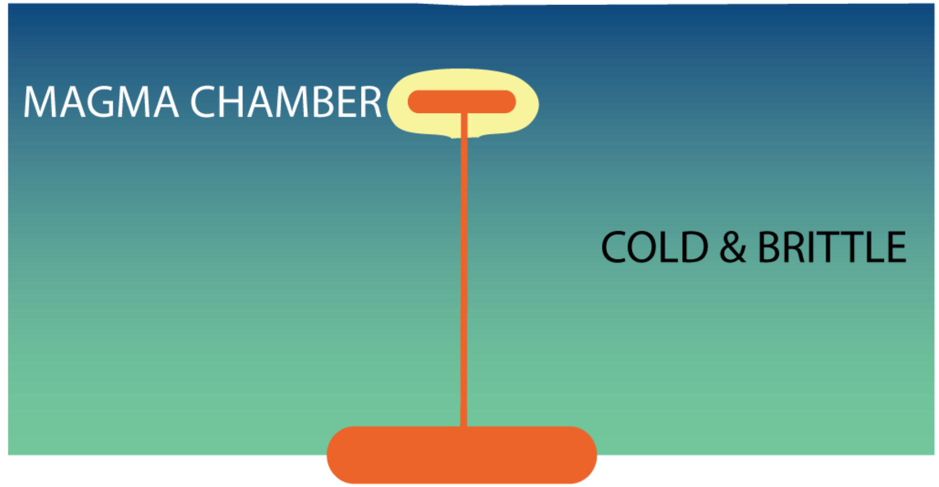
Controls on the Frequency of Dike Episodes At Spreading Centers

Dabbahu,Ethiopia

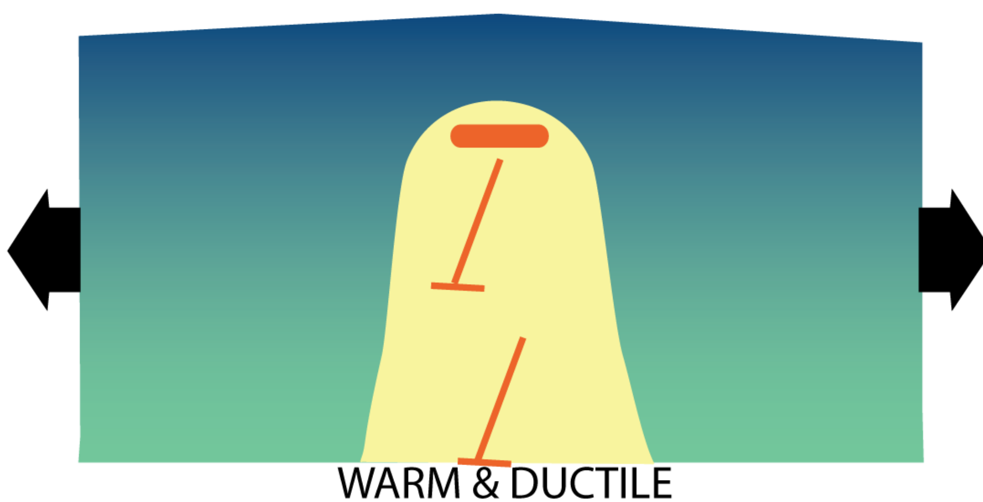
Krafla, Iceland

EPR, 9° N

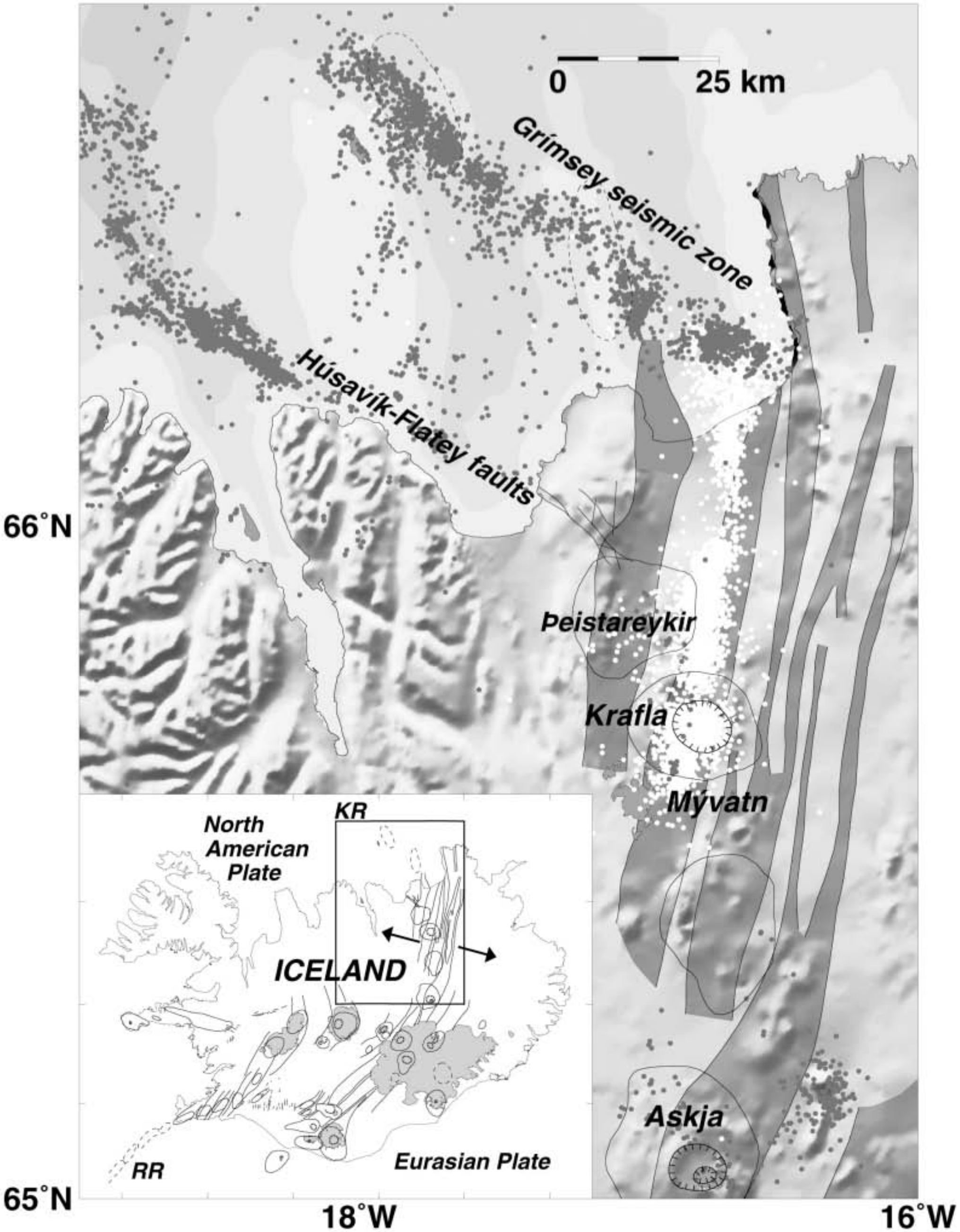
‘Bottom Up’
driving of dikes requires magma overpressure



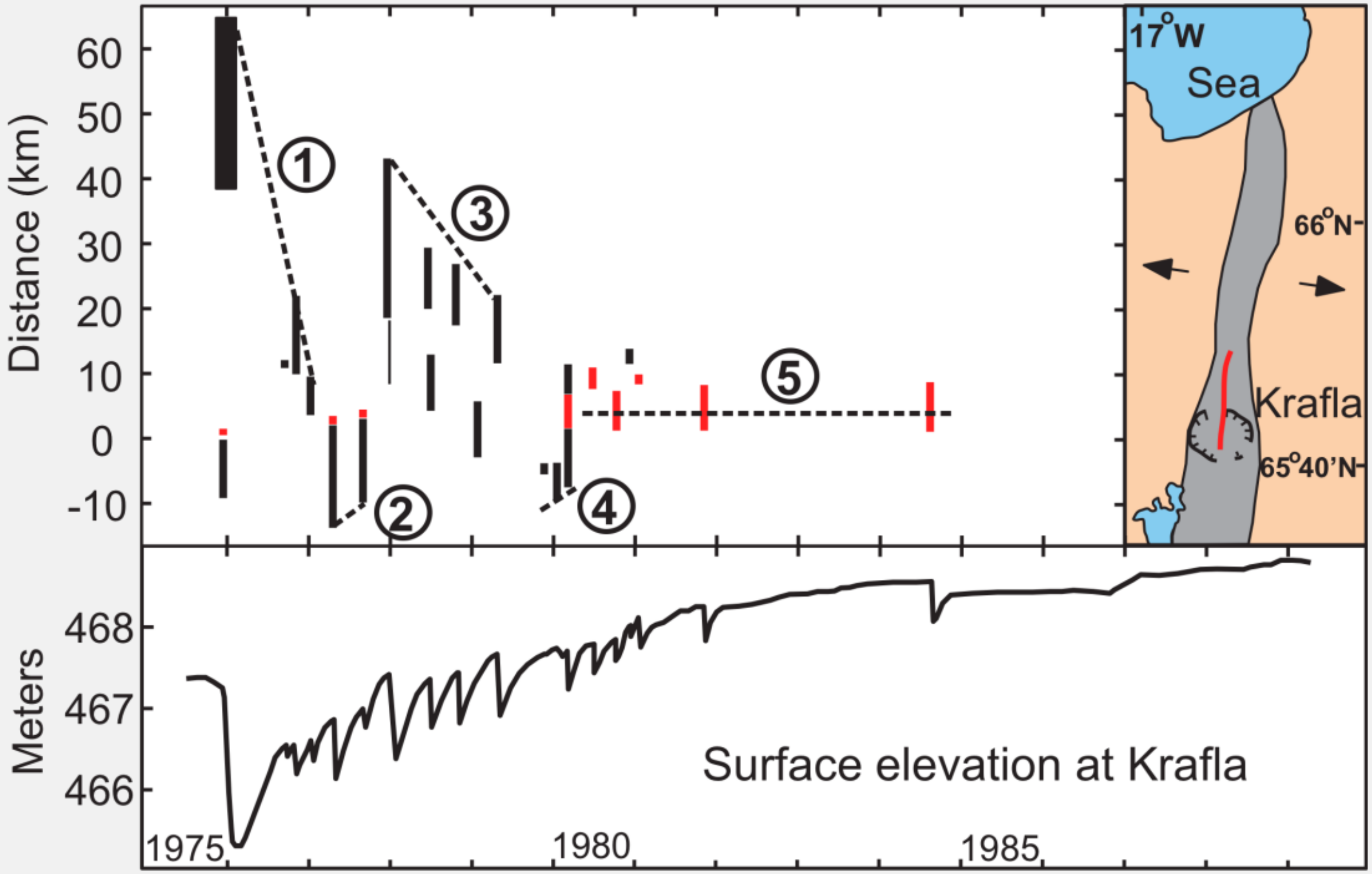
‘Top Down’
driving of dikes tectonic stress



Krafla, Iceland
Earthquake and Fissure Locations
(by Bryndis Brandsdottir)

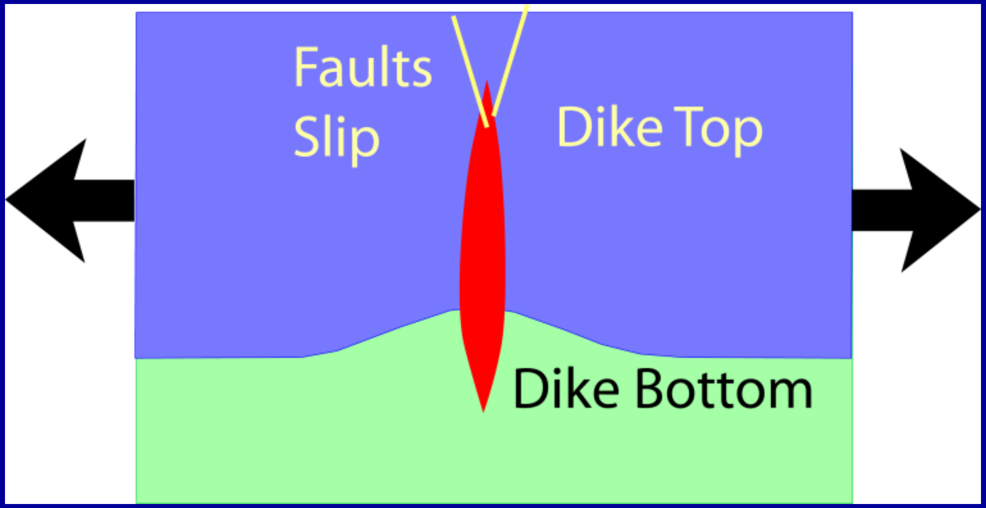


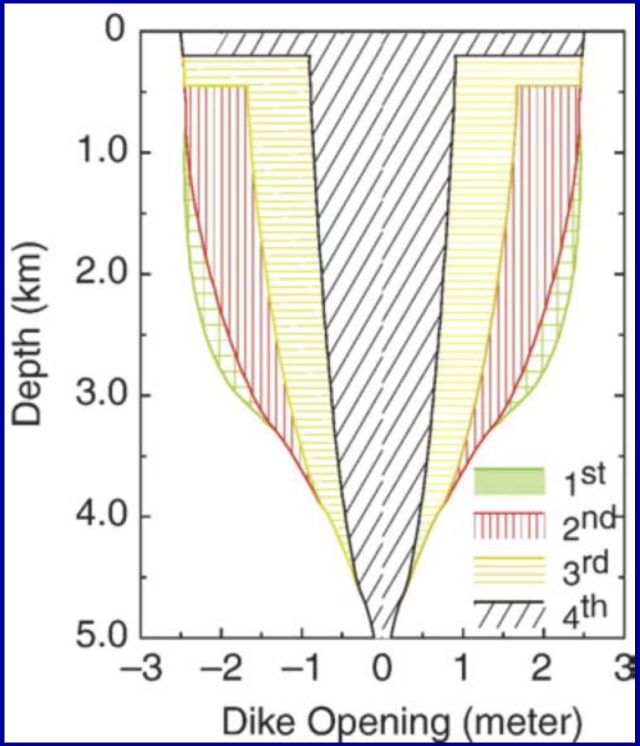
1975-1984 Krafla Rifting Episode



(Adapted from Einarsson, 1991)

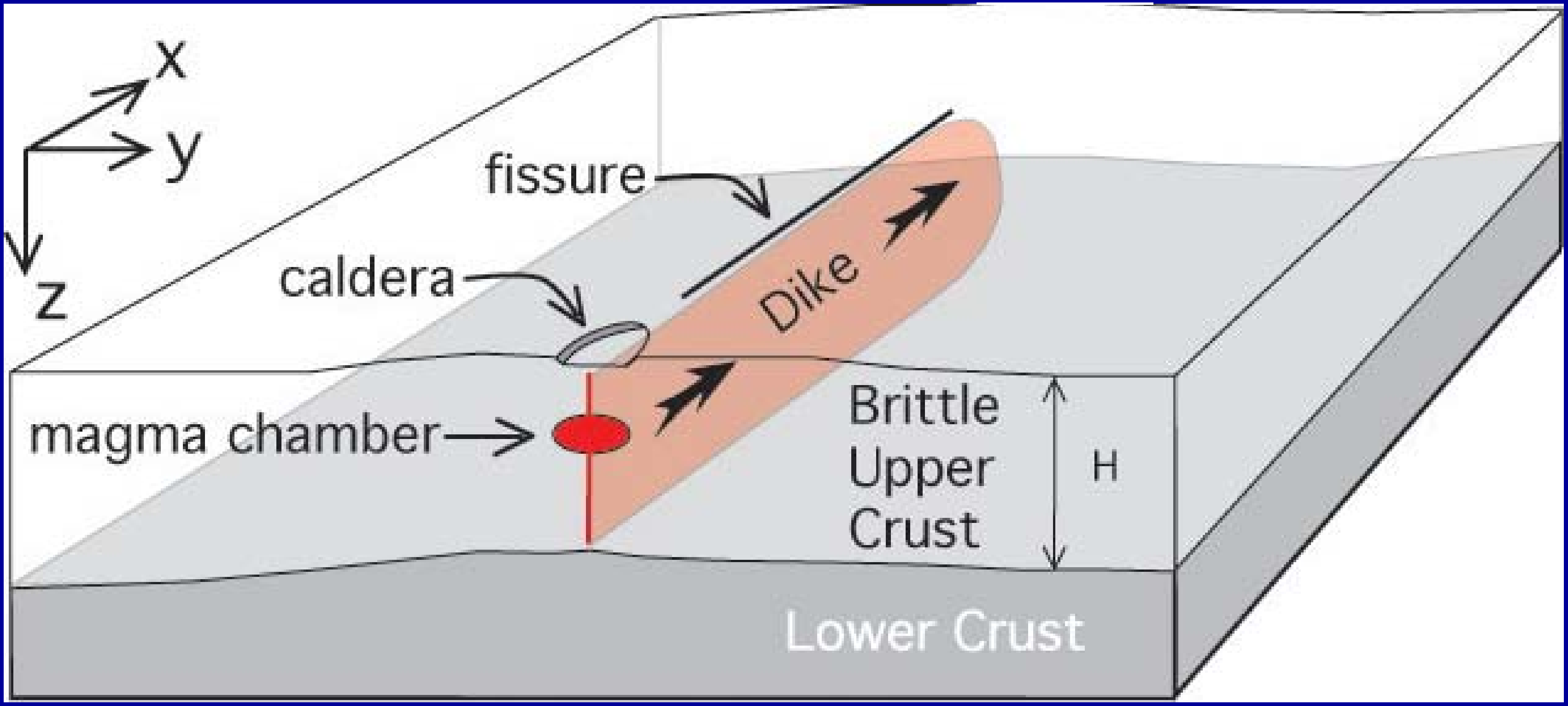
Stress Relaese by one dike makes next dike shallower





After Rubin and Pollard (1987)

Qin and Buck, 2007


x
y
z
fissure
caldera
Dike
magma chamber
Brittle
Upper
Crust
H
Lower Crust

Inferences from Krafla

1. Micro-seismicity before first event

2. First event was different from other events
   (e.g. wider, hit segment end)

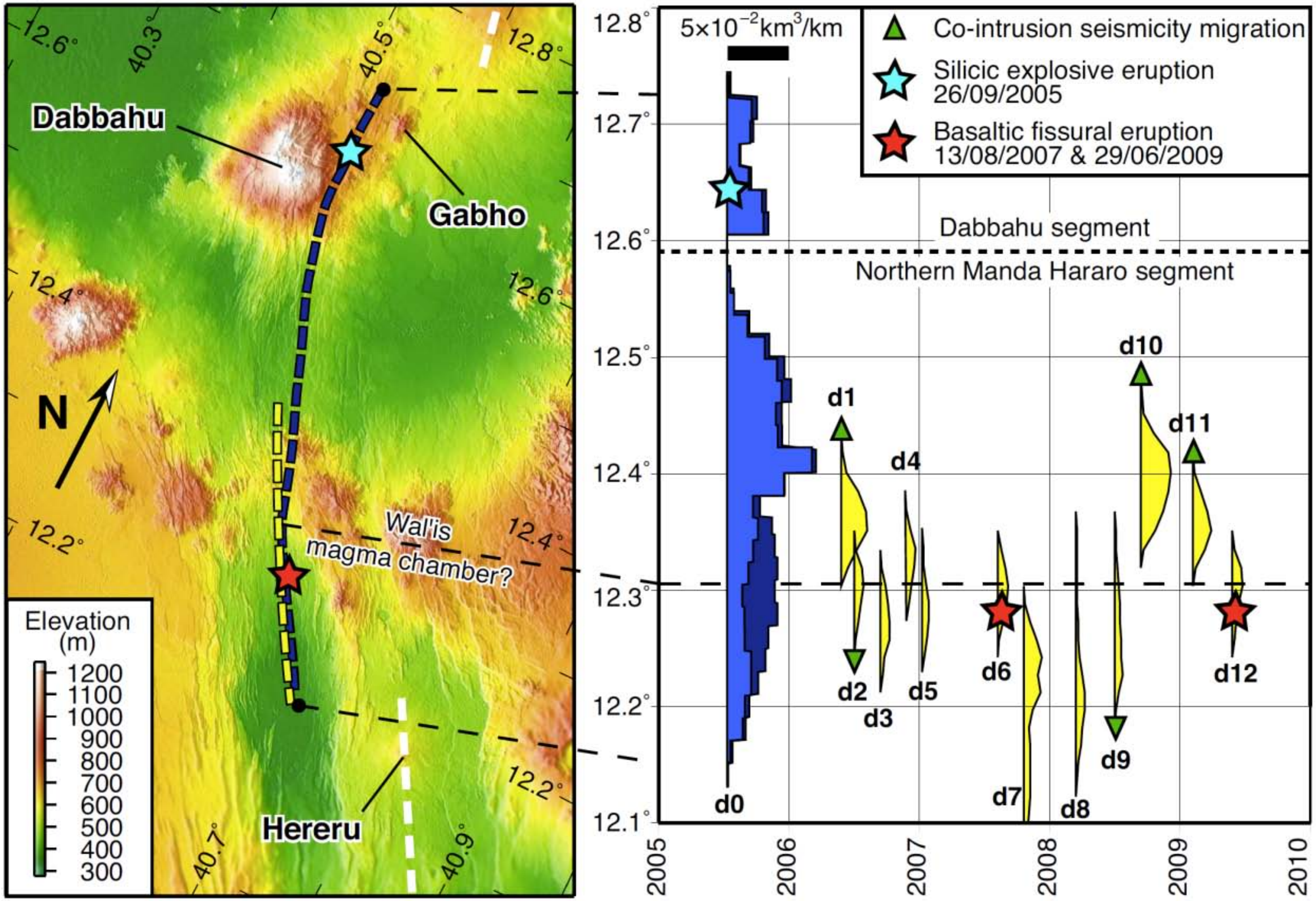
3. Events continue until tectonic stress relieved

4. Time interval between recent episodes 250 years,
   so extension since last event was 5 m.

5. Depth of magma chamber is 3 km.


Dabbahu

(2010)



12.6°
40.3°
40.5°
12.8°
Dabbahu
Gabho
12.4°
12.6°
N
12.2°
Wal'is
magma chamber?
12.4°
Elevation
(m)
1200
1100
1000
900
800
700
600
500
400
300
12.2°
Hereru
40.7°
40.9°
12.8°
12.7°
12.6°
12.5°
12.4°
12.3°
12.2°
12.1°
5×10^−2 km^3/km
Co-intrusion seismicity migration
Silicic explosive eruption
26/09/2005
Basaltic fissural eruption
13/08/2007 & 29/06/2009
Dabbahu segment
Northern Manda Hararo segment
d0
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
2005
2006
2007
2008
2009
2010

Inferences from Dabbahu

1. Micro-seismicity not known

2. First event was different from other events
   (e.g. much wider, went farther)

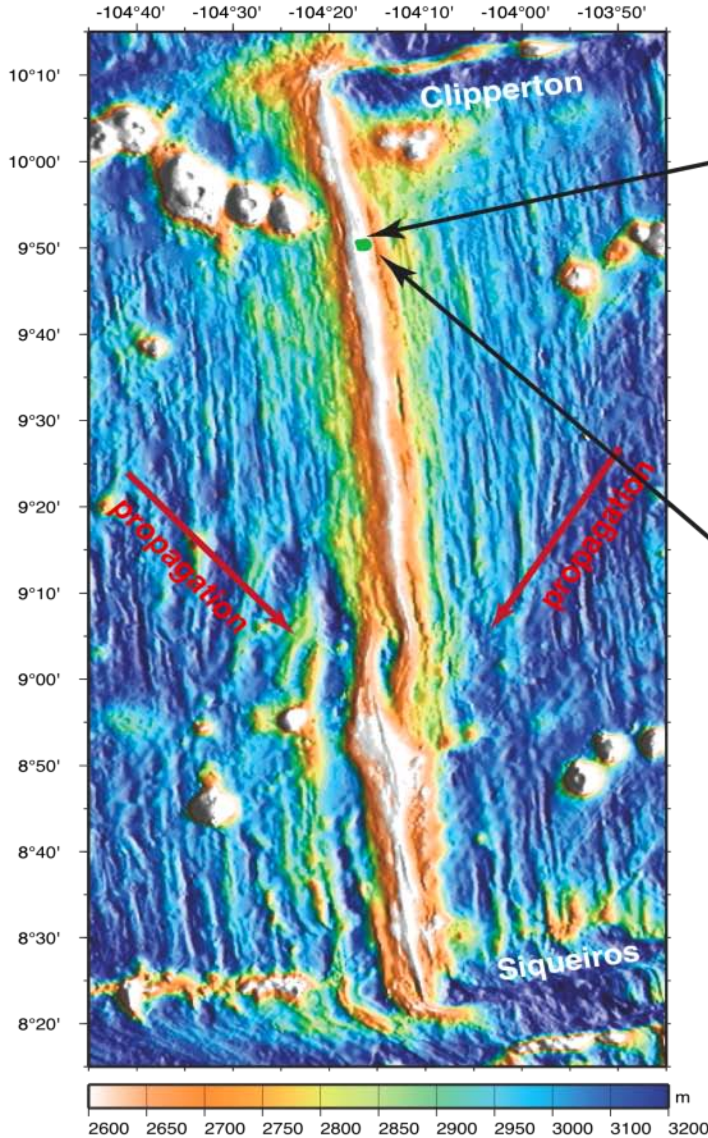
3. Events continue until tectonic stress relieved?

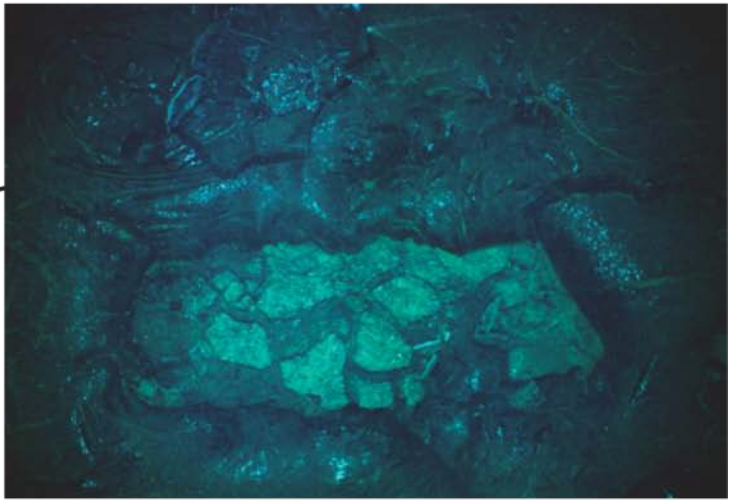
4.Time interval between recent faulting episodes 1700 +/-?? Years, opening >10m.

5.Depth of magma chamber is unknown.

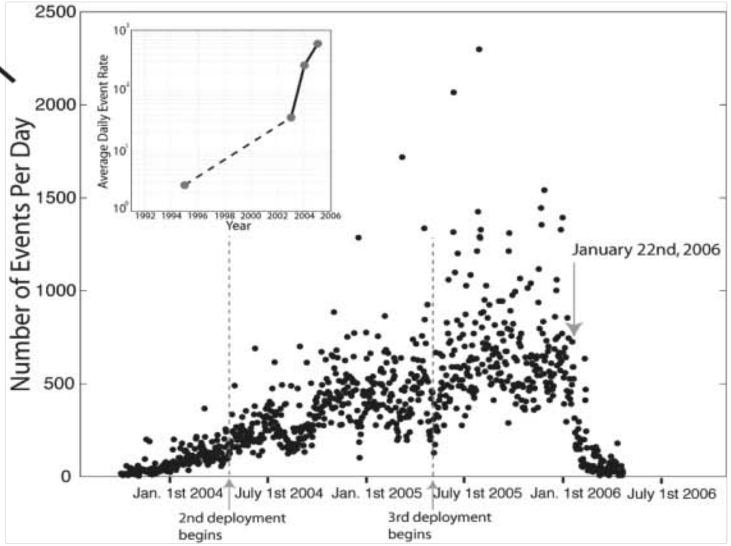
9°N East Pacific Rise

~ 15 Years Between Fissure Eruptions
at 9° 50′ on the East Pacific Rise





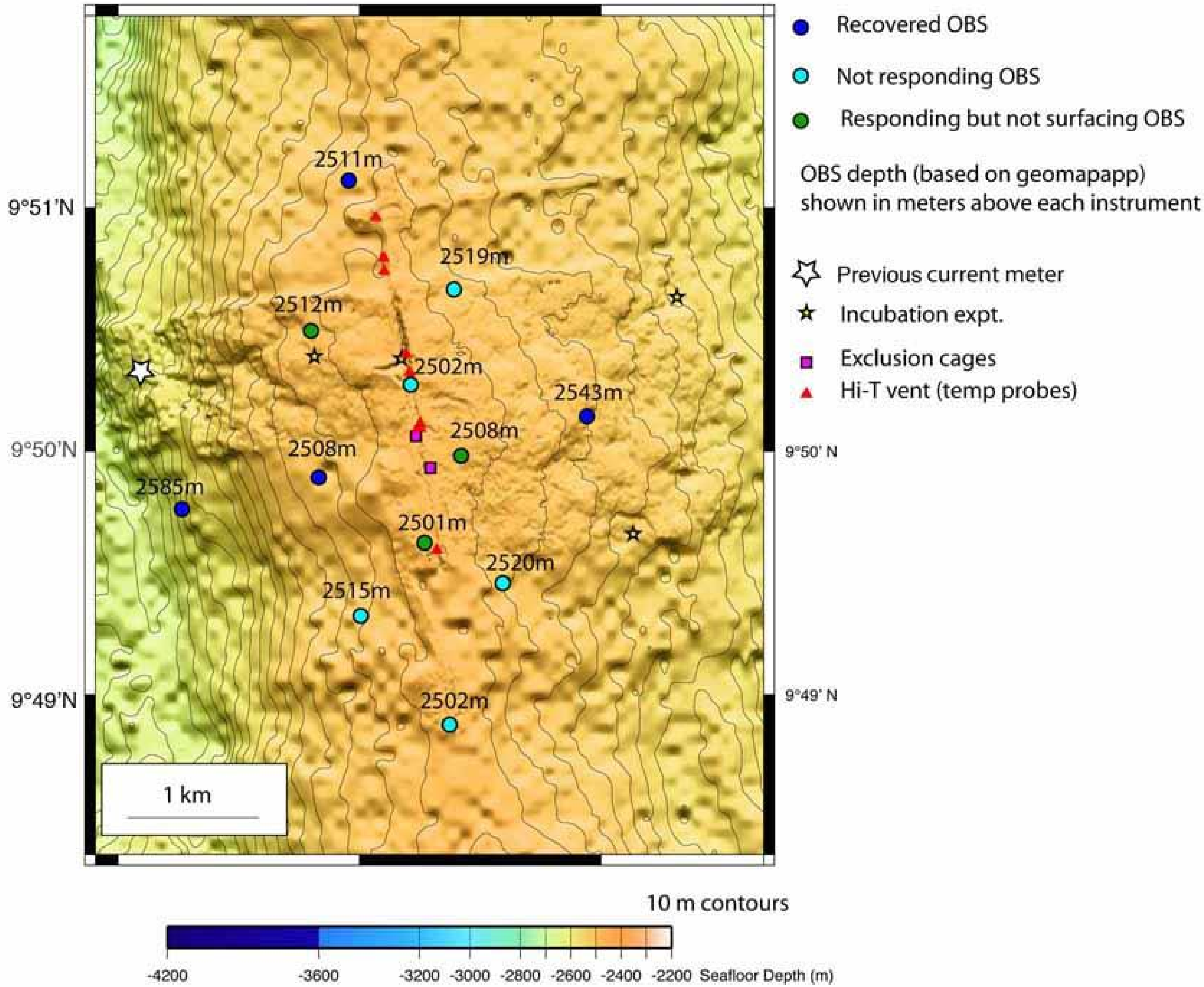
Fresh Glassy Basalt at 9° 47′N taken May 2006 by Fornari and Shanks



2003-2006 microseismic events from Tolstoy et al. (2006).
1994 average event rate point from Sohn et al. (1999).

EPR 9°50'N ISS Bull's-Eye
Map of deployed instruments and OBS recovery

Tolstoy, Waldhauser, Weeks
Seismicity Experiment



Inferences from 9° 50’N EPR

1. Rising micro-seismicity before first event

2. No information on number of events

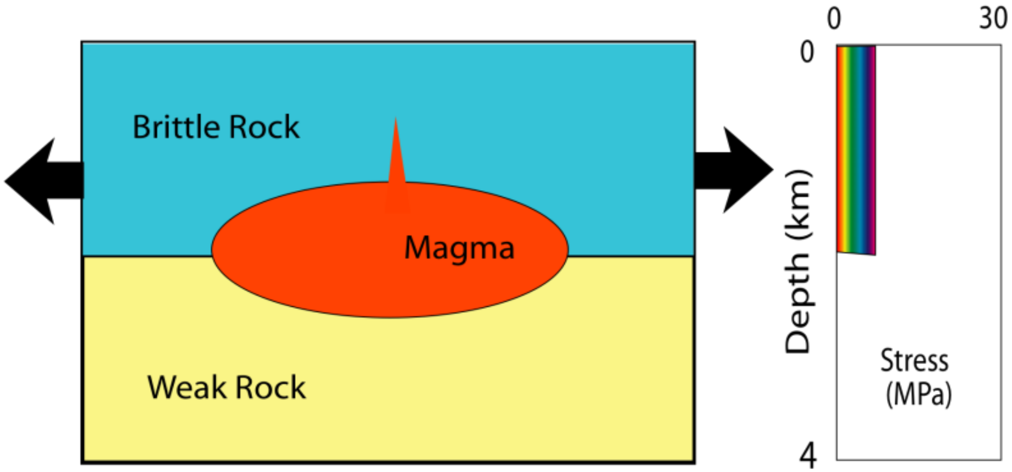
3. Lava flows indicate that tectonic stress relieved

4. Time interval between recent episodes 15 years, so extension since last event was 1.9 m.

5. Depth of magma chamber is ~1 km.

Old Model

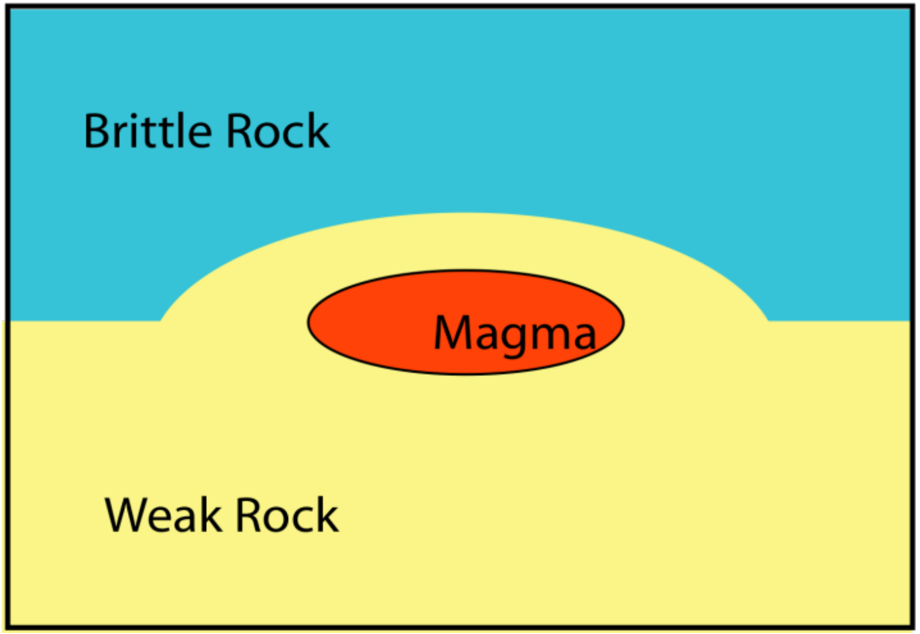
Noting that most dikes formed at spreading centers are about a meter wide a simple model for dike frequencey has been widely discussed (e.g. Gudmundsson, 1993). Spreading center magma chambers are assumed to be in contact with the brittle upper crustal lithosphere that is stressed by plate motion.



Dike intrusion reguires low viscosity magma in contact with elastically stressed rock. Stress builds so that a 1 meter-wide dike can form.

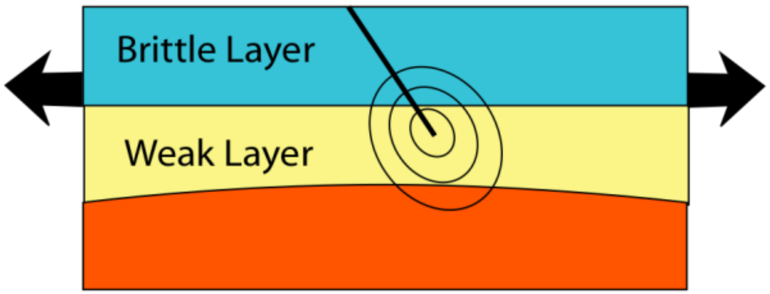
New Model

For quasi-steady-state magma chambers at spreading centers there may be a "buffer zone" of weak rock between fluid magma and brittle rock

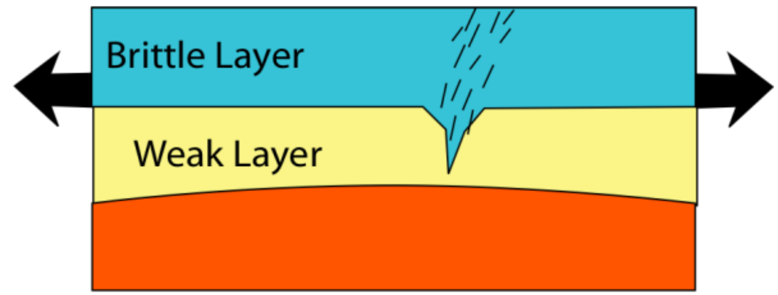


To get dikes may require earthquakes to connect magma and stressed rock.
This may ocur in different ways.

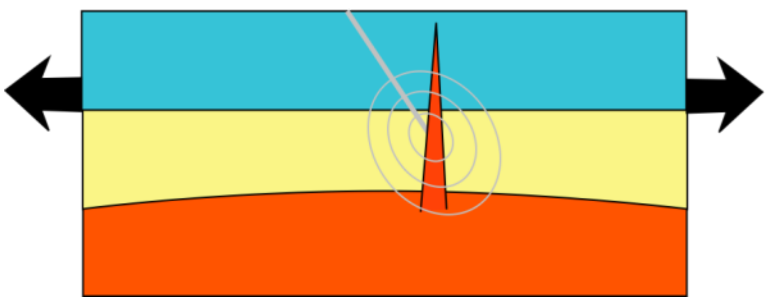
A. Big Earthquake Stresses Buffer Zone



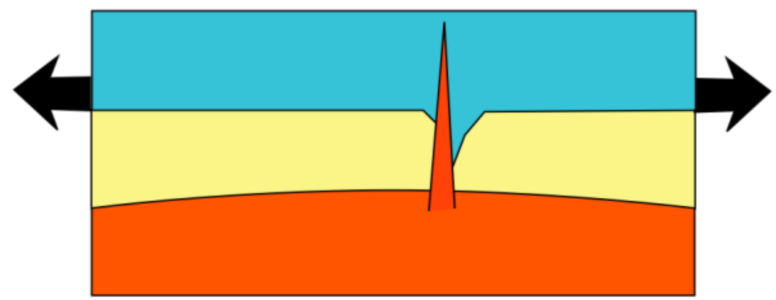
B. Many Small Earthquakes Leads to Hydrothermal Thinning of Buffer Zone



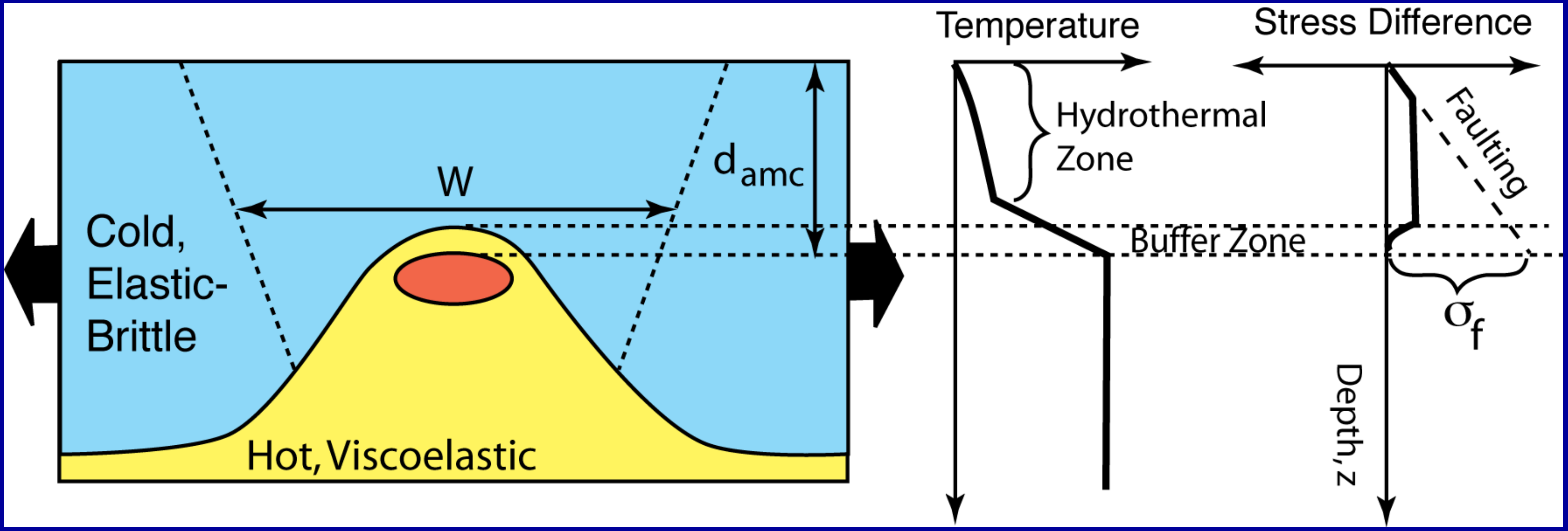
Dike Triggered as Weak Buffer Cracks

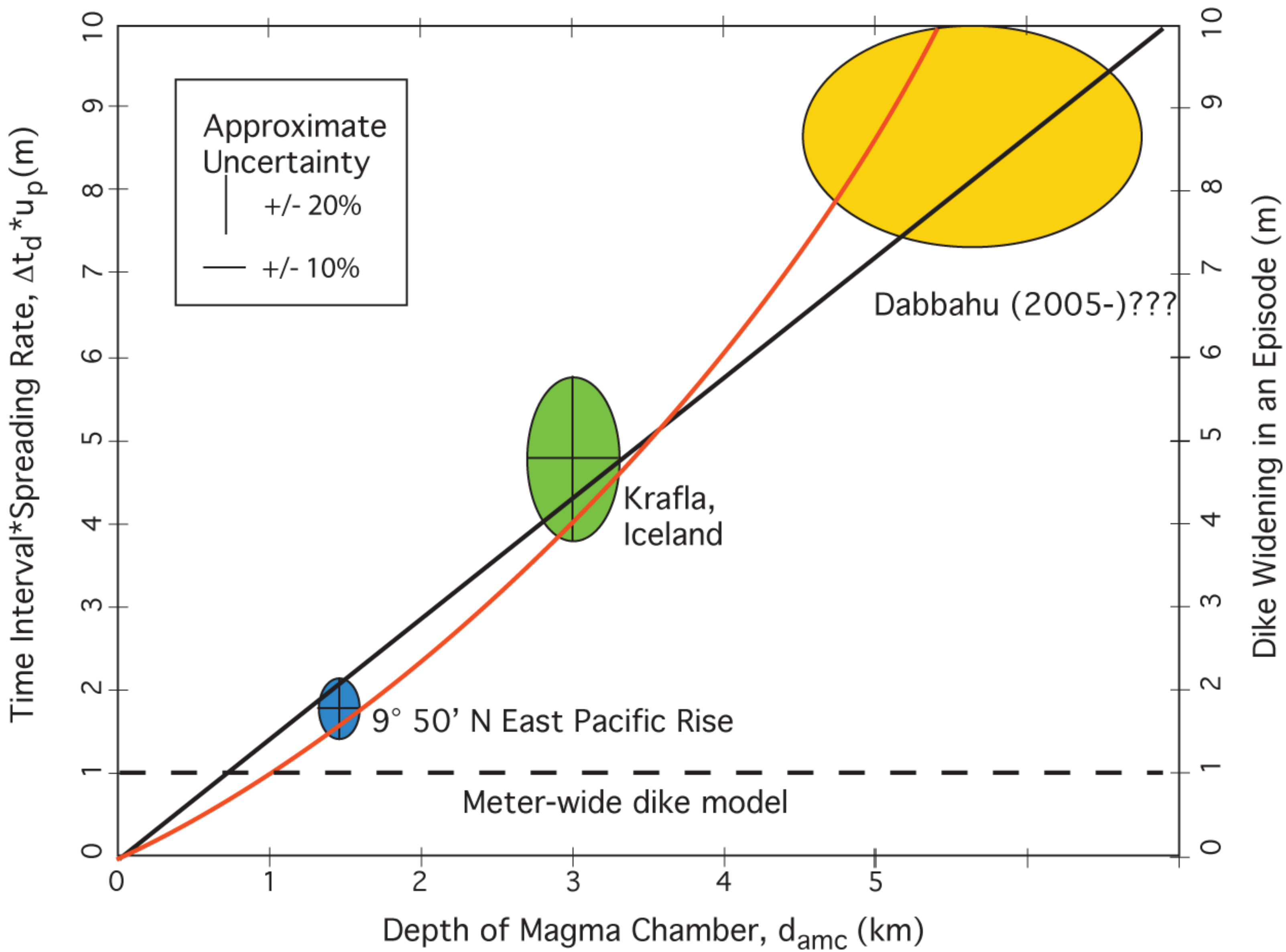


Dike Triggered as Small Quake Cracks Buffer



If
Faulting is needed to trigger diking
and
A dike episode relieves stress differences
then
We can estimate the time between Dike Episodes





Approximate Uncertainty
+/- 20%
+/- 10%
Dabbahu (2005-)???
Krafla, Iceland
9° 50' N East Pacific Rise
Meter-wide dike model
Time Interval*Spreading Rate, $\Delta t_d * u_p$ (m)
Dike Widening in an Episode (m)
Depth of Magma Chamber, d_{amc} (km)
0
1
2
3
4
5
6
7
8
9
10

Conclusion

Fault triggering of spreading center dikes explains:

1. Frequency of dikes at different spreading centers

2. Onset and buildup of seismicity before diking