DEVONIAN GLACIATION IN GONDWANA
A PROXY SECTION IN MONTANA

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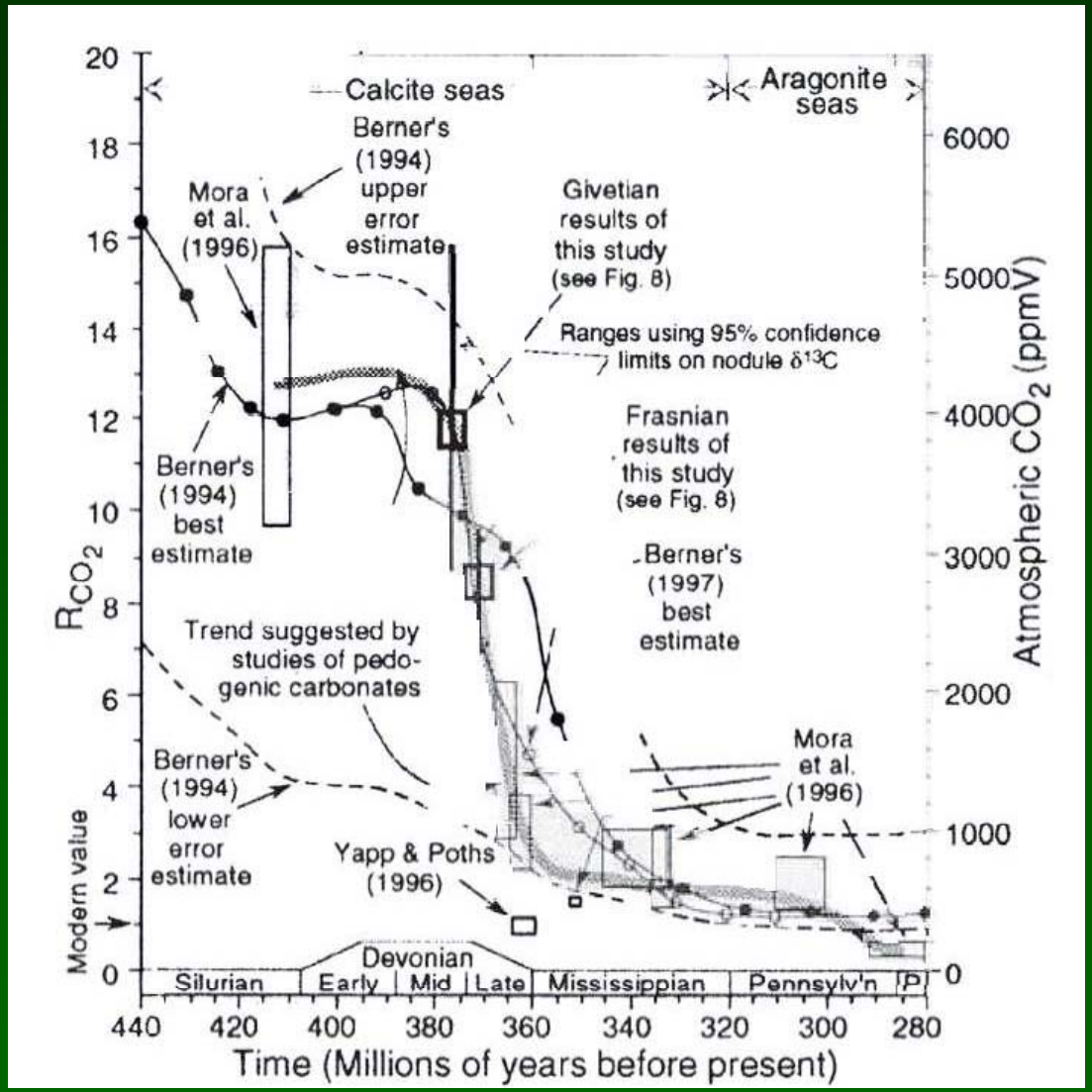
LATE DEVONIAN

- **Gondwana Glaciation** – first described in Brasil, expanded into Bolivia and Peru, probable beds in Central African Republic and Niger, and Appalachians *(Caputo, 1985; Isaacson et al., 1999, 2008; Diaz-Martinez, 2004; Censier, et al., 1995; Lang et al., 1991; Brezinski et al., 2010)*

Late Devonian carbon dioxide drop



Cox et al., 2001

FIRST DESCRIPTION: DEVONIAN GLACIATION

Brasil

Amazonás and Solimöes basins' subsurface

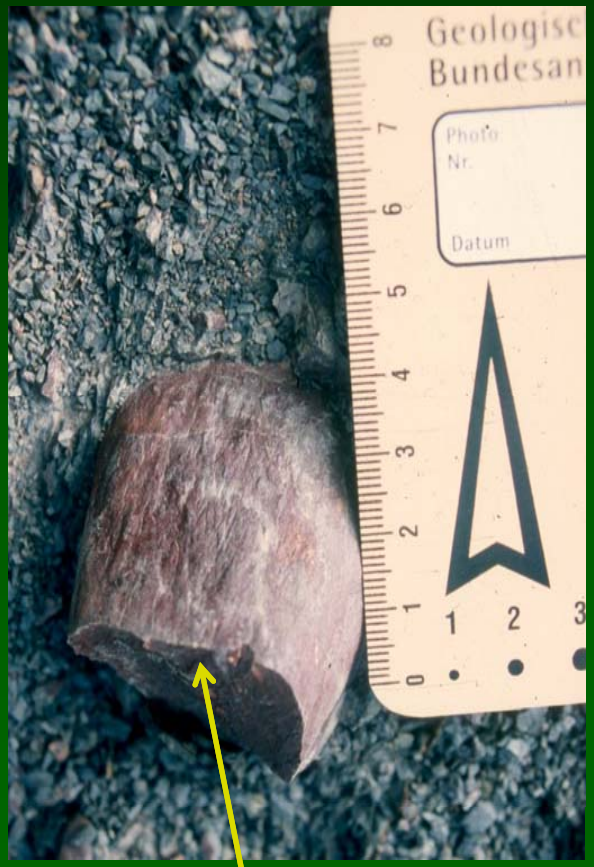
and

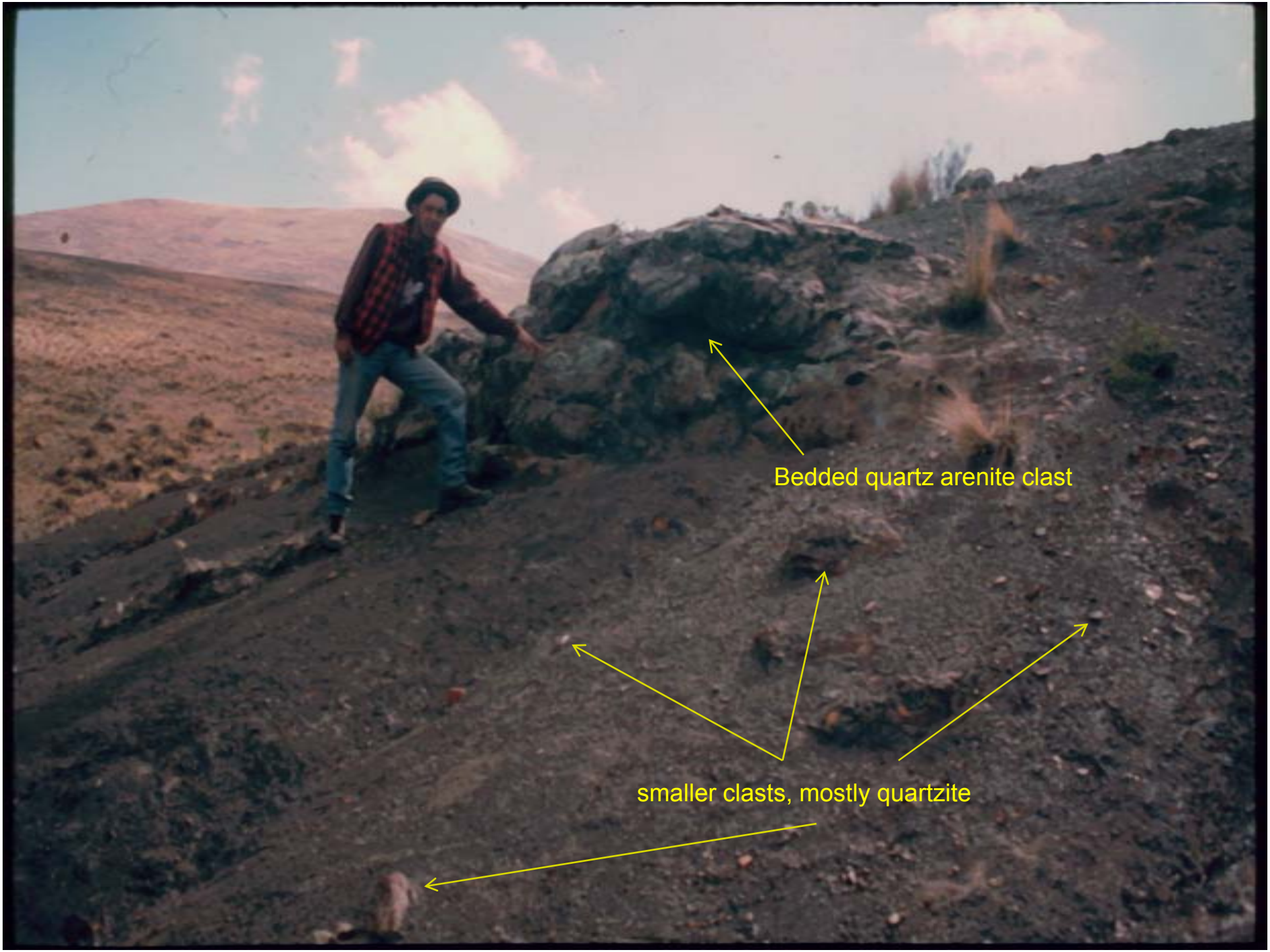
Devonian Glacial Grooves

Parnaíba Basin

Caputo, 1985, and unpub. photos

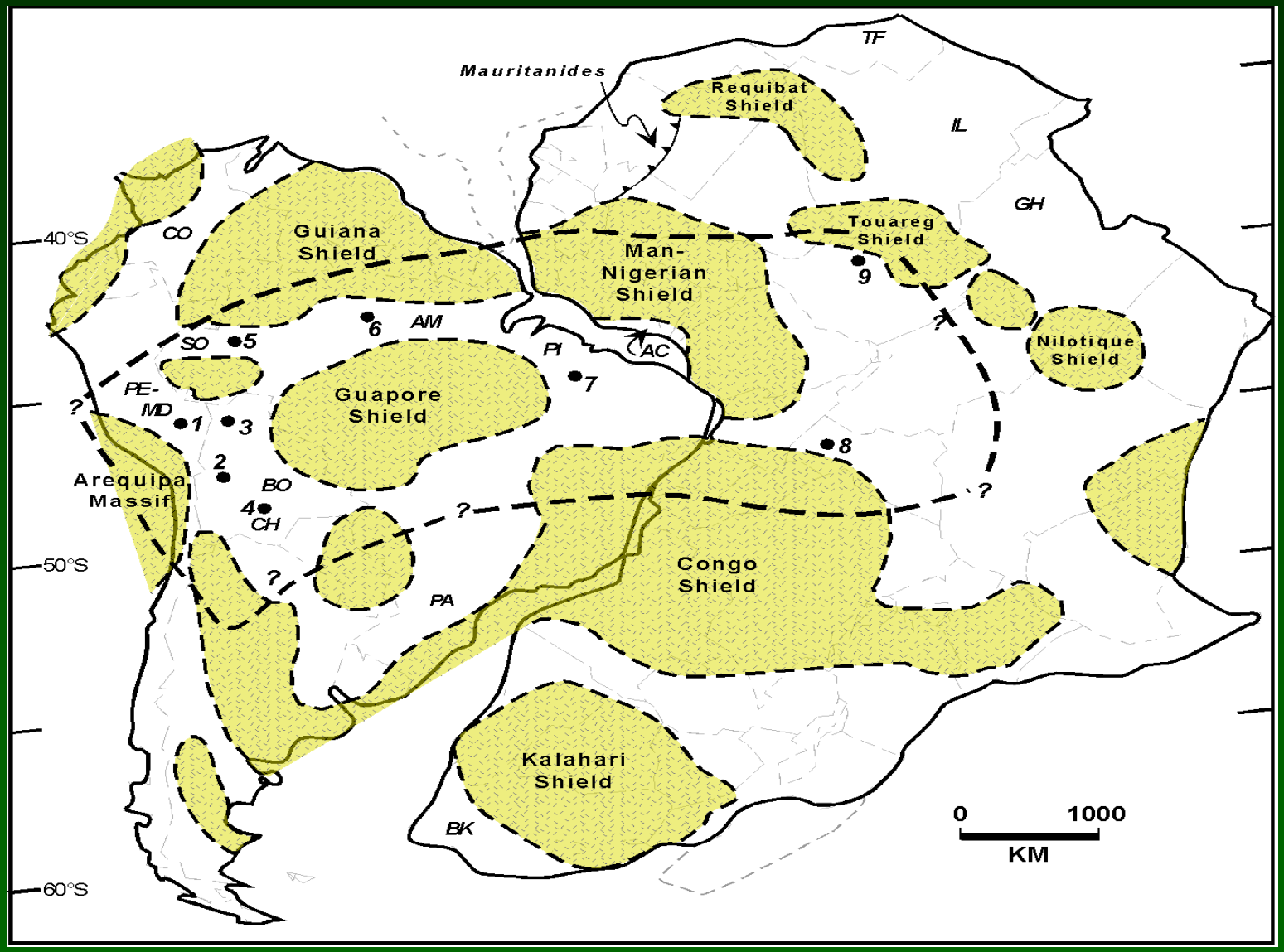
Glacial clasts:
Cumaná Fm., Bolivia




Bedded quartz arenite clast
smaller clasts, mostly quartzite

Preliminary estimate of ice extent

1,600,000 km^2 minimum

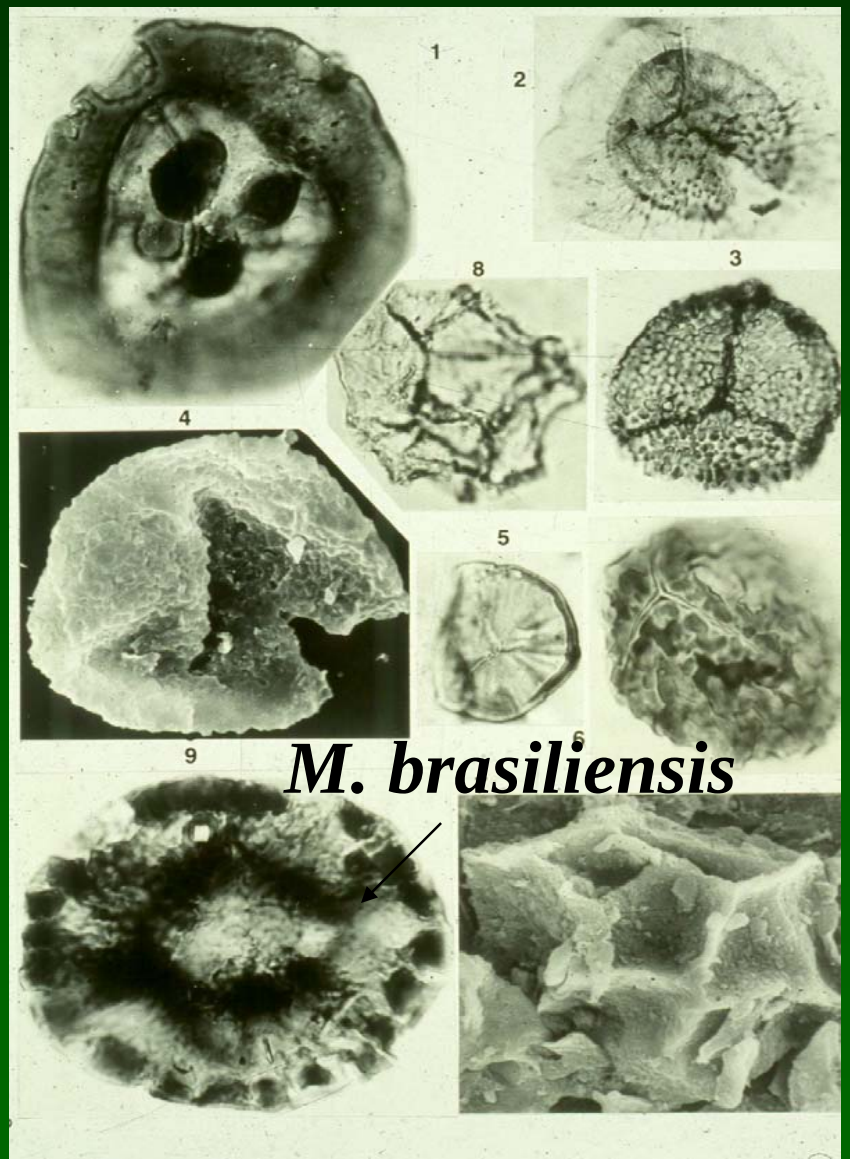


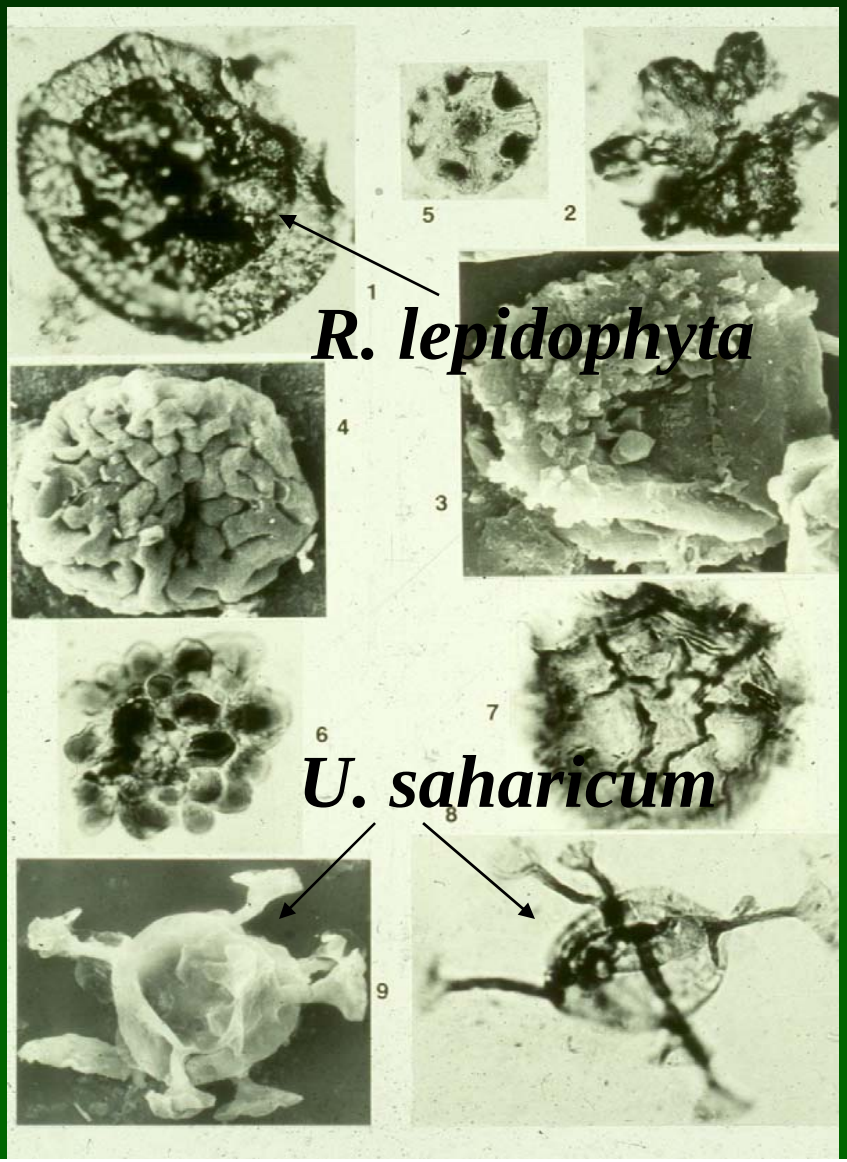
Isaacson et al., 2008

Famennian palynology

Cumaná Fm.

Vavrdová et al., 1993





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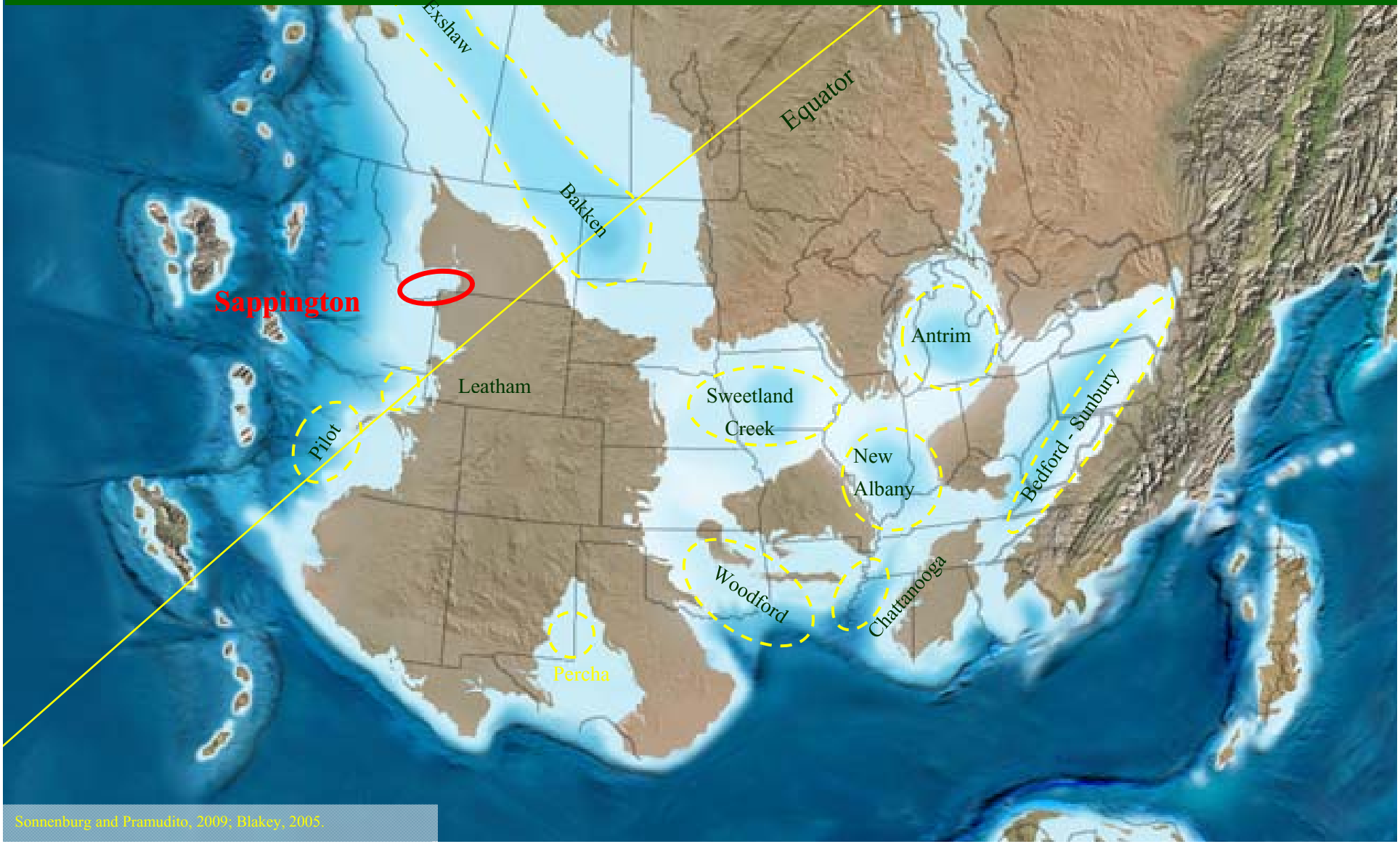
- **PROBLEM:** Proxy sections necessary to date glacial ice advances and retreats

Sappington Formation Montana

- Ideal proxy section deposited at low paleolatitude

Late Devonian Correlative Shale Formations



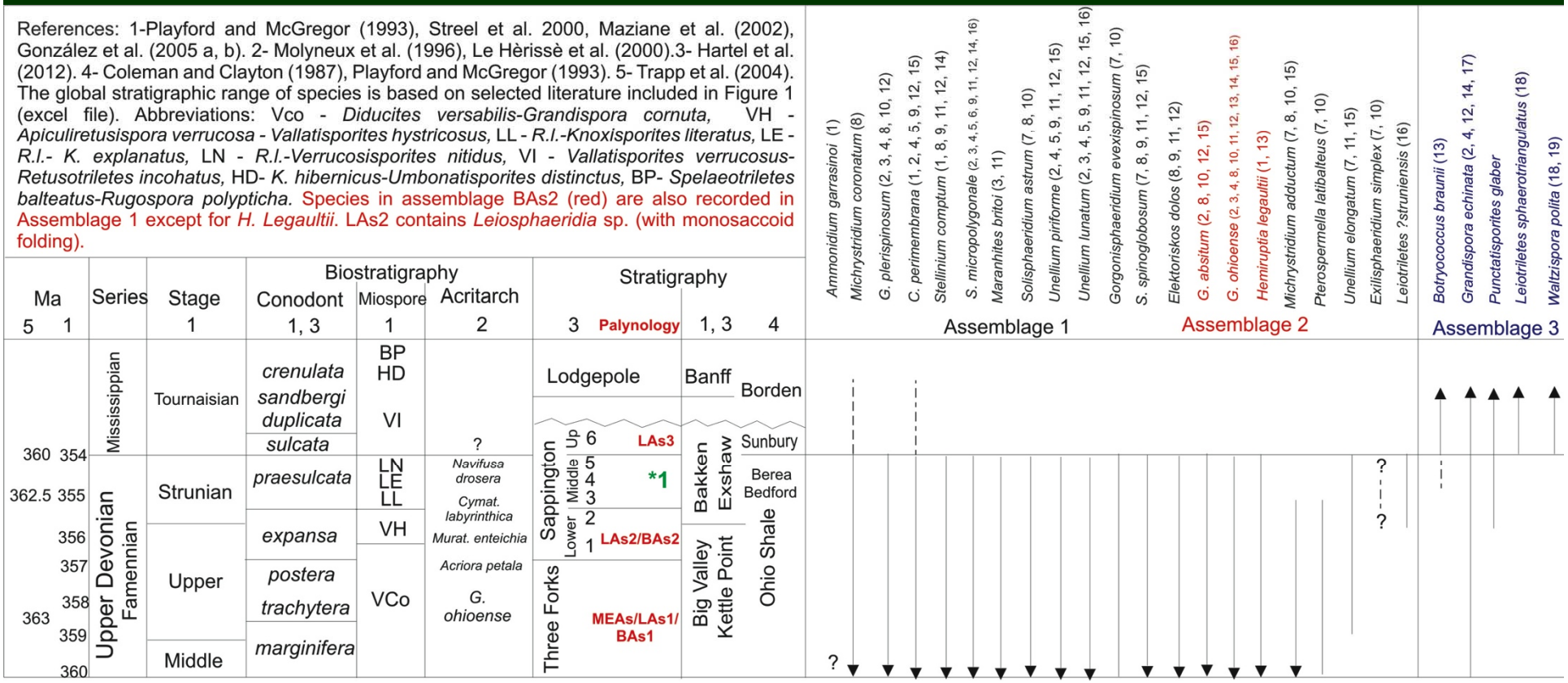
Sonnenburg and Pramudito, 2009; Blakey, 2005.

Sappington Formation Montana

- Ideal proxy section deposited at low paleolatitude
- Bridges D-C boundary (excellent biostratigraphy potential)

Preliminary palynomorph recovery
Di Pasquo et al. (2012)

References: 1-Playford and McGregor (1993), Streel et al. 2000, Maziane et al. (2002), González et al. (2005 a, b). 2- Molyneux et al. (1996), Le Hèrissè et al. (2000).3- Hartel et al. (2012). 4- Coleman and Clayton (1987), Playford and McGregor (1993). 5- Trapp et al. (2004). The global stratigraphic range of species is based on selected literature included in Figure 1 (excel file). Abbreviations: Vco - *Diducites versabilis-Grandispora cornuta,* VH - *Apiculiretusispora verrucosa - Vallatisporites hystricosus,* LL - *R.l.-Knoxisporites literatus,* LE - *R.l.- K. explanatus,* LN - *R.l.-Verrucosisporites nitidus,* VI - *Vallatisporites verrucosus-Retusotriletes incohatus,* HD- *K. hibernicus-Umbonatisporites distinctus,* BP- *Spelaeotriletes balteatus-Rugospora polypticha.* Species in assemblage BAs2 (red) are also recorded in Assemblage 1 except for *H. Legaultii*. LAs2 contains *Leiosphaeridia* sp. (with monosaccoid folding).



Localities/studied Assemblages: ME (Milligan East), L (Logan section), B (Bakken Formation, NE Montana, Big Skye 1 core).

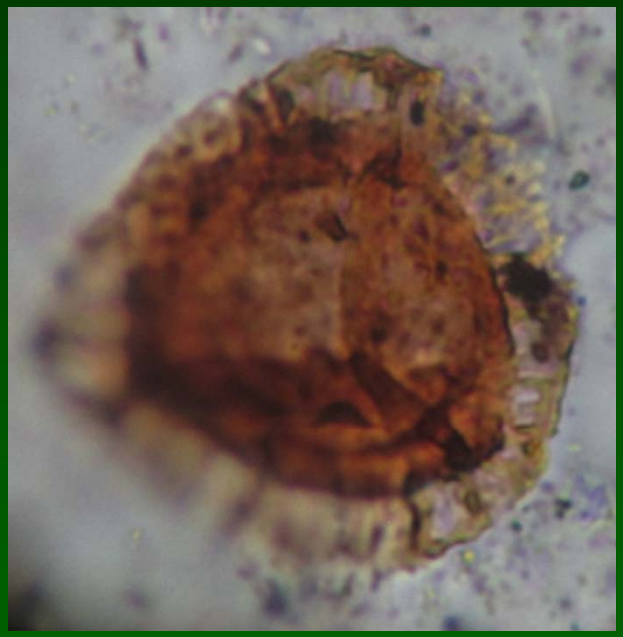
*1- Sandberg et al. (1972) described and illustrated conodonts and from the Sappington Formation in Montana, defining *Siphonodella praesulcata* and its fauna. A spore assemblage (seven samples) containing abundant *Retispora lepidophyta* was recorded at Peak 9559, Bridger Range, bracketed by the *praesulcata* conodont fauna in Unit 4 of Sandberg (1965 in Sandberg et al. 1972). It was deposited in a restricted clastic regressive-marine lithofacies lacking normal marine specie.

References of species stratigraphic distribution: 1- Ottone (1996), 2- Playford (1993), 3-González et al. (2005 a, b), 4-Playford and McGregor (1993), 5-Wicander and Playford (1985), 6-Playford (1981), 7-Wicander (1974), 8-Wicander and Loeblich (1977), 9- Wicander and Playford (1985), 10-Wicander (1975), 11-Le Herisse et al. (2000), 12- Lu and Wicander (1988), 13- Pöthe de Baldis (2000), 14- Molyneux et al. (1984), 15- Filipiak (2005), 16- Paris et al. (1988), 17- Sandberg et al. (1972), 18- Smith and Butterworth (1967), 19-Azcuy and di Pasquo (2005).

Current project: Warren

Retispora lepidophyta

- **Key Strunian (very latest Devonian, at D-C boundary) index fossil**
- **miospore – from land plant**
- **Widely distributed in North America, South America, Russia, China, Australia, Europe, Africa**
- **Found in Middle Member Sappington at Frazier Lake and Logan Gulch localities (Warren)**
- **Thermal maturation in early oil generation (2+ to 3) window**

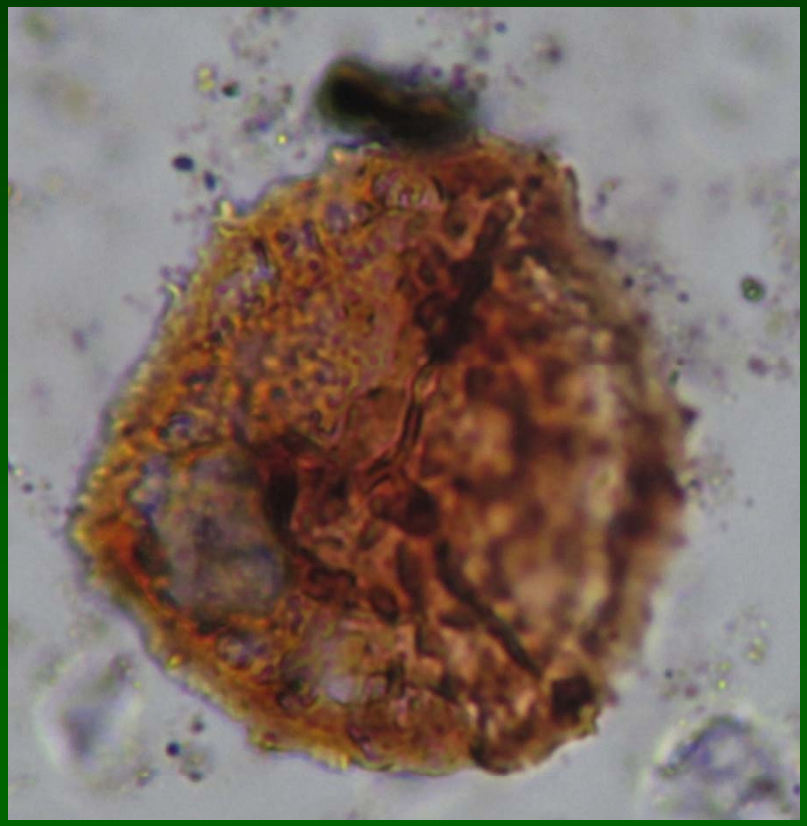


This important taxon was not found in Di Pasquo et al. (2012) study.

Other Miospores

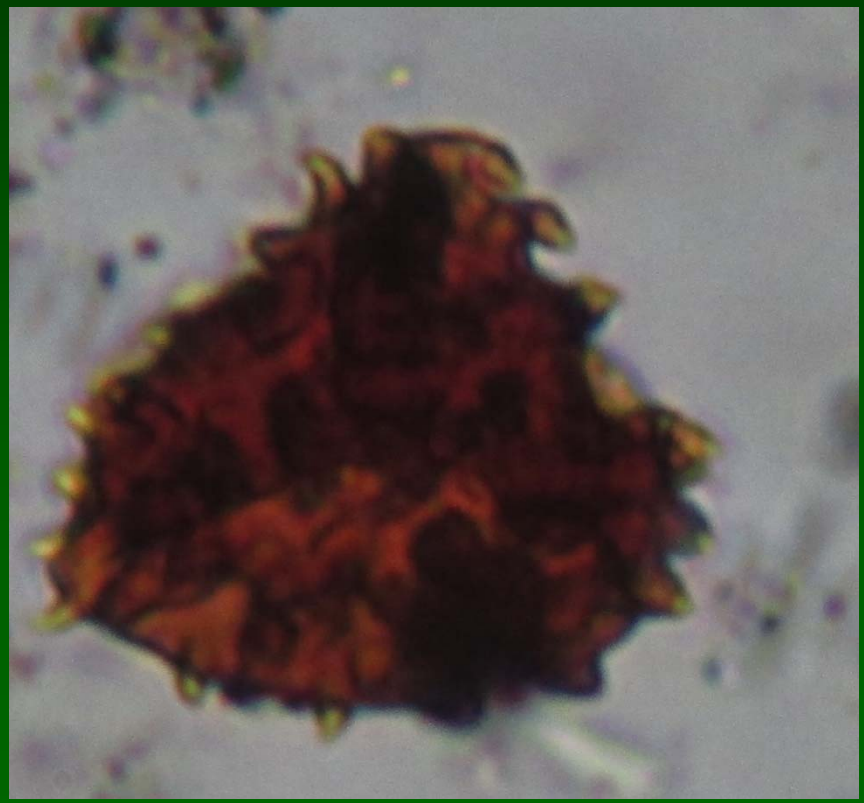
Vallatisporites vallatus

mid-Strunian - Tournasian



Grandispora saurota

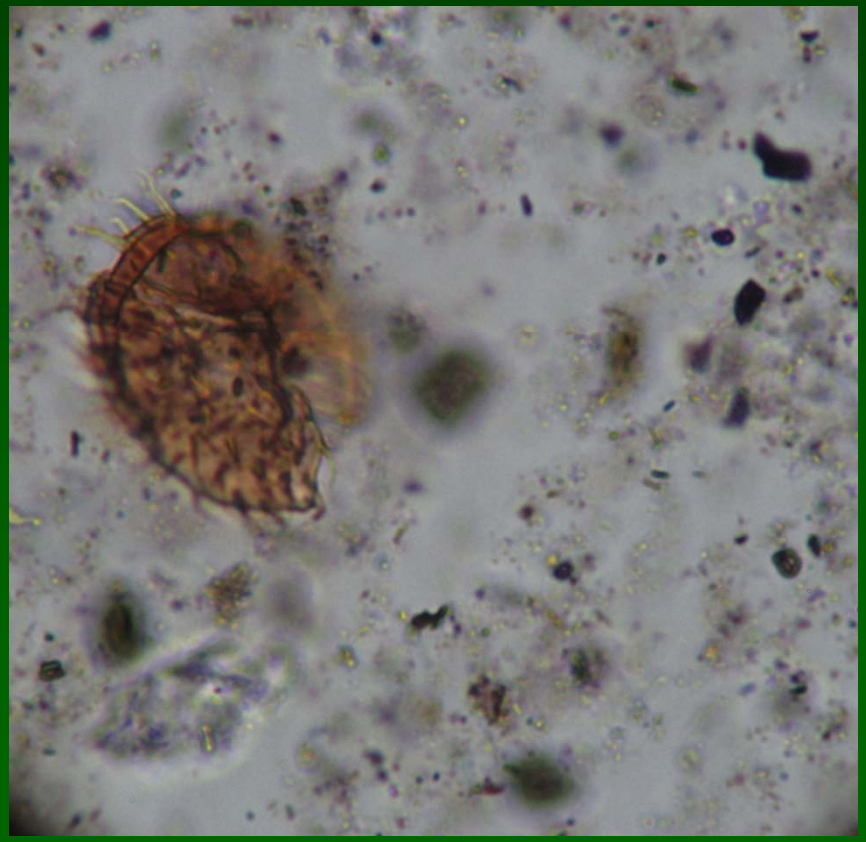
mid-Strunian - Tournasian



Marine Acritarchs

Gorgonispaeridium plerispinosum

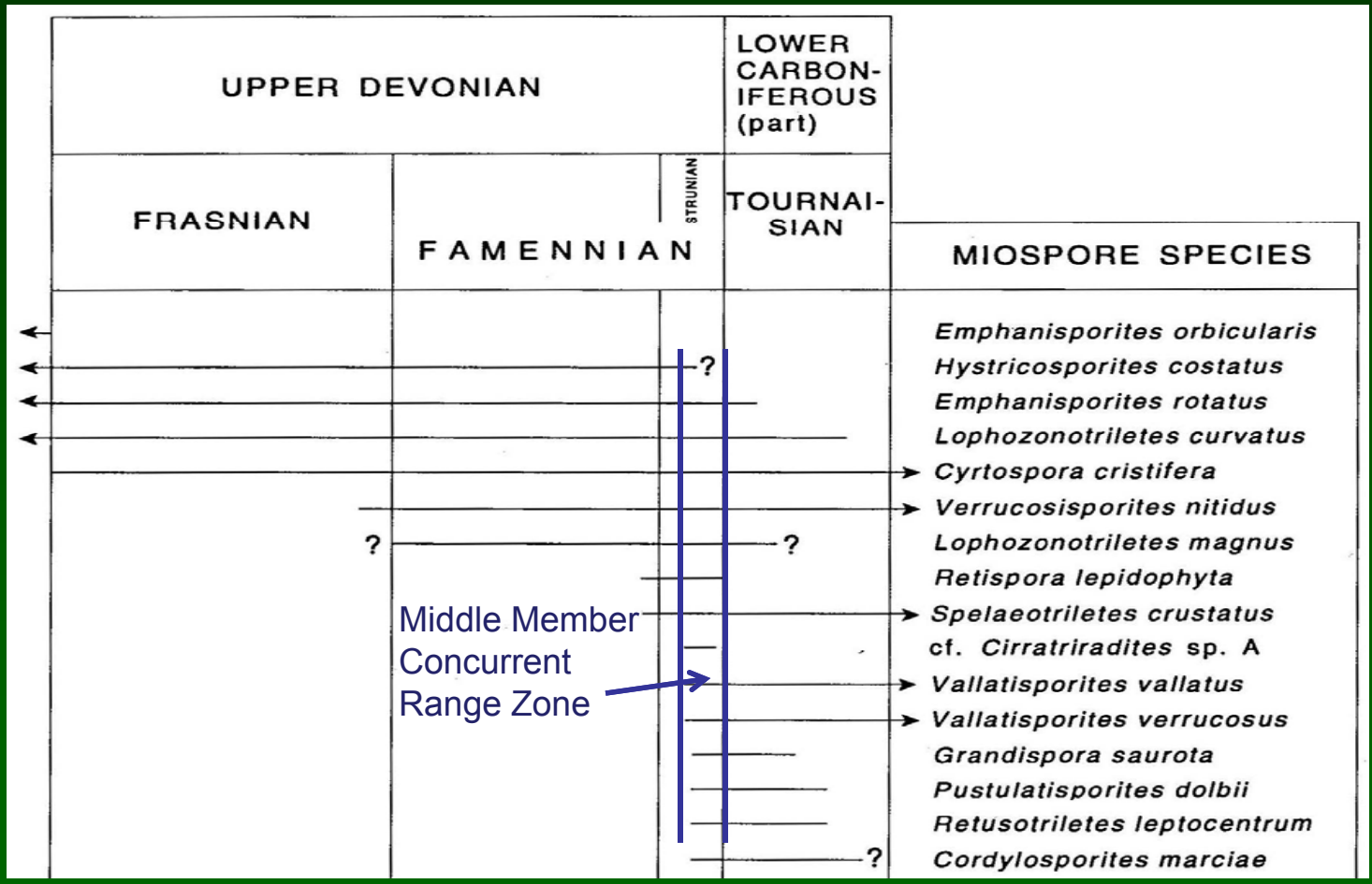
late Frasnian – end Strunian



Micrhystridium

Frasnian - Tournasian

Middle Shale Biostratigraphy
= mid- to late- Strunian

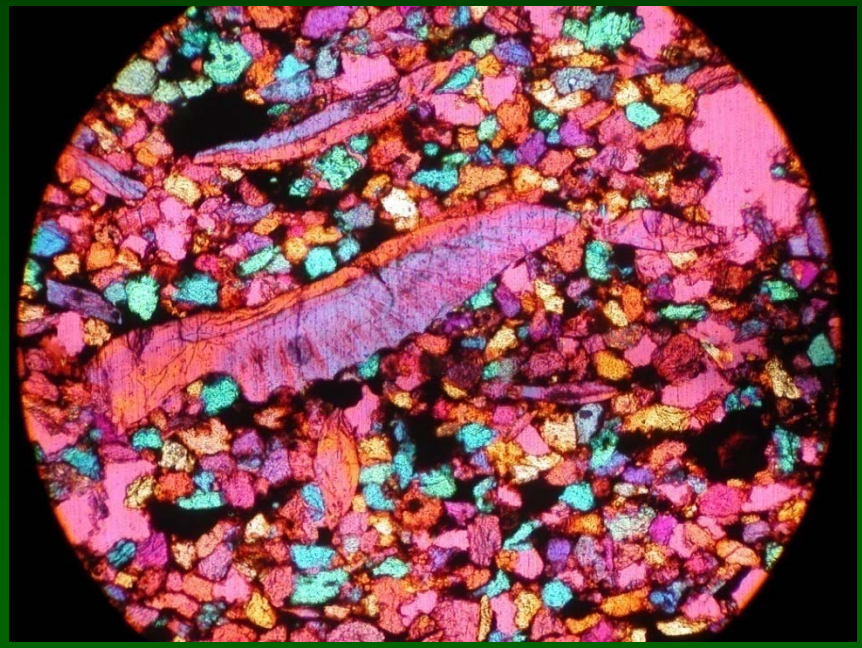


From Playford and McGregor, 1993

Conodonts

Very abundant in some units, suggesting current reworking and possible recycling.

Bedding plane with several S elements
Smith River, Unit 22



Photomicrograph with P elements
lower siltstone

Siphonodella isosticha (P element)

Thermal Alteration Index (TAI) = 1.5-2.0, approx. 70 -130 C

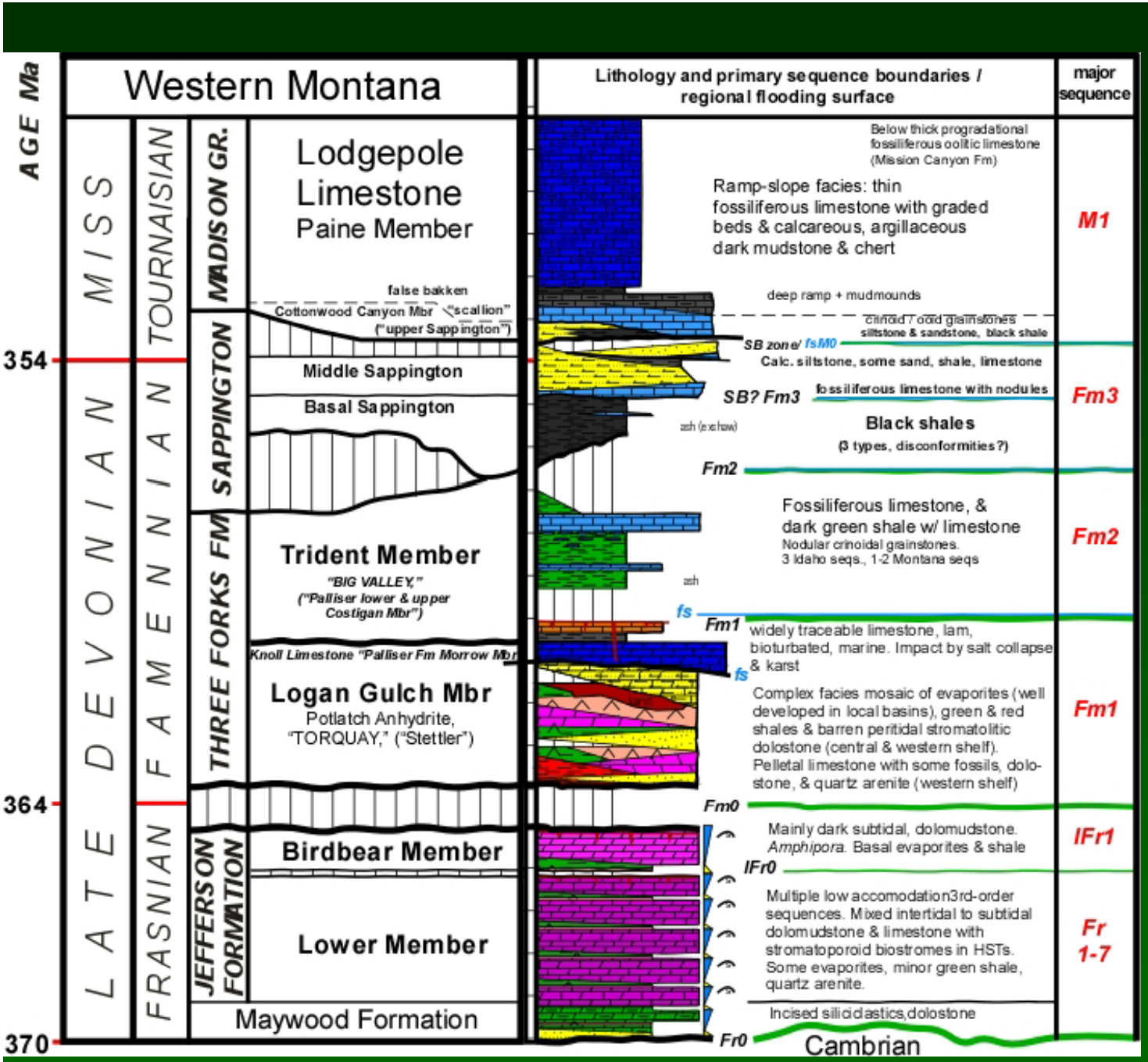
Lower Mississippian zone named for this taxon (note: P elements are essential for biostratigraphy), indicating that three Tournaisian (Kinderhookian) conodont zones are missing

Bar = 1 mm

Scallion Mbr., Lodgepole Fm. at L-C Caverns

Sappington Formation Montana

- Ideal proxy section deposited at low paleolatitude
- Bridges D-C boundary (excellent biostratigraphy potential)
- Several depositional environments, including marine, peri-tidal and paleosol settings with subaerial exposure and unconformities



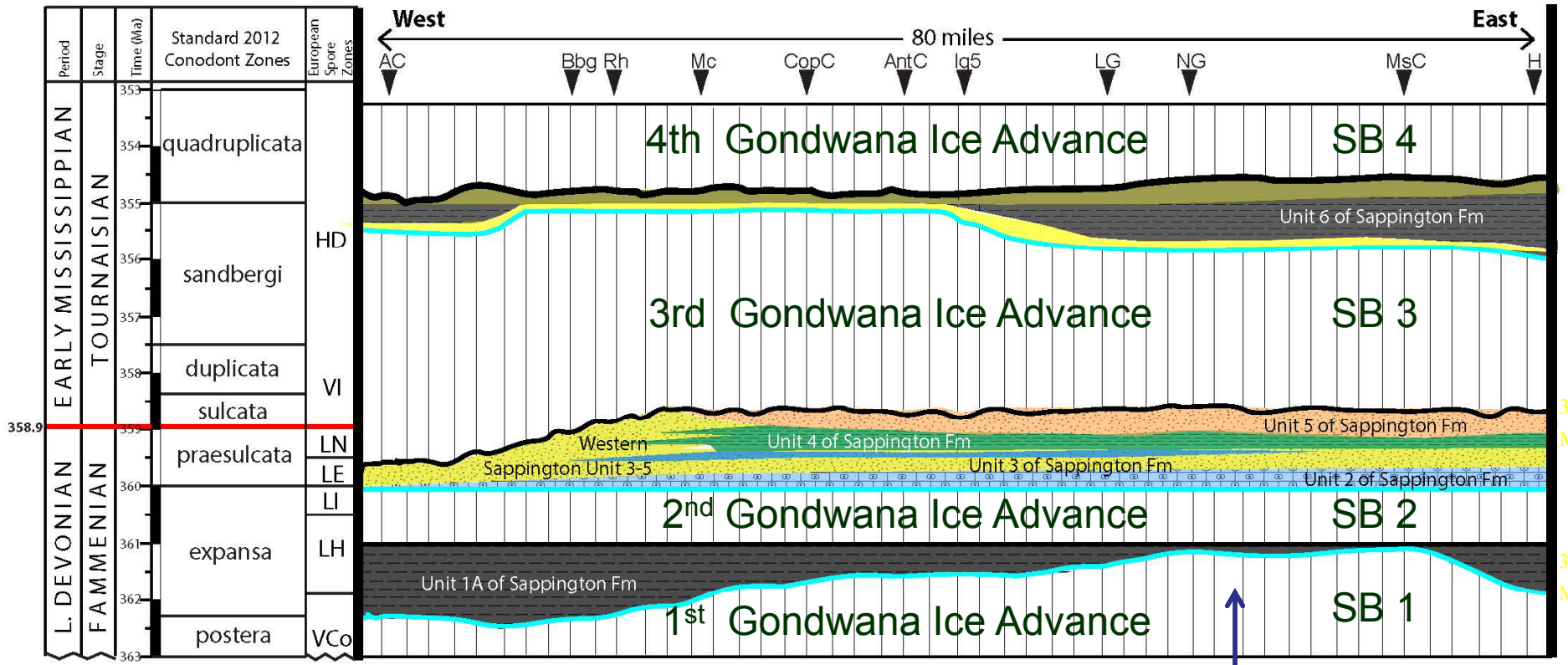
European Black shales and mass extinctions

Hangenburg event and end Famennian Mass extinction

Kellwasser event and F/F mass extinction

Grader, 2012

Wheeler Diagram



Globally Correlatable SBs

(Haq and Shutter, 2008); (Sandberg et al., 1972)

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

Socrates, ca 410 BC