Hypogene Processes in the Edwards Aquifer in South-Central Texas, a New Conceptual Model to Explain Aquifer Dynamics*

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Abstract

The Balcones Fault Zone Edwards Aquifer of south-central Texas is one of the most important karst aquifers in the United States and provides water to 1.7 million people and for critical habitat for endangered species. The Edwards Aquifer extends 400 kilometers from Del Rio, east to San Antonio though Austin, and northeast to Bell County. The aquifer is from 10 to 60 kilometers wide and in places, more than 1,200 meters. The aquifer is contained within the Edwards Group limestone and associated units (Georgetown limestone). The Edwards and associated units were deposited in late Early Cretaceous time and are 150 to more than 300 meters thick. The Edwards Limestone, since deposition, has undergone subaerial exposure, burial in the middle Cretaceous, faulting in the Miocene, uplift and erosion. Faulting is mainly northeast-southwest trending, down to the gulf, en echelon normal faulting. Researchers have proposed epigene (near surface) karst processes, driven by circulating meteoric waters, formed the aquifer along paleokarst features. New interpretations suggest an additional process that contributed to the formation and structure of the Edwards Aquifer. Epigenetic karst theory assumes karst features are produced only during its downward or horizontal groundwater movement, but Klimchouk (2008) concludes that rising waters from depth are important agents of karst development. Regional flow systems, such as the Edwards Aquifer, terminate in springs where the groundwater returns to the surface. Karst processes, in general, and mixing corrosion specifically, can and do operate in the artesian zone of the aquifer. Secondary permeabilities in carbonate fabrics, formed by upward transverse speleogenesis, is an important role in water and oil reservoir formation.

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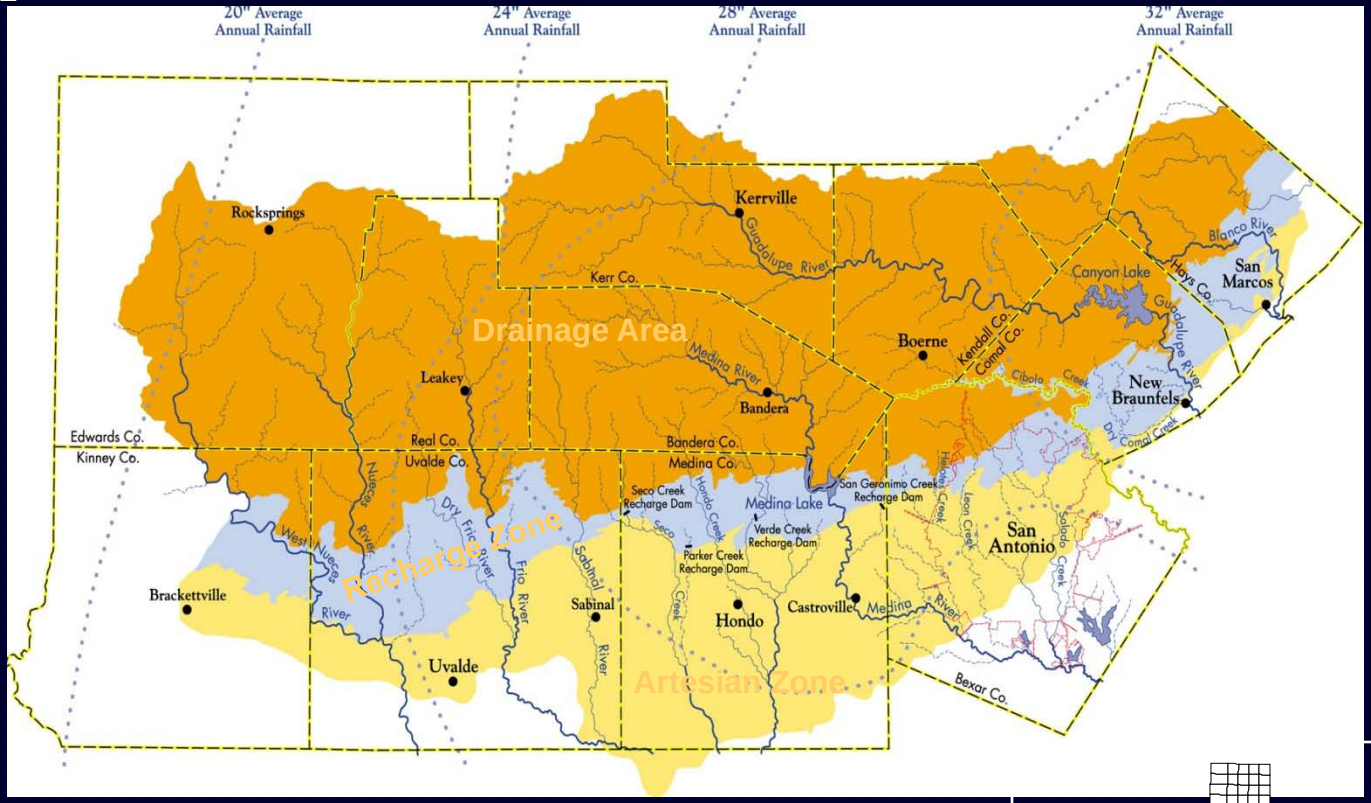
Presented to:
AAPG,
San Antonio, Texas

Presented by:
Geary M. Schindel
Steven Johnson
E. Calvin Alexander

What is the Edwards Aquifer

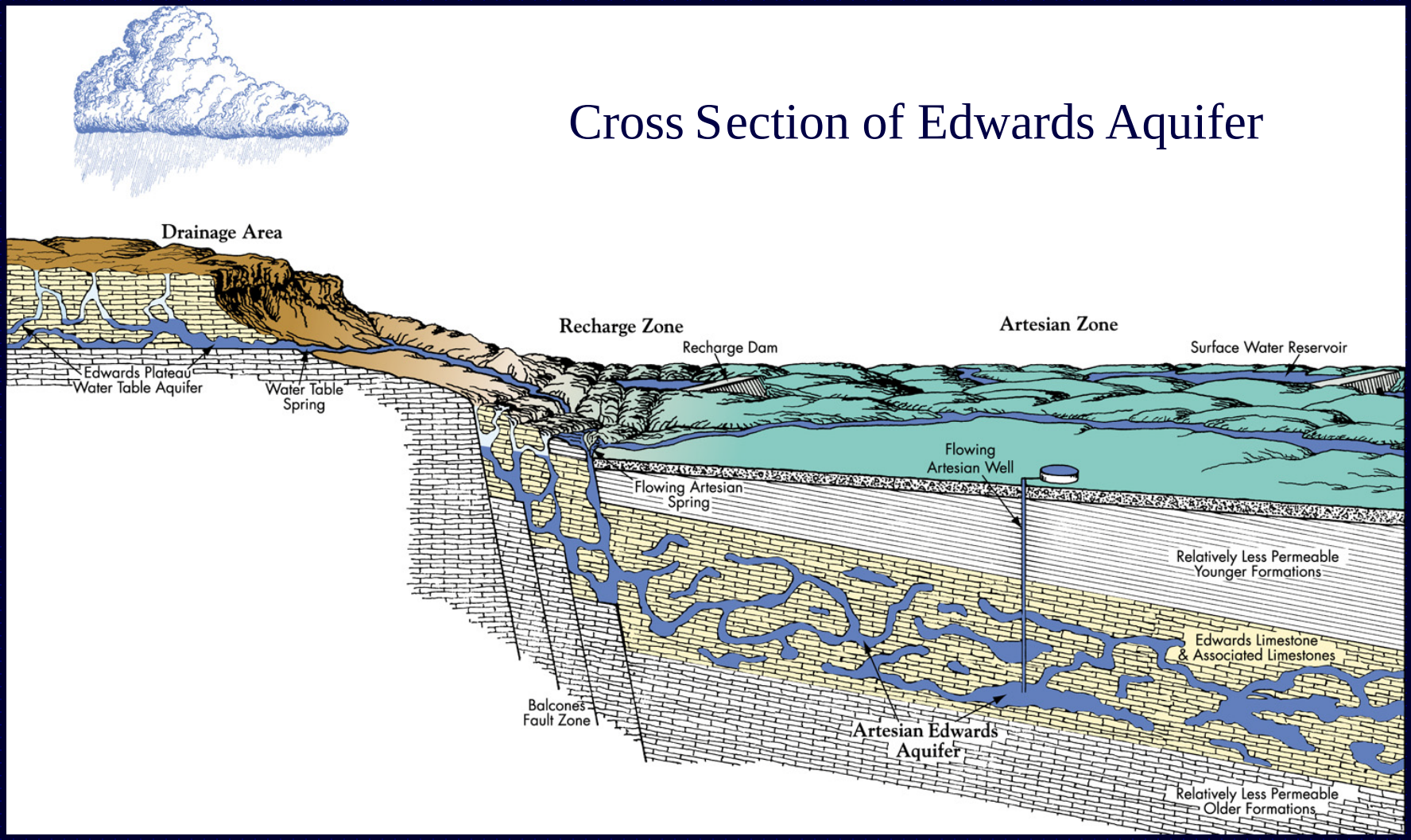
- Edwards Limestone
- 240 kilometers long
- 8 to 60 kilometers wide
- Freshwater occurs >1,000 meters below surface
- Recharge zone / artesian zone
- Regional Flow System
  - Low yields in Recharge Zone
  - High yields in Artesian Zone

EDWARDS AQUIFER REGION



Location of the Edwards Aquifer in Texas

Cross Section of Edwards Aquifer



What is karst?

Karst is "an hydrogeologic mass-transfer system in soluble rocks with a permeability structure dominated by conduits dissolved from the rock and organized to facilitate the circulation of fluids"

(Huntoon, 1995, Klimchouk and Ford, 2000)

How do you get high permeabilities in the deep Artesian Zone?

Dissolution Processes

- Chemistry
  - Carbonic Acid – shallow or deep sources
  - Sulfuric Acid – usually deep sources (sulfates and petroleum)
- Physical Processes
  - Initial undersaturated conditions
  - Mixing corrosion
  - Free Convection – fluid density
  - Temperature

Dissolution Processes

Carbonic Acid Process

- $CO_2 + H_2O <=> H_2CO_3 <=> H^+ + HCO_3^-$
- $2CaCO_3 + H_2CO_3 <=> 2Ca^{2+} + 2HCO_3^-$
- $Ca(HCO_3)_2(aq) <=> CO_2(g) + H_2O(l) + CaCO_3$

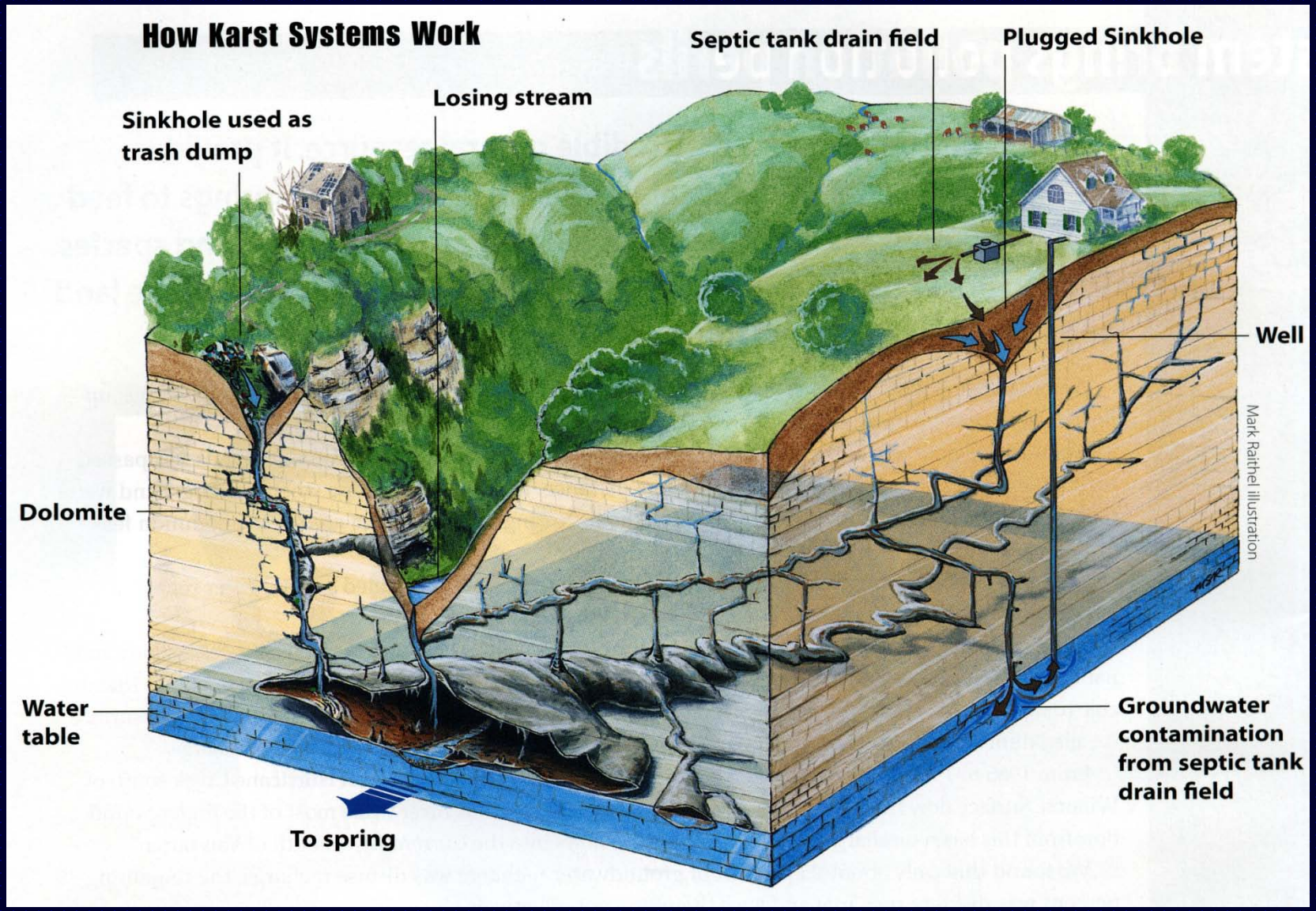
Sulfuric Acid Process

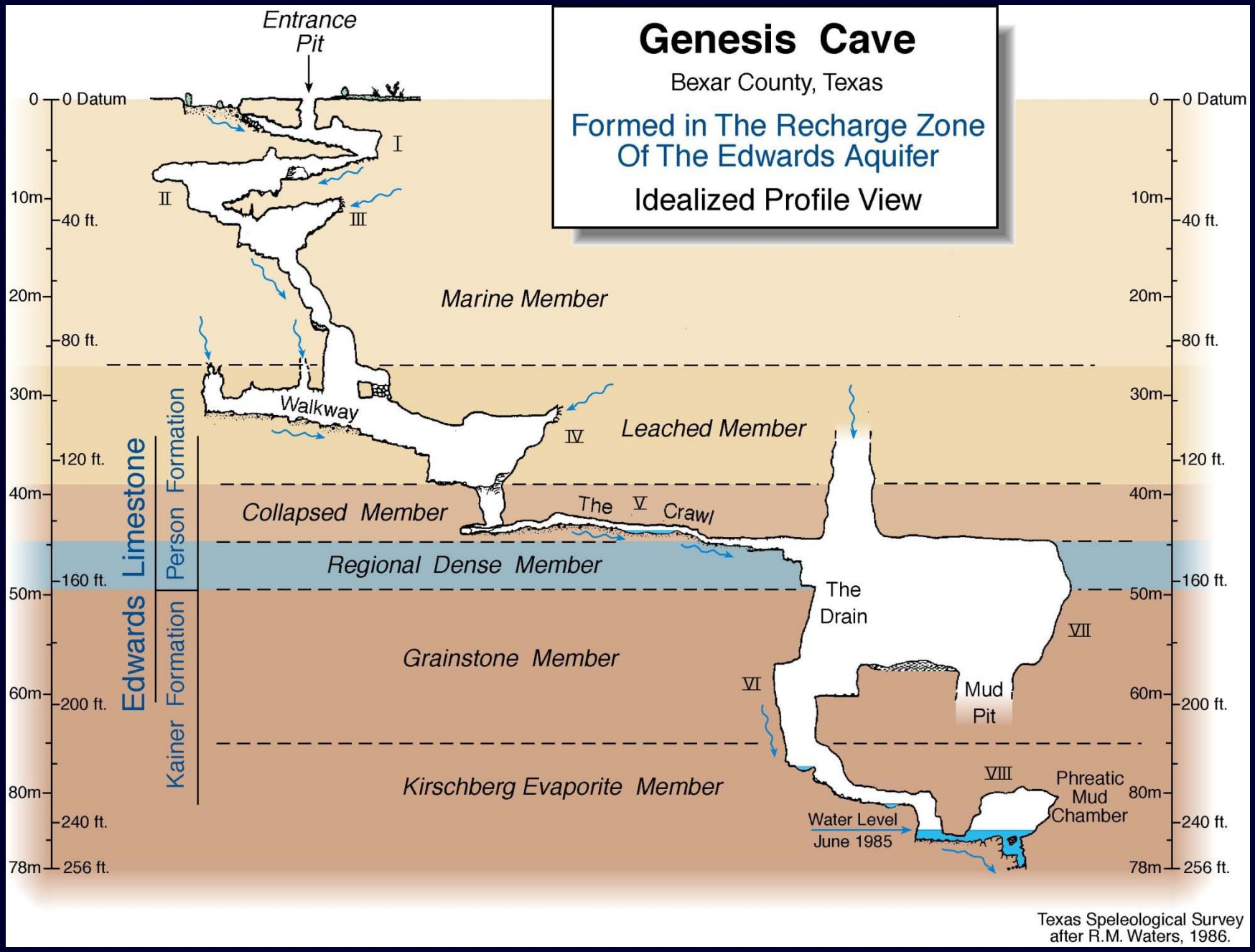
- $SO_3 + H_2O => H_2SO_4 + CaCO_3 + H_2O => CaSO_4 + 2H_2O + CO_2$

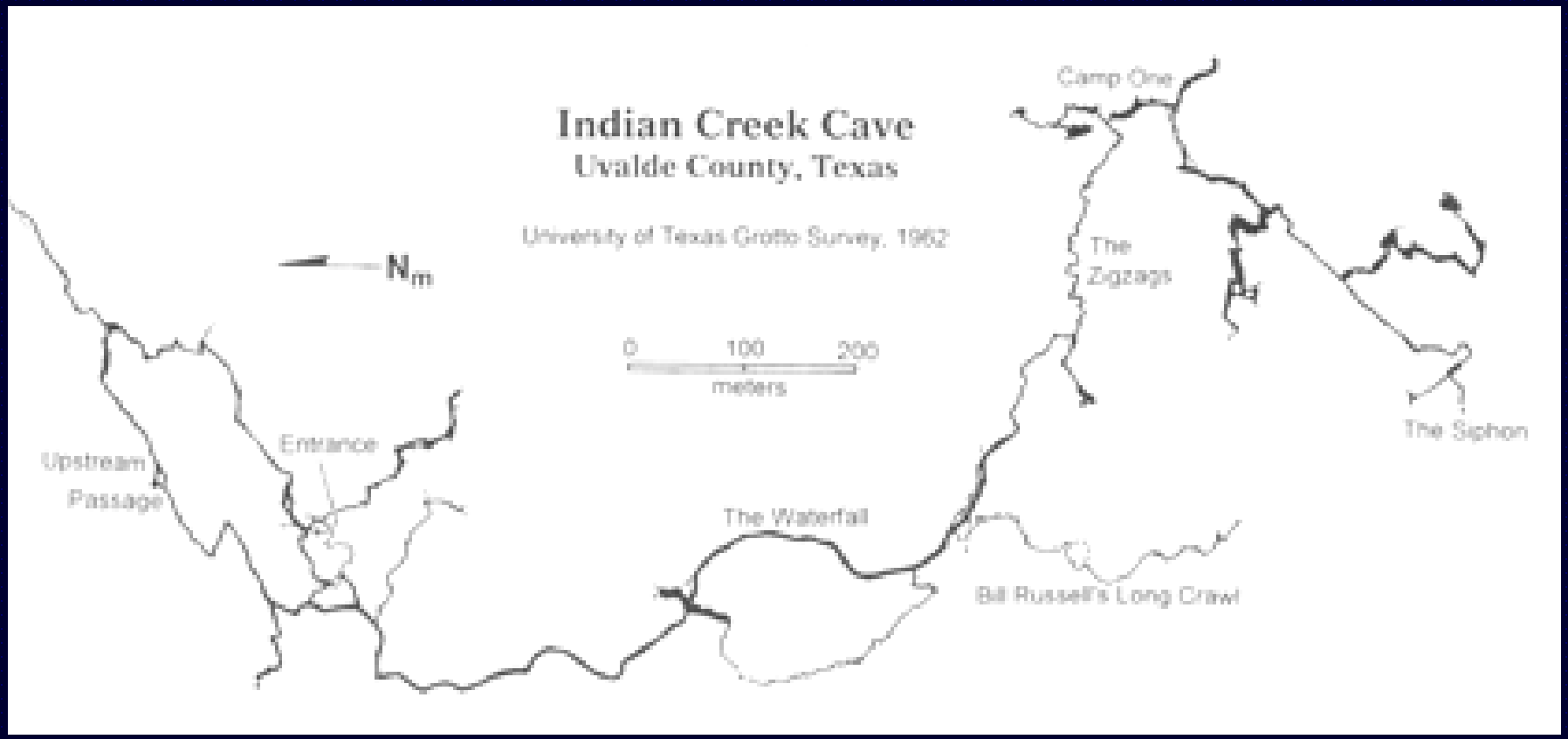
Epigenic Karst Characteristics

- Unconfined conditions (Edwards Aquifer Recharge Zone)
- Dominated by gravity-driven flow
- Predominately local flow systems
- Rapid groundwater velocities
- Highly variable water quality and quantity.

Epigenic flow system




Genesis Cave
Bexar County, Texas
Formed in The Recharge Zone
Of The Edwards Aquifer
Idealized Profile View
Entrance
Pit
0 Datum
10m
40 ft.
20m
80 ft.
30m
120 ft.
40m
160 ft.
50m
60m
200 ft.
80m
240 ft.
78m
256 ft.
Edwards Limestone
Person Formation
Kainer Formation
Marine Member
Leached Member
Collapsed Member
Regional Dense Member
Grainstone Member
Kirschberg Evaporite Member
Walkway
The Crawl
The Drain
Mud Pit
Phreatic Mud Chamber
Water Level
June 1985
I
II
III
IV
V
VI
VII
VIII
Texas Speleological Survey
after R.M. Waters, 1986.

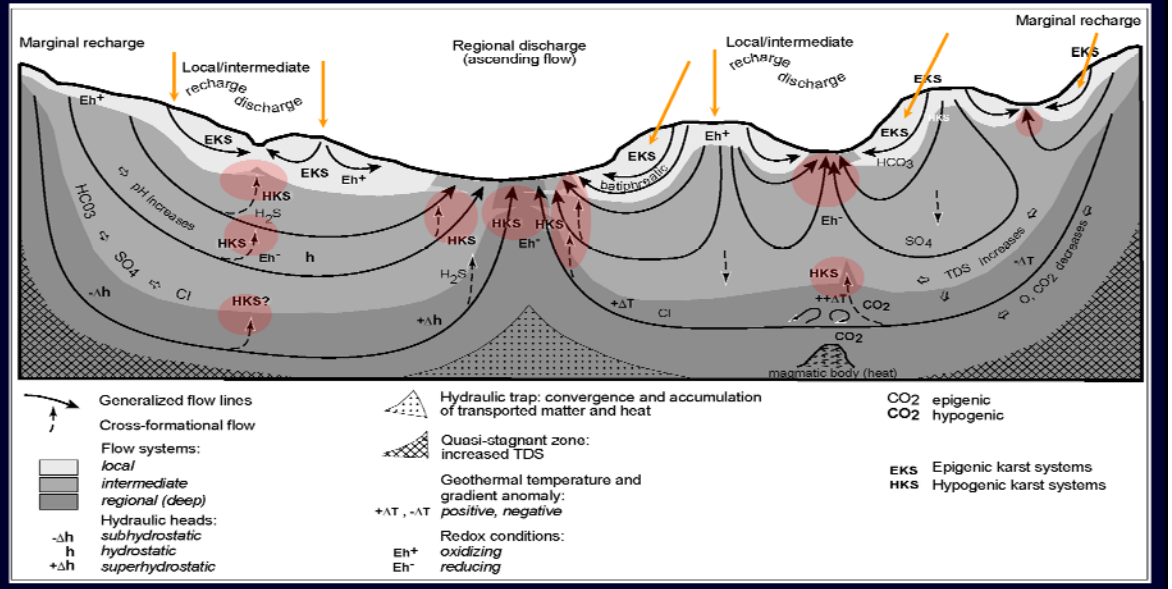


Source: Elliott and Veni, 1994

Hypogenic Karst Characteristics

- Confined conditions (Edwards Aquifer Artesian Zone) – not related to surface features
- Mixed flow system
  - Gravity, temperature, solute density gradients
- Intermediate and discharge side of regional flow systems
- Water quality parameters vary little over time.
- Meteoric waters involved

The distinctions between epigenic and hypogenic speleogenesis can be best appreciated from the hydrogeologic perspective



From: Klimchouk, 2008

Epigenic and hypogenic karst systems are associated with different types and segments of groundwater flow systems:

Epigenic karst systems
are predominantly local flow systems, and/or parts of recharge segments of intermediate and regional flow systems.

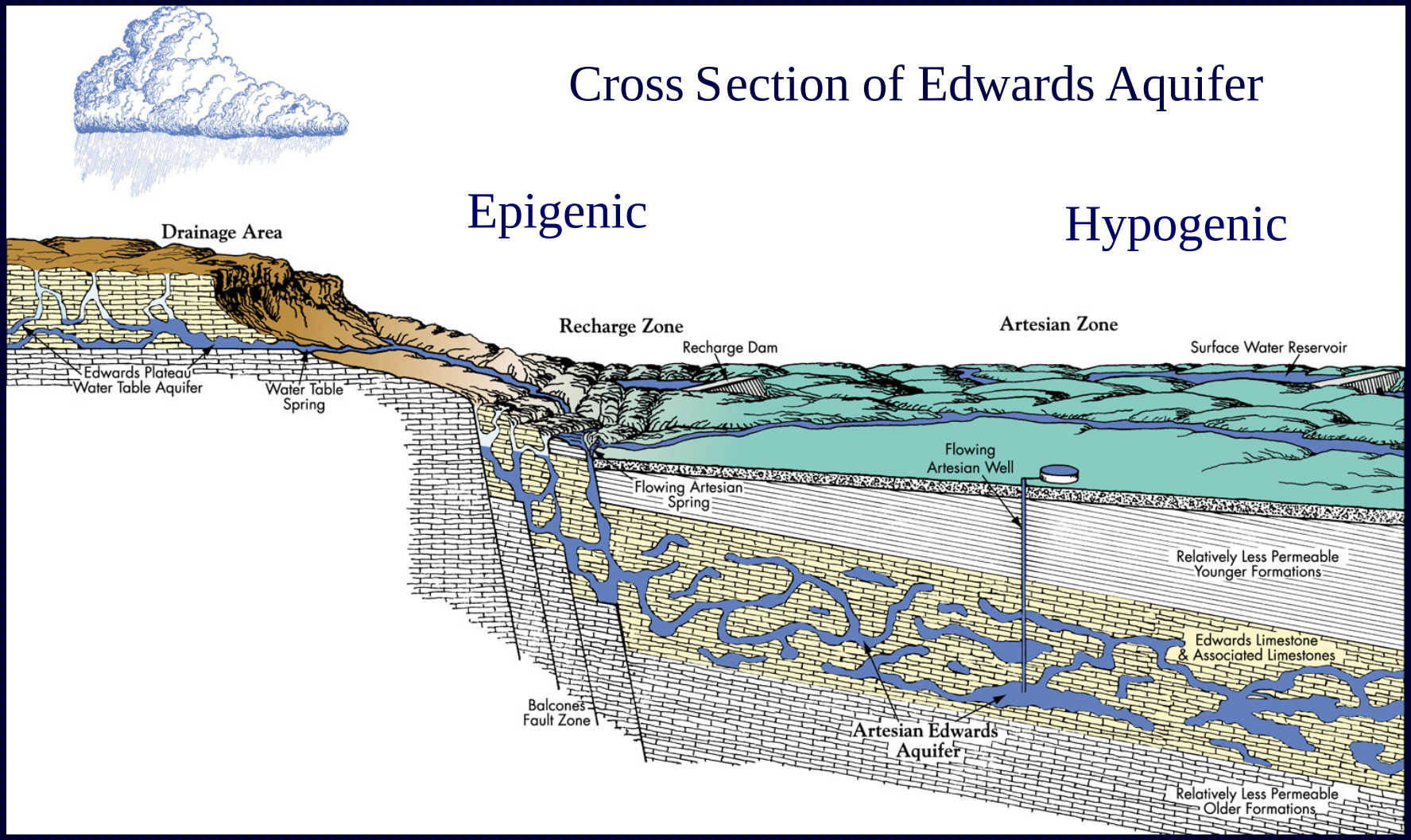
Hypogenic karst systems
are associated with discharge regimes of regional or intermediate flow systems.

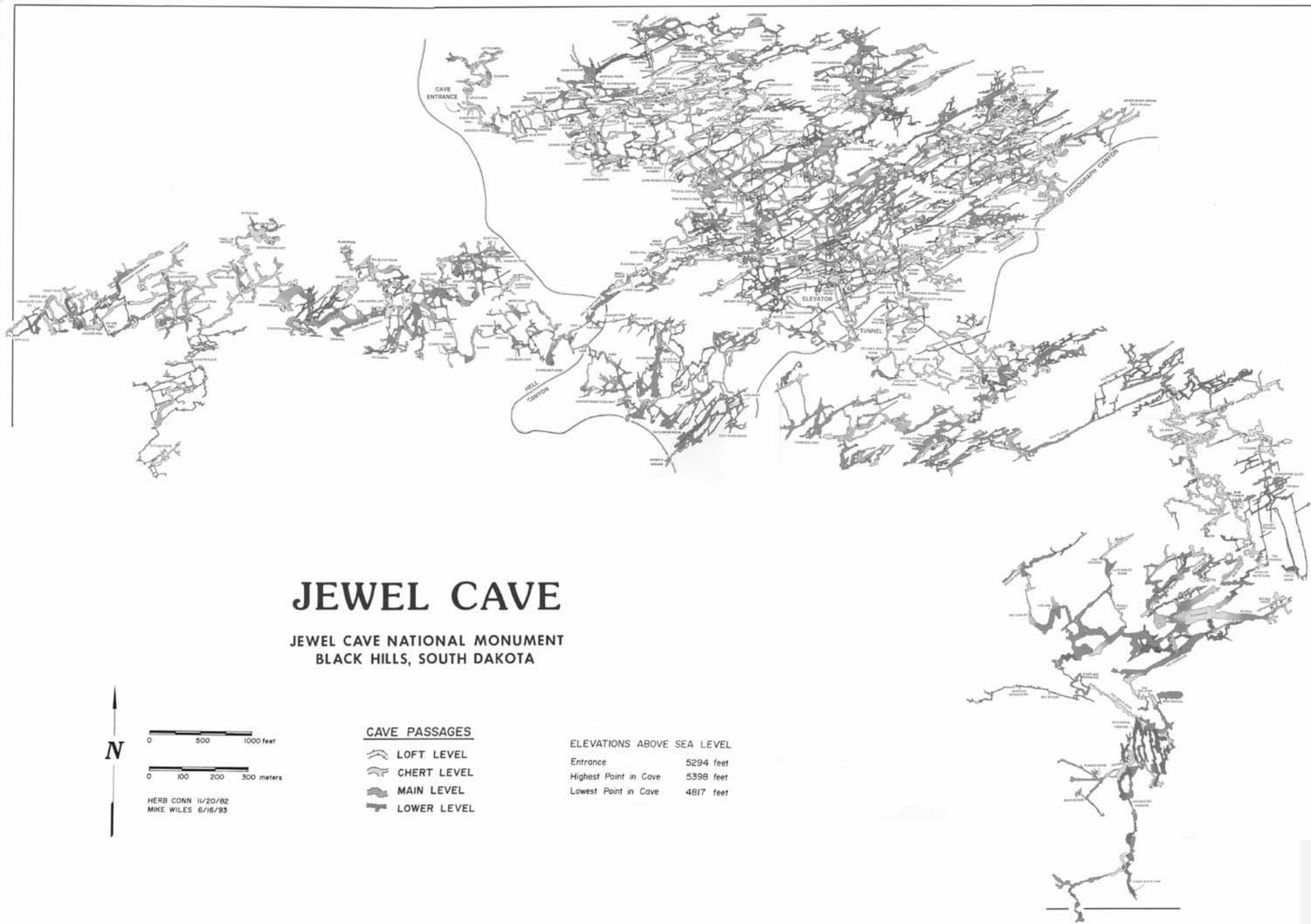
Energy, flow and geochemical conditions are inherently different for epigenic and hypogenic speleogenesis.

Cross Section of Edwards Aquifer

Epigenic

Hypogenic





JEWEL CAVE

JEWEL CAVE NATIONAL MONUMENT
BLACK HILLS, SOUTH DAKOTA

N

0 500 1000 feet

0 100 200 300 meters

HERB CONN 11/20/82
MIKE WILES 6/16/93

CAVE PASSAGES

- LOFT LEVEL
- CHERT LEVEL
- MAIN LEVEL
- LOWER LEVEL

ELEVATIONS ABOVE SEA LEVEL

Entrance	5294 feet
Highest Point in Cave	5398 feet
Lowest Point in Cave	4817 feet

Edwards Aquifer

- Edwards limestone has limited initial permeability
- Secondary/tertiary permeability
  - Epigenic processes –Recharge Zone
  - Hypogenic process – Artesian Zone
- Somewhat selective depending upon geography
  - Kinney Co.-Uvalde Co line - low yields
  - Central Uvalde Co. – higher yields
- High yield wells very common in Artesian Zone
  - High permeability in Cyclic Marine and Leached and Collapsed Units and Kirschberg Units located below less permeable units

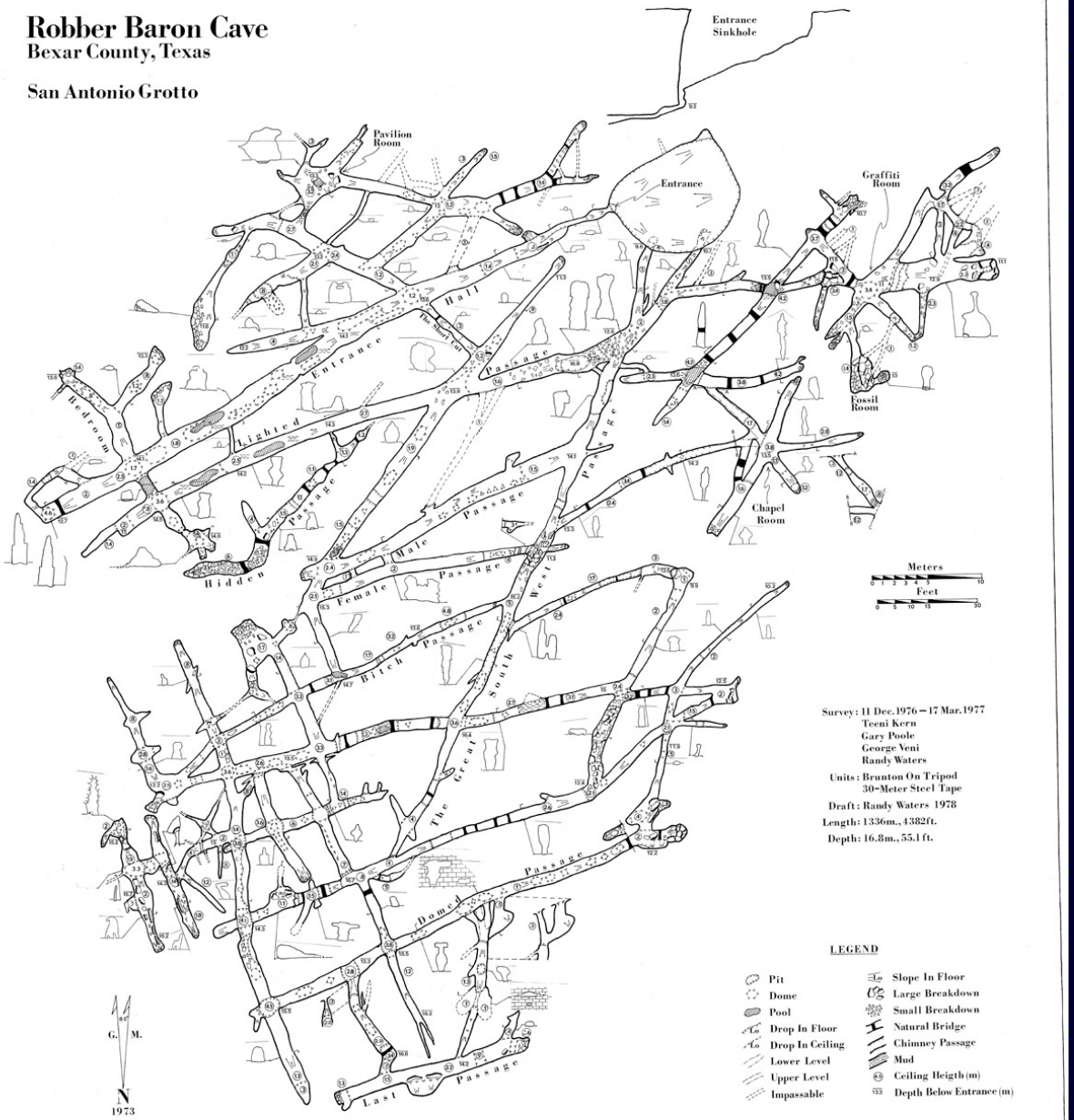
Edwards Aquifer

- Breccia zones increase permeabilities across units
- Convergent flowpaths to springs
- Analysis of Robber Baron Cave shows hypogene morphology (Paleo Spring)
- High assimilative capacity
  - Water quality will ultimately come into equilibrium with recharge waters
- Allows quality and quantity management on regional basis

Robber Baron Cave

Bexar County, Texas

San Antonio Grotto



Survey: 11 Dec. 1976 – 17 Mar. 1977
Teeni Kern
Gary Poole
George Veni
Randy Waters

Units: Brunton On Tripod
30-Meter Steel Tape

Draft: Randy Waters 1978

Length: 1336m., 4382ft.

Depth: 16.8m., 55.1 ft.

LEGEND

- Pit
- Dome
- Pool
- Drop In Floor
- Drop In Ceiling
- Lower Level
- Upper Level
- Impassable
- Slope In Floor
- Large Breakdown
- Small Breakdown
- Natural Bridge
- Chimney Passage
- Mud
- Ceiling Heigth (m)
- Depth Below Entrance (m)

Texas Blind Salamander