Dicot Wood Anatomy: A Tool for Reconstructing Late Cretaceous Paleoclimate

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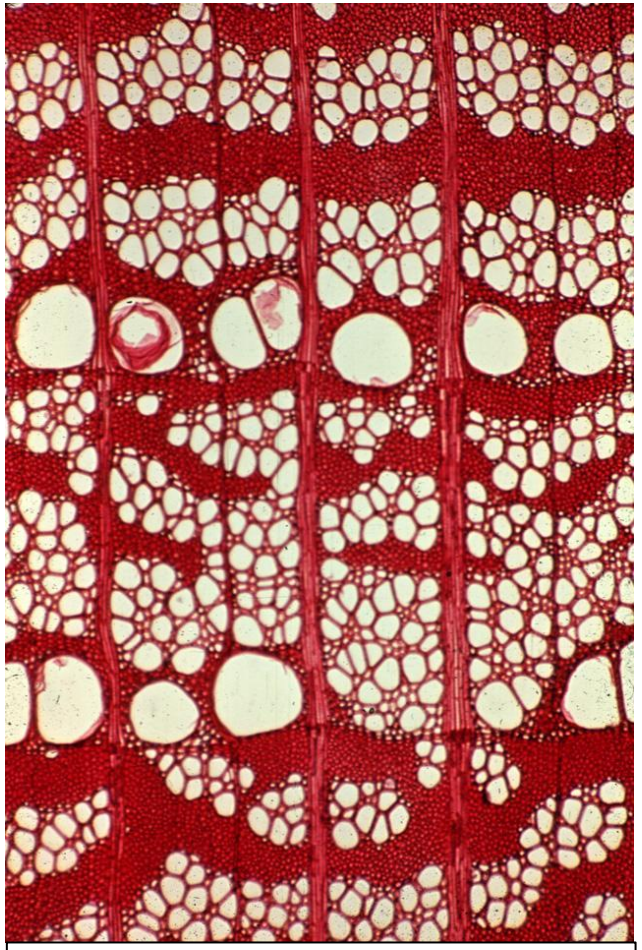
Introduction

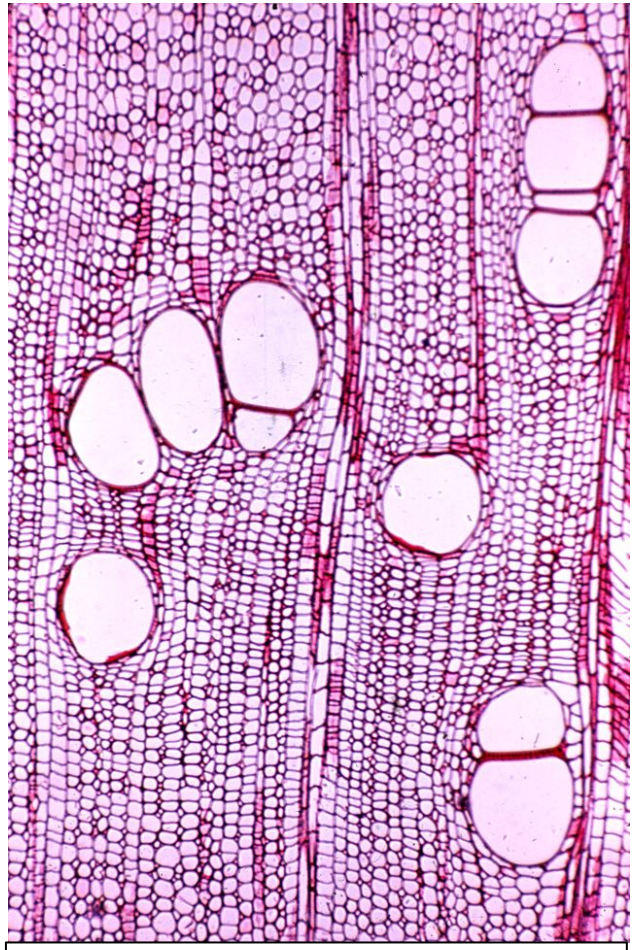
- Wood anatomy has long provided quantitative information on paleoclimate
  - Analysis of growth rings, Pleistocene-Holocene
    - Individual species
    - Patterns of growth variation related to climatic parameters
    - Multiple regression
- Diverse wood anatomical characters can provide information for climatic reconstruction in deep time.
  - Presence/absence of growth rings in conifers, dicots
    - Seasonality
  - Characteristics of whole assemblages of dicots
    - Temperature, precipitation
    - Relative diversity of species with different characteristics

Dicot Wood Cross Sections: Tropical vs. Temperate

- Temperate (elm wood)
  - Annual rings
  - Variation in diameter of vessels (water transport cells)
    - Seasonal variation, water use
  - Well developed fibers (hard tissue)
- Tropical (balsa wood)
  - No annual rings
  - No variation in vessel diameter
  - High volume of parenchyma (soft tissue)



Ulmus (elm) wood

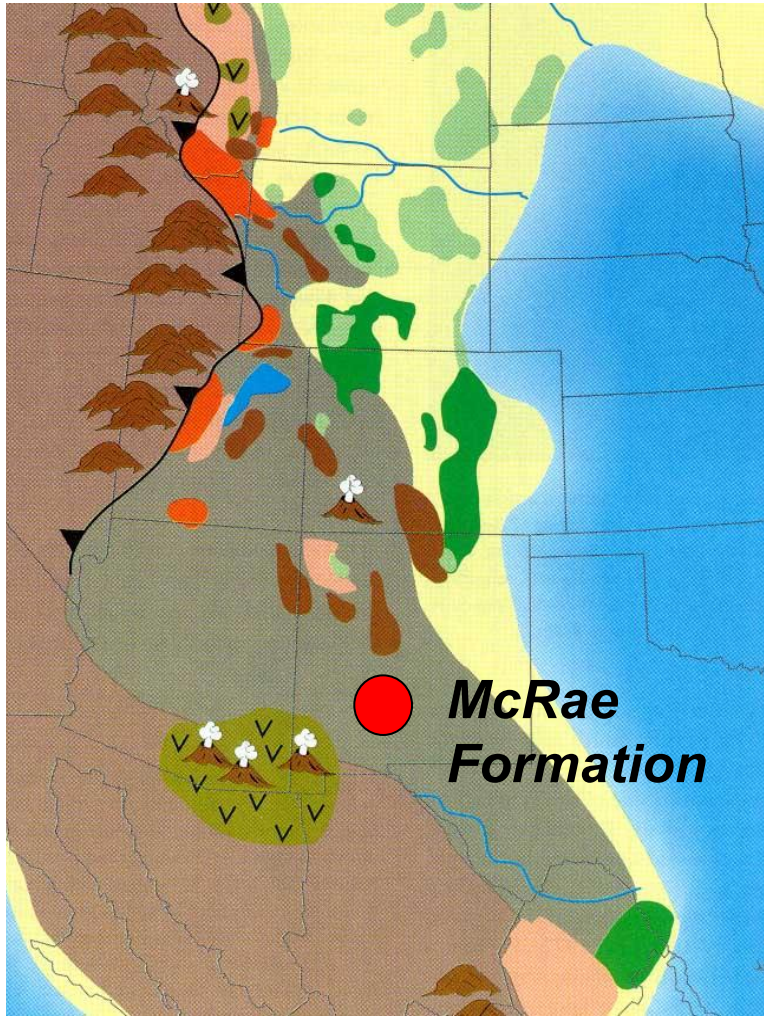


Ochroma (balsa) wood

Questions addressed by this talk

- Can dicot wood anatomy be used to infer Late Cretaceous terrestrial climate?
  - Beyond presence/absence of seasonality
- Does dicot wood anatomy provide quantitative climate estimates congruent with other proxies?
  - Mean Annual Temperature: MAT
  - Cold Month Mean Temperature: CMMT
  - Mean Annual Range of Temperature: MART
  - Mean Annual Precipitation: MAP
  - Length of Dry Season: DRY

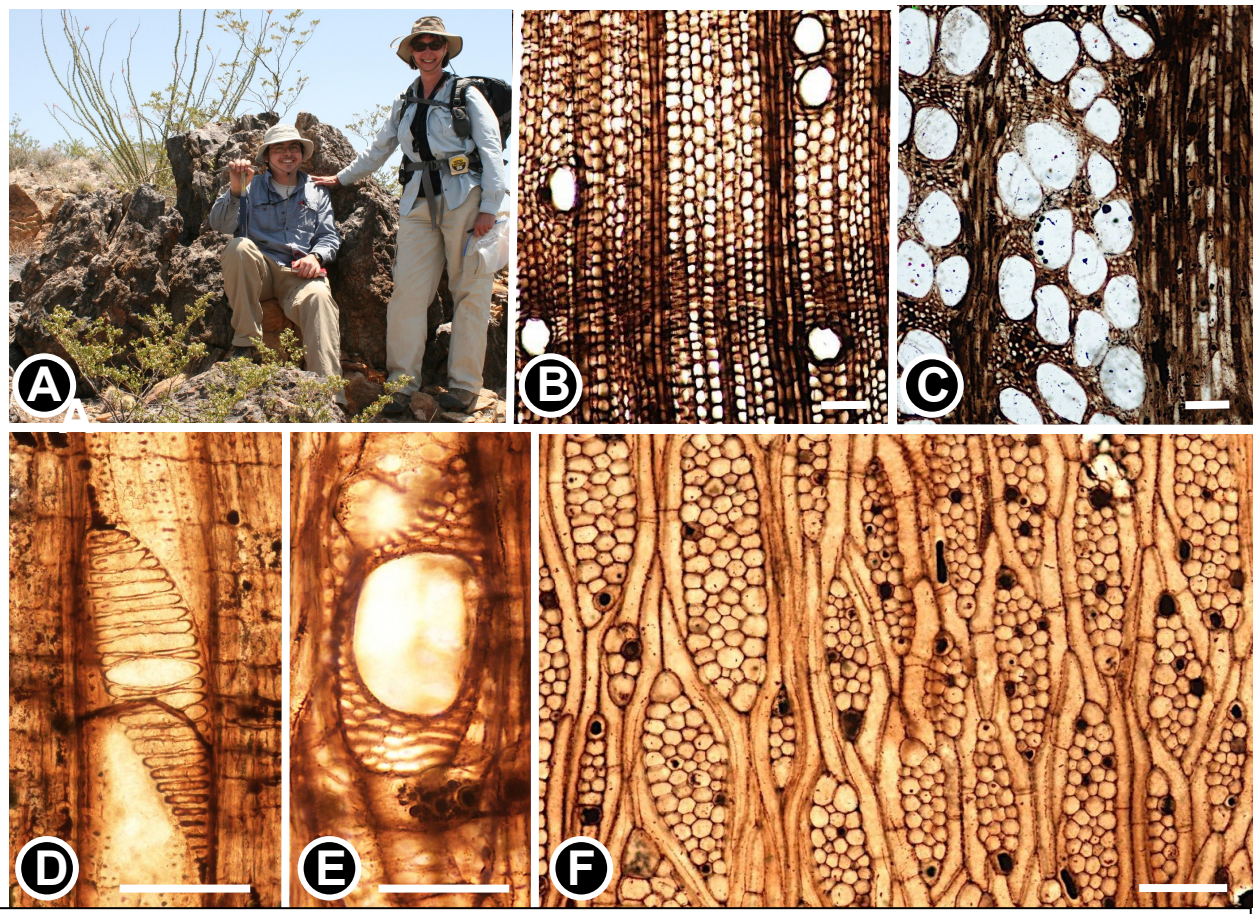
The Late Cretaceous Jose Creek Flora



- Jose Creek Member, McRae Formation
  - South-central New Mexico, USA
  - Interior setting, >100 km from seaway
- Late Campanian: 76–72 Ma
  - U-Pb dating, volcanic ashes
- Diverse flora of leaves, woods, fruits, seeds
- Abundant, diverse, well-preserved woods
  - Conifers
  - Dicots
  - Monocot stems (palms, others)
- *In situ* woods (stumps), logs, wood fragments
- Data sources
  - Publications of Estrada-Ruiz et al. (*Int. J. Plant Sci.)*
  - Unpublished dissertation, Joan Parrott (available online)

The Jose Creek Dicot Wood Flora

- Diverse fossil wood flora
  - 38 dicot wood types
  - At least 20 from trees
- Excellent preservation
  - Silicification
  - Abundant volcanic ash
- Sufficiently high species diversity for transfer functions
- Majority of species are trees
  - Wood-climate relations derived from trunk wood, not branch wood

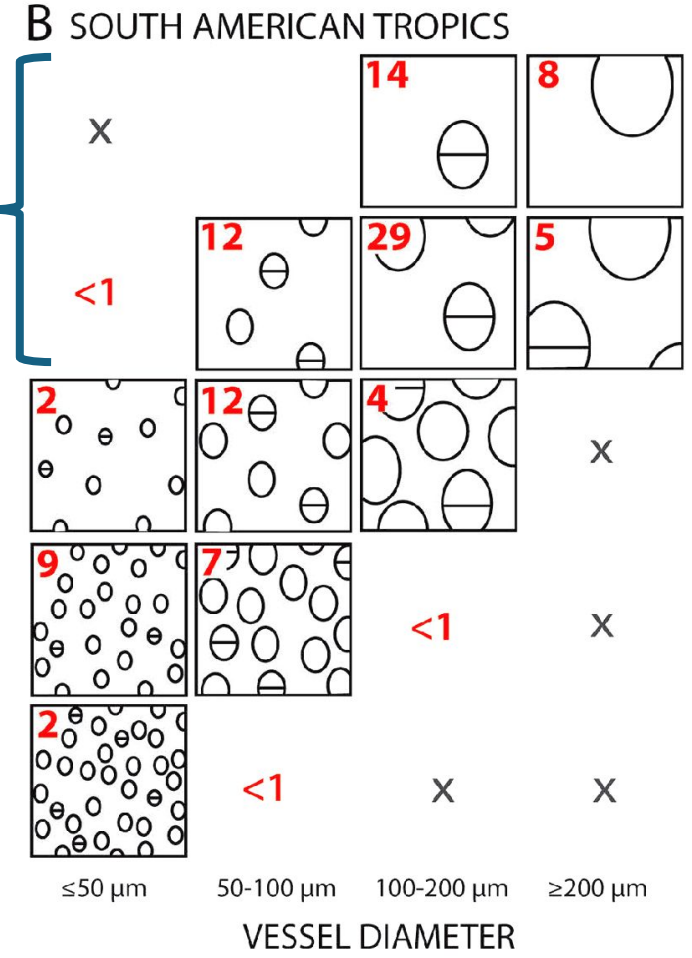


A. Stump of fossil dicot that measures 3.7 m in diameter at the base. Drs. Emilio Estrada-Ruiz and Joan Parrott provide scale. **B,C.** Cross section of two different fossil dicot woods. The large circular cells are vessel elements, which transport water inside the plant. **D.** Side view of vessel element with ladderlike (scalariform) perforations, which connect two adjacent cells. **E.** Side view of vessel element with a simple perforation. **F.** Side view of wood showing elongate fiber cells that run up and down, and storage tissue called rays. The dark spots are secretory cells in the rays.

Estimating Climate From Fossil Dicot Woods

- Qualitative indicators
  - Based on anatomical measurements
  - Presence/absence of annual rings
  - Vulnerability to air embolisms: V
  - Mesomorphy (“Goldilocks” characteristics): M
  - Patterns of vessel density and diameter
    - Tropical vs temperate
- Physiognomic transfer functions
  - Multiple regression functions
    - Subset of 10 independent characters that relate to climate
  - Percentage species with particular characters
  - Temperature
    - Mean Annual Temperature (MAT), Cold Month Mean Temperature (CMMT)
  - Moisture
    - Mean Annual Precipitation (MAP), Length of dry season (DRY)

Characteristic of tropics



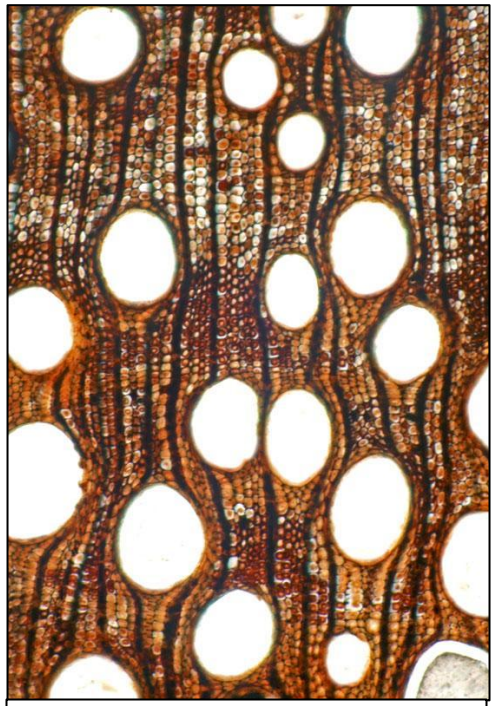
Vessel diameter vs. density: Woodcock (2022), *Int. J. Plant Sci.*, v. 183, p. 240

Qualitative Overview, Jose Creek Dicot Woods

- Absence of growth rings
  - >90% of wood types
  - No freezing
- Vulnerability to air embolisms
  - V = 10
  - Characteristic of modern wet tropics
    - Not dry or freezing climates
- Mesomorphy: M
  - 5800
    - Most like extant primitive dicots
    - Distinct from dicots of dry and cold climates
- Tropical pattern, vessel diameter vs. density, tree species
  - 45% of species
    - 65%, modern tropical South America
    - <2%, North America north of Mexico

Metcalfeoxylon

Paraphyllanthoxylon



Fulleroxylon

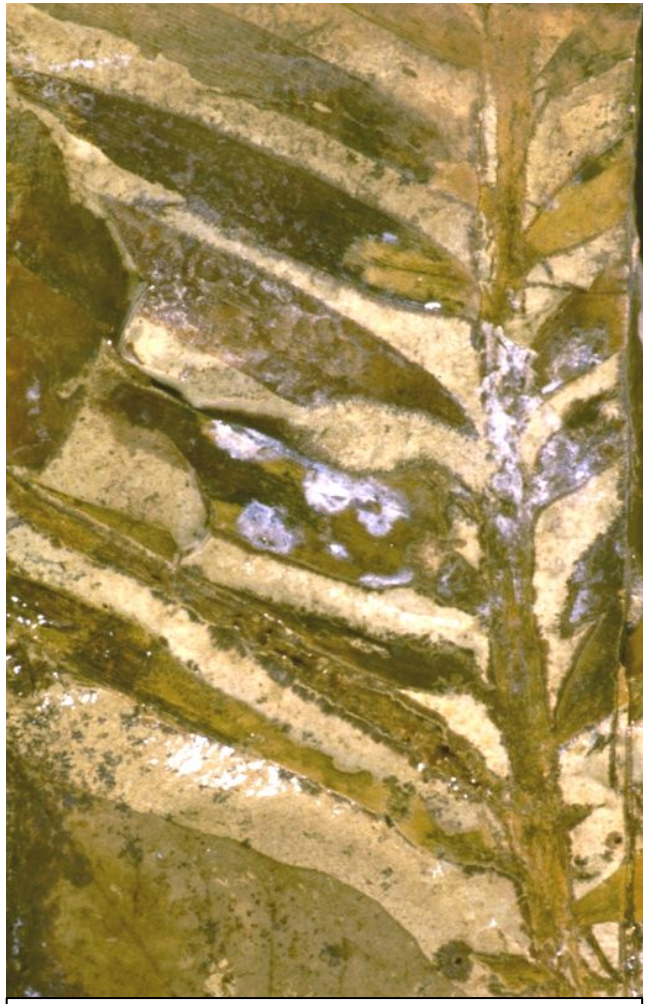
Physiognomic Transfer Functions: MAT

- Weimann et al., 1998
  - *Palaeogeography, Palaeoclimatology, Palaeoecology,* v. 139: 83–100.
- Weimann et al., 1999
  - *Palaios,* v. 14: 459–474.
- Multiple equations for MAT
  - One to five different anatomical characters
- Three equations, lowest S.D. for modern flora
  - MAT = 28°C, 21°C, 22°C
  - MAT average = 24°C
  - Overlap of 2 S.D. for equations
    - 24–26°C
- Other MAT indicators
  - Leaf Margin Analysis, Dori's Tuff leaf flora, Jose Creek
    - MAT = 21°C
  - TEX_{86}, Mississippi Embayment, Shuqualak Core
    - MAT = 28°C

Physiognomic Transfer Functions: CMMT

- One equation
- CMMT = 23–24°C
  - 4–5°C lower than highest MAT equation
- All 3 MAT equations: CMMT = 16–24° C
- MART ~10°C (?)
- Other CMMT indicators
  - Diverse palms
  - Cycads
  - >90% wood types with no rings
  - CMMT ≥5°C

Metcalfeoxylon: No rings



Zamioid cycad leaf

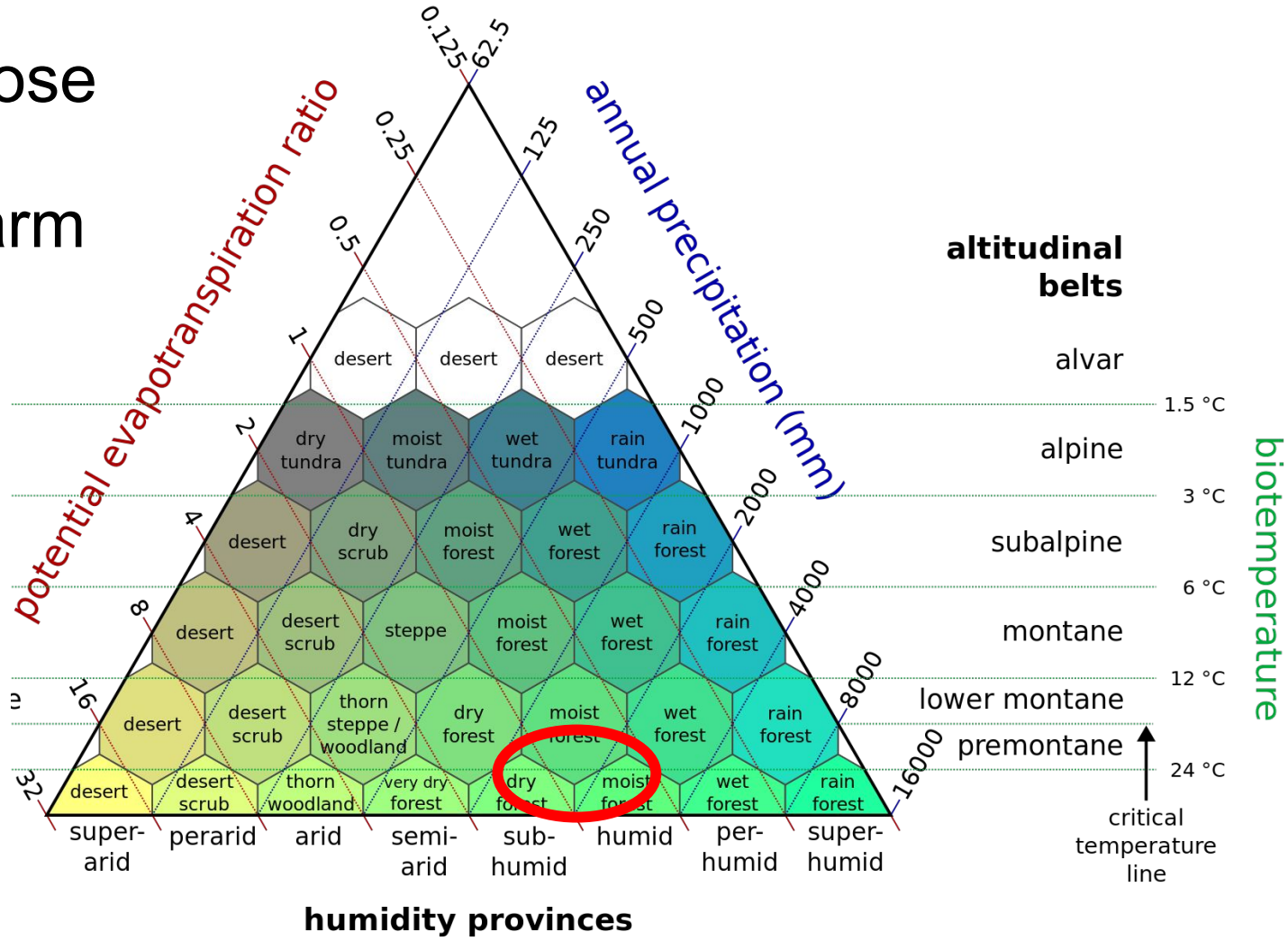
Physiognomic Transfer Functions: MAP & DRY

- Caveat: Paleobotanical estimators almost always overestimate MAP, sometimes severely.
  - MAP = 290 cm
  - DRY = -6 months (negative dry season)
    - **No dry season**
- Other estimators
  - Paleosols
    - Absence of pedogenic carbonate
    - No dry season
    - MAP <150 cm
  - Leaf Size Analysis
    - Consistent with paleosols
    - MAP varies with equation

Platanoxylon, stump of an extinct sycamore, 0.40 m in diameter, with no growth rings, rooted in a non-calcareous paleosol

Summary and Conclusions

- Dicot wood anatomy of the Jose Creek flora is comparable to that of the modern tropics/warm subtropics.
  - MAT most likely 24–26°C
  - Megathermal climate, ~40° paleolatitude
  - Within range of other MAT indicators
- Moist to wet climate.
  - No dry season
- Holdridge Life Zones



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    - Tom Waddell (manager)
    - Ted Turner (owner)
- Sources of data
  - Estrada-Ruiz et al., *Int. J. Plant Sci.* (2012, 2018)
  - Dissertation of Joan Parrott, Texas State University (2019)

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