EXPLOSIVE CO_2-DRIVEN SOURCE MECHANISMS FOR AN ENERGETIC OUTFLOW "JET" AT AROMATUM CHAOS, MARS. N. Hoffman, Victorian Institute of Earth and Planetary Science, La Trobe University, Melbourne 3086, Australia. Email: n.hoffman@latrobe.edu.au

Introduction: Catastrophic outburst flows from chaos zones are amongst the most energetic debris transport processes in the solar system. Although volumetric considerations of subsurface fluid availability limit conventional water-outburst models to a series of brief flow episodes separated by long recharge periods, the active flow events themselves involve the release of gravitational potential energy equivalent to Megatons of TNT release.

Alternative models using subsurface liquid CO_2 as a stored pressurised volatile permit an entire chaos zone to form in a single extended collapse and flow episode. The size and timescale of these events compares to paroxysmal volcanic eruptions on Earth. An example from Aromatum Chaos, Mars illustrates the process.

Mechanisms: The breakdown of intact regolith impregnated with liquid volatiles to generate catastrophic outburst flows is normally viewed as a rapid but relatively passive process. In the conventional model of chaos formation, liquids escape on decollement planes at depths of a few km and undermine the backwall of the chaos. The result is collapse of large (km scale) blocks of regolith which are further broken up to form smaller resistant blocks and the debris that is transported by the ensuing catastrophic floods [e.g. 1-3].

New mechanisms that involve liquid CO_2 as the stored volatile [4], rather than liquid water, have a more interesting behaviour. The descriptive term "liquifer" [5] is henceforth used for subsurface liquid CO_2 reservoirs.

In effect, the entire local region of saturated regolith contains a mild explosive agent, which is activated by exposure to atmospheric pressure, rather than confinement by lithostatic pressure. Thus the freshly-exposed cliff face of the chaos zone will not passively seep water, but explosively eject CO_2 gas, shattering the regolith and blasting large amounts of debris into a fluid cloud that forms a cryogenic density flow.

Aromatum chaos (Figure 1) is a particularly well-defined elongate chaos zone feeding into a small channel system. MOLA profiles and good Viking-era images allow the construction of a local topographic model. Steep side and back walls of the chaos define boundaries to the expanding gas/debris cloud. Escape routes for material are restricted to vertical ejection and overspill of the chaos rim, and to a single constricted opening to the East.

The density of the thick, debris-laden, cloud allows gravity to act as a "lid" on the system, so only limited amounts of dilute material can escape upwards and sideways. The vast bulk of the solid material must escape downstream to the East.

The analogue for this system is a relatively low-pressure rocket combustion chamber, with escape of the "exhaust" through the venturi-like constriction to the east (Figure 2). With time, the walls of the "chamber" are "combusted" and the chamber enlarges from a (presumed) initial small cavity to the size we see today.

Explosive degassing of liquid CO_2 at minus 30^o Centigrade develops a vapour pressure of ~10 Bars, sufficient to accelerate the debris (like the propellant in a rocket chamber) to an exit velocity in excess of 500 m/sec.

Figure 3 shows a cross-section of the chaos zone as it might have been at the height of the flow, with a thick and dense debris cloud overspilling the exit ramp to drive a powerful density flow.

Flow features downstream of the exit of Aromatum chaos can be interpreted in terms of lateral expansion and deceleration of the "exhaust plume" as it adapts to the pure gravitational drive of the downslope flow away from the high-velocity aperture.

The very high flow velocities achieved in the immediate vicinity of the source regions explain why the outburst flows are so powerfully erosive even close to their source areas.

Calculations of the duration of flow from Aromatum chaos are interesting. A conventional water-based flow model would require 5-10 small short-lived flows, each draining a wide aquifer around the collapse zone. Slow recharge between each flow episode extends the activity of Aromatum chaos to 1 to 10 Ma. Recharge is necessary in water flow models to balance the fluid requirements of a relatively dilute flow, compared to the limited porosity available in granular regolith material.

In contrast, the CO_2-based model needs no recharge because the CO_2 expands many hundred times from stored phase (liquid) to transporting phase (vapour). Indeed, the process is as difficult to stop once initiated as a solid-fuel rocket and will continue until exhaustion of the local liquifer of CO_2, or choking of the exit orifice by accumulated debris.

Based on the flow rate, channel dimensions, and solids content of the high-velocity exit flow, the entire 10,000 cubic km of Aromatum chaos may have been eroded in essentially a single continuous flow episode. The calculated timescale is equivalent to paroxysmal volcanic eruptions on Earth associated with caldera collapse of equivalent dimensions – i.e. a matter of hours.

These very short flow durations for any individual local chaos zone reflect the one-time transport of an unstable deposit of pressurised liquid CO_2 out from the subsurface liquifer and towards the northern plains. (strictly speaking, the debris is transported into the northern plains while the volatiles escape into the atmosphere and are ultimately collected by the polar winter freeze-out that determines atmospheric pressure on Mars). The short lifetime of individual chaos activity in a CO_2-based "White Mars" model has interesting implications for the entire chronology of chaos zones and individual channel activity on Mars. In essence, a great deal of Mars' history may be compressed into a relatively short timescale.

References: : [1] Baker V.R. & Milton, D.J. (1974) *Icarus 23*, 27-41 [2] Carr M.H. (1996) *Water on Mars* – OUP [3] Komatsu, G. et al. *LPSC XXXI* abstract 1434 [4] Hoffman, N. (2000) *Icarus 146*, 326-342 [5] Vlassopoulos, D (1997) *LPI Workshop on Early Mars*. abstract 3008

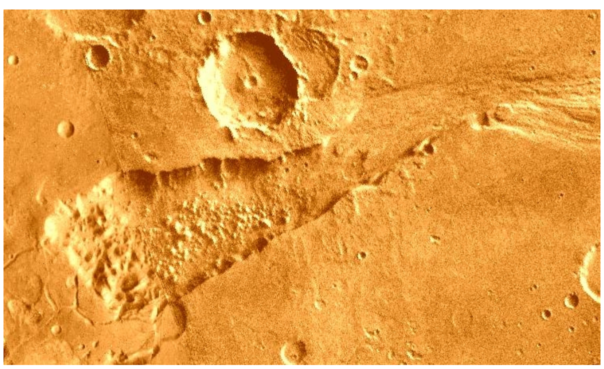

Figure 1: Aromatum chaos from Viking b/w MDIM with artificial toning added. The chaos has been "frozen" in time, showing the dynamic processes of explosive regolith breakdown and CO_2-fuelled density flow expulsion.

From headwall to the narrow exit, this chaos zone is some 80 km long, with a maximum width of 40 km. **Image NASA/USGS**

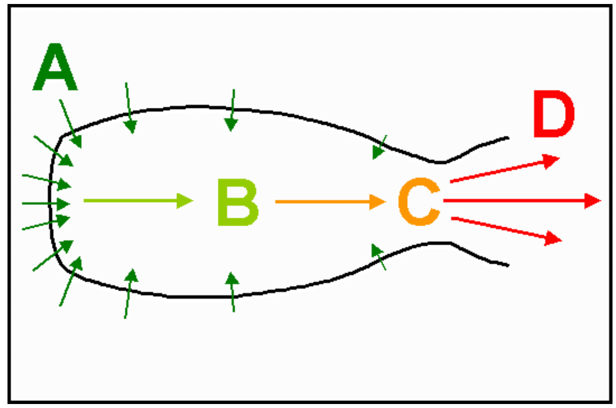

Figure 2: Rocket Chamber model for Aromatum Chaos. In a monopropellant rocket, fuel is added at the top of the engine (A) and combusts during its passage through the chamber (B). The Venturi nozzle (C) restricts the aperture of the motor and controls the acceleration of the spent propellant. In the expansion bell (D) the exhaust jet is controlled. For a solid propellant rocket the combustion chamber is a progressively enlarging cavity formed by consumption of the fuel grain by surface burning.

In the Chaos analogue the solid propellant is regolith saturated with high pressure liquid CO_2. The "combustion" process is the progressive breakdown of large regolith blocks to smaller and smaller fragments, all outgassing their CO_2. The Venturi is a physical restriction formed by resistant CO_2-poor wall rock, and the expansion plume of the emerging jet carves a trail across the Martian landscape. Vertical confinement is provided by gravity.

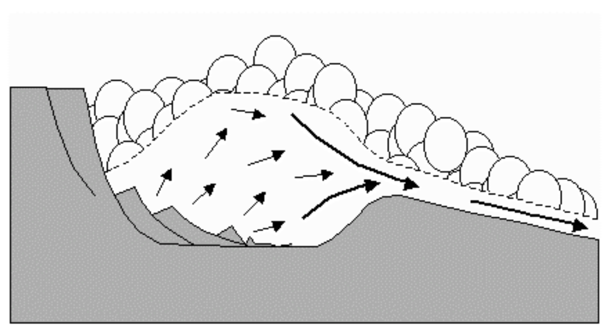

Figure 3: Horizontal section of Aromatum Chaos in active flow conditions showing extent of dense gas cloud within topographic trap, and outflowing density current originating from high velocity exit "jet". Bubble texture depicts much less dense "ashcloud" escaping upwards. Vertical dimension ~6 km