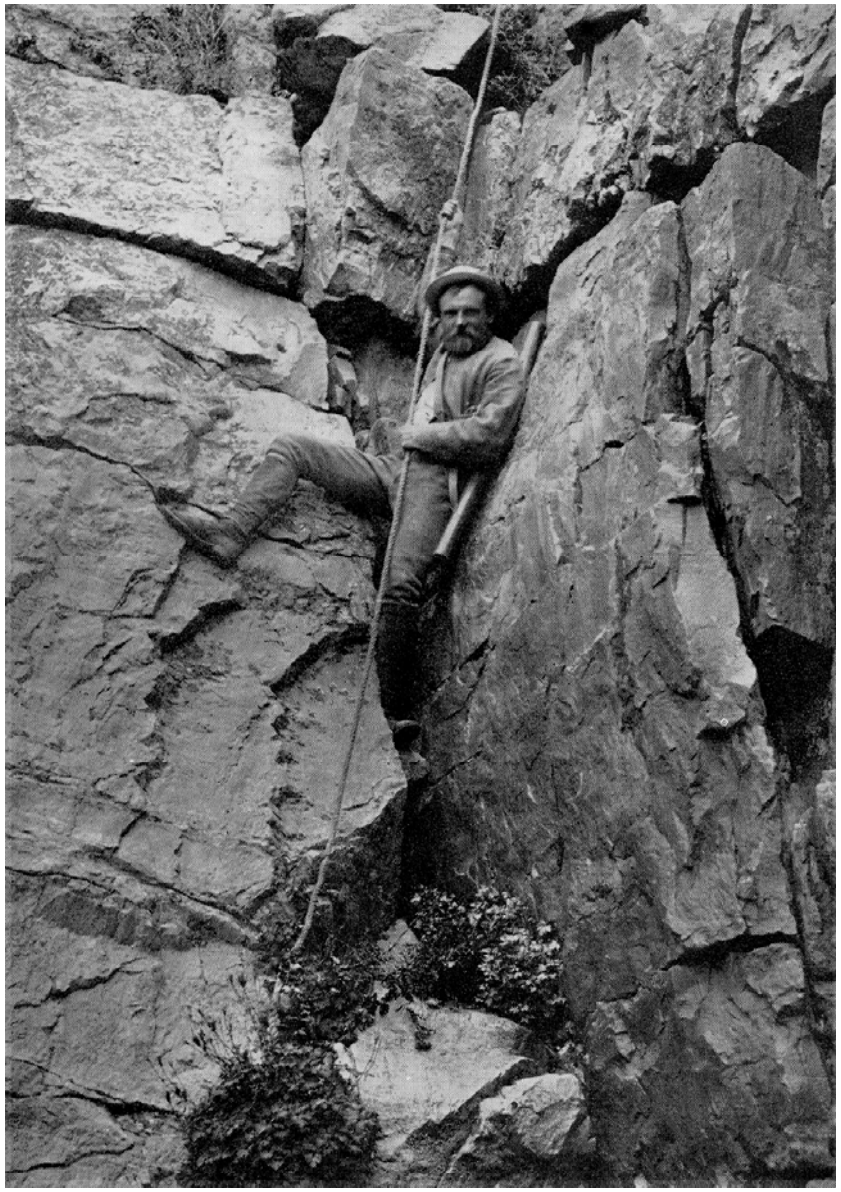
O. C. Marsh

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

J. T. Gregory

National Geographic, December 2005



Yale graduate Clarence King,leader of the 40th Parallel Survey and founder of the U.S. Geological Survey

Yale Mountaineering Club geologis•t rock climbi•ng at Ragged Mountain

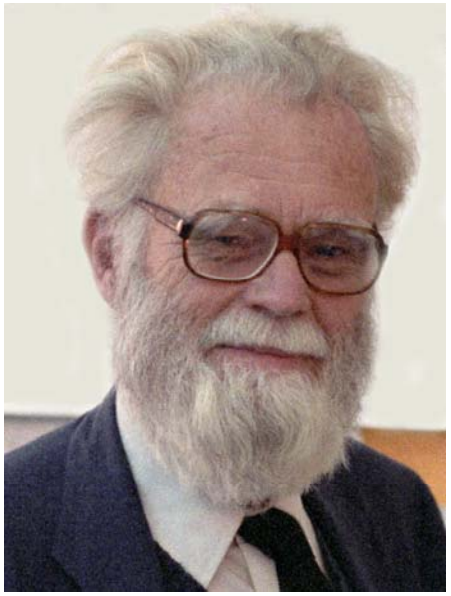
The “Rat’s Nest”

YALE GEOLOGY FACULTY (1955-1962)

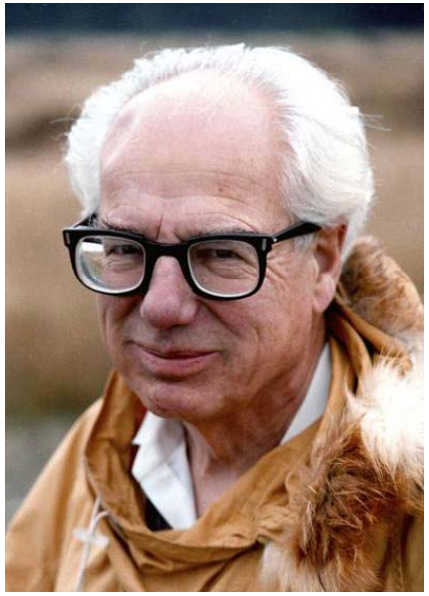
Chester Longwell & John Rodgers

Carl Dunbar & stratigraphy class at Katerskill Creek,NY

Dick Flint



John Rodgers



Link Washburn

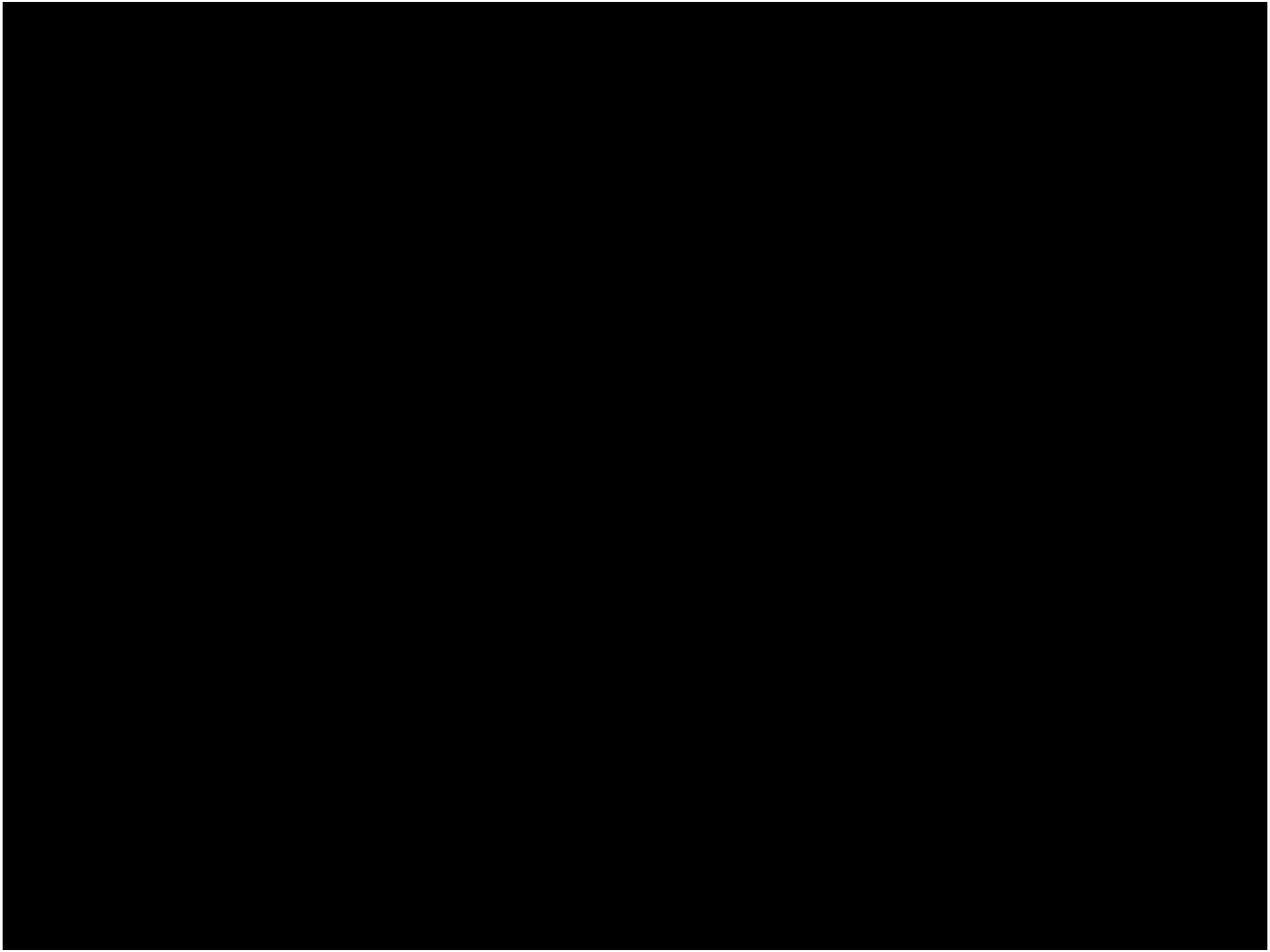
What we “knew” in the late 1950s:

- The Pleistocene began 1 million years ago
- There were 4 Pleistocene glaciations in North America and in Europe (5 in the Alps)
- Alpine glaciers fluctuated in phase and in relative magnitude with the large Pleistocene ice sheets
- The Croll-Milankovitch theory was considered inadequate to explain Pleistocene climatic changes

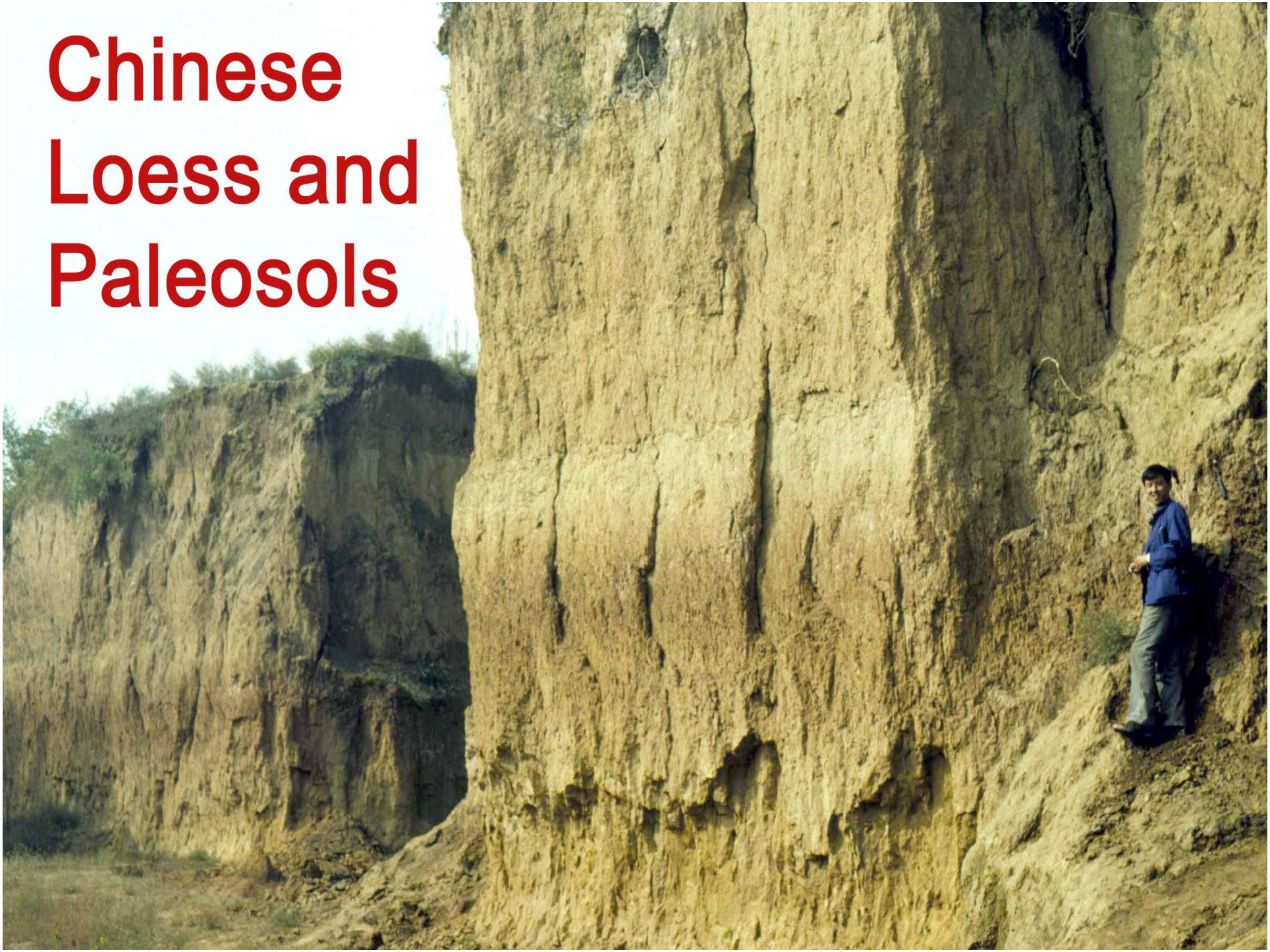
Some things we lacked or did not anticipate in the late 1950s:

- Plate tectonics
- Long ice- and marine-core paleoclimate time-series
- An array of advanced dating techniques:

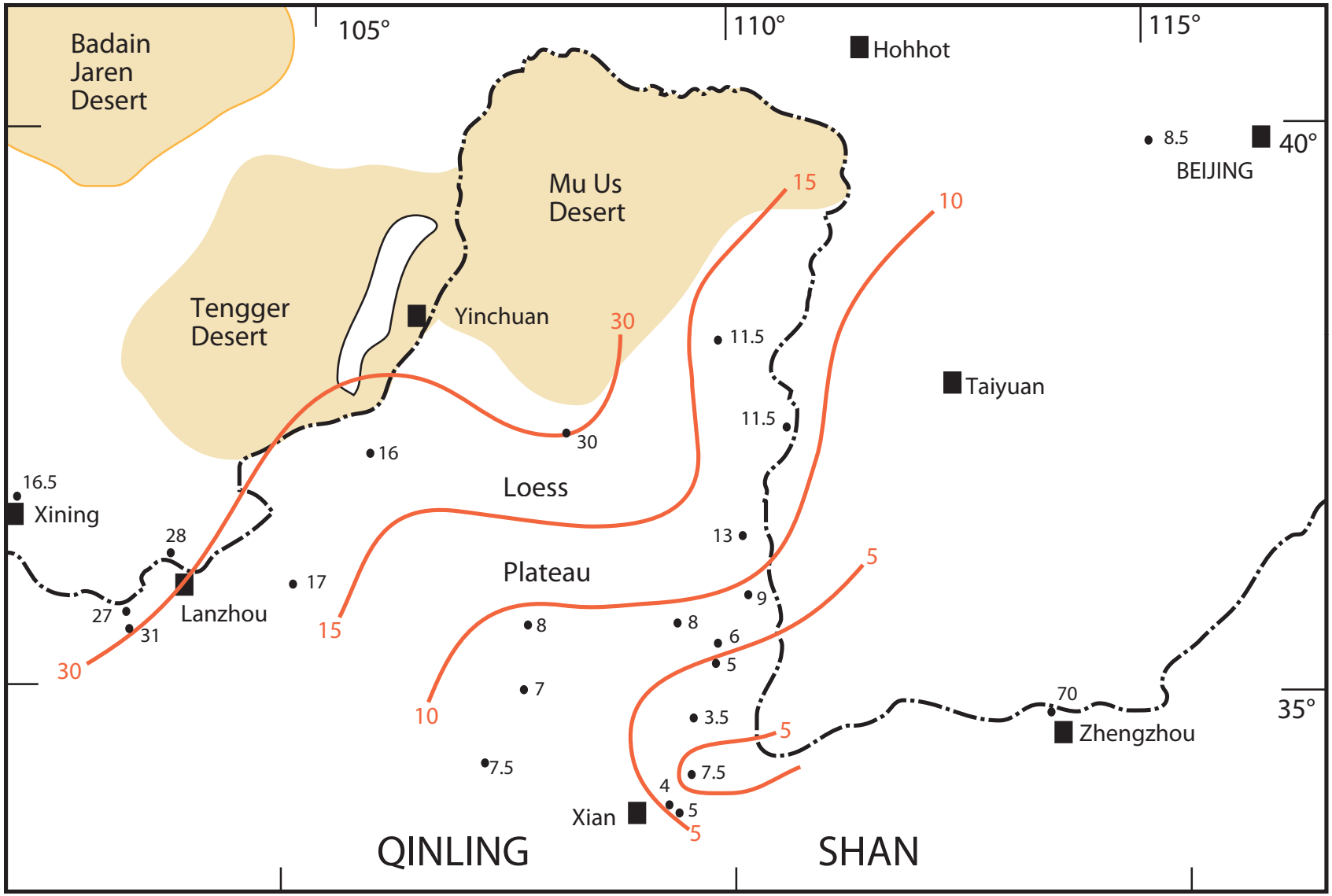
  AMS ^{14}C, magnetic-reversal chronology, K/Ar, ESR, OSL, fission-track, amino-acid, cosmogenic-isotopes (e.g.,^{10}Be, ^{36}Cl)
- High-speed desktop computers for glacier and climate modeling
- Affirmation of the Croll-Milankovitch theory

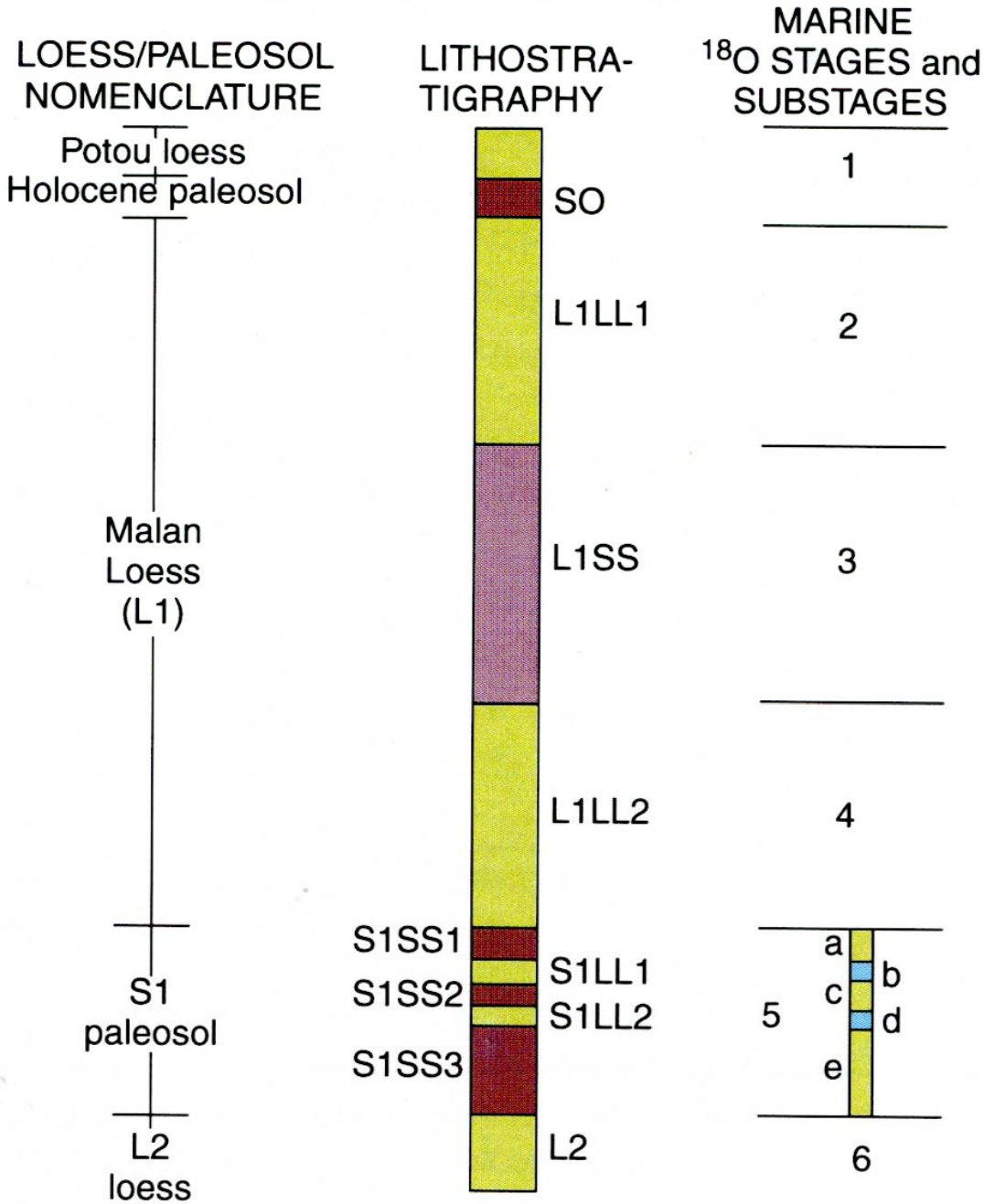


Chinese Loess and Paleosols



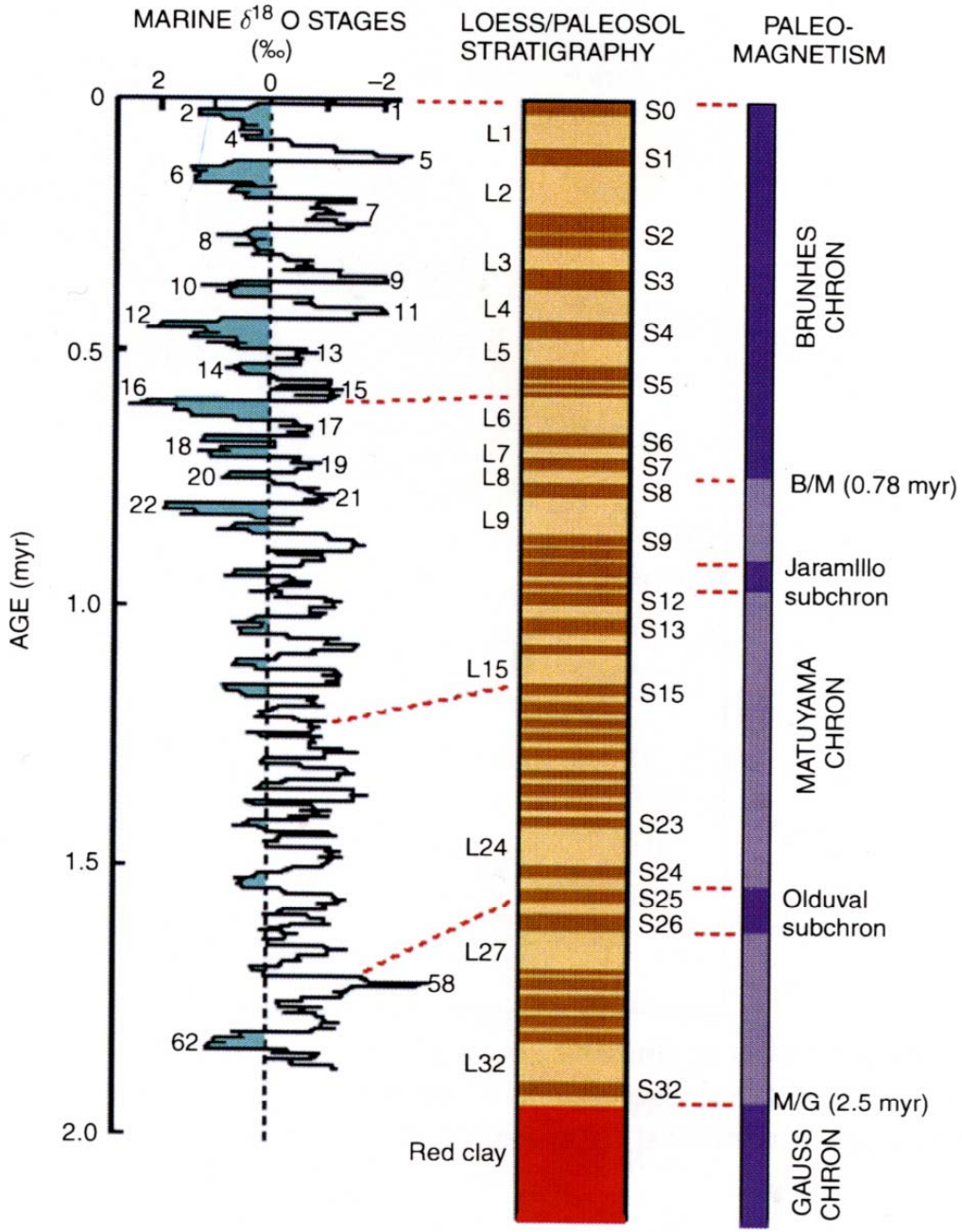
MALAN LOESS ISOPACHS (m)

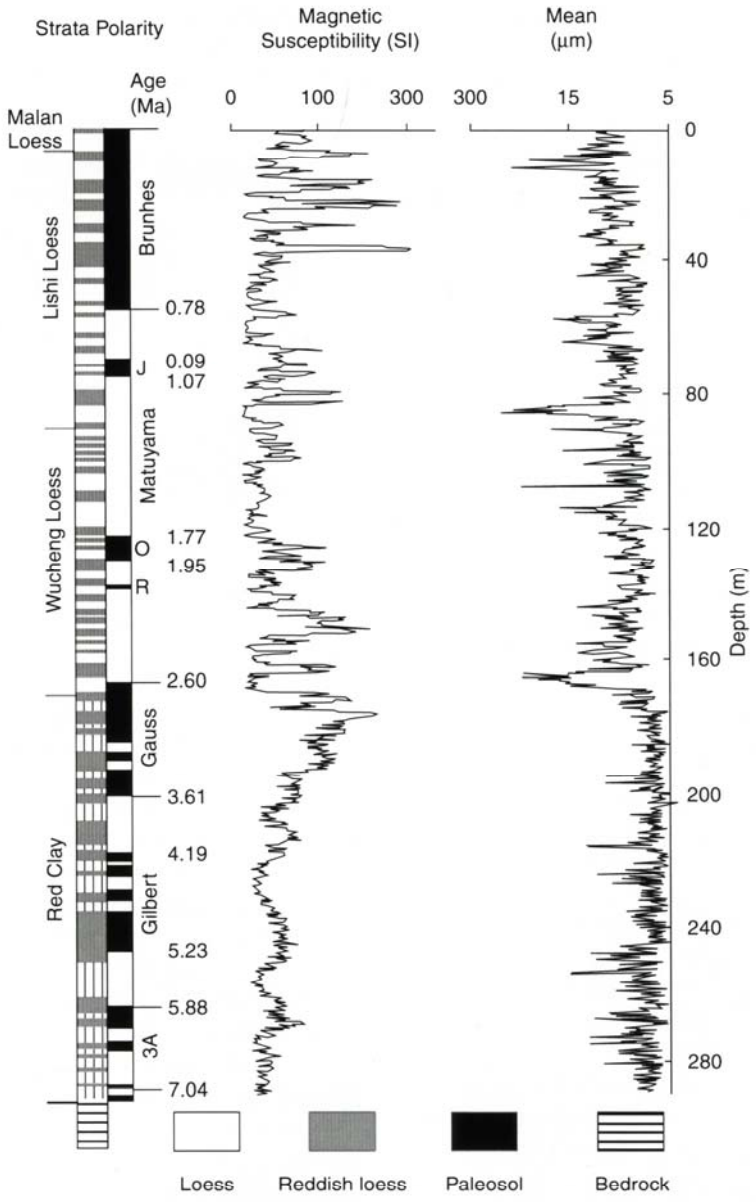



LOESS/PALEOSOL NOMENCLATURE
LITHOSTRA-TIGRAPHY
MARINE ^{18}O STAGES and SUBSTAGES
Potou loess
Holocene paleosol
Malan Loess (L1)
S1 paleosol
L2 loess
SO
L1LL1
L1SS
L1LL2
S1SS1
S1LL1
S1SS2
S1LL2
S1SS3
L2
1
2
3
4
5
a
b
c
d
e
6

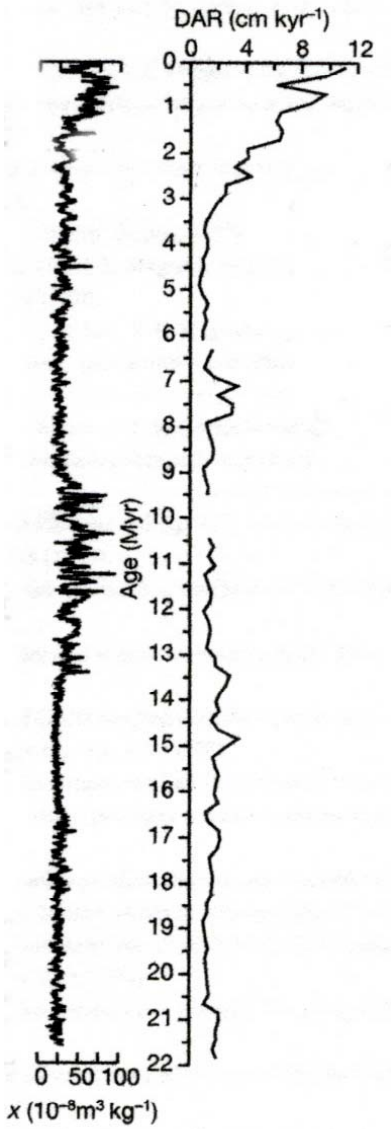

Loess
Terrace gravel
“Red Clay”


S1
L2 = MIS 6
S2
S3
S4
S5
S6
S7
S8
L9 = MIS 22


MARINE δ^{18} O STAGES
(‰)
2
0
–2
0
0.5
1.0
1.5
2.0
AGE (myr)
1
2
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
58
62
LOESS/PALEOSOL
STRATIGRAPHY
L1
L2
L3
L4
L5
L6
L7
L8
L9
L15
L24
L27
L32
Red clay
S0
S1
S2
S3
S4
S5
S6
S7
S8
S9
S12
S13
S15
S23
S24
S25
S26
S32
PALEO-
MAGNETISM
BRUNHES
CHRON
B/M (0.78 myr)
Jaramllo
subchron
MATUYAMA
CHRON
Olduval
subchron
M/G (2.5 myr)
GAUSS
CHRON

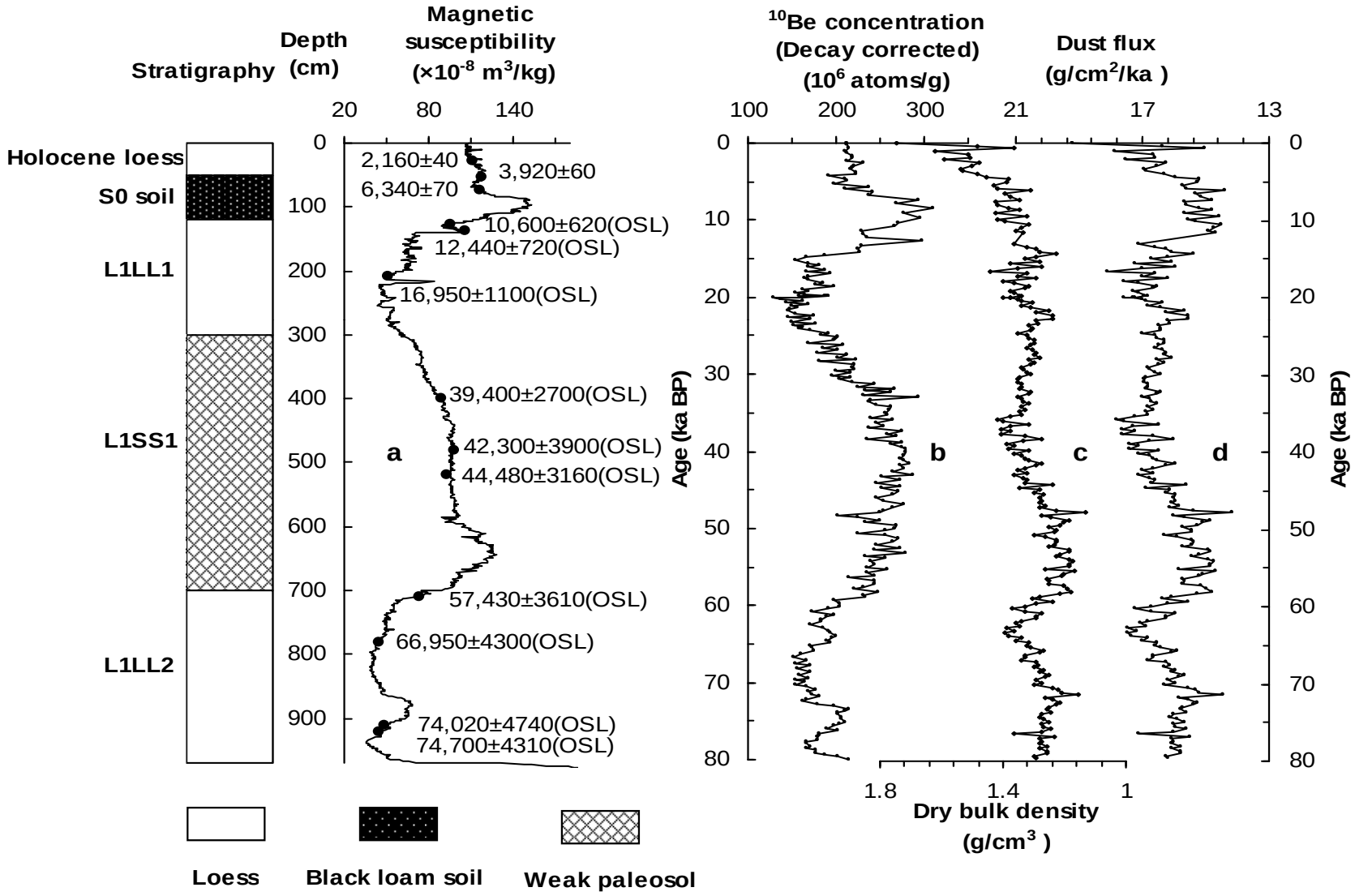


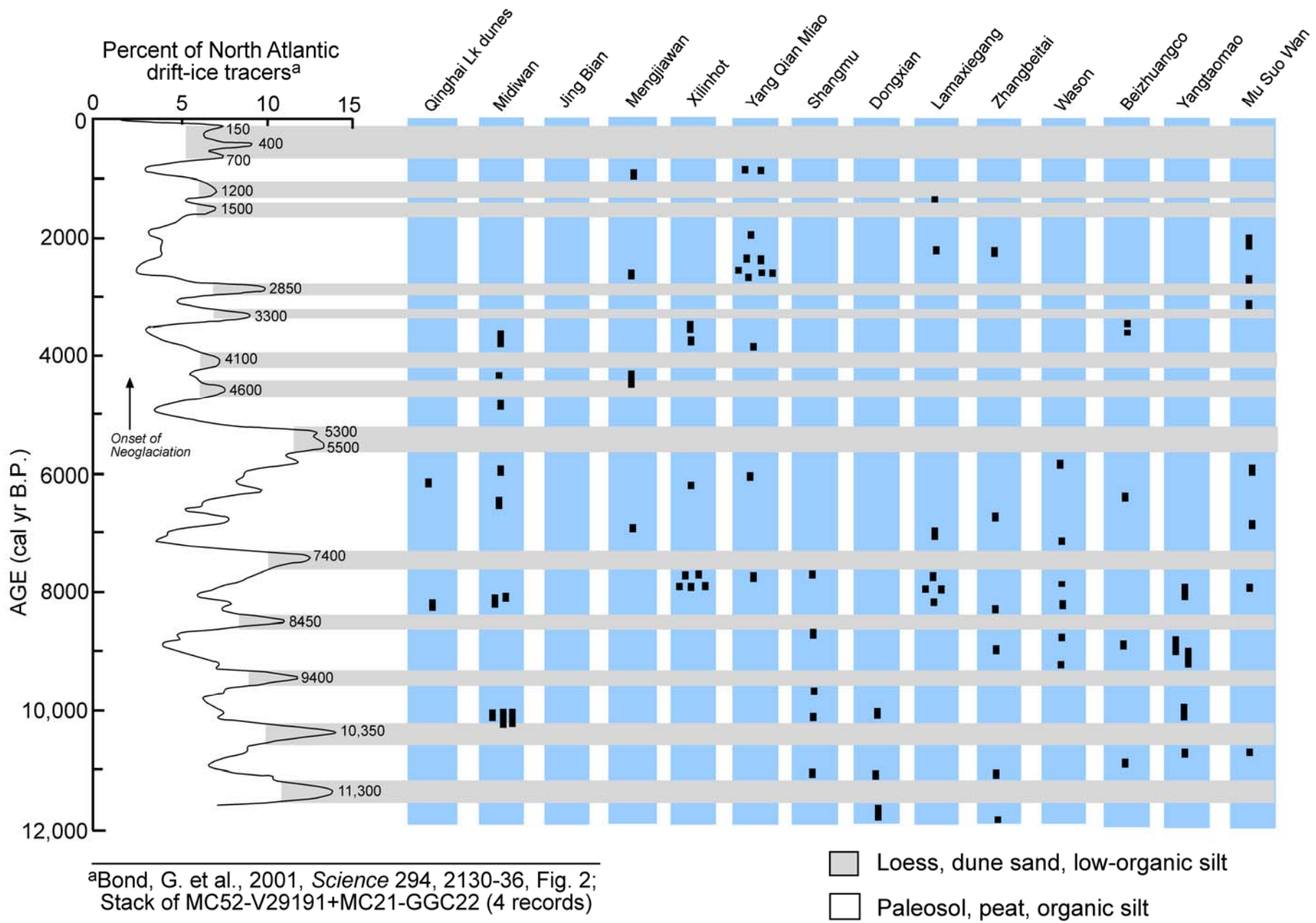
Lingtai, Shaanxi
(0-7 myr)



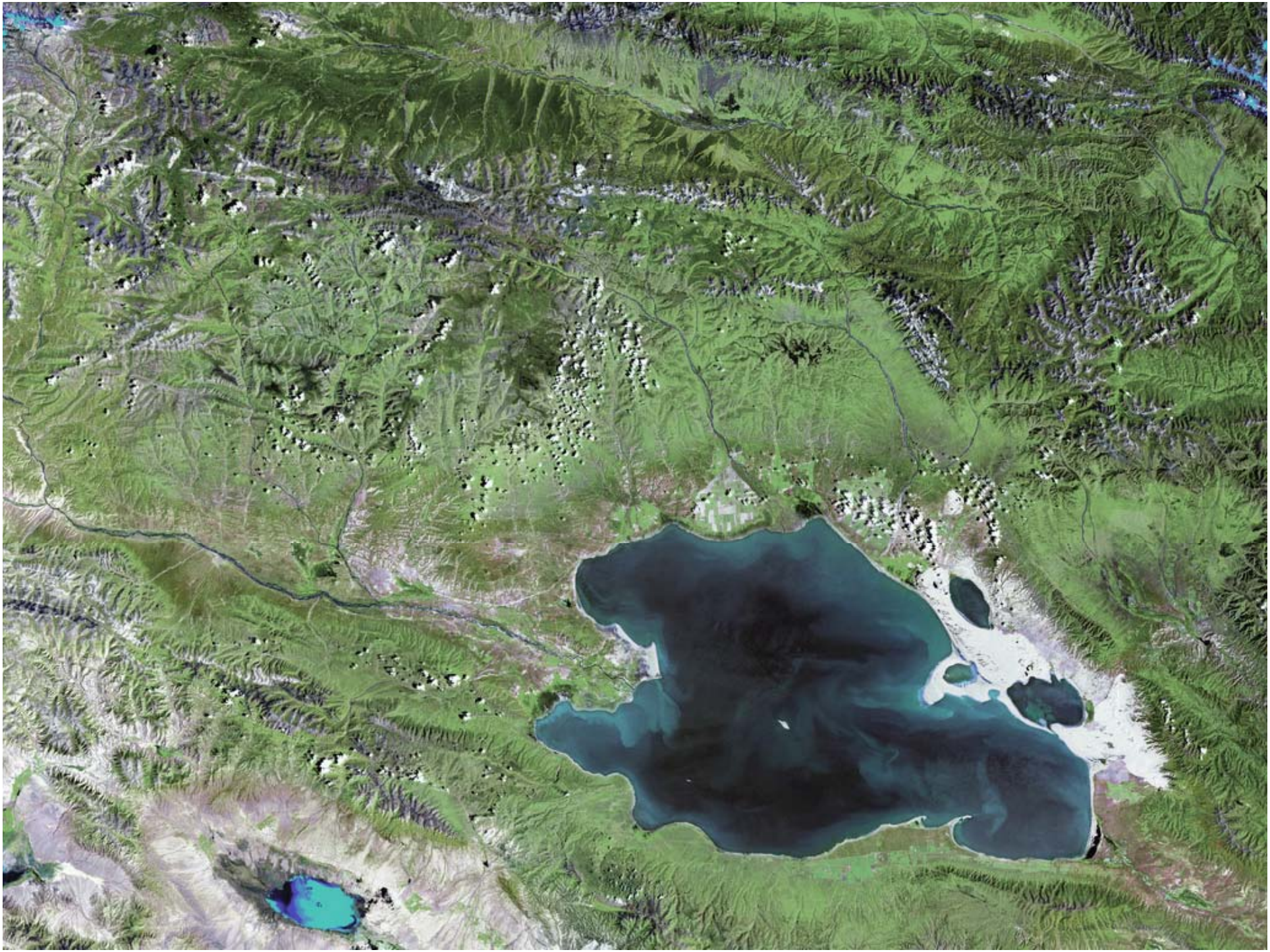
Qinan, Gansu
(0-22 myr)

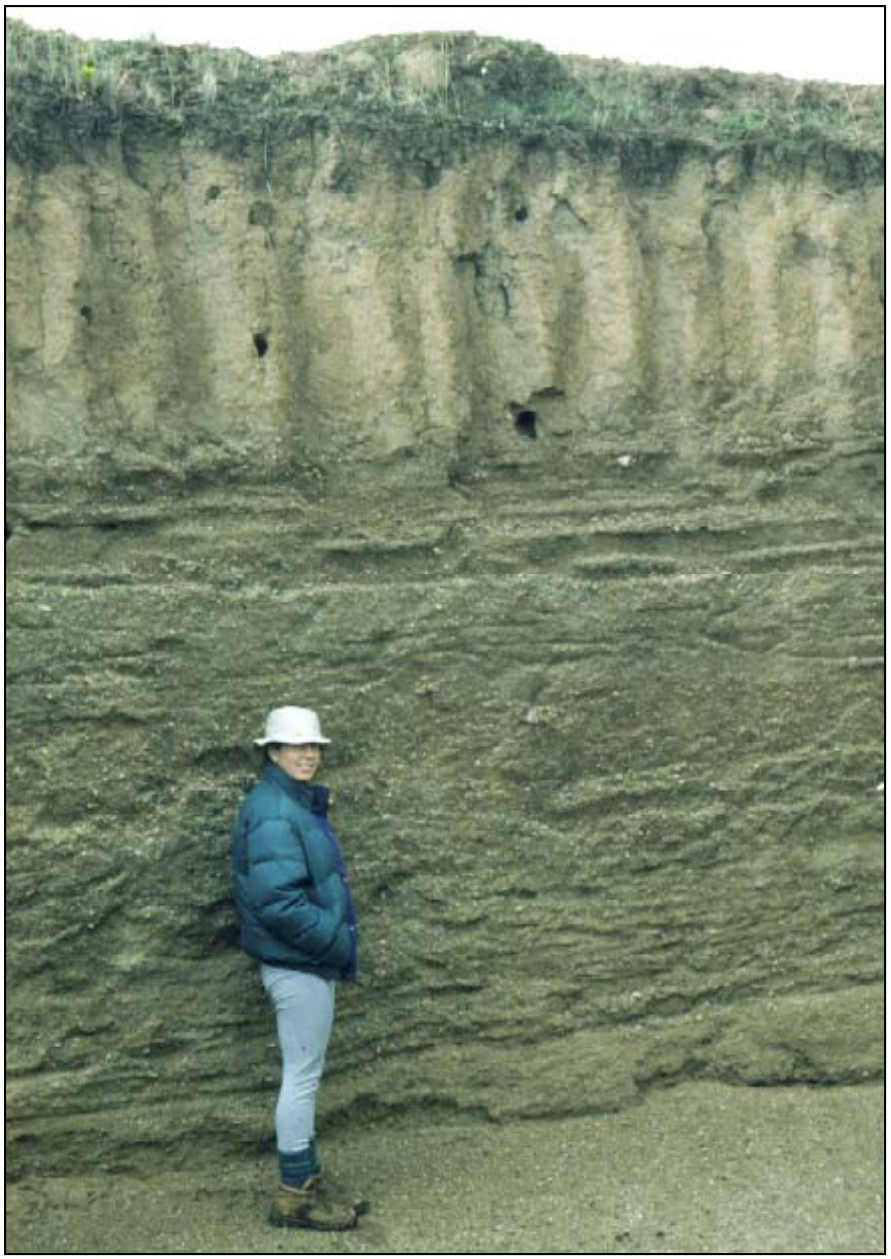
Loess magnetic and ^{10}Be stratigraphy at Luochuan





[a]Bond, G. et al., 2001, *Science* 294, 2130-36, Fig. 2; Stack of MC52-V29191+MC21-GGC22 (4 records)





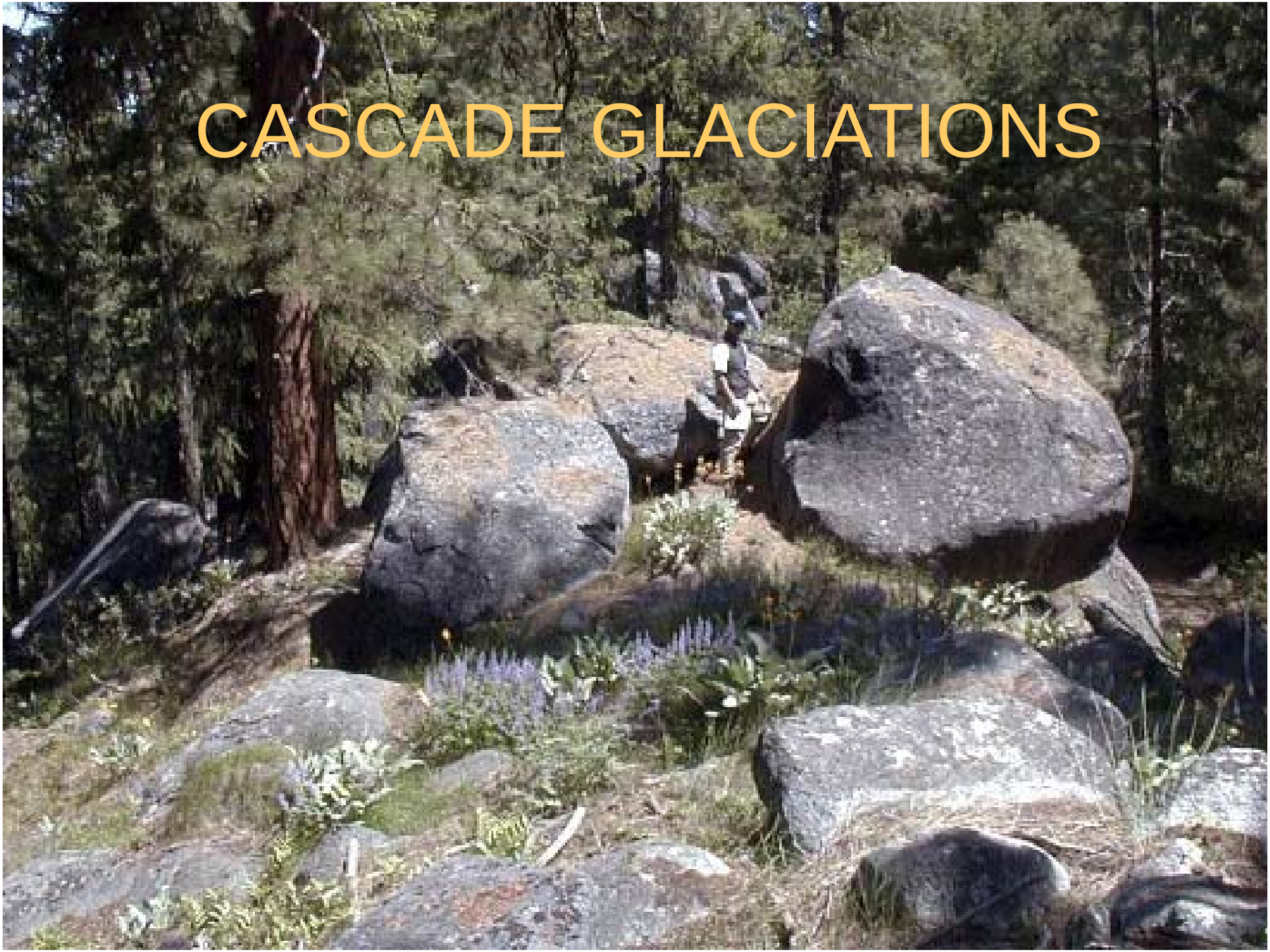
Postglacial loess (15-5 ka)

Disconformity & discontinuous paleosol (MIS 2) (~30-15 ka)

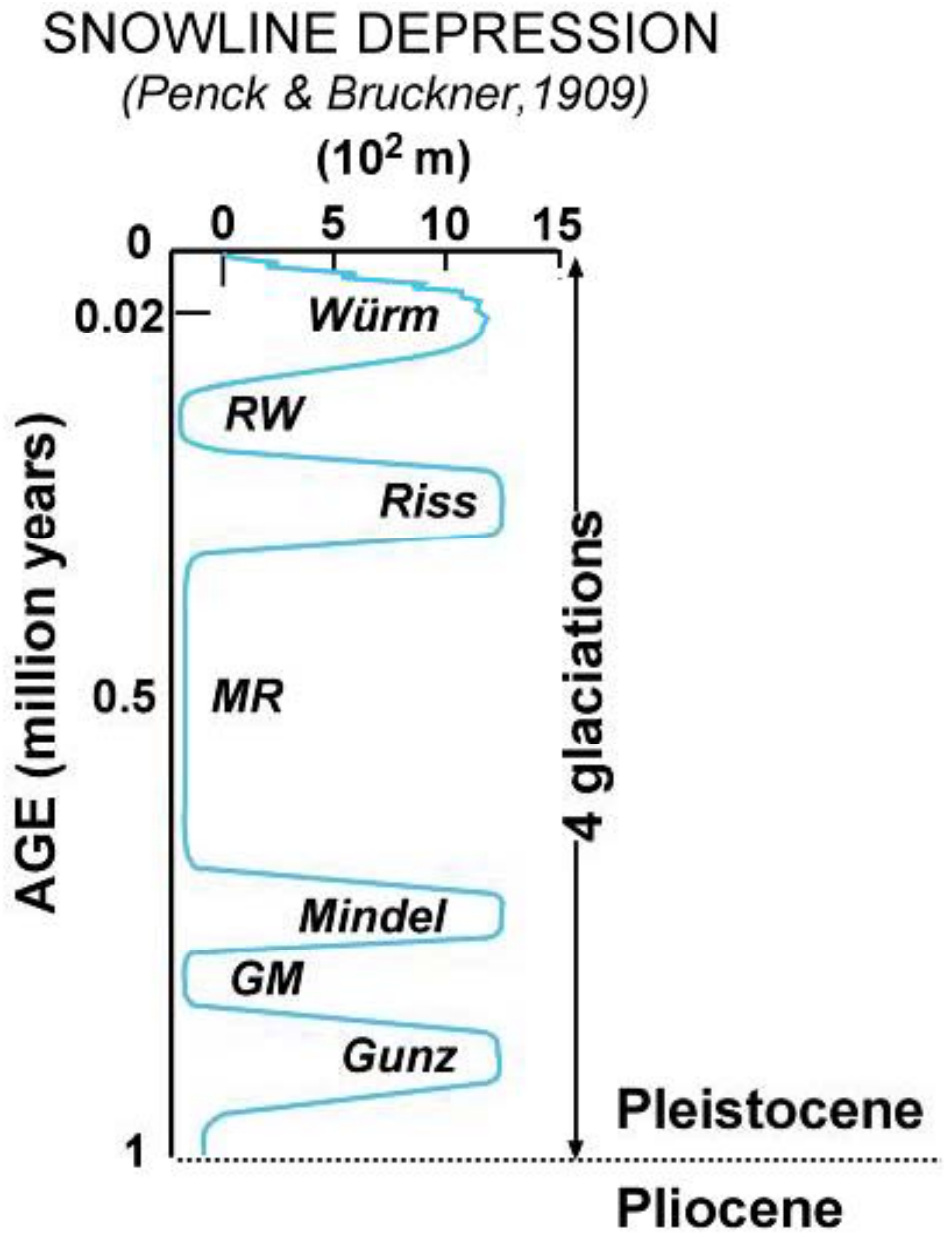
MIS 3 alluvium (45-30 ka)

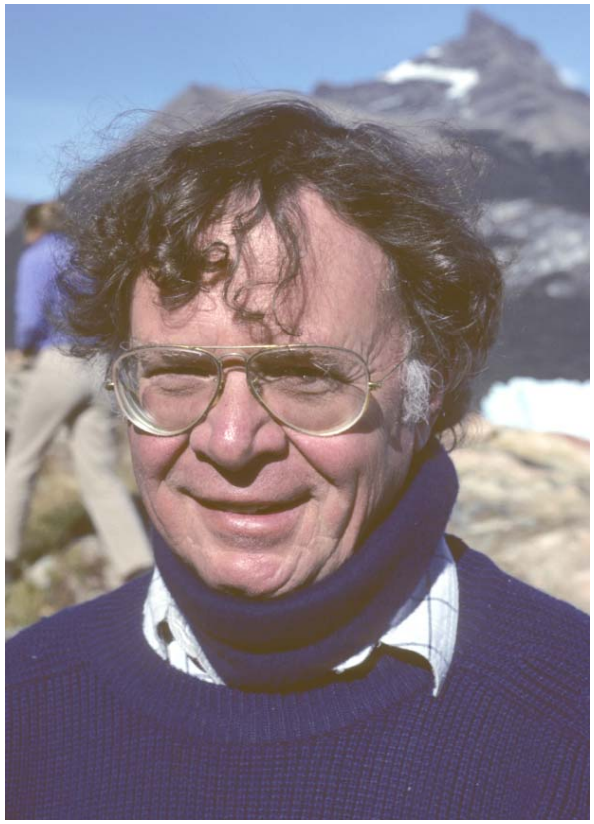
POSTGLACIAL LOESS ABOVE MAJOR DISCONFORMITY, NEAR QINGHAI LAKE

CASCADE GLACIATIONS



Albrecht Penck

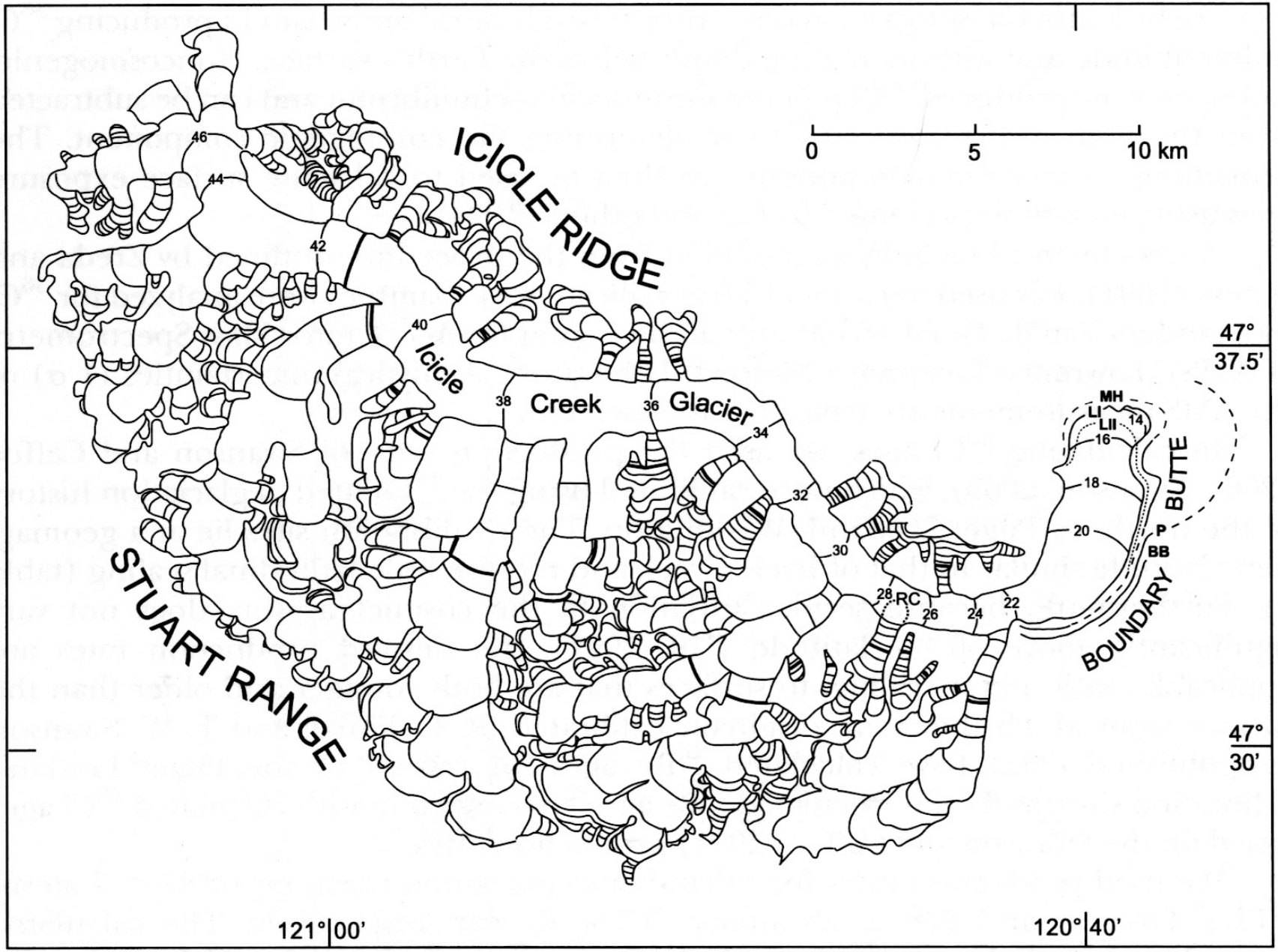


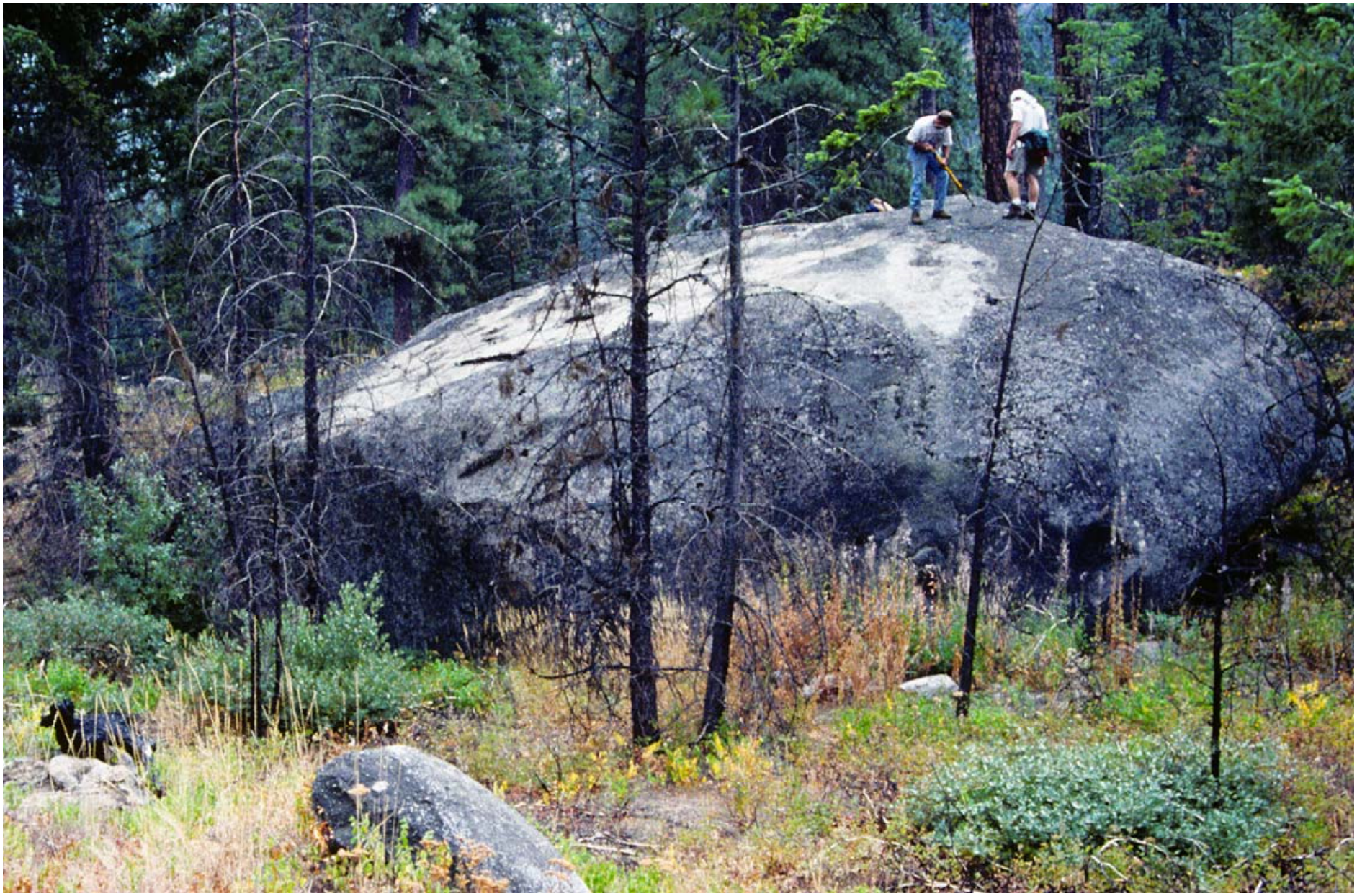


In 1965 Wally Broecker prophetically stated that

“The Cl^{36} method offers one of the few hopes for establishing the ages of mountain glaciation.”

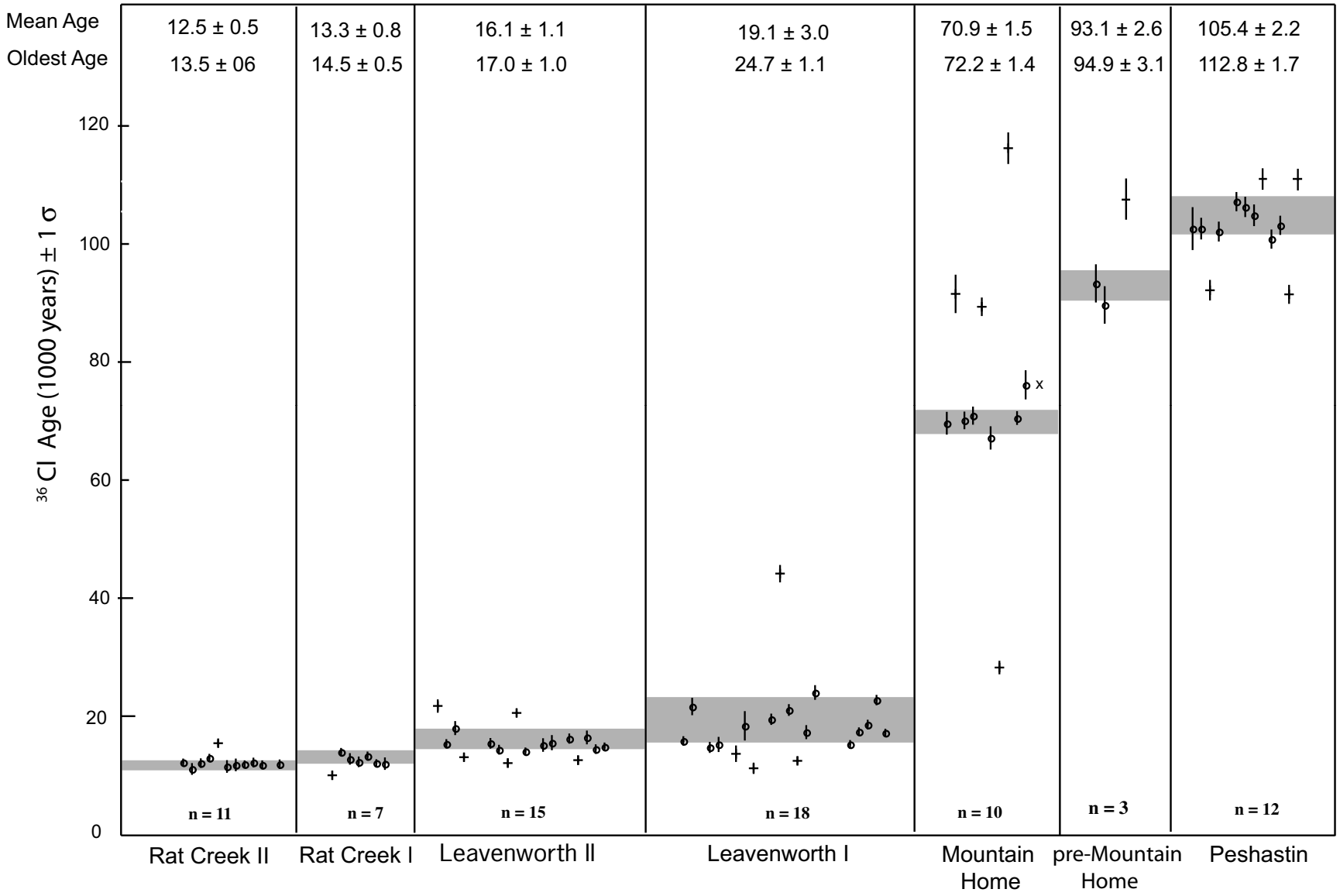
In Wright, H. E., Jr. and Frey, D. G., The Quaternary of the United States Princeton University Press, p. 740.


ICICLE RIDGE
STUART RANGE
Icicle
Creek
Glacier
BUTTE
BOUNDARY
MH
LI
LII
RC
P
BB
0
5
10 km
47°
37.5'
47°
30'
121°
00'
120°
40'
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14

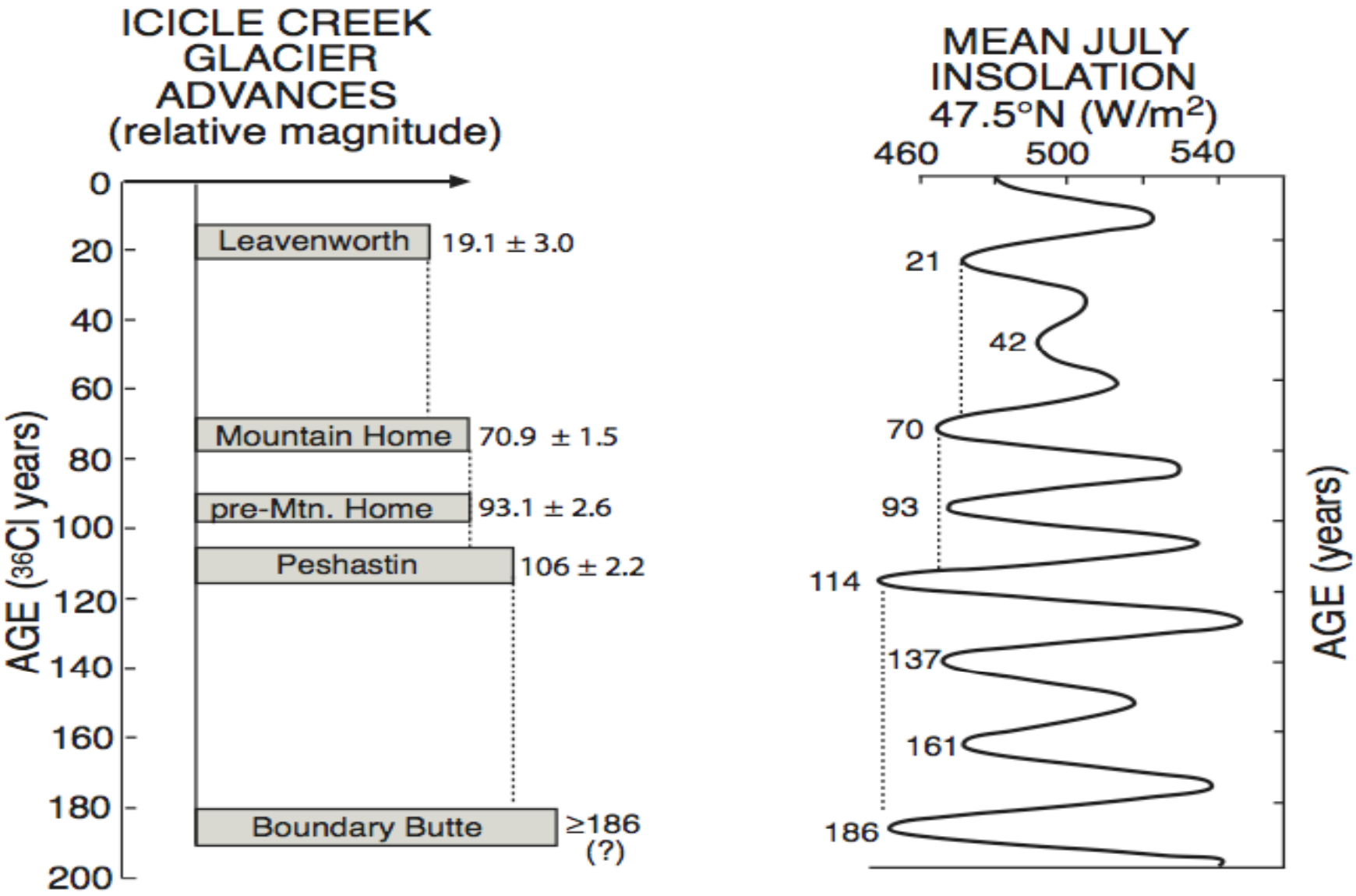


Cosmogenic Isotopes

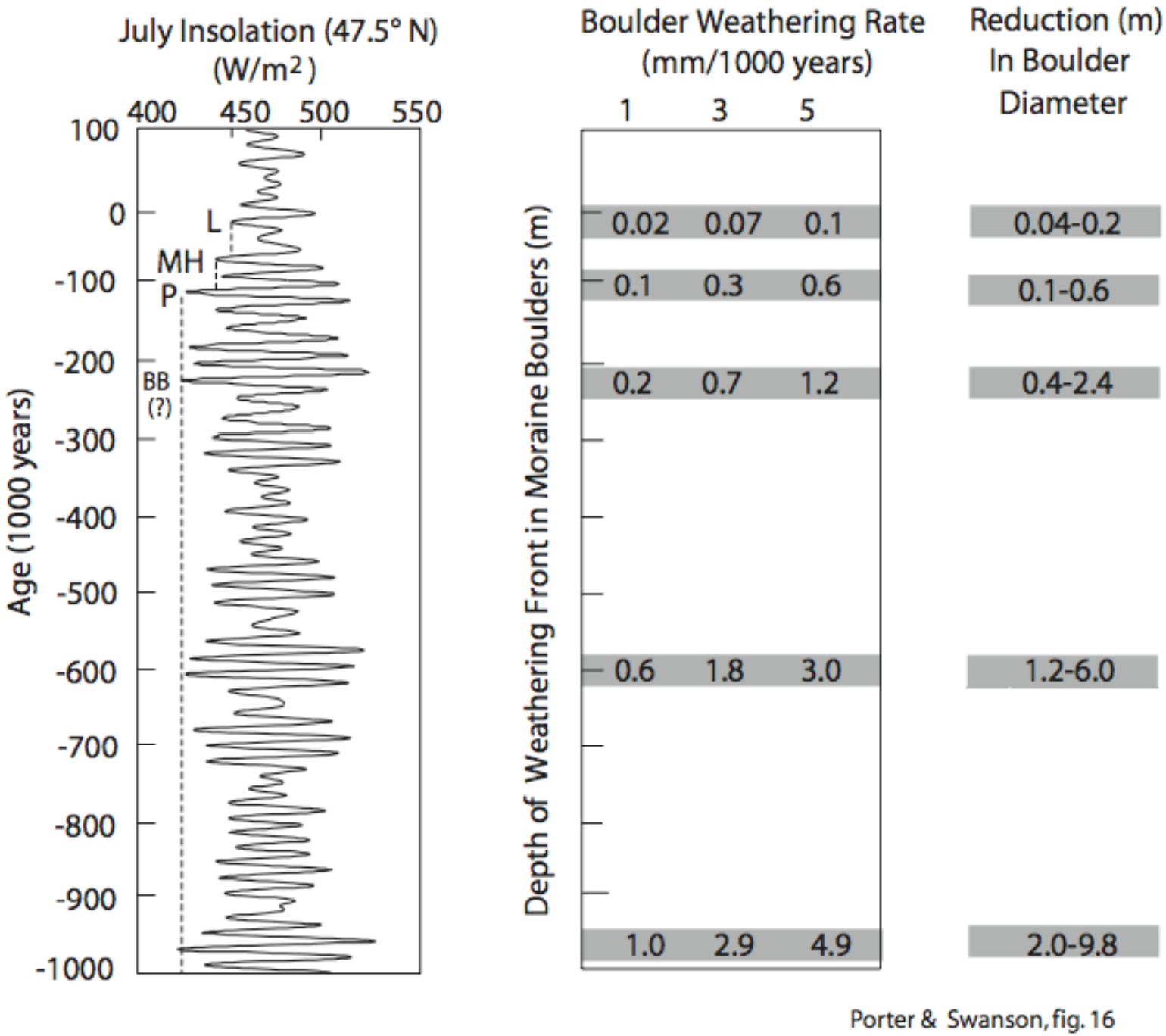
Rat Creek II boulder
12,700 ± 600 ^{36}Cl yr



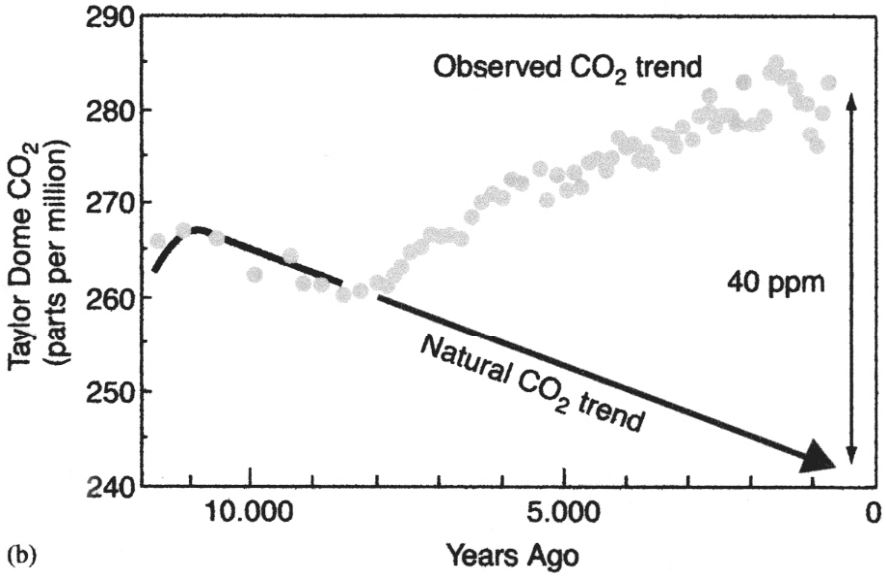
Porter and Swanson, figure 14

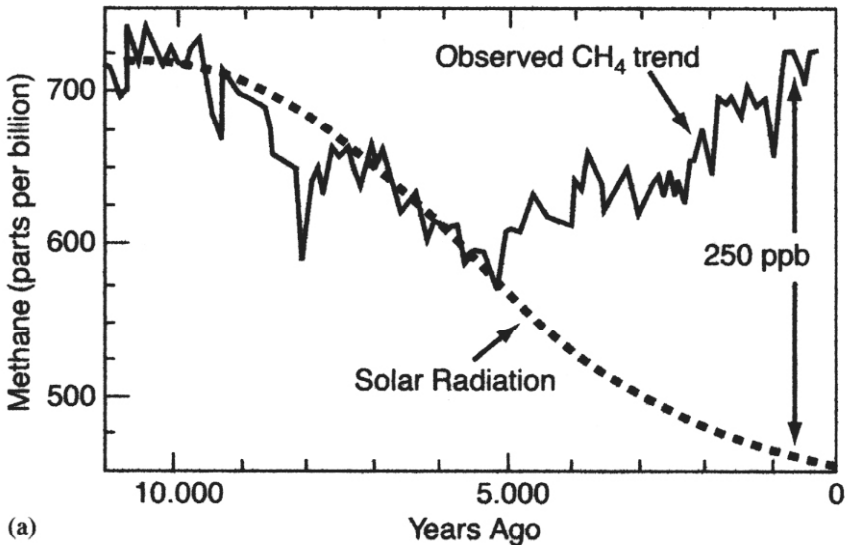


Porter, S. C. and Swanson, T. W., 2008, A J S



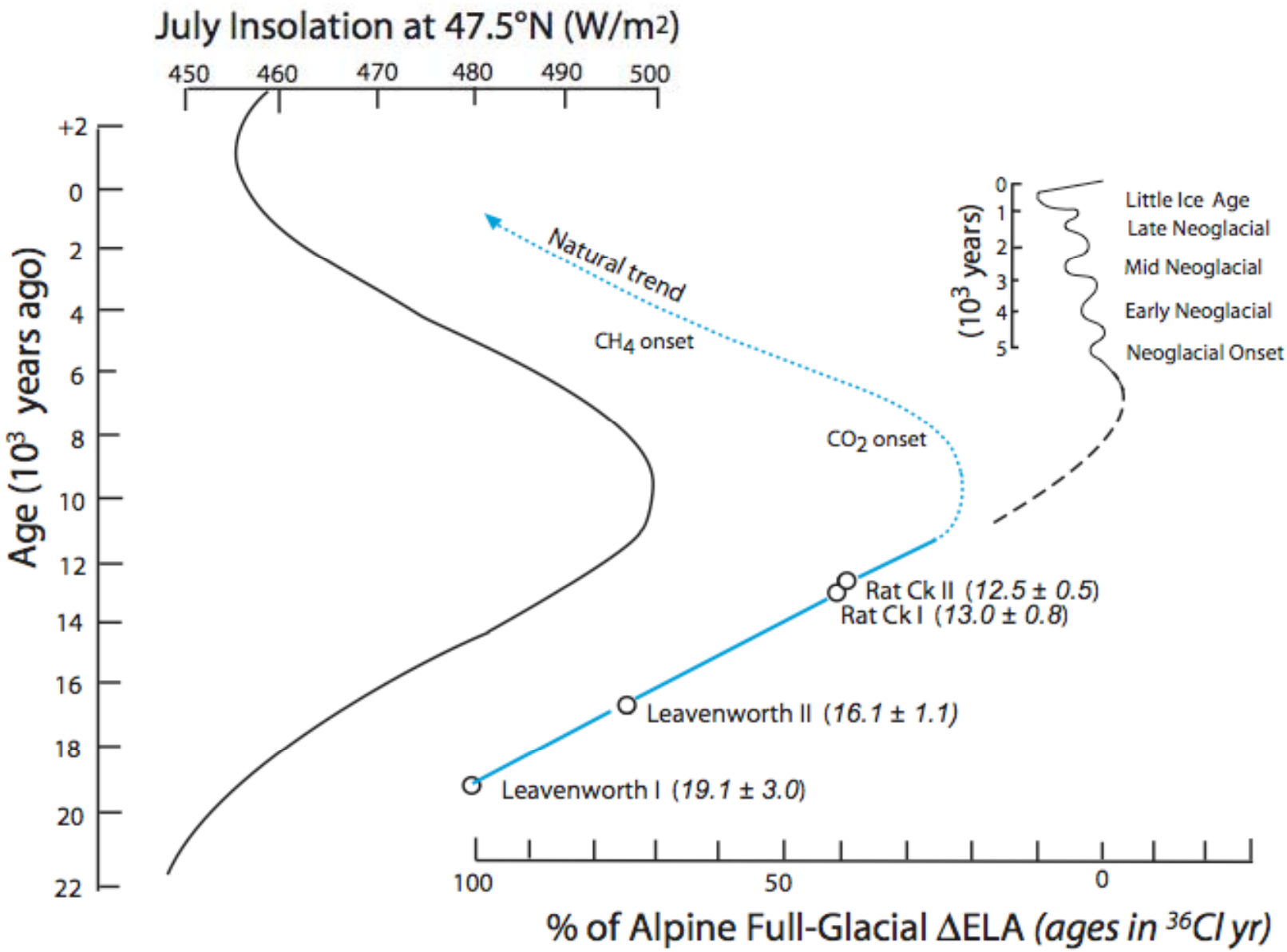
Porter & Swanson, fig. 16





"Without any anthropogenic warming, Earth's climate would no longer be in a full interglacial state but well on its way toward the colder temperatures typical of glaciations".

Ruddiman, W. F. et al. (2005),QSR 24, Fig. 1)


July Insolation at 47.5°N (W/m2)
450
460
470
480
490
500
Age (10³ years ago)
+2
0
2
4
6
8
10
12
14
16
18
20
22
Natural trend
CH4 onset
CO2 onset
(10³ years)
0
1
2
3
4
5
Little Ice Age
Late Neoglacial
Mid Neoglacial
Early Neoglacial
Neoglacial Onset
Rat Ck II (12.5 ± 0.5)
Rat Ck I (13.0 ± 0.8)
Leavenworth II (16.1 ± 1.1)
Leavenworth I (19.1 ± 3.0)
100
50
0
% of Alpine Full-Glacial ΔELA (ages in ³⁶Cl yr)