

Accretionary growth?: Exploring the evolution of the literature on stromatolite morphogenesis



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Introduction

- **Stromatolites** are **laminated sedimentary features** that are constructed by **microbes**.
 - Relationships between **environmental** or **biological** factors and stromatolite **morphology** remain poorly understood.
 - Here, we quantify the evolution of the literature on **stromatolite morphogenesis**. Ultimately, we want to understand what ideas have solidified (and which have been forgotten).

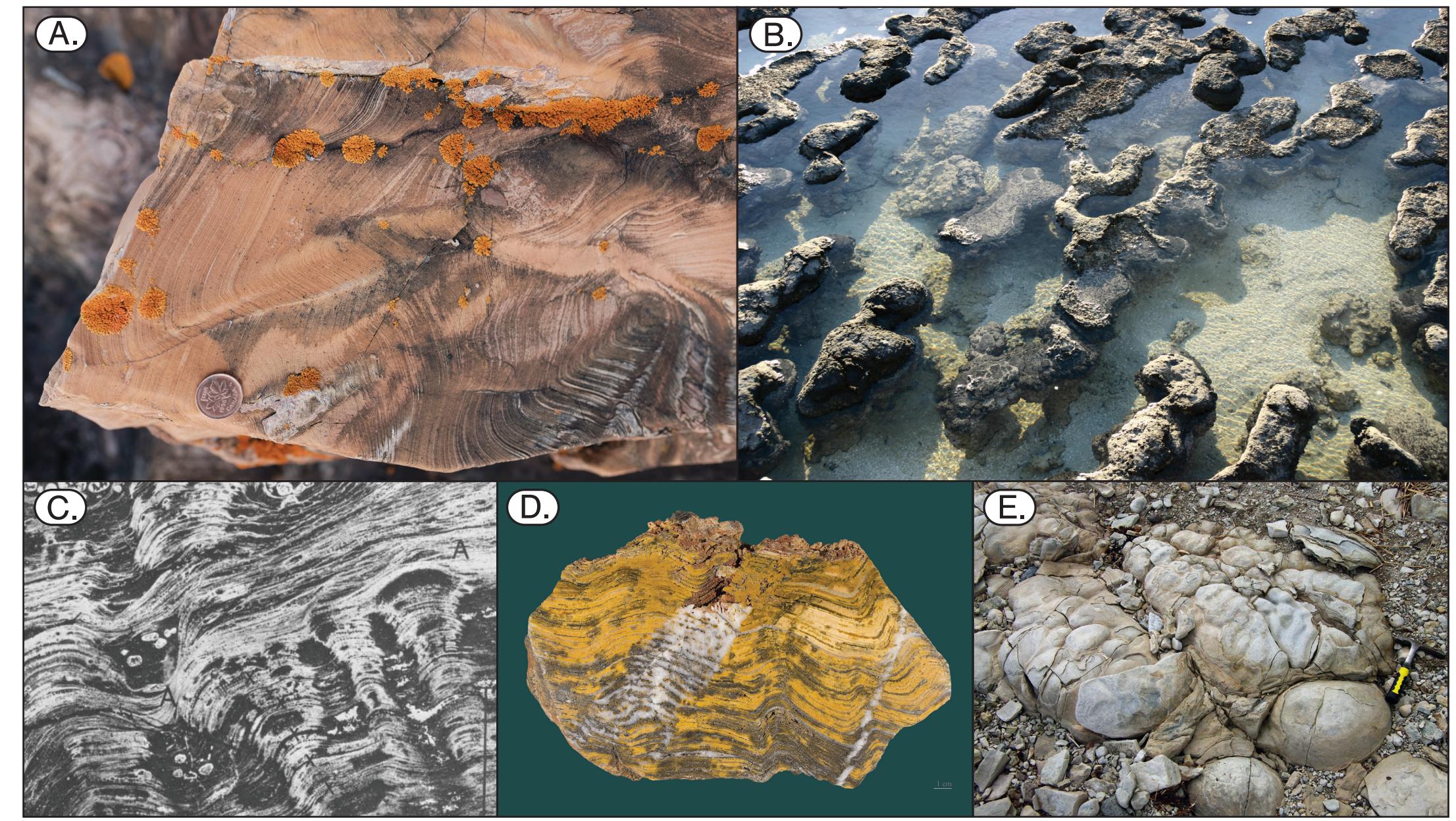


Figure 1. (a) 1.9 billion year old stromatolite from the Pethei Group at Tu Nedhé (modern Great Slave Lake, NWT, CA). (b) Modern stromatolites at Gutharraguda (modern Hamelin Pool, Shark Bay, Australia; Martin Kraft, 2004). (c) 1.9 billion year old stromatolite laminae from the Gunflint Formation (near Animkii Wajiw, modern Mink Mountain, ON, CA). Scale 1 cm (Pannella, 1976). (d) 3.4 billion year old stromatolite in Strelley Pool Chert from the Pilbara Craton (Western Australia; Didier Descouens, 2011). (e) 425 million year old stromatolites from the Soeginina Beds in Estonia (Tõnu Pani, 2011).

Background

- First recorded observations of stromatolites date back to **1825** (Steel, 1825).
 - First use of the term “stromatolite” was in **1908** (Kalkowsky, 1908).
 - A major review was published in **2013** (see Bosak, et al., 2013), but stromatolites are discussed in other recent, targeted reviews.

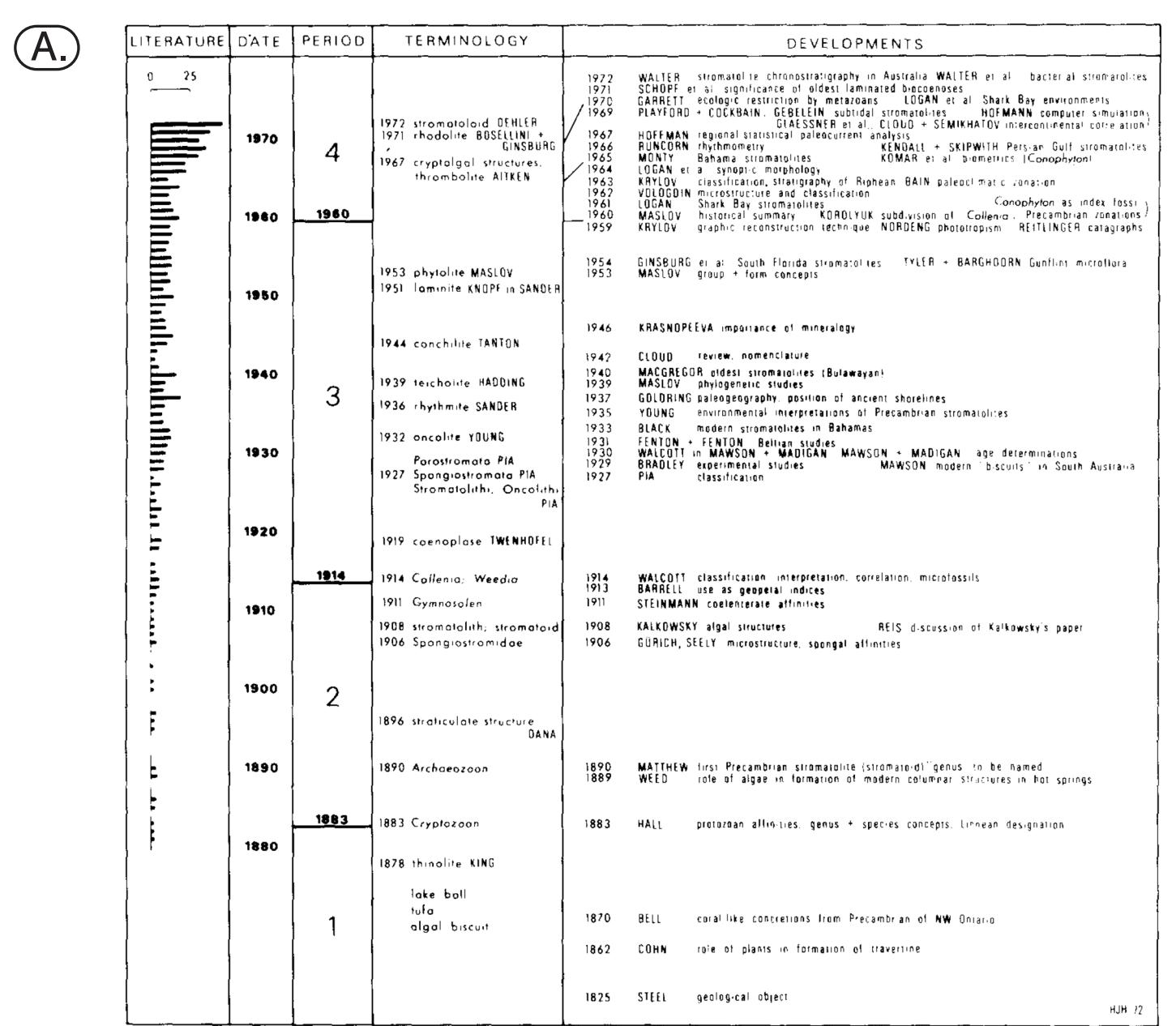
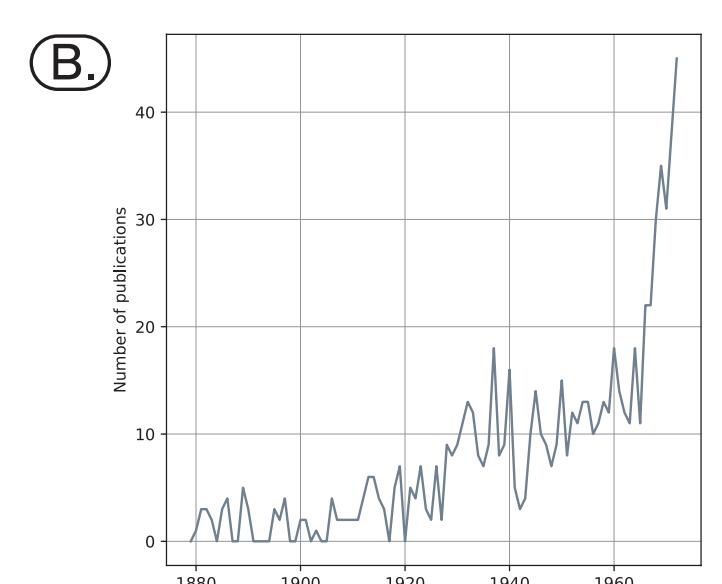


Figure 2. (a) Quantification of the literature on stromatolites circa 1973 (Hofmann, 1973). (b) Digitization of publication data from Hofmann, 1973.



- **Large literature databases** (e.g., xDD, Web of Science, Google Scholar) provide searchable repositories of publication data from disparate sources.
 - **Bias** towards dominant languages and geographies, limitations in data licensing, etc., in large databases can produce **misrepresentative datasets**, elevating the risk for aberrant interpretation(s) (e.g., Mehra, et al., 2021).

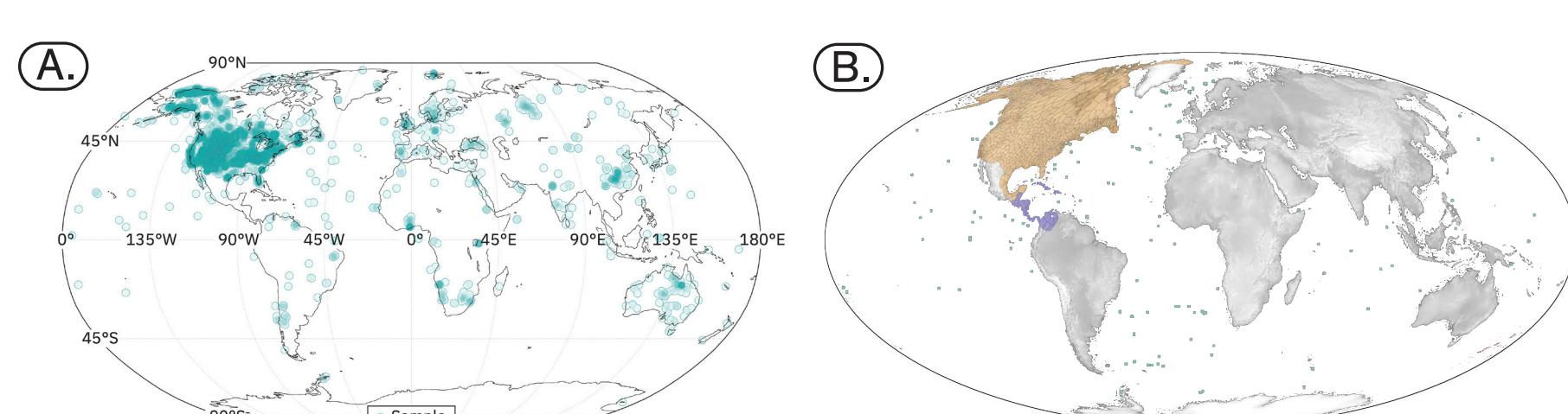


Figure 3. (a) Sample locations in the Sedimentary Geochemistry and Paleoenvironments Project database. (b) Distribution of stratigraphic columns in the Macrostrat database.

Workflow

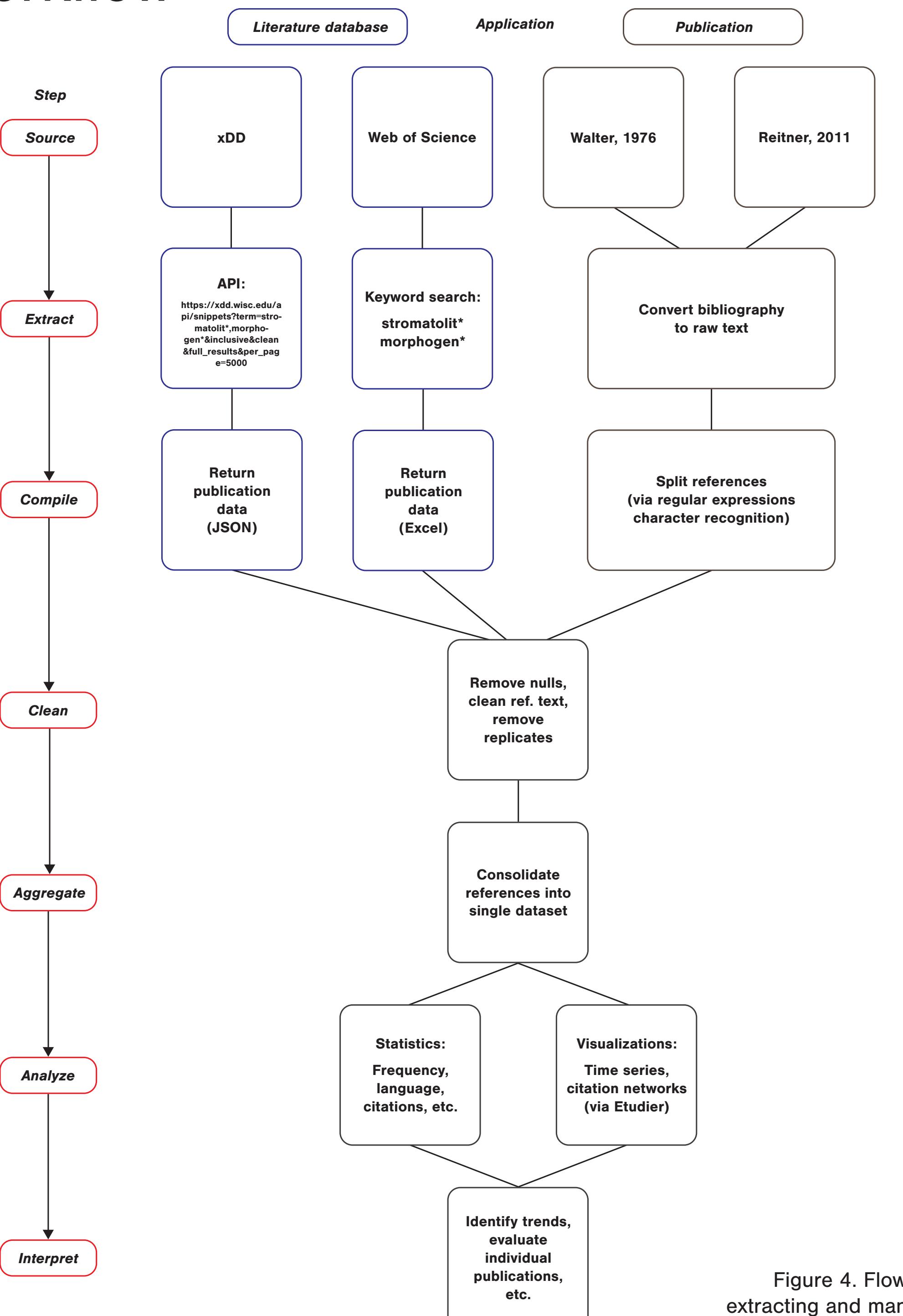


Figure 4. Flowchart for extracting and manipulating publication-specific data

Output

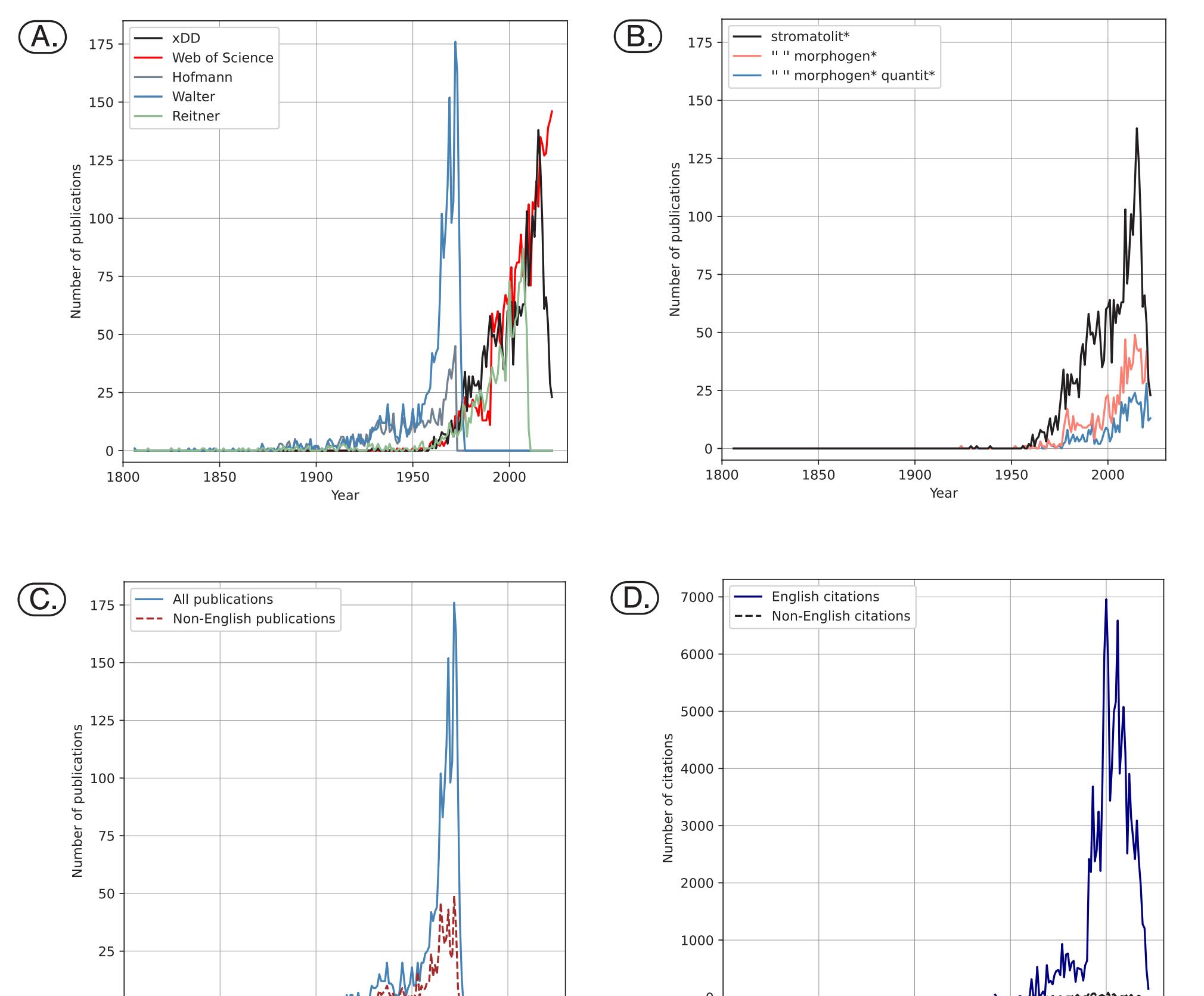


Figure 5. (a) Total **number of publications** on stromatolites from 1806 to present, with different colors representing different sources. (b) **xDD corpus** plotted by year with keyword filters for “**morphogen***” and “**quantit***”. (c) **Bibliography** from Walter, 1976, plotted by year and filtered for non-English publications. (d) Total **number of citations** for **English** and **non-English** literature by publication year

Findings

- Discussion of “**morphogenesis**” begins in **1966 (Semikhato^v, et al., 1966)**.
 - **Morphogenesis-specific** publications comprise **36%** of the corpus.
 - **48%** of morphogenesis-specific publications refer to “**quantitative**” methods.
 - **Non-English** publications make up **33%** of the bibliography from Walter, 1976, totalling **667** references. **57%** of these publications are authored in **Russian**.
 - Comparatively, **9%** of the references in Bosak, 2013 are associated with the **Russian cohort**, with only **3%** of citations authored in **non-English** languages.

Discussion

- **Morphogenesis** is a **consistent theme** throughout the evolution of stromatolite research and holds **historical significance** for questions regarding the **evolution of life and the environment**.
 - Large literature databases are limited in their representation of the corpus—for example, **non-English publications are missing** from databases. Recognizing this limitation provides us with an opportunity to apply **underexplored contributions** to open research questions.

Future work

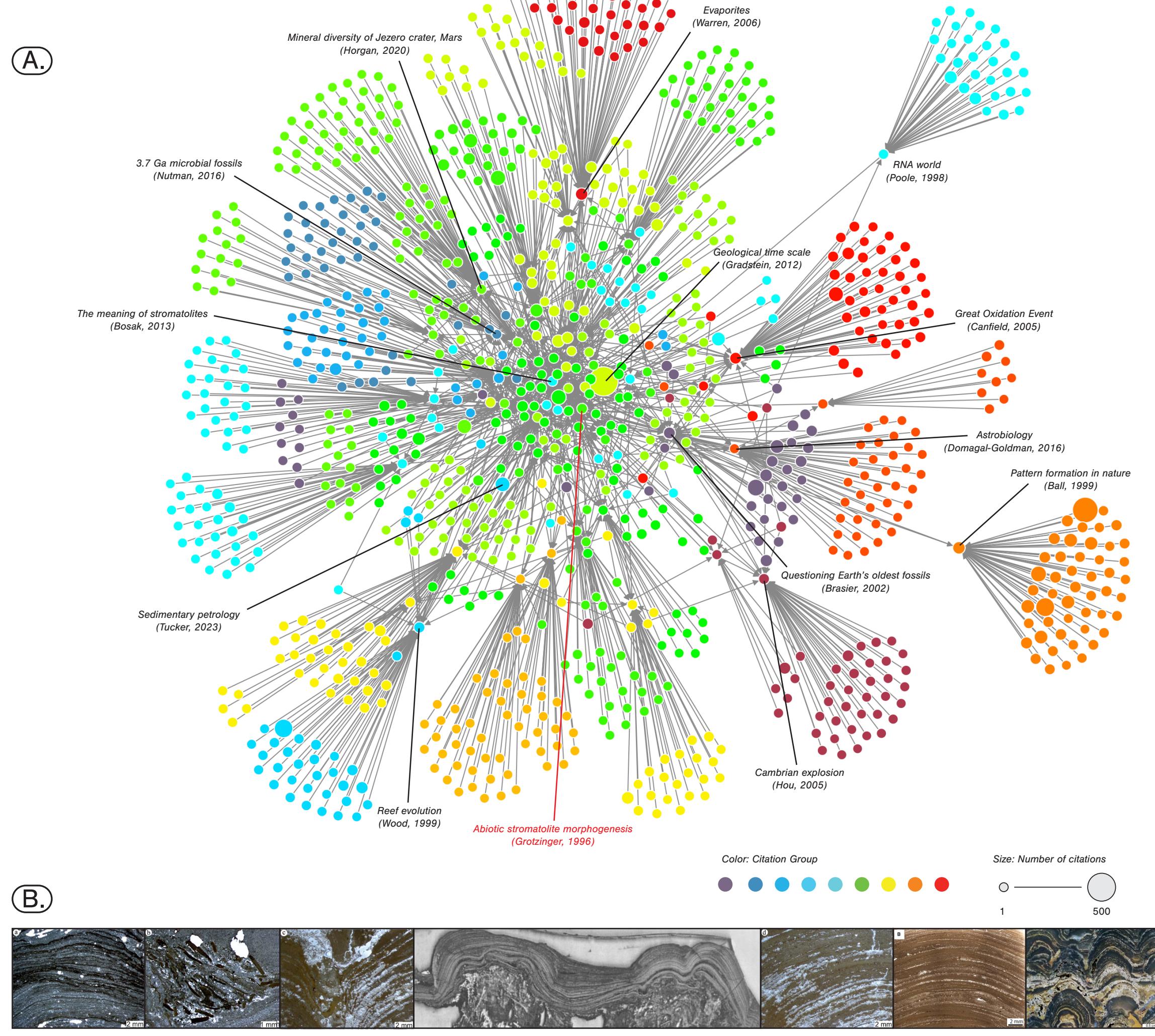


Figure 6. (a) Citation network of the highest-cited publication on stromatolite morphogenesis: “An abiotic model for stromatolite morphogenesis” (Grotzinger, 1996). Network generated using source code available at <https://github.com/edsu/etudier>. Nodes are annotated with abbreviated publication titles. (b) Images of stromatolite laminae. We will use similar images to generate a neural network for image processing and morphological characterization. (Image sources listed in references.)

- Translate non-English publications and evaluate for novel hypotheses.
 - Characterize the evolution of stromatolite research using **citation networks** and **large language models**.
 - Publish this work (and references within) in an easily accessible **database**.
 - Develop a stromatolite morphology **image dataset** (e.g., Geyman, personal correspondance)

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Image sources for Figure 6:

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