火砕流発生条件に対する火口形状の影響

3次元噴煙モデルの火口条件に関する考察

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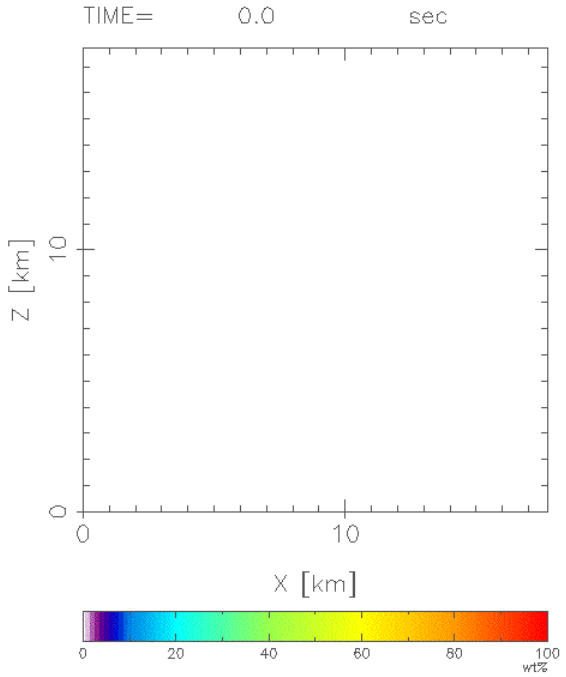
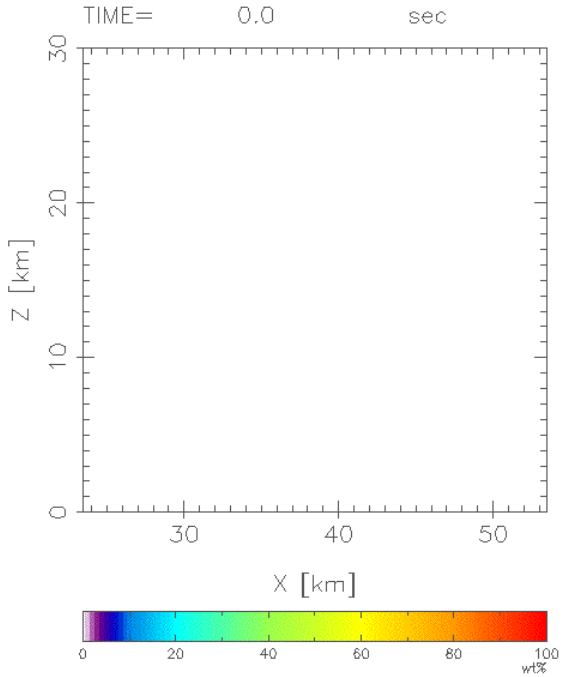


Plinian column



Pyroclastic flow

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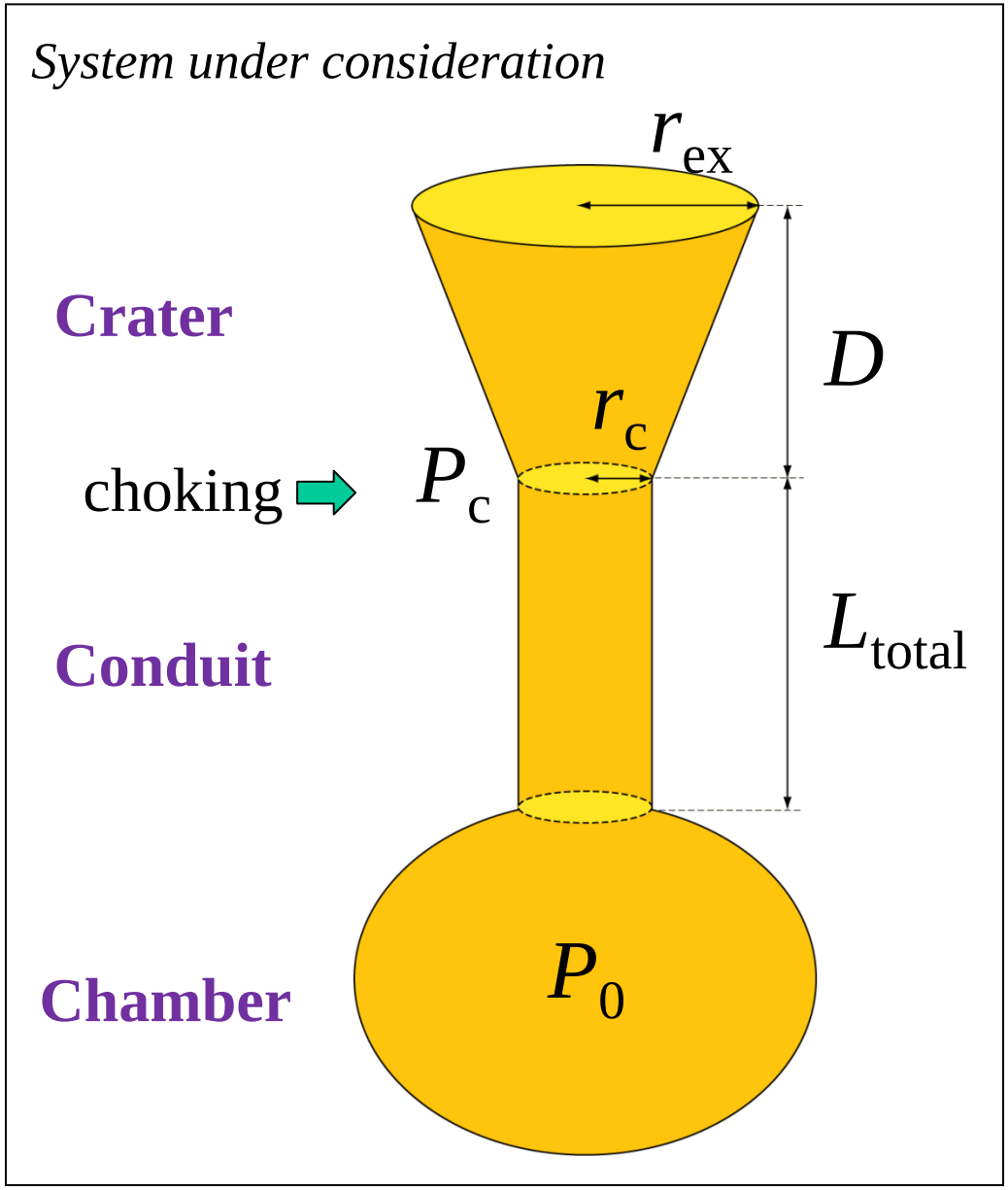
Problems to solve



Column dynamics

3-D simulation (this study)
Bursik and Woods (1991)
Kaminski and Jaupart (2001) etc.

Flow inside crater

Woods and Bower (1995) etc.

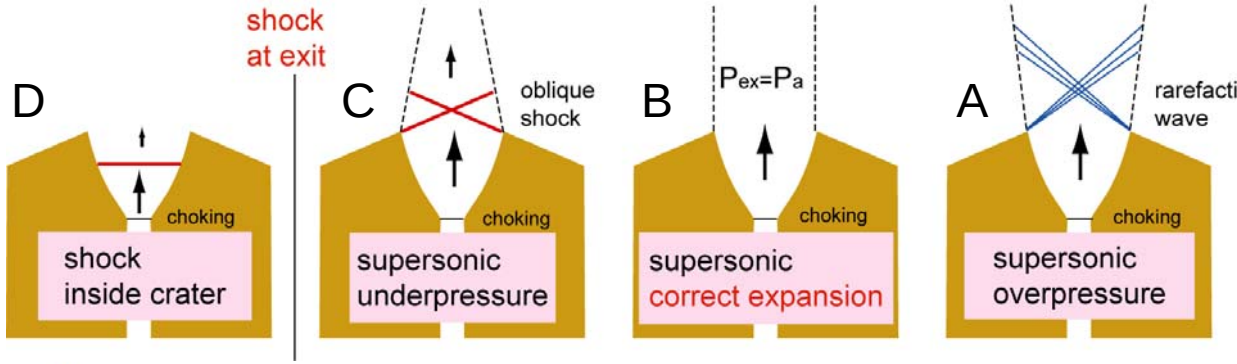
Flow in conduit

Wilson et al. (1980)
CONFLOW (2000)
Koyaguchi (2005) etc.

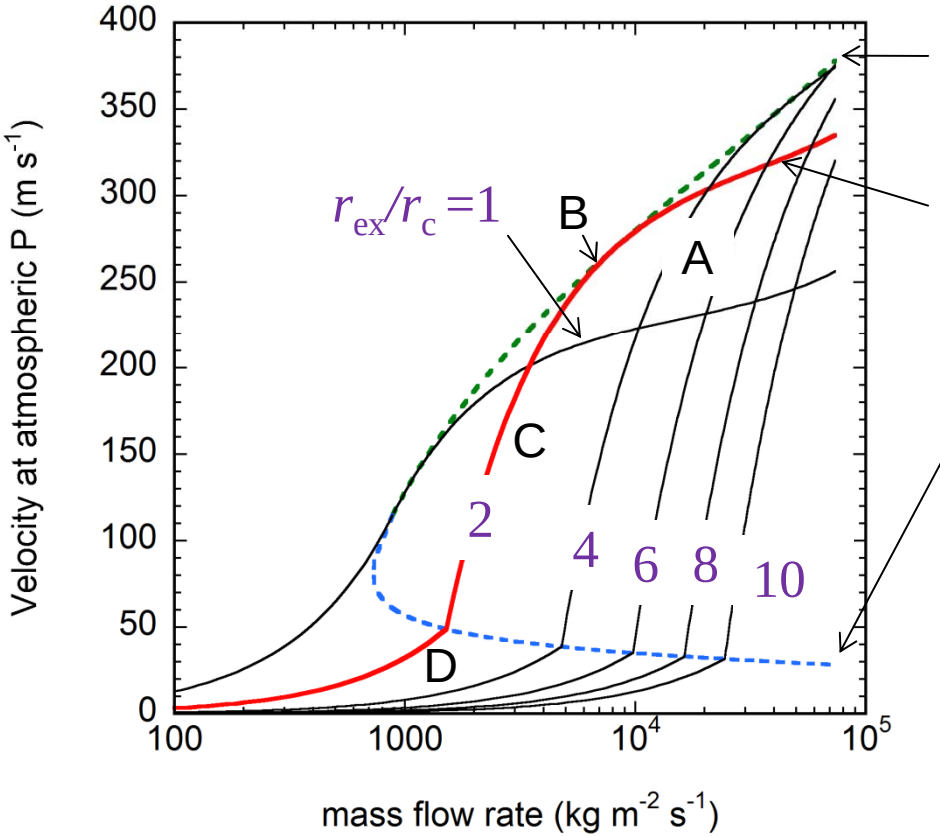
First problem: Flow inside crater

(e.g., Woods and Bower, 1995)

large r_{ex}/r_c
small *MFR*



small r_{ex}/r_c
large *MFR*



Correct expansion

Velocity change for given $r_{ex}/r_c(=2)$

Shock at exit

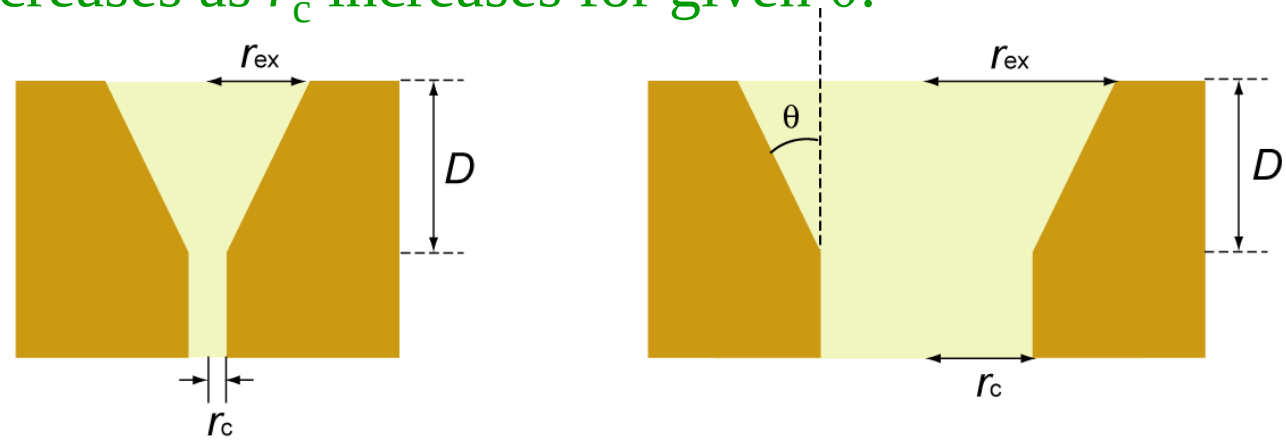
Mass flow rate (*MFR*)

$$q \equiv \rho_c v_c = \frac{P_c}{\sqrt{n_f RT}}$$

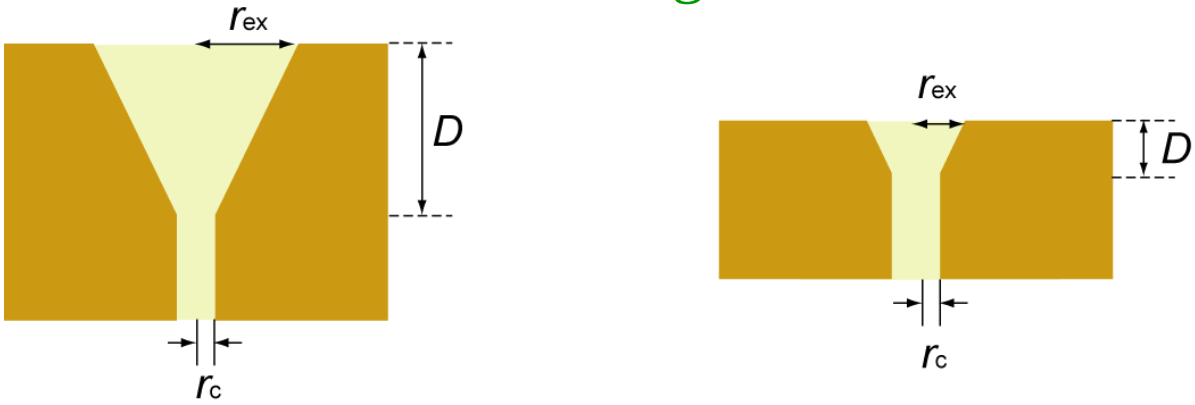
Effect of the crater shape on r_{ex}/r_c ratio

$$\frac{r_{ex}}{r_c} \approx 1 + \frac{D \tan\theta}{r_c}$$

r_{ex}/r_c decreases as r_c increases for given θ.

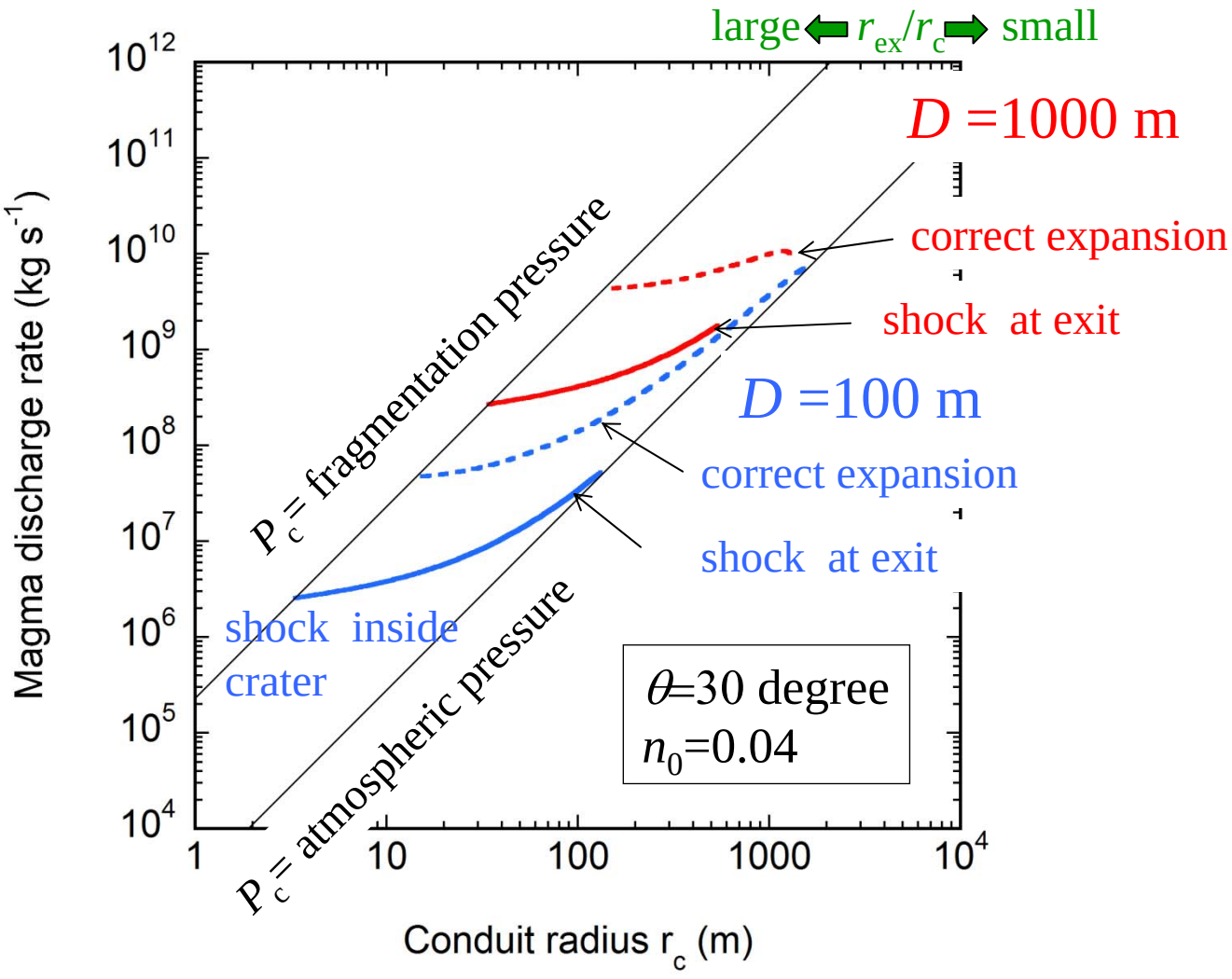


r_{ex}/r_c decreases as D decreases for given θ.

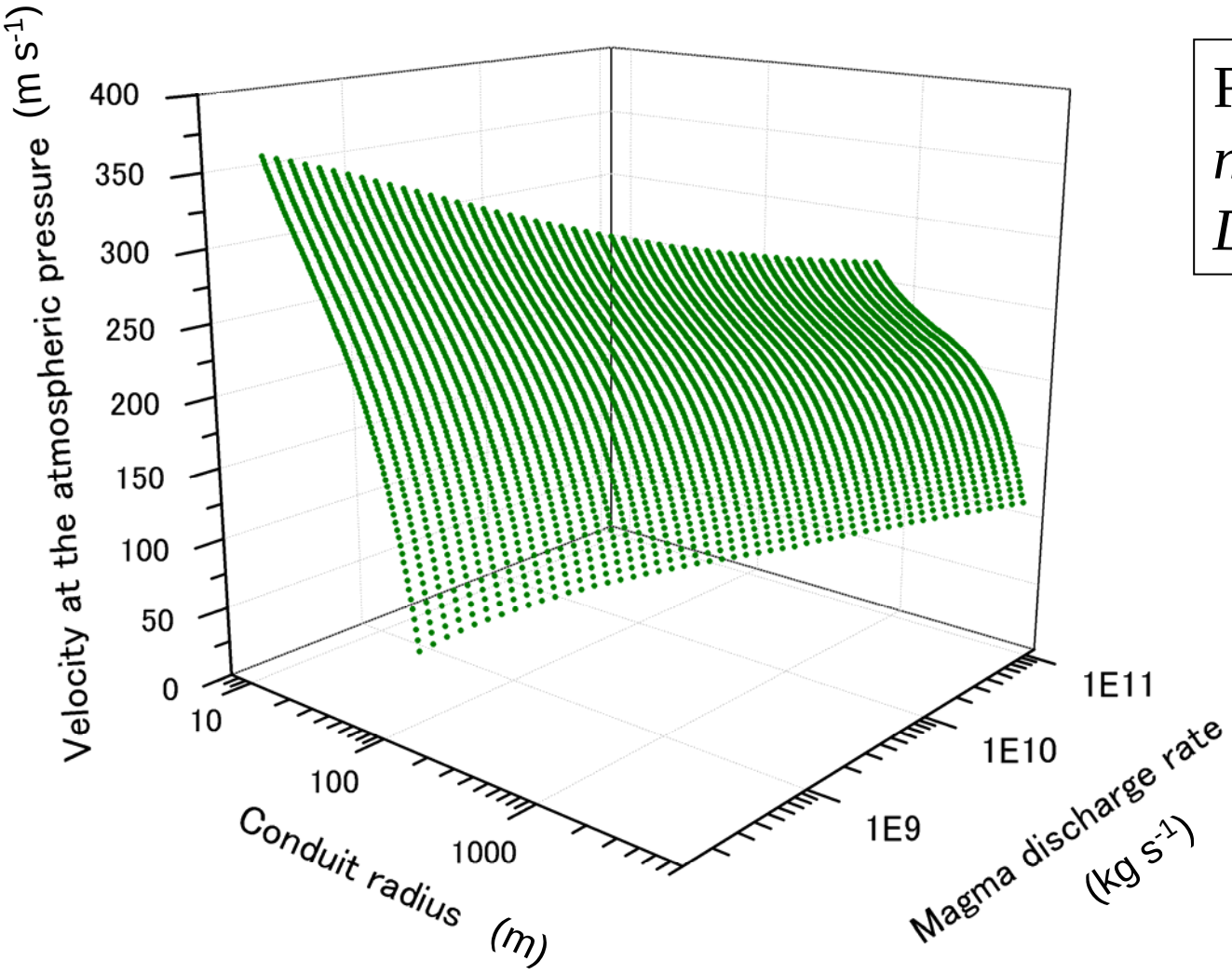


Flow regimes on "magma discharge rate vs r_c diagram"

$$\pi r_c^2 q = \frac{\pi r_c^2 P_c}{\sqrt{n_f RT}}$$

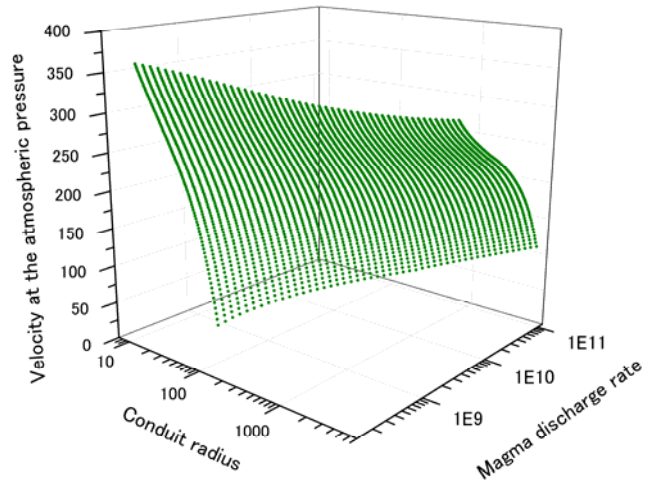


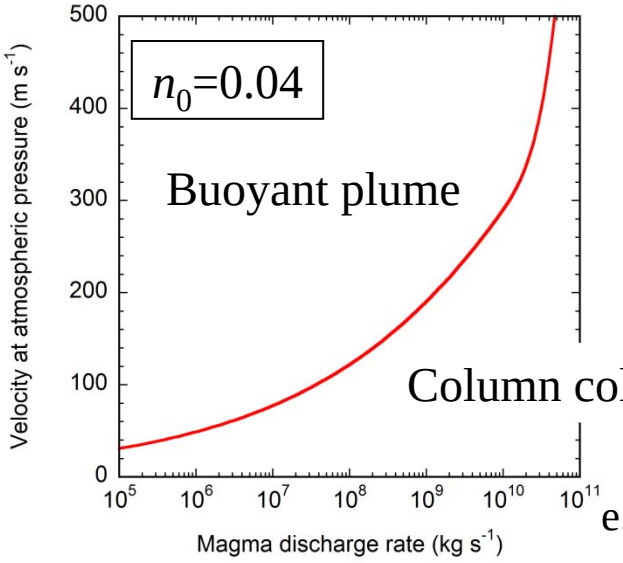
Velocity at the atmospheric P on "magma discharge rate vs r_c diagram"

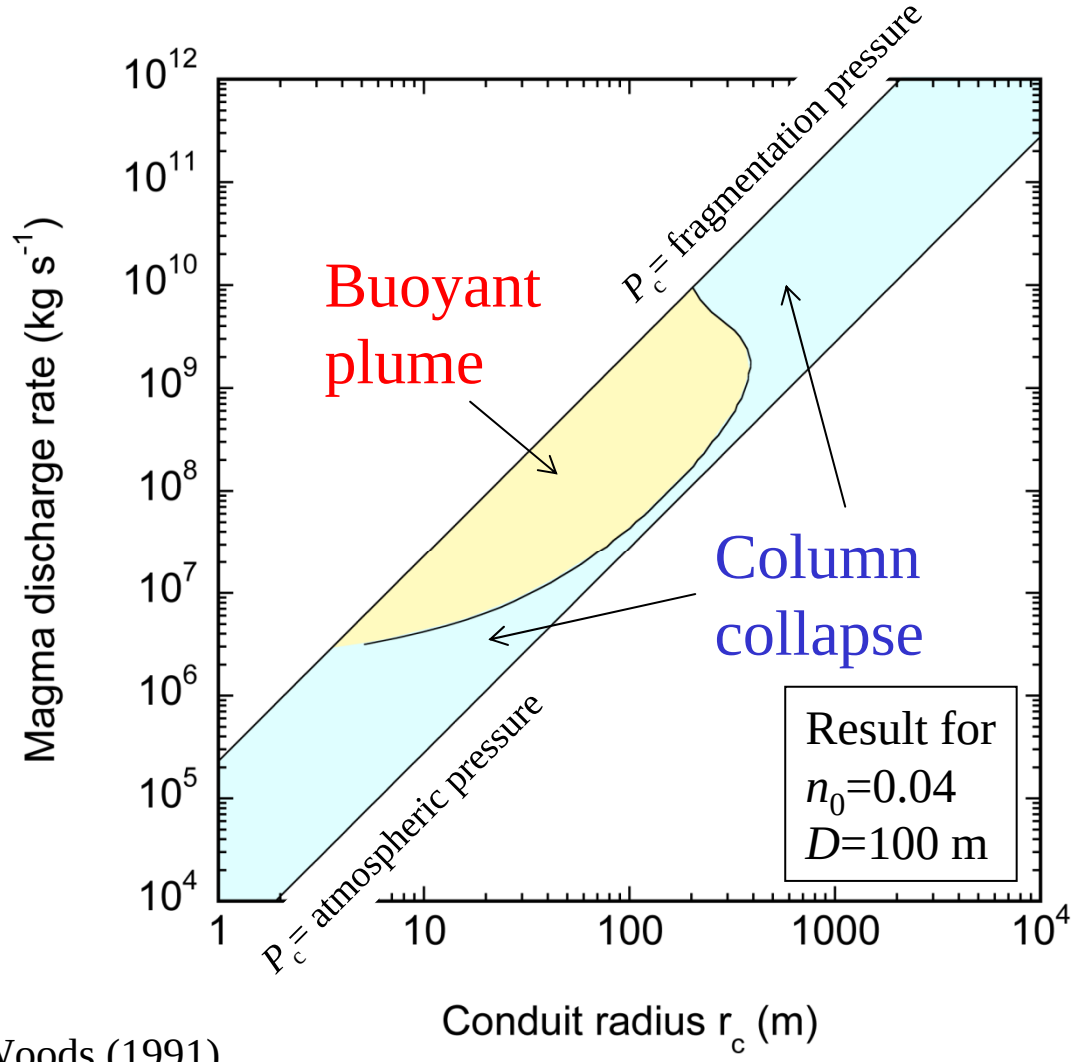


Result for
n_0=0.04
D=100 m

Column collapse condition on "magma discharge rate vs r_c diagram"



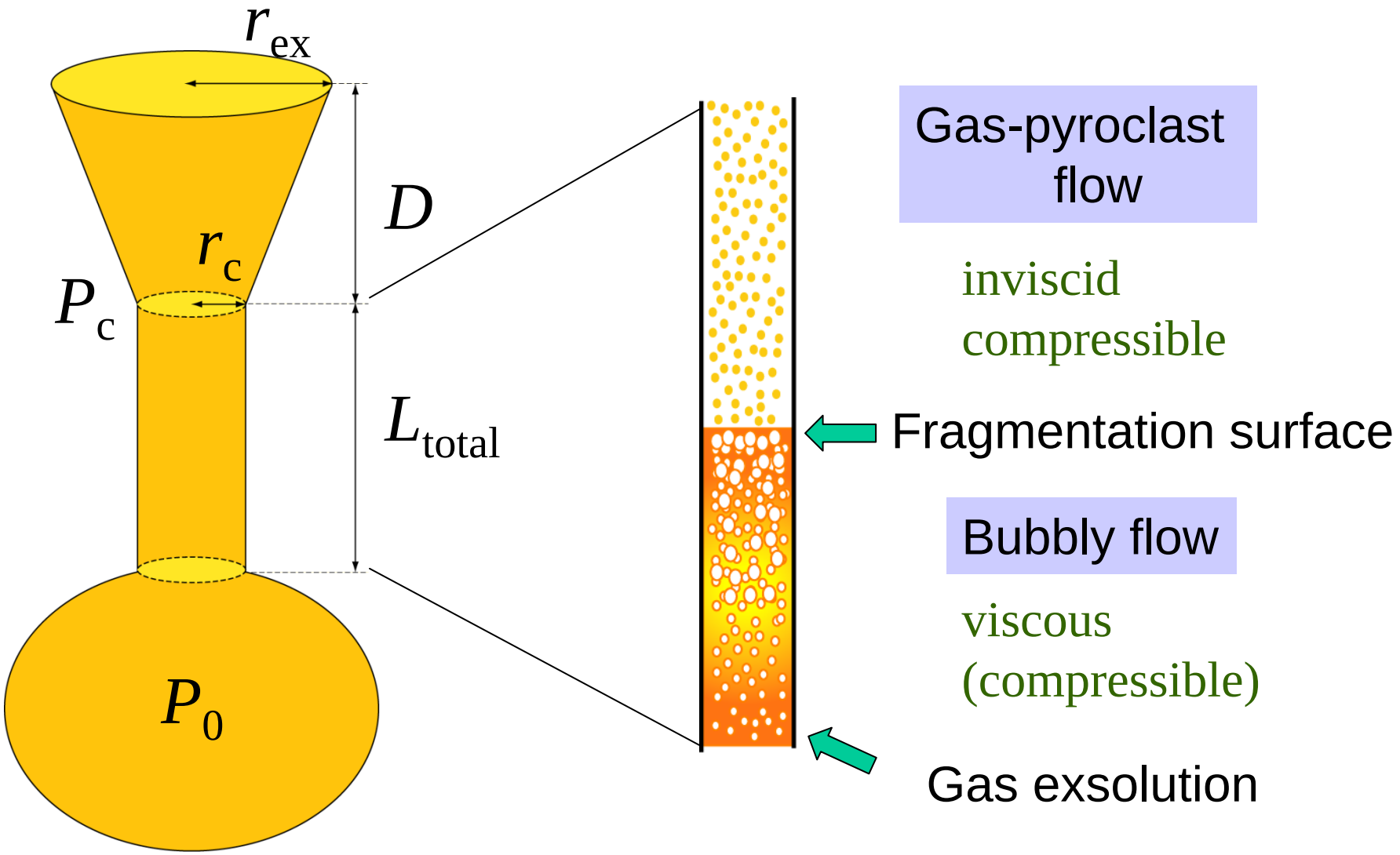




e.g., Bursik and Woods (1991)

Second problem:

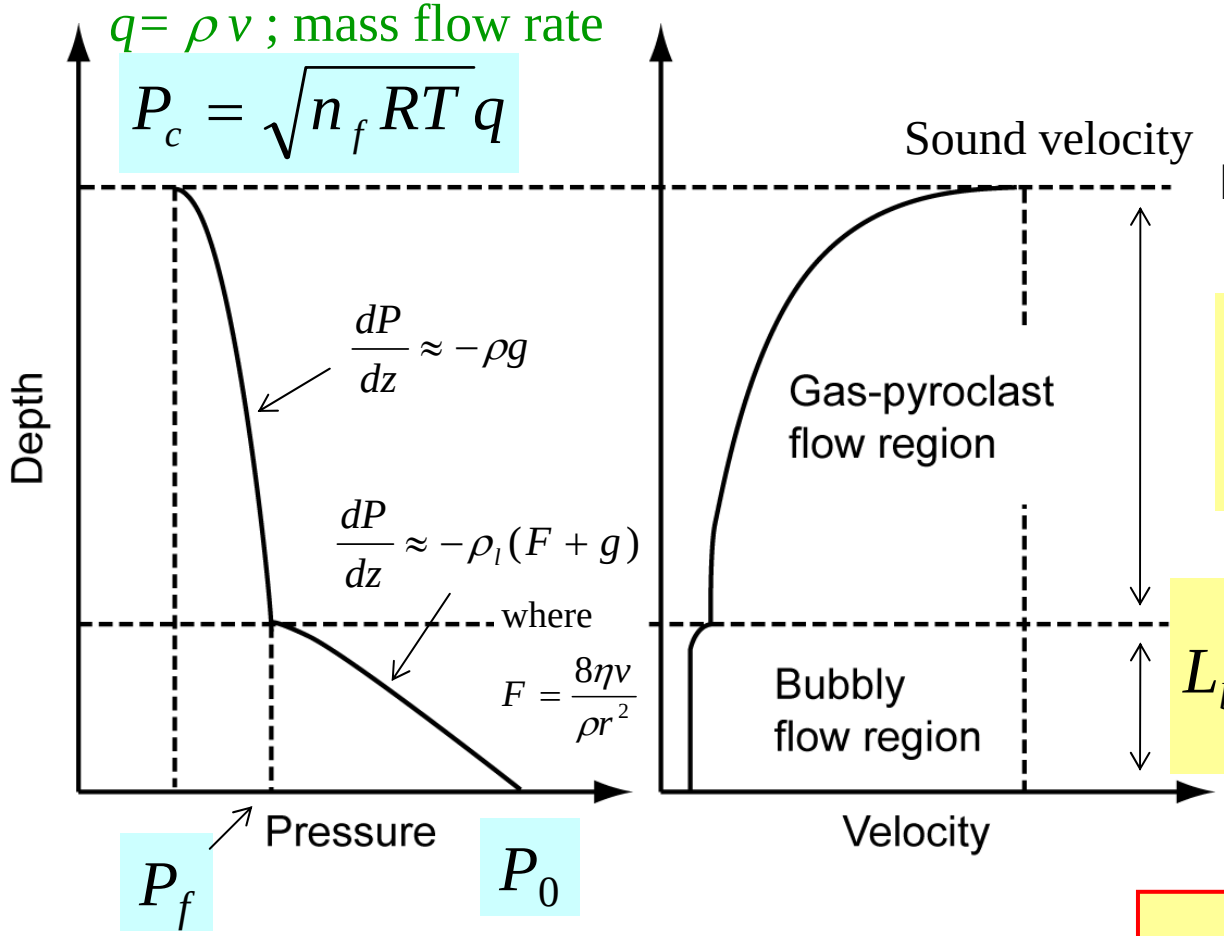
1-D conduit flow model (e.g., Wilson et al., 1980)



Semi-analytical solution of 1-D steady conduit flow (Koyaguchi, 2005)

$q = \rho v$; mass flow rate

$$P_c = \sqrt{n_f RT}\, q$$



$$L_g \approx -\frac{n_f RT}{g} \ln\left(\frac{P_c}{P_f}\right)$$

$$L_b \approx \frac{P_0 - P_f}{\rho_l (g + F)} \approx \frac{P_0}{\rho_l (g + F)}$$

Solution for
2-point boundary value problem

$$L_{total} = L_b + L_g$$

Pressure at the base of crater

derived from the asymptotic behavior of $\boldsymbol{L_{total}=L_b+L_g}$

small ⟵ $\gamma \equiv \dfrac{g\rho_l^2 r_c^{\,2}\sqrt{n_f RT}}{8\eta P_f}$ ⟶ large

$\gamma << 1$

$$\frac{P_c}{P_f} \approx \exp\left(-\frac{gL_{total}}{n_f RT}\right)$$

Chamber depth control

L_{total} : chamber depth.

$\gamma >> 1$

$$\frac{P_c}{P_f} \approx \exp\left(-\frac{\Delta P}{\rho_l n_f RT}\right)$$

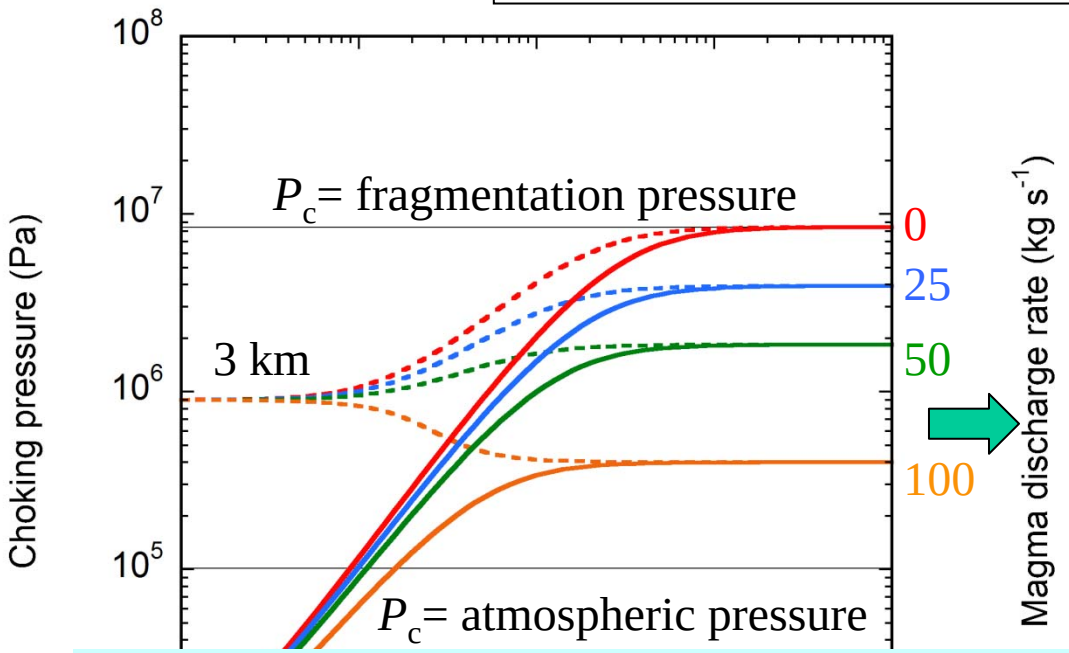
Chamber pressure control

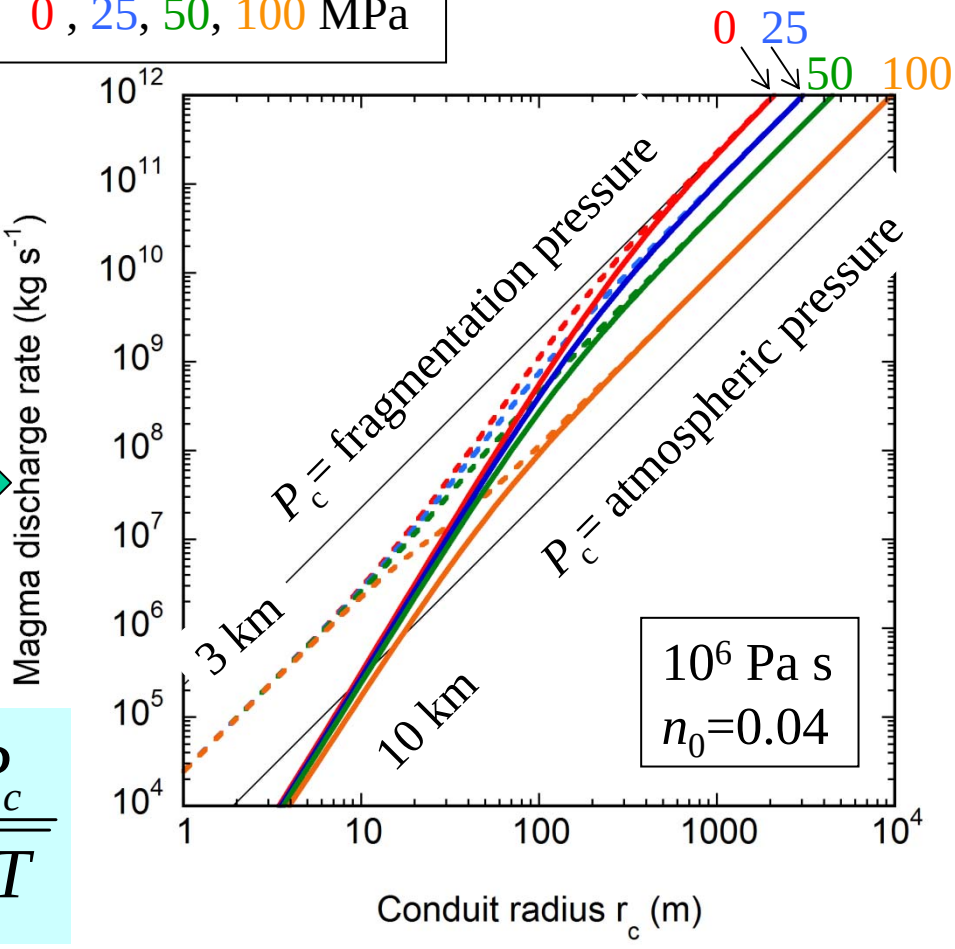
$\Delta P = P_{lith} - P_0$: degree of chamber under-pressure.

"Magma discharge rate vs r_c relationship" derived from 1-D conduit flow model

Chamber depth ----- 3 km
—— 10 km

Chamber under-presure 0 , 25, 50, 100 MPa



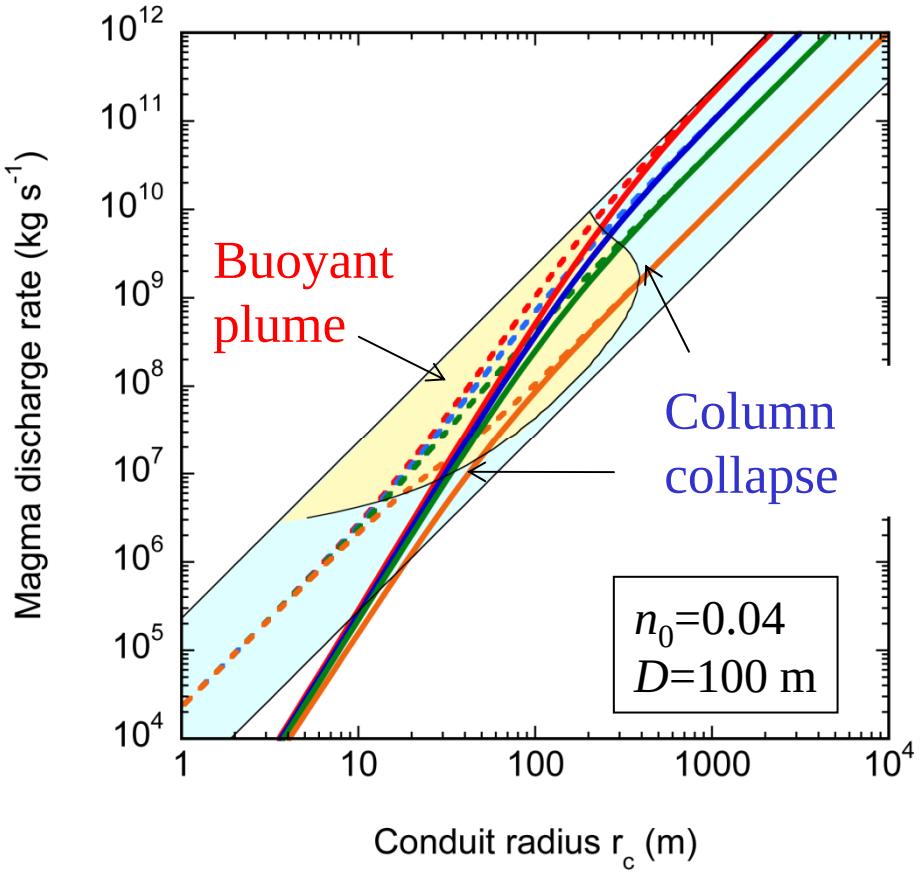


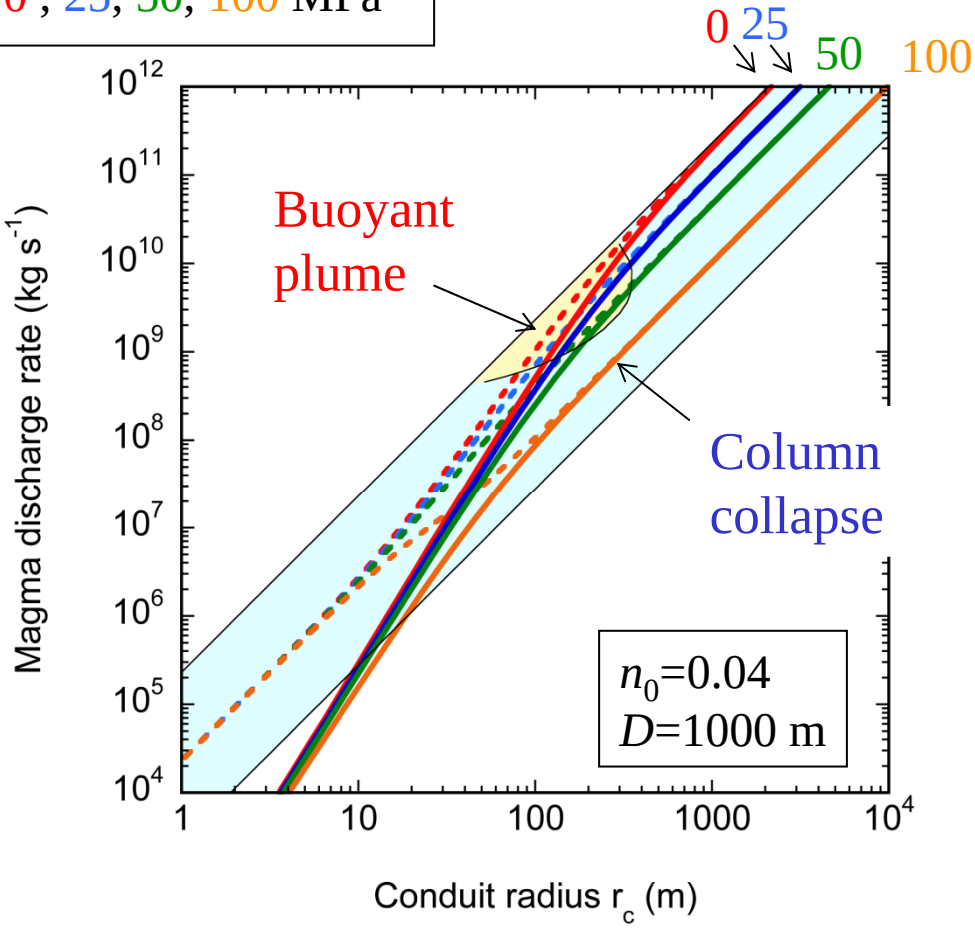
$$\text{magma discharge rate} = \frac{\pi r_c^{\,2} P_c}{\sqrt{n_f RT}}$$

Column collapse condition on "magma discharge rate vs r_c diagram"

Chamber depth ----- 3 km —— 10 km

Chamber under-presure 0 , 25, 50, 100 MPa

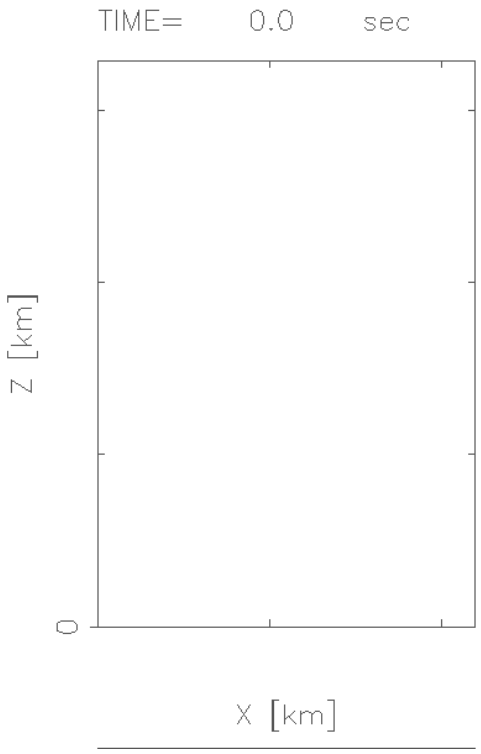




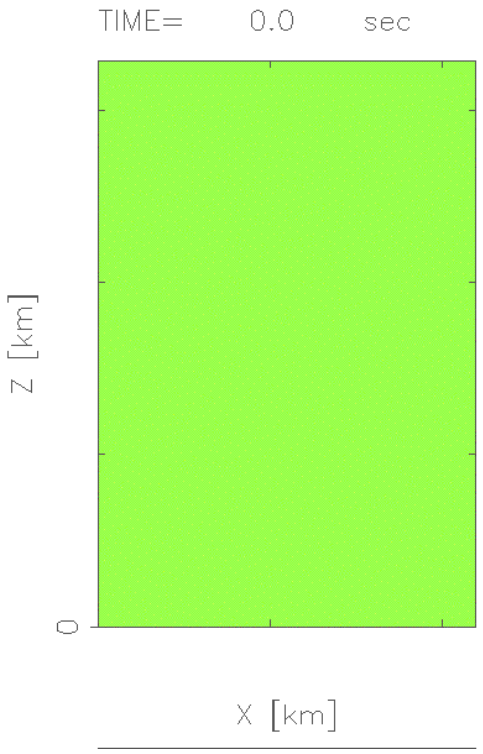
Column collapse with oblique shock wave above the crater

3-D simulations of eruption column dynamics

Mass fraction of ejecta



Pressure difference



343 m/s 0.425 x 10^5 Pa

Overpressure
Underpressure

Conclusions

•A comprehensive parameter study for the conduit-crater model allows us to determine the condition of column collapse on the magma discharge rate vs r_c diagram.

•For shallow craters (D=100 m), column collapse occurs at separate conditions with small (10^6 kg/s) or large (10^{10} kg/s) magma discharge rates, whereas for deep craters (D=1000 m), column collapse with intermediate magma discharge rates (10^8 to 10^9 kg/s) is possible.

•Column collapse with intermediate magma discharge rates is induced by the decrease in magma chamber pressure during the waning stage of an explosive eruption. This type of column collapse is characterized by deceleration due to the compression at the oblique shock wave outside the crater.