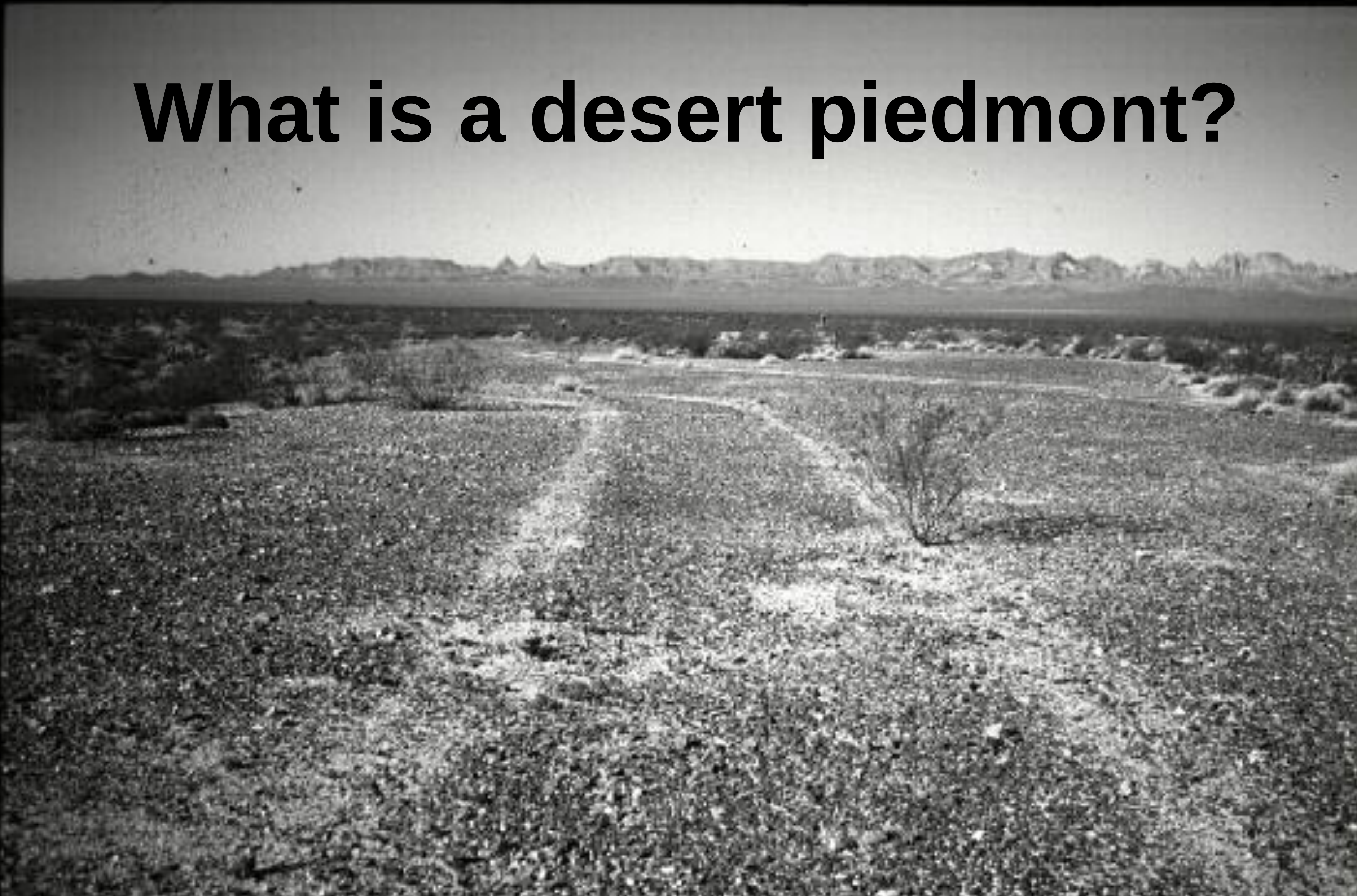
Quantifying Desert Surface Processes Using ^{10}Be and ^{26}Al

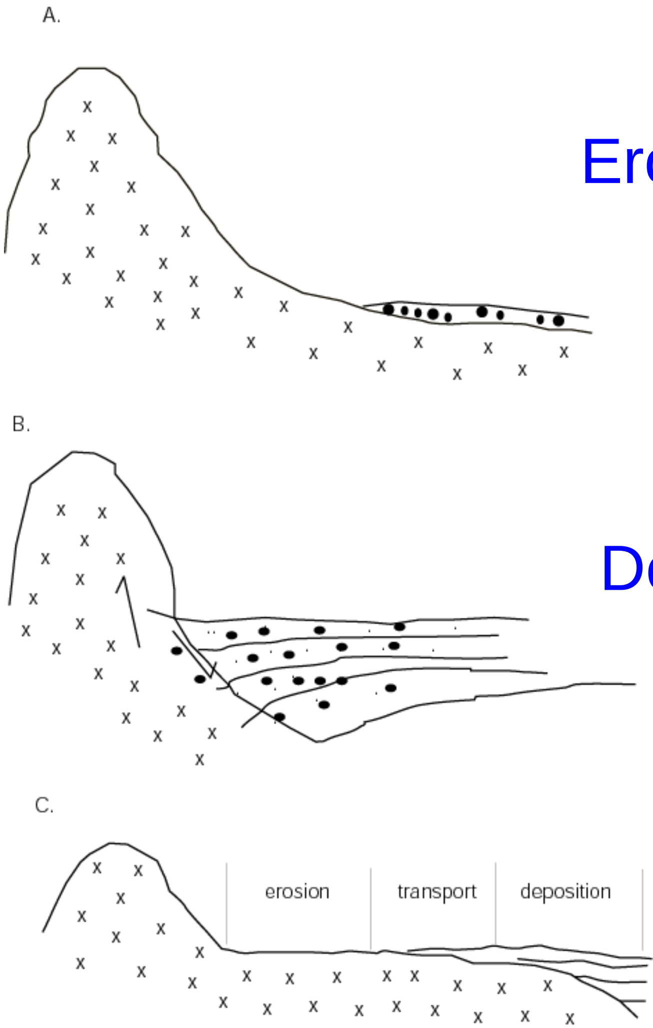
Kyle K. Nichols

School of Natural Resources

What is a desert piedmont?



Three common types of desert piedmonts



Erosional

Depositional

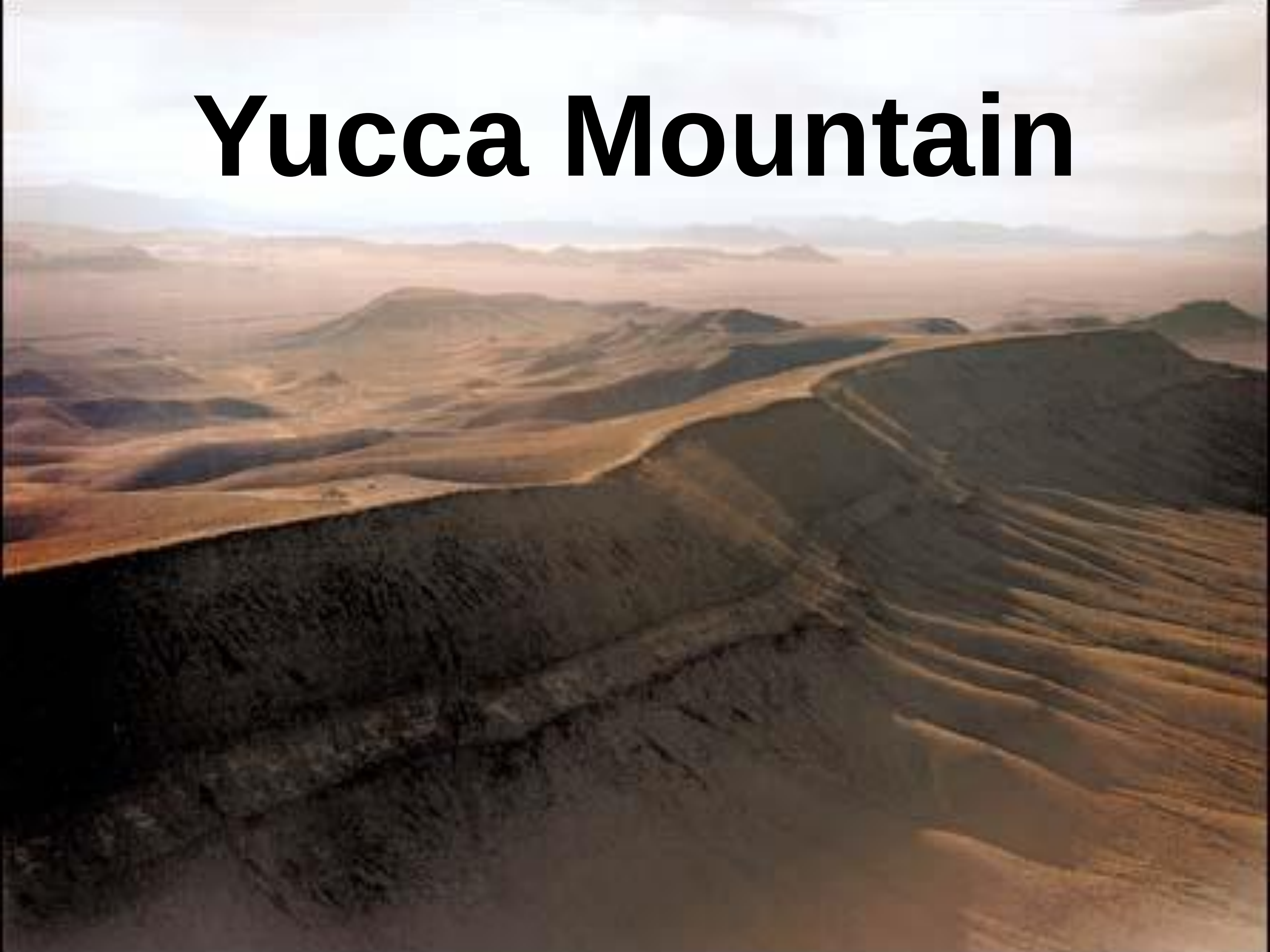
Why should we care about piedmonts?

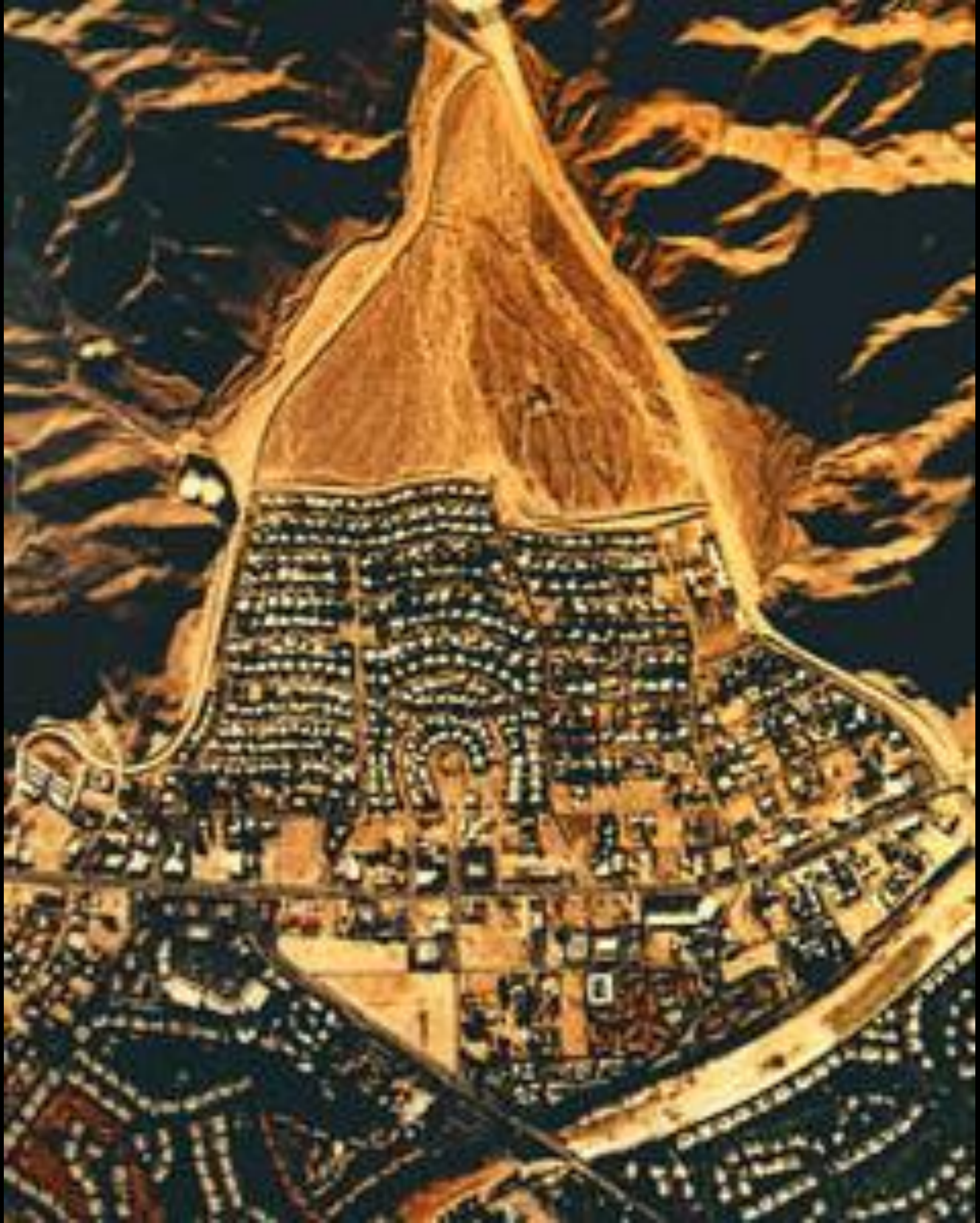
- Ubiquitous landforms in the American southwest (and in all deserts worldwide)
- Easily developed (low gradient, sediment cover easy to excavate)
- Greatly studied (100+ years), but long-term process rates are poorly quantified (slow rates of change)

Need to understand long-term piedmont processes (and short-term too!)

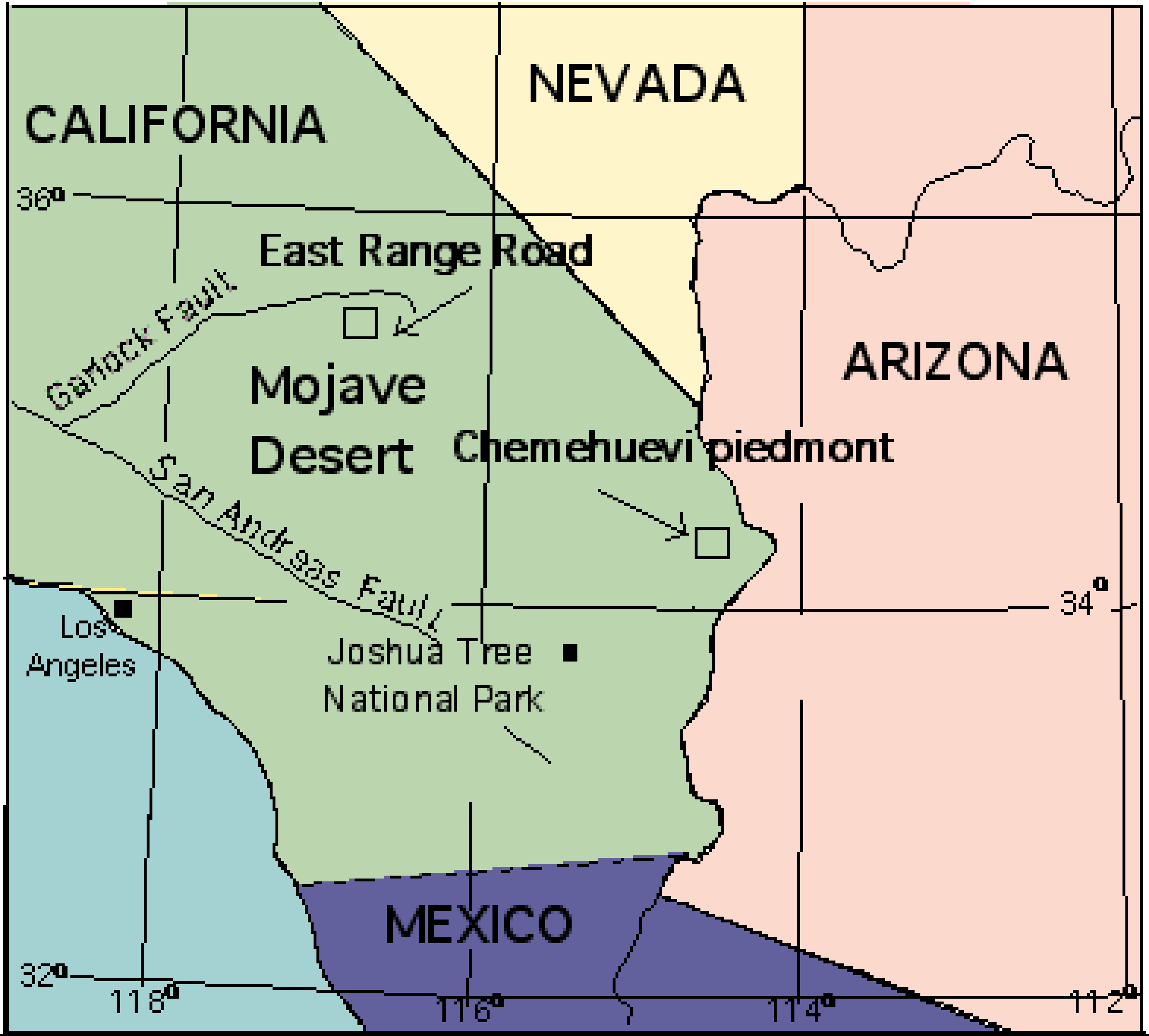
- Quantify long-term process rates to understand the background dynamics of piedmonts
- Quantify short-term processes to determine present day behavior piedmonts
- Compare the rates to understand human impact on desert ecosystem

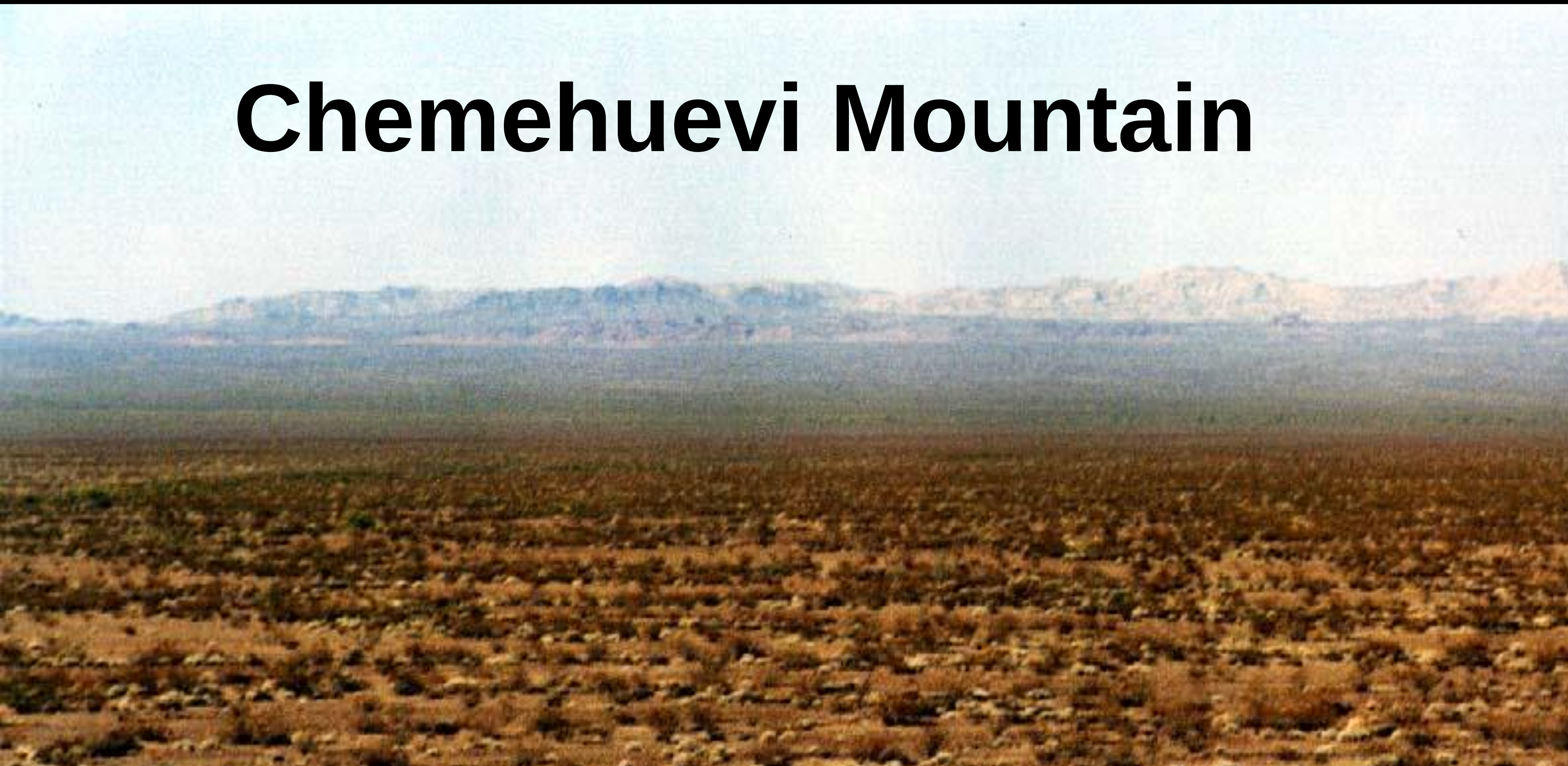
Yucca Mountain





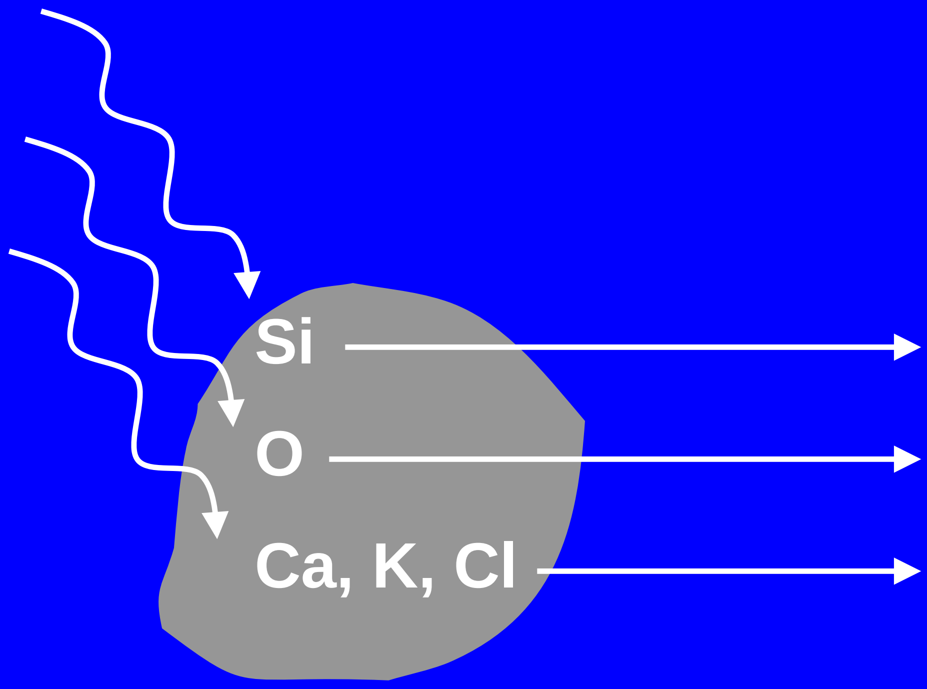

Landslides
Flash-flood and debris flow path
Landslides
Flash-floods
Flash-floods
Approximate flash-flood hazard zone
Matthew C. Larsen, USGS


NEVADA
CALIFORNIA
36°
East Range Road
Garlock Fault
Mojave
Desert
ARIZONA
Chemehuevi piedmont
San Andreas Fault
34°
Los
Angeles
Joshua Tree
National Park
MEXICO
32°
118°
116°
114°
112°


Chemehuevi Mountain


East Range Road

Cosmogenic Nuclides



^{26}Al, ^{21}Ne, ^{3}He

^{10}Be, ^{14}C, ^{3}He

^{36}Cl, ^{3}He

The isotopes are like a suntan.

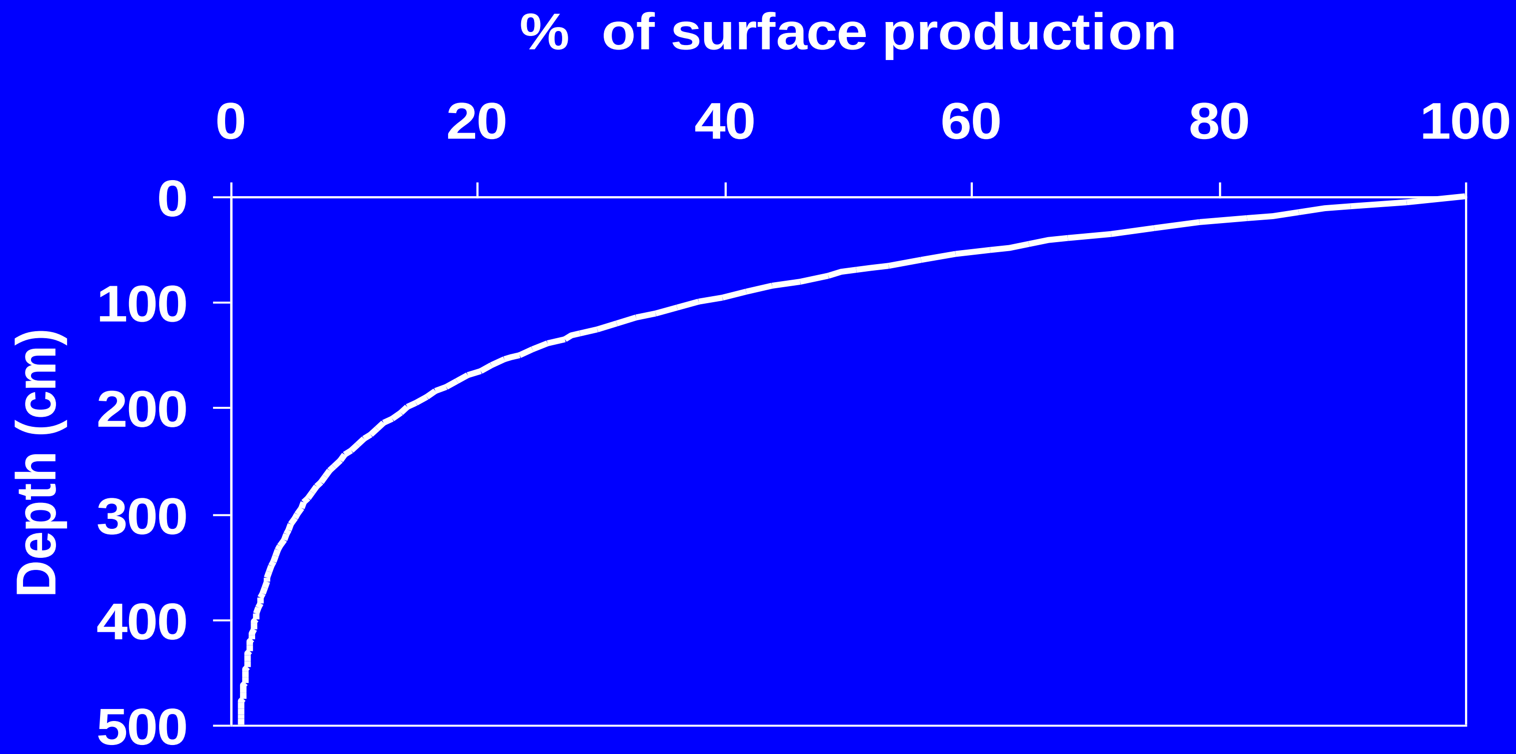
Why use ^{10}Be and ^{26}Al?

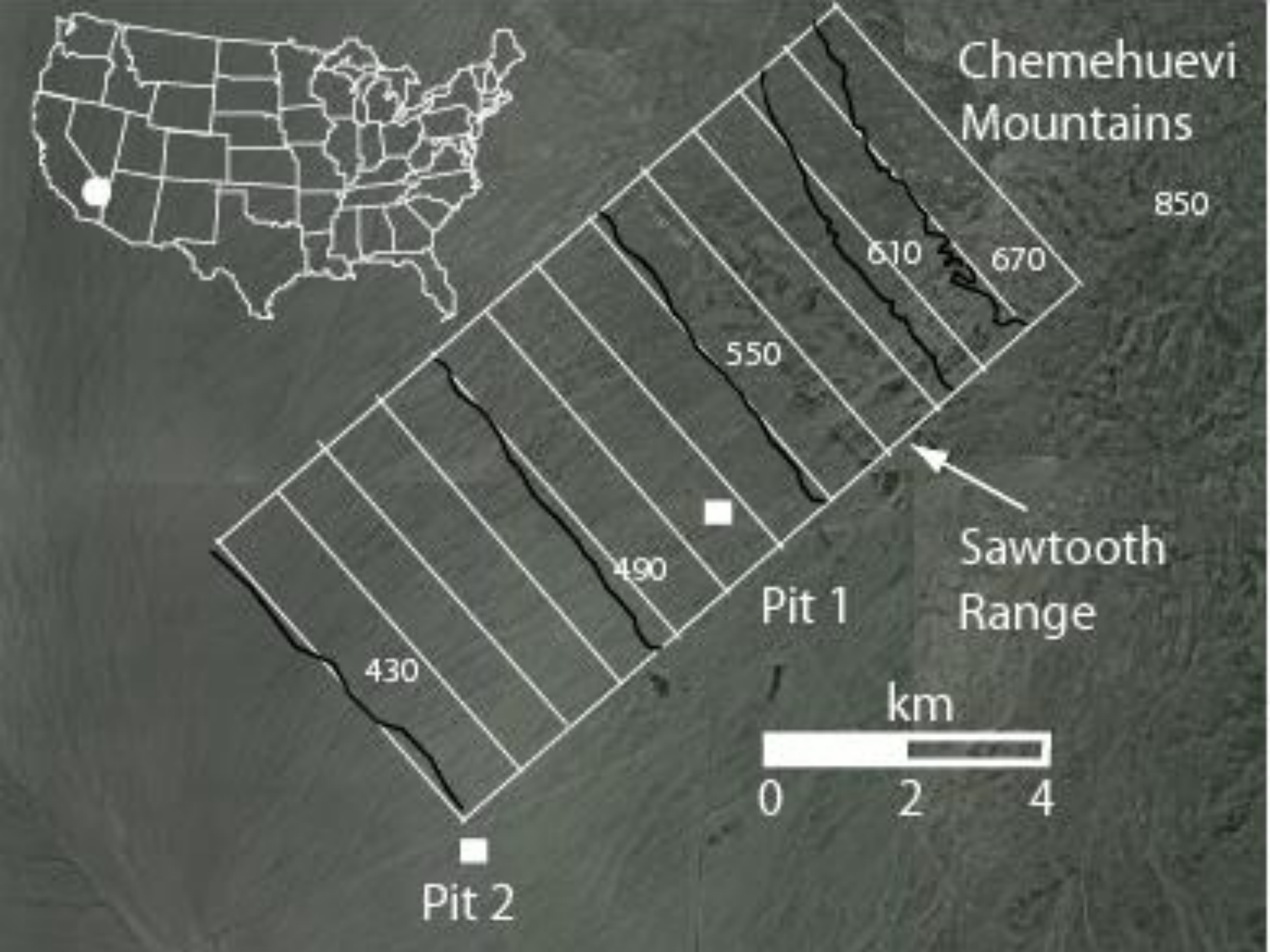
- Target mineral is quartz, an abundant mineral on Earth
- Production rates are well known (Nishiizumi et al., 1989; Clark et al., 1995; Bierman et al., 1996; Larsen et al., in revision)
- Latitude and altitude corrections are well known (Lal, 1991; Dunai, 2000)
- Use as dosimeters to model near surface history

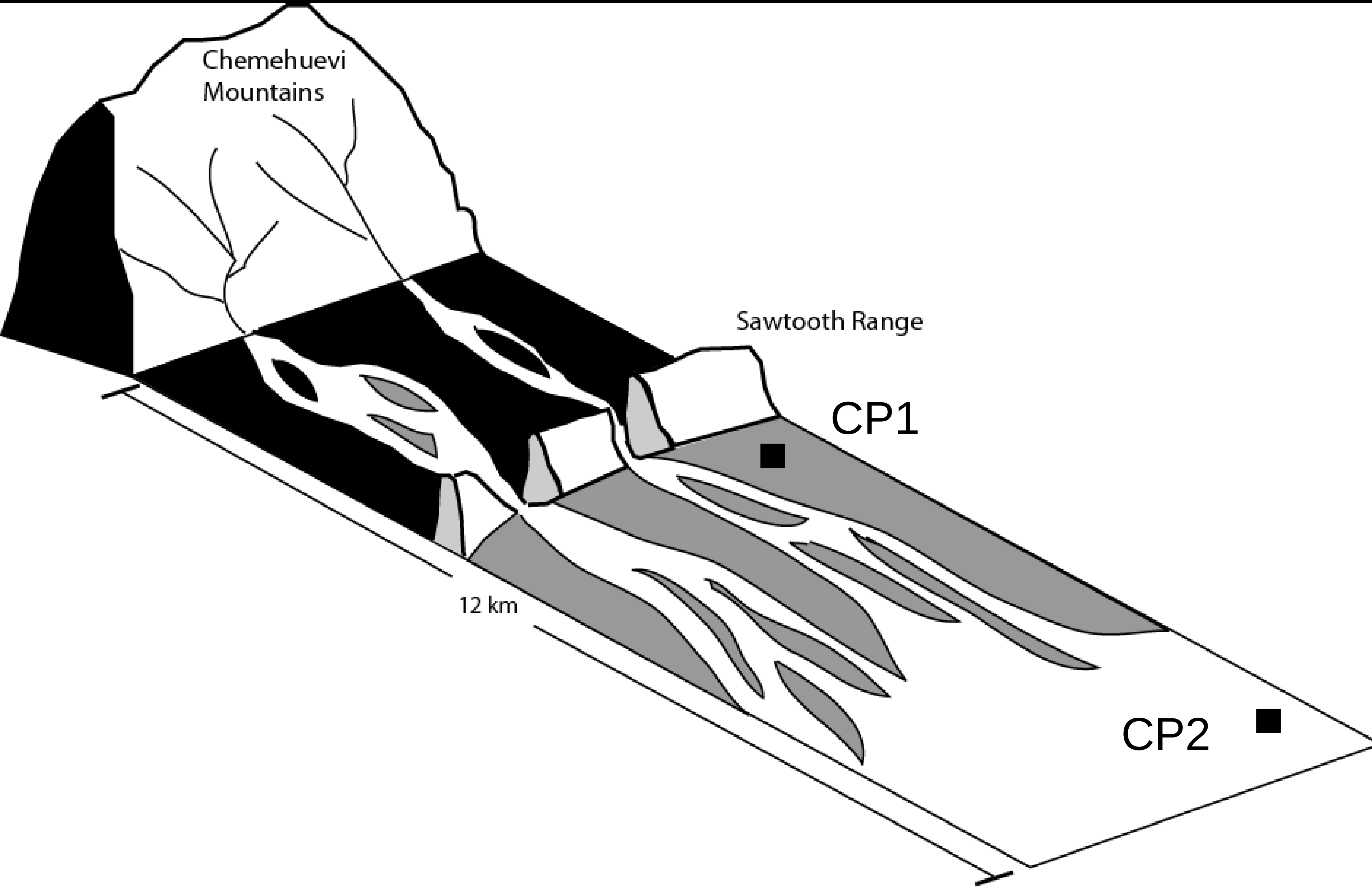
^{10}Be and ^{26}Al for desert piedmonts

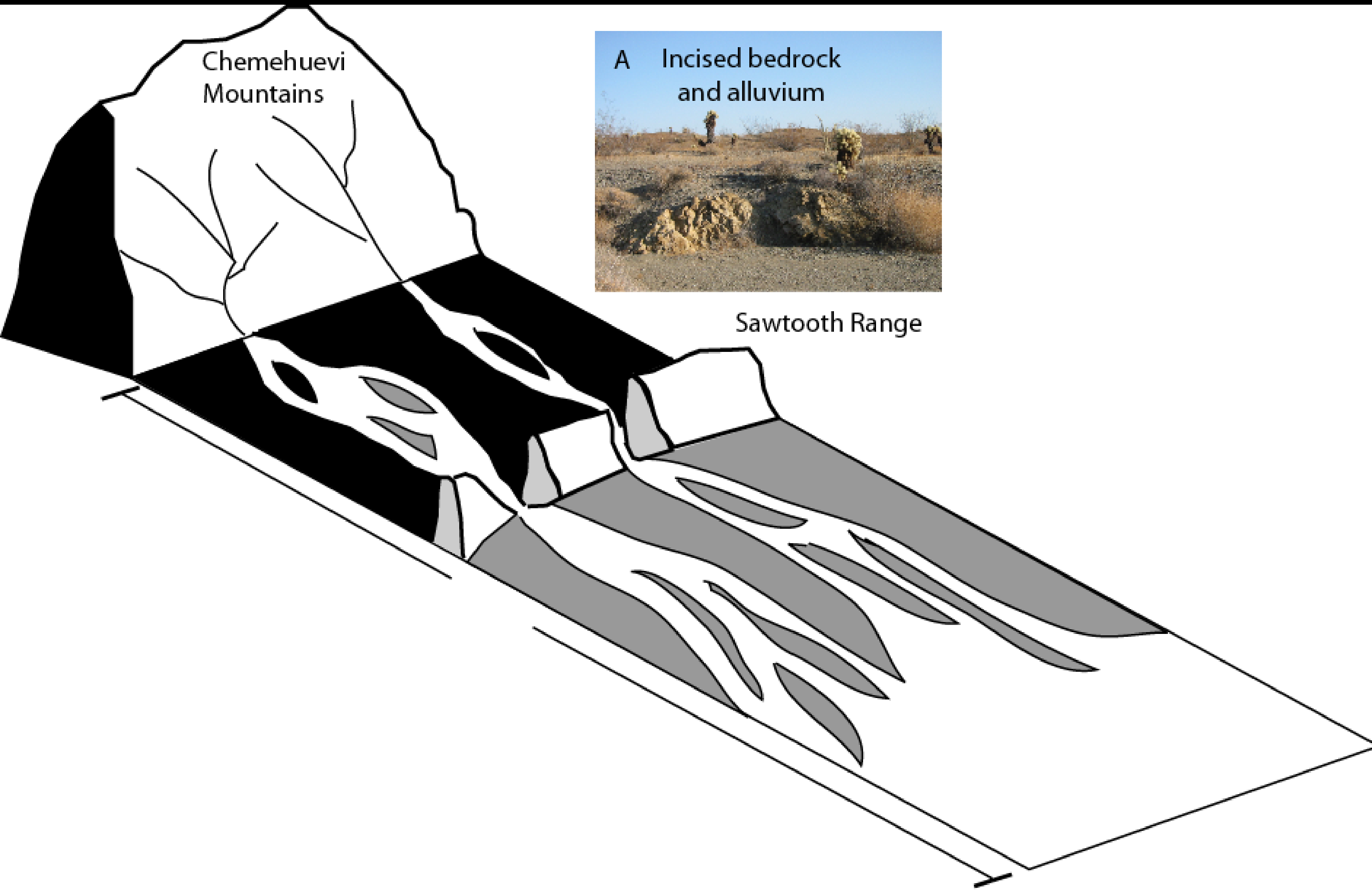
- Measure ^{10}Be and ^{26}Al in sediment to quantify
  - sediment yield from source basins at top of piedmont
  - Sediment transport across piedmonts
  - Long-term surface histories (such as deposition) on piedmont (if any)

Depth profile of ^{10}Be production in sediment

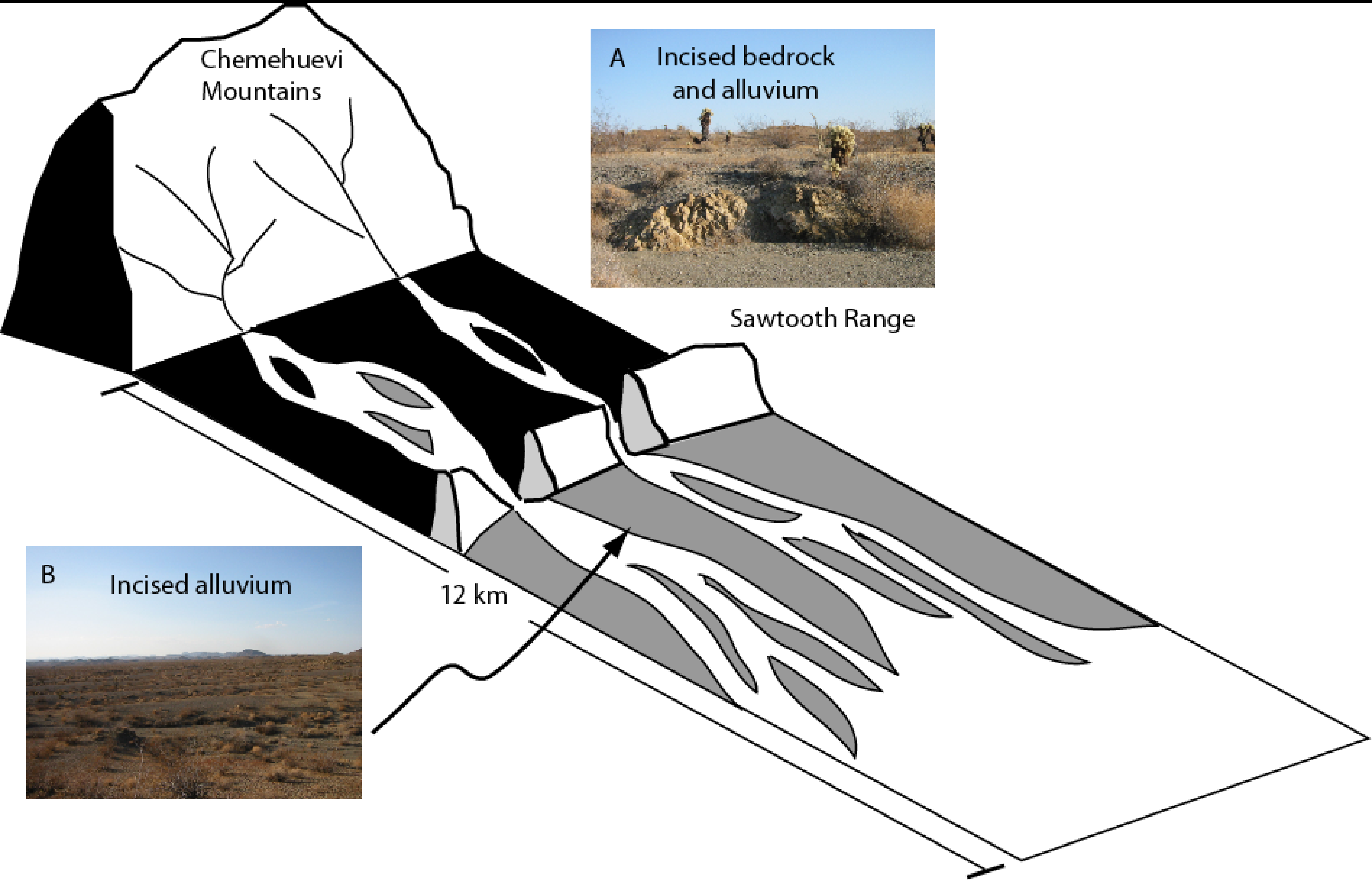


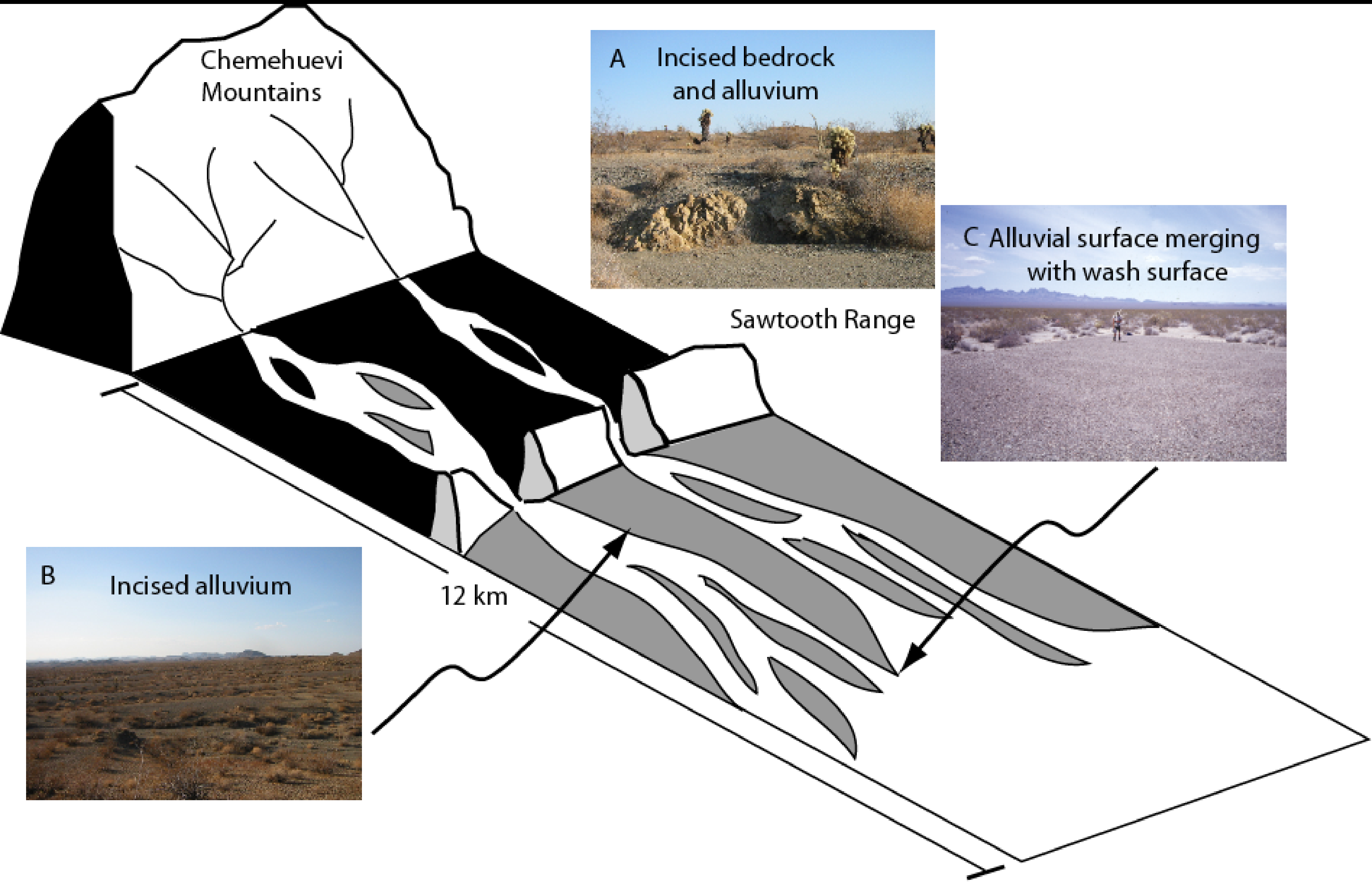

Chemehuevi
Mountains
850
610
670
550
490
430
Pit 1
Pit 2
Sawtooth
Range
km
0
2
4


Chemehuevi
Mountains
Sawtooth Range
CP1
12 km
CP2

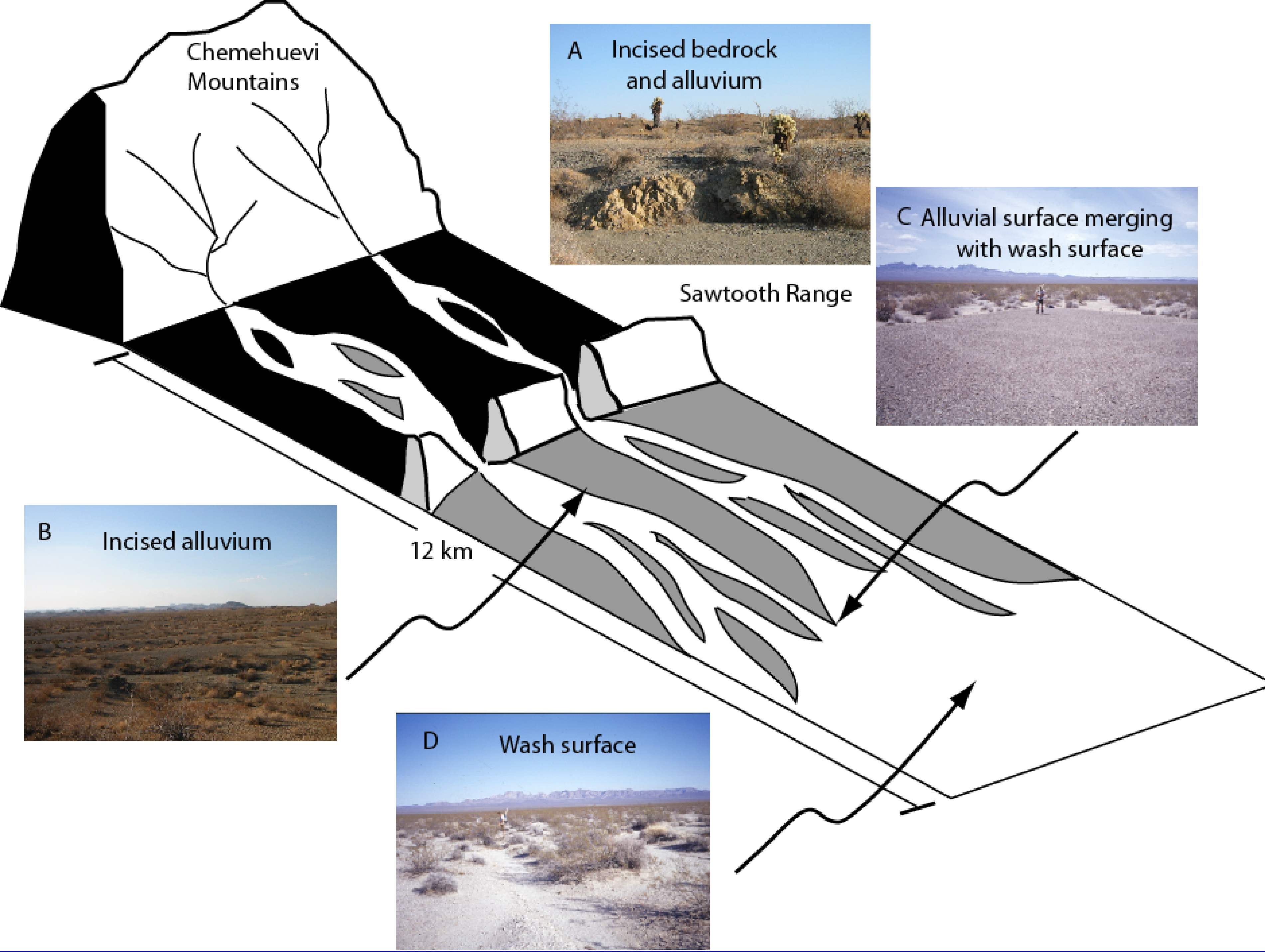


Chemehuevi
Mountains
A
Incised bedrock
and alluvium
Sawtooth Range


Chemehuevi Mountains
A
Incised bedrock and alluvium
Sawtooth Range
B
Incised alluvium
12 km



Chemehuevi Mountains
A Incised bedrock and alluvium
C Alluvial surface merging with wash surface
Sawtooth Range
B Incised alluvium
12 km



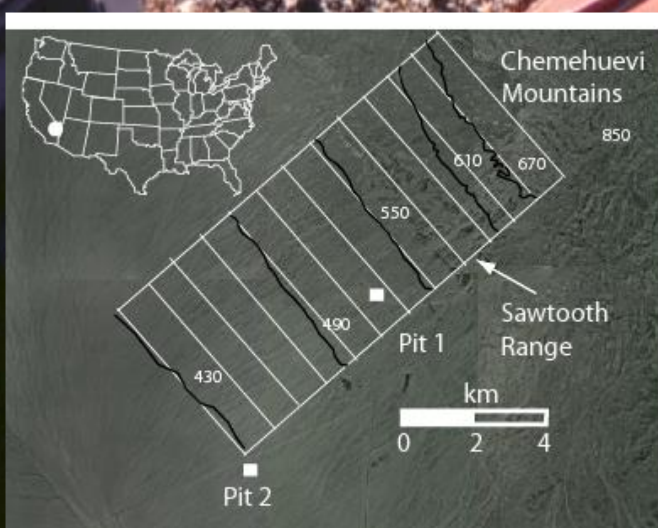
Chemehuevi Mountains
A Incised bedrock and alluvium
C Alluvial surface merging with wash surface
Sawtooth Range
B Incised alluvium
12 km
D Wash surface

Field Methods

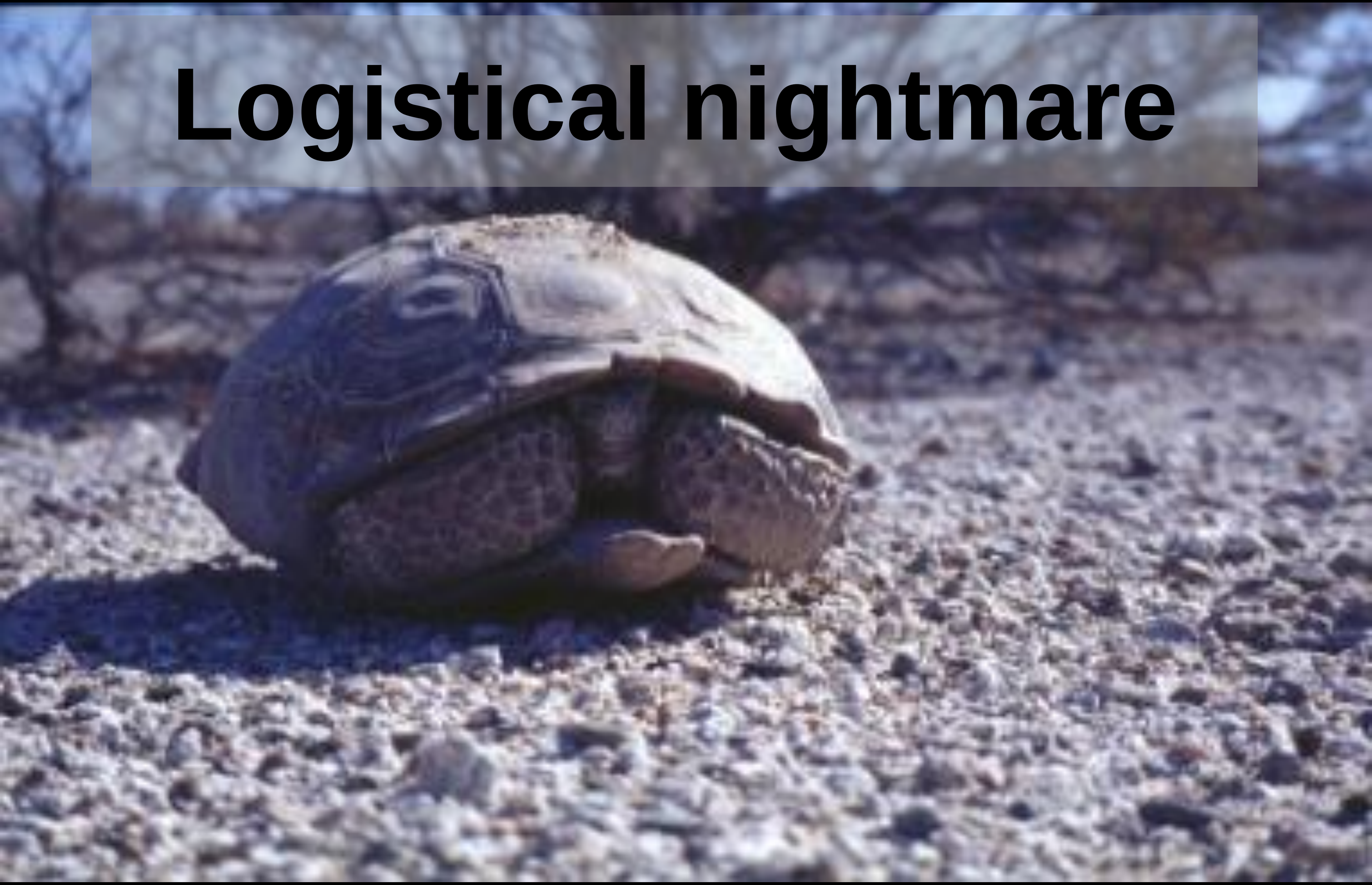
- Three types of samples
  - Source basin sample
  - Transect samples
  - Soil pit samples
- Provides a 4-D look into piedmont processes

Source basin samples

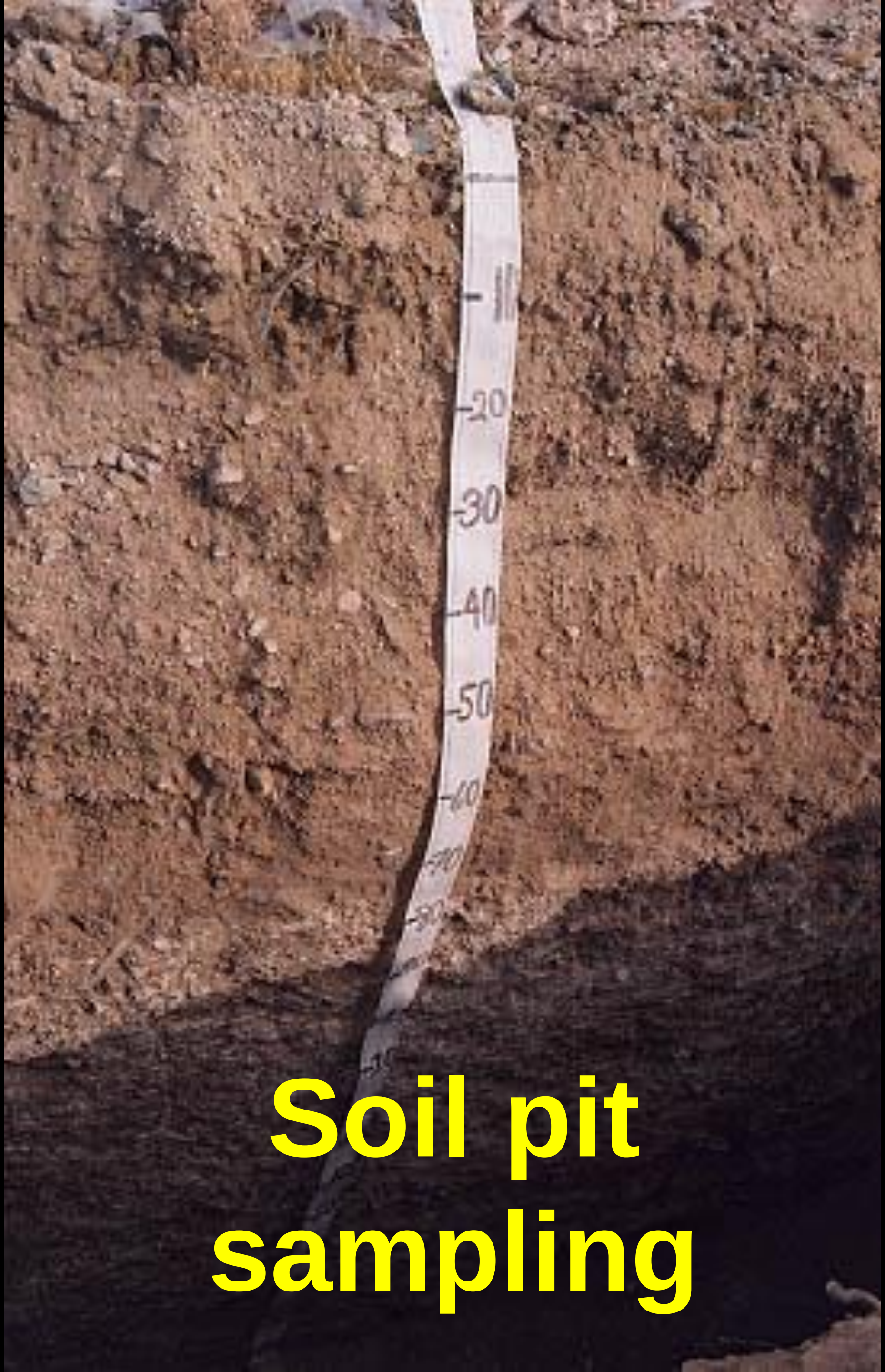
Transect Samples



- Ephemeral Channels
- Incised alluvium
- Bedrock
- Colluvium


Logistical nightmare

Soil pit samples

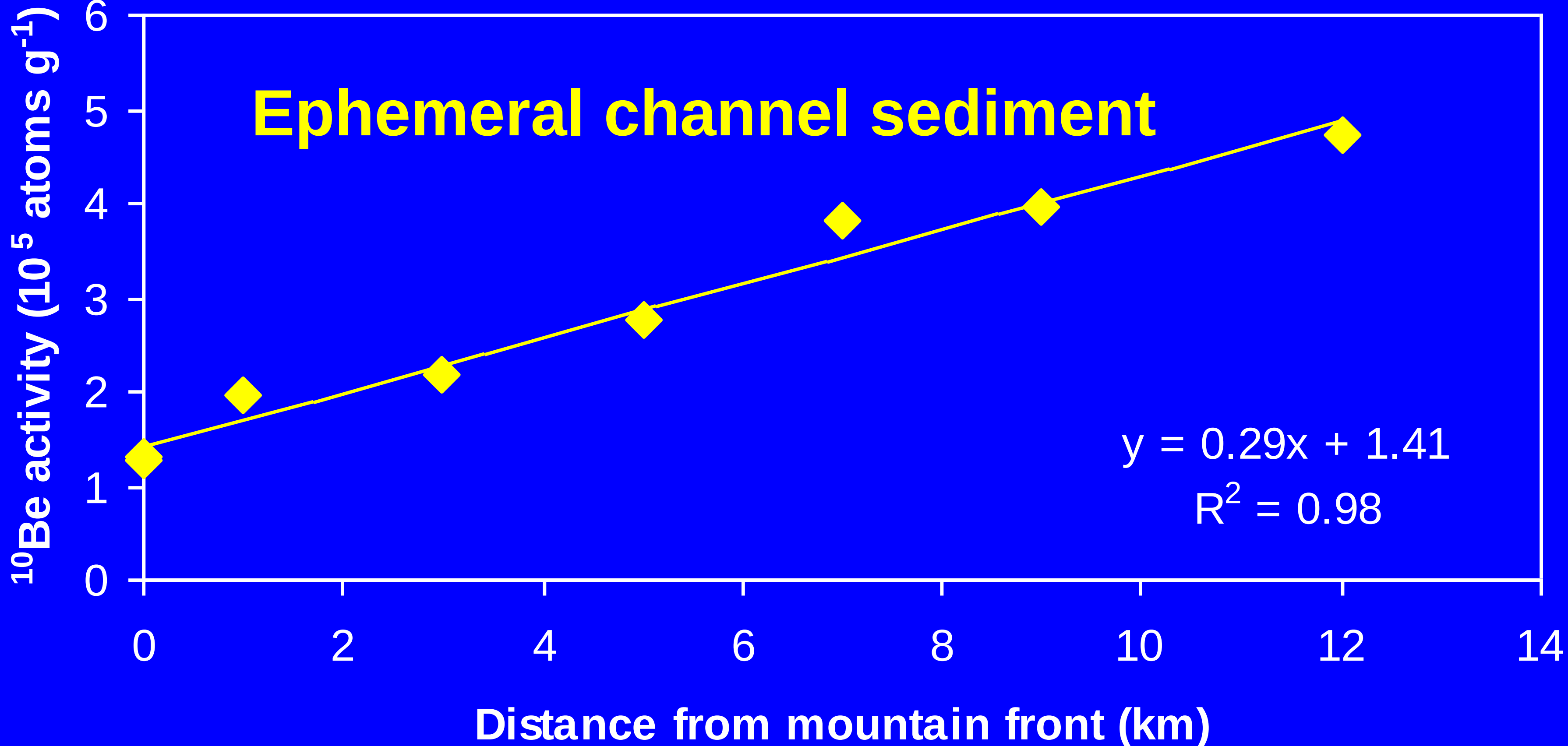

Soil pit sampling

Shallow Soil Pits Active Transport Layer

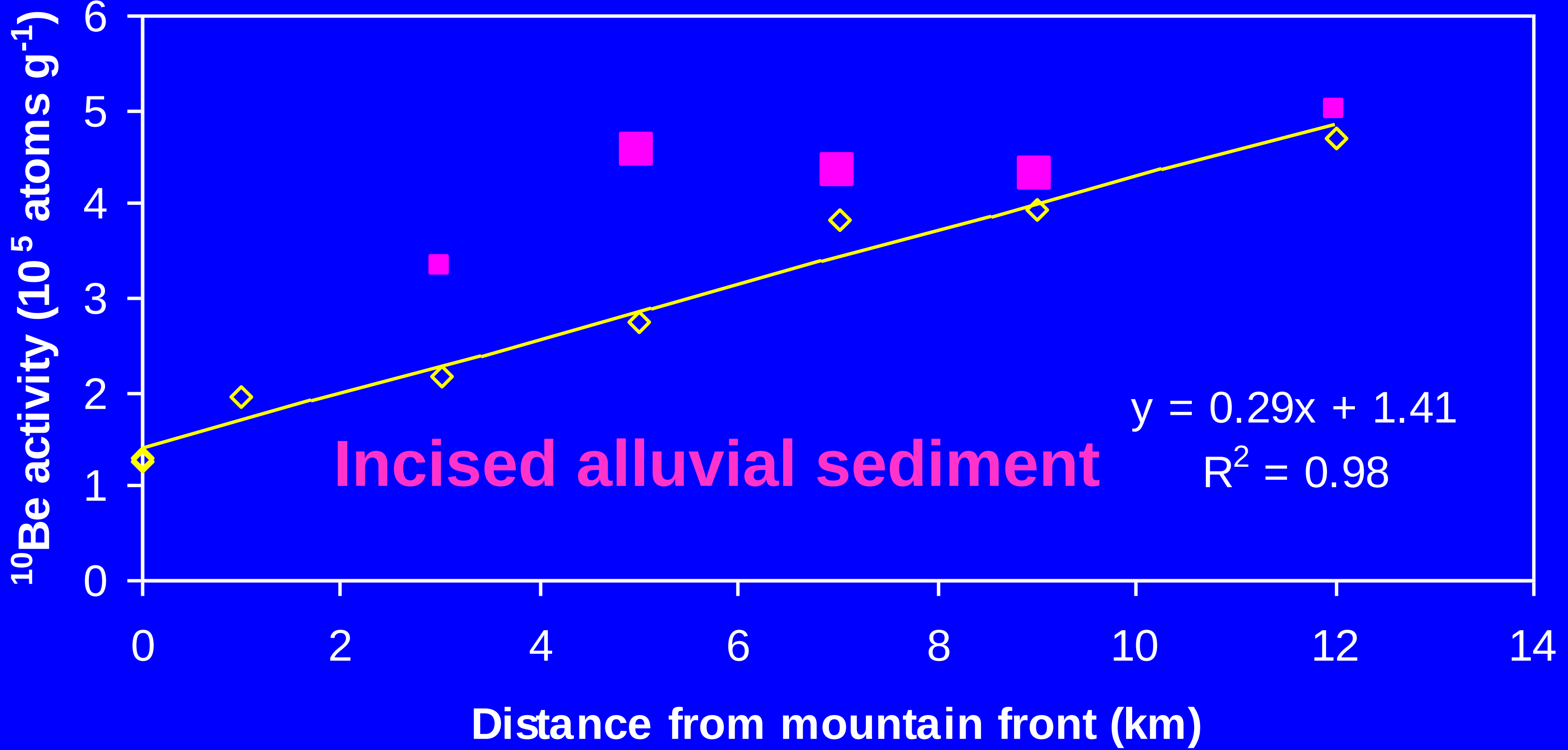
Laboratory Methods

- Sieve sediment for 0.5 to 0.85 mm
- Separate quartz with HCl and HF/Nitric acid baths
- Dissolve quartz and extract Be and Al
- Analyze for ratios ($^{10}Be:^{9}Be$ and $^{26}Al:^{27}Al$) at LLNL on AMS

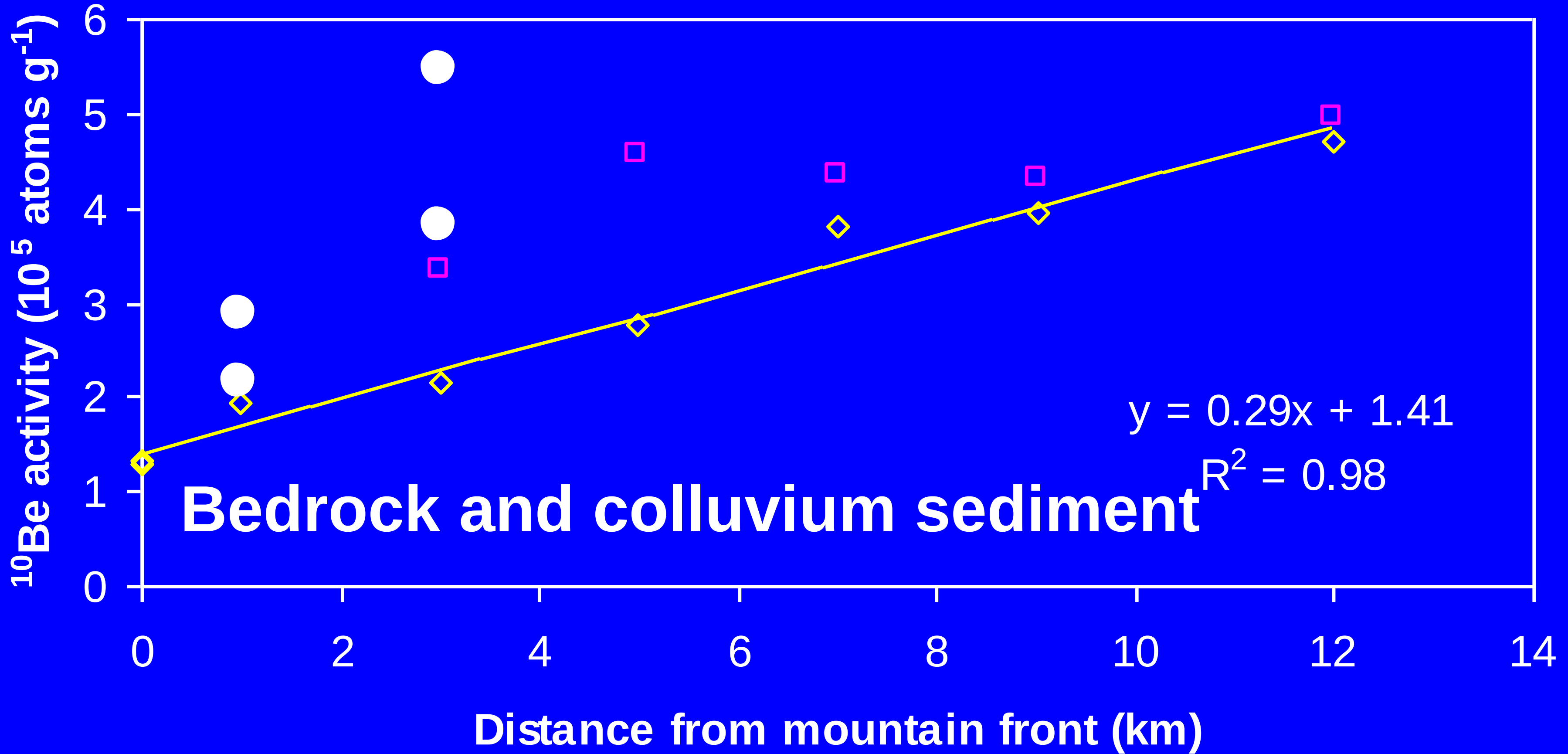
Chemehuevi Transect Samples



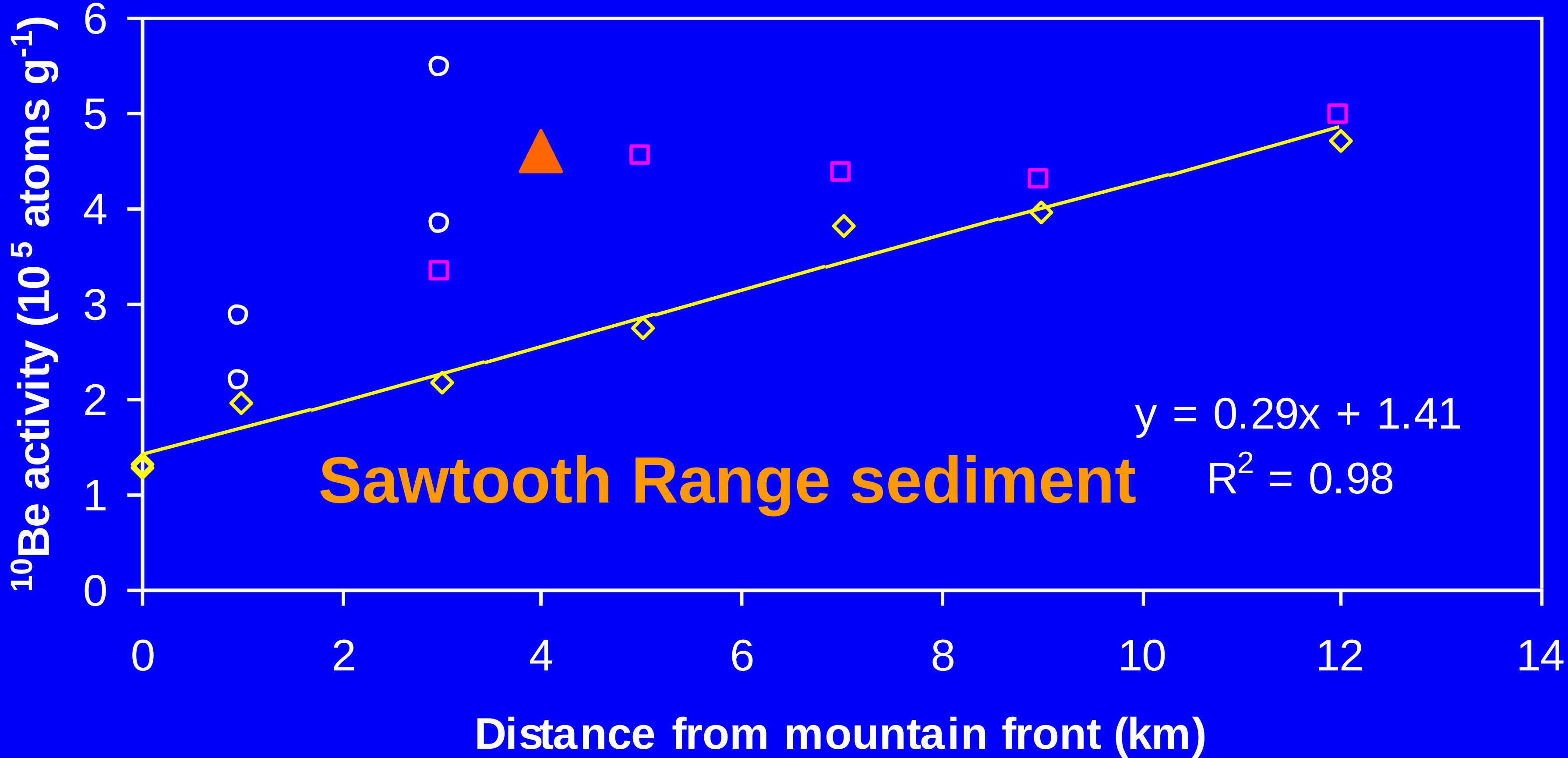
Chemehuevi Transect Samples

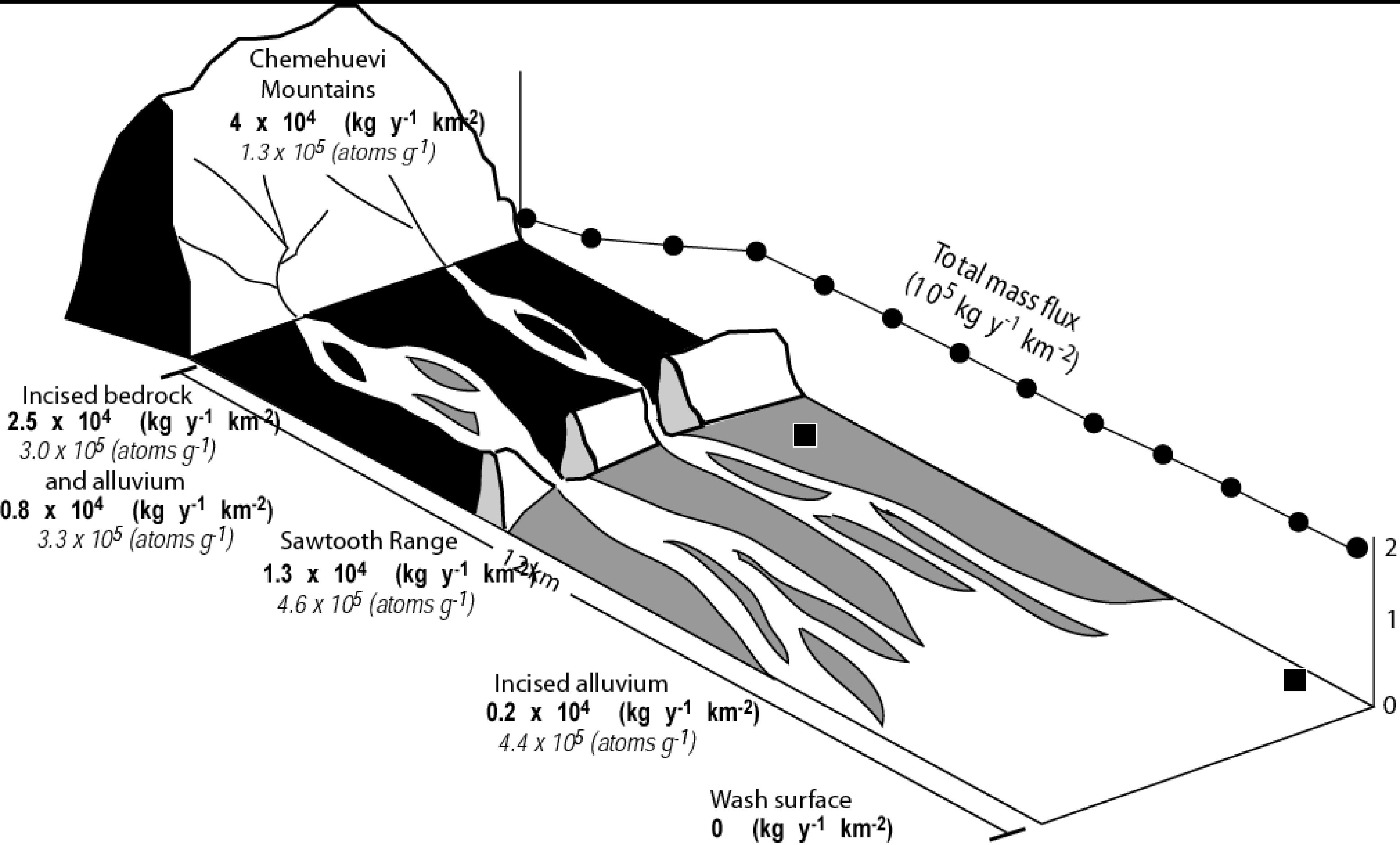


Chemehuevi Transect Samples



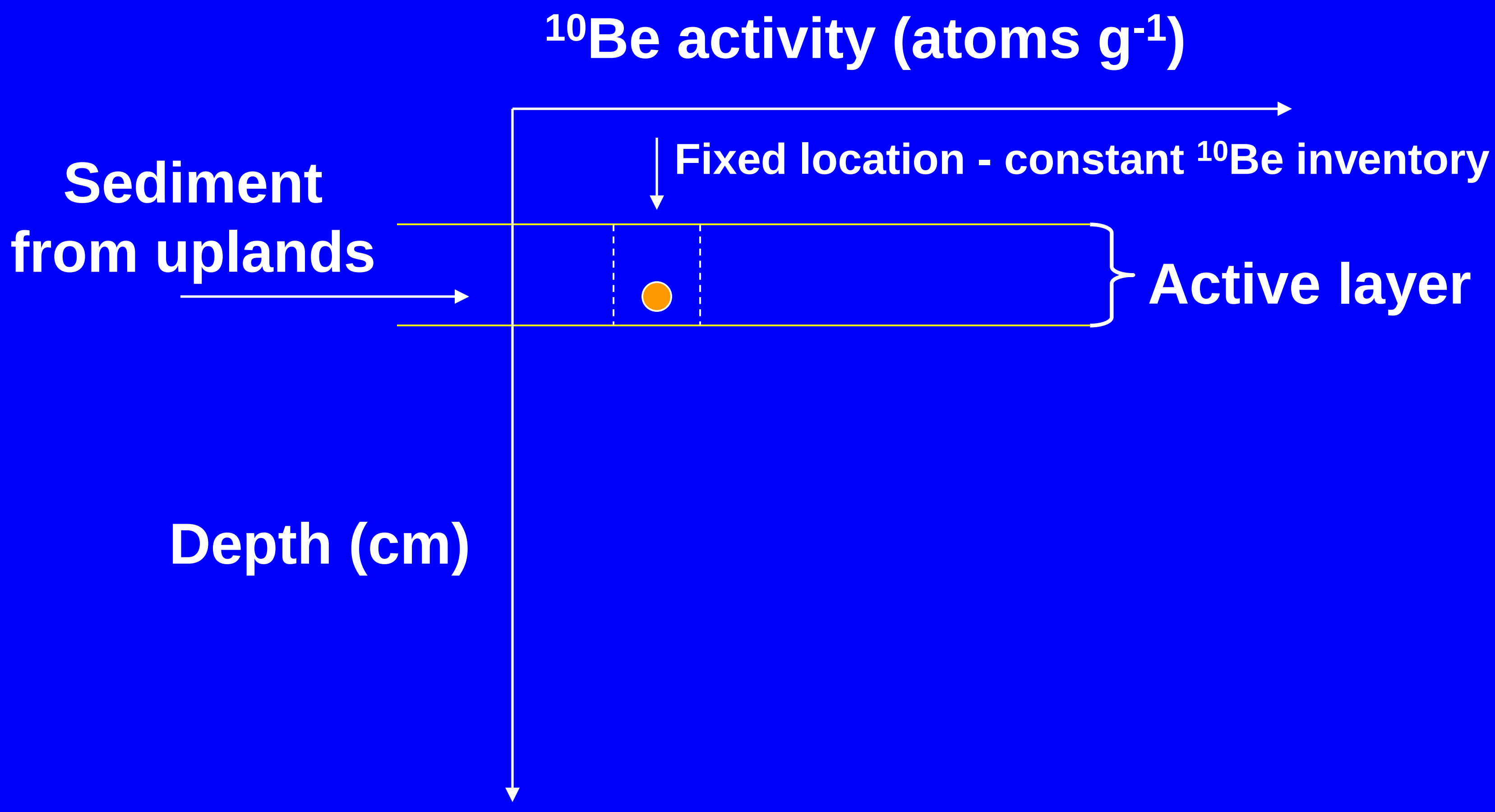
Chemehuevi Transect Samples



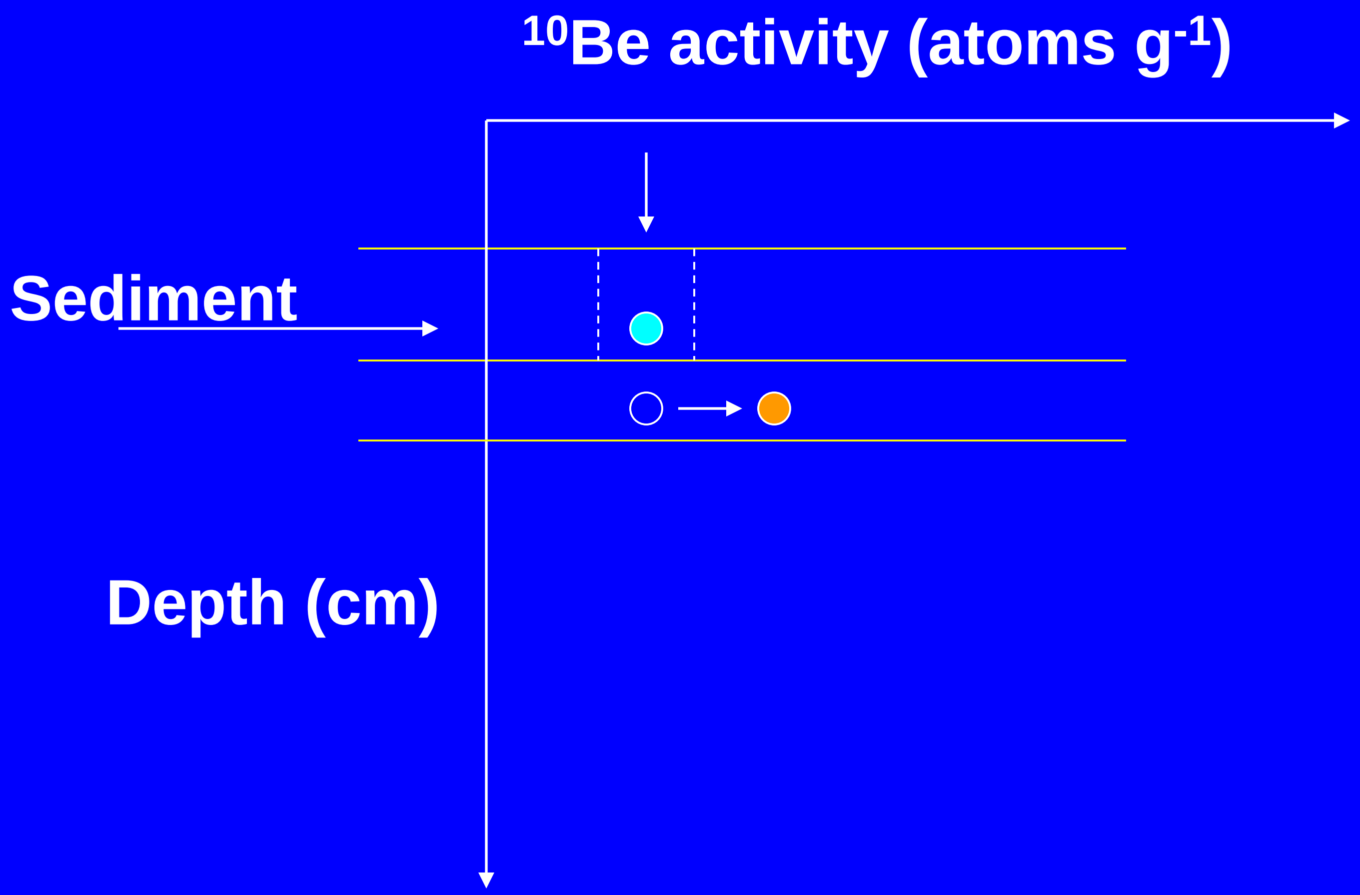


Chemehuevi
Mountains
4 x 10^4 (kg y^-1 km^-2)
1.3 x 10^5 (atoms g^-1)
Total mass flux
(10^5 kg y^-1 km^-2)
2
1
0
Incised bedrock
2.5 x 10^4 (kg y^-1 km^-2)
3.0 x 10^5 (atoms g^-1)
and alluvium
0.8 x 10^4 (kg y^-1 km^-2)
3.3 x 10^5 (atoms g^-1)
Sawtooth Range
1.3 x 10^4 (kg y^-1 km^-2)
4.6 x 10^5 (atoms g^-1)
12 km
Incised alluvium
0.2 x 10^4 (kg y^-1 km^-2)
4.4 x 10^5 (atoms g^-1)
Wash surface
0 (kg y^-1 km^-2)

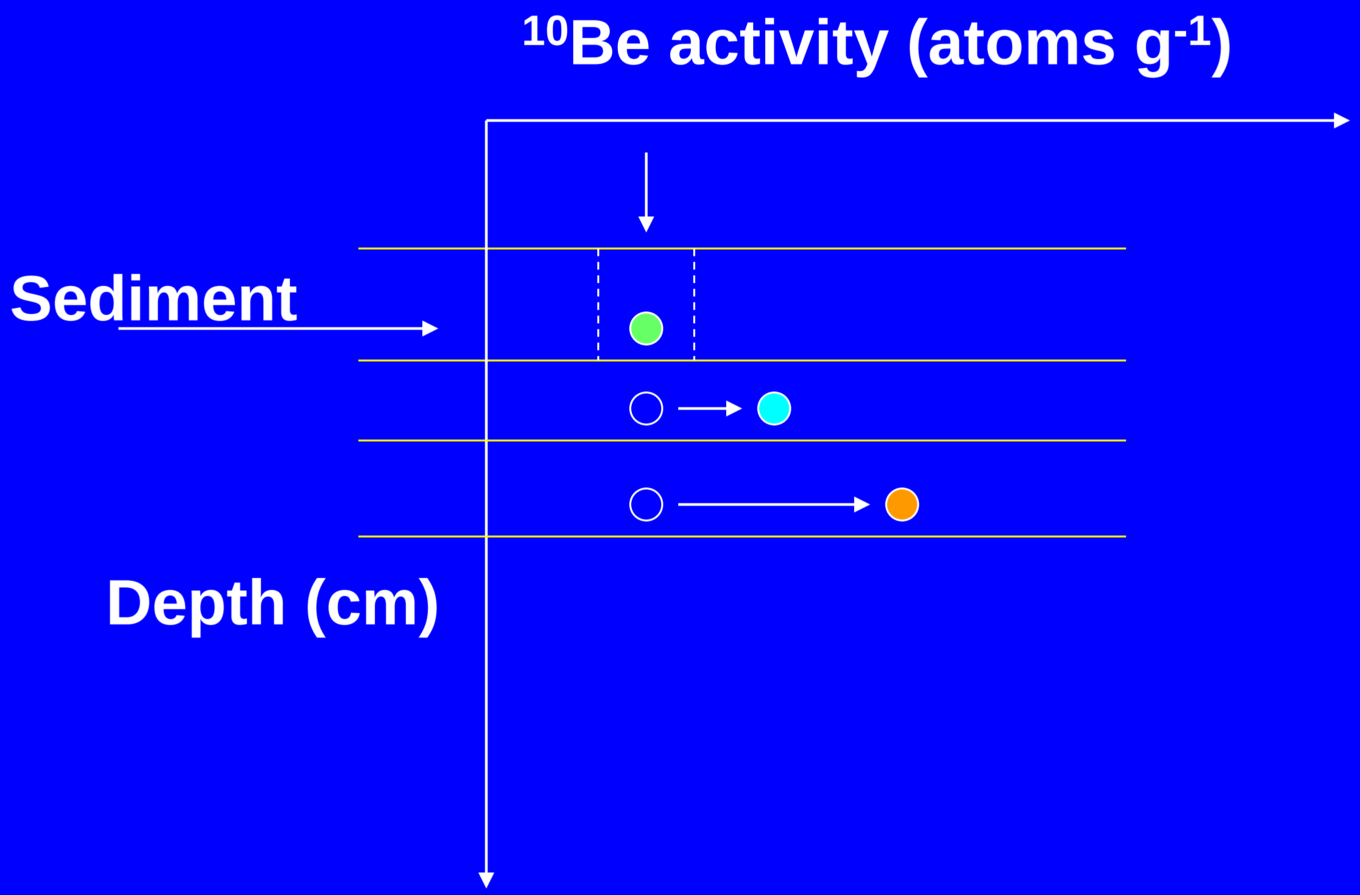
Deposition signature



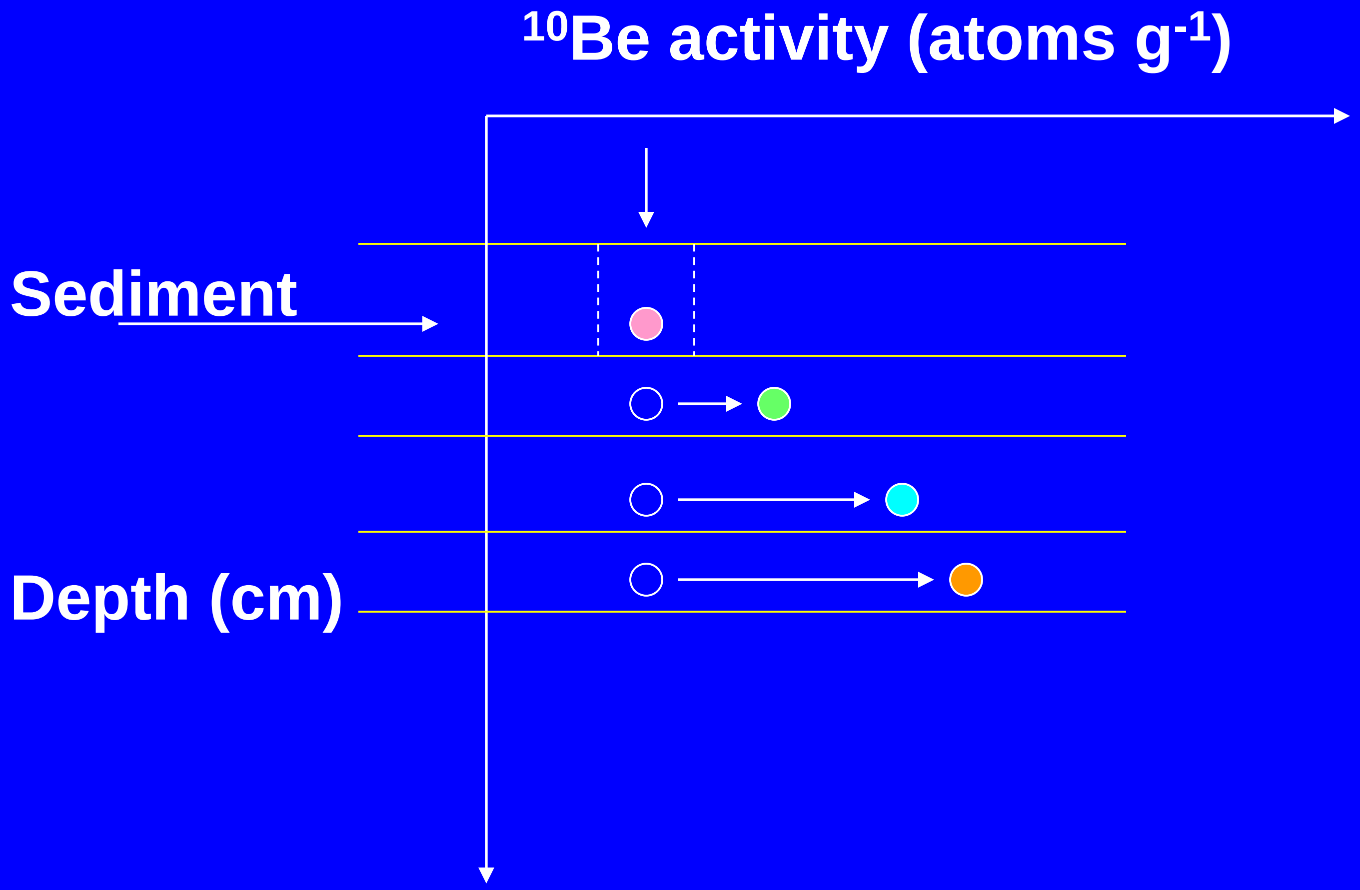
Deposition signature



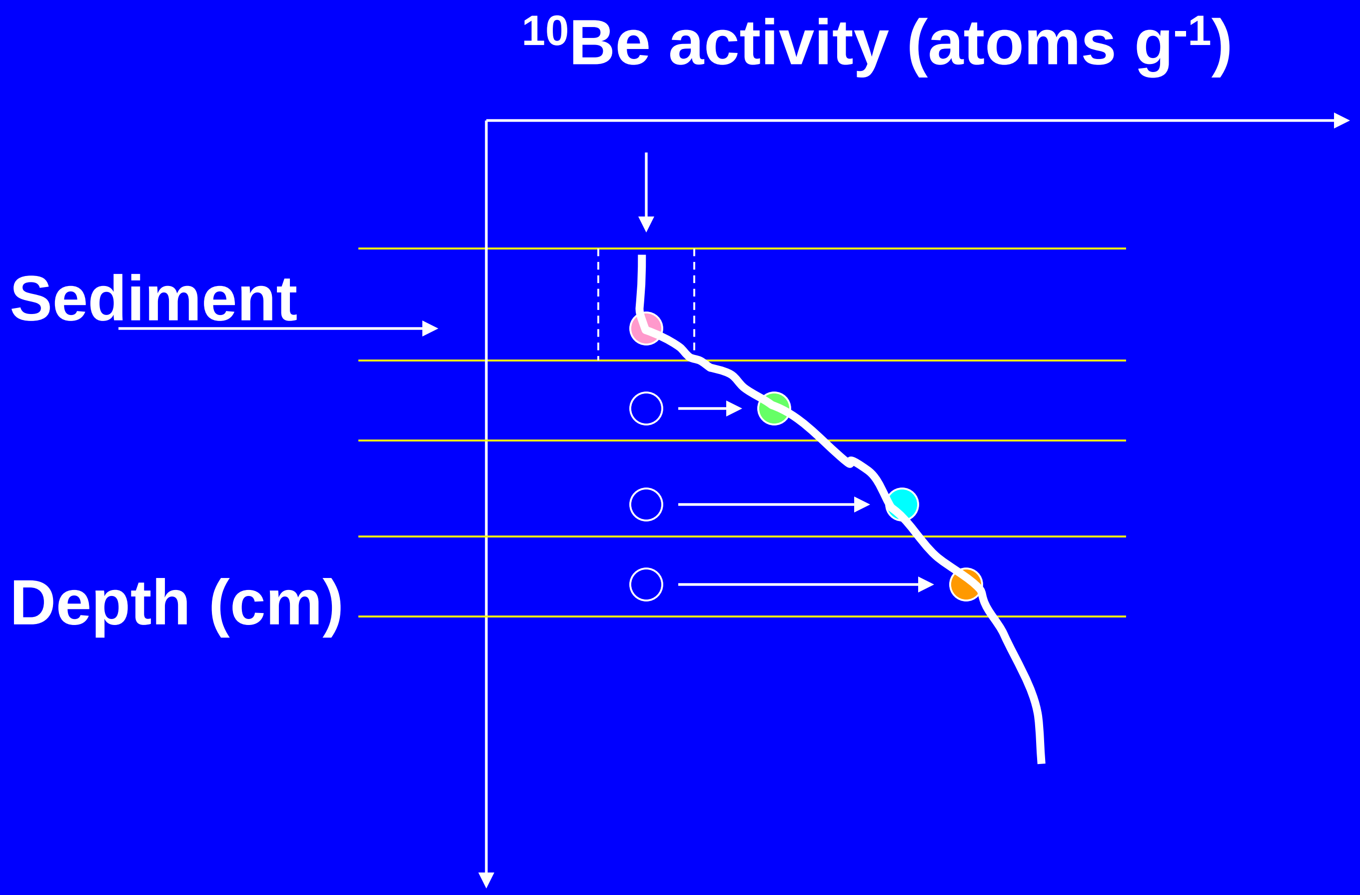
Deposition signature



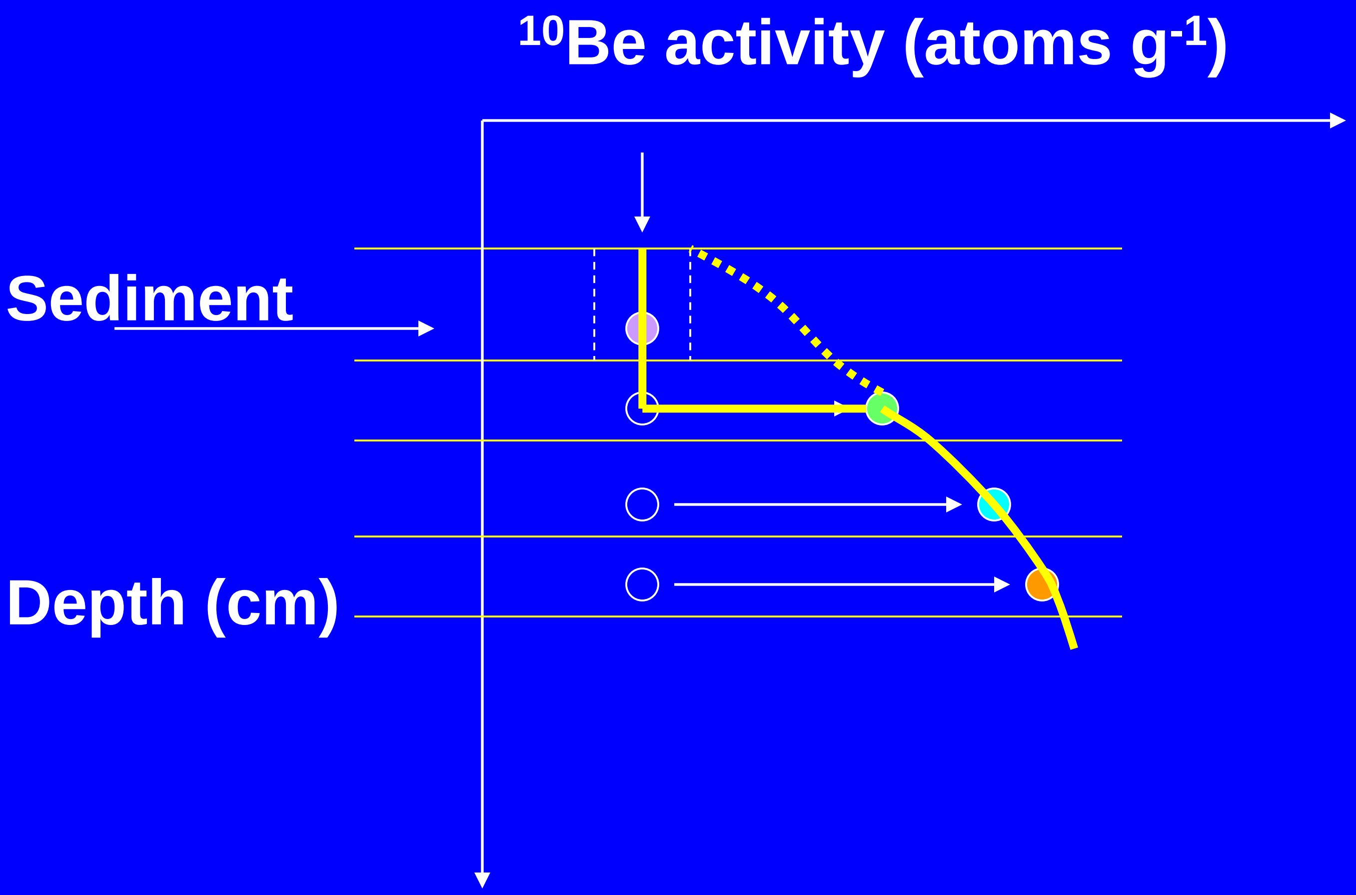
Deposition signature



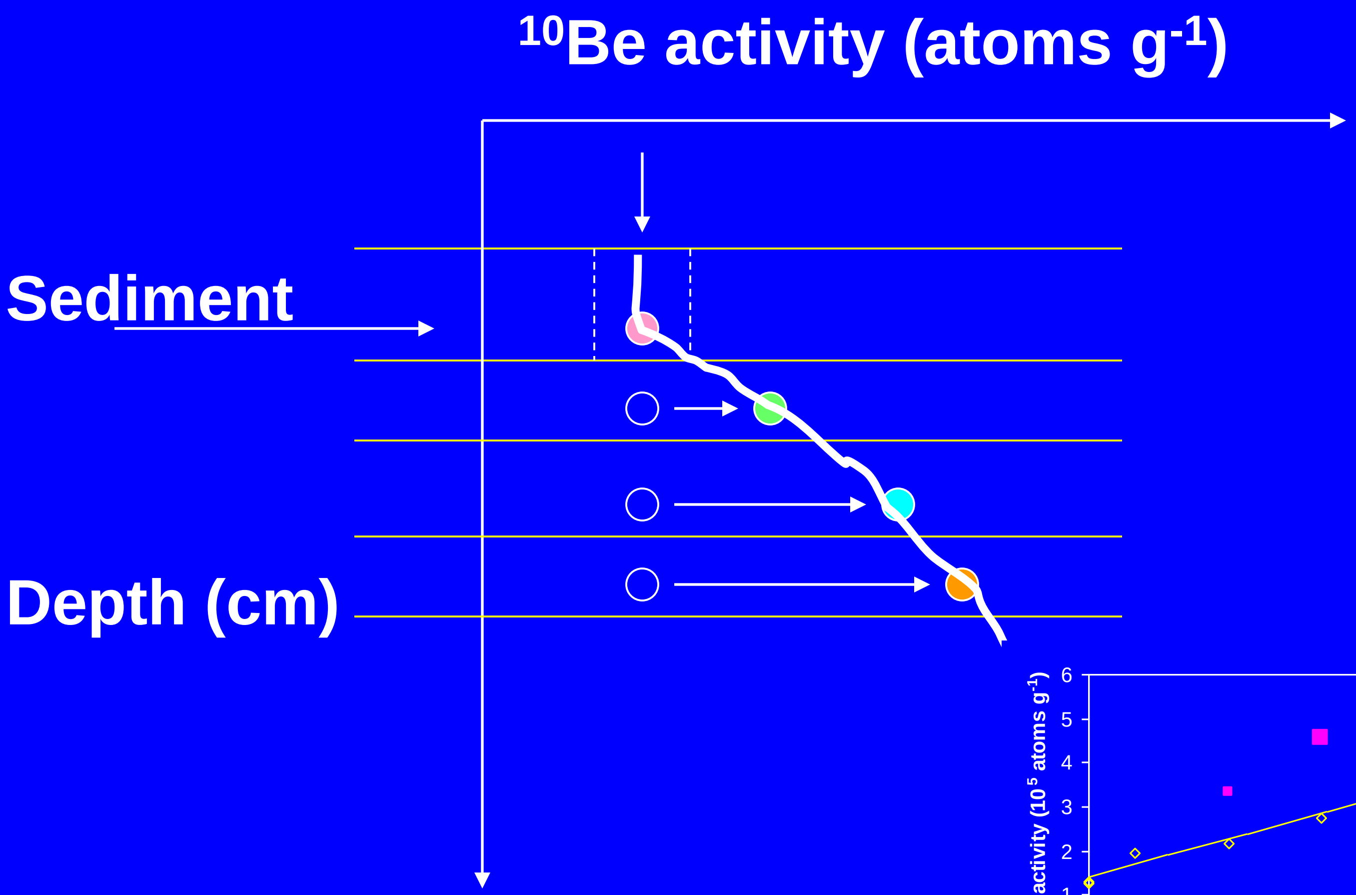
Deposition signature

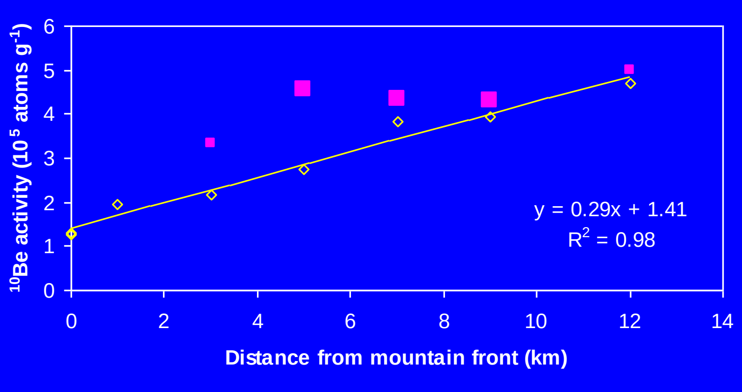


Hiatus in deposition

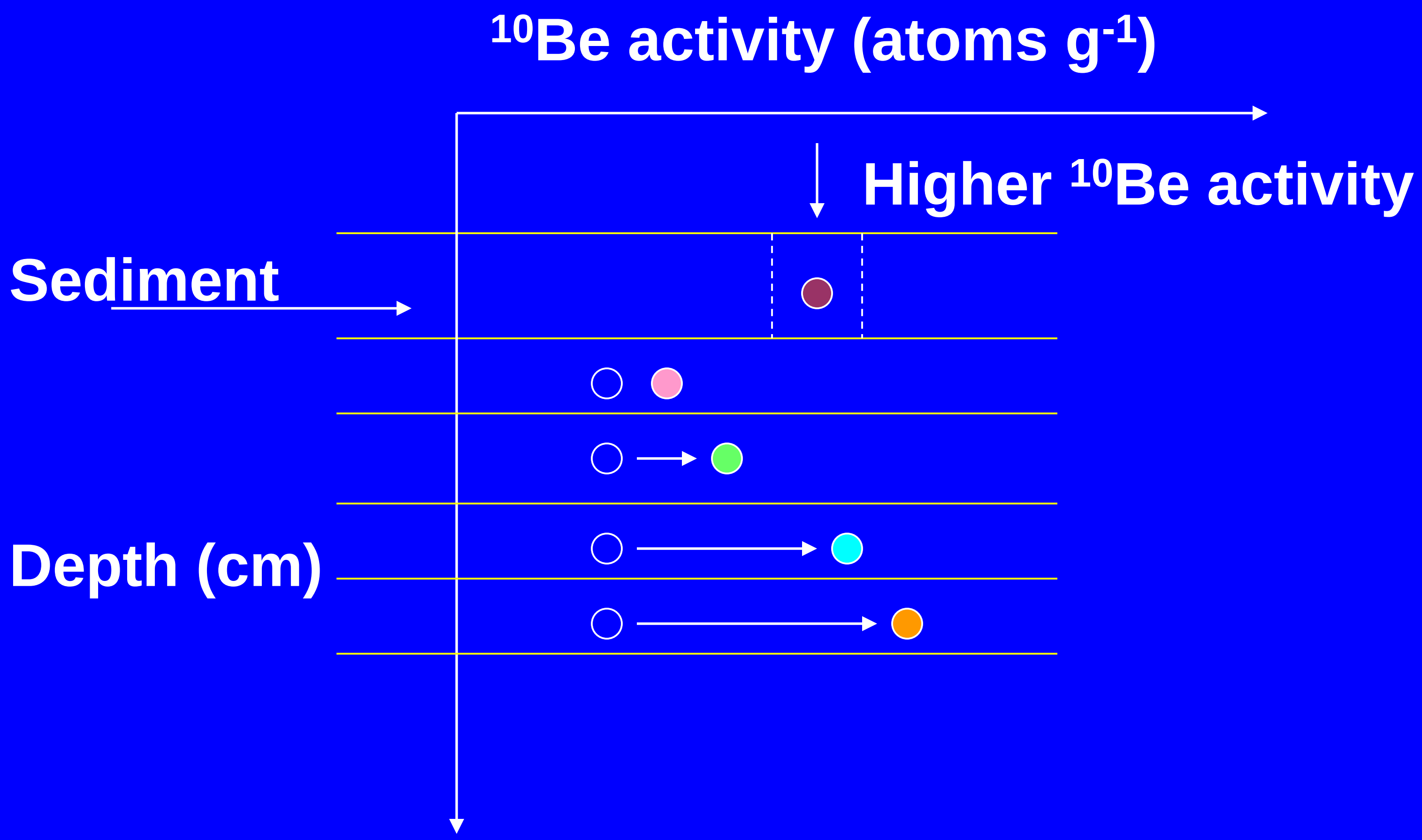


Deposition signature

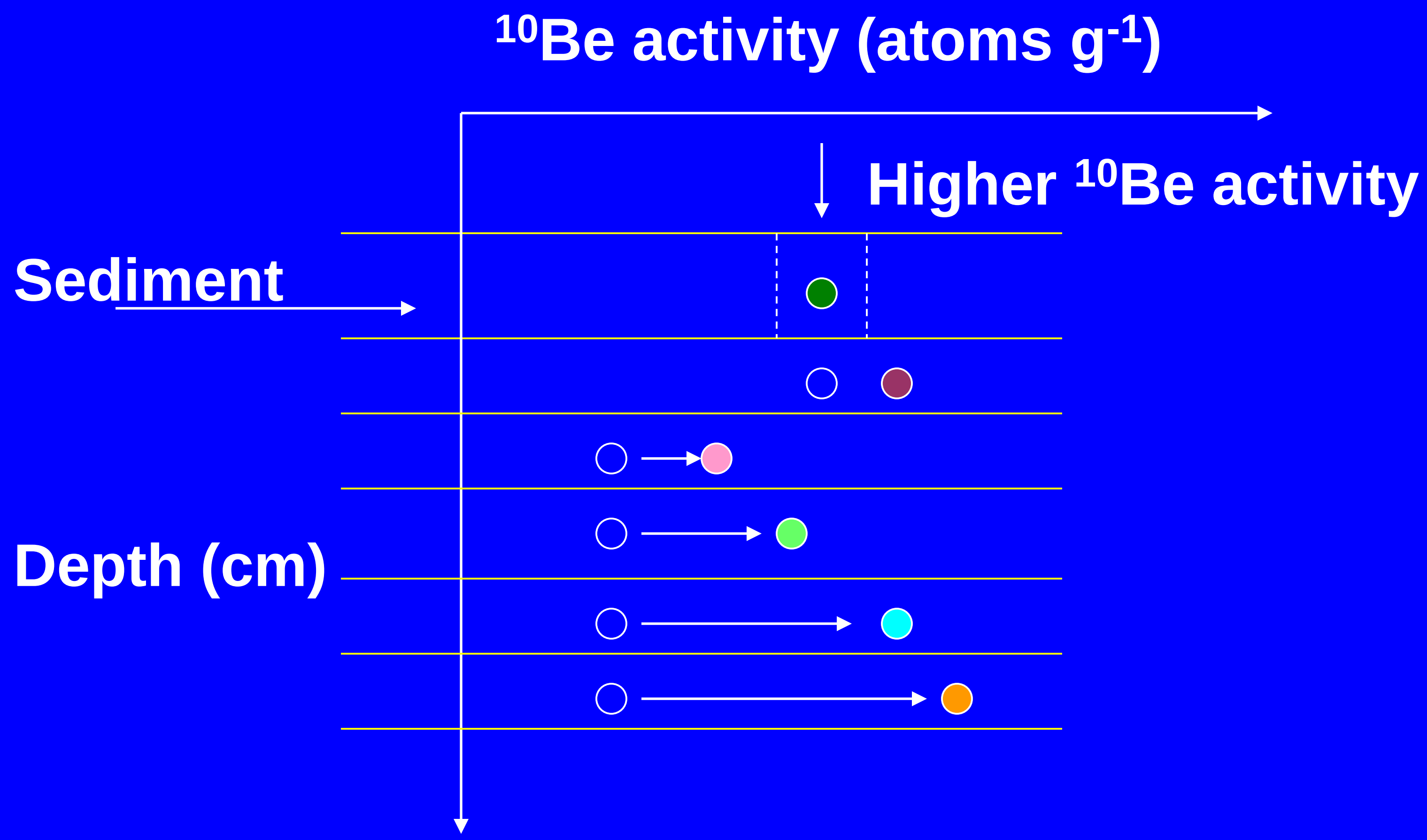




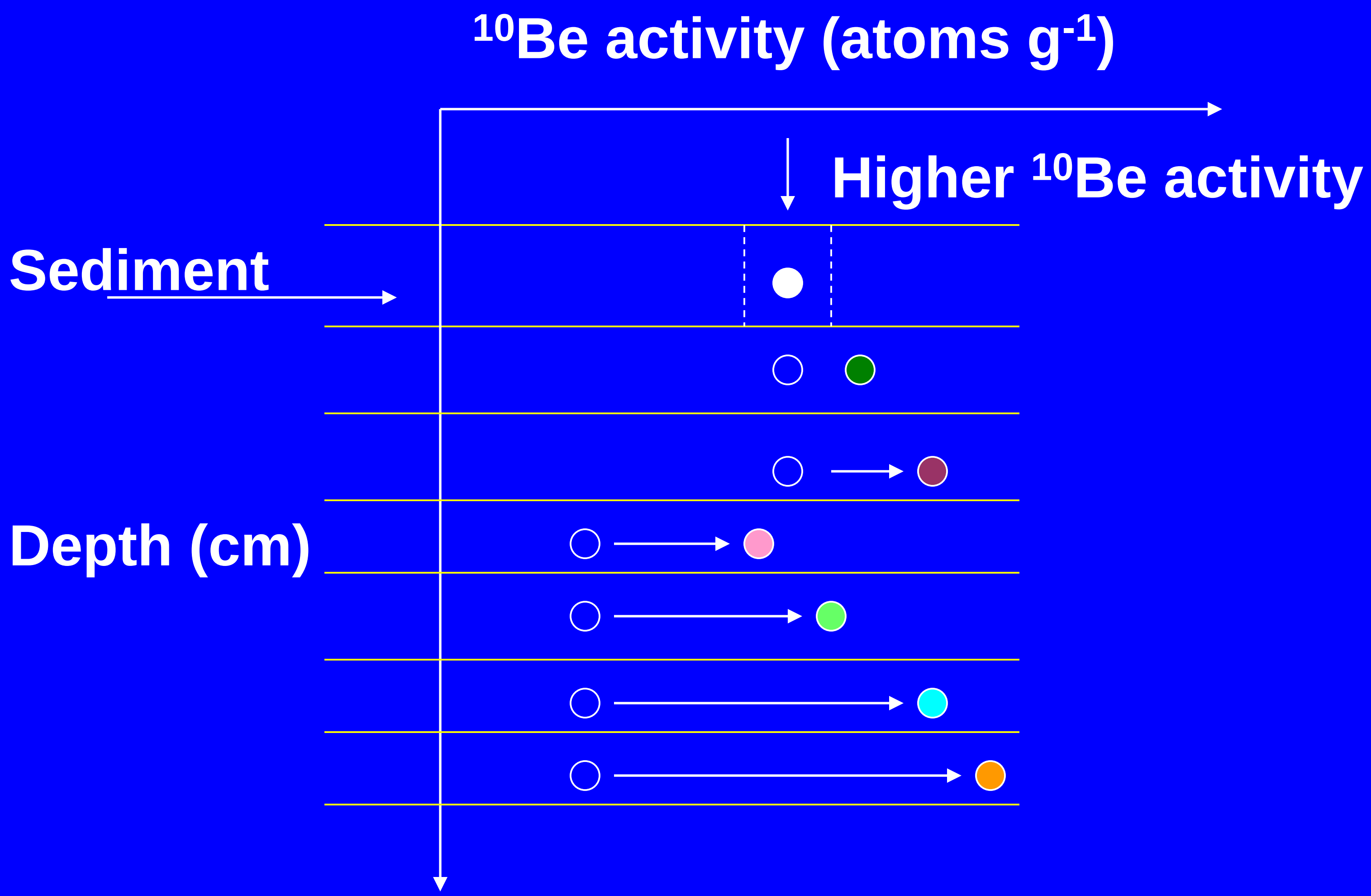
Deposition signature



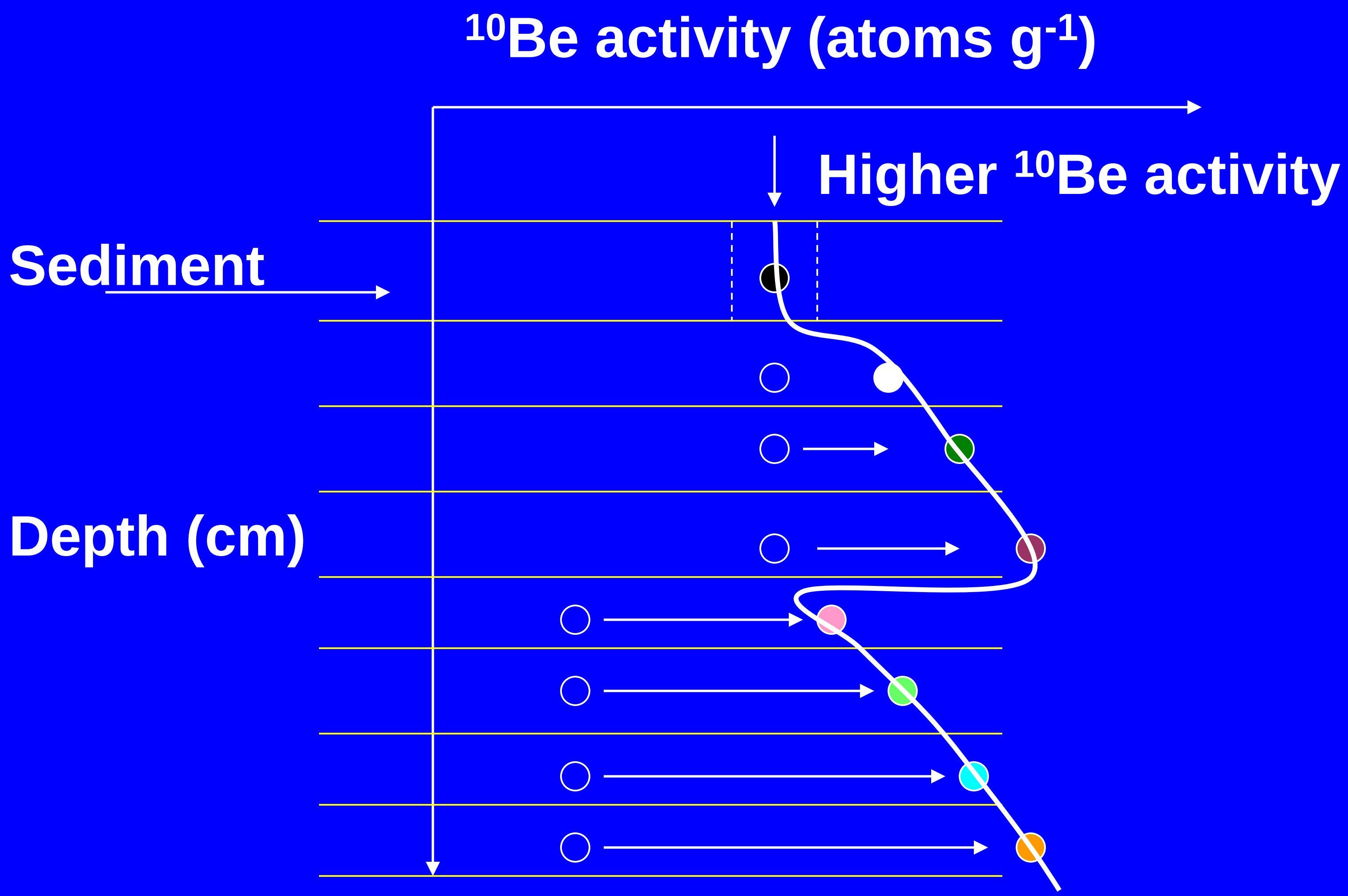
Deposition signature

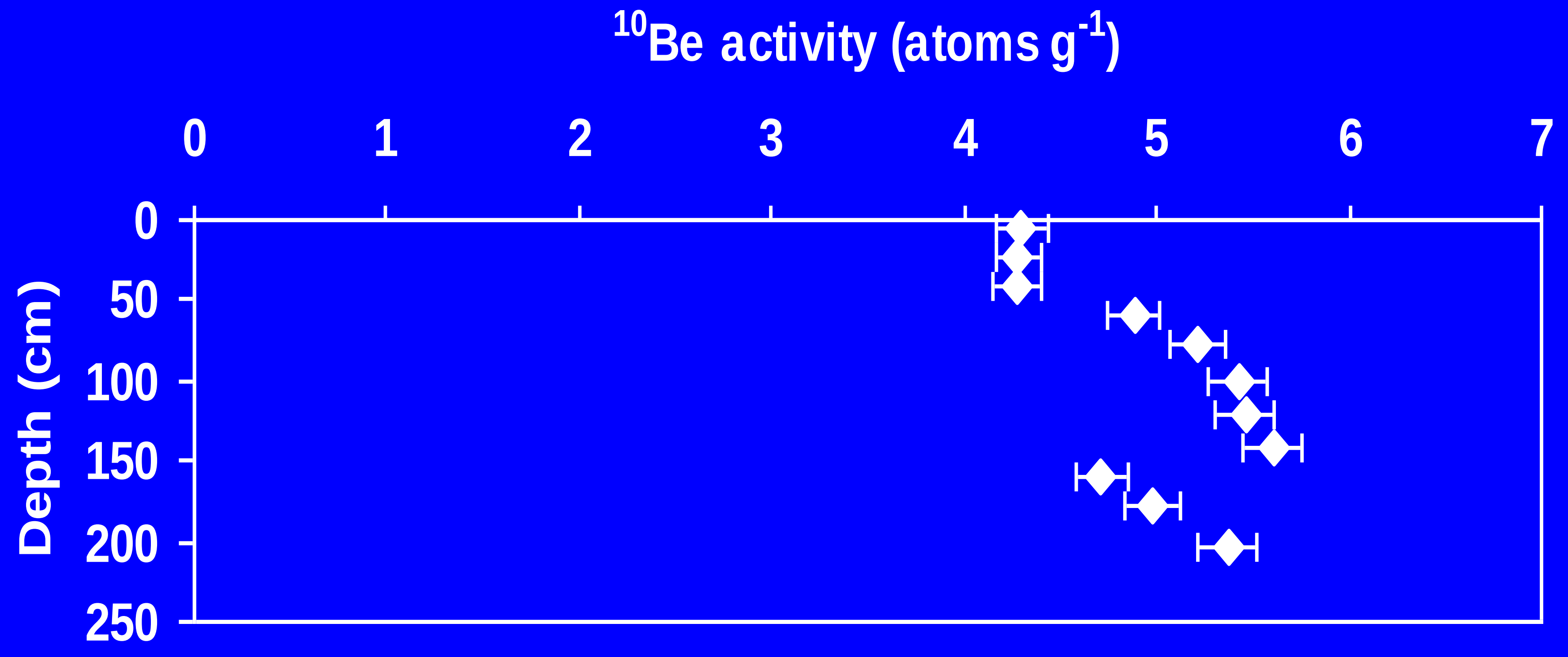


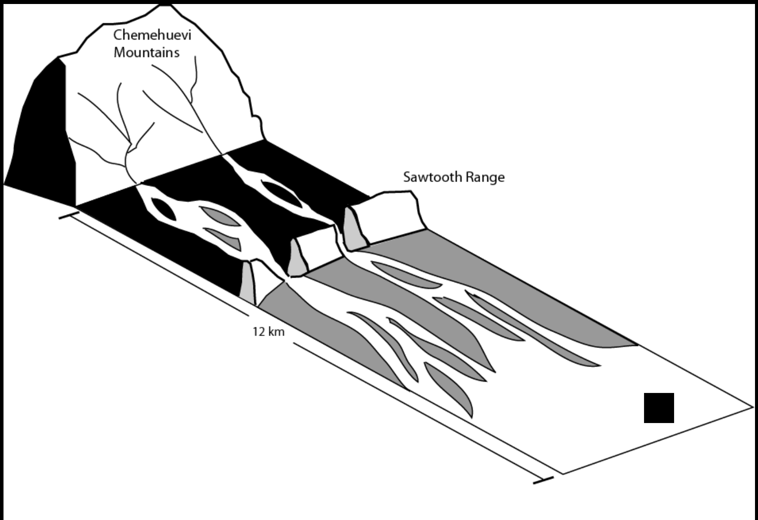
Deposition signature



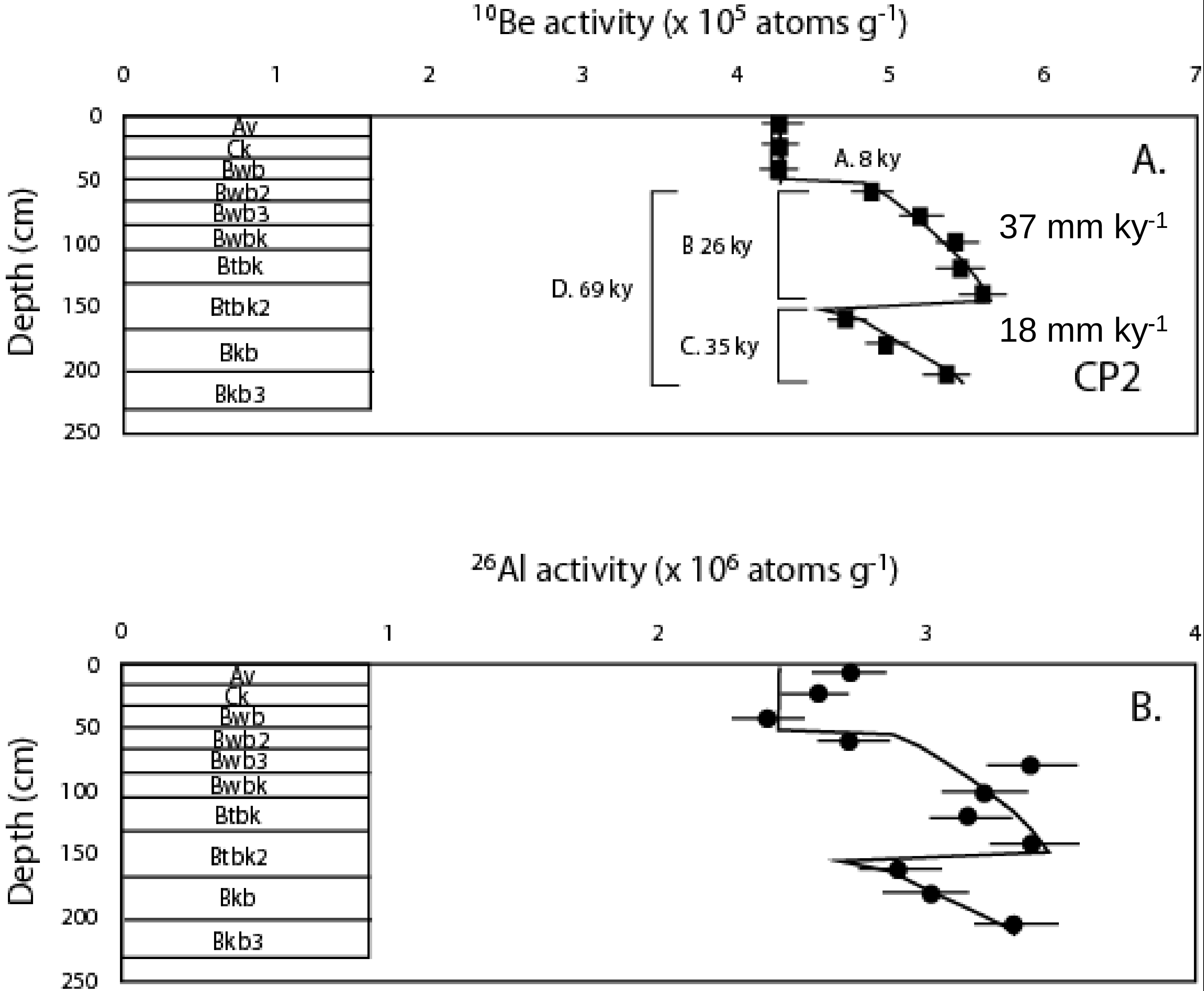
Deposition signature





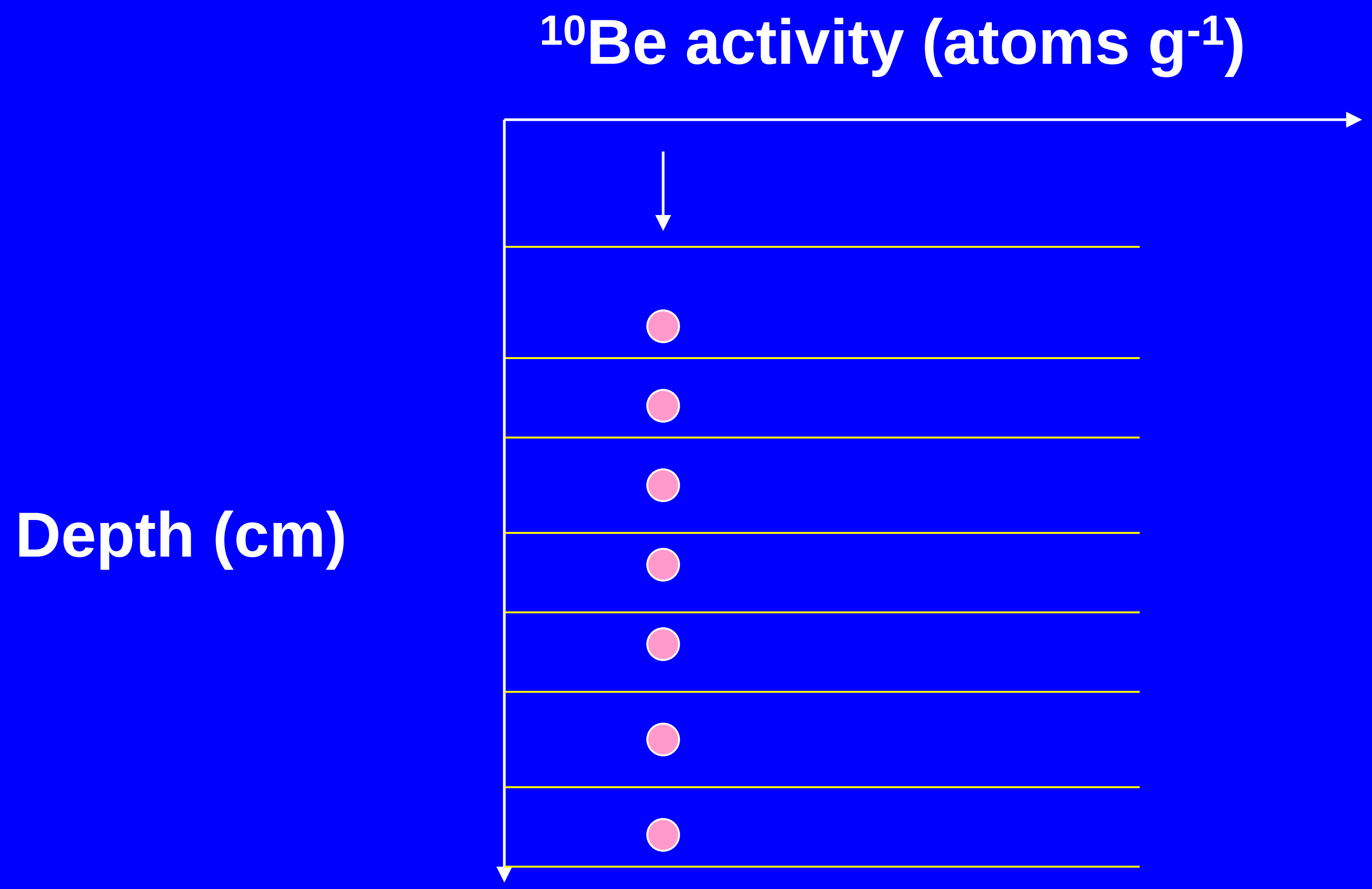


CP2 - wash surface
12 km from mountain front

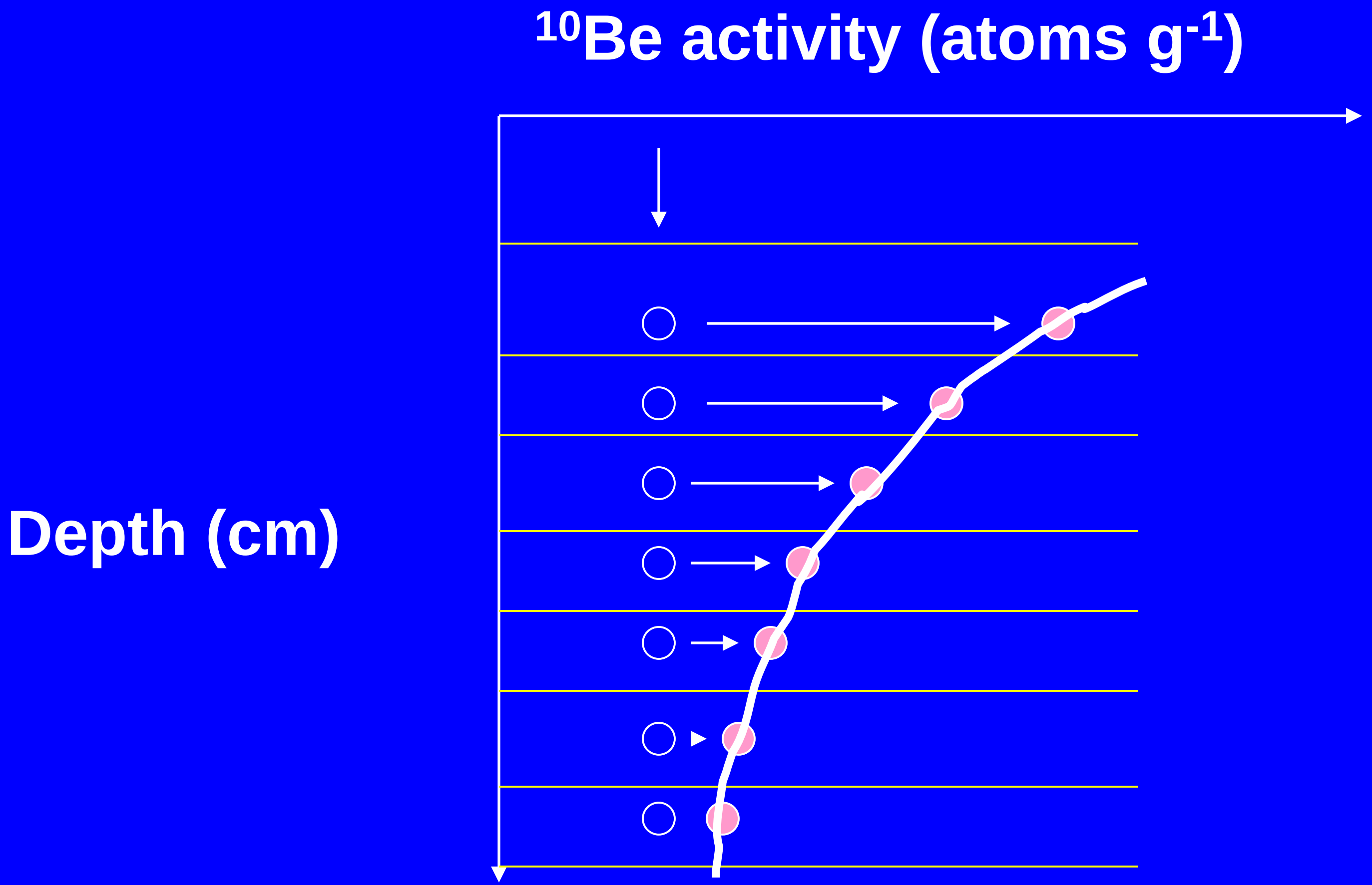


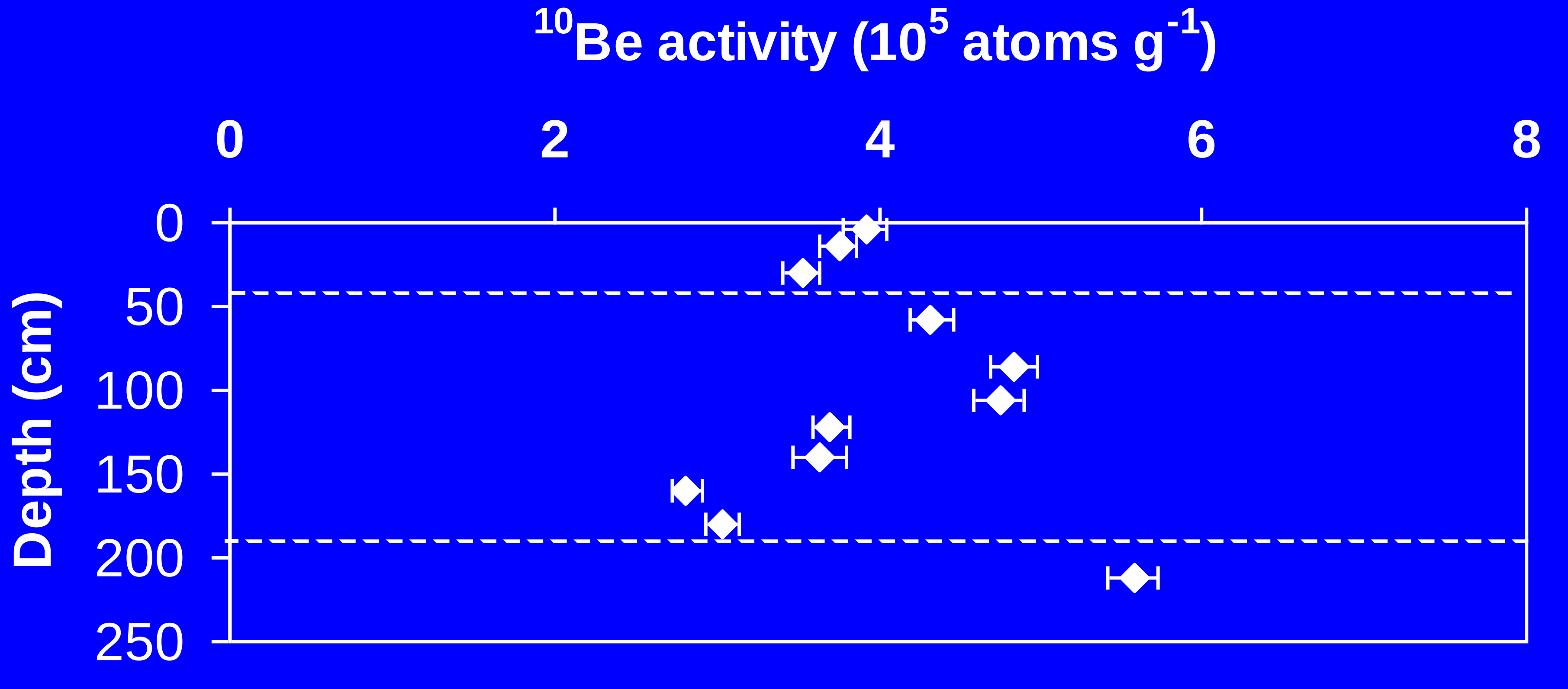
^{10}Be activity (x 10^5 atoms g^{-1})
0 1 2 3 4 5 6 7
Depth (cm)
0 50 100 150 200 250
Av
Ck
Bwb
Bwb2
Bwb3
Bwbk
Btbk
Btbk2
Bkb
Bkb3
A. 8 ky
B 26 ky
C. 35 ky
D. 69 ky
A.
37 mm ky^{-1}
18 mm ky^{-1}
CP2
^{26}Al activity (x 10^6 atoms g^{-1})
0 1 2 3 4
Depth (cm)
0 50 100 150 200 250
Av
Ck
Bwb
Bwb2
Bwb3
Bwbk
Btbk
Btbk2
Bkb
Bkb3
B.

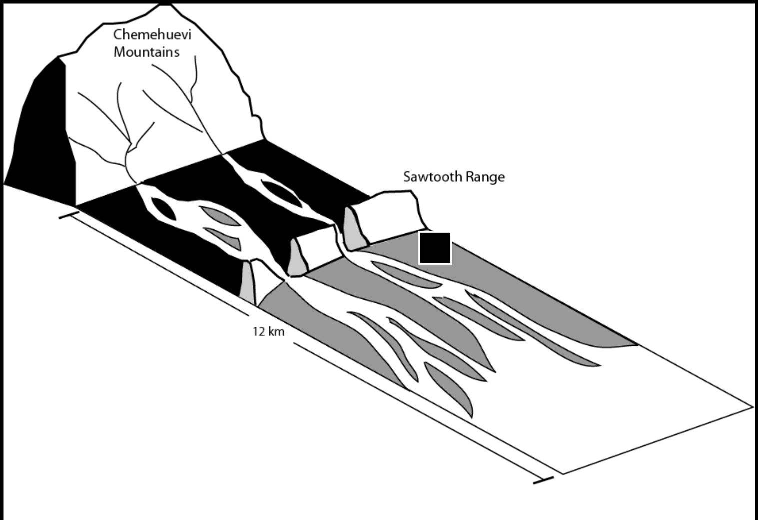
Rapid deposition followed by stable surface



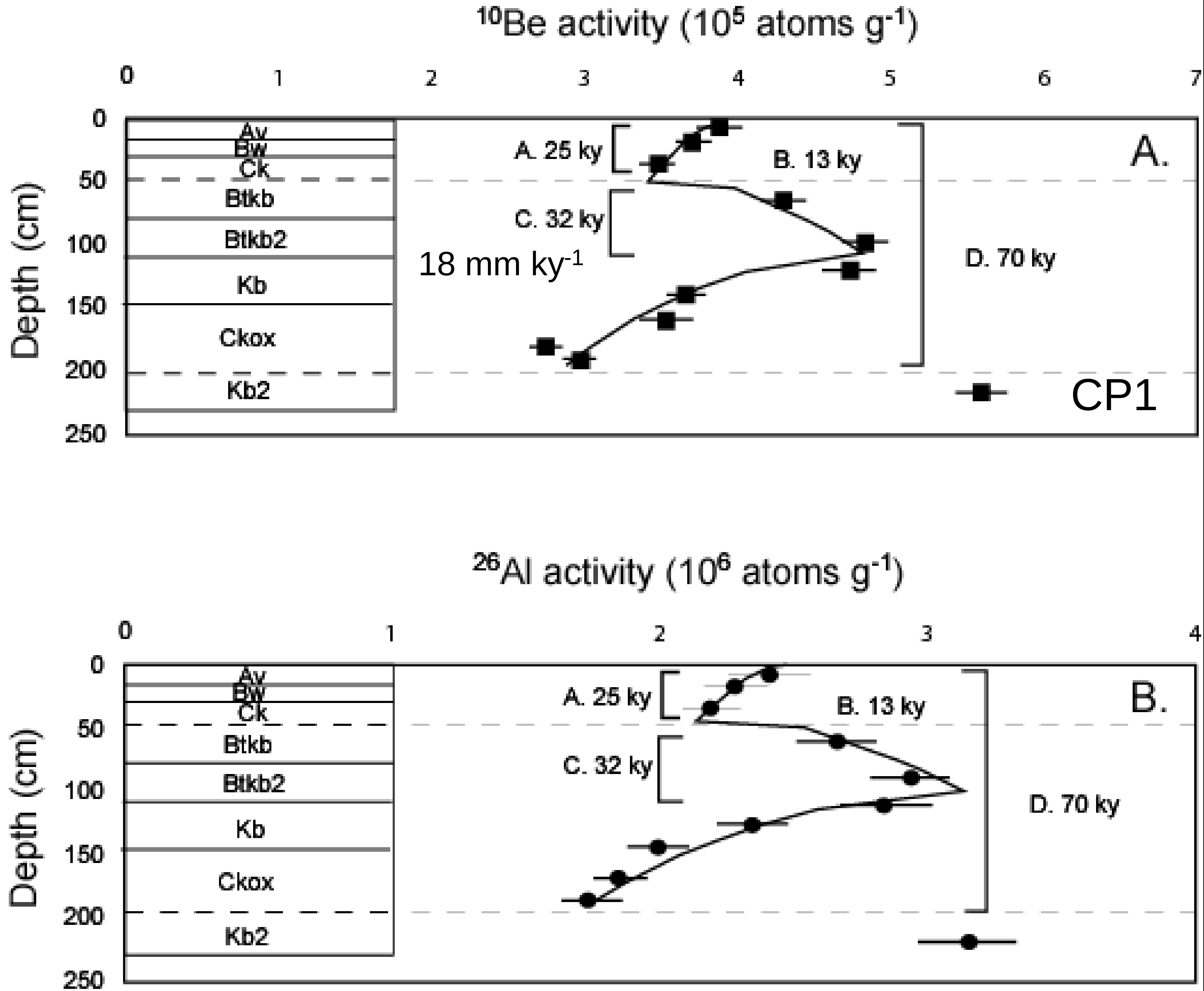
Rapid deposition followed by stable surface







CP1 - proximal surface
6 km from mountain front

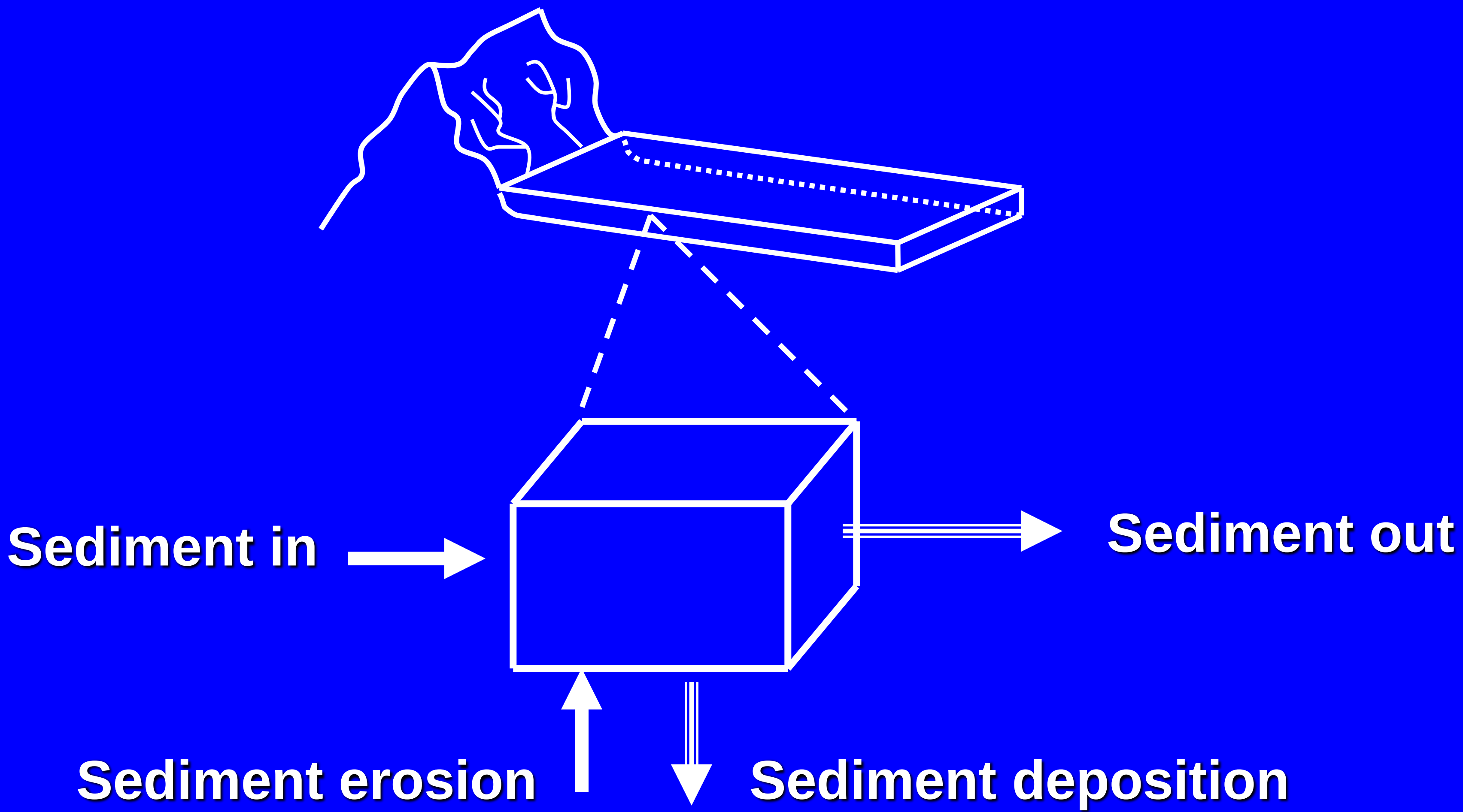


10Be activity (10^5 atoms g-1)
Depth (cm)
Av
Bw
Ck
Btkb
Btkb2
Kb
Ckox
Kb2
A. 25 ky
B. 13 ky
C. 32 ky
D. 70 ky
18 mm ky-1
A.
CP1
26Al activity (10^6 atoms g-1)
B.

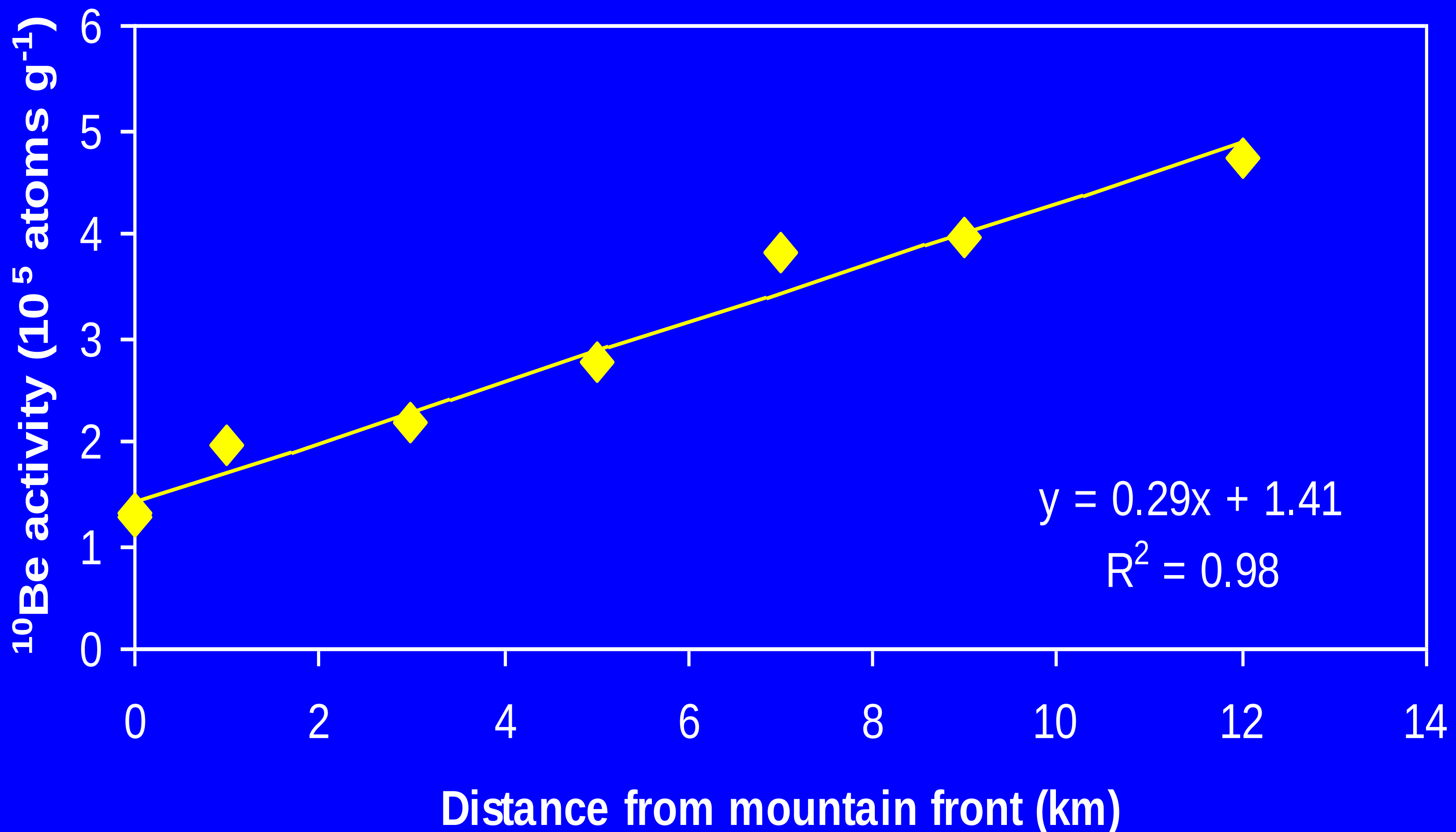
Soil Pit comparison

- Deposition 18 mm ky^{-1} from 70 to ~34 ky ago piedmont wide (both soil pits)
- Erosion of alluvial sediment ~34 ky ago (CP1)
- Increased deposition rates (37 mm ky^{-1}) on wash surface and higher nuclide activities ~34 ky ago (CP2)
- Change from sediment deposition to transport on wash surface ~ 8 ky ago

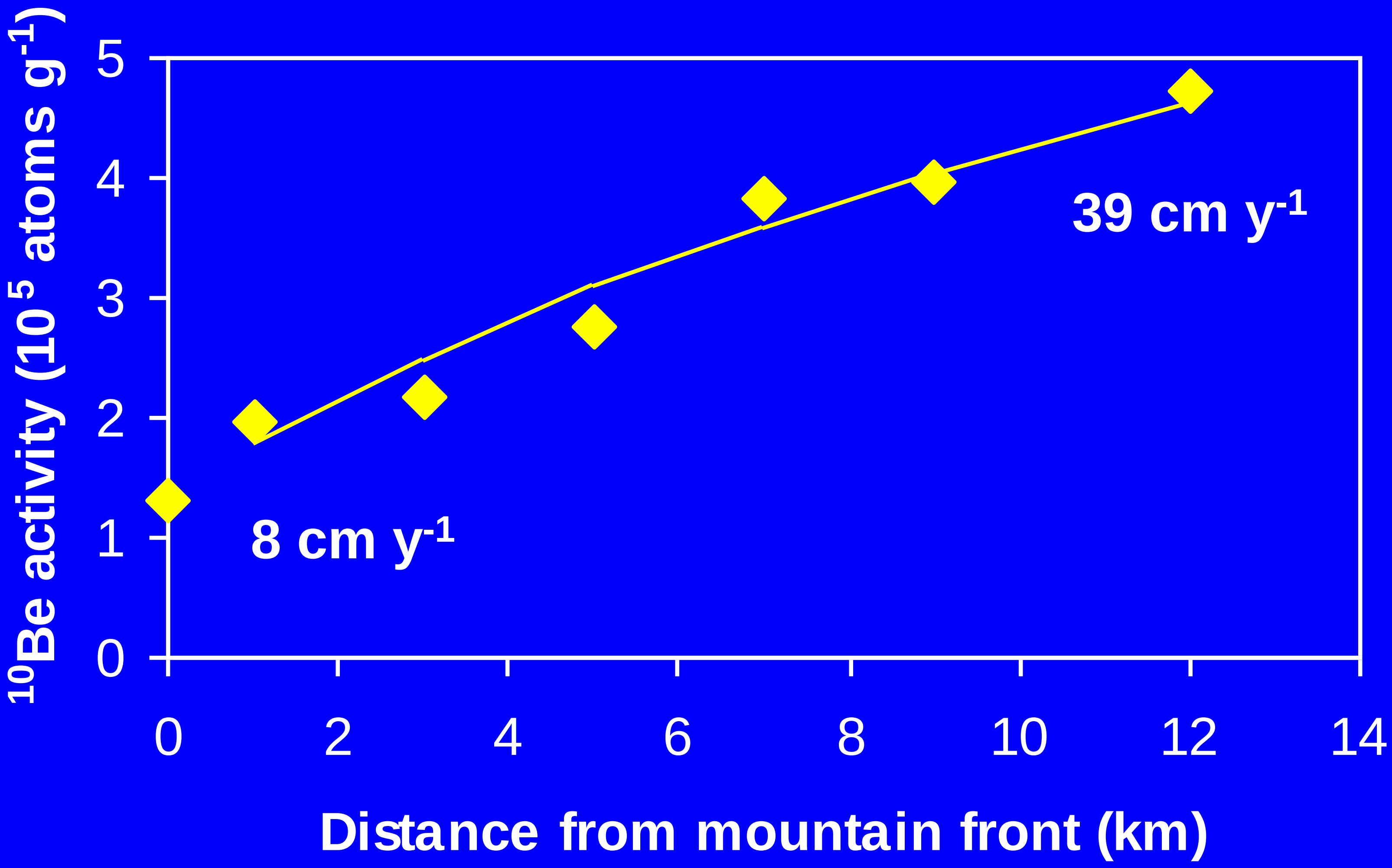
Model Equation



Chemehuevi Ephemeral Channel Samples

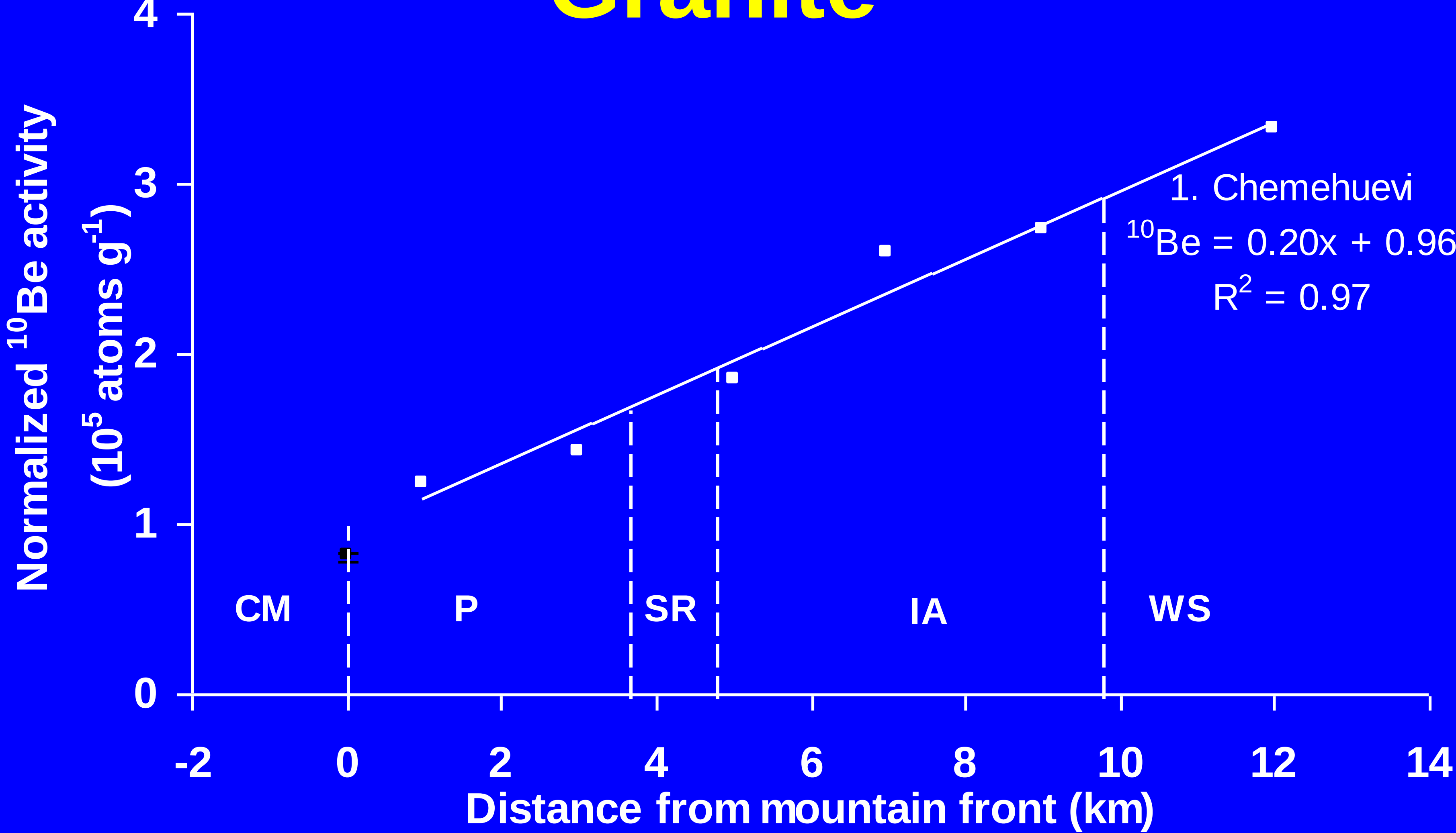


Sediment velocities

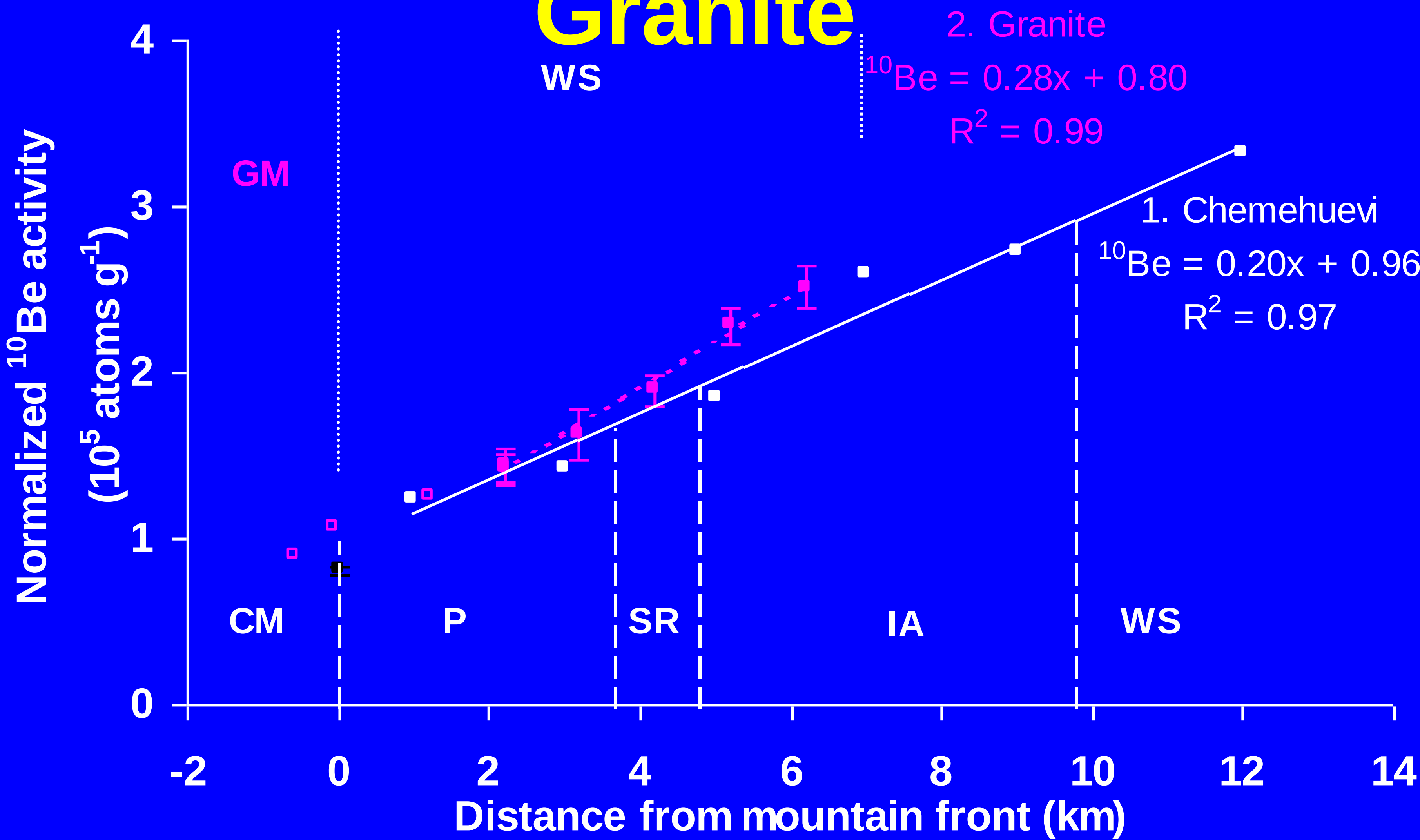


Iron and Granite Mountain piedmonts

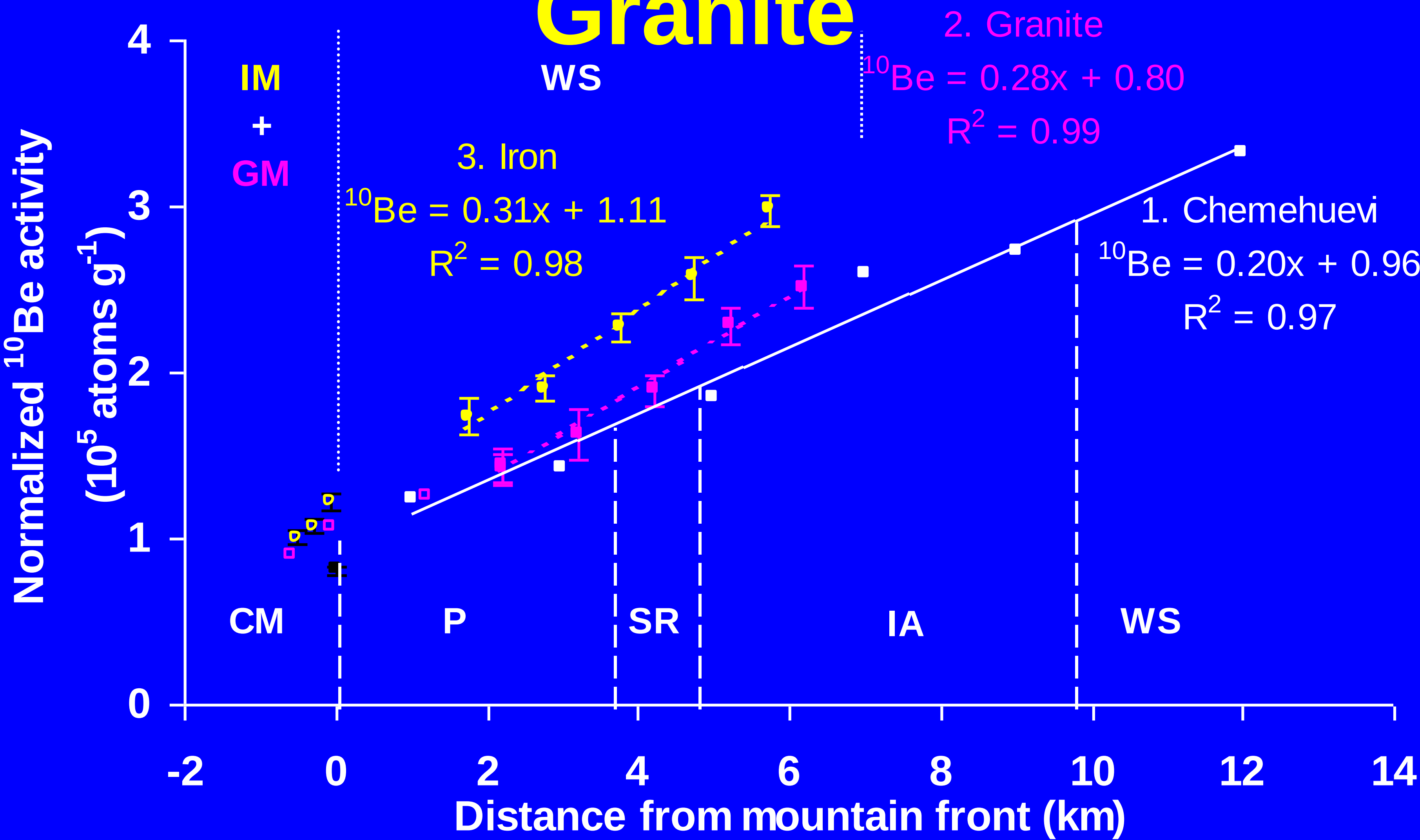
Chemehuevi vs. Iron and Granite



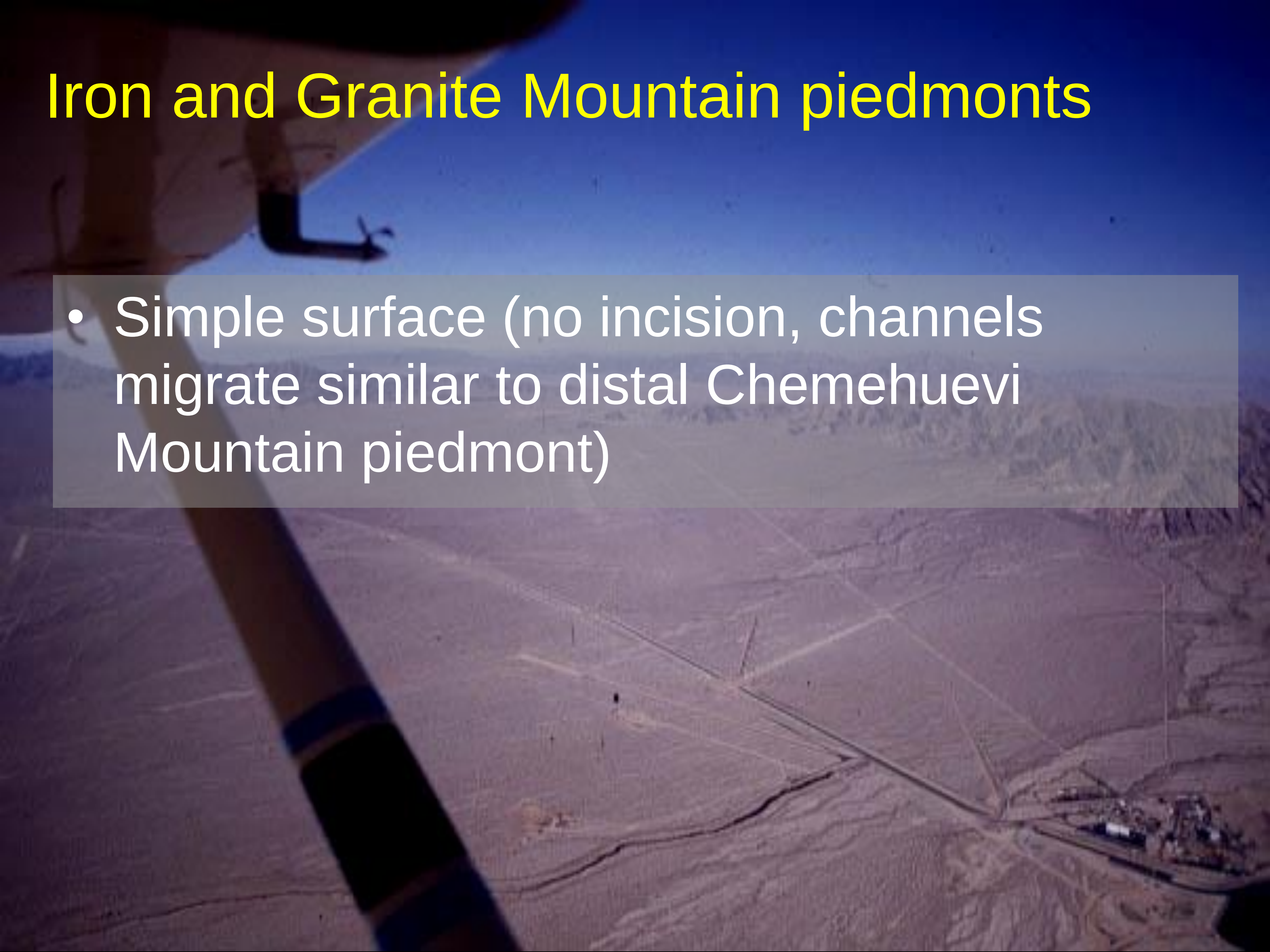
Chemehuevi vs. Iron and Granite



Chemehuevi vs. Iron and Granite

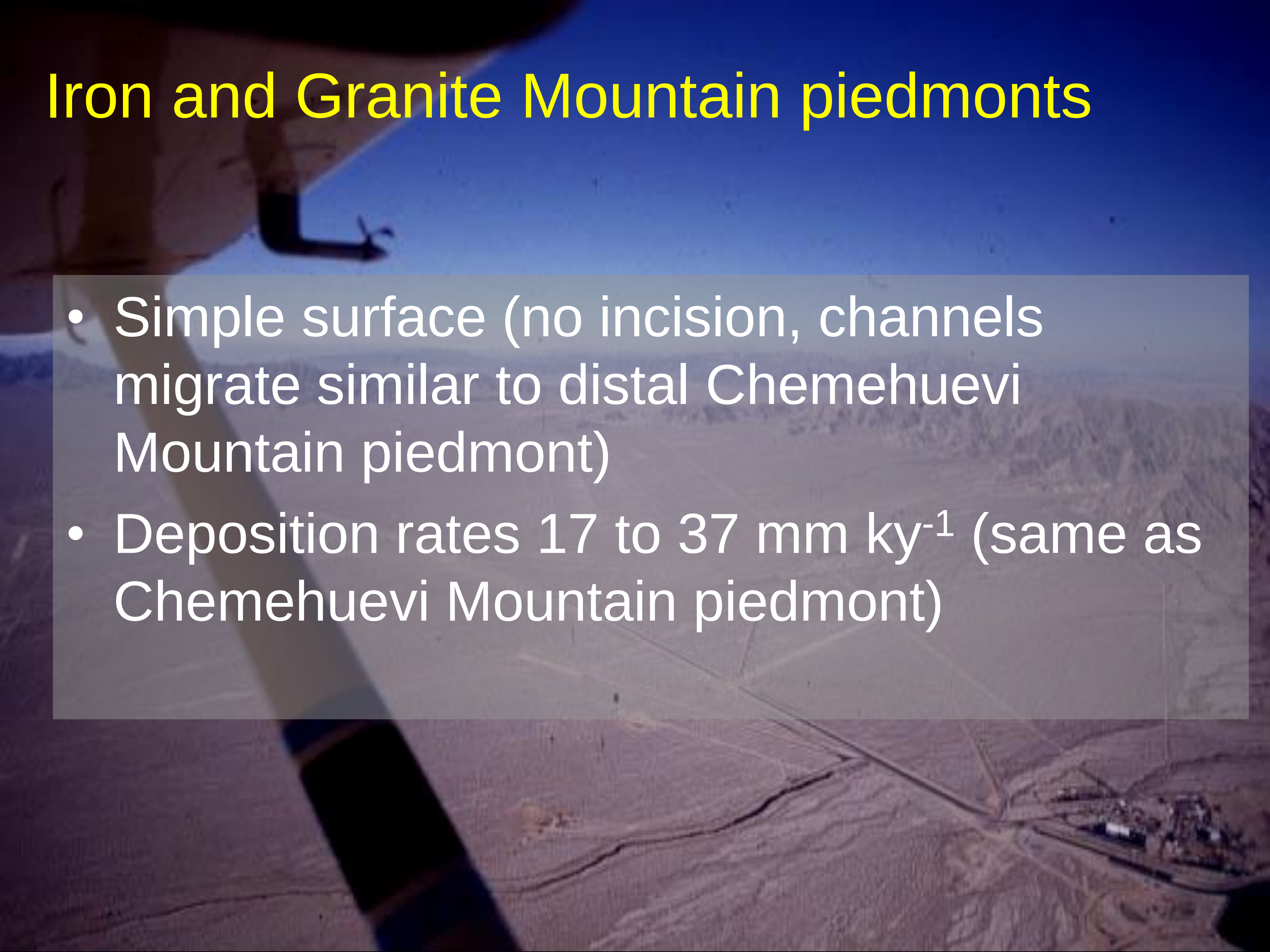


Iron and Granite Mountain piedmonts



- Simple surface (no incision, channels migrate similar to distal Chemehuevi Mountain piedmont)

Iron and Granite Mountain piedmonts



- Simple surface (no incision, channels migrate similar to distal Chemehuevi Mountain piedmont)
- Deposition rates 17 to 37 mm ky^{-1} (same as Chemehuevi Mountain piedmont)

Iron and Granite Mountain piedmonts

- Simple surface (no incision, channels migrate similar to distal Chemehuevi Mountain piedmont)
- Deposition rates 17 to 37 mm ky^{-1} (same as Chemehuevi Mountain piedmont)
- Depositional hiatus at Holocene-Pleistocene climate transition (~10 ky ago)

Iron and Granite Mountain piedmonts

- Simple surface (no incision, channels migrate similar to distal Chemehuevi Mountain piedmont)
- Deposition rates 17 to 37 mm ky^{-1} (same as Chemehuevi Mountain piedmont)
- Depositional hiatus at Holocene-Pleistocene climate transition (~10 ky ago)
- Sediment velocities are decimeters per year

Conclusions

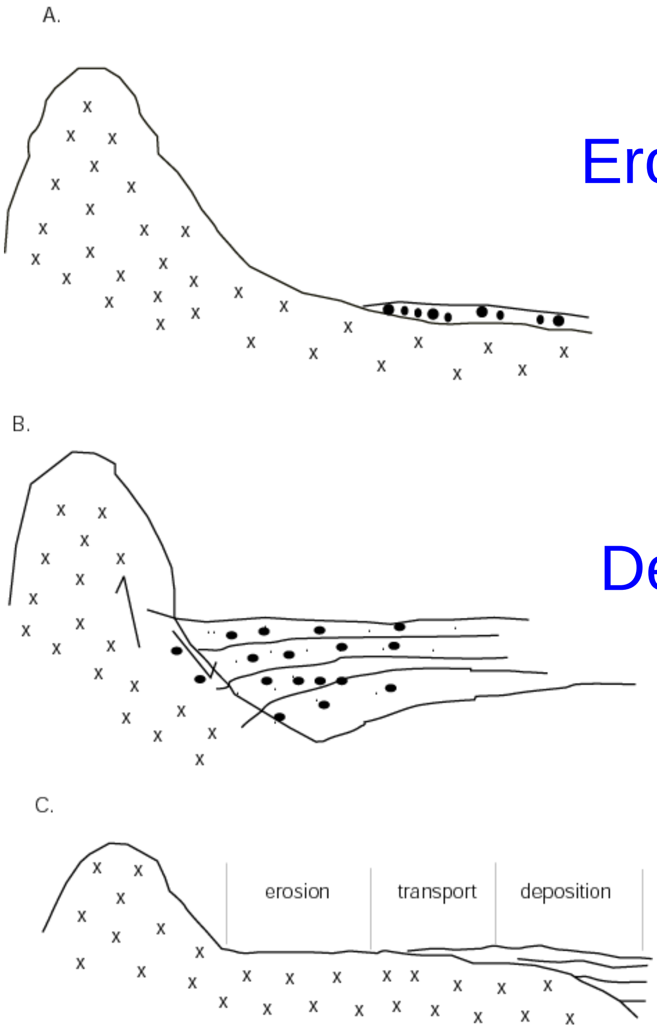
- Sediment velocities are not dependent on piedmont morphology (simple vs. complex)

East Range Road Upper Surface

East Range Road Wash Surface

Source Basin Sample

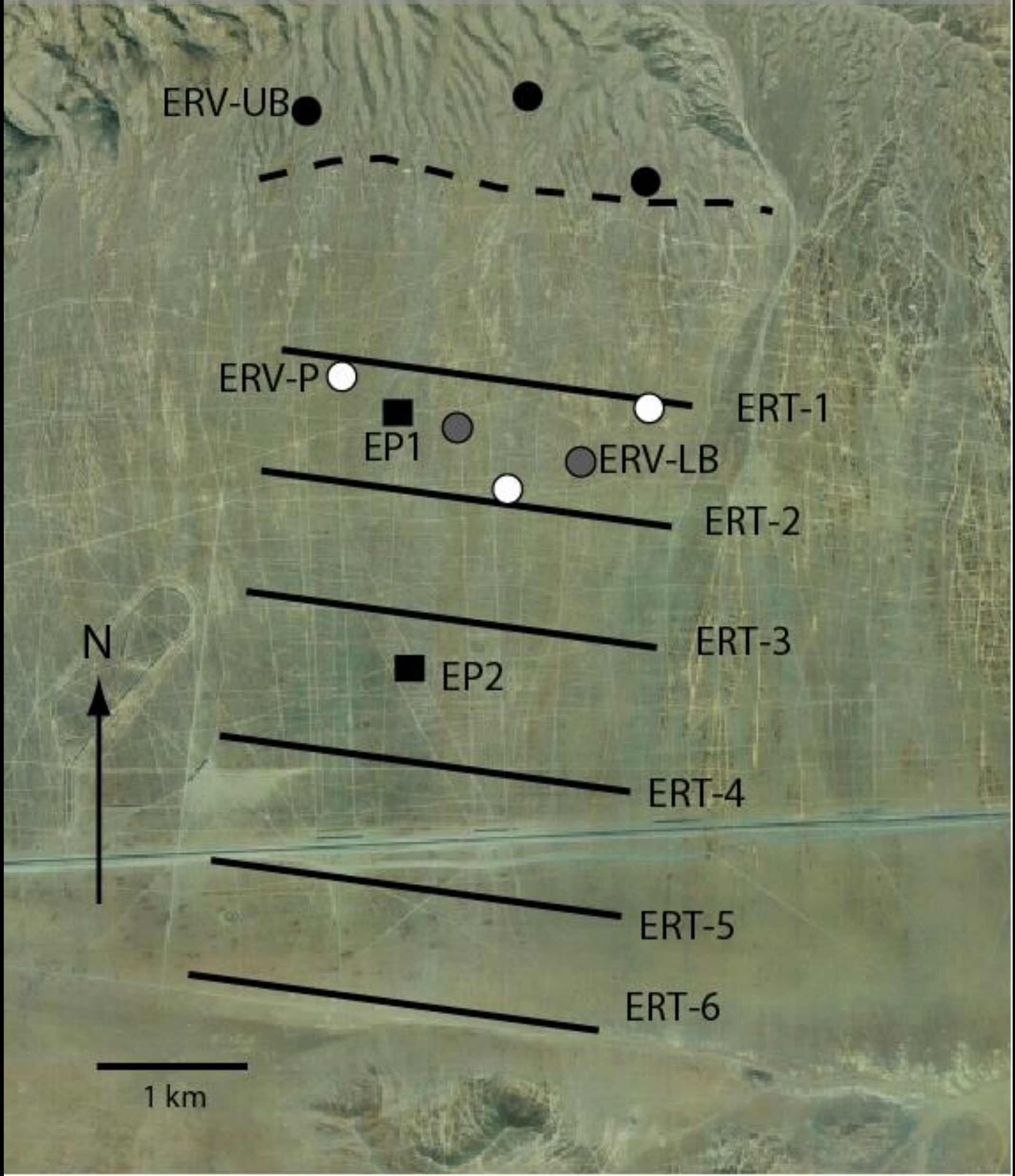
Three common types of desert piedmonts

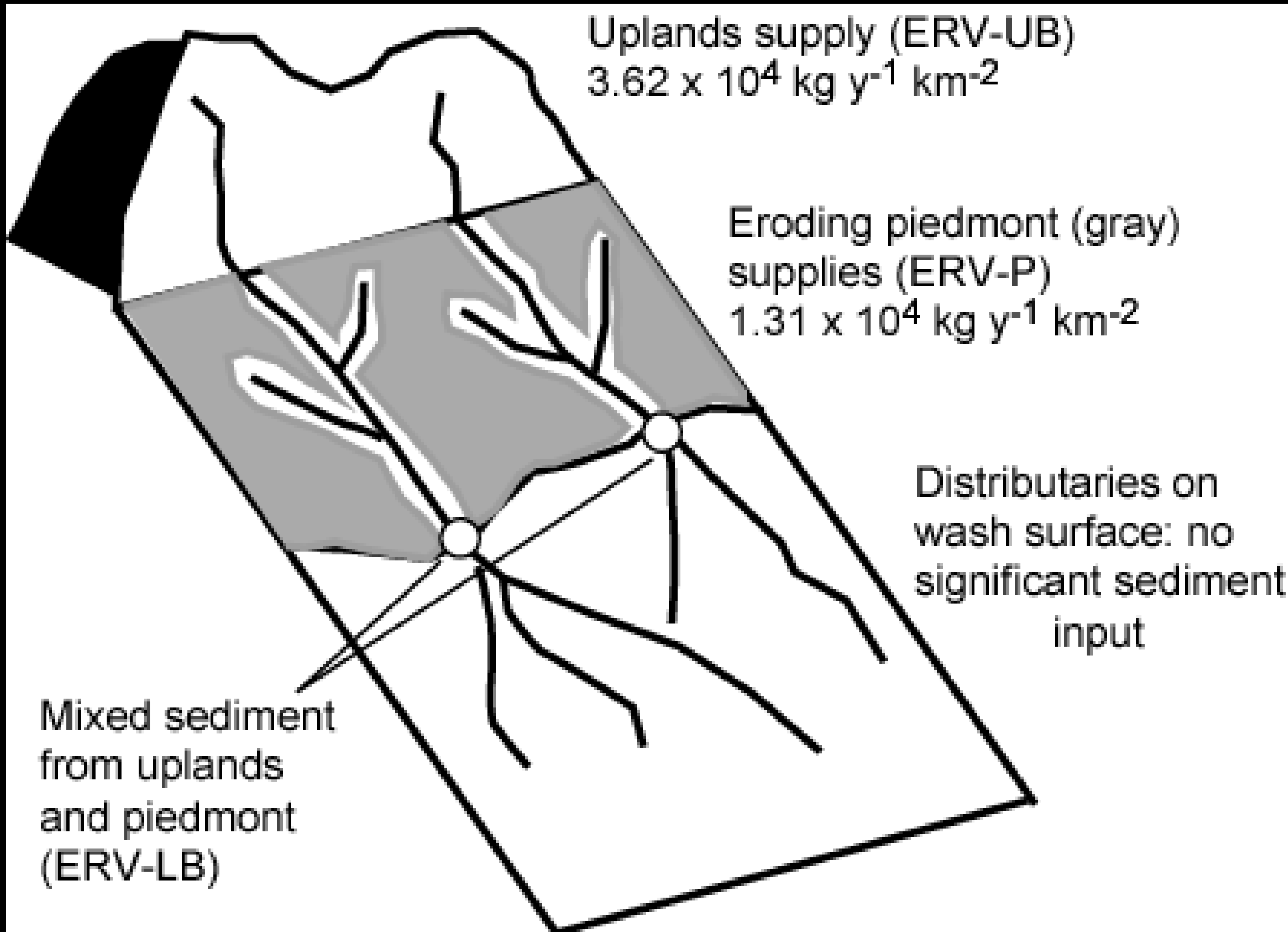


Erosional

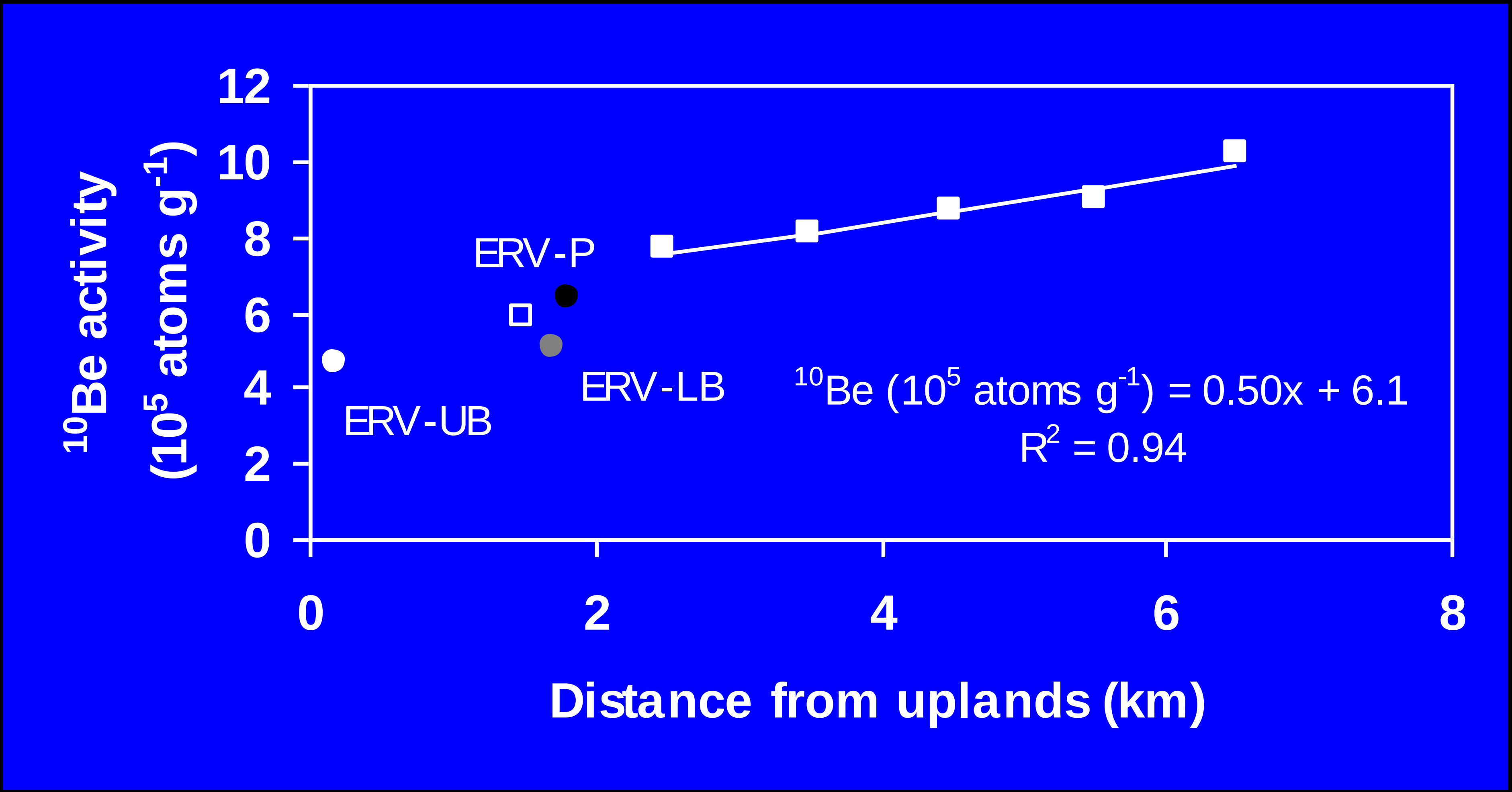
Depositional

East Range Road

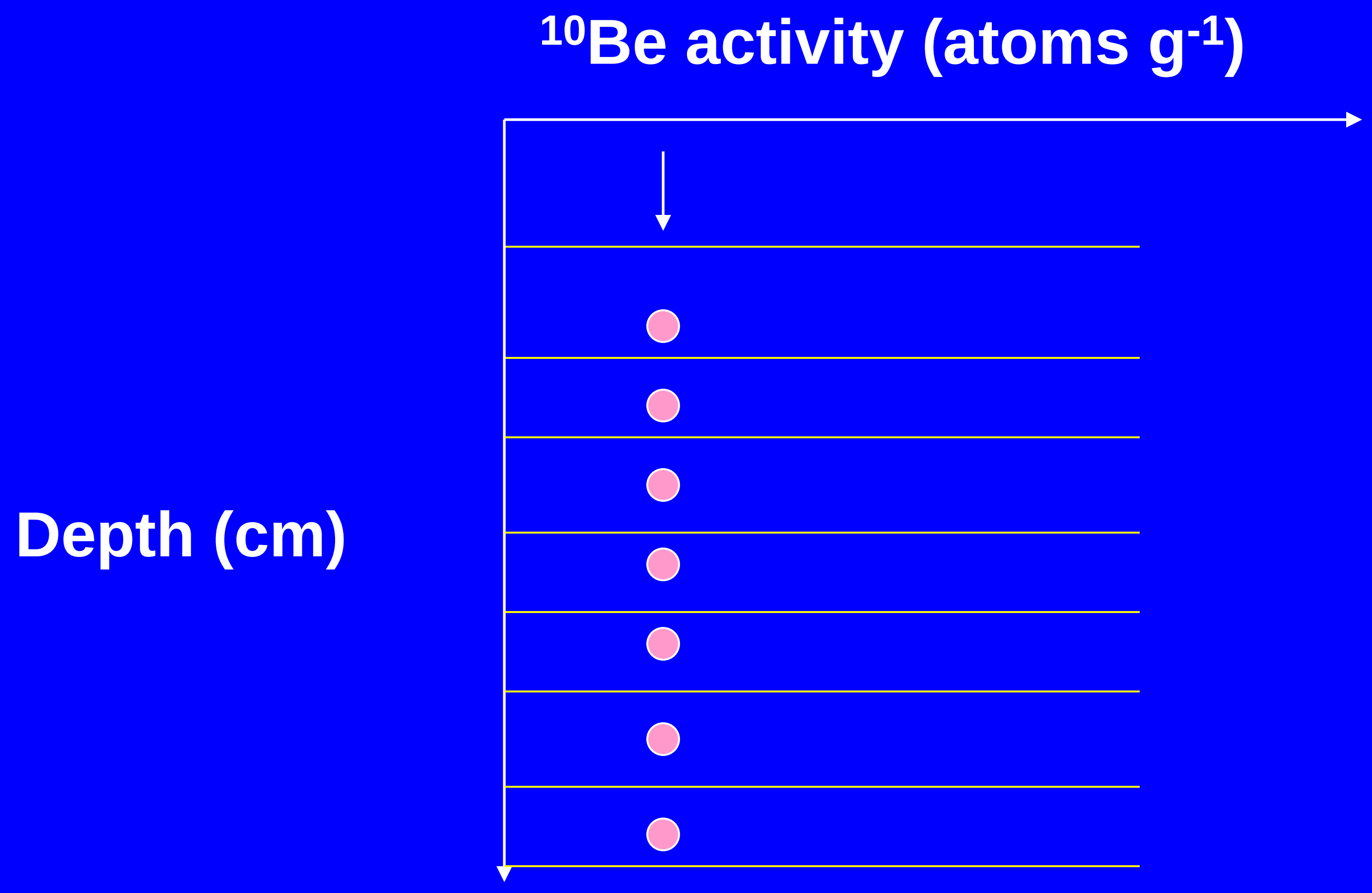



Uplands supply (ERV-UB)
3.62×10^4 kg y^{-1} km^{-2}
Eroding piedmont (gray) supplies (ERV-P)
1.31×10^4 kg y^{-1} km^{-2}
Distributaries on wash surface: no significant sediment input
Mixed sediment from uplands and piedmont (ERV-LB)

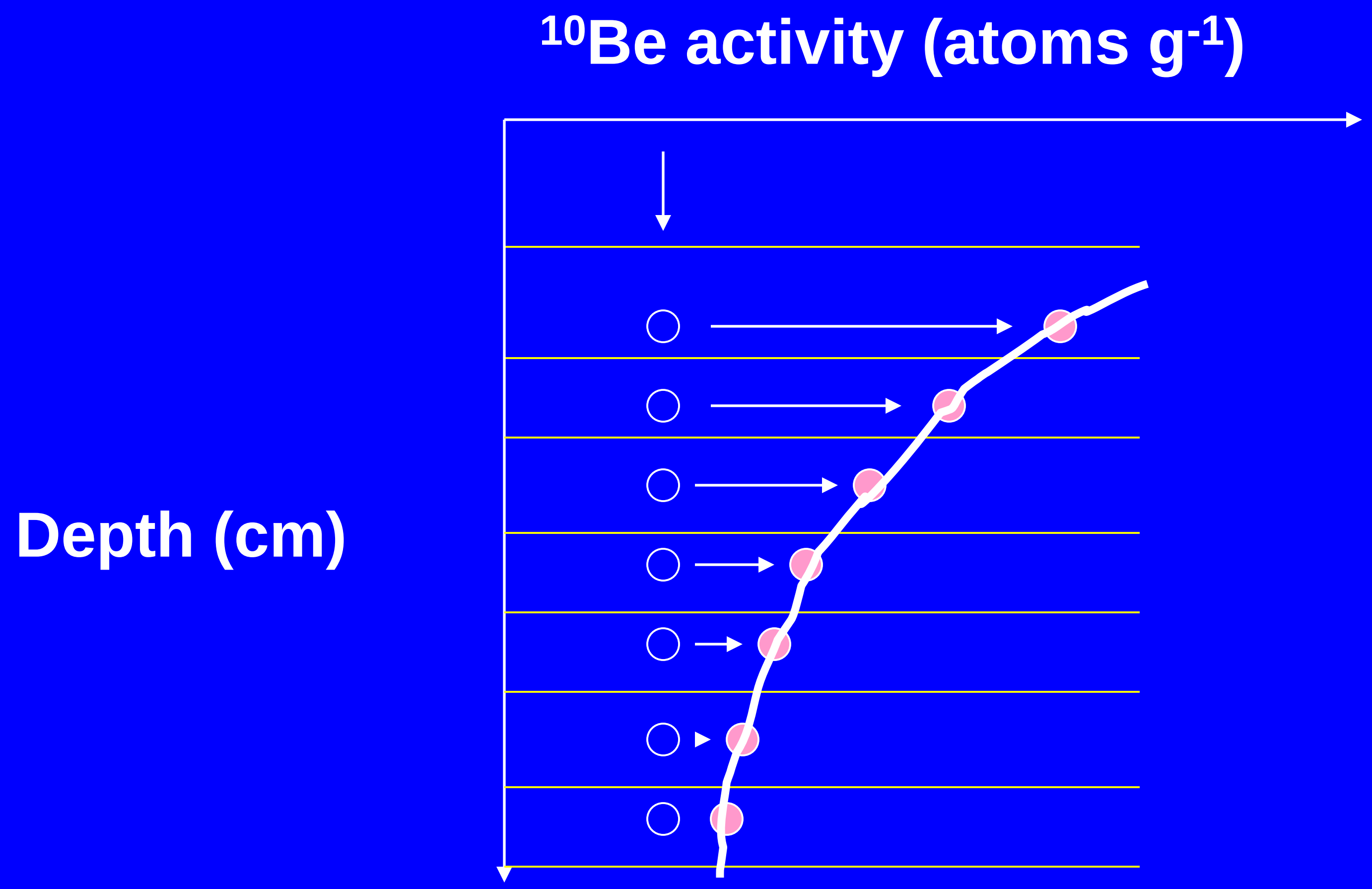
Transect data

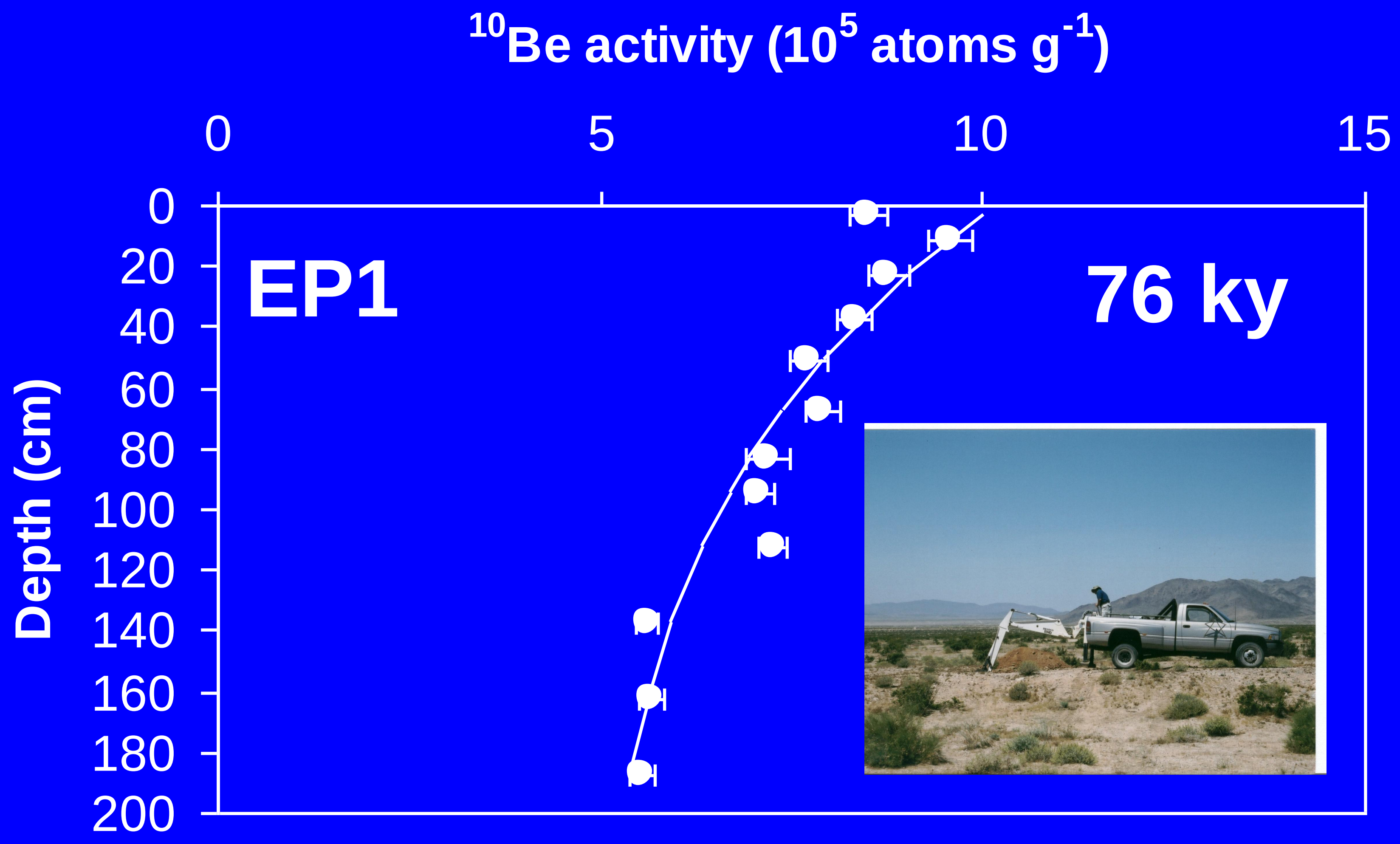


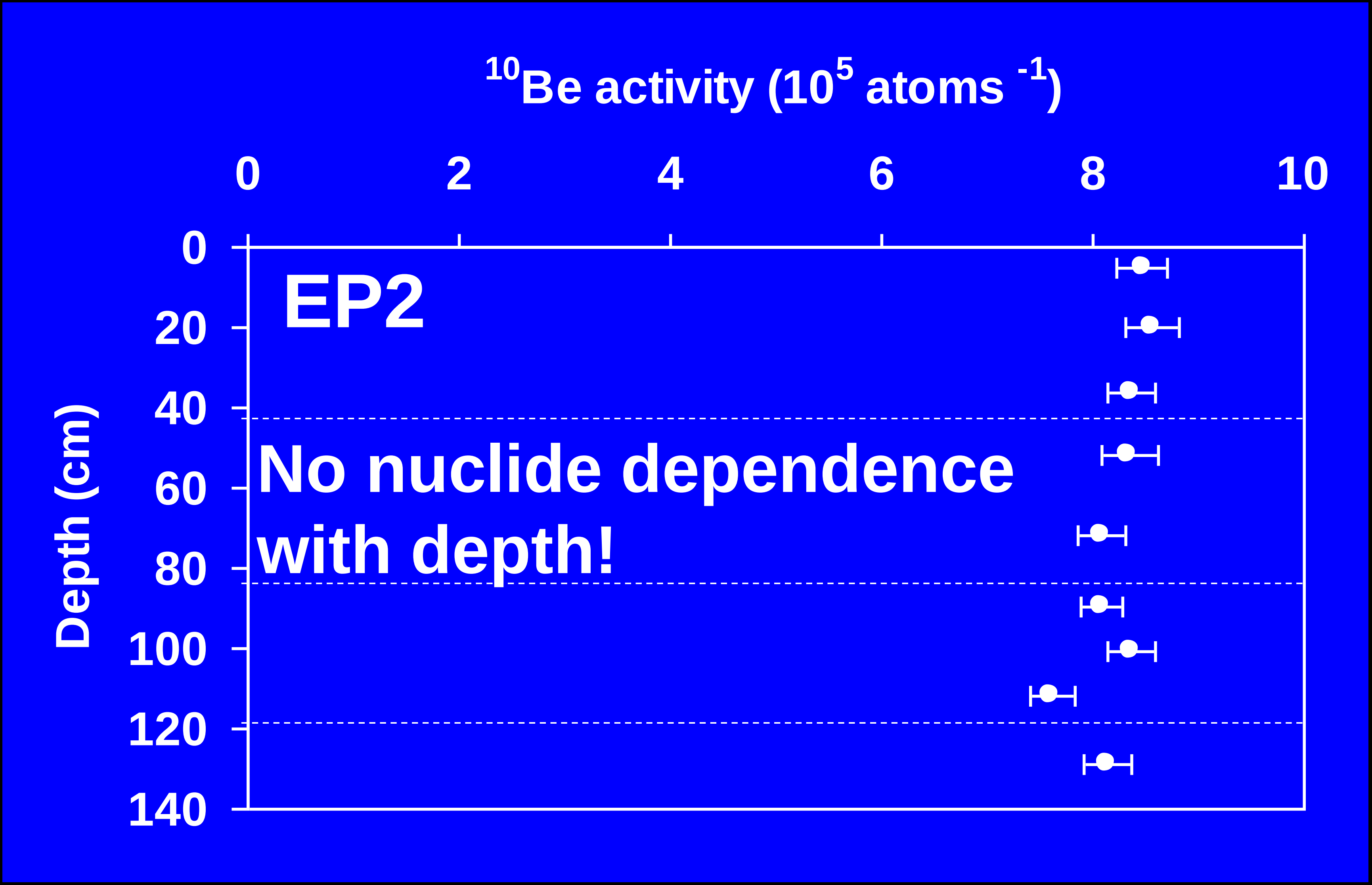
Rapid deposition followed by stable surface

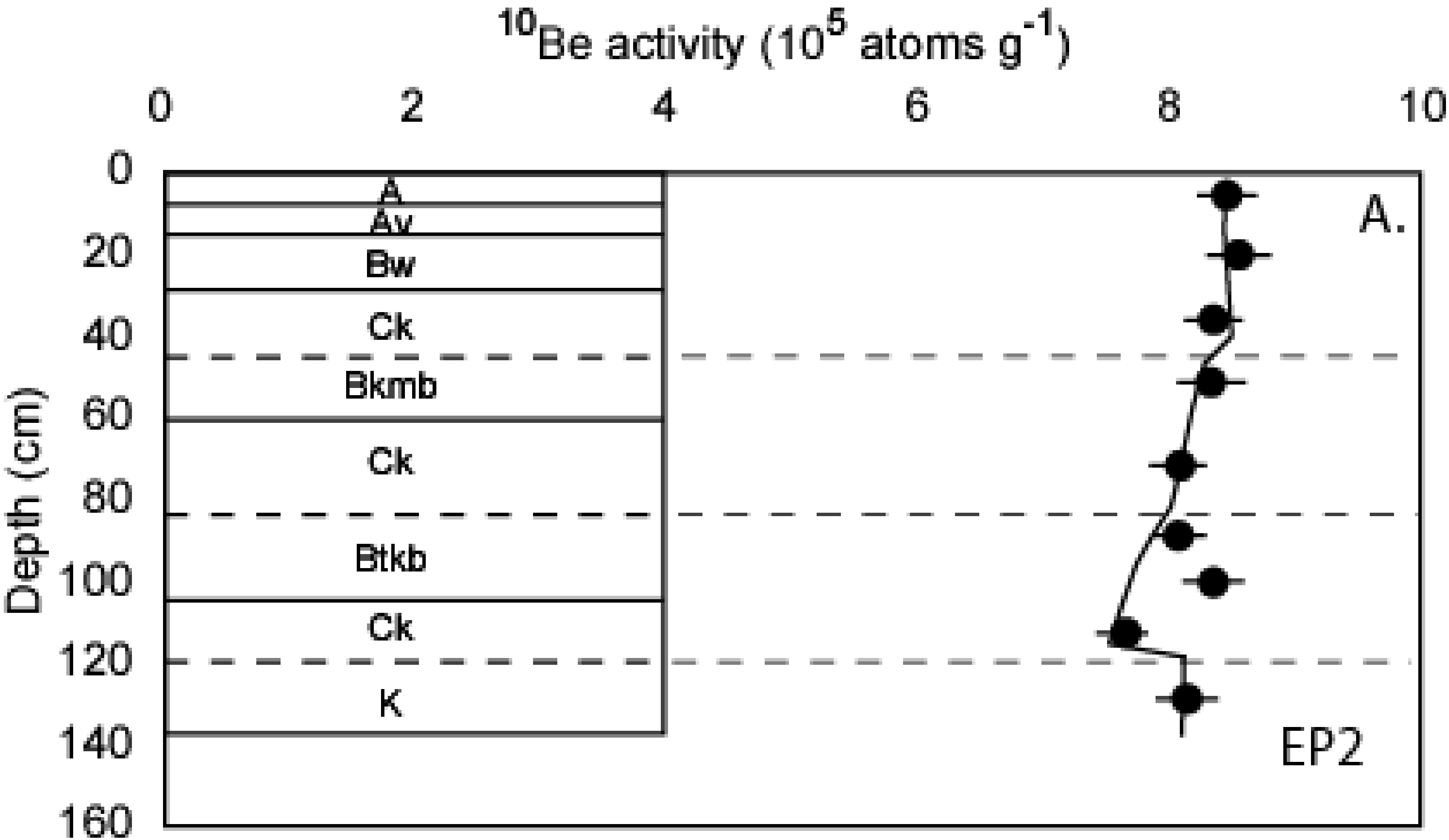


Rapid deposition followed by stable surface

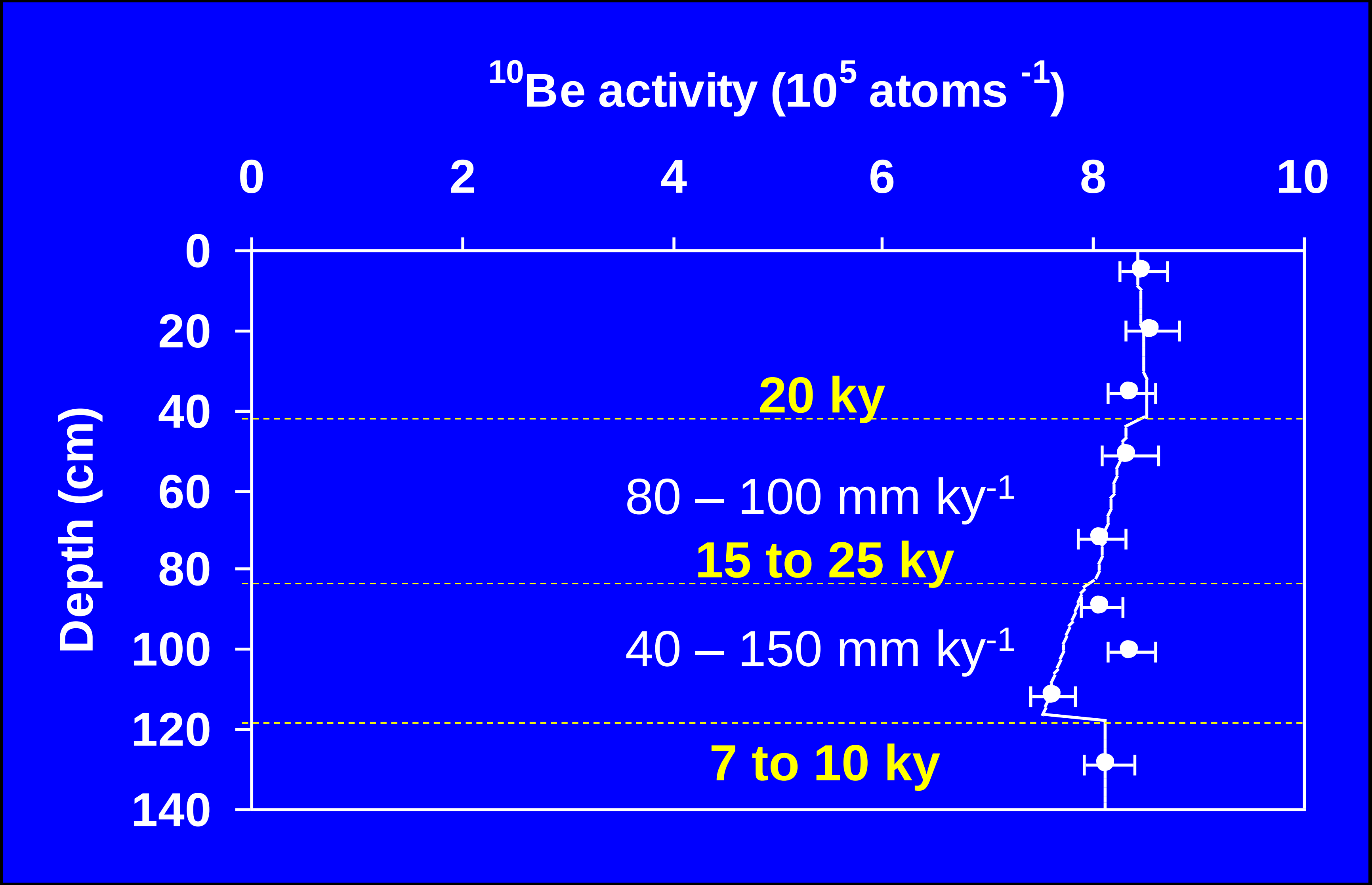



^{10}Be activity (10^5 atoms g^{-1})
0
5
10
15
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
EP1
76 ky

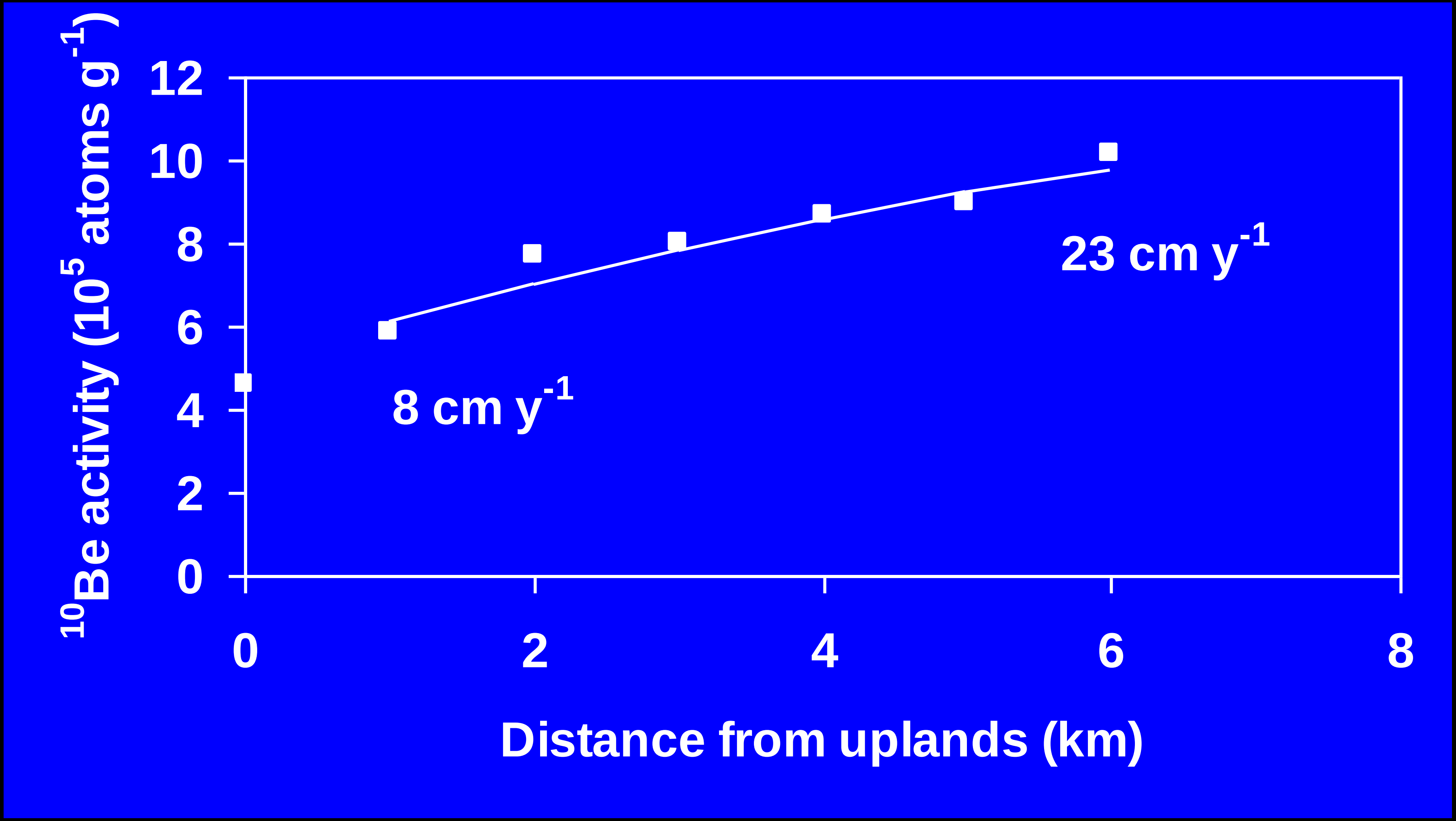

^{10}Be activity (10^5 atoms $^{-1}$)
0
2
4
6
8
10
0
20
40
60
80
100
120
140
Depth (cm)
EP2
No nuclide dependence
with depth!



10Be activity (10^5 atoms g^-1)
0
2
4
6
8
10
0
20
40
60
80
100
120
140
160
Depth (cm)
A
Av
Bw
Ck
Bkmb
Ck
Btkb
Ck
K
A.
EP2



^{10}Be activity (10^5 atoms $^{-1}$)
0
2
4
6
8
10
Depth (cm)
0
20
40
60
80
100
120
140
20 ky
80 – 100 mm ky^{-1}
15 to 25 ky
40 – 150 mm ky^{-1}
7 to 10 ky



^{10}Be activity (10^5 atoms g^{-1})
12
10
8
6
4
2
0
23 cm y^{-1}
8 cm y^{-1}
0
2
4
6
8
Distance from uplands (km)

Conclusions

- Sediment velocities are not dependent on piedmont morphology (simple vs. complex)
- Sediment velocities are the same for undisturbed and disturbed piedmonts

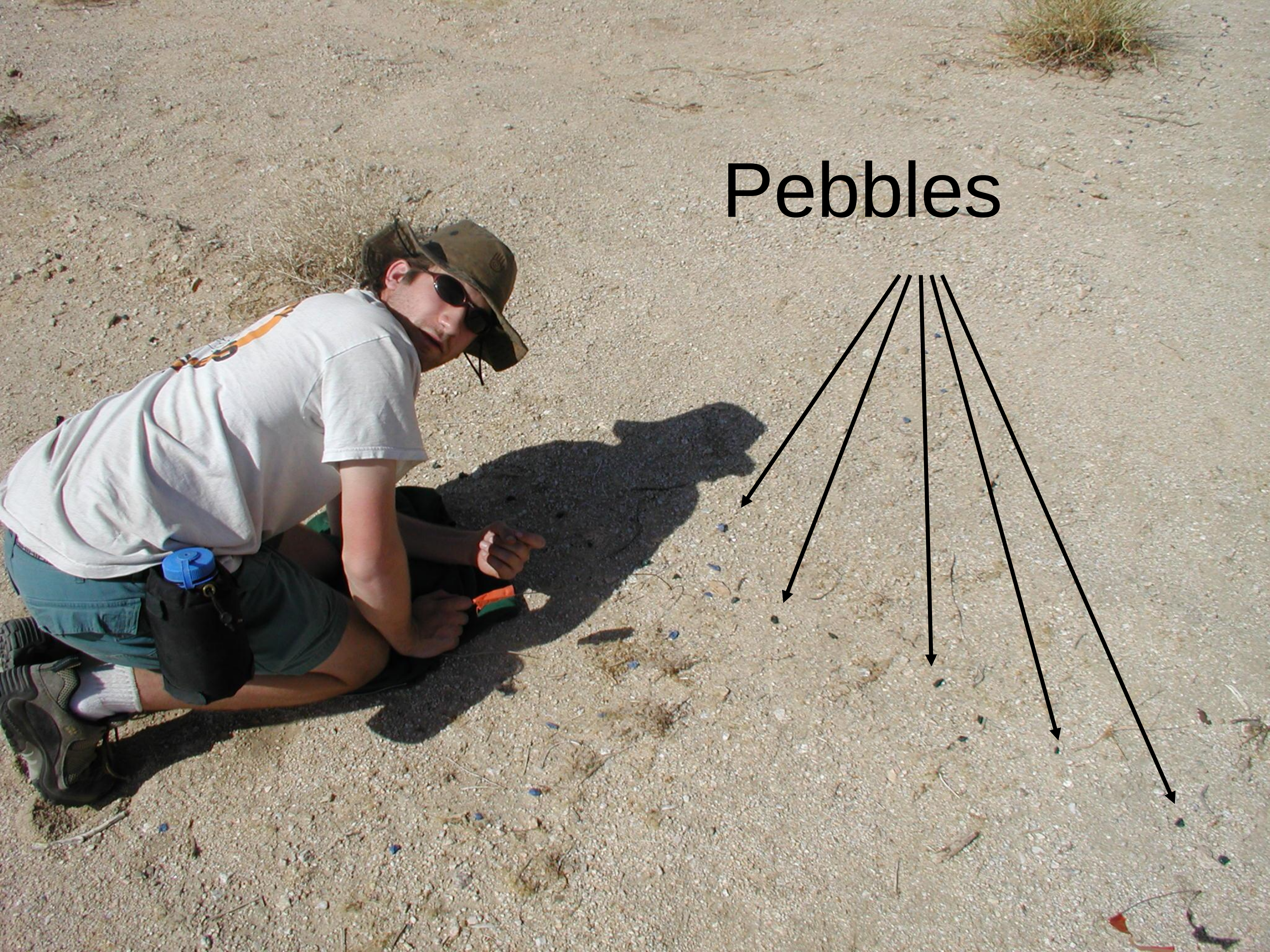
Conclusions

- Sediment velocities are not dependent on piedmont morphology (simple vs. complex)
- Sediment velocities are the same for undisturbed and disturbed piedmonts
- Large-scale structural controls do not affect long term process rates

Conclusions

- Sediment velocities are not dependent on piedmont morphology (simple vs. complex)
- Sediment velocities are the same for undisturbed and disturbed piedmonts
- Large-scale structural controls do not affect long term process rates
- Quantify baseline process rates on disturbed piedmonts

What effect do Army tanks have on sediment movement?


Pebbles

Long-term vs. Short-term

- Long-term sediment movement based on cosmogenic nuclides is 8 to 23 cm y^{-1}

Long-term vs. Short-term

- Long-term sediment movement based on cosmogenic nuclides is 8 to 23 cm y^{-1}
- Contemporary measurements suggest sediment movement is 80 cm y^{-1}

Long-term vs. Short-term

- Long-term sediment movement based on cosmogenic nuclides is 8 to 23 cm y^{-1}
- Contemporary measurements suggest sediment movement is 80 cm y^{-1}
- Disturbance by tanks, trucks, and troops increases sediment movement from ***4 to 10 fold!***

Conclusions

- Sediment velocities are not dependent on piedmont morphology (simple vs. complex)
- Sediment velocities are the same for undisturbed and disturbed piedmonts
- Quantify baseline process rates on disturbed piedmonts
- Large-scale structural controls do not affect long term process rates
- Contemporary sediment movement rates can be up to 10 fold greater than baseline rates on disturbed piedmonts

Acknowledgements

- Funding from DEPSCoR grant #DAAD199910143 and the Jonathan O. Davis and J. Hoover Mackin scholarships
- Ruth Sparks and the ITAM crew at Ft. Irwin for logistical support
- Needles BLM crew for Chemehuevi soil pits
- Missy Eppes for soils descriptions


The picture can't be displayed.


Thanks Lyman!
THE MIGHTY MIGHTY BOSSTONES

Thanks Paul !


SARATOG