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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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
  - Low yields in Recharge Zone
  - High yields in Artesian Zone
- Regional Flow System
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
- \( \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \)
- \( 2\text{CaCO}_3 + \text{H}_2\text{CO}_3 \rightleftharpoons 2\text{Ca}^{2+} + 2\text{HCO}_3^- \)
- \( \text{Ca(HCO}_3)_2\text{(aq)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{O(l)} + \text{CaCO}_3 \)

Sulfuric Acid Process
- \( \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 + \text{CaCO}_3 + \text{H}_2\text{O} \rightarrow \text{CaSO}_4 + 2\text{H}_2\text{O} + \text{CO}_2 \)
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

How Karst Systems Work

- Sinkhole used as trash dump
- Losing stream
- Septic tank drain field
- Plugged Sinkhole
- Well
- Dolomite
- Water table
- Groundwater contamination from septic tank drain field
- To spring
Mapped length is 6.7 kilometers

4th longest cave in Texas

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
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
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
Texas Blind Salamander