LATE PALEOZOIC ICE AGE (LPIA)

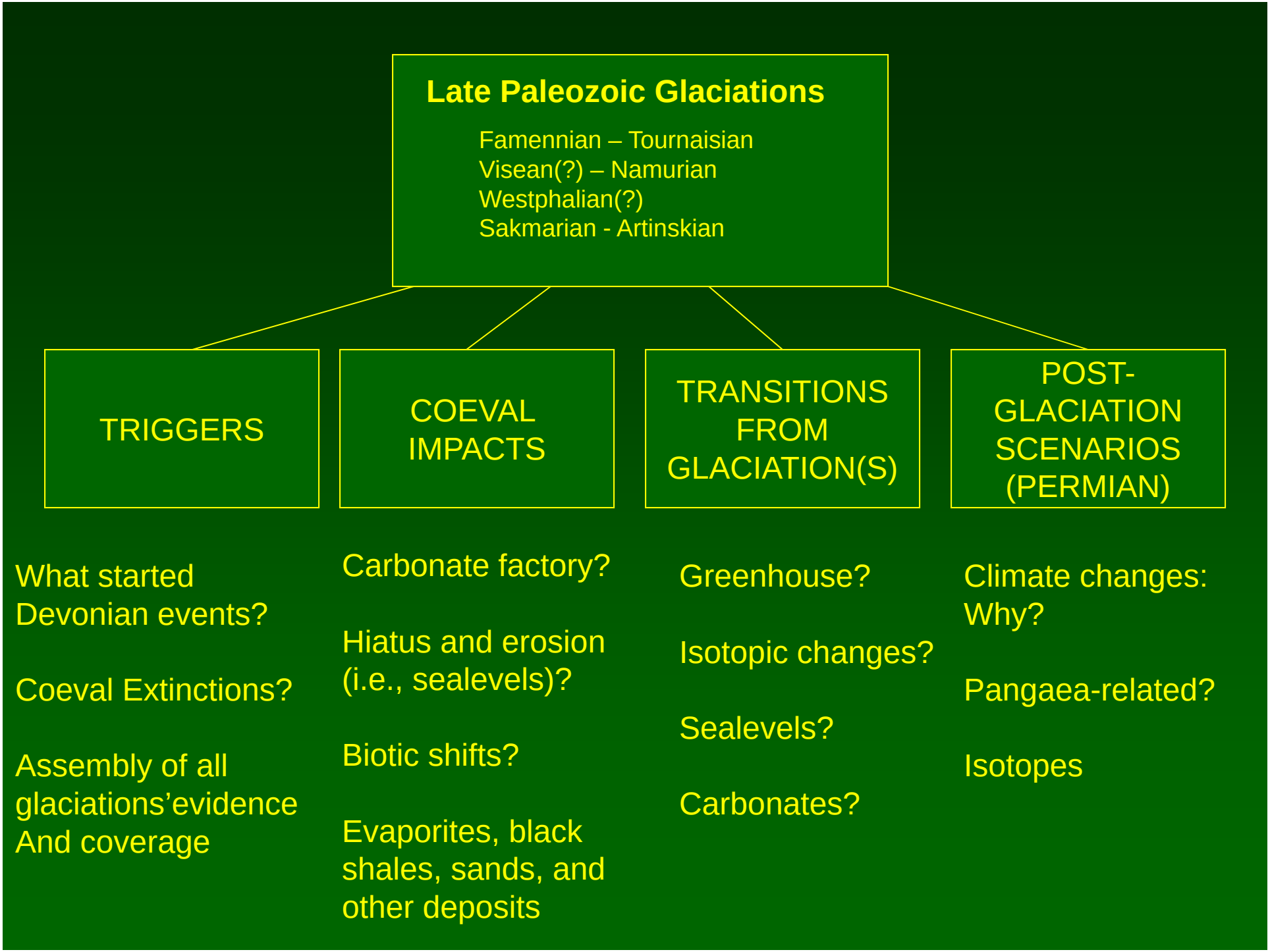
Gondwana glaciations and their proxies in the US Cordillera

LPIA

1. When were the glaciations?
1. What are glacial “deposits?”
3. Were the glaciations episodic?
3. How extensive (areally) were the glaciations?
4. How do we date the glaciations?

Proxy beds

1. Sappington Fm., Montana - Devonian/Carboniferous boundary, biostratigraphy and sequences
2. Foreland, Idaho – Late Mississippian, distinguishing tectonic from eustatic events
3. Copacabana Formation, Bolivia – Pennsylvanian records of glacigenic dust


Late Paleozoic Glaciations
Famennian – Tournaisian
Visean(?) – Namurian
Westphalian(?)
Sakmarian - Artinskian
TRIGGERS
COEVAL IMPACTS
TRANSITIONS FROM GLACIATION(S)
POST-GLACIATION SCENARIOS (PERMIAN)
What started Devonian events?
Coeval Extinctions?
Assembly of all glaciations'evidence And coverage
Carbonate factory?
Hiatus and erosion (i.e., sealevels)?
Biotic shifts?
Evaporites, black shales, sands, and other deposits
Greenhouse?
Isotopic changes?
Sealevels?
Carbonates?
Climate changes: Why?
Pangaea-related?
Isotopes

TRIGGER?
Late Devonian CO_2 drop

- Orogenies add nutrients to marine ecosystem
- Plants reduce carbon dioxide and enhance weathering (= more nutrients)
- Seas become hyperproductive
- Eutrophication (e.g., Woodford, Bakken shales)

A PARADIGM CHANGE:
Late Devonian onset of Gondwana glaciation and its proxies

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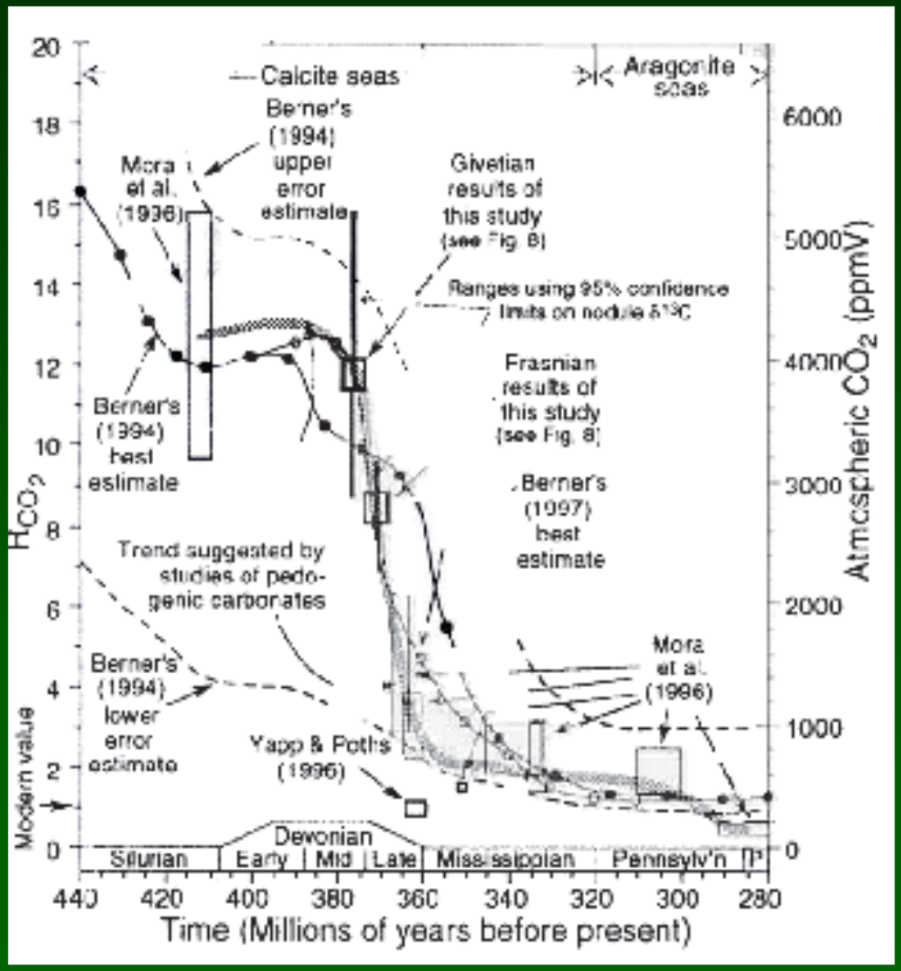
Late Devonian carbon dioxide drop



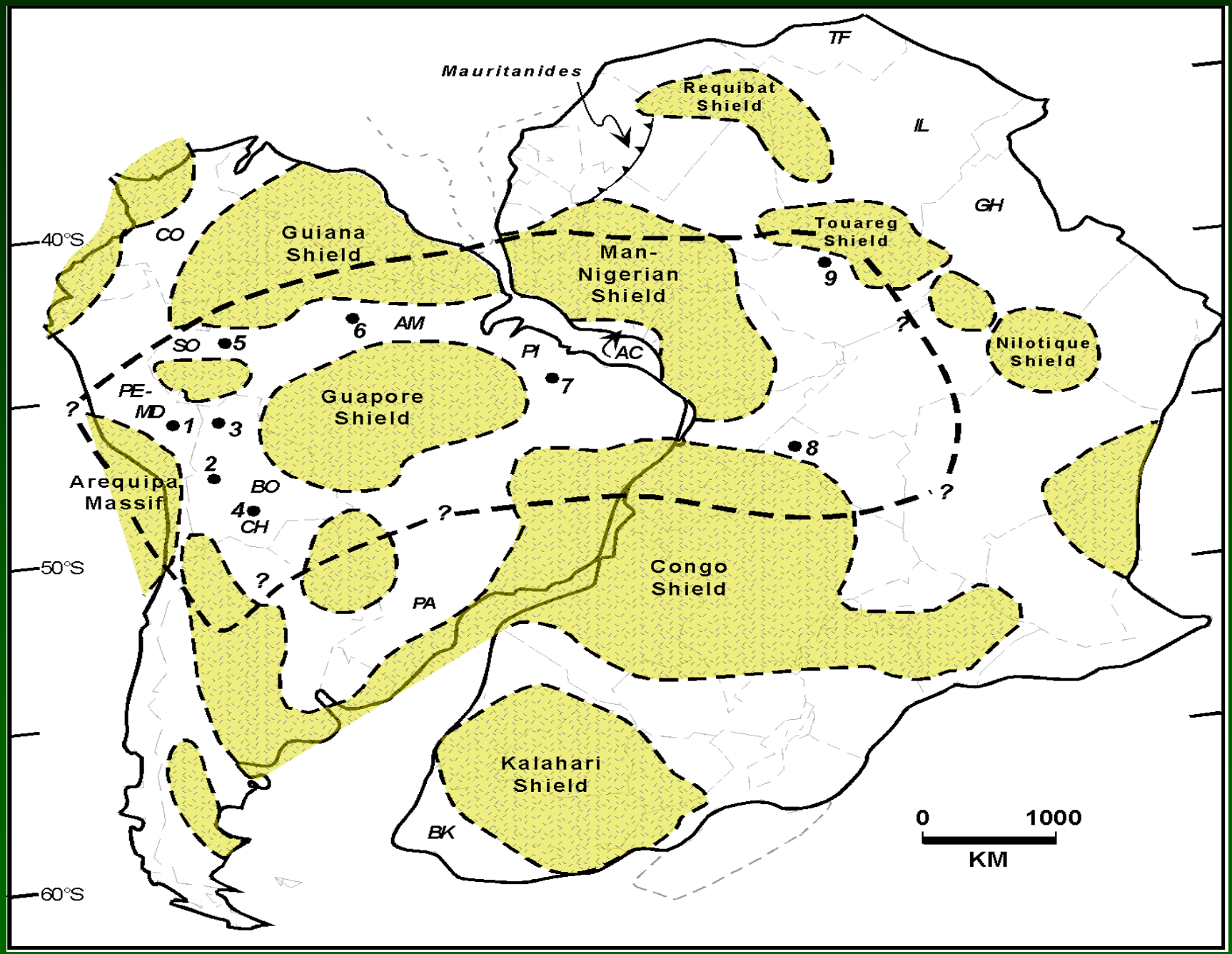
Cox et al., 2001

Gondwana Glaciation

- Brasil is possible center (Parnaíba, Amazonas, Solimöes basins – more?)
- Andes: Bolivia, Perú, probably Argentina
- Africa: Central African Republic, Niger, South Africa?
- Laurentia

Parnaíba Basin Devonian pavement
Courtesy of M. Caputo

Glacial clasts:
Cumaná Fm., Bolivia


Mauritanides
TF
Requibat Shield
IL
GH
Touareg Shield
Guiana Shield
Man-Nigerian Shield
Nilotique Shield
CO
40°S
SO
5
6
AM
AC
PI
7
9
PE-MD
1
3
2
Arequipa Massif
BO
4
CH
8
Guapore Shield
Congo Shield
50°S
PA
Kalahari Shield
BK
60°S
0
1000
KM

Ice Volume

- Glaciated area = 1.6 x 10^6 km^2 minimum
- With South Africa, northern Argentina, and more of Arequipa, area increases
- Thickness was variable; average = 500 m?
- The Devonian event, therefore, could significantly lower sea levels (50 m, minumum?) in 4^{th} and 5^{th} order cycles… beyond biostratigraphic ordering

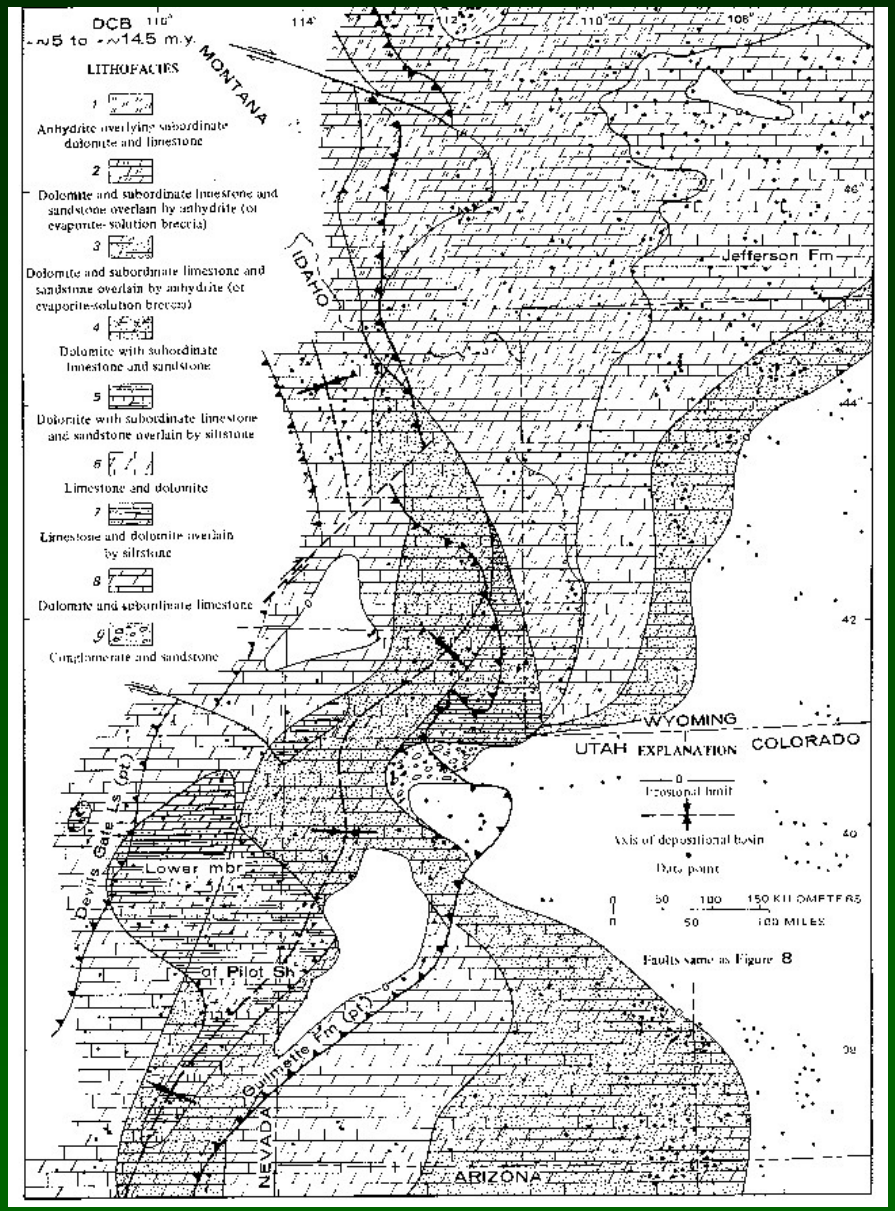
Coeval Events = Collateral Damage?

- Worldwide high TOC values in glacial beds, European carbonates, Appalachian black shales, western interior carbonates (eutrophication?)
- Craton sand invading western U.S.A.
- Megabreccias (Idaho and Montana, U.S.A.)
- Evaporites (Montana, U.S.A.)
- Iron oolites (Libya)
- Hiatuses (Western Canada and U.S.A.)

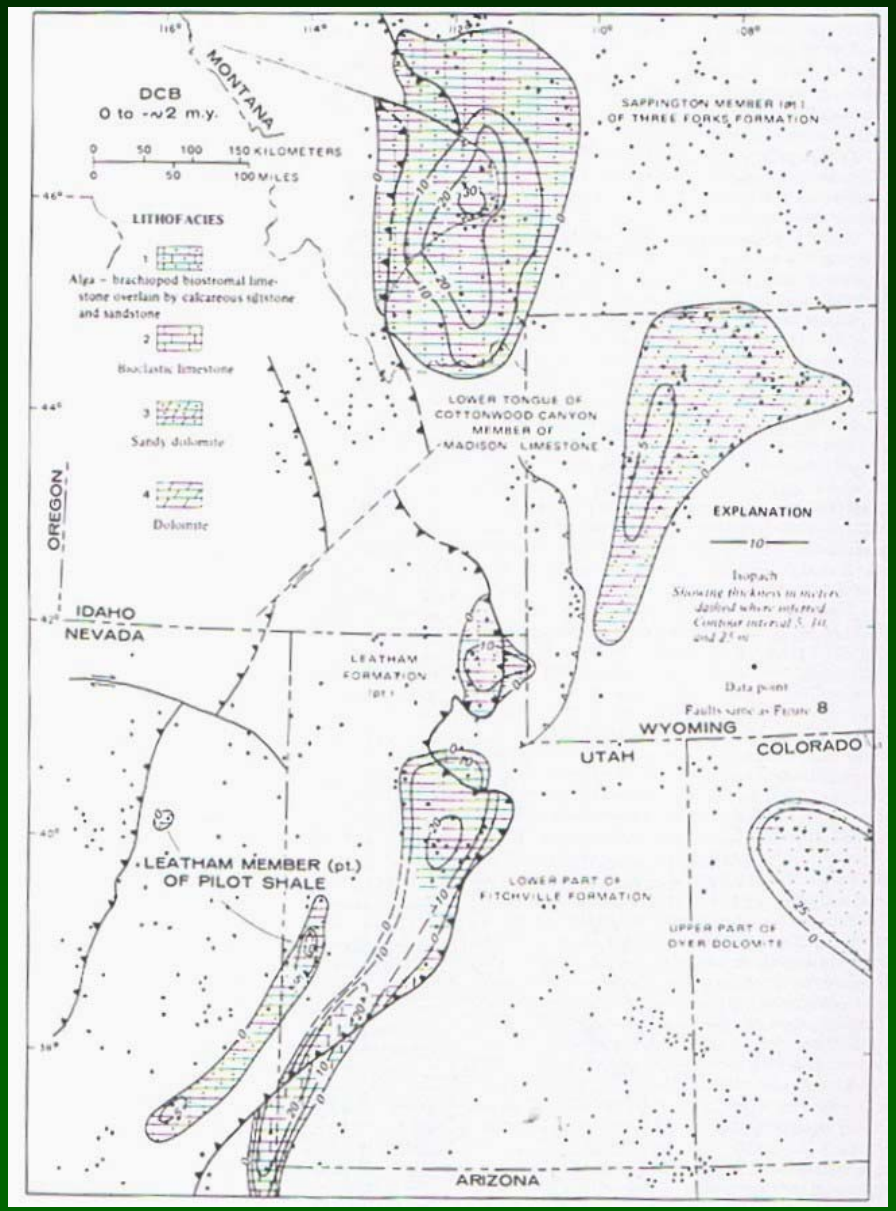
TABLE II

Late Devonian (Famennian) geologic phenomena responding to glacially-induced sealevel drawdown

Parameter	Locations	Depositional Settings	References
Breccias, Karst	Nevada(?), Idaho, Montana Moravia, Czech Republic Xiangzhou, South China	Phreatic zone weathering of Frasnian-age carbonate banks, Subaerial exposure	Mylroie and Carew (1995) Grader (1998) Blount (1986), M'Gonigle (1986) Kalvoda and Kukal (1987)
Craton sand	Bierdneau Fm., Idaho Jefferson Fm., Idaho	Subaerial exposure	Beus (1968), Grader (1998) Isaacson et al. (1999)
Black Shales, organic enrichment	Chattanooga Shale, U.S.A. Ohio Shale, U.S.A. Exshaw Shale, W. Canada Cumaná Fm., Bolivia	Ocean basin restriction and eutrophication, causing hyperproductivity and abundant phytoplankton deposition	Peterson (1993) Peters et al.(1996)
Evaporites	Wabamum Group, Canada Three Forks Shale, Montana Dneiper-Donetz Basin, Belorus	Ocean basin restriction	Halbertsma (1994) Sandberg (1963) Avkhimovich and Demidenko (1985)
Lacunae	Three Forks Shale, Idaho-Montana Pilot Shale, Nevada Canada	Periodic subaerial exposure	Sandberg et al. (1983) Giles and Dickinson (1995)
Other features	Iron oolites and forests, Libya Microbial buildups, China	Periodic exposure	Van Houten and Karasek (1981) Shen (2003, pers. commun.)



Late Frasnian



Late Famennian

Sandberg et al., 1983

Late Devonian Pilot Shale, Nevada

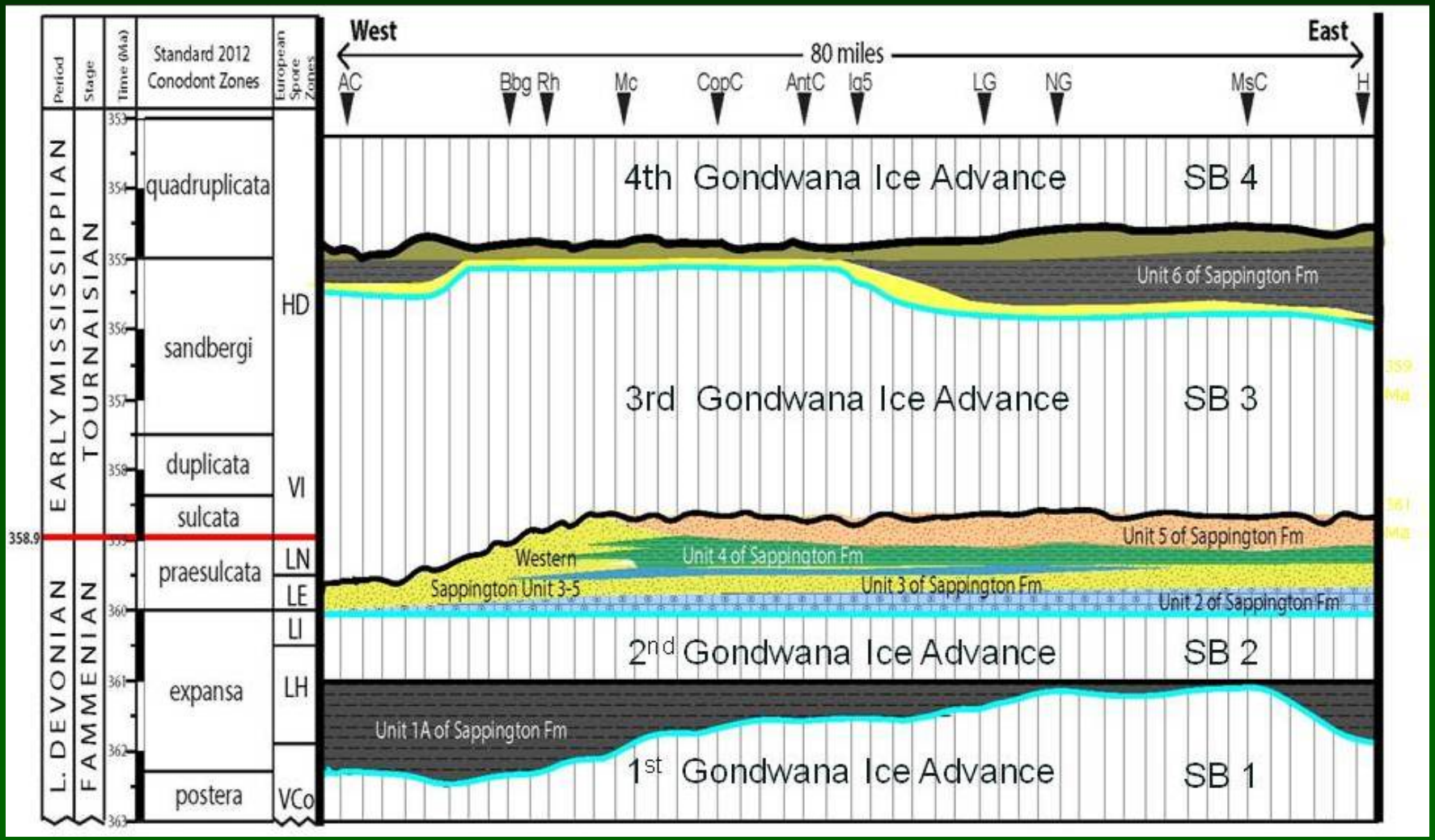
4th order cycles?

Proxy Record

***Presentations, this session**

- Sappington Formation, Montana: Devonian-Carboniferous boundary lacunae (*Grader et al., di Pasquop et al., Rice et al.)*****
- Surrett Canyon and Arco Hills formations, Idaho: Late Mississippian glacioeustatic eustasy overprinting tectonic subsidence *(Batt et al., 2008)*
- Copacabana carbonates, Bolivia: Pennsylvanian glacigenic dust - coeval with glacials in southern Bolivia and Argentina *(Carvajal et all; Schiappa; Anderson-Folnagy et al.)*****

Sappington Formation, Montana

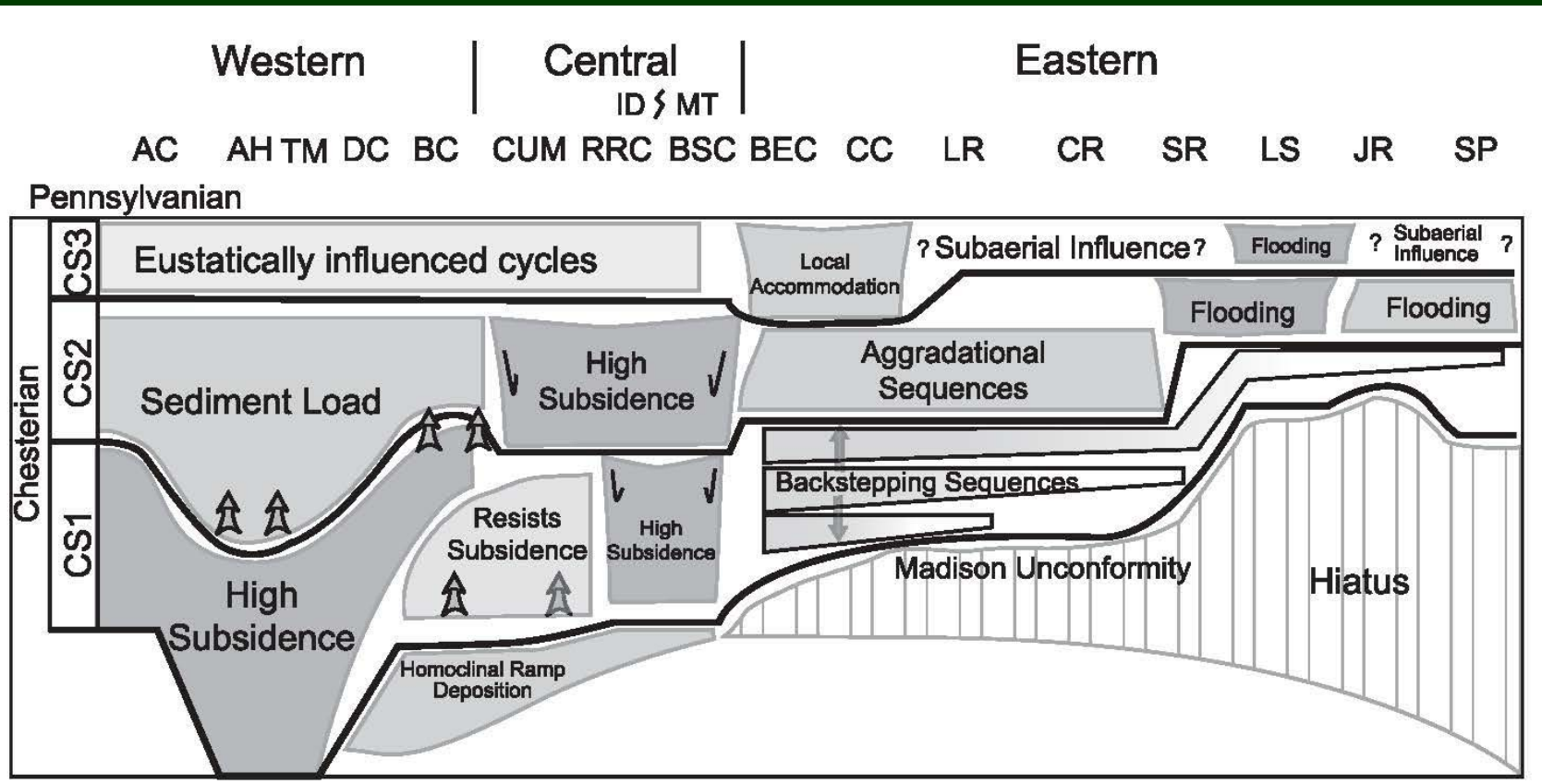


Problem of missing conodont zones

Late Mississippian Proxy

Surrett Canyon and Arco Hills formations, Idaho

distinguishing tectonic and eustatic sequences



Batt et al., 2007

Western European miospore zones.

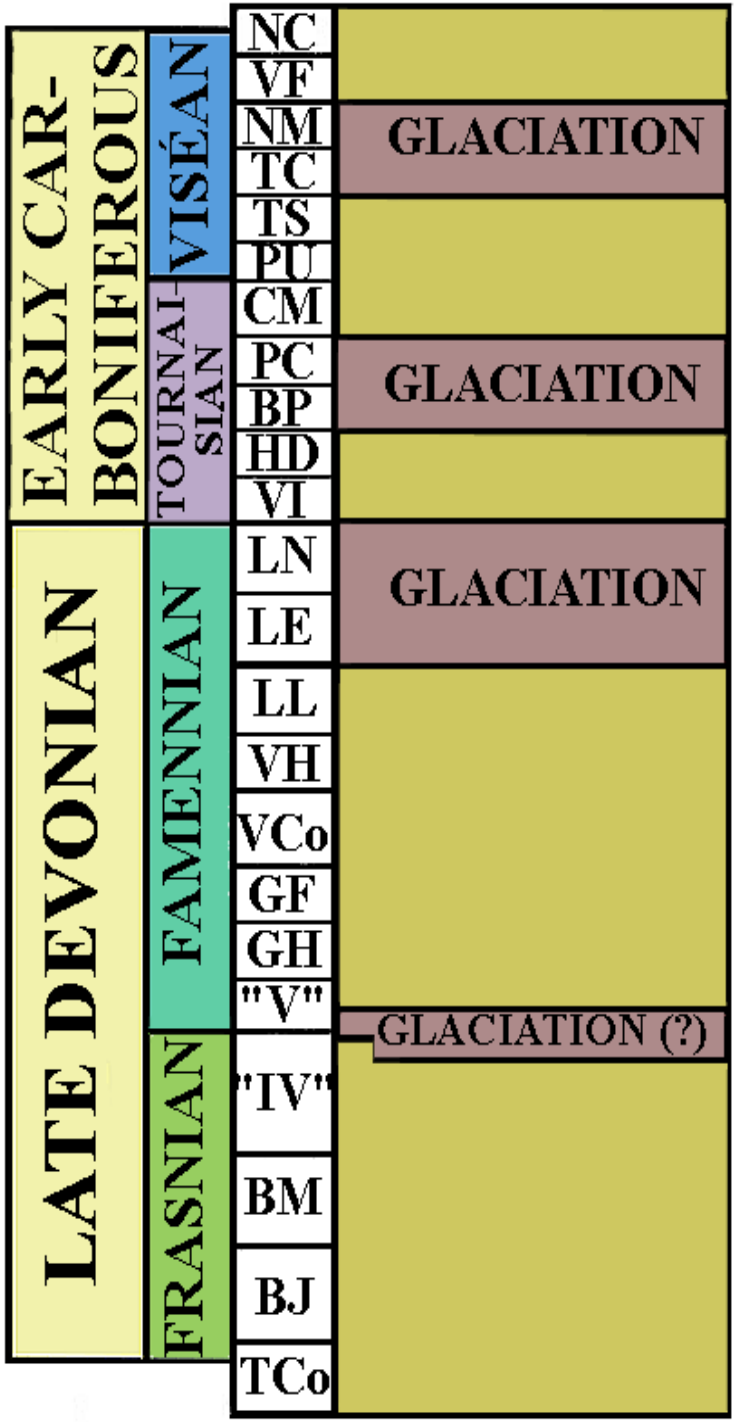
from Caputo et al., 2010

Viséan: ***Perotrilites tessellatus-Schulzospora campyloptera*** **(TC) to** ***Rainstrickia nigra-Triquitrites marginatus*** **(NM).**

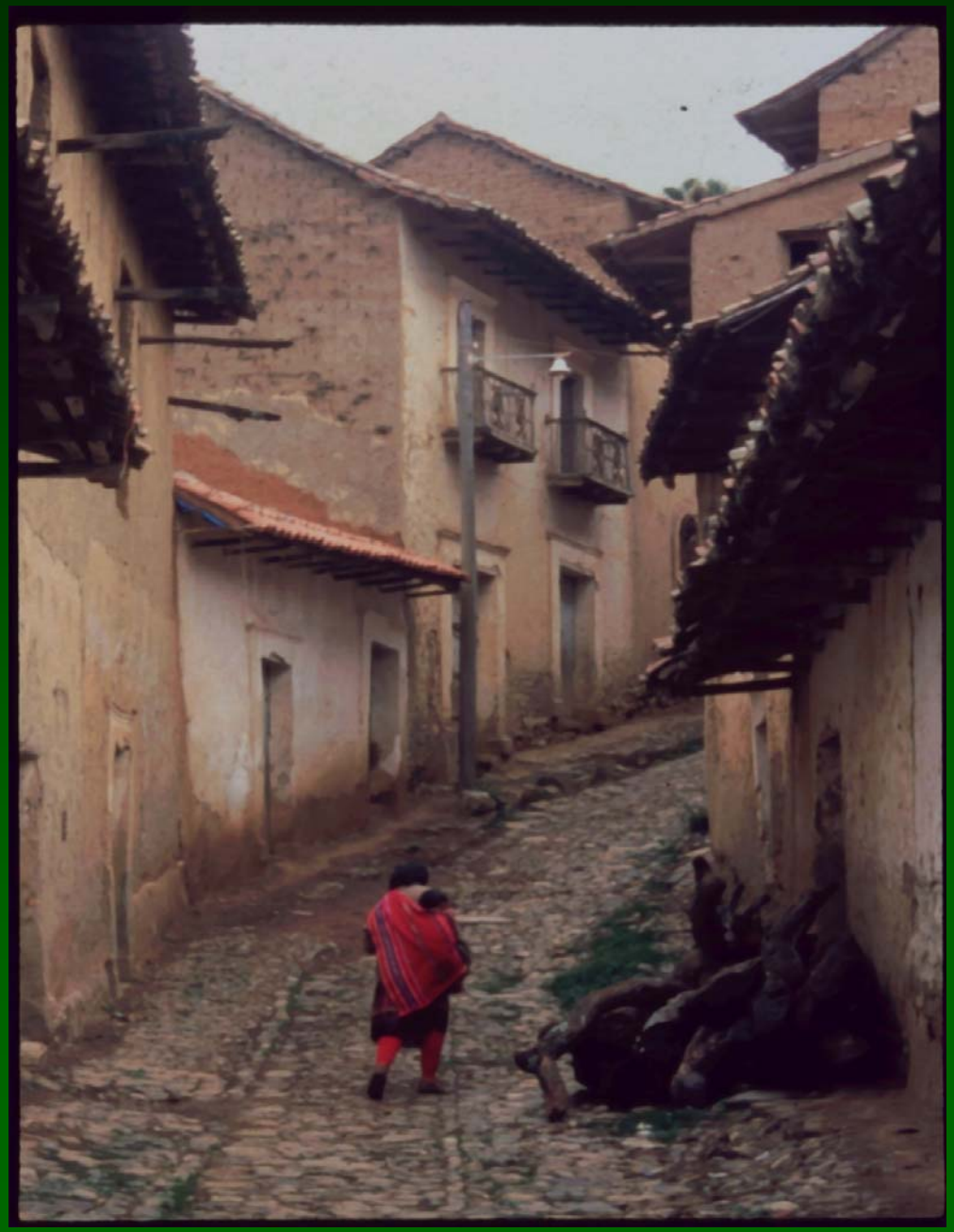
Tournaisian: ***Spelaeotriletes balteatus-Rugospora polyptycha*** **(BP) to** ***Spelaeotriletes pretiosus-Raistrickia clavata*** **(PC).**

Latest Famennian: ***Retispora lepidophyta-Indotriradites explanatus*** **(LE) to** ***Retispora lepidophyta-Verrucosisporites nitidus*** **(LN).**

Frasnian-Famennian Boundary : ***Teichertospora torquata-Auroraspora pseudocrista (TP)(~"IV" / "V" Transit.)***



“I know one thing, and that is I know nothing.”



***Socrates**, ca 410 BC*