TIMING OF LATE QUATERNARY EARTHQUAKES ON THE HEBGEN LAKE FAULT BY COSMOGENIC CHLORINE-36 DATING OF BEDROCK FAULT SCARP

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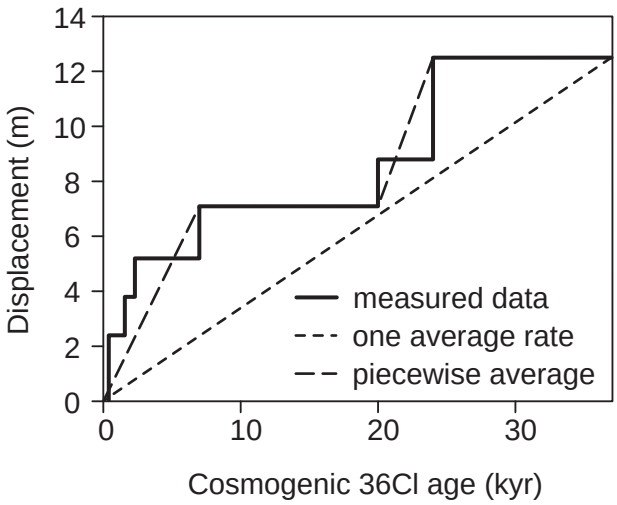
Fault scarps along the Hebgen Lake fault, Montana, recorded multiple large paleoearthquakes, including the most recent earthquake in 1959. We used cosmogenic 36Cl in bedrock scarp faces exposed at the surface due to recurring faulting to determine ages of paleoearthquakes at Hebgen Lake. The technique measures how long the different, episodically offset parts of the scarp have been exposed to cosmic radiation.

Twenty-seven samples collected every 0.5 m from the bottom (0 m) to the top (12 m) of the scarp yielded the following exposure ages: 0.4 (for the 1959 scarp), 1.7, 2.6, 7.0, 20, 24 and 37 ky (maximum age). The data indicate two periods of heightened earthquake activity during which the displacement occurred: from 0 to 7 kyr ago and from 20 to 24 kyr ago, and two periods of quiescence: from 7 to 20 kyr and from 24 to 37 kyr. This temporal pattern suggests that the Hebgen Lake fault may be cyclic, with period of 15-20 kyr, presently in its active state. The average displacement rate during the two active periods is about 1 m/kyr, twice as high as that calculated over the entire geological history of the fault recorded in the scarp.



cosmogenic-36Cl, exposure-dating, paleoearthquakes, fault-scarps, Hebgen-Lake

Geological Society of America, 51st Annual Meeting, Rocky Mountain Section
April 8-10, 1999, Pocatello, Idaho.

Presentation outline

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Dating of paleoearthquakes

BY COSMOGENIC CHLORINE-36 IN FAULT SCARPS

Marek Zreda
&
Jay Noller

Pocatello, April 1999

Goal

To determine the applicability of cosmogenic ^{36}Cl to:

Dating of bedrock fault scarps

Measuring displacement rates

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Production and accumulation of ^{36}Cl

neutron activation:

$^{35}Cl\ (n,\gamma)\ ^{36}Cl$

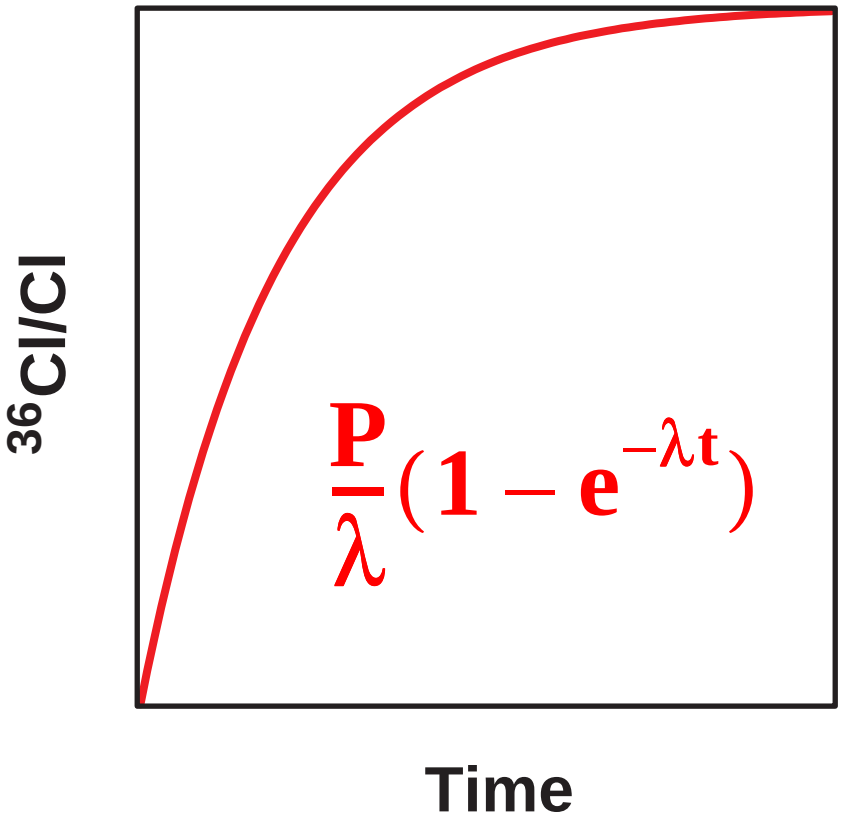
spallation:

$^{39}K\ (n, 2n2p)\ ^{36}Cl$

$^{40}Ca\ (n, 2n3p)\ ^{36}Cl$

negative muon capture:

$^{40}Ca\ (\mu^-, \alpha)\ ^{36}Cl$



Corrections

Global:

Latitude

Elevation

Apparent ^{36}Cl ages

Local:

Topographic shielding

Subsurface production

Corrected ^{36}Cl ages

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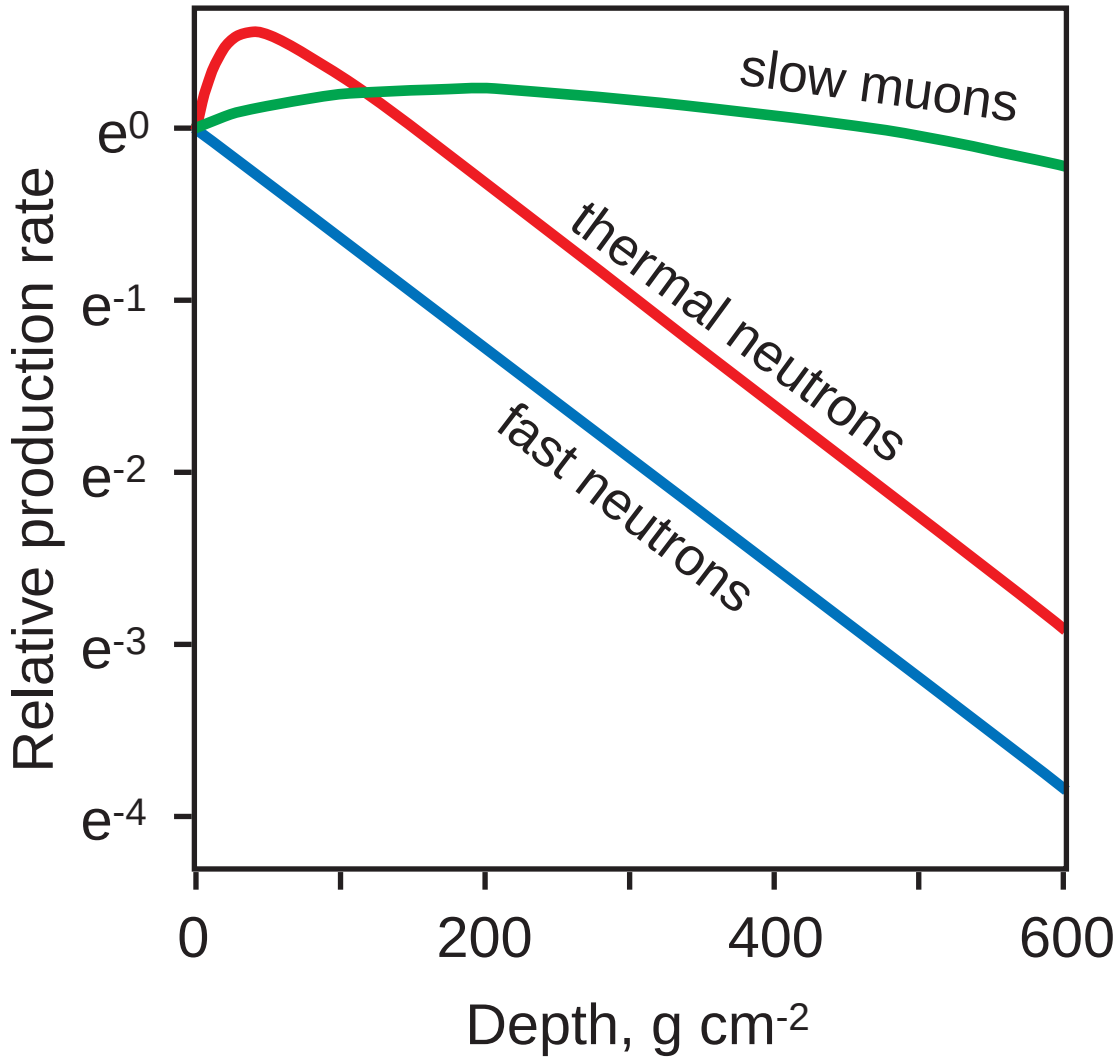
Subsurface distribution of cosmic rays



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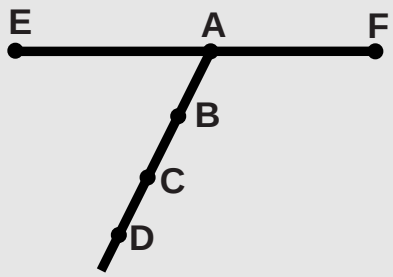
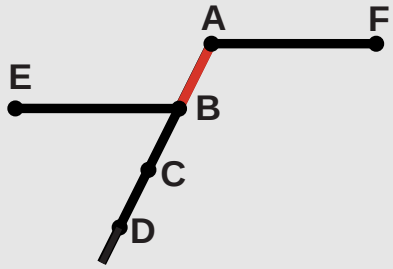
Episodic exposure of scarp

t = 0



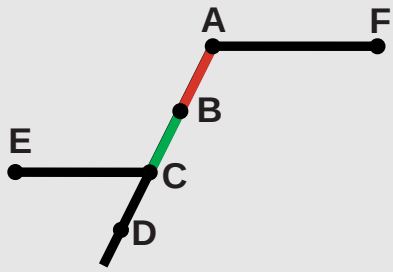
Prior to faulting
Slow buildup of cosmogenic 36Cl below the surface

t = t1



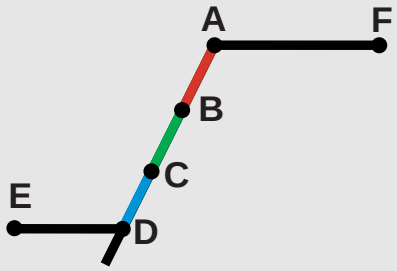
First faulting episode
Face AB exposed
Cosmogenic buildup in AB
Slower buildup in BC and CD

t = t2



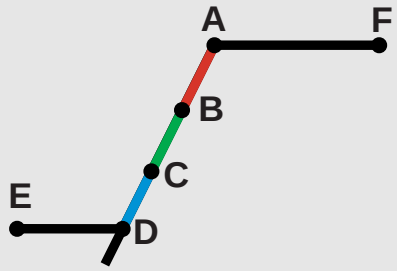
Second faulting episode
Face BC exposed
Buildup continues in AB
Buildup starts in BC
Slower buildup in CD

t = t3



Third faulting episode
Face CD exposed
Buildup continues in AB, BC
Buildup starts in CD

t = tnow



AB exposed from t1 till now
BC exposed from t2 till now
CD exposed from t3 till now

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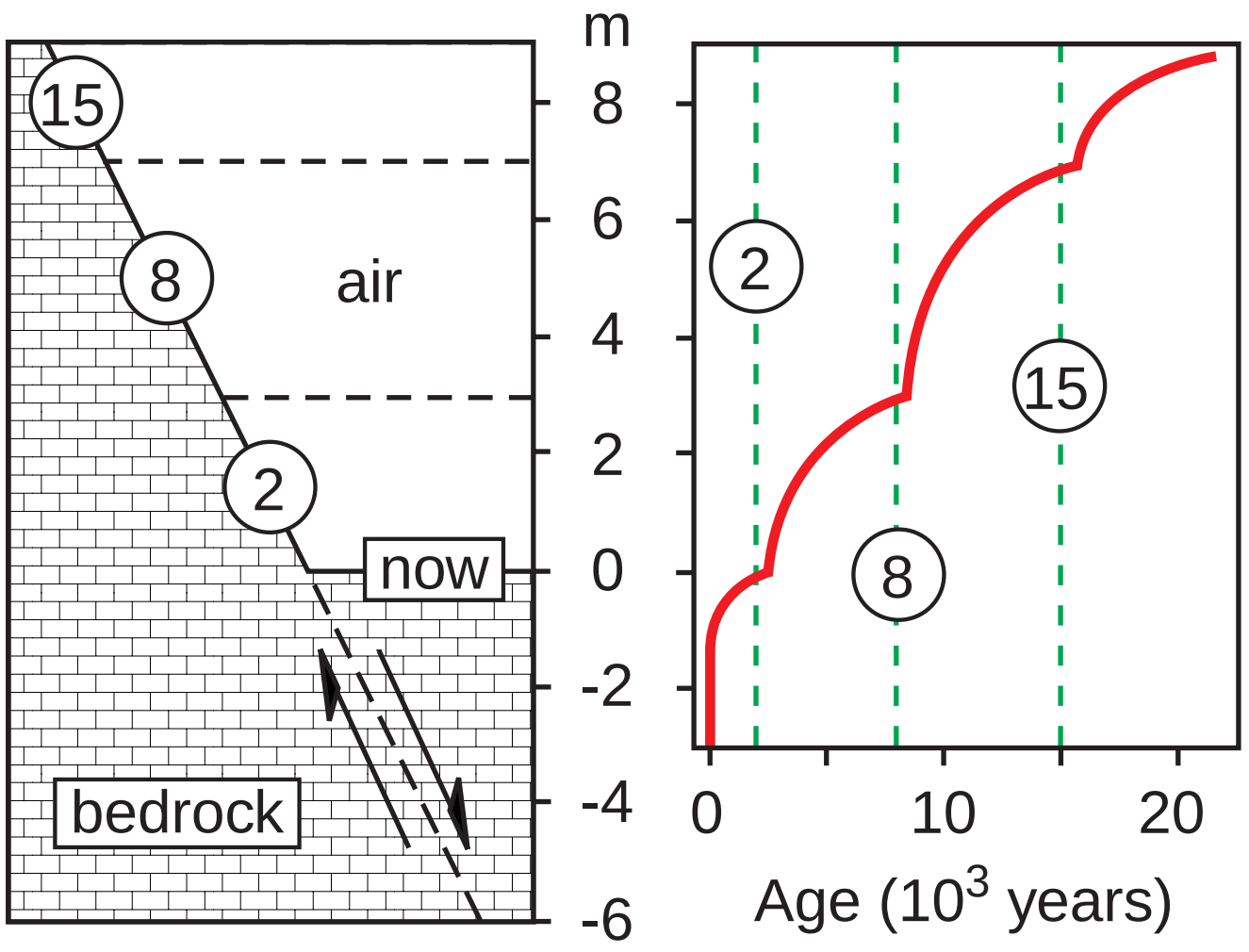
Episodic exposure of fault scarp



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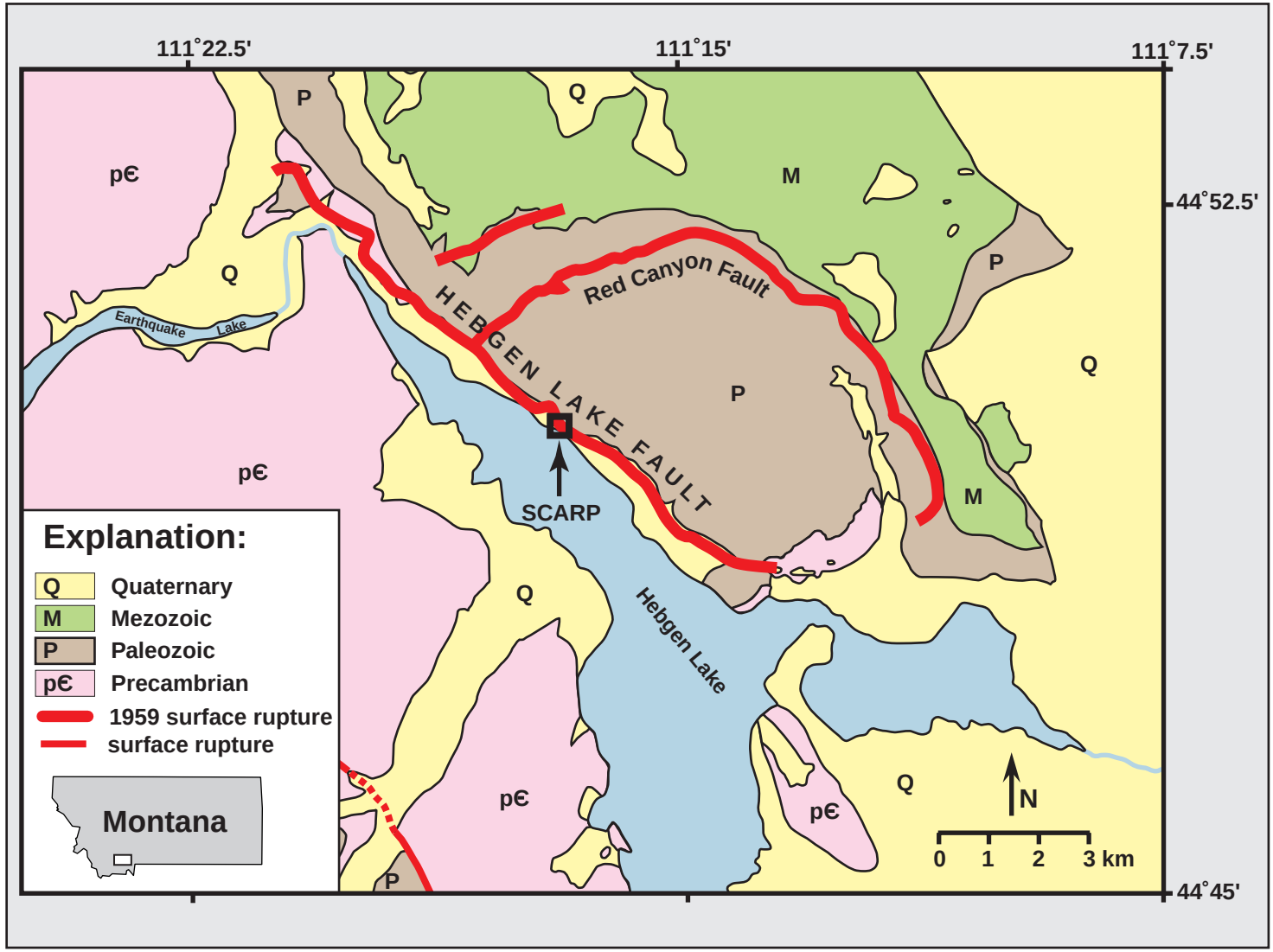
Hebgen Lake area



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Hebgen Lake fault scarp

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Scarp - close up

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Scarp - side view

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Scarp - sampling

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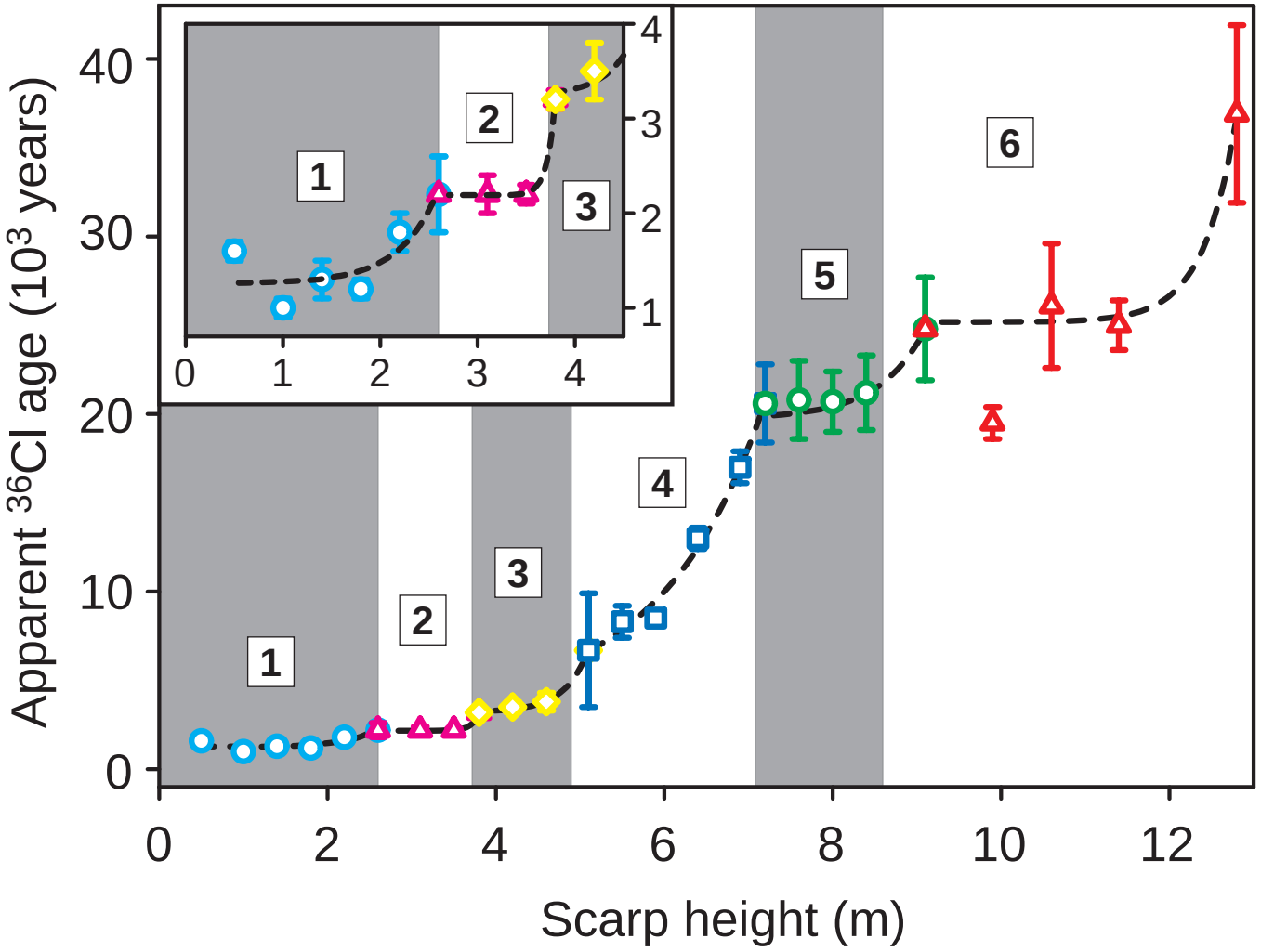
Apparent ^{36}Cl ages



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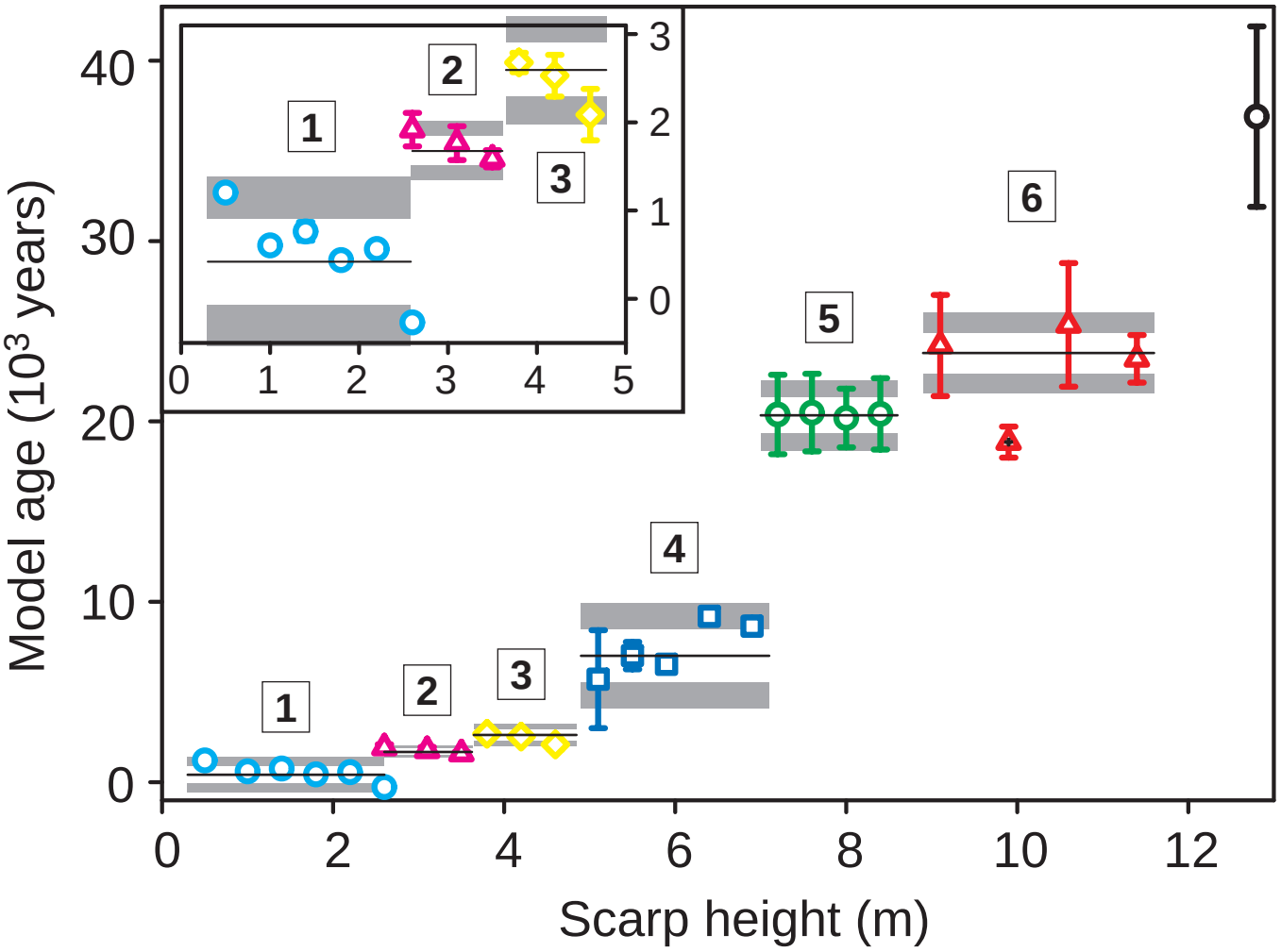
Surface exposure ages

Height [m]	Age [ky]
9.1 - 11.4	23.8 ± 1.1
7.2 - 9.1	20.3 ± 1.0
5.1 - 7.2	7.0 ± 1.5
3.8 - 5.1	2.6 ± 0.3
2.6 - 3.8	1.7 ± 0.2
0.5 - 2.6	0.4 ± 0.5

Corrected ^{36}Cl ages



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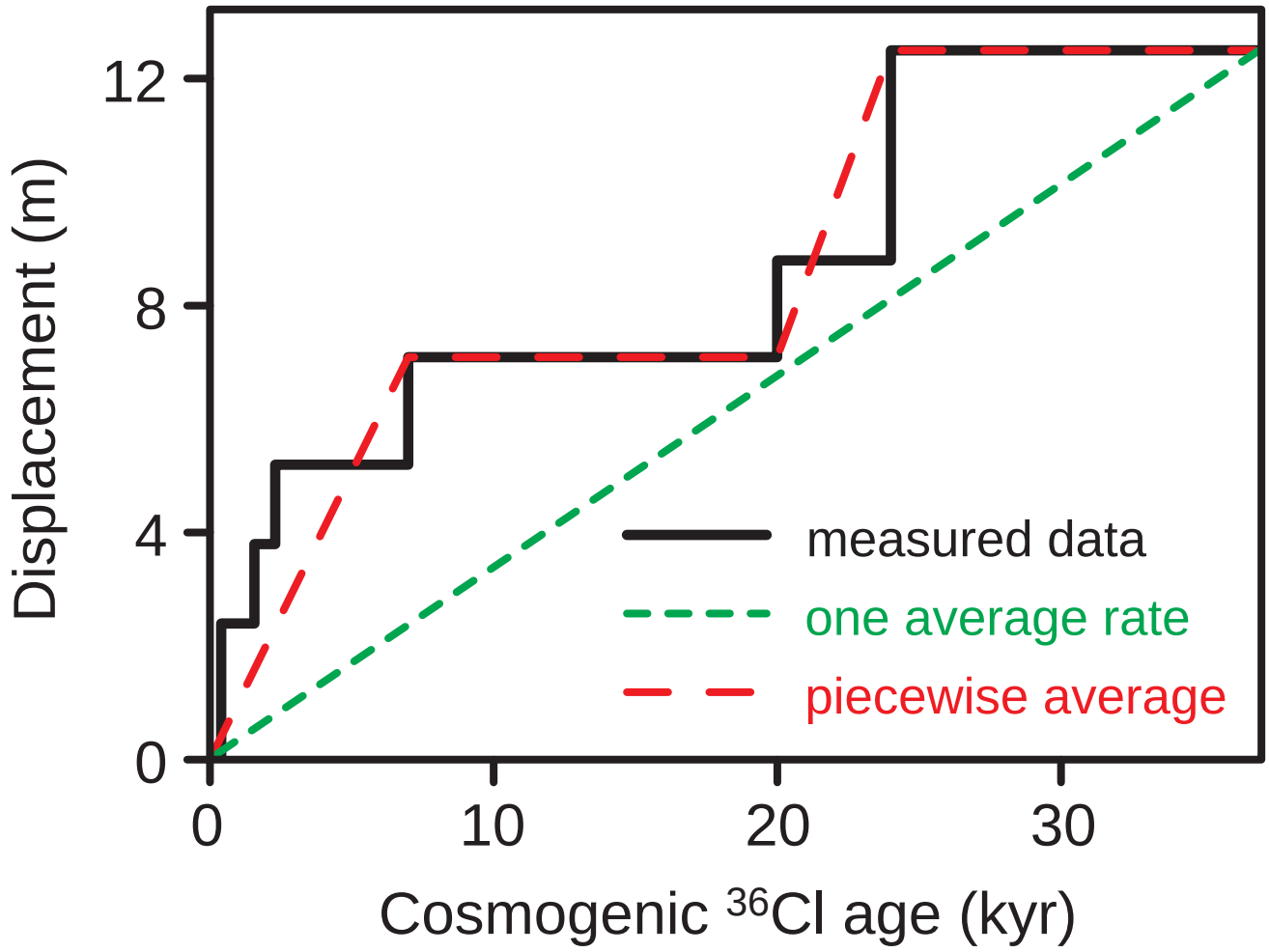
Temporal clustering of earthquakes



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Vertical slip rates

Time [ky]	Slip rate [m/ky]
0 - 2.6	2.0
0 - 7.0	1.0
0 - 20	0.45
0 - 24	0.5
0 - 37	0.33
7.0 - 20	0
20 - 24	1.25

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Validity of ^{36}Cl approach

- **Good chronology**
  - ^{36}Cl ages follow predicted pattern
  - they are compatible with scarp degradation data
- **Reasonable displacement rates**
  - comparable to recent measurements
- **Clearly-defined clusters**

Advantages of ^{36}Cl approach

- Can date previously undatable bedrock fault scarps
- Can obtain complete record of multiple earthquakes at single site
- Dating range: 10^3 - $10^{5.5}$ years
- Dating precision and accuracy: 10-20%

Conclusions

Cosmogenic ^{36}Cl dating of bedrock fault scarps is feasible

At Hebgen Lake, earthquakes are clustered in two time intervals: 0-7 ky and 20-24 ky

During active periods vertical slip rate is 1-2 m/ky

Long-term vertical slip rate is 0.5 m/ky