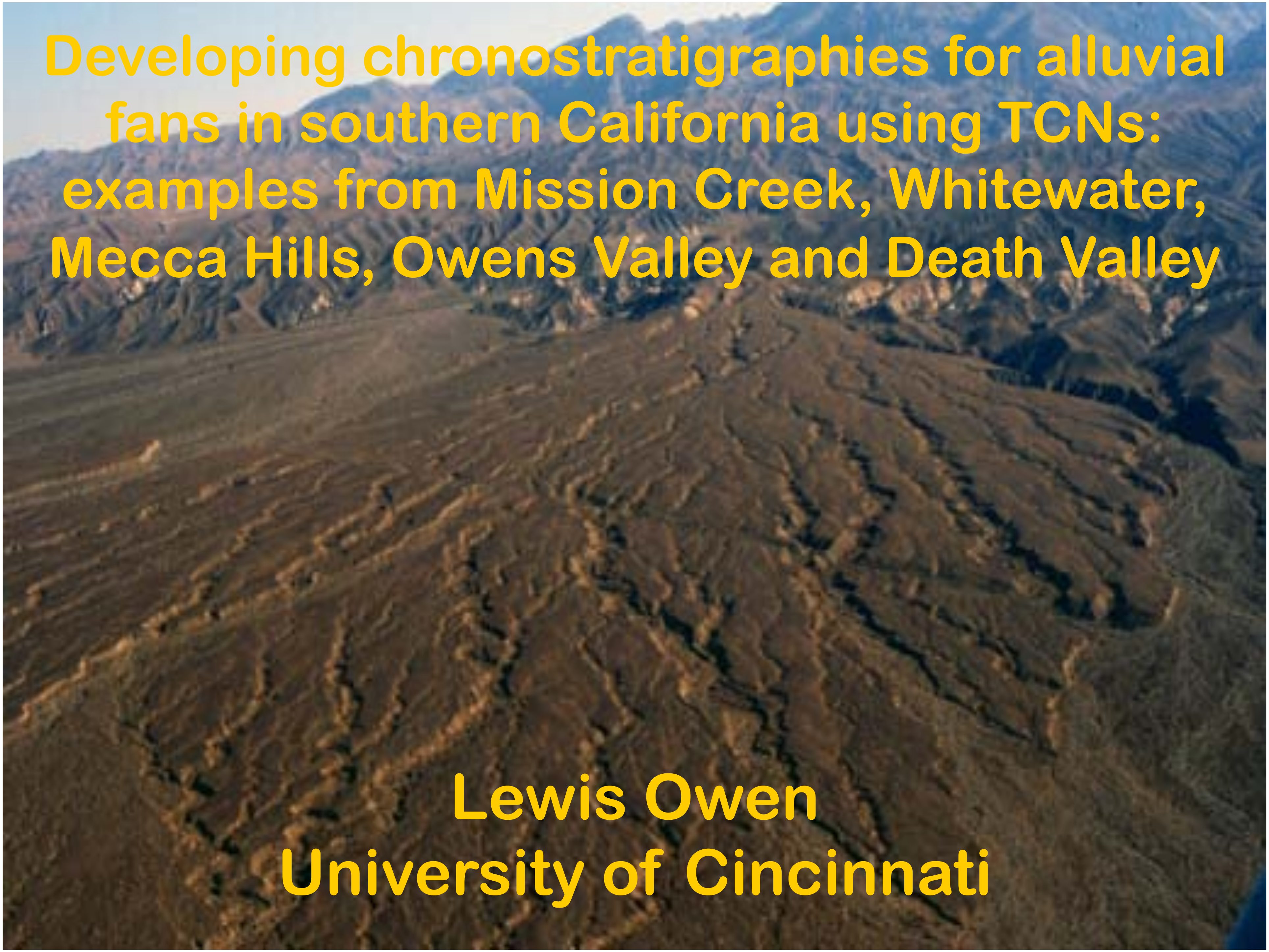
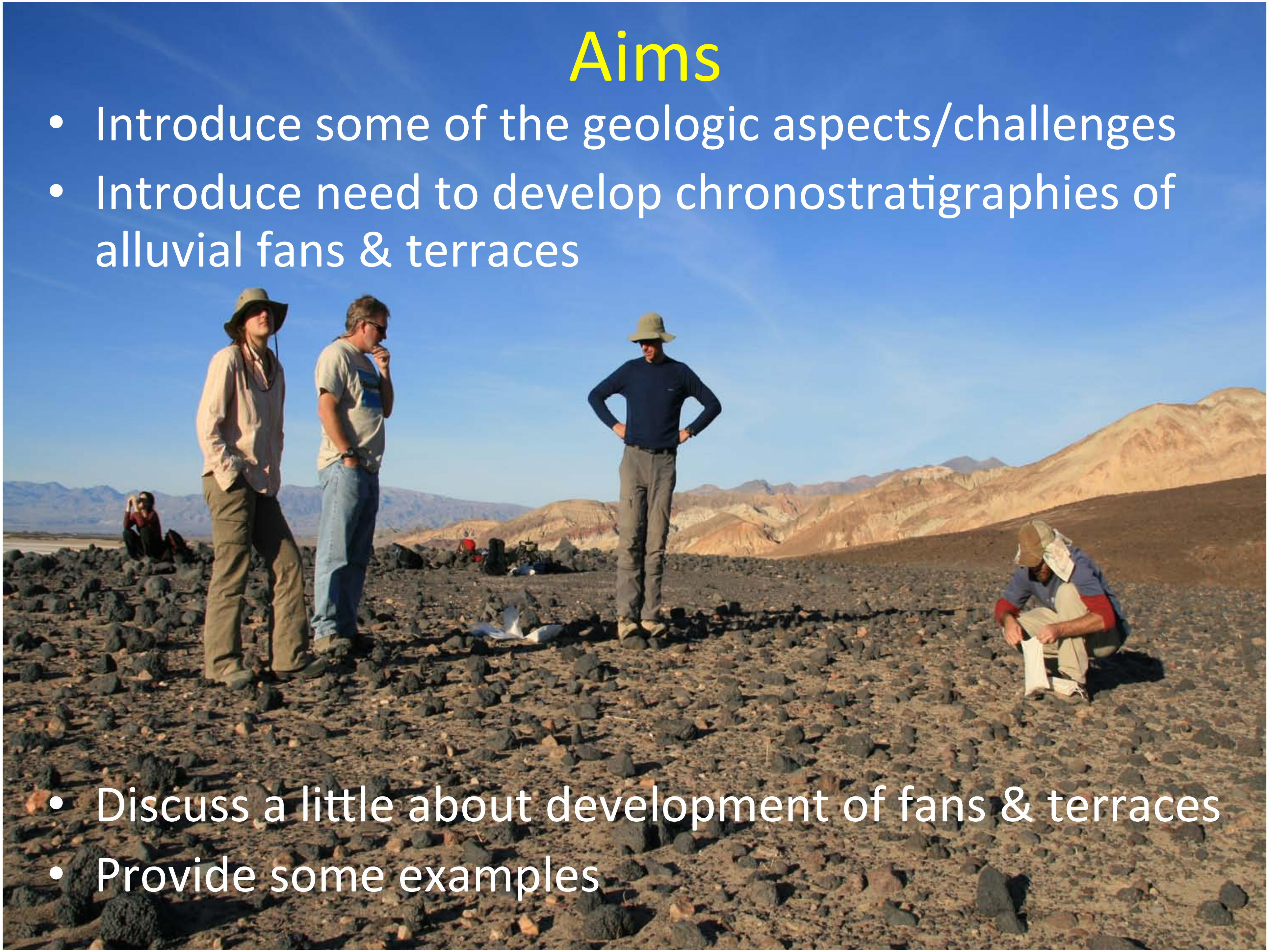

Developing chronostratigraphies for alluvial fans in southern California using TCNs: examples from Mission Creek, Whitewater, Mecca Hills, Owens Valley and Death Valley
Lewis Owen
University of Cincinnati

Aims

- Introduce some of the geologic aspects/challenges
- Introduce need to develop chronostratigraphies of alluvial fans & terraces



- Discuss a little about development of fans & terraces
- Provide some examples

Acknowledgements

Phil Armstrong, Douglas Benn, Kim Blisniuk, Marc Caffee, Sam Clemens, James Dolan, Jason Dortch, Bob Finkel, John Fletcher, Markus Fuchs, Plamen Ganev, Harrison Gray, Jeff Knott, Jeff Lee, Shannon Mahan, Sally McGill, David Miller, Mike Oskins, Fred Phillips, Tom Rockwell, Ron Spelz

Some examples:

Death and Fish Lake valleys

Owens Valley

Whitewater-Mission Creek

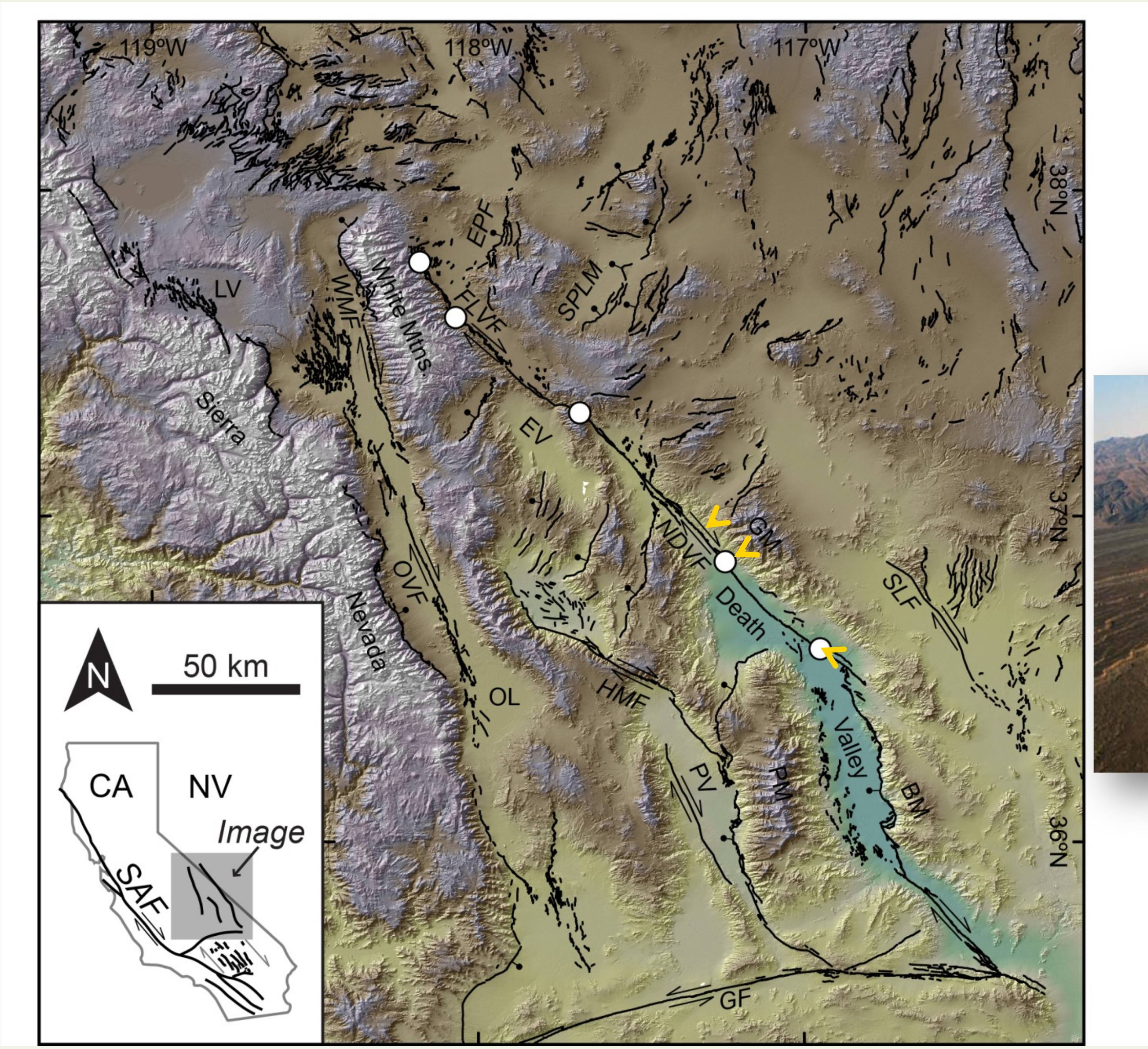
Mecca Hills

Alluvial Fan Stratigraphies

e.g., Death Valley

	Denny, 1965	Hunt and Mabey, 1966	Reynold, 1969	Hooke, 1972[1]	Moring, 1986	Bull, 1991[2]	Hooke and Dorn, 1992	Nishiizumi et al., 1993[2]	Klinger, 2001a; Frankel and Dolan, 2007	Machette et al., 2008
			Q1	Qa	Qf4/Qs	Q4b			Q4b	
	Qgv	Qg4		Qai	Qmu	Q4a	Q4		Q4a	Qay
Holocene			Q2			Q3c			Q3c	
	Qgv	Qg3		Qat	Qf3	Q3b			Q3b	Qayo
			Q3			Q3a			Q3a	Qai
									Qlm4/Ql r	
		Q1m			Qf2c	Q2c			Q2c	
				Qay	Q1		Q3	3a		Qaio
	Qgp	Qg2	Q4		Qf2b	Q2b			Q2b	
Pleistocene				Qai	Qf2a		Q2	2a	Qlm3	Qao
						Q2a			Q2a	
									Qlm2	
				Qao		Q1	Q1	1a	Q1c	QTa
					Qf1					
									Q1b	
		QTg1								
									Qlml	
Pliocene					Tg/Tb				QT1a	
		Tfc								

Death Valley-Fish Lake Valley Fault System

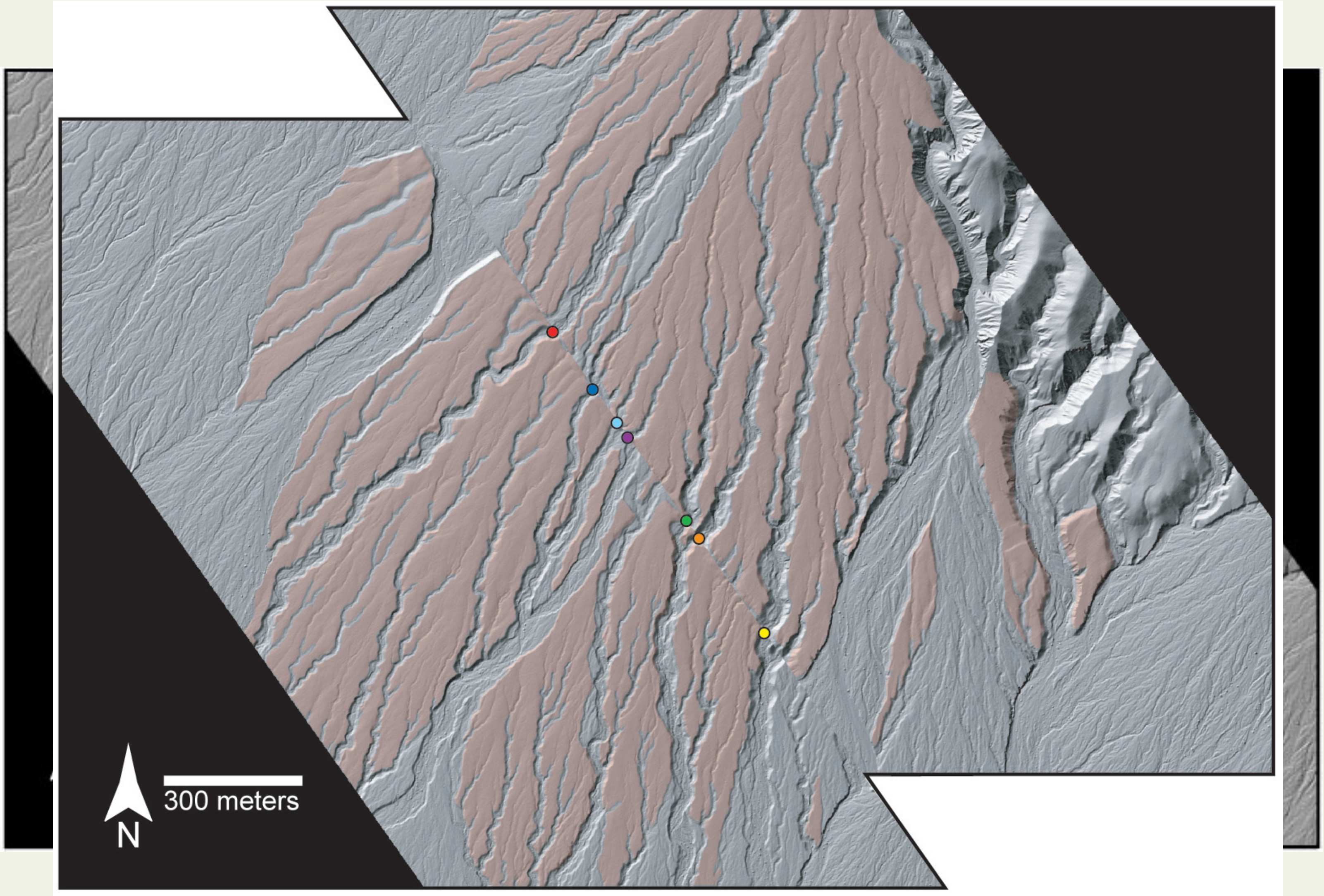


Big Dip Canyon

Red Wall Canyon

S. Mud Canyon

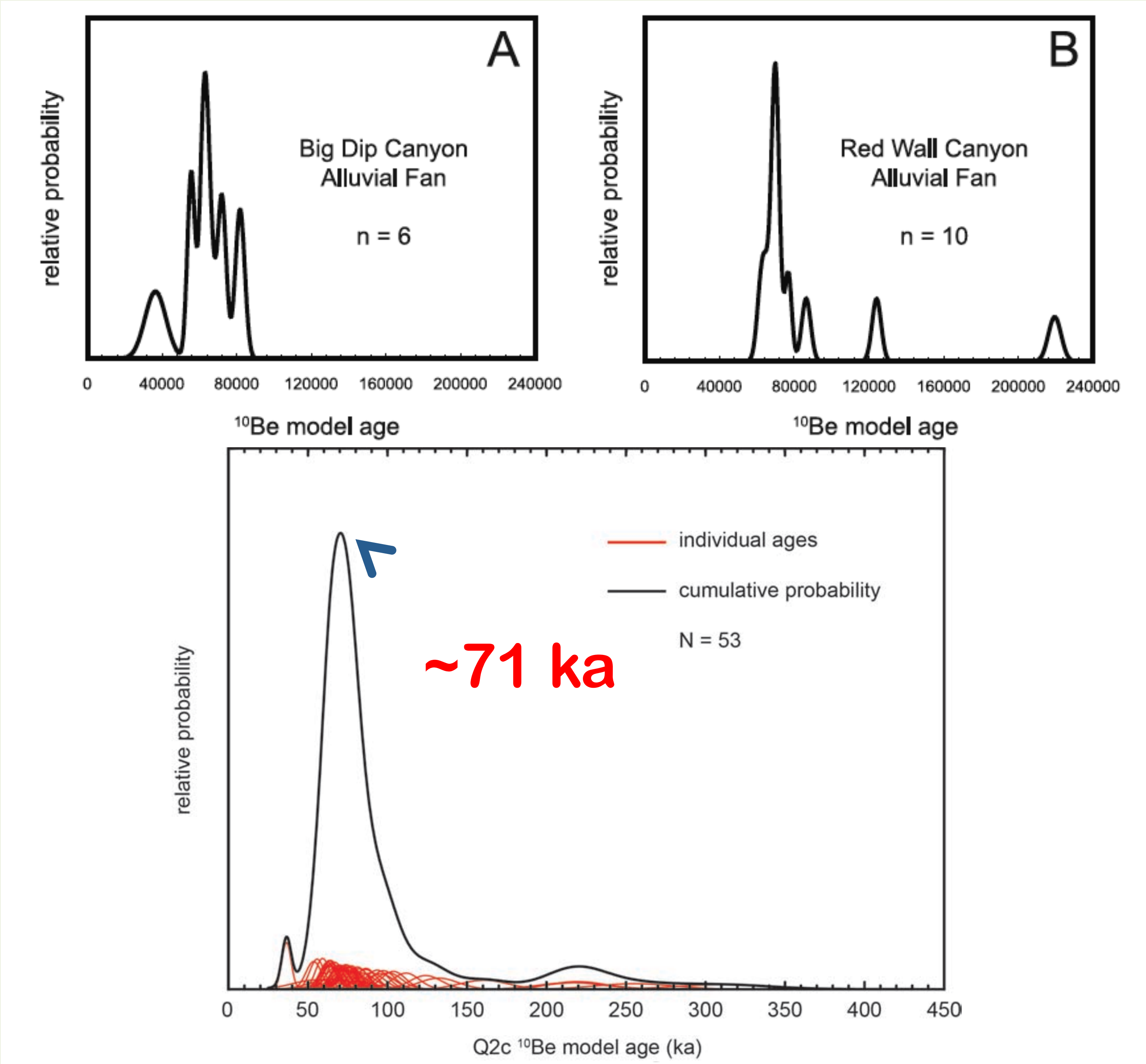
Red Wall Canyon Offset - Q2c surface



- total amount of offset = 297 ± 9 meters

Frankel et al., 2007, *JGR - Solid Earth*

Be-10 ages for boulders on Q2c surface in Death and Fish Lake valleys



Data from Frankel et al. (*2007a,b, 2011*), Hoeft and Frankel (*2010)*, Owen et al. (2011) and Ganev et al. (2010)

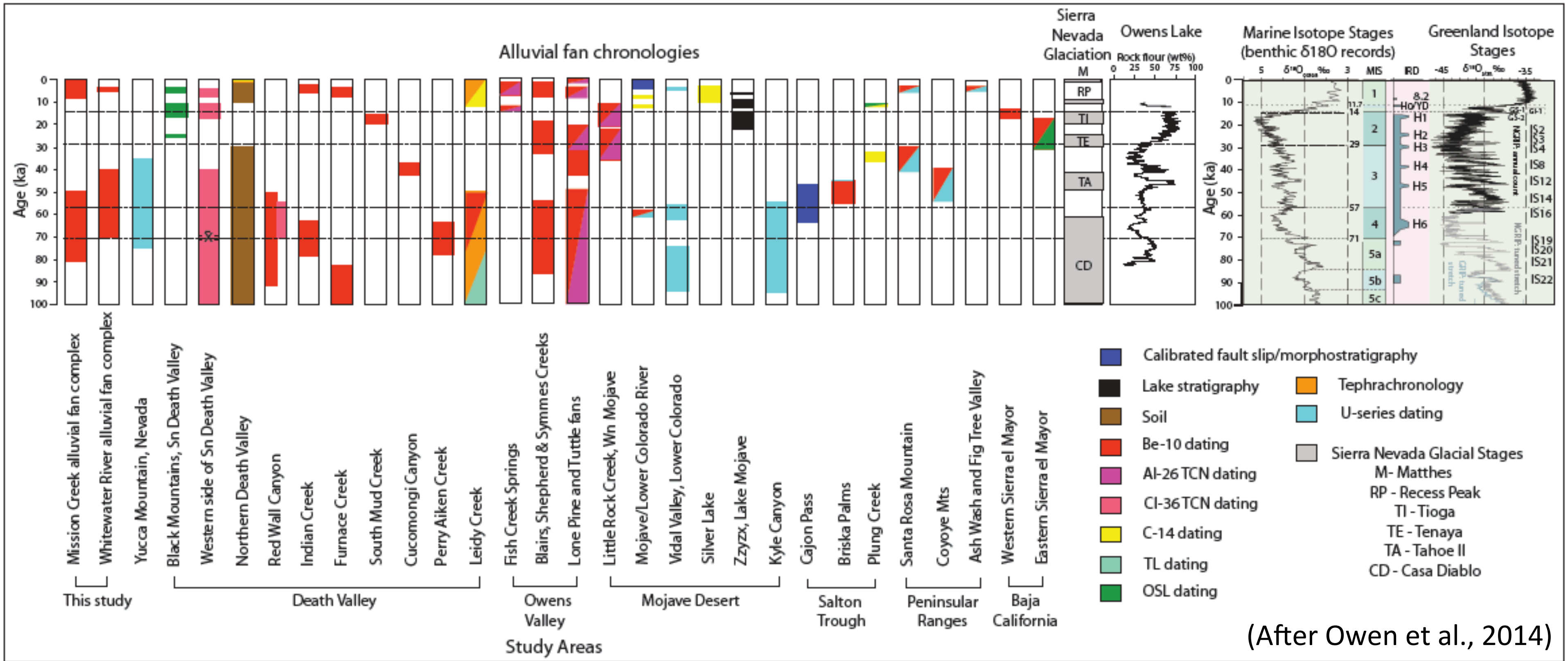
Development of alluvial fans

Process-response model

Arid fan model

Increase aridity and temp ➔ Decrease soil moisture & decrease vegetation density ➔
Reduced soil infiltration & exposes soil to erosion ➔ Increases sediment supply & valley aggravation ➔
Sed. supply decreases as colluvium removed/or colluvium stabilized by higher veg. cover ➔ Incision occurs

Fans begin to aggrade at wet/cool-dry/warm (Glacial-Interglacial or Stadial-Interstadial) transitions till sediment exhausted and then incise – should have interglacial/stadial ages



(After Owen et al., 2014)

Development of alluvial fans

Process-response model

Arid fan model

Increase aridity and temp ➔ Decrease soil moisture & vegetation density ➔
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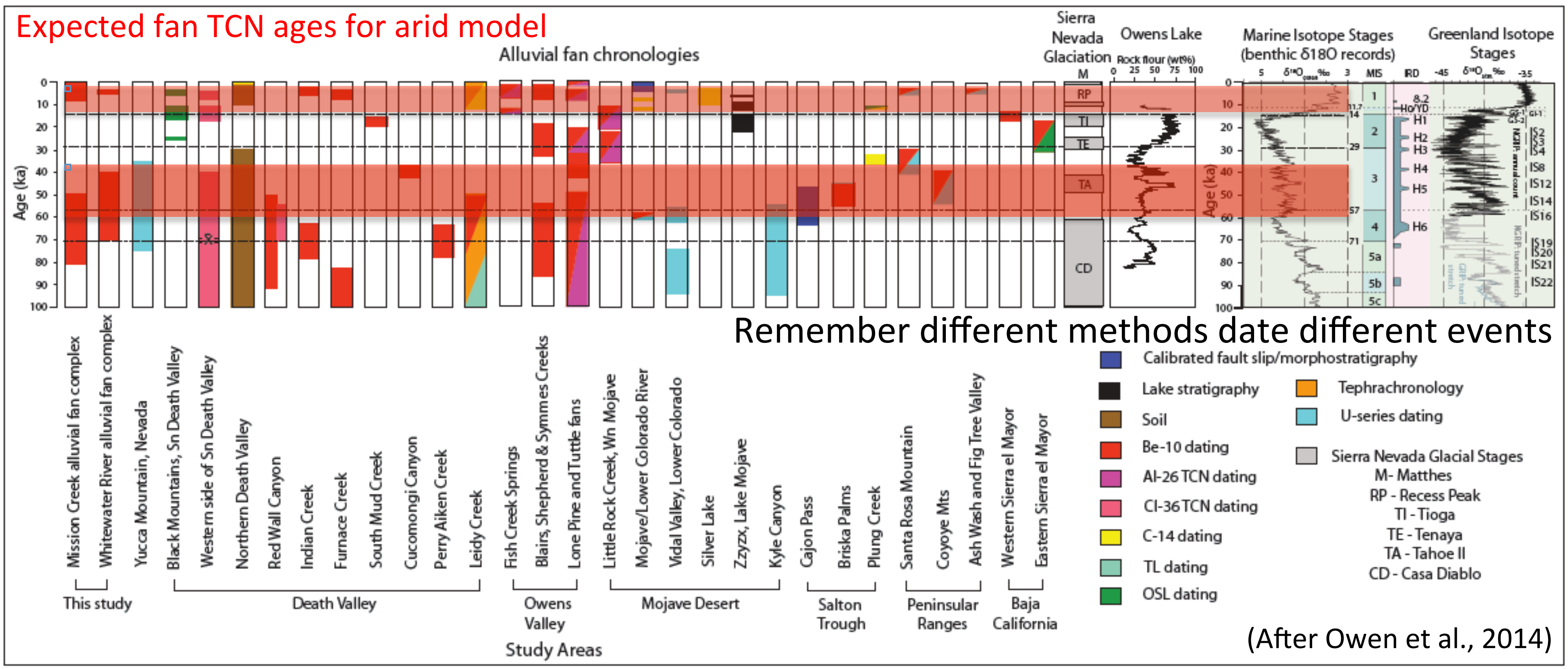
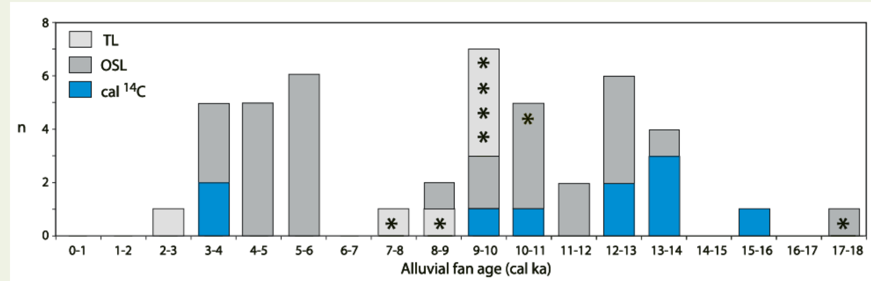


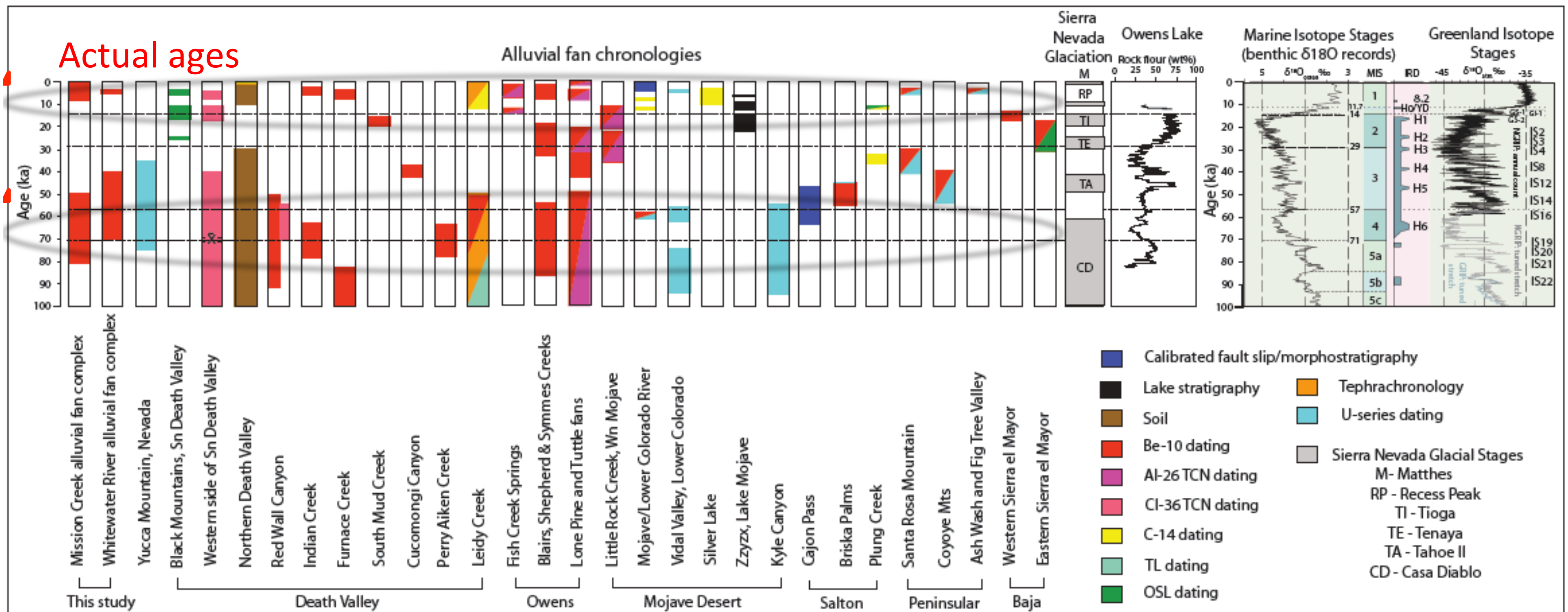
Development of alluvial fans

Process-response model



Humid model, e.g., mid-Holocene - 3-6 ka.
Intense summer season storms (Miller et al., 2010)

Paraglacial model, e.g., western Owen valley
Alluvial fans (Benn et al., 2006)



(After Owen et al., 2014)

How good is the TCN dating?

Active channel boulder ages!

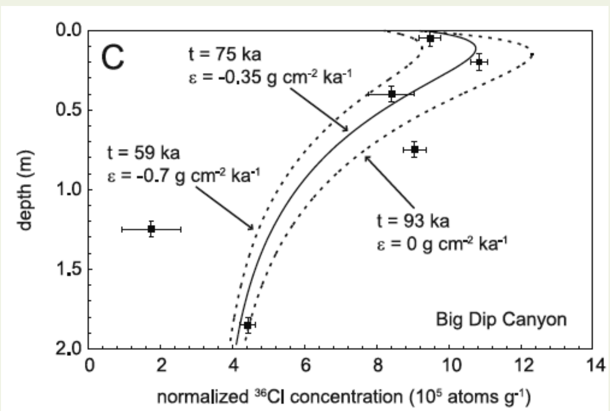
7.7±6.7 ka

18.5±1.8 ka

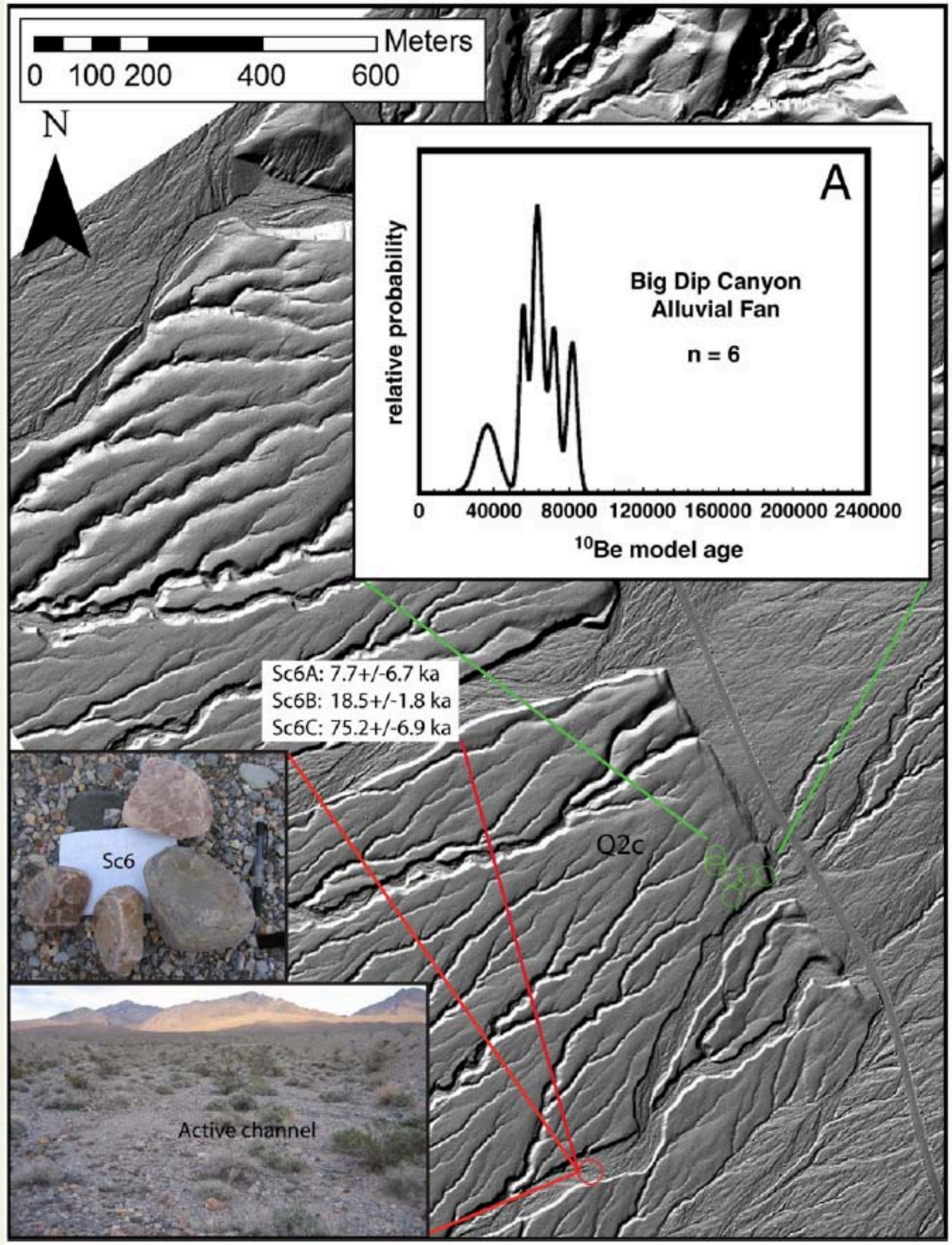
75.2±6.9 ka

So do we have much inheritance on Q2c?

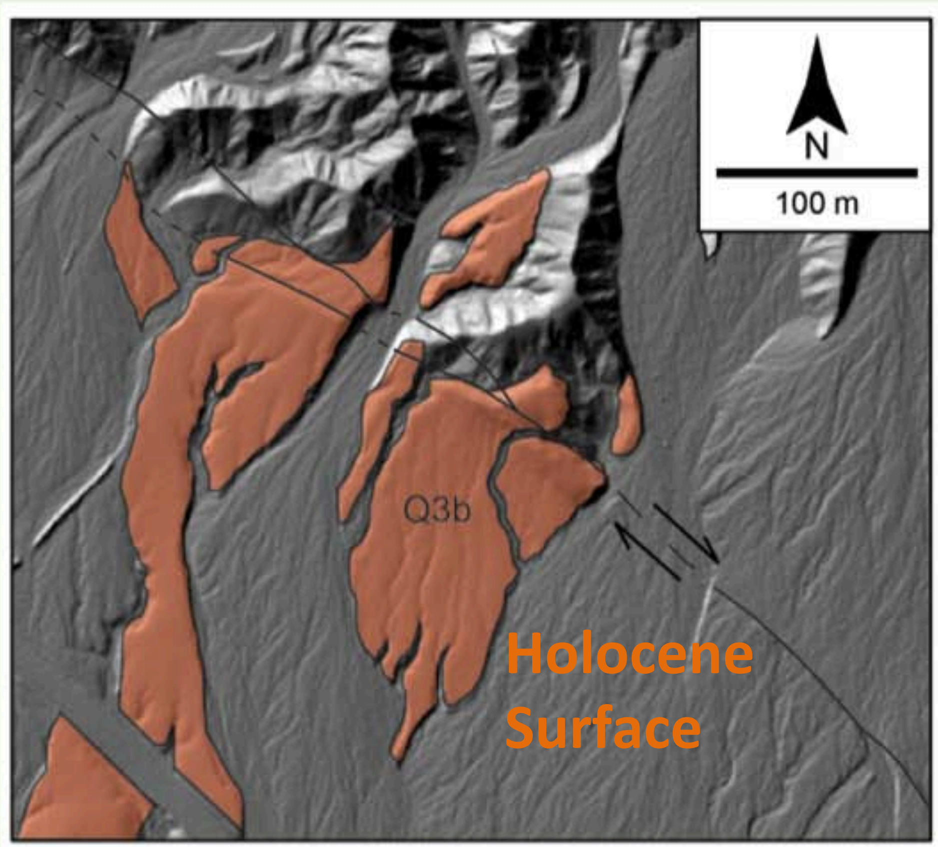
Depth profiles give age of ~63±8 ka!

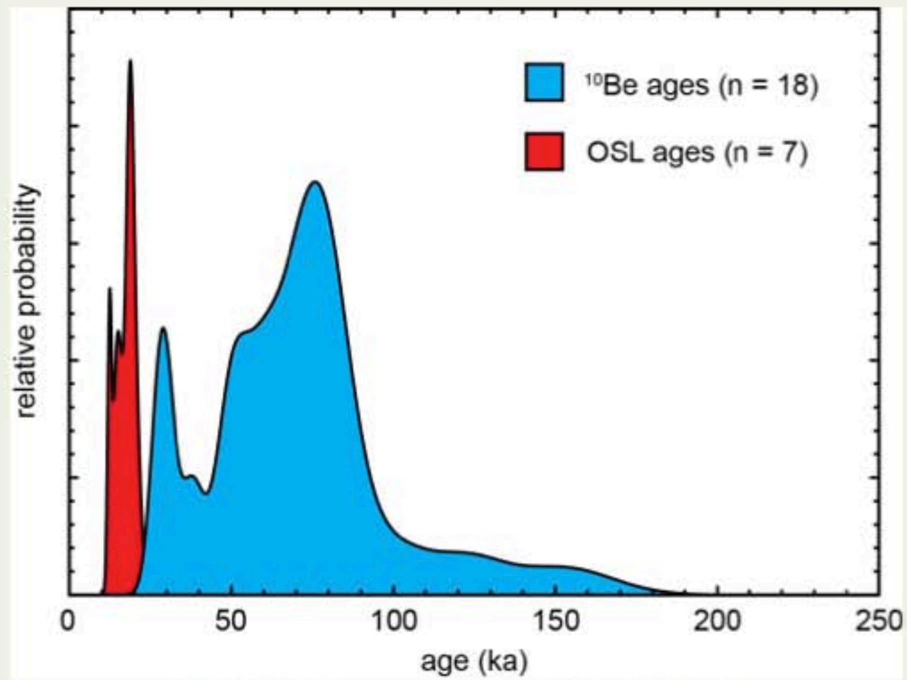


So does amount of inheritance vary over time, e.g., is it greater in Holocene?



South Mud Canyon Offset – Q3b





total offset = 37 ± 7 m

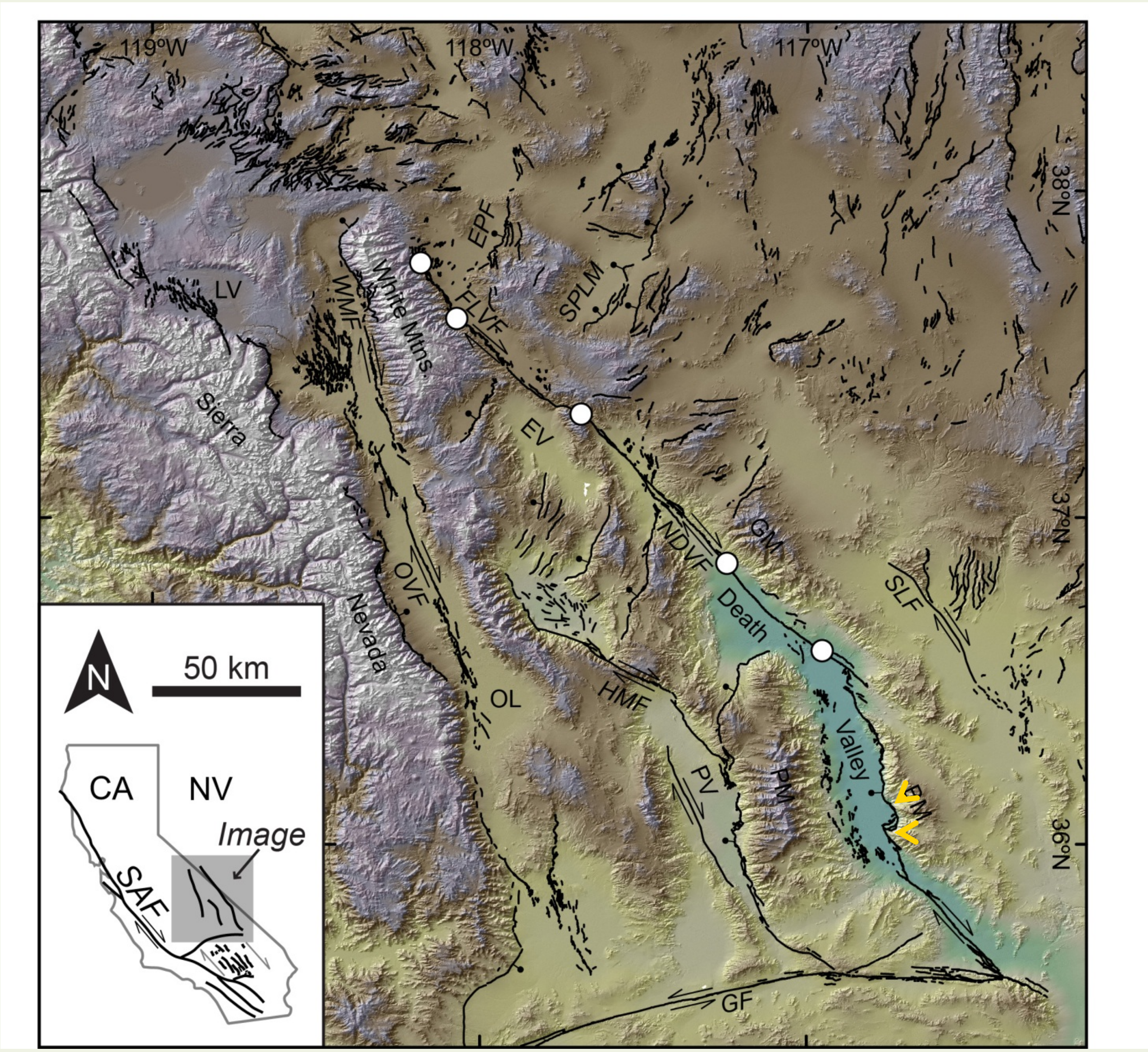
OSL = 17 ± 2 ka

^{10}Be = 38 to 153 ka

slip rate =

2.1 +0.5/-0.4 mm/yr

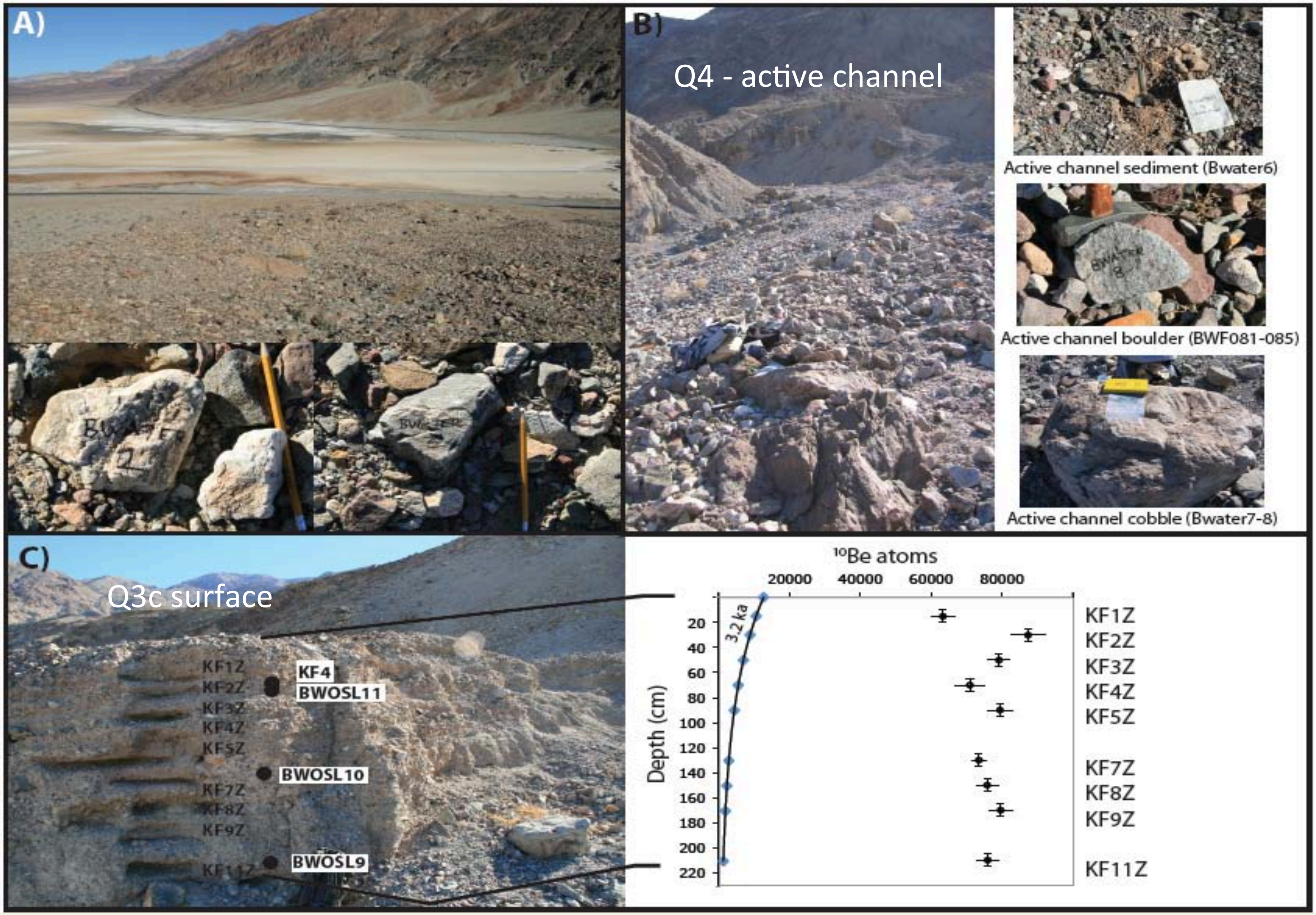
Black Mts Fault



Badwater

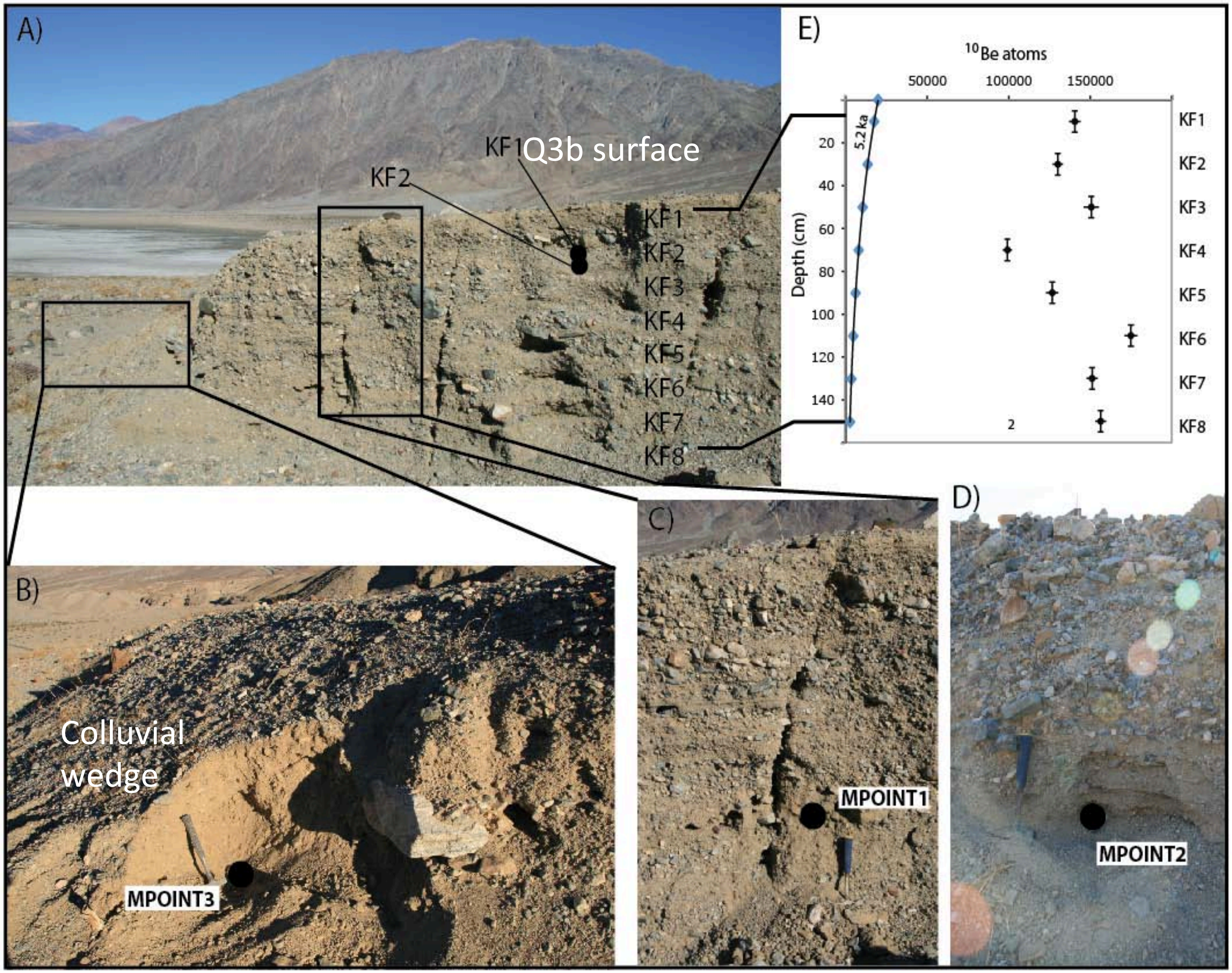
Mormon Point

Badwater

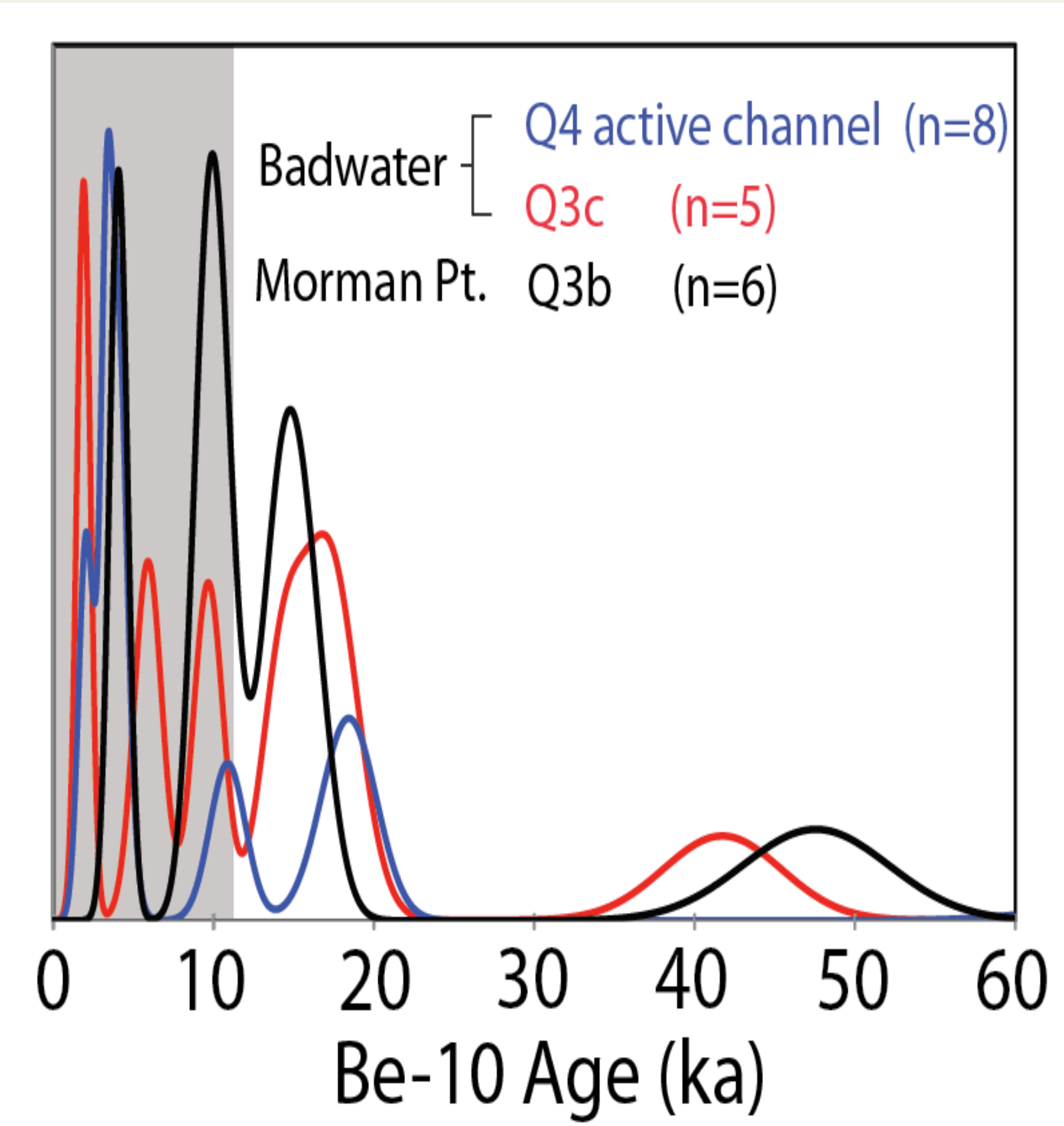


A)
B)
Q4 - active channel
Active channel sediment (Bwater6)
Active channel boulder (BWF081-085)
Active channel cobble (Bwater7-8)
C)
Q3c surface
KF1Z
KF2Z
KF3Z
KF4Z
KF5Z
KF7Z
KF8Z
KF9Z
KF11Z
KF4
BWOSL11
BWOSL10
BWOSL9
^{10}Be atoms
20000
40000
60000
80000
Depth (cm)
20
40
60
80
100
120
140
160
180
200
220
3.2 ka
KF1Z
KF2Z
KF3Z
KF4Z
KF5Z
KF7Z
KF8Z
KF9Z
KF11Z

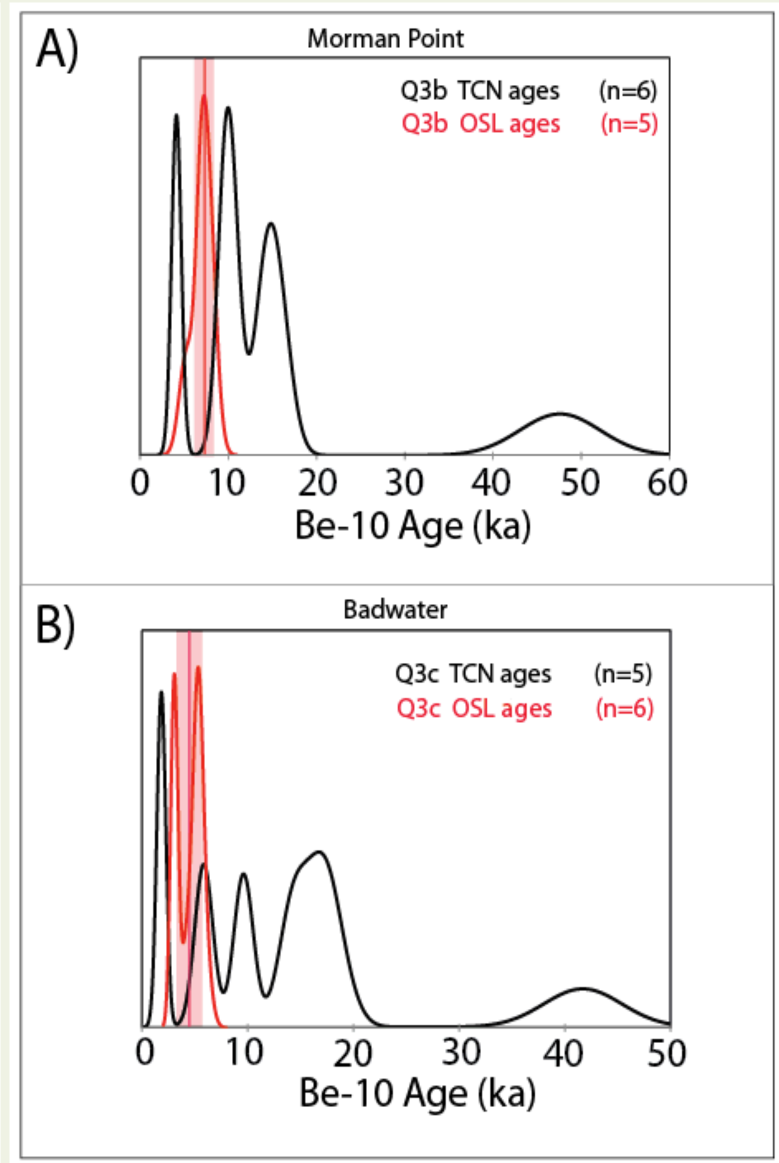
Morman Point



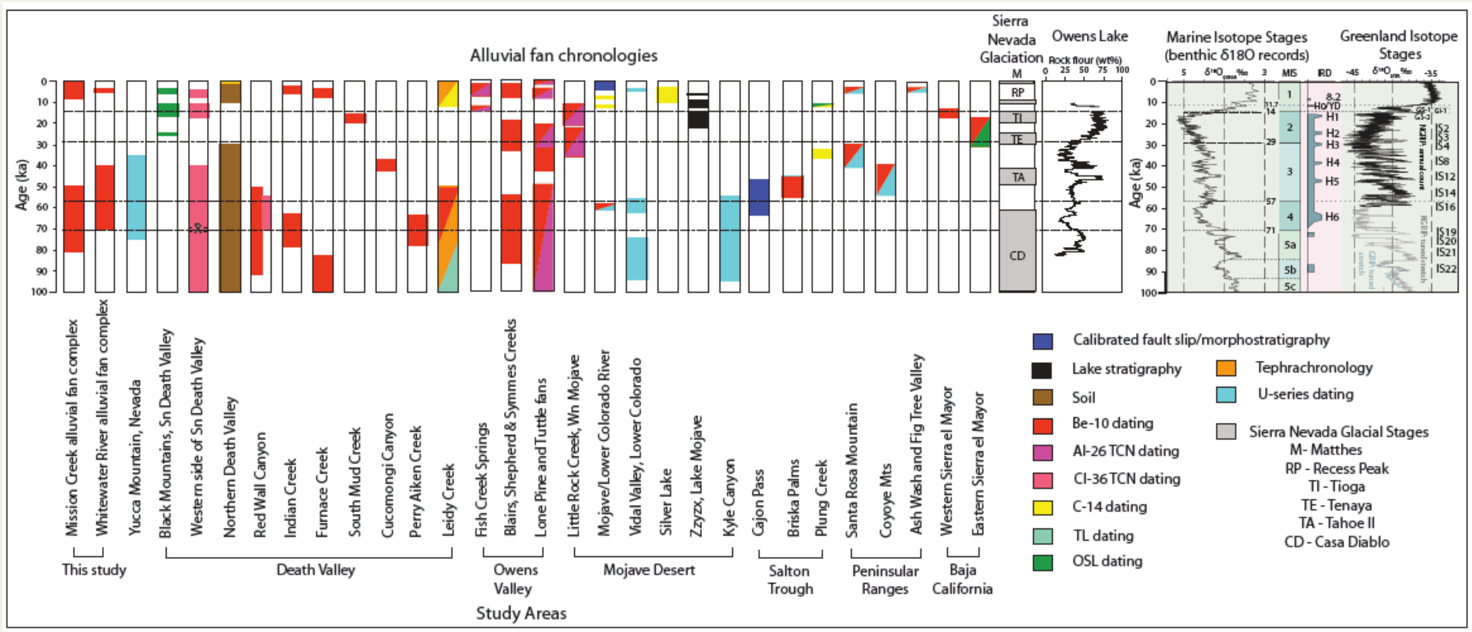
Be-10 surface boulder ages



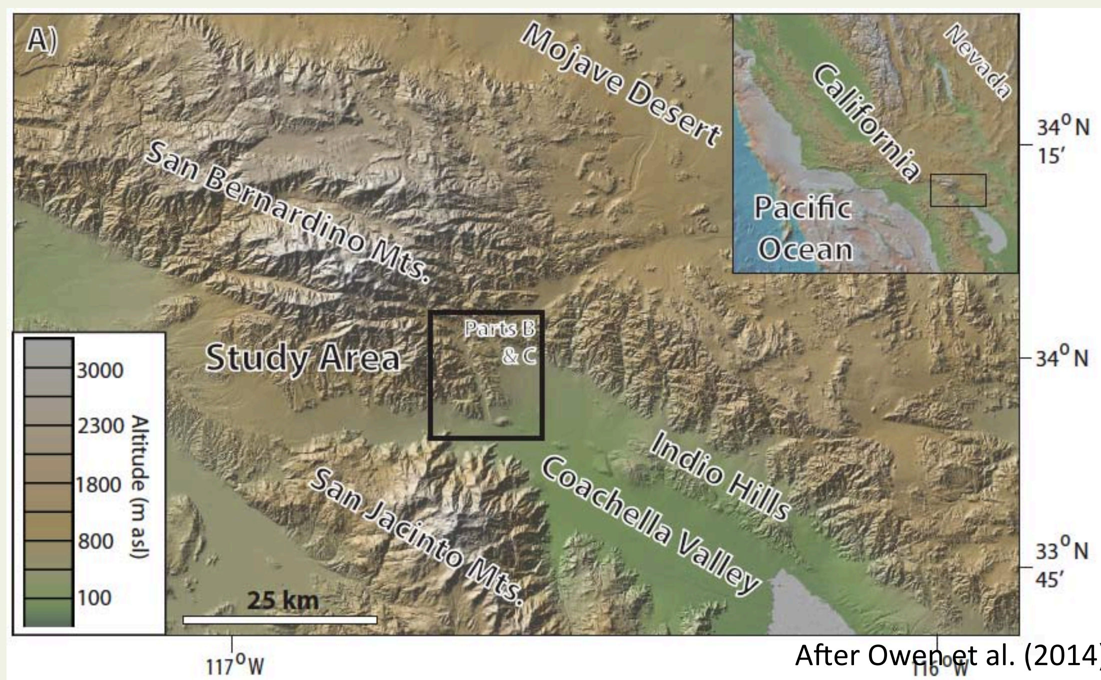
Be-10 cf. OSL ages



Can we see regional correlations? And what's the best time ranges?

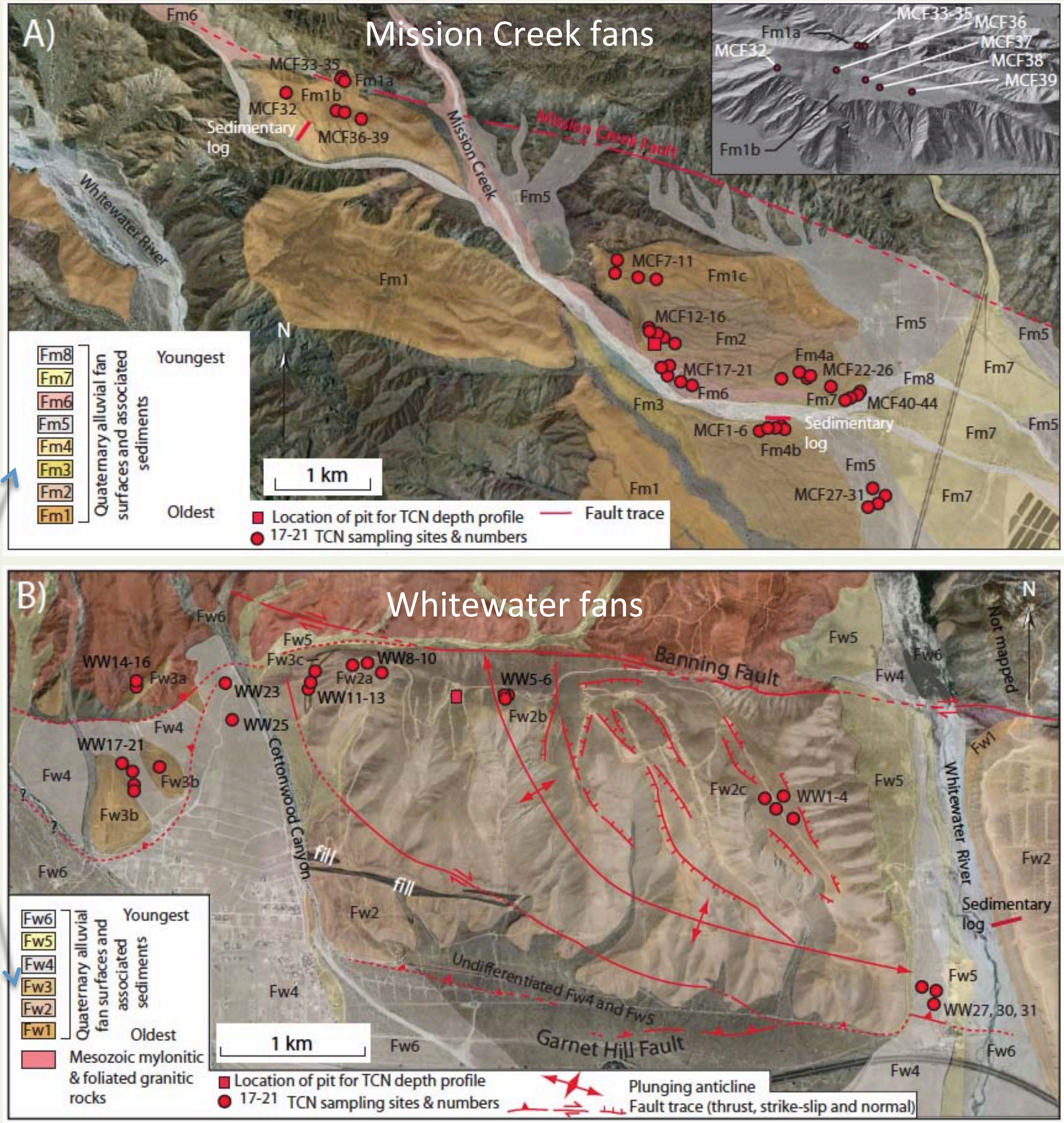


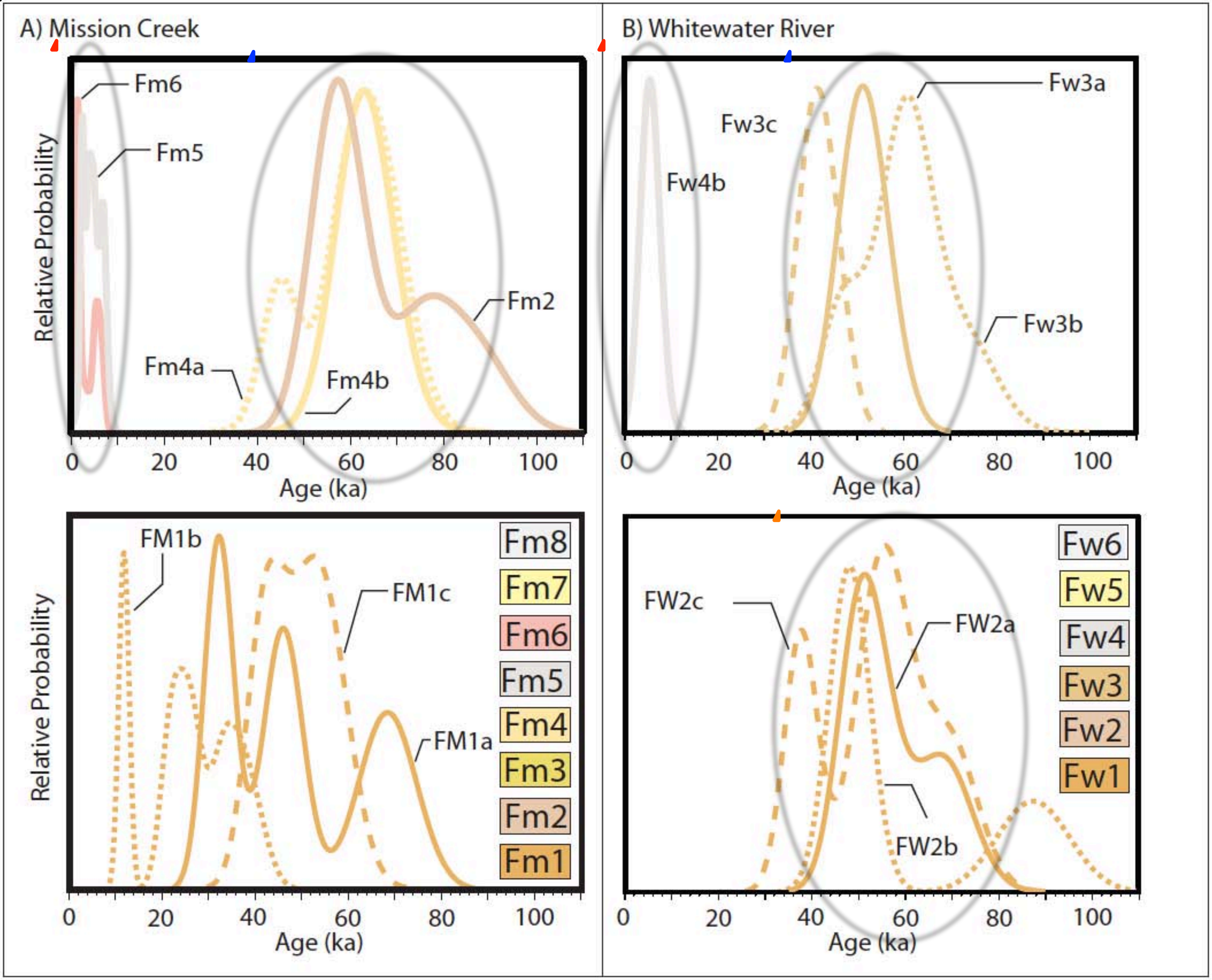
Mission Creek and Whitewater



After Owen et al. (2014)

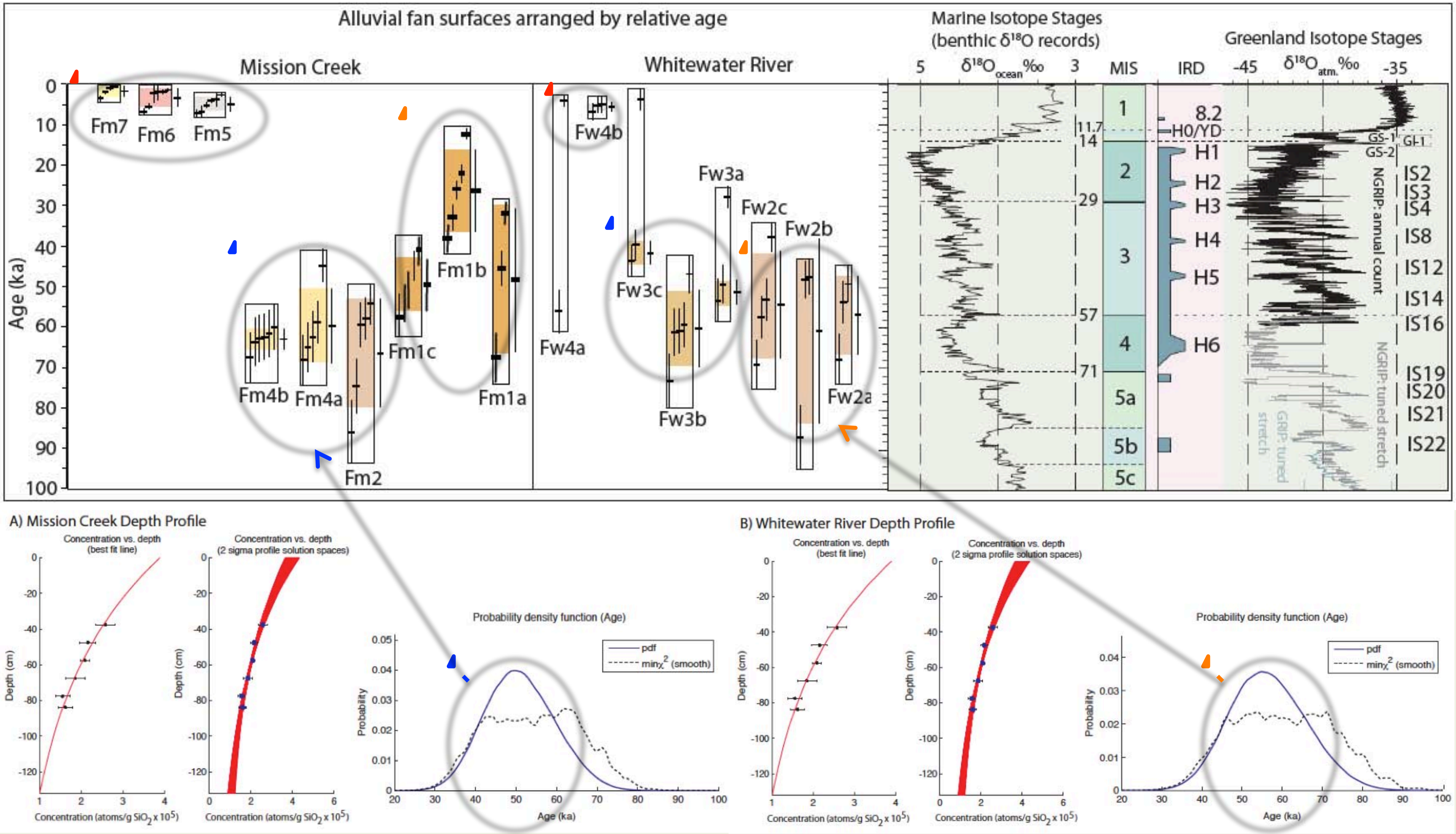
Alluvial Fan chronologies



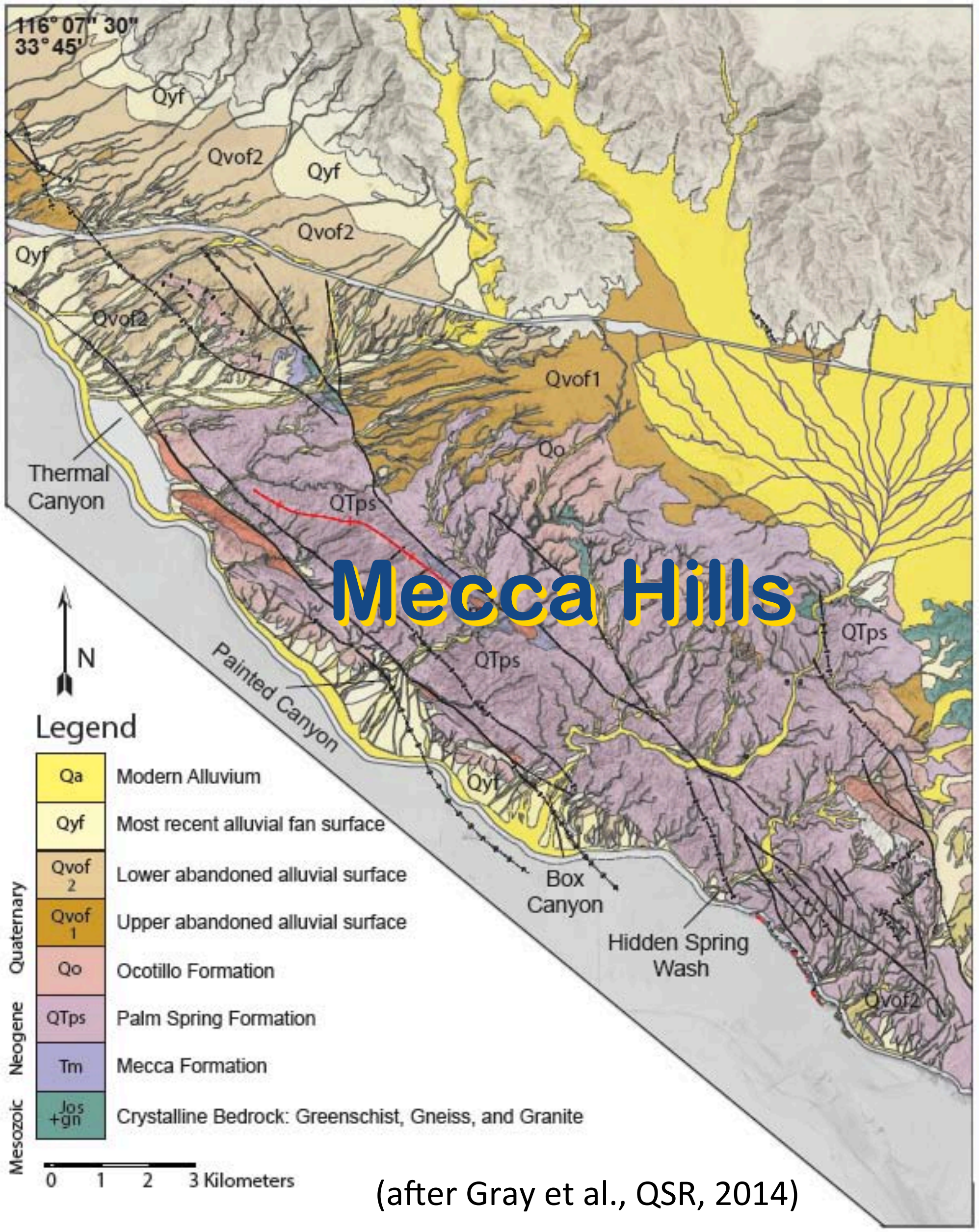


A) Mission Creek
B) Whitewater River
Relative Probability
Age (ka)
Fm6
Fm5
Fm4a
Fm4b
Fm2
Fw3a
Fw3c
Fw4b
Fw3b
FM1b
FM1c
FM1a
Fm8
Fm7
Fm6
Fm5
Fm4
Fm3
Fm2
Fm1
FW2c
FW2a
FW2b
Fw6
Fw5
Fw4
Fw3
Fw2
Fw1
0
20
40
60
80
100

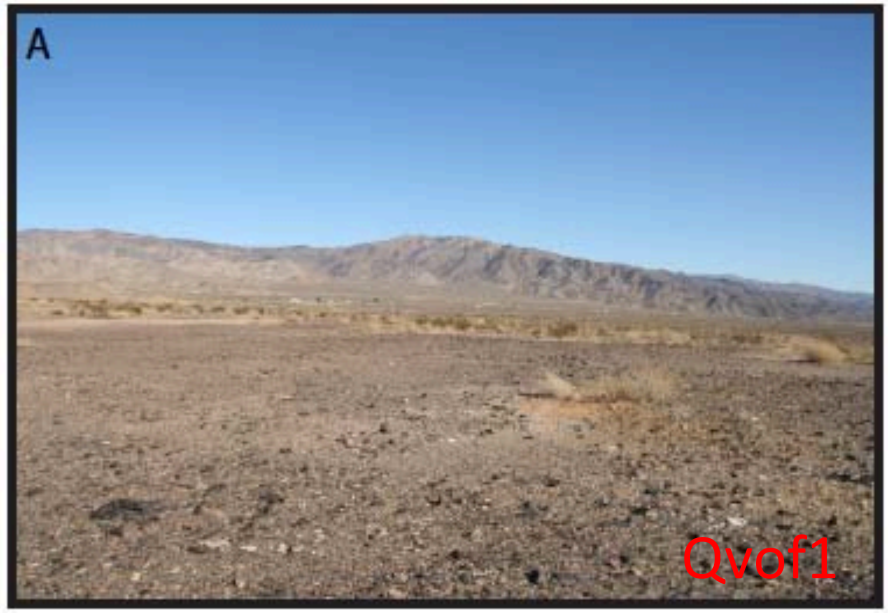
Mission Creek –Whitewater Chronology

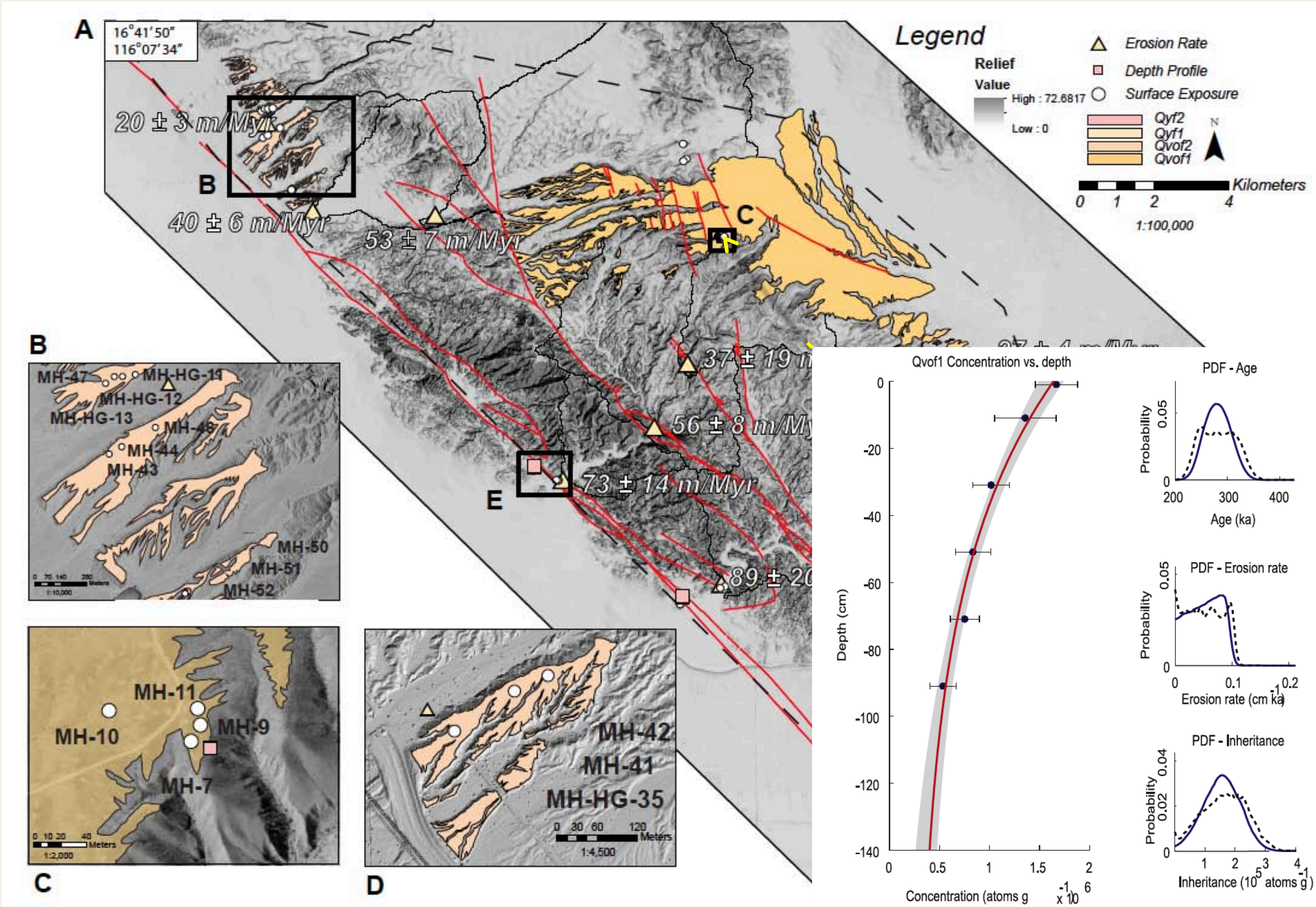


What are the age limitations with TCNs methods?

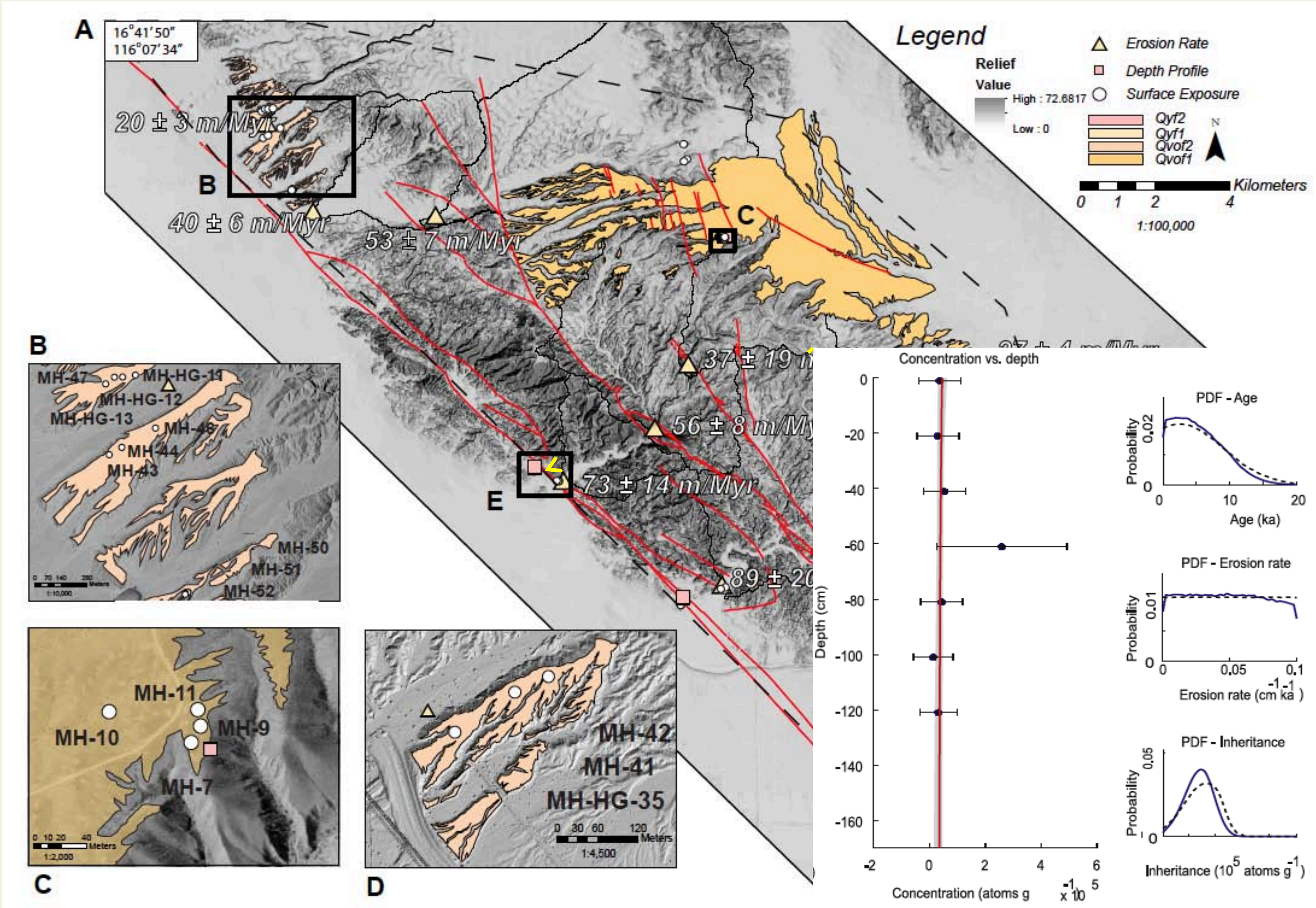


(after Gray et al., QSR, 2014)



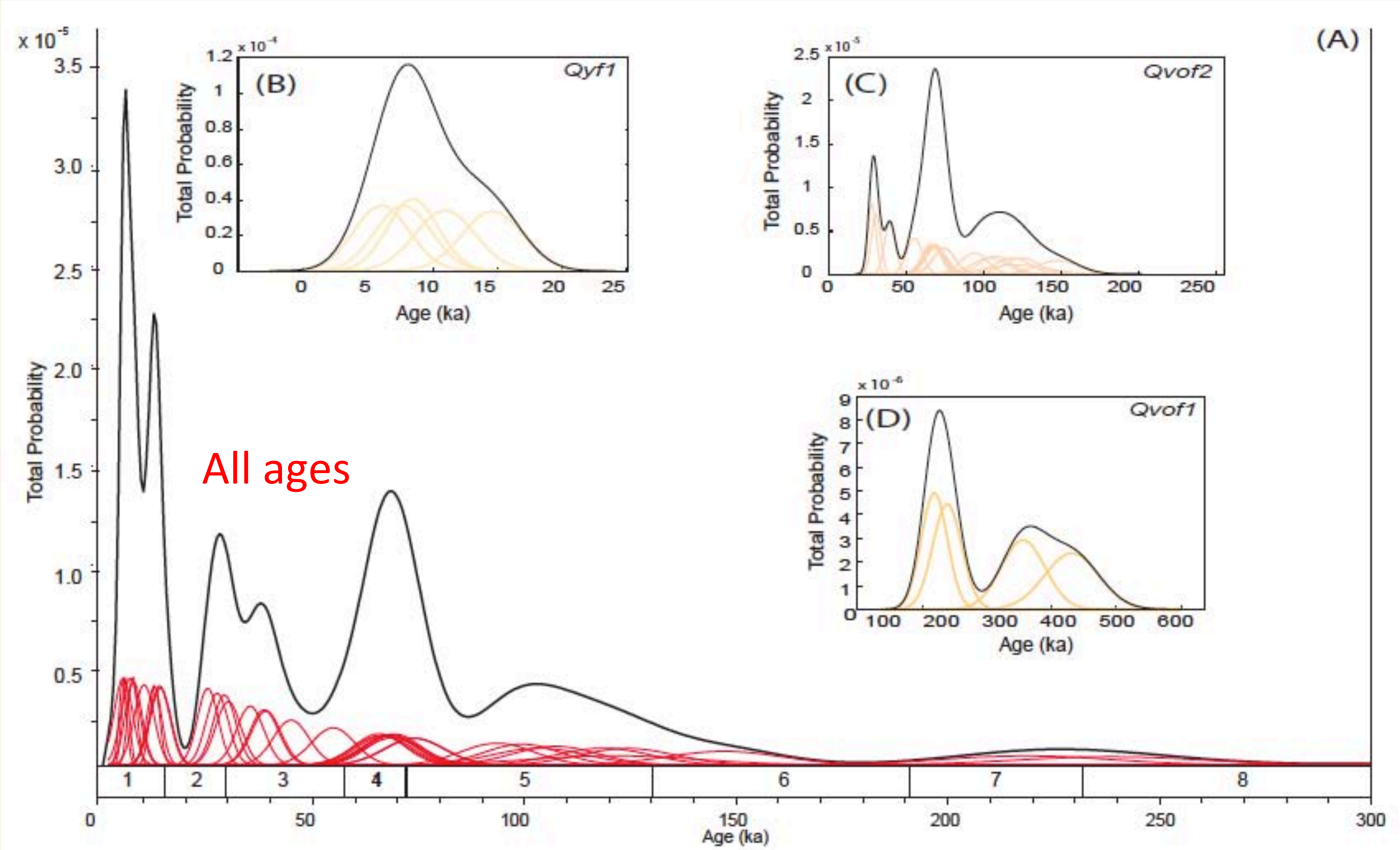


(after Gray et al., 2014, QSR)

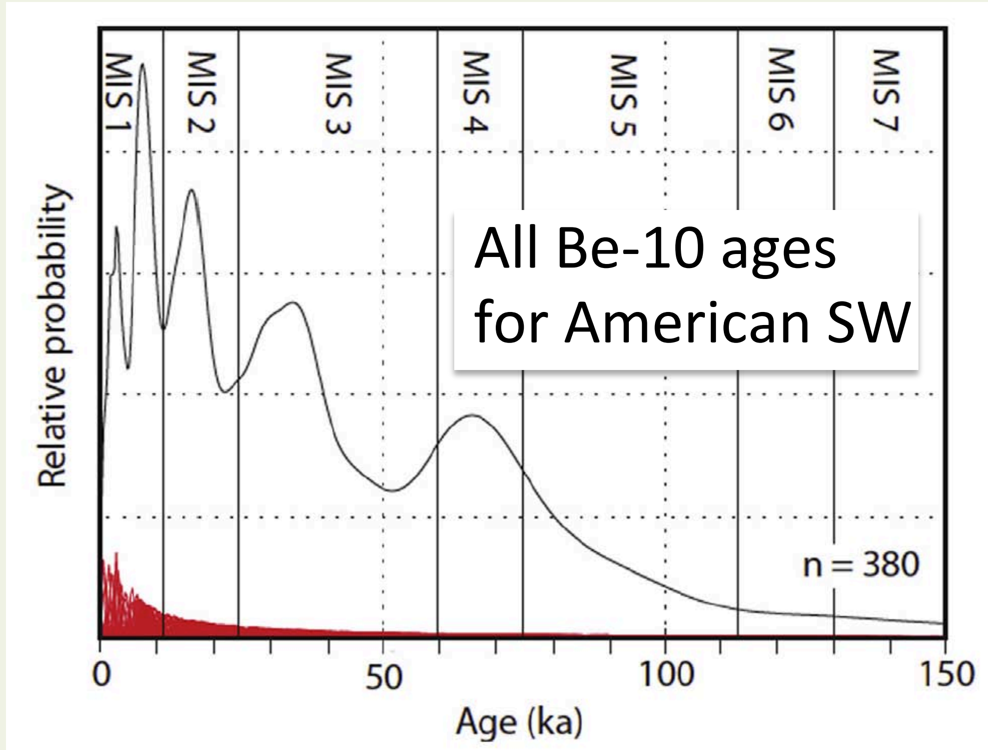


(after Gray et al., 2014, QSR)

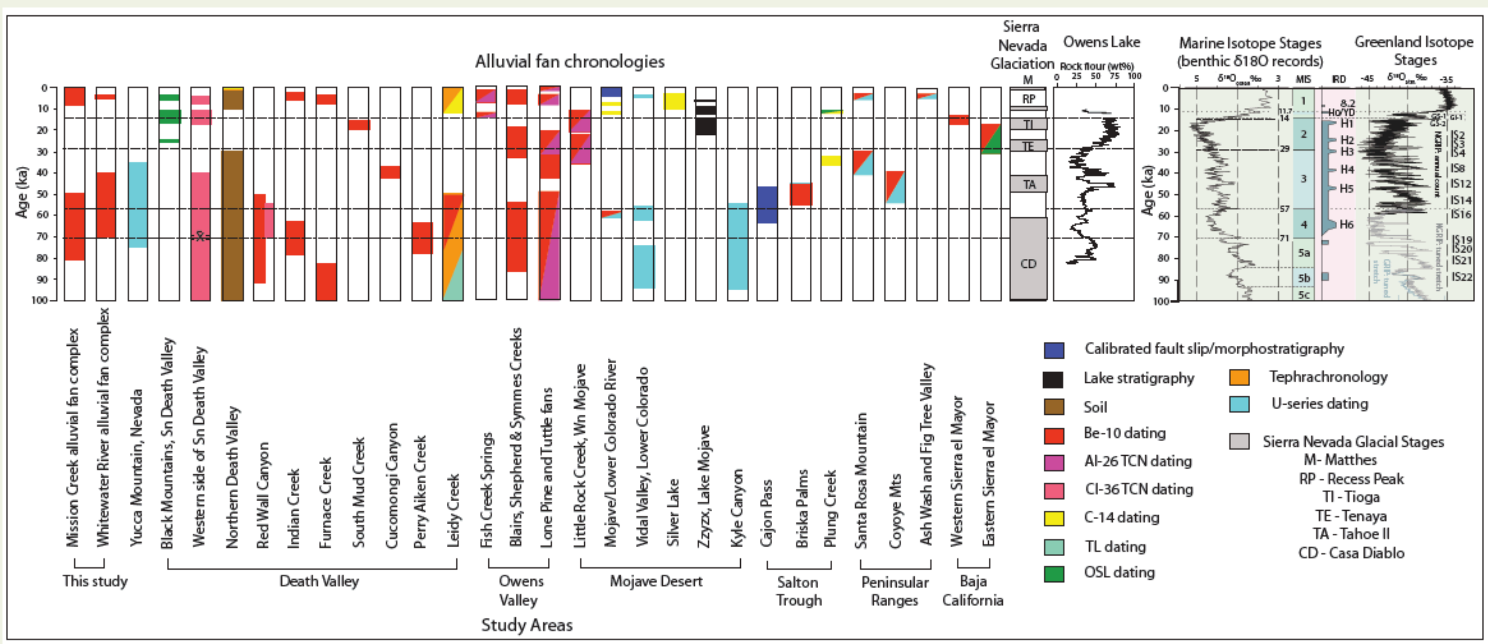
Mecca Hills Be-10 boulder ages



(after Gray et al., 2014, QSR)

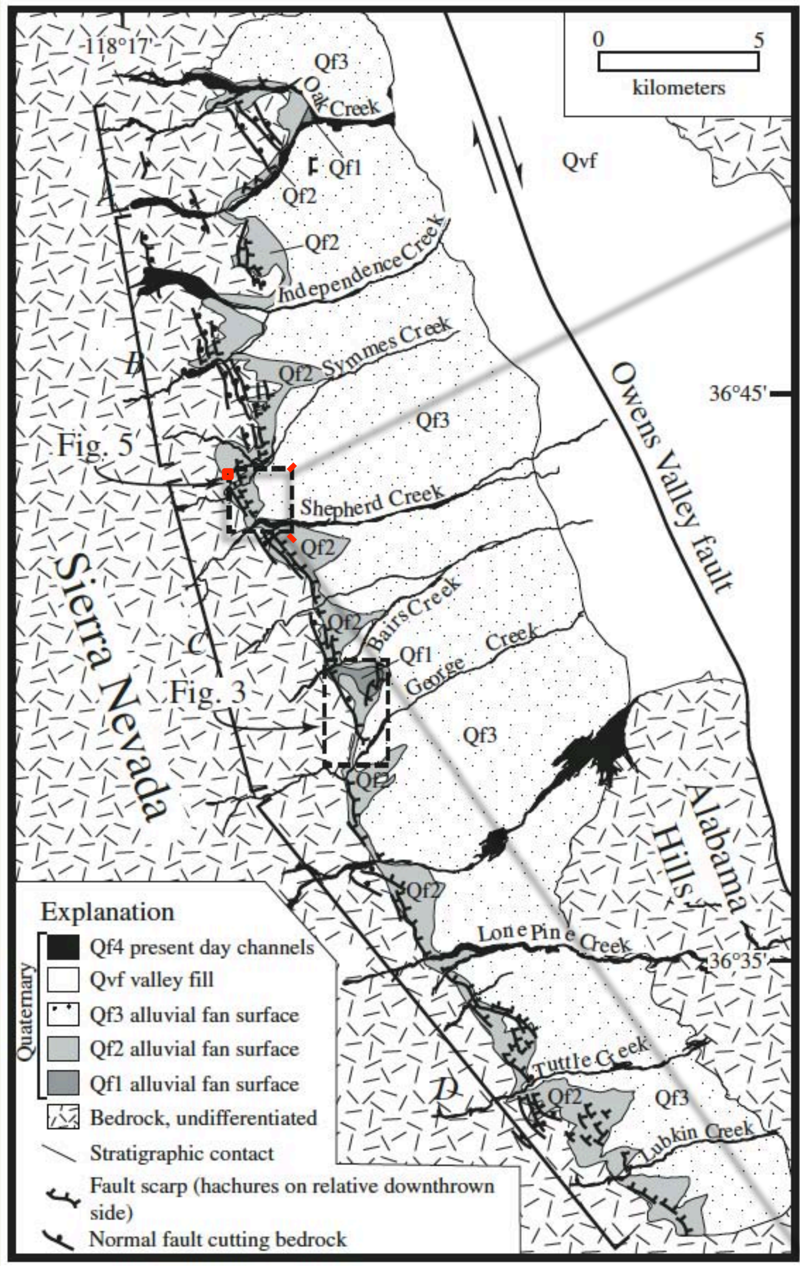


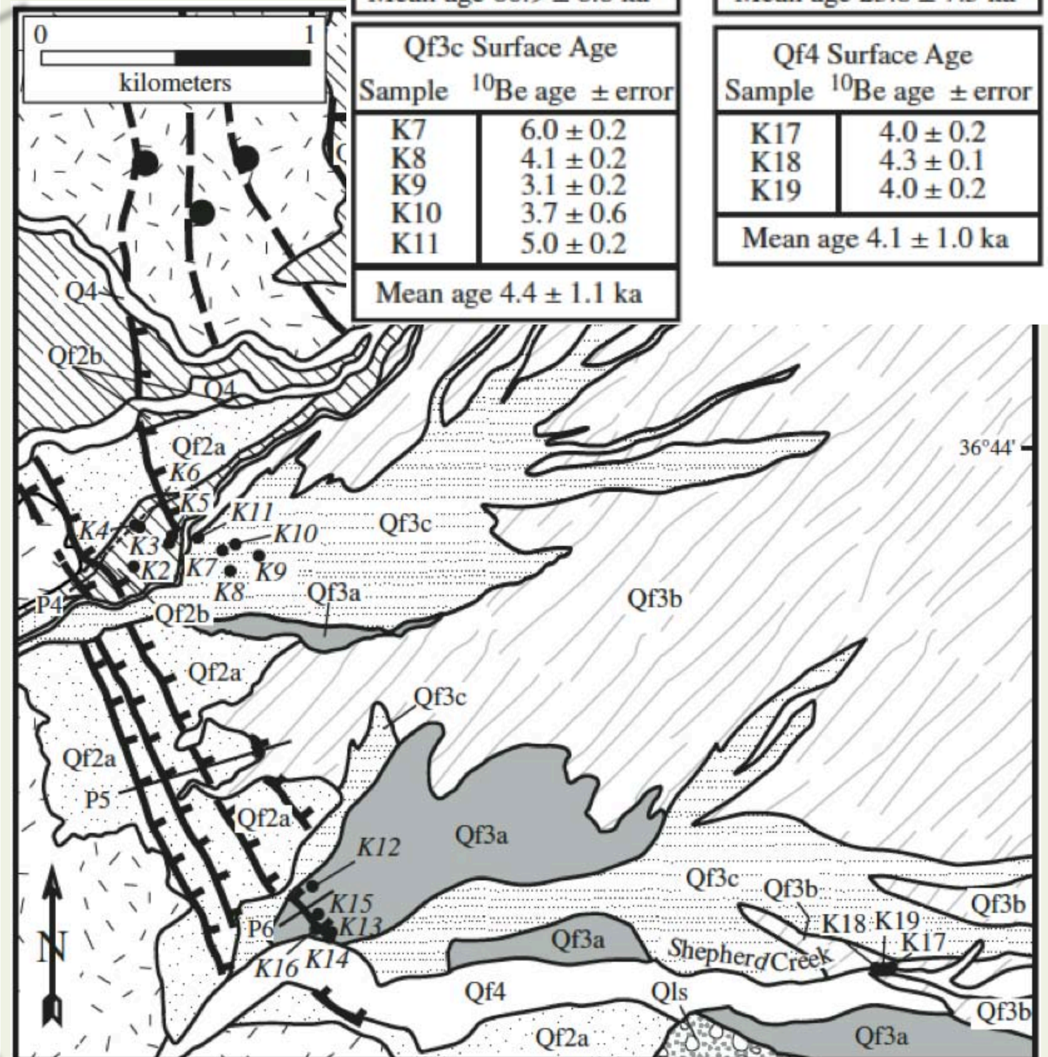
All Be-10 ages
for American SW
Relative probability
MIS 1
MIS 2
MIS 3
MIS 4
MIS 5
MIS 6
MIS 7
n = 380
0
50
100
150
Age (ka)



Alluvial fan chronologies
Sierra Nevada Glaciation
Owens Lake
Rock flour (wt%)
Marine Isotope Stages (benthic δ18O records)
Greenland Isotope Stages
Age (ka)
Mission Creek alluvial fan complex
Whitewater River alluvial fan complex
Yucca Mountain, Nevada
Black Mountains, Sn Death Valley
Western side of Sn Death Valley
Northern Death Valley
Red Wall Canyon
Indian Creek
Furnace Creek
South Mud Creek
Cucomongi Canyon
Perry Aiken Creek
Leidy Creek
Fish Creek Springs
Blairs, Shepherd & Symmes Creeks
Lone Pine and Tuttle fans
Little Rock Creek, Wn Mojave
Mojave/Lower Colorado River
Vidal Valley, Lower Colorado
Silver Lake
Zzyzx, Lake Mojave
Kyle Canyon
Cajon Pass
Briska Palms
Plung Creek
Santa Rosa Mountain
Coyoye Mts
Ash Wash and Fig Tree Valley
Western Sierra el Mayor
Eastern Sierra el Mayor
This study
Death Valley
Owens Valley
Mojave Desert
Salton Trough
Peninsular Ranges
Baja California
Study Areas
Calibrated fault slip/morphostratigraphy
Lake stratigraphy
Soil
Be-10 dating
Al-26 TCN dating
Cl-36 TCN dating
C-14 dating
TL dating
OSL dating
Tephrachronology
U-series dating
Sierra Nevada Glacial Stages
M- Matthes
RP - Recess Peak
TI - Tioga
TE - Tenaya
TA - Tahoe II
CD - Casa Diablo

Other potential problems!





Qf2b Surface Age	
Sample	^{10}Be age ± error
K2*	89.2 ± 2.1
K3	53.4 ± 1.7
K4*	23.1 ± 0.9
K5	66.0 ± 2.2
K6	63.2 ± 2.3
Mean age 60.9 ± 6.6 ka	

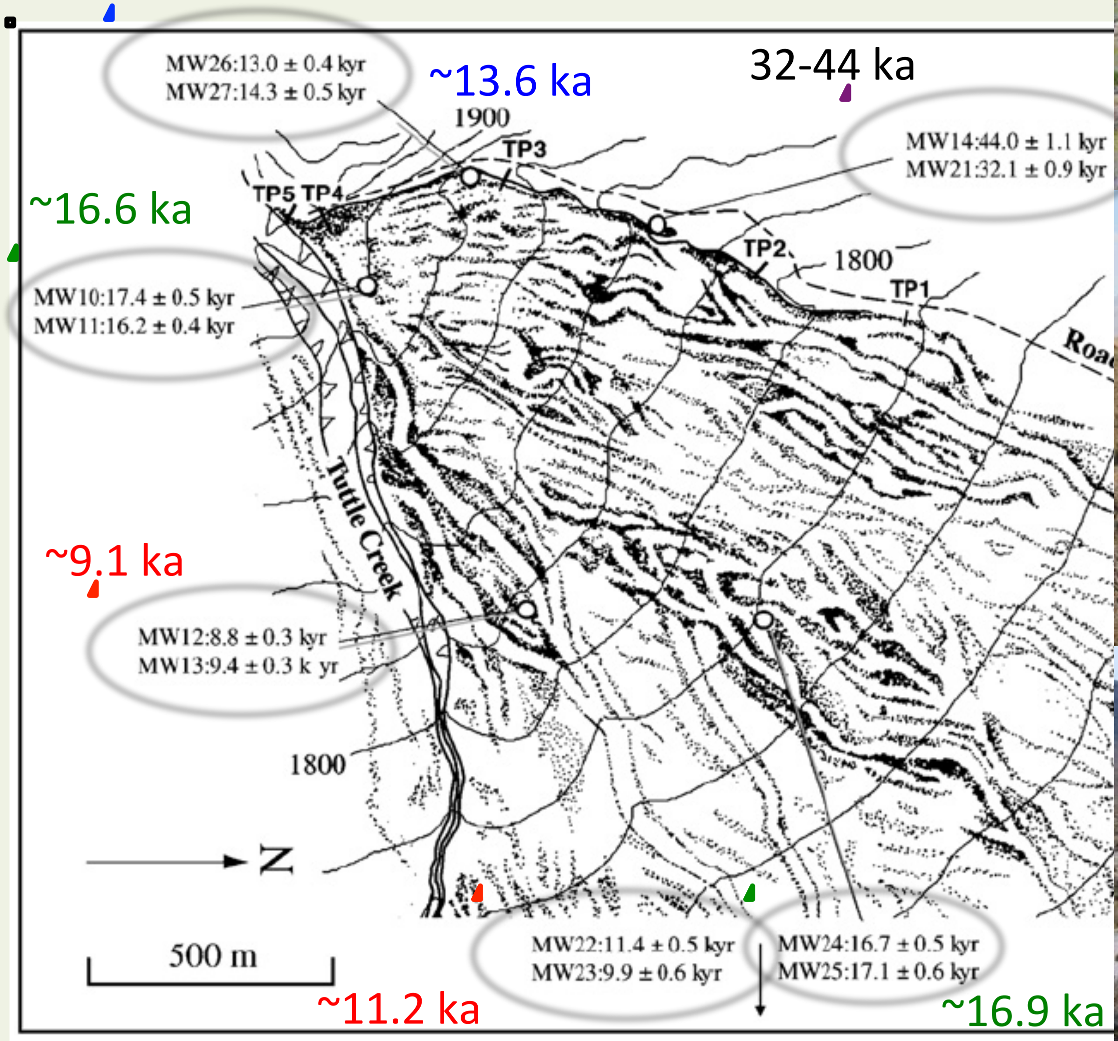
Qf3a Surface Age	
Sample	^{10}Be age ± error
K12	36.6 ± 0.8
K13	23.5 ± 0.5
K14	17.6 ± 0.5
K15	29.9 ± 0.9
K16	21.2 ± 0.5
Mean age 25.8 ± 7.5 ka	

Qf3c Surface Age	
Sample	^{10}Be age ± error
K7	6.0 ± 0.2
K8	4.1 ± 0.2
K9	3.1 ± 0.2
K10	3.7 ± 0.6
K11	5.0 ± 0.2
Mean age 4.4 ± 1.1 ka	

Qf4 Surface Age	
Sample	^{10}Be age ± error
K17	4.0 ± 0.2
K18	4.3 ± 0.1
K19	4.0 ± 0.2
Mean age 4.1 ± 1.0 ka	

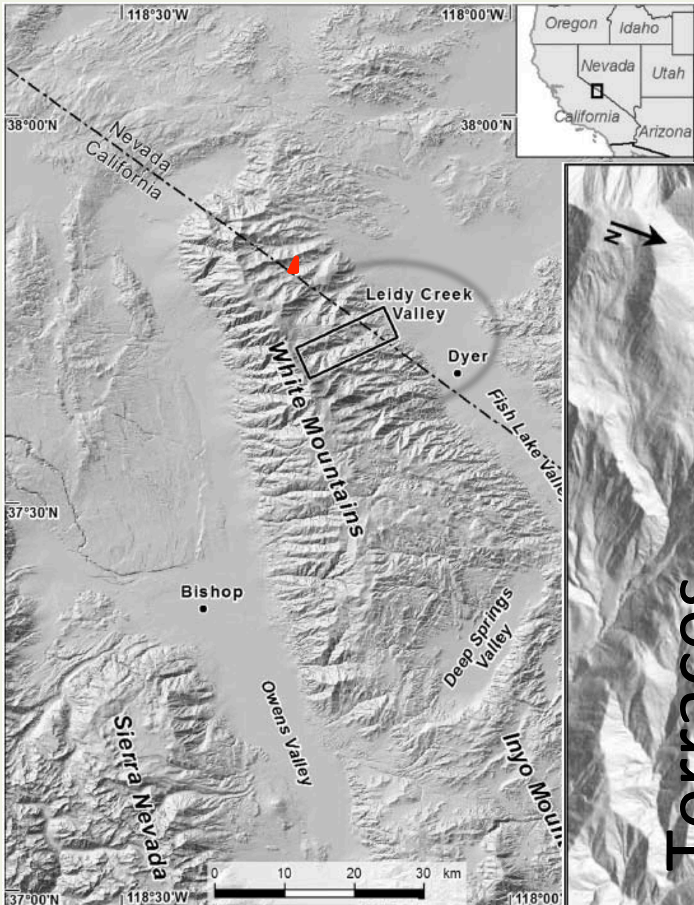
After Le (*Blisniuk*) et al. (2007, GSAB)

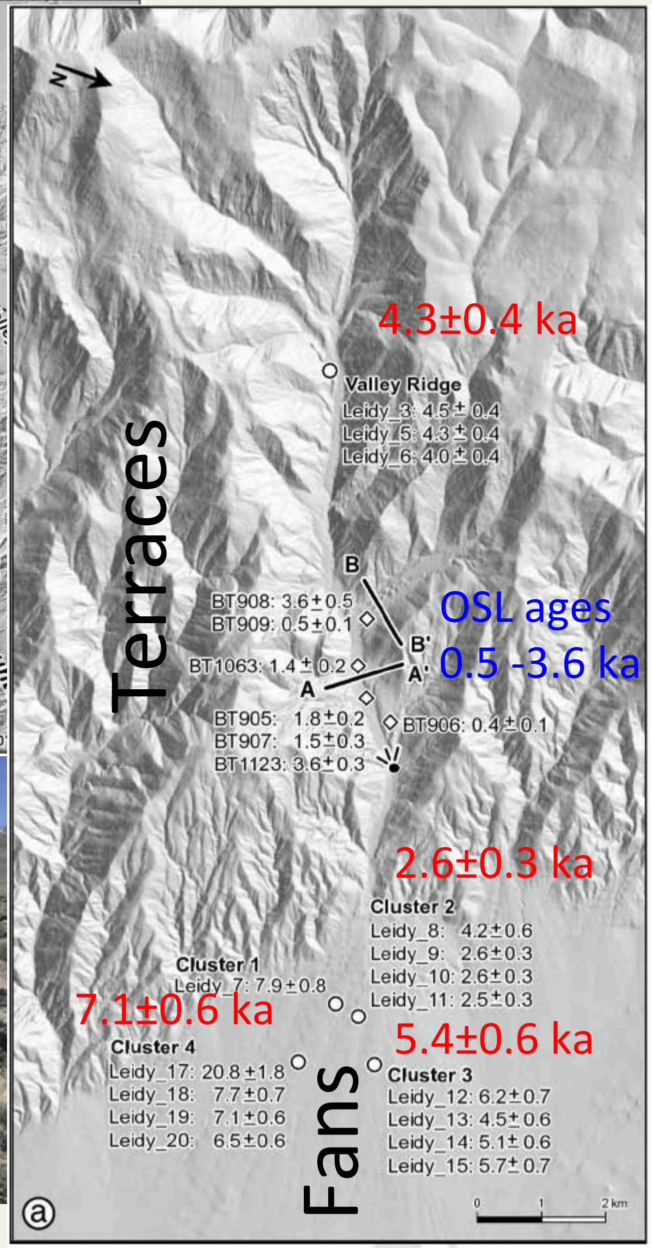
Glacial lake outburst floods & alluvial/ paraglacial fans

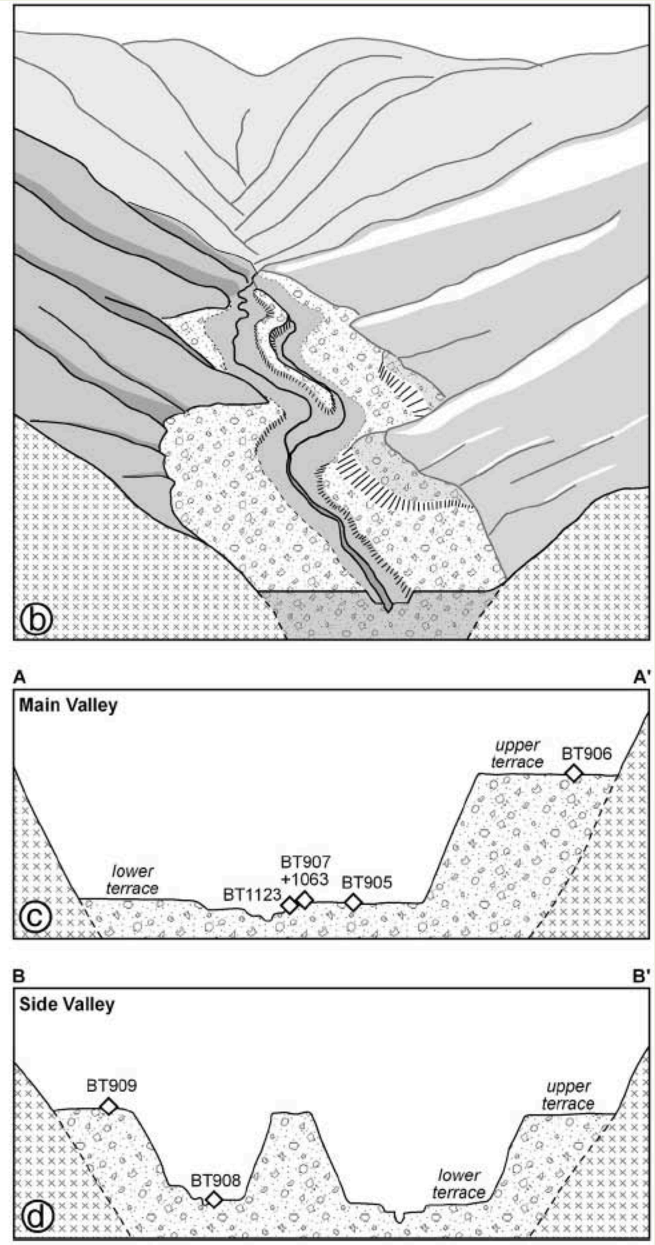


(After Benn et al., 2006, QSR)

Flash floods in mid-Holocene induced by summer thunderstorms







(After Fuchs et al., in press, QR)


COTTONTAIL
RANCH
BROTHEL

Standard reporting of TCN data

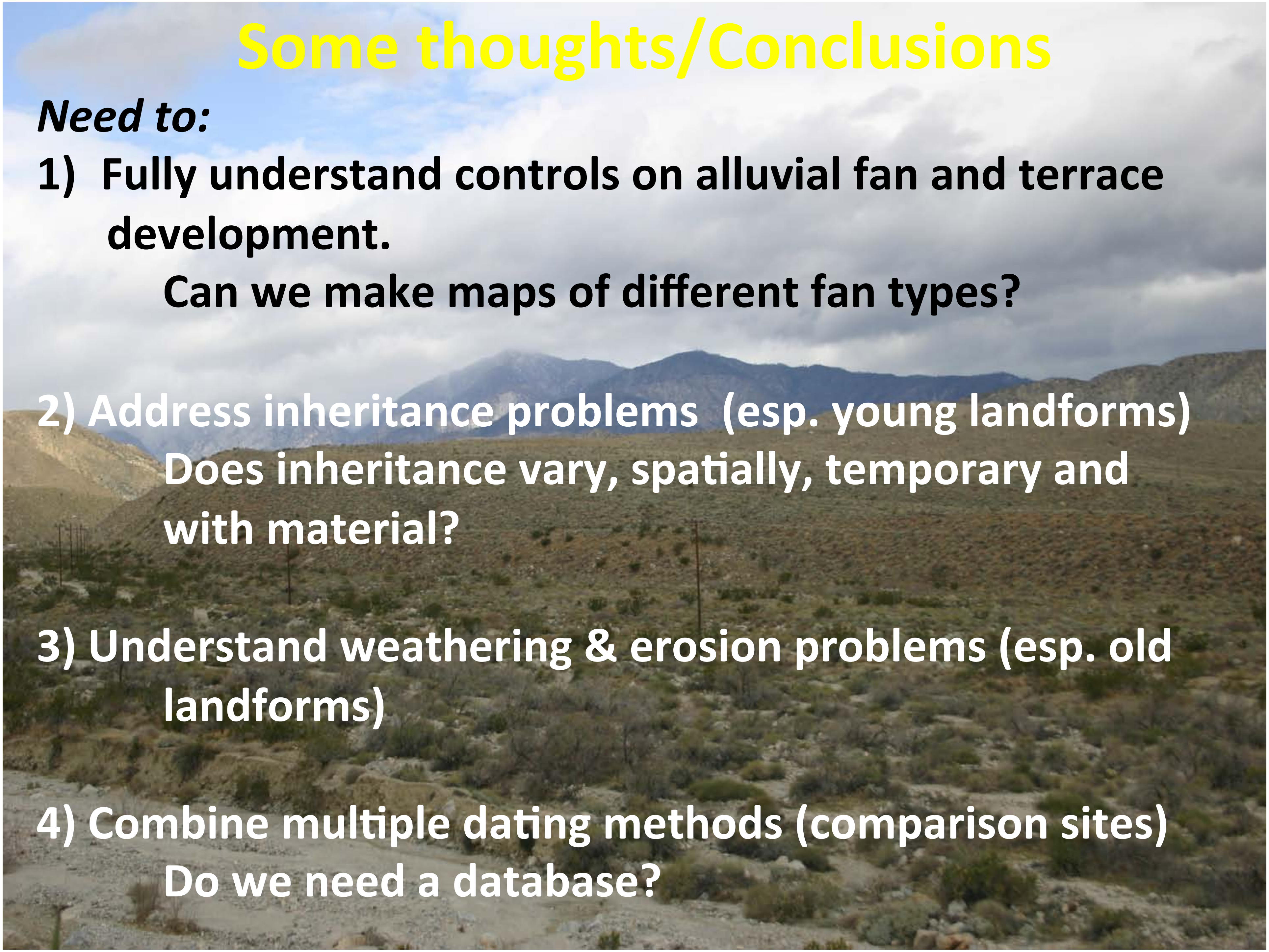
Table 1. Example of a Table for Reporting Analytical Results of Terrestrial Cosmogenic Nuclide ^{10}Be Geochronology

Sample	**Location (°N/°W)**	**Elevation (m above sea level)**	**Thickness[a] (cm)**	**Production Rate (atoms g^{-1} yr^{-1})**		**Shielding[d] Factor**	**Denudation Rate (mm yr^{-1})**	**Quartz[e] (g)**	**Be Carrier (mg)**	**^{10}Be/^{9}Be[f,g] ($\times 10^{-13}$)**	10Be Concentra-tiong,h,i (106 atoms g-1 SiO2)	**Age[g,j,k] (ka)**
				Spallation[b]	**Muons[c]**							
EOS-1	37.5947/118.0571	1750	1	17.33	0.35	1	0	20.0923	0.2668	25.16 ± 0.36	2.23 ± 0.04	129.9 ± 11.8
EOS-2	37.5946/118.0570	1752	2	17.21	0.349	1	0	20.3301	0.2671	24.60 ± 0.32	2.16 ± 0.04	126.4 ± 11.5
EOS-3	37.5947/118.0589	1730	2	16.94	0.346	1	0	20.0780	0.2657	26.36 ± 0.34	2.33 ± 0.04	139.0 ± 12.7
EOS-4	37.5948/118.0588	1753	3	17.08	0.348	1	0	20.1309	0.2628	23.18 ± 0.30	2.02 ± 0.03	119.0 ± 10.8
EOS-5	37.5943/118.0537	1760	2	17.30	0.35	1	0	20.1210	0.2641	22.09 ± 0.28	1.93 ± 0.03	112.4 ± 10.2
EOS-6	37.5950/118.0537	1729	3	16.79	0.345	1	0	20.1563	0.2641	19.21 ± 0.31	1.68 ± 0.03	100.2 ± 9.1

[a]The tops of all samples were exposed at the surface.
[b]Constant (time-invariant) local production rate based on *Lal* [1991] and *Stone* [2000]. A sea level, high-latitude value of 4.8 at ^{10}Be g^{-1} quartz was used.
[c]Constant (time-invariant) local production rate based on *Heisinger et al.* [2002a, 2002b].
[d]No geometric shielding correction for topography was necessary (horizon < 20° in all directions).
[e]A density of 2.7 g cm^{-3} was used based on the granitic composition of the surface samples.
[f]Isotope ratios were normalized to ^{10}Be standards prepared by *Nishiizumi et al.* [2007] with a value of 2.85×10^{12} and using a ^{10}Be half-life of 1.36×10^{6} years.
[g]Uncertainties are reported at the 1σ confidence level.
[h]A mean blank value of 53,540 ± 10,845 ^{10}Be atoms (^{10}Be/^{9}Be = $2.994 \times 10^{-15} \pm 6.03 \times 10^{-16}$) was used to correct for background.
[i]Propagated uncertainties include error in the blank, carrier mass (1%), and counting statistics.
[j]Propagated error in the model ages include a 6% uncertainty in the production rate of ^{10}Be and a 4% uncertainty in the ^{10}Be decay constant.
[k]Beryllium-10 model ages were calculated with the Cosmic-Ray Produced Nuclide Systematics (CRONUS) Earth online calculator [*Balco et al.*, 2008] version 2.1 (http://hess.ess.washington.edu/).

Table 1. Sample Format for Reporting Analytical Results of Terrestrial Cosmogenic Nuclide ^{10}Be Geochronology

(after Frankel et al. 2010, *EOS*)


Some thoughts/Conclusions
Need to:
1) Fully understand controls on alluvial fan and terrace development.
Can we make maps of different fan types?
2) Address inheritance problems (esp. young landforms)
Does inheritance vary, spatially, temporary and with material?
3) Understand weathering & erosion problems (esp. old landforms)
4) Combine multiple dating methods (comparison sites)
Do we need a database?