"NEEDLE MODEL" FOR SURVIVING ENTRY: IMPLICATIONS OF THE CARANCAS IMPACT. P. H. Schultz, Brown University, Department of Geological Sciences, 324 Brook Street, Box 1846, Providence, RI 02912-1846 (peter_schultz@brown.edu)

Introduction: The Carancas crater was formed by a stony meteorite traveling 1-3 km/s based on the presence of one to two sets of planar microstructures [1] and observations during entry [2,3]. This raises significant questions about the survival process for small stony meteorites (<50 kg) during entry. One possible solution is the non-catstrophic disruption of the incoming mass with containment of resulting meteoritic debris within the mach cone. This possibility was explored using the NASA Ames Vertical Gun Range.

Possible Explanation: During entry, smaller meteoritic masses are disrupted by gas-dynamic pressures that exceed their yield strength. Trailing shock waves around each fragment act to spread spread fragments laterally, thereby producing a pancake-like dispersion [4,5] as shown in Figure 1 (left). Smaller stony meteorites (< 10^8 kg) are vulnerable to such catastrophic disruption. Surviving fragments decelerate to near terminal speeds and produce either meteorite strewnfields or meteorites with compression pits [5].

Experiments [6,7] also reveal, however, that weak or fragmented objects will reassemble and reshape during entry, which reduces aerodynamic drag and stresses. Small fragments cannot "jump" across the shock front extending from the leading mass(s); consequently, they trail behind within the mach cone (Fig. 1, right). This conceptual model is called the "needle" model, rather than the "pancake model." This configuration cannot survive indefinetly. The assemblage will eventually decelerate and disperse as ablation and winnowing reduces its effective mass.

In laboratory experiments, Pyrex projectiles disupted as pass through a thin (1.5mil) mylar sheet and enter the large AVGR chamber filled with gas (e.g., argon). Shadowgraphs capture the distribution of debris in flight (Fig. 1) while high-speed imaging records the deceleration during entry. Witness plates (aluminum blocks or thin sheets) provide data on the effective energy at impact. Under low atmospheric pressures (< 0.5 bars), the distribution of debris in flight and at impact confirm the pancake model with widely dispersed pits. At high atmospheric pressures, however, both witness plates and solid targets indicate that the fragmented projectile did not disperse (Fig. 2). In a solid aluminum block, a single crater is formed with an unusual diameter-to-depth ratio (1:2). This resembles armour-piercing artillery where multiple and trailing projectiles result in deep penetration.

Implications: Eyewitnesses for the Carancas impact did not report a fireball breaking apart or shedding fragments during entry [1,2]. Rather, the mass entered the atmosphere at a relatively high angle (>45°) and at high speed (from first appearance to impact). The calculated diameter of the object at impact ranges from 0.5m to 1.5m, depending on scaling assumptions and speed. Such a small mass should not have survived entry to such a low altitude and at such a high speed without significant disruption and ablation [5]. The "needle" model, however, allows much deeper atmospheric penetration than individual fragments alone.

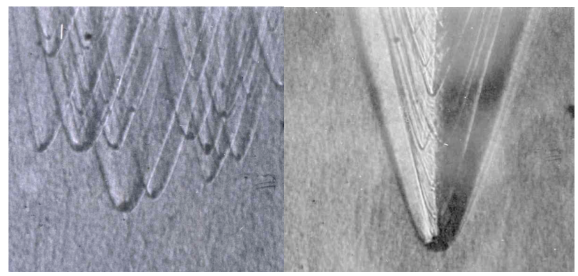

Figure 1: Pyrex projectiles were disrupted during entry into the AVGR impact chamber. Under low atmospheric pressures (170mm argon), interacting shocks spread fragments apart (left). Under high atmospheric pressures (700mm argon), however, disrupted fragments are contained within the mach cone. The leading mass in front is composed of Pyrex fragments clustered together. The assemblage of fragments reshapes during entry and minimizes aerodynamic drag.

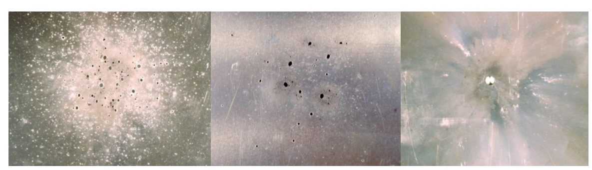

Figure 2: Witness plates of disrupted impacting Pyrex projectiles under increasing atmospheric pressures. Under vacuum, the shattered fragments create a dispersed debris cloud (left). At 170mm argon, however, interacting shocks spread fragments apart (center). At high atmospheric pressures (700mm argon), a single hole corresponding to the assmblage of particles contained by the mach cone.

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