Shock Wave Models & Igneous Activity

by

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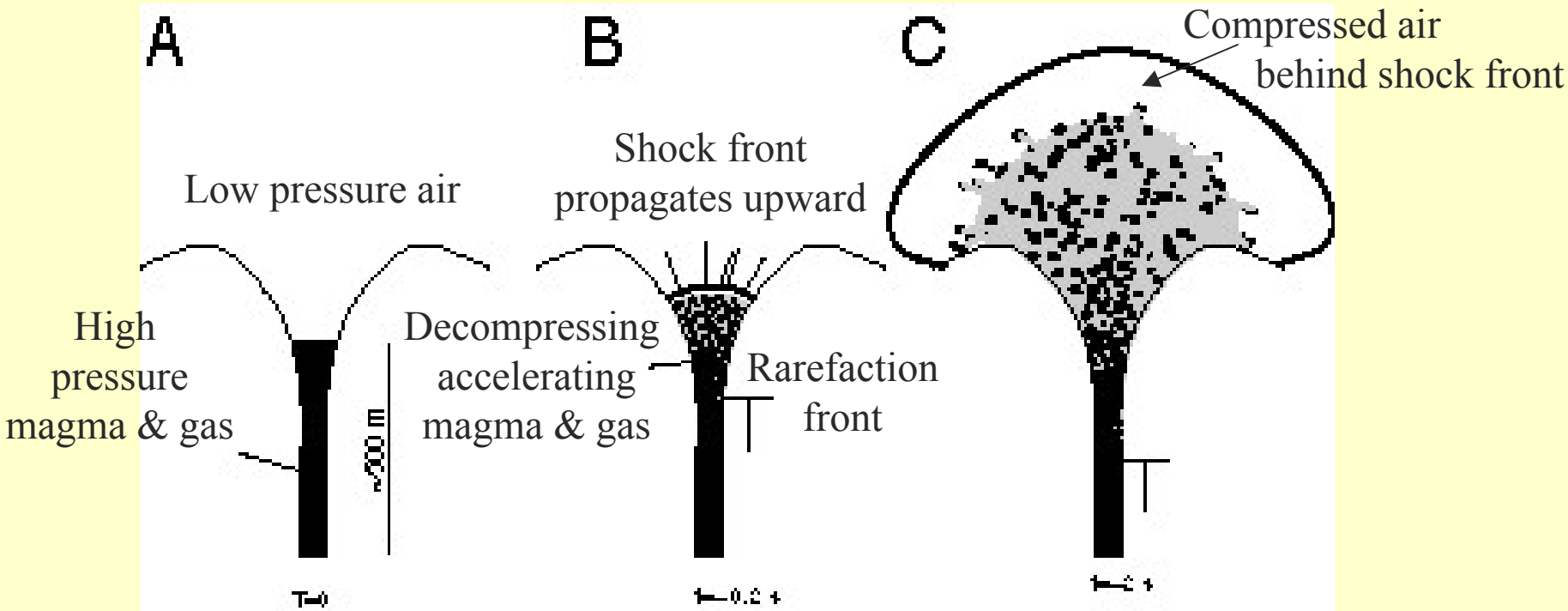
Shock Wave Review

Where? A shock wave occurs in a volcanic setting where there exists a steep pressure gradient between adjacent compressible fluids (gas > liquid) - such as a volcanic vent at the onset of an explosive eruption.

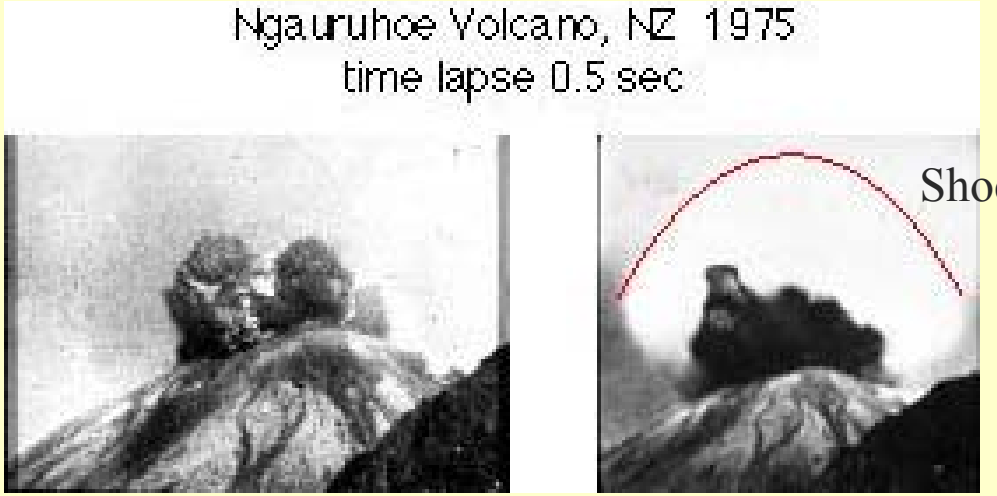
Why? The high pressure fluid compresses the low pressure fluid to raise its pressure. This action creates a sound wave or shock wave depending on the pressure difference and compressibility of the low pressure fluid.

Mechanics of shock generation



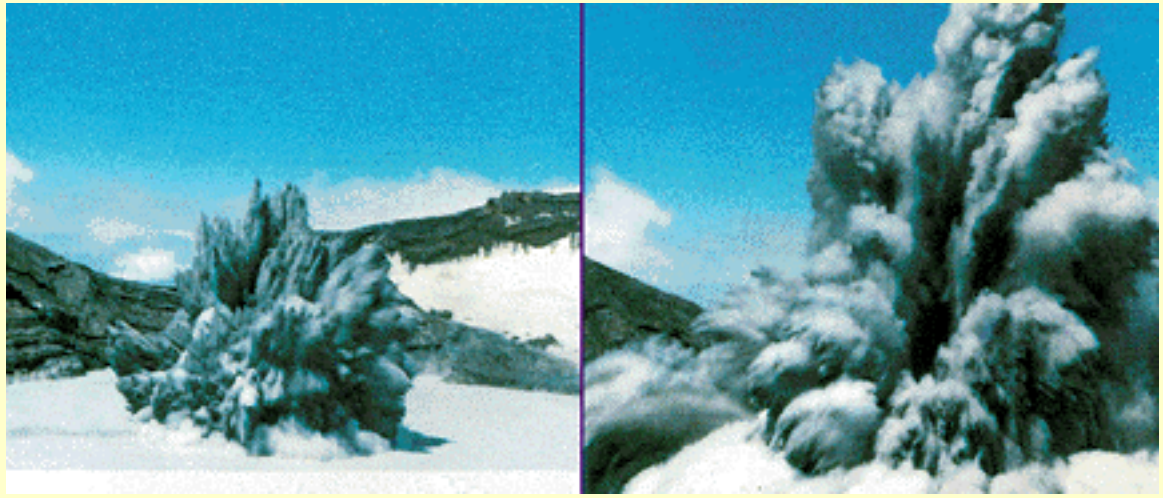
Examples

1975
@
Ngauruhoe, NZ



Shock wave

1995
@
Ruapehu, NZ



Examples of recorded air shocks.

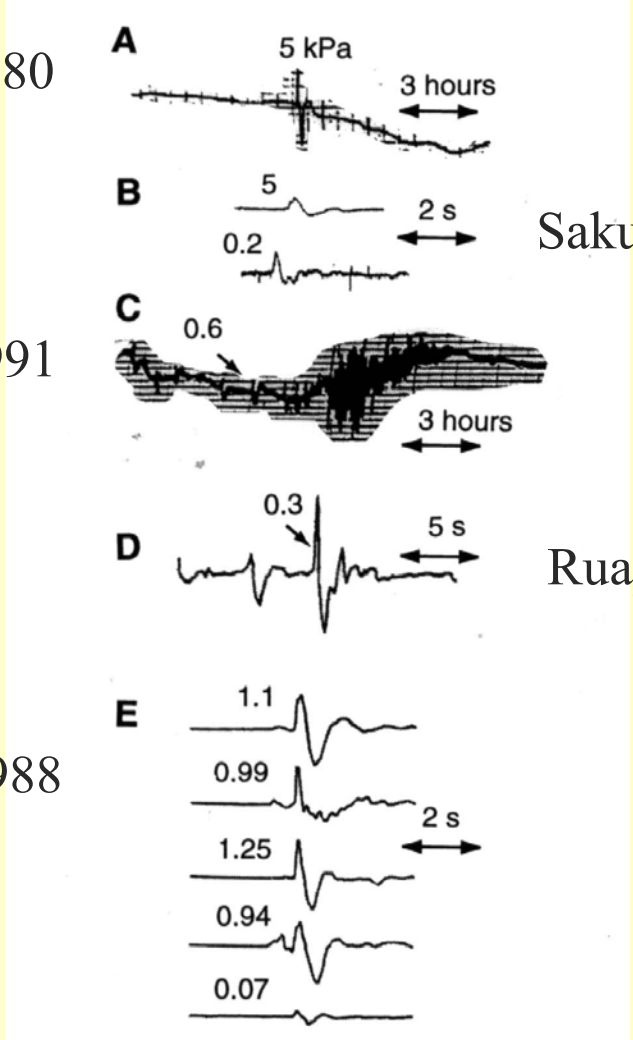
Mount St. Helens 1980

Sakurajima, Japan 1989

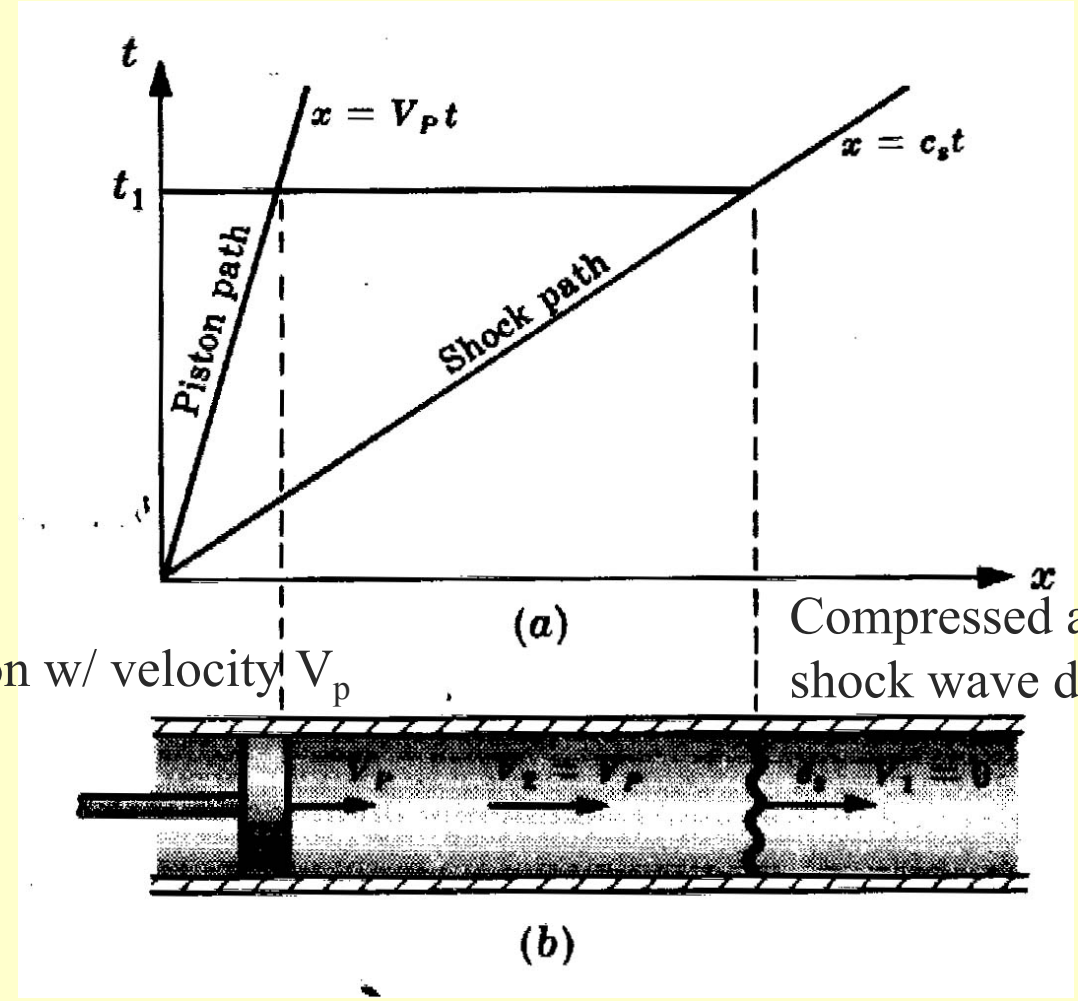
Mount Pinatubo 1991

Ruapehu, NZ 1995

Mount Tokachi, Japan 1988



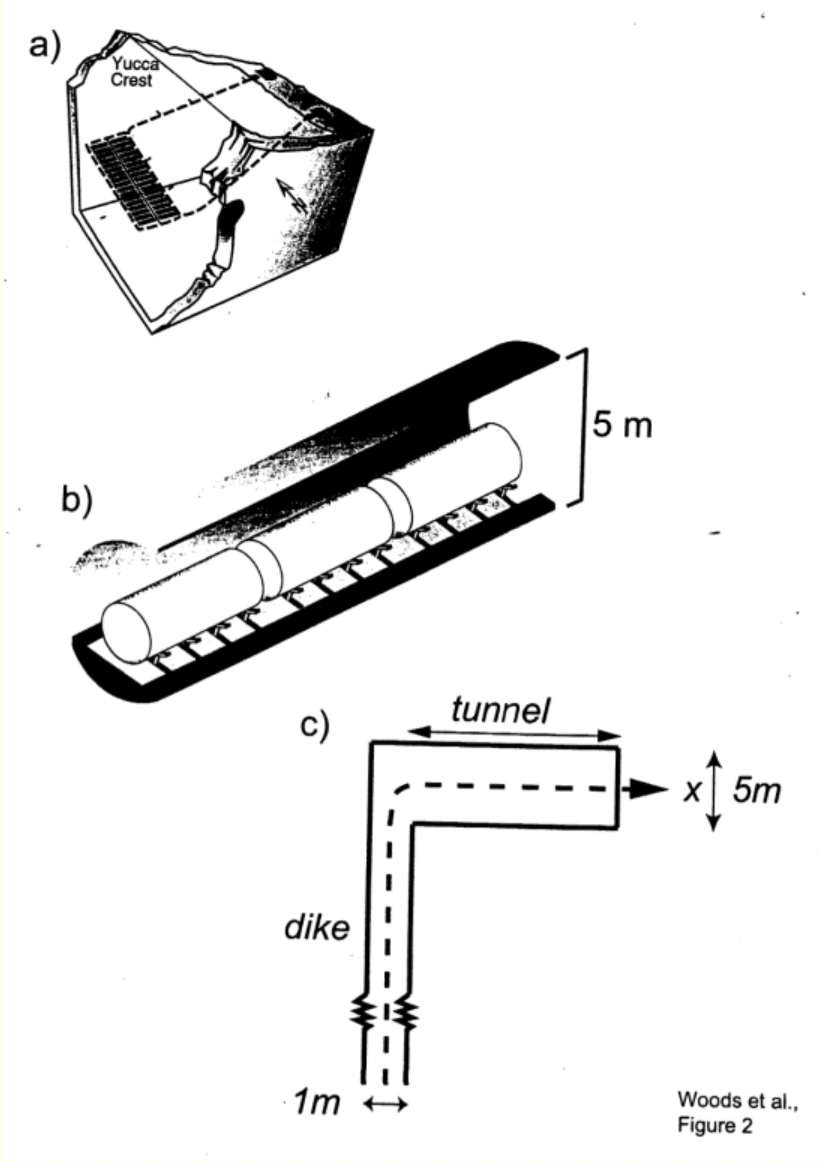
Shock Tube



Driving piston w/ velocity V_p

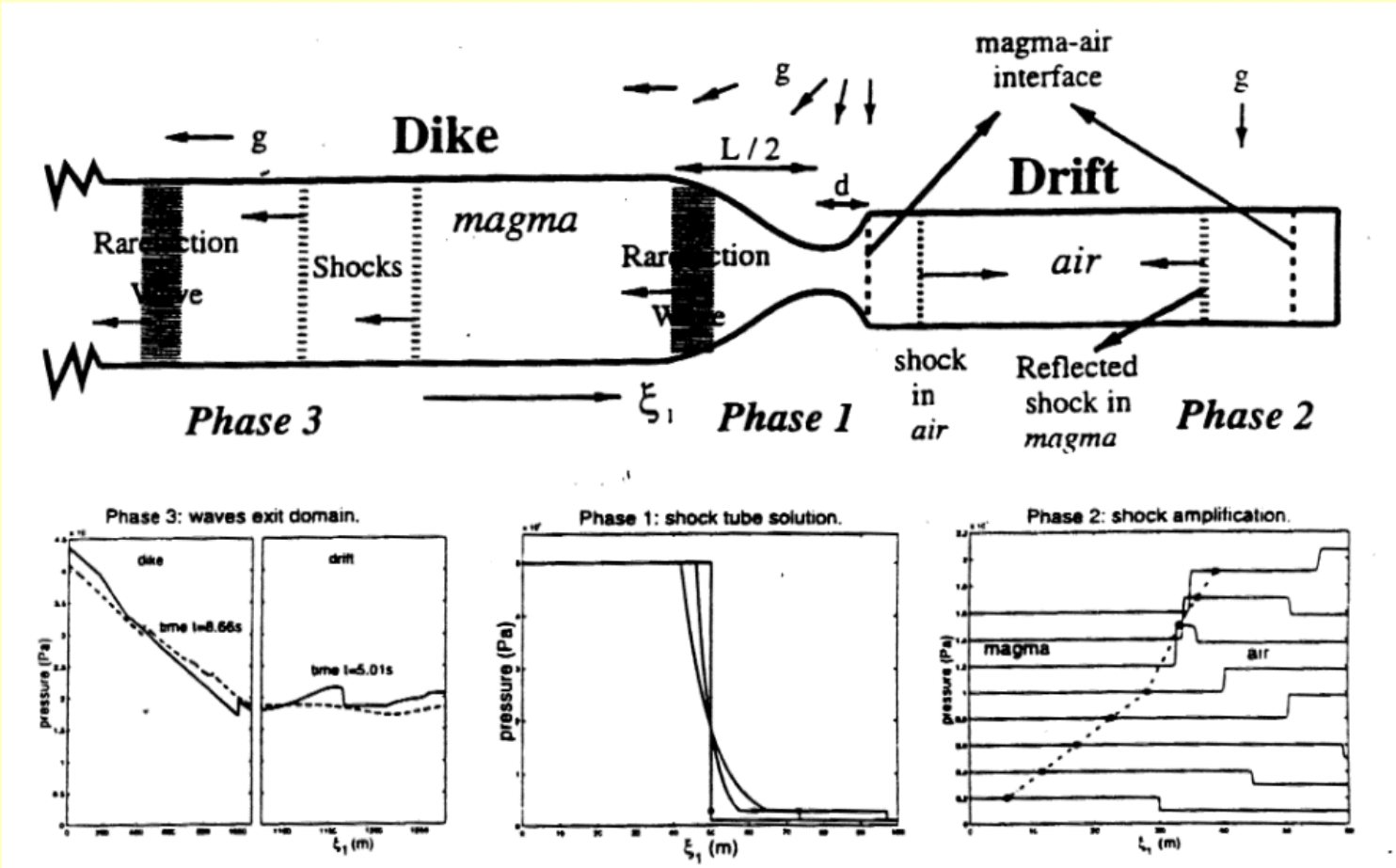
Compressed air moves as shock wave down tube.

Bokhove and Woods Model



Assumptions

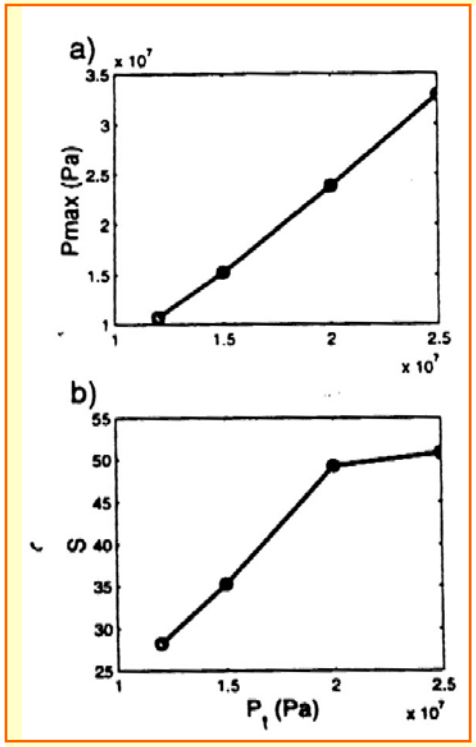
- 1-D shock tube with gravity accounting for turn at intersection.
- Magma enters drift as foam, contains 1-2.5 wt% H_2O and void fraction < fragmentation level.
- Neglects presence of waste packages.
- Dike geometry is fixed or prescribed.
- Magma enters drift at 20 MPa and 1000 K.
- Viscous effects accounted for by frictional term.



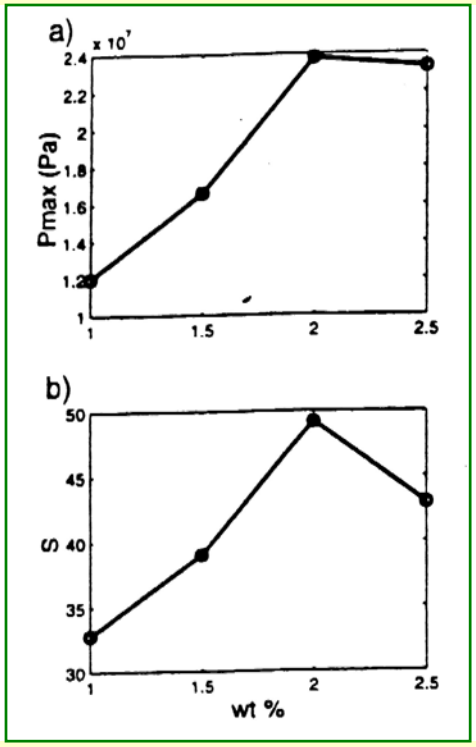
- Rarefaction or expansion wave acts to lower the pressure of magmatic fluid.
- Shock wave acts to raise the pressure of air.
- Reflected shock waves increase in pressure depending on the boundary condition. Wall: no energy is transmitted ; Magma/air interface: energy is transmitted into magma depending on its state.

Parametric Study

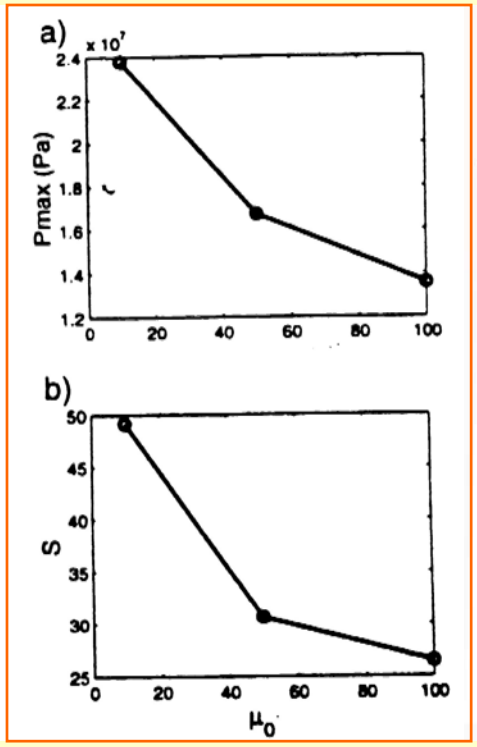
P_t : 12-25 MPa



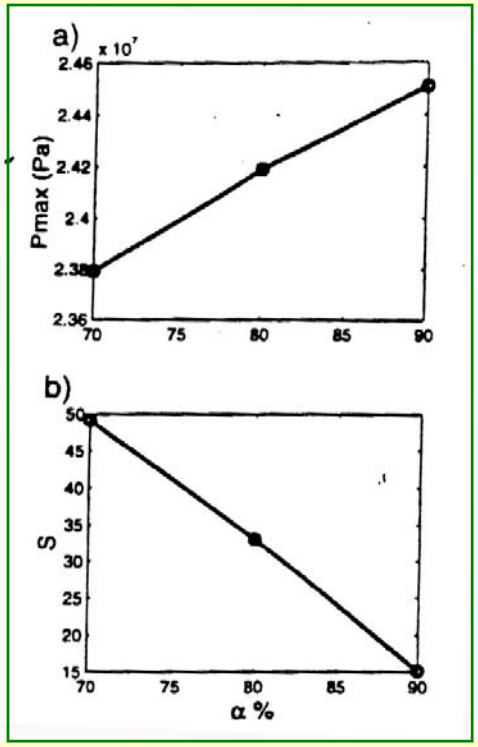
H_2O : 1-2.5 %

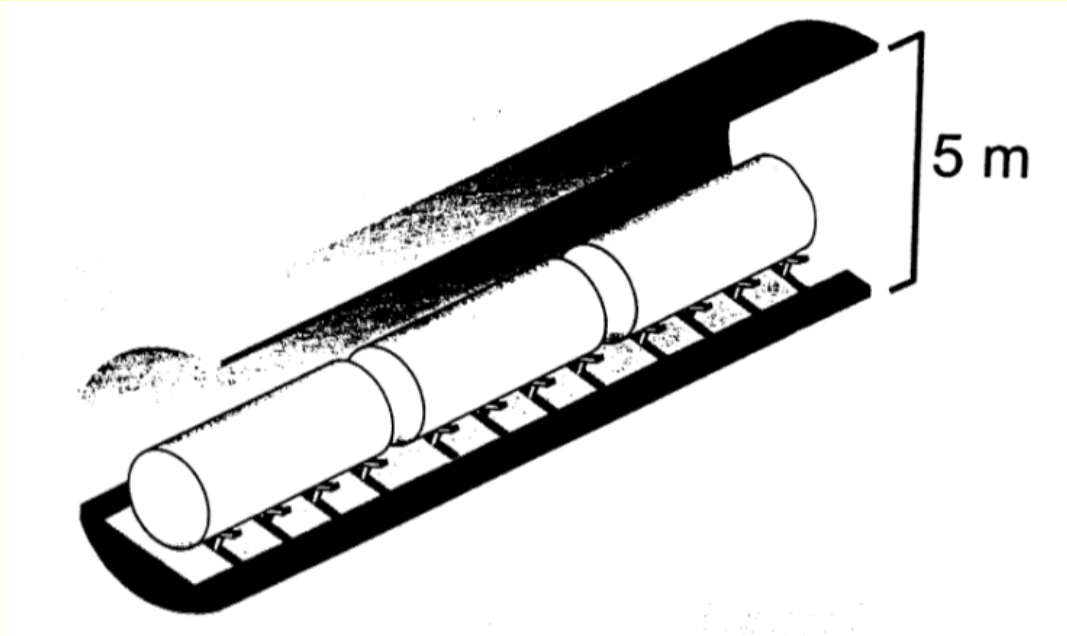


Friction



Foam Void %





B&W's shock tube scenario with packages in tunnel

- Shock wave will propagate around packages assuming spacing is small. The shock wave will pressurize the tunnel and packages.
- Shock wave will reflect off the end of first package (package will experience a hammering force).
- Large pressure build up air between the oncoming magmatic fluid and first package from reflected wave.
- Package near end wall may get pushed by reflected shock depending if it bends or expands as it propagates over last package before encountering the wall.

Assumptions

1. 1-D shock tube with gravity accounting for turn at intersection.
2. Magma enters drift as foam, contains 1-2.5 wt% H_2O and void fraction < fragmentation level.
3. Neglects presence of waste packages.
4. Dike geometry is fixed or prescribed.
5. Magma enters drift at 20 MPa and 1000 K.
6. Viscous effects accounted for by frictional term.

Oversights in Model

1. Shock wave may reflect off side wall of tunnel producing a series of reflecting shocks down the tunnel.
2. Unlikely at 300-400 m depth. Magma should explosively fragment generating an explosive mixture of ash and gas into tunnel or magma will rapidly expand into tunnel not passively enter tunnel. Magma is rising from below crust will little or no residence time to degas.
3. Previously discussed.
4. Dike tip geometry likely to change as magma enters tunnel.
5. Pressure may be too high.
6. Viscous magma will absorb more energy from reflected shock as will walls.

How realistic is the model?

- It's fairly realistic. If a magma intrudes into the tunnel, it will likely generate a leading shock wave. B&W's model demonstrates how the shock wave may develop in the tunnel. The magnitude of the shock wave depends on the driving force of the magmatic fluid, mechanical properties of the magmatic fluid and wall, and the initial thermodynamic state of air inside tunnel.

Uncertainties of the model?

- Behavior (and pressure) of ascending magma: will it be rich in volatiles and ready to explosively expand when it reaches the tunnel or will it behave as a partially degassed foam and passively enter the tunnel?
- Lateral propagation of shock wave. Any angle or turn upon entry will cause some deflection on the leading shock which may result in a series of reflecting shock waves off the sides of the tunnel. This scenario will result in impulsive disturbances acting on the packages.

How to engineer tunnel for shock waves

- Enable walls to absorb or transmit energy.
- Pressurize and cool tunnel.
- Strength packages and mounts to withstand pressurization and hammering from shock waves.
- Design the end of first package to deflect the shock wave.