D at Manicouagan [4] is one example of a tighter bound on CDC diameter than the values of D_S (on average ~0.85D) determined by [3] based on remote lunar observations. Some scatter about the scaling relation of [3] is expected because D_Q is target dependent so that target lithologies will have some influence. Nonetheless, observations at other terrestrial impact structures [4] clearly deviate from the relationship of [3]. The geophysical evidence from the magnetic data (Figure 1) is more in accord with morphometric relationships [4] derived from geologic mapping.

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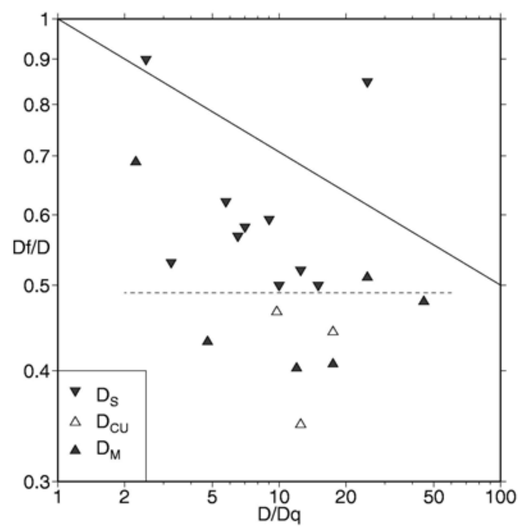

Figure 1 Plot of scaled estimated bounds on collapsed disruption cavity diameter versus scaled crater diameter (as used in [3]). Filled triangles (▲) = diameter of melt (D_M). Outlined triangles (△) = diameter of central uplift (D_{CU}). Inverted triangles (▼) = diameter of innermost slump block (D_S). Solid line = relation from [3] $D_{TC} = Dq^{0.15}D^{0.85}$. Dashed line = best fit to data from this study. Df = diameter of feature (D_{CU}, D_M or D_S). Dq = simple-/complex transition diameter; D = crater diameter.