EXCAVATION FLOW AND CENTRAL PEAK RINGS: IS THERE A CONNECTION? V. L. Sharpton[1] and B. O. Dressler[2], [1]Geophysical Institute, University of Alaska Fairbanks, 903 Koyukuk Drive, Fairbanks, AK 99775 (buck.sharpton@gi.alaska.edu); 2 Lunar and Planetary Institute, 3600 Bay Area Blvd, Houston, TX 77058.

Introduction: To approximate the conditions associated with the excavation stage of the impact process, many numerical simulations rely on some form of the Z-model [1-5], where the radial velocity of particles below the ground surface is given by:

$$u_R = \alpha(t)/R^Z$$

and R is the radial distance from the flow origin, α is a strength parameter, and Z determines the velocity change with radial distance. While inherited from studies of explosion cratering [1-3], the Z-model has been shown to provide a first order approximation of excavation flow in simple craters as long as some appropriate effective depth of Z-model flow (EDOZ) is provided. EDOZ is usually assumed to be equivalent to one projectile diameter [e.g., 1,2,4]. The most-often applied form of this model is the steady-flow version where α, Z (~3) and EDOZ are assumed to be time constants [e.g. 1,2,5,6]. This practice, however, seems to be based on convenience rather than on sound theoretical grounds as (1) the steady flow assumption allows the flow field to be explicitly evaluated at all times [2] but (2) violates conservation of energy [1]. Furthermore, studies of laboratory-scale impacts [4,5] indicate a time-dependence to the Z-model parameters. Despite these limitations, the Z-model's ability to provide qualitative insights into the dominant spatial features of the early-time impact flow field has been emphasized [1-3]. While this may be true for laboratory scale craters and even simple craters on planetary surfaces, observations from a well-studied terrestrial complex crater indicate that neither excavation flow nor the shape of the excavation cavity are well approximated by the Z-model.

Haughton Crater. The ~24 km diameter Haughton impact crater is located at 75º 22´ N; 89º 41´ W on the western portion of Devon Island in the Canadian Arctic [7,8]. The geological map shown in Fig. 1 is derived from previous studies [9,10] with modifications resulting from our 1997 field expedition. These observations, combined with the results of reflection seismic studies [11] provide useful constraints on the target and how it was affected by the impact event. Here, we use these data to evaluate models of the size and shape of the excavation cavity generated during the formation of Haughton crater and show that these characteristics cannot be reconciled with the constant-flow Z-model. Our analysis suggests that the poorly organized peak ring at this crater reflects radial inflections in the original excavation crater prior to its uplift during late-stage modification.

The target is a nearly flat-lying sequence of Paleozoic platform rocks, ~1.8 km thick, overlying high-grade crystalline basement. The platform sequence consists of the following units [9]: **1**. The Allen Bay Fm. (OSA) limestone and dolomites, ~450 m thick. This unit forms the present surface around the crater and is found to within ~4.5 km of the center. **2**. The Cornwallis Group (OCTI) shales and carbonates with a combined thickness of ~110 m. OCTI crops out along the walls of steep valleys to the northeast of the crater. **3**. The Bay Fiord Fm. (OCB) carbonates and gypsum, ~330 m thick. Large exposures of OCB occur within 5-7 km of the crater center, as well as in valley floors as close as 8 km east of the crater center. **4**. The Eleanor River Fm. (OE) chert-bearing carbonates, ~400 m thick. Inliers of OE, representing the central uplift, occur between 0.7 and 4.8 km from crater center. The closest authochthonous OE outcrops occur ~16.5 km from the crater center. **5**. Undifferentiated Lower Ordovician-Cambrian (OCU) shale, sandstone, dolomite, and conglomerates, ~420 m thick. No parautochthonous units of OCU have been discovered within the crater; however, near the center abun-

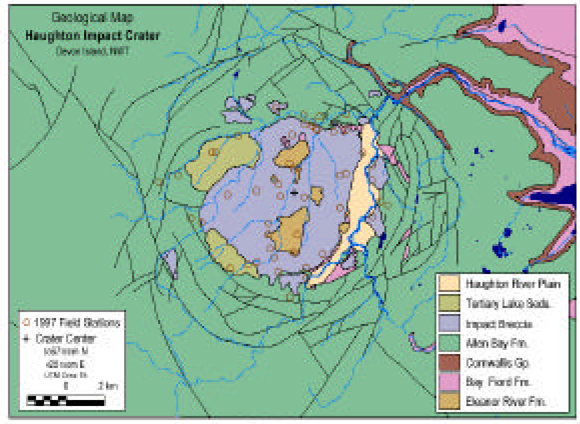

Figure 1

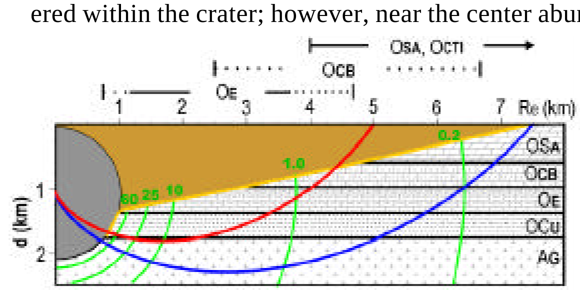

Figure 2. OCTI (not shown) is located between OSA and OCB. Shock pressures after [12].

dant highly shocked blocks of sandstone probably represent the OCU Blanley Bay Fm. Authochthonous exposures have been mapped 32 km east of crater center.

Excavation Depth and Central Uplift. Filling the shallow central basin (radius of ~5 km), the allogenic impact breccia forms a nearly continuous unit that ranges from ~10 m to over 100 m in thickness. Breccia outliers also exist beyond this deposit, with the farthest mapped deposit located ~7.8 km southeast of center. The matrix and clasts of this breccia were derived primarily from the platform rocks; however, clasts of partially melted, highly shocked, and weakly shocked clasts of Archaean high-grade metamorphic rocks (AG, Fig. 2) prove that the excavation cavity penetrated into the subjacent crystalline basement. Modal analysis [9] indicates ~10-15% of the breccia clasts are derived from the crystalline basement. Extending ~1 km from the crater center are large and extensively shatter-coned outcrops of OE (with minor OCB; Figs. 1 and 2) that form a discontinuous ring of uplifted but otherwise coherent target rocks. As their structural heights exceed the basal height of the Tertiary lake beds that filled the crater shortly after it formed, these OE exposures represent a true topographic, albeit incipient, peak ring.

Reconstructing the Excavation Crater. The excavated diameter De=2Re has been estimated at 10 km based on the incoherent zone in reflection seismic data [11]. Redeker and Stöffler [10] prefer De=15 km, based on shock isobar constraints from the Kieffer and Simonds [12] model and the need to excavate crystalline rocks. Fig. 2 shows the half-space shape of the Z=2.71 model for both the 10-km *(red line)* and 15-km *(blue line)* excavation craters predicted for Haughton crater.

Discussion. When assessed against the geological constraints provided by outcrops of parautochthonous target rocks, substantial problems with these models become evident: **1**. The Re=5 model predicts excavation completely through OE to a distance of ~3.3 km; Re=7.5 removes OE to a distance of nearly 6 km. Both therefore fail to account for the central uplift (OE derived from beneath the excavation crater) that is observed within 1.2 km of the center. **2**. Similarly, the models predict that OCB would be completely removed within 4 km (Re=5) or 6.8 km (Re=7.5) yet outcrops occur within 3 km of center and are abundant within a radius of 5 km. **3**. The Re=5 model does not account for the proportion of crystalline rock clasts observed in the allogenic breccia [10].

Conclusions. The geological constraints at Haughton crater are not compatible with a constant Z excavation flow field regardless of the choice of Re. Observations presented here constrain the zone of deep excavation to be less than 1 km from center. The *yellow line*, Fig. 2 indicates the maximum depth to the excavation crater boundary permitted by geological constraints. The resulting shape is characterized by a localized near-center zone of deep excavation – from which the crystalline rocks originate – flanked by a broad zone of shallow excavation at least 4-5 times the width of the central zone. Off-axis, deep excavation, and thus a Z-model-type of excavation flow are not incompatible with the Haughton crater observations *if and only if* Z is a strong function of time. High-Z flow (deep, near-center excavation, steep ejection angles) would occur during the earliest excavation stage and as ejection proceeded, Z, excavation depth, and ejection angle would decay.

At Haughton, the uplifted outcrops form the cusp separating two distinct sub-domains in the excavation crater: the broad outer zone of shallow excavation and the narrow, centrally located zone of deep excavation. Consequently this peak ring seems to represent a fundamental structural inflection in the base of the excavation crater that was subsequently uplifted during late-stage modification.

It is not clear whether the excavation-crater model for peak ring formation can be extended to all central peak rings, or even to those in other craters formed in layered targets. Similar excavation geometries, however, have been reported at several other complex craters with central rings [e.g. 13,14] in layered targets where such reconstructions are possible.

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