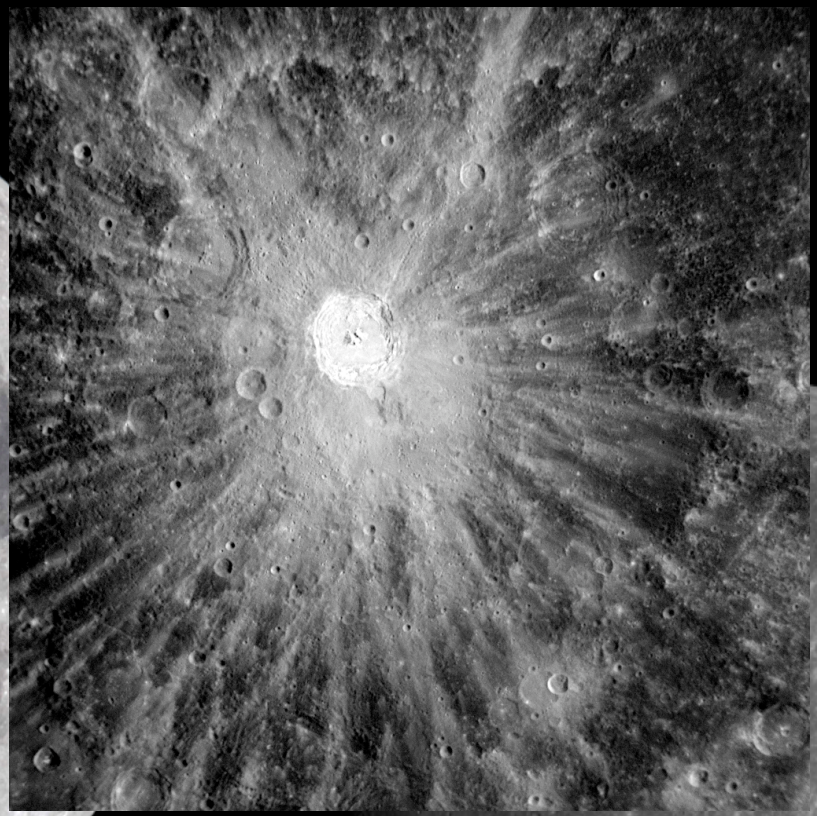
粉体への衝突現象で見られる エジェクタ地形の分類

A. Suzuki[1], T. Kadono[2], M. Arakawa[3], A. M. Nakamura[1],
K. Wada[4], S. Yamamoto[5]

[1]CPS/Grad. School Sci., Kobe Univ., [2]Inst. Laser Eng., Osaka Univ.,
[3]Grad. School Env. Studies, Nagoya Univ., [4]PERC, Chitech,
[5]National Inst. Env. Studies

Center for Planetary Science

Rayed craters on planets



Kuiper, D=62 km

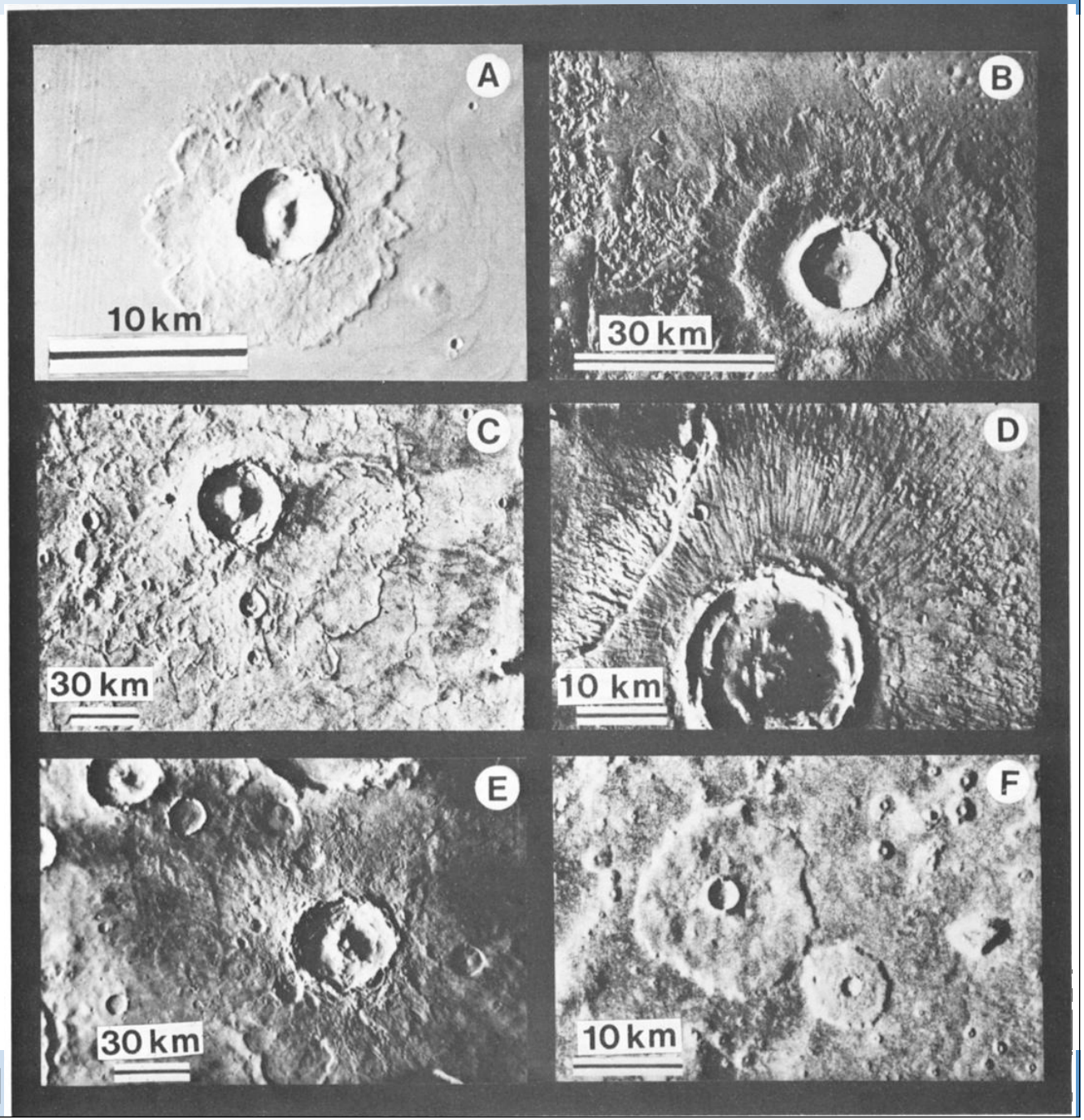
Moon

Mercury

NASA/Johns Hopkins Univ. APL/Carnegie Inst. of Washington

- The nature, origin, age, and formation processes have long been the subject of major controversies [e.g. Hawke et al., 2004]

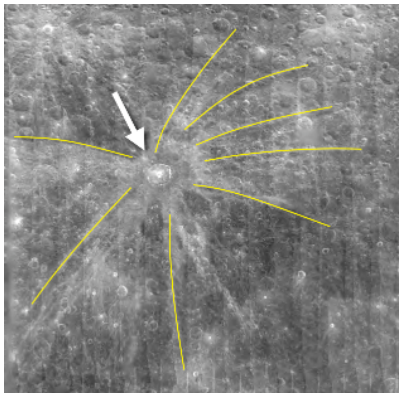
火星エジェクタのバリエーション

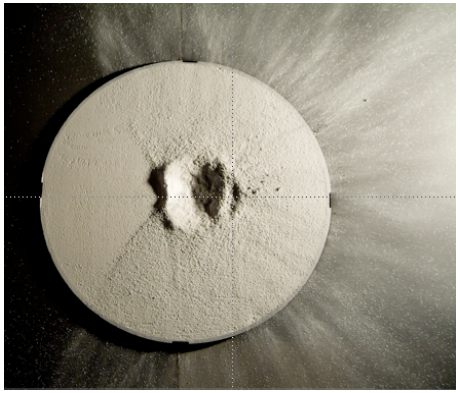


[Mouginis-Mark, 1979]

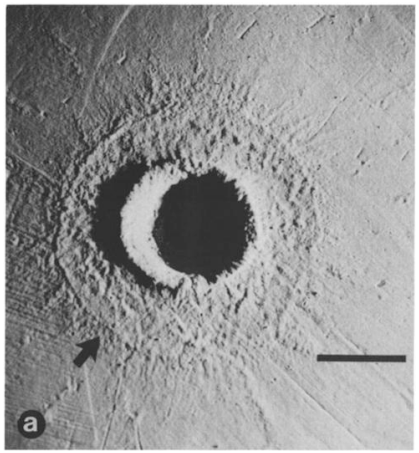
ejecta in the laboratory

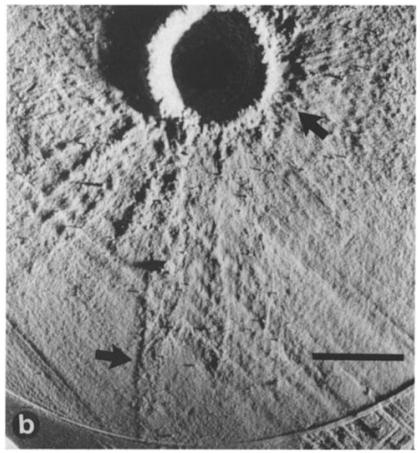
- Uprange ray pattern -- interpreted as an evolving excavation flow field [Schultz et al., 2009]

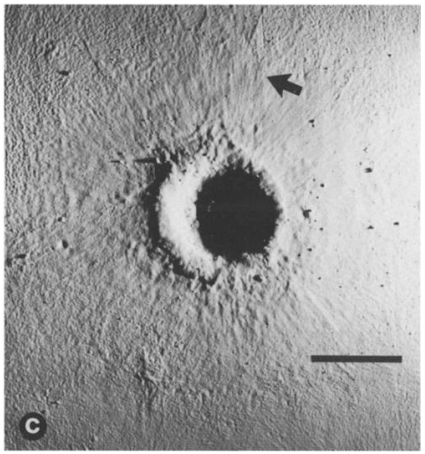




[Schultz et al., 2009]







[Schultz, 1992]

[private communication with S. Yamamoto]

目的

- ガラスビーズターゲットに衝突をさせ、実験条件（大気圧，衝突速度，粒径など）を変化させたときにどのようなエジェクタ地形ができるかを調べ，分類する
- 相図を描き、エジェクタ地形の形成条件を制約する

実験条件とパラメータ

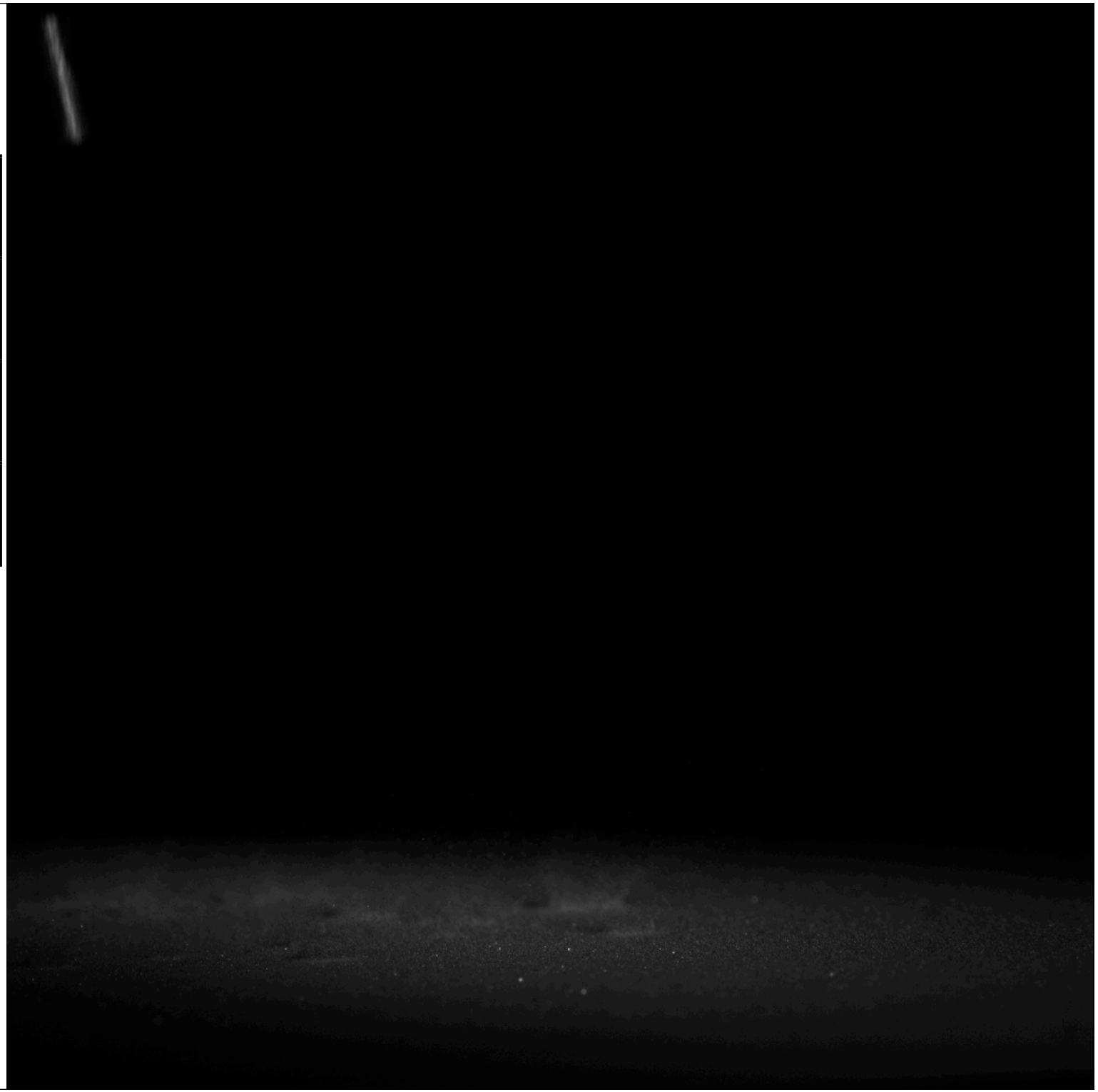
- 標的 : ガラスビーズ 100 μm (50, 420 μm)
- ターゲット準備状況 : well-packing / loose packing
- チェンバー内大気圧 : 10^2 Pa ～ 10^5 Pa (大気圧)
- 衝突速度 : 数 ～ 百数十 m/s

projectile					ambient pressure	facilities
diameter	mass	material	shape	impact velocity		
25.0 mm	63.6 g	Fe	sphere	a few m/s	atmos.	free fall
24.6 mm	19.2 g	glass	sphere	a few m/s	atmos.	free fall
29.7 mm	39.1 g	Al	sphere	a few m/s	atmos.	free fall
24.5 mm	67.4 g	Fe	sphere	a few m/s	10^2-10^5 Pa	free fall
9.53 mm	0.5 g	Nylon	sphere	20 ~ 40 m/s	atmos.	gun in Nagoya
9.53 mm	0.5 g	Nylon	cylinder	20 ~ 40 m/s	atmos.	gun in Nagoya
10 mm	6.0 g	Stainless	cylinder	~ 50 m/s	~ 10^3 Pa	gun in Kobe
10 mm	0.9 g	Polycarbonate	cylinder	50 ~ 120 m/s	10^3-10^5 Pa	gun in Kobe
10 mm	2.1 g	Al	cylinder	50 ~ 120 m/s	10^3-10^5 Pa	gun in Kobe

Results：

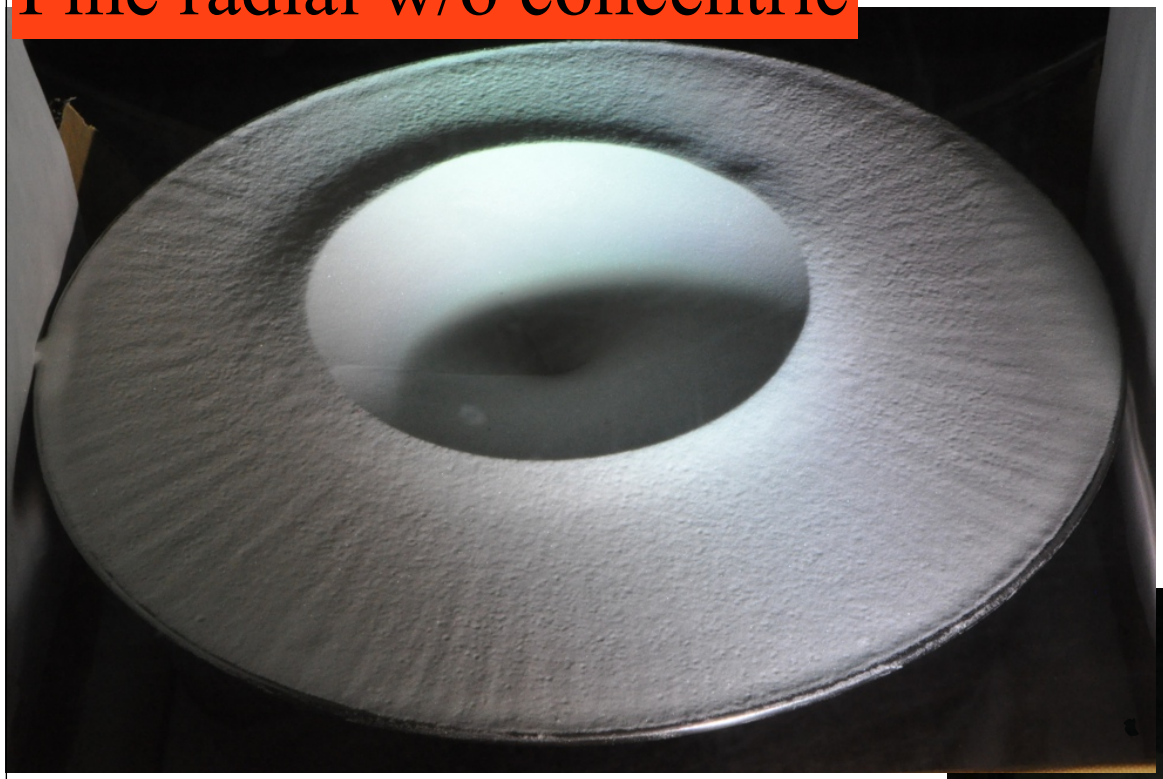
target mean diameter	100 μm
target initial condition	well-packing
ambient pressure	10^3 Pa
impact velocity	52.8 m/s

recorded in 5000 fps



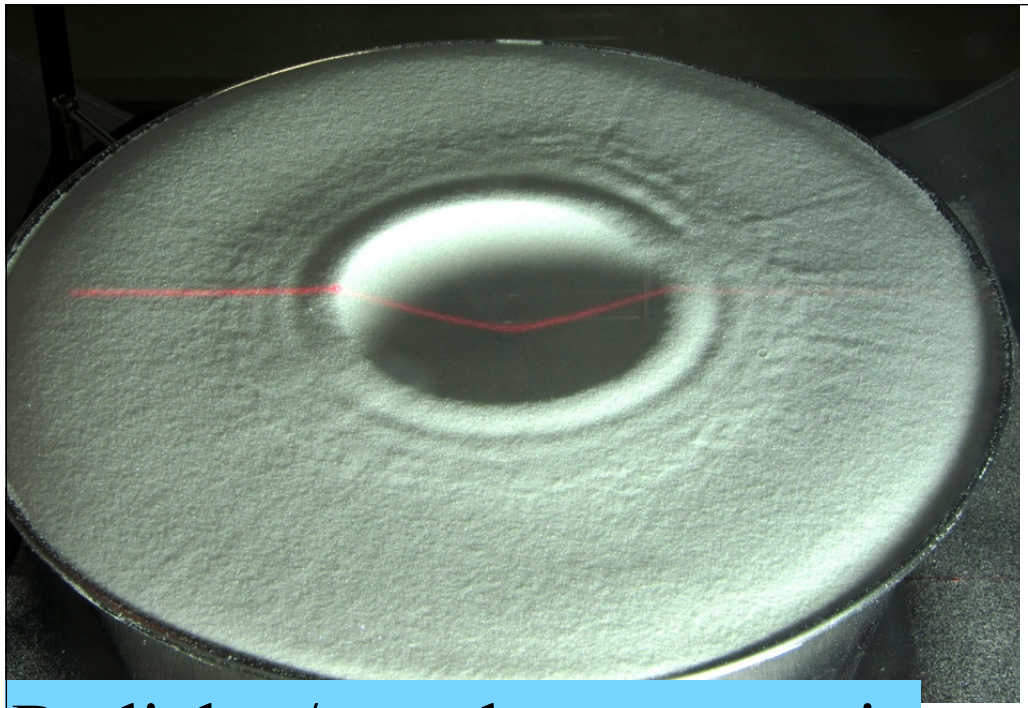
地形の分類

Fine radial w/o concentric

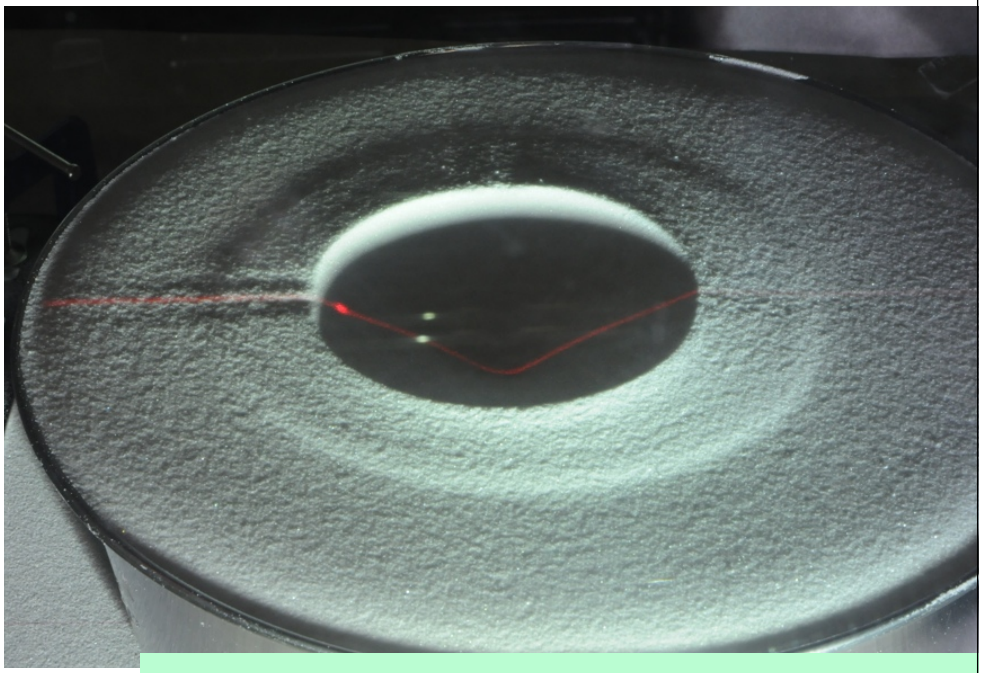


Knobby radial w/o concentric

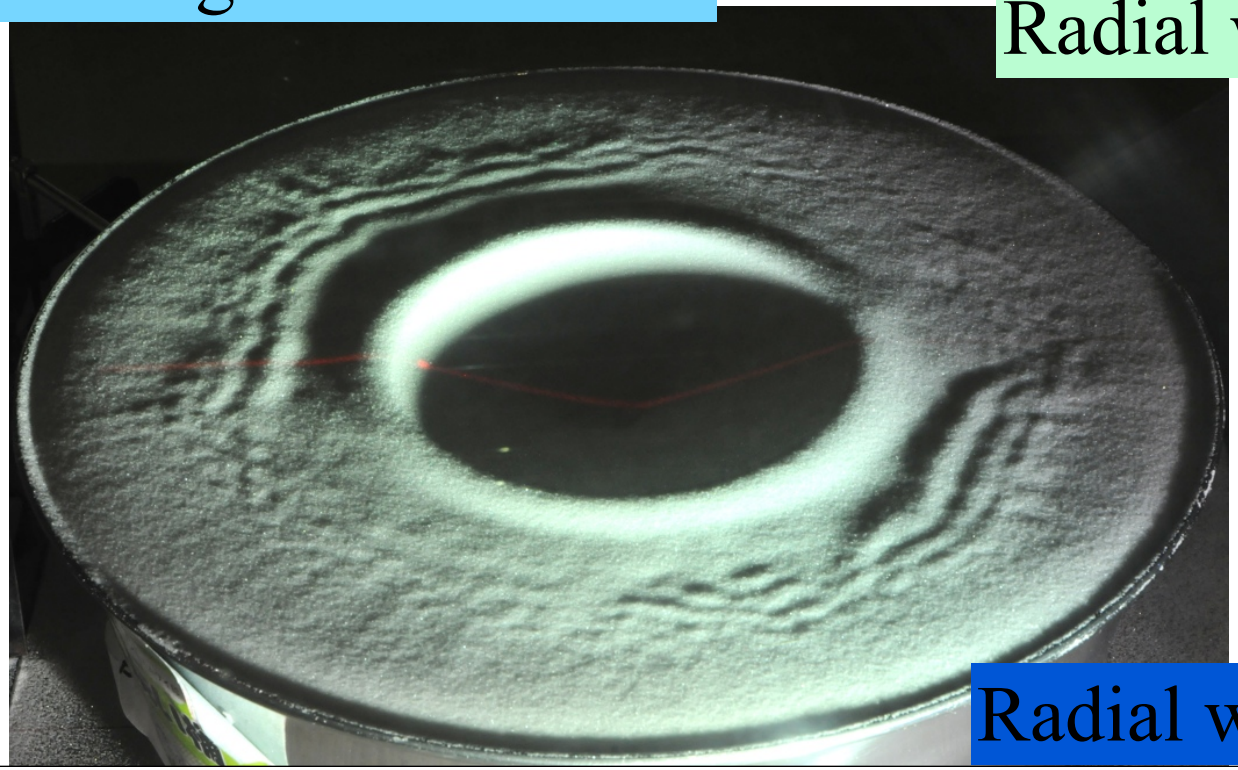
CPS Center for Planetary Science



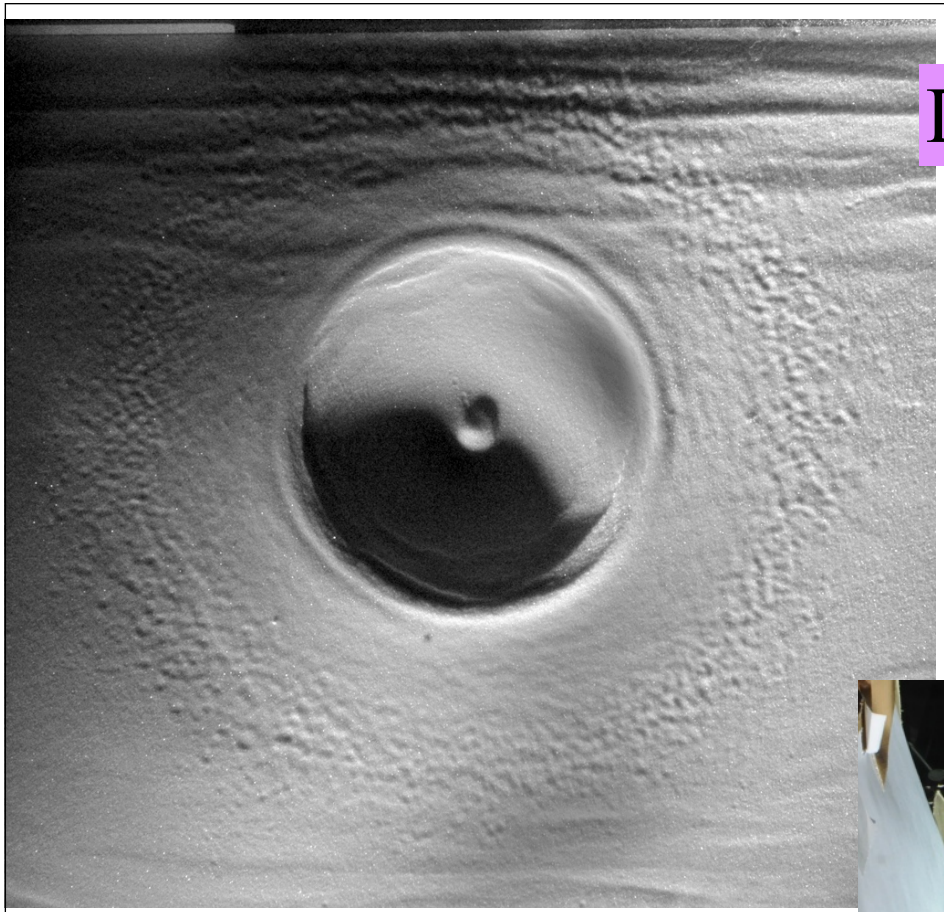
Radial w/ regular concentric



Radial w/ thick concentric

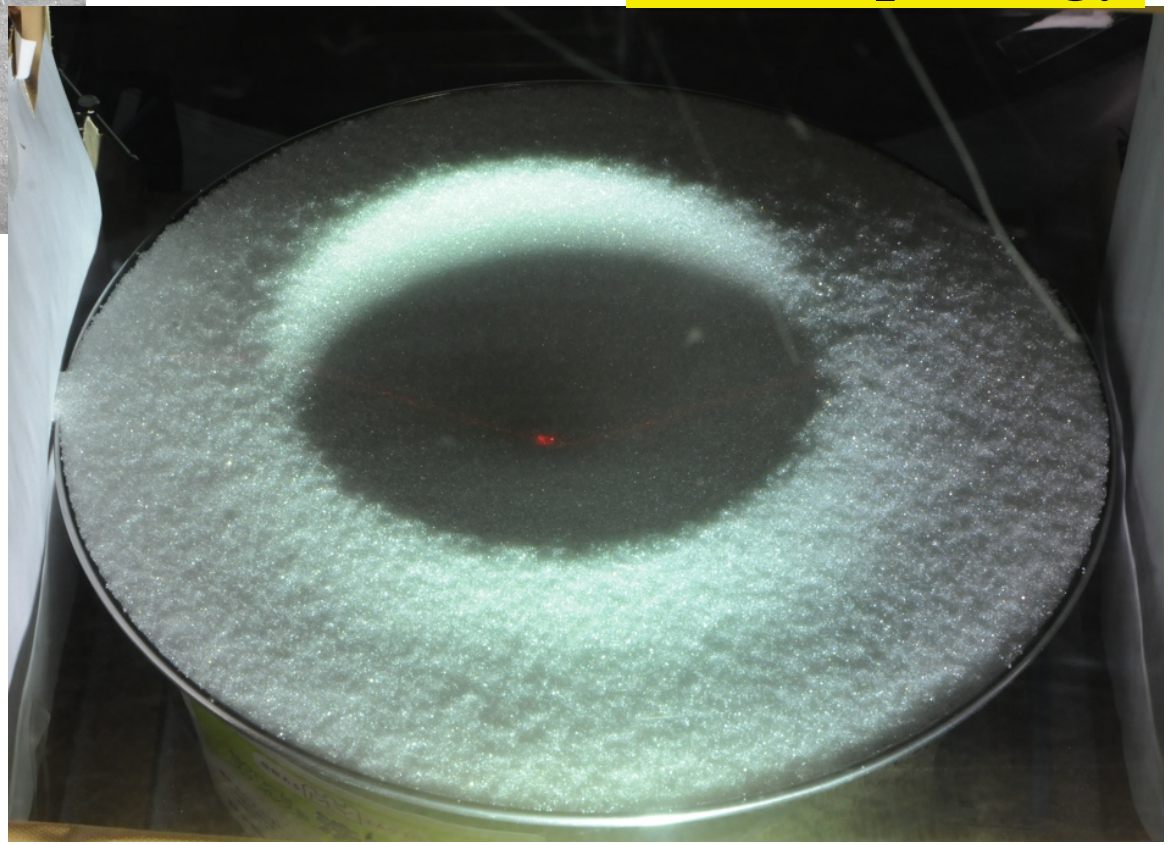


Radial w/ wavy concentric

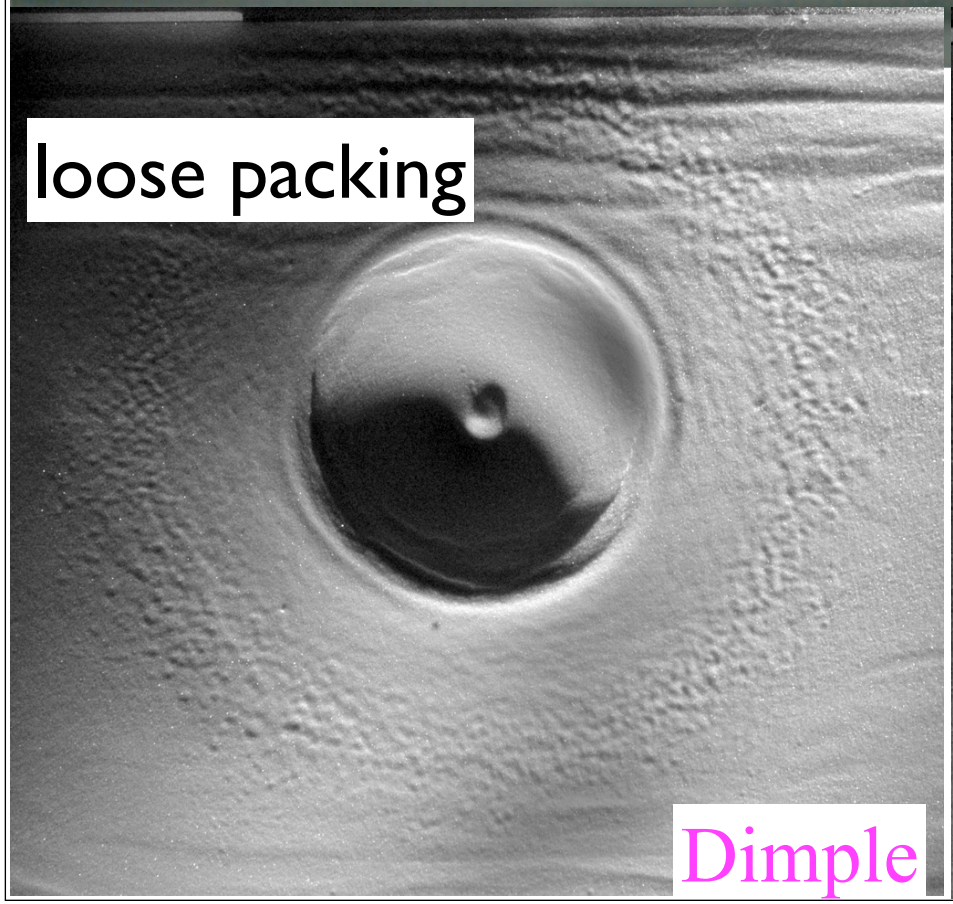


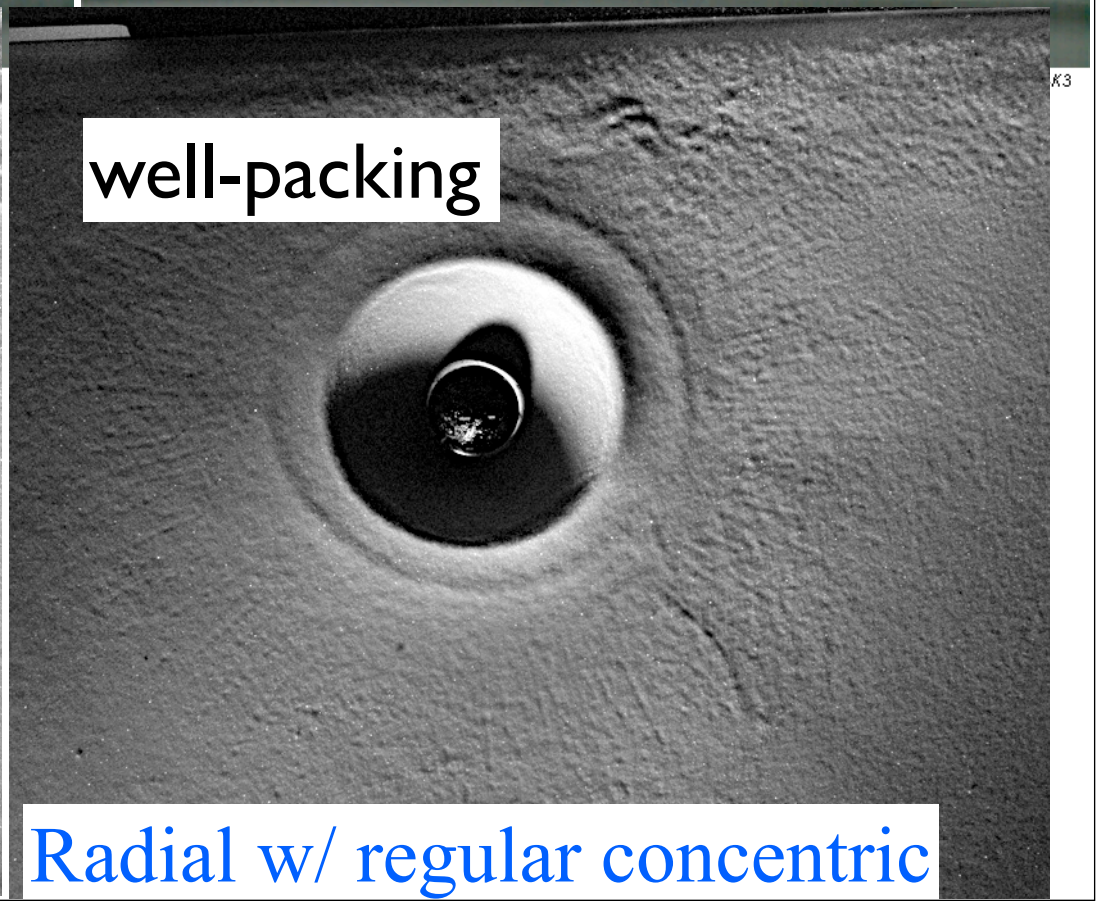
Dimple

No morphology

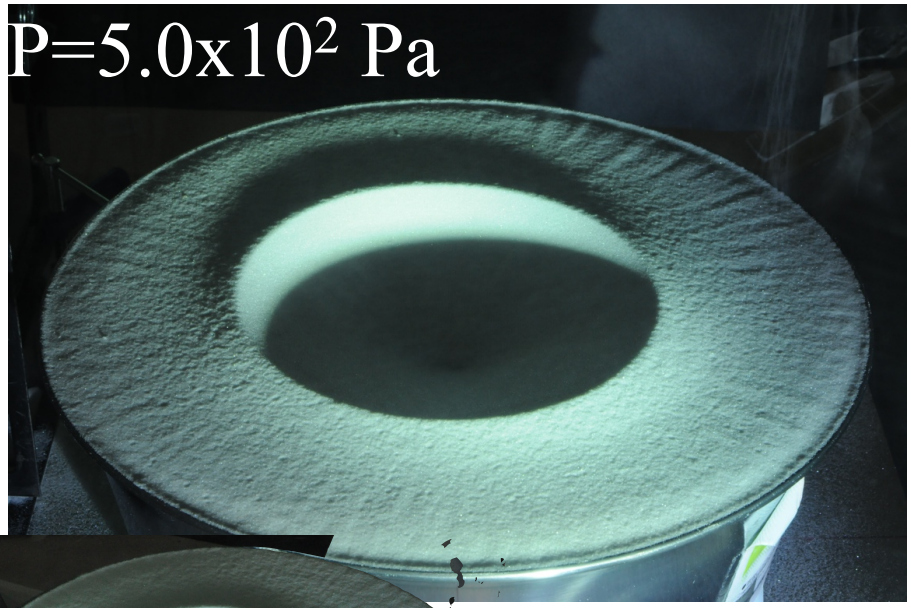


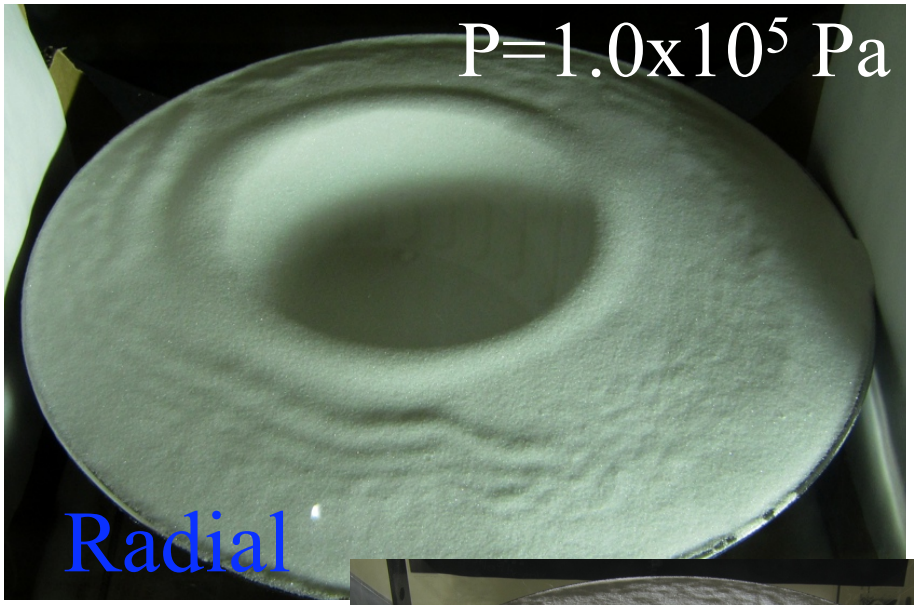
ターゲット準備状態による地形の違い





大気圧による地形の違い



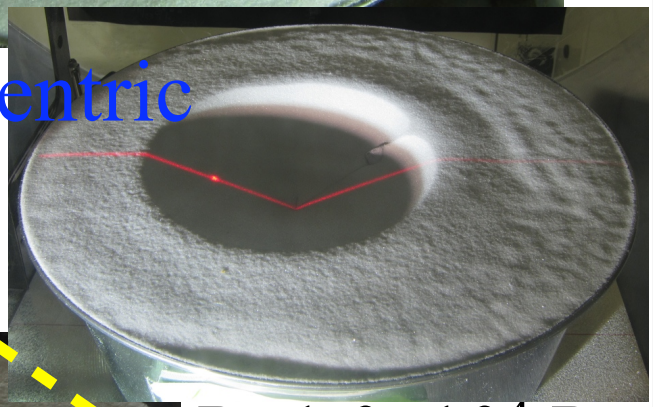


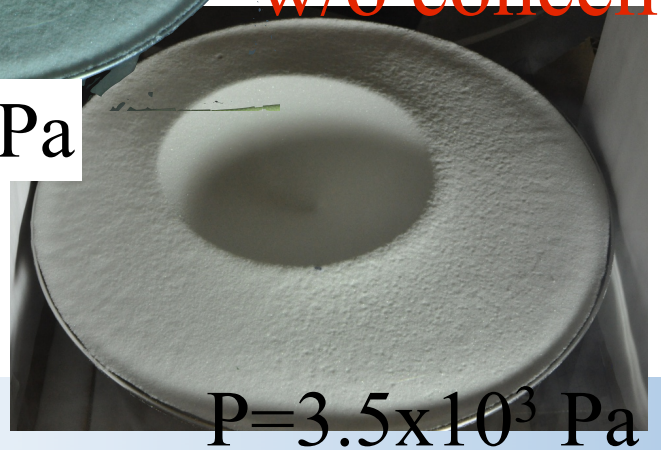
Radial

w/ concentric

Radial

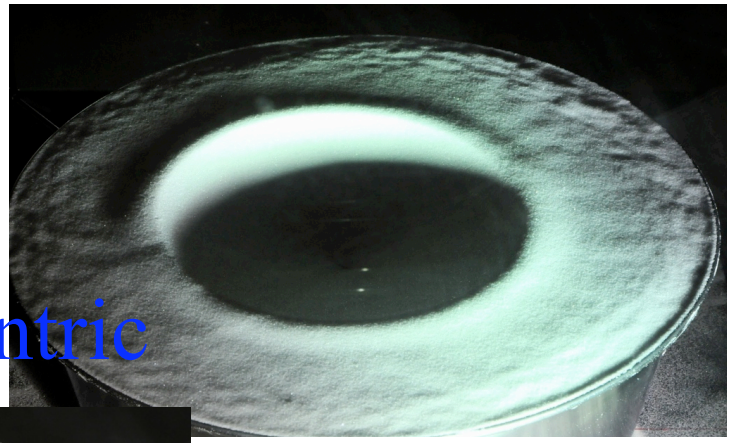
w/o concentric





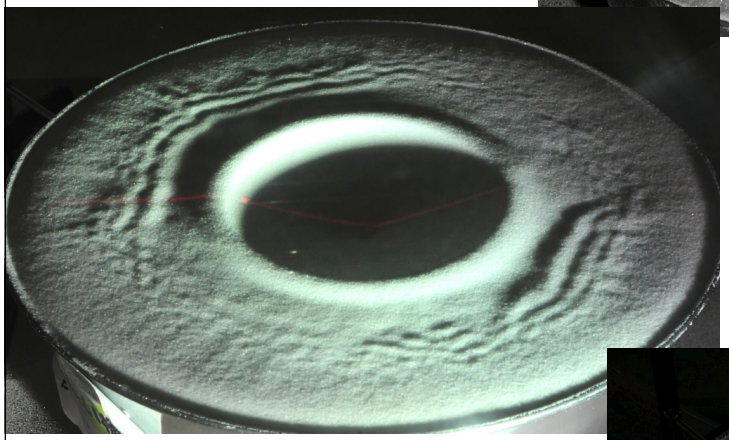
CPS Center for Planetary Science

衝突速度による地形の違い



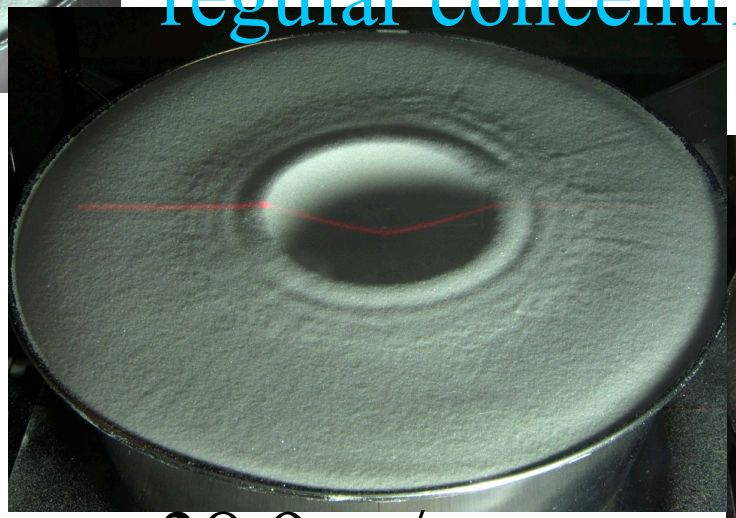
Radial w/
wavy concentric

v = 83.8 m/s



v = 58.3 m/s

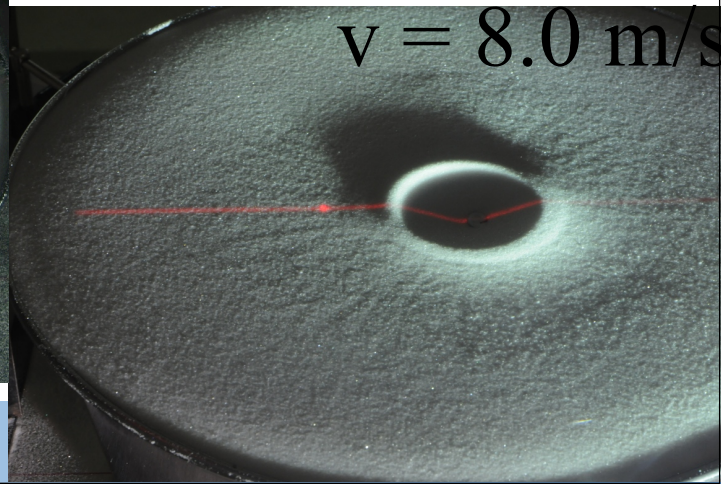
Radial w/
regular concentric



v = 38.9 m/s

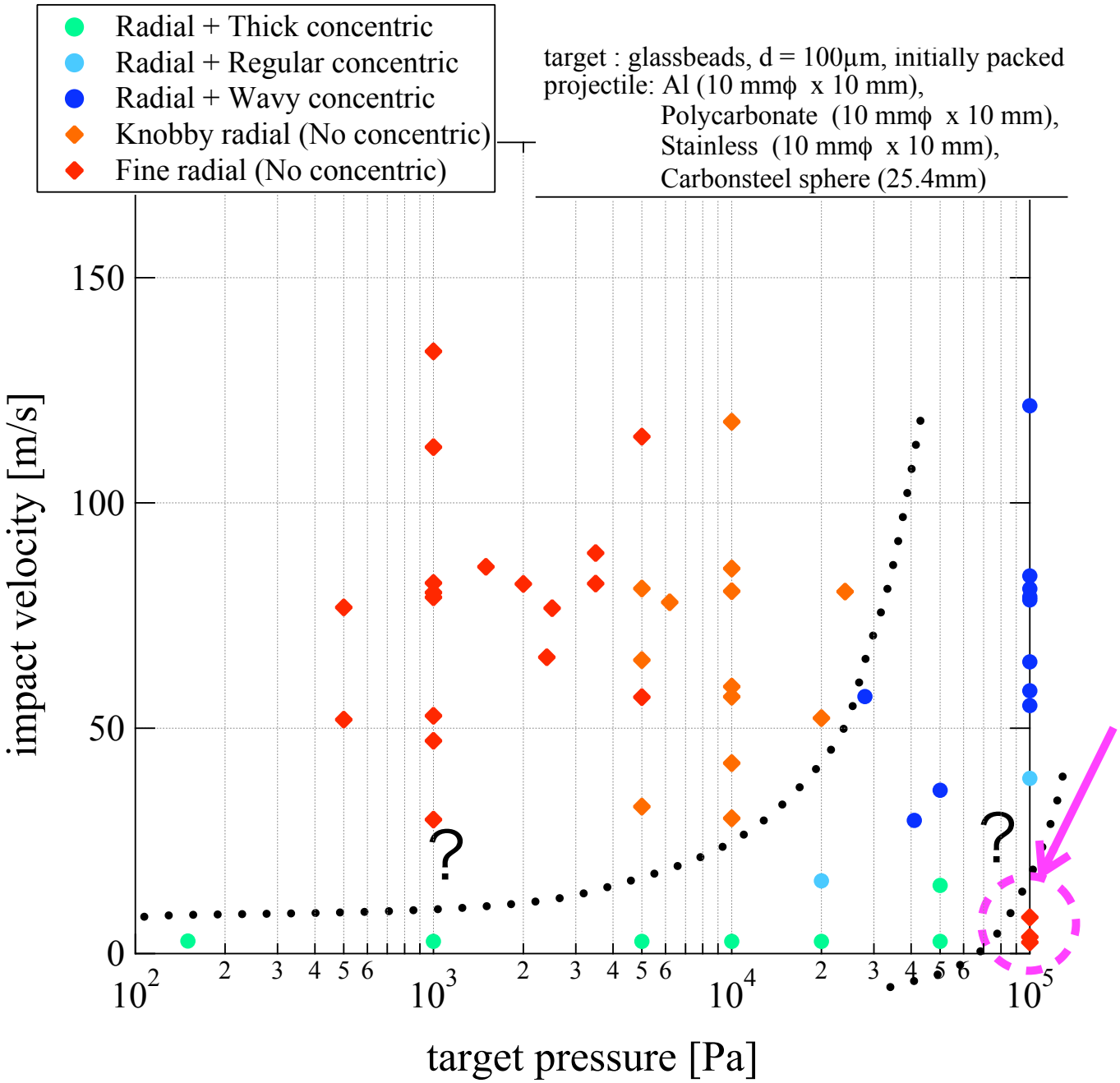
target mean diameter	100 μm
target initial condition	well-packing
ambient pressure	10^5 Pa
impact velocity	-

Radial
w/o concentric



v = 8.0 m/s

大気圧と衝突速度を用いた相図



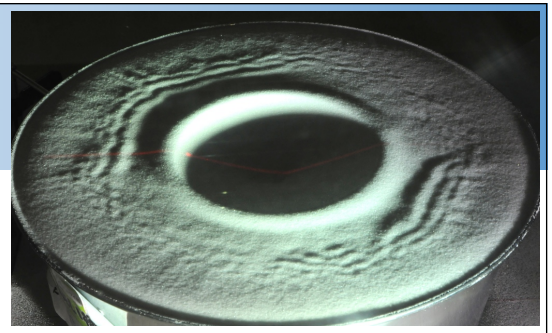
target mean diameter	100 μm
target initial condition	well-packing
ambient pressure	-
impact velocity	-

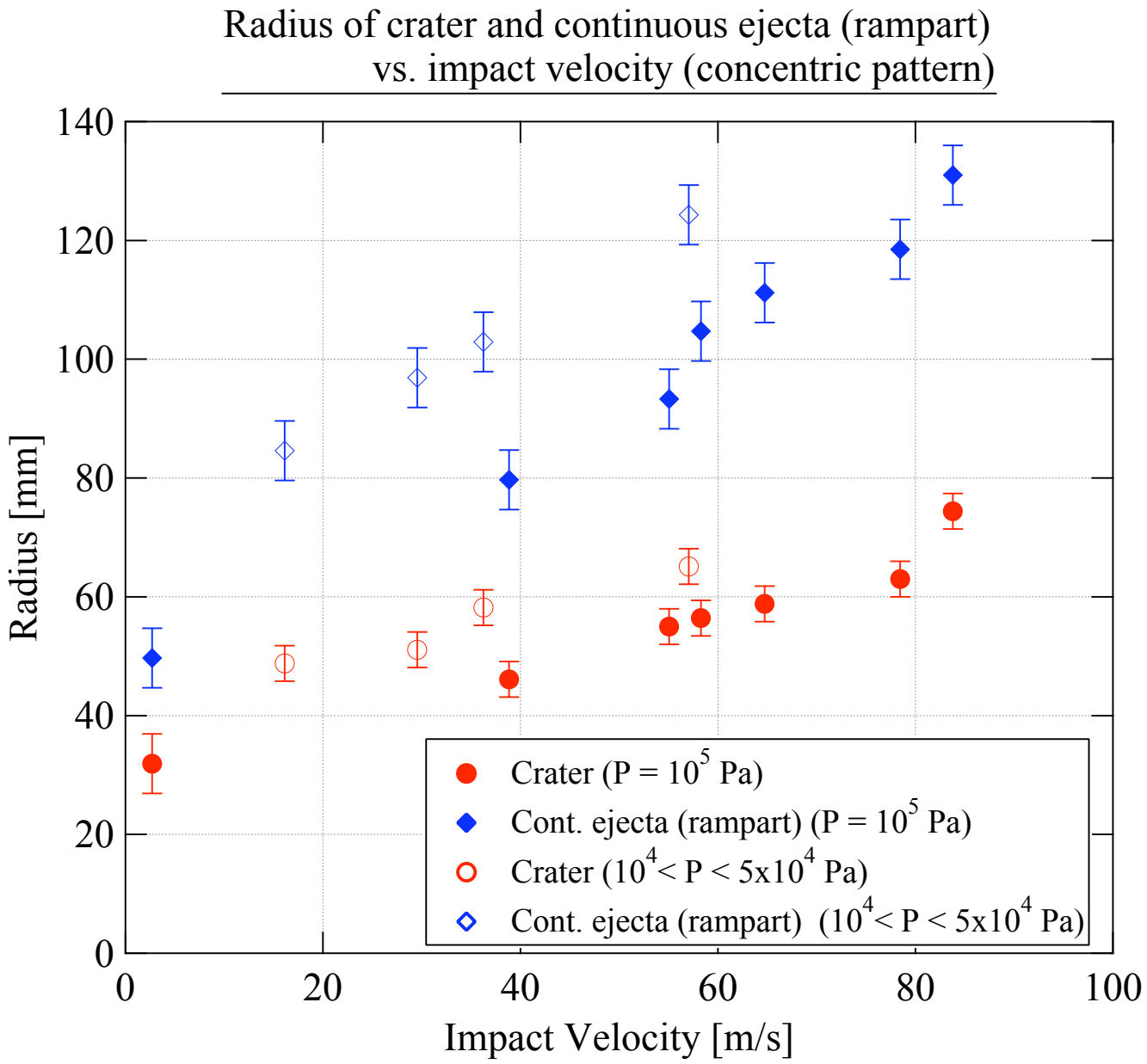
Dimple mode (loose packing)

50 μm : trend is similar

420 μm : no pattern

concentric パターン

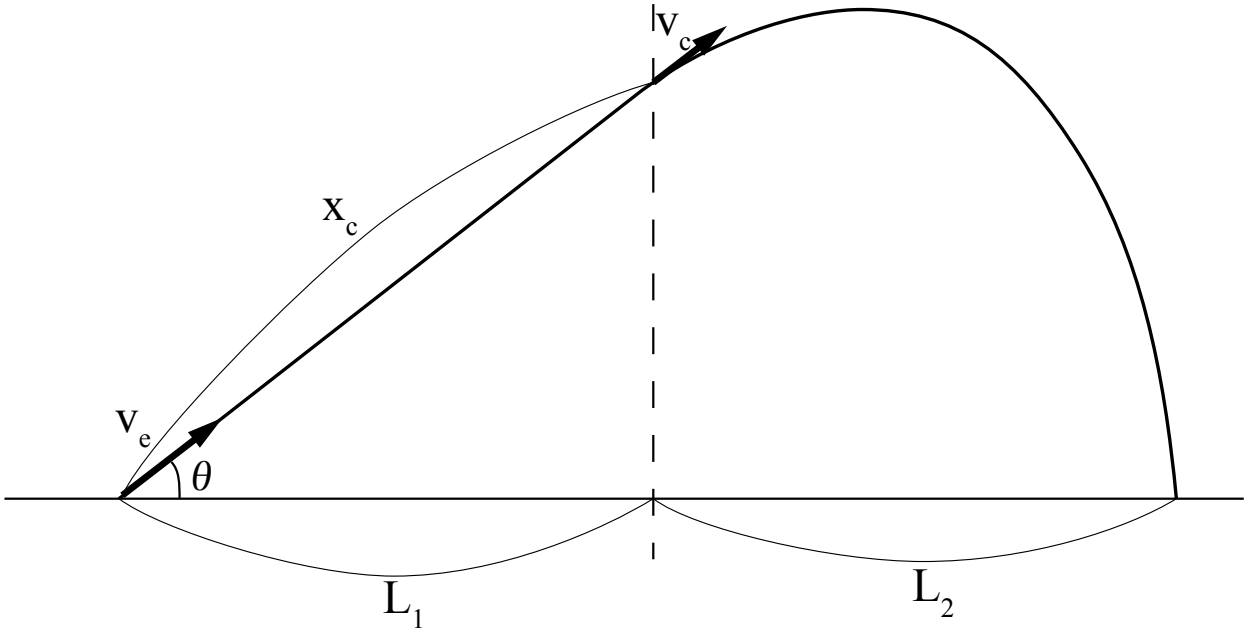




エジェクタ到達距離の簡易モデル

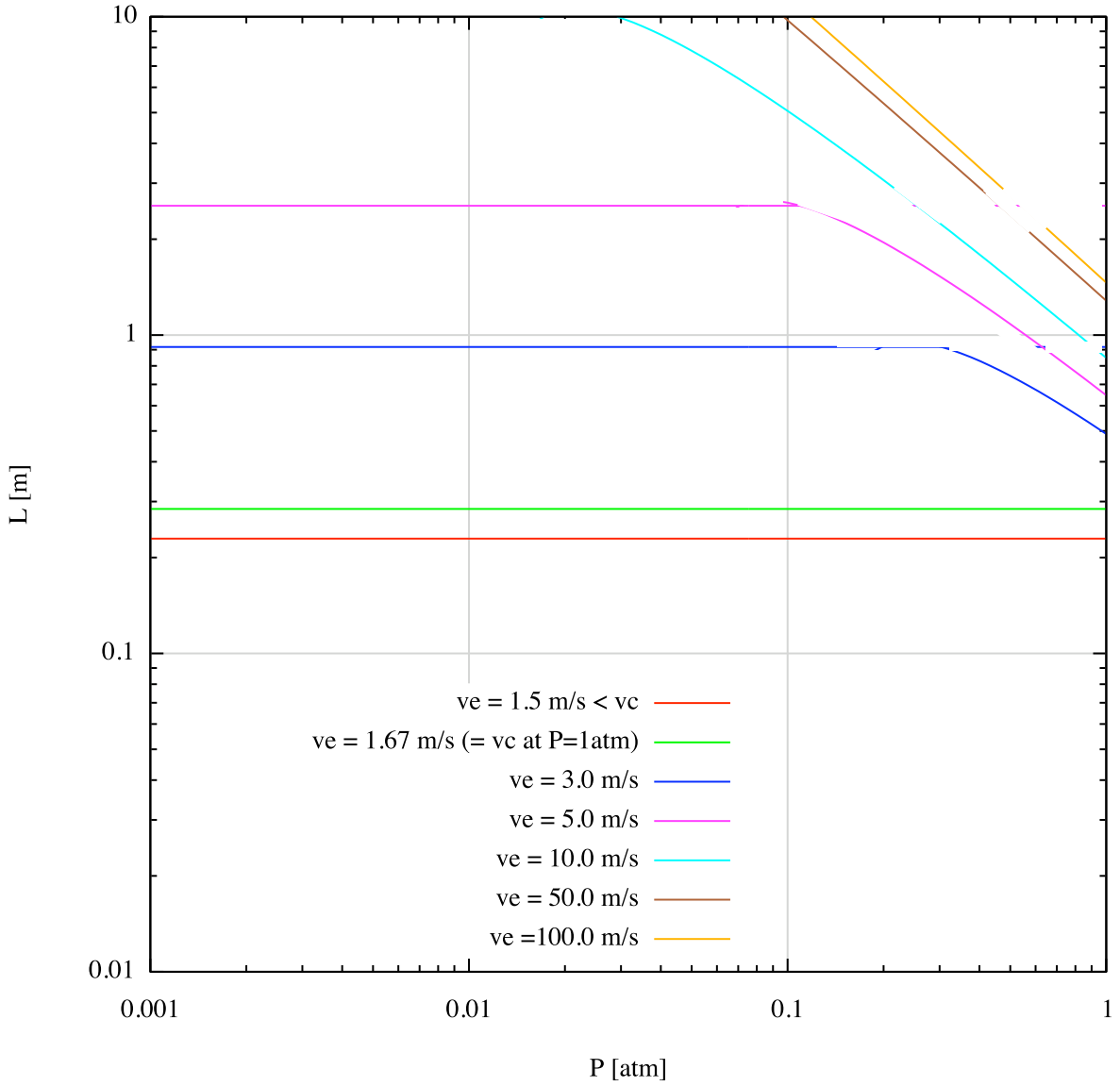
$$m\frac{d\mathbf{v}}{dt} = m\mathbf{g} - k\frac{\mathbf{v}}{|\mathbf{v}|}|\mathbf{v}|^2,$$

$$v_c = \sqrt{\frac{mg}{k}}$$

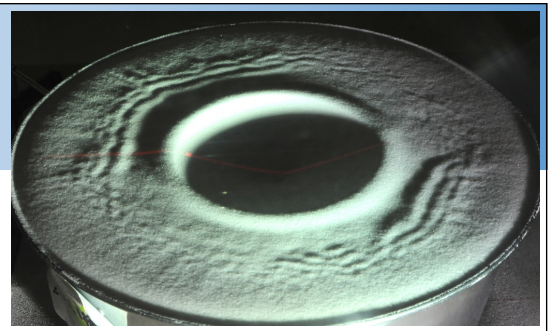


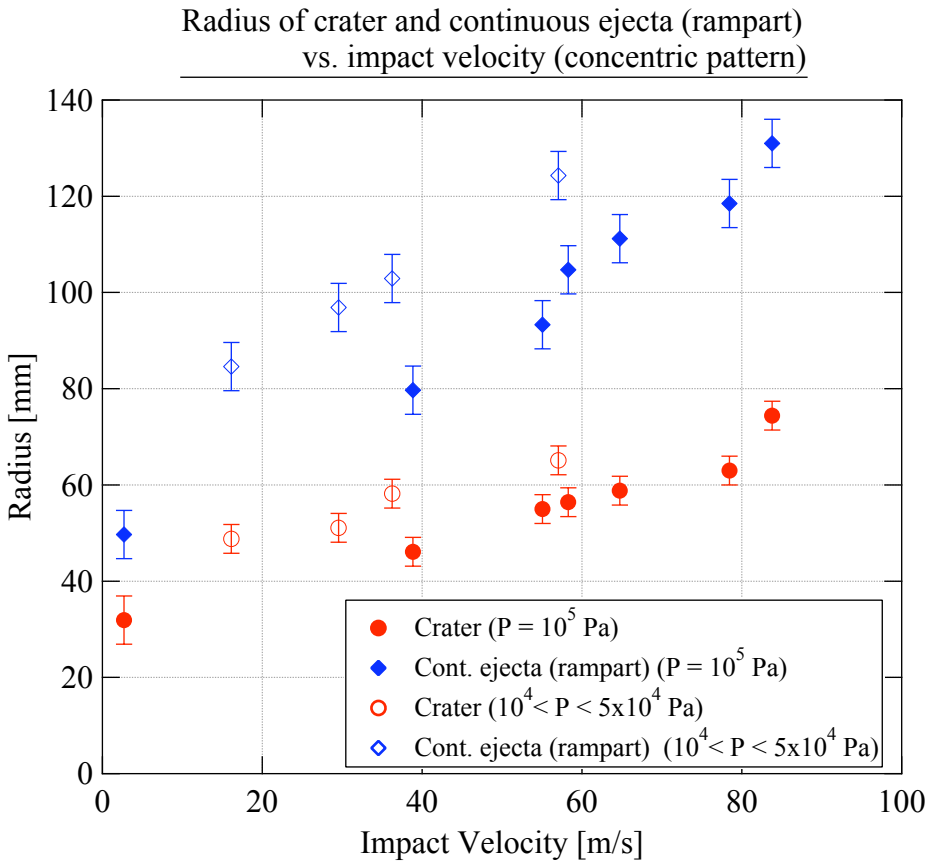
$$L_{\text{total}} = 0.200\left(\frac{P}{10^5}\right)^{-1}\left\{\ln\left(\frac{v_e}{1.67}\left(\frac{P}{10^5}\right)^{\frac{1}{2}}\right) + \frac{1}{\sqrt{2}} + \sqrt{\sqrt{2}\ln\left(\frac{v_e}{1.67}\left(\frac{P}{10^5}\right)^{\frac{1}{2}}\right) + \frac{1}{2}}\right\},$$

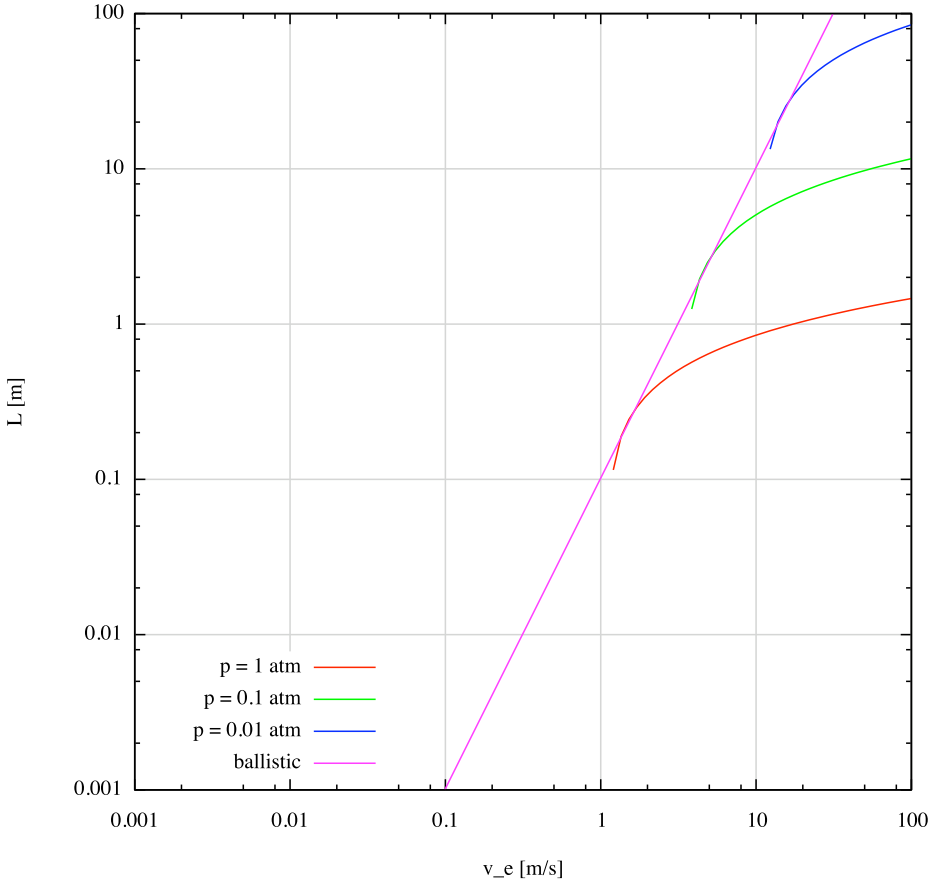
モデルにおけるエジェクタの到達距離



concentric パターン







Summary

◉ 粒径による違い

- 50, 100 μm -> Radial / Radial w/ concentric. / Dimple
- 420 μm -> No morphology

◉ ターゲット準備状態による違い（大気圧下のみ）

- well-packing (low porosity) -> Radial mode
- loose packing (high porosity) -> Dimple

◉ 相図を描いた

- 大気圧，速度，粒径によって地形の違いができる

◉ エジェクタ到達距離の簡易モデル

- concentric パターンを作っているエジェクタは，かなり遅い速度で放出された
- 大気圧による減速は実験では観測された．別の減速モデルの必要性