HYDROLOGY OF YUCATAN: AN EXAMPLE OF LARGE SCALE FRESHWATER RESERVOIR

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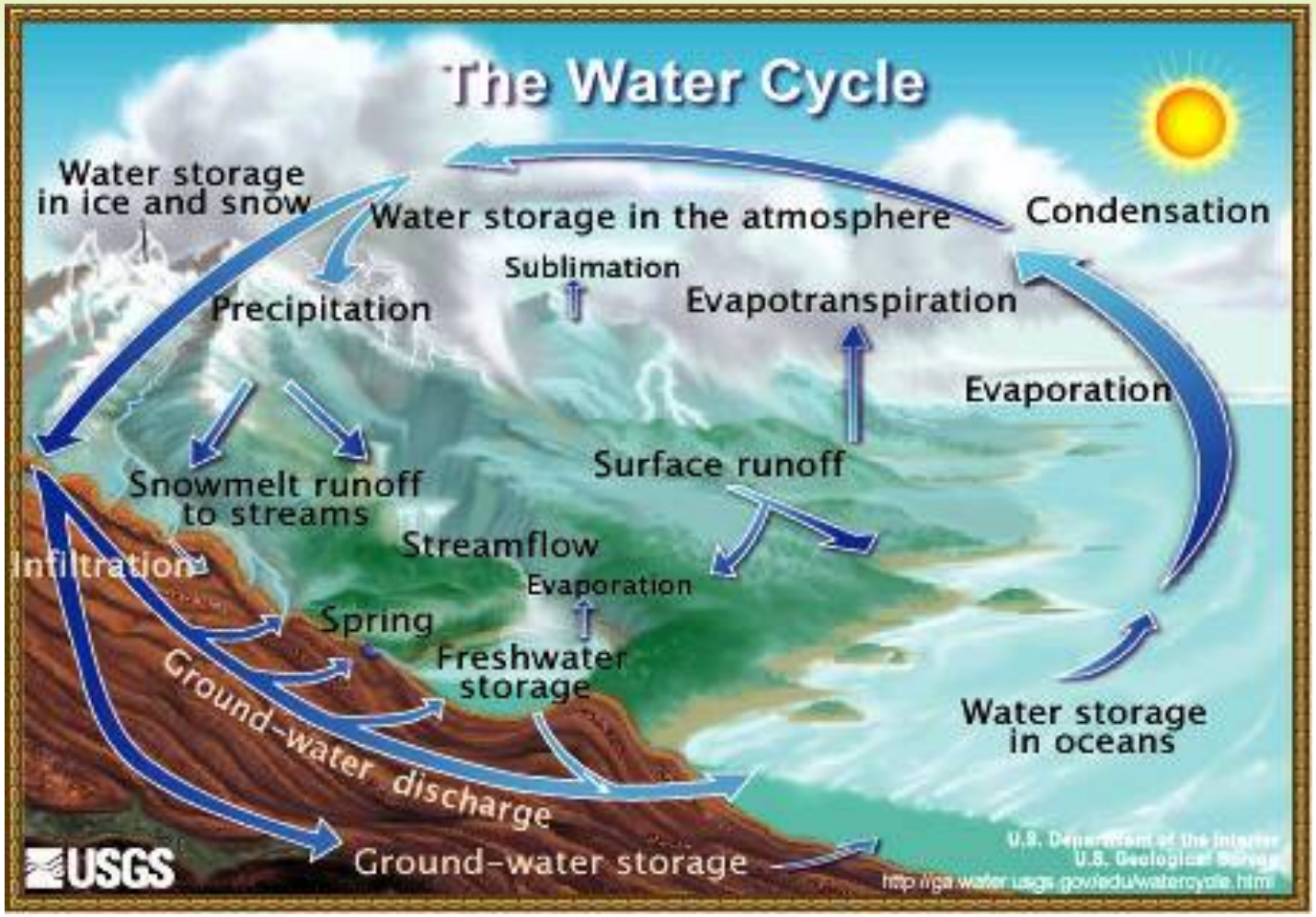
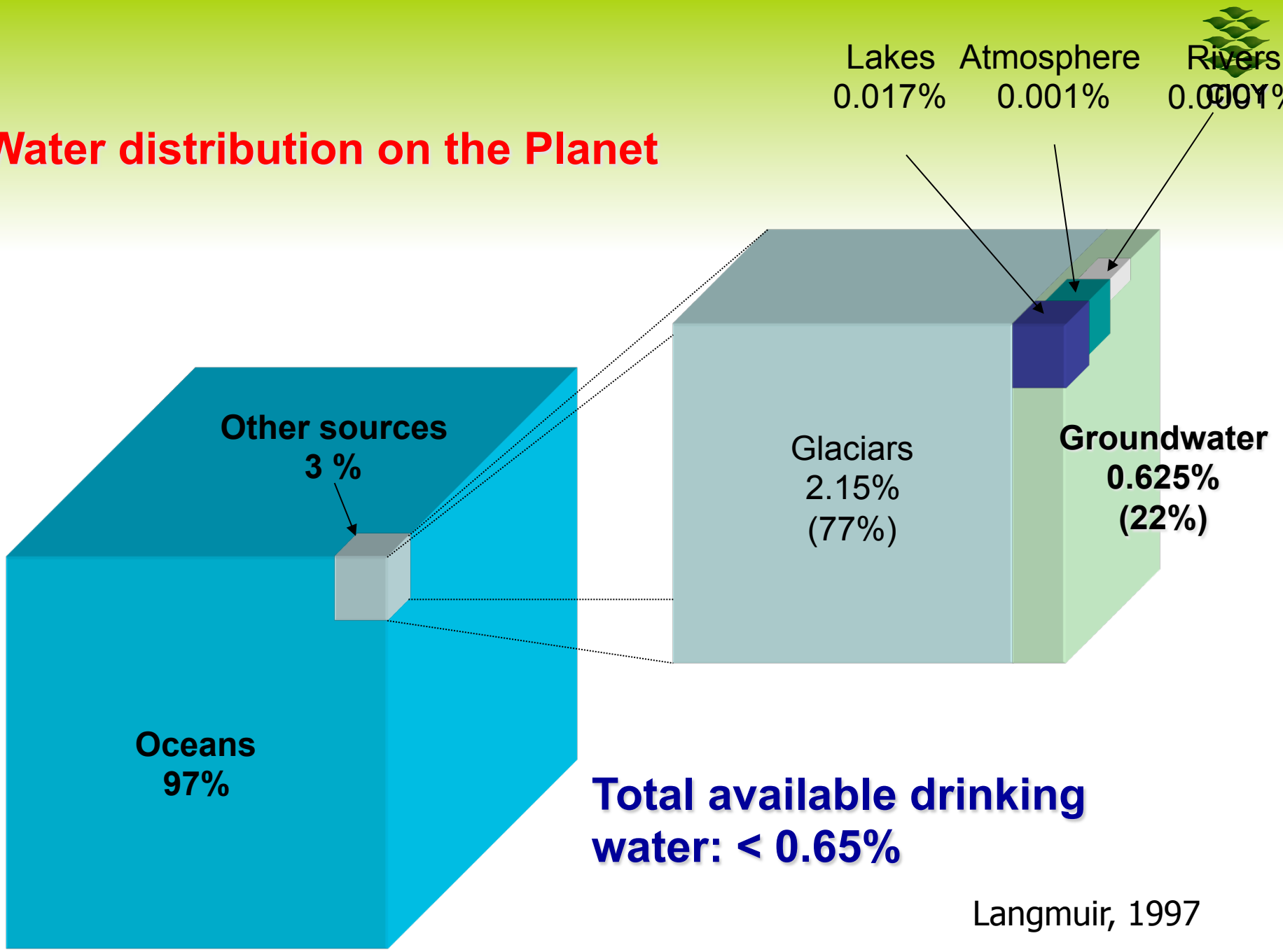

The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Surface runoff
Snowmelt runoff to streams
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
USGS
Ground-water storage
U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

Water distribution on the Planet



Total available drinking water: < 0.65%

Langmuir, 1997

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Gravel
well sorted, high porosity

Gravel - Sand - Clay
poorly sorted, low porosity

Cemented Sandstone
low porosity

Clay
high porosity

Limestone
low porosity

Shale
low porosity

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TABLE 11.2 Porosity and Hydraulic Conductivity of Selected Earth Materials

	Material	Porosity (%)	Hydraulic Conductivity[1] (m/day)
Unconsolidated	Clay	50	0.041
	Sand	35	32.8
	Gravel	25	205.0
	Gravel and sand	20	82.0
Rock	Sandstone	15	28.7
	Dense limestone or shale	5	0.041
	Granite	1	0.0041

[1] In older works, may be called coefficients of permeability.

Modified after Linsley, Kohler and Paulhus, 1958. *Hydrology for Engineers*. New York McGraw-Hill. Copyright © 1958 by McGraw-Hill Book Company. Used by permission of McGraw-Hill Book Company.

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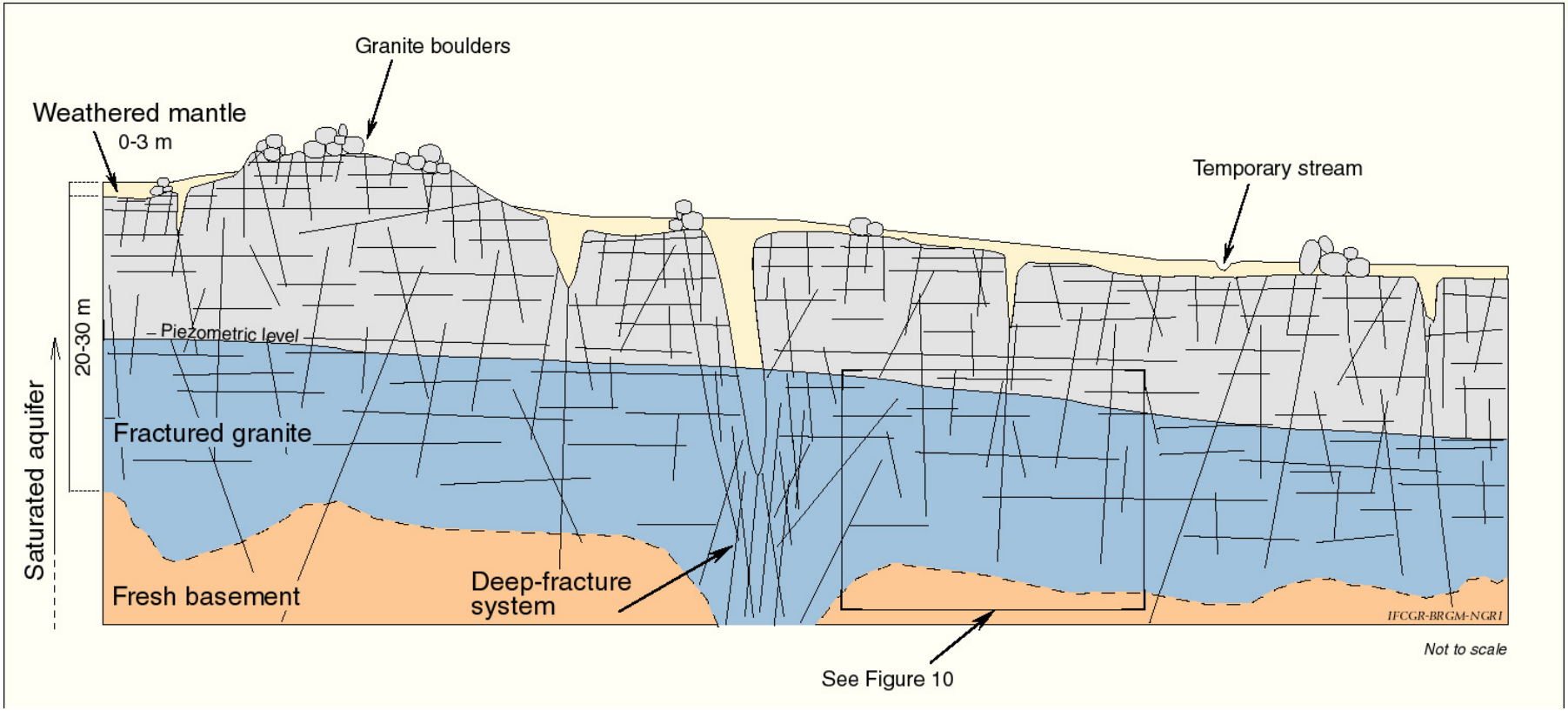
Granite boulders
Weathered mantle
0-3 m
Temporary stream
20-30 m
Piezometric level
Saturated aquifer
Fractured granite
Fresh basement
Deep-fracture system
IFCGR-BRGM-NGR1
Not to scale
See Figure 10

Karst

- Karstic comes from the German word karst, that in turn derives from the Slovenian word “kras”, which is a region located in Slovenia, Croatia and Italy. Originally, in the XIX century, karst referred to a deforested, rocky and arid region located in these three countries. Later, this region has been used to define the topographic characteristics of a karst, that, today, refers to a limestone terrain, with dissolution structures, fractures and collapses due to groundwater circulation (Gams, 1991).

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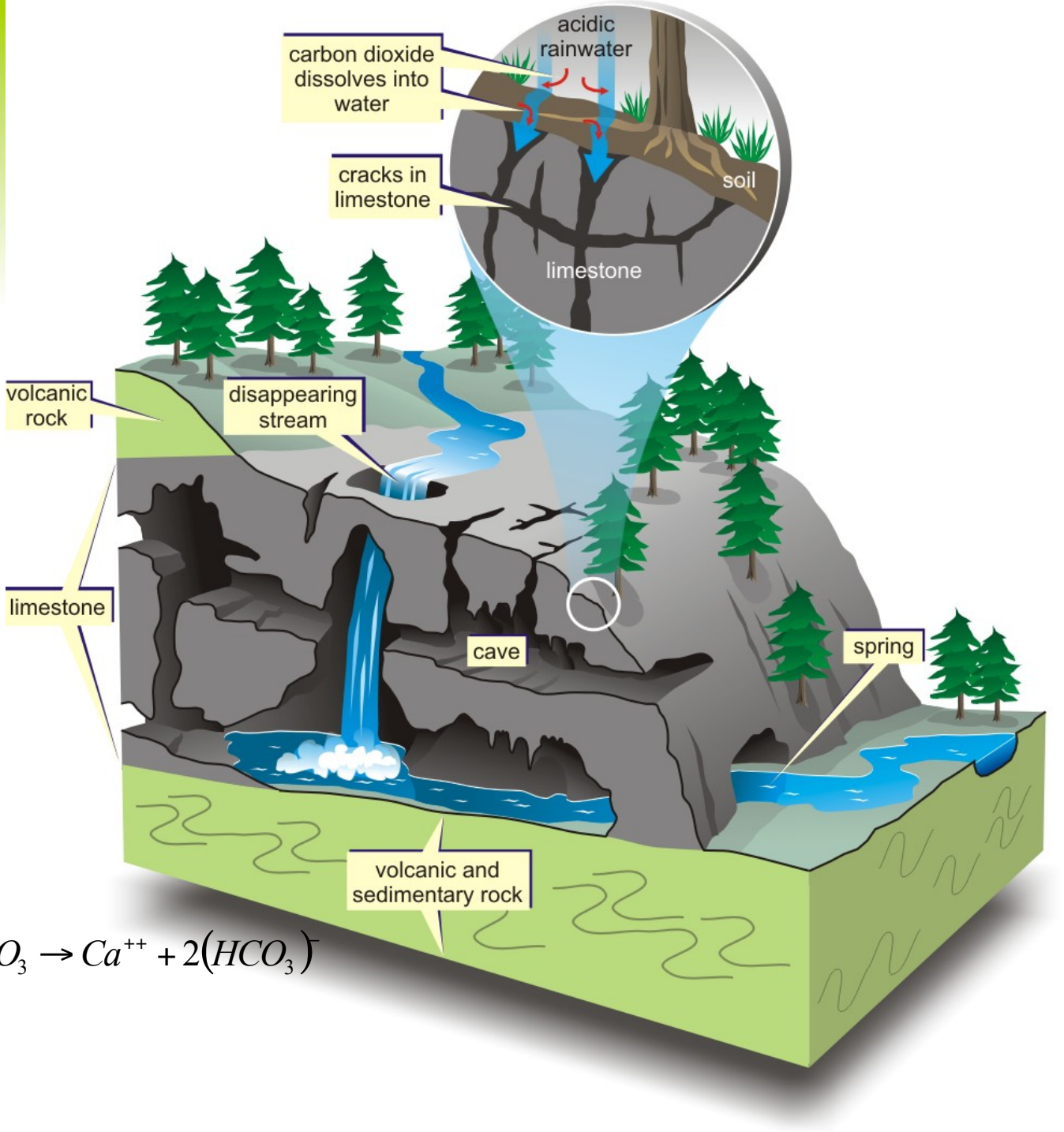
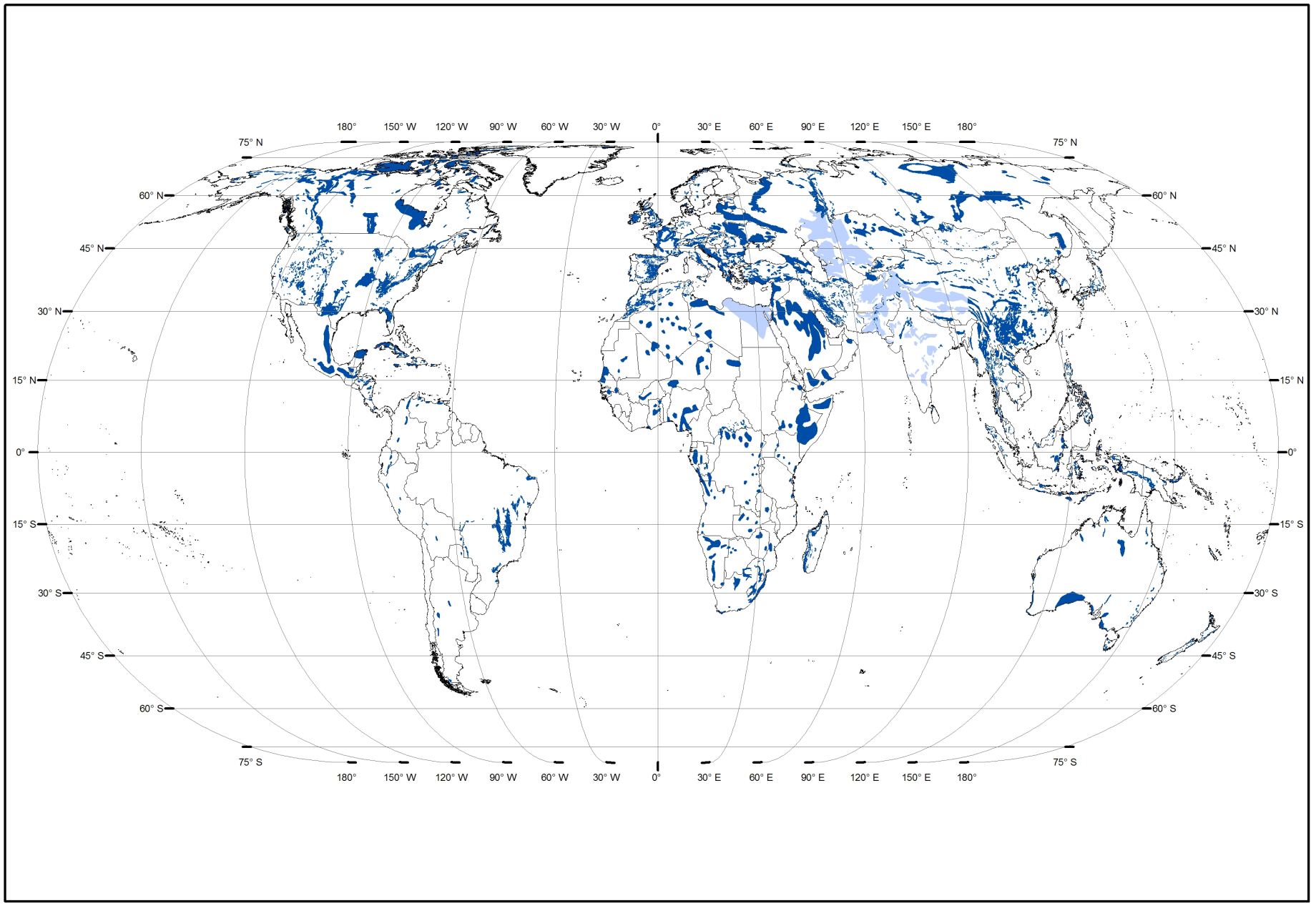
14°
15°
16°
17°
47°
46°
45°
AUSTRIA
HUNGARY
ITALY
KARAWANKEN MOUNTAINS
JULIAN ALPS
Triglav Mountain 9,395 ft.
Lake Bled
Jesenice
Kranj
Javornik
Idrija
Nova Gorica
Ljubljana
Postojna
KRAS PLATEAU
Gulf of Venice
Koper
ISTRIA
Adriatic Sea
Drava
Mura
Murska Sobota
Maribor
Ptuj
Velenje
Celje
Trbovlje
Zagorje
Hrastnik
Sava
Krško
Novo Mesto
Kočevje
Zagreb
CROATIA
BOSNIA AND HERZEGOVINA
0 25 50 mi
0 25 50 km
©2001, Encyclopædia Britannica, Inc.



$$H_2O + CO_2 \rightarrow H_2CO_3 + CaCO_3 \rightarrow Ca^{++} + 2(HCO_3)^-$$

Karst in the World



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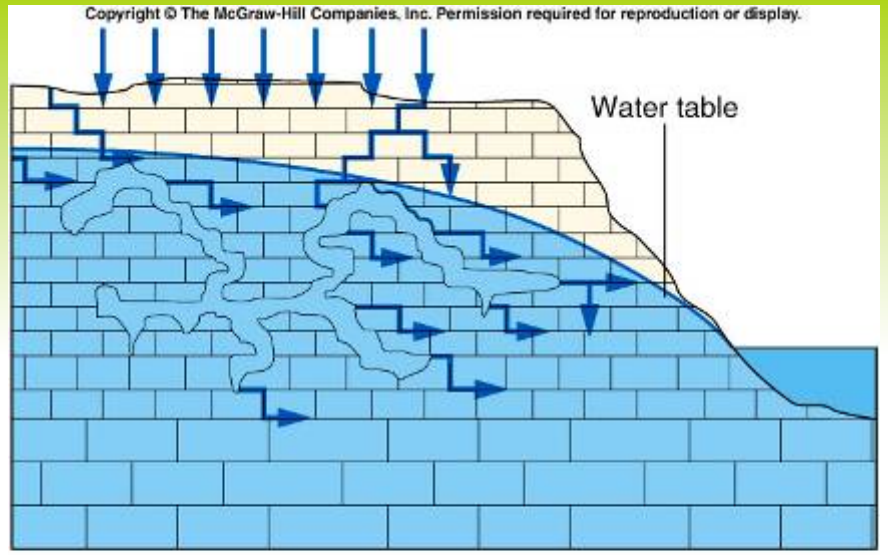
Karst in China

Madagascar



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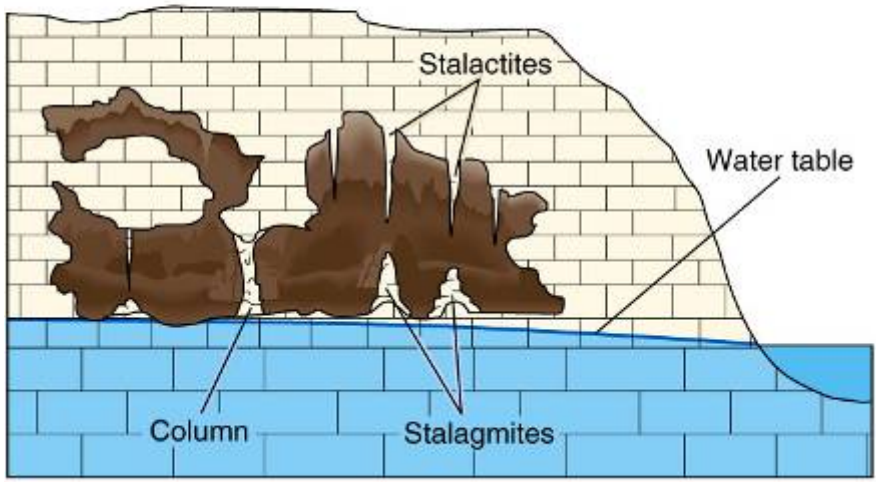
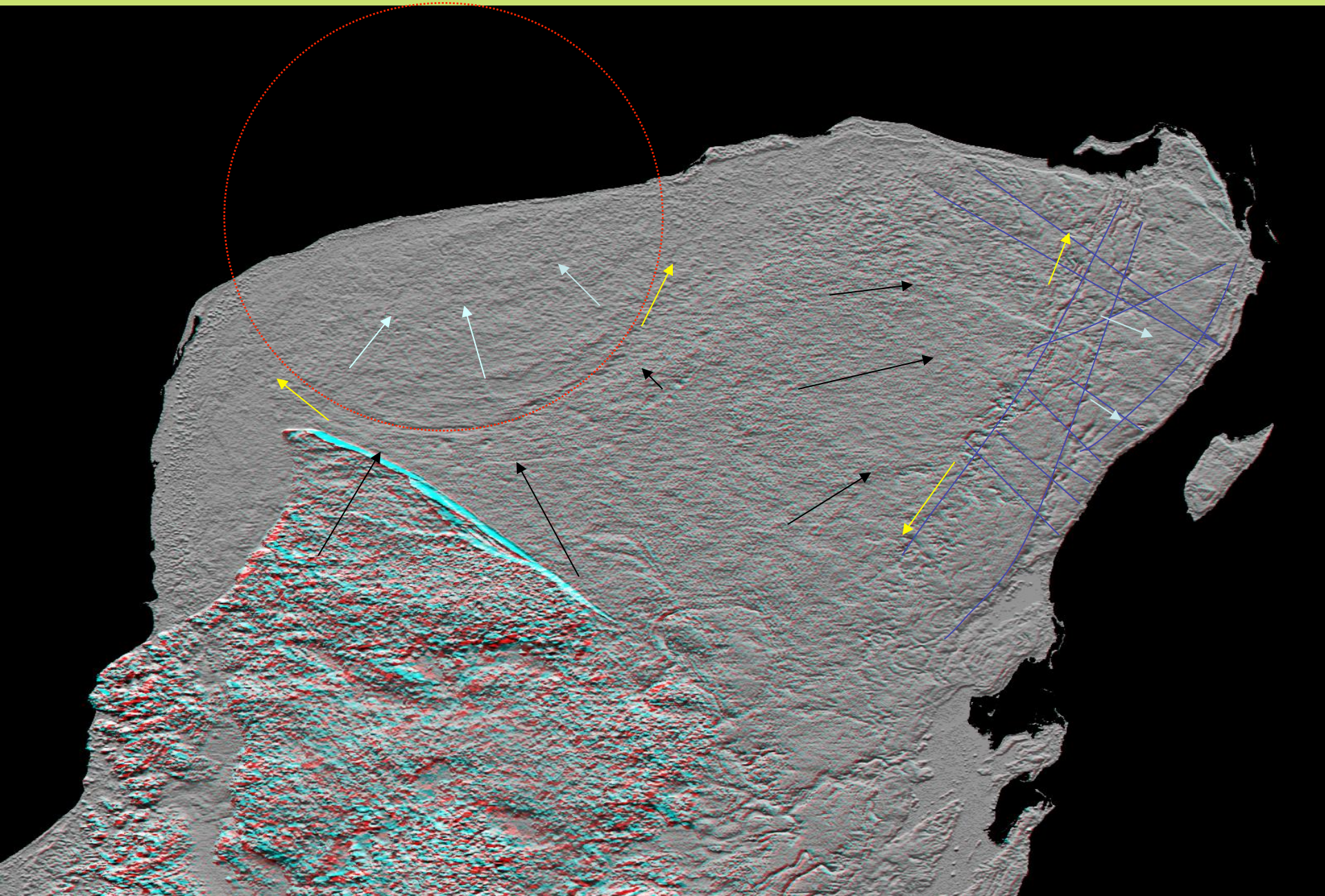


B

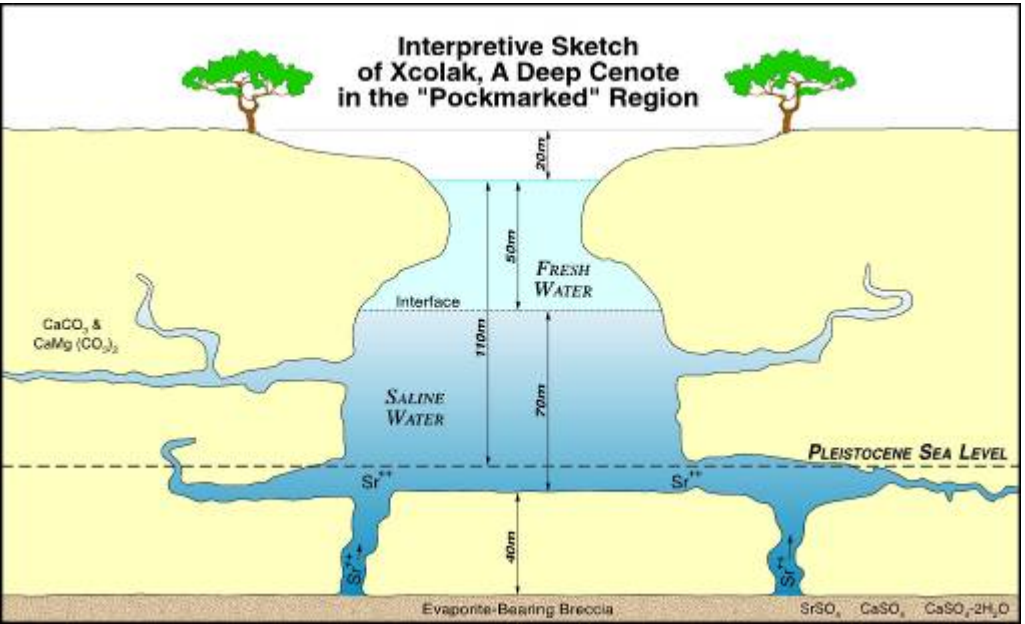
Plummer et al., 2005

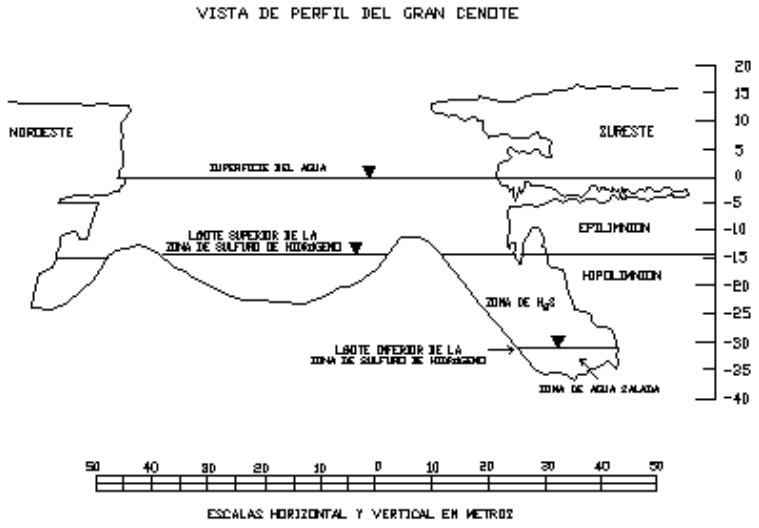
$$H_2O + CO_2 \rightarrow H_2CO_3 + CaCO_3 \rightarrow Ca^{++} + 2\left(HCO_3\right)^-$$



Cenotes

CICY





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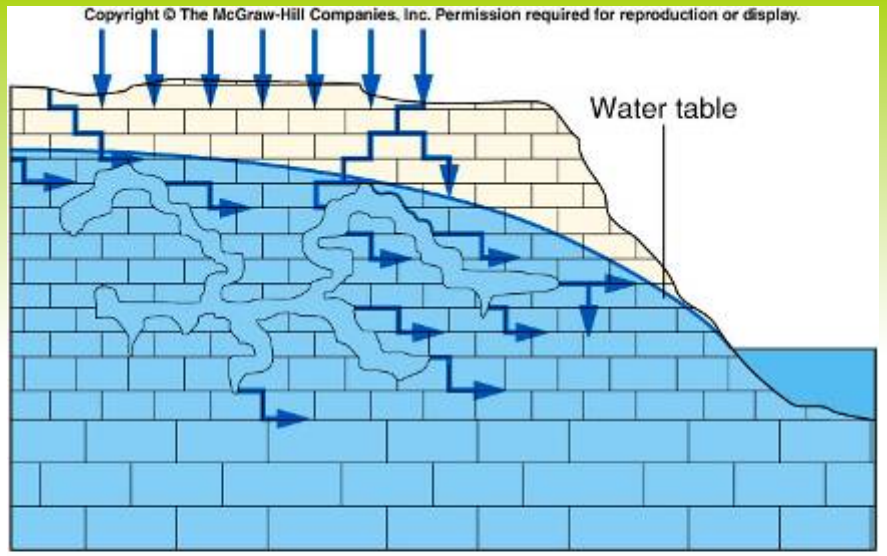

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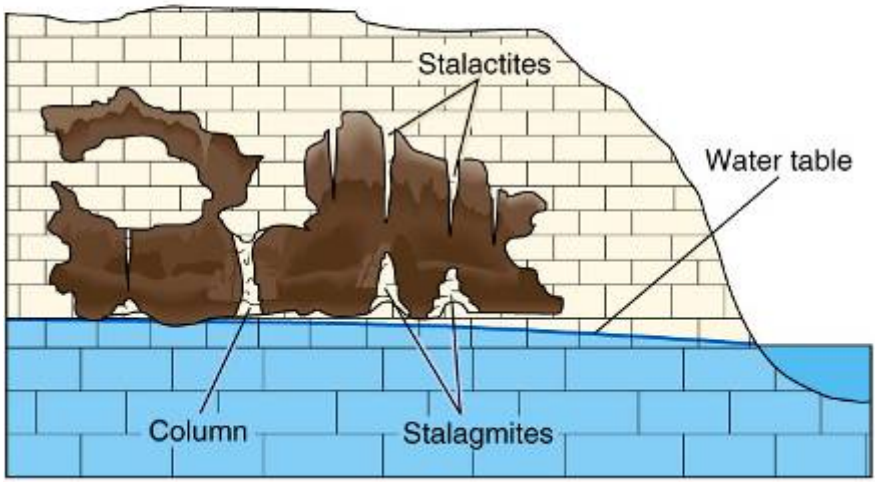


B

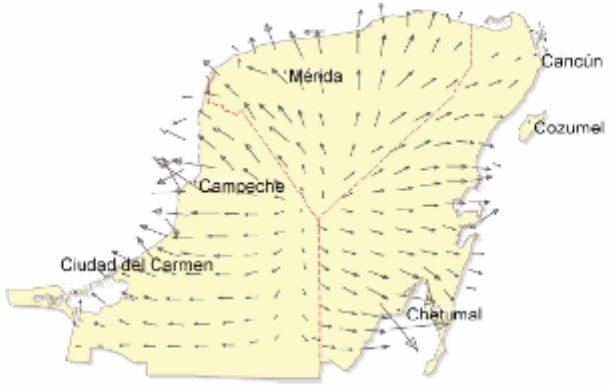
Plummer et al., 2005

$$H_2O + CO_2 \rightarrow H_2CO_3 + CaCO_3 \rightarrow Ca^{++} + 2(HCO_3)^-$$

Hydrogeology of Yucatan

CICY

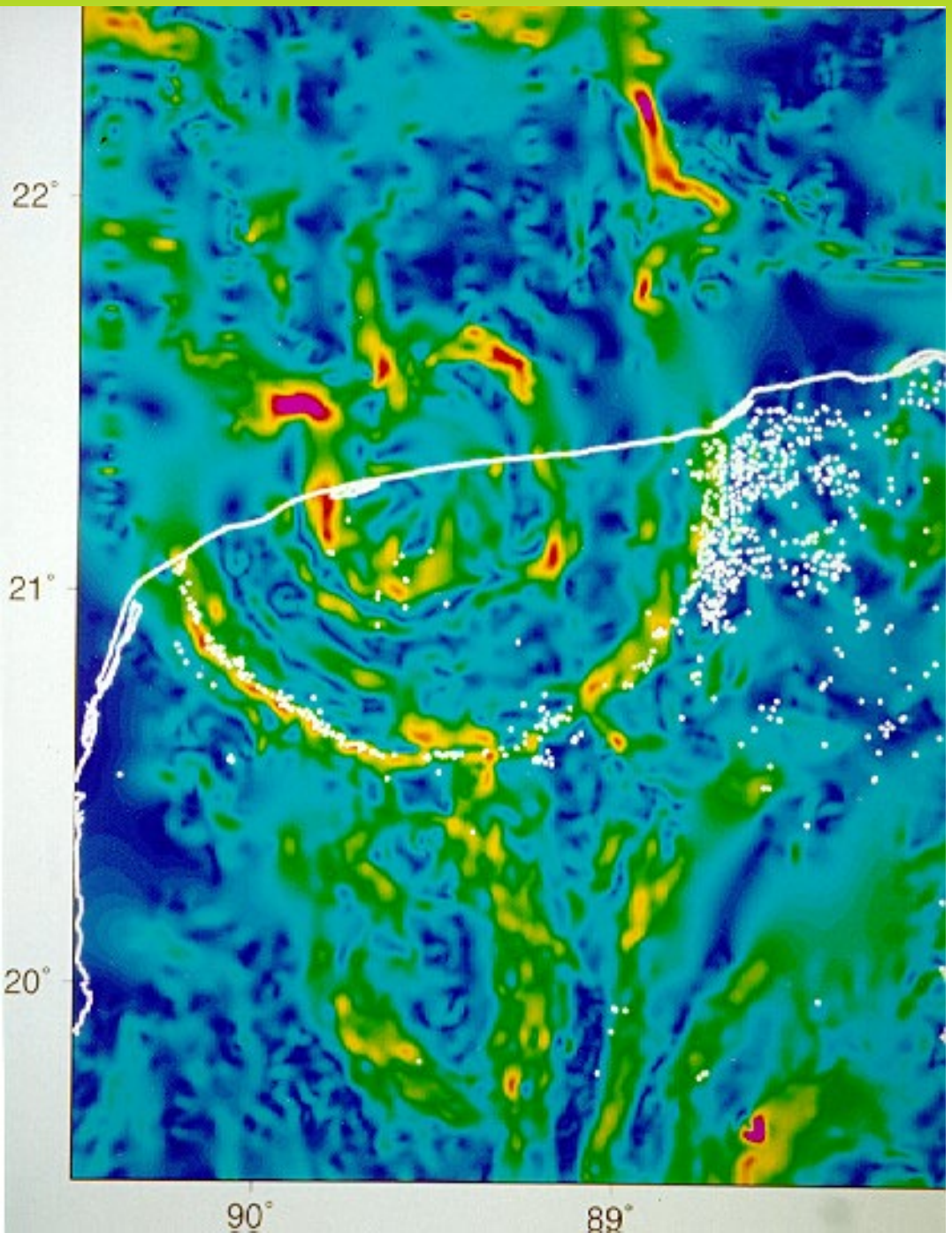
Esquema conceptual de la dirección del flujo del agua subterránea en la Península de Yucatán



Fuente: GRPY. Subgerencia Técnica. CNA

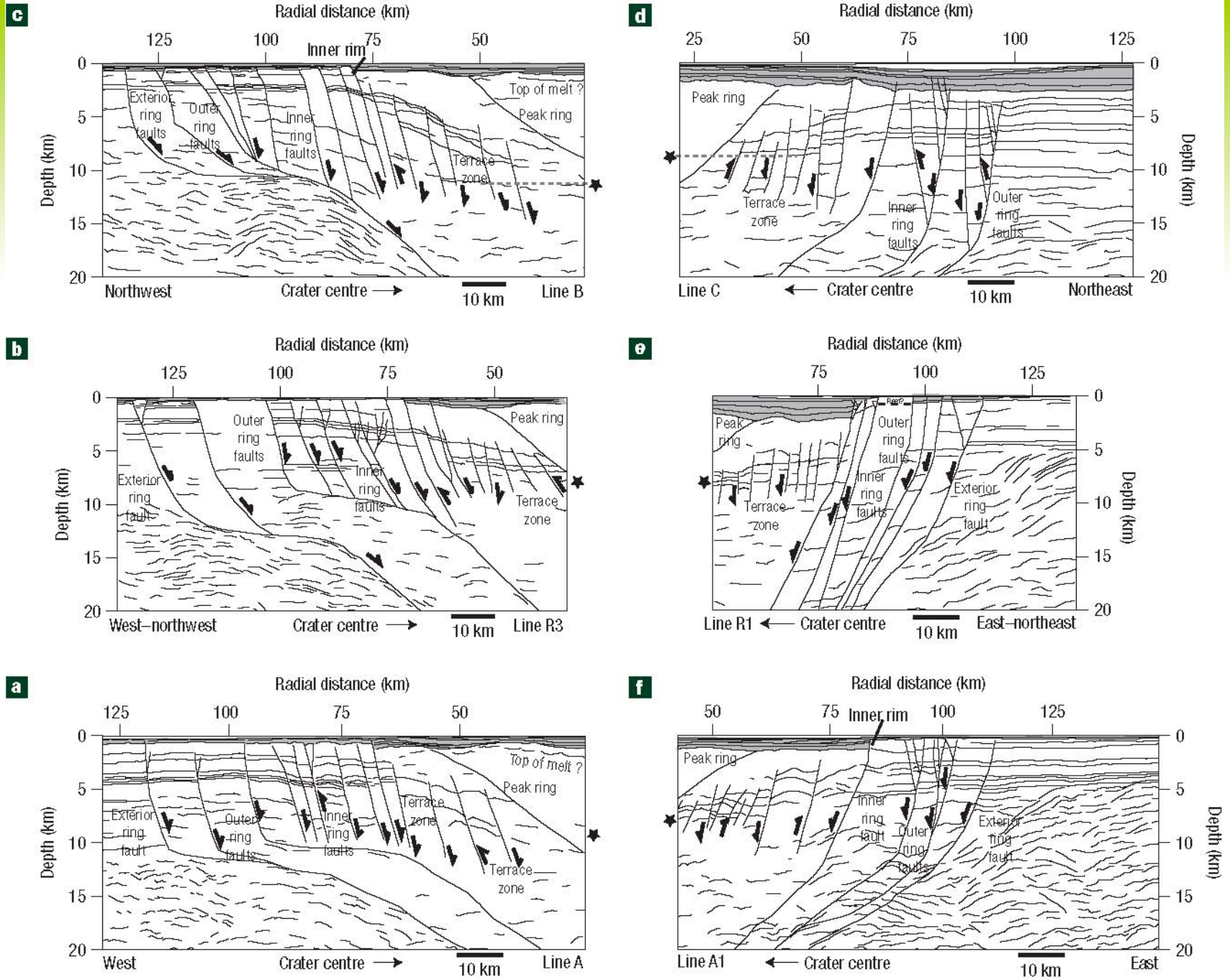
Perry, et al., 2002

CICY



Ring of cenotes ~270 km

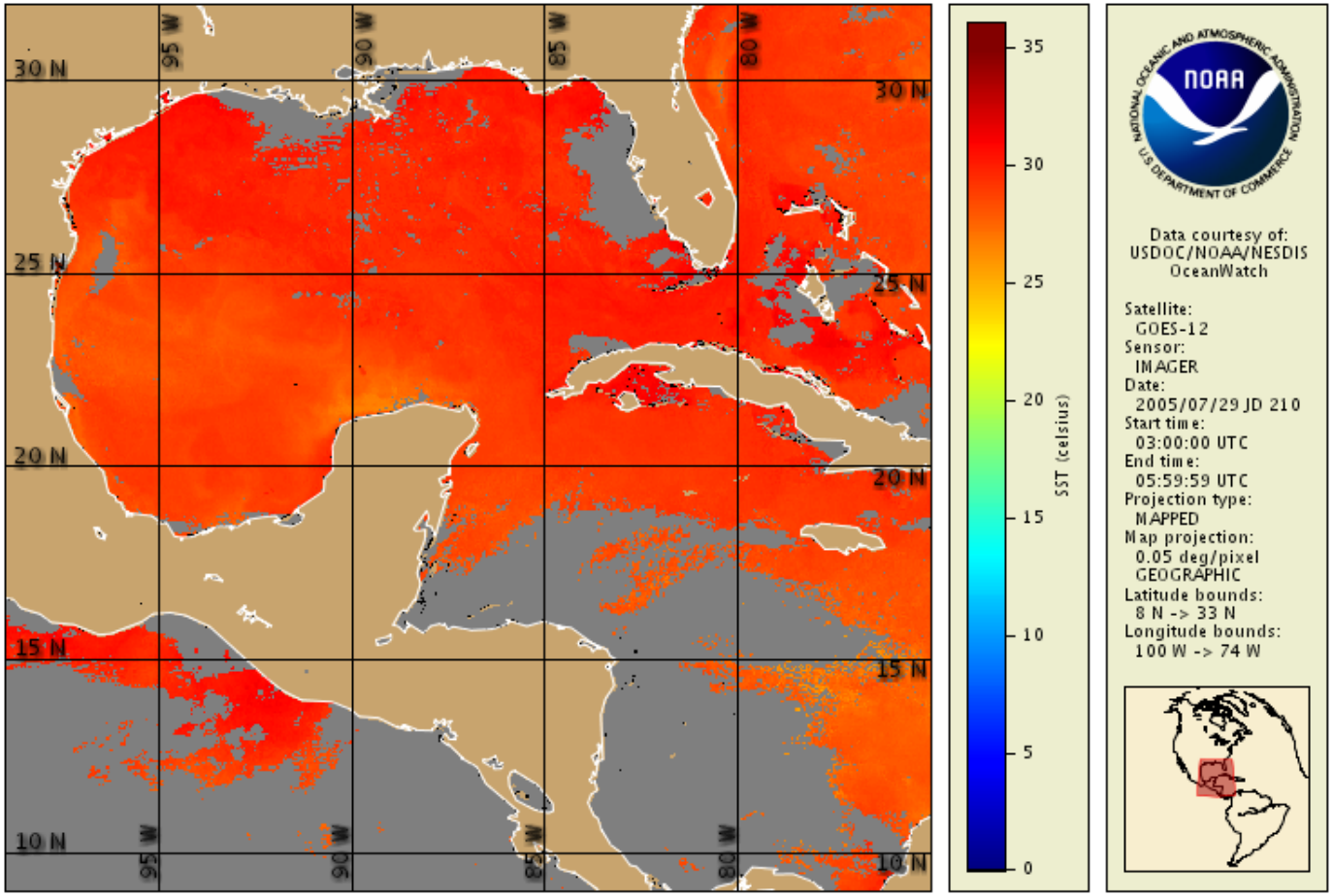
Hildebrand et al. (1991)



Gulick et al. 2008

Sea Surface Temperature
(29 of July, 2005)

CICY



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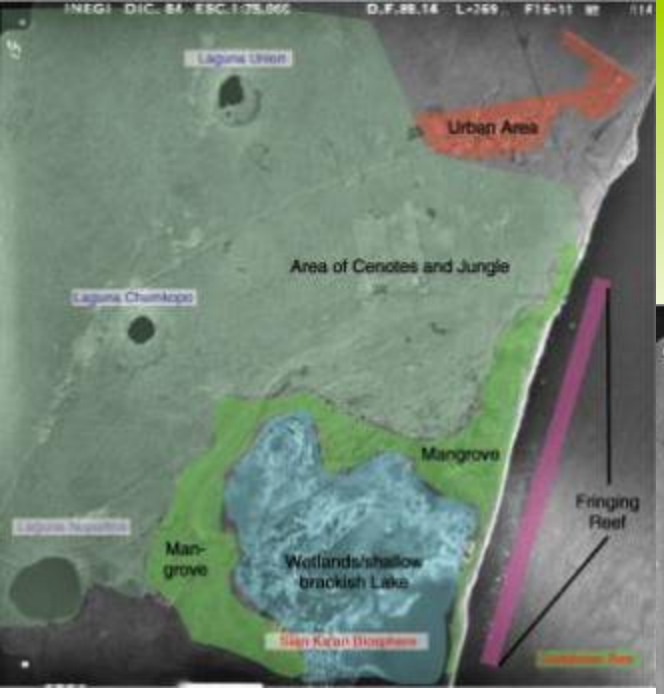
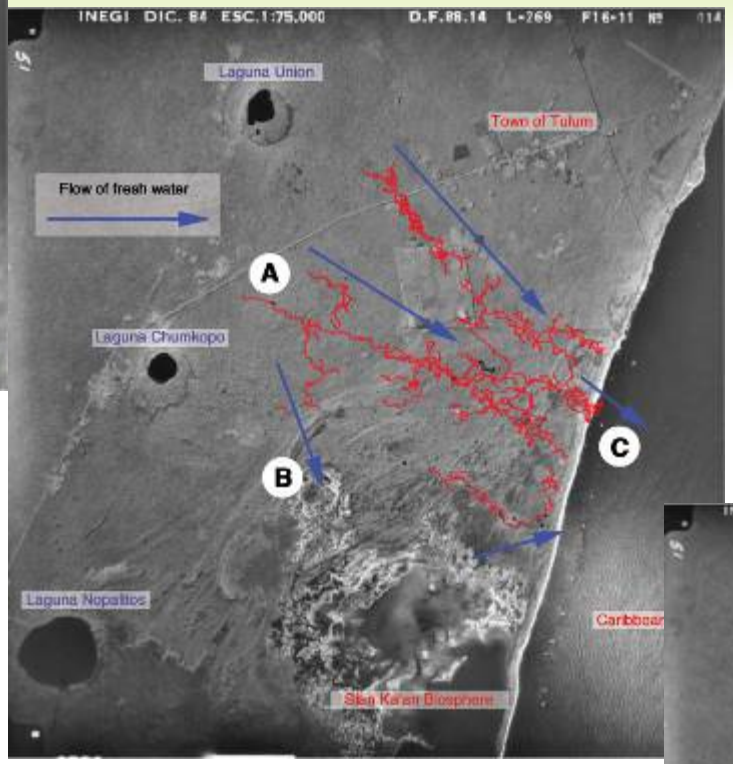
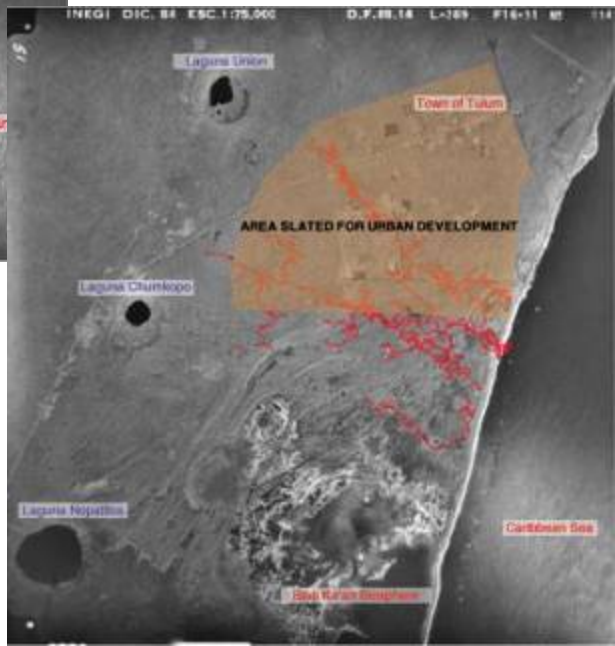






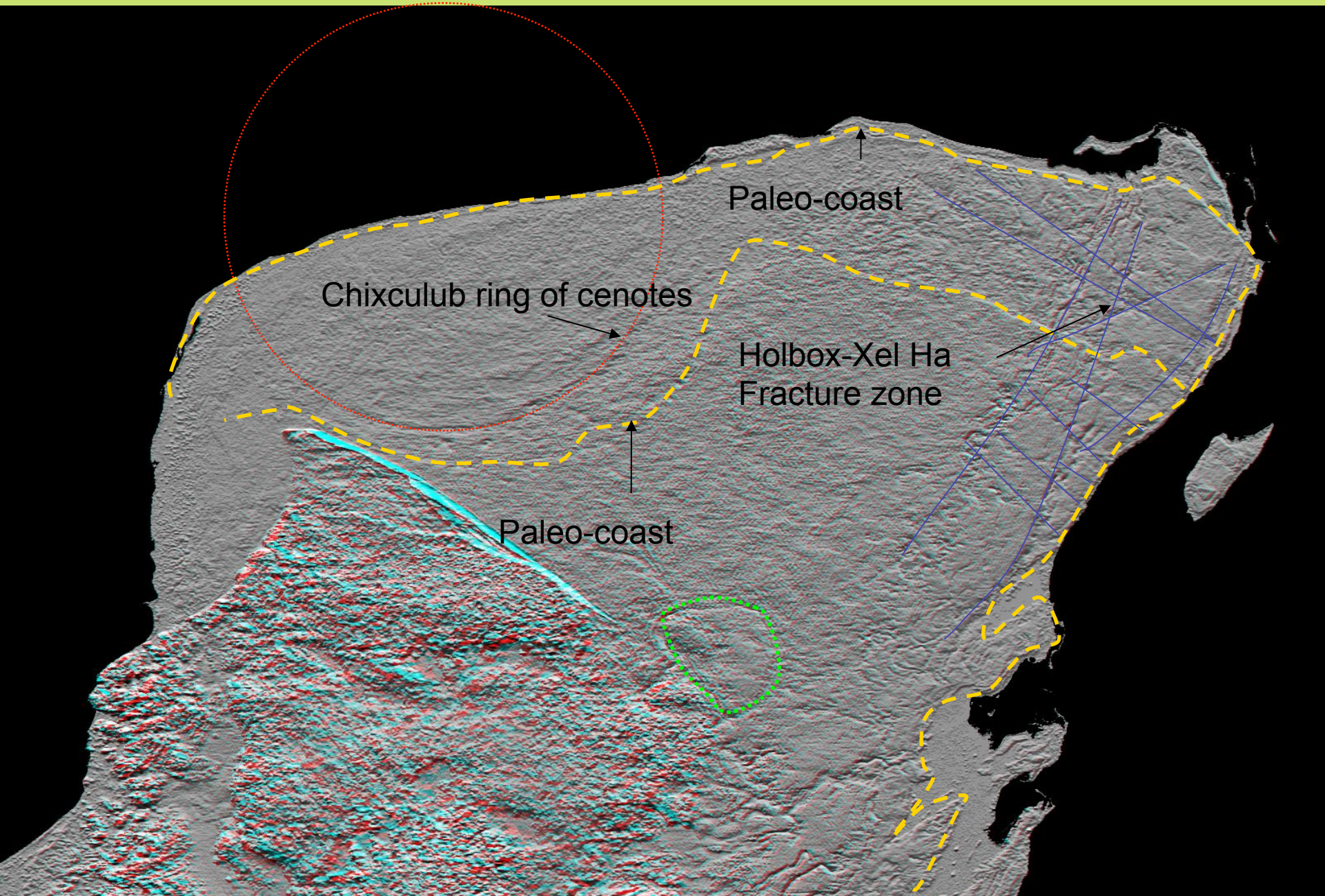
Courtesy CINDAQ.

Akumal

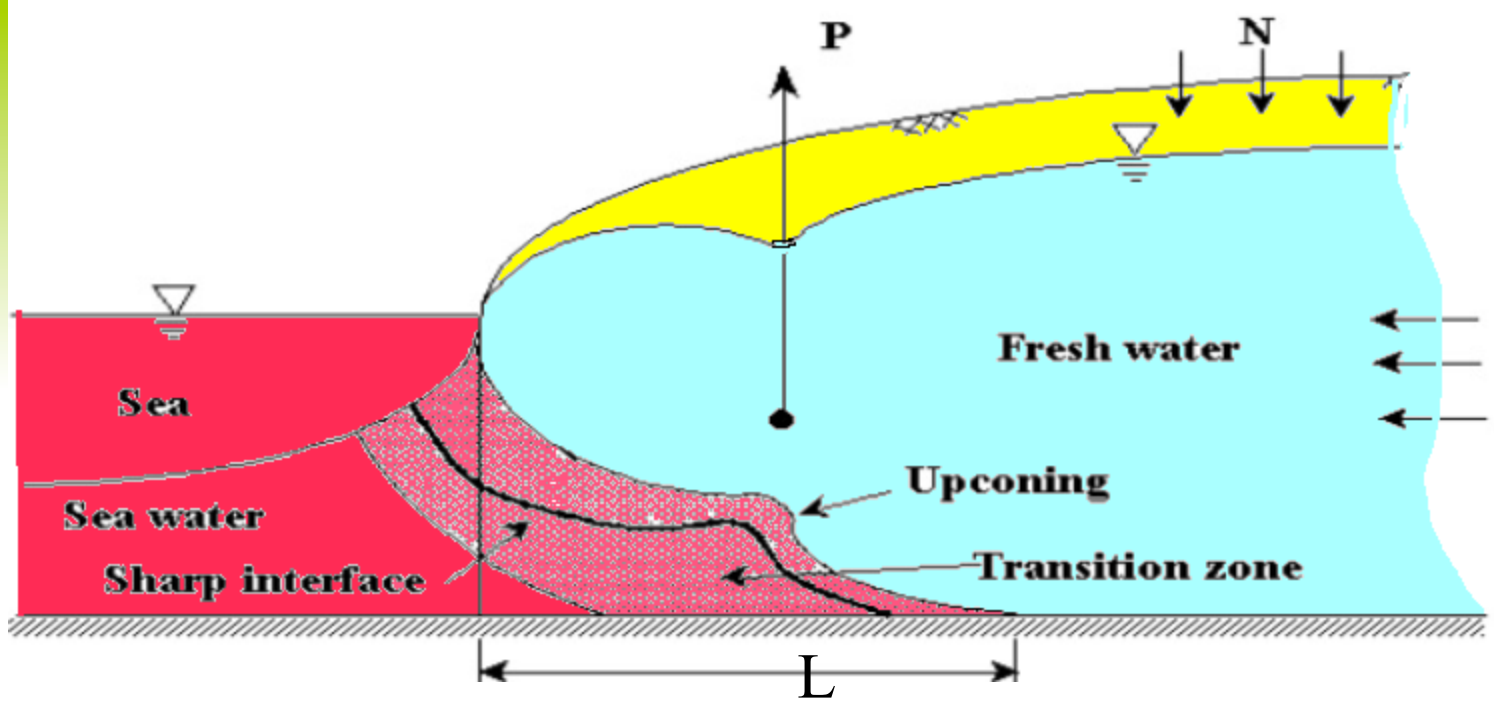
CICY

Xel-Ha


Image © 2006 DigitalGlobe
©2005 Google
Pointer 20°19'01.65" N 87°21'39.14" W elev 3 ft
Streaming 100%
Eye alt 8661 ft


Paleo-coast
Chixculub ring of cenotes
Holbox-Xel Ha
Fracture zone
Paleo-coast

CICY



- Hydraulic head reduced by pumping
- Less fresh water flow to the ocean
- Increases seawater intrusion
- Increases transition zone
- Depletion of water quality by salinitazition

Electrical soundings in two wells and one sinkhole

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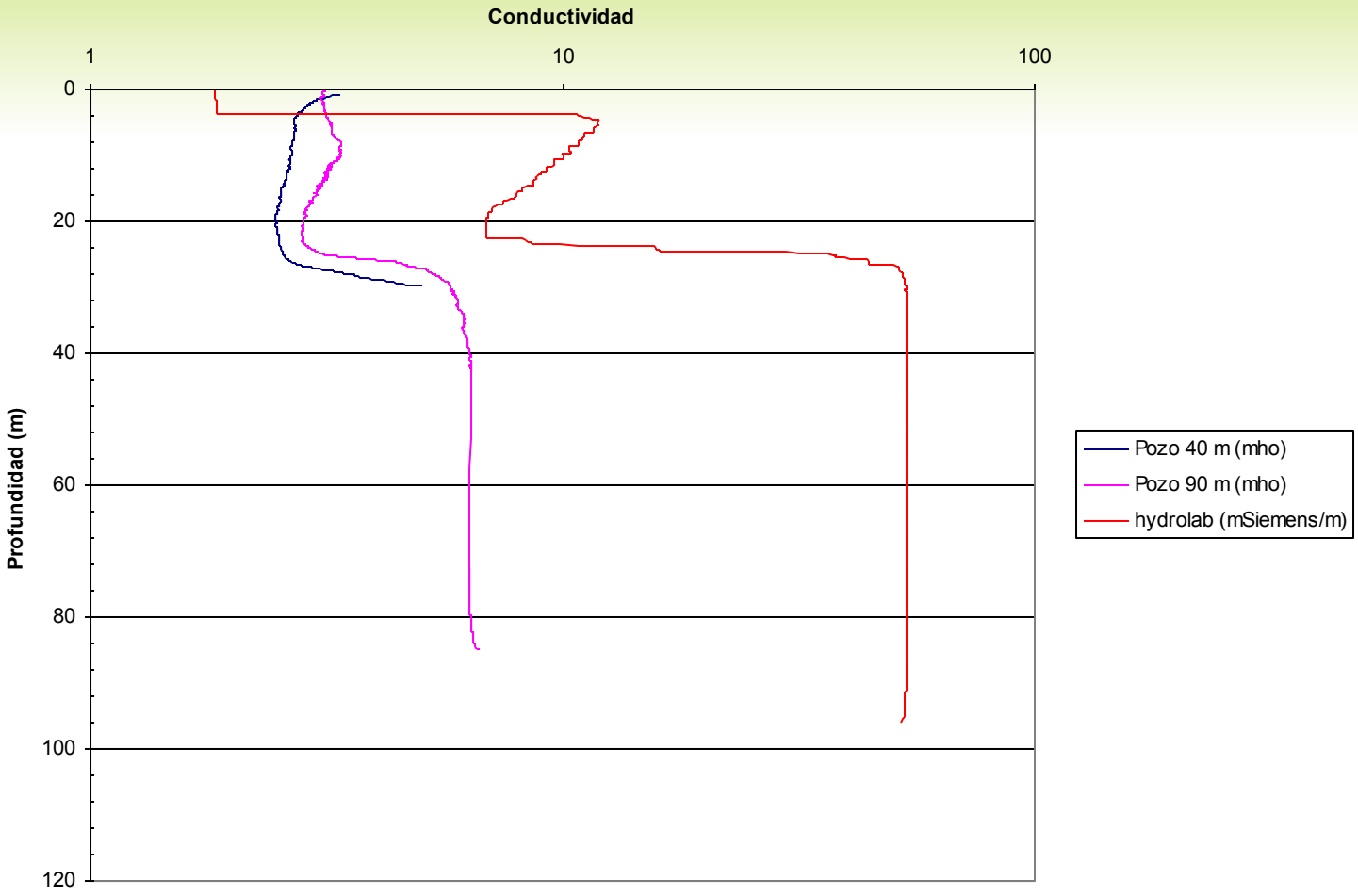

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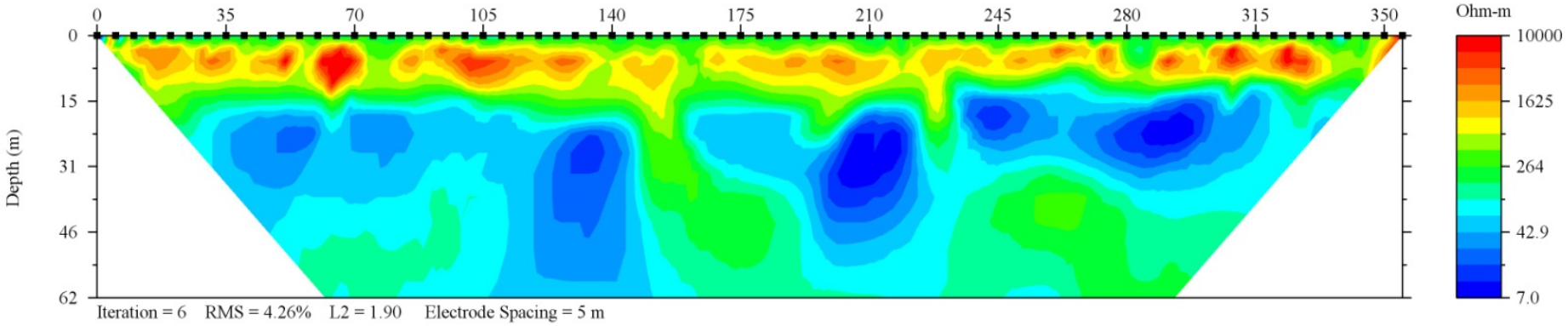
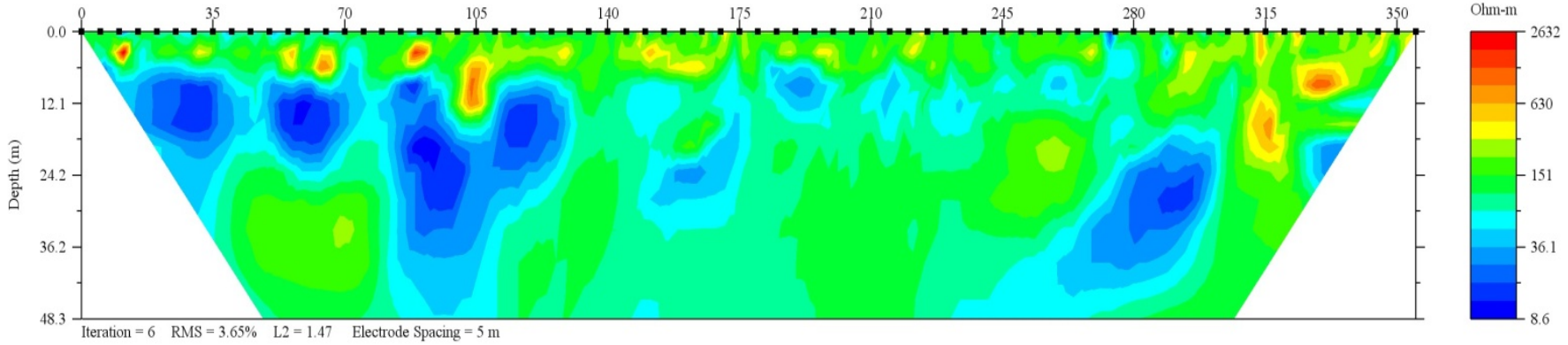
Inverted Resistivity Section



Inverted Resistivity Section Xlabon Zubin



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Modified after Linsley, Kohler and Paulhus, 1958. *Hydrology for Engineers*. New York McGraw-Hill. Copyright © 1958 by McGraw-Hill Book Company. Used by permission of McGraw-Hill Book Company.

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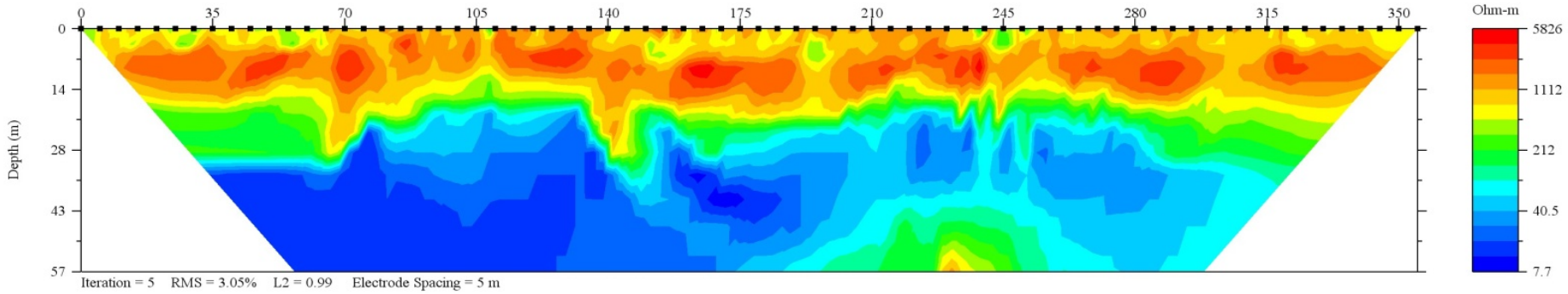
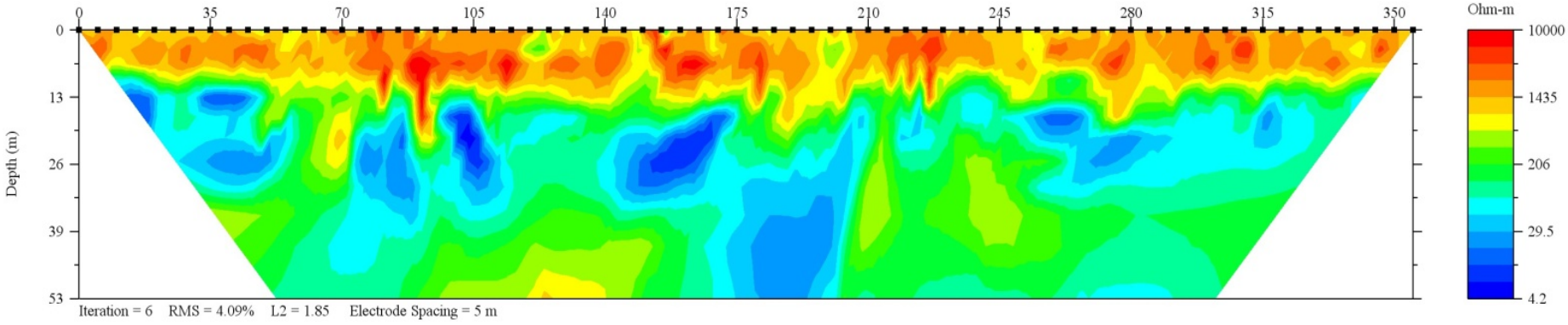
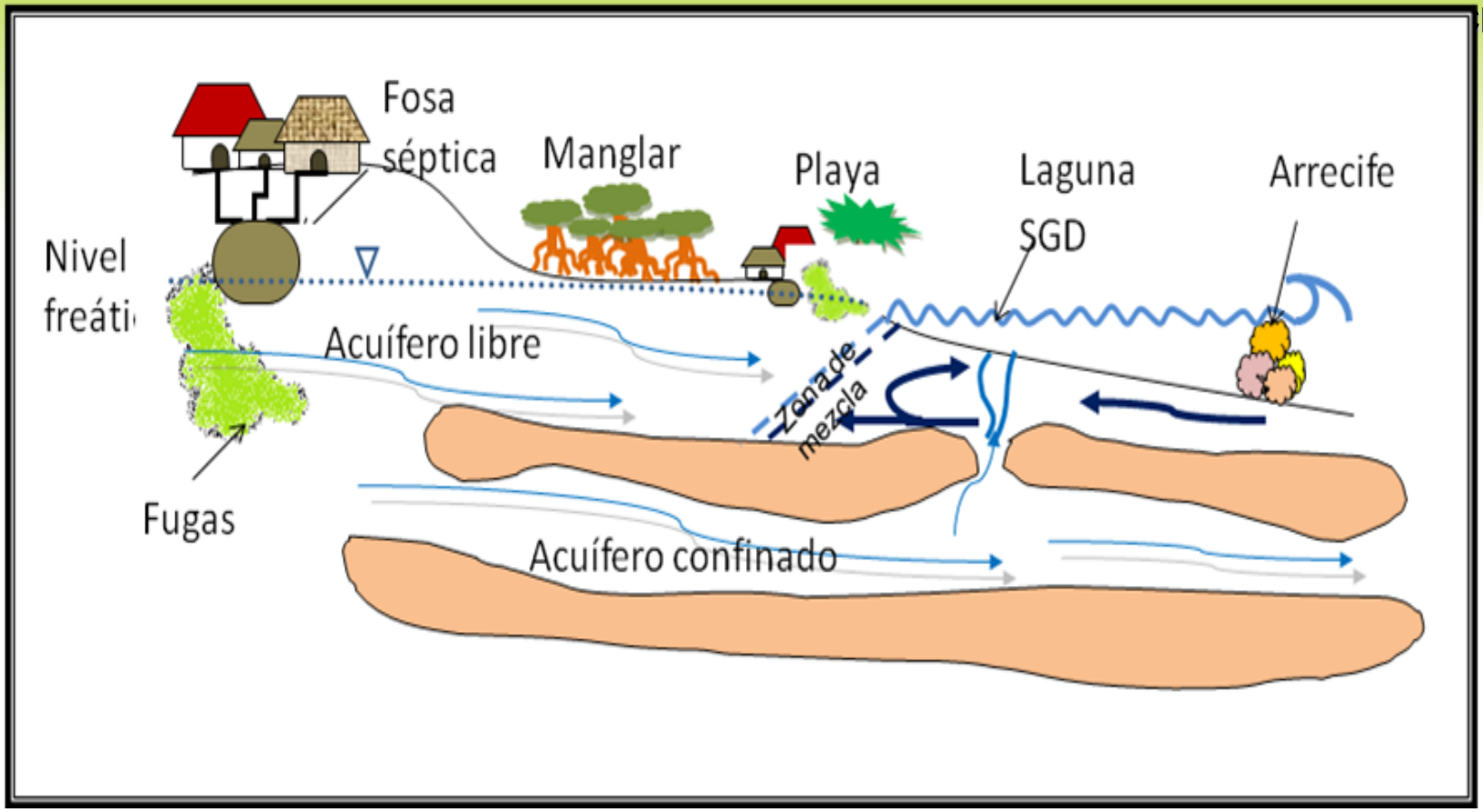
Inverted Resistivity Section Chunkanan

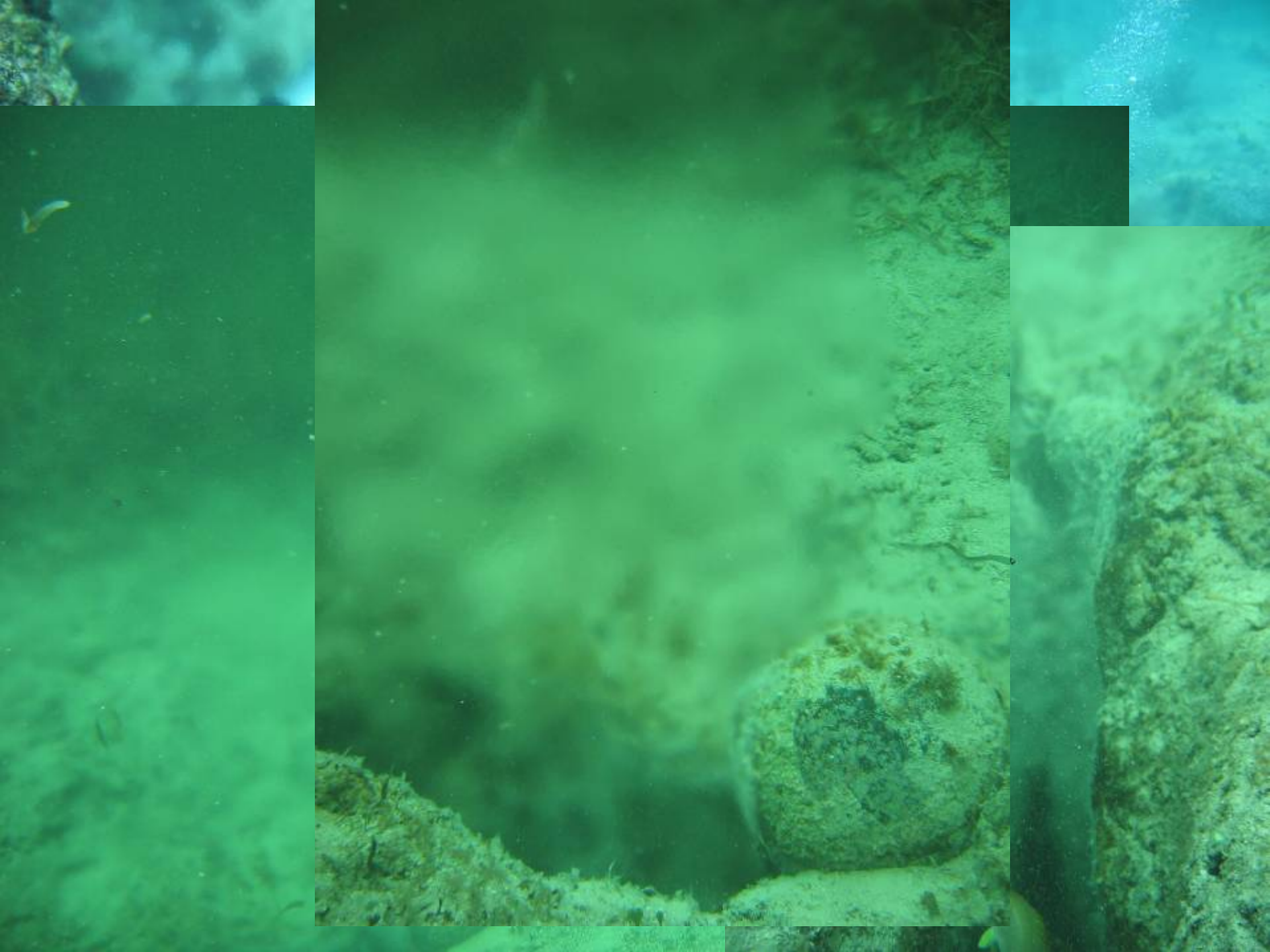


Inverted Resistivity Section Calcuch





(Modified from Slomp and Van Clappellen, 2004)



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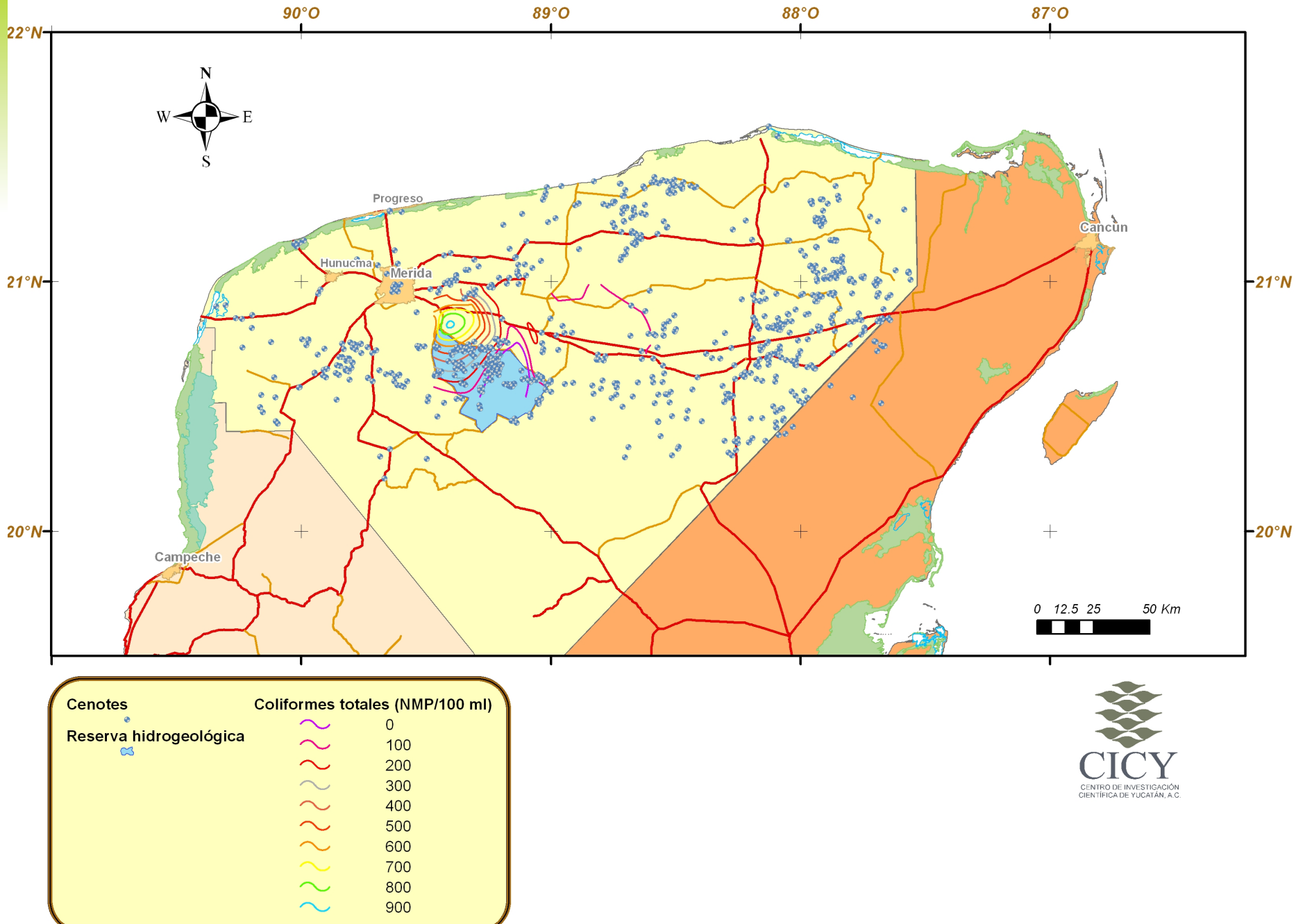
Map of sediment delivery to Mesoamerican Barrier Reef
Caribbean Sea
MEXICO
BELIZE
Belmopan
Gulf of Honduras
GUATEMALA
Guatemala
HONDURAS
Tegucigalpa
EL SALVADOR
San Salvador
NICARAGUA
Capitals
Coral Reefs
Rivers
Lakes
Basins analyzed
Relative sediment delivery by watershed, not actual dispersal extent.
Source: WRI 2006


90°O
89°O
88°O
87°O
22°N
21°N
20°N
N
W
E
S
Progreso
Hunucmá
Mérida
Cancún
Campeche
0 12.5 25 50 Km
Cenotes
Reserva hidrogeológica
Coliformes totales (NMP/100 ml)
0
100
200
300
400
500
600
700
800
900
CICY
CENTRO DE INVESTIGACIÓN CIENTÍFICA DE YUCATÁN, A.C.

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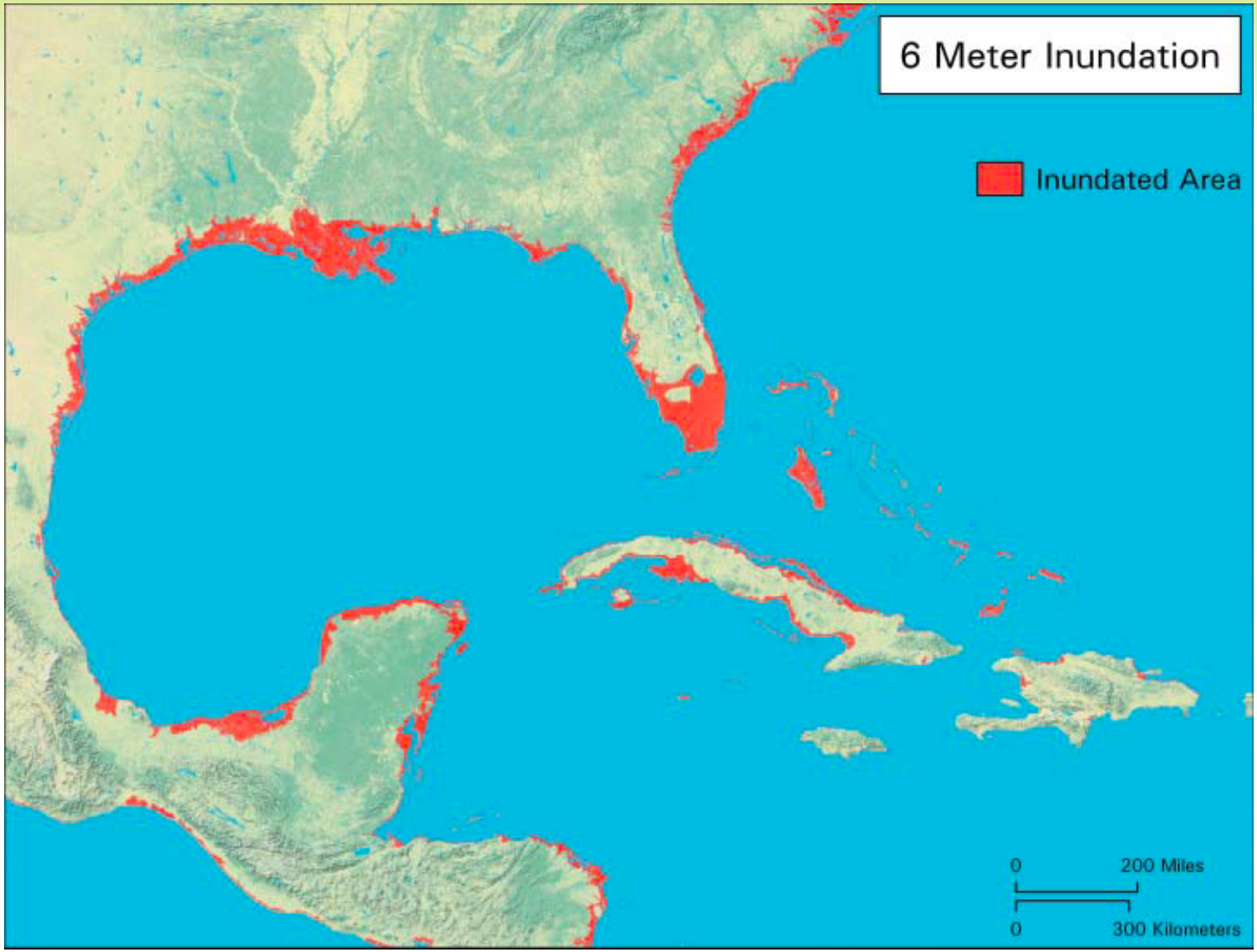
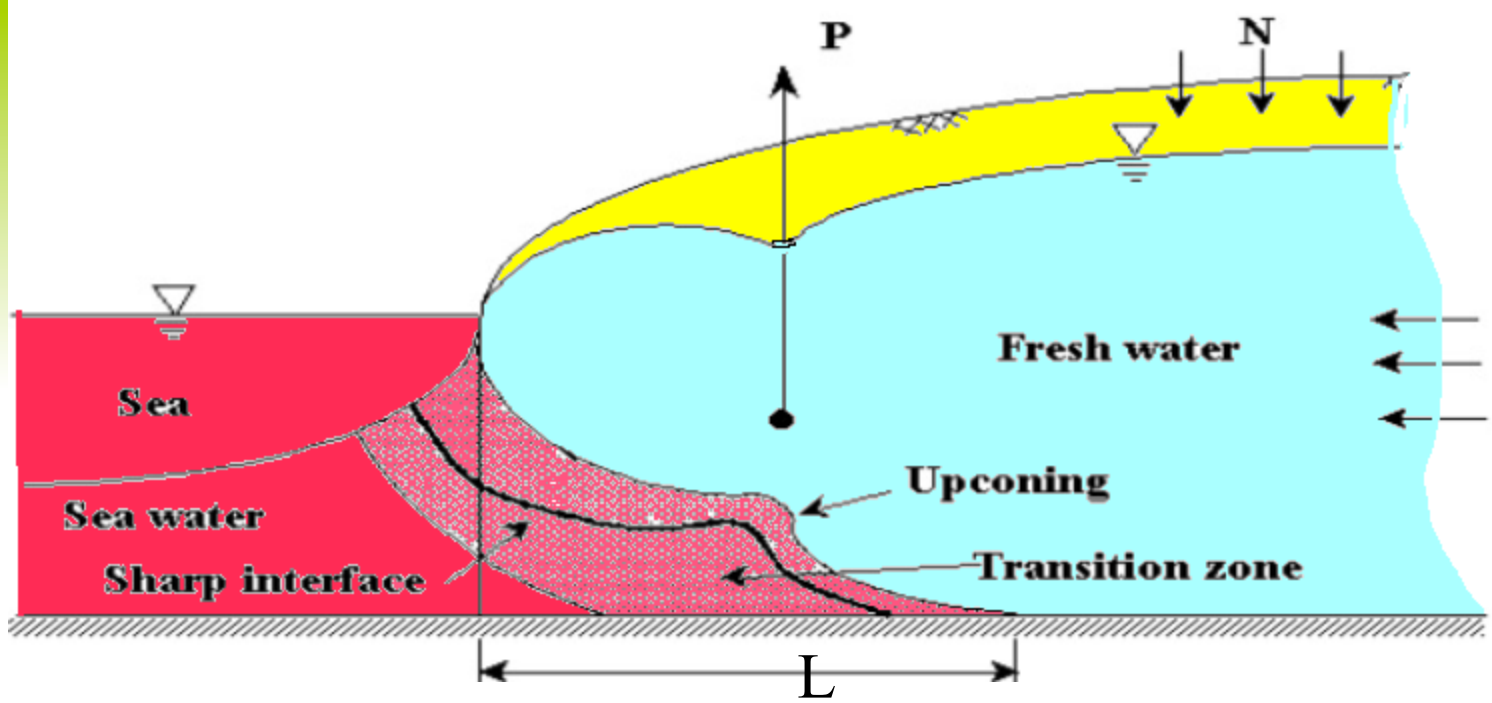

6 Meter Inundation
Inundated Area
0
200 Miles
0
300 Kilometers



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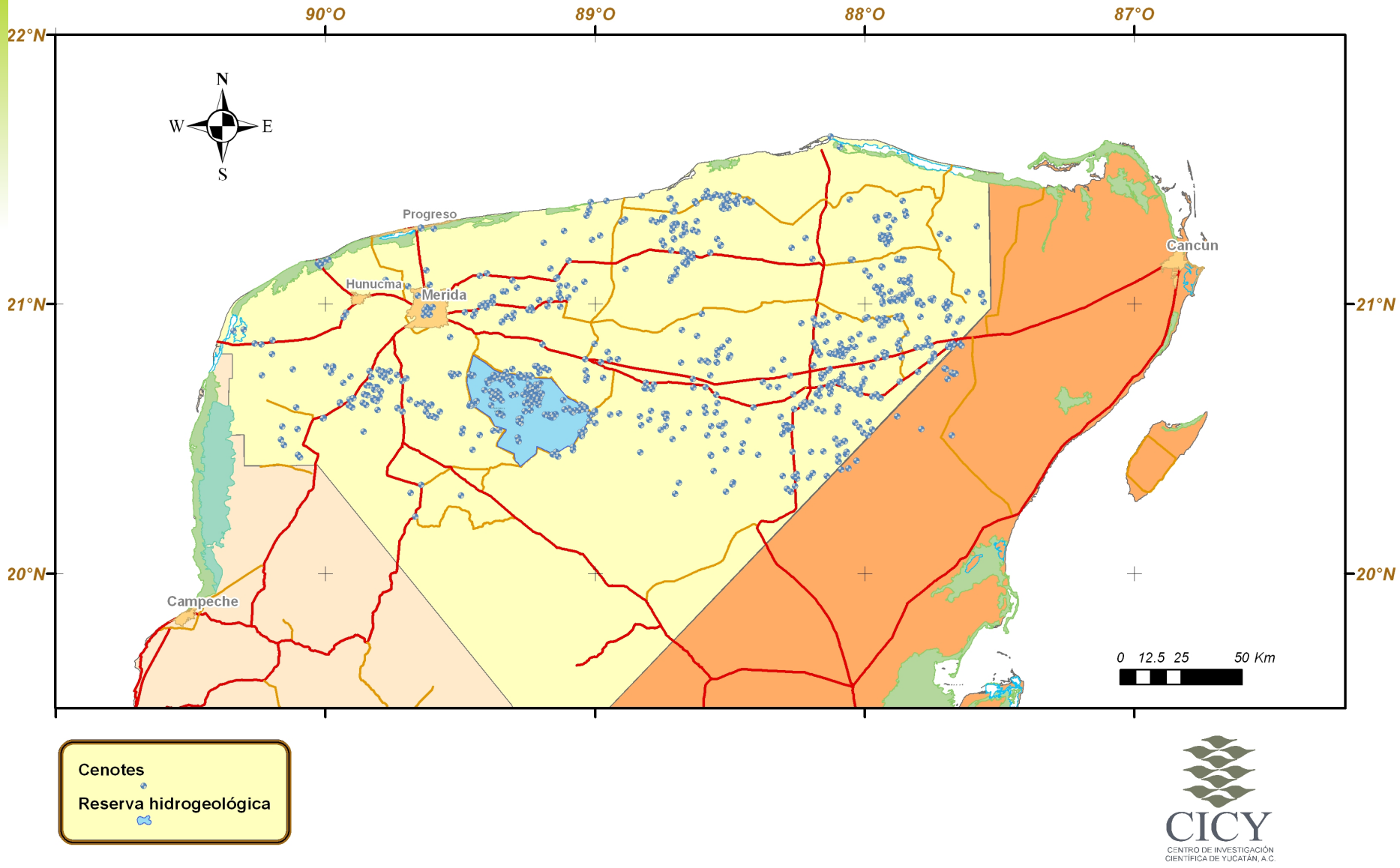

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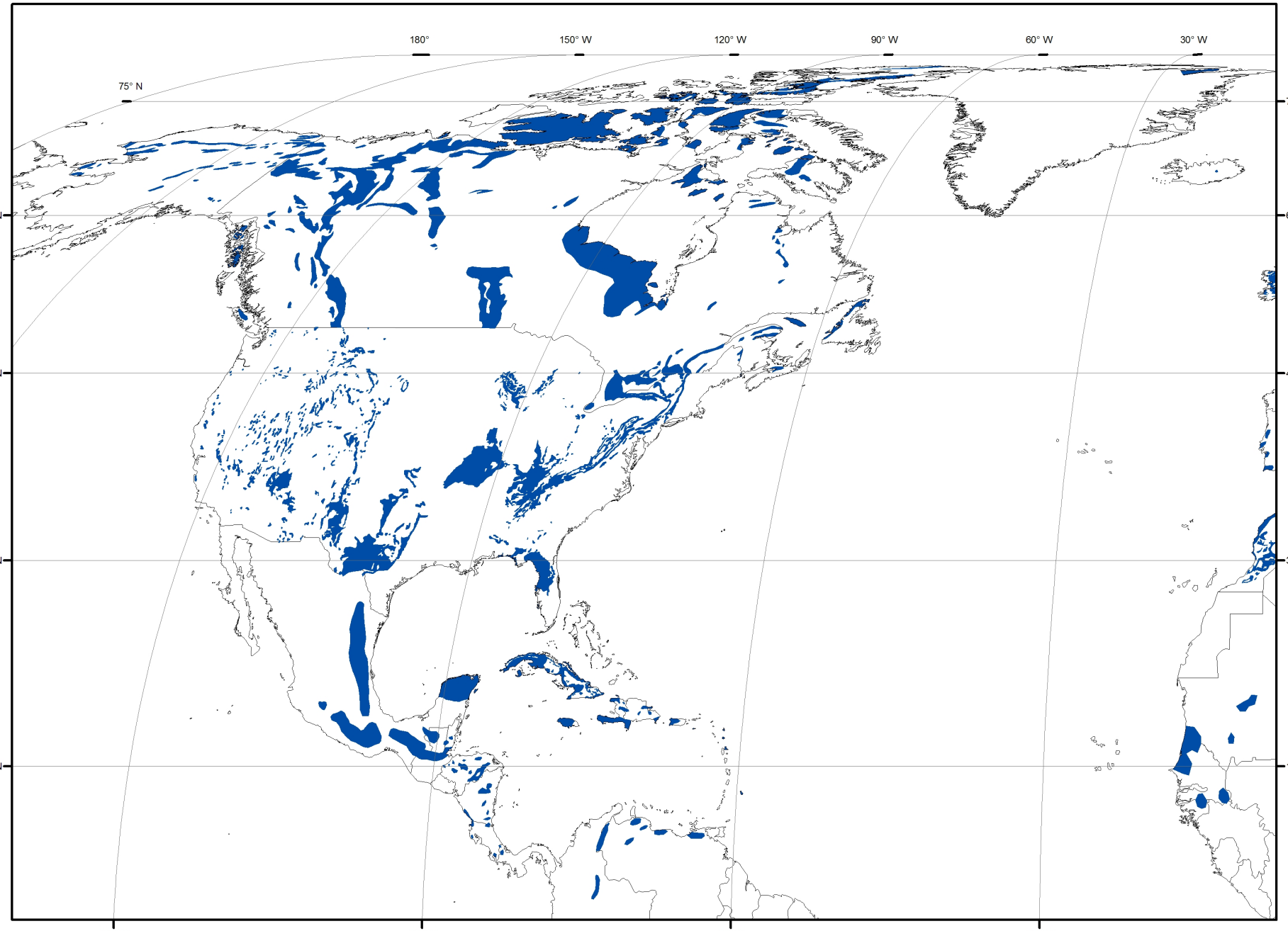
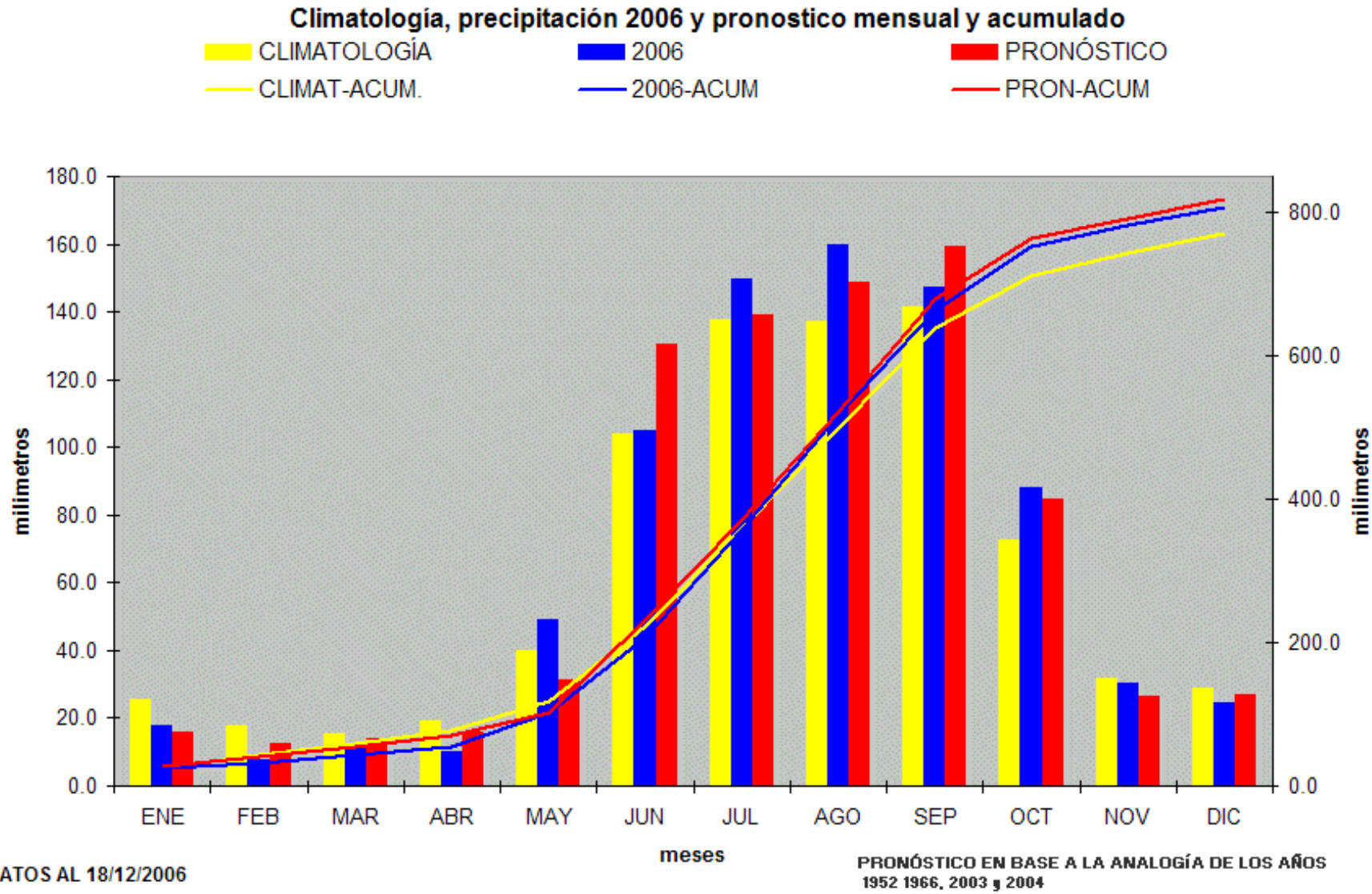
CENTRO DE INVESTIGACIÓN CIENTÍFICA DE YUCATÁN, A.C.


Thank you!
marior@cicy.mx

Zonas kársticas en Norteamérica





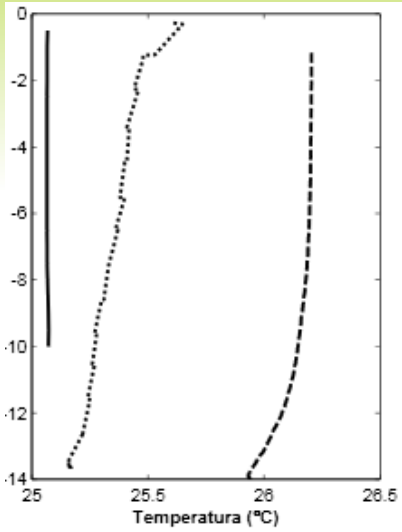
DATOS AL 18/12/2006

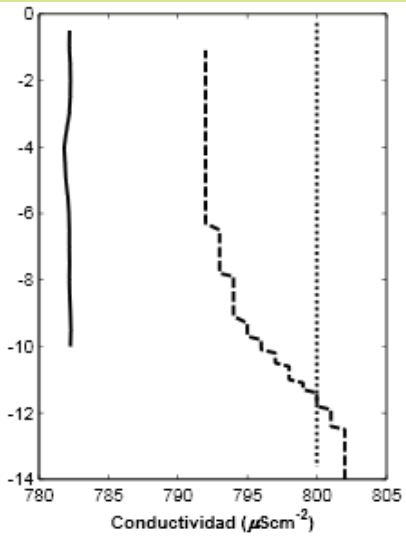
PRONÓSTICO EN BASE A LA ANALOGÍA DE LOS AÑOS 1952 1966, 2003 y 2004

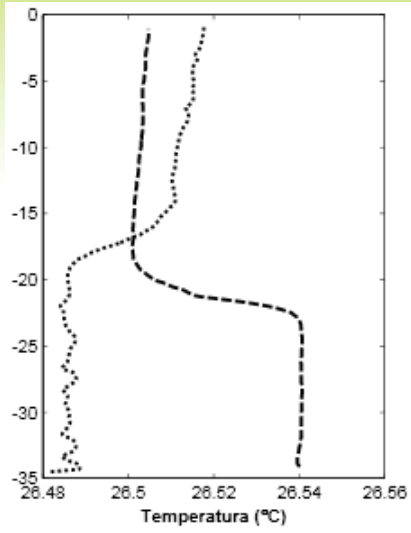
Calcuch

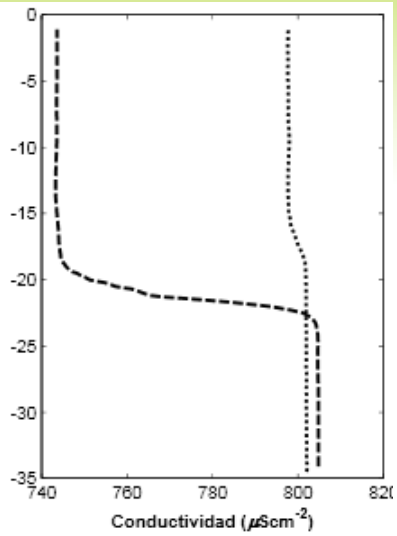
Tanimax

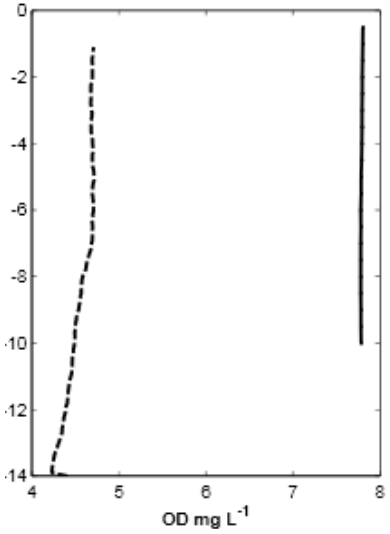
CICY

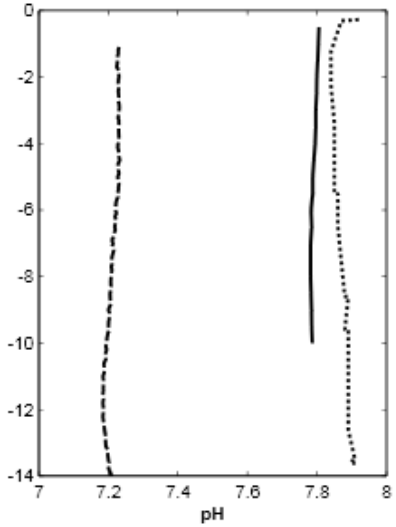


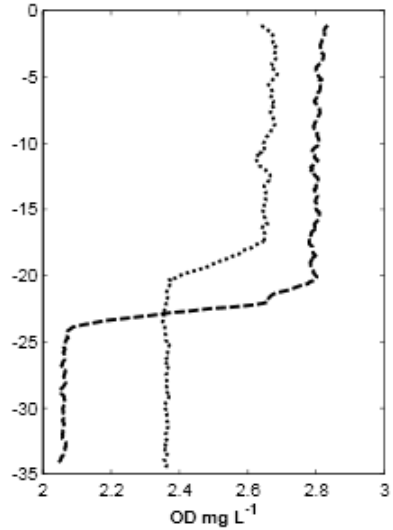


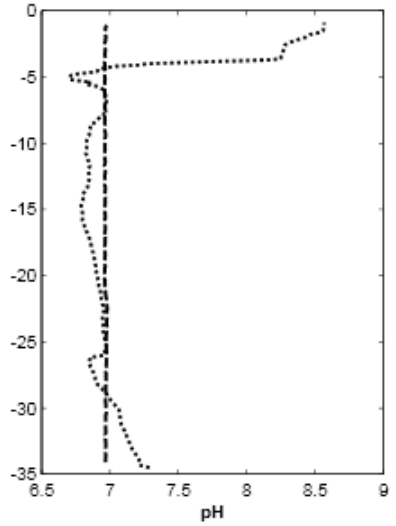






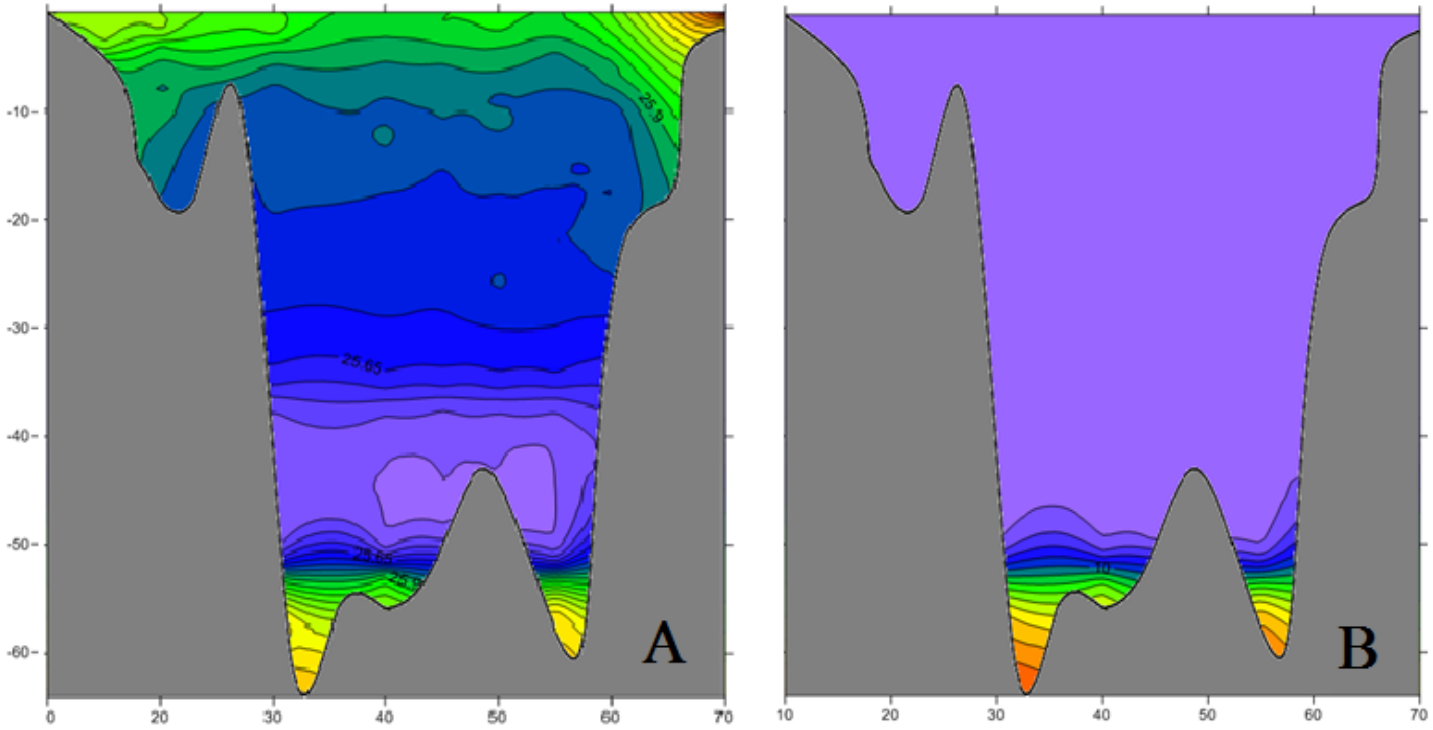




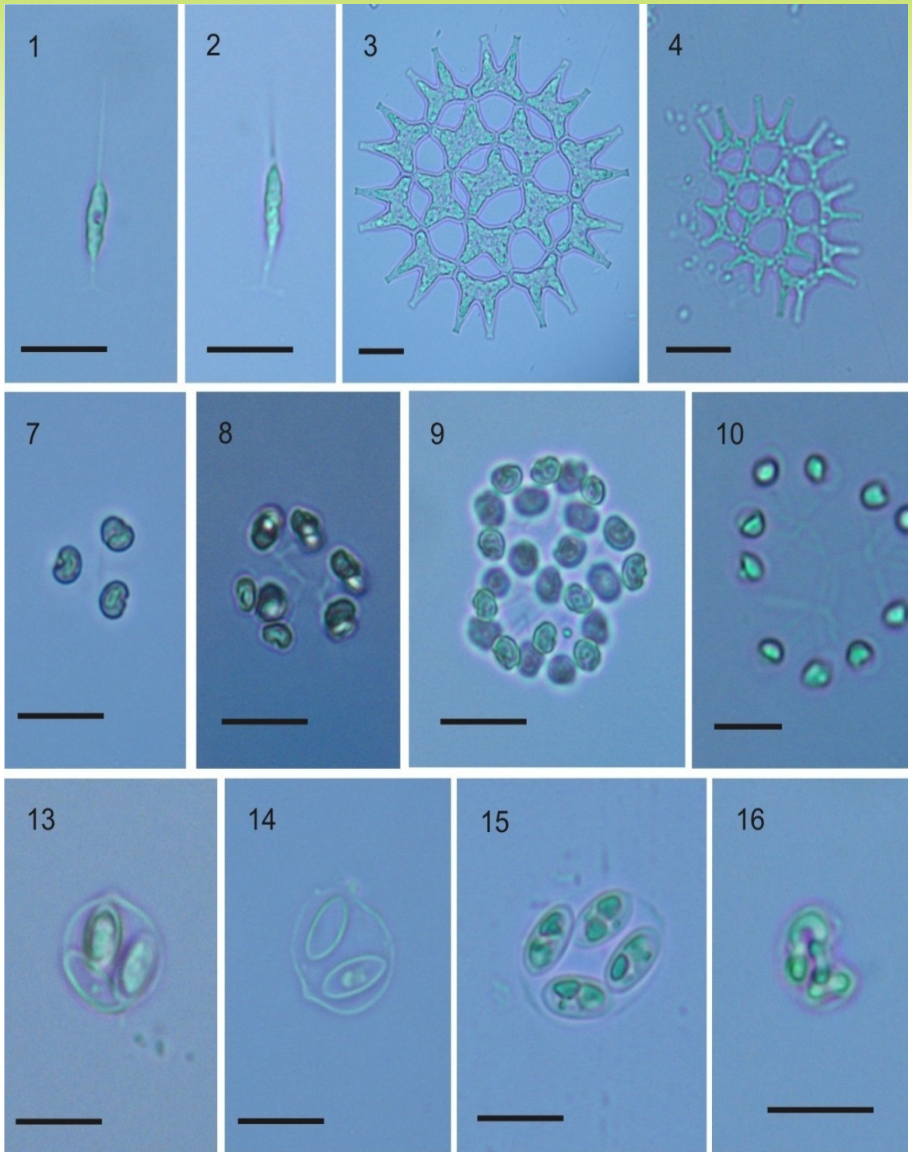


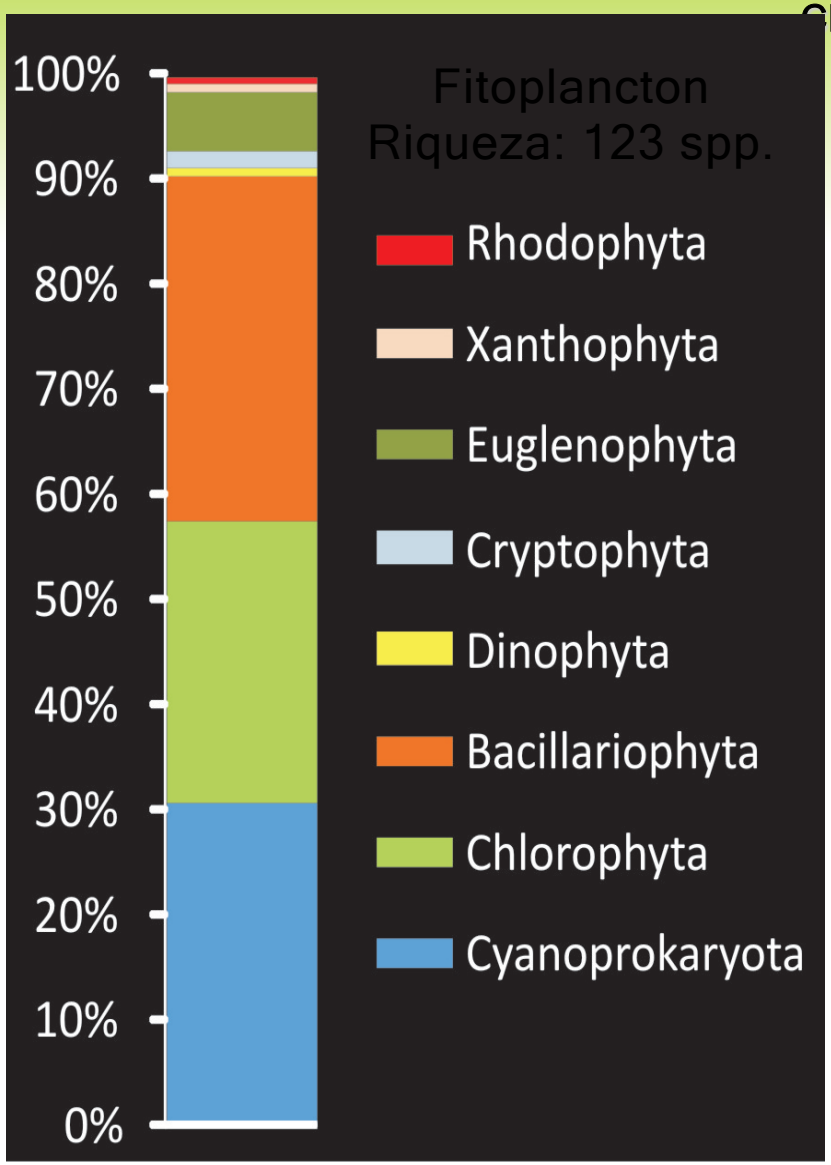
Xlabom Subim

Profundidad	70 m
Diámetro	80 m
Z_{DS}	9 m



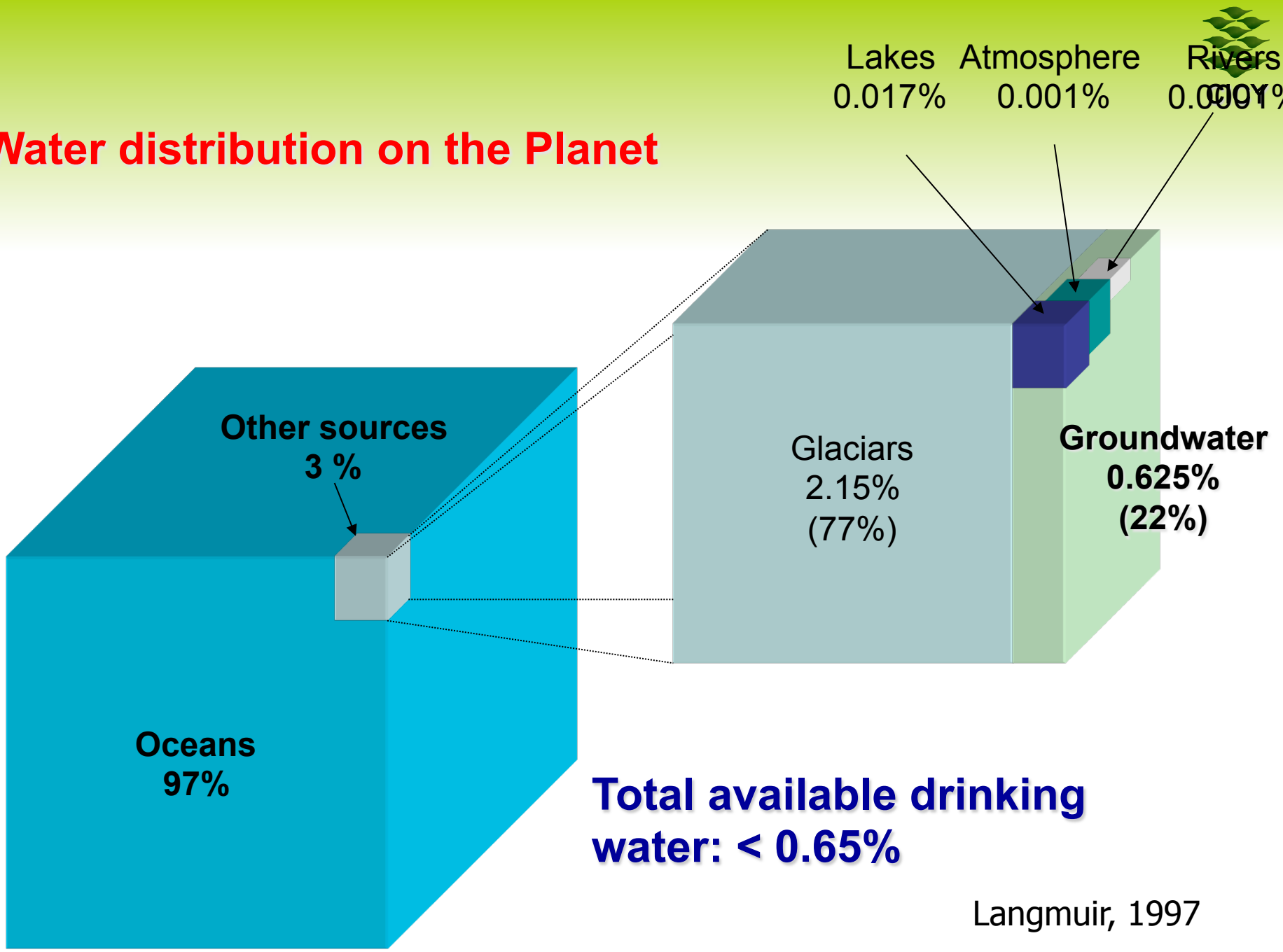
Composición de especies





RESULTADOS

Water distribution on the Planet



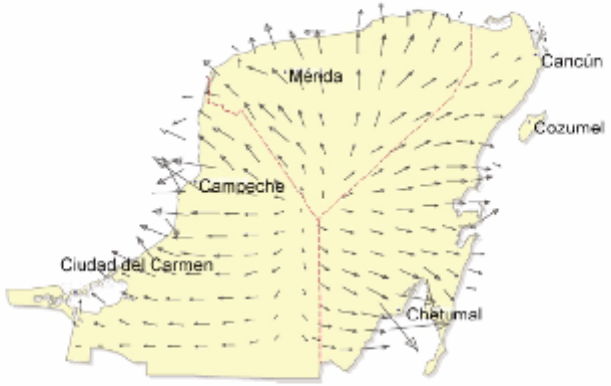
Total available drinking water: < 0.65%

Langmuir, 1997

Hydrogeology of Yucatan

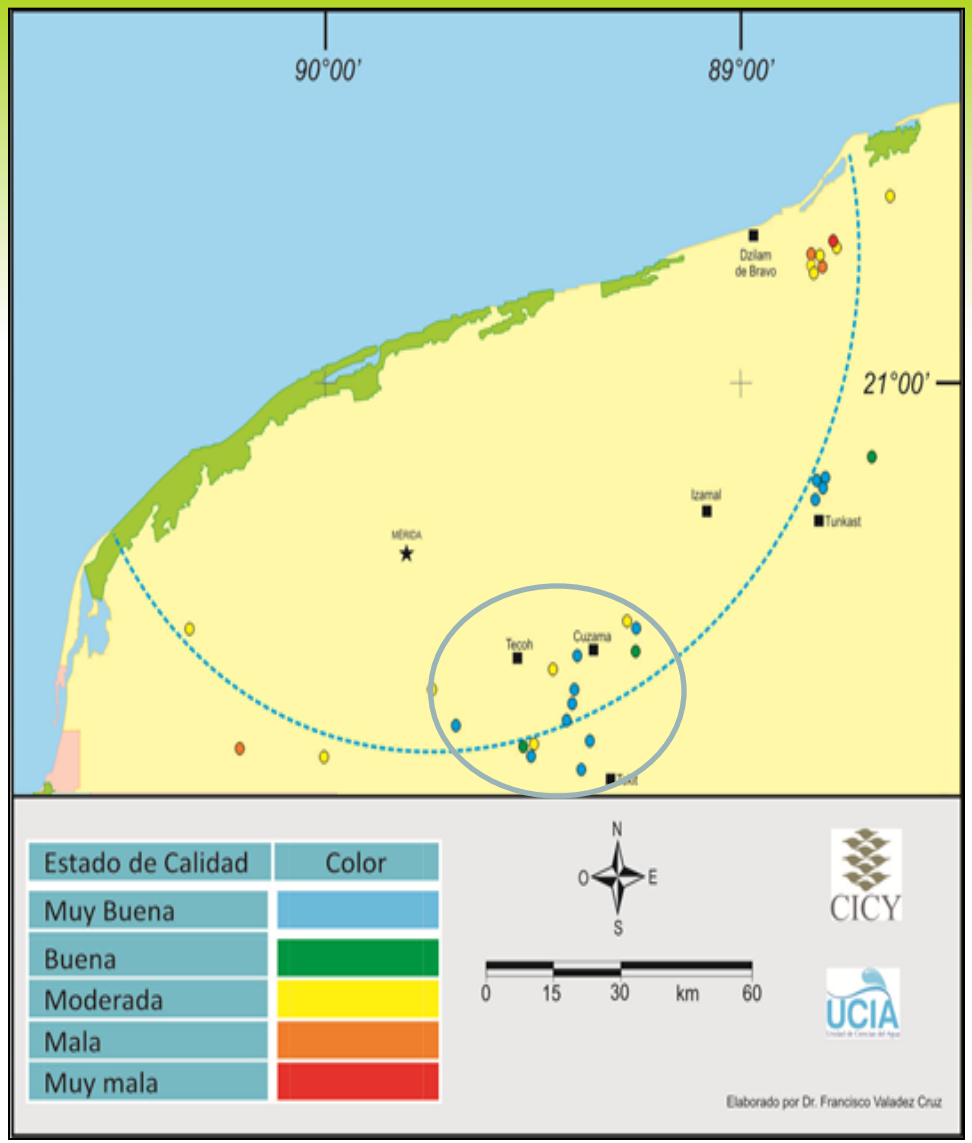
CICY

Esquema conceptual de la dirección del flujo del agua subterránea en la Península de Yucatán



Fuente: GRPY. Subgerencia Técnica. CNA

Perry, et al., 2002



Conjunto de cenotes "C"

Células ml^{-1}	Grupo
300	Bacillariophyta

Achnanthidium spp., Diploneis spp.

Células ml^{-1}	Grupo
300 – 3,000	Cyanoprokaryota - Chlorophyta

Aphanocapsa delicatissima
Microcystis aeroginosa
Coelastrum indicum
Didymocystis fina
Kirchneriella lunaris
Tetrastrum komarekii

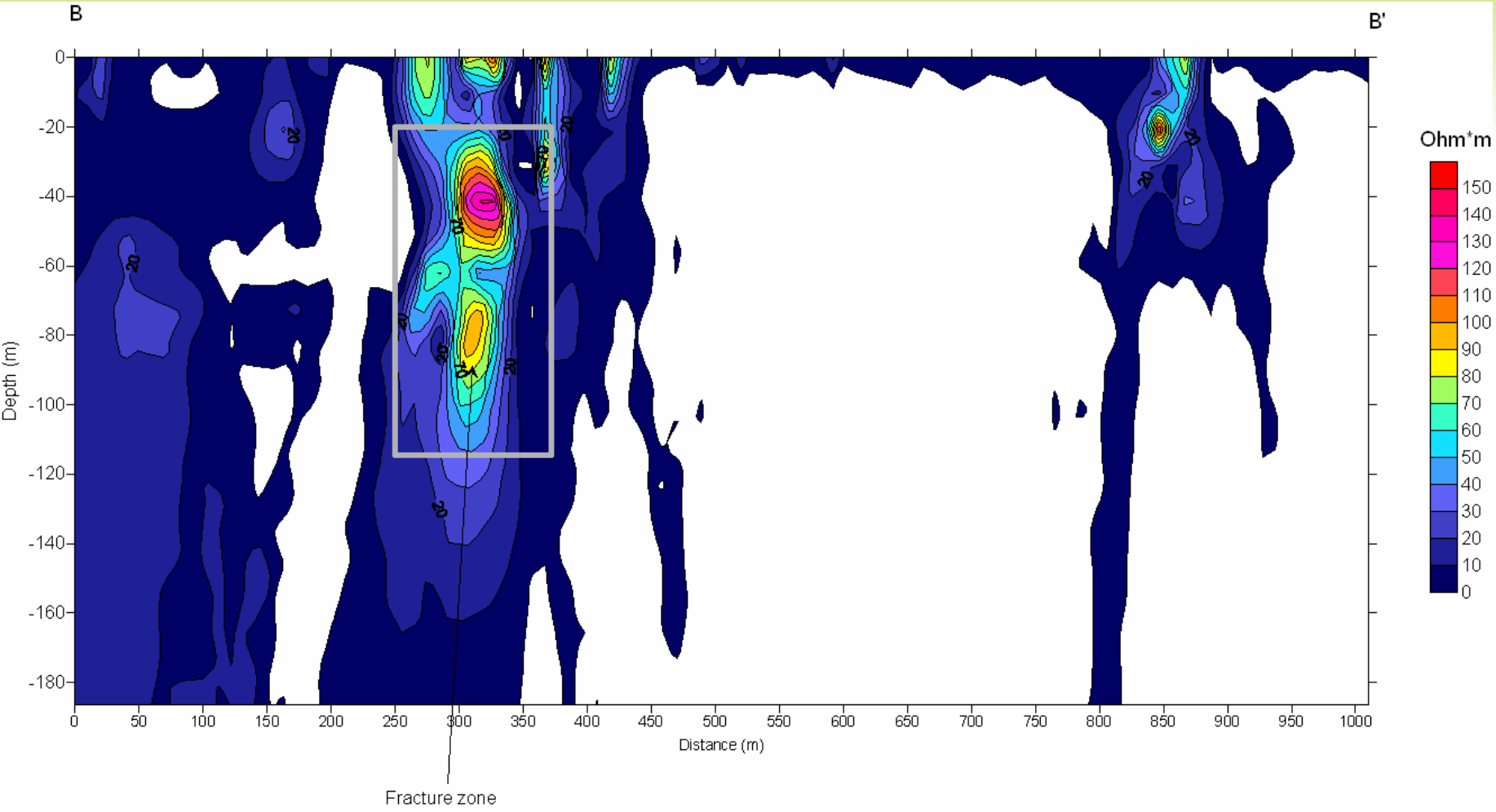
Células ml^{-1}	Grupo
3,000 – 700,000	Cyanoprokaryota

Microcystis aeroginosa
Phormidium tergestium
Merismopedia minima ç
Phoormidium nigro-viride

Estado de la calidad del agua de los cenotes asociados al anillo de cenotes en el norte del estado de Yucatán

TDEM

CICY


B
B'
Depth (m)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Distance (m)
Fracture zone
Ohm*m
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0