DYKE PROPAGATION BENEATH A VOLCANIC EDIFICE

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1. **Introduction.**

Distribution of erupted lavas.

2. Magma reservoir only, no edifice.

3. The edifice.

Stress field due to an edifice.

Magma chamber behaviour.

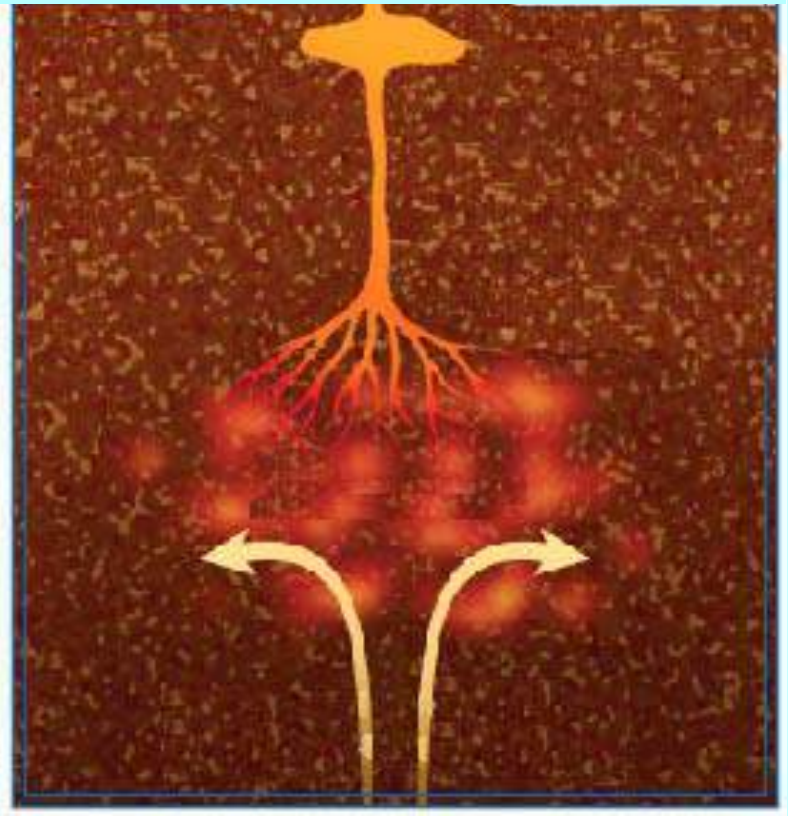
4. Dyke propagation.

Along the vertical: eruption or no eruption.

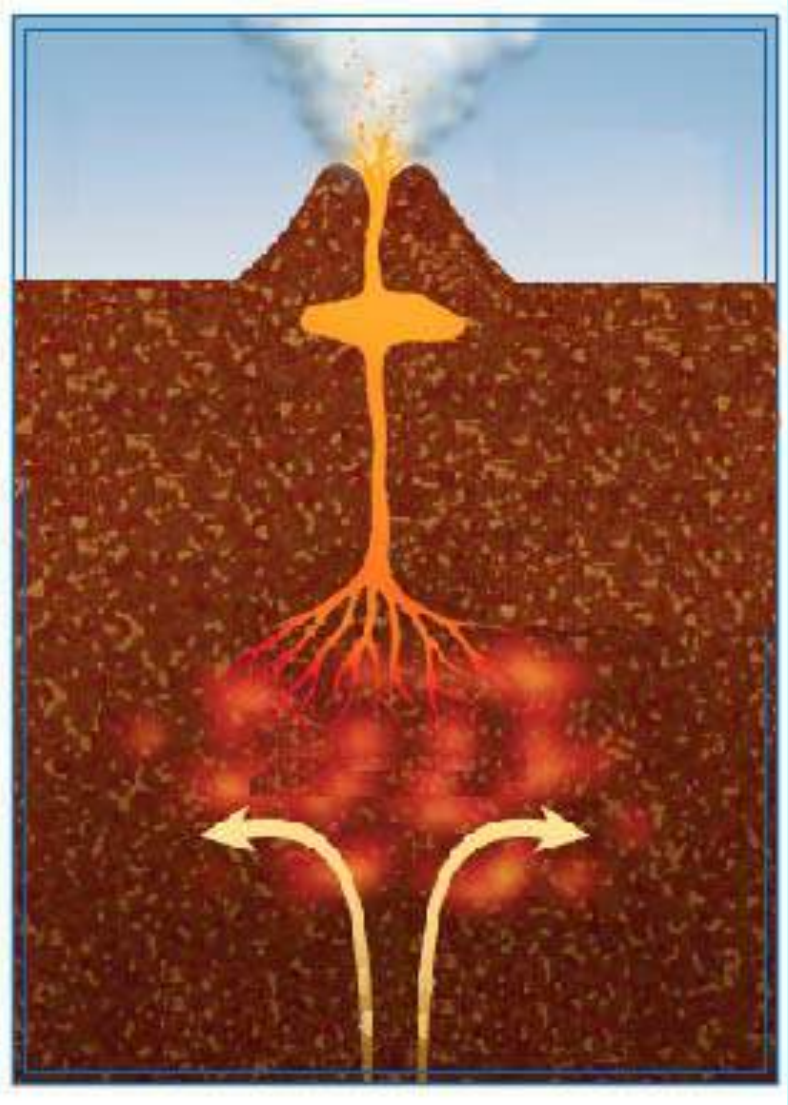
Along the horizontal: distribution of eruptive centers.

Formation of storage zones (reservoirs ?).

A MAGMATIC/VOLCANIC SYSTEM

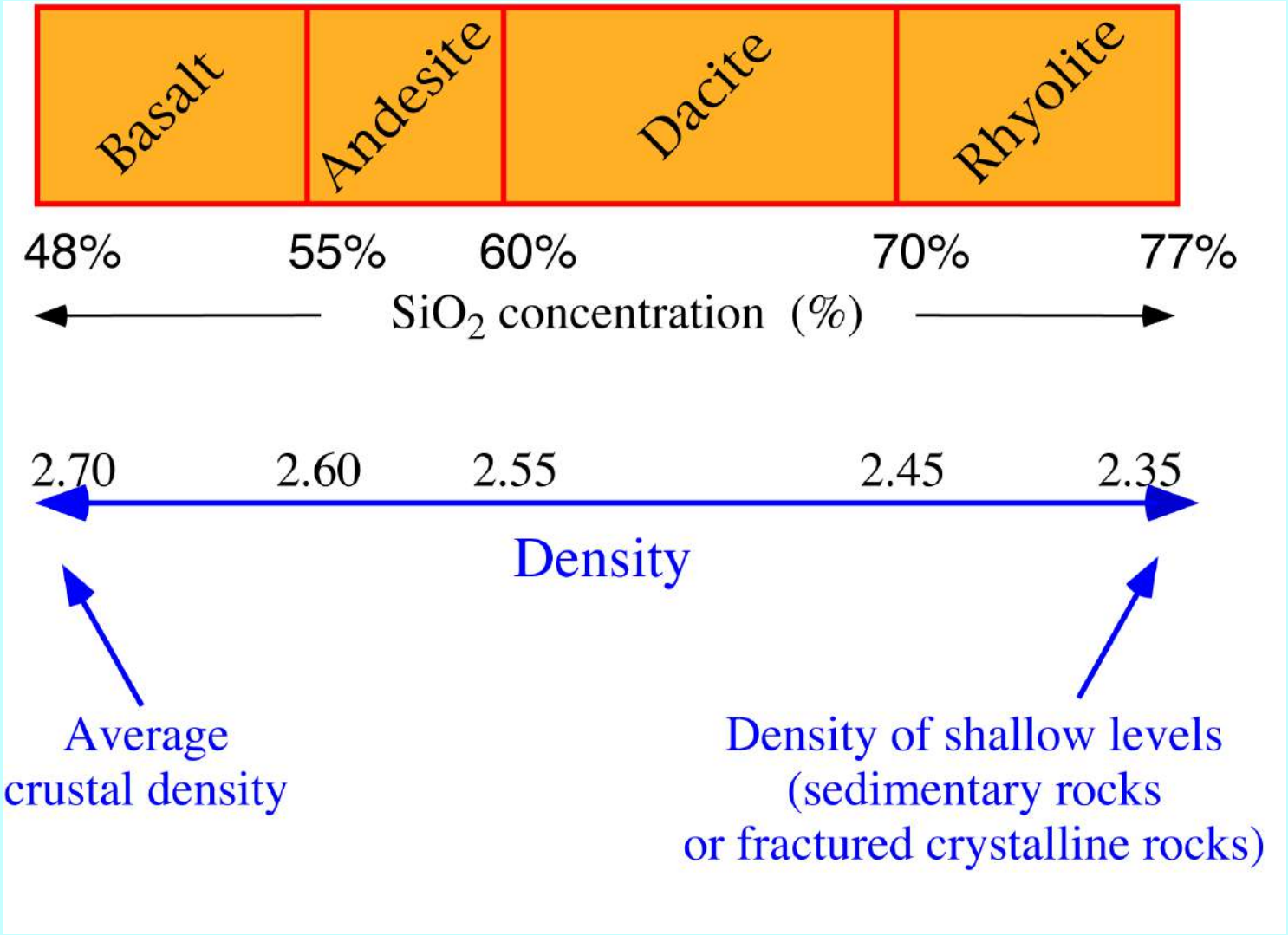


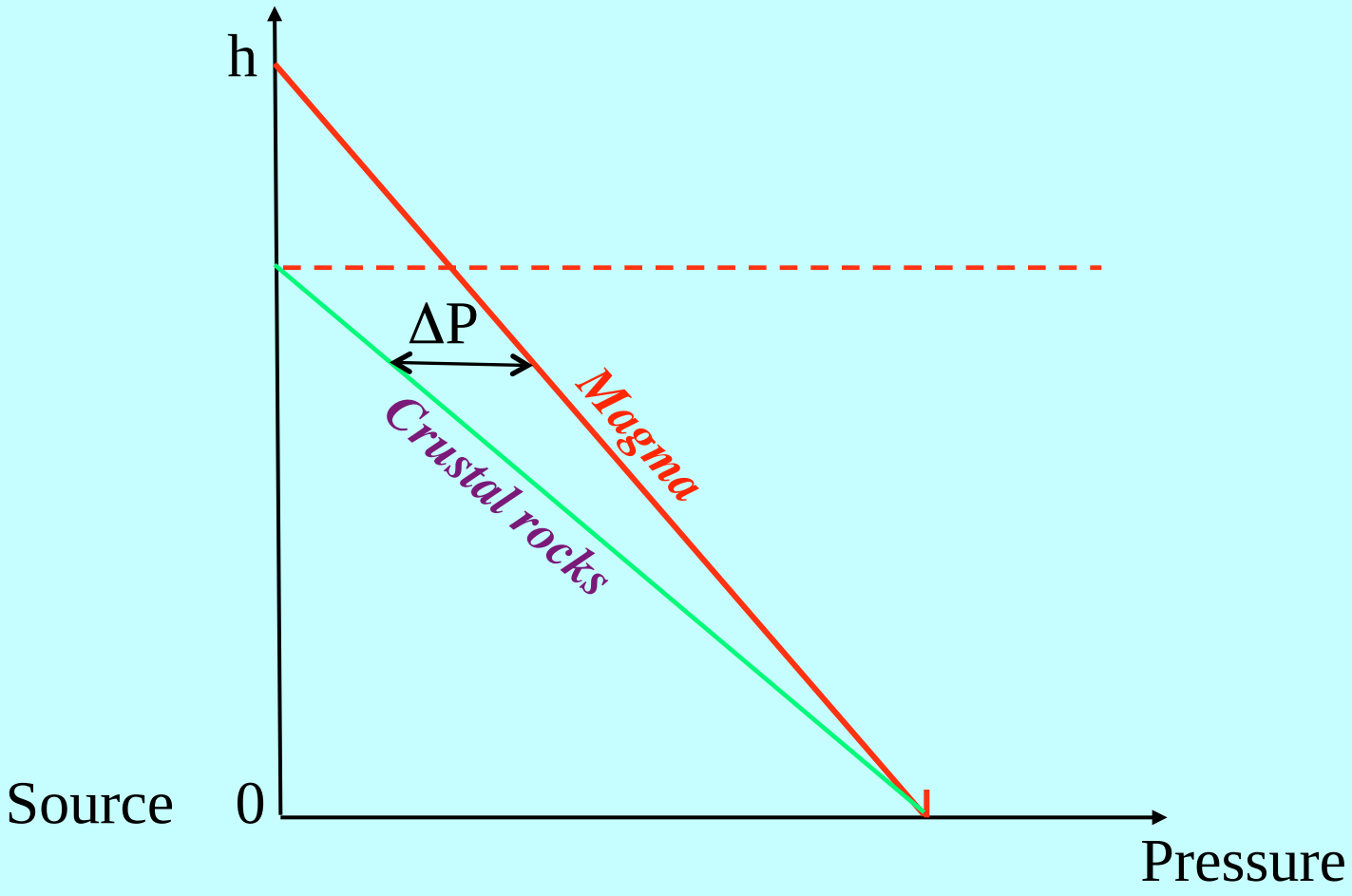
A MAGMATIC/VOLCANIC SYSTEM



GOAL

To evaluate the role of the edifice.


Basalt
Andesite
Dacite
Rhyolite
48%
55%
60%
70%
77%
SiO2 concentration (%)
2.70
2.60
2.55
2.45
2.35
Density
Average crustal density
Density of shallow levels (sedimentary rocks or fractured crystalline rocks)



Magma pressure $\Delta P = (\rho_r - \rho_m)\, g\, z$

Volcanic edifices

Shield volcano

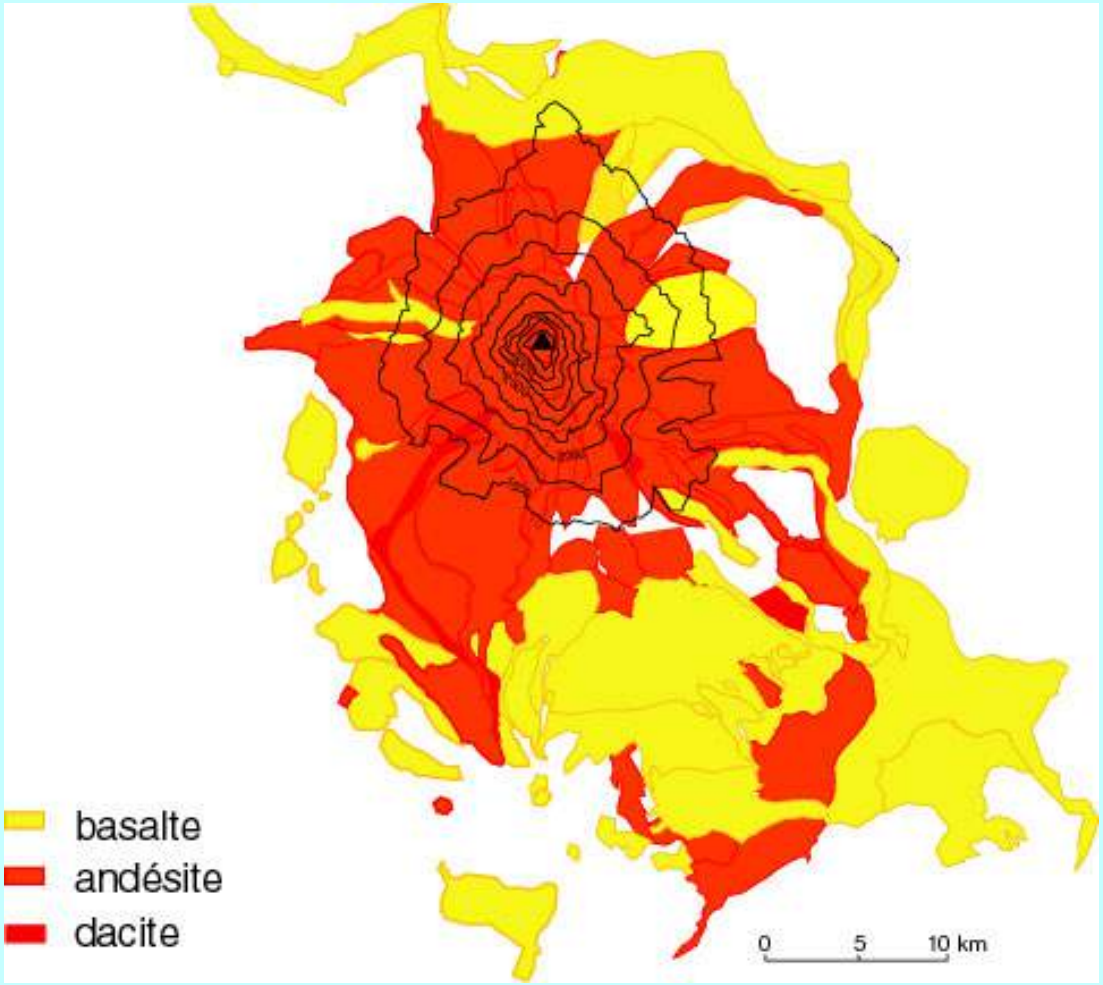
Ex: Medicine Lake, USA
radius : 24 km
height : 800 m

Stratovolcano

Ex: Mount Adams, USA
radius : 10 (+) km
height : 2500 m

Large loads distributed over large areas.

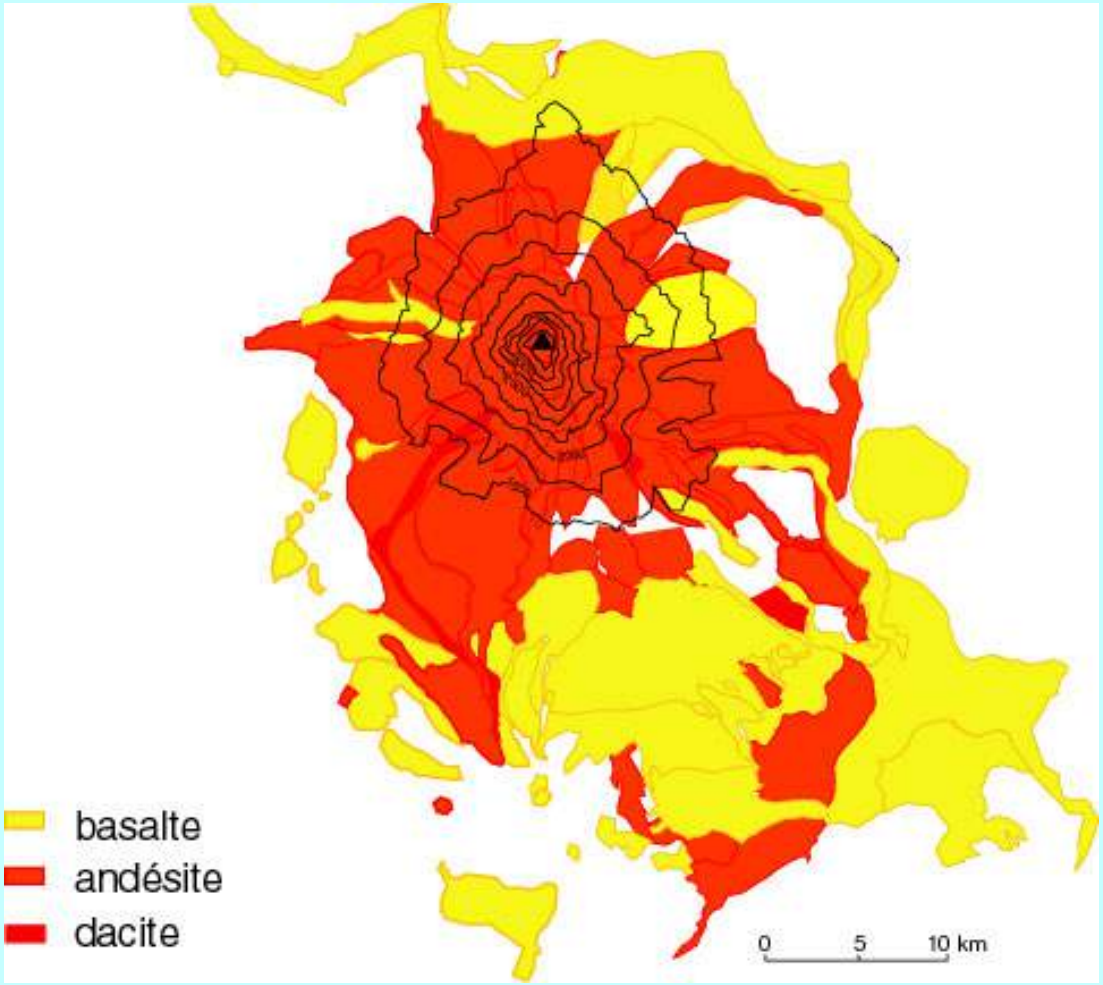
Spatial distribution of erupted lavas



Dense primitive basalt is erupted throughout the volcano lifetime.

When the edifice is large, basalt only erupts through distal fissures and vents.

Mount Adams, USA (*Hildreth, 94*)



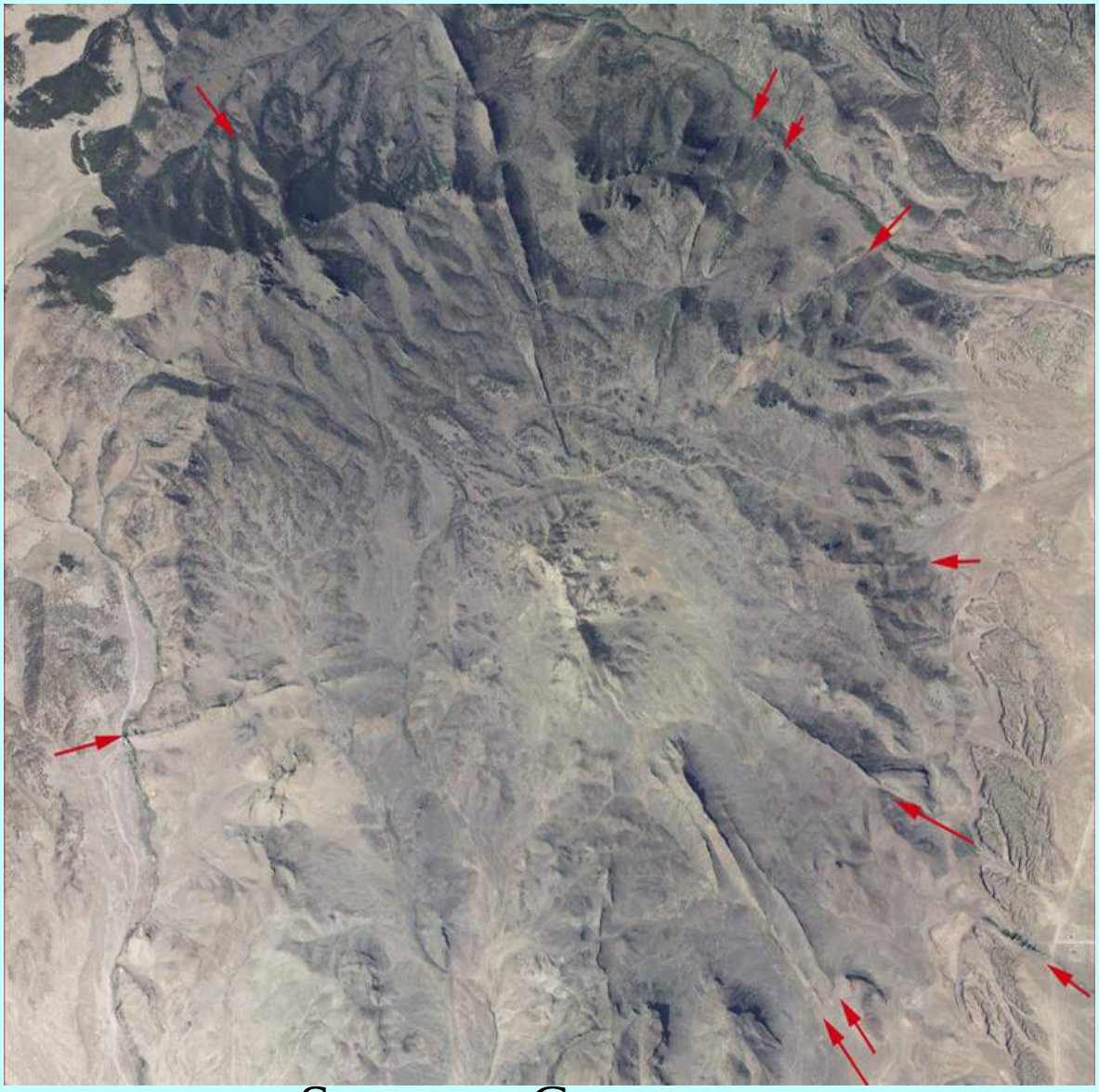
Key fact : basaltic (primitive) melts are erupted through the whole history of the volcanic system.

QUESTIONS

Why do the majority of eruptions proceed through a small focal area ?

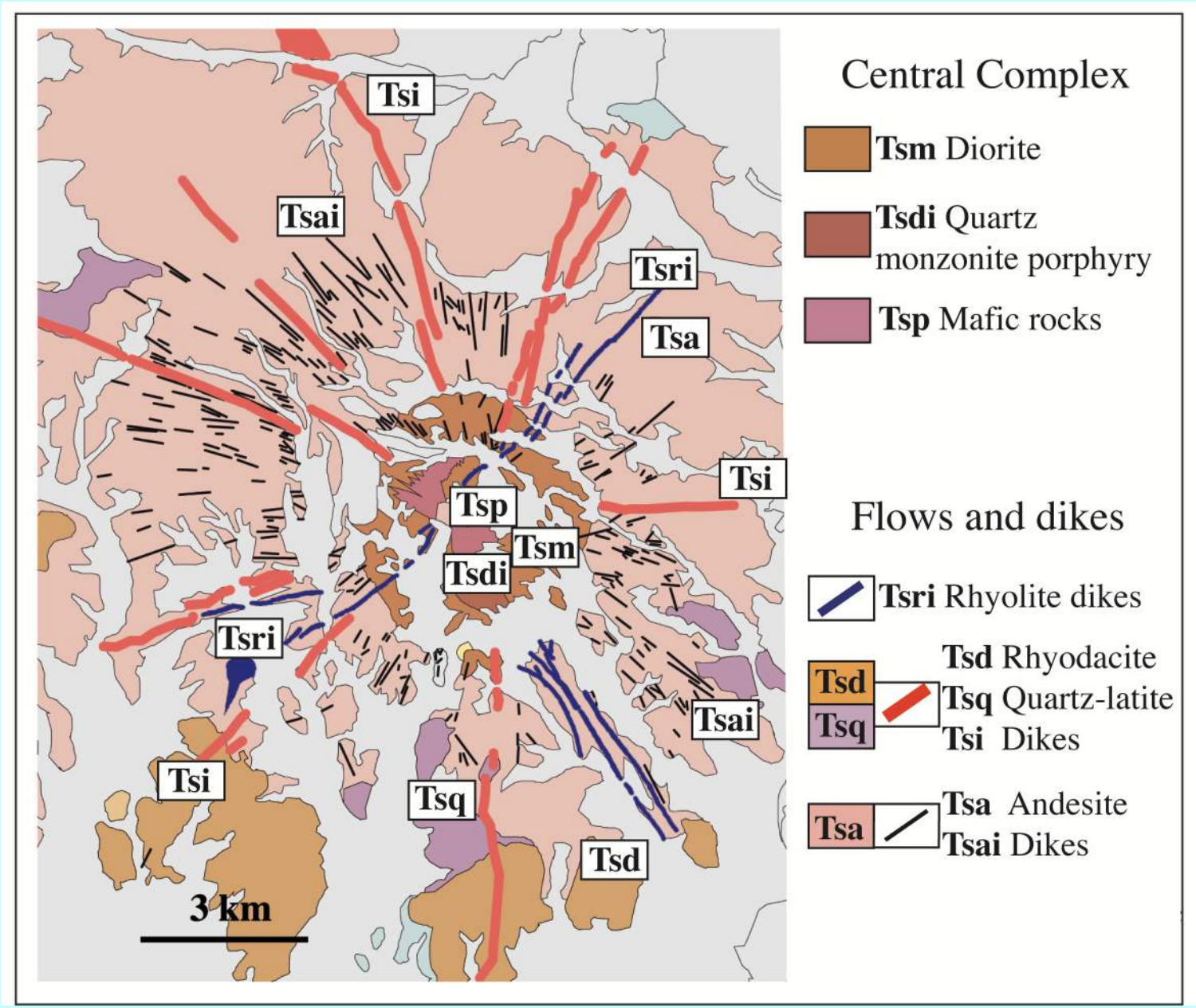
What determines the spatial distribution of lavas ?

Summer Coon volcano, Colorado



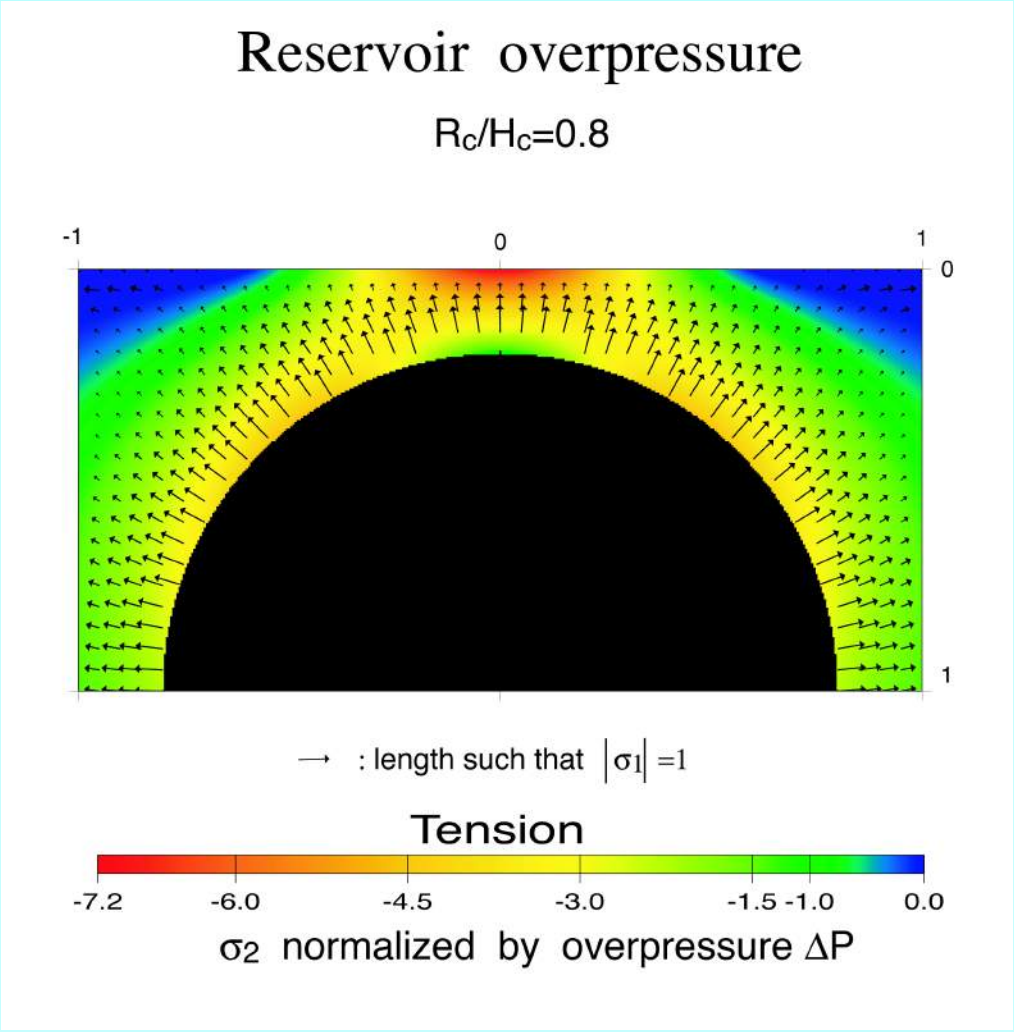
Summer Coon

Summer Coon volcano, Colorado

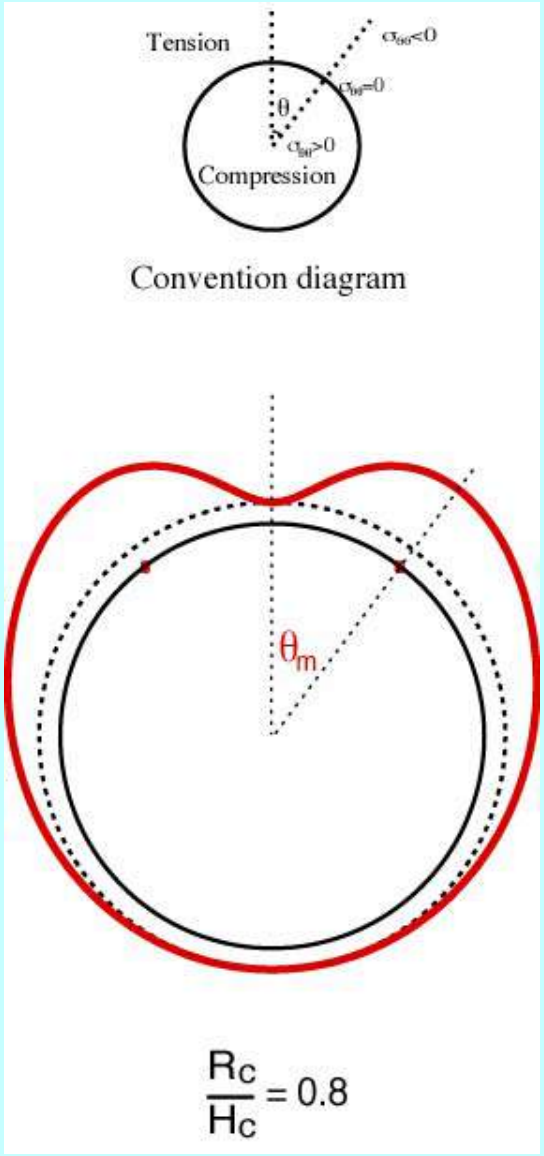


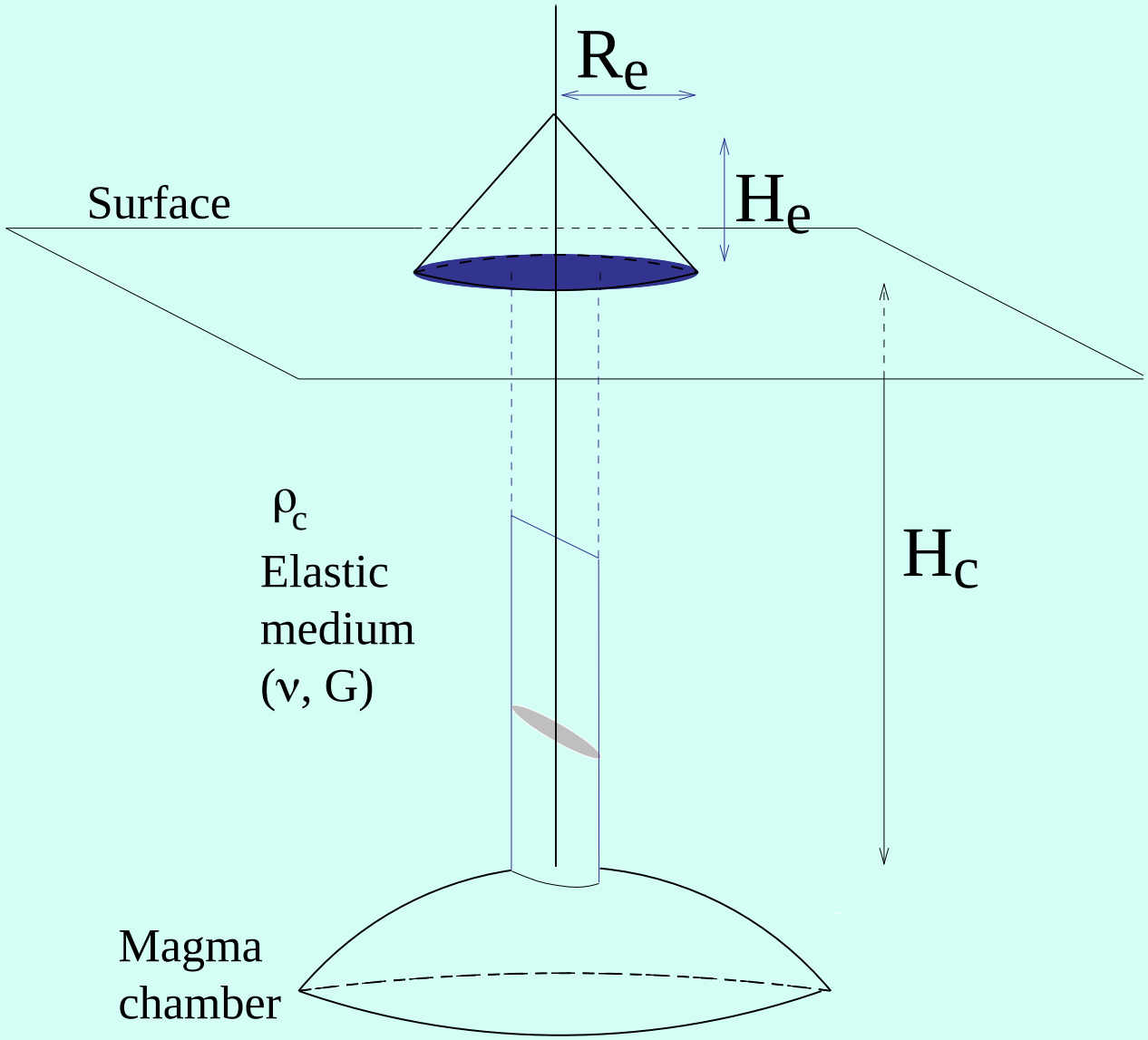
MAGMA RESERVOIR BEHAVIOUR

Eruption without an edifice.
Failure of reservoir walls.



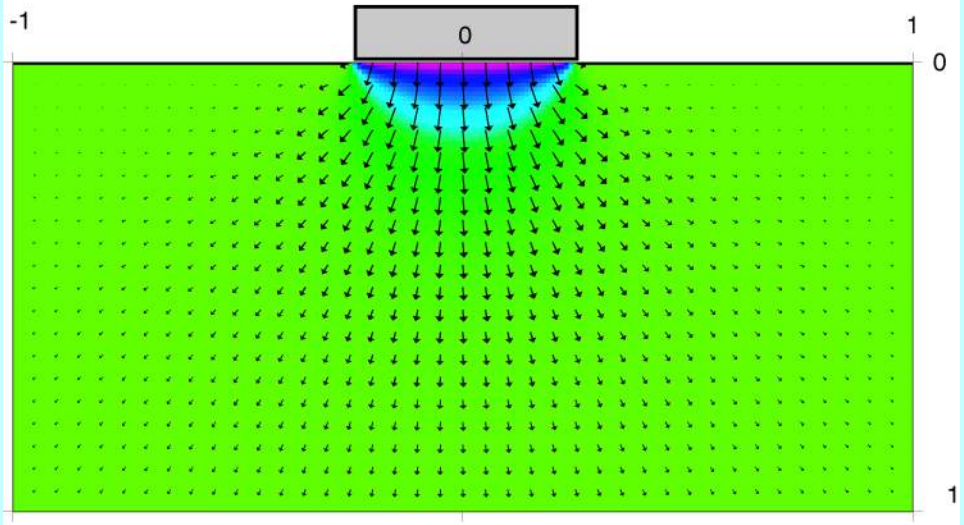
DEVIATORIC STRESS AT RESERVOIR WALLS



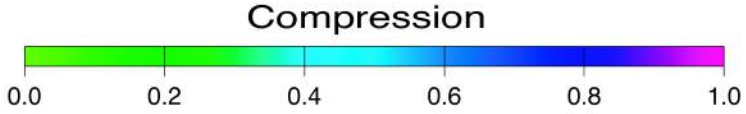

R_e
H_e
Surface
ρ_c
Elastic
medium
(ν, G)
H_c
Magma
chamber

Edifice load

R_e=0.25



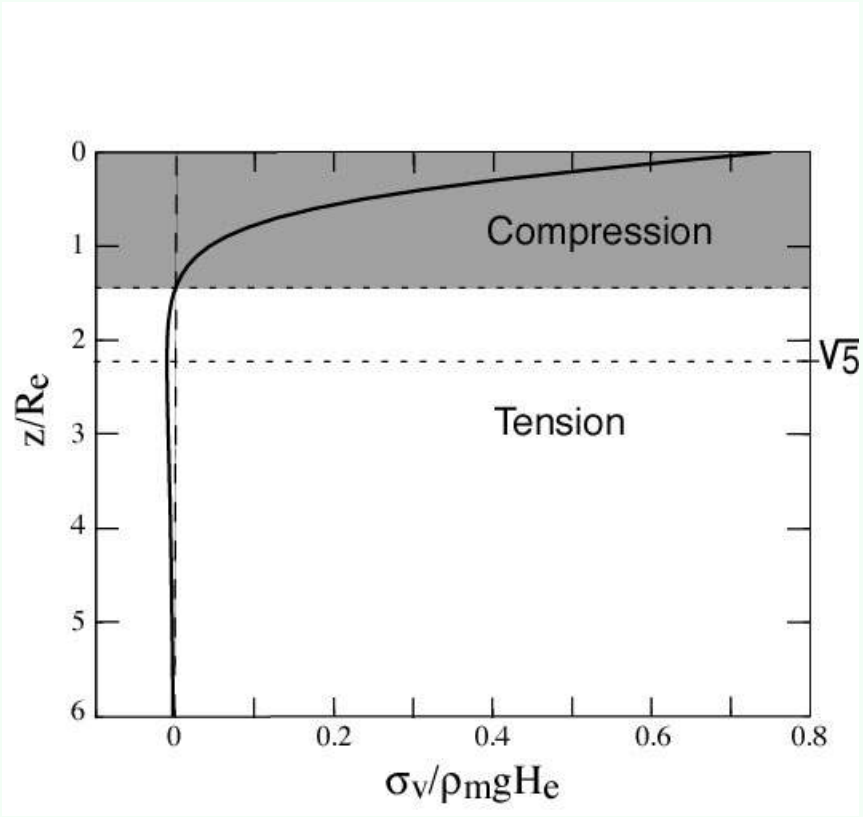
→ : length for $|\sigma_1| = 1$

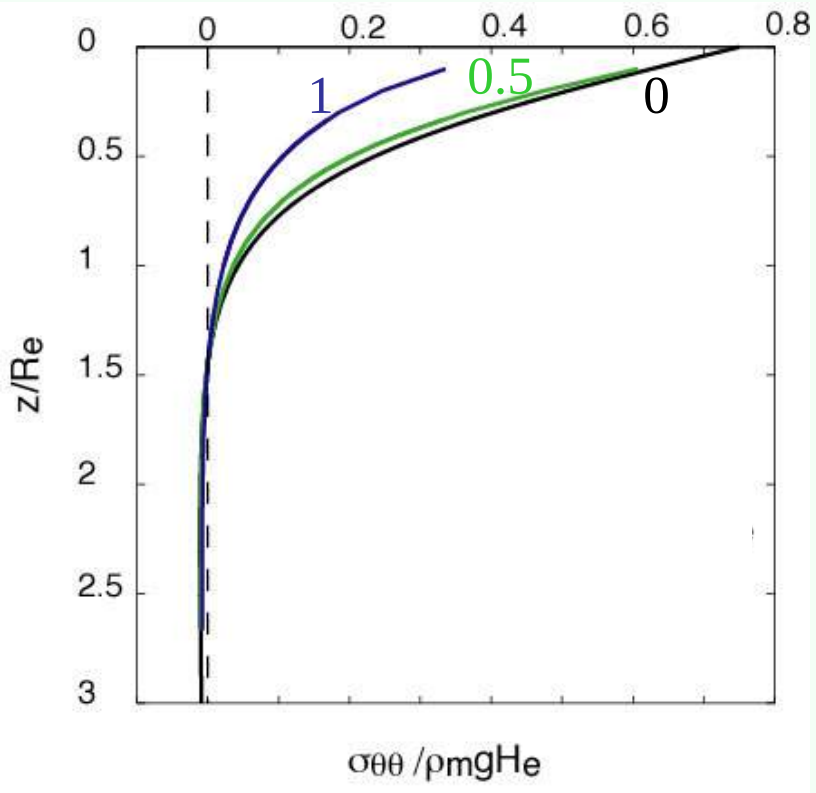


Stress values normalized by edifice load ρ_m g H_e

"Edifice" stress decreases with :

- depth
- increasing radial distance

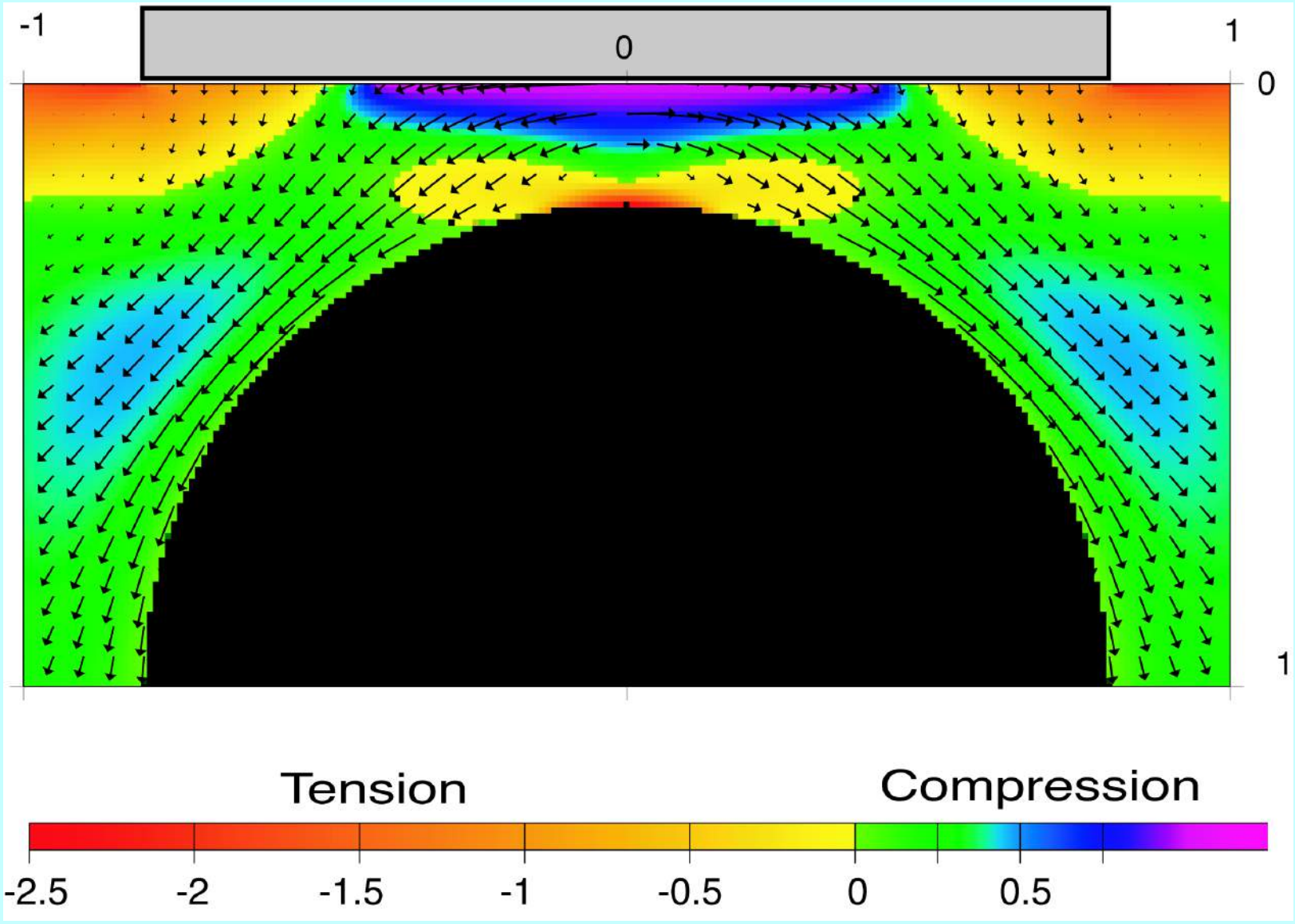




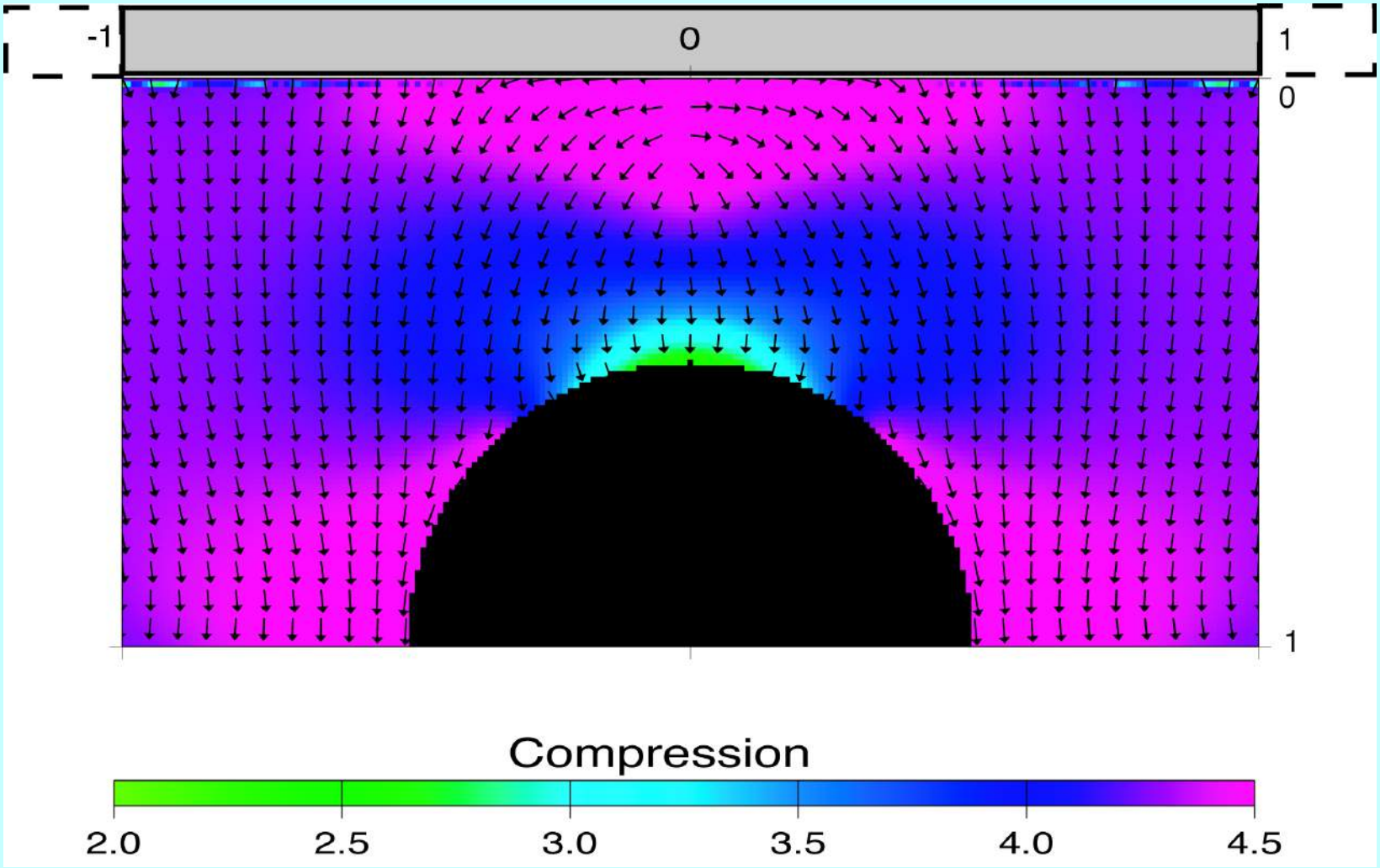
Spatial distribution at depth depends on edifice radius R_e

WITH A MAGMA RESERVOIR : EDIFICE LOAD ONLY

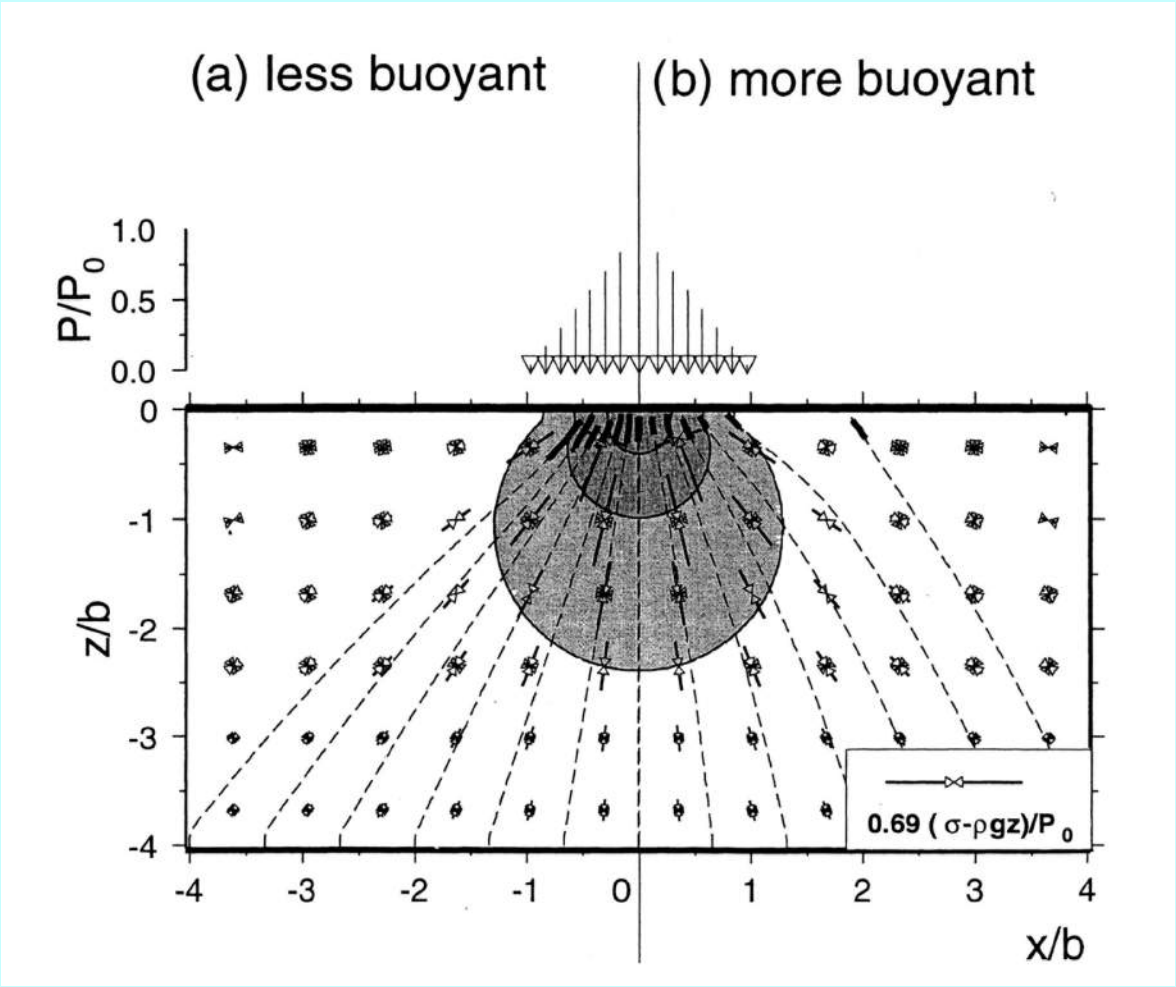
$R_c/H_c = 0.8$ $R_e/H_c = 0.8$



EDIFICE LOAD + RESERVOIR OVERPRESSURE



WITHOUT A MAGMA RESERVOIR



Dyke trajectories beneath an edifice: deflected towards the axis

(Dahm, 2000)

An edifice acts to focus
magma transport in central area
(with or without a reservoir).

MOUNT ADAMS

(1) Evolved lavas confined to focal area

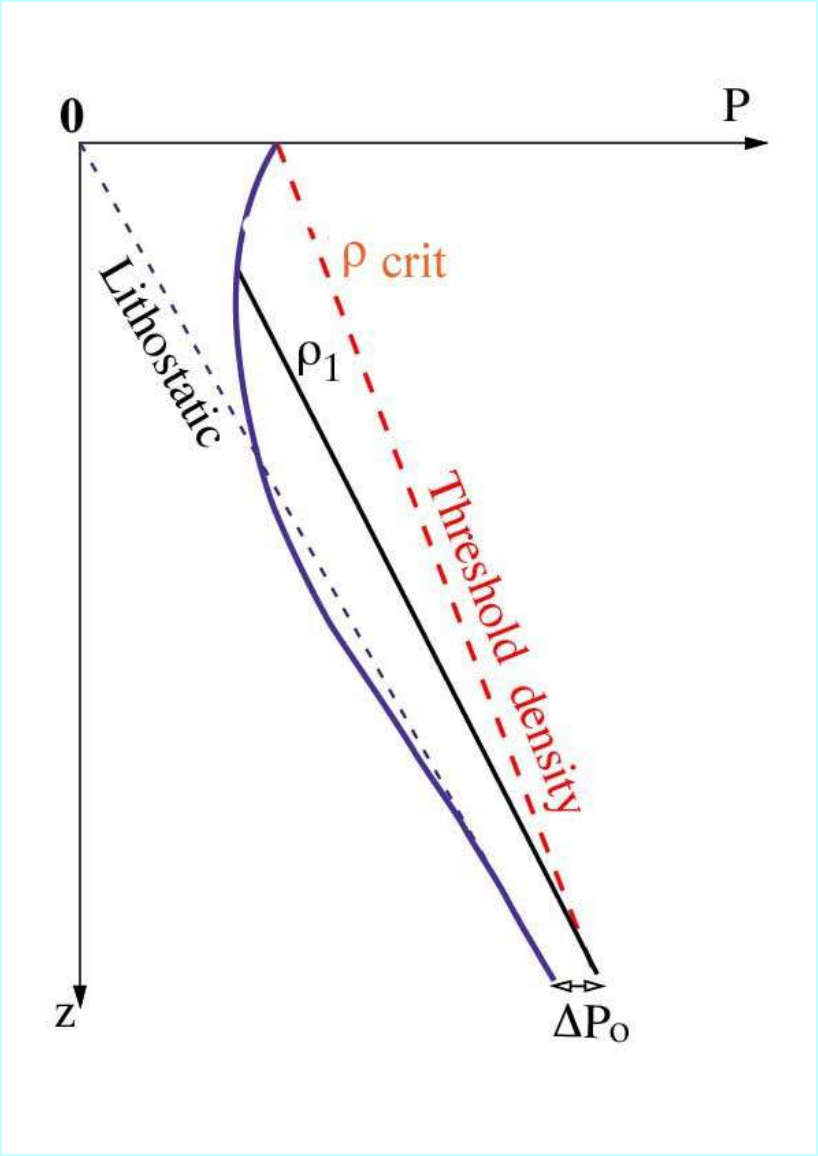
(2) Amount of evolved lavas becomes significant only after the first cone-building episode

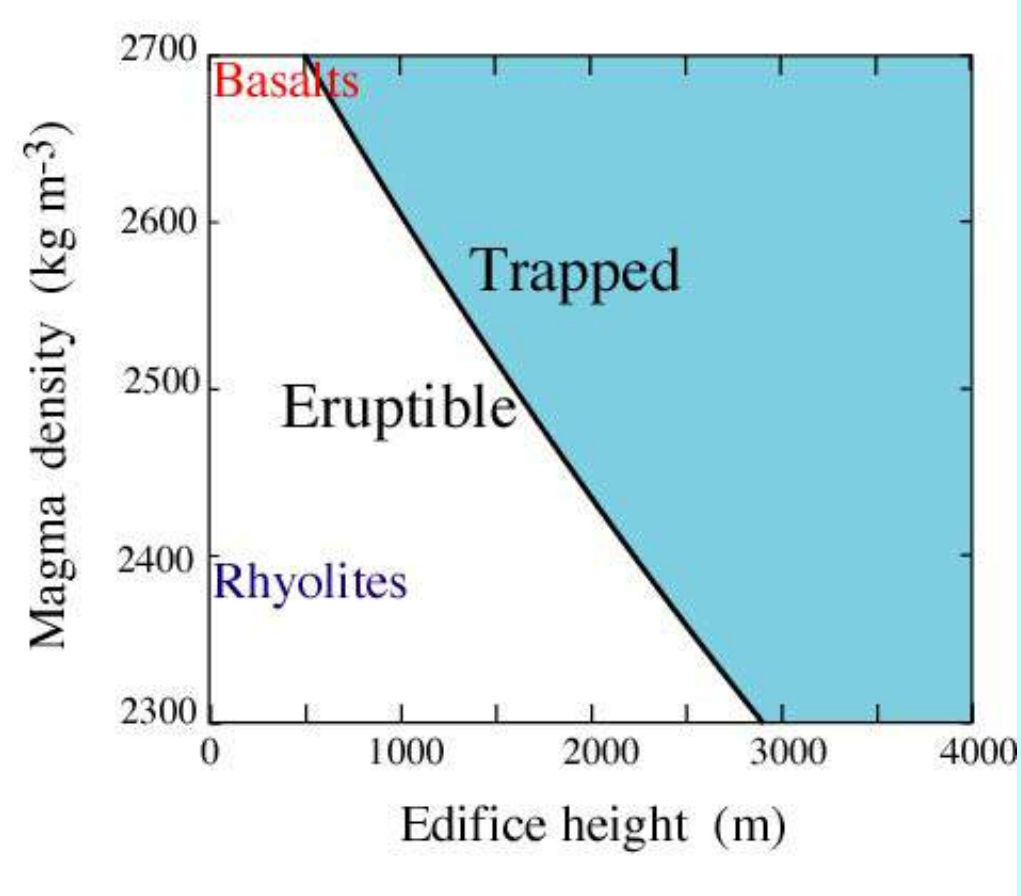
VERTICAL DYKE PROPAGATION

Depends on initial driving pressure,

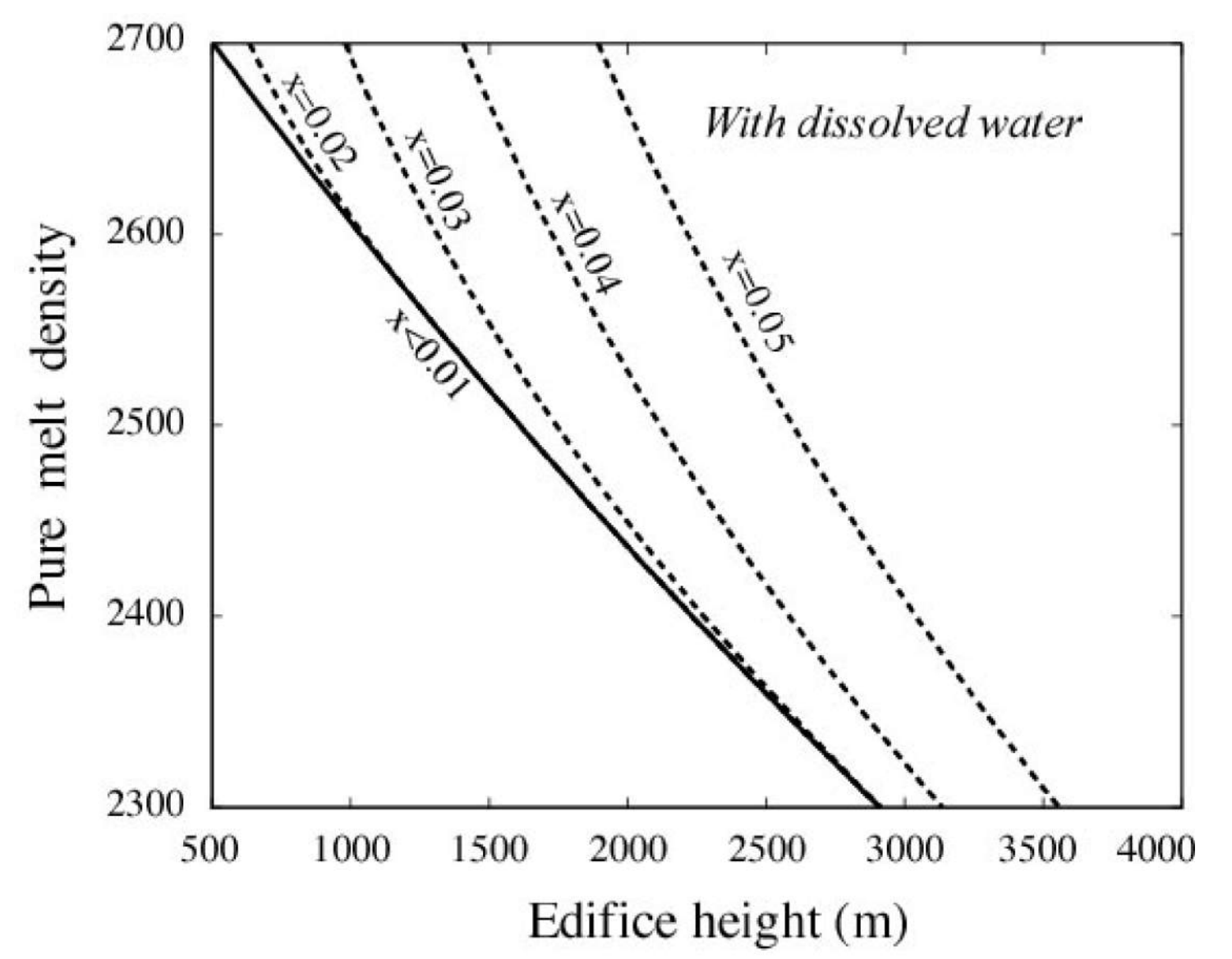
magma density

and ambient stress field


0
P
ρ crit
Lithostatic
ρ1
Threshold density
z
ΔPo

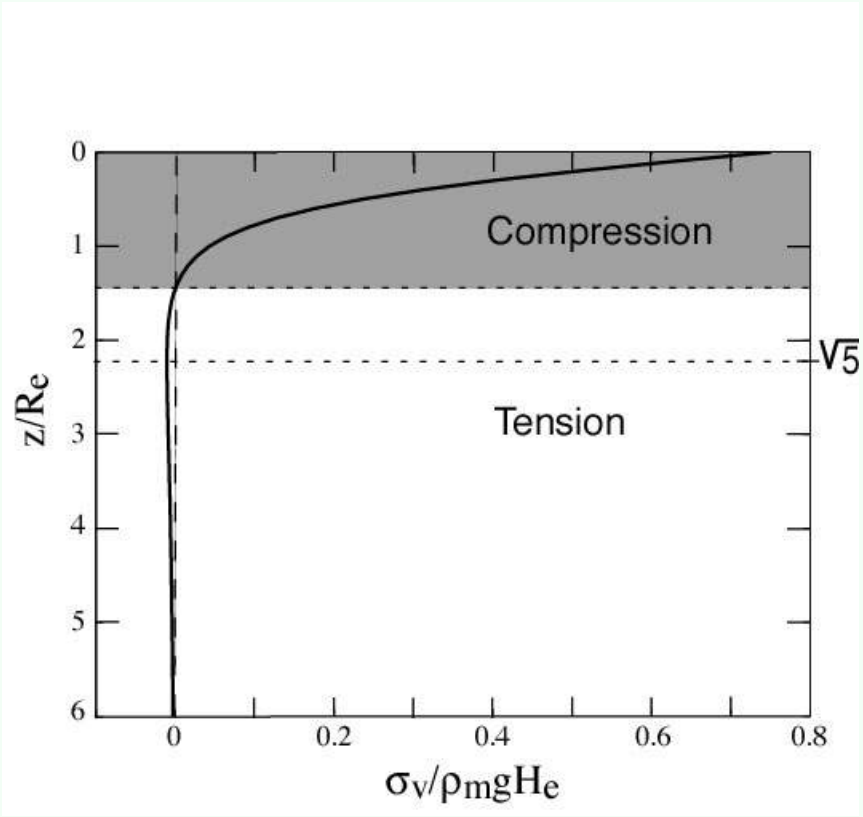


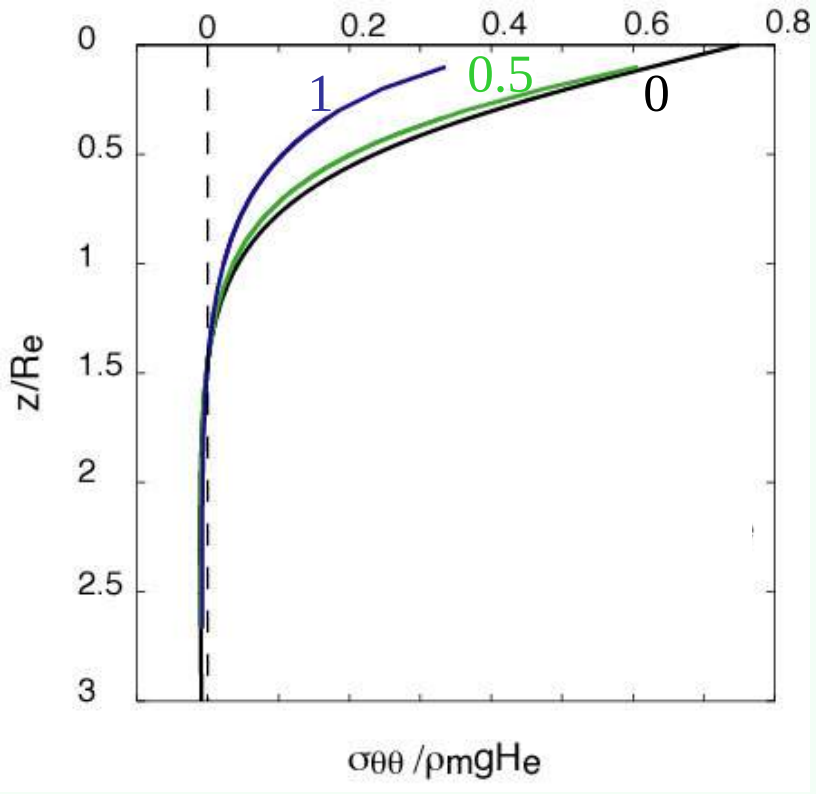
(Pinel & Jaupart, 2000)


With dissolved water
x=0.02
x=0.03
x=0.04
x=0.05
x≤0.01
Pure melt density
2700
2600
2500
2400
2300
500
1000
1500
2000
2500
3000
3500
4000
Edifice height (m)

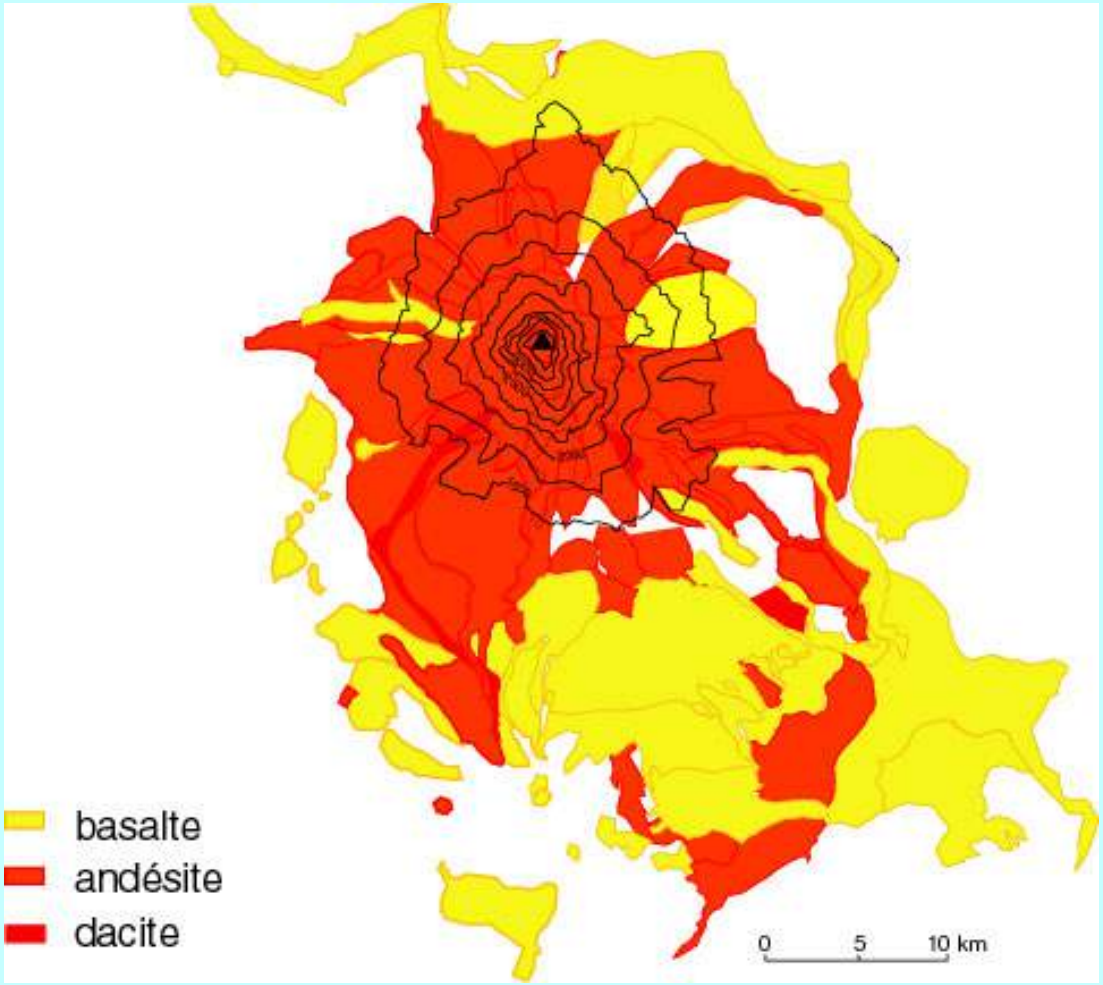
“Edifice” stress decreases with :

- depth
- increasing radial distance





Spatial distribution of erupted lavas



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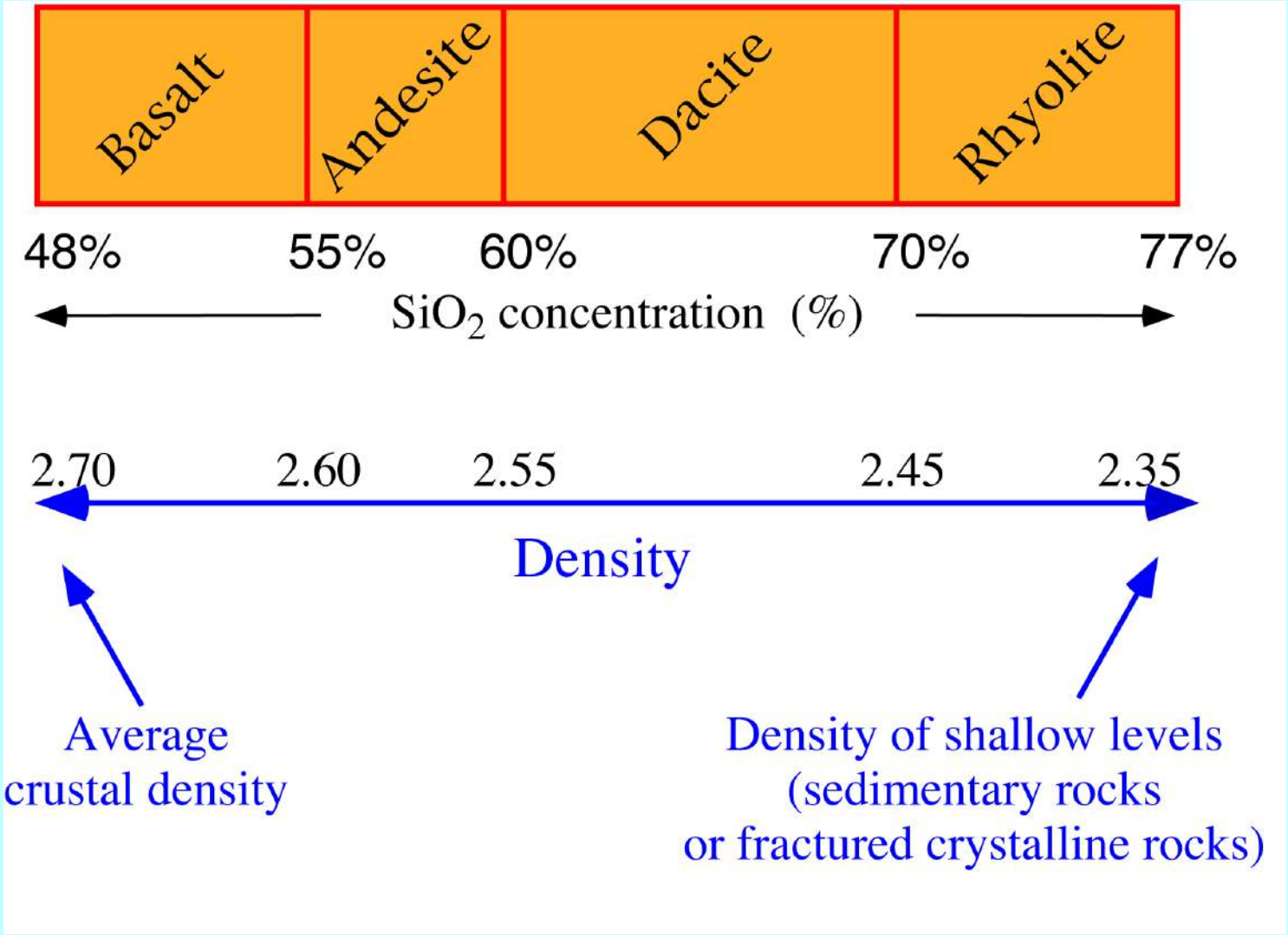
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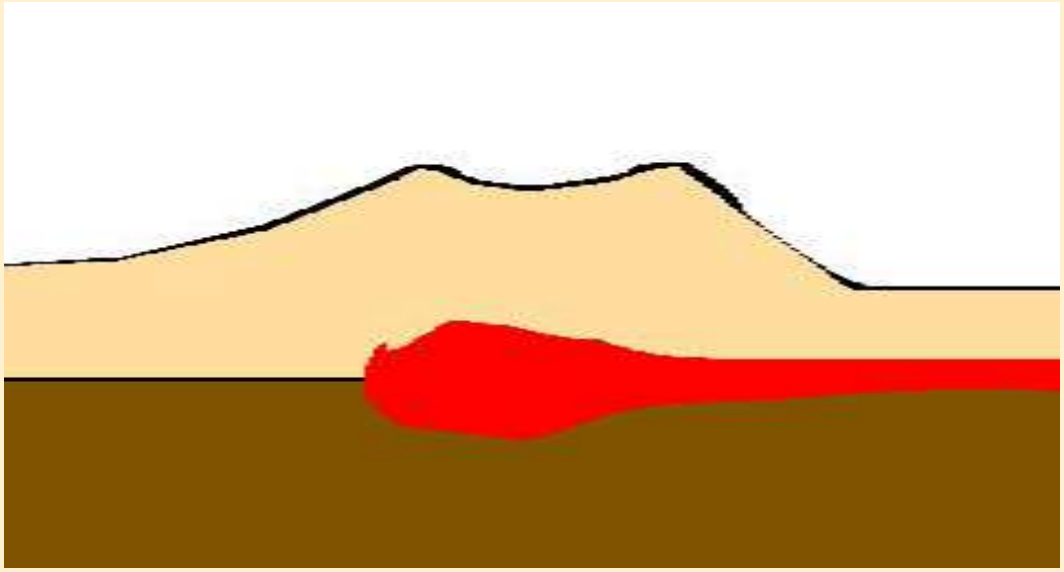
Average crustal density
Density of shallow levels (sedimentary rocks or fractured crystalline rocks)

HORIZONTAL DYKE PROPAGATION

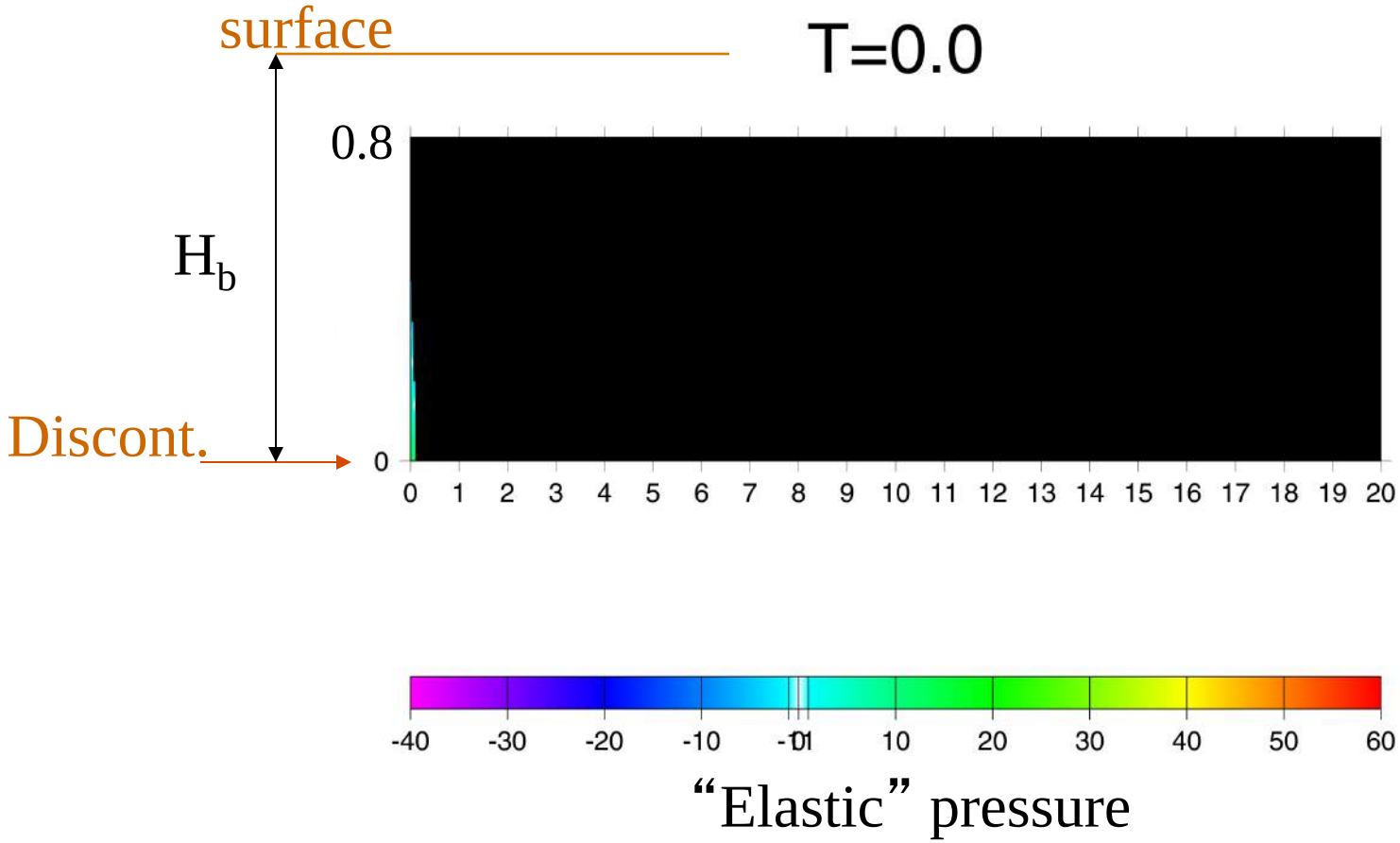


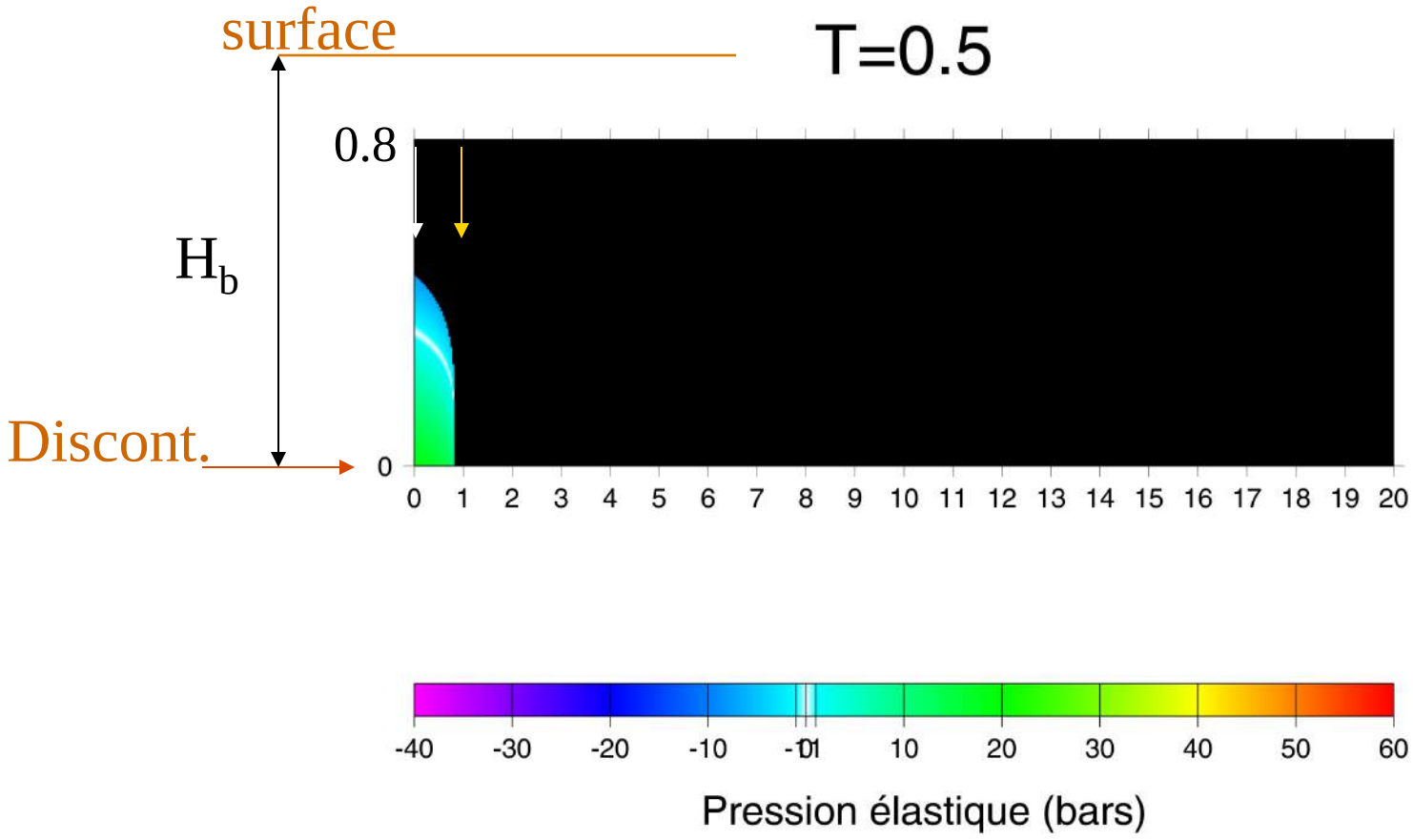
At a density interface
(we return to this later)

Without an edifice

(Lister, 1990b)

Dyke in vertical cross-section

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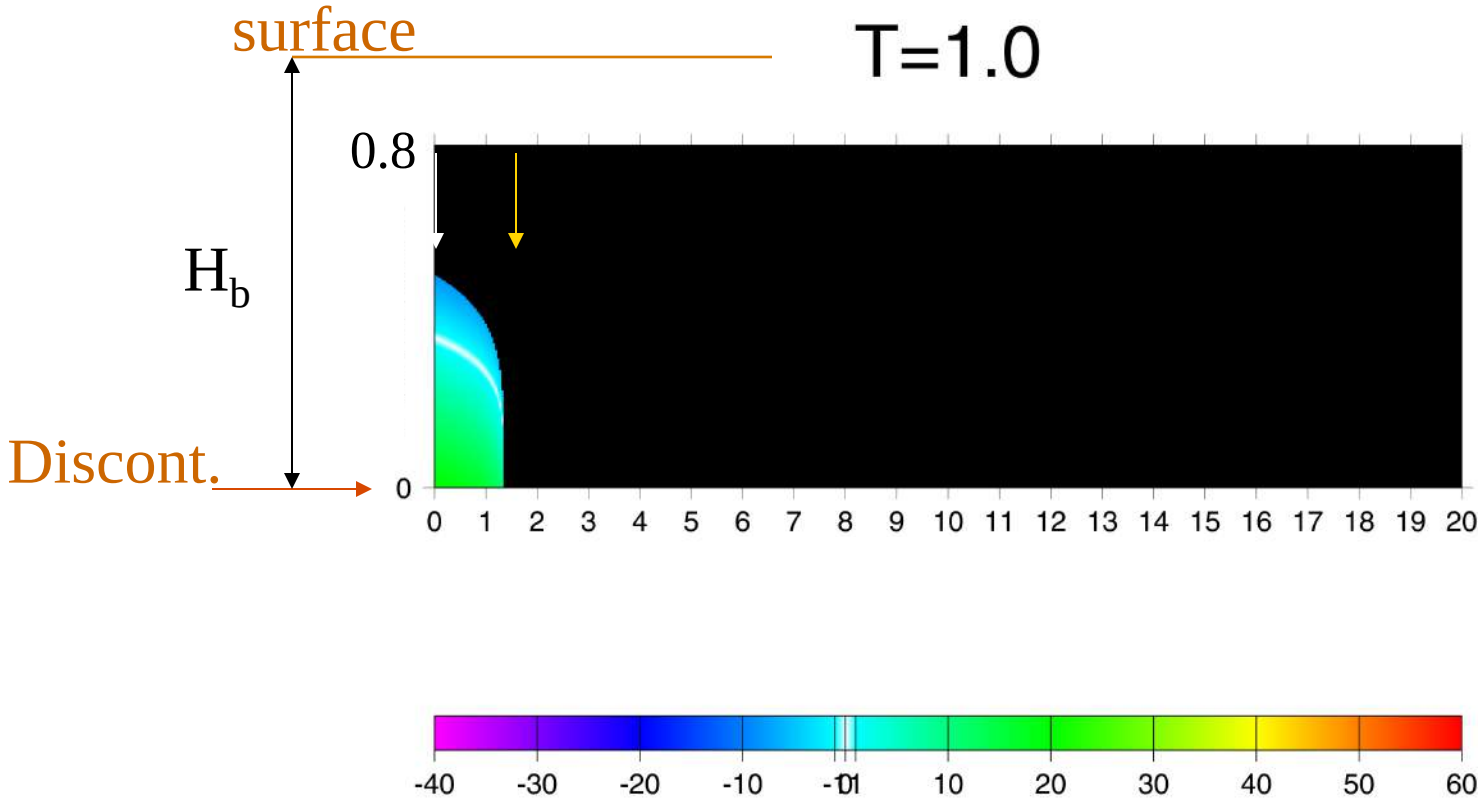
Pression élastique (bars)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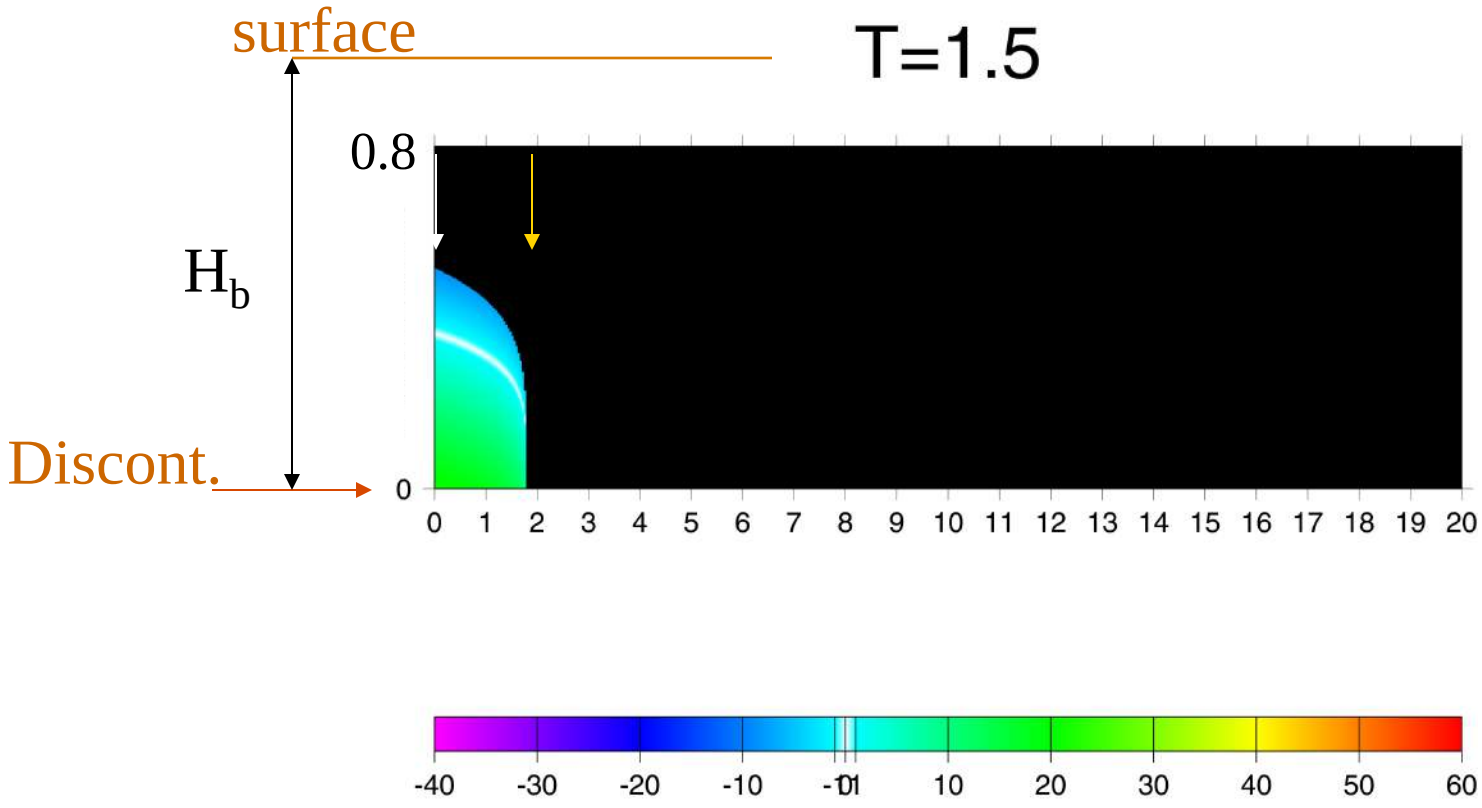
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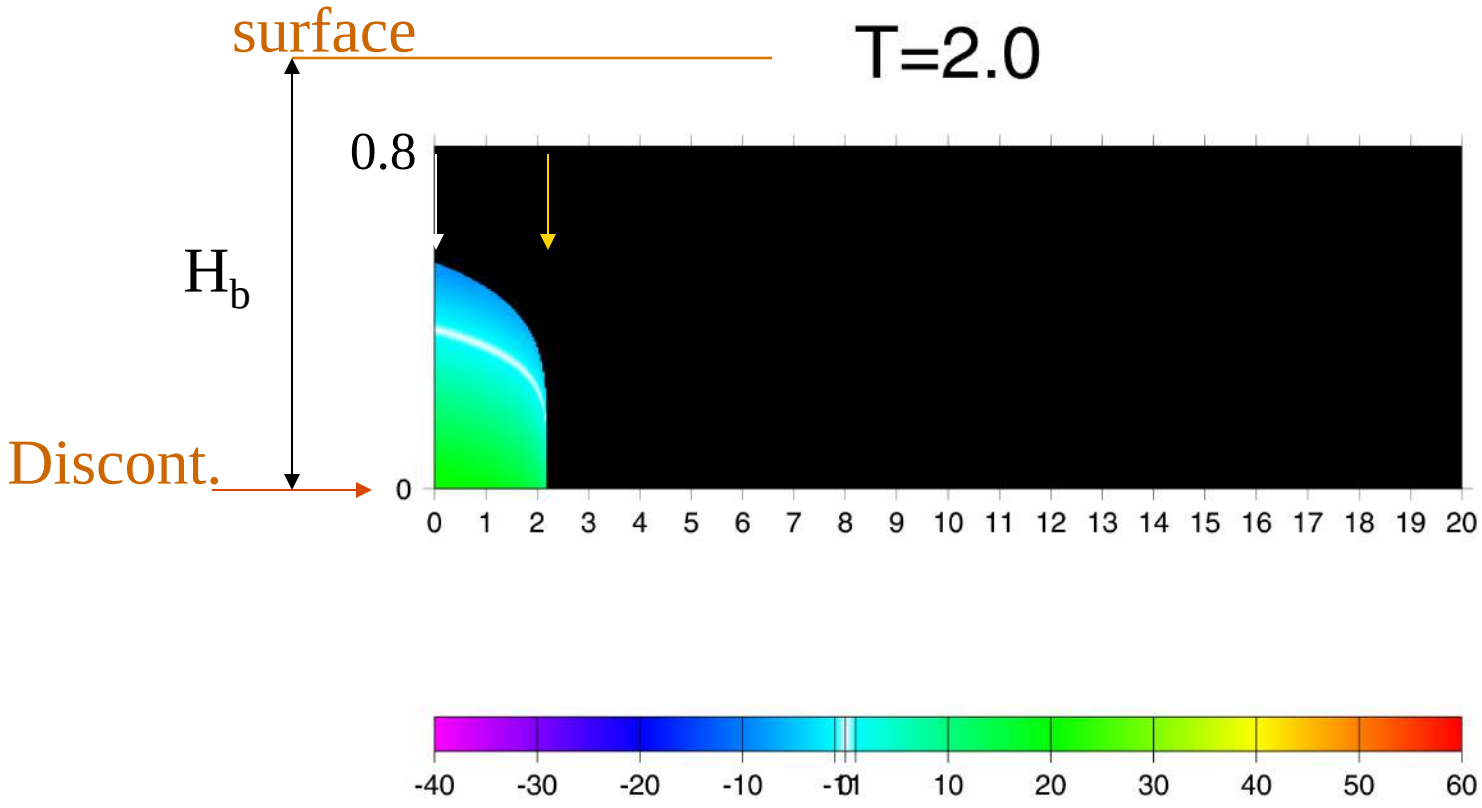
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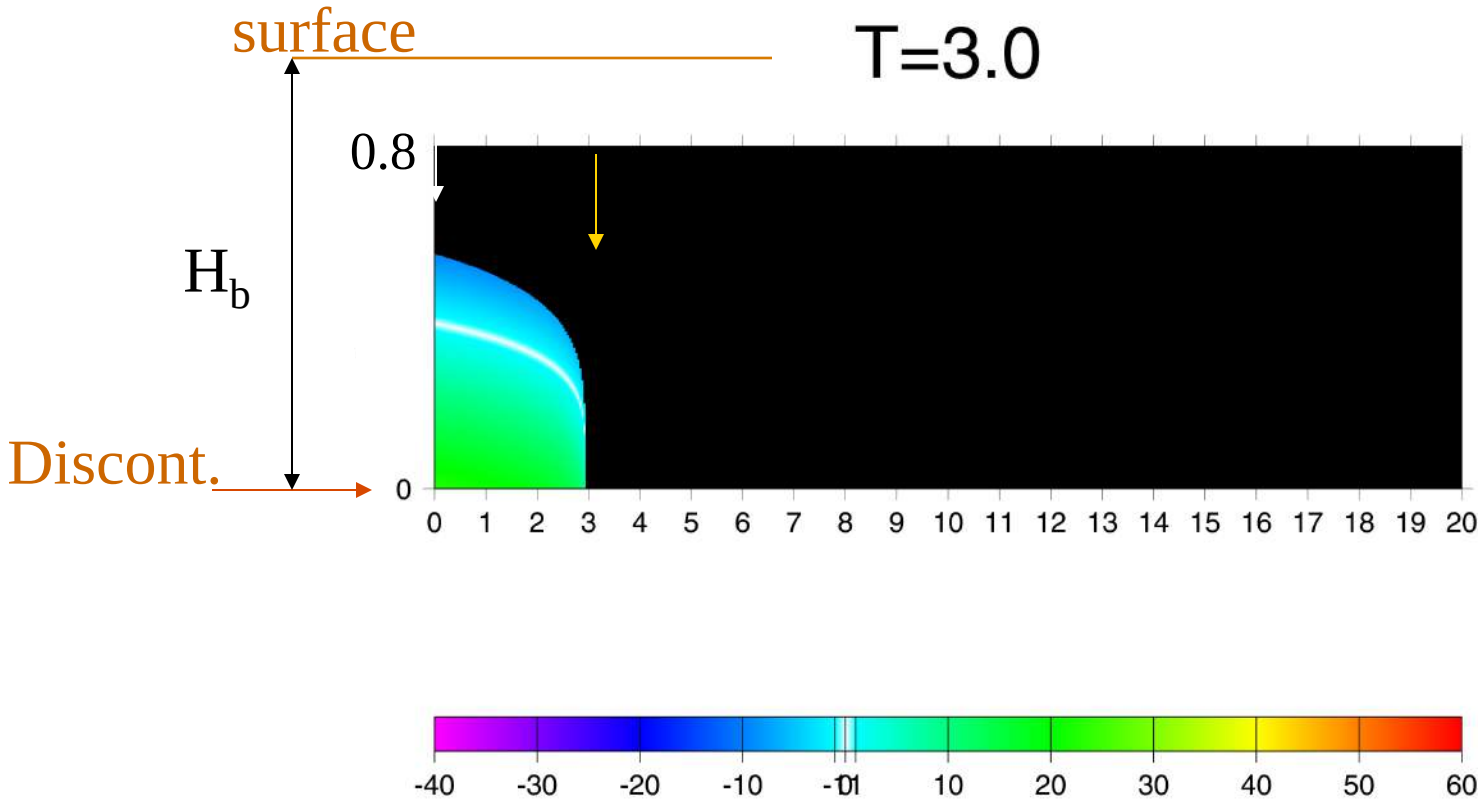
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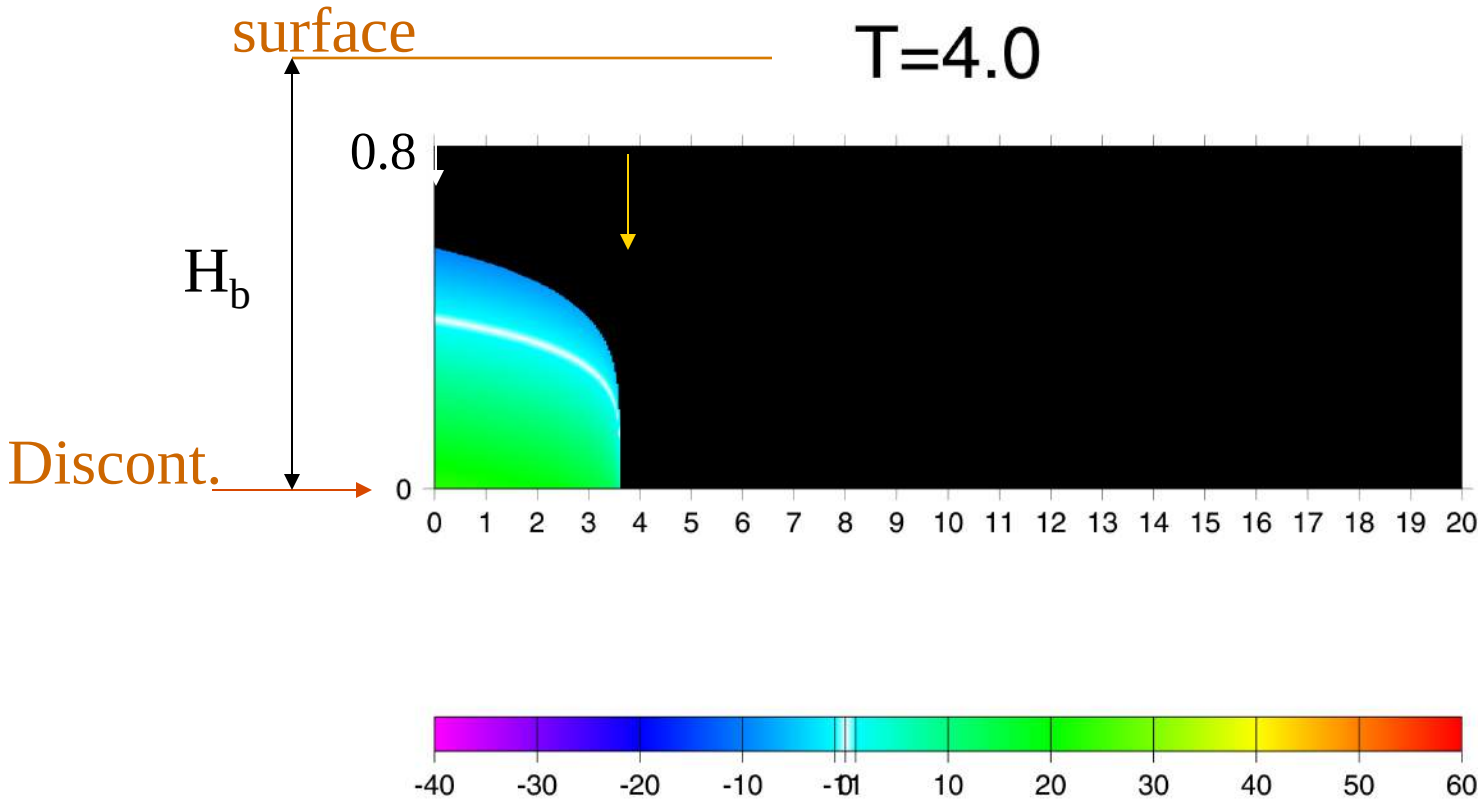
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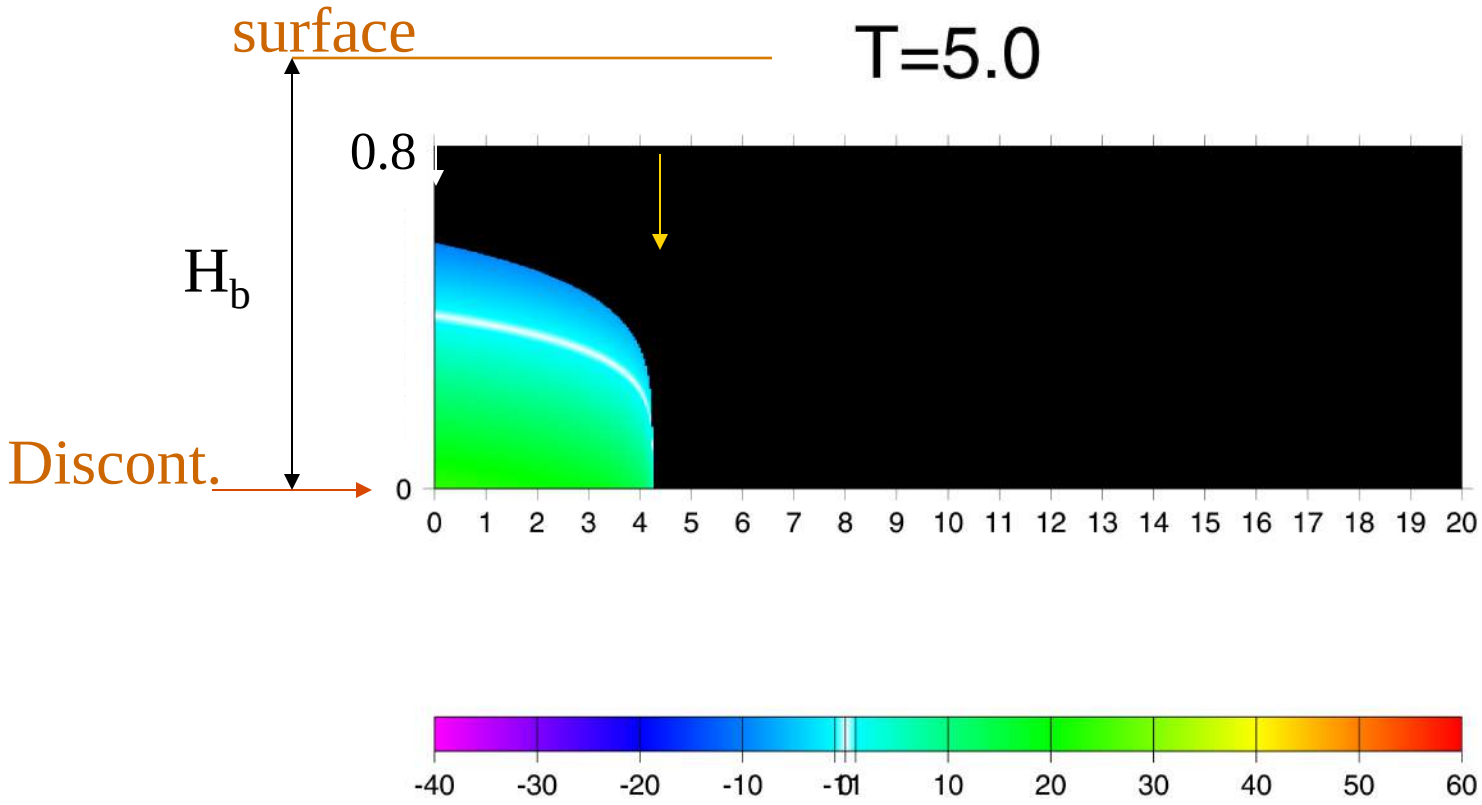
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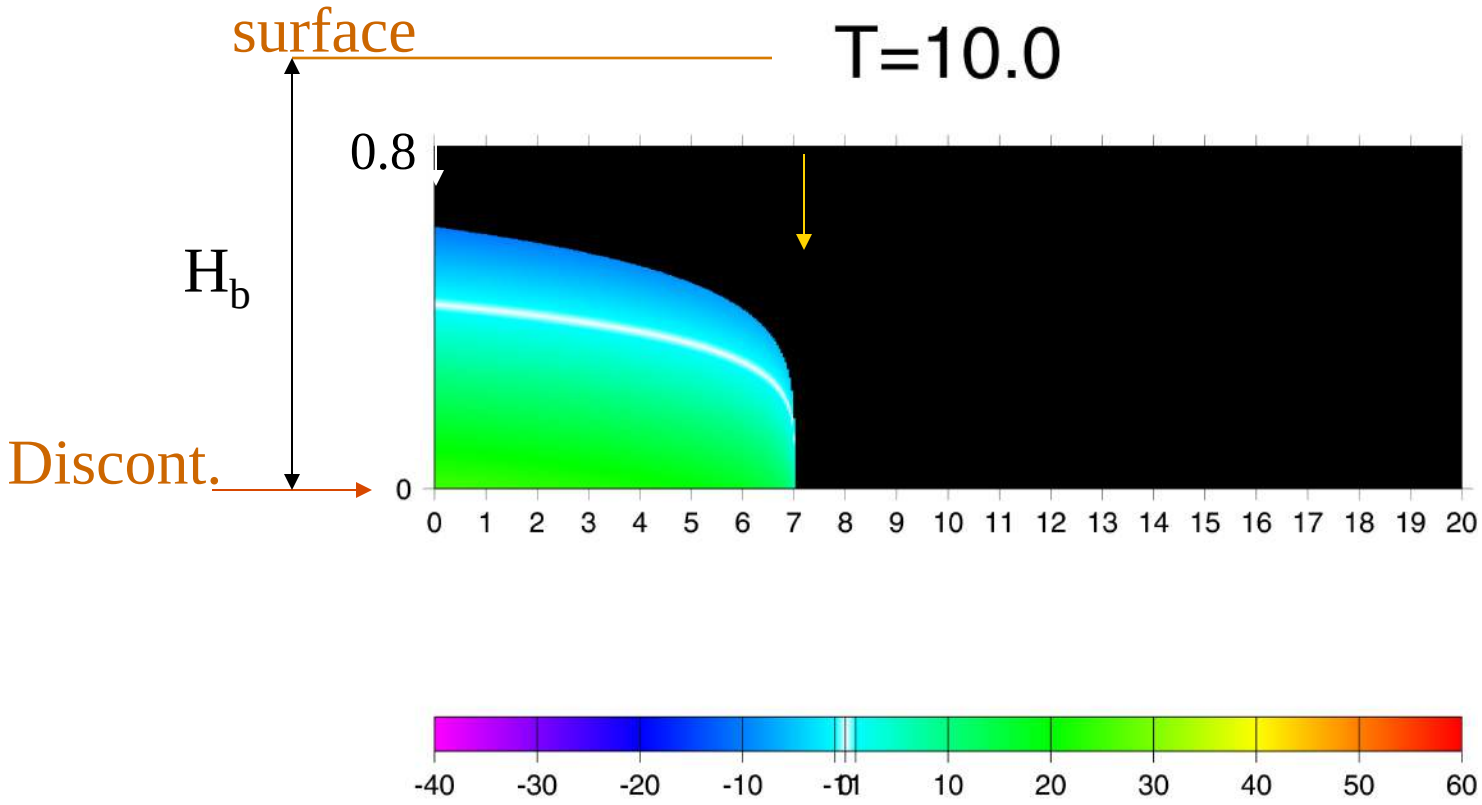
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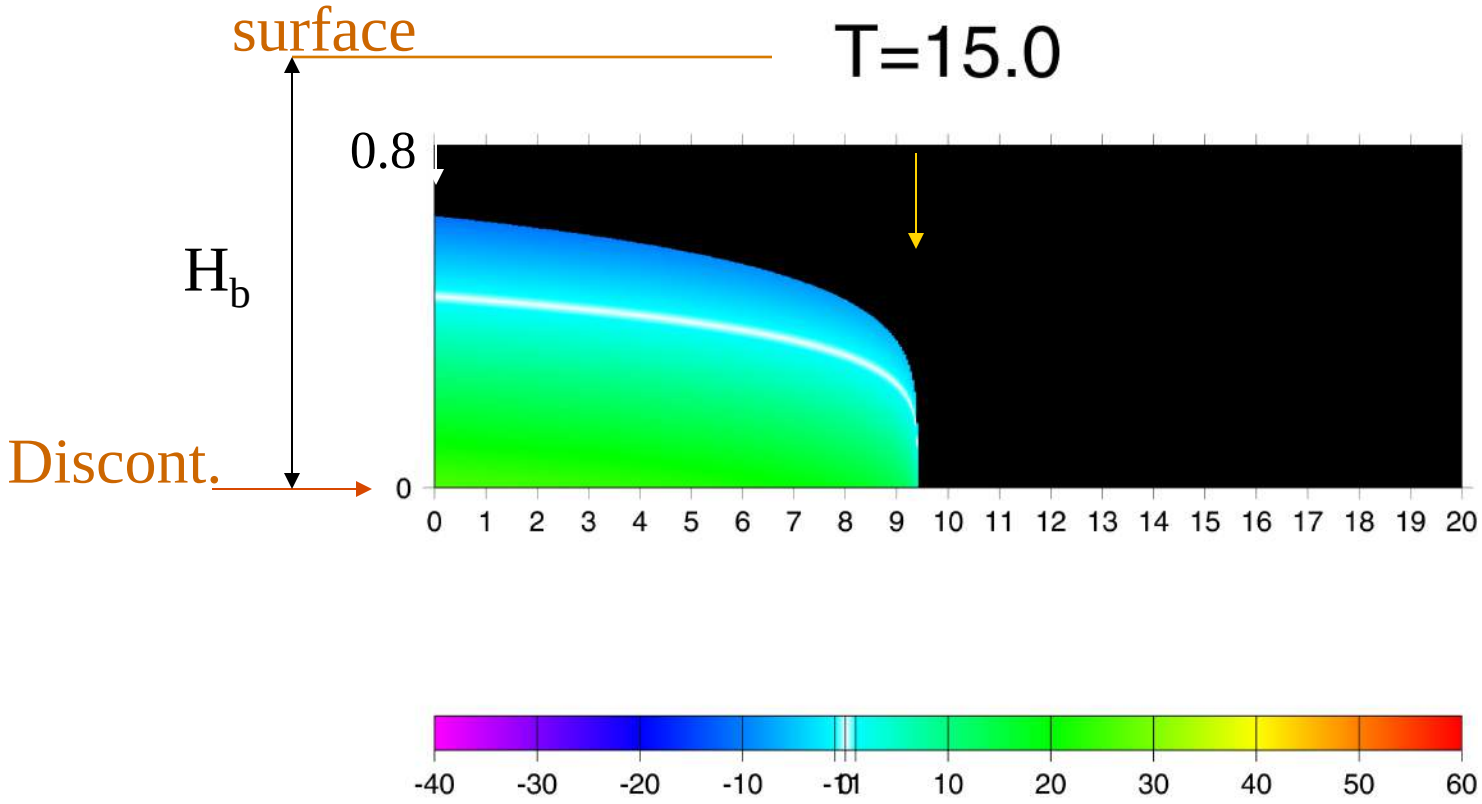
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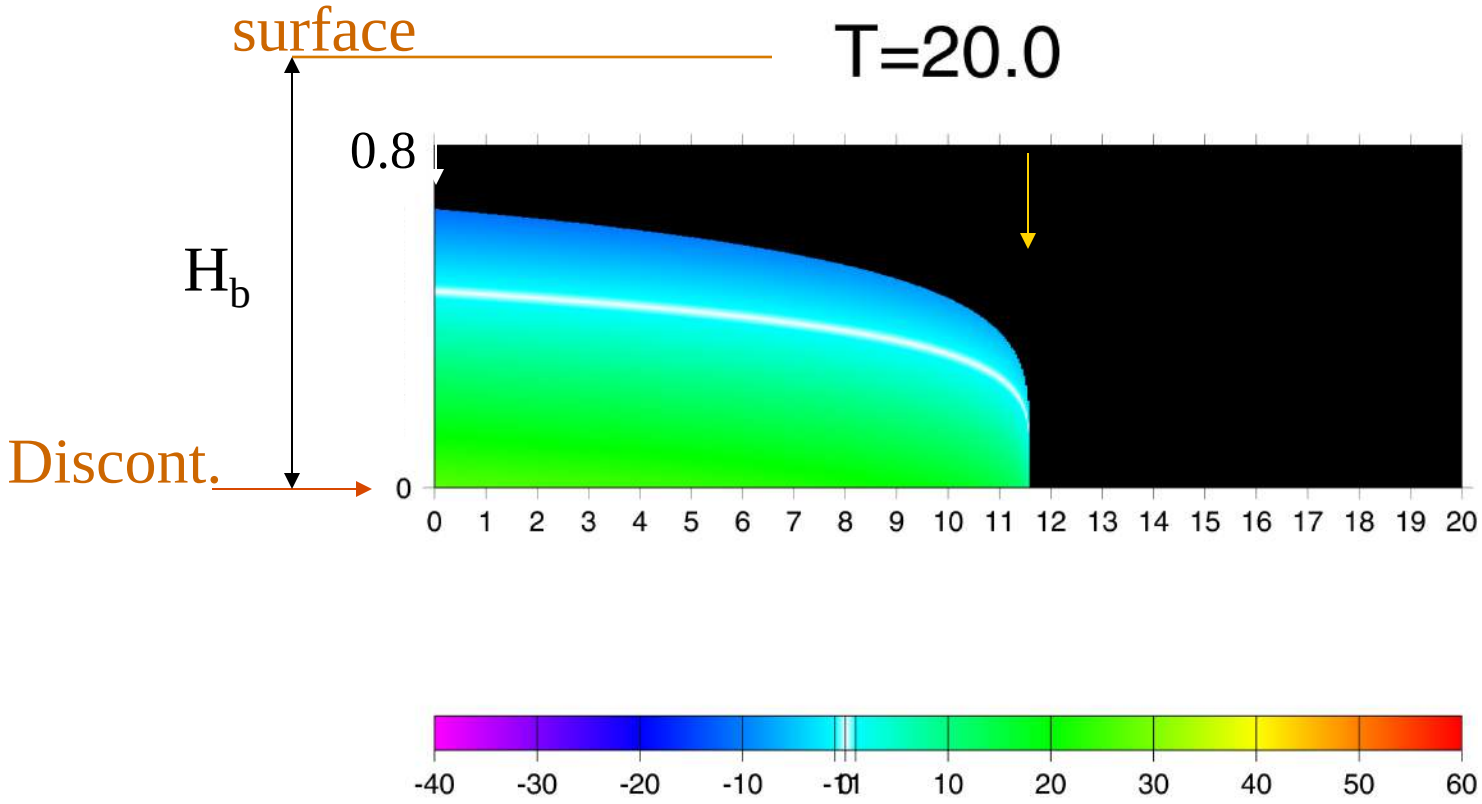
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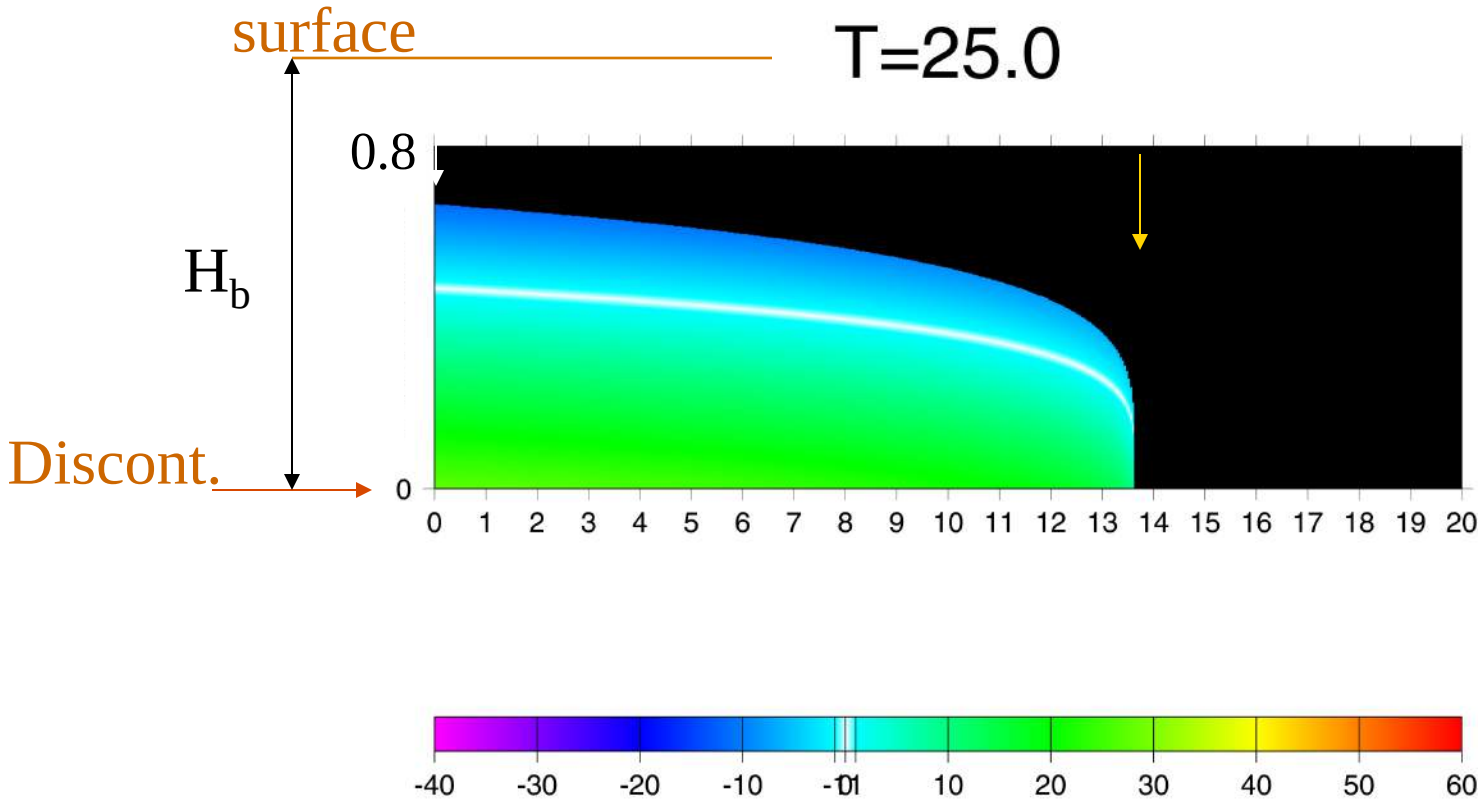
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Without an edifice :

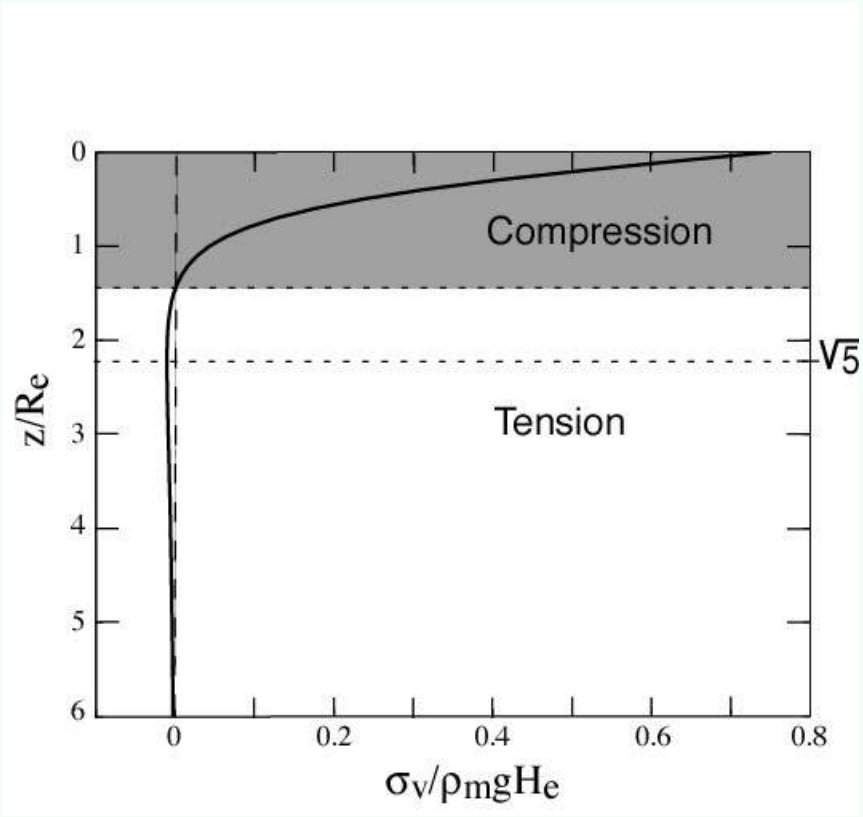
the dyke is always tallest
at the injection point

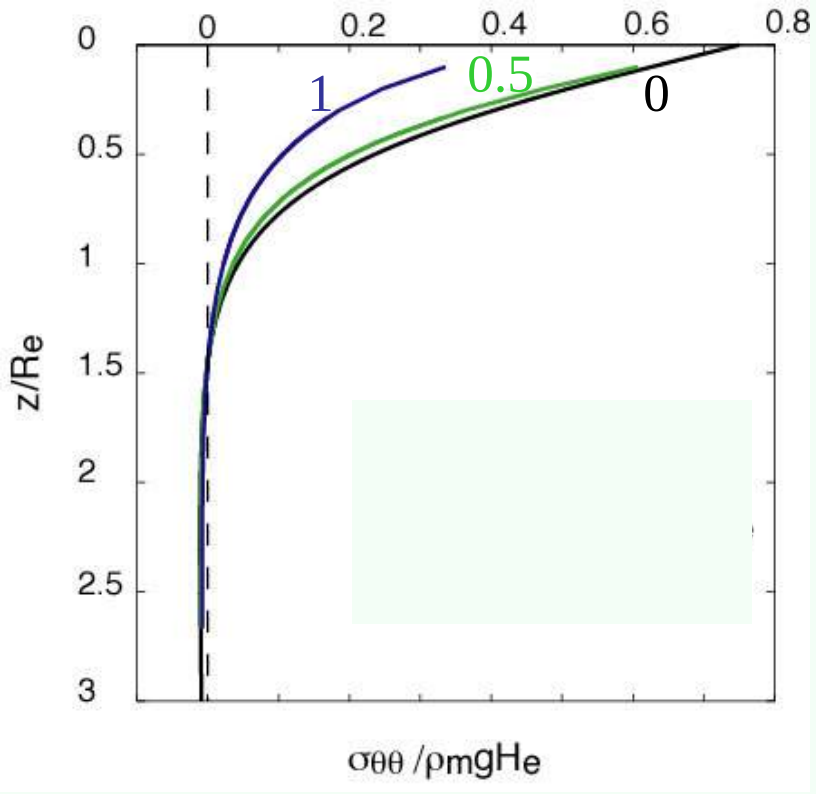
therefore:
eruption occurs in the focal area
(no distal vent or fissure).

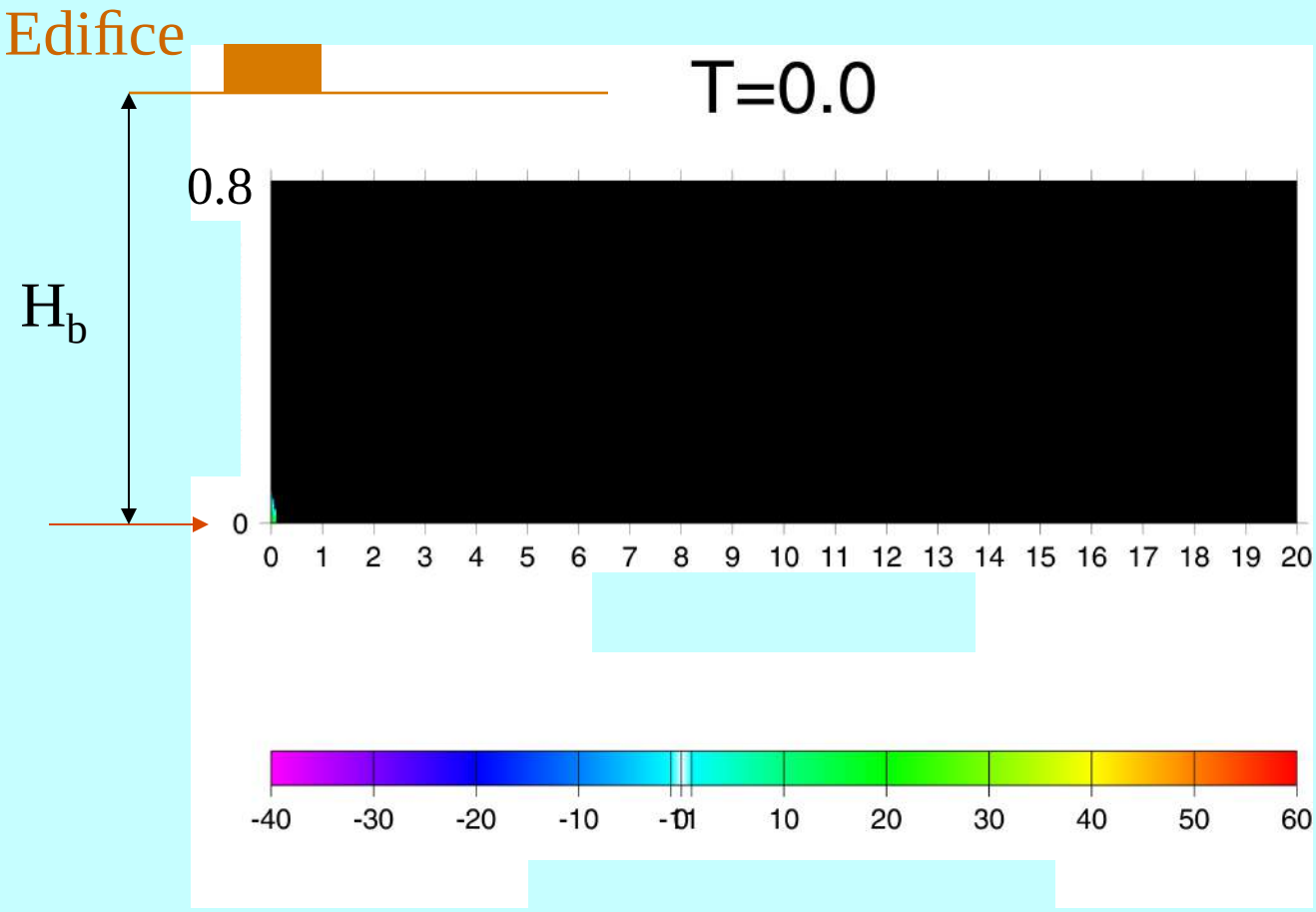
With an edifice

“Edifice” stress decreases with :

- depth
- Increasing radial distance



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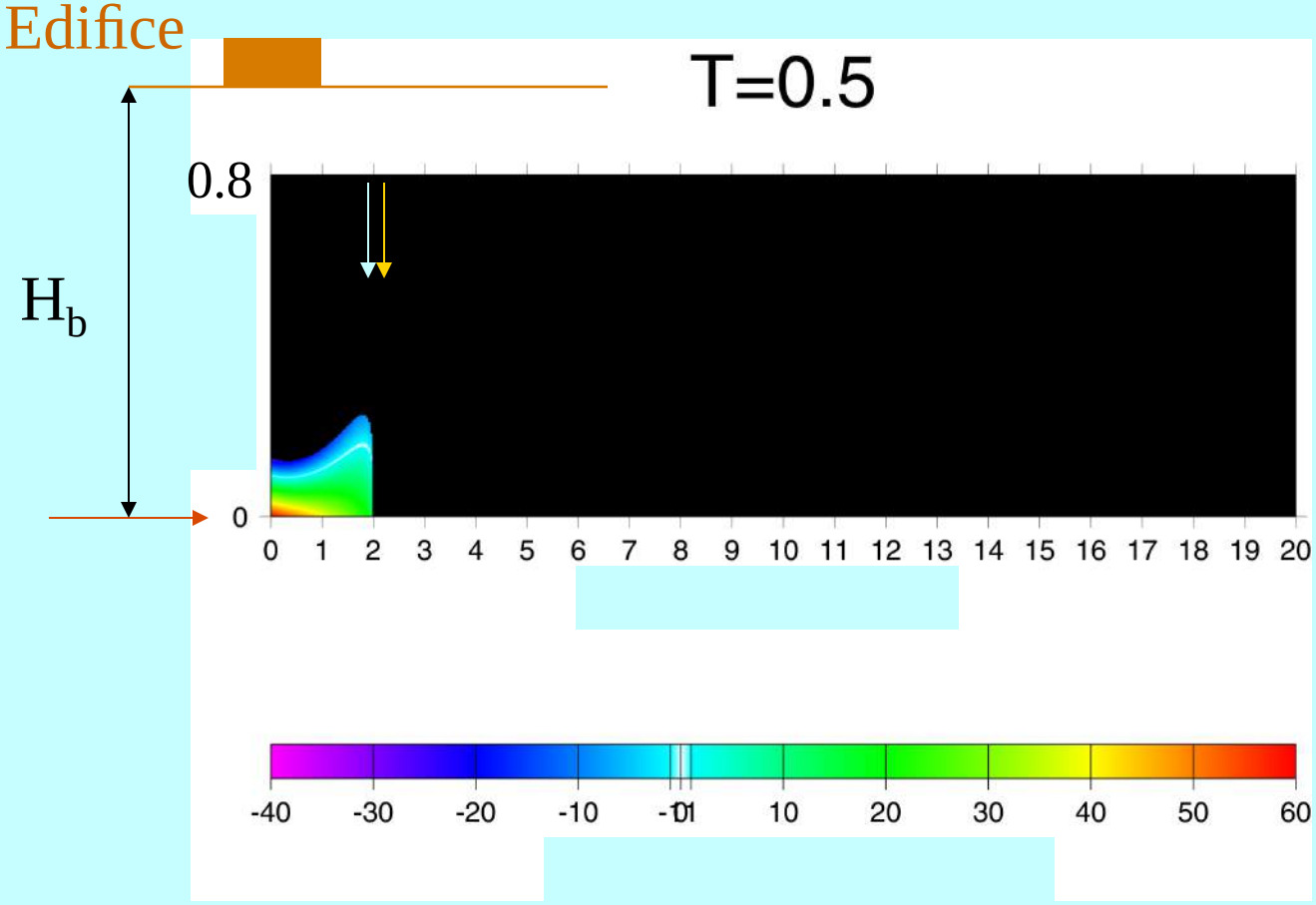
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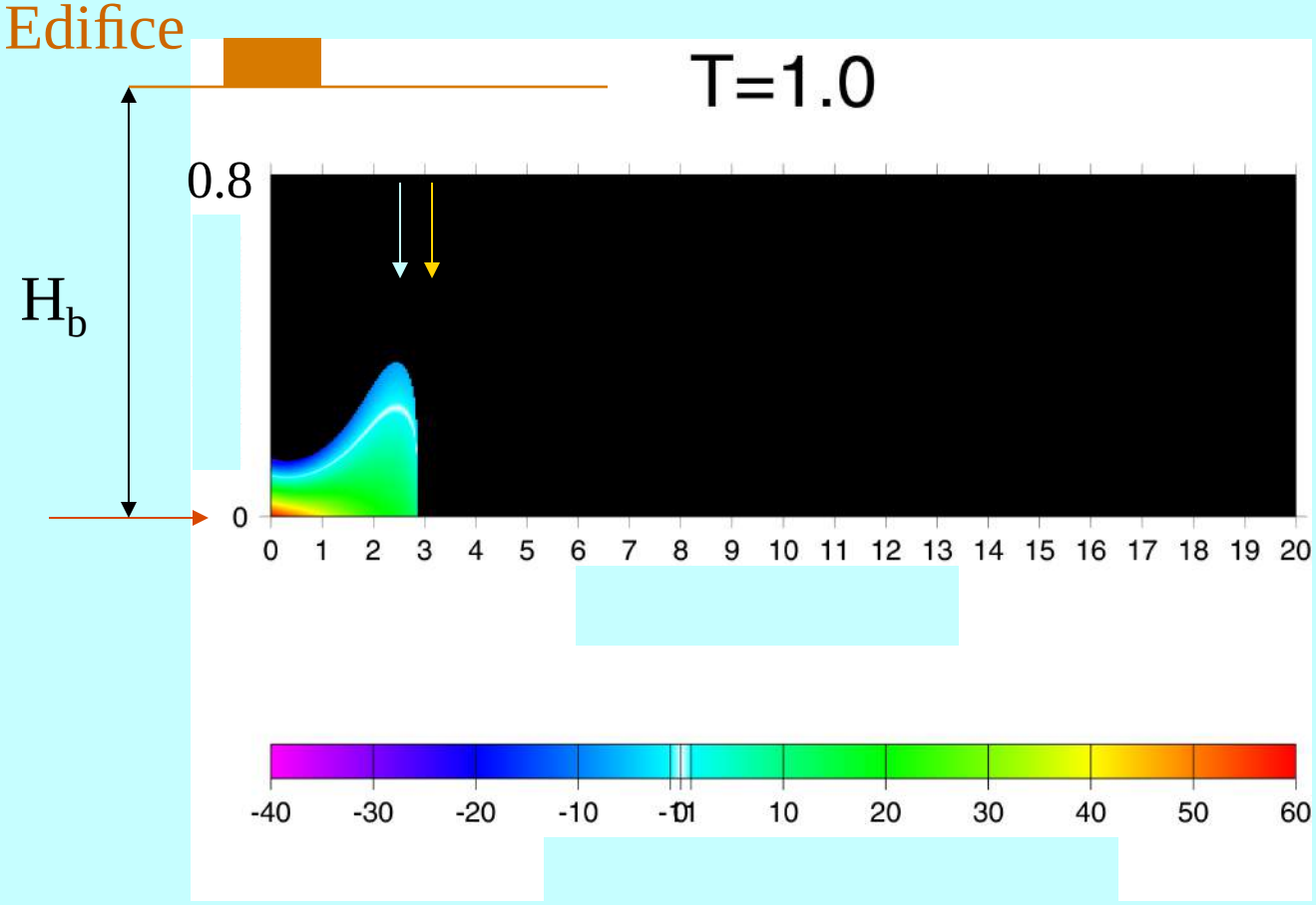
Edifice
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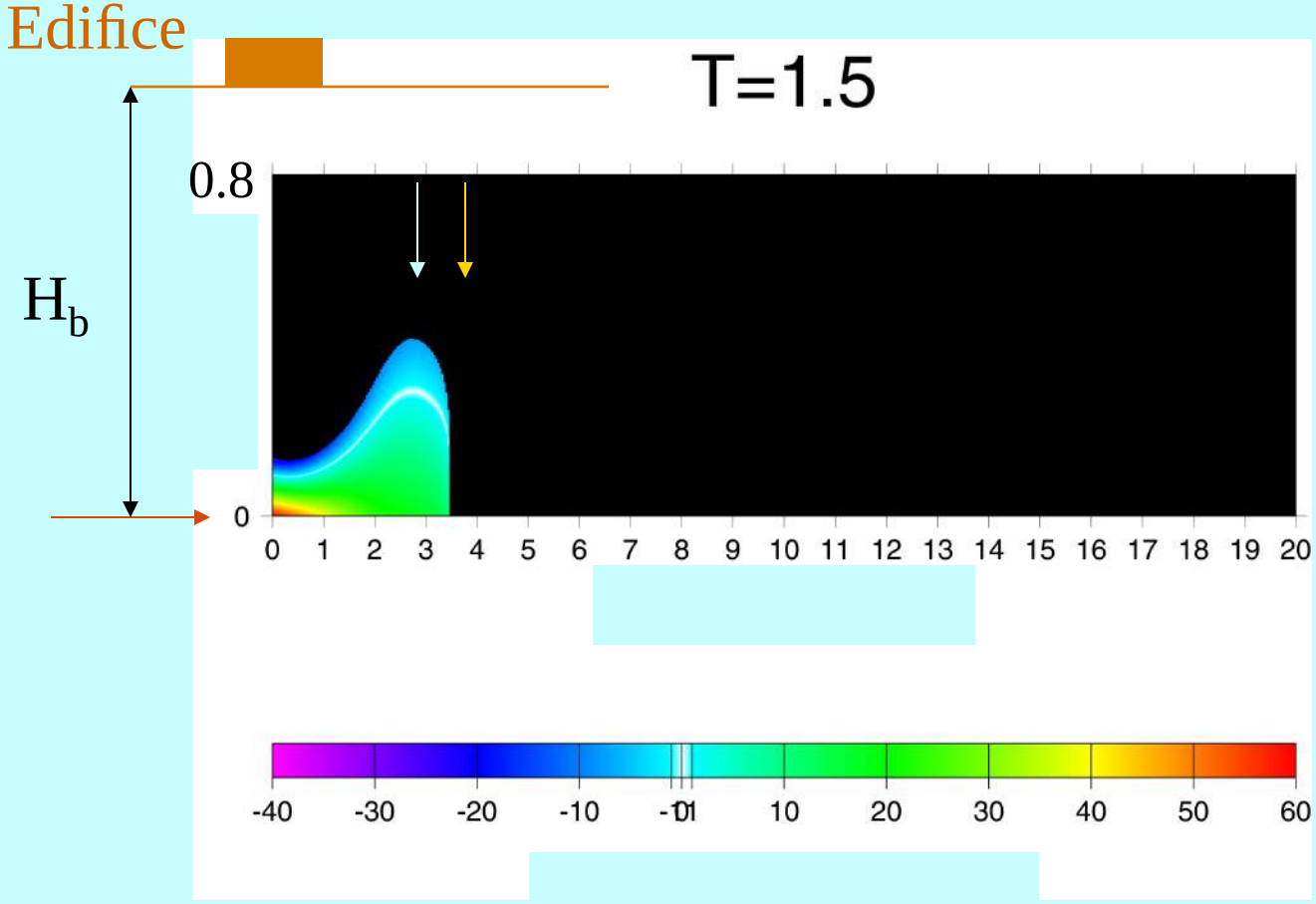
Edifice
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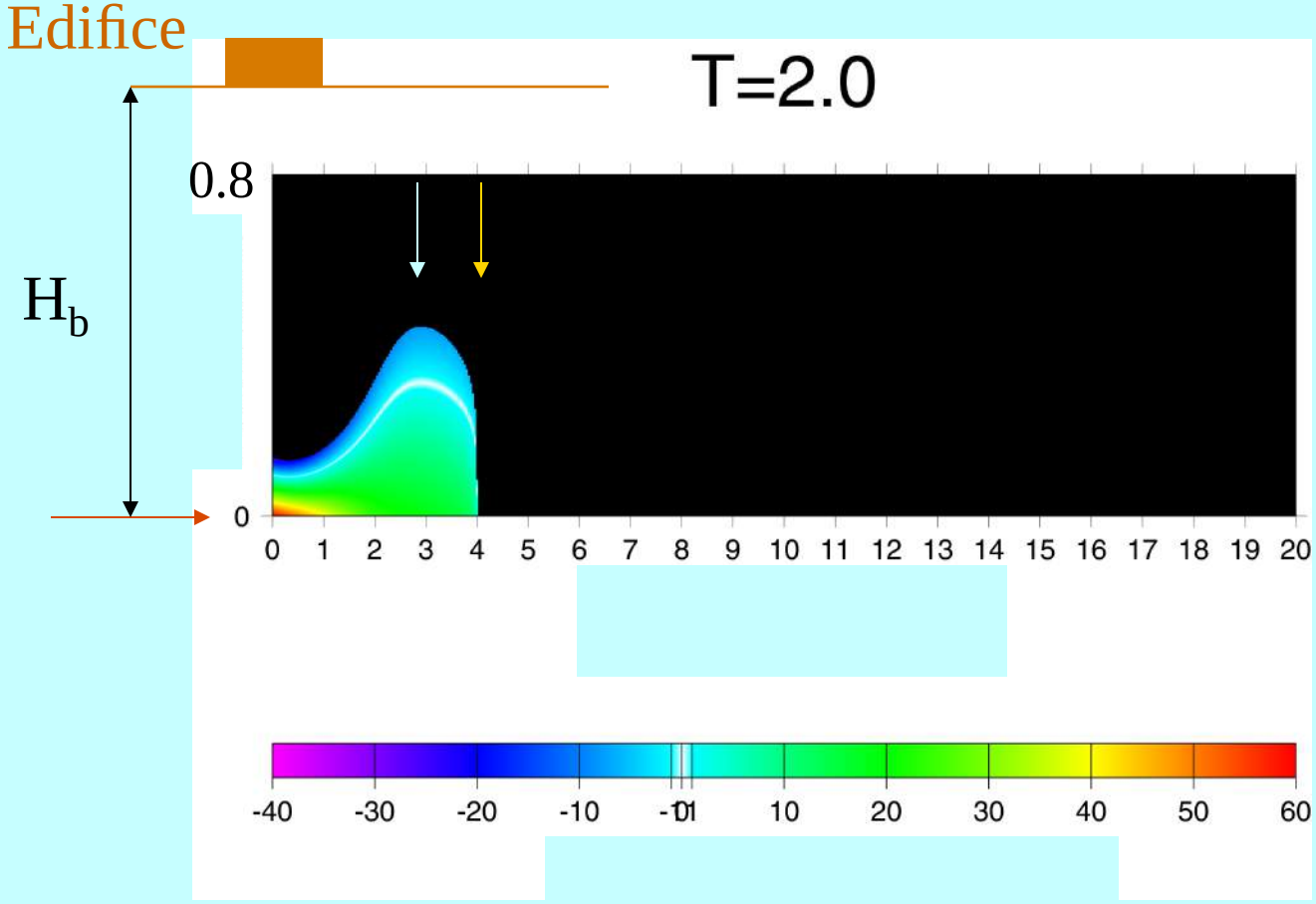
-40 -30 -20 -10 -1 1 10 20 30 40 50 60


Edifice
T=2.0
0.8
H_b
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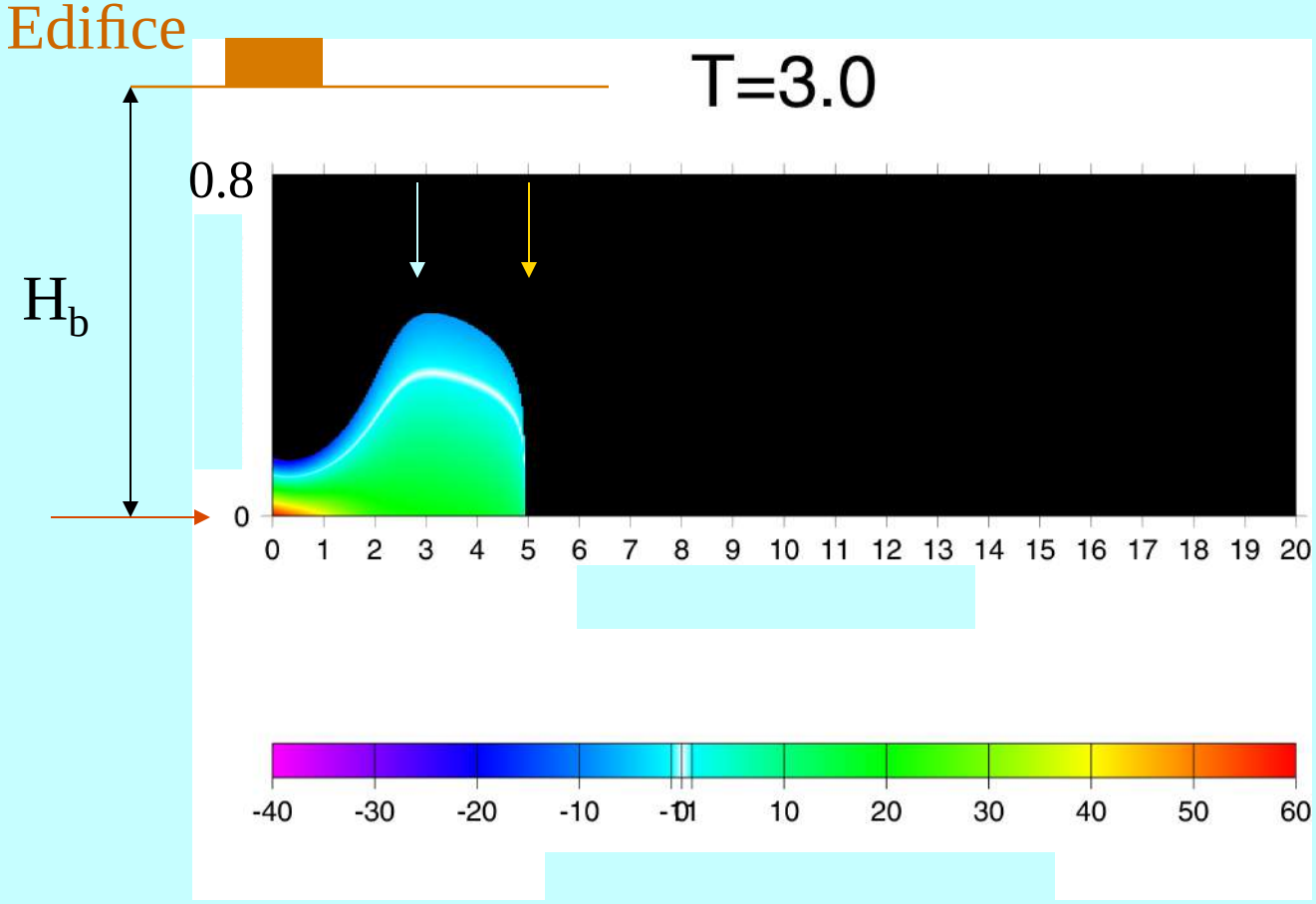
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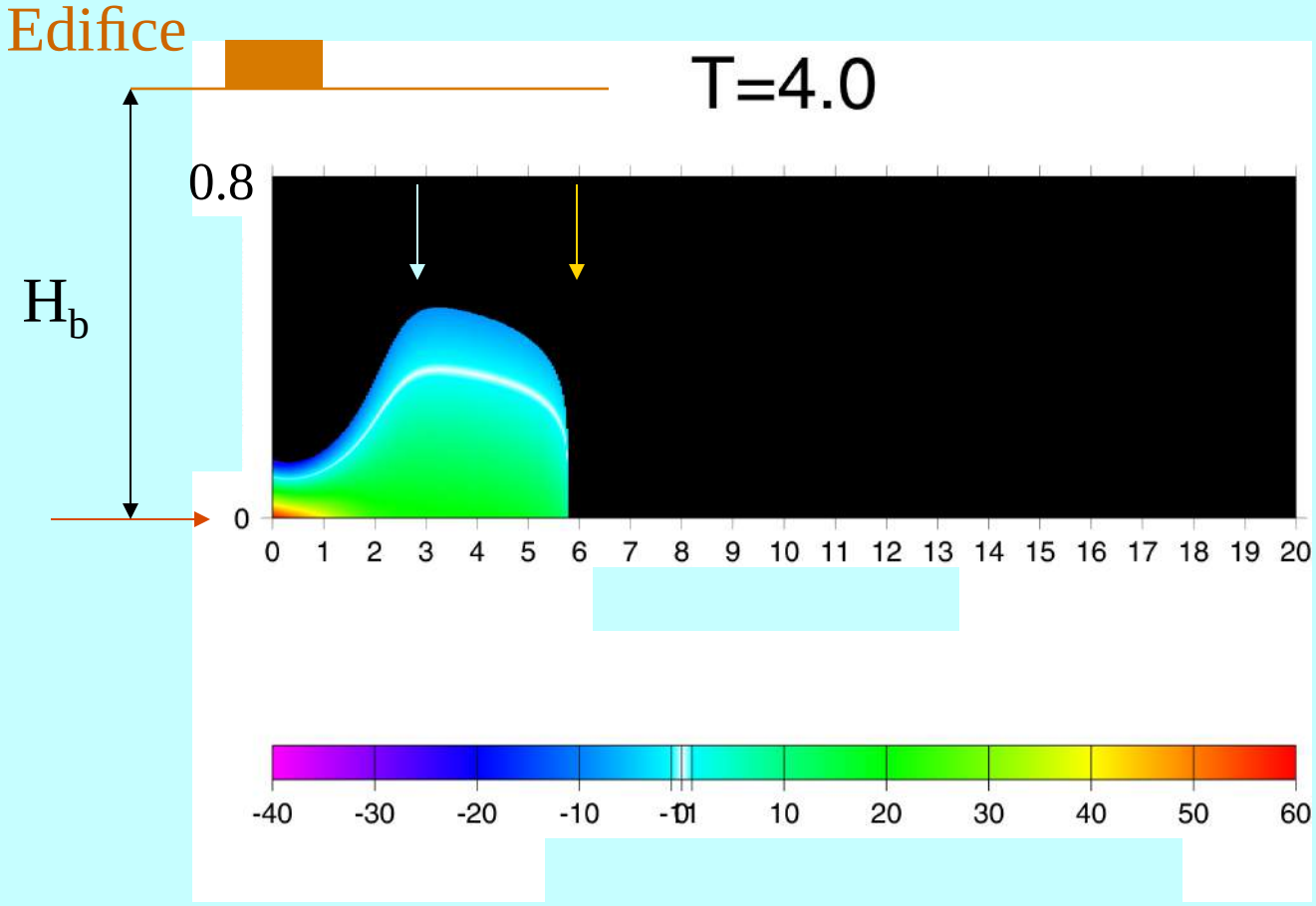
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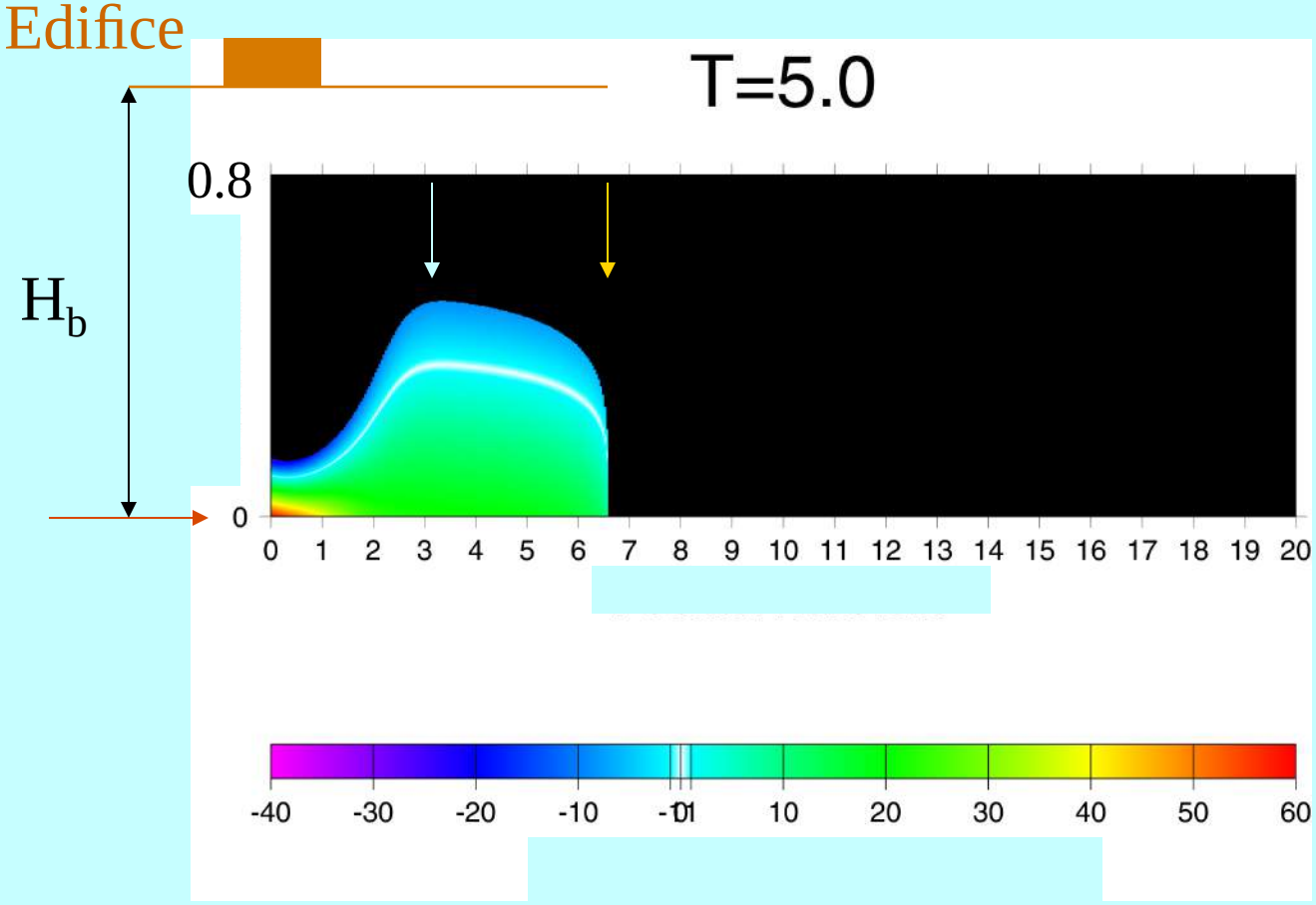
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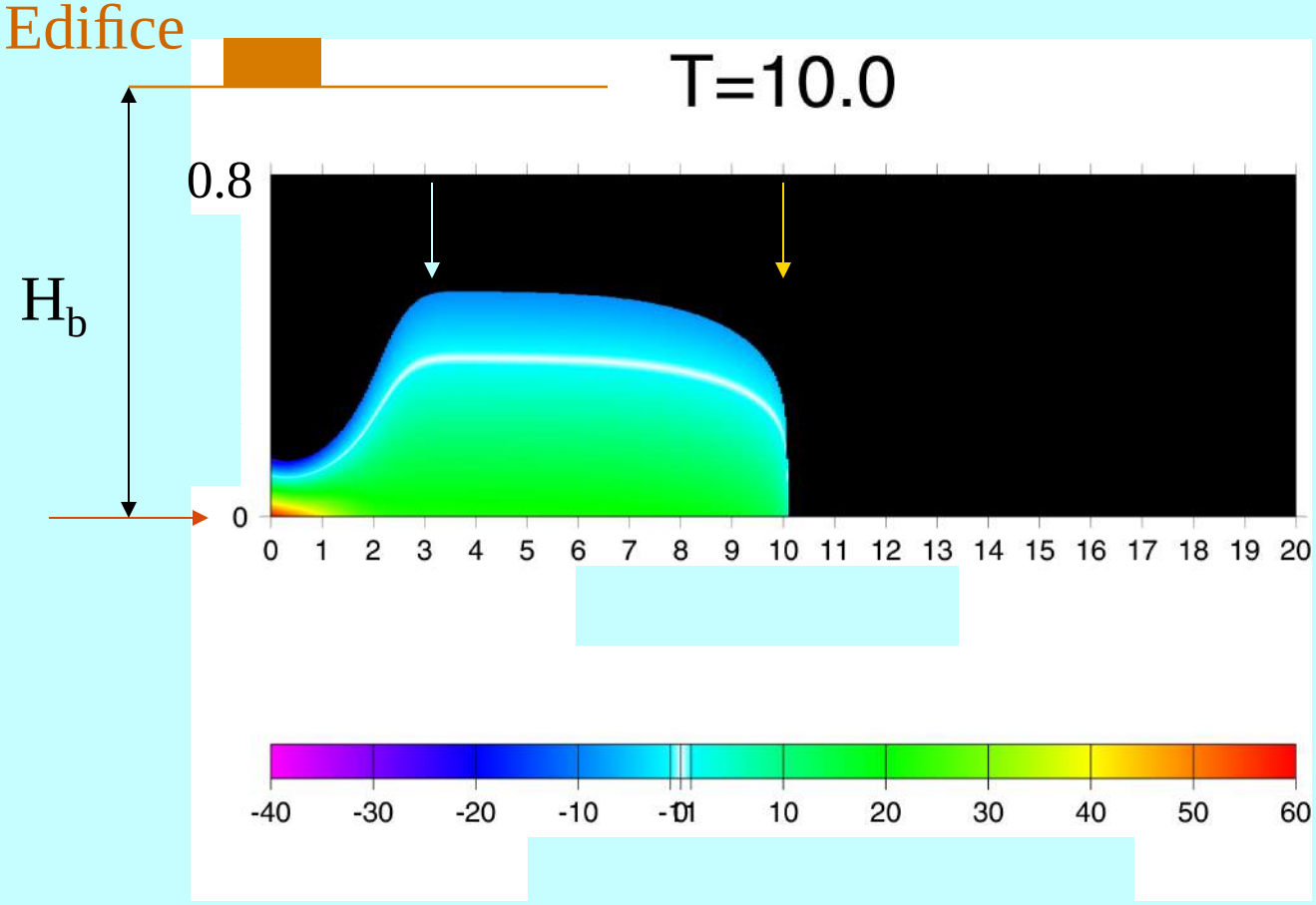
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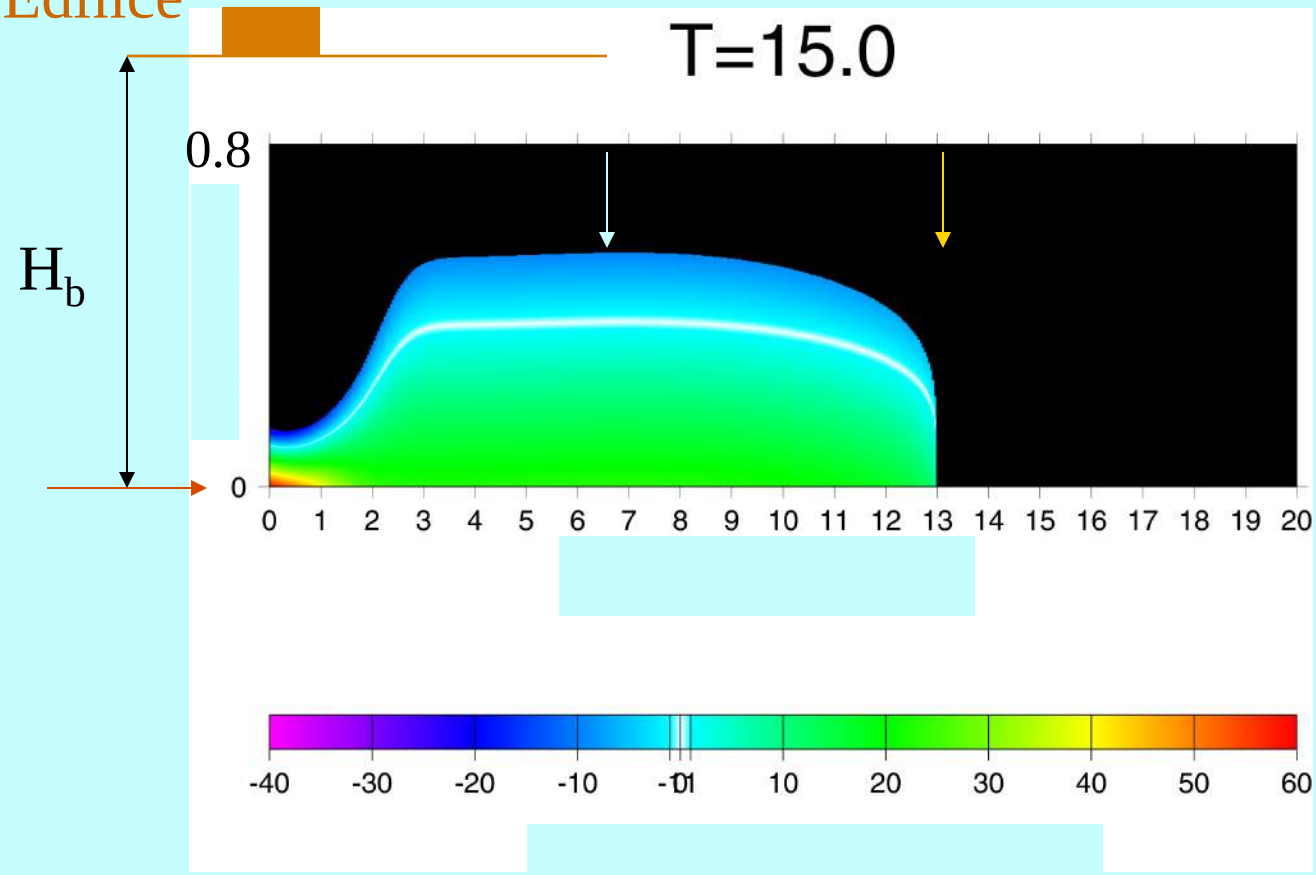
Edifice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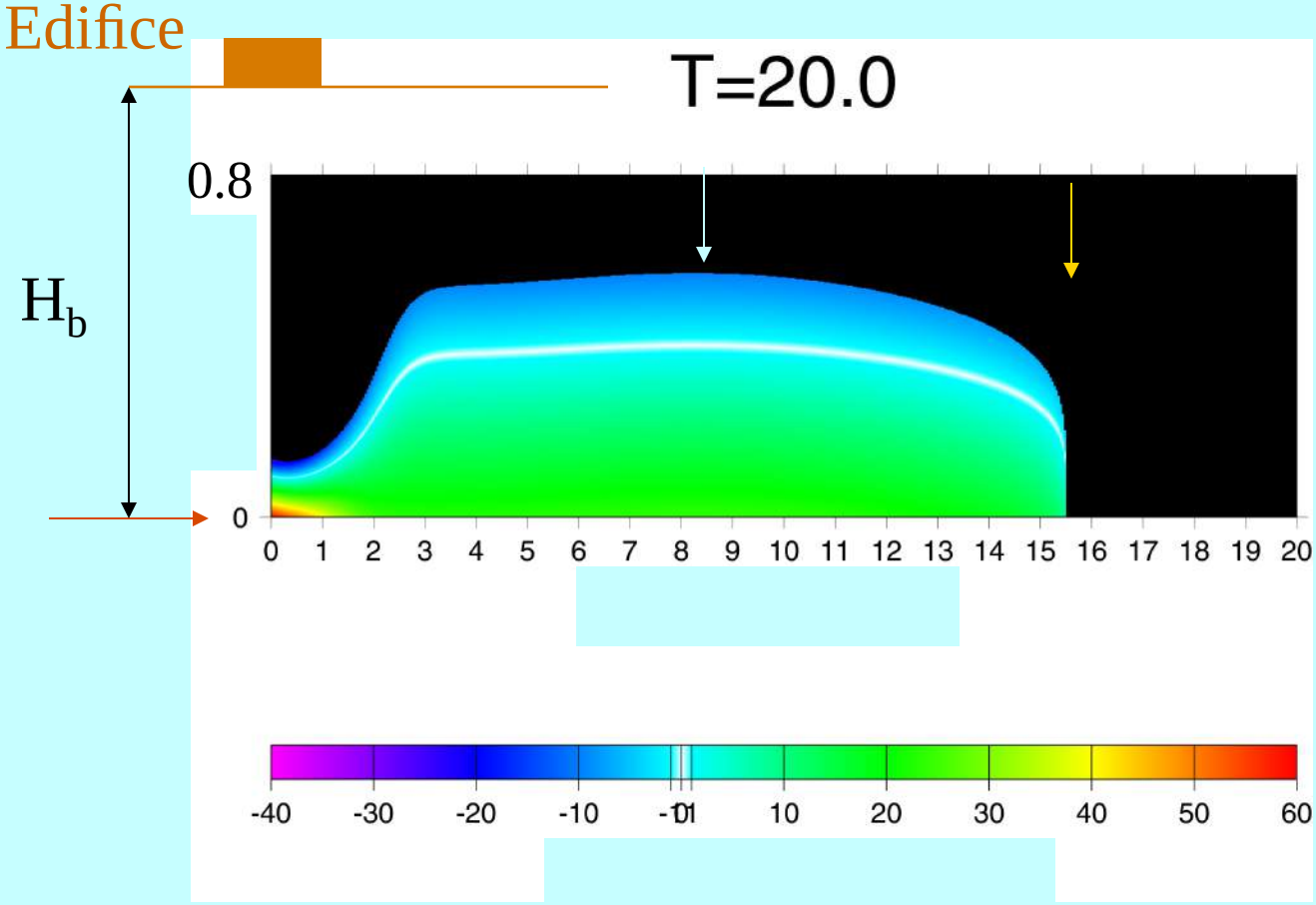
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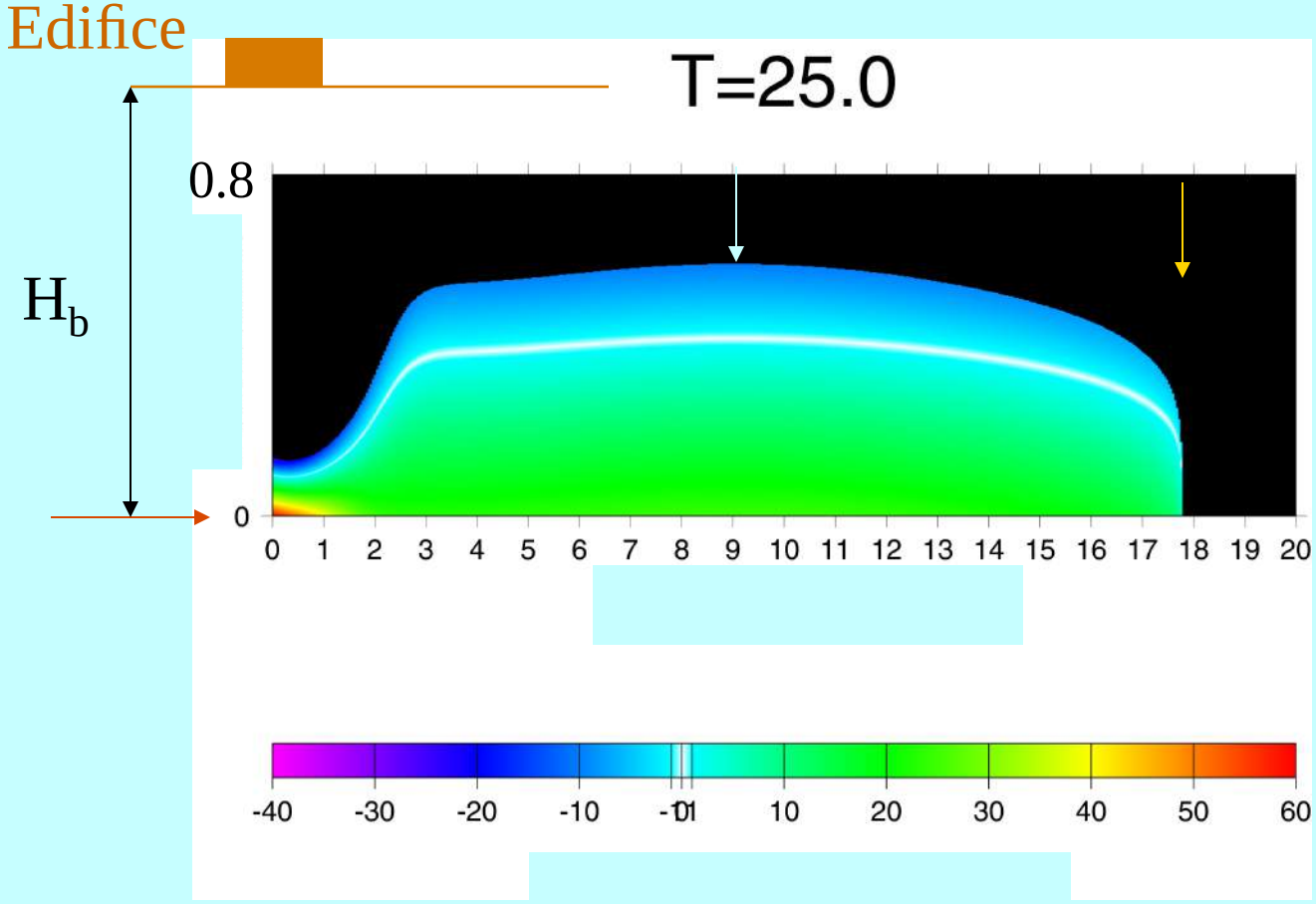
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With an edifice :

a horizontal dyke extends vertically
at some distance from the injection point
(away from the edifice load)

therefore:
eruption occurs
through a distal vent or fissure.

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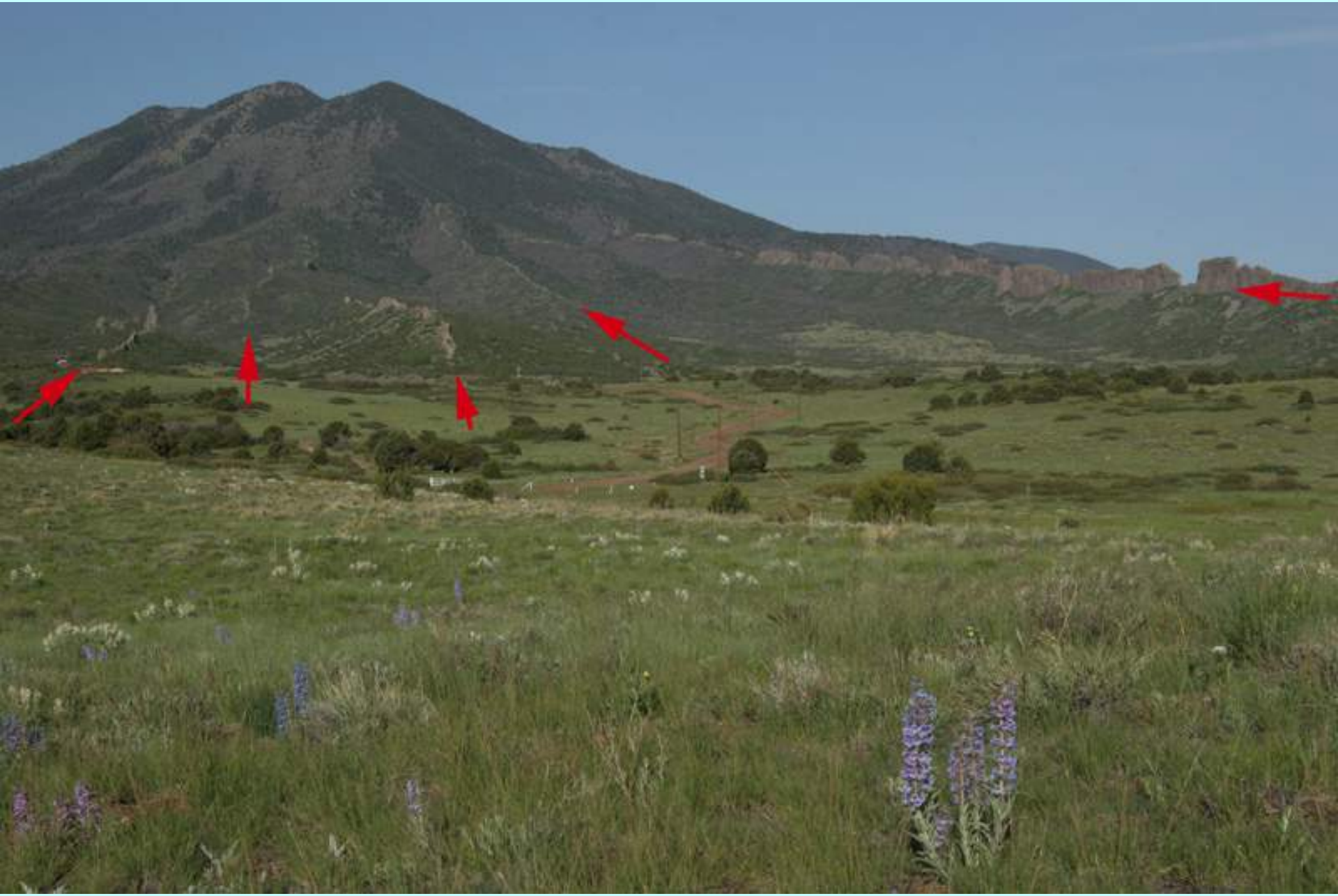
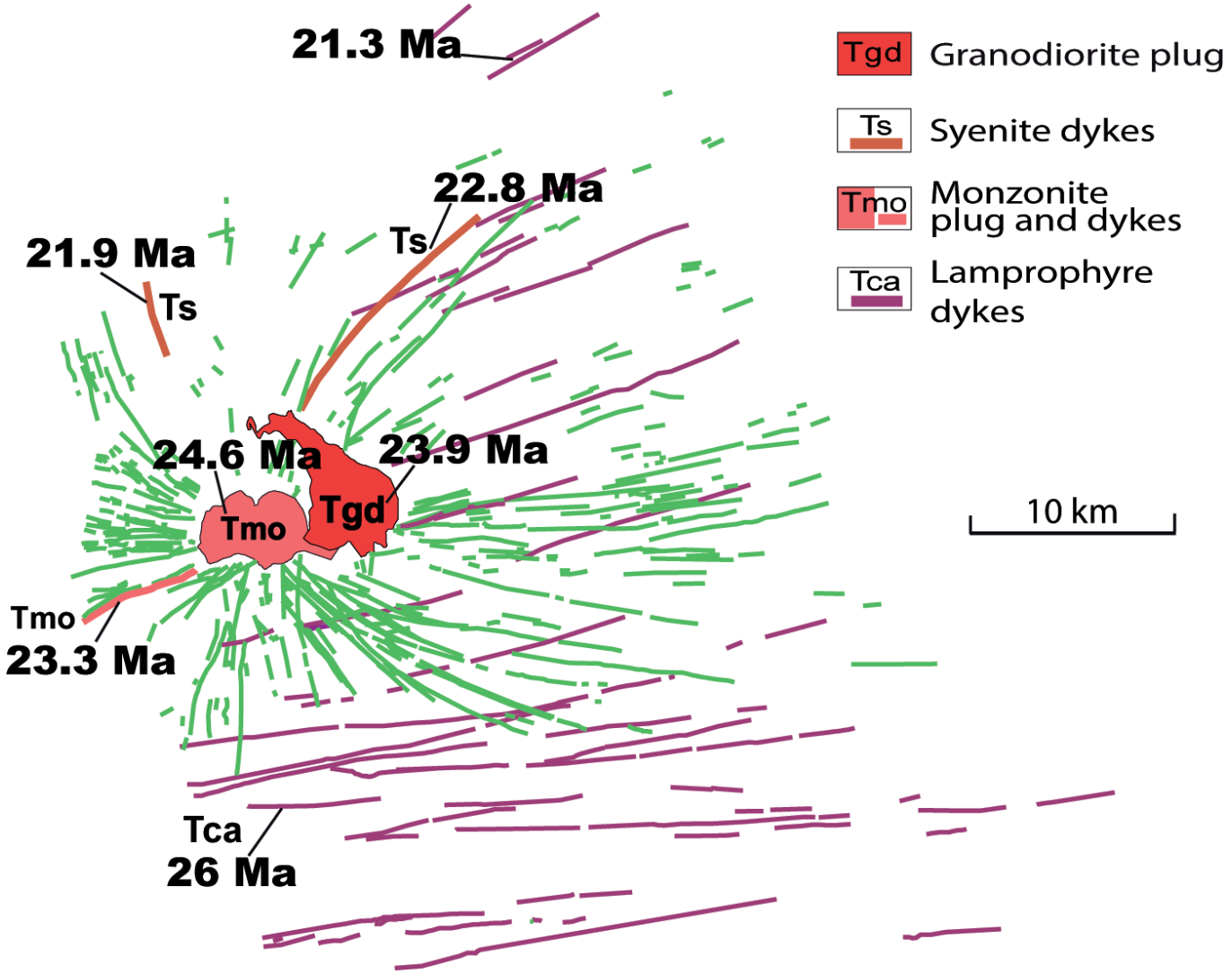
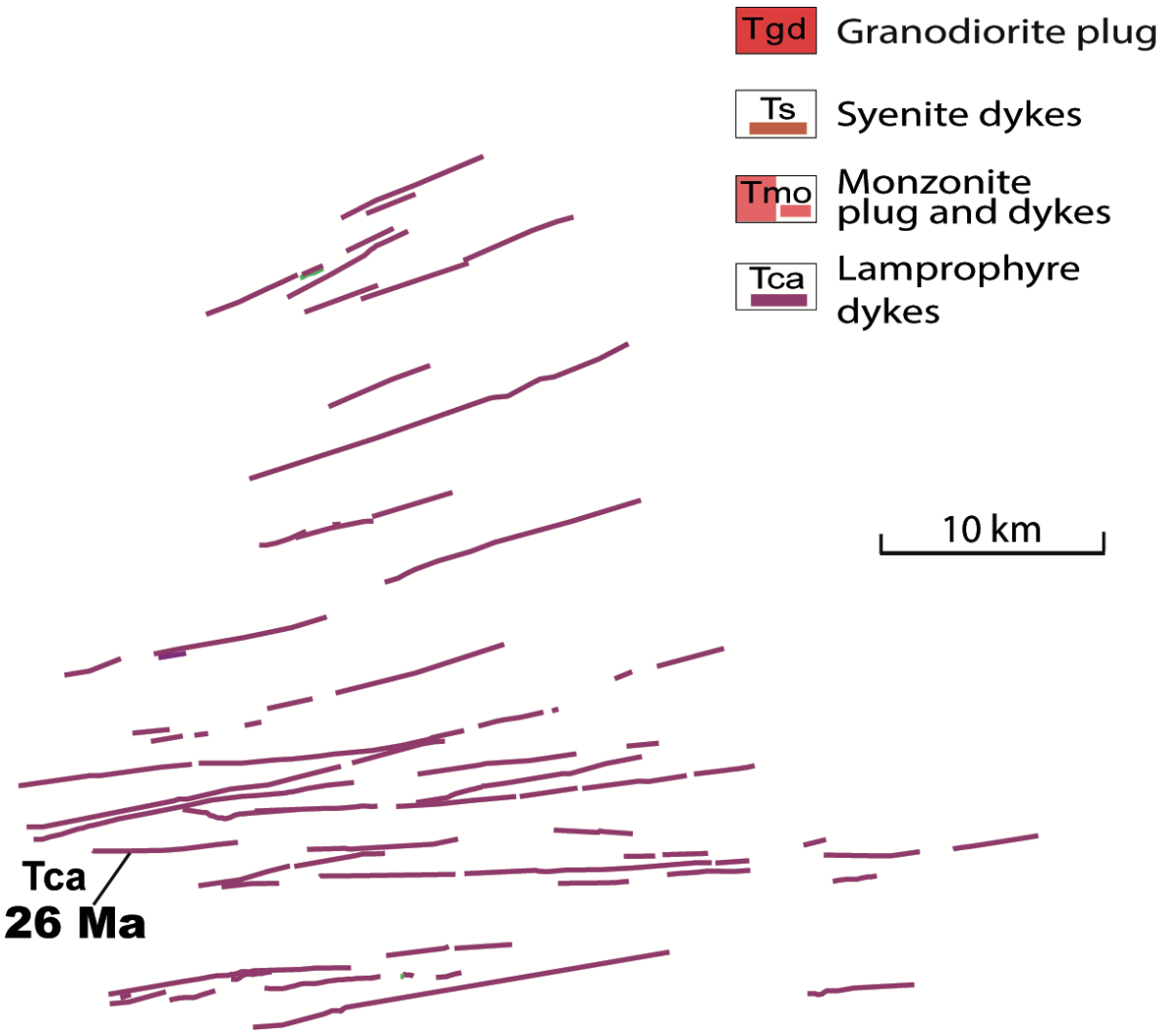
Location of eruptive site depends on magma density:
Primitive magmas (dense) = distal
Evolved magmas (buoyant) = closer to axis

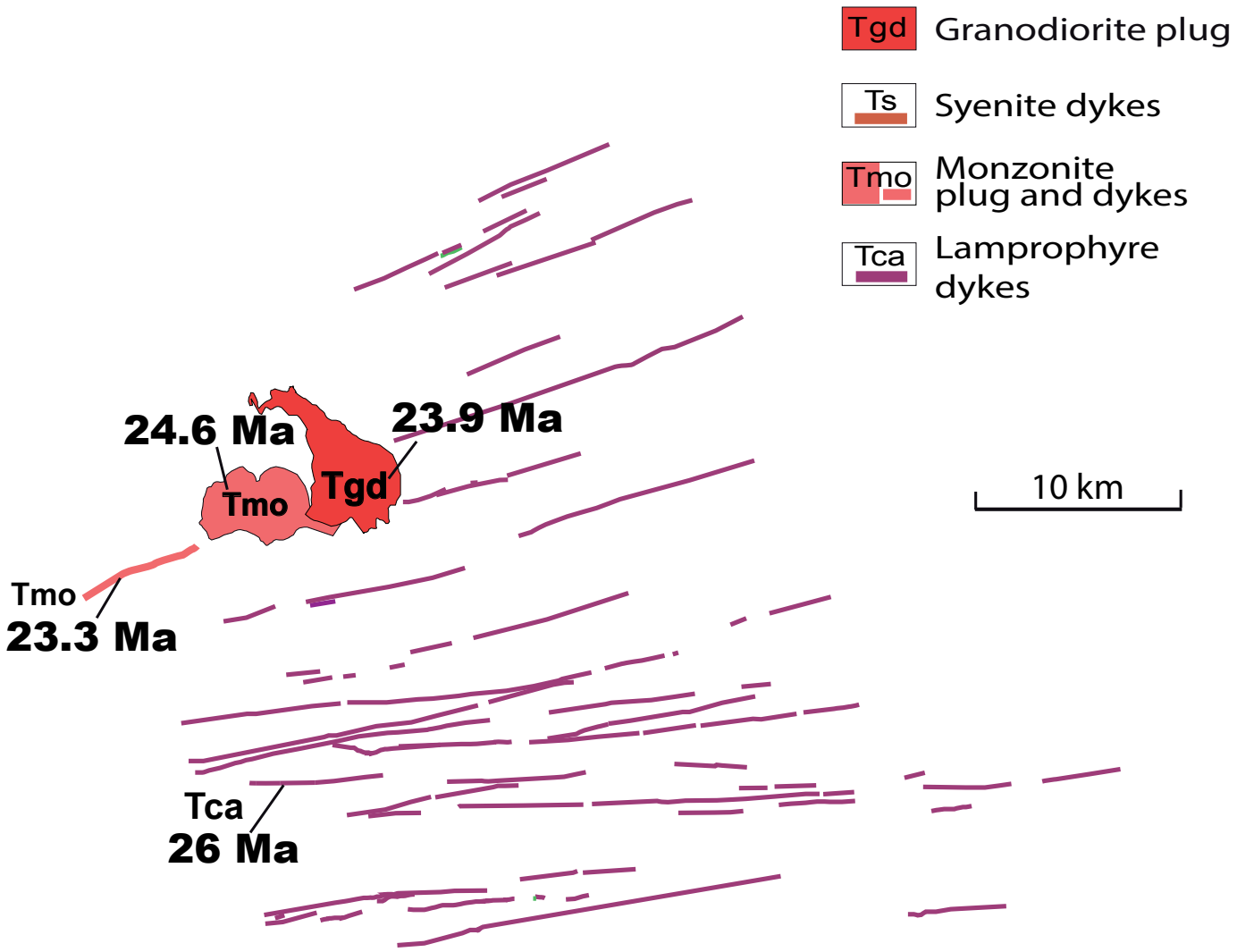
Dyke swarm, Spanish Peaks, Colorado



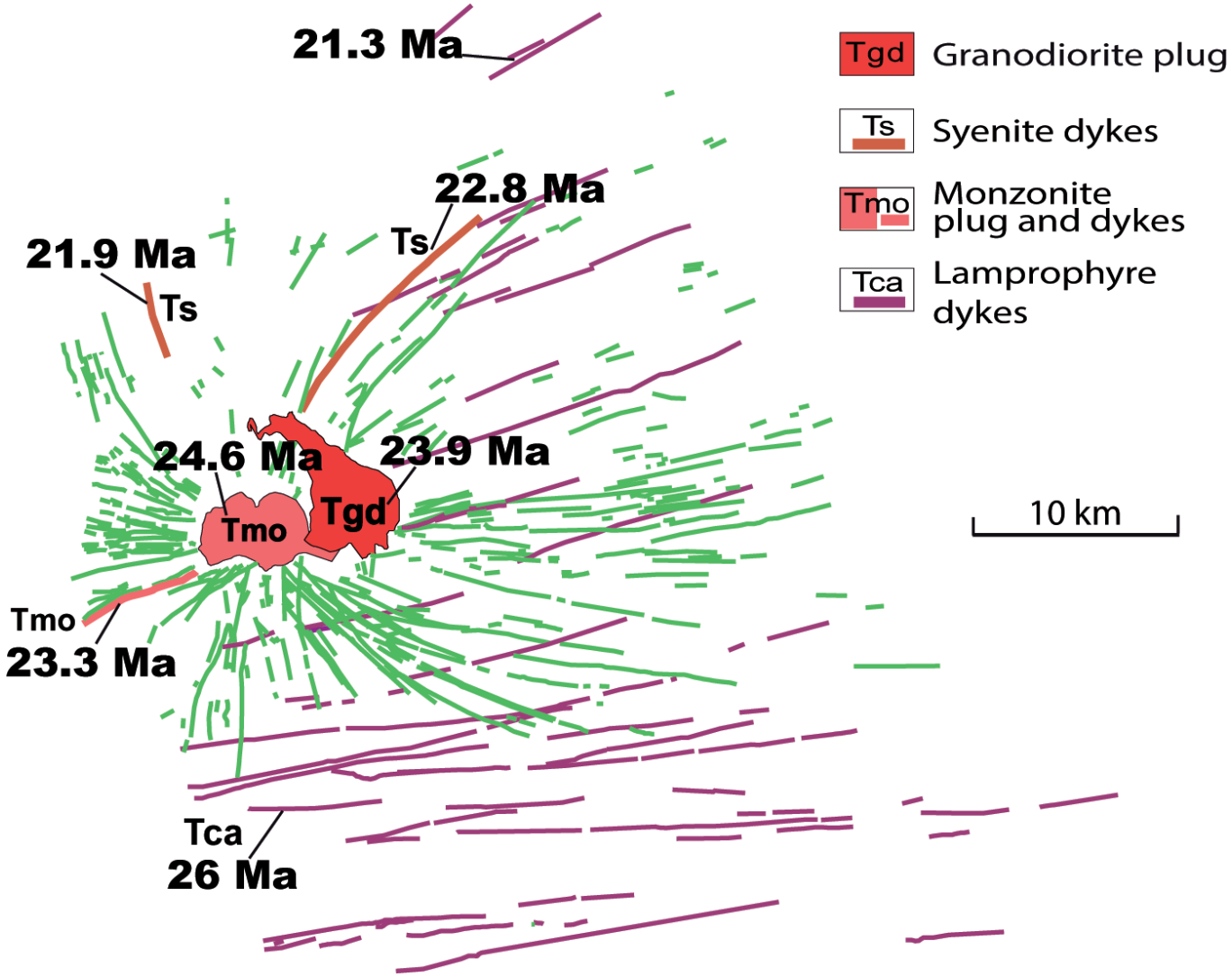

21.3 Ma
22.8 Ma
Ts
21.9 Ma
Ts
24.6 Ma
23.9 Ma
Tmo
Tgd
Tmo
23.3 Ma
Tca
26 Ma
Tgd
Granodiorite plug
Ts
Syenite dykes
Tmo
Monzonite plug and dykes
Tca
Lamprophyre dykes
10 km



Phase 1 : no edifice, primitive magma

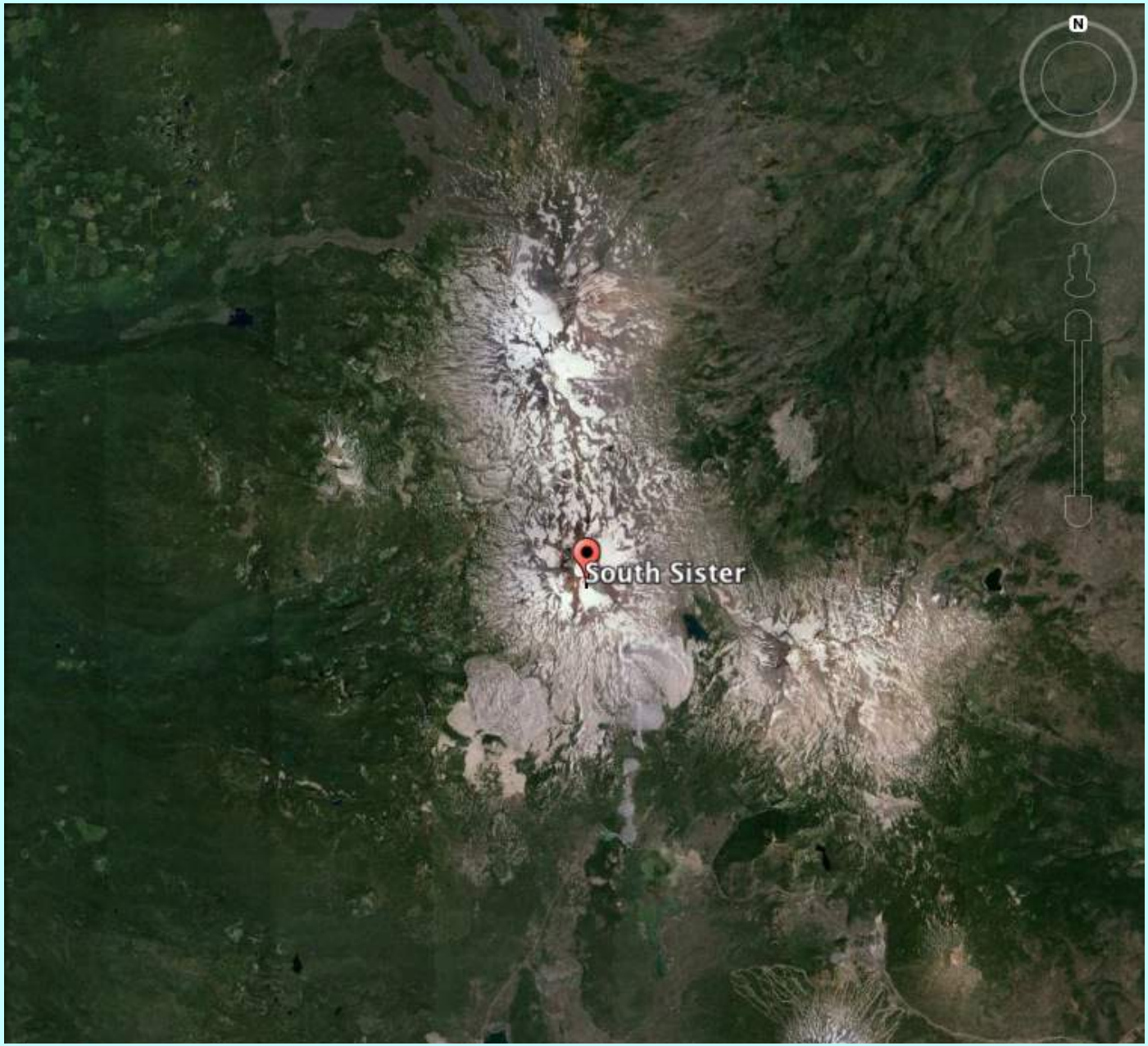


Phase 2 : edifice builds up, generation of evolved magmas



Phase 3 : edifice, primitive magma diverted sideways

Three Sisters, Oregon




SOUTH
NORTH
South Sister
Middle Sister
"Black Hump"
North Sister
Black Crater
Broken Top
lava flows
Green Lakes
Newberry flow
USGS

A volcanic edifice acts as a « compositional » filter :

- prevents dense (primitive) magma from erupting in focal area,
- favors storage at shallow level beneath an edifice,

- and induces lateral dyke injection.

CONCLUSION

The surface edifice is part and parcel of the magmatic/volcanic system.

Ship Rock, Arizona