New Kinematic Analysis of Late Pleistocene Faulting in the Blackfoot Rift Zone, Idaho

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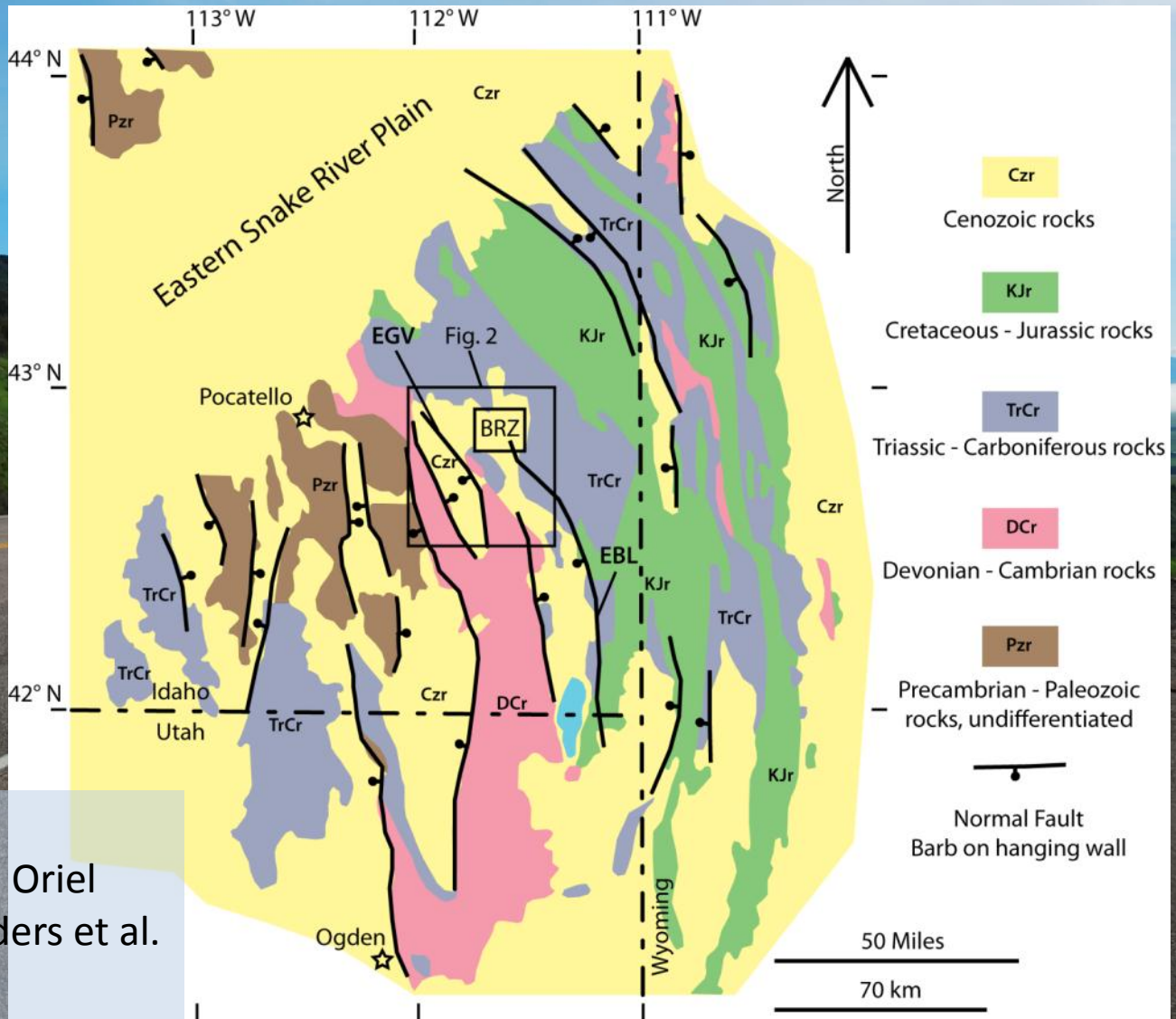
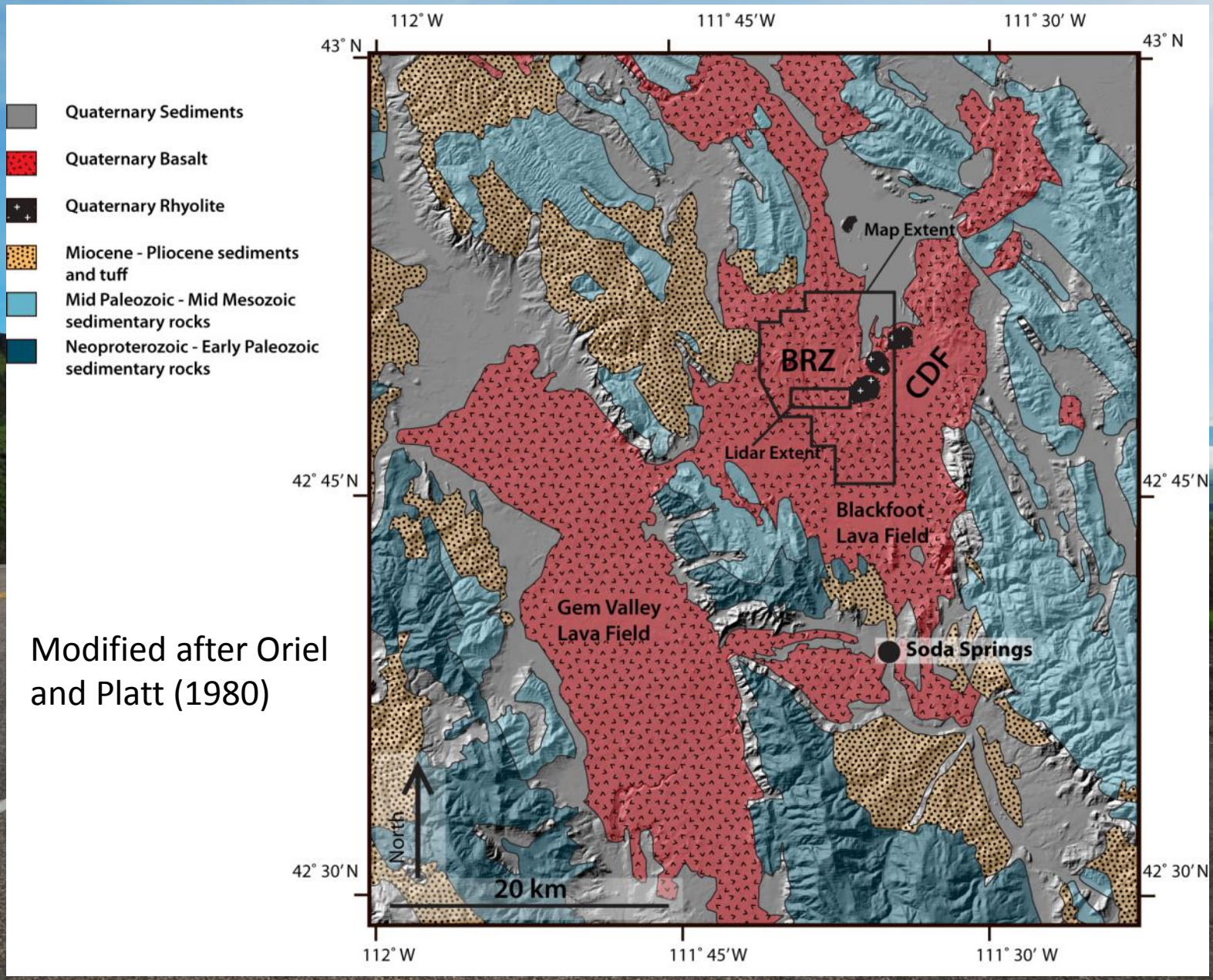
Cenozoic Extension in Southeast Idaho



Modified after Armstrong and Oriel (1965) and Anders et al. (1989)

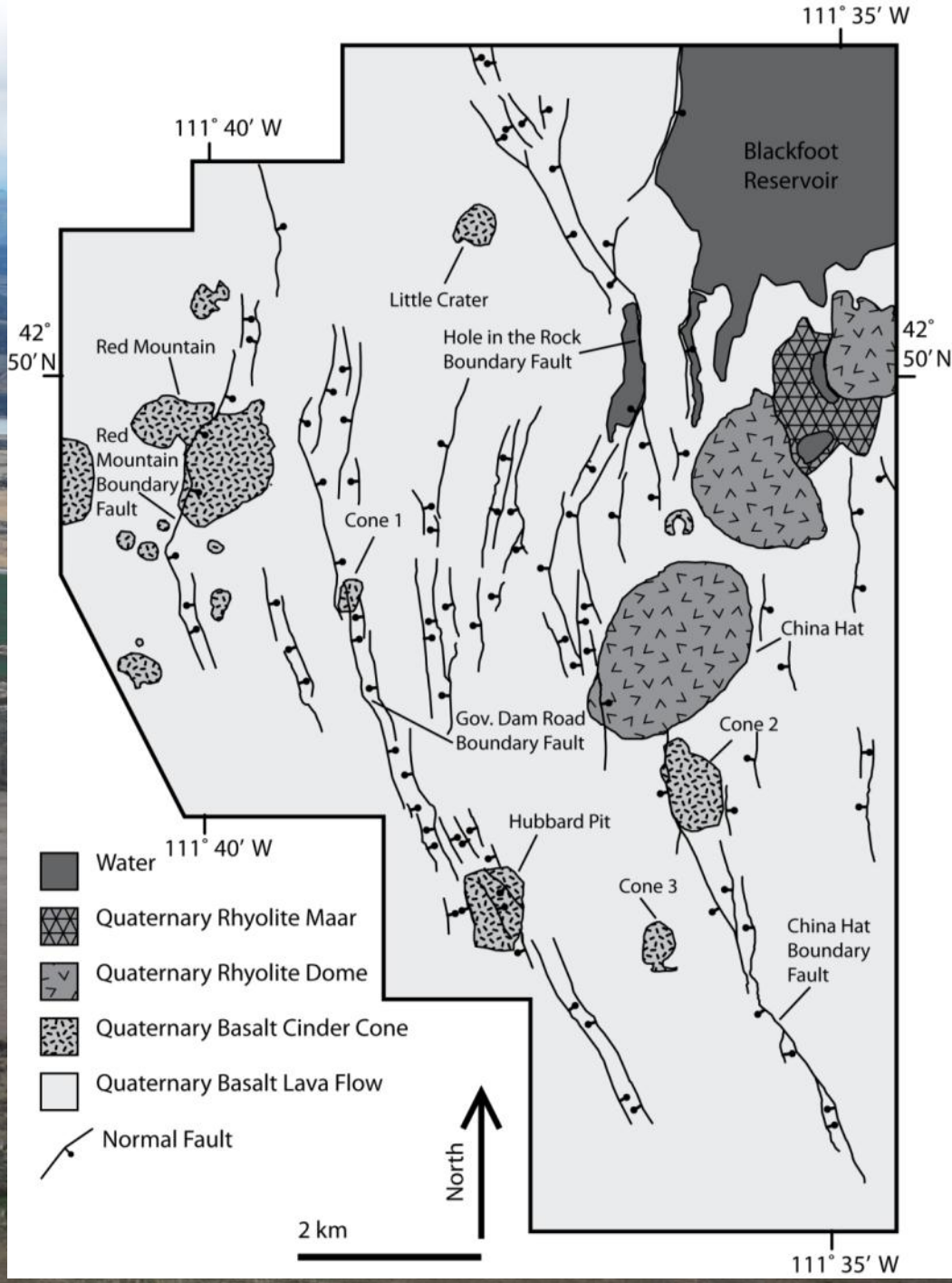
Local Geology

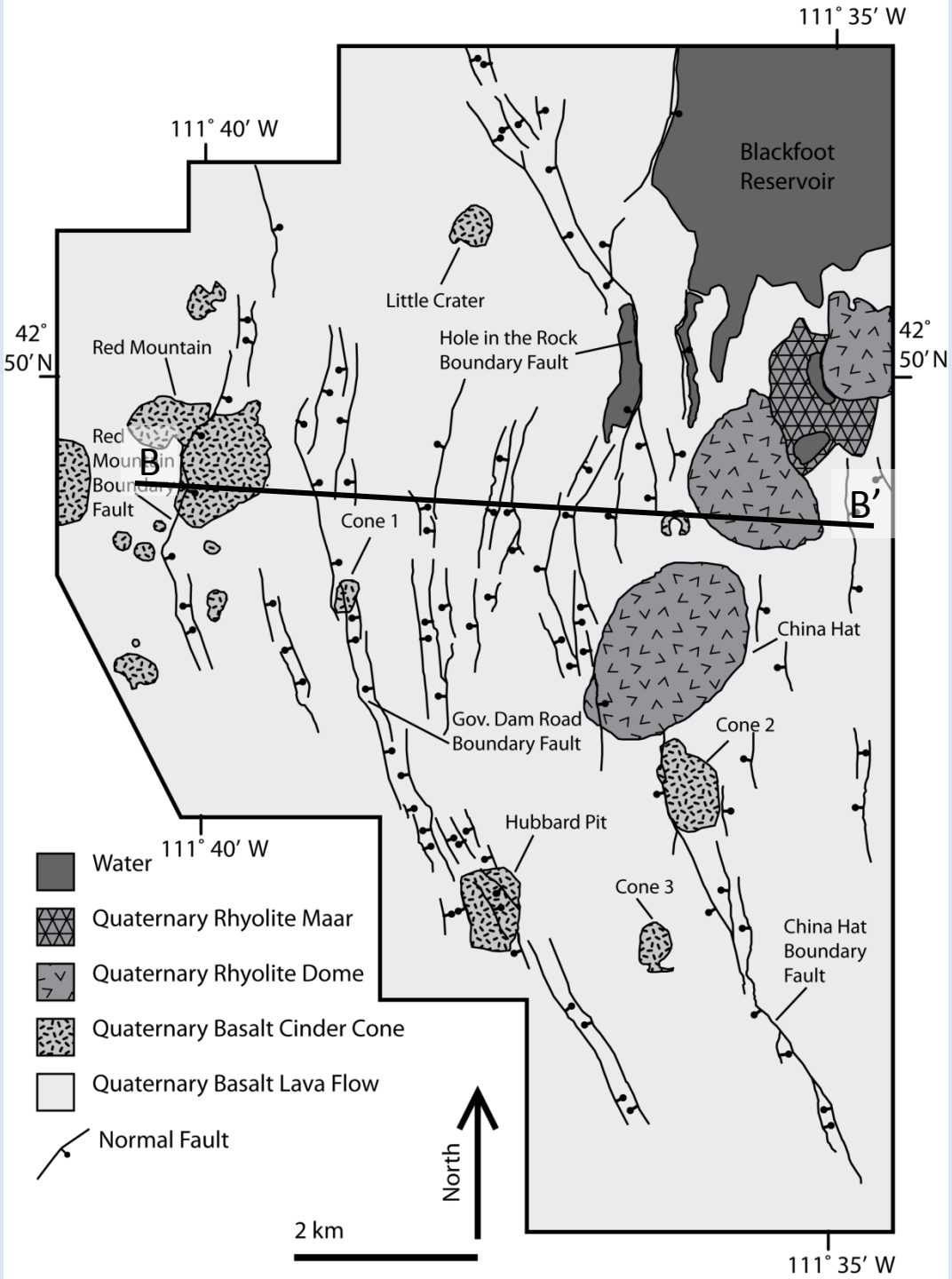


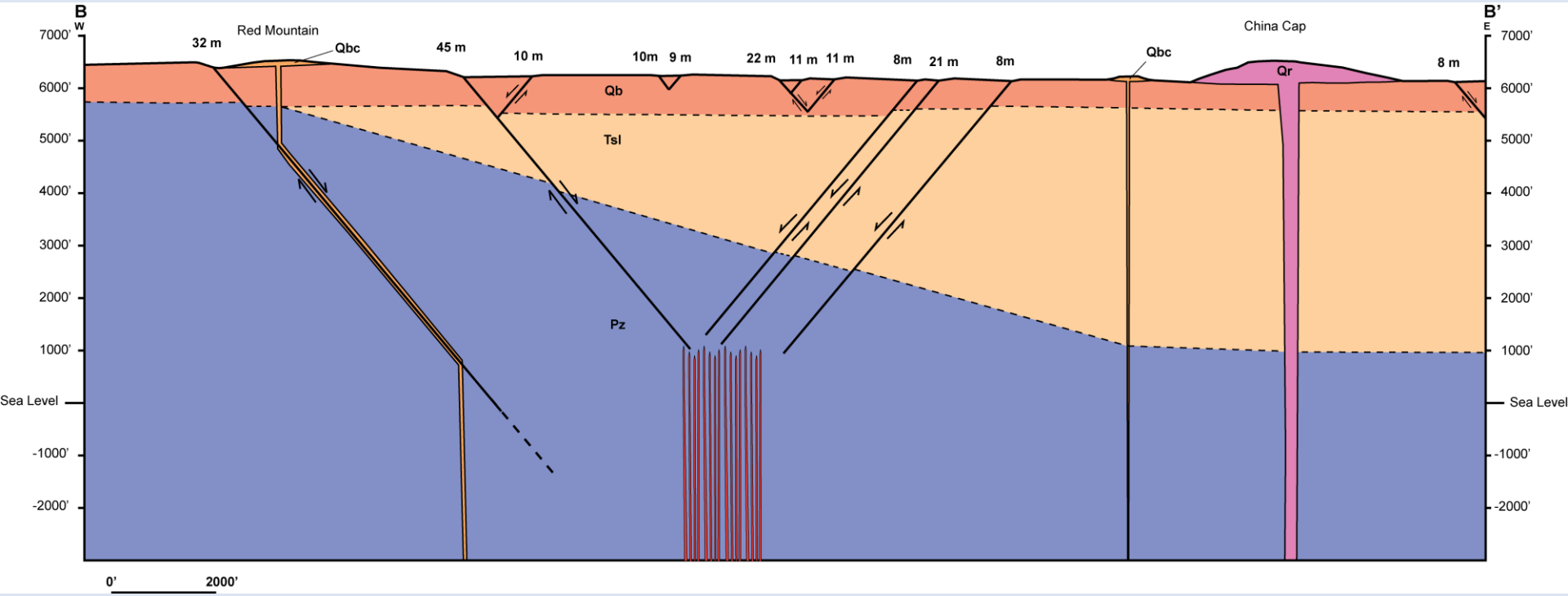
Modified after Oriel and Platt (1980)

The Blackfoot Rift Zone

- System of northwest – north striking graben forming normal faults
- Vertical offset of individual faults ranges from 5 – 50 m




111° 35′ W
111° 40′ W
Blackfoot Reservoir
Little Crater
42° 50′ N
Red Mountain
Hole in the Rock Boundary Fault
Red Mountain Boundary Fault
B
B′
Cone 1
China Hat
Gov. Dam Road Boundary Fault
Cone 2
Hubbard Pit
Cone 3
China Hat Boundary Fault
Water
Quaternary Rhyolite Maar
Quaternary Rhyolite Dome
Quaternary Basalt Cinder Cone
Quaternary Basalt Lava Flow
Normal Fault
North
2 km


B
W
B'
E
Red Mountain
China Cap
32 m
Qbc
45 m
10 m
10m
9 m
22 m
11 m
11 m
8m
21 m
8m
Qbc
Qr
8 m
Qb
Tsl
Pz
7000'
6000'
5000'
4000'
3000'
2000'
1000'
Sea Level
-1000'
-2000'
0'
2000'

Blackfoot Rift Zone: Age

- Faults in the BRZ are younger than:
  - Basalt lava flows (undated but normally magnetized; < 780 ka, Mabey and Oriel, 1970)
  - Basalt cinder cones (undated)
  - Rhyolite lava dome (58 ± 7 ka; Heumann, 2004)
- Faults in the BRZ are older than:
  - Rhyolite lava dome (58 ± 7 ka; Heumann, 2004)
  - Loess? (<58 ka, Pierce et al., 1982)

Research Questions

1. Did dike injection within the Blackfoot Rift Zone accommodate a significant amount of regional extension in the late Pleistocene?

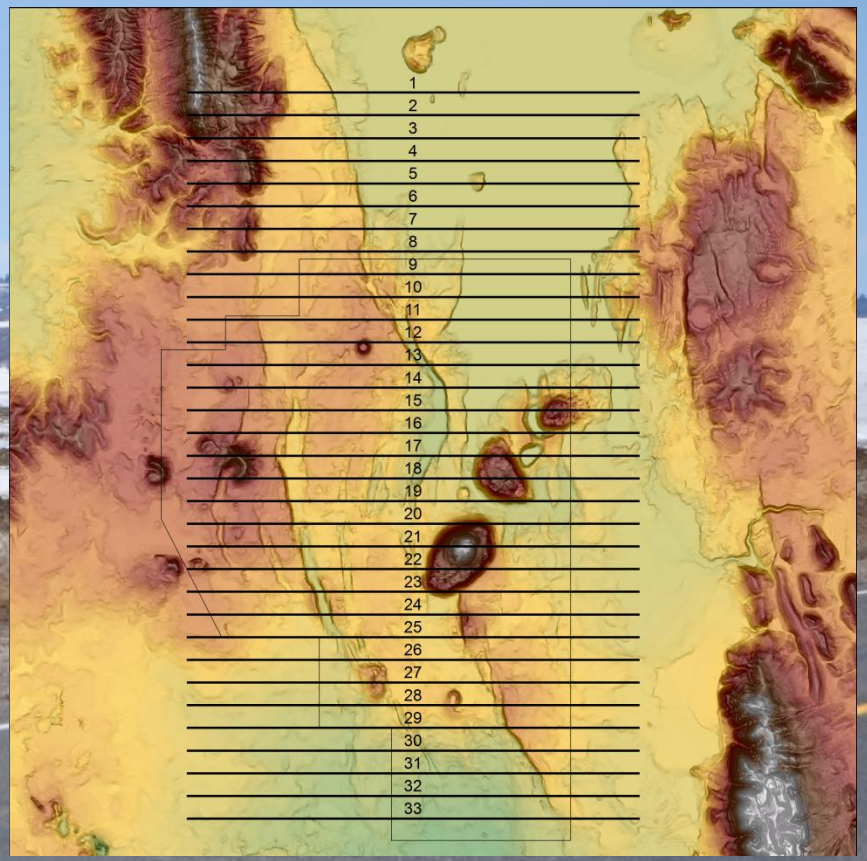
2. Was the eruption of rhyolites forming in the CDF structurally controlled by activity in the BRZ?

Kinematic Analysis: Approach

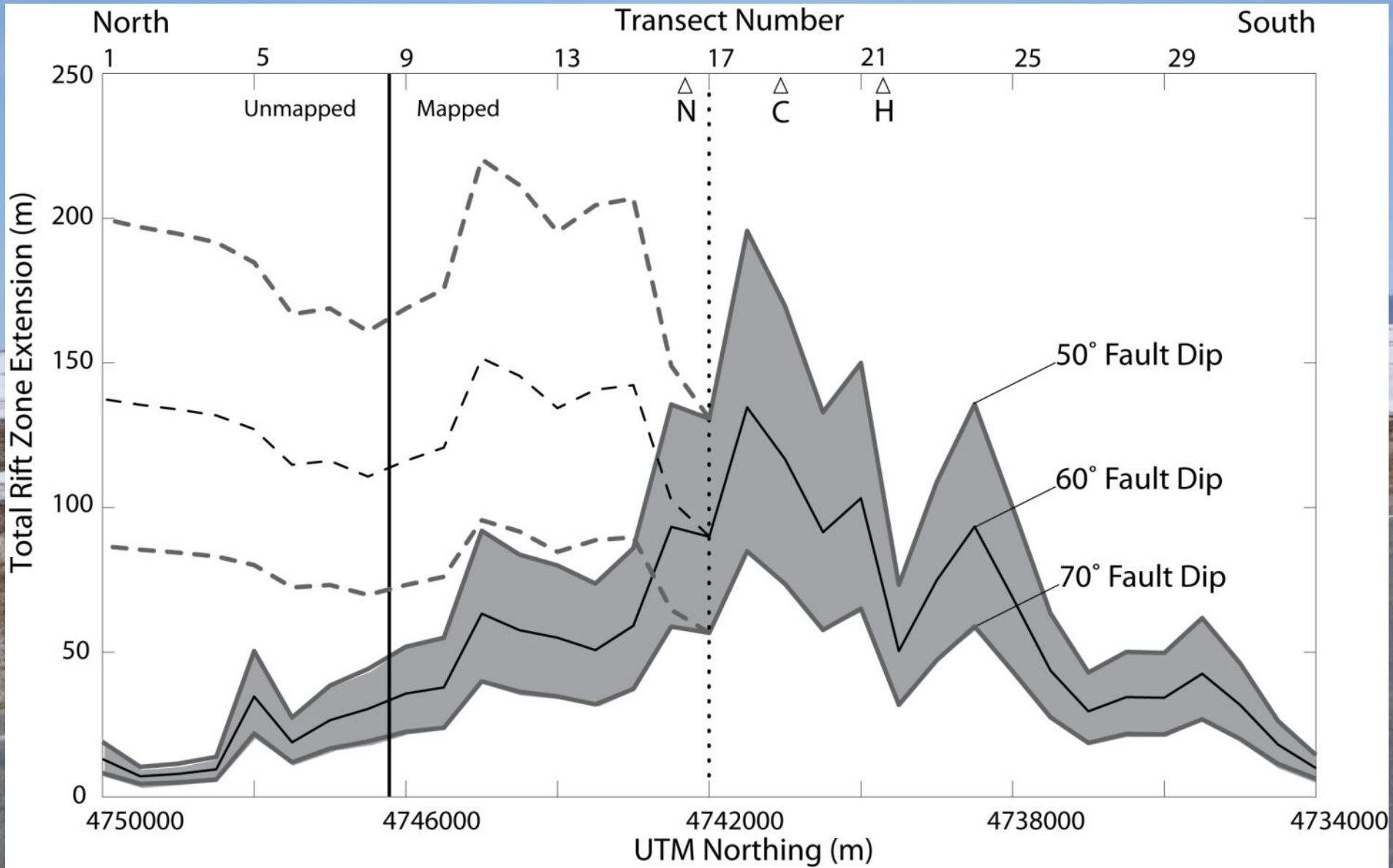
- Find vertical offset (throw) for each fault along each of 33 E-W transects
- Given an assumed fault dip (θ), calculate horizontal extension as

$$E = \frac{\text{throw}}{\tan(\Theta)}$$

- Find cumulative extension for each transect



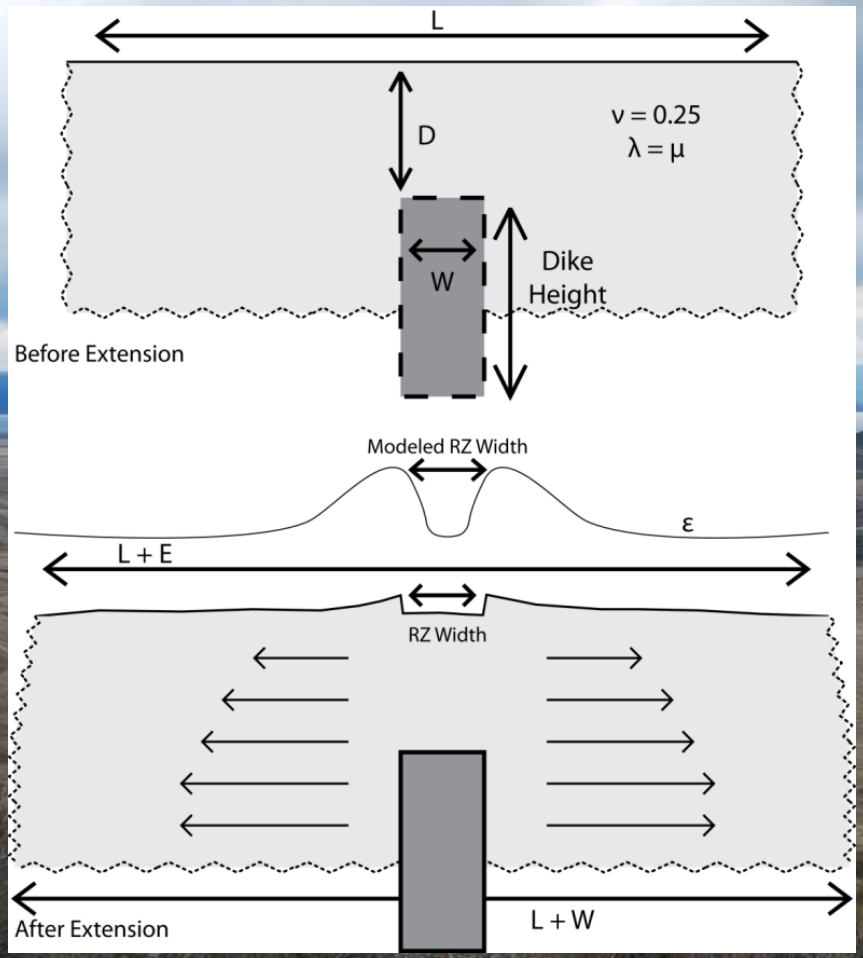
East Directed Surface Extension



Modeling: Approach

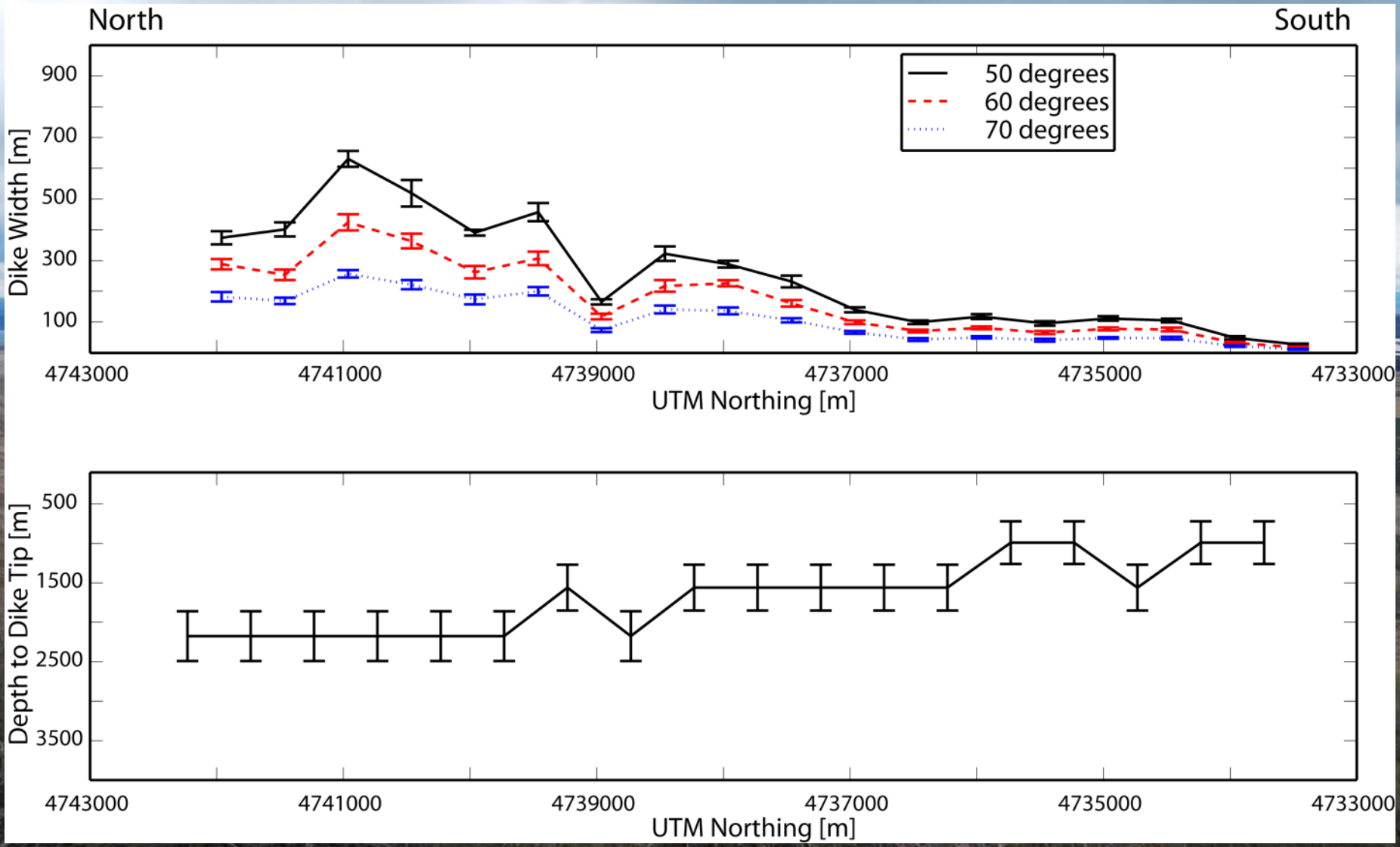
- Invert dike geometry using Okada's (1985) closed solutions for surface deformation related to the opening of a rectangular dike at depth
- Relate rift zone width to dike depth and relate surface extension to dike width
- Dikes are assumed to have been emplaced as a rectangular swarm at roughly the same time

Modeling: Conceptual Model



- Known: E, RZ Width
- Modeled: D, W
- Model Outputs: E, ε, Modeled RZ Width
- Assumed: L, ν, λ, μ, Dike Height

Modeling: Results



Discussion: Regional Tectonics

- Kinematic analysis of faulting indicates a maximum of 75 – 200 m extension at the surface
- Inversion of surface extension data indicates a maximum emplaced dike width of 200 – 600 m
- Strain rates were calculated given:
  - This extension occurred over 25 km of valley floor
  - Most conservative duration estimate of 750 ka

Discussion: Regional Tectonics

- BRZ minimum strain rates:
  - Surface: 1.3 – 3.4 x 10^{-16} s^{-1}
  - Subsurface: 3.4 – 10.2 x 10^{-16} s^{-1}

Region	Type	Extension Rate (mm/yr)	Strain Rate (s^{-1})	Distance (km)	Source
Southern Arm of the Tectonic Parabola: Southeast Idaho and Western Wyoming					
Soda Springs	Seismic	0.12	$2.7x10^{-17}$	140	1
Soda Springs	Geological	0.14	$3.8x10^{-17}$	120	1
Western Wyoming	Seismic	0.07	$1.4x10^{-17}$	160	1
Western. Wyoming	Geological	0.74	$2.9x10^{-16}$	80	1
Northern Arm of the Tectonic Parabola: Central Idaho / North Basin and Range					
Central Idaho	Geodetic	2.13	$1.78x10^{-16}$	380	2
Lost River Range	Geological	0.27	$2.90x10^{-16}$	27	3
Central Idaho	Seismic	2.0	$3.3x10^{-16}$	200	1
Central Idaho	Geological	0.08	$1.3x10^{-17}$	200	1

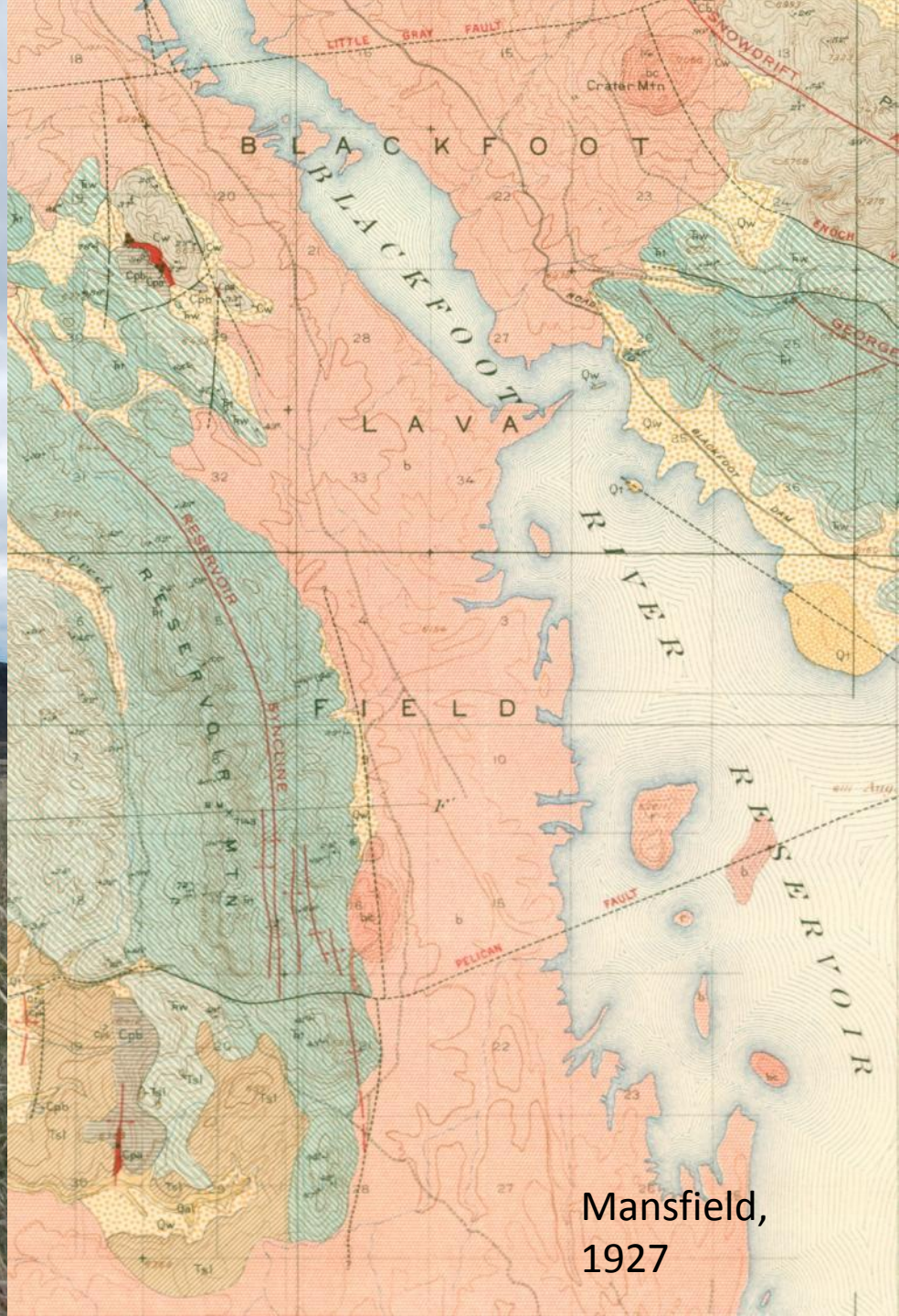
References: **1**: Eddington et al., 1987; **2**: Payne et al., 2008; **3**: Parsons et al., 1998

Discussion: CDF Eruption

- The domes of the CDF correlate with the maximum amount of E-W surface extension in the BRZ
- However, there are no indications of extension directed perpendicular to the CDF trend
- Thus, there is no direct evidence for a structural control for eruption of the CDF

CDF Eruption

- Alternatively, the CDF could have a structural control from preexisting Cenozoic normal faults
- Magma might preferentially use one of these faults to reach the surface, assisted by oblique extension associated with the BRZ



Mansfield, 1927

Conclusions

- The BRZ is a volcanic rift, recording ~75 – 200 m of surface extension in the late Pleistocene
- Simple elastic models indicate that a maximum of ~ 200 – 600 m dike width is emplaced at a depth of 2000 – 1000 m beneath the BRZ
- Even assuming the most conservative timing constraints, strain rates calculated for the BRZ are great enough to have accommodated most to all accumulated regional strain
- The CDF does not appear to be structurally controlled by activity in the BRZ
  - However, pre-existing structures may have been reactivated in relation to BRZ activity to bring rhyolites to the surface