MICROPALEONTOLOGY INVESTIGATIONS AND NEUTRON ACTIVATION ANALYSIS OF CARBONACEOUS METEORITES

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INTRODUCTION

Meteorites are Typically Classified on the Basis of Mineralogy, Structure, Physical Properties and Chemical Composition.

Polonnaruwa has Abundant REE; Platinum Group Metals(Ir, Ru, Re); Ti, W & U

Radiochemical Neutron Activation Analysis is Powerful Tool for Study of these Meteorites

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INTRODUCTION

Environmental and Field Emission Scanning Electron Microscopy (ESEM & FESEM) with Energy Dispersive X-Ray Spectroscopy (EDS) and 2D X-Ray Maps has Provided a Powerful Tool to Search for Biological Remains in Uncoated Meteorites and Detect C & N to Distinguish Indigenous Microfossils from Post-Arrival Biological Contaminants

CARBONACEOUS METEORITES

Class of Chondrites with 8 Known Groups

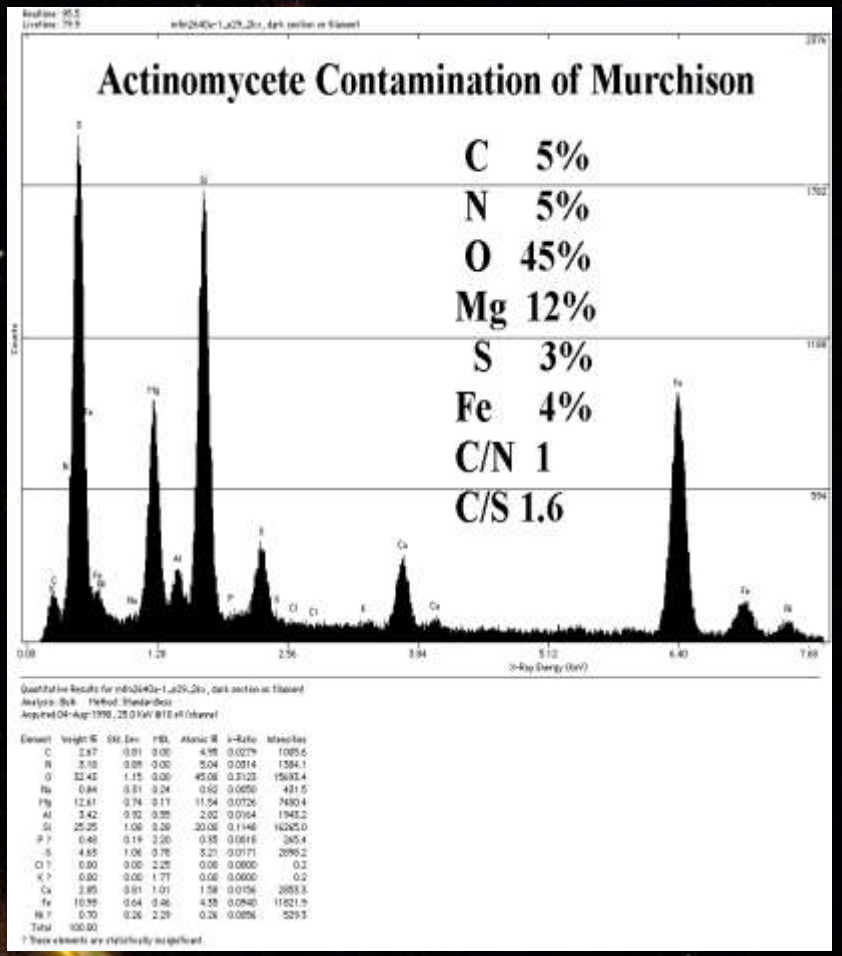
Primitive Meteorites: Elements~Solar Photosphere
CI & CM ~ 3%-22% Deuterium Enriched Water
and ~ 4 Wt% Extraterrestrial Carbon

Volatiles & Organics Indicate Heating < 200 C;
Organic Grains in Matrix ~ Kerogen or Coal

Have Extraterrestrial Nucleobases & Biomolecules
(Murchison: Uracil $\delta^{13}C$ = +44.5‰; Xanthine = +37.7‰)

Aqueous Alteration of Minerals & D/H Ratio Prove
Presence of Liquid Water on CI&CM Meteorites
Probable Parent Bodies: Comets or C-Asteroids

Nitrogen & Beam Damage to Detect Recent Contaminants in Meteorites



Nitrogen @ 5% Indicates Recent Bio-Contaminant

Micropaleontology of Carbonaceous Meteorites

Fossils in Carbonaceous Meteorites Mainly Cyanobacteria. Permineralized Carbon-rich Sheaths with Size & Morphology of Many Known Genera & Species of Cyanobacteria & Acritarchs

DIVERSE MODES OF REPRODUCTION: Distinctive Characteristics of Life

Septate Binary Fission & Cleavage

Multiple Fission (Baeocytes)

Trichomic Fragmentation (Hormogonia)

Resting Cells/Germination (Spores & Akinetes)

Micropaleontology of Carbonaceous Meteorites

CYANOBACTERIA

("Blue-Green Algae")

Oxygenic Photosynthetic Prokaryotes

Photoautotrophs-Use H2O as Photoreductant & CO2 as Source of C for Energy & release Oxygen

Some are Facultative Chemoheterotrophs and use PSII for *Anoxygenic Photosynthesis of H_2S*

Precise Size & Characteristics of Cells, Sheath, Trichome & Filament are Taxonomic Diagnostics

Strong Biomarkers in Murchison CM2 and Orgueil CI1 Meteorites

In Nature Only from Complex Metabolic Bio-Pathways

Chiral Amino Acids with Moderate to Strong L-Excess

Engel & Nagy, *Nature,* **296,** 837, 1982; Engel *et al.* in *Perspectives in Astrobiology,* 2005.

Pristane ($C_{19}H_{40}$, Phytane $C_{20}H_{42}$, & NorPristane $C_{18}H_{38}$

Kissin, *Geochm. Cosm. Acta,* 67, 1723-1735, 2003

Pristane --(2,6,10,14-tetramethylpentadacane)

Phytane - (2,6,10,14-tetramethylhexadacane)

Pristane & Phytane-C19 & C20 isoprenoid hydrocarbons derived from phytol chain of the Photosynthetic Chlorophyll Biomolecules

NO MECHANISMS ARE KNOWN FOR ABIOTIC PRODUCTION OF THE COMPLEX CHLORIN BIOMOLECULE CHLOROPHYLL

Chemical Biomarkers: Biological Fractionation of Stable Isotopes

Terrestrial Life Prefers ^{12}C over ^{13}C

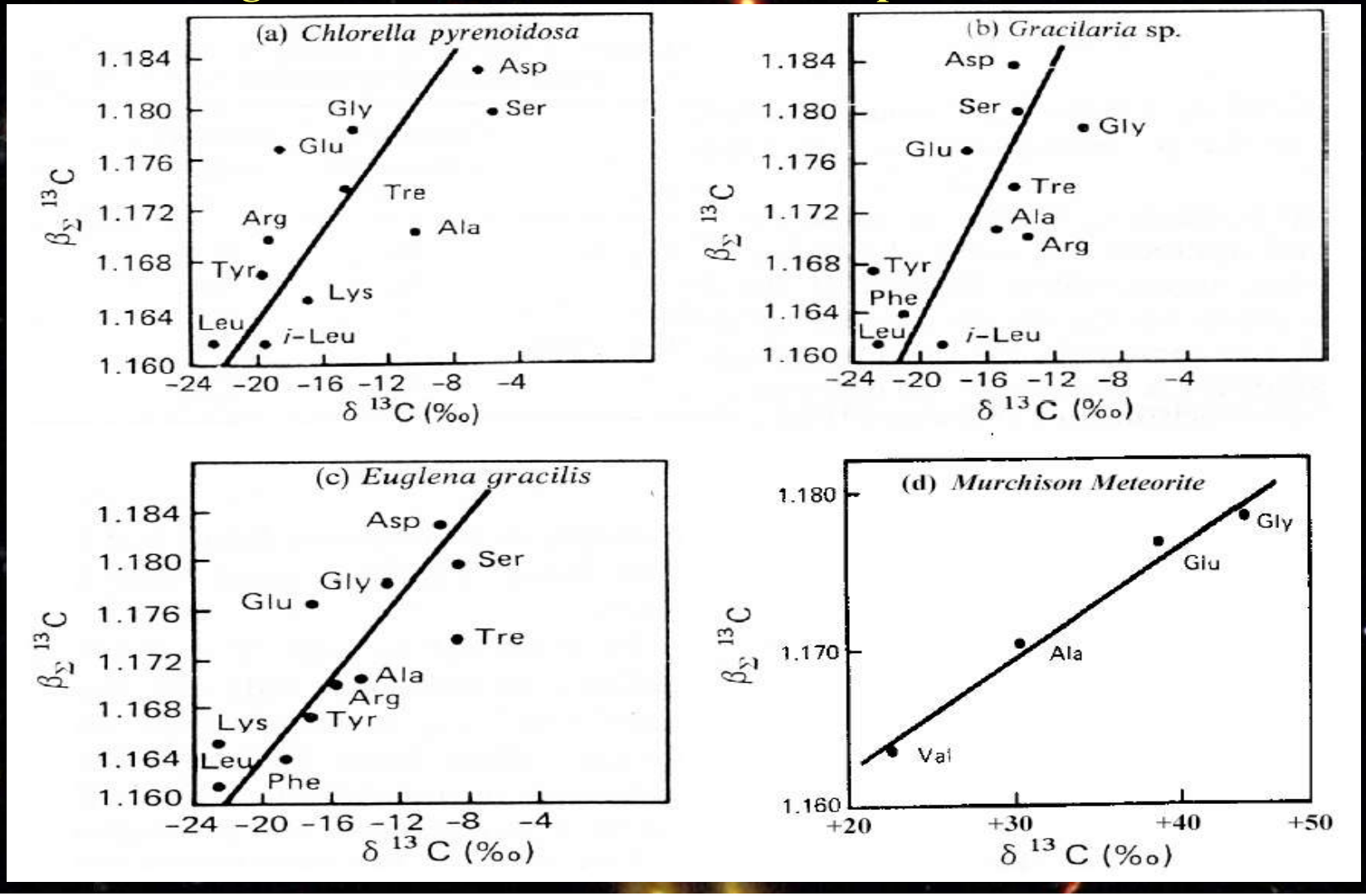
$\delta^{13}C \sim$ +5 to –9 for inorganic Carbon on Earth
$\delta^{13}C \sim$ –5 to –39 ‰ for C4 Plants & Cyanobacteria
$\delta^{13}C \sim$ –20 to –42 ‰ for Methanogenic bacteria
$\delta^{13}C \sim$ –25 to –85 ‰ for Methanotrophic bacteria
$\delta^{13}C \sim$ +10 to +60 ‰ Carbonaceous Meteorites

Galimov: **Thermodynamic Fractionation; $\beta\Sigma^{13}C$ of Carbon in amino acids of Carbonaceous Meteorites**

"Stable Isotopes show Carbon in Meteorites is clearly Extraterrestrial but analogous to terrestrial biology"

Carbon Isotope Biomarkers in Meteorites:

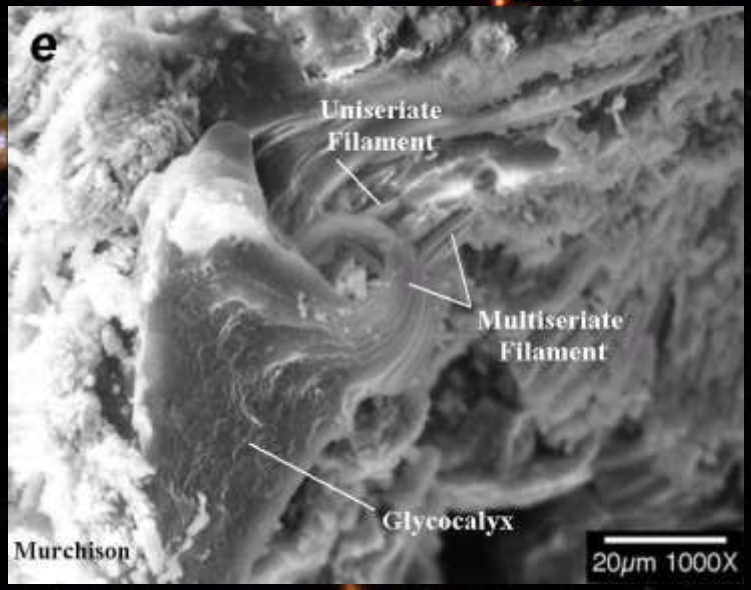
Analogous Fractionation of Stable Isotopes in Amino Acids

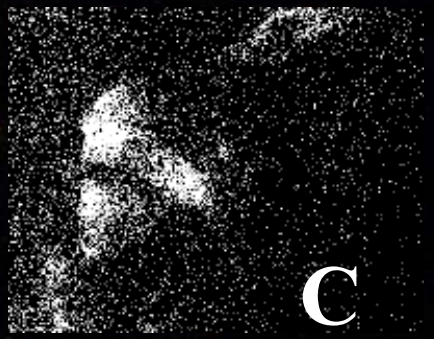


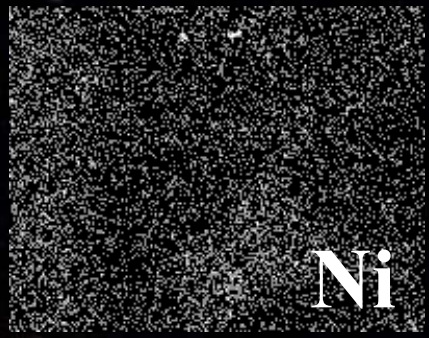
Thermodynamic Isotopic Fractionation $\beta_\Sigma = \frac{1}{n}\sum_i \beta_i$

Galimov, Eric M., "The Biological Fractionation of Stable Isotopes" Academic Press, New York, p. 98, (1985).

Morphotypes of *Microcoleus, Phormidium, and Nostoc* - Carbonized Glycocalyx



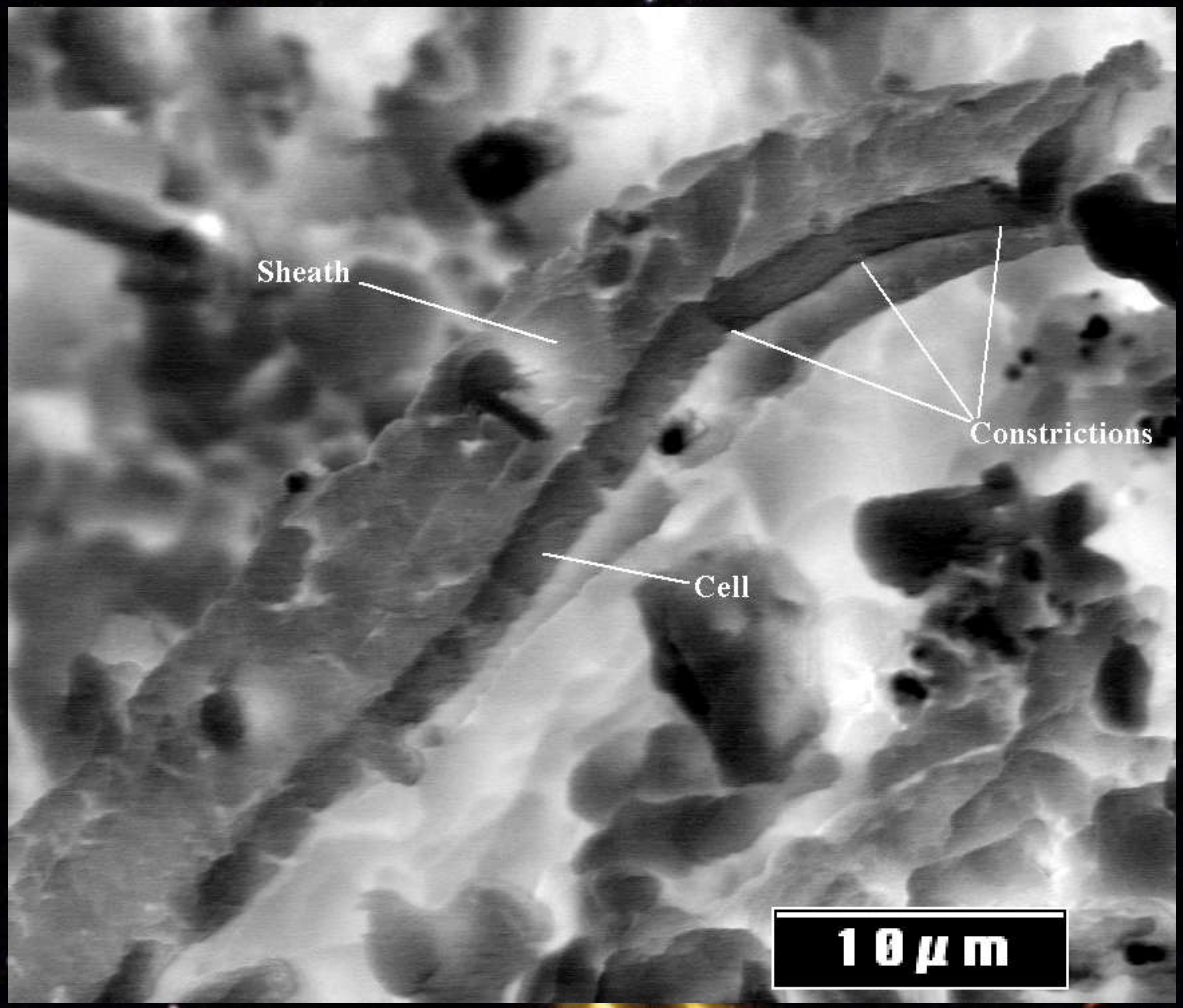




- 2D EDS X-Ray Maps of Indigenous Microfossils in Murchison

Reproductive Modes in Orgueil Microfossils

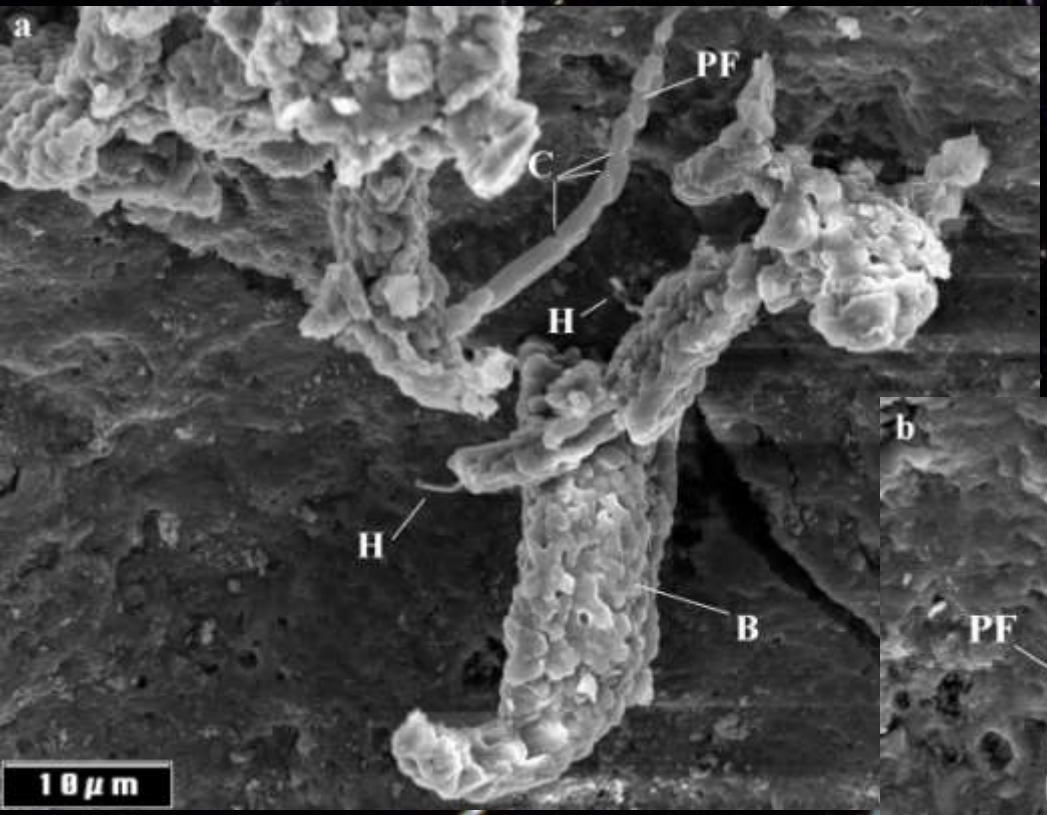
Septate Binary Fission & Cleavage



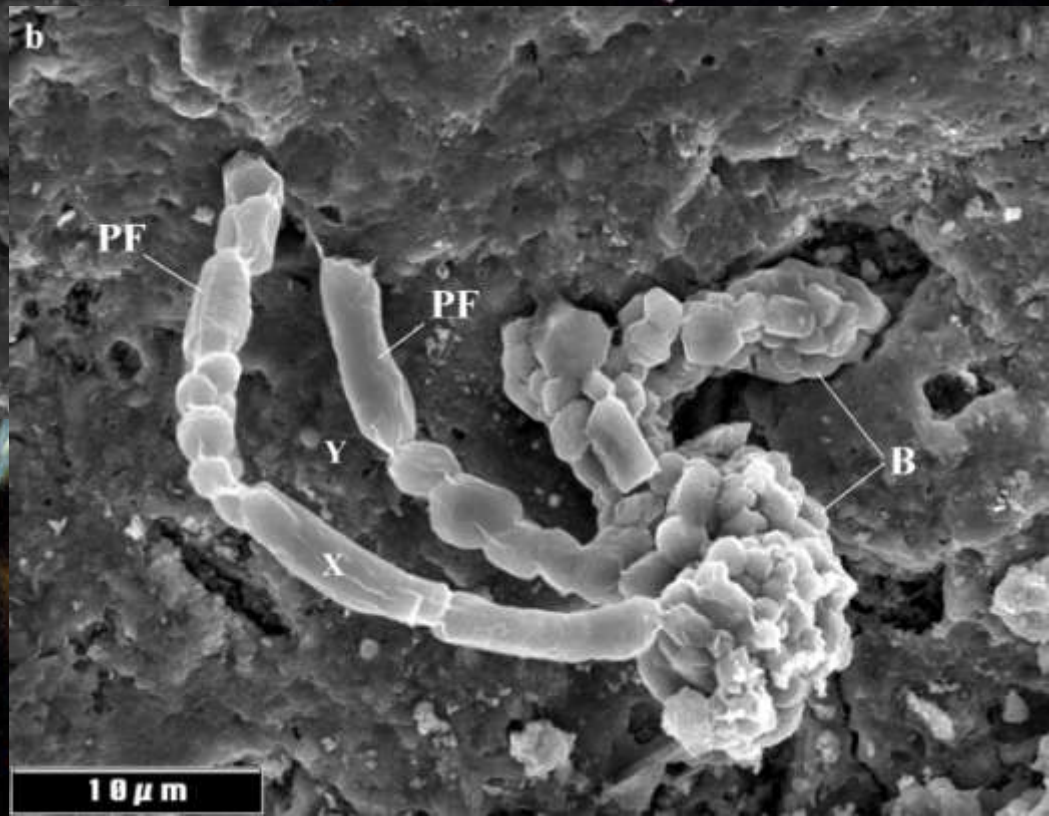
BSED image of 10 µm diameter filament with thick electron transparent sheath enclosing Uniseriate Linear Chain of 1.8 µm dia. X 5.5 µm Long Cells in Trichome

Orgueil Microfossils of Order: *Pleurocapsales*

Reproduction by Multiple Fission (Baeocytes)



Nitrogen-Fixing by Cells Sausage-Shaped Chains with Reproduction by Baeocyte Formation

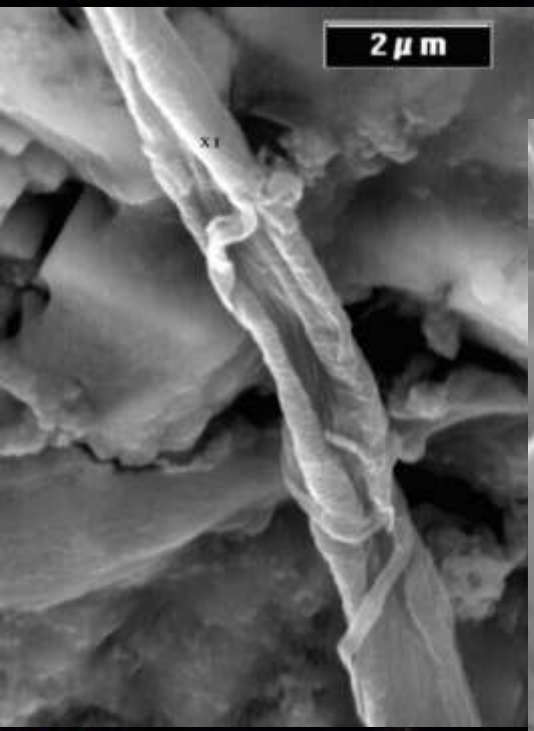


Polygonal Coccoids in Pseudo-filaments with Terminal Hairs and Carbonaceous Sheaths

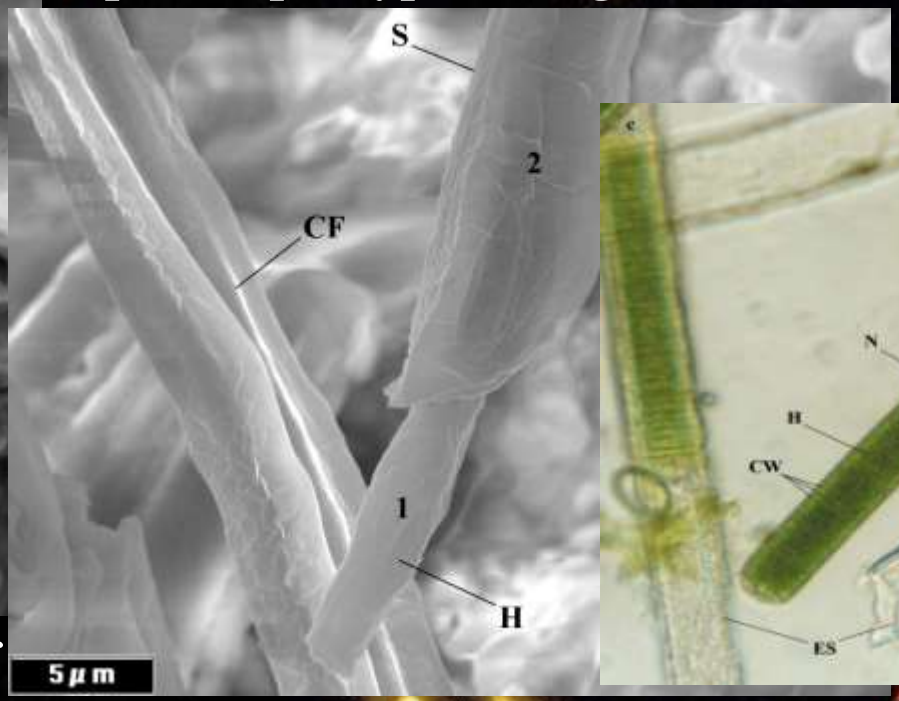
Reproductive Mode: Emergent Hormogonia in Orgueil Similar to Living Cyanobacteria

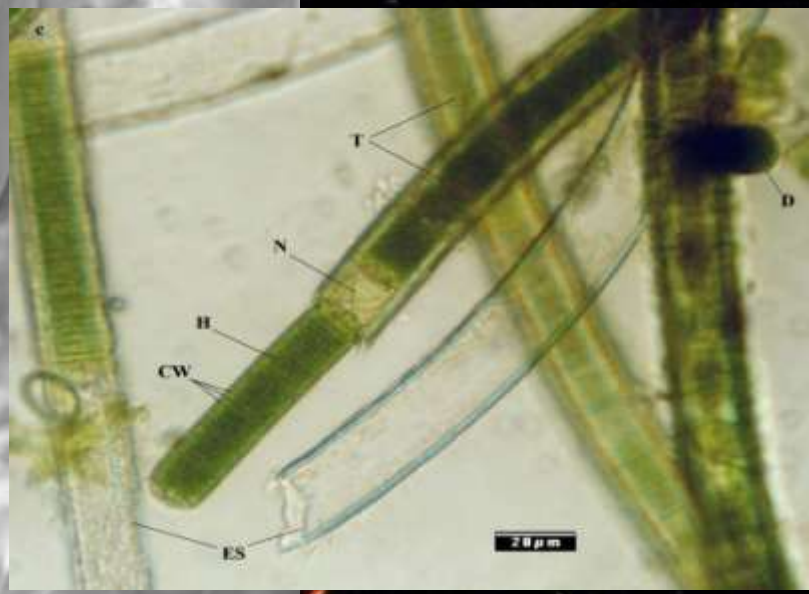
Trichomic Fragmentation (Hormogonia)

Collapsed Sheath & Filament with thick sheath and Emergent Hormogonia of Fossil *Lyngbya* sp. morphotype in Orgueil CI1 Meteorite



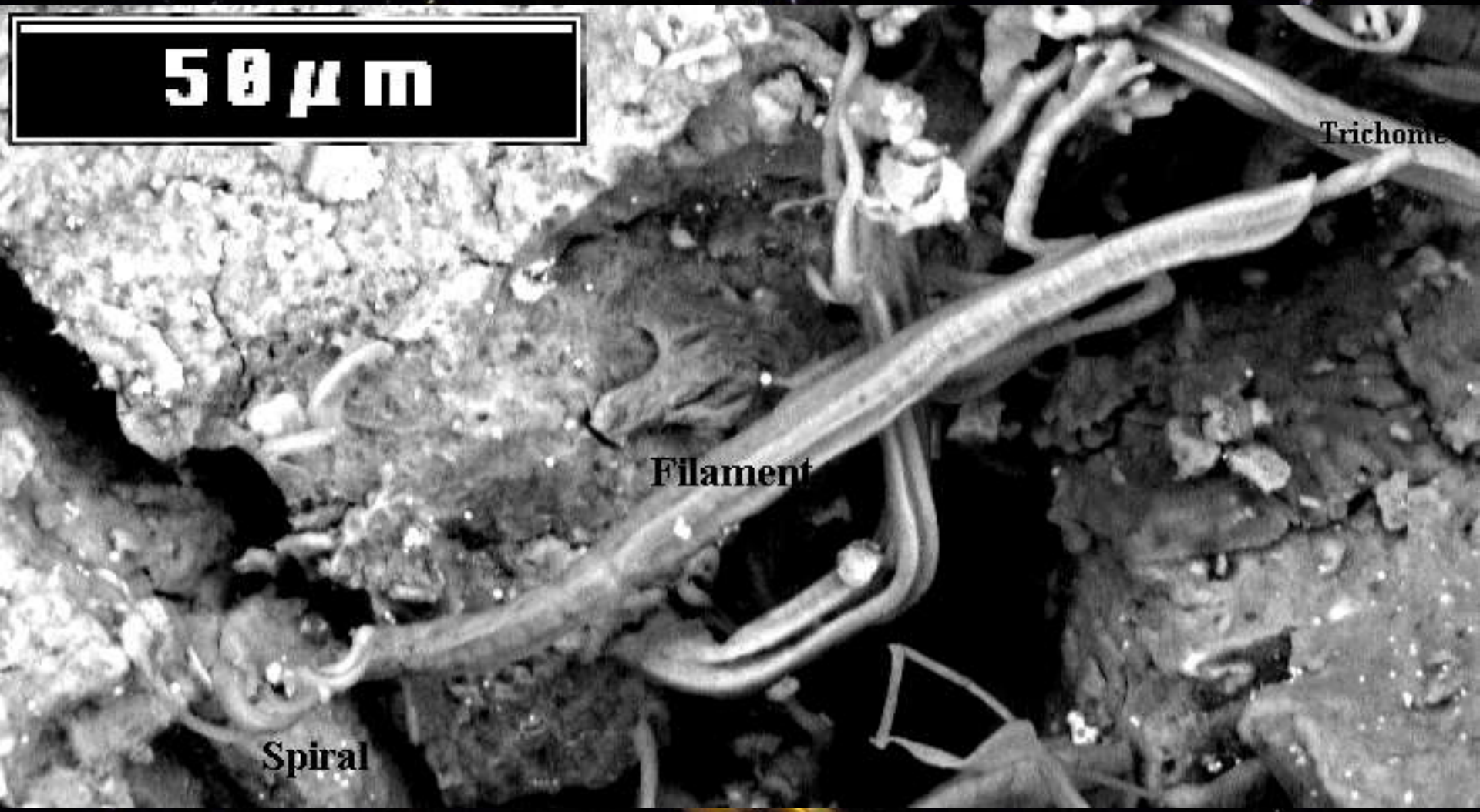
Collapsed Filament of Living *Oscillataria lud*





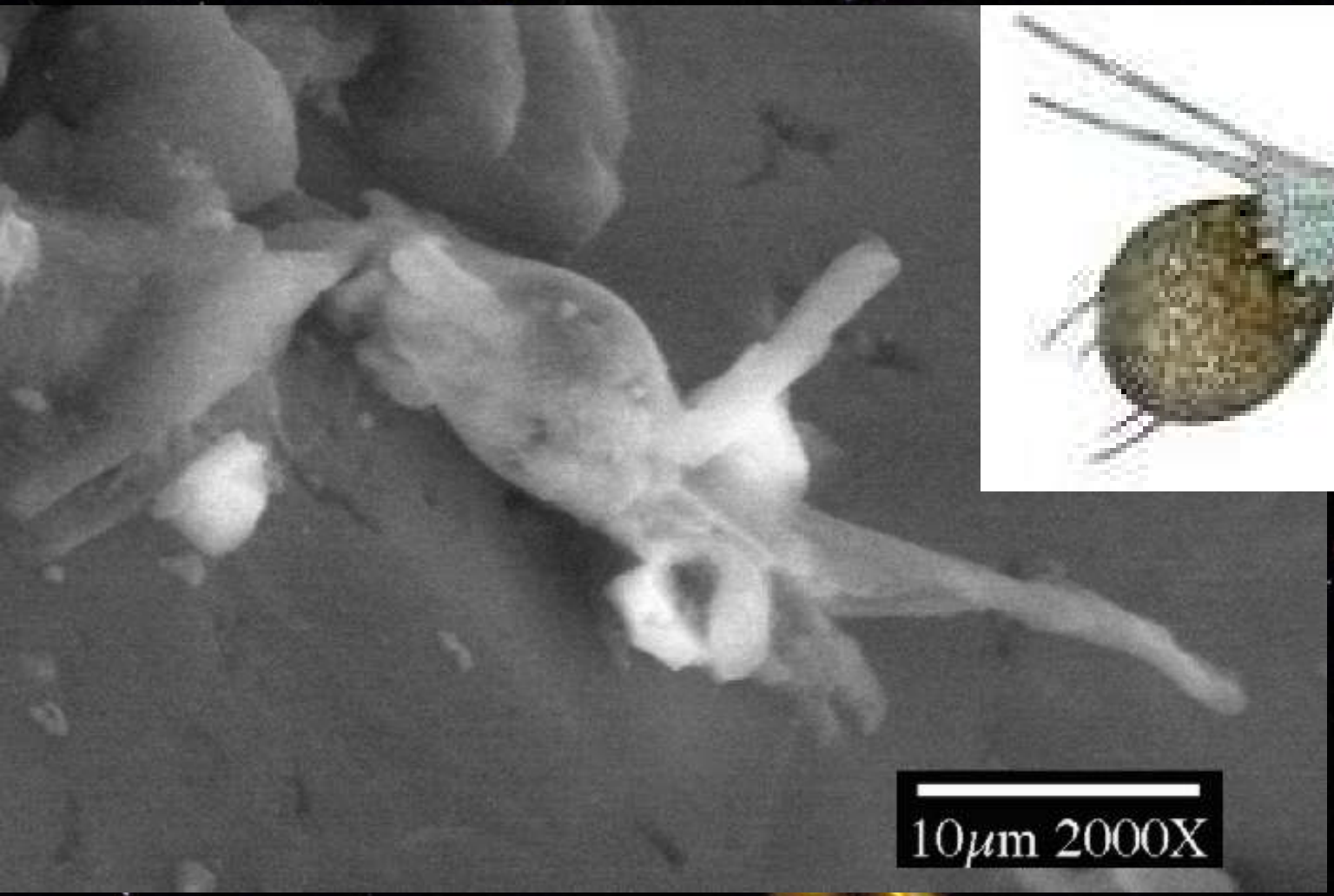
Collapsed Sheath & Emergent Hormogonia in Living *Lyngbya wollei* in Pure Culture at NSSTC

Oscillatoriacean MOTILITY IN ORGUEIL CI1 CARBONACEOUS METEORITE



Spiral Filament (7 µ) of Uniseriate Trichomic (3 µ) Prokaryote Morphotype of Cyanobacteria (cf. *Lyngbya spiralis*)

PROTOZOAN IN EFREMOVKA CV3.5 CARBONACEOUS METEORITE



Eukaryote- Rhizopod or Testate Amoeba Protist with segmented Pseudopodia In Efremovka , CV3,5 Kazakhstan (Cf. *Sarcodina* sp.)

The Polonnaruwa Meteorite

Observed Fall: 29/12/2012 6:30 PM - Bright Yellow Fireball in NW-SE trajectory. Black stones fell in Polonnaruwa District of Central Sri Lanka (N 7º 52' 59.5" E 81º 9' 15.7") in Paddy Fields & Roads like "Twinkling Green Fireflies"

Meteorite with Fusion Crust Found by Hoover on 29/01/2013

The Polonnaruwa Meteorite

Jet-Black Stones Contain Carbon (~4%) & Kerogen Microfossils

Witnessed Fall, N. Central Sri Lanka

Very Low Density (~0.6-) ~ Pummice, Diatomite and Comets

GCMS Data shows Significant Deuterium Enhancement over Terrestrial Abundances;

ICP-OES & Neutron Activation Analysis Show High Level Iridium

X-Ray Powder Diffraction at Cardiff University: Amorphous Silica, Cristobalite and Anorthite $CaAl_2Si_2O_8$; Anorthite found in Sample Recovered from Wild 2 by *STARDUST Mission*

Polonnaruwa Stones Unlike *KNOWN Meteorites & Terrestrial Rocks*

May Represent New Group of Carbonaceous Meteorites

Fossils of : Pennate Centric Diatoms in Meteorite Rock Matrix

Heterocystous Nitrogen Fixing Cyanobacteria

Morphotypes of Acritarchs and Hystrichospheres

Genera & species of Freshwater & Marine Diatoms

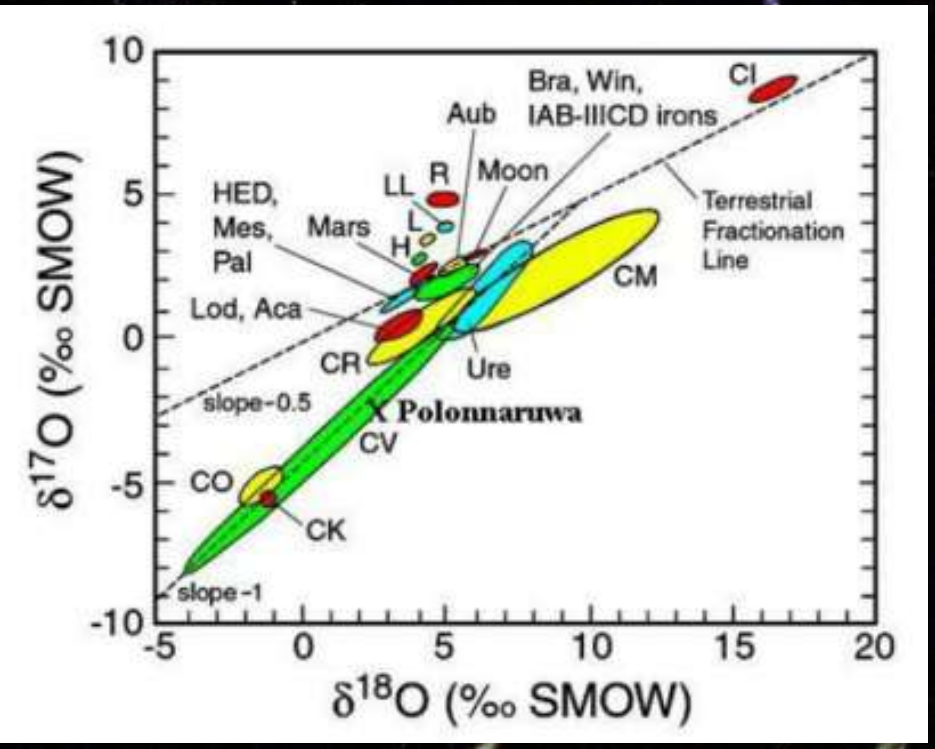
Polonnaruwa Oxygen Isotopes

Independent Laser Fluorination Measurements of Triple Oxygen Isotopes by Prof. Dr. Andreas Pack University of Göttingen and Prof. Eizo Nakamura Okayama University Produced Consistent Results with $\Delta^{17}O$ Far Away from Terrestrial Fractionation Line

TABLE I
TRIPLE OXYGEN ISOTOPE DATA

Measurement	$\delta^{18}0$	$\delta^{17}0$	$\Delta^{17}0$
Prof. Dr. Andreas Pack	17.816	8.978	-0.335
Prof. Eizo Nakamura - Run 1	20.84	10.60	-0.328
Prof. Eizo Nakamura-Run 2	20.75	10.59	-0.296

Polonnaruwa Oxygen Isotopes



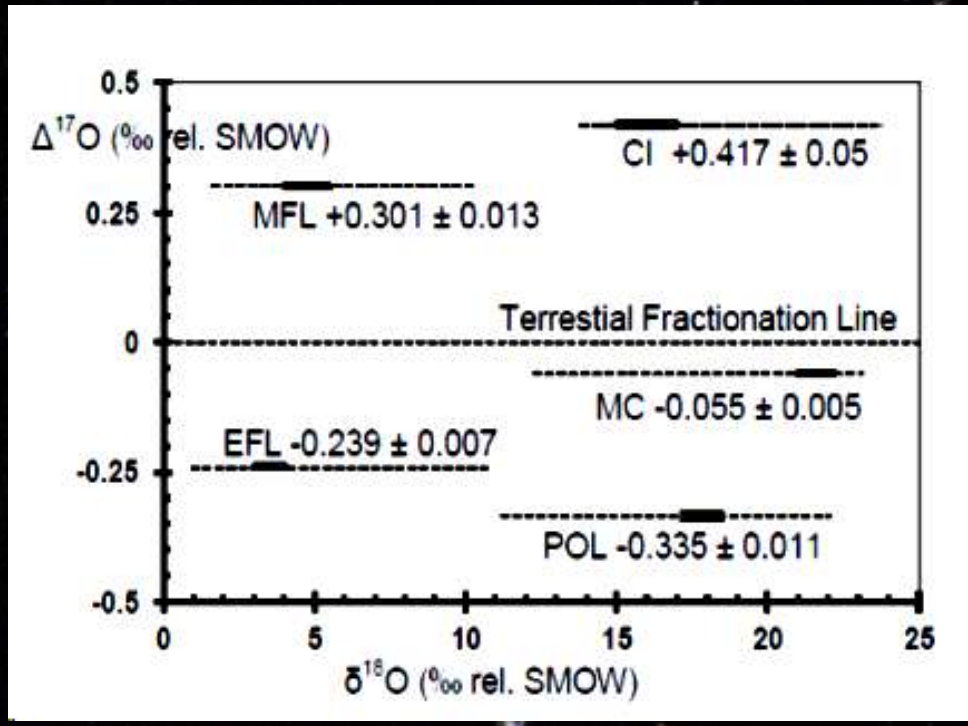
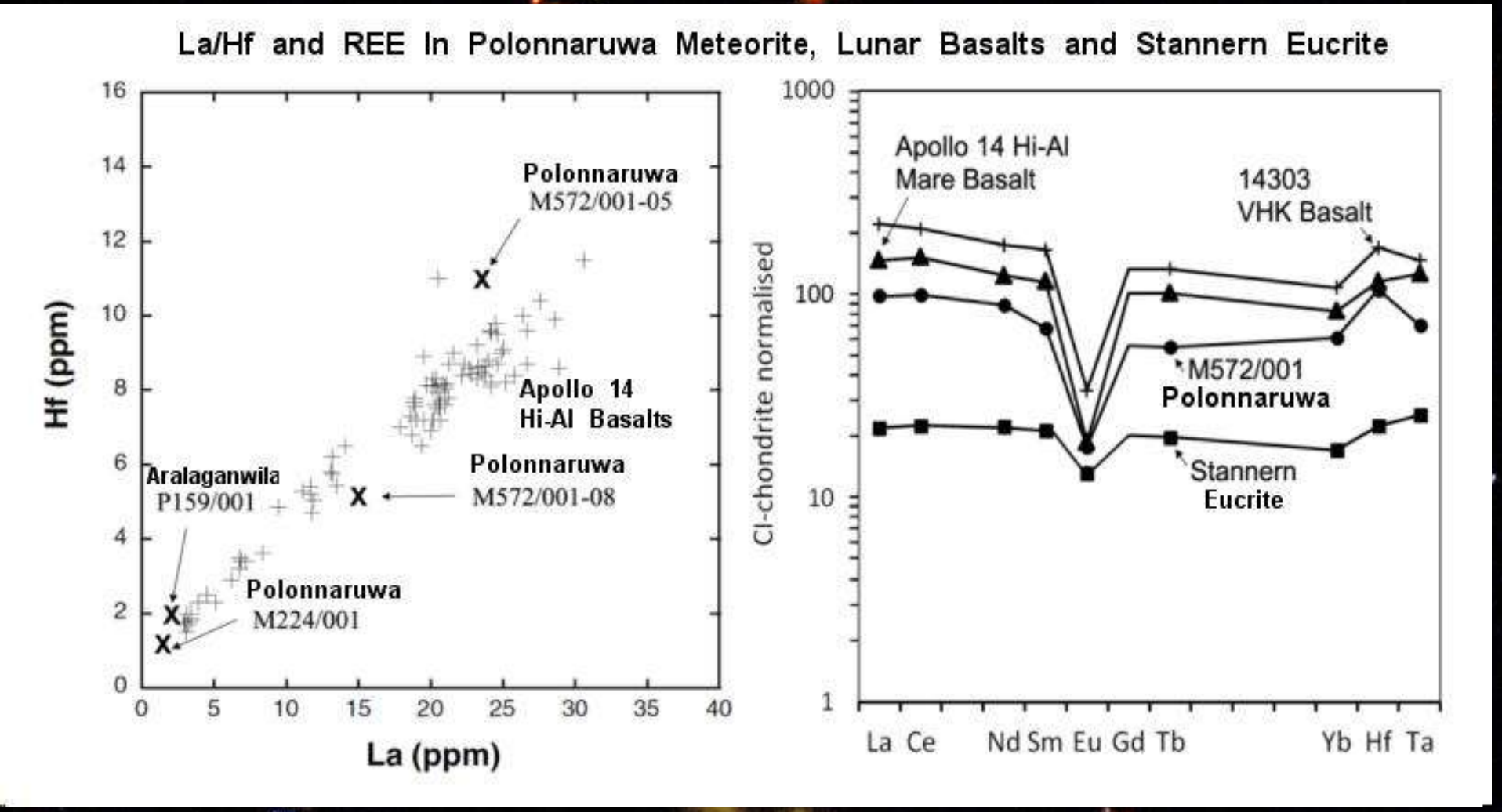


Fig. 1. Triple Oxygen Isotope measurements by laser fluorination at the Stable Isotope Laboratory of the University of Göttingen in Germany by Prof. Dr. Andreas Pack revealed the Polonnaruwa samples were far away from the Terrestrial Fractionation Line and could not be logically considered typical Earth rocks.

Polonnaruwa La/HF & REE Data



Hf/La & REE Plots for Aralaganwila/Polonnaruwa, Lunar Basalts and Stannern Eucrite from Vesta

Micropaleontology of Polonnaruwa

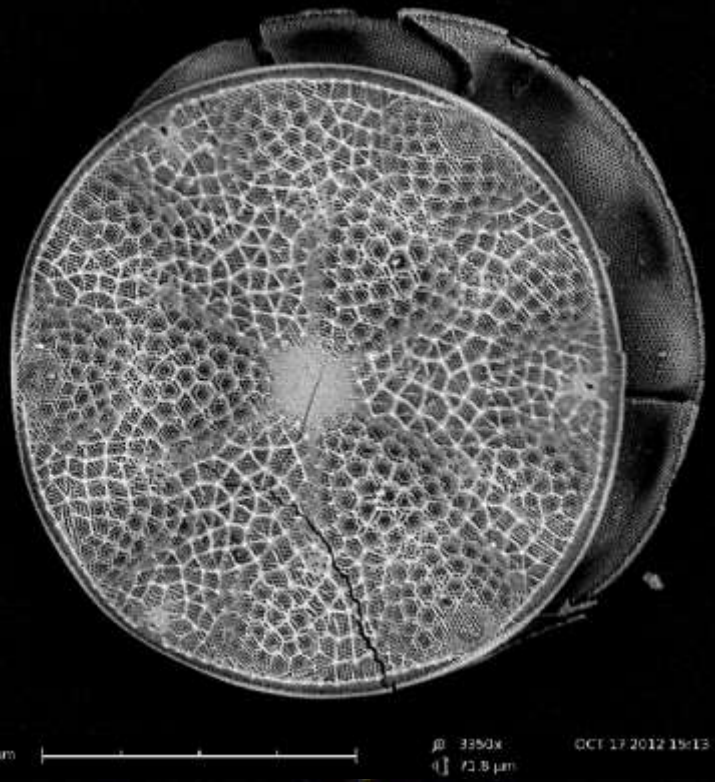
DIATOMS

- Diatoms are one of the largest and ecologically most significant groups of organisms on Earth
- Easiest to recognize due to unique cell structure, silicified cell wall and life cycle
- Occur wherever Water & Light Co-Exist

(Most diatom species need light for photosynthesis)

Produce Over 20% Global Photosynthetic Carbon Fixation (> All Tropical Rainforests of Earth)

Fossil Diatoms



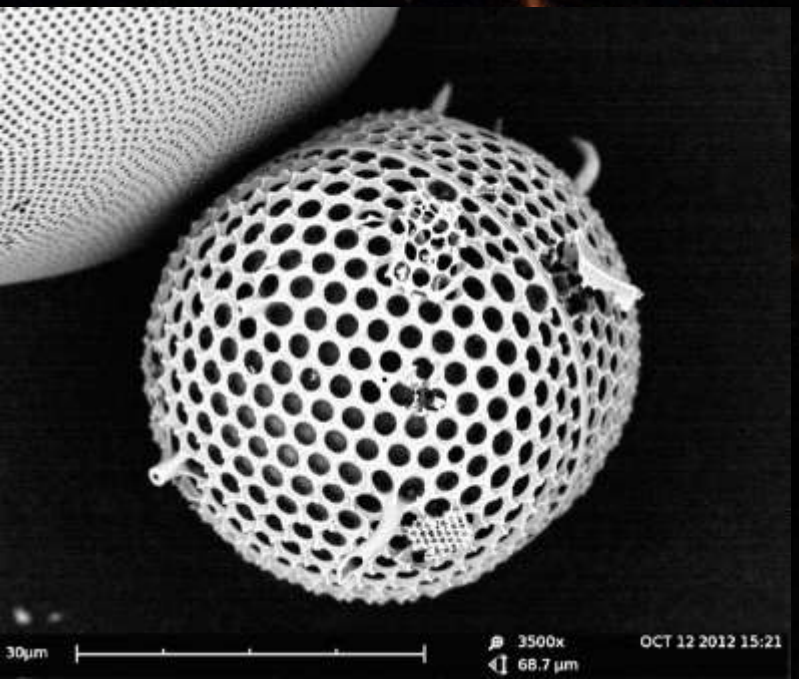
Diatoms: Microscopic Single Celled Aquatic Plants that build Shells of Silica. Photosynthetic Plants Need Sunlight for Energy. Pennate Diatoms Swim; Centric Diatoms Float

Micropaleontology of Diatoms

Origin of Diatoms

Marine Diatoms (Pyxidicula bolensis) appeared on Earth abruptly during Jurassic (190 Ma)

Freshwater Diatoms Not Until Paleocene (60 Ma)



130 Ma Gap Implies Cosmic Injection and not Earth Origin

***Pyxidicula* sp., Marine, Lower Cretaceous, Panoche Hills, CA**

Photo: *Richard B. Hoover*

Athens State University

Fossil Record of Diatoms on Earth

Freshwater Diatoms
Raphid Pennates
Paleocene (Russia)
Late Eocene (North America)
(45-65 Ma)

Marine Araphid Pennates
Late Cretaceous
(Cenemonian-Maastrichtian)
(65-96 Ma)

Diverse Marine Centrics
Early Cretaceous
(Aptian-Albian Stage, Weddell Sea)
(112-124 Ma)

Pyxidicula (*P. liassica; P. Bollensis*)
Jurassic, Toarcian Stage
Liassic Boll Shales, Wurtenburg
(190 Ma)

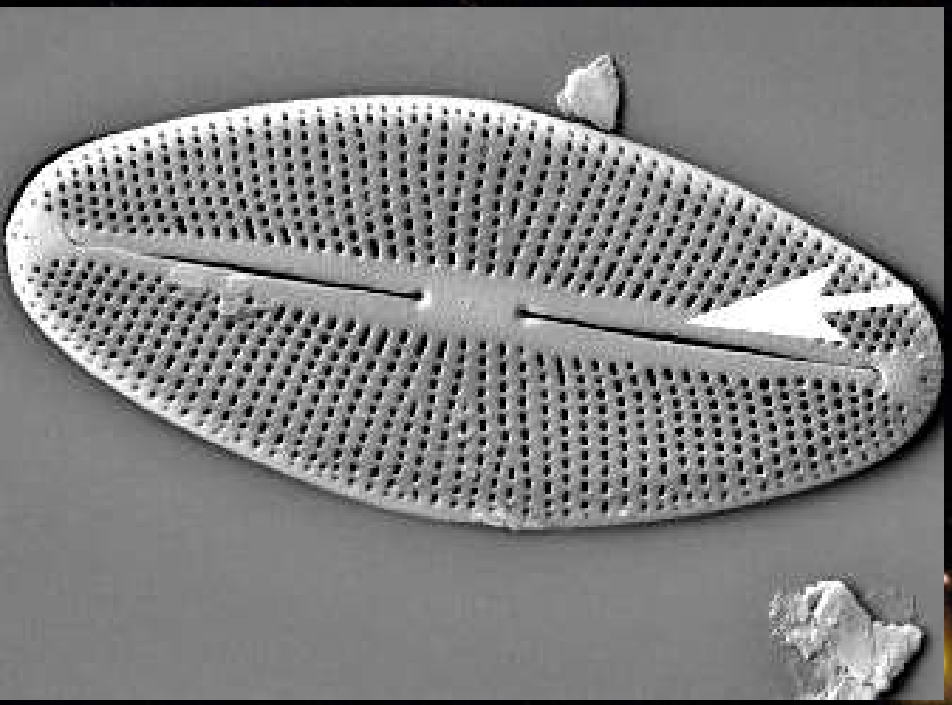
Eon	Era	Period	Epoch	Age Ma
Appearance of Diatoms	Cenozoic	Quaternary	Holocene	0.01
			Pleistocene	1.64
		Neogene	Pliocene	5.2
			Miocene	23.3
		Palaeogene	Oligocene	35.4
Freshwater Raphid Pennates (45-50 Ma)			Eocene	56.5
			Palaeocene	65.0
Marine Araphid Pennates (67-96 Ma)	Mesozoic	Cretaceous		145.6
Marine Centrics (112-124 Ma)				
Phanerozoic Pyxidicula 190 Ma		Jurassic		208.0
		Triassic		245.0
	Palaeozoic	Permian		290.0
		Carboniferous		362.5
		Devonian		408.5
		Silurian		439.0
		Ordovician		510.0
		Cambrian		570.0
Proterozoic				2500
Archean				4000

Geologic Time Scale Based on Harland, 1989

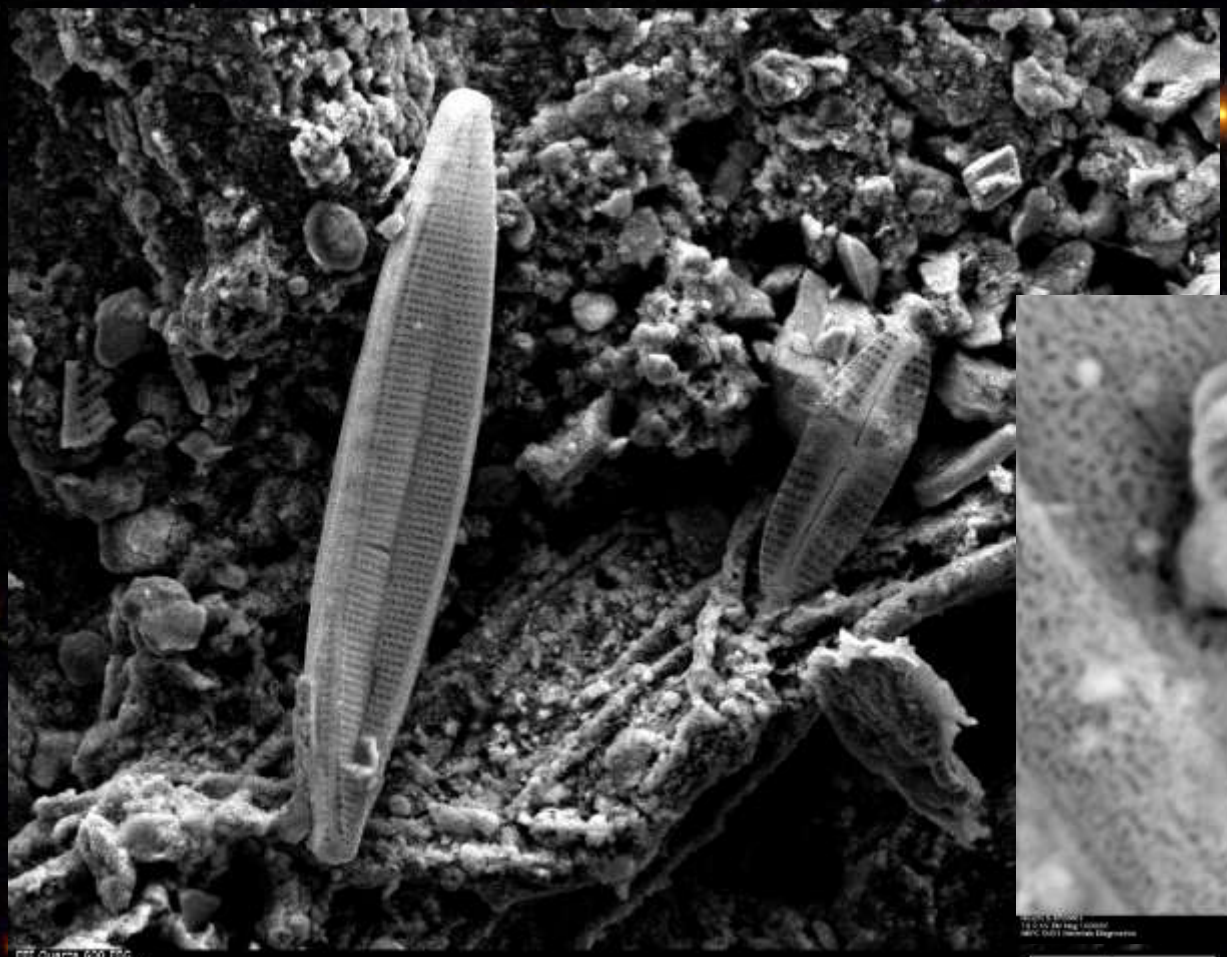
Fossil Diatoms in the Polonnaruwa Meteorite

Marine Araphid Pennates in Upper Cretaceous ~ 70 ma;

– Freshwater Pennates with Raphe in Paleocene ~ 60 ma

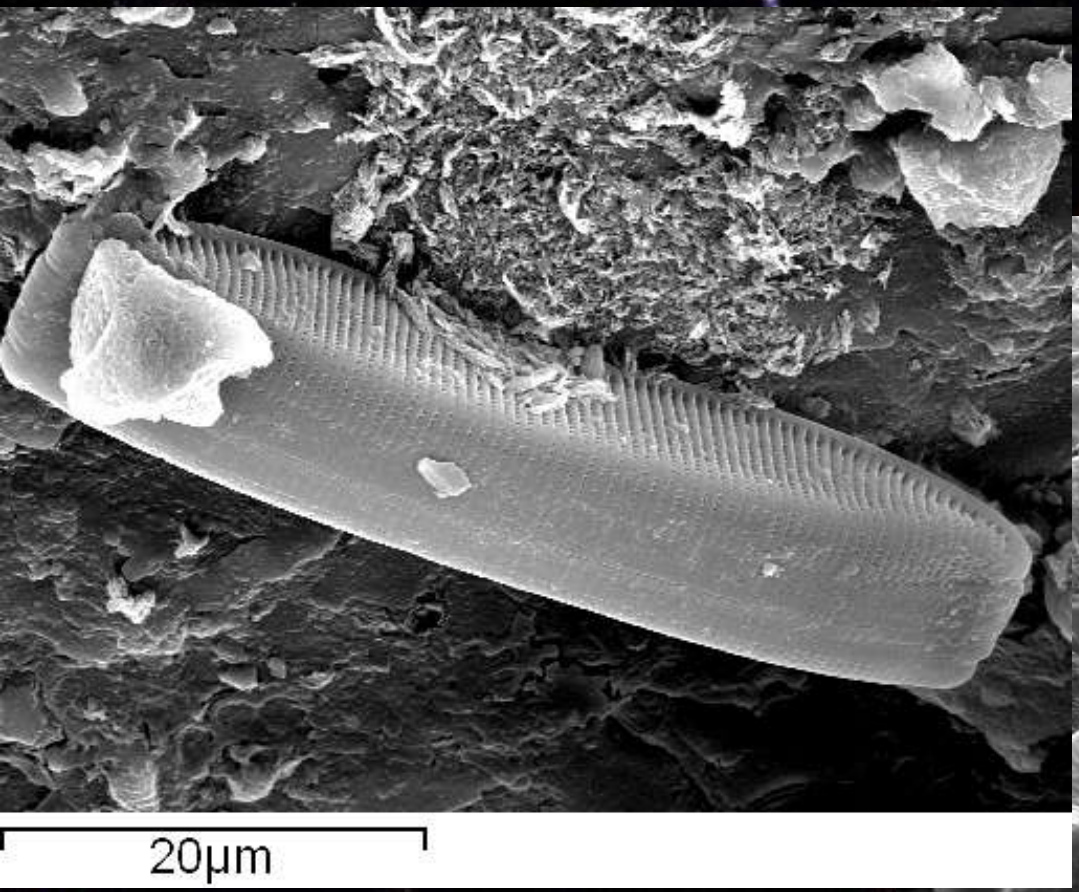


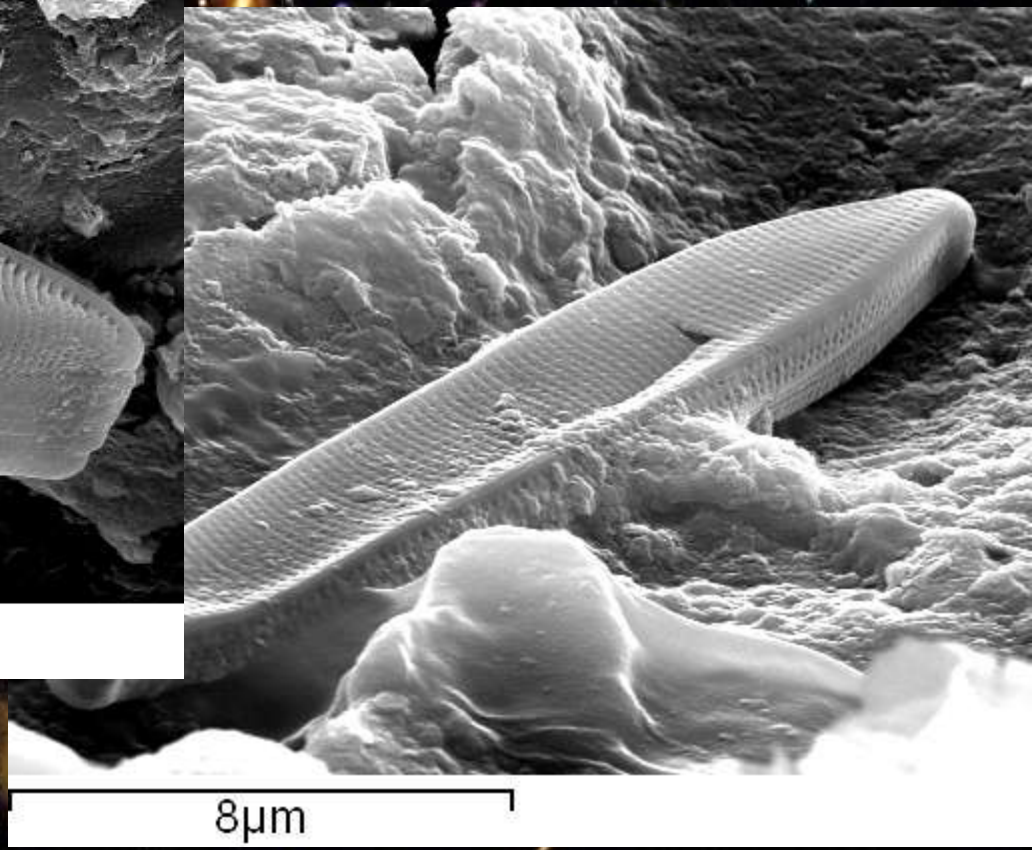
Diatoms and Cyanobacteria in Polonnaruwa Meteorite



Nitzschia frustulum*, *Reimeria sinuata* & *Placoneis* sp. with cyanobacteria *Microcoleus chtonoplastes

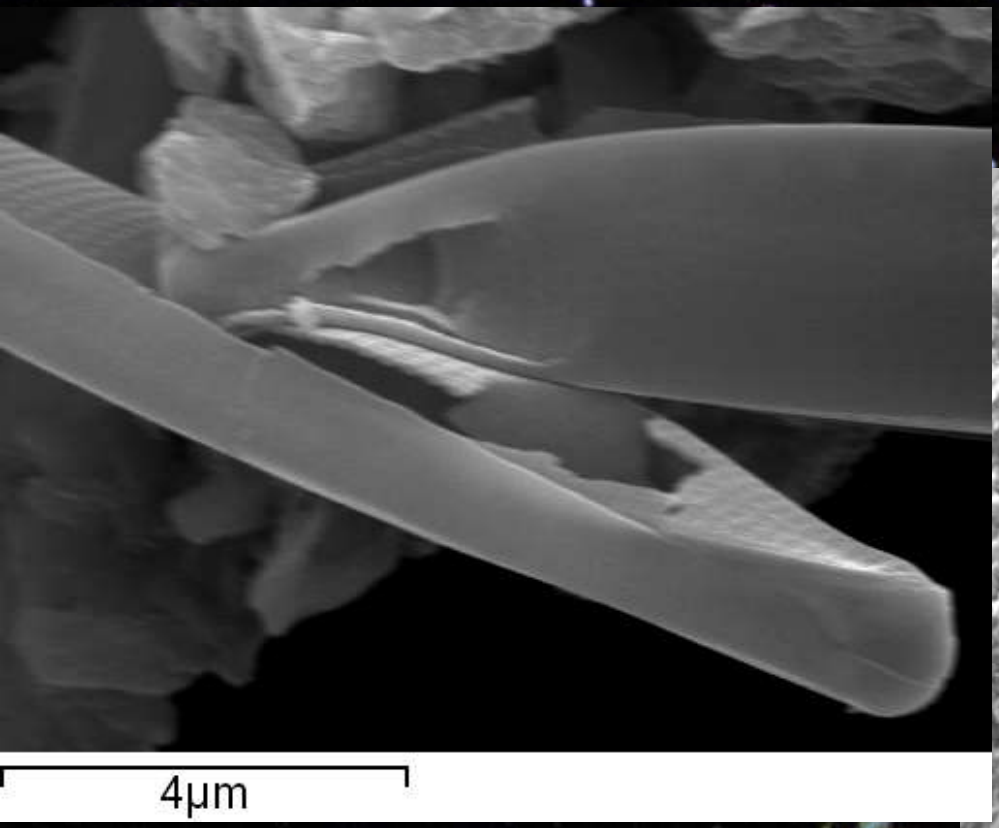
Araphid Pennates (Marine Diatoms) in Polannaruwa Meteorite

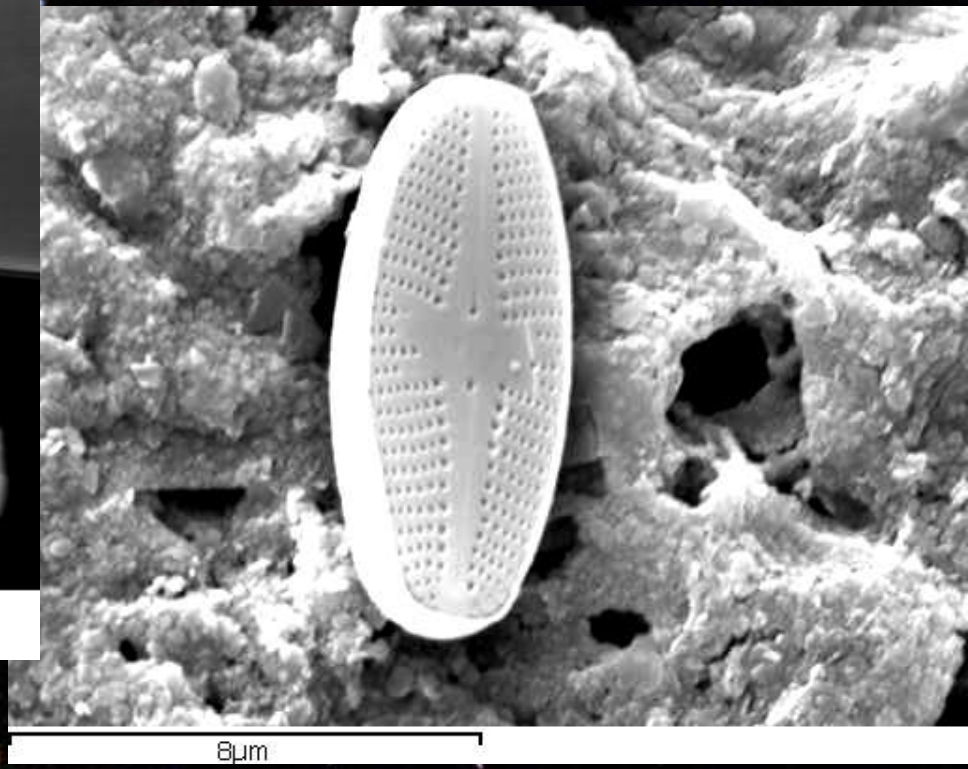




Intact Araphid Diatoms cf.*Ardissonea robusta*

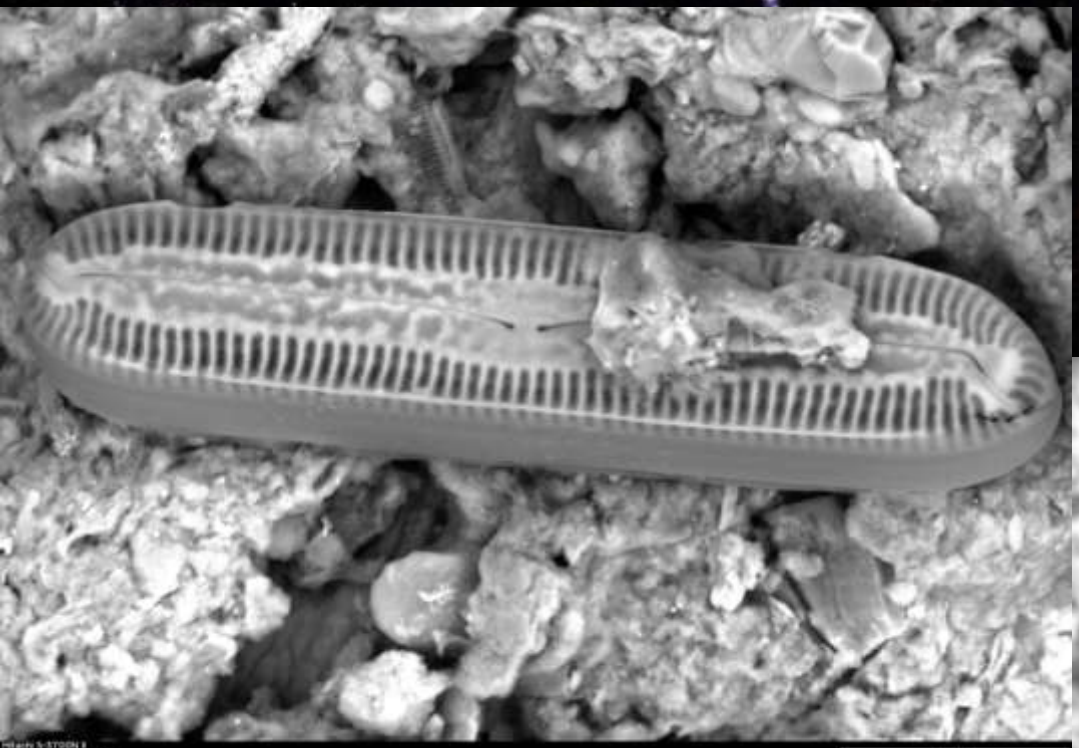
Fossil Marine Diatoms in Polannaruwa Meteorite





Internal Septa of Fossil Marine Araphid Pennate *Rhabdonema minutum* Kutzing & New Species

Embedded Pinnularia species in Polannaruwa

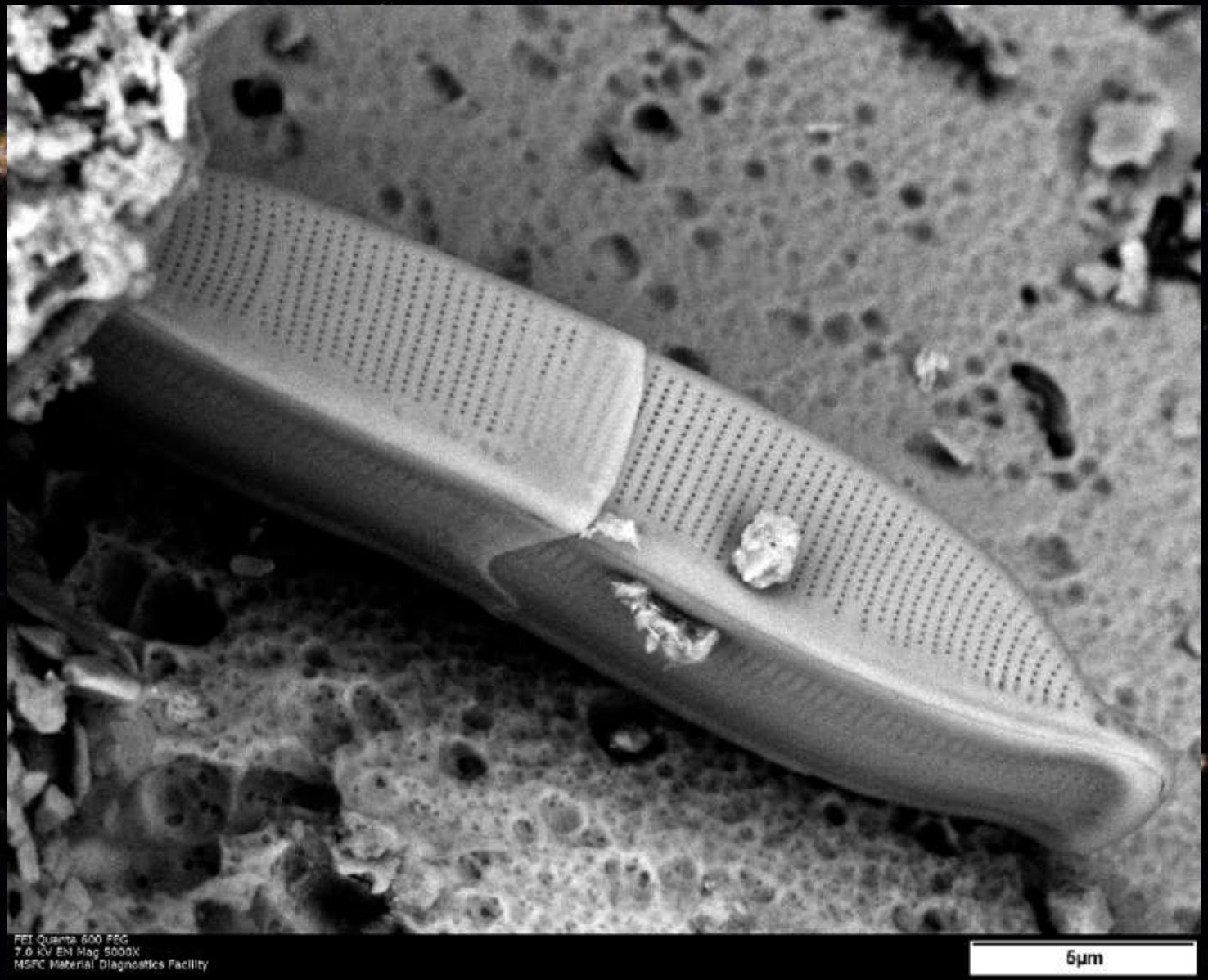


Pinnularia spp.

Intact Diatom Frustules in Polonnaruwa Meteorite

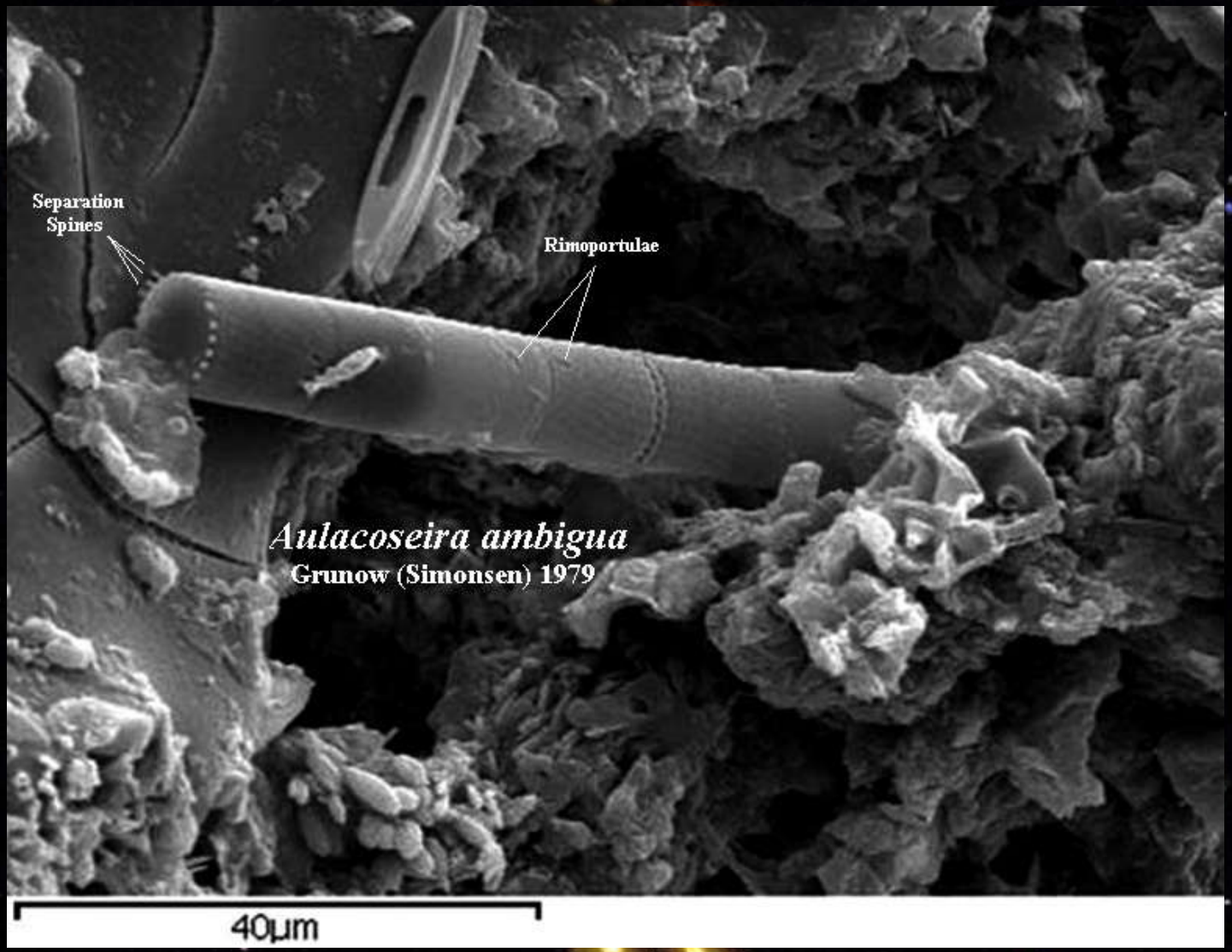
Nitzschia species with Raphe on Keel

Diatoms in Polonnaruwa Meteorite



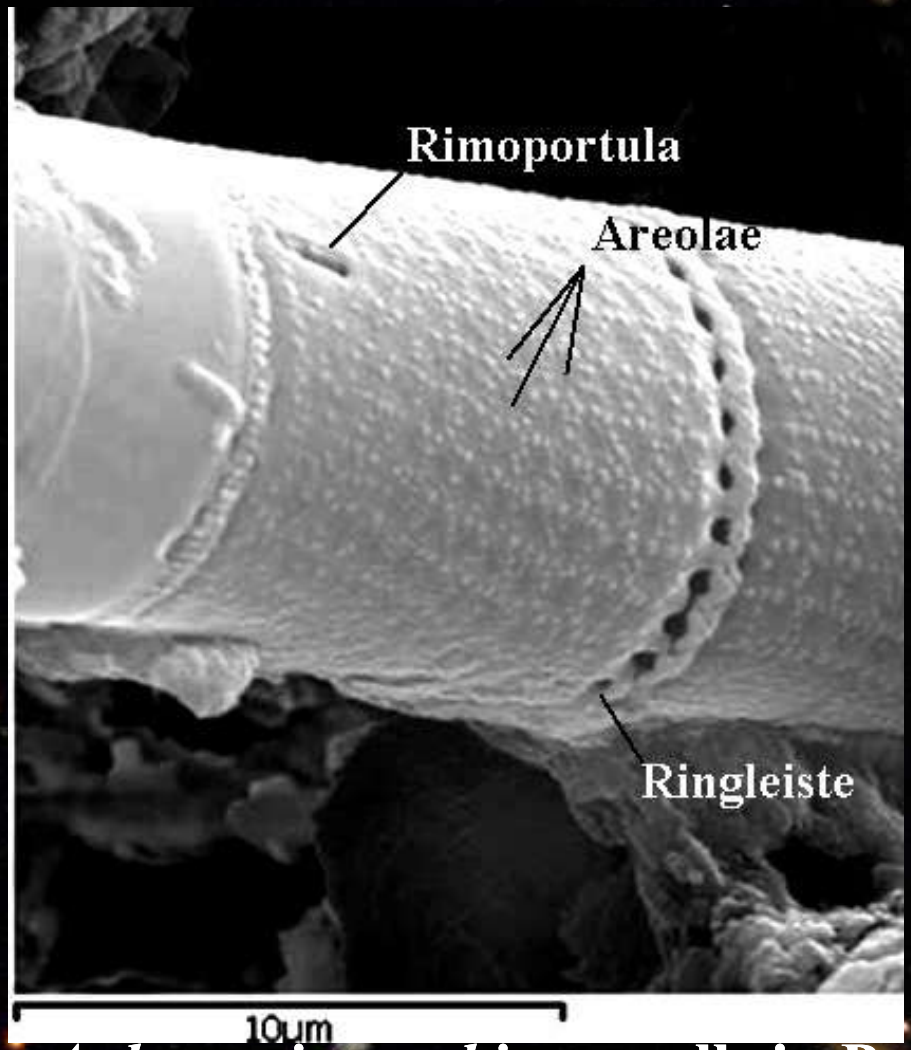
Exotic Pennate with Strange Morphology

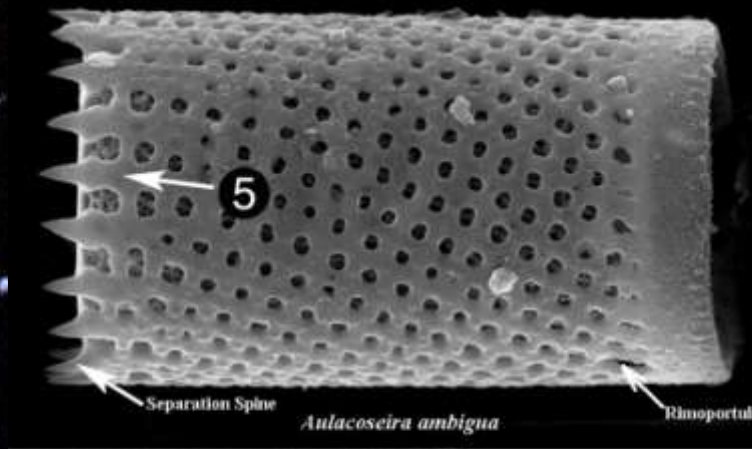
Marine Diatoms in Polonnaruwa Meteorite

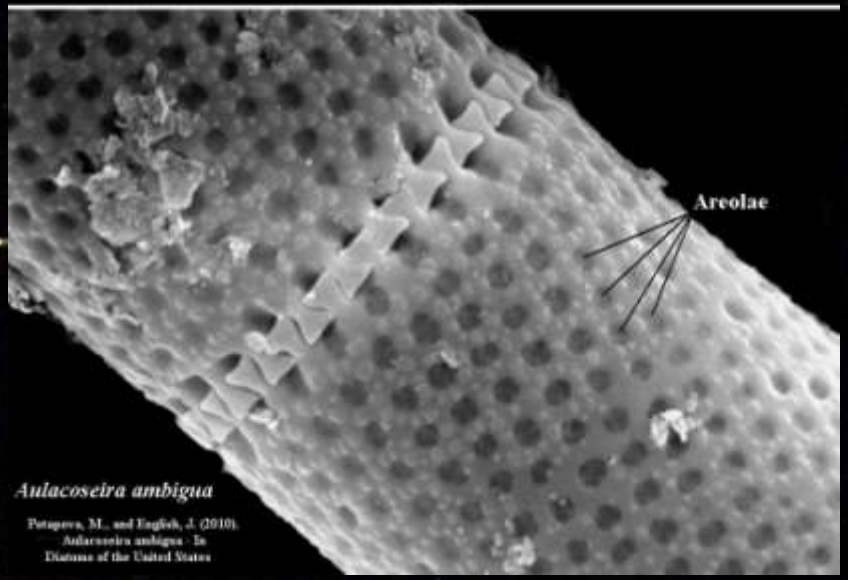


Embedded *Aulacoseira ambigua* Filament and Marine Araphid Pennate *Rhabdonema* sp.

Planktonic Diatoms in Polonnaruwa Meteorite



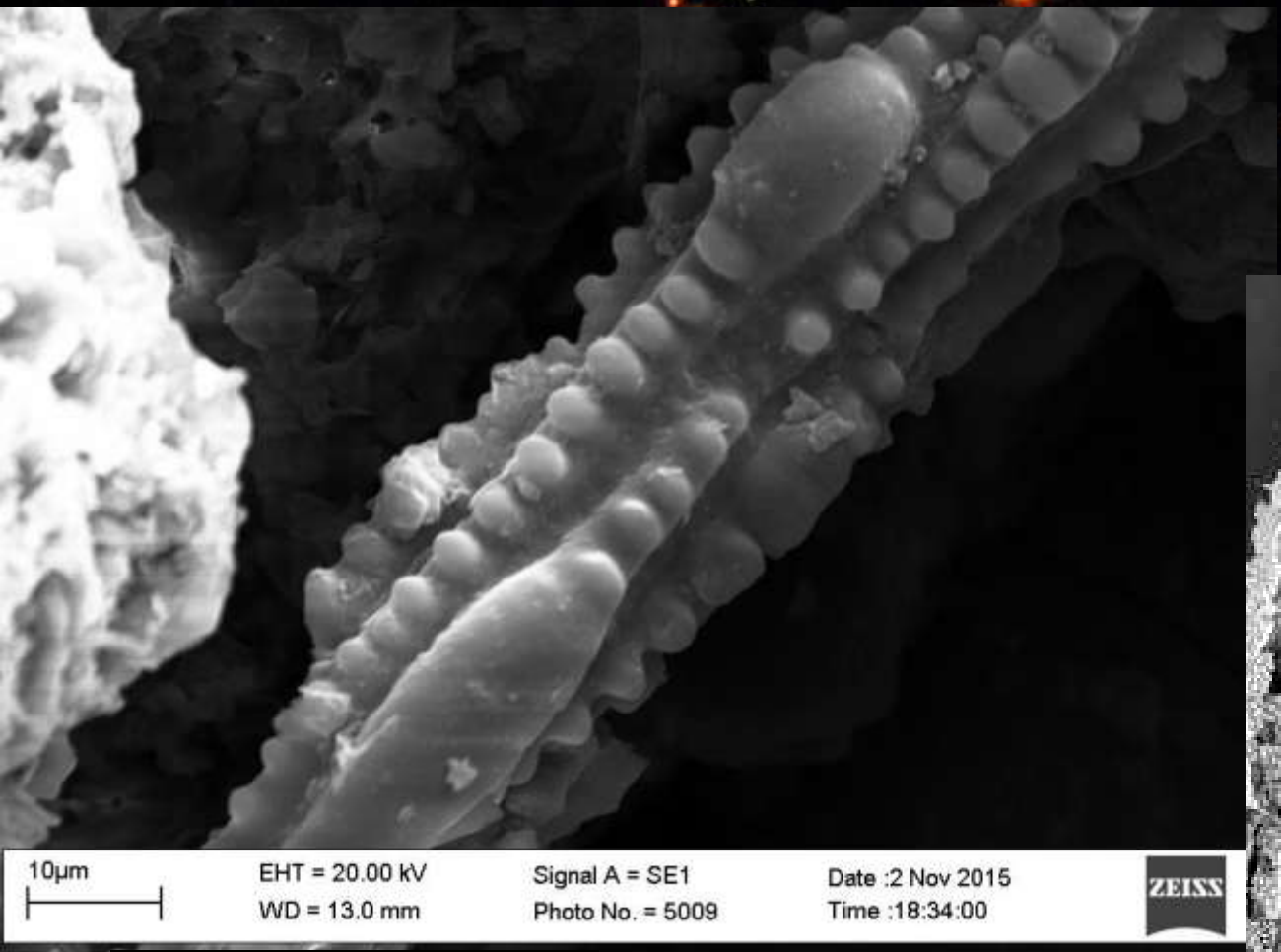


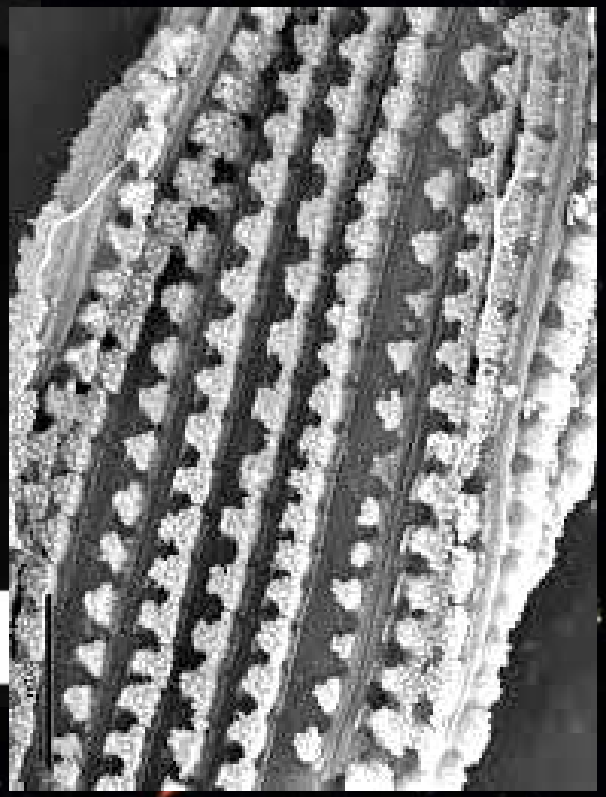


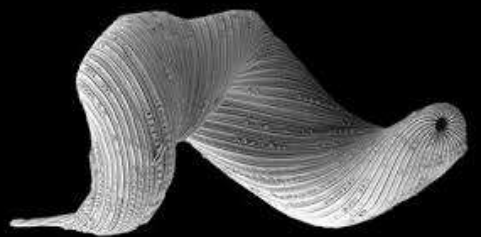
Aulacoseira ambigua cells in Polonnaruwa (8.6µm dia. x 9.5 µm mantle height) with Rimoportula and Ringleiste marked.

Terrestrial Forms Length Range 3-12 µm; Width Range 5-15 µm

Polonnaruwa Eukaryote @ PIN



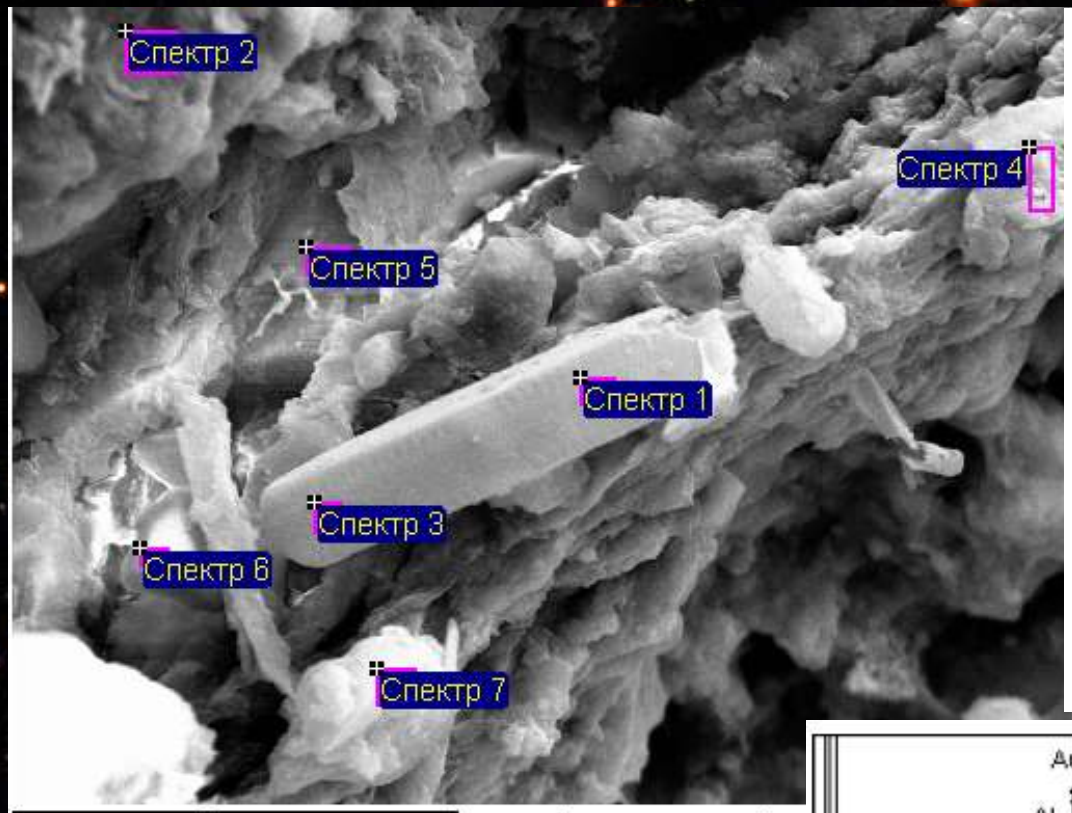


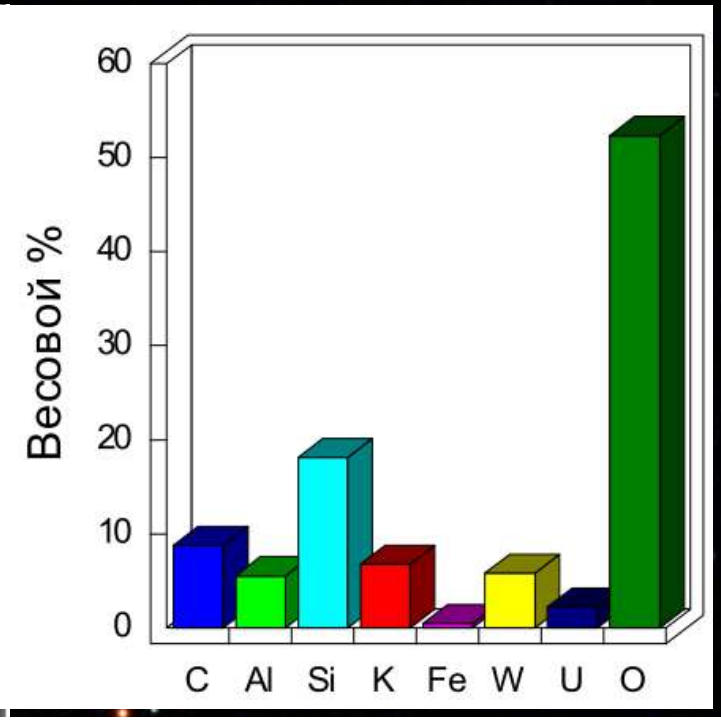


Euglena: *Lepocinclis spirogyra*

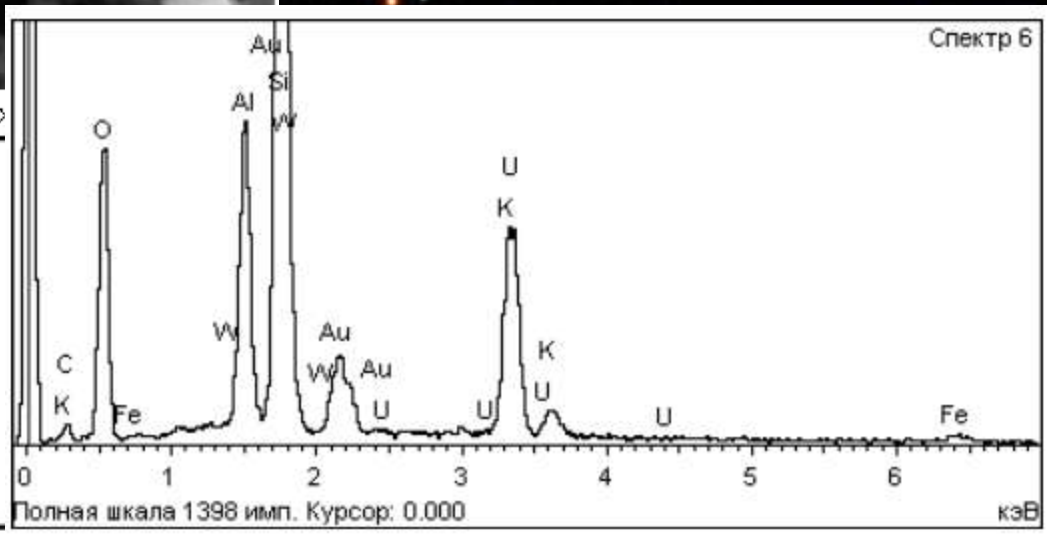
Unknown Polonnaruwa Protist @ PIN

Polonnaruwa Diatom @ PIN





Элемент	Весовой %	Атомный%	Соед.%	Формула
C K	8.76	14.37	32.09	CO2
Al K	5.53	4.04	10.44	Al2O3
Si K	18.12	12.71	38.76	SiO2
K K	6.79	3.42	8.18	K2O
Fe K	0.43	0.15	0.56	FeO
W M	5.81	0.62	7.33	WO3
U M	2.19	0.18	2.63	UO3
O	52.37	64.50		
Итоги	100.00			



MICROPALEONTOLOGY INVESTIGATIONS AND NEUTRON ACTIVATION ANALYSIS OF CARBONACEOUS METEORITES

Conclusions

- Microfossils (Mostly Prokaryotes) found in all Groups of Carbonaceous Meteorites but Never in Other Meteorites
- Polonnaruwa stones Unlike Known Meteorite Groups Observed to Fall in North Central Sri Lanka 29/12/2013
- Density, Mineralogy & Triple Oxygen Isotopes Establish Stones are not Terrestrial
- Polonnaruwa Stones Have Anomalous Abundances of Rare Earth Elements, Rare Earth Metals, PGE's and Contain Diatoms & Many Exotic Extinct Microfossils
- Absence of Nitrogen Indicates Fossils are Indigenous
- Neutron Activation Analysis May Help Resolve Mystery

MICROPALEONTOLOGY INVESTIGATIONS AND NEUTRON ACTIVATION ANALYSIS OF CARBONACEOUS METEORITES