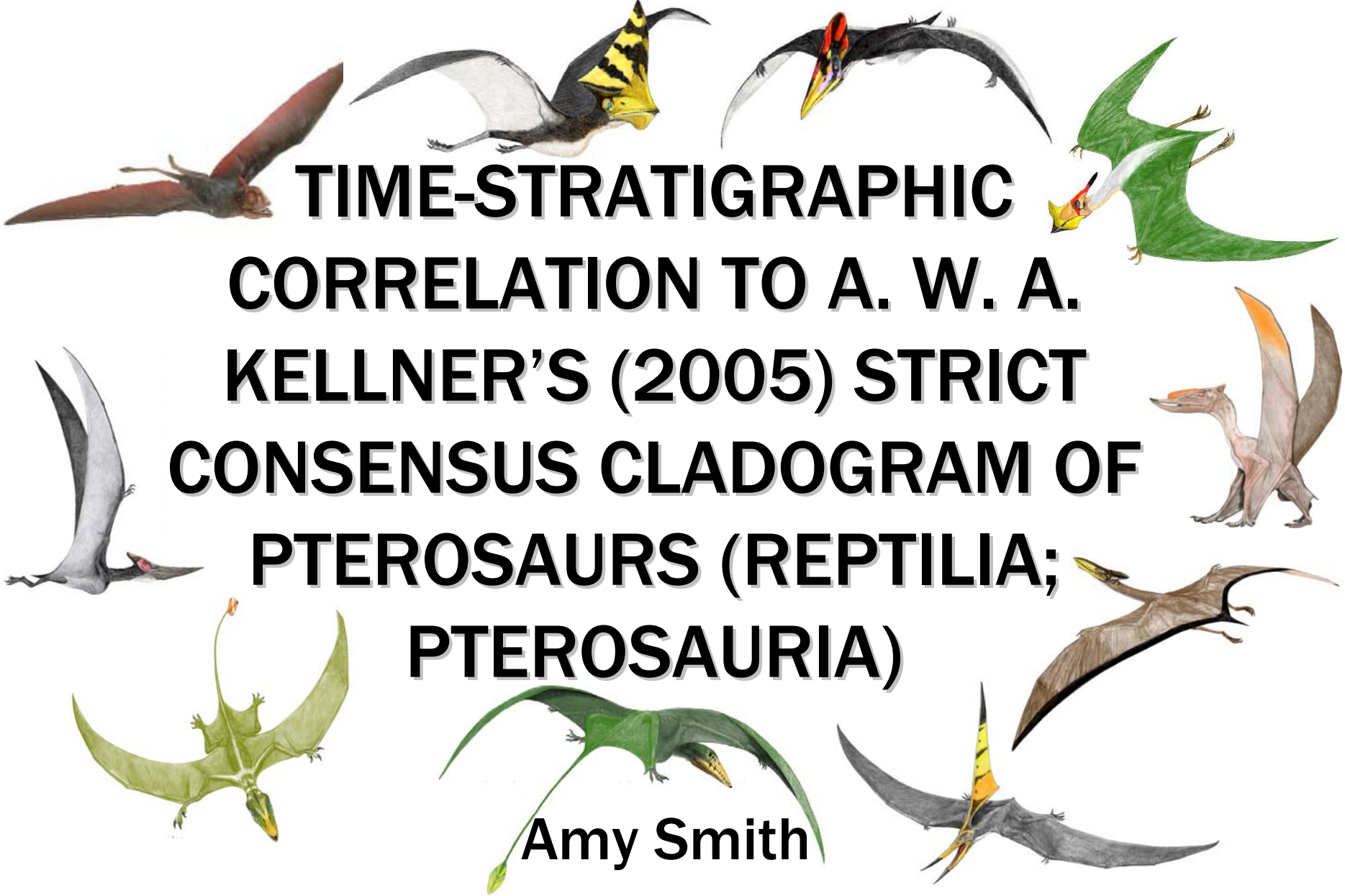


TIME-STRATIGRAPHIC CORRELATION TO A. W. A. KELLNER'S (2005) STRICT CONSENSUS CLADOGRAM OF PTEROSAURS (REPTILIA; PTEROSAURIA)

Amy Smith

havoc127@vt.edu

Established Methods of Comparing Stratigraphic Data to Cladistic Data

1. Spearman Rank Correlation (SRC): examines correlation between stratigraphic and cladistic data in respect to the order of group origins

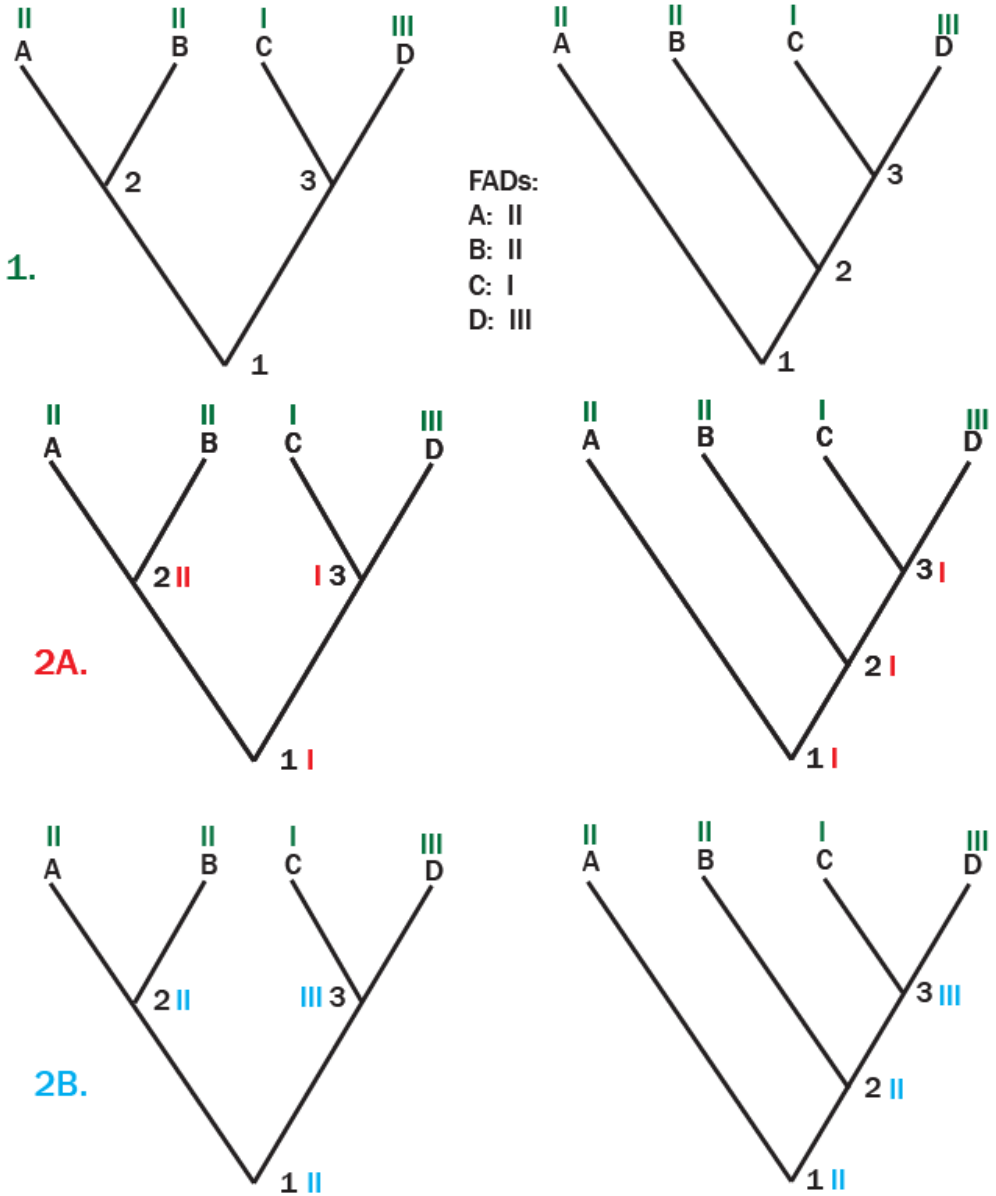
2. Stratigraphic Completeness Index (SCI): ratio of # of stratigraphically consistent nodes to # of internal nodes (excluding root)

3. Relative Completeness Index (RCI): compares known stratigraphic ranges to inferred stratigraphic ranges of a cladogram

4. Modified Manhattan Stratigraphic Measure (MSM*): based on the number and extent of ghost lineages

5. Gap Excess Ratio (GER): describes proportion of total ghost ranges necessitated by constraints of cladogram

Proposed Method of Comparing Stratigraphic Data to Cladistic Data: An Example



3. Neither cladogram shows any inconsistencies between divergence times of the various clades.

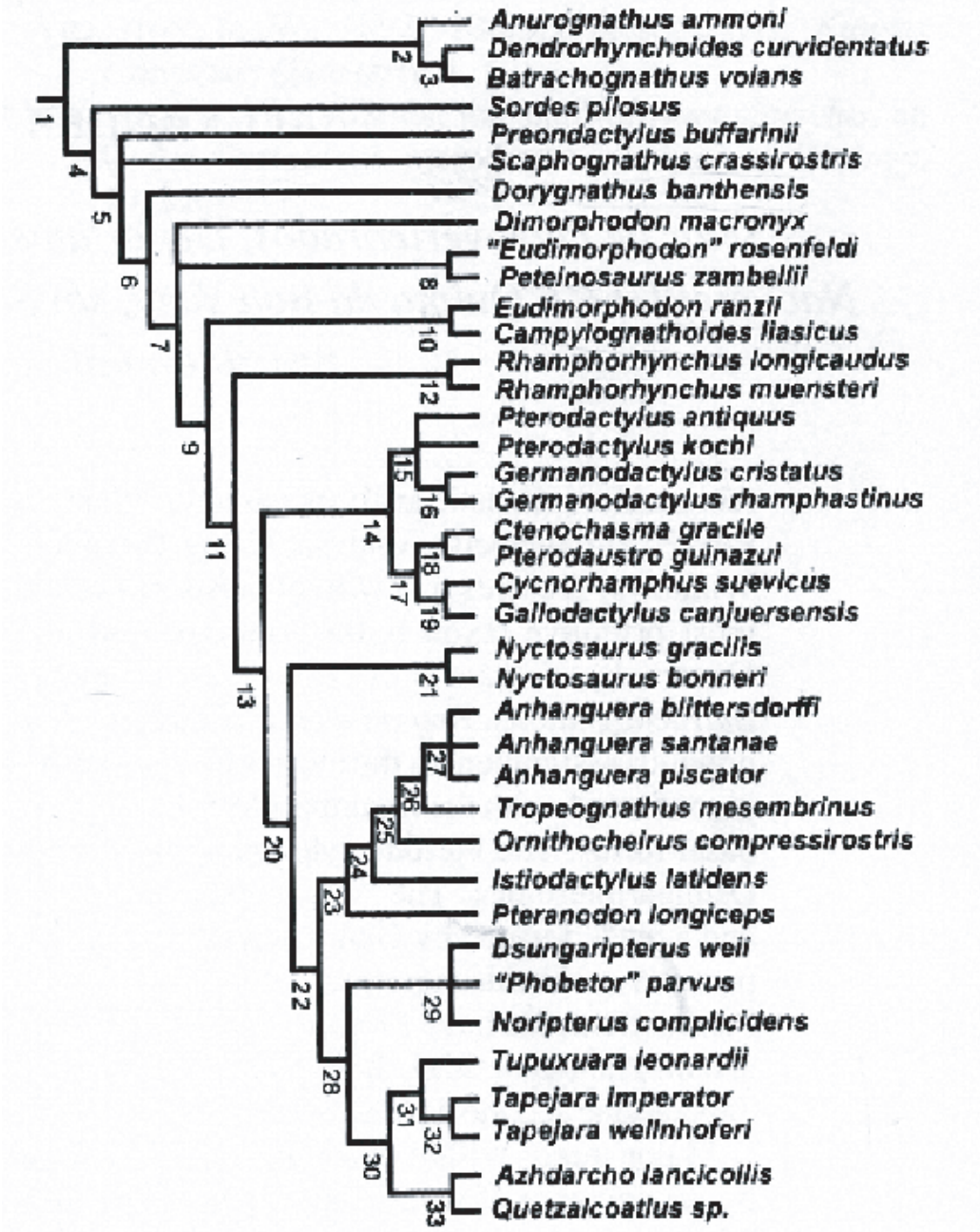
Differences between the Proposed Method and Previously Established Methods

Differences:

- The established methods result in index values that can be used to select an optimum phylogenetic hypothesis from competing phylogenies. This method, although theoretically capable of comparing competing phylogenetic hypotheses if both hypothesis contain the same taxa, focuses on specific inconsistencies within a single phylogenetic hypothesis in regards to ghost lineages and polytomies.

- Each individual node is seen to represent 2 separate times or events: the time of origination of all taxa within that clade, and the time of divergence of that clade.

Kellner's (2005) Strict Consensus Cladogram of Pterosaurs



Inconsistencies between Times of Clade Divergences

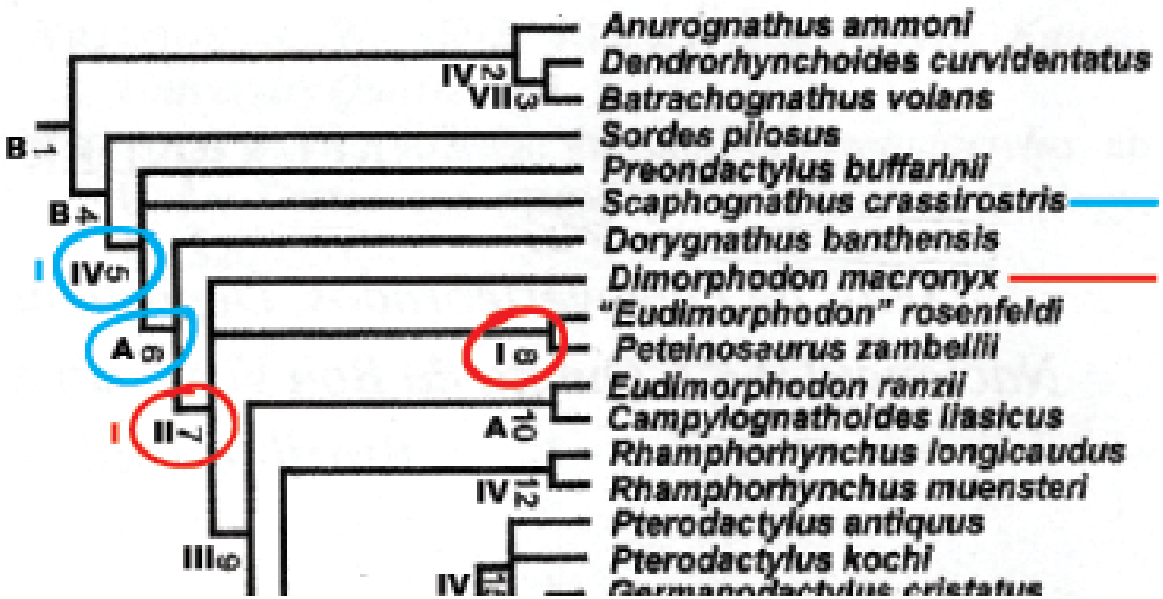
Overview:

Of the ten inconsistencies between divergence times of clades present in this cladogram:

- Two inconsistencies occur at sites of polytomies
- Six inconsistencies are unambiguous and do not occur at sites of polytomies
- Two inconsistencies are ambiguous due to poor stratigraphic resolution; one occurs at sites of a polytomy

Inconsistencies between Times of Clade Divergences

Two Pairs involving Polytomies



First Pair: The clades at nodes 7 and 8

The presence of *D. macronyx* at node 7 causes this clade to diverge in the Hettangian, after the clade at node 8 diverges (and the clade at node 9 originates) in the Norian.

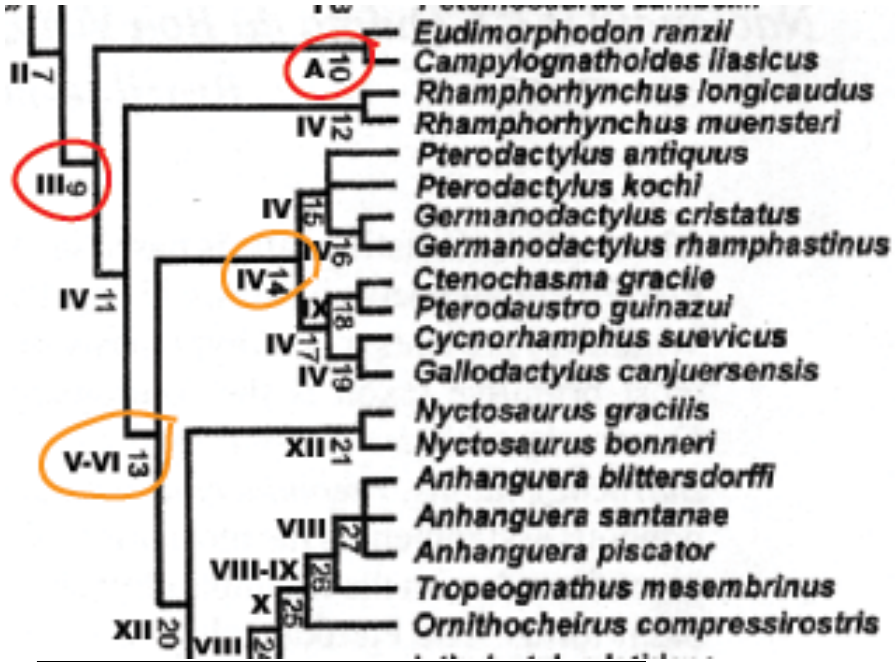
Symbol	Age	Symbol	Epoch
I	Norian		
II	Hettangian	A	Lower Jurassic
III	Kimmeridgian	B	Upper Jurassic
IV	Tithonian		
V	Berriasian	C	Lower Cretaceous
VI	Valanginian		
VII	Barremian		
VIII	Aptian		
IX	Albian		
X	Turonian		
XI	Coniacian		
XII	Santonian		
XIII	Maastrichtian		

Second Pair: The clades at nodes 5 and 6

The presence of *S. crassirostris* at node 5 causes this clade to diverge in the Tithonian, after the clade at node 6 diverges in the Lower Jurassic. However, a conflict is created between nodes 5 and 4.

Inconsistencies between Times of Clade Divergences

Six Pairs of Unambiguous Inconsistencies



Symbol	Age	Symbol	Epoch
I	Norian		
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VI	Valanginian		
VII	Barremian		
VIII	Aptian		
IX	Albian		
X	Turonian		
XI	Coniacian		
XII	Santonian		
XIII	Maastrichtian		

First Pair: The clades at nodes 9 and 10

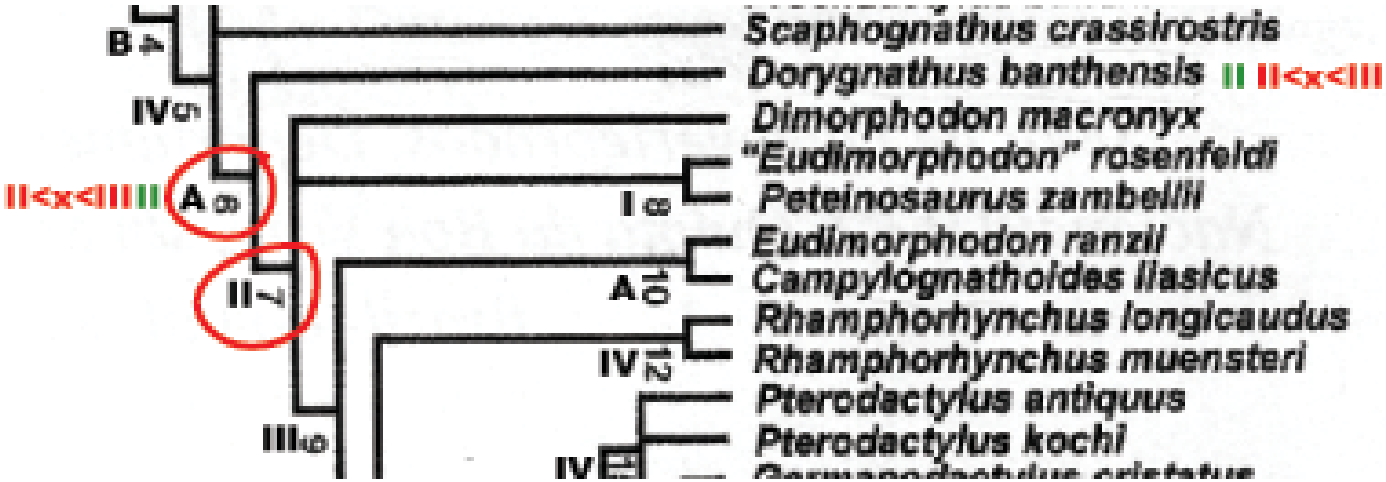
The clade at node 9 diverges in the Kimmeridgian (when the clade at node 11 originates) after the clade at node 10 diverges in the Lower Jurassic.

Second Pair: The clades at nodes 13 and 14

The clade at node 13 diverges in the Berriasian or Valanginian (when the clade at node 20 originates) after the clade at node 14 diverges in the Tithonian.

Inconsistencies between Times of Clade Divergences

Two Pairs of Ambiguous Inconsistencies



Symbol	Age	Symbol	Epoch
I	Norian		
II	Hettangian	A	Lower Jurassic
III	Kimmeridgian	B	Upper Jurassic
IV	Tithonian		
V	Berriasian	C	Lower Cretaceous
VI	Valanginian		
VII	Barremian		
VIII	Aptian		
IX	Albian		
X	Turonian		
XI	Coniacian		
XII	Santonian		
XIII	Maastrichtian		

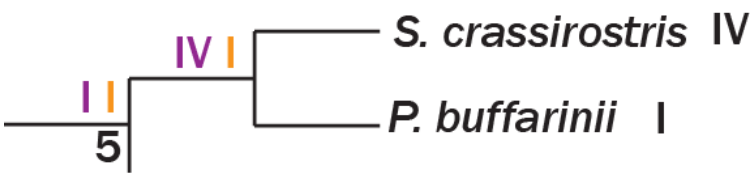
First Pair: The clades at nodes 6 and 7

If *D. banthensis* occurs only in the Hettangian, the clade at node 6 diverges in the Hettangian, presumably before the clade at node 7 diverges in the Hettangian.

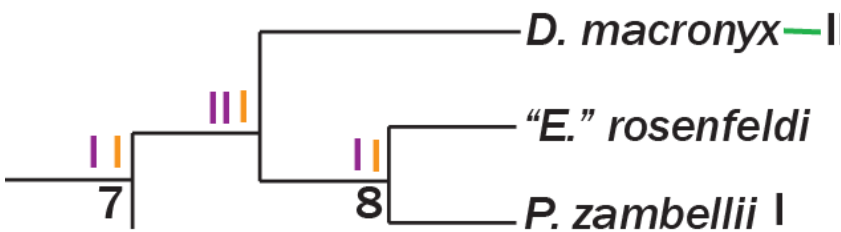
If *D. banthensis* instead occurs in an Age between the Hettangian and Kimmeridgian (ie., during any of the eight Ages that span between these times), then the clade at node 6 diverges after the clade at node 7 diverges in the Hettanginian.

Conclusions

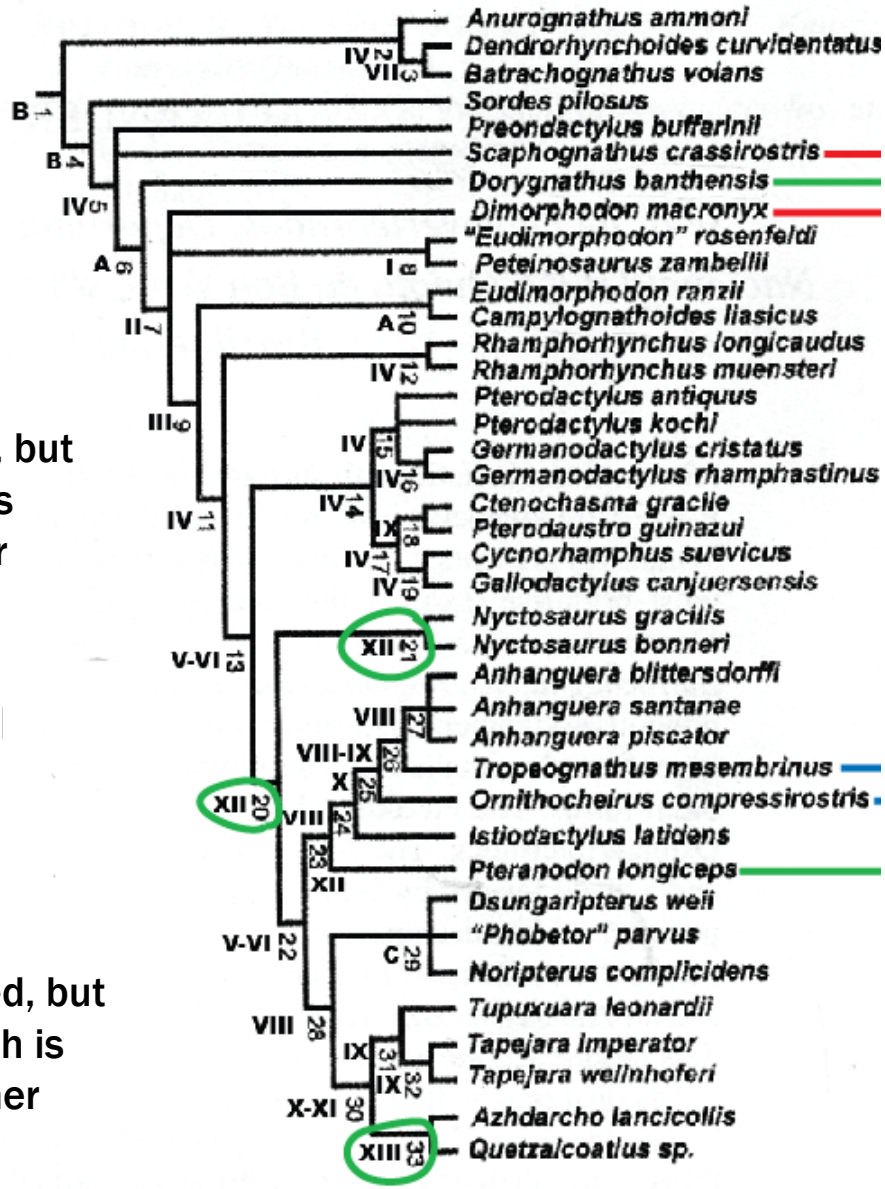
1. In the case of polytomies with inconsistencies, some taxa may be misplaced, in addition to having ghost lineages.



The conflict between nodes 5 and 6 is resolved, but a conflict arise between nodes 5 and 4, which is resolved by a ghost lineage proposed by Kellner (2005) for *Sordes*.

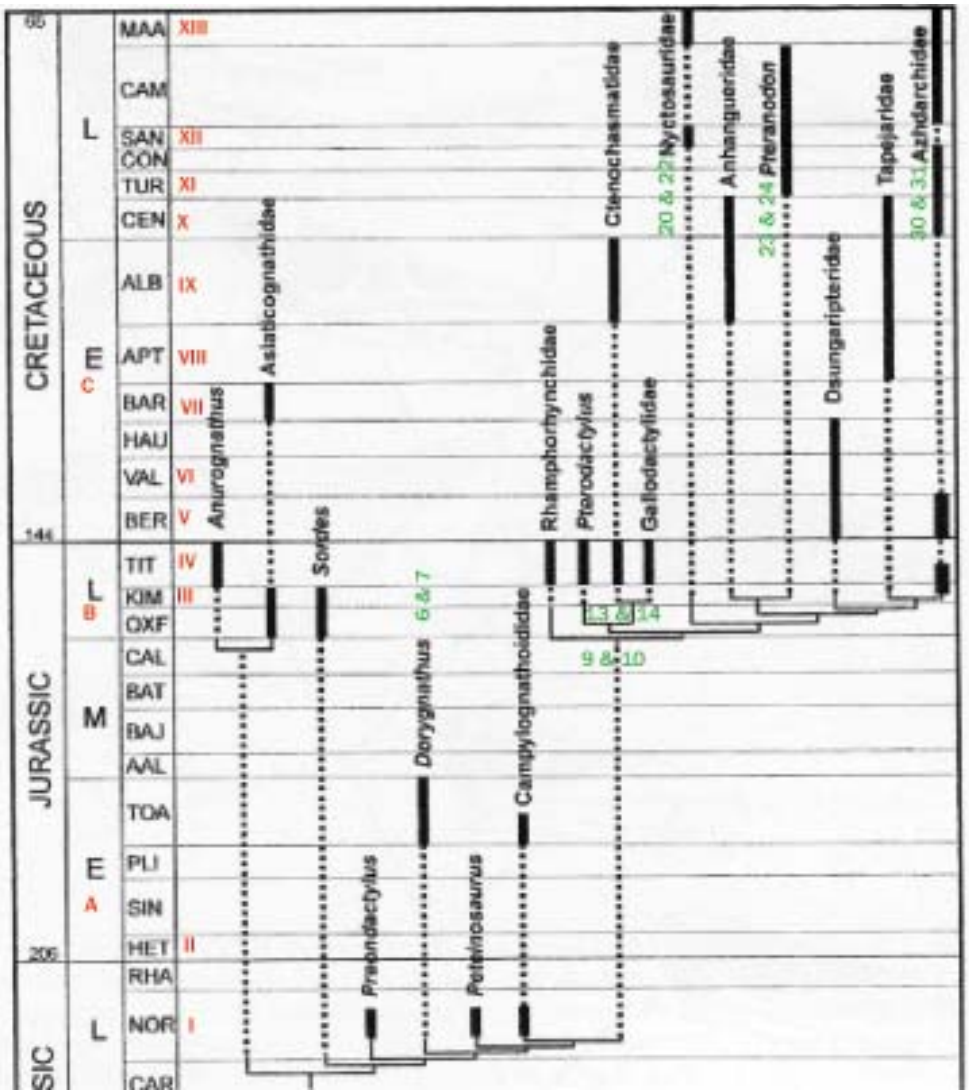


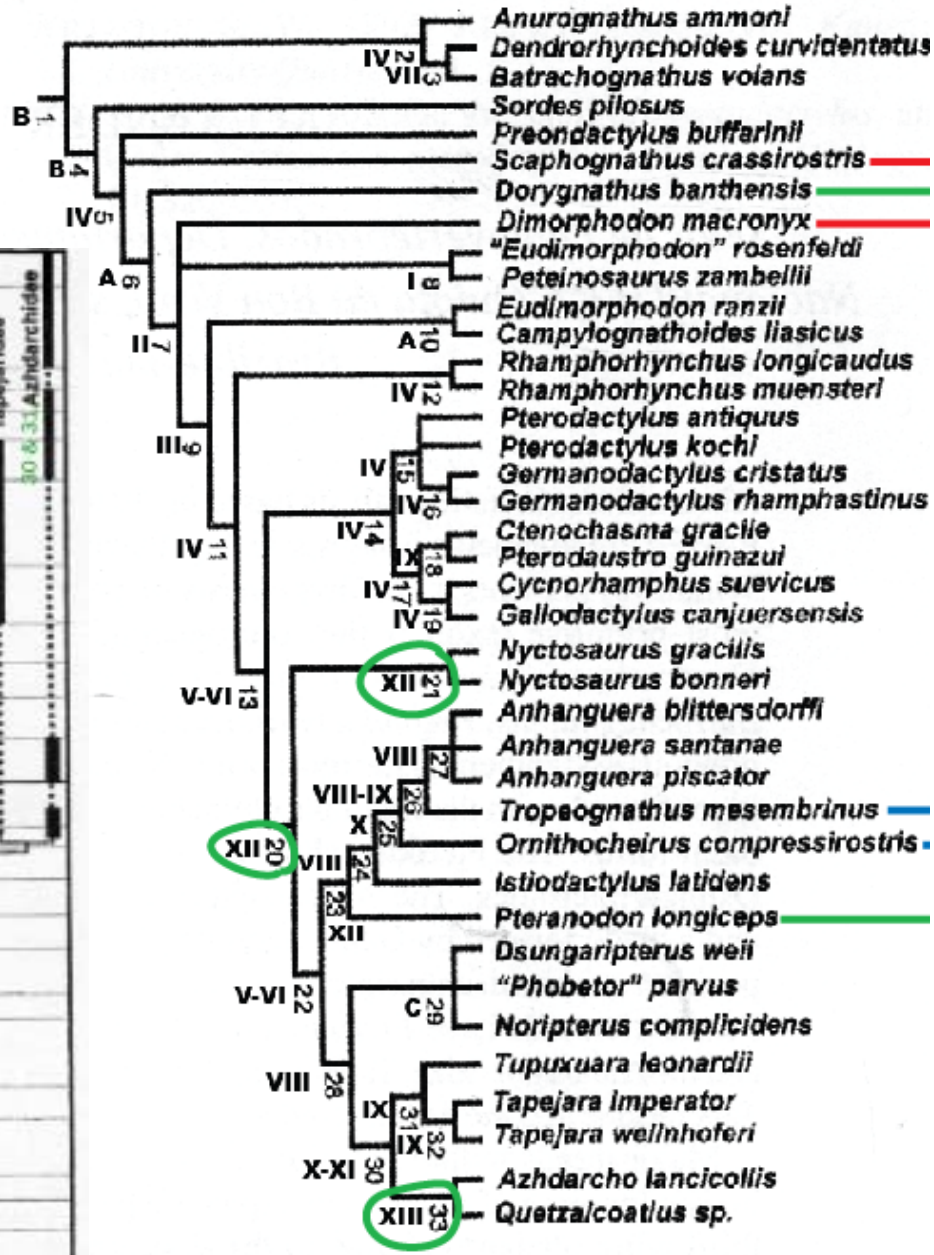
The conflict between nodes 7 and 8 is resolved, but a conflict arises between nodes 7 and 6, which is resolved by a ghost lineage proposed by Kellner (2005) for *Dorygnathus*.



Conclusions

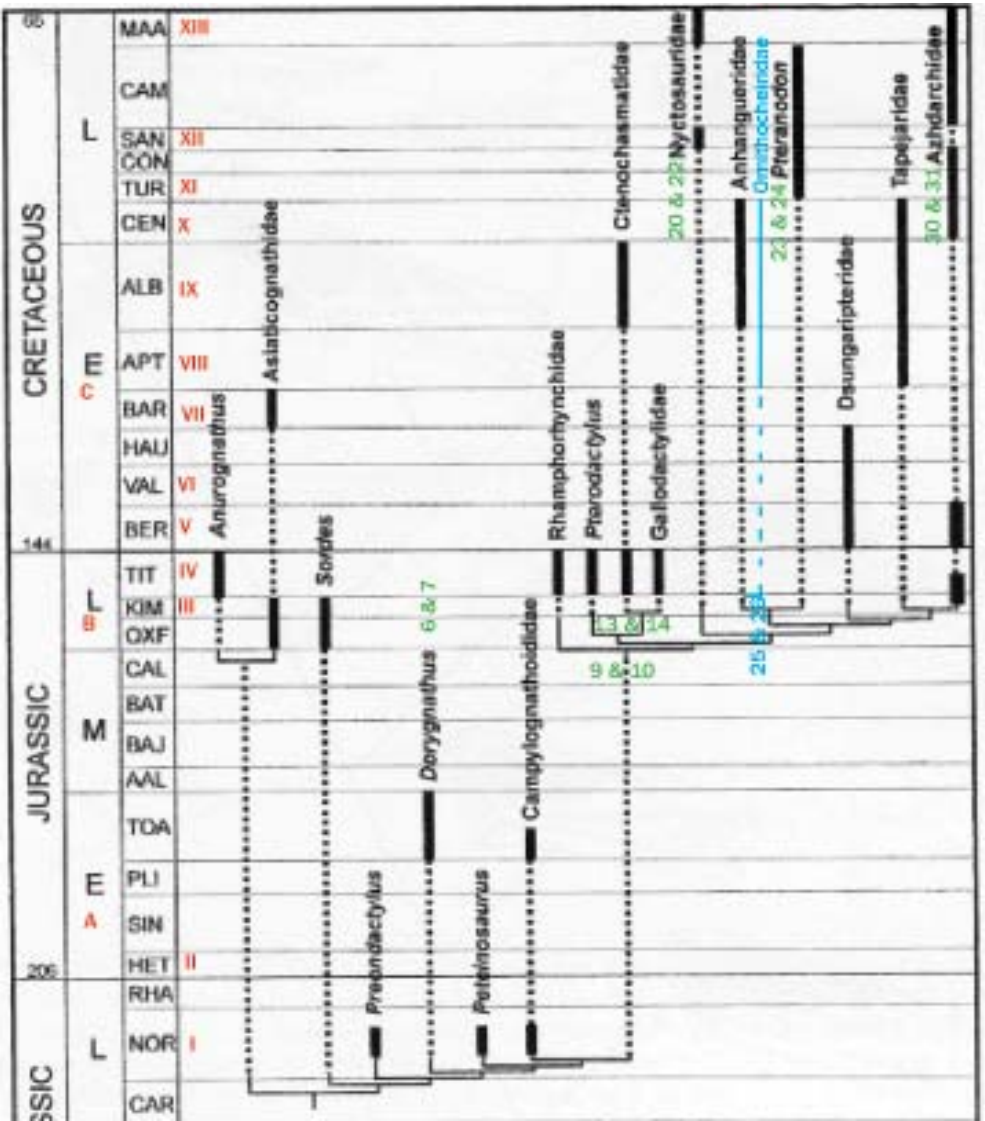
2. Ghost lineages presented in Kellner's (2005) biochronology explain some inconsistencies.

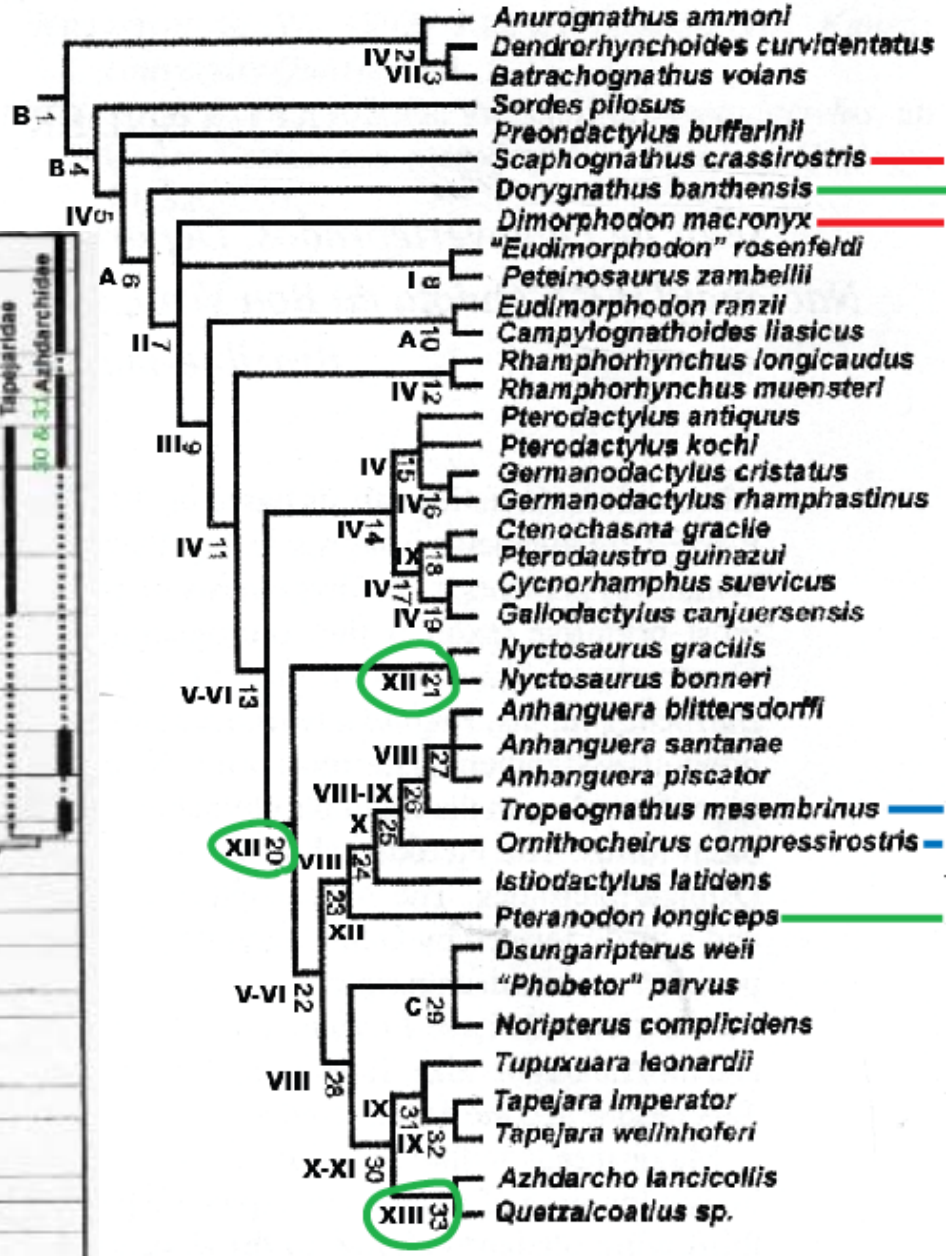




Conclusions

3. Previously undescribed ghost lineages may explain the rest of the inconsistencies.





Directions for Future Work

Search for statistically significant correlations between polytomies and stratigraphic inconsistencies within several different phylogenetic hypotheses.

Null hypothesis: There is no correlation between polytomies and stratigraphic inconsistency.