Eruptive activity driven by discrete subsurface explosions
(focus on phreatomagmatic maar-diatremes)

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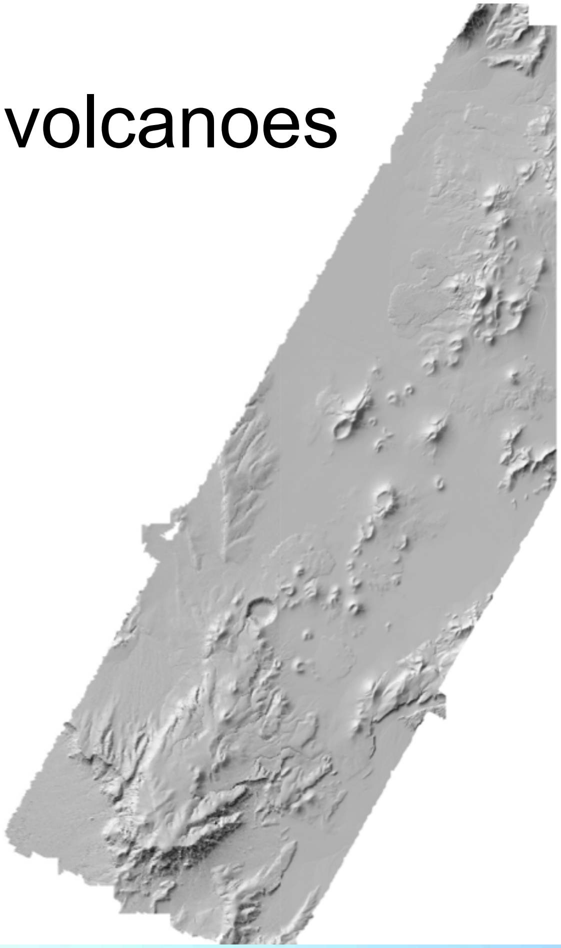
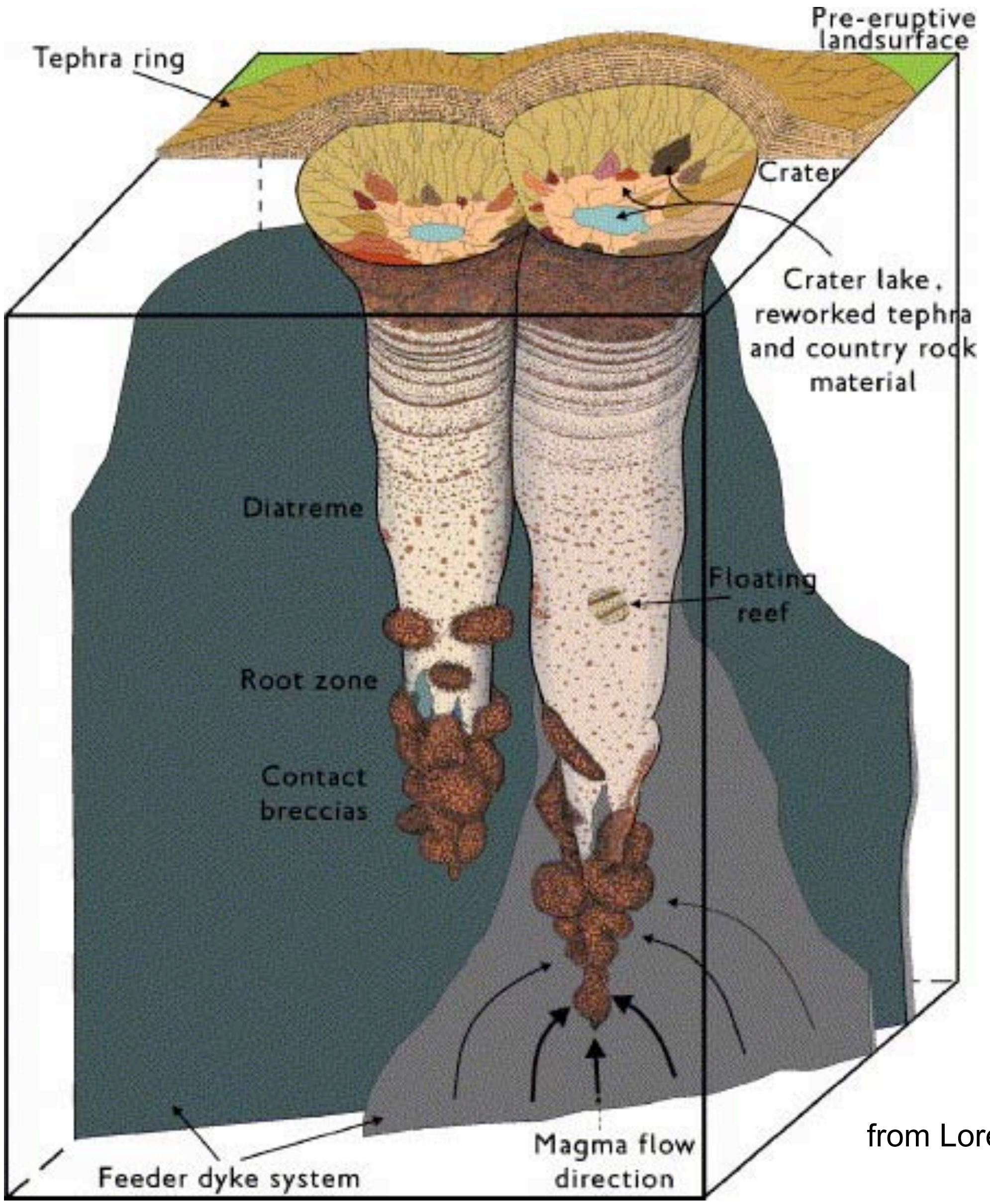
And many collaborators, chief among them Alison Graettinger, Ingo Sonder (both at Buffalo)

Maar-diatreme volcanoes



Valentine et al 2011, *Bull. Volc.*

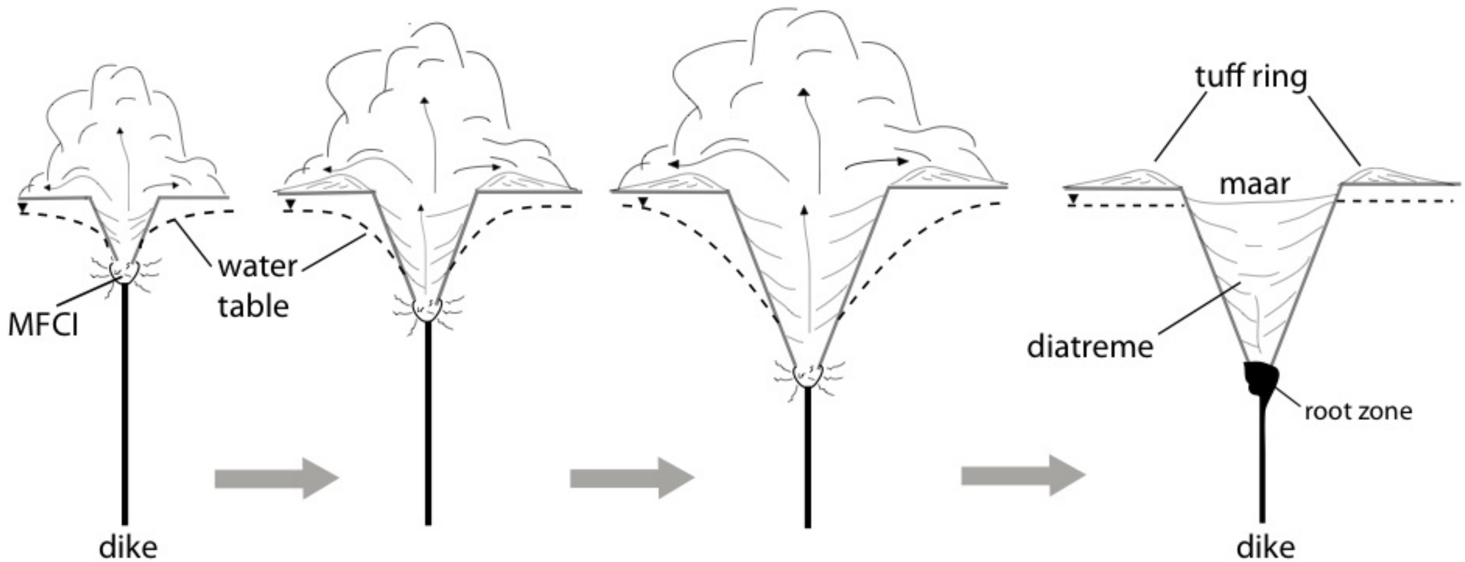
Maar-diatremes – most of the work is underground



from Lorenz & Kurszlaukis (2006), *J. Volcanol. Geotherm. Res.*

A widely accepted model

(Lorenz, 1986, *Bull. Volc.*)



- Explosions occur near water table
- Progressive drawdown equals deepening explosions
- Maar-diatreme widens as it deepens (subsidence and ejecta)
- Tephra deposits have progressively deeper lithics upward in stratigraphy

Recent work suggests…

- Explosions can occur at any depth within a developing diatreme at any time (diatreme fill variably saturated)
- Growth may be largely from the center outward (more than from top down)
- Low magma flux into system – contorted dikes and sills, some may not explode, some reach surface and erupt non-phreatomagmatically

See White and Ross (2011, JVGR), Valentine & White (2013, Ge

Questions

- How does final crater size relate to explosion energies and depths?
- How are eruption processes affected by progressive crater development and explosion depth?
- Is deepening of explosions necessary to explain progressively deeper-seated lithics in tephra stratigraphy?
- How do diatreme structures relate to explosion processes?

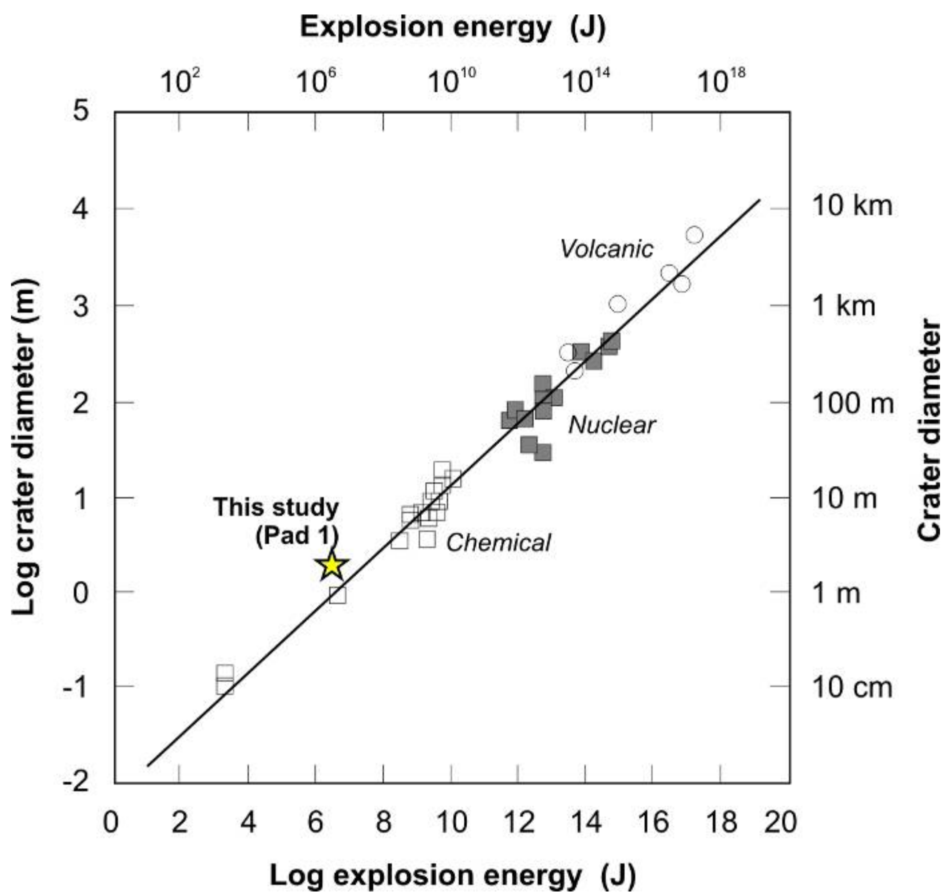
Scaling of craters is well established for single blasts

Physical dimensions of subsurface blast processes scale with $E^{1/3}$

Scaled depth = $D/E^{1/3}$ (m $J^{-1/3}$)

For a given blast energy E there is an "optimal scaled depth" that will produce the maximum crater excavation (~4×10^{-3} m $J^{-1/3}$)
(no eruption at >10^{-2} m $J^{-1/3}$)

Crater diameter proportional to $E^{1/3}$
At optimal scaled depth



Sato & Taniguchi 1997, *Geophys. Res. Lett.*

Ross et al 2013, *J. Volcanol. Geotherm. Res.*

Methods

Geohazards Field Station (University at Buffalo, NY)

Photo A. Graettinger 2013

Methods

PRE-BLAST STRATIGRAPHY

EXPLOSIVES

1/3 to 1 lb PETN-TNT buried at ~50-70 cm from original ground surface

CRATERS & PROBE PROFILES

EXCAVATION

Series of vertical sections every 10-30 cm

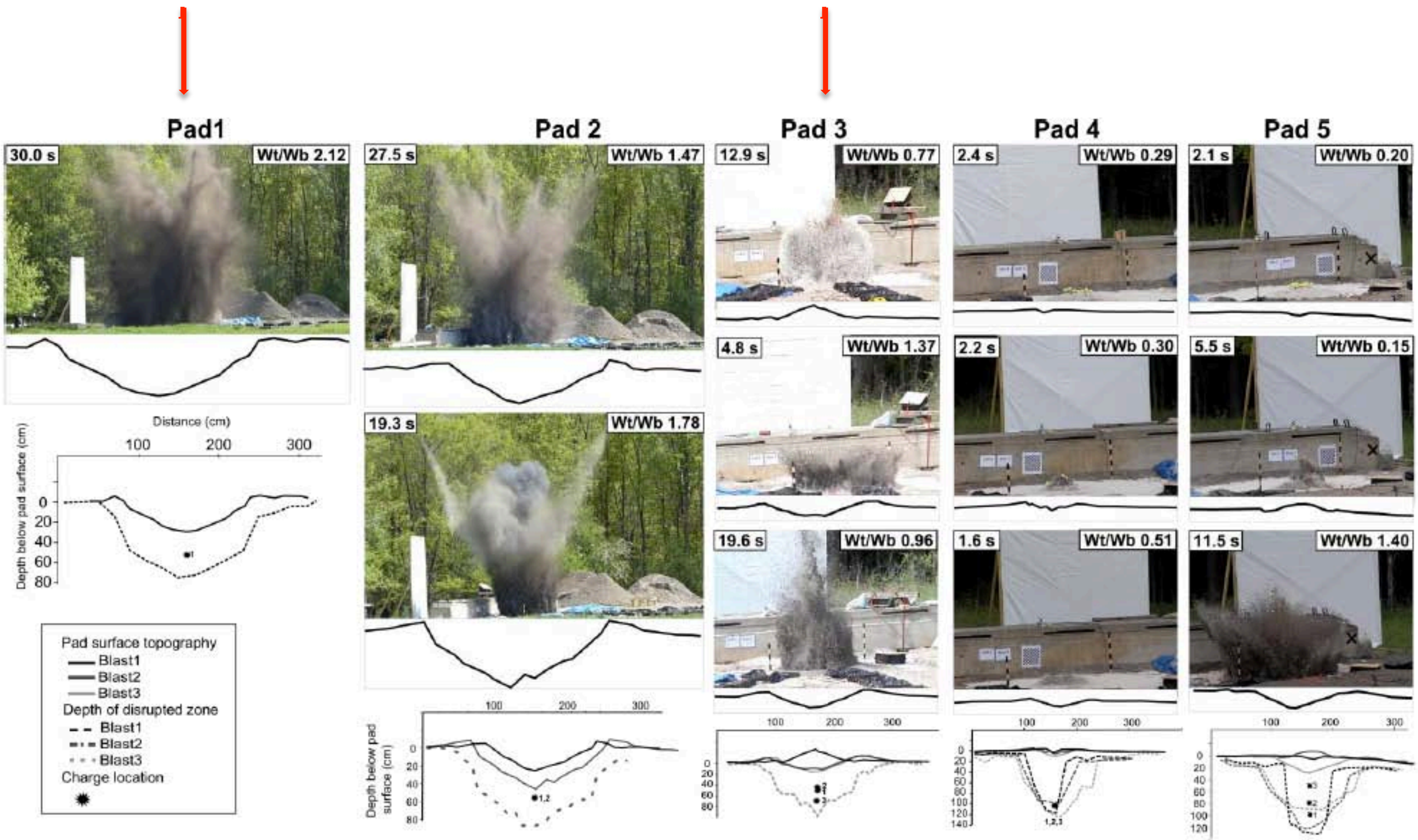
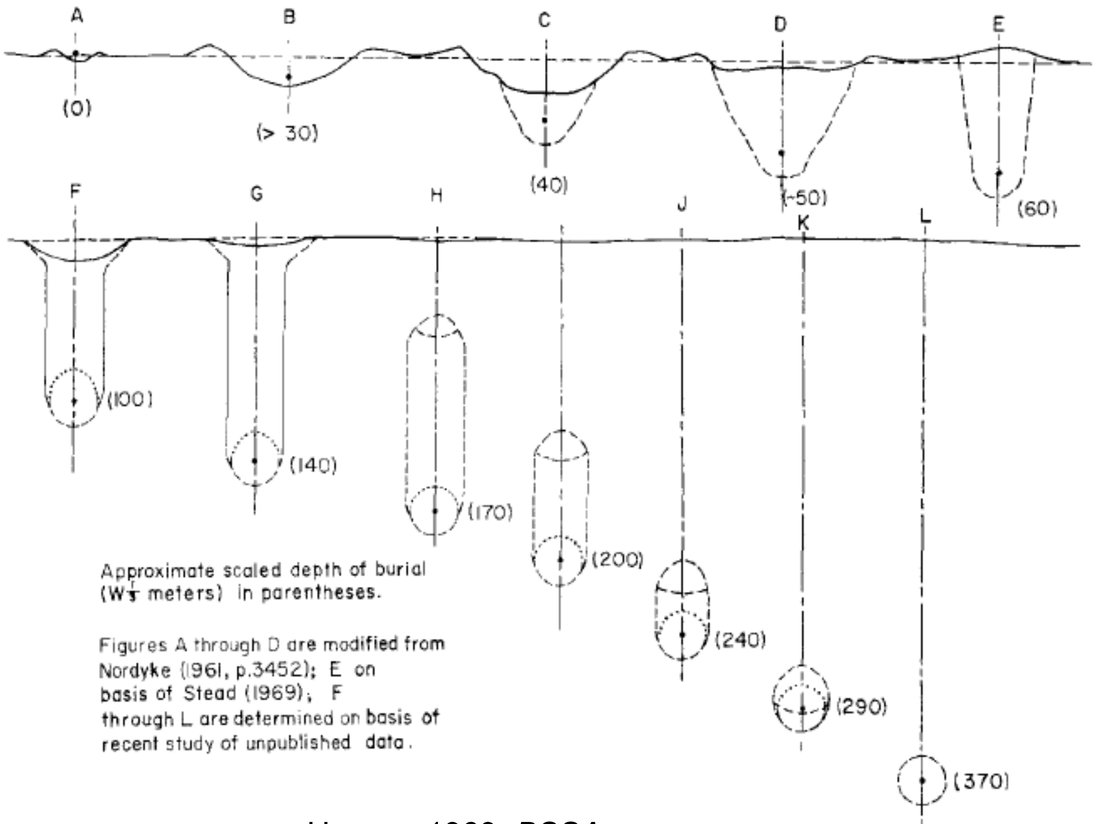


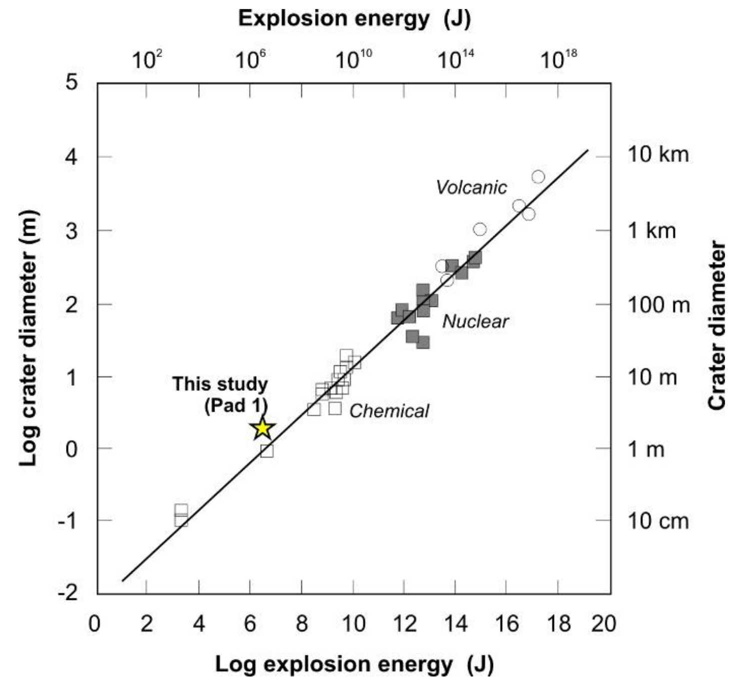
Figure 2: Image captures from high definition video of blast experiments. For each blast jet shape, resulting crater, and probe profiles are included. Deposition duration is listed on the upper left corner of the jet image. The dimensions of the jet width of top/width of bottom are listed on the upper right hand corner. Charge location is located on the probe profiles. For pads 1 and 2 the white background is 4 m tall. For pads

Graettinger et al (in press)

Scaling – changes in crater morphology with scaled depth



Houser, 1969, *BSSA*



Phreatomagmatic explosions expected to be ~10^9-10^{14} J

Nuclear explosives craters as function of scaled depth – same dependence noted in our experiments

Optimal depth of burst

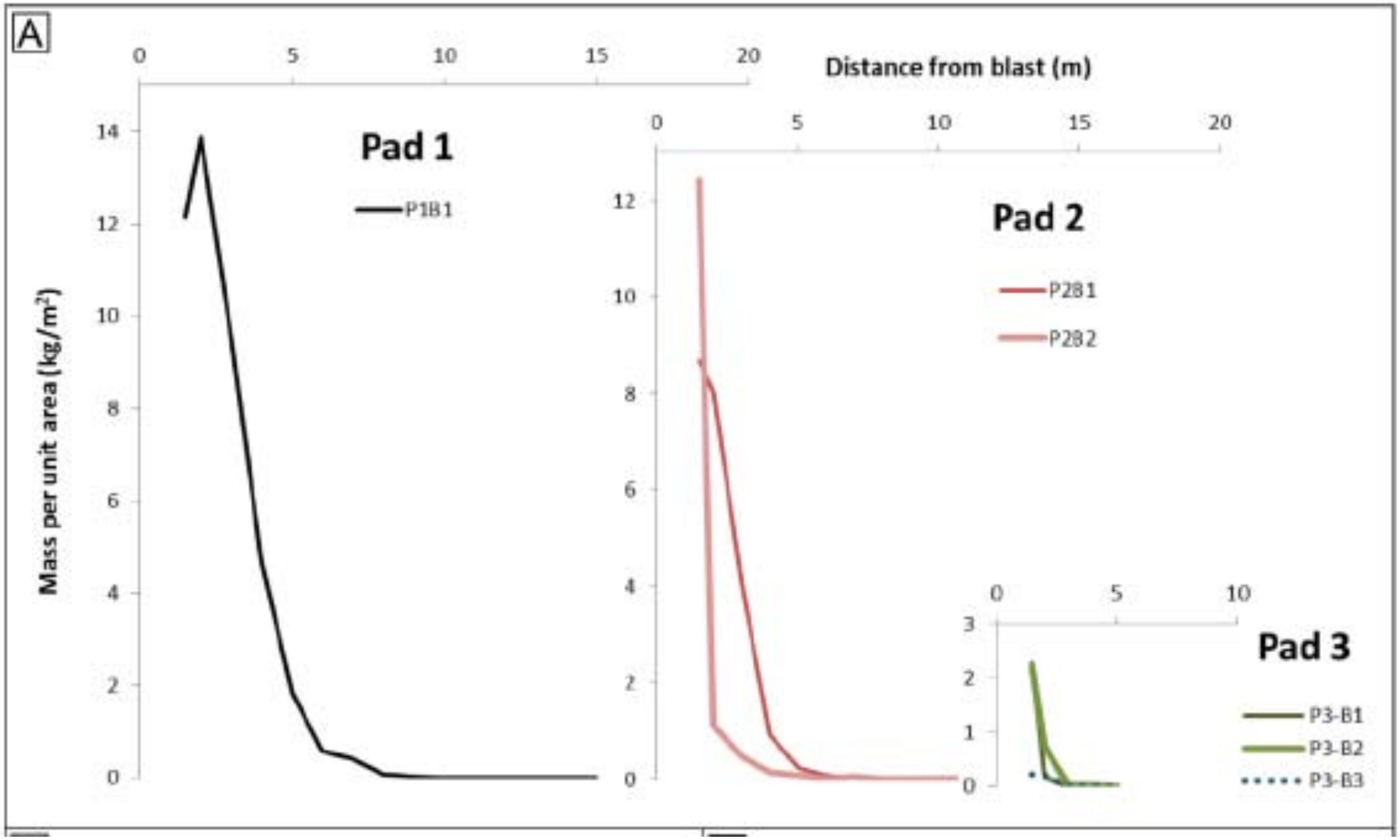
DOB > optimal, flat pre-blast surface

DOB > optimal, “retarc” from previous blast

DOB > optimal, crater from previous blast

DOB >> optimal, fully contained

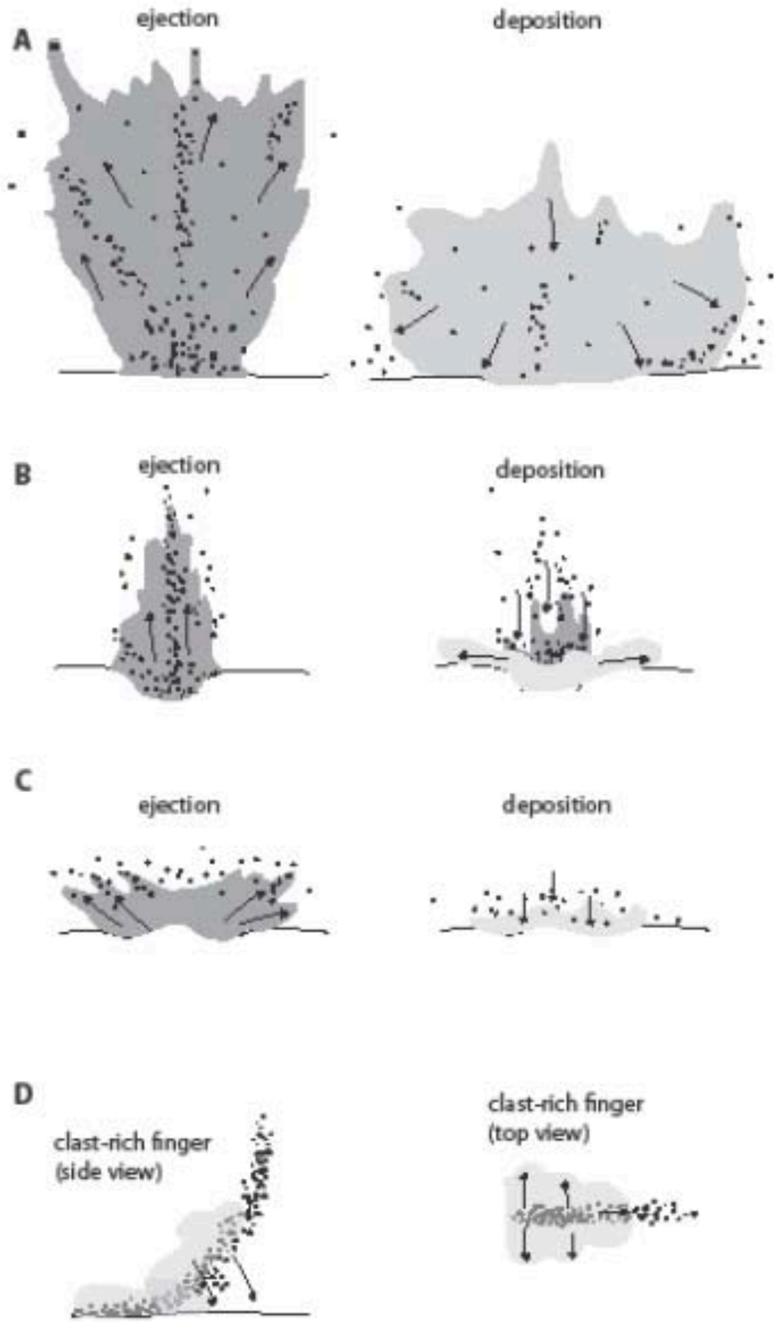
Sedimentation around craters



Graettinger et al, in press

Optimal depth of burst

Example of “fines expulsion” density current



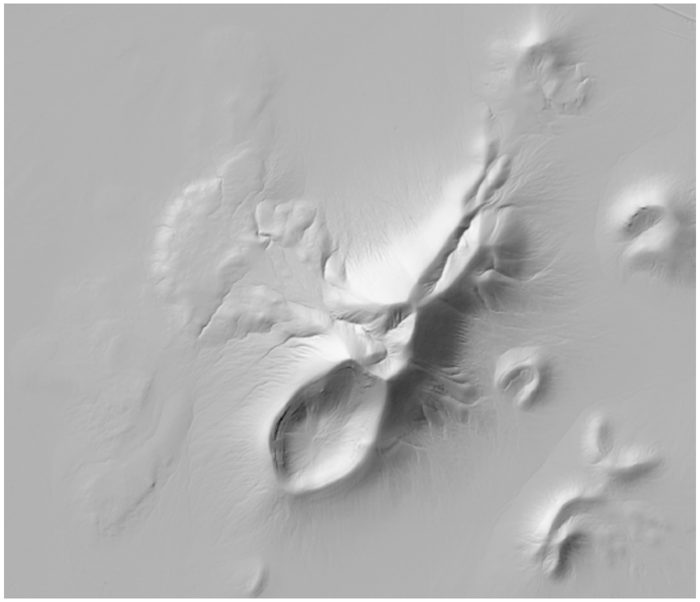
Resulting pyroclastic density currents (surges) and inferred deposits

Direct jet collapse surge – poorly sorted, beds should have coarse base, fine top

Expulsion-driven surge – fine-grained deposits, isolated ballistic impacts

Jet finger collapse surge – similar to direct jet collapse but with lobate distribution

Graettinger et al (in prep)

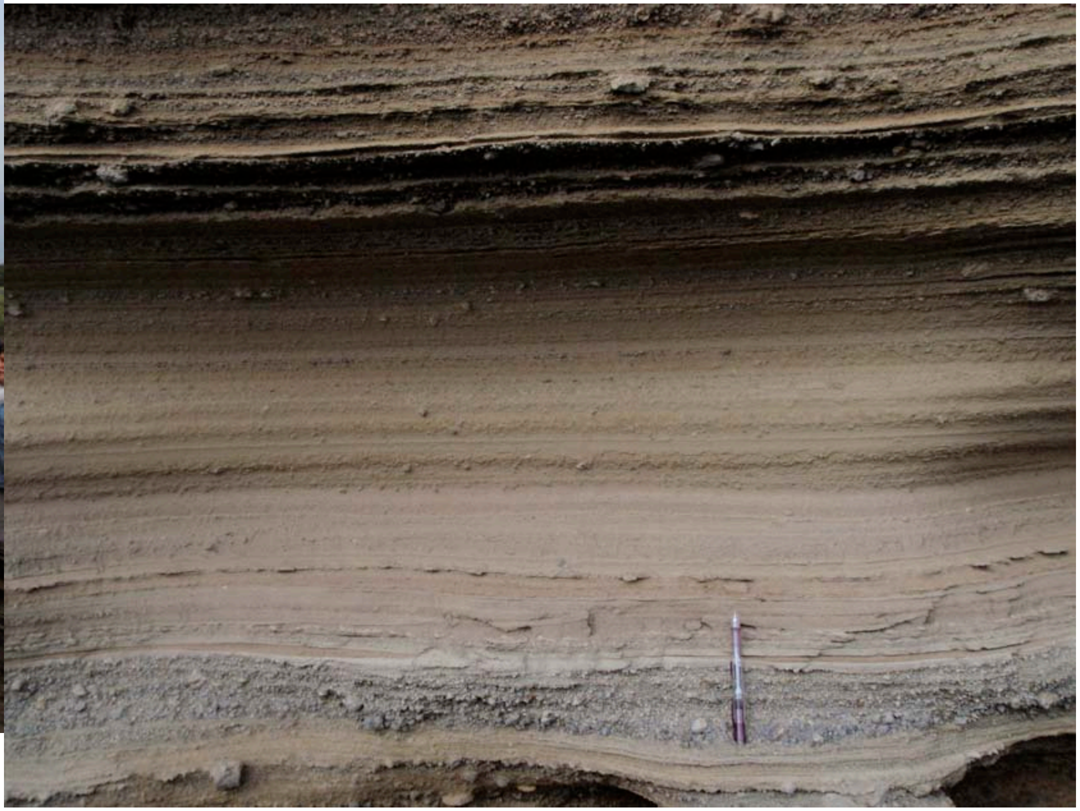


Deposits – different explosion mechanisms or effects of crater or scaled depth?

Easy Chair

Valentine & Cortes 2013, *Bull. Volc.*

Tower Hill (Australia)



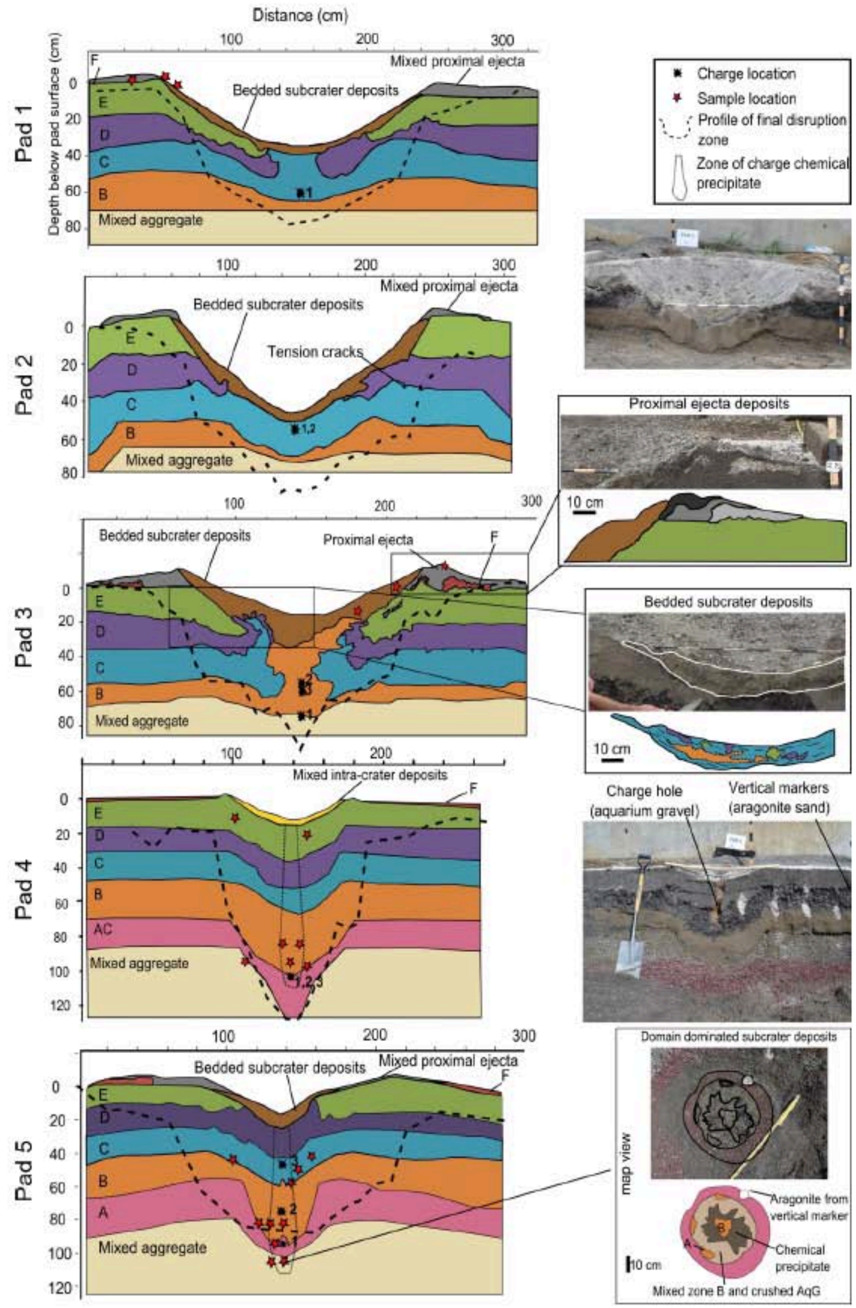


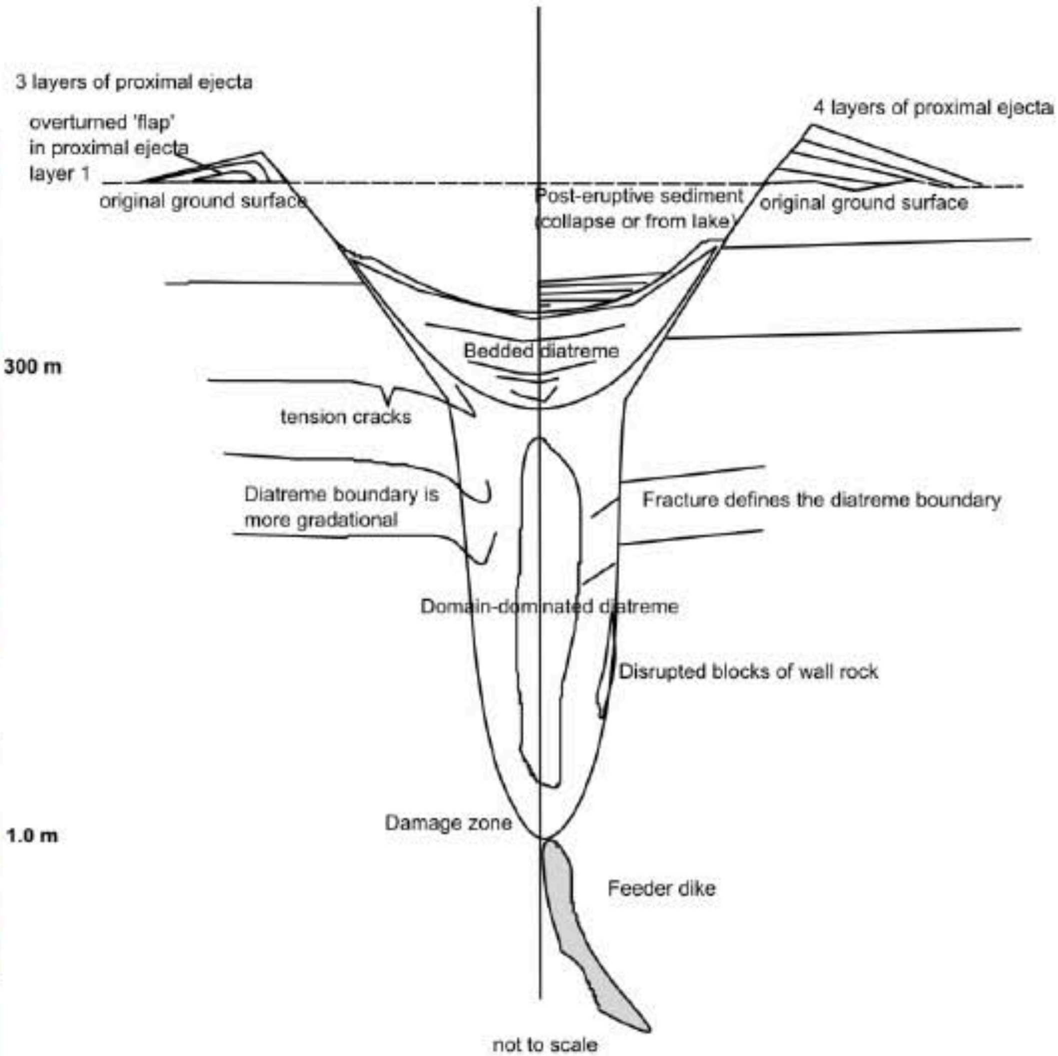
Figure 6 Excavation Cross-sections of excavated blast sites for all pads. Colors represent different components that are consistent throughout the figures. Sample locations and blast positions are noted

Graettinger et al (in prep)

Suoana Crater, Miyakejima Japan

Pad 3 excavation this study

2013 Experiments Geshi et al. 2011



Graettinger et al (in prep)

Preliminary results

- **Eruption processes are affected by progressive crater development**
  - Existence of a crater or/and too-deep scaled depth focuses eruptive jet in vertical direction, favors collapse back into crater and “expulsion-initiated” pyroclastic surges
- **Only shallow explosions “erupt”**
  - Ejecta only derived from material overlying the explosion site
  - Stratigraphic upward appearance of deeper-seated material due to progressive mixing within diatreme
- **Diatremes facies and role of subsidence**
  - “bedded” and “domain-dominated” (upper and lower) – material that is lofted but collapses back into crater, and material that is mixed in subsurface by explosions but may never “erupt”
  - Subsidence plays an important role when there are deep explosions

Graettinger et al, G-Cubed, 2014

Additional analyses in progress

- Infrasound signals combined with high-speed video (Bowman et al, in review)
- Acceleration and distribution of ballistics (Taddeucci et al)
- Jet front expansion dynamics as functions of scaled DOB (Sonder et al)
- Pitot tube measurements of near-field pressure (Lube et al)

Experiments so far suggest value of “field scale” – includes a range of particle sizes, and time and space scales that start to approach natural eruptions, and produces deposits

Some classification issues
(applicable to any eruptions with discrete explosions)

- Explosion energy – but how to estimate in geologic record?
- Dispersal not necessary reflective of different eruption processes
- PDCs and their grain size not necessarily reflective of fundamentally different eruption/fragmentation processes
- Absence of deep lithics in deposit not related to lack of explosions at that depth