Modelling the ascent and eruption of picritic lunar magmas

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Introduction

The volatile content of a magma is a fundamental control on:

> Eruption processes: magma ascent, fragmentation [1]
> Magma properties: rheology, compressibility [2]
> Eruption style: explosivity, eruption products [3]

Understanding the volatile content of lunar magmas also gives us information about the formation of the Earth-Moon system. Previous approaches for understanding the volatile content of lunar magmas have mainly involved measurements of returned samples [4]. We use a volcanological approach to glean information on the volatile content of the lunar interior, focussing on magma which erupted to form pyroclastic material. Here, we present the first step in this project: modelling magma ascent on the Moon.

Aims:

1) To quantify the effect of varying magmatic volatile content on magma ascent on the Moon.
2) To compare the results of various ascent processes with existing estimates and models for these processes.

Method

Magma ascent model
> Pre-existing model for terrestrial magma ascent within a circular conduit
> Fortran-90 based, 1-dimensional, multiphase model [5]

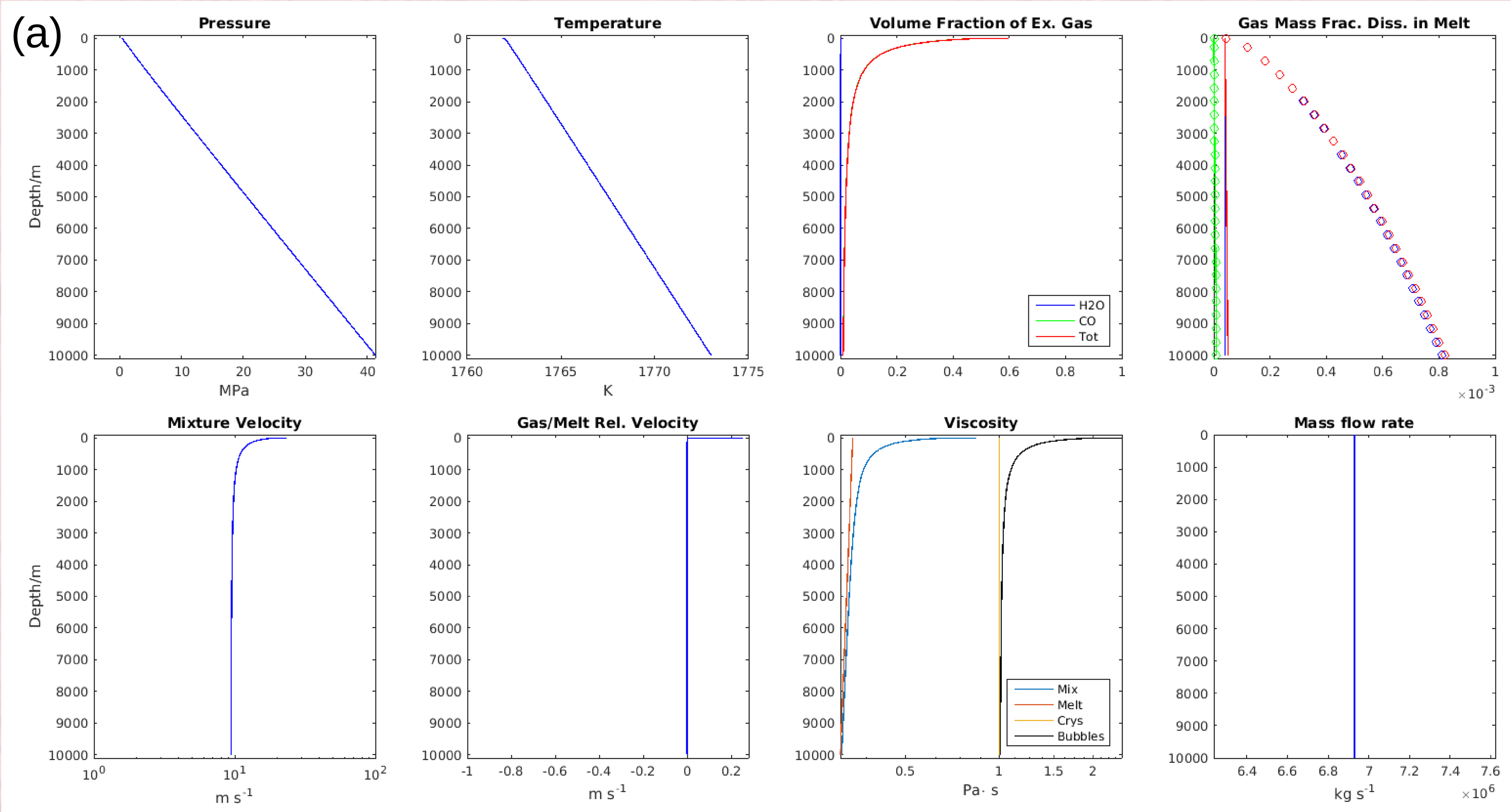
Adjusting model parameters
> Gravity
> Conduit depth
> Pressure
> Temperature
> Oxygen fugacity
> H_2O solubility, according to Moore et al. (1998) model [6]
> CO solubility, according to Wetzel et al. (2013) model [7]

Parameters varied in this study
> Magma metal oxide composition, for 5 compositions of picrite
> Initial H_2O content according to Saal et al. (2008) [8] measurements
> Initial CO content
> Conduit radius

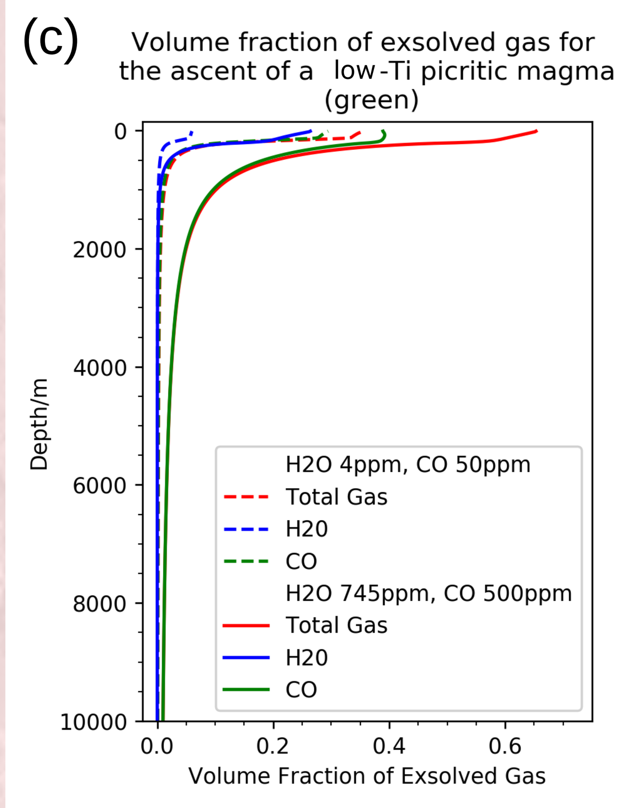
Model outputs
> Pressure
> Temperature
> Gas exsolution
> Amount of crystals
> Density of various phases
> Viscosity
> Mass flow rate

Results

(a)



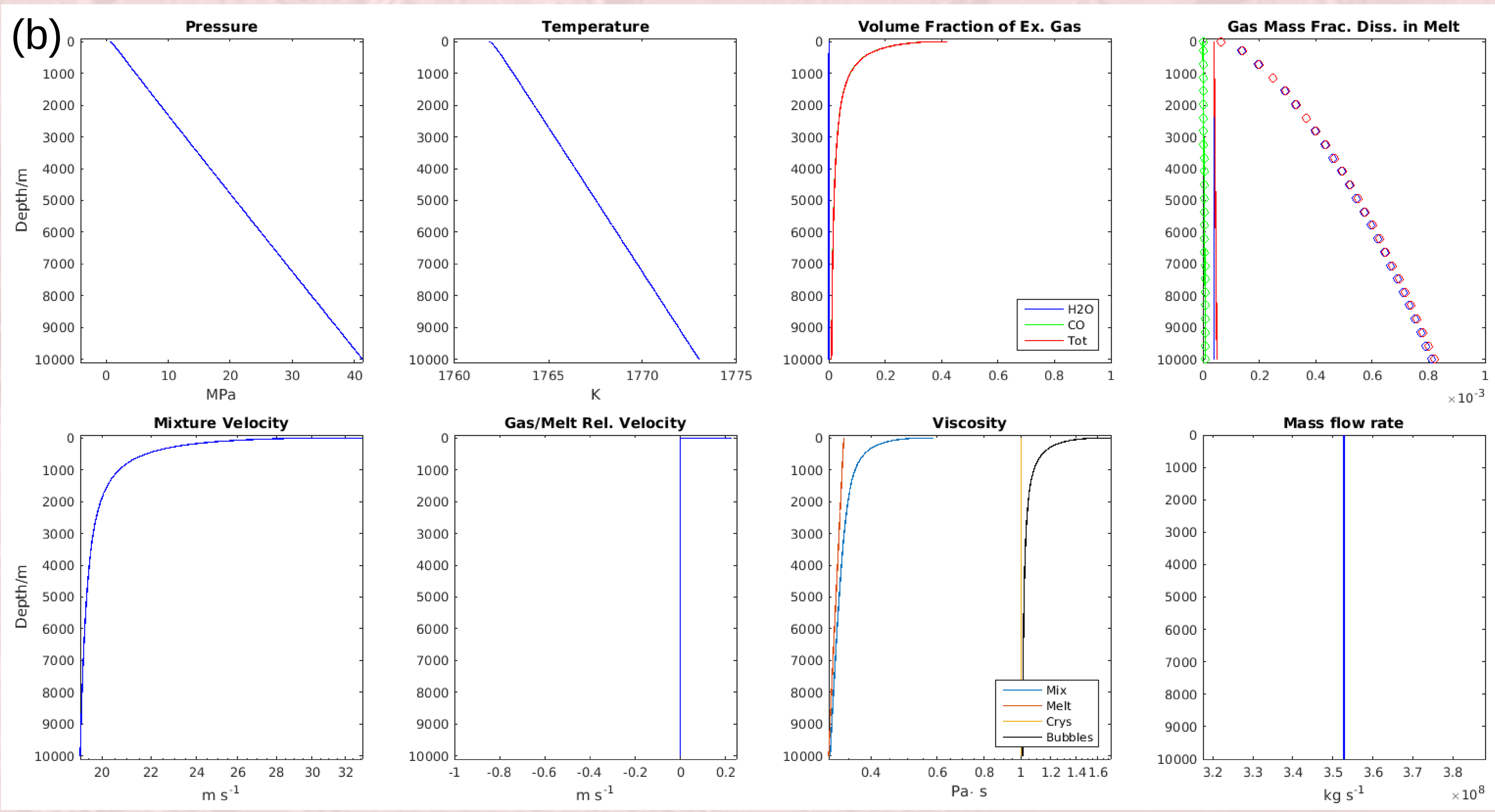
(c)



changing conduit radius

changing composition

(b)



(d)

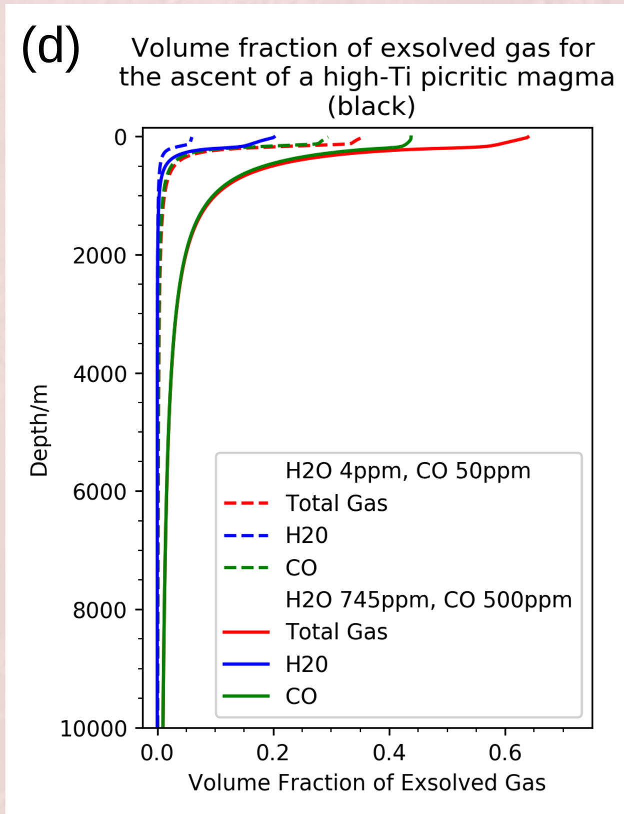


Fig. a: magma ascent model results for a green picritic magma, with 40 ppm H_2O and 500 ppm CO, in a conduit with a 10 m radius. **Fig. b**: magma ascent model results for a green picritic magma, with 40 ppm H_2O and 500 ppm CO, in a conduit with a 50 m radius. **Fig. c**: gas exsolution profile for a green picritic magma, showing the minimum and maximum initial volatile contents used. **Fig. d**: gas exsolution profile for a black picritic magma, showing the minimum and maximum initial volatile contents used.

Discussion

> Model outputs were sensitive to different input parameters:
  > viscosity to magma major element composition
  > mass flow rate to conduit radius
  > volatile content had the greatest effect on: depth at which volatile exsolution initiated, magma velocity, and gas-melt relative velocity

> CO content was more significant than H_2O content during magma ascent, even when H_2O content was greater

> We have compared our results with work from Rutherford et al. (2017) [9]
  > Rutherford et al. (2017) simulated magma ascent using initially high-T and -P experiments, for an analogue orange picritic magma
  > They examined the exsolution behaviour of H_2O and CO_2
  > As shown in Fig. e, our magma ascent model results predict similar gas exsolution depths to the results of Rutherford et al. (2017).

(e)

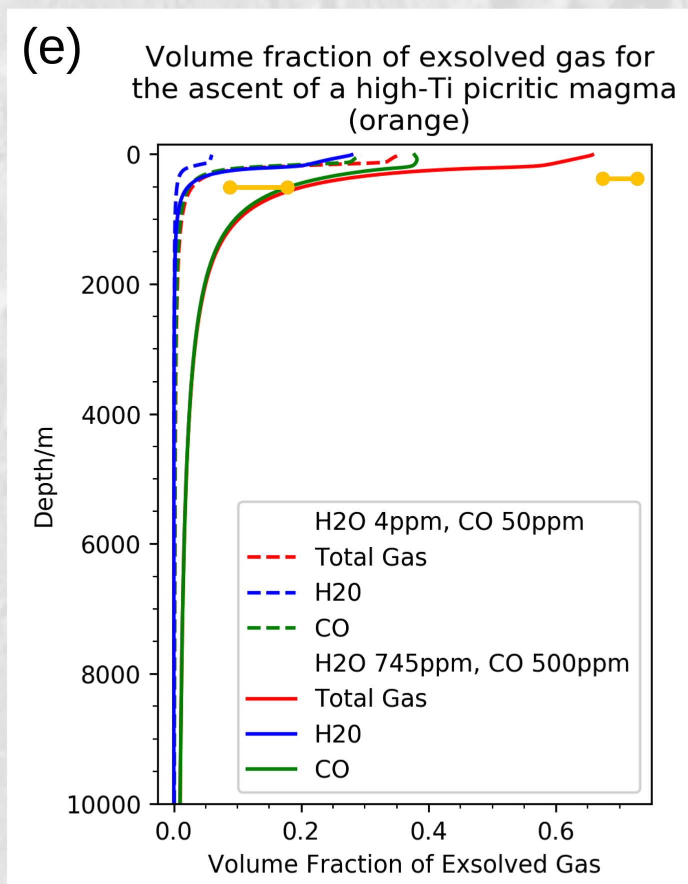


Fig. e: gas exsolution profile for an orange picritic magma, with minimum and maximum amounts of H_2O and CO. Orange bars indicate Rutherford et al. (2017) results for H_2O (left) and CO_2 (right) for comparison.

Future Work

> The next step will be to use results from the magma ascent model in an eruption model, more specifically, a 2-dimensional pyroclast dispersal model
> The results of the pyroclast dispersal model will then be compared with images and elevation models of the lunar surface
> The images and elevation models will be from LROC images and LOLA data

References

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