# PALEOMAGNETISM AND GEOCHRONOLOGY OF MESOPROTEROZOIC DIABASE SILLS FROM DEATH VALLEY, CALIFORNIA:

## EVALUATING THE BIFURCATING PLUME HYPOTHESIS FOR THE SW LAURENTIA LARGE IGNEOUS PROVINCE (SWLLIP)

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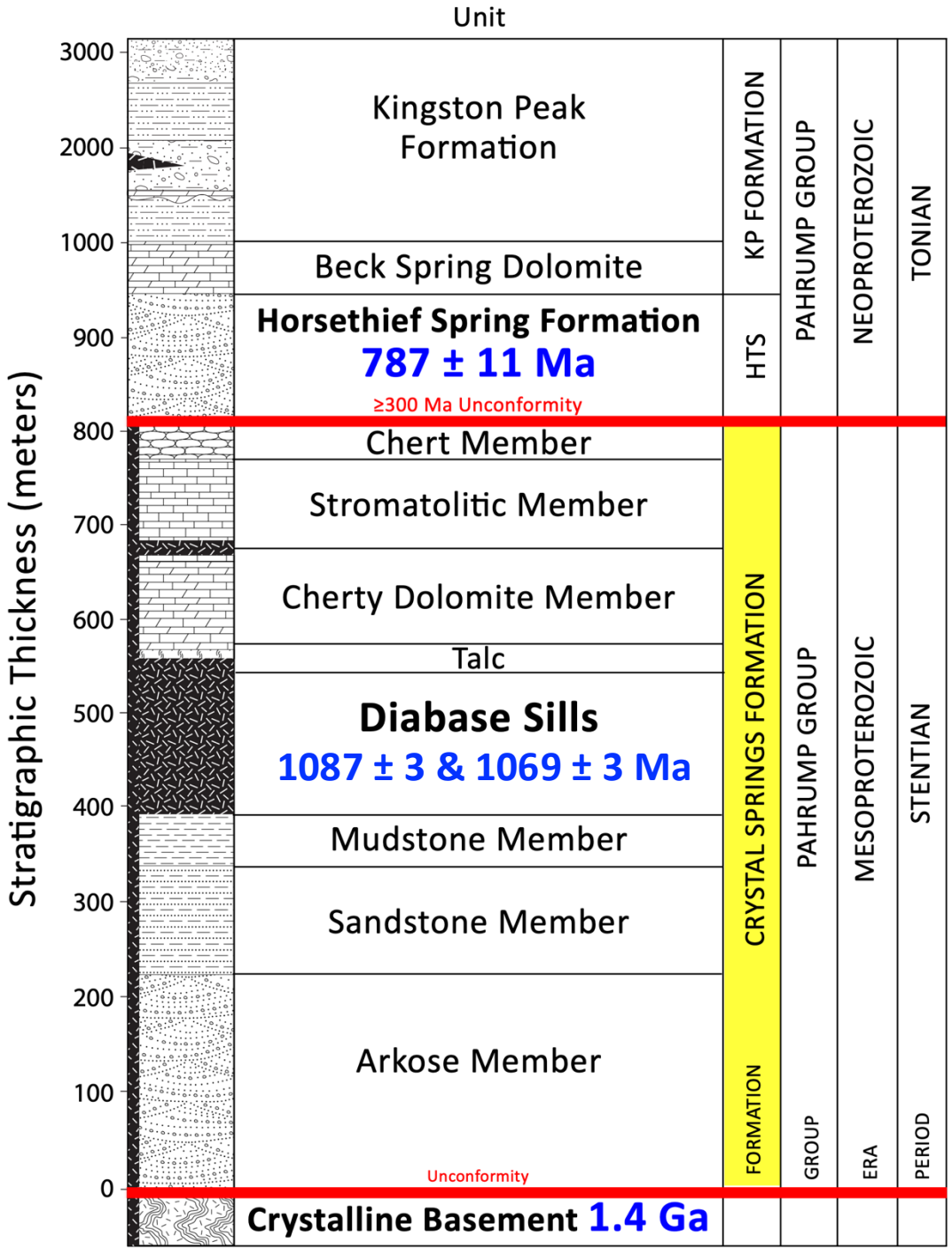


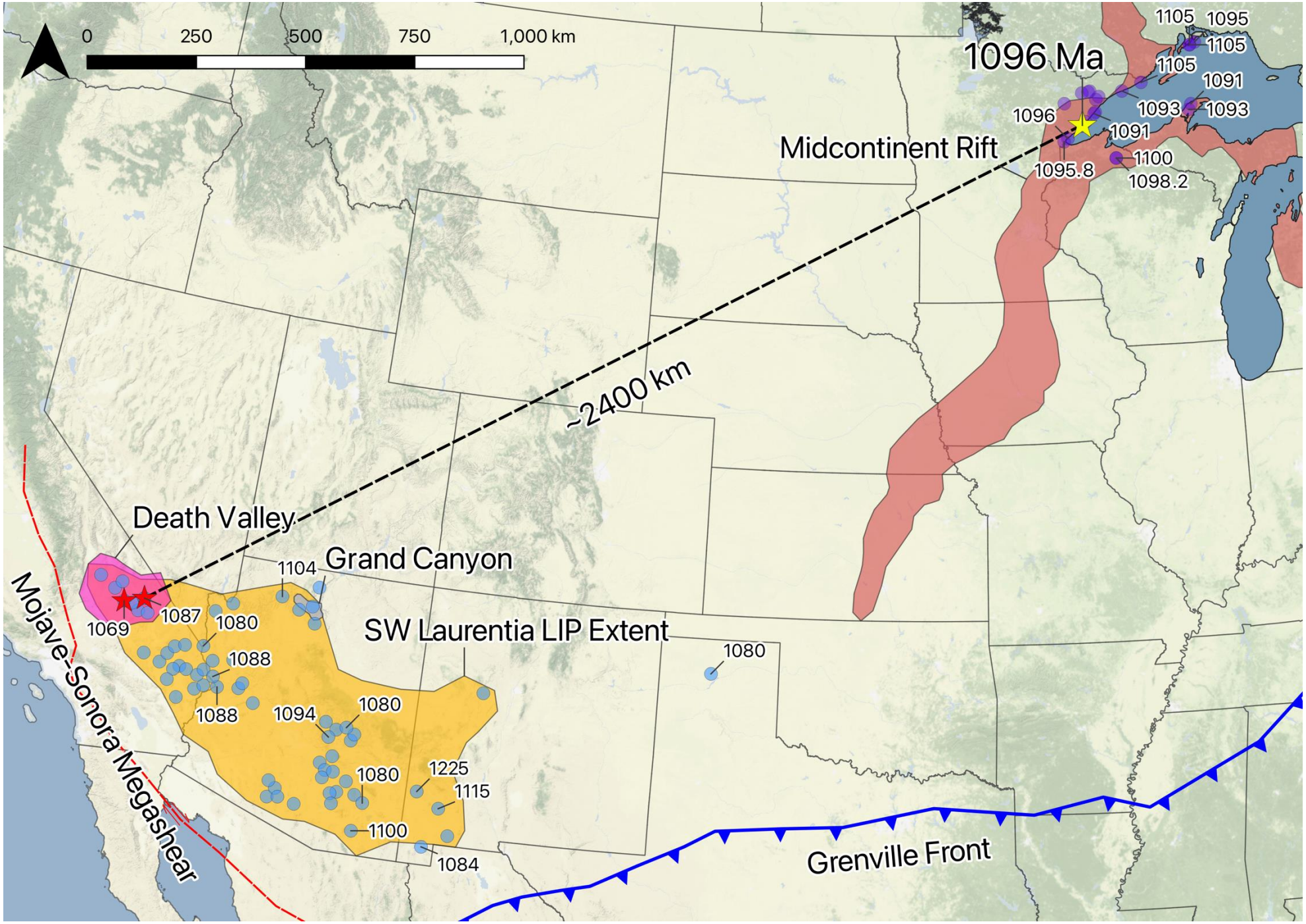

# Simplified Pahrump Group & Crystal Springs Formation Stratigraphy

# Previous SW Laurentian Magmatic Ages

- SW Laurentia LIP ages:
  1163 – 1040 Ma (123 Ma)
  THERMOCHRON, SHRIMP, LA-ICP-MS, TIMS

- Midcontinent Rift ages:
  1105 – 1083 Ma (22 Ma)
  CA-ID-TIMS

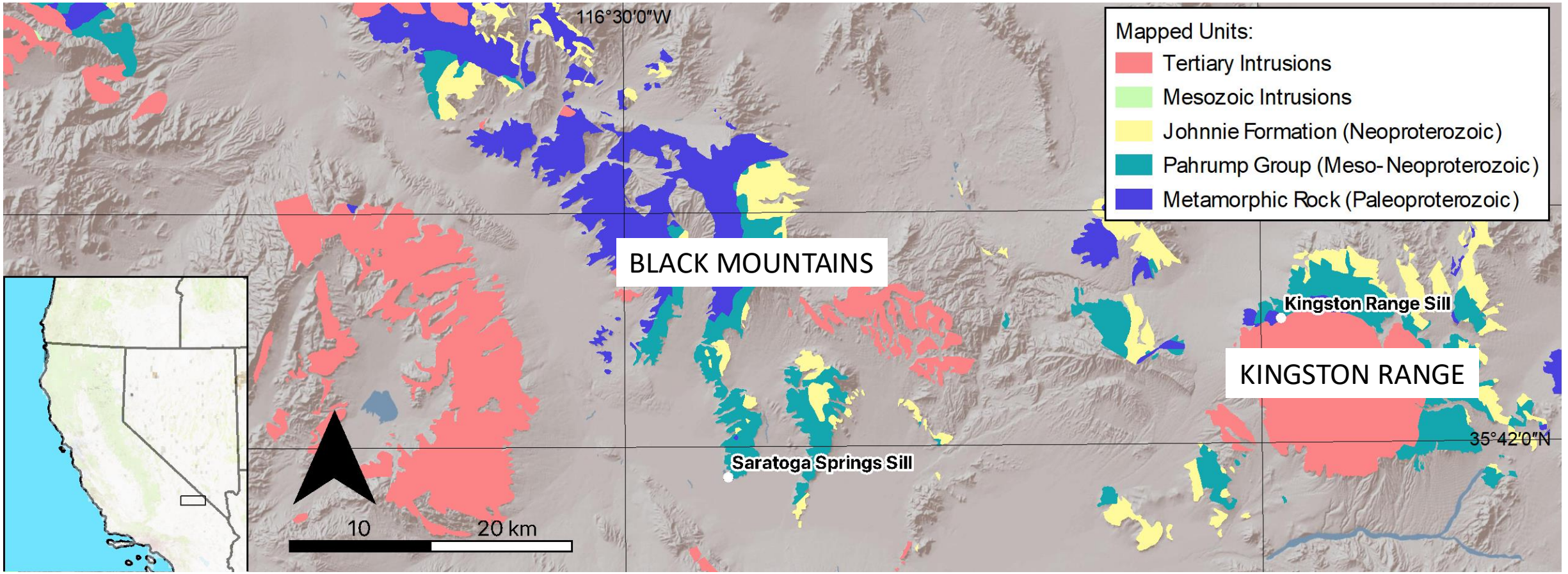
- Real or artefact of data quality?

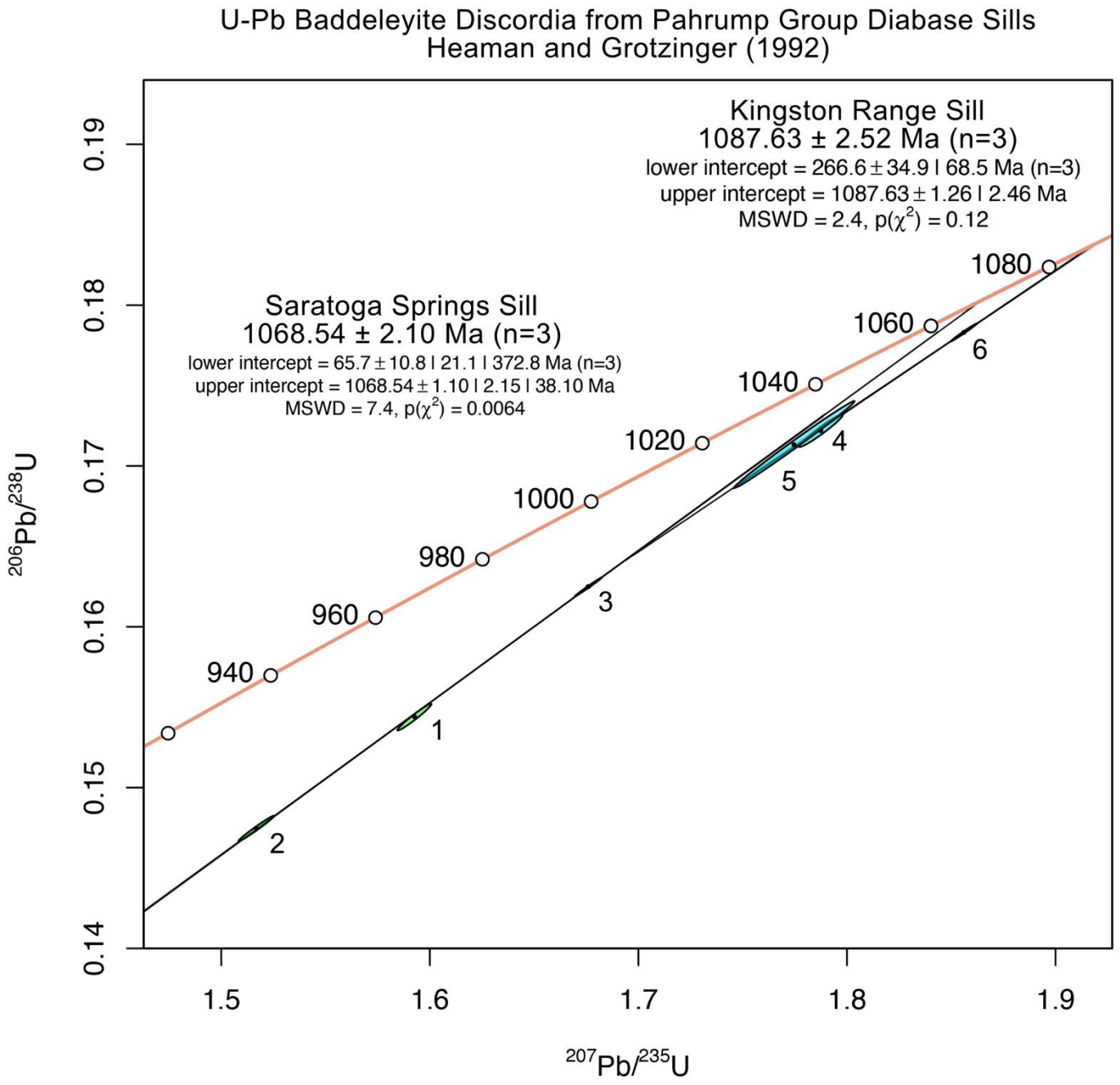


# Outline

- Review previous geochronology
- Sample collection
- CA-ID-TIMS - *New dates!!*
- Relate SW Laurentia LIP to Midcontinent Rift via paleomag and geochron
- Bifurcating Plume Model

# Pioneering Geochronology:
## Heaman and Grotzinger (1992)
## Death Valley diabase sill sample locations






# Pioneering Geochronology: Heaman and Grotzinger (1992)

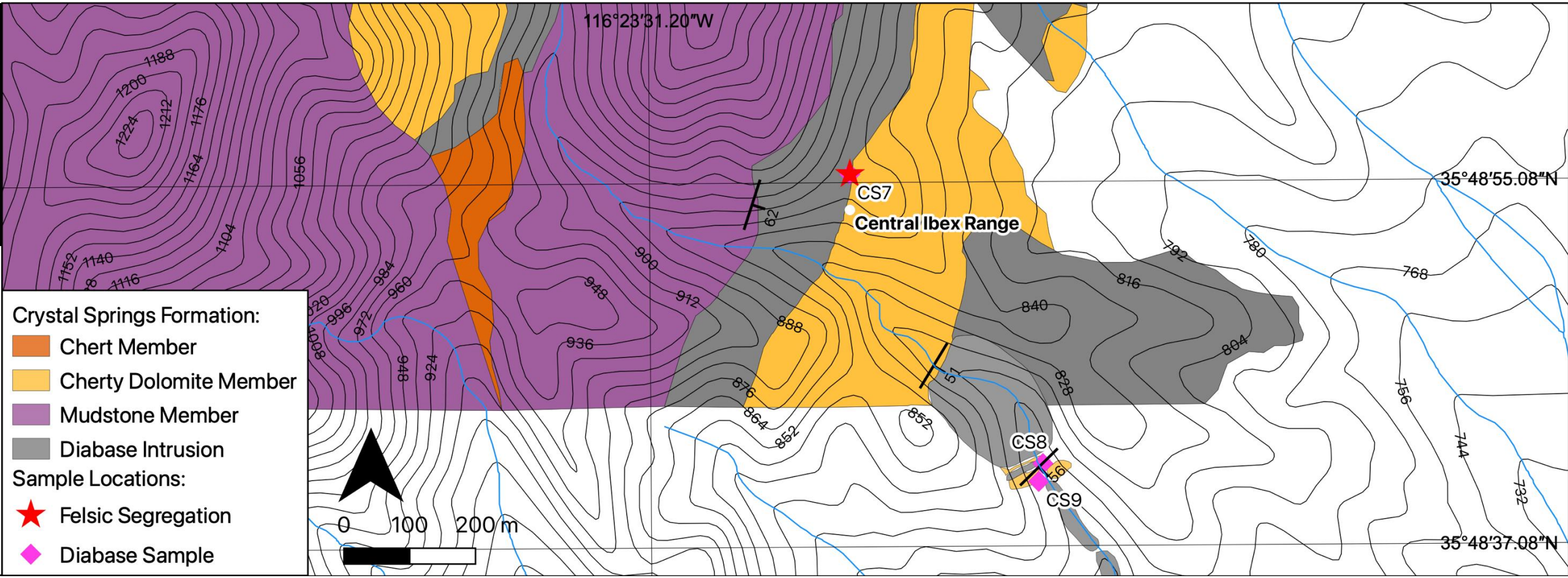
Upper intercept ages produced from multi-grain thermal-ionization mass spectrometry (TIMS) of baddeleyite ($ZrO_2$)

Published ages:

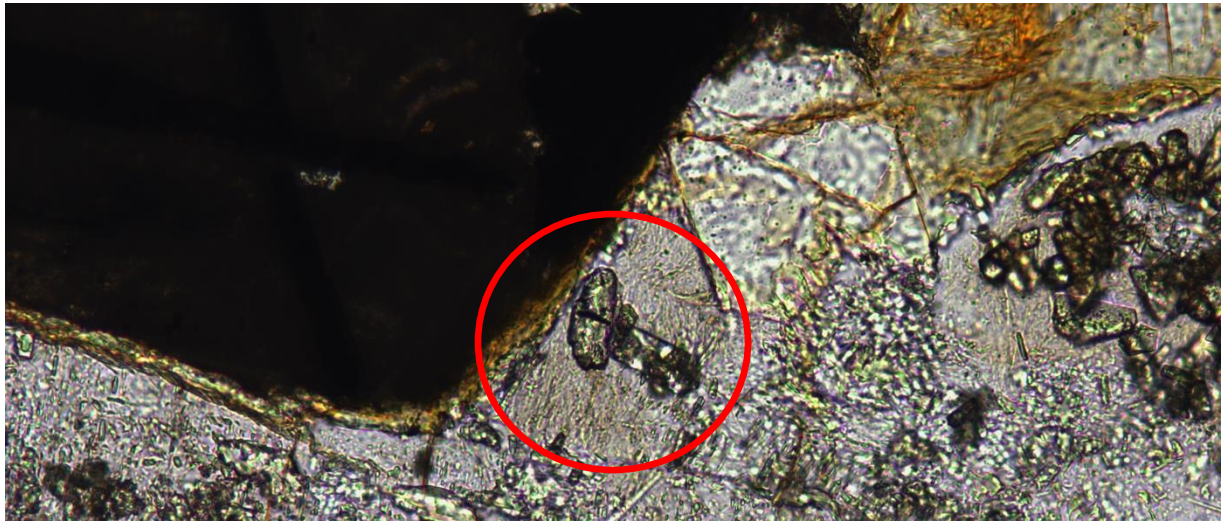
Saratoga Springs Sill: 1069 ± 3

Kingston Range Sill: 1087 ± 3

# Death Valley Paleomagnetic and Geochronology Sample Sites



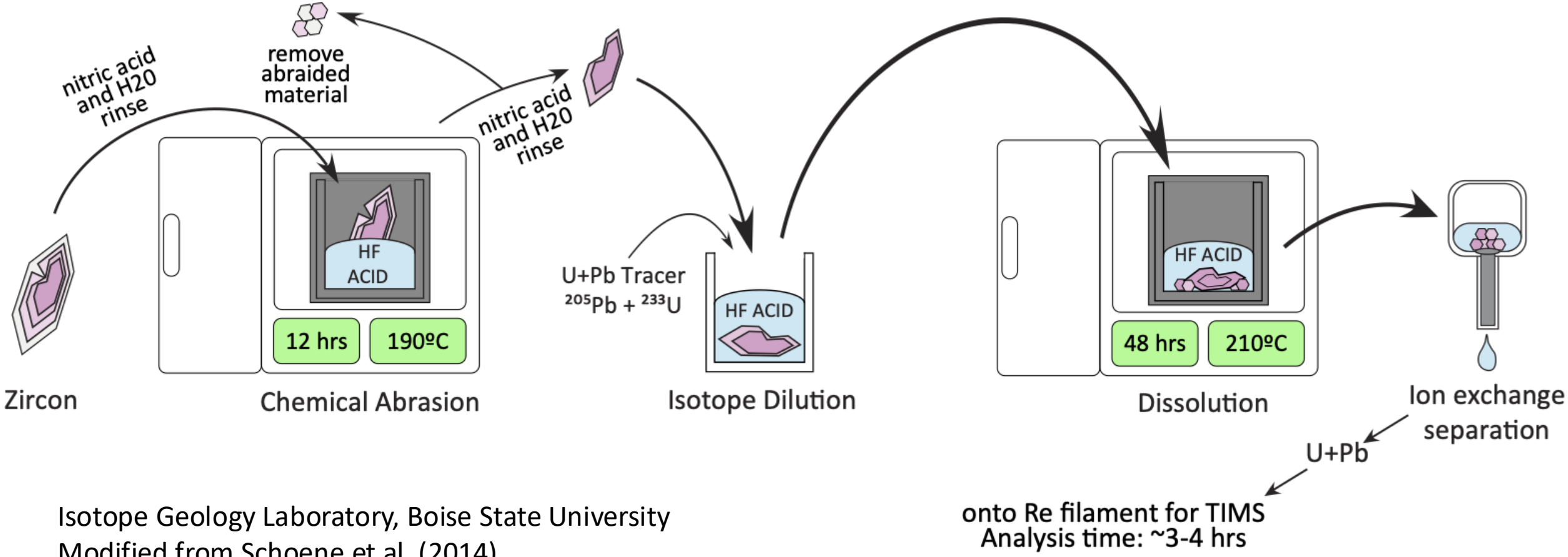
# diabase sill interiors with late stage zircon-bearing melt segregations



Zircon adjacent to oxide in CS4 granophyre - 200X, XPL

~1 m melt segregation within diabase sill interior
F2020_5, Warm Springs Canyon

# $^{206}Pb/^{238}U$ chemical abrasion-isotope dilution-thermal ionization mass spectrometry from single dissolved zircon grains

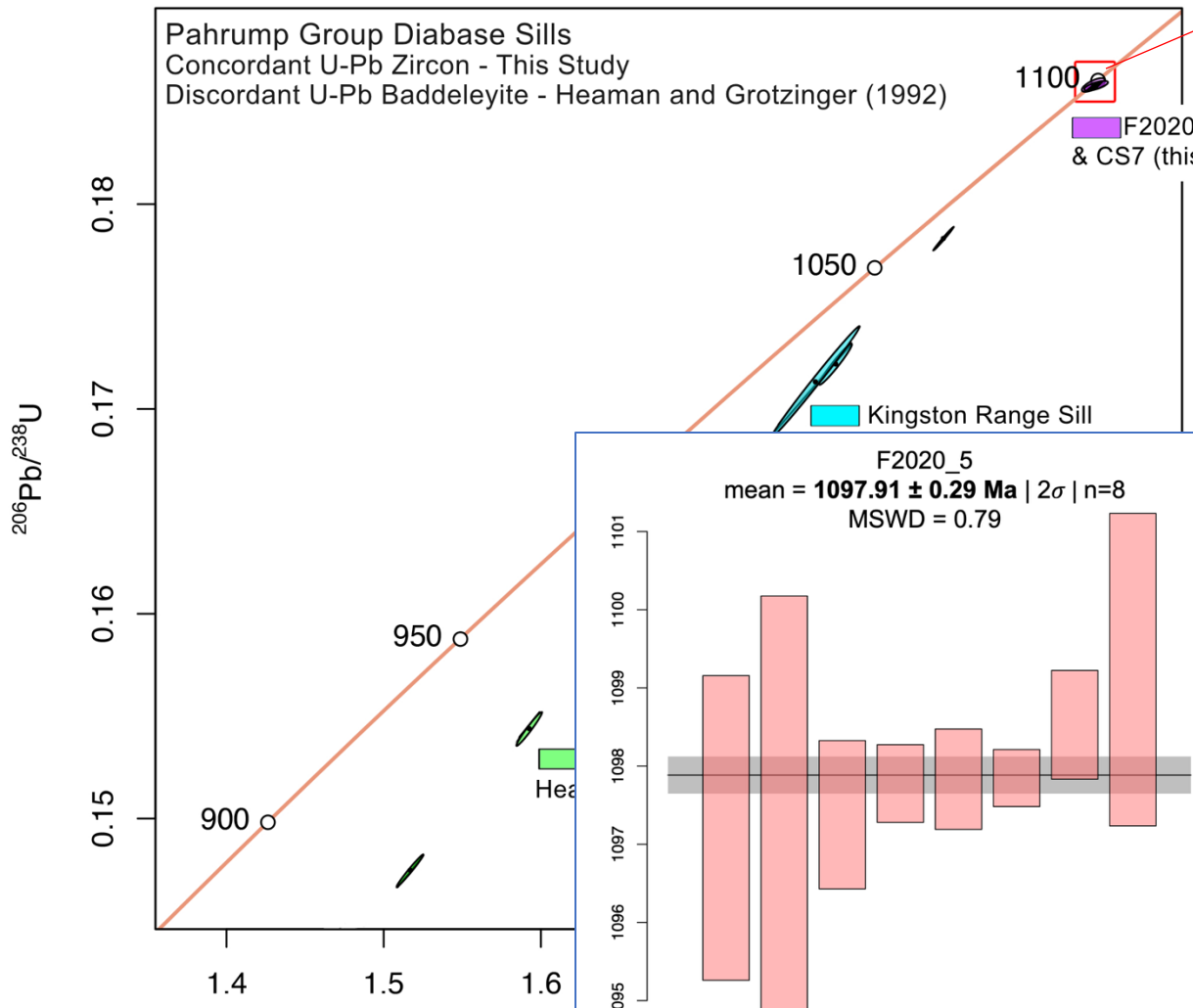


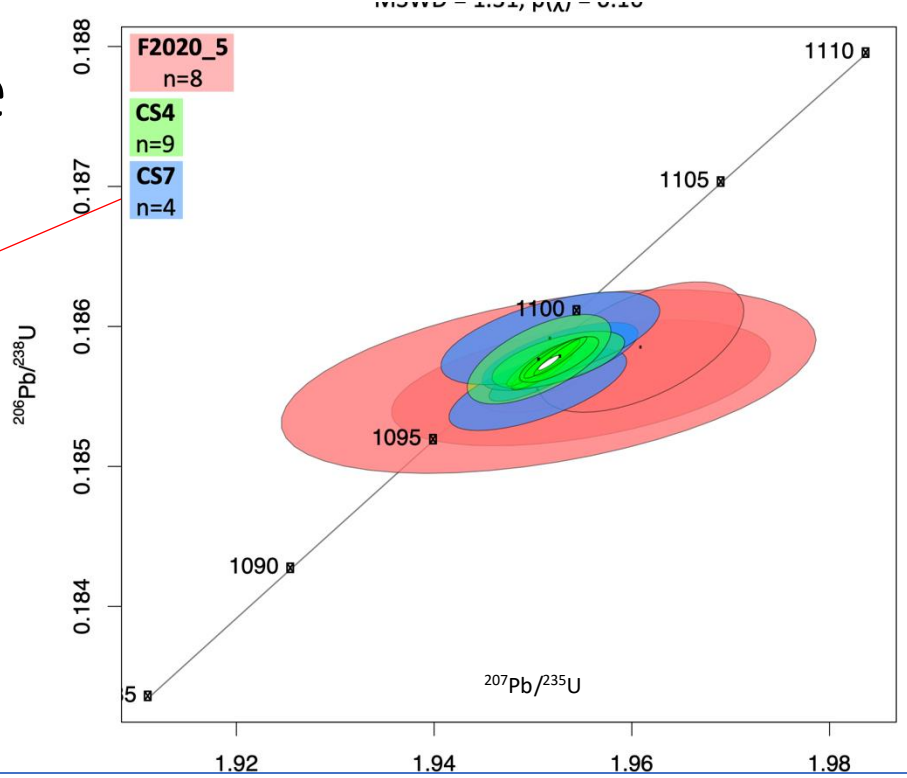

Isotope Geology Laboratory, Boise State University
Modified from Schoene et al. (2014)

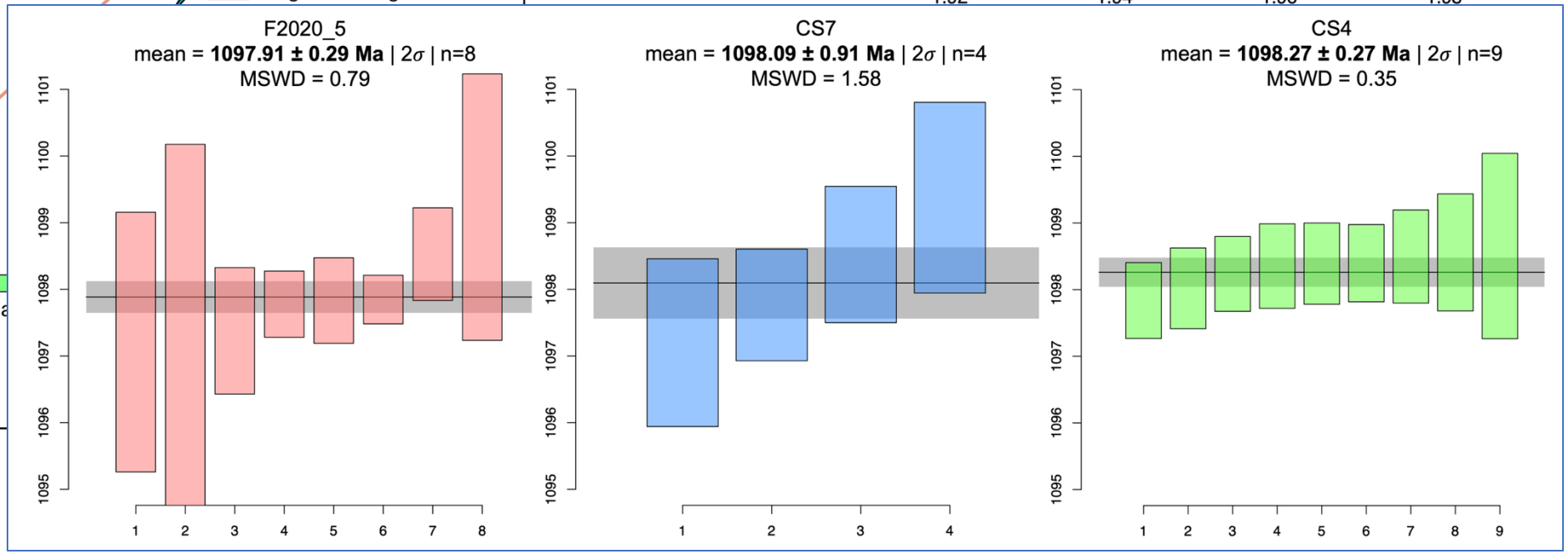
# F2020_5, CS4, CS7 Concordia + Ranked Age

## 1097.91 ± 0.29, 1098.09 ± 0.91, 1098.27 ± 0.27 Ma

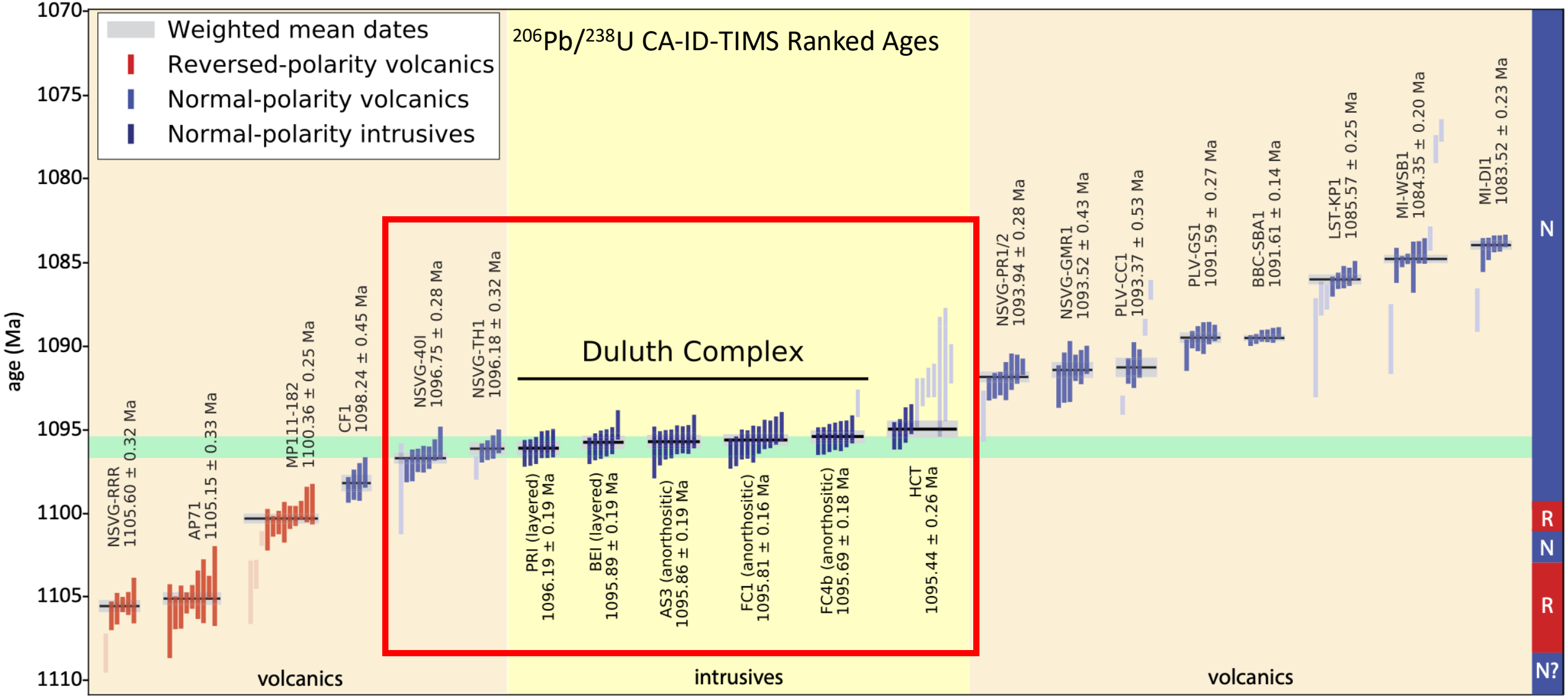
## Age: ~1098 Ma



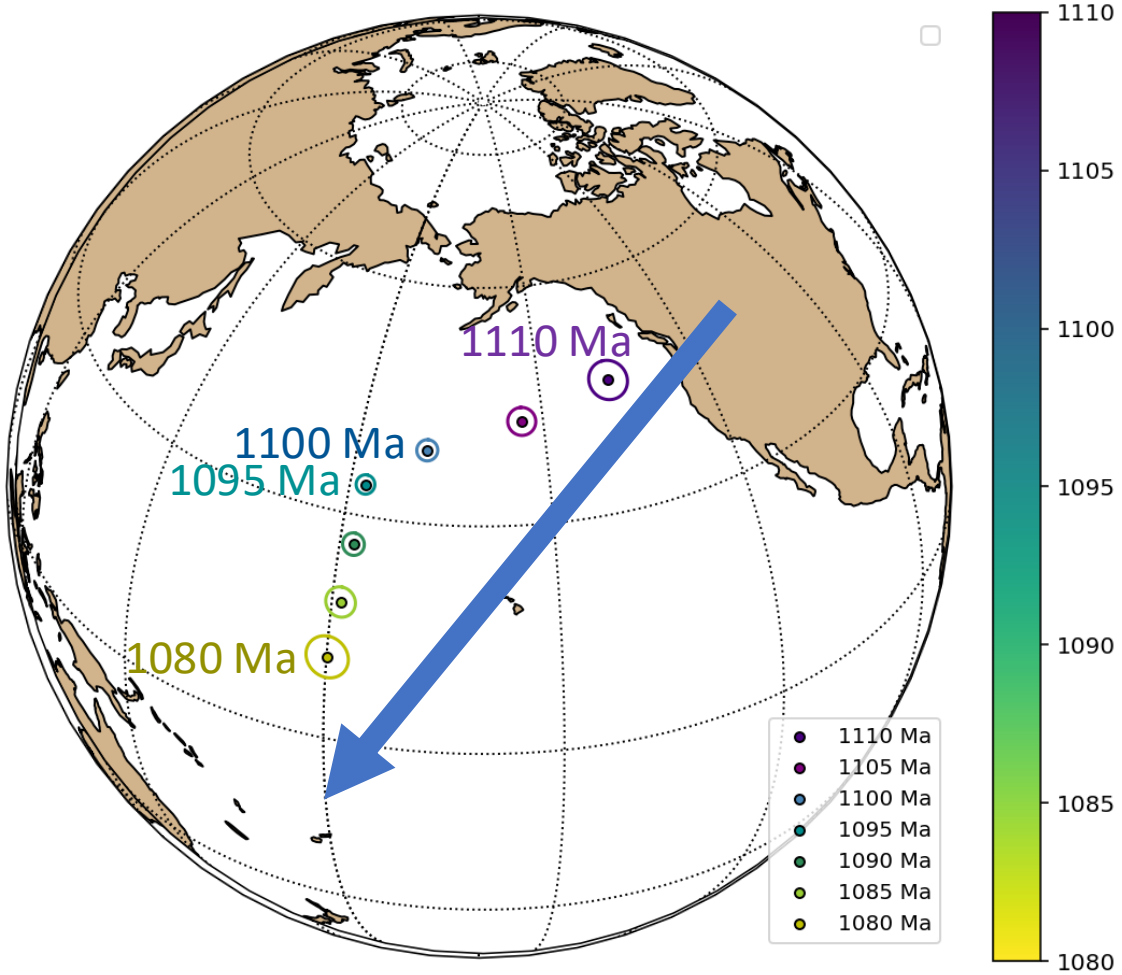



# Midcontinent Rift Magmatic Events

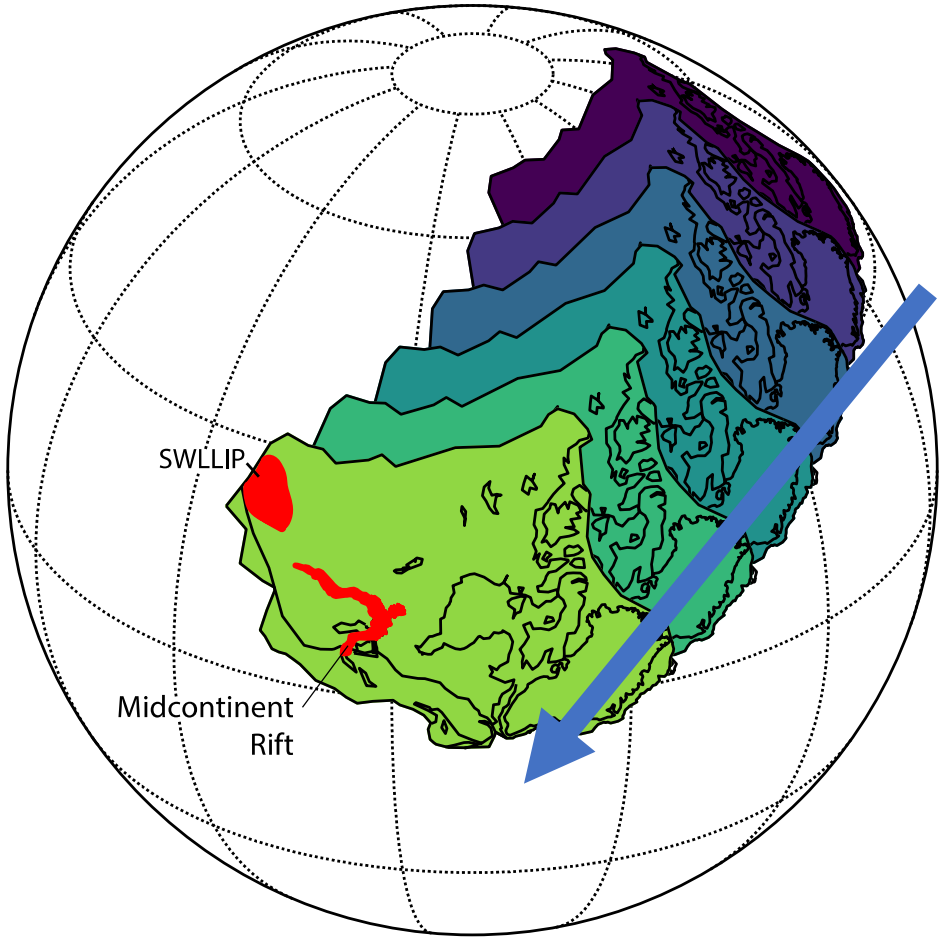



Swanson-Hysell et al., 2021

# Midcontinent Rift Apparent Polar Wander Path + Laurentia motion



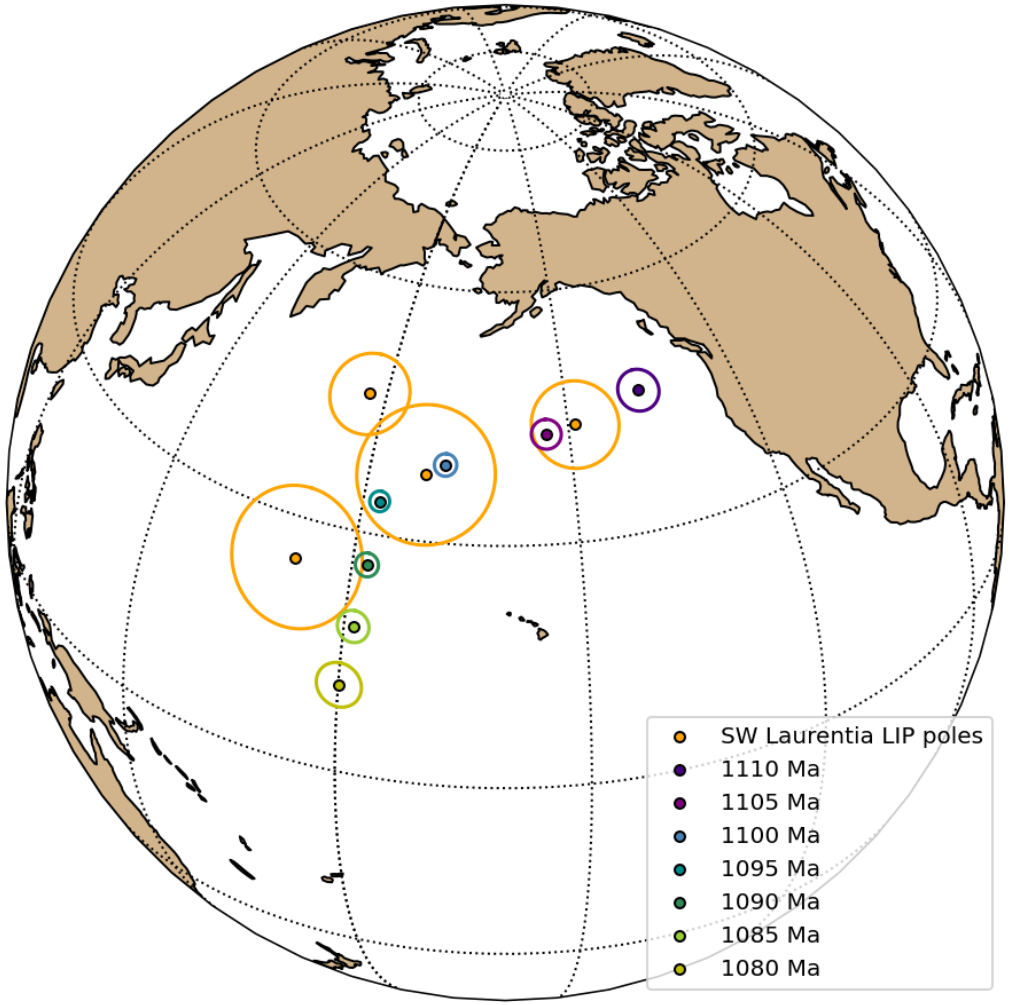

Paleomagnetic poles for Midcontinent Rift magmatic events



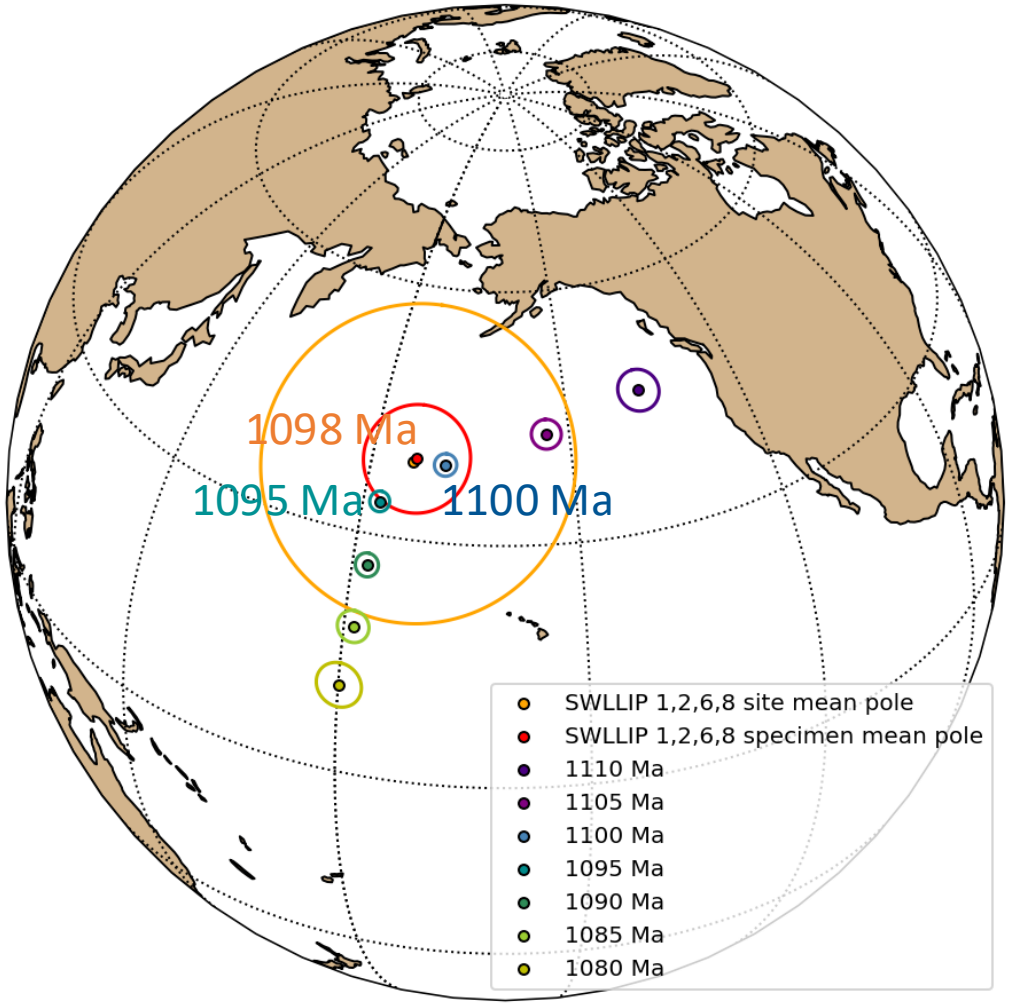

Laurentia drifting equatorward at >27 cm/yr ca. 1083 – 1105 Ma

Swanson-Hysell et al.

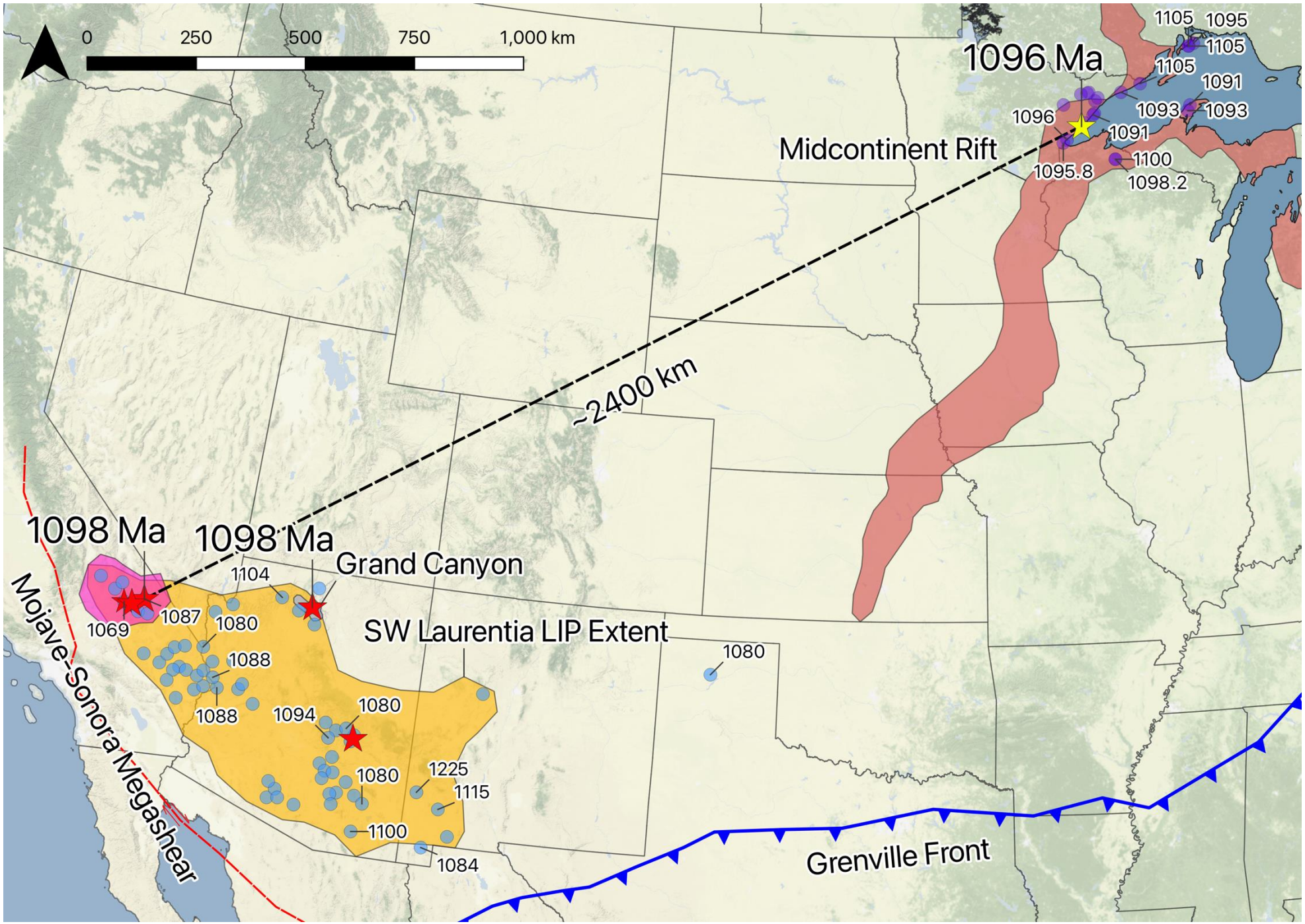
# Paleomagnetic Age Comparison against Keweenawan Track




Paleomagnetic poles for CS sites 1, 2, 6 & 8




Site and specimen mean poles for for CS 1, 2, 6 & 8




Could these pulses be related?

# Bifurcating Plume Model – Lubrication Theory

$$velocity \sim \frac{dR}{dt} \sim \frac{\Delta\rho g H^3}{R n_p}$$

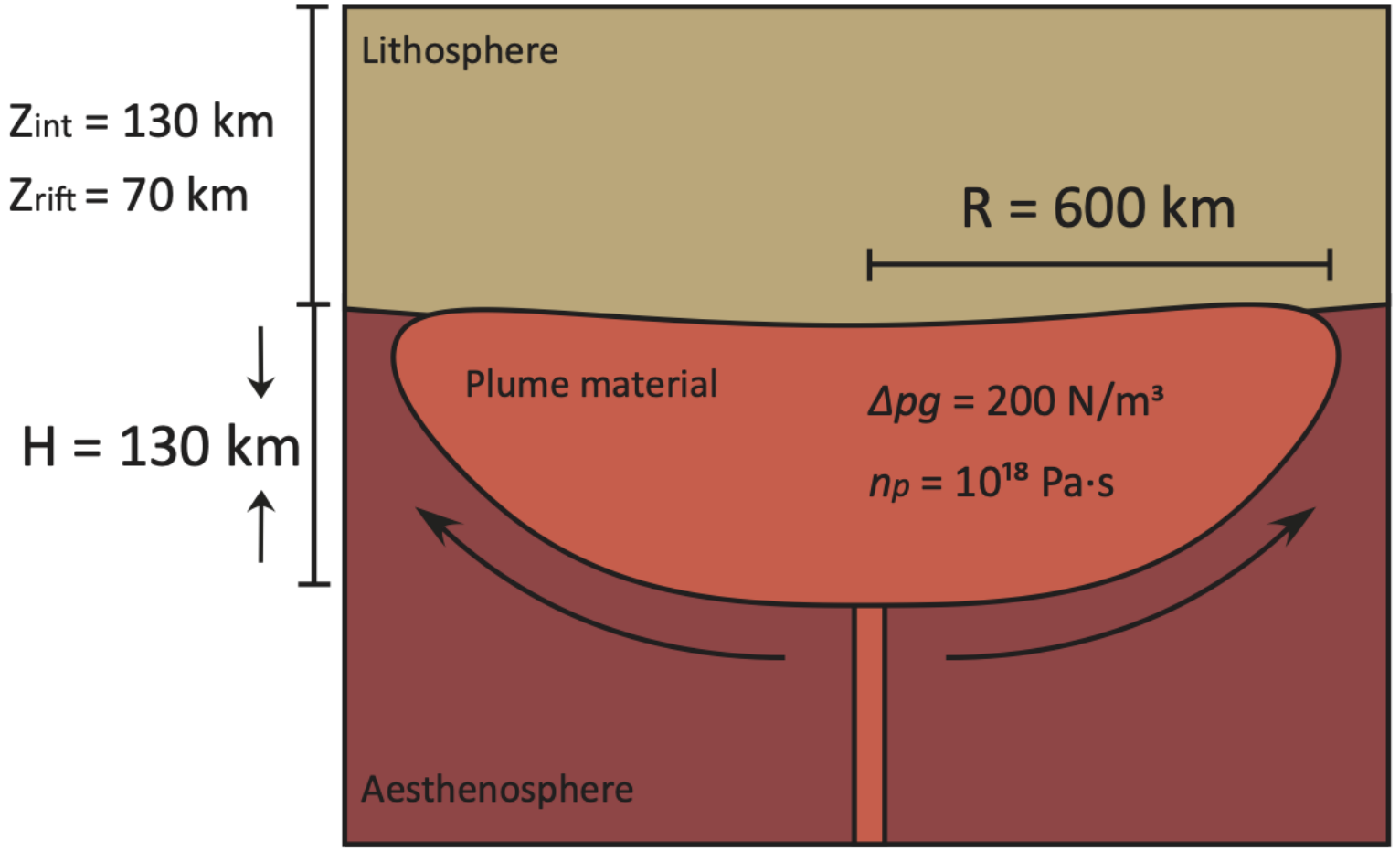
$$volume\ is\ conserved\ *$$

$$so\ \pi R^2 H = \text{constant} = \text{K}$$

$$\text{H} = \frac{K}{\pi R^2}$$

$$v \sim \frac{\Delta\rho g H^3}{R n_p} \sim \frac{\Delta\rho g K^3}{\pi^3 R^6 R n_p} \sim \frac{\Delta\rho g K^3}{\pi^3 R^7 n_p}$$

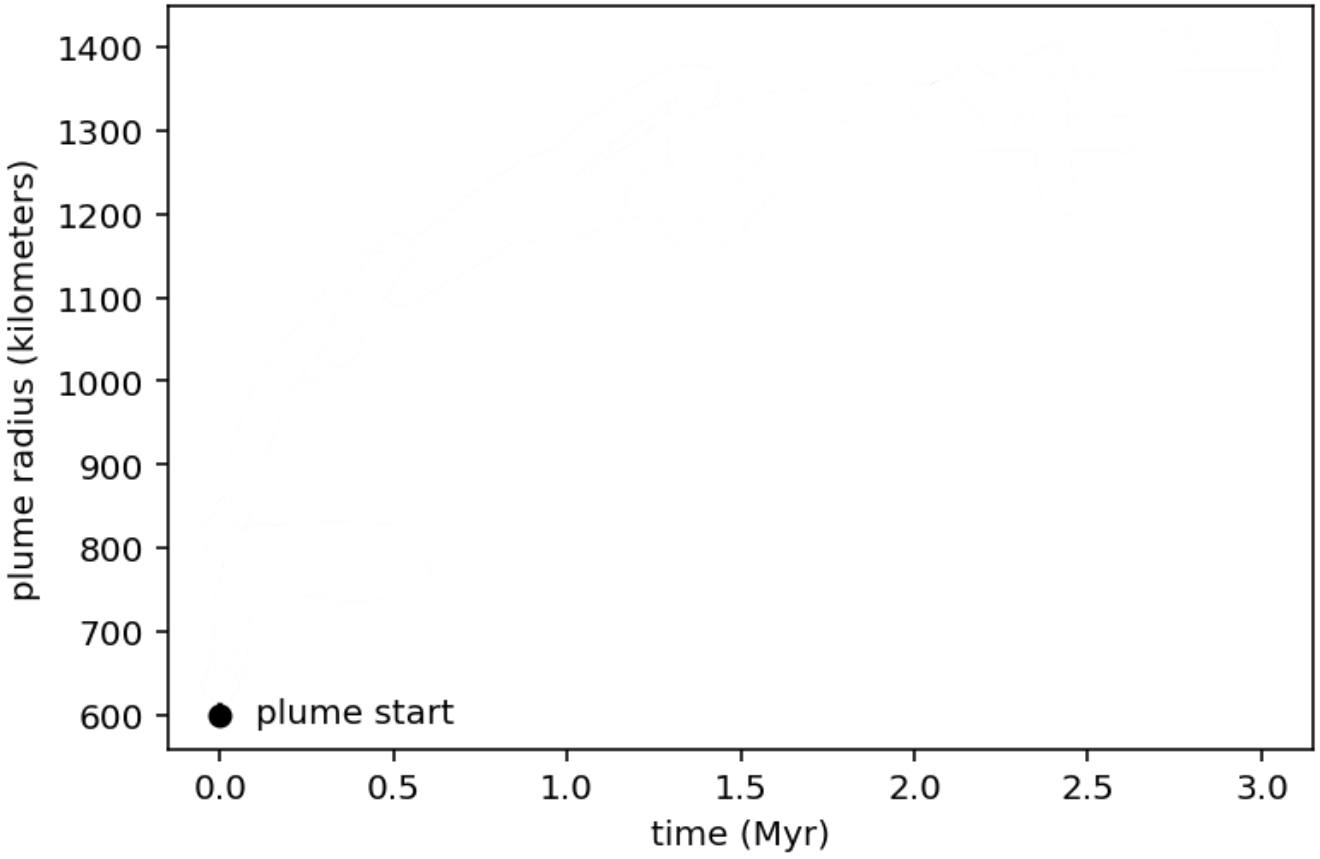
$$v \sim \frac{dR}{dt} \sim \frac{1}{R^7} \therefore R(t) \sim t^{1/8}$$



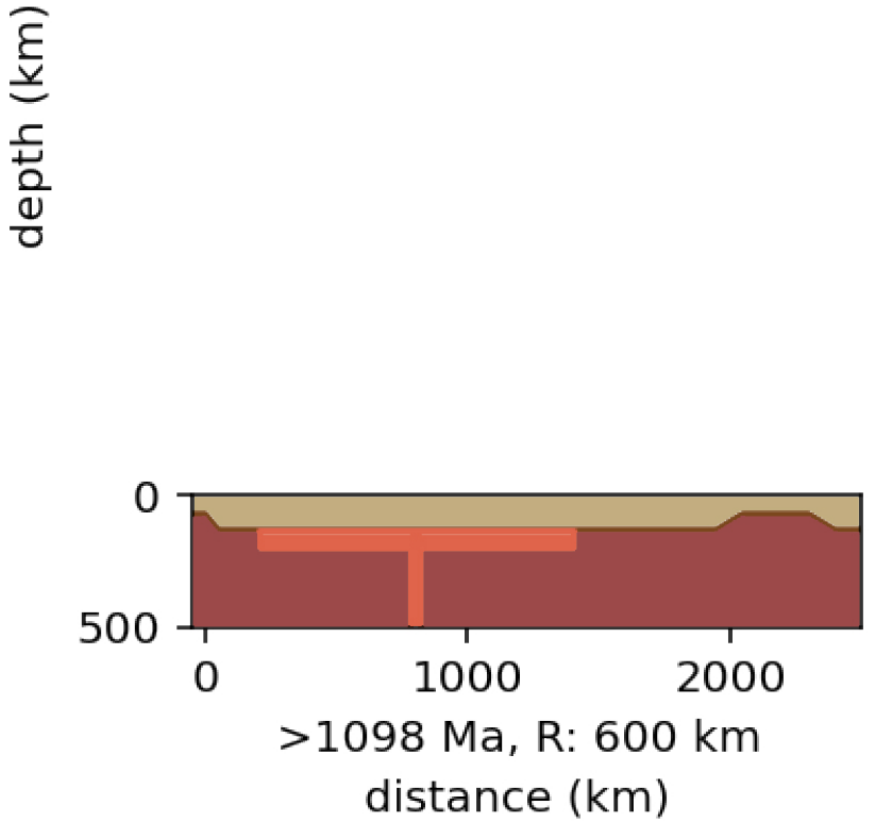

*Plume doesn't solidify in model and is not constantly fed from below

Lubrication Theory - Based on Sleep (1997)
Lithosphere Thickness – Based on Steinberger & Becker (2016)

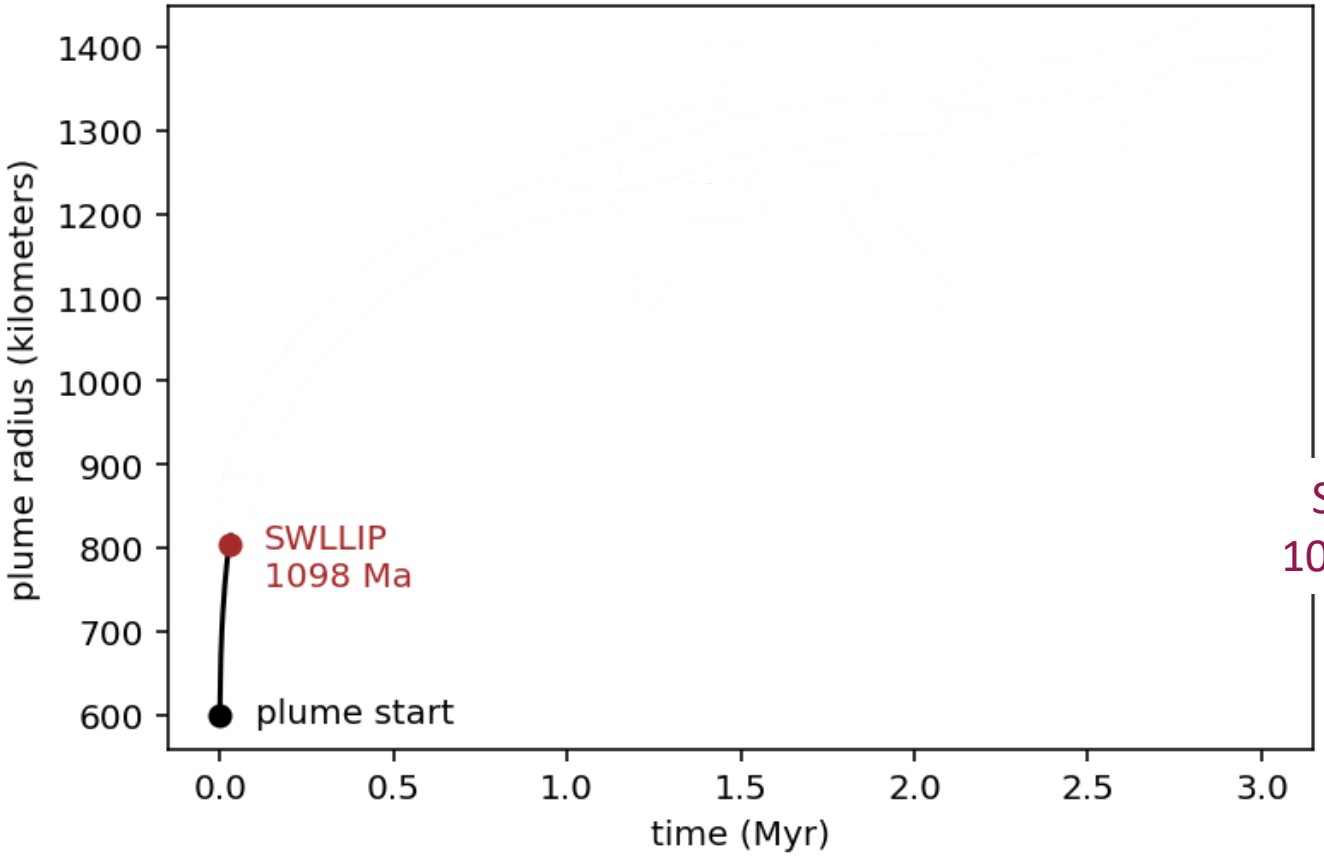
# Evaluating the Bifurcating Plume Theory




$$v \sim R(t) \sim t^{1/8}$$

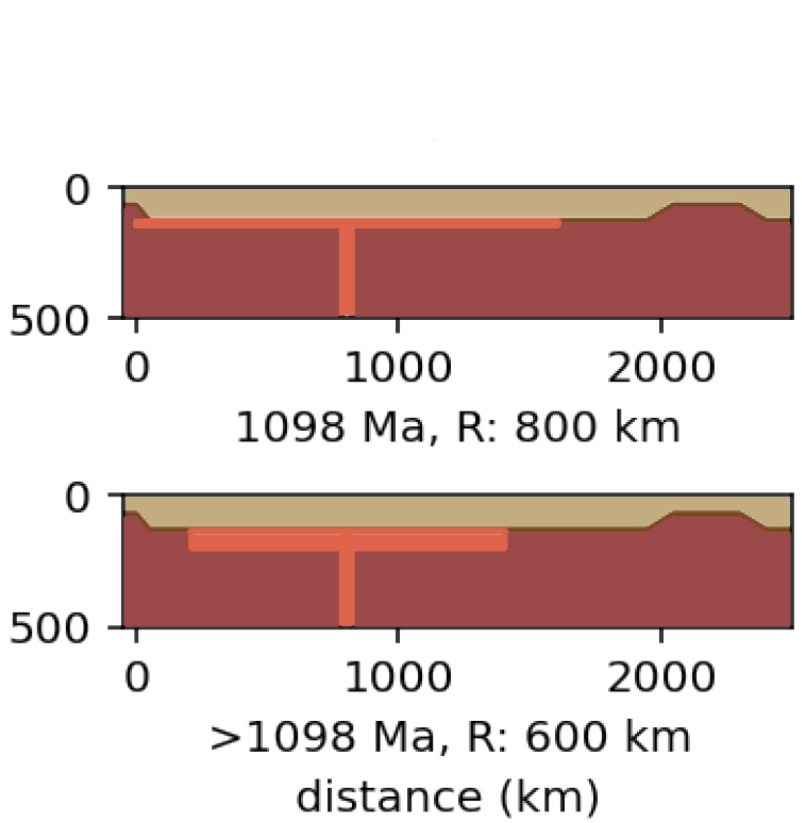


# Evaluating the Bifurcating Plume Theory




$$v \sim R(t) \sim t^{1/8}$$

SWLLIP
1098 Ma



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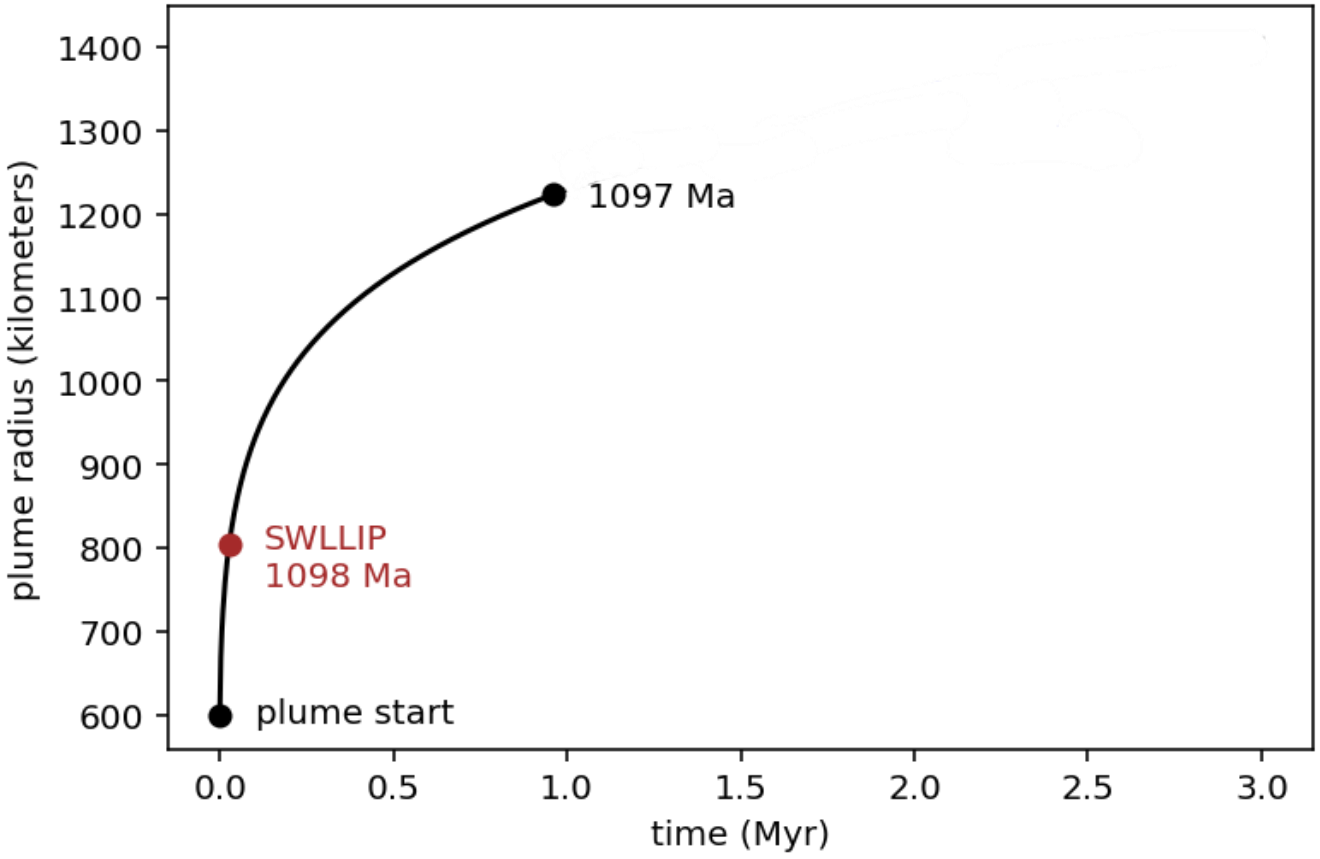
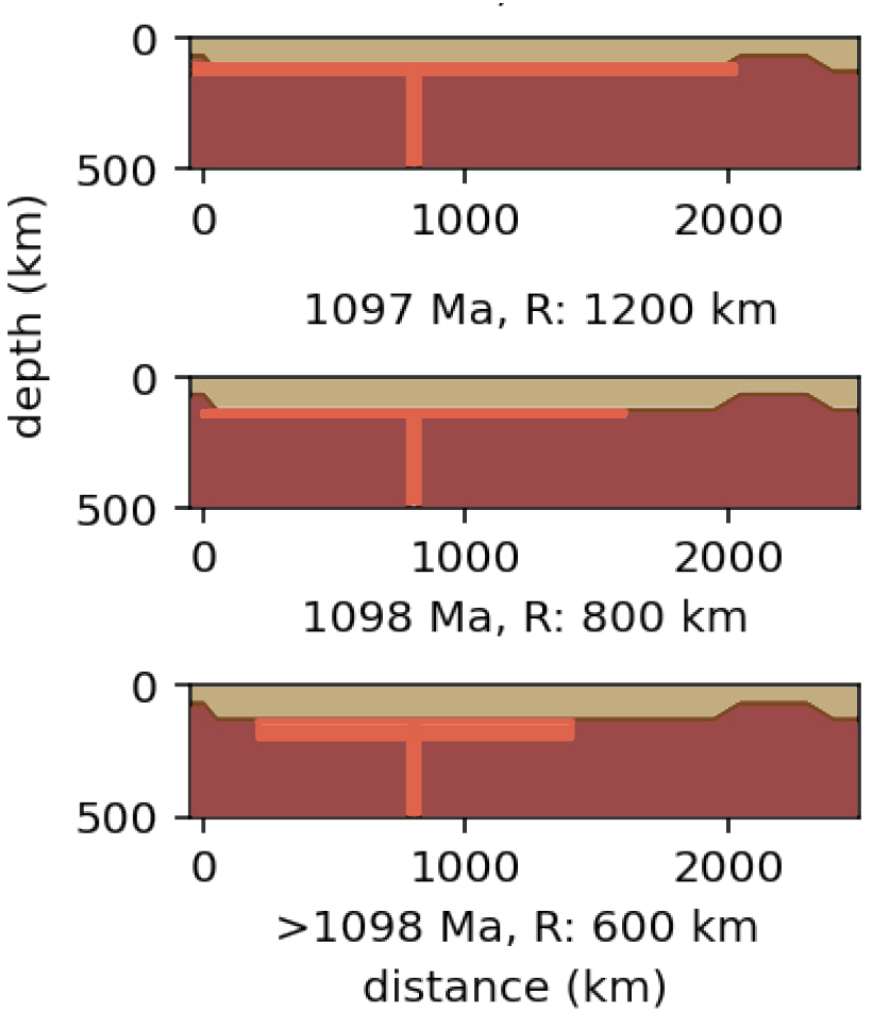



$$v \sim R(t) \sim t^{1/8}$$



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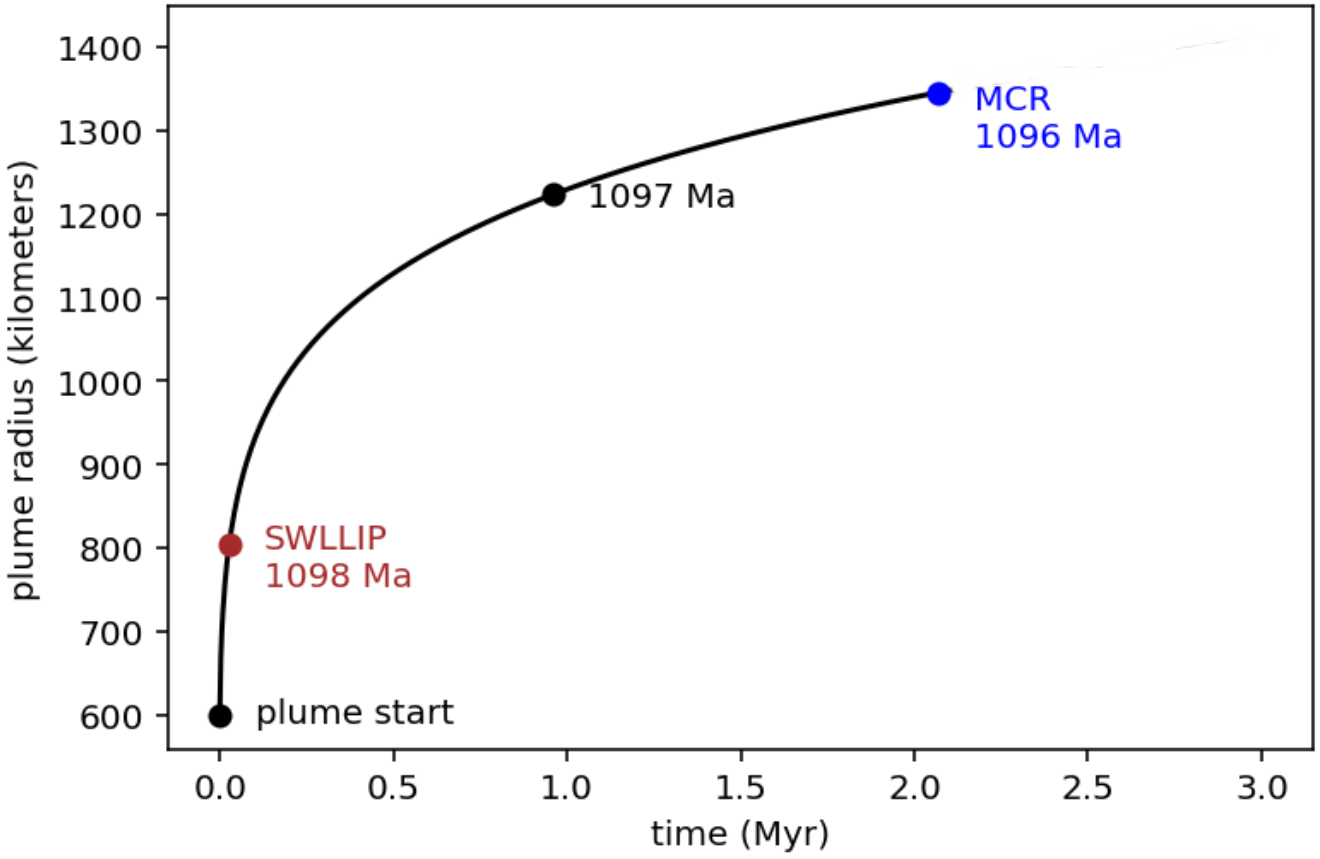
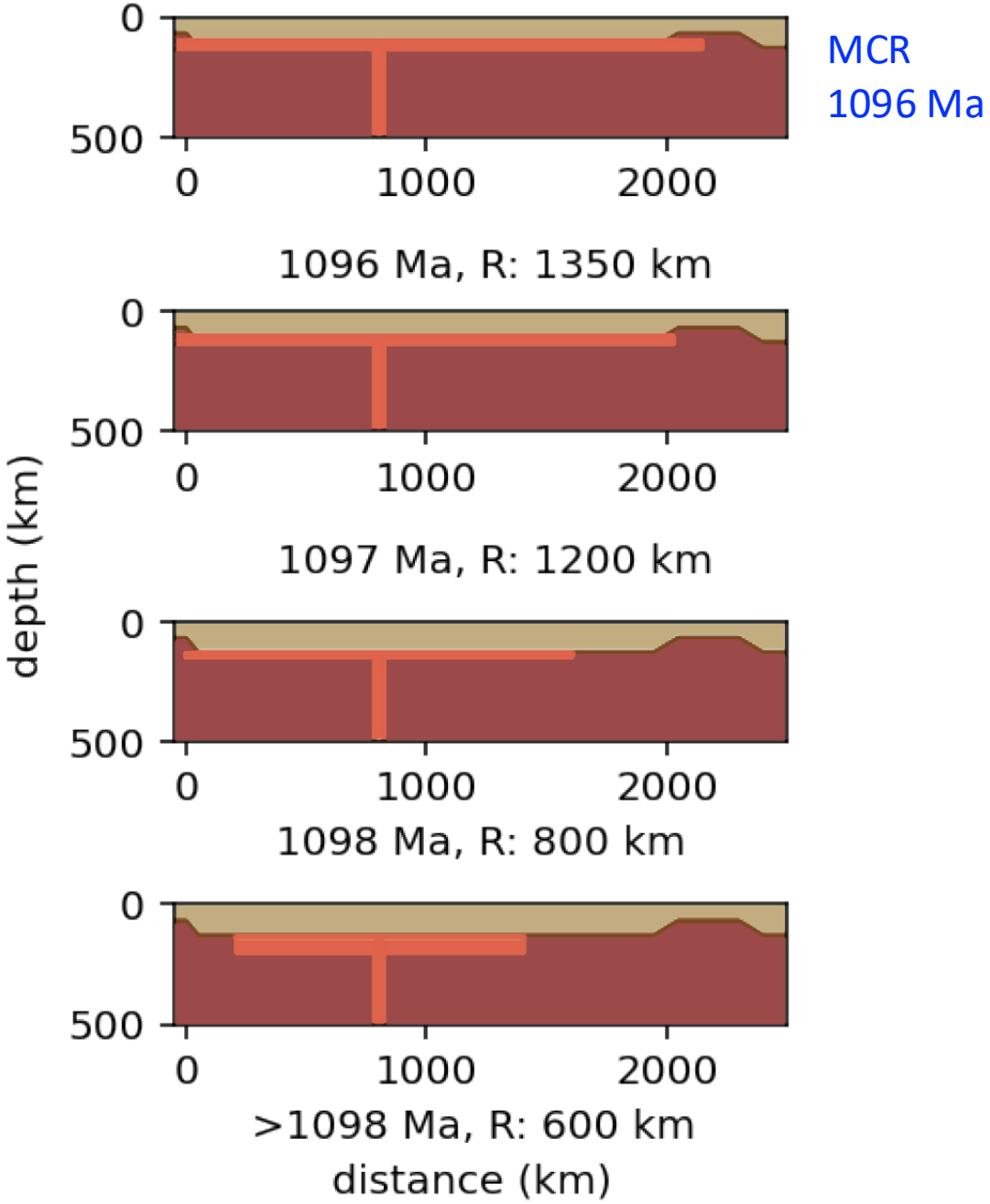
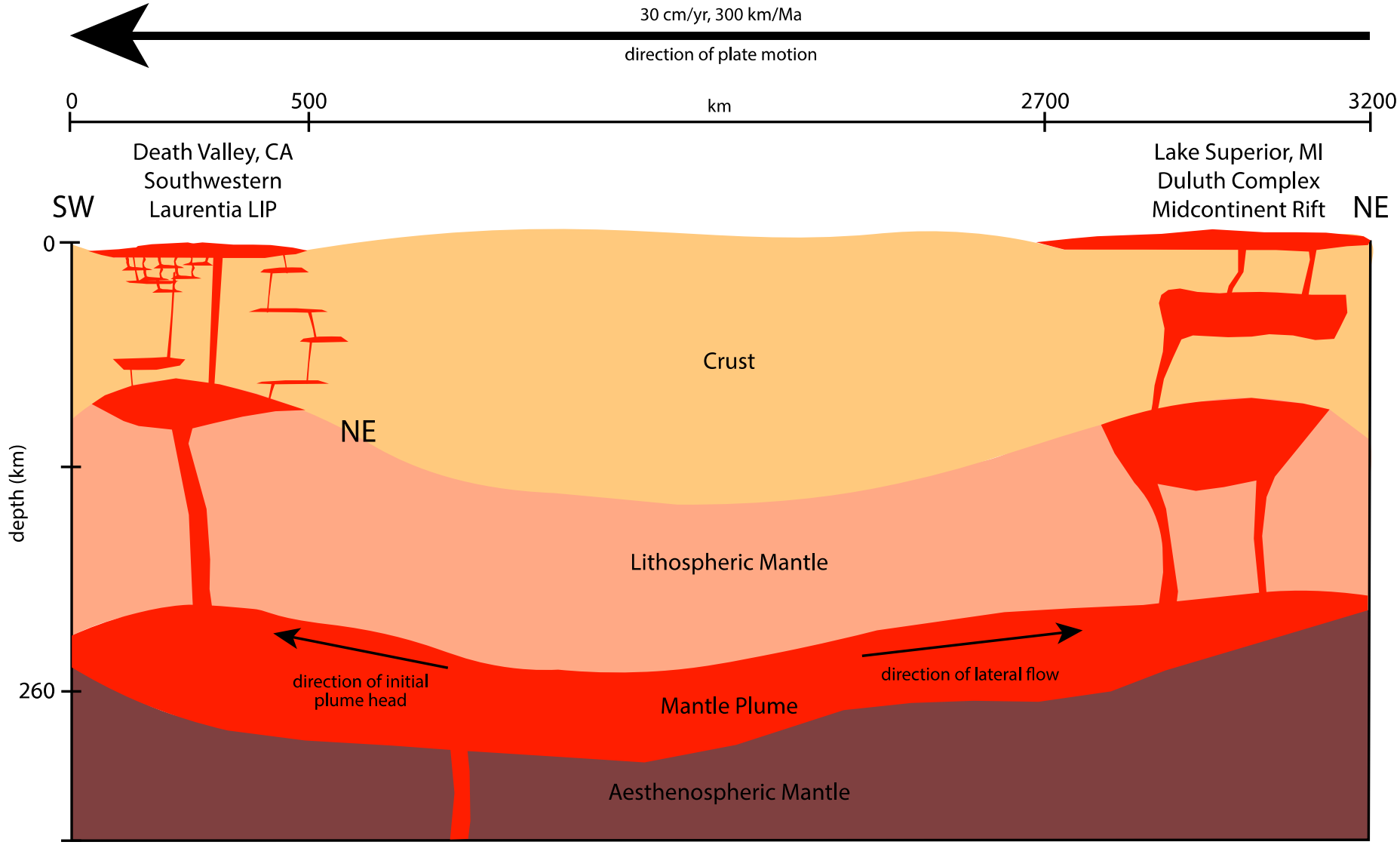



$$v \sim R(t) \sim t^{1/8}$$



# Schematic Bifurcating Plume Cross Section




Modified from Ernst 2014, Bright et al. 2014 and Zhang et al. 2019

# Issues with the bifurcating plume model

- Widespread intraplate magmatism seen before and after 1098 in SW Laurentia and 1096 Ma in Midcontinent Rift
- Geochemically the magmas differ
  Is 2 Ma differentiation + crustal assimilation enough?
- Laurentia is moving ~300 km/my SW
  Lack of a hotspot track
  Why would magma continuously pool in the same places?
- Other theories:
  lithospheric shearing of a fast-moving plate, dextral shearing,
  rift + back arc extension, lithospheric delamination

# Conclusions

- SW Laurentia LIP Crystal Springs Diabase is 1098 Ma
  1097.91 ± 0.29, 1098.09 ± 0.91, 1098.27 ± 0.27 Ma

- SW Laurentia LIP pulse at 1098 Ma may be related to 1096 Ma pulse at the Midcontinent Rift via bifurcating plume hypothesis but other mechanisms may be needed