Origins and Strength of the Proto-Kern Canyon Fault, Sierra Nevada Batholith, and implications for the strength of continental lithosphere along a long-lived transpressional fault

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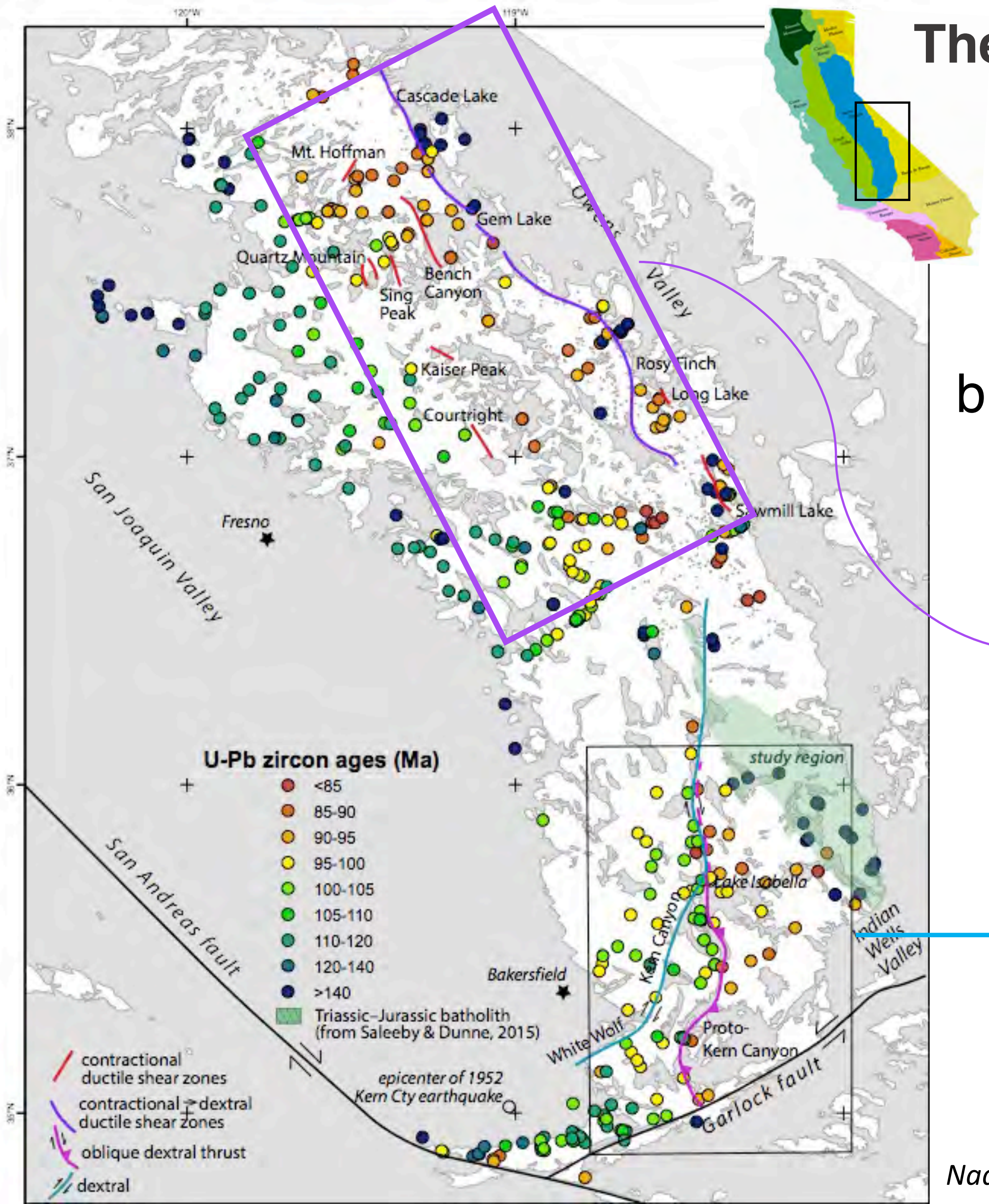
Discussion section: questions on shear zones that arose during this year's Structural Geology & Tectonics Forum

There are lots of preserved shear zones in the central and southern SNB

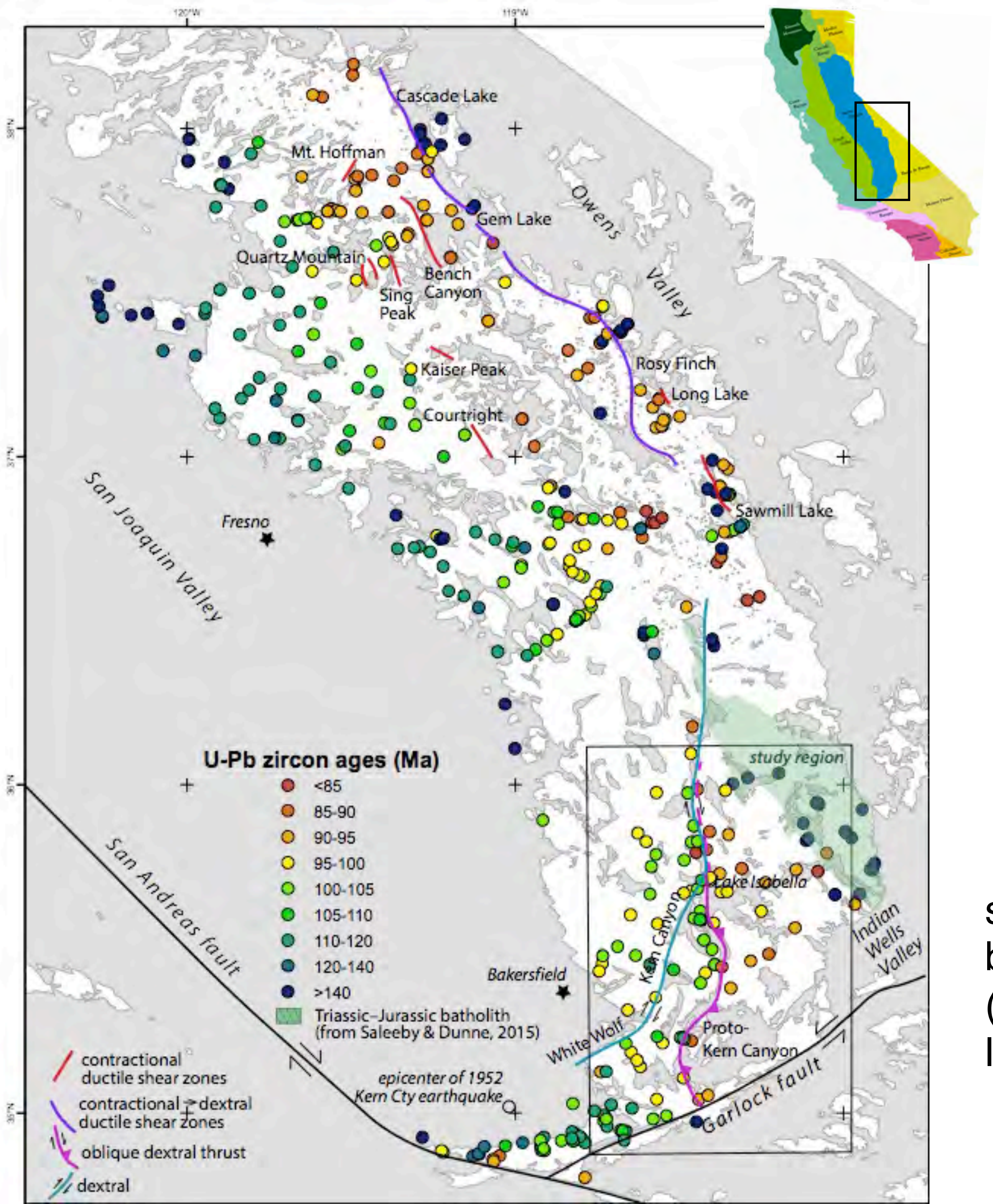


Intra-arc deformation recorded by 14 mapped discrete ductile and ductile-brittle shear zones that are preserved at plutonic levels

Well studied: timing, sense of motion, P/T conditions, rock fabrics

New/in progress: timing, deformation conditions, stress/strain estimates

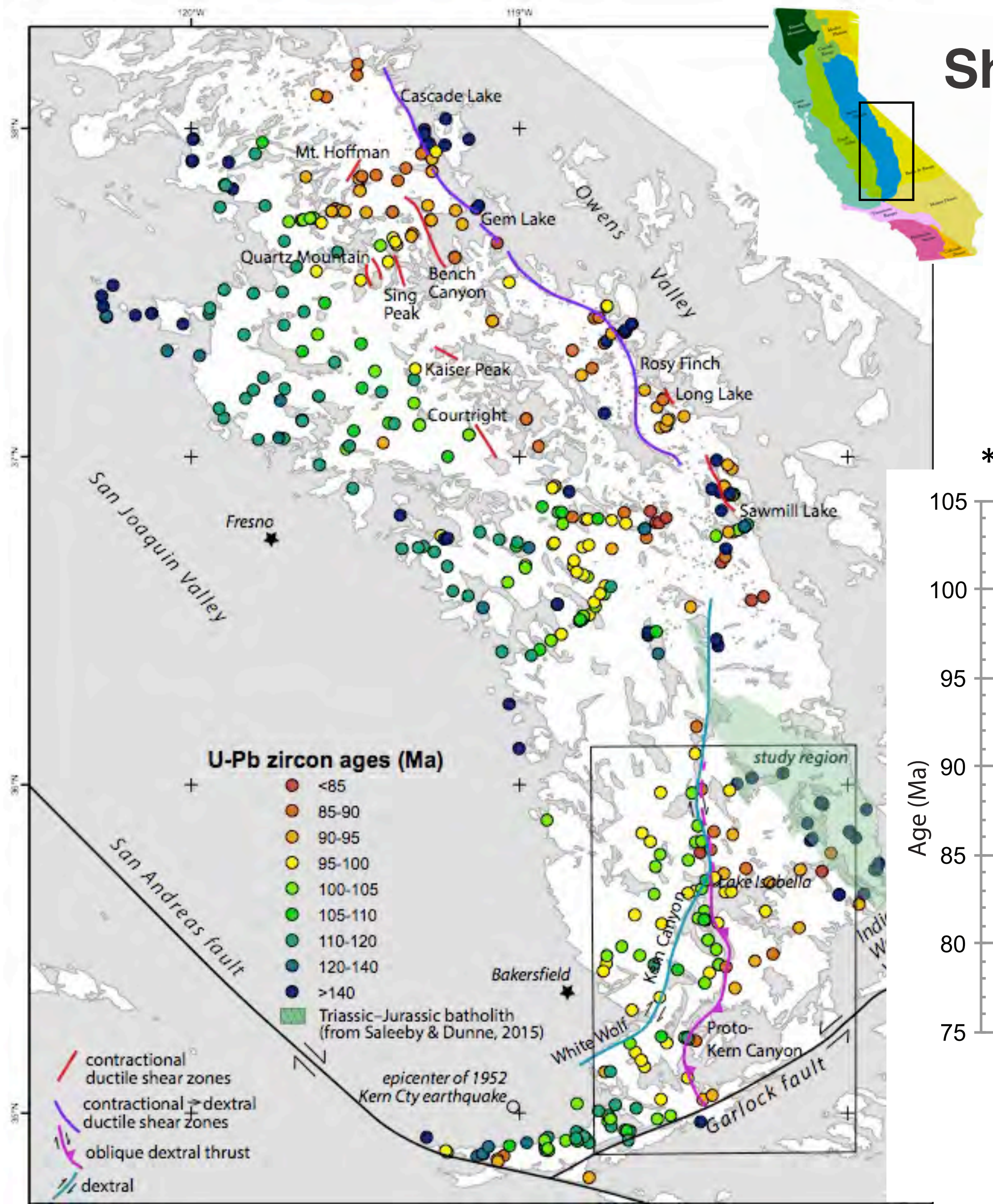
Nadin et al., 2016



Shear zones follow age gradients

Located between
older/colder (>100 Ma) and
younger/hotter (<95 Ma)
sections of the batholith

strong horizontal thermal gradients developed between longitudinal age zones of the batholith (Barton & Hanson, 1989) --> ideal for strain localization



Shear zones young from west to east

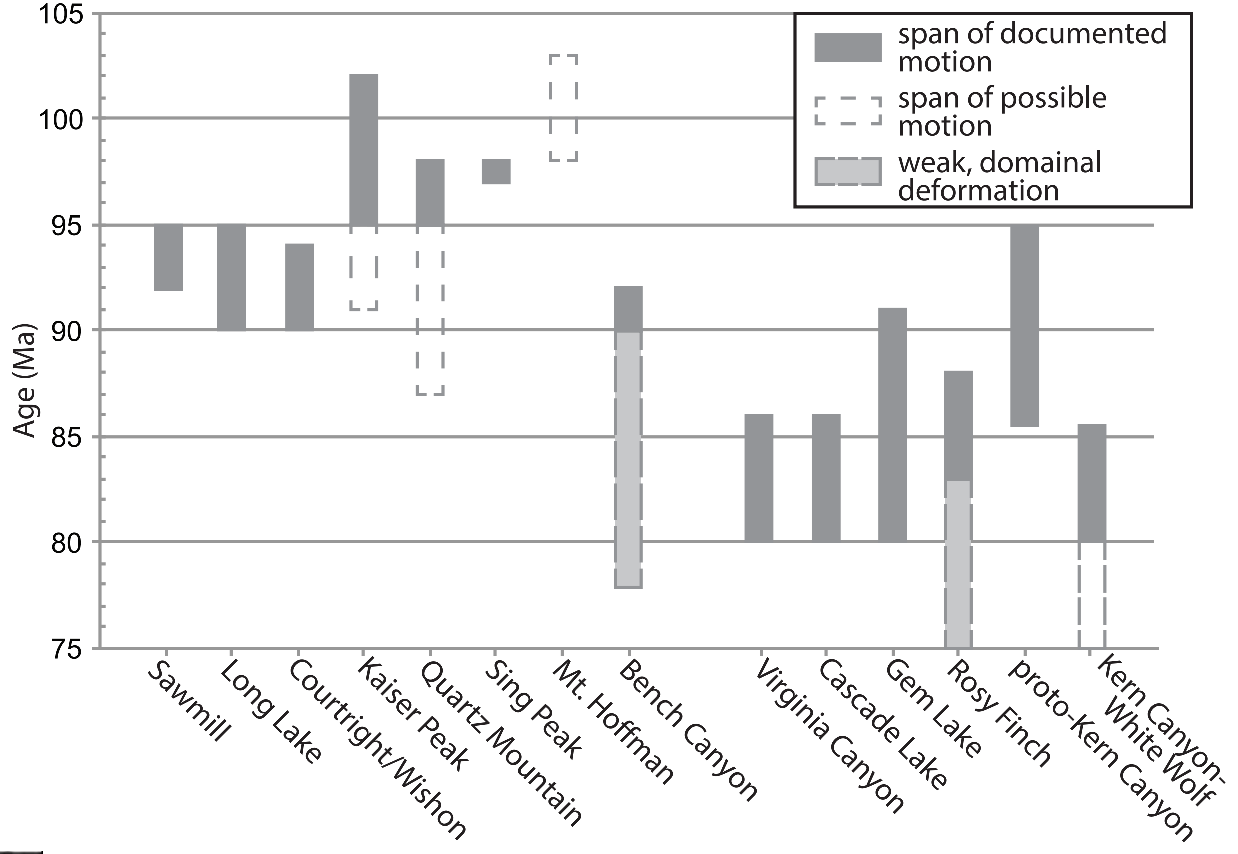
deformation style changes from north to south*

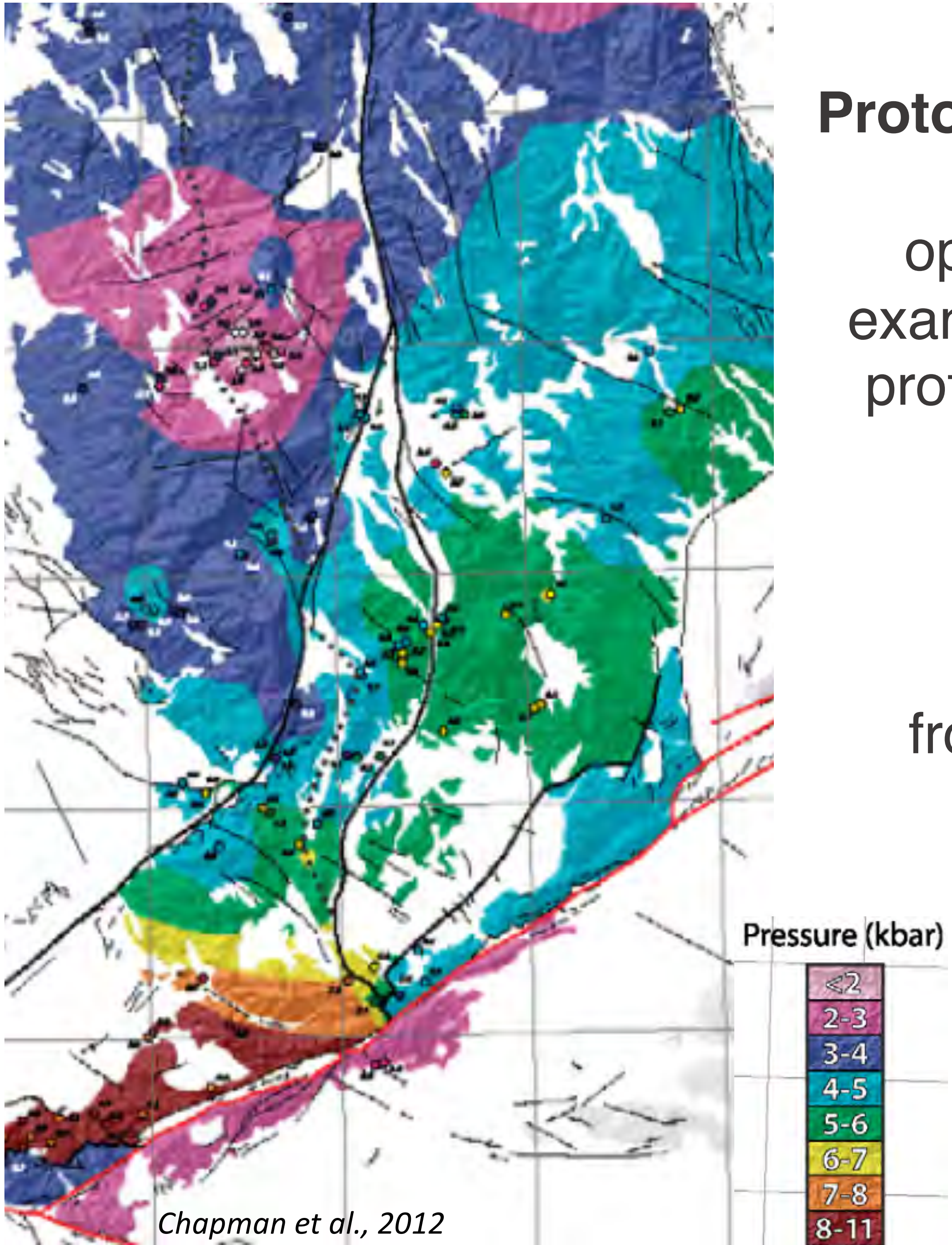
Contractional

Contractional→dextral

Dextral

*or at least it seems south is different from central

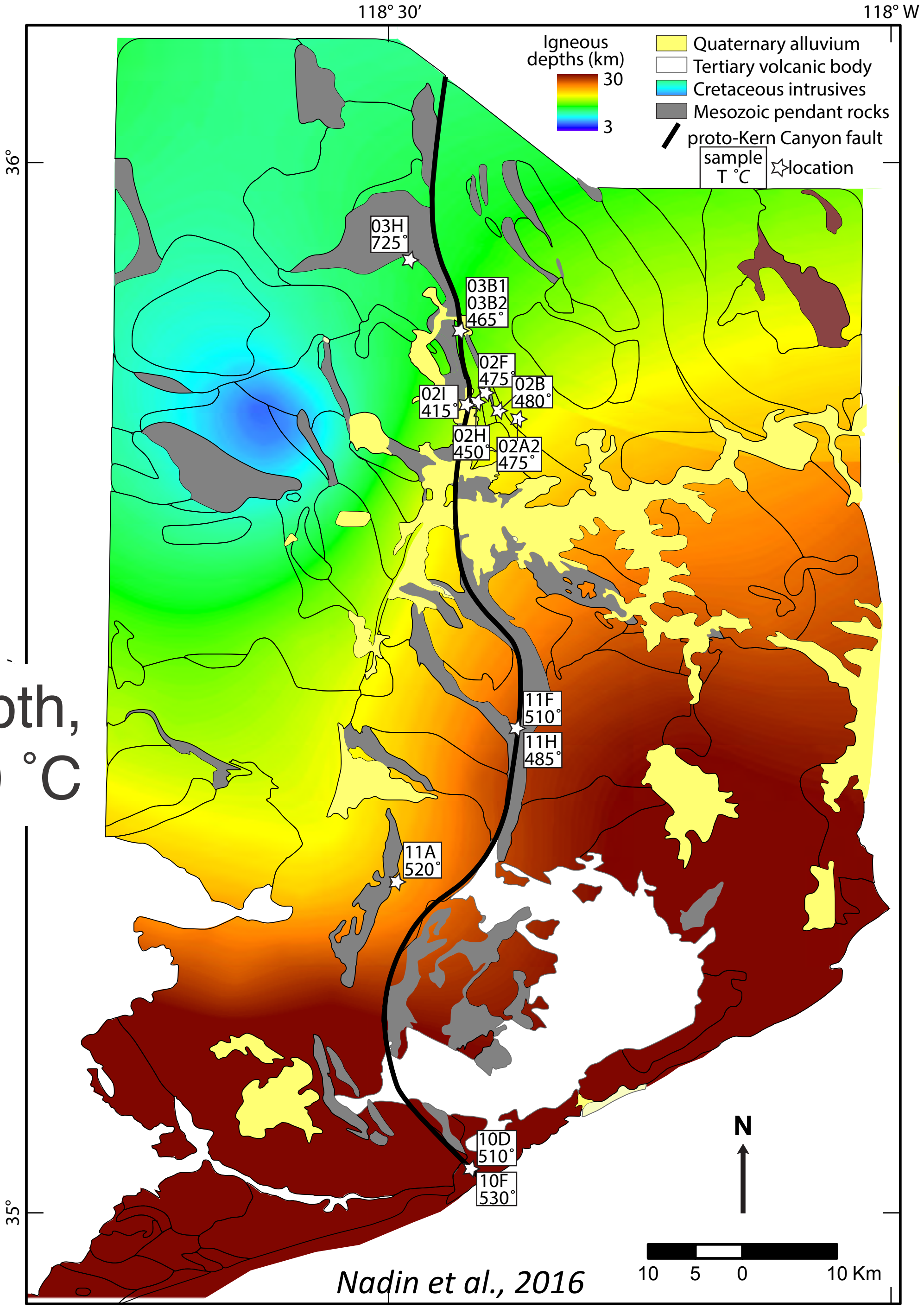




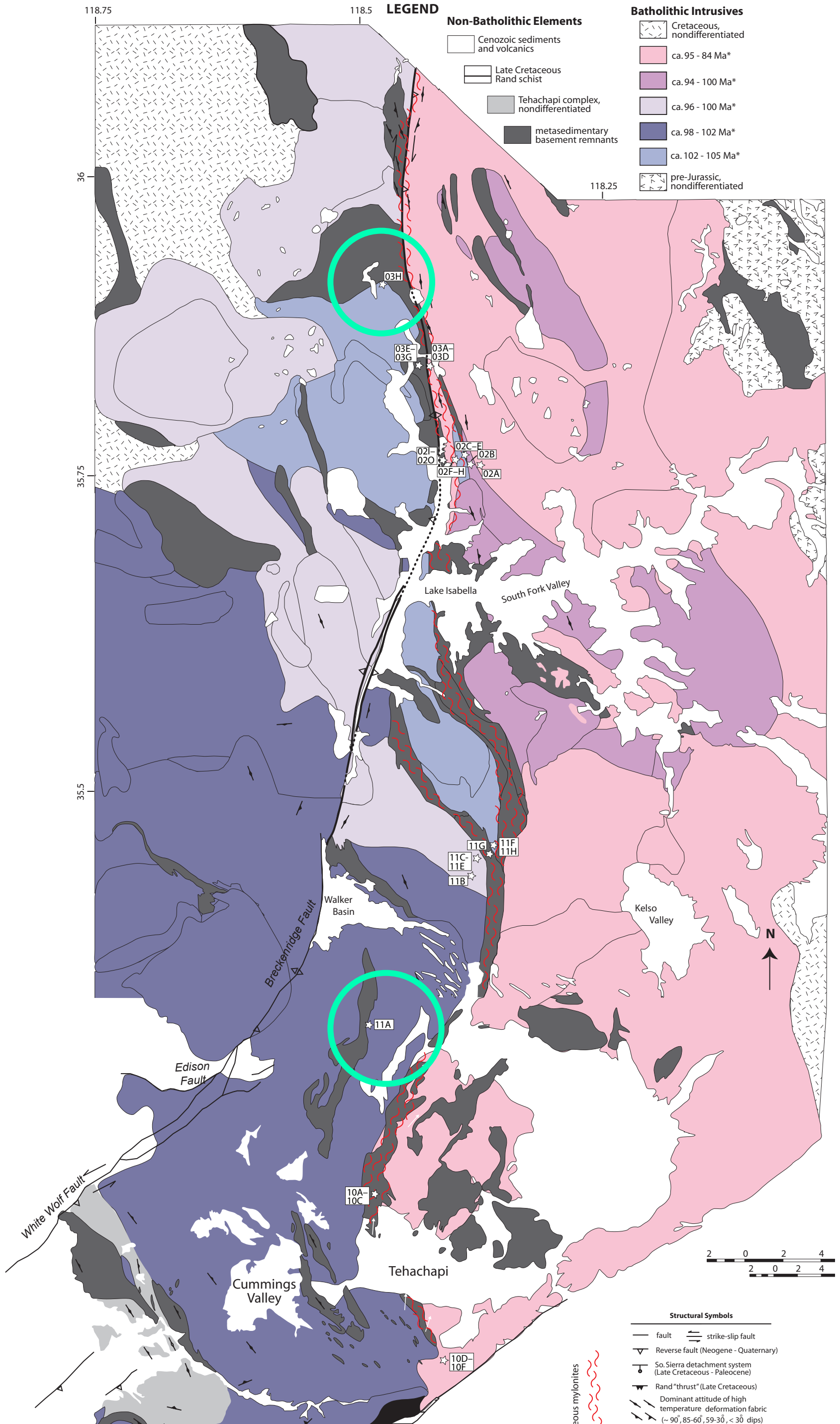
Proto-Kern Canyon Fault:

opportunity to examine a vertical profile of a shear zone

T varies with depth, from ~415 to ~530 ˚C



Pole plots are of quartz c axes, lower hemisphere

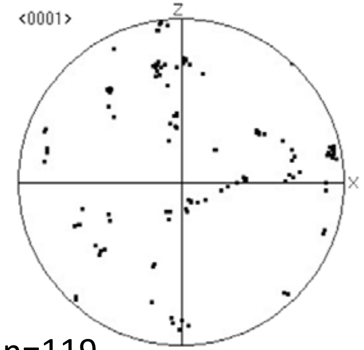


Pre-faulting pluton (102 Ma)

Quartz axes = random

T ~725 ˚C (TitaniQ)

P ~3.5 kbar (~11 km) (Al-in-hbl)



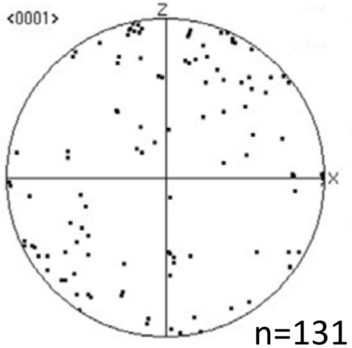
n=119

Pre-faulting pluton (102 Ma)

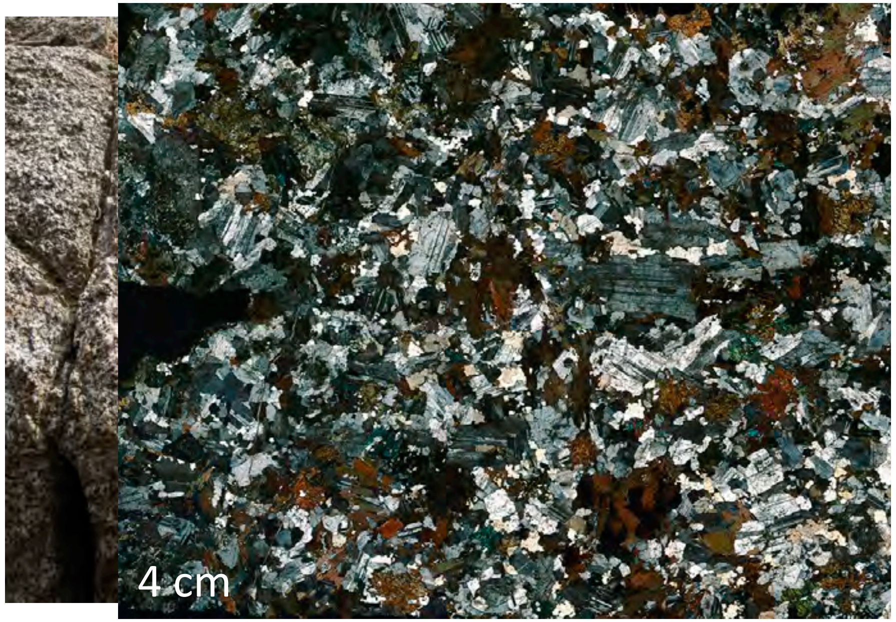
Quartz axes = random

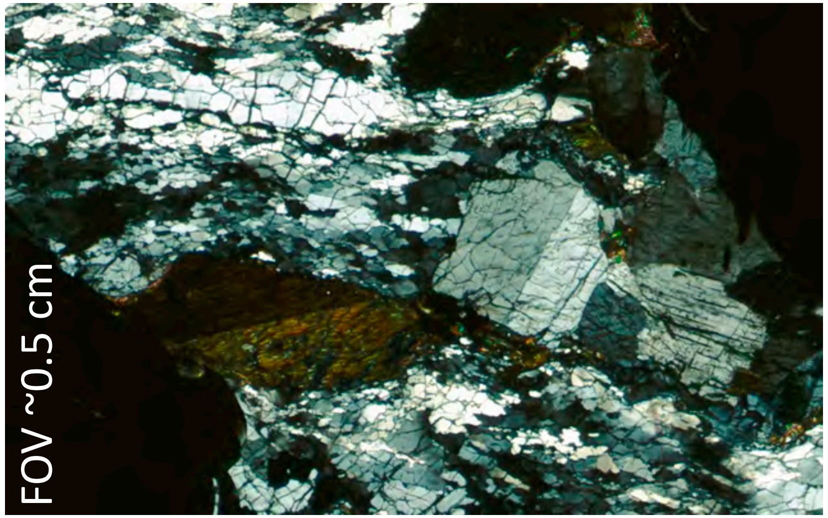
T ~520 ˚C (TitaniQ)

P ~4 kbar (~13 km) (Al-in-hbl)

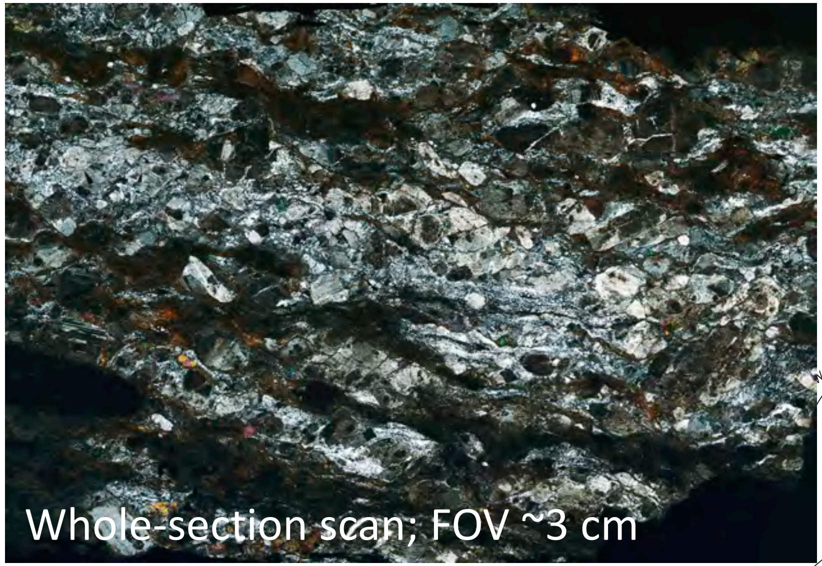


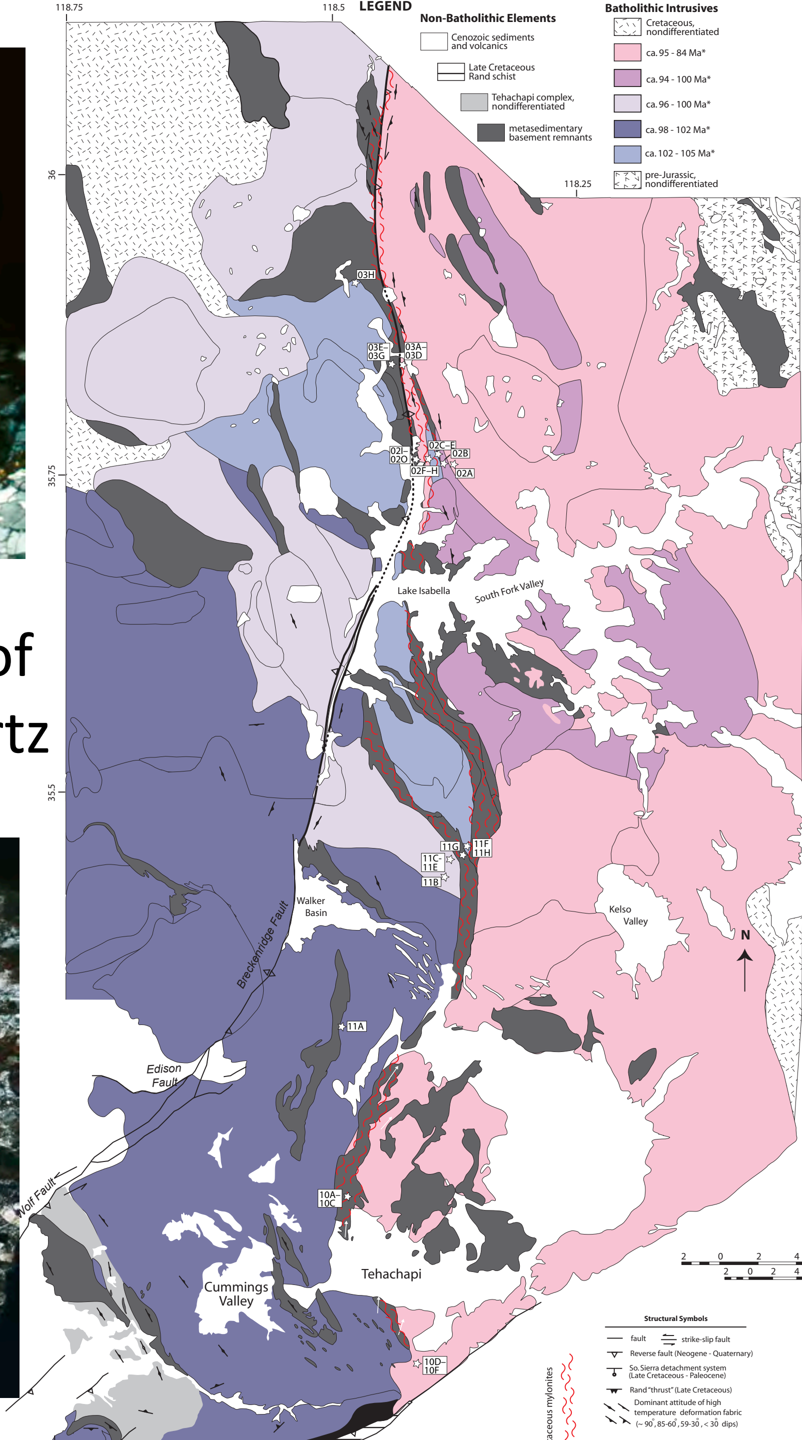
n=131



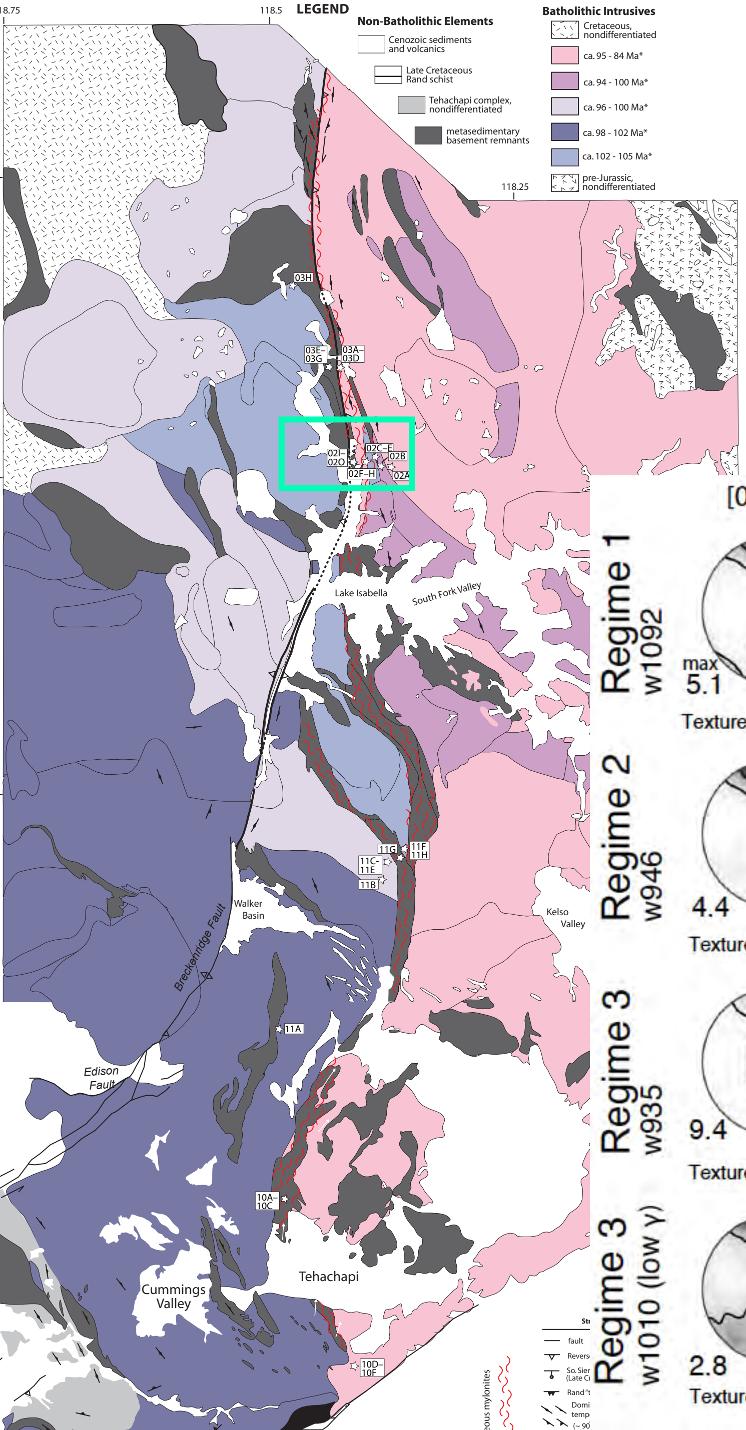


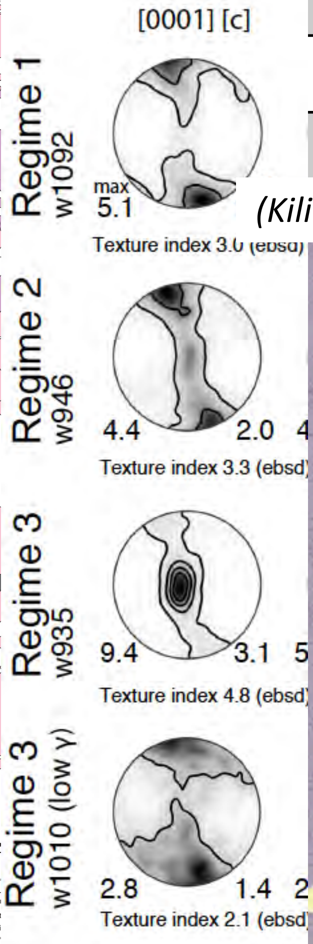
EBSD: measured single grains of dynamically recrystallized quartz



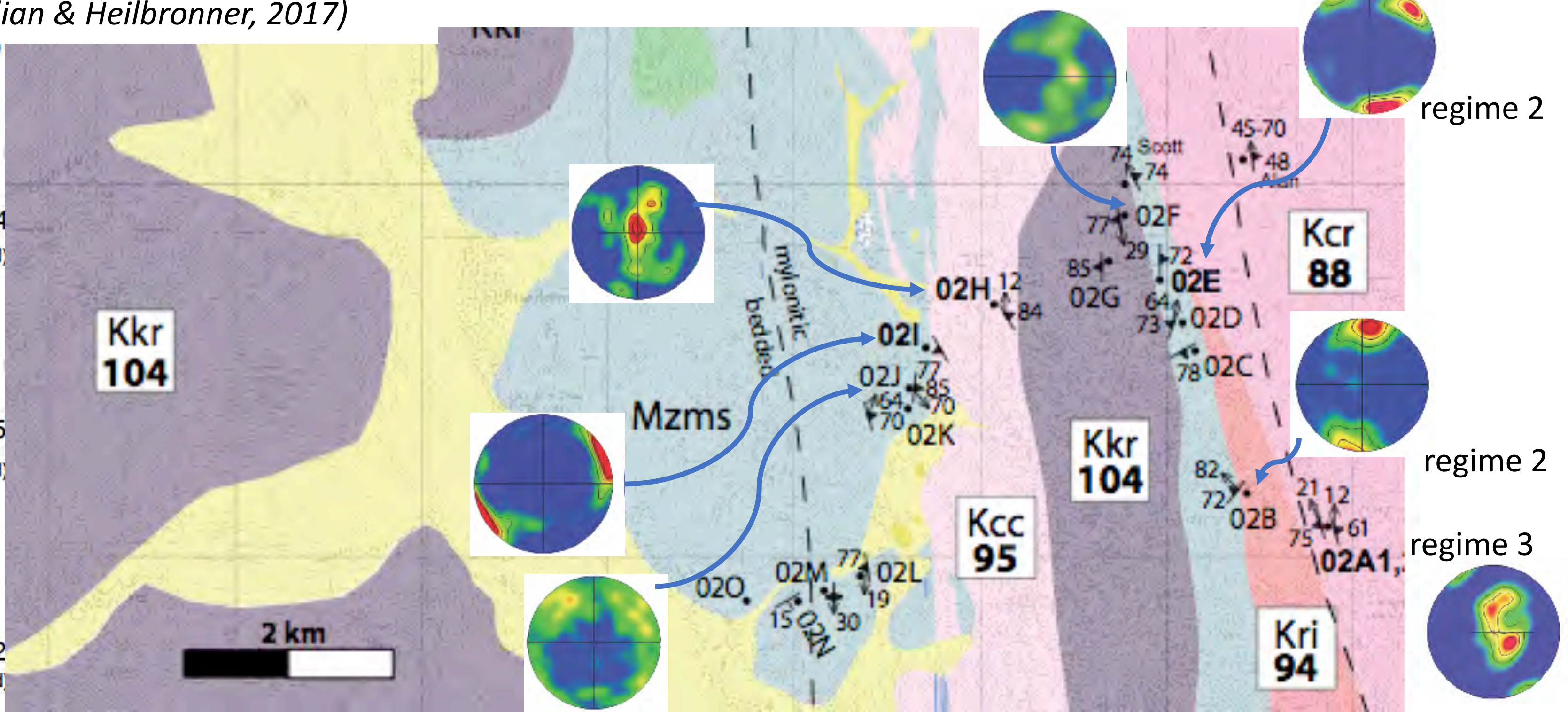


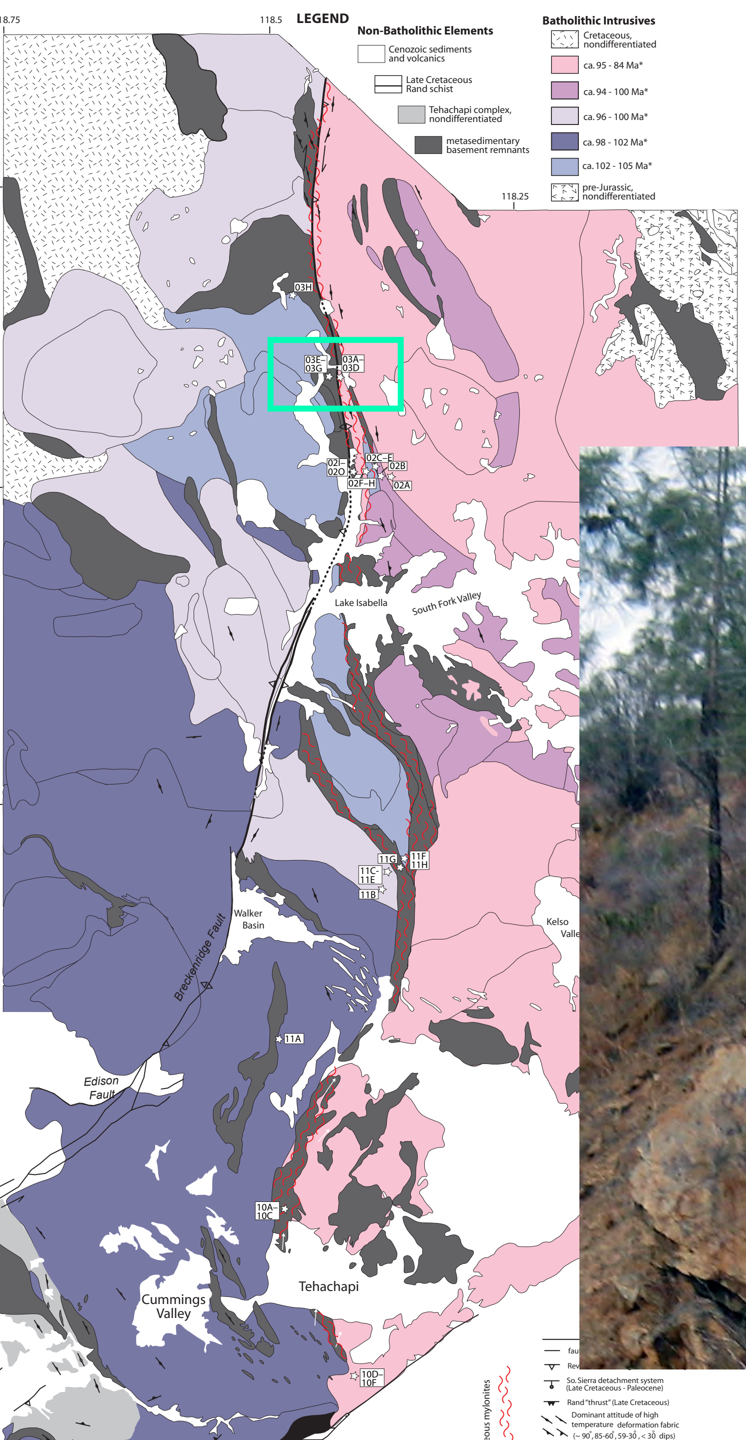
Sample	Age (Ma)	T (˚C)	Depth (km)	Regime
02A	89	725 xlization; 475 deformation	11	3
02B	94	480	11	2
02F	104	475	12	1
02H	95	485	11	3
02E	Met.			2
02I	Met.	415		2
02J	Met.			none



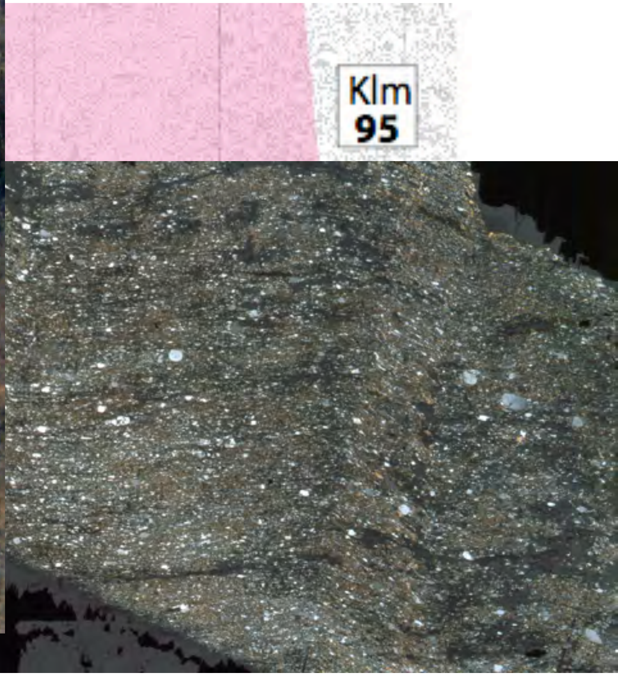


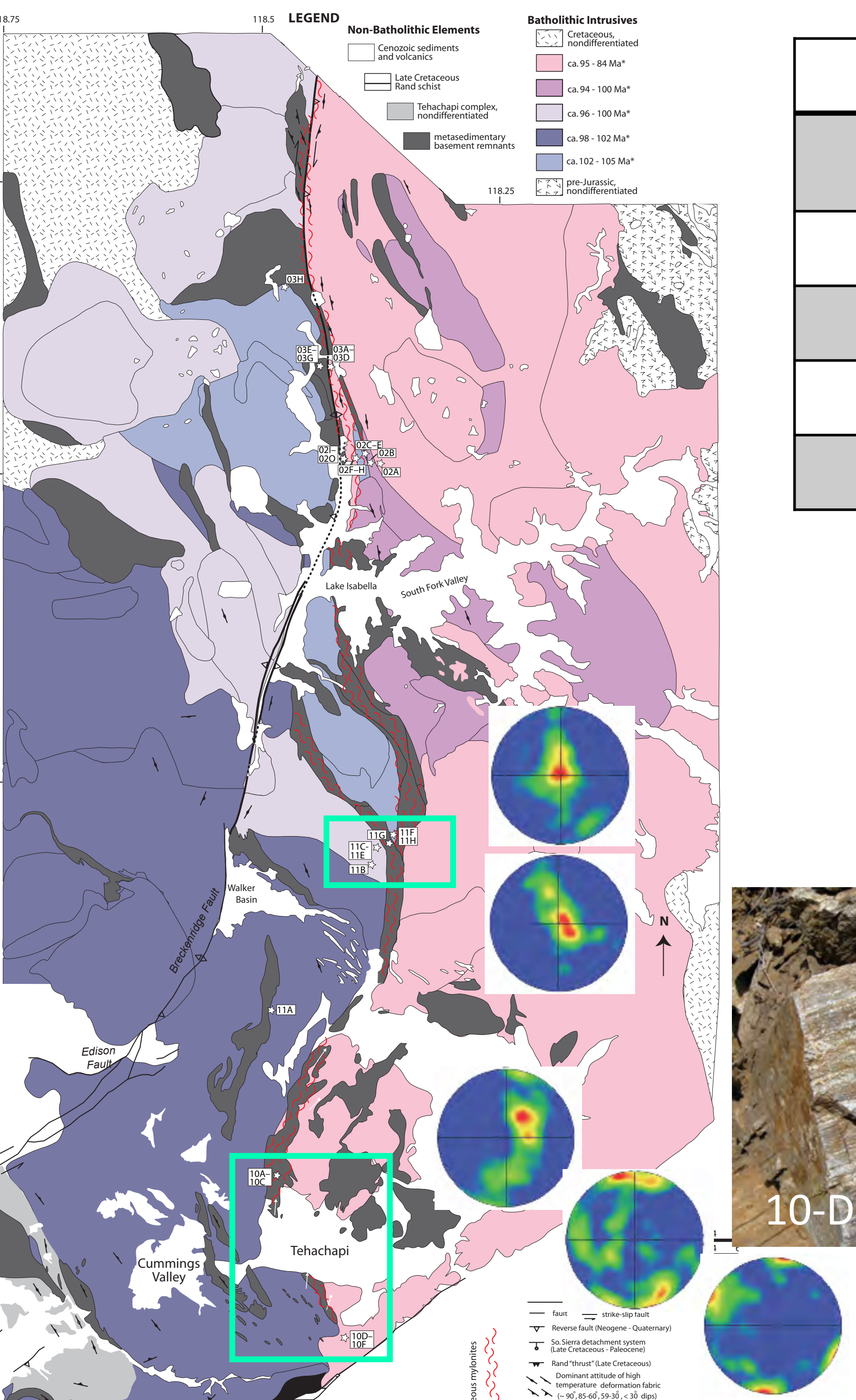
(Kilian & Heilbronner, 2017)



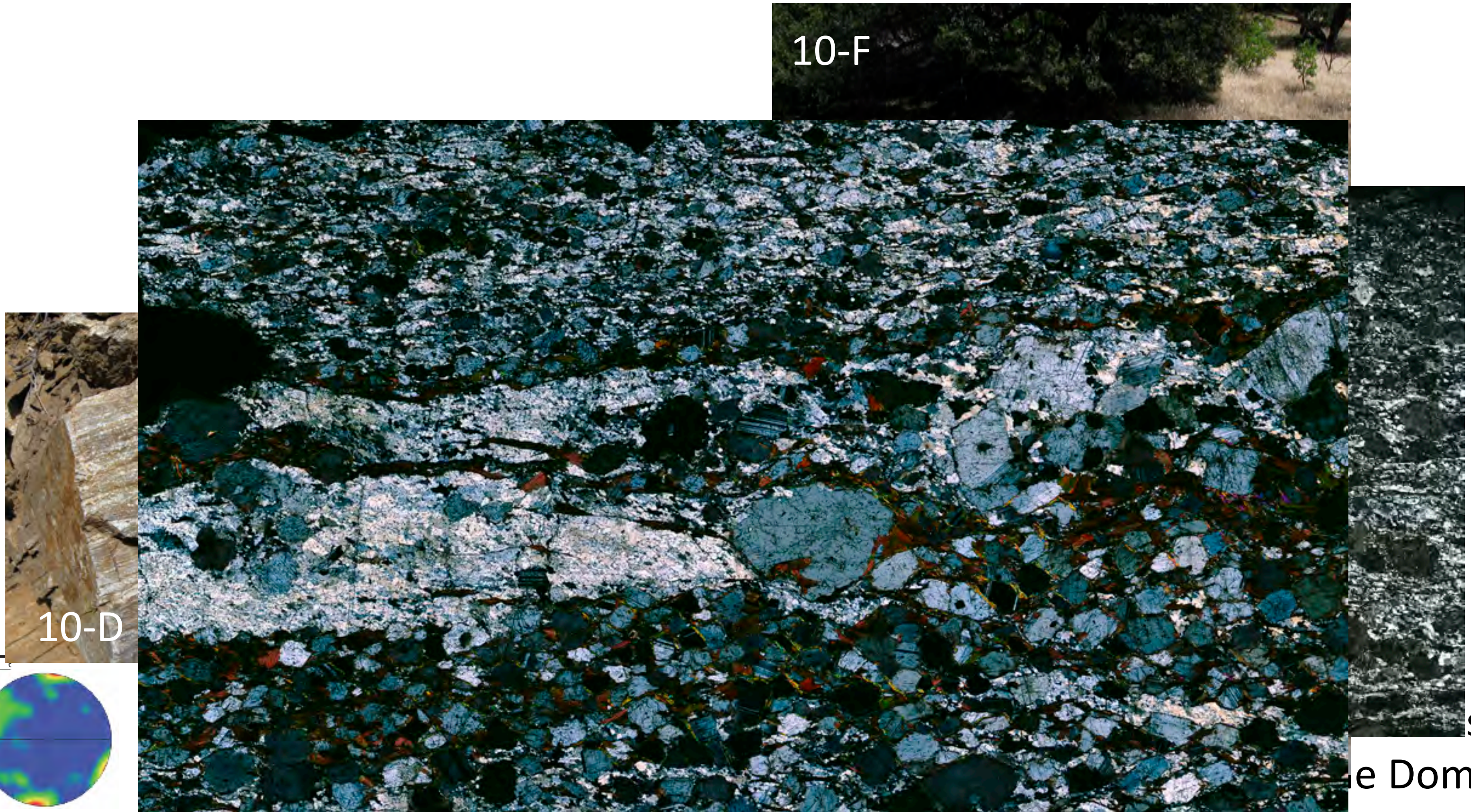


Sample	Age (Ma)	T (˚C)	Depth (km)	Regime
03B	86	550 (2-feldspar)→ 450	12	3
03C	Quartzite			1?
				none
				none



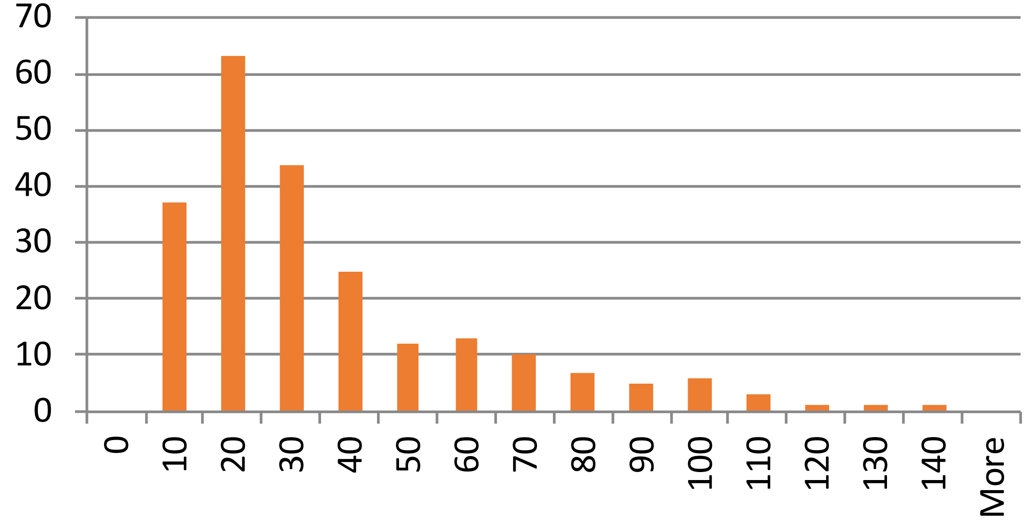


Sample	Age (Ma)	T (˚C)	Depth (km)	Regime
11F	103	510	15	3
11H	vein	485		3
10A	ca. 115*		20	3
10D	ca. 100	510	20	3 lo-strain?
10F	ca. 100	530	20	?



sedimentary
e Domelands suite

02B (northern fault section)

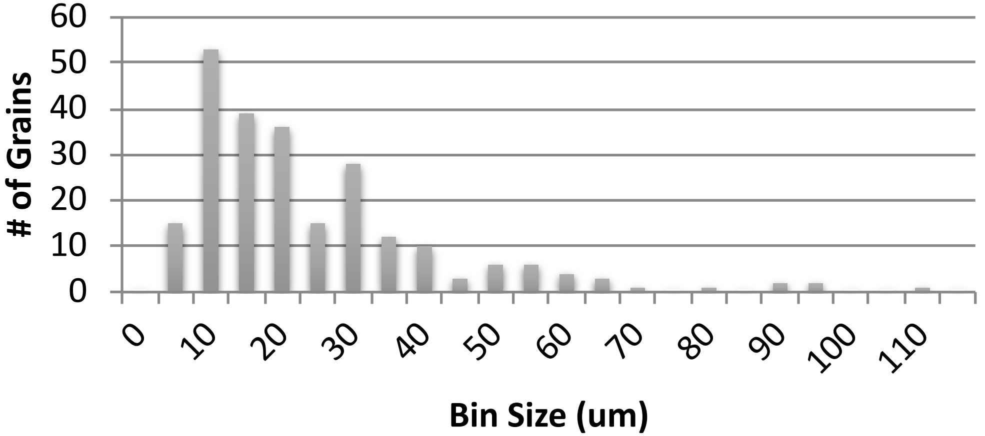


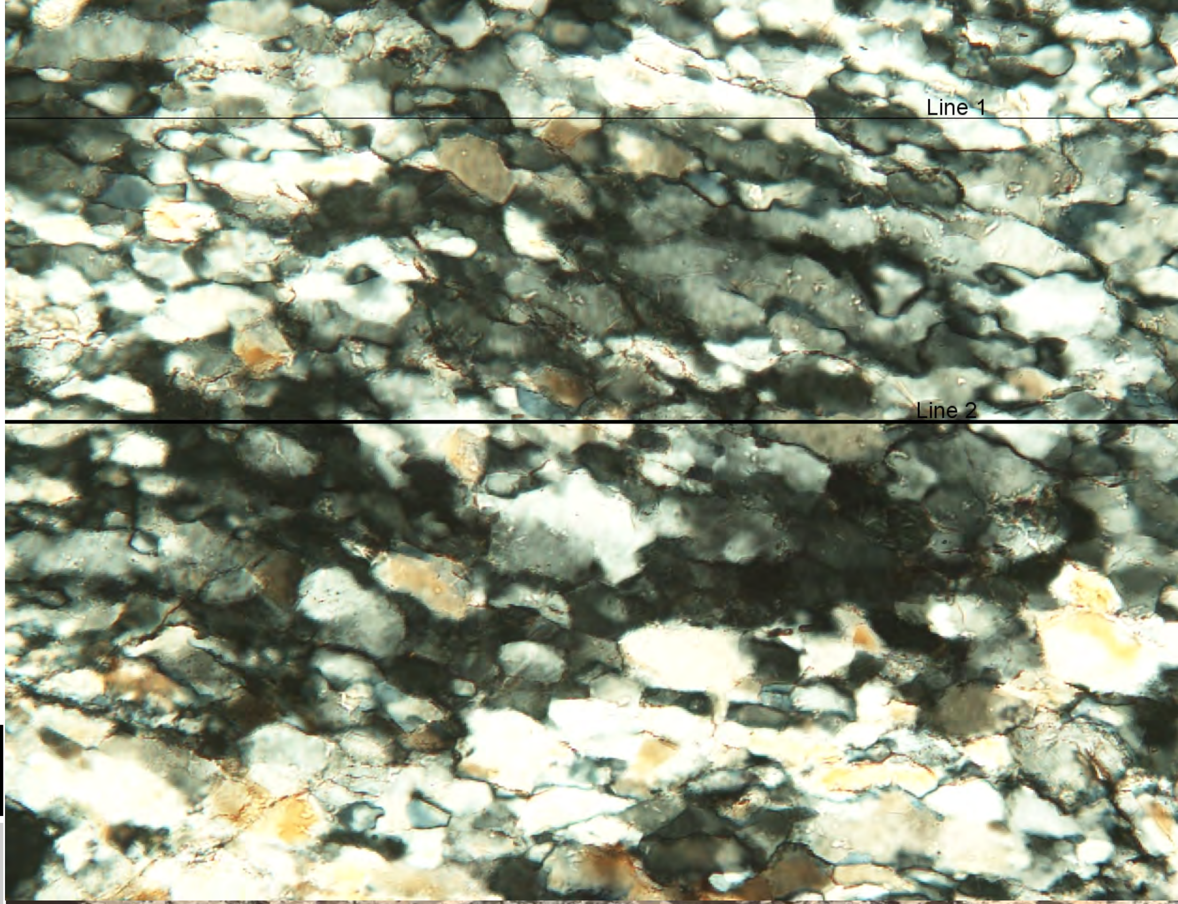
$$D = 10^{3.56}\,\sigma^{-1.26}$$

(Stipp & Tullis, 2003)

Sample	02B	02H	03B1	03B2	03G	11H
Stress (Mpa)	62	62	78	85	78	108

11H (southern fault section)





Sample	σ (Mpa)	T est (˚C)	Depth (km)	Strain Rate
03B1	78	465 +/-22	12	~10^{-12}
03B2	85	465 +/-22	12	~10^{-12}
02B	62	479 +/-28	11	10^{-12}–10^{-13}
02H	62	486 +/-7	11	~10^{-13}
02I	40	414 +/-4		~10^{-14}
11H	108	483 +/-41	15	10^{-11}–10^{-12}

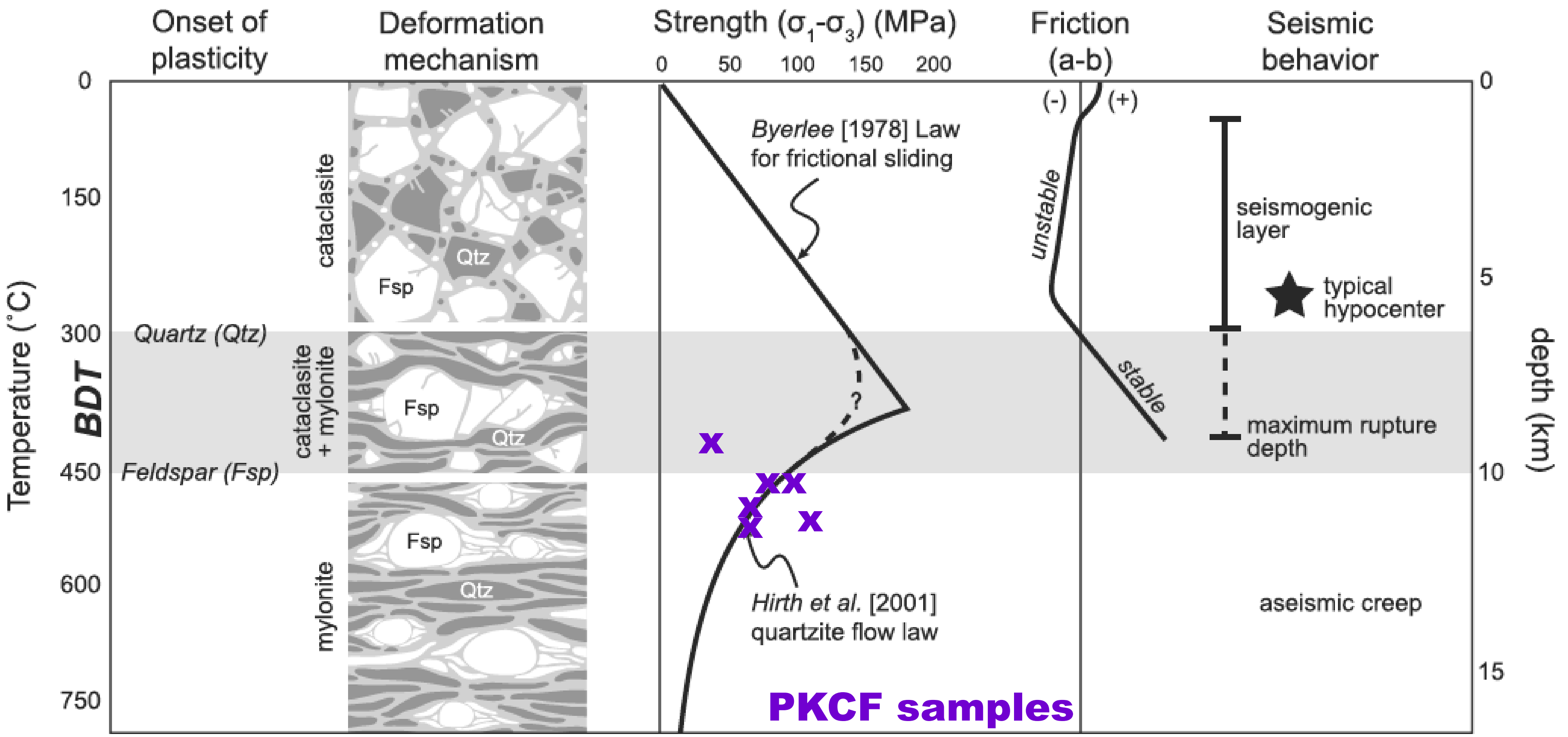
(Probably cooled/exhumed during/before deformation)

Strain rate equation:

$$\dot{\varepsilon} = A f_{H_2O}^{m} \sigma^{n} \exp(-Q/RT)$$ *from Hirth et al., 2001*

Governed by: deformation regime (dislocation creep); differential stress (grain size); temperature; fugacity

Geothermal gradient = 45C/km assumed for magmatic arc



Nevitt et al., 2017

CONCLUSIONS

1. Exhumed fault zones are excellent natural laboratories that need further study in order to constrain realistic rock strengths in deformation zones

2. The Proto-Kern Canyon fault was active during Sierra Nevada magmatic activity (95–85) Ma, as a transpressional structure. The fault is exhumed to depths from ~10–20 km, and overprints igneous and metamorphic rocks

3. Deformation is effectively halted along the western contact with older (>100 Ma) intrusives, and is spaced through the younger intrusives along the eastern edge. Deformation fabrics are most intense in the youngest and warmest intrusive rocks.

4. Estimated **fault stresses range from ~40–110 MPa**, which, coupled with **temperature estimates from 400–500 ˚C**, yield **strain rates from ~10^{-14}** (in older, reheated metamorphic rocks) **to 10^{-11} MPa** (in the deepest/warmest rocks). [This is consistent with other shear zone studies in the SNB, i.e., Nevitt et al., 2017].

Discussion Questions from January SGTF

Strength of shear zones

- Can equilibrium mineral assemblages in shear zone rocks be used to reliably quantify water content at time of deformation and therefore be used as evidence for hydrolytic weakening?

- How can we quantitatively relate quartz microstructures found in experimentally deformed rocks to those found in naturally deformed rocks? (I.e., when relating naturally deformed rocks to experimentally deformed rocks, how can we be sure we're comparing apples to apples?)

- What mechanisms control shear zone width?

- Given a large-scale shear zone that narrows through time and space as strain localizes, what evidence would be required in order to quantify shear zone thickness (width) at a given time?