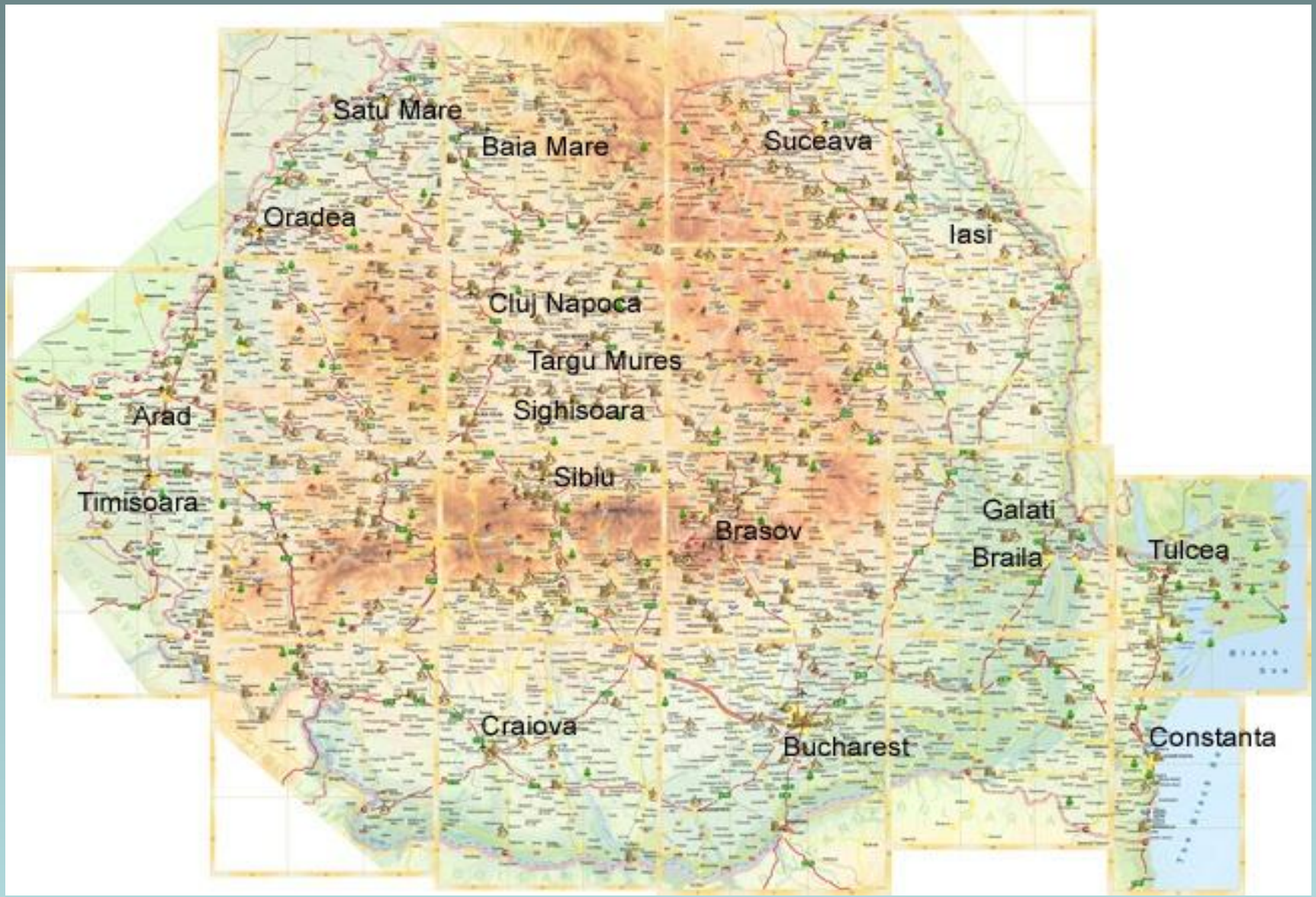
Life Without Light: Chemoautotrophically Based Cave Biology

Serban M. Sarbu, Ph.D.

- In 1890, *Sergei Nikolaevich Vinogradskii* (or *Winogradsky*) proposed a novel life process called chemosynthesis.

- **chemosynthesis** is the biological conversion of one or more carbon molecules (usually CO_2 or CH_4) and nutrients into organic matter using the oxidation of inorganic molecules (e.g. H_2 gas, H_2S) or CH_4 as a source of energy, rather than sunlight, as in photosynthesis.

The publication of Emil Racovita's work *Essai sûr les problèmes Bioespéleologiques* (1907) laid the foundations for *biospeleology* (the study of organisms that live in caves) as a separate scientific discipline.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Baia Mare
Suceava
Oradea
Iasi
Cluj Napoca
Targu Mures
Arad
Sighisoara
Sibiu
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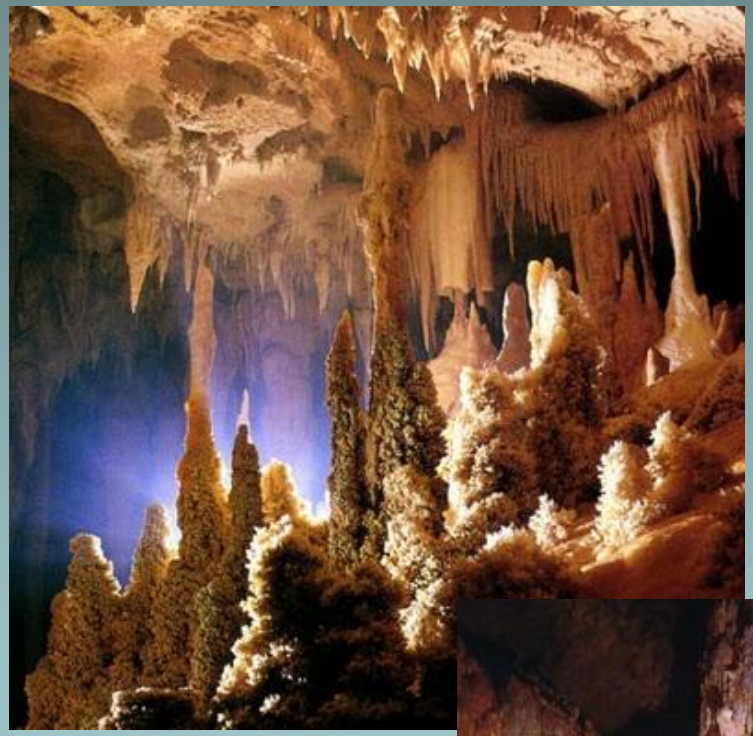
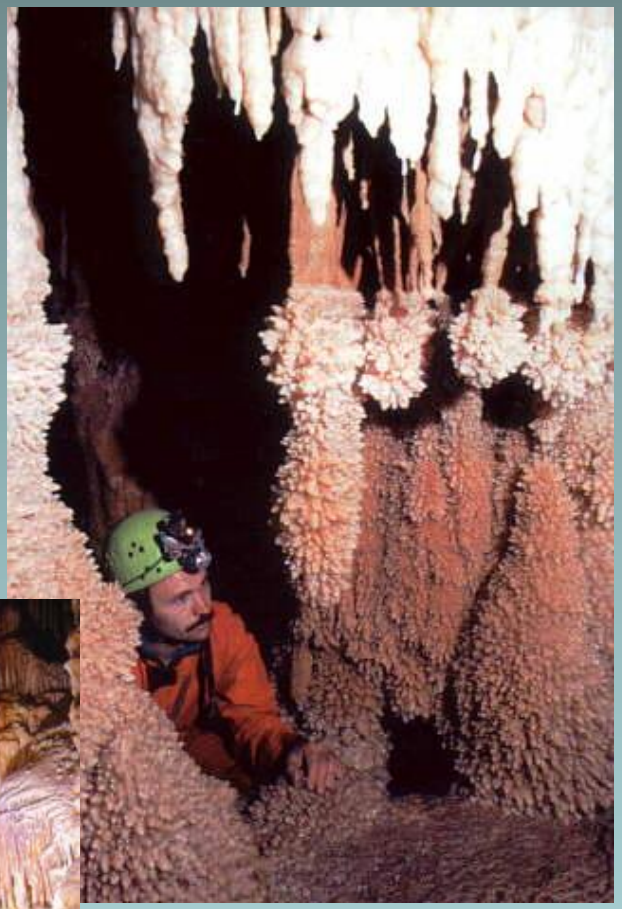
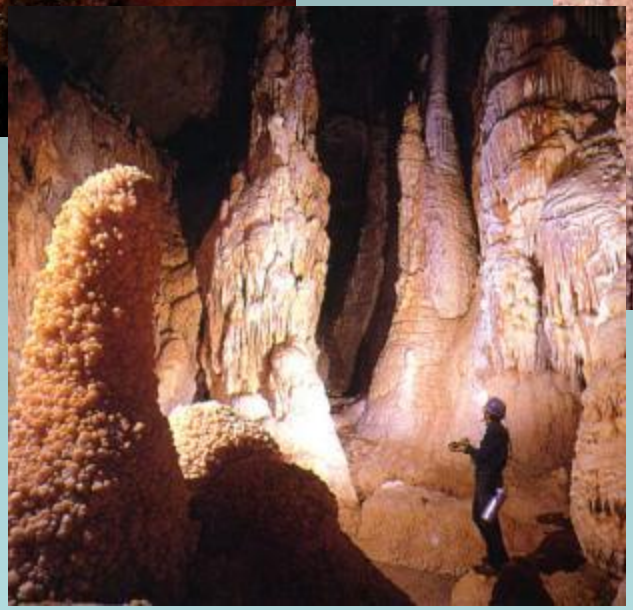
Galati
Brasov
Braila
Tulcea
Craiova
Bucharest
Constanta

Romania





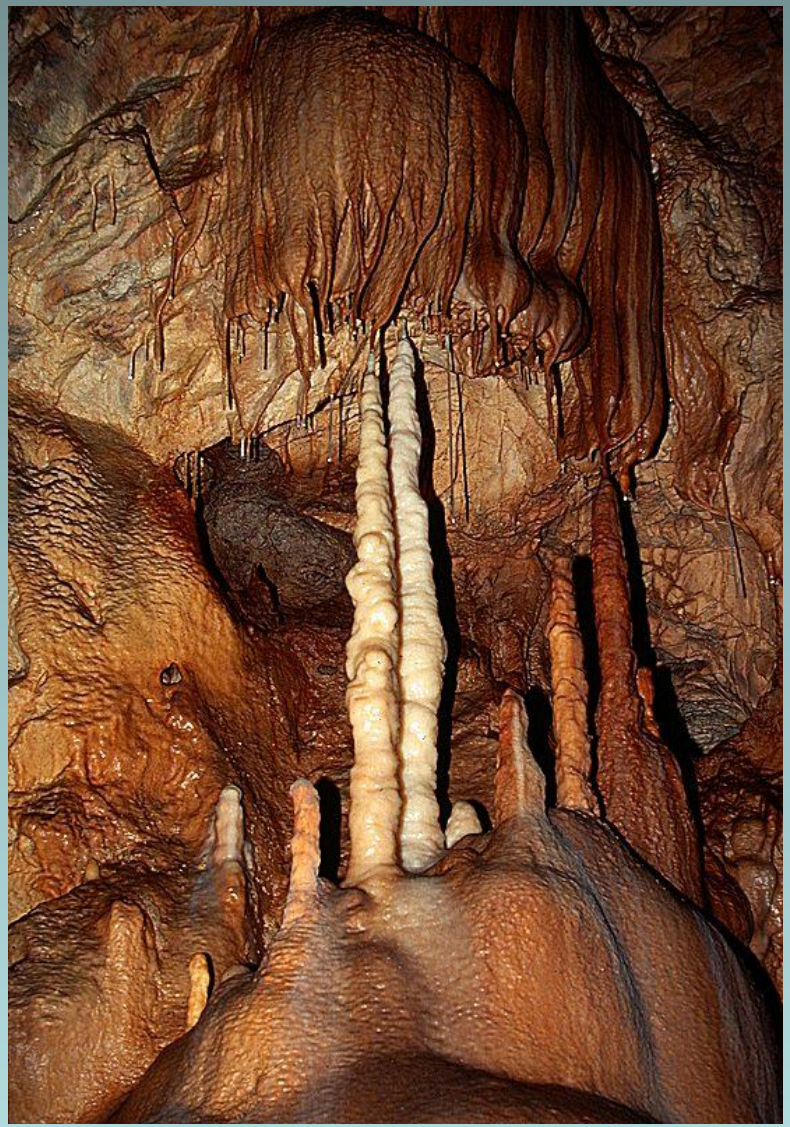


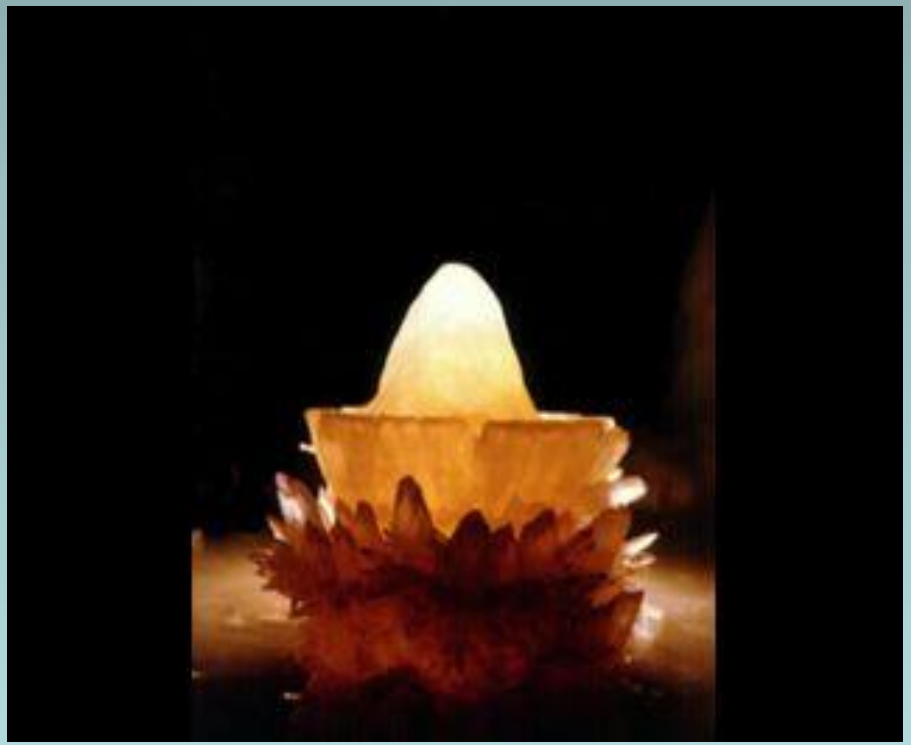
Carbonic acid speleogenesis

- $H_2O + CO_2 \leftrightarrow H_2CO_3$

- $CaCO_3 + H_2CO_3 \leftrightarrow Ca(HCO_3)_2$

  insoluble soluble

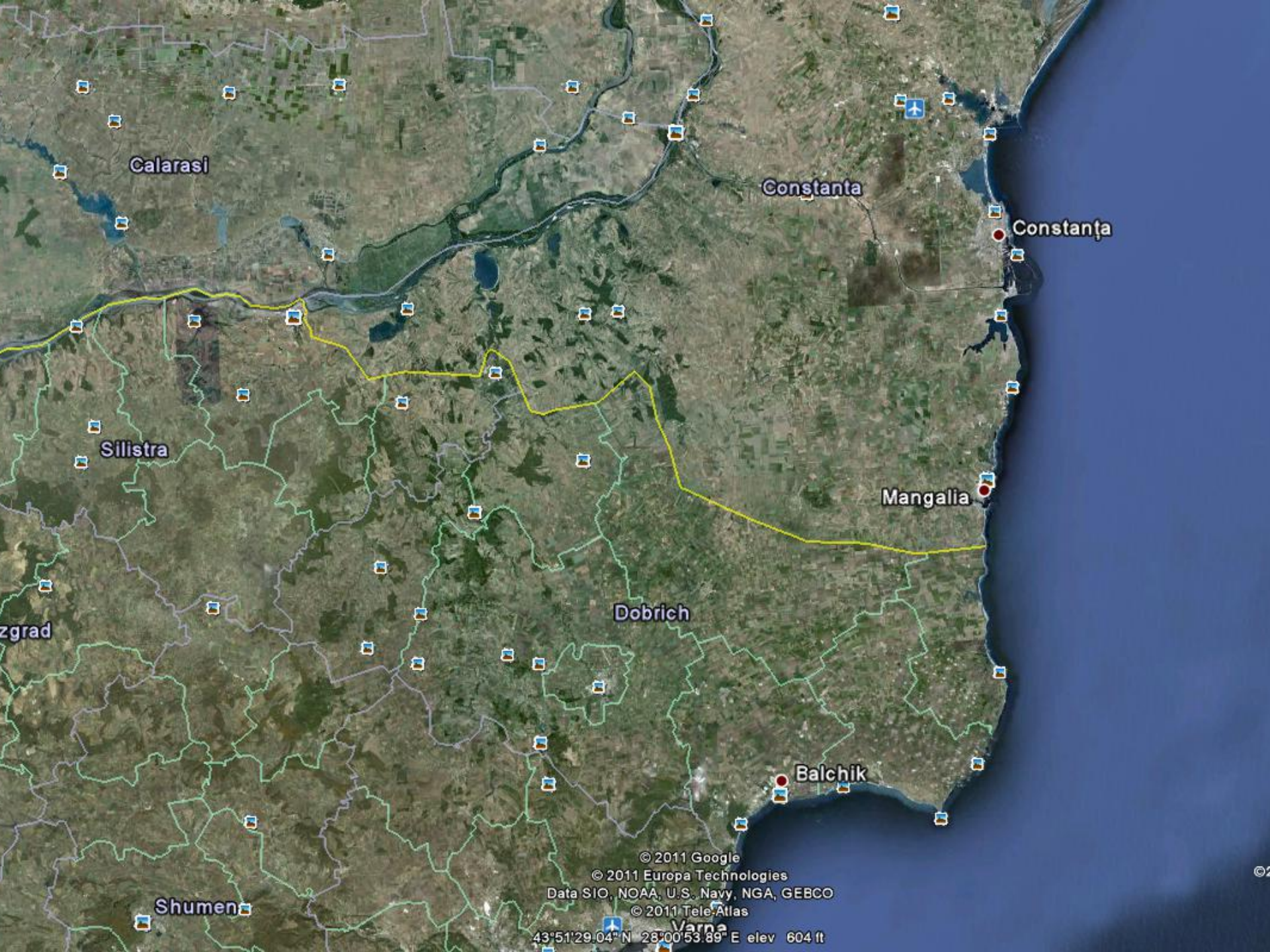




- Permanent darkness
- No plant life
- Small amounts of food coming from the surface
- Very few life forms present

Deep Sea Vents

Movile Cave, 1986


Calarasi
Constanta
Constanța
Silistra
Mangalia
Dobrich
zgrad
Balchik
Shumen
Varna
© 2011 Google
© 2011 Europa Technologies
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2011 Tele Atlas
43°51'29.04" N 28°00'53.89" E elev 604 ft


N
© 2009 Basarsoft
Image © 2010 DigitalGlobe
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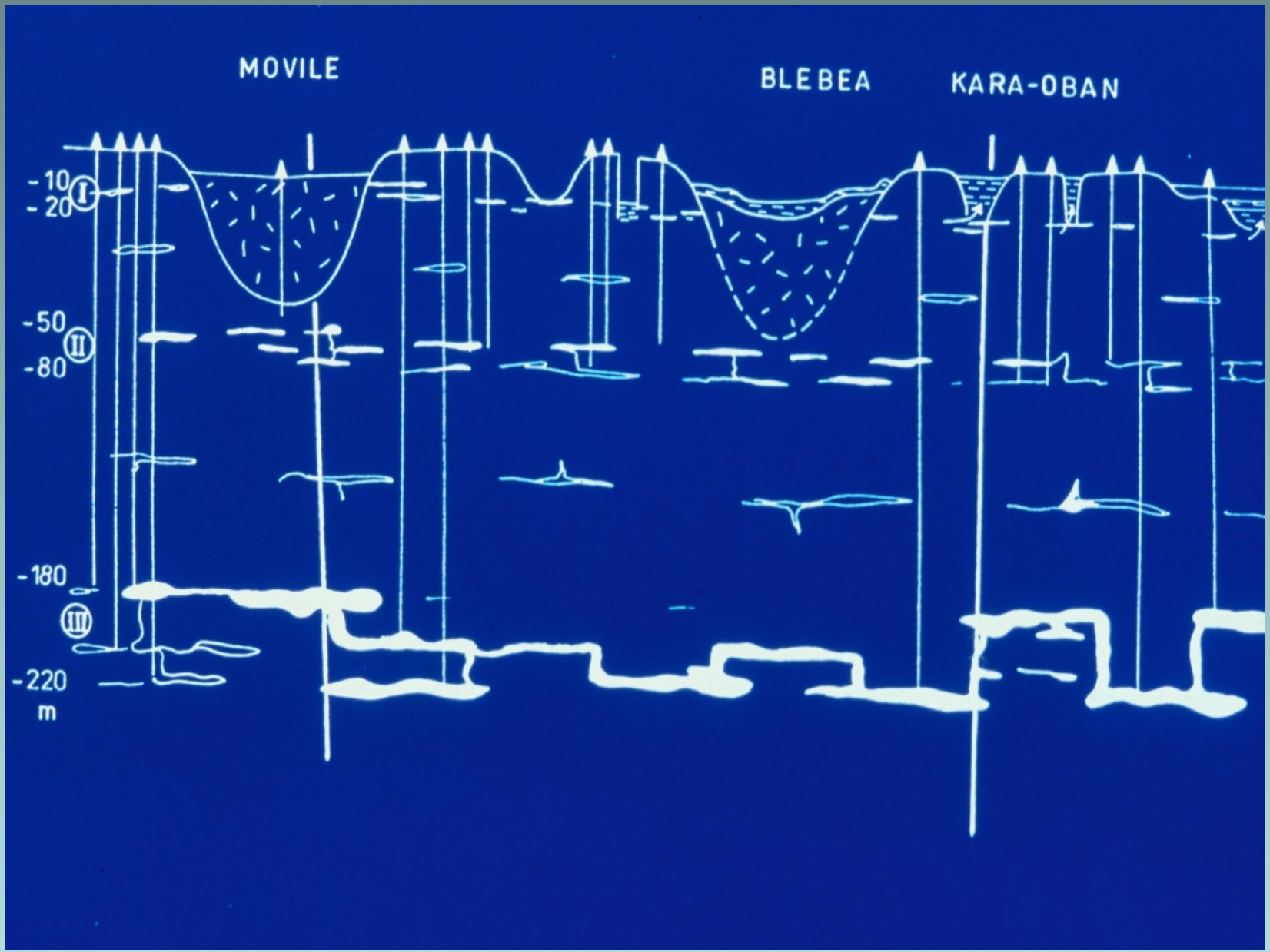
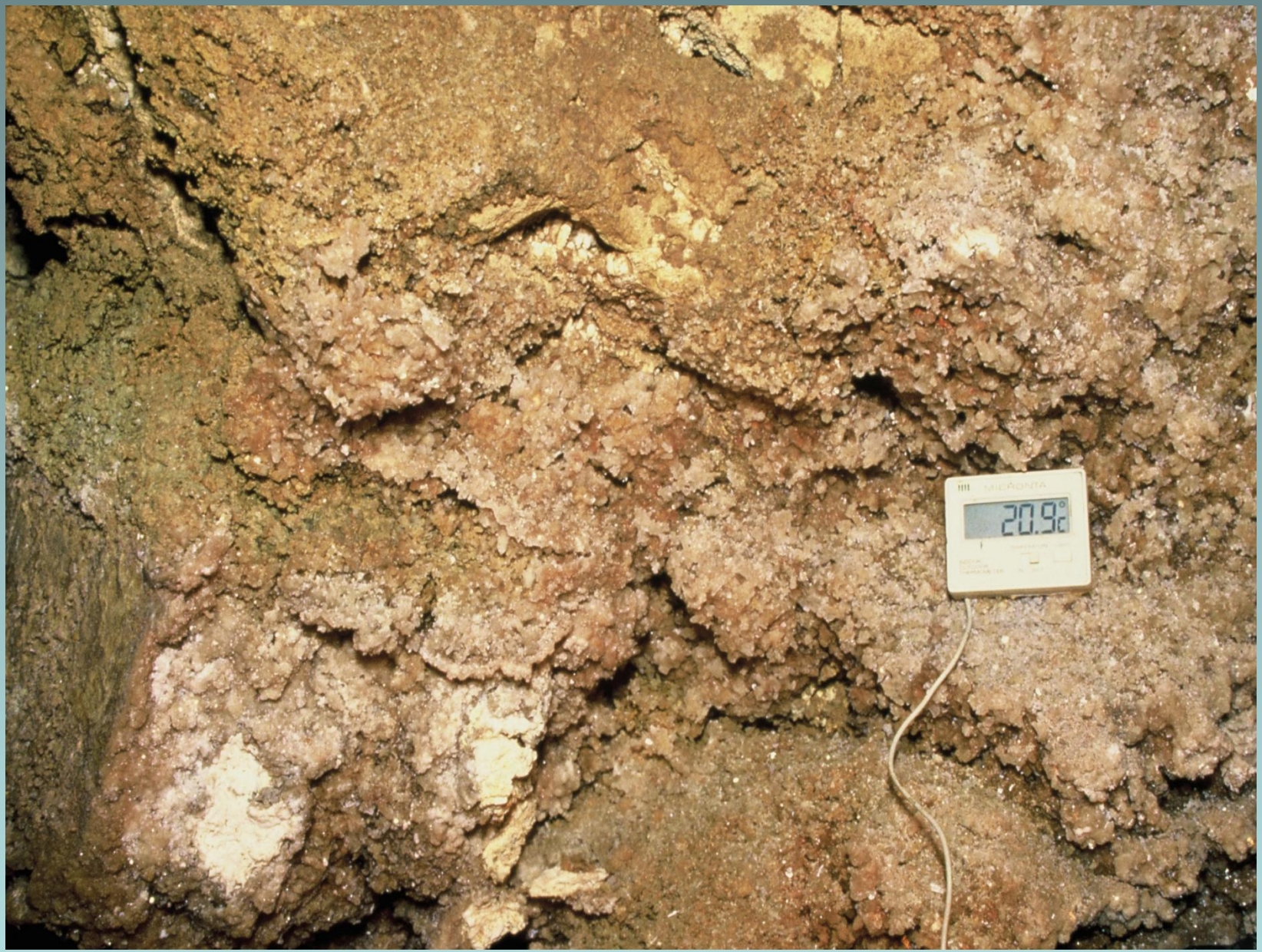
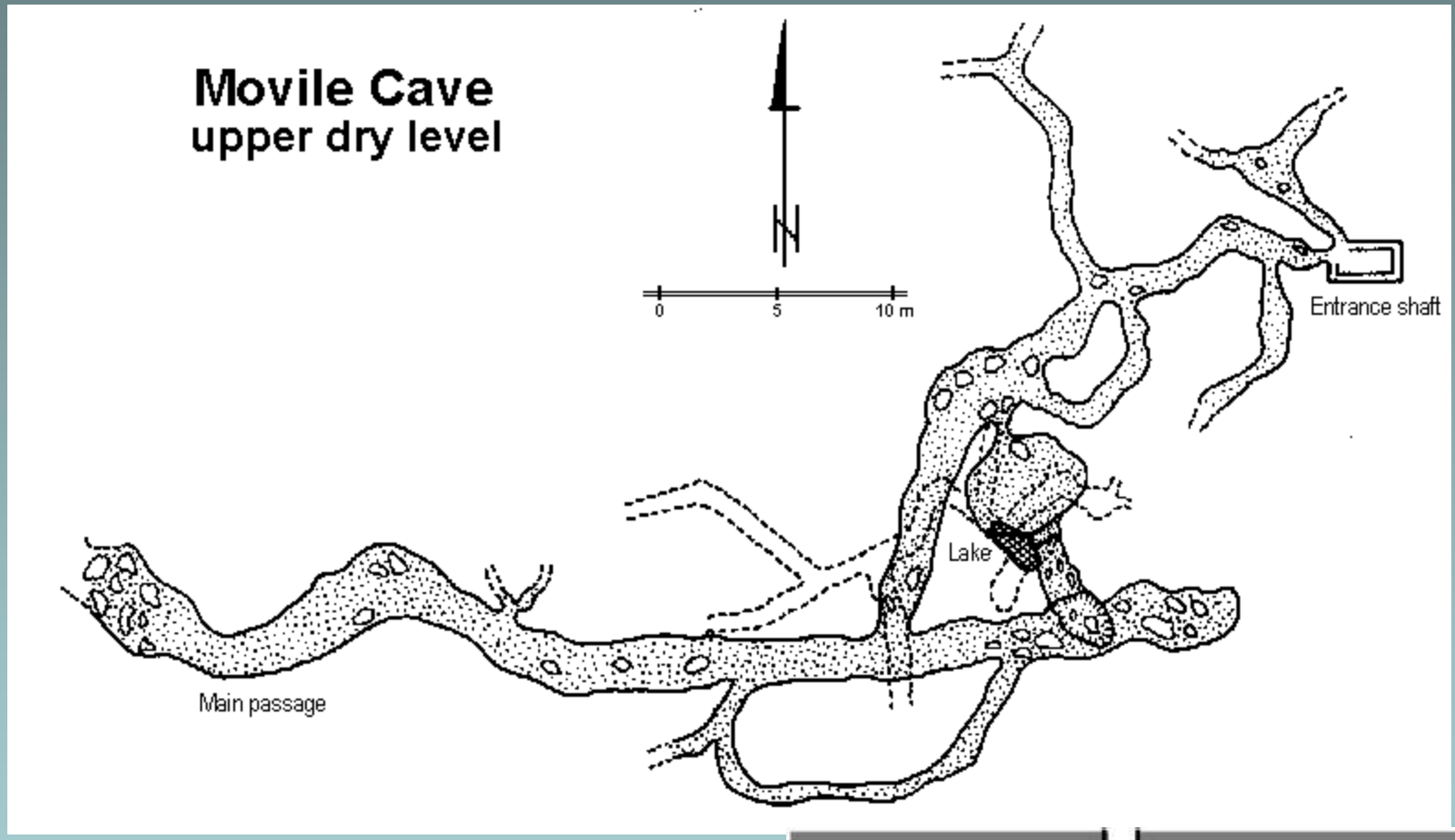
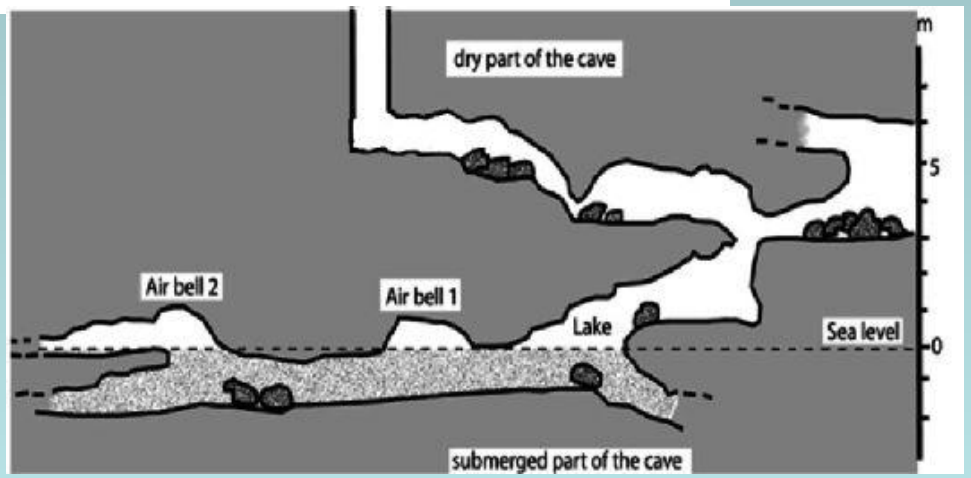
- Oct 30, 2007
43°50'13.83" N 28°34'15.01" E elev 49 ft
Eye alt 13814 ft


MOVILE
BLEBEA
KARA-OBAN
-10
-20
I
-50
II
-80
-180
III
-220
m


N
© 2009 Basarsoft
Image © 2010 DigitalGlobe
© 2009 Google
© 2009 Tele Atlas
Google
Imagery Date: Oct 30, 2007
43°49'38.90" N 28°33'43.44" E elev 83 ft
Eye alt 3859 ft

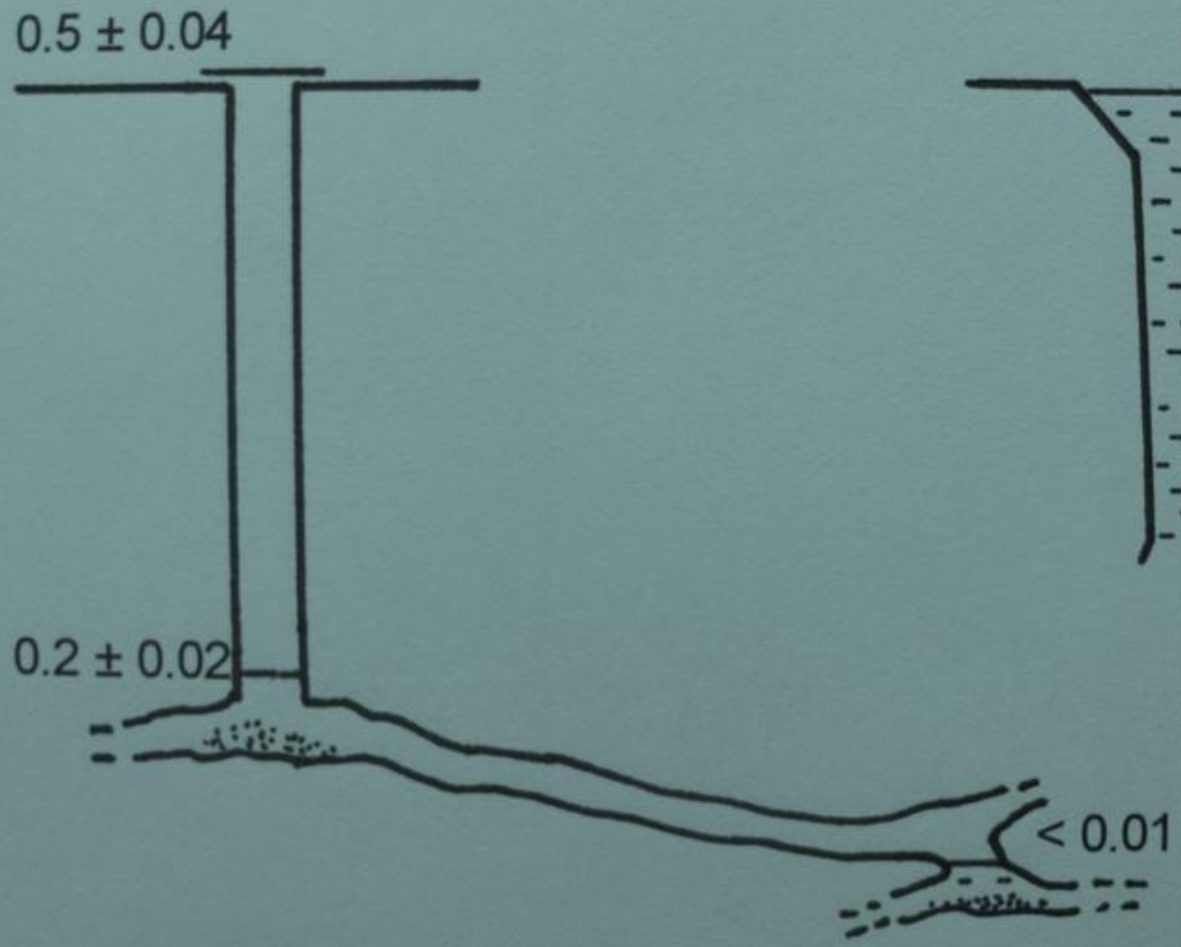

20.9°C


Movile Cave
upper dry level
0
5
10 m
Entrance shaft
Lake
Main passage

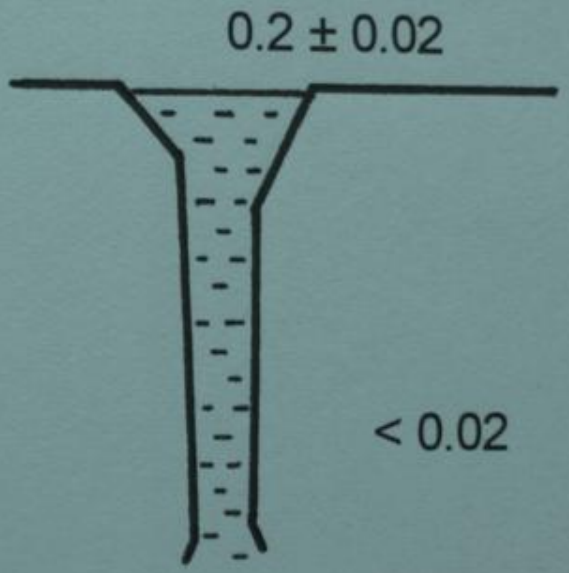

dry part of the cave
m
5
0
Air bell 2
Air bell 1
Lake
Sea level
submerged part of the cave

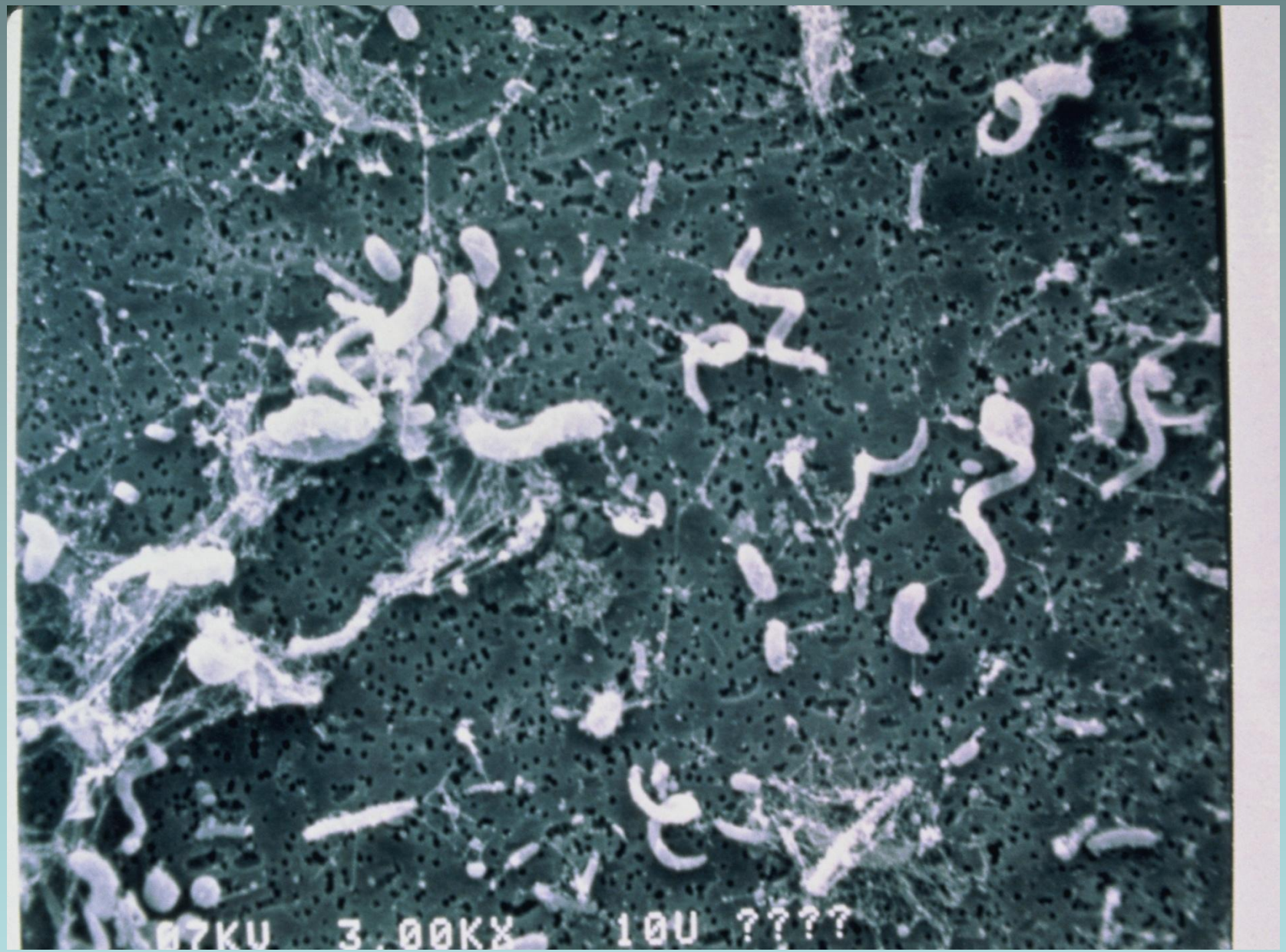

[µm]
100

^{137}Cs in surface soil and cave sediments (pCi/g)
April 1992
Movile Cave



^{137}Cs in sediment (pCi/g)
April 1992
Radu Spring




07KV 3.00KX 10U ????

Stable isotopes: ^{12}C (99%), ^{13}C (1%)

The number of neutrons varies

$\delta^{13}C‰$ vs [std.]= $(R_{sample} - R_{std}) / R_{std}$ X 1000

Isotopic Fractionation: enzymes select for light isotopes:

CO_2 ($\delta^{13}C$ -7‰) $\longrightarrow$ Sugar ($\delta^{13}C$ -27‰)

RuBisCO

Fractionation of -21‰

Food Web Analysis using Stable Isotopes

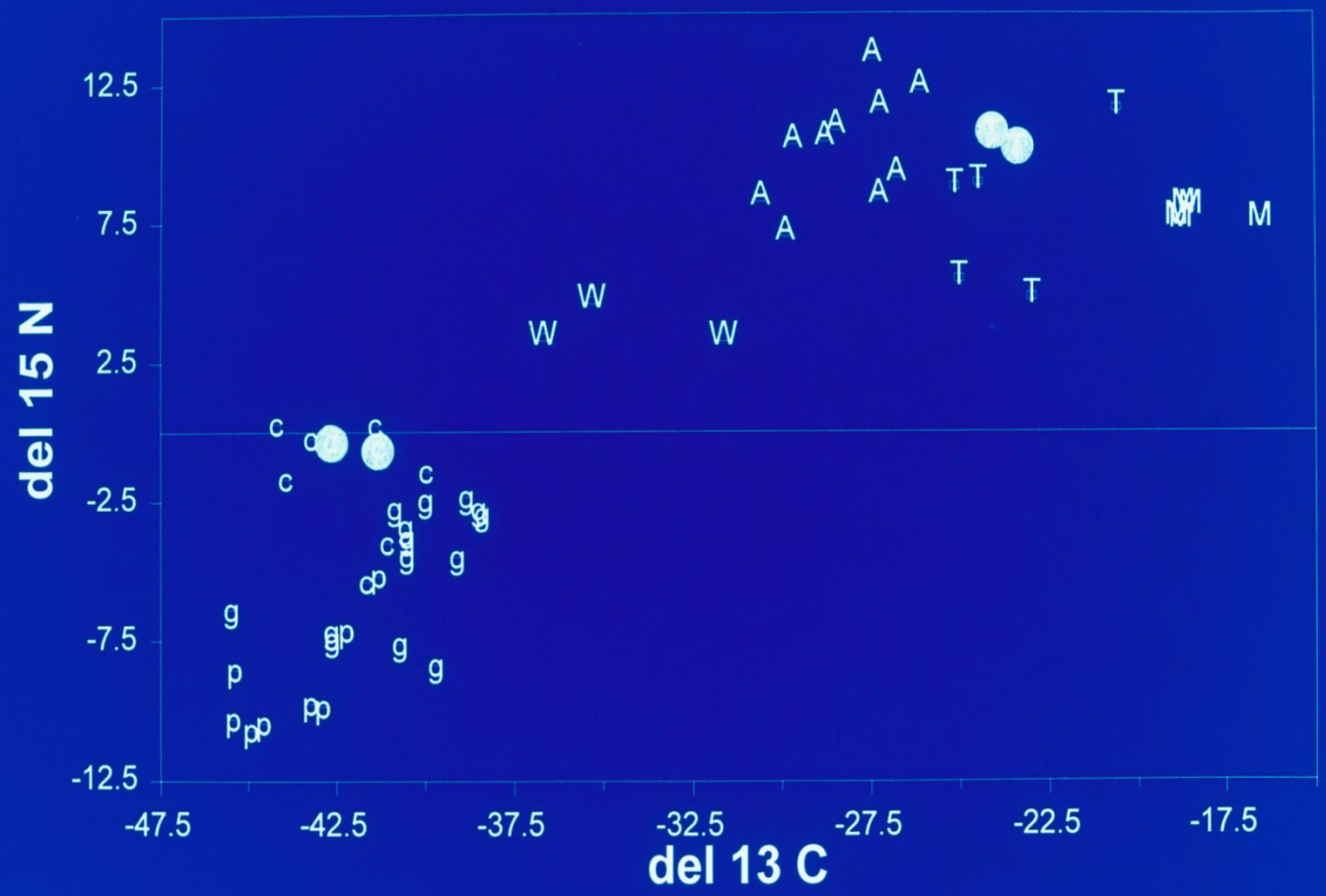
"We are what we eat + 1.5 ‰"

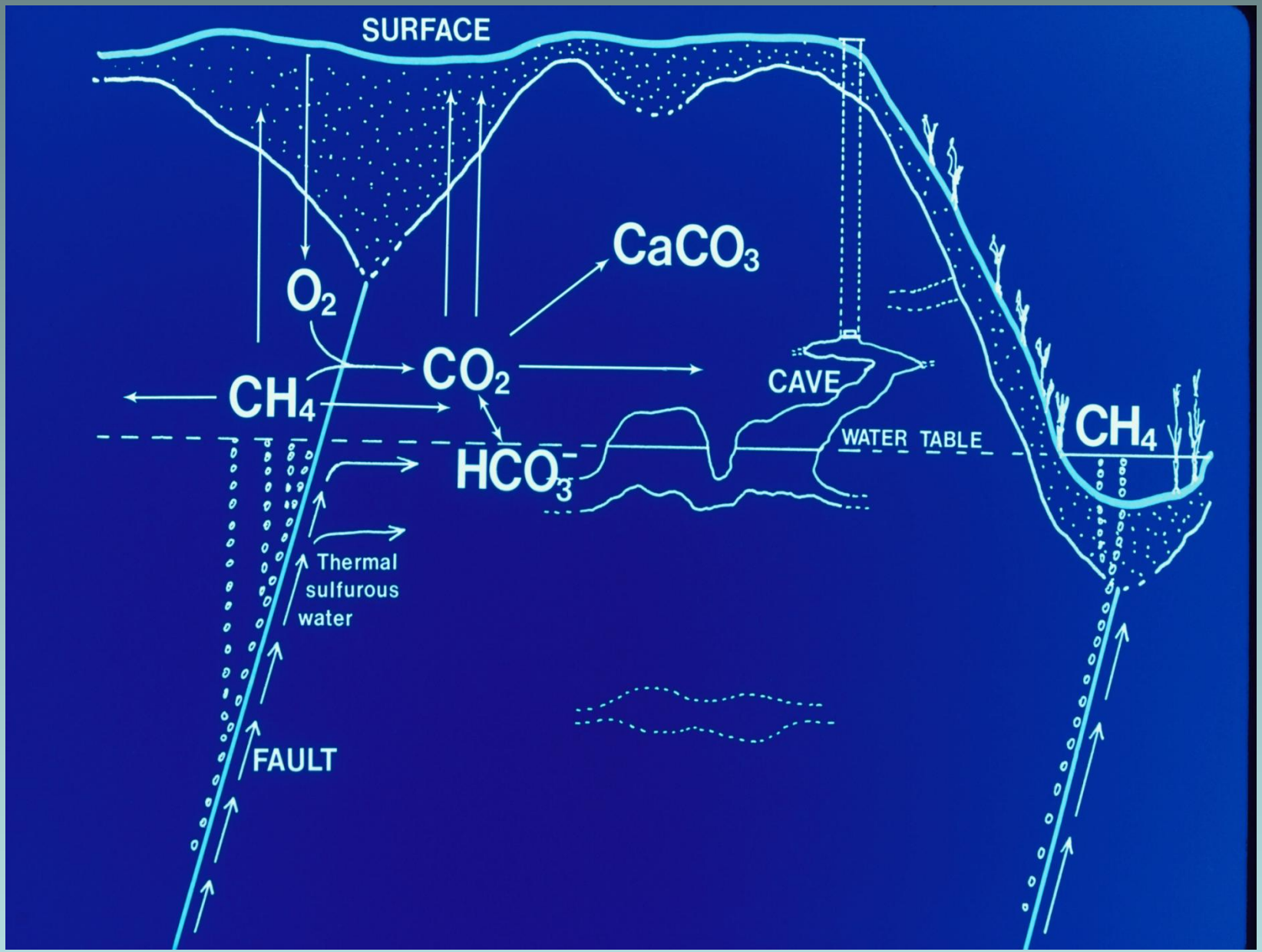
Grass	Deer	Wolf	Flees	Mites
-27‰*	-25.5‰*	-24‰*	-22.5‰*	-21‰*

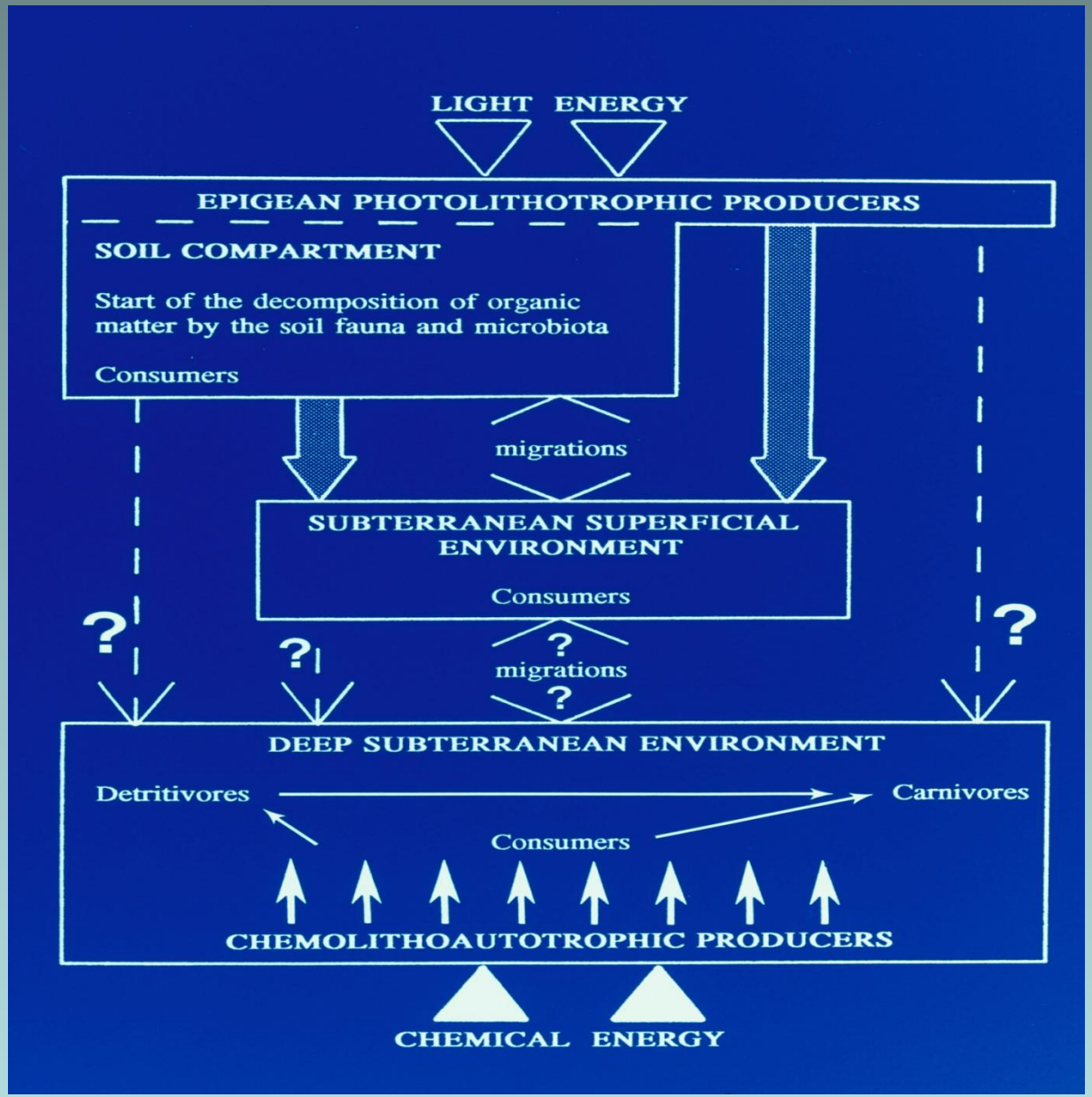
* $\delta^{13}C$‰ values

del 13C vs del 15N

Cryptops sp., Cryptopidae, Chilopoda

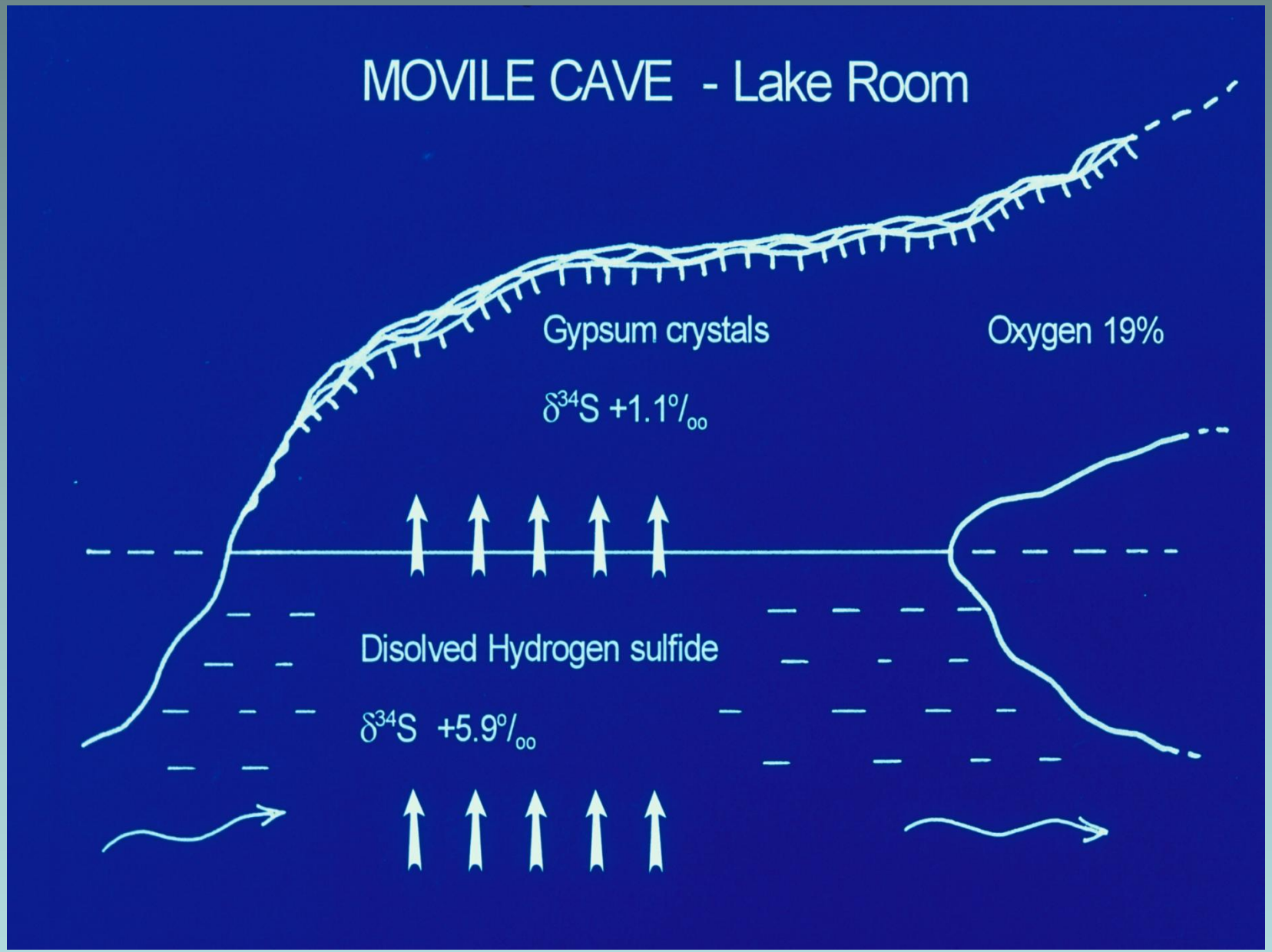


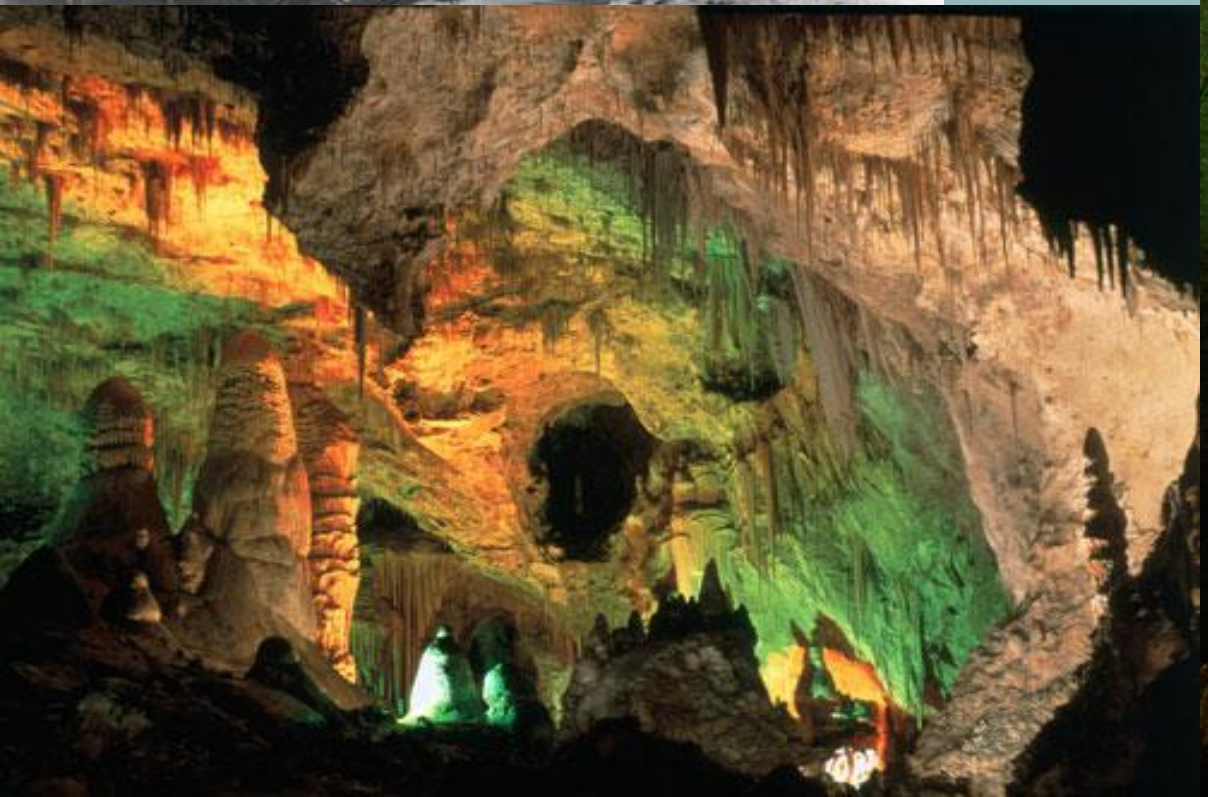

SURFACE
O_2
$CaCO_3$
CO_2
CH_4
CAVE
WATER TABLE
HCO_3^-
CH_4
Thermal
sulfurous
water
FAULT


LIGHT ENERGY
EPIGEAN PHOTOLITHOTROPHIC PRODUCERS
SOIL COMPARTMENT
Start of the decomposition of organic matter by the soil fauna and microbiota
Consumers
migrations
SUBTERRANEAN SUPERFICIAL ENVIRONMENT
Consumers
?
?
?
migrations
?
?
DEEP SUBTERRANEAN ENVIRONMENT
Detritivores
Carnivores
Consumers
CHEMOLITHOAUTOTROPHIC PRODUCERS
CHEMICAL ENERGY

Ongoing Research Projects:

- Geographic extent of the thermal aquifer
- Descriptions of new species
- Origins of the subterranean fauna
- Ecosystem studies
- Microbiology:
    - Sulfur and Methane Oxidation and Nitrification
    - Microbial Community Studies
    - Symbioses


MOVILE CAVE - Lake Room
Gypsum crystals
Oxygen 19%
$\delta^{34}S$ +1.1‰
Disolved Hydrogen sulfide
$\delta^{34}S$ +5.9‰



Sulfuric Acid Speleogenesis

$H_2S + O_2 \leftrightarrow H_2SO_4$ (Sulfuric acid)

(A) $CaCO_3 + H_2SO_4 \leftrightarrow CaSO_4 + H_2CO_3$

Limestone — Gypsum (soluble) — Carbonic Acid

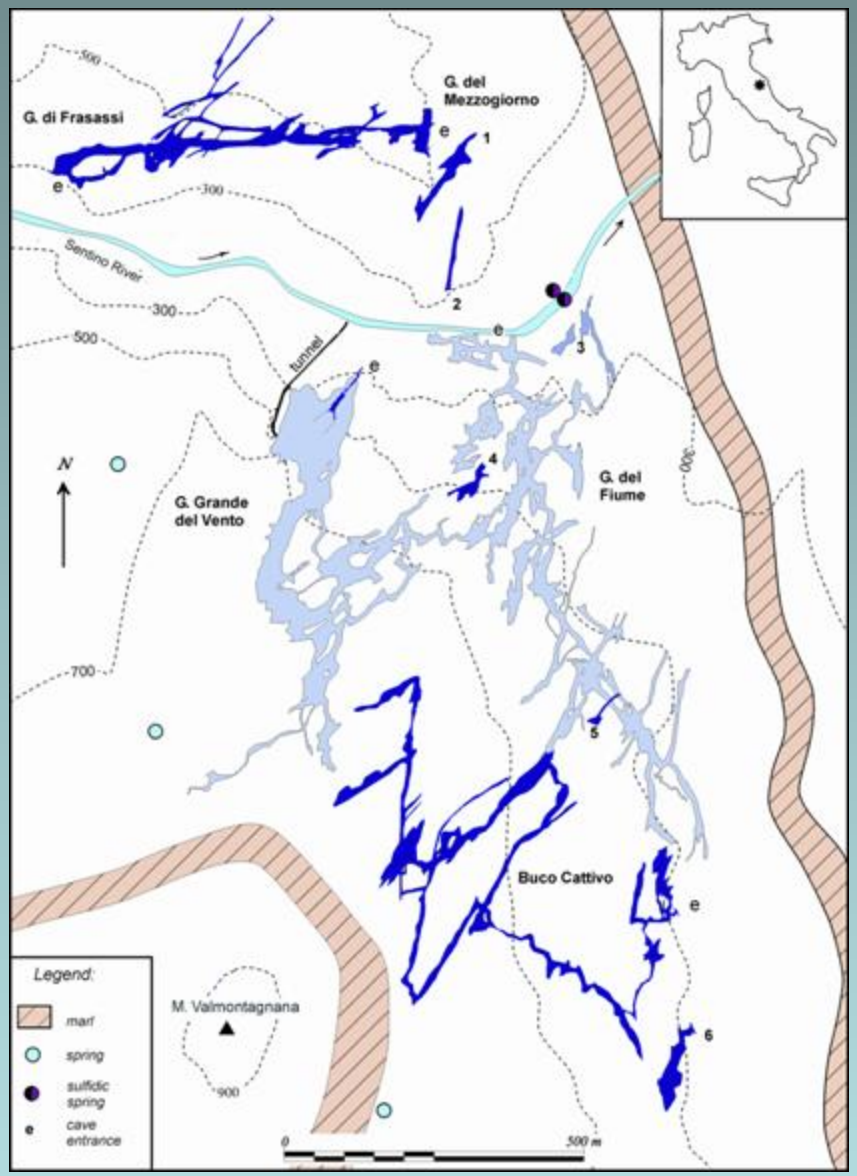
(B) $CaCO_3 + H_2CO_3 \leftrightarrow Ca(HCO_3)_2$

Limestone

Double dissolution: two $CaCO_3$ removed for each H_2S oxidized

Chemoautotrophically Based Cave Ecosystems

- Romania: Movile Cave
- Italy: Frasassi Caves
- Israel: Ayyalon Cave, En Nur Spring
- USA: Lower Kane Caves
- Mexico: Cueva de Villa Luz, Tabasco
- Libya: Cave at Bengazi



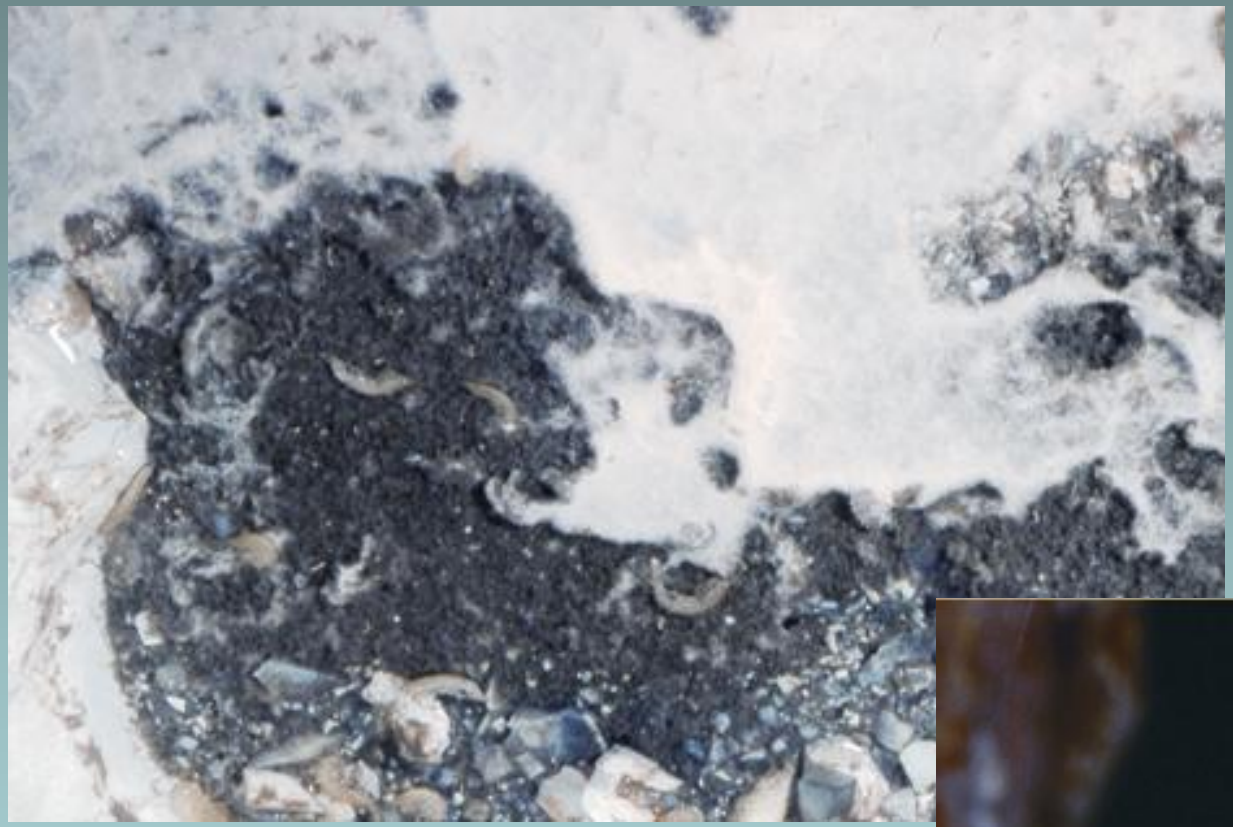
The Frasassi caves are the most studied hypogenic caves in Italy.

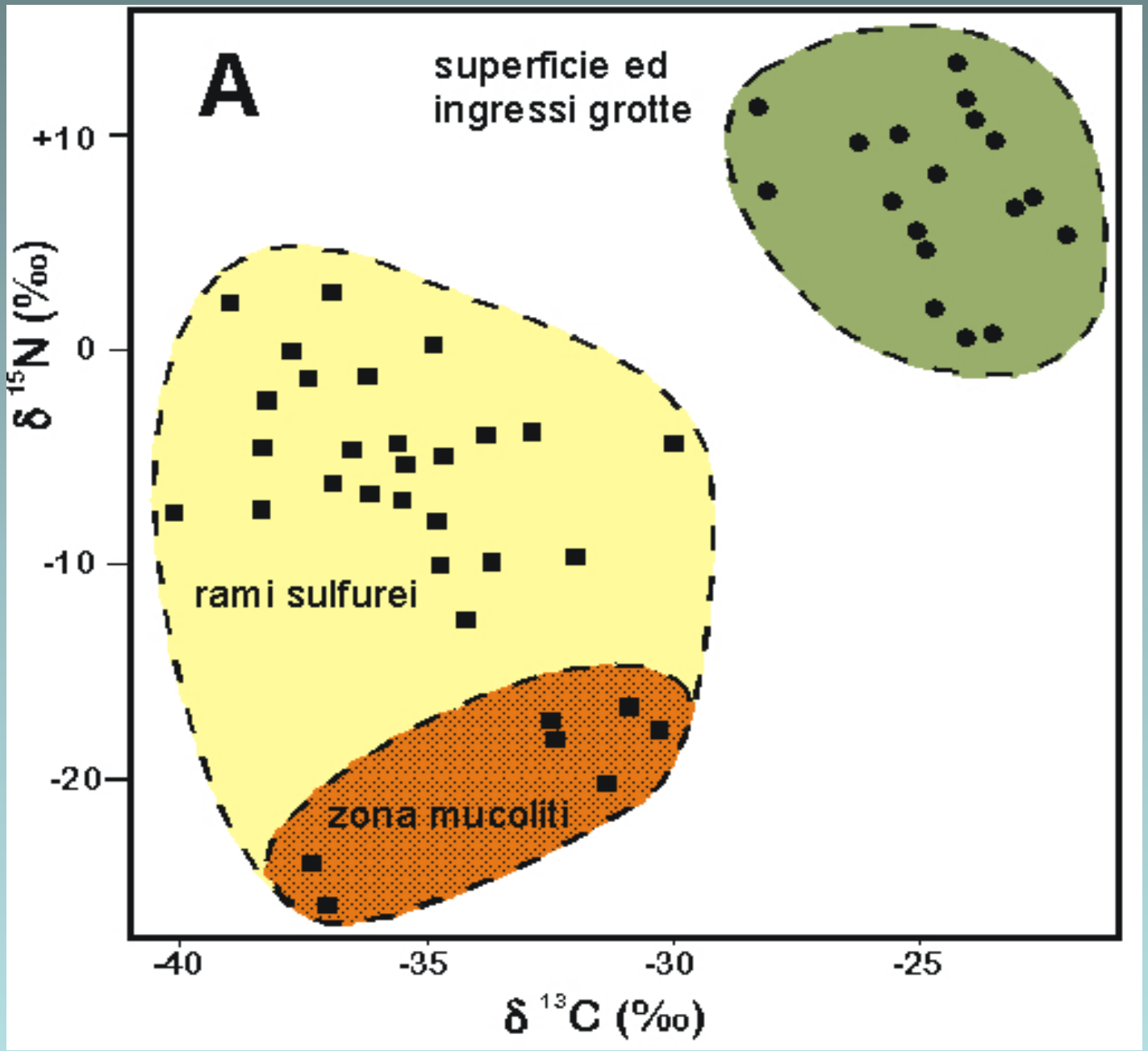
The caves consist of a network of ramifying, mainly sub-horizontal passages in which wide rooms (up to ~10^6 m^3) alternate with smaller tubes.

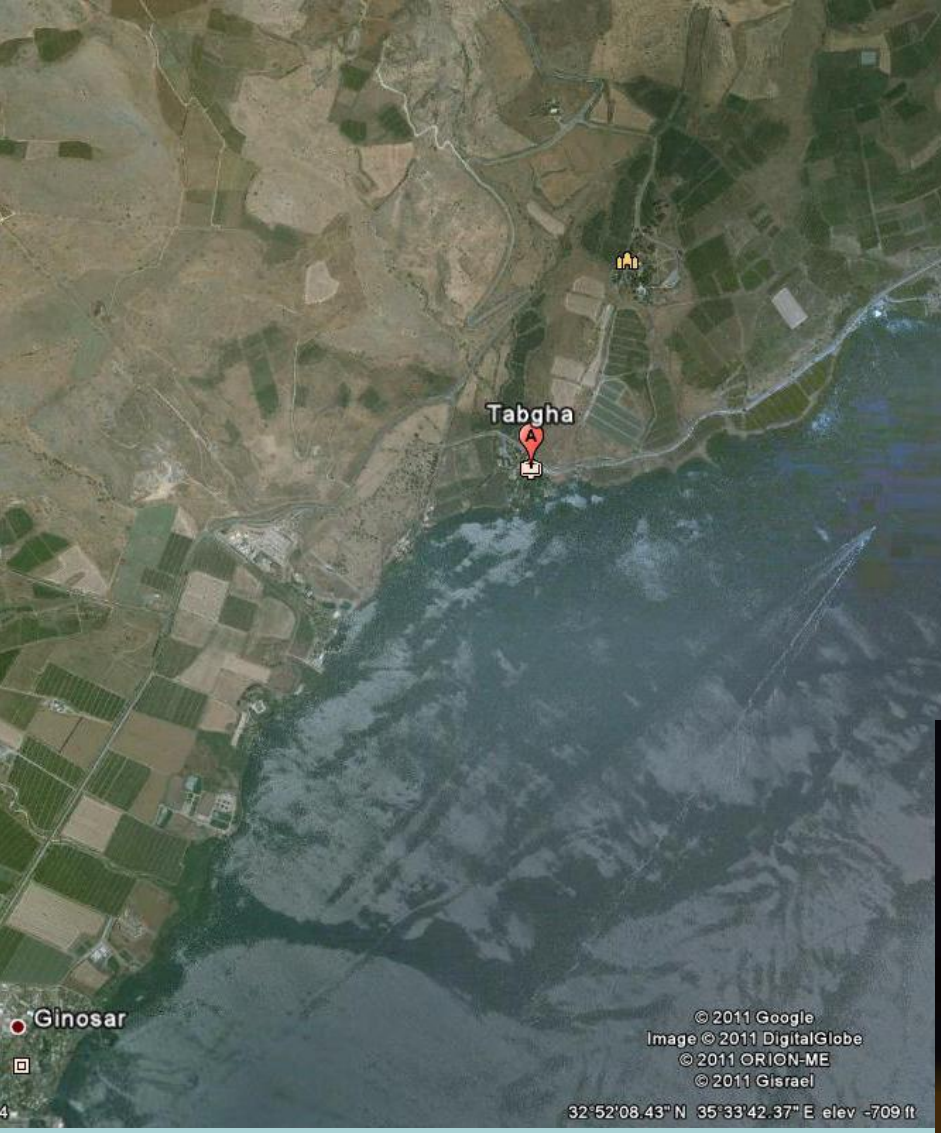
“Snotites”

pH = 0.0 – 0.3

Corroded Limestone




A
superficie ed
ingressi grotte
rami sulfurei
zona mucoliti
+10
0
-10
-20
δ 15N (‰)
-40
-35
-30
-25
δ 13C (‰)



Tabgha – En Nur Spring

Israel

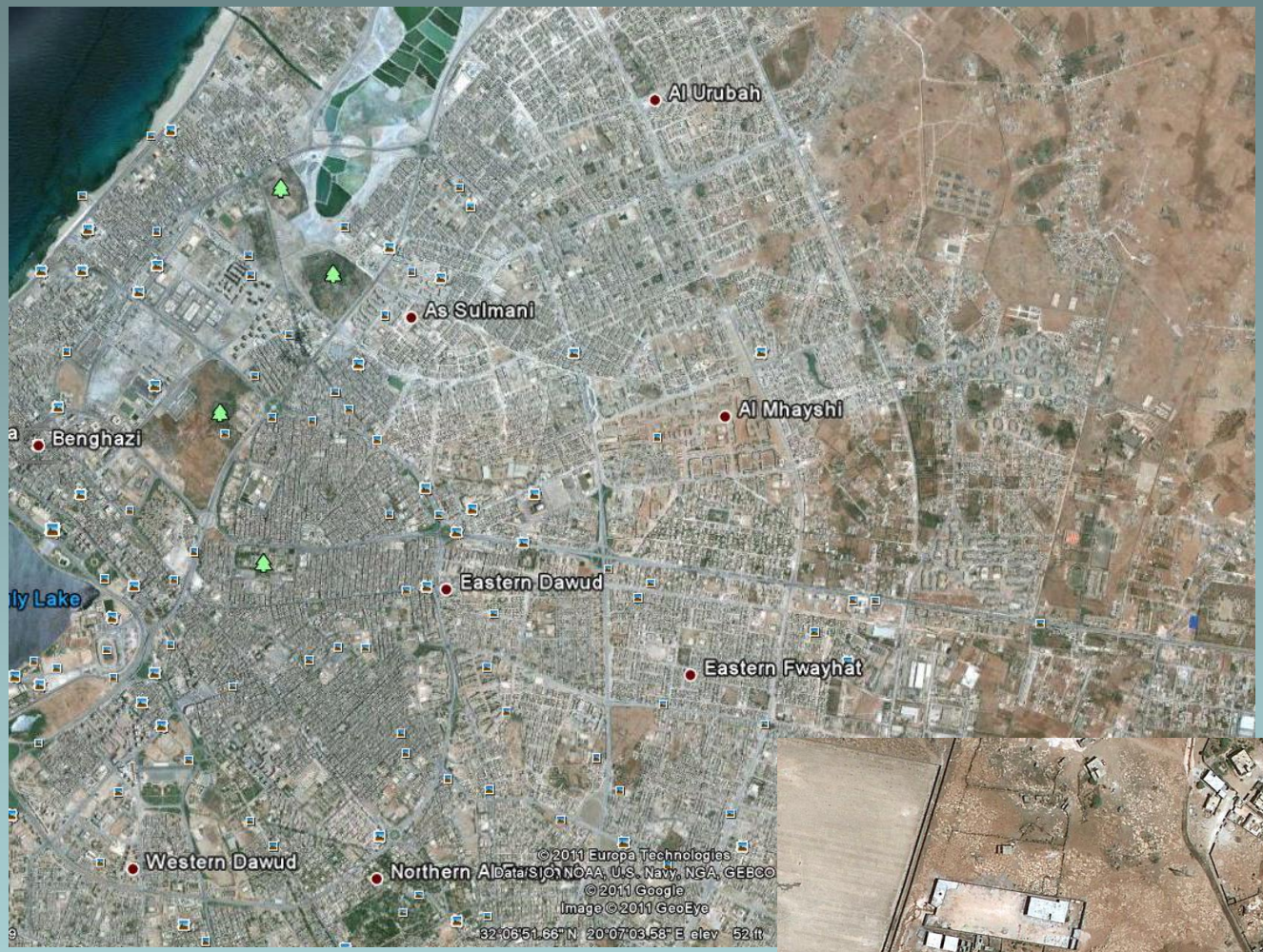
Ayyalon Cave

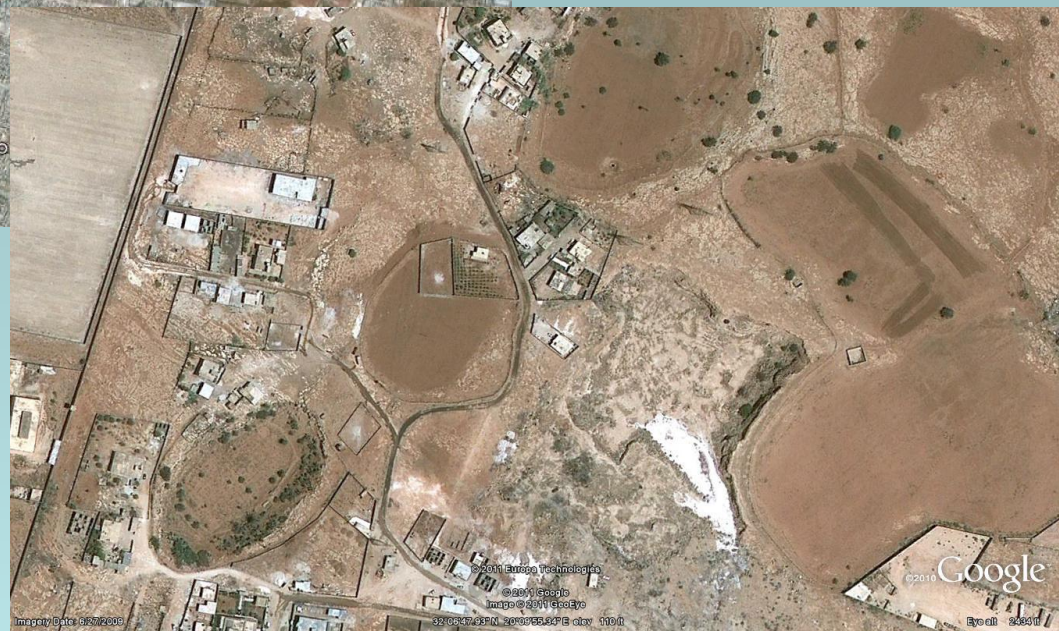
Israel

Lower Kane Cave

Wyoming

Cueva de Villa Luz, Tabasco, Mexico





Bengazi

Libya

Many Thanks to:

- Cristian Lascu – the discoverer of Movile Cave
- My scientific advisors (Cincinnati and Romania)
- Numerous friends who helped with the field work
- Volunteers from several spelunking clubs
- Funding agencies that supported our research
- Scientists who analyzed samples for this project
  and who helped me interpret the results

I would like to thank them all for their patience and tenacity, their love for caves, and their interest in cave science.