Devonian and Mississippian Hydrocarbon Generation and Migration in Southern West Virginia, Appalachian Basin*

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Abstract

The primary objective of this study was to gain an understanding of the fluid network and connectivity of the Devonian and Mississippian system (DMS) in southern West Virginia. This analysis led to a conceptual model describing hydrocarbon generation and migration, as well as the present-day pressure regime within this system.

The primary data include fluid inclusion, pressure, aquifer, and chemical tracer data sets. Many of the data sets are seemingly unrelated to one another, but taken as a whole are informative for understanding the mechanisms of hydrocarbon generation and migration. The data were interpreted using both statistical analyses and geologic mapping.

Possible hydrocarbon sources include the Rhinestreet, Dunkirk and Sunbury intervals. Based on TOC, maturity and thickness data the Dunkirk is the primary source, although some degree of mixing from the Rhinestreet and Sunbury is likely. The high degree of statistical similarity between the fluid inclusions of the Greenbrier and Onondaga, which are separated by 3000 feet, imply that both intervals were charged by the same or very similar fluids. Unique pressure compartments are not evident, based on the pressure data. Review of USGS aquifer mapping supplemented by water-saturation calculations indicates that the overlying aquifer is regionally extensive and coincidental with the top of the modern gasifer. The chemical-tracer data were characterized by rapid vertical and lateral communication with the offset monitoring wells; this is indicative of present-day connectivity.

The conceptual model derived from the data indicates that the DMS in southern West Virginia has likely gone through several phases of development. Prior to the Mississippian the system was normally pressured and water-saturated. At the onset of liquid-hydrocarbon generation during the Pennsylvanian, water was flushed or partially flushed from the system, and the pressures were normal to

overpressured. Maximum burial after the Alleghanian orogeny led to thermal cracking from liquid hydrocarbon to gas during Permian time. This resulted in the DMS becoming overpressured, thereby further flushing a bulk of the remaining water. Subsequent hydrocarbon leakages resulted in the present-day system defined by an underpressured gasifer overlain by a normally pressured aquifer.

Reference

Law, B.E., 2002, Basin centered gas systems: AAPG Bulletin, v. 86, p. 1891-1919.

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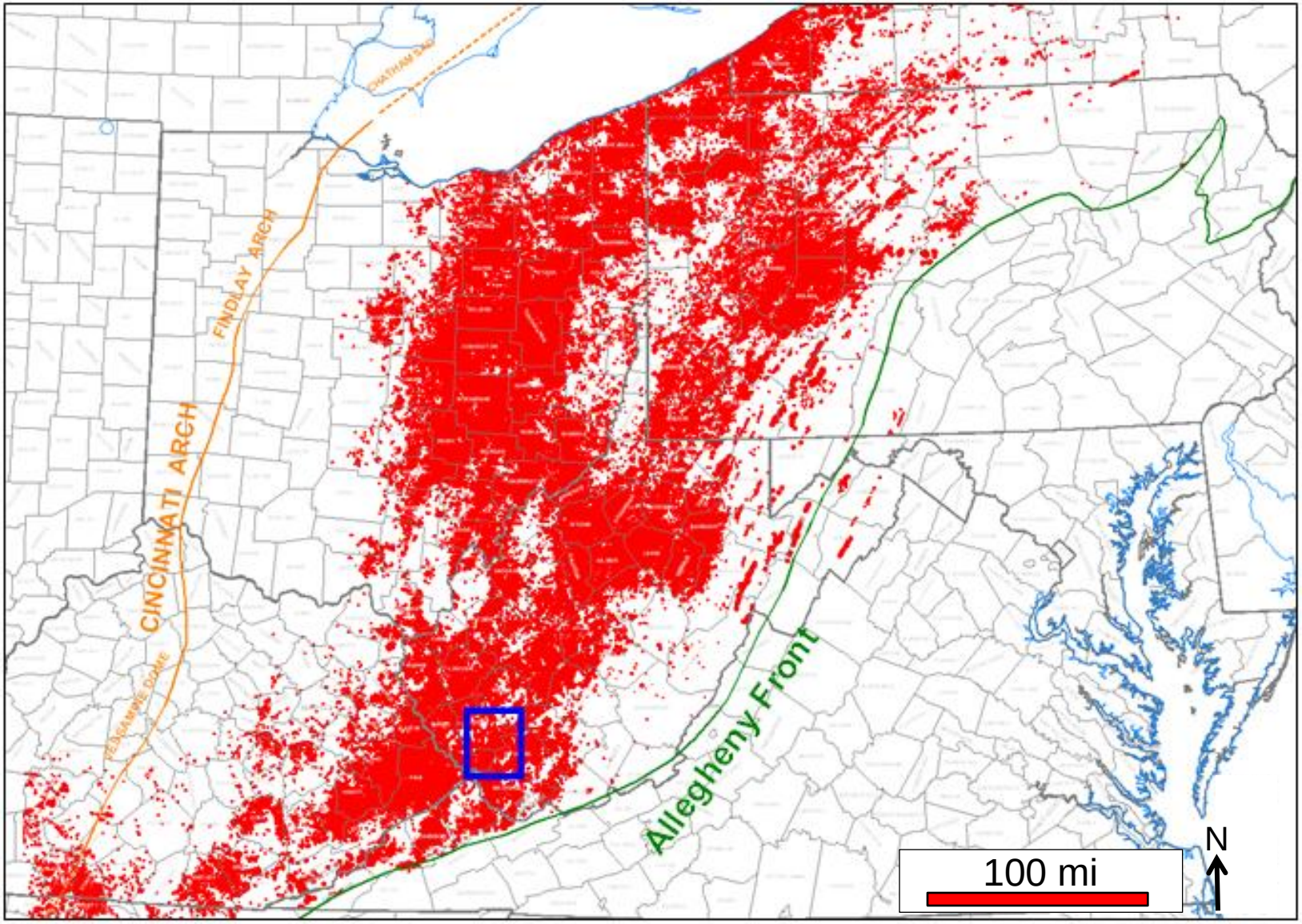
Outline

- Study area
- Tight gas systems
- Data summary
- Working model
- Conclusion

Study Location



Type Stratigraphic Column (southern WV)

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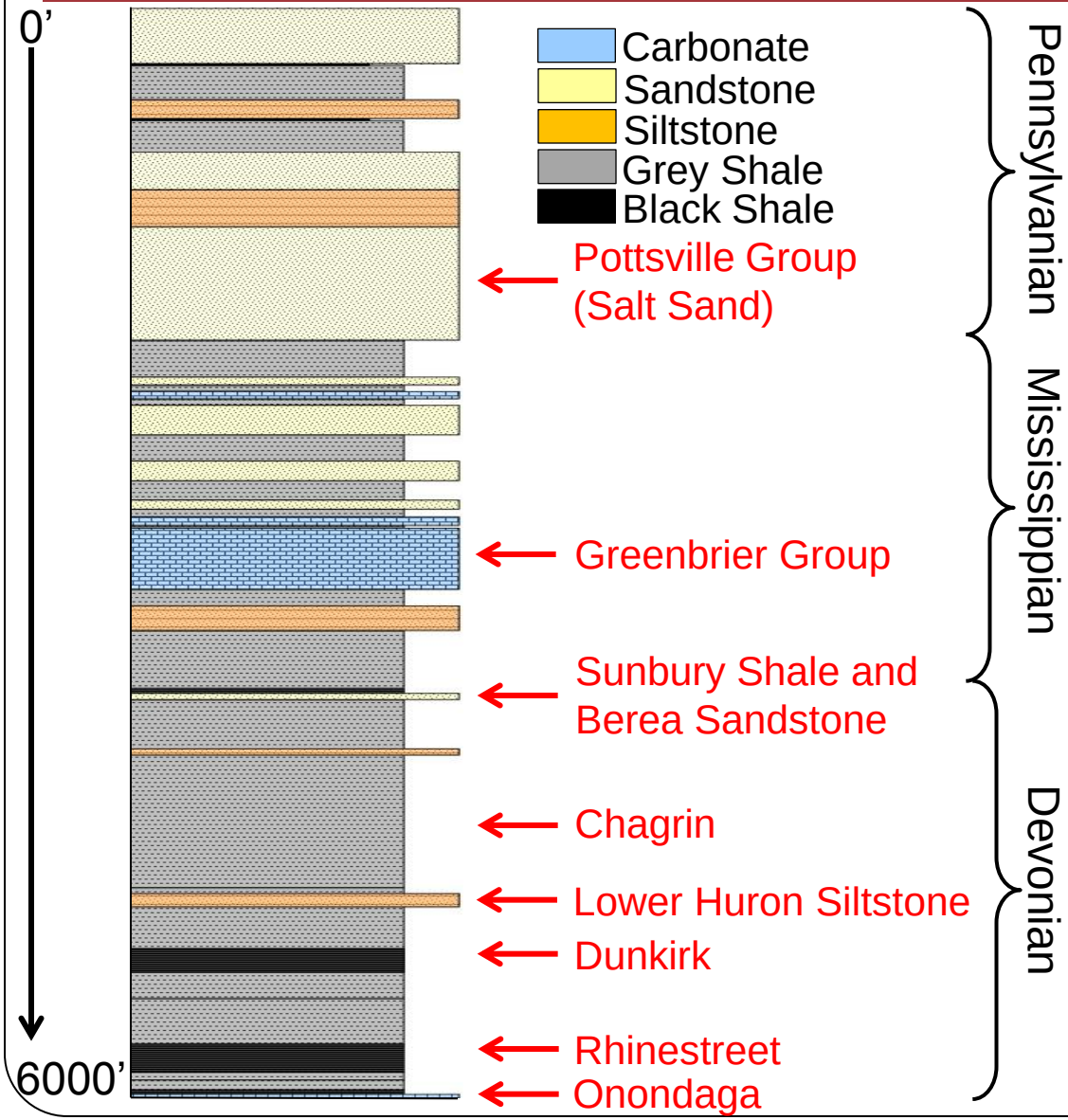

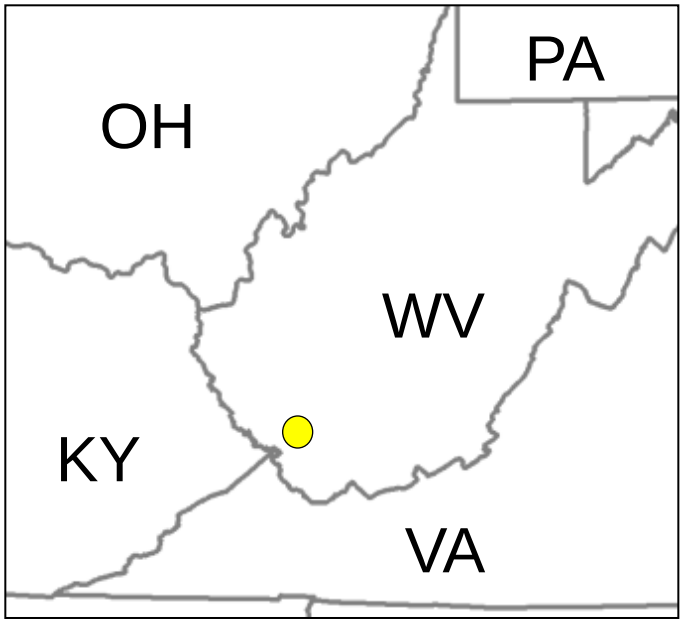

Note: strat column is drawn to scale

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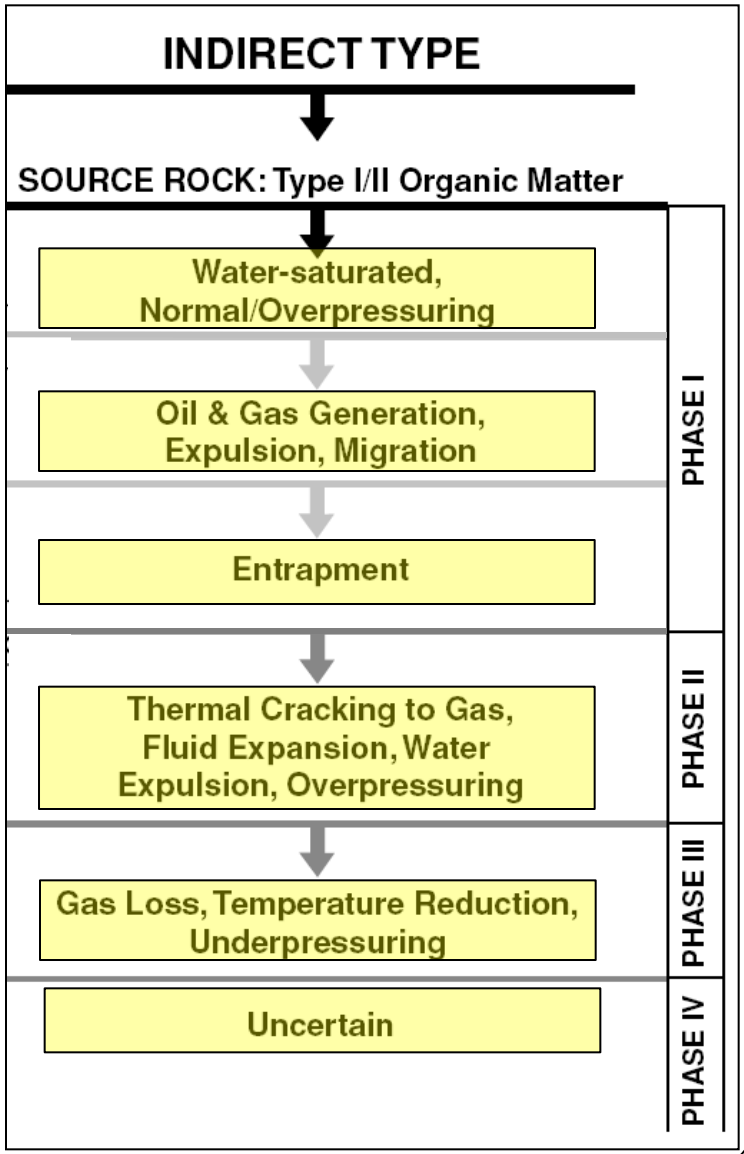
Tight Gas System (Basin-Centered)

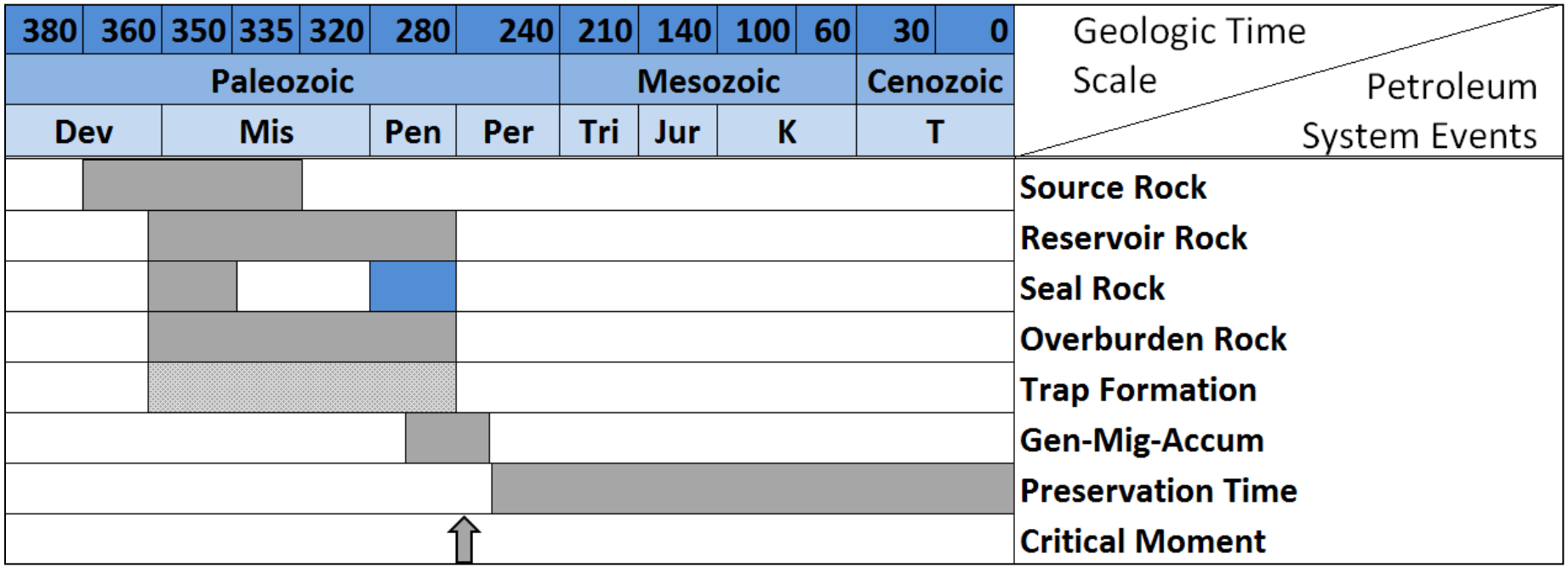
- **Work in analog basins has led to various conceptual models regarding tight gas systems.**
- ***In general, BCGAs are regionally pervasive accumulations that are gas-saturated, abnormally pressured (high or low), commonly lack a downdip water contact, and have low-permeability reservoirs.****
- **How do the data from the study area relate to this conceptual model?**



*Law, B.E., 2002, Basin Centered Gas Systems: AAPG Bulletin, v. 86, p. 1891-1919.

Law, 2002, AAPG Bulletin

Tight Gas System (Conventional)



- **How can the data be used to better understand the mechanics of the various events?**
  - Pressure history
  - Migration pathways
  - Seal
- **At this stage, components of both BC and conventional systems are being utilized.**

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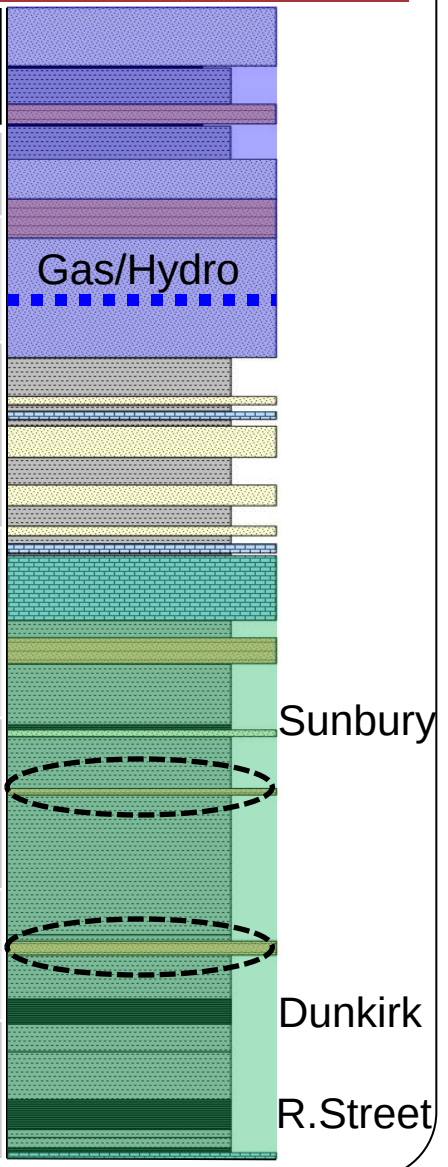
Data Summary

Data Set	Interpretation
TOC	Used to identify potential source intervals
Vitrinite Reflectance (Ro)	Wet to dry gas expected (1.3-1.7)
Modern Fluid Chemistry	-Dry Gas (C1-C2) -Paleo-chemistry indicates wetter gas (C1-C4) -Lateral migration inferred
Paleo Fluid Chemistry	-Liquid charge (pyrobitumen) -FI data characterized by C1-C4 -Lateral conduits inferred from AMU vs Lith. Char.
Chemical Tracers	-Lateral conduits (inferred from geographic extents) -Vertical conduits (inferred from shallow wells)
Pressure Data	-Underpressured prior to drilling -Gas and hydro gradient intersection infers seal
Aquifer Data	-Regional aquifers documented by USGS -Salt-water aquifers defined by drilling reports



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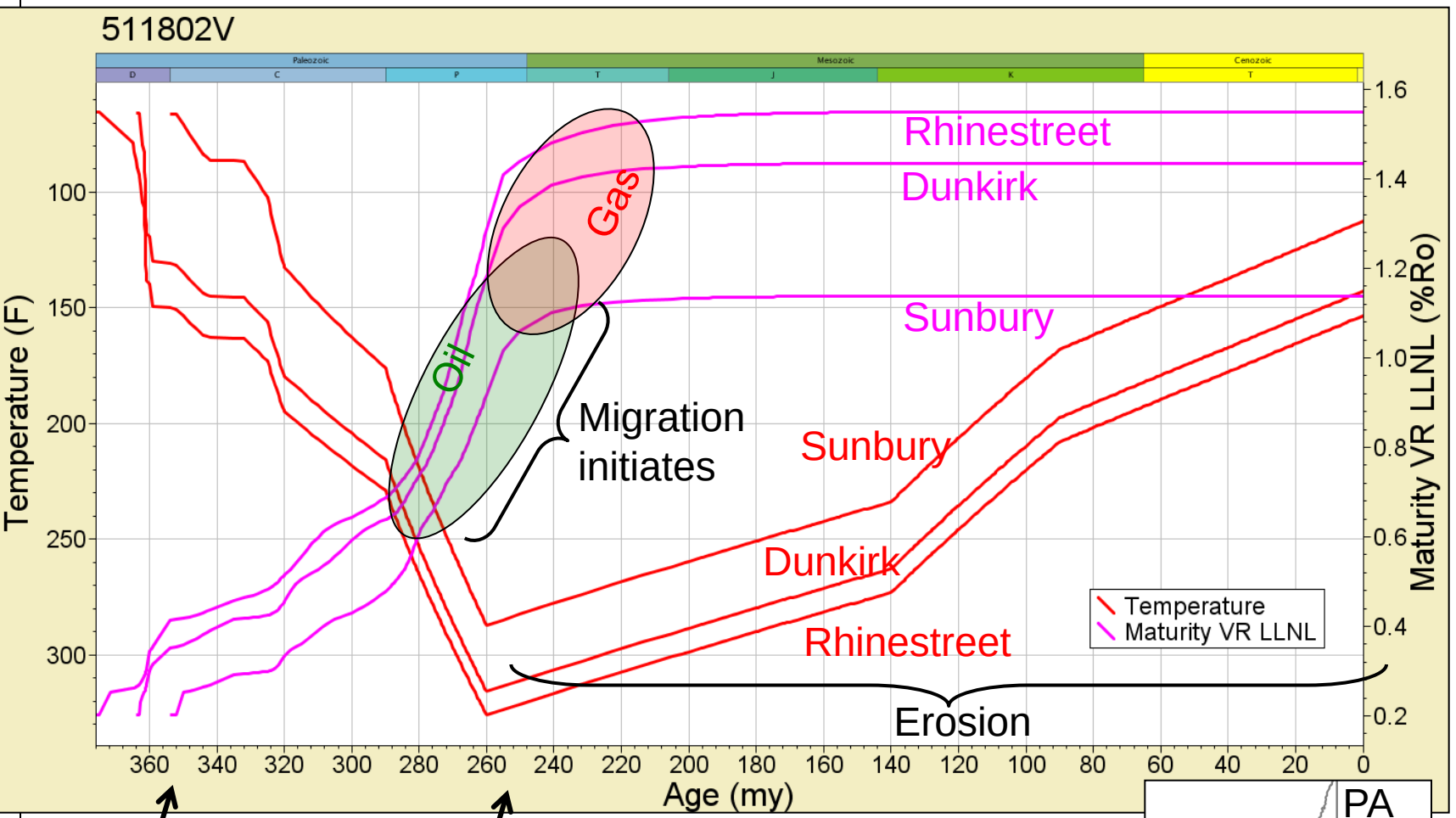
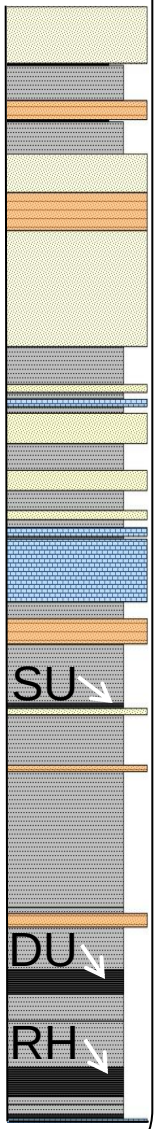
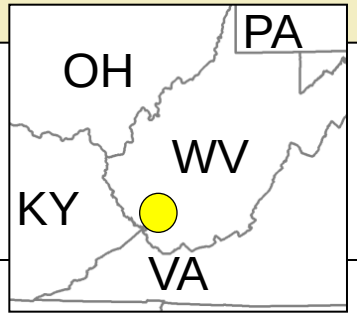
1D Basin Model, Southern WV



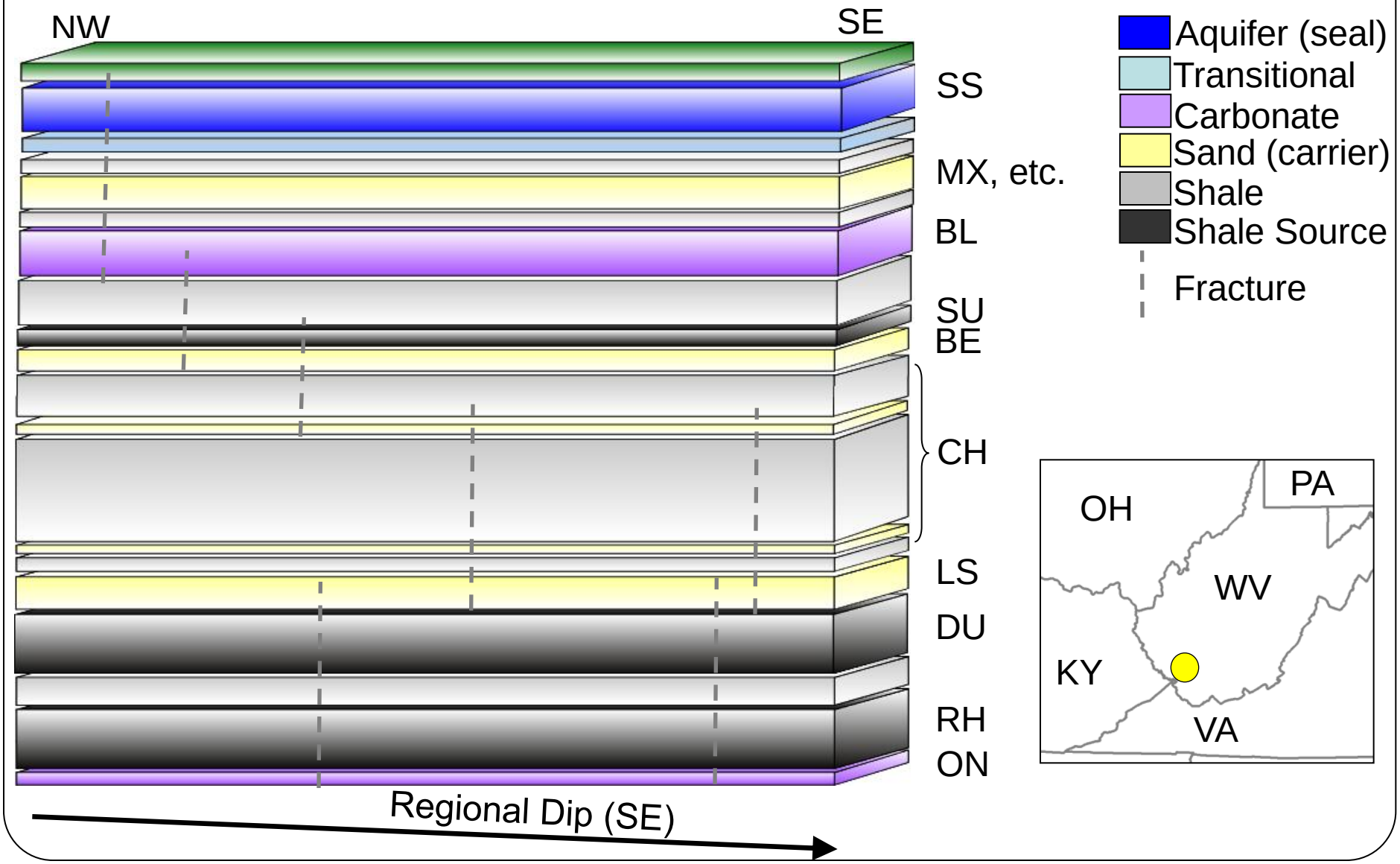


~End Acadian

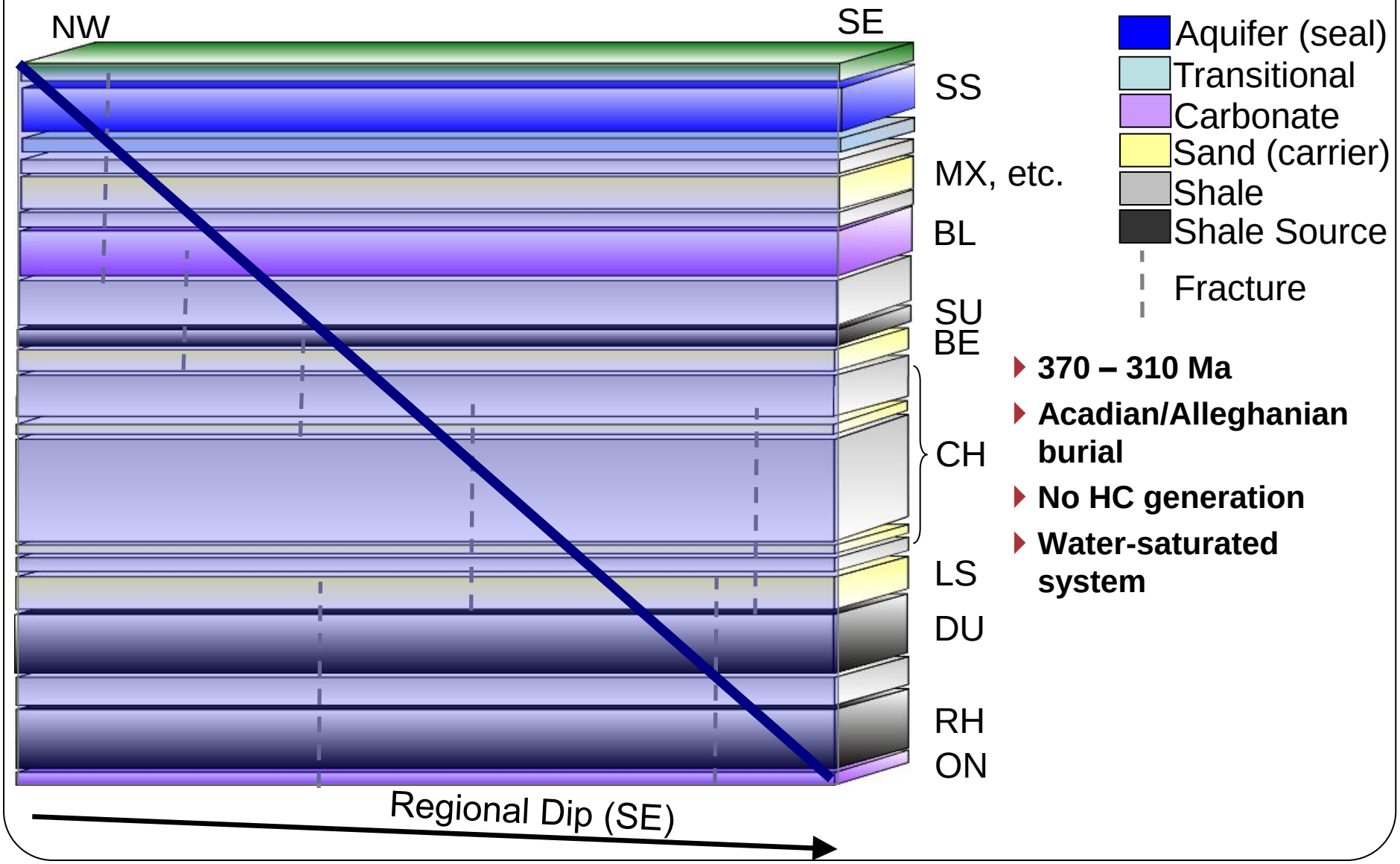
~End Alleghanian



Working Model (Schematic)

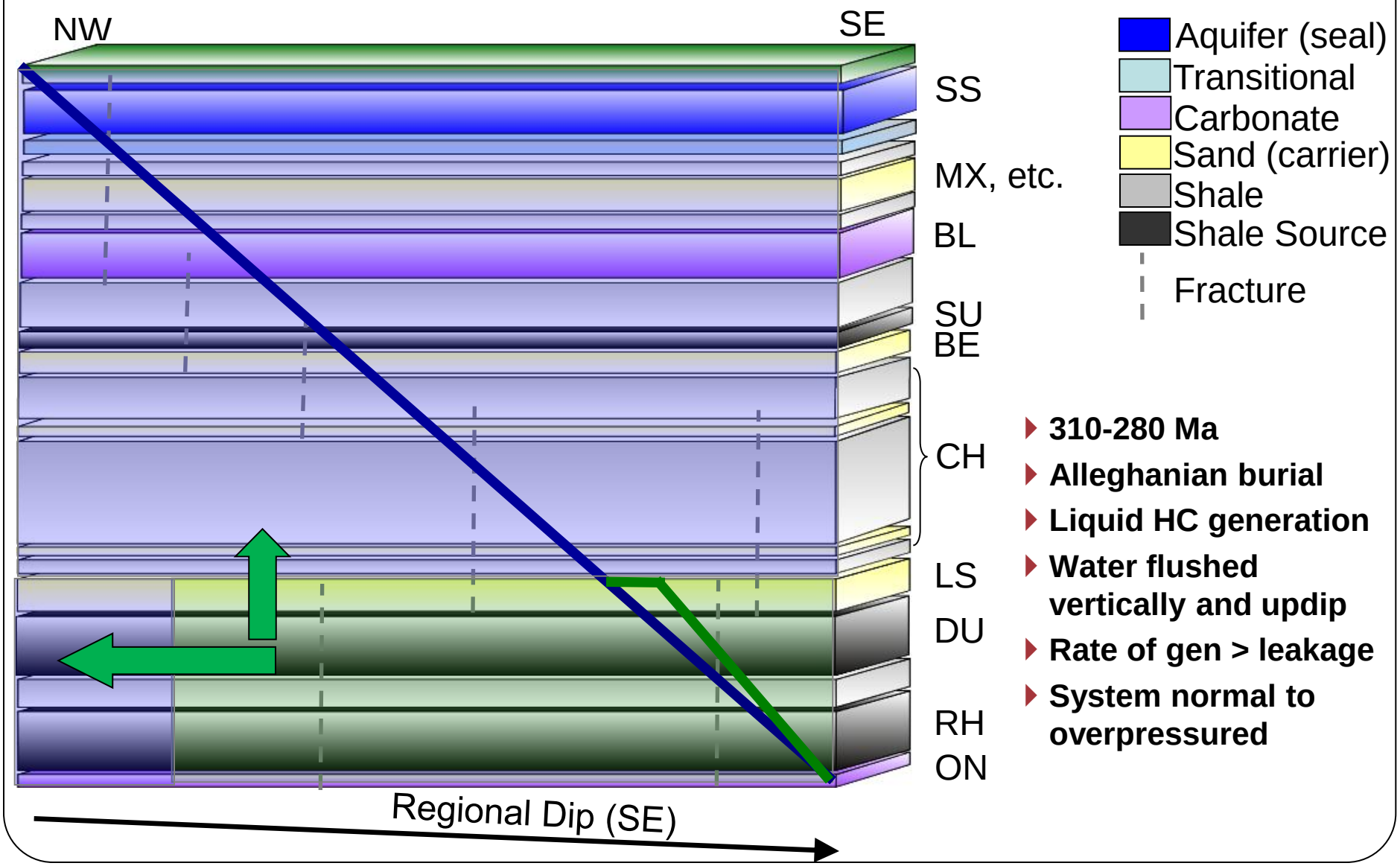


Working Model (Time 0, Water-Saturated)



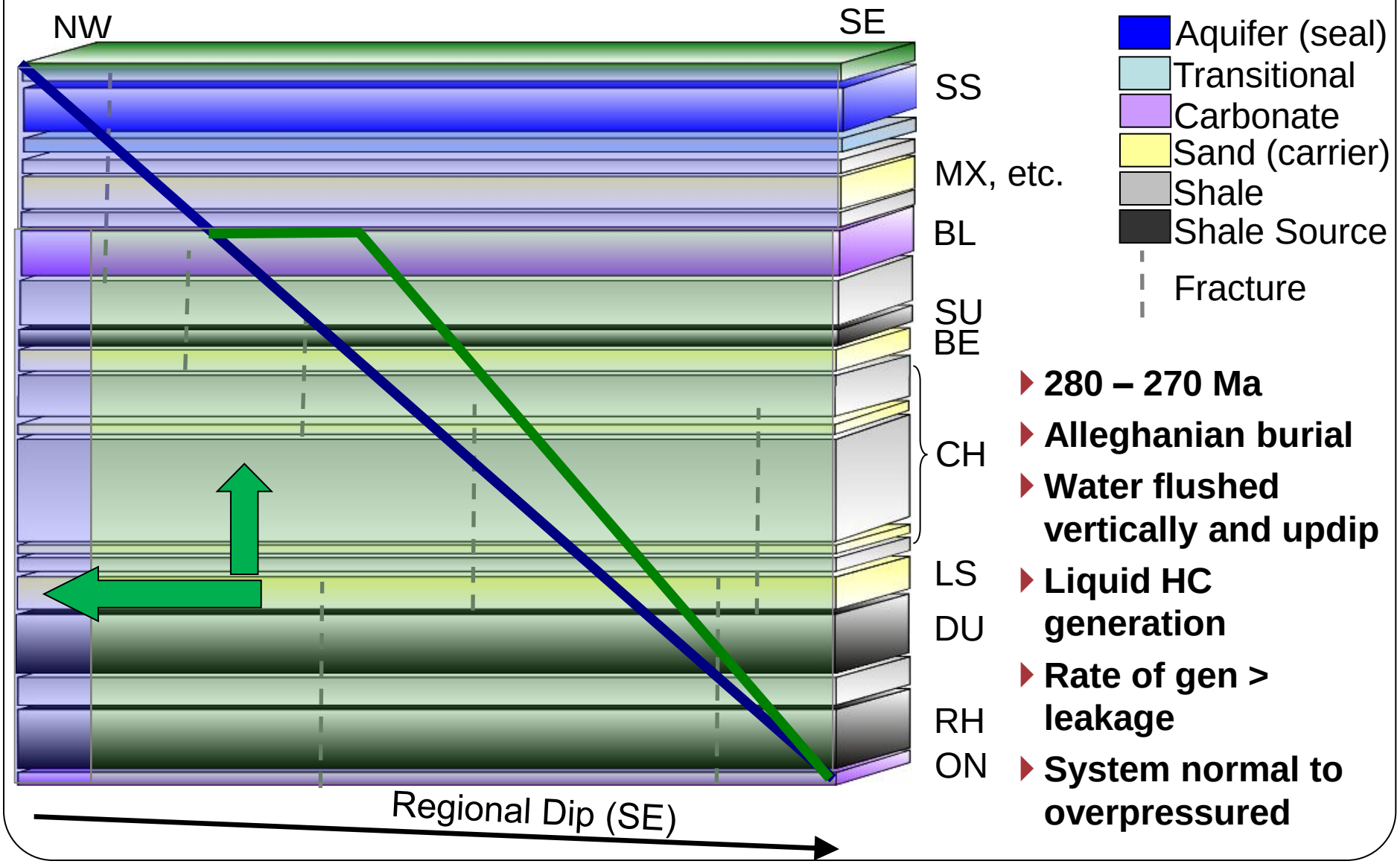
- **370 – 310 Ma**
- **Acadian/Alleghanian burial**
- **No HC generation**
- **Water-saturated system**

Working Model (Time 1, Early Genesis)



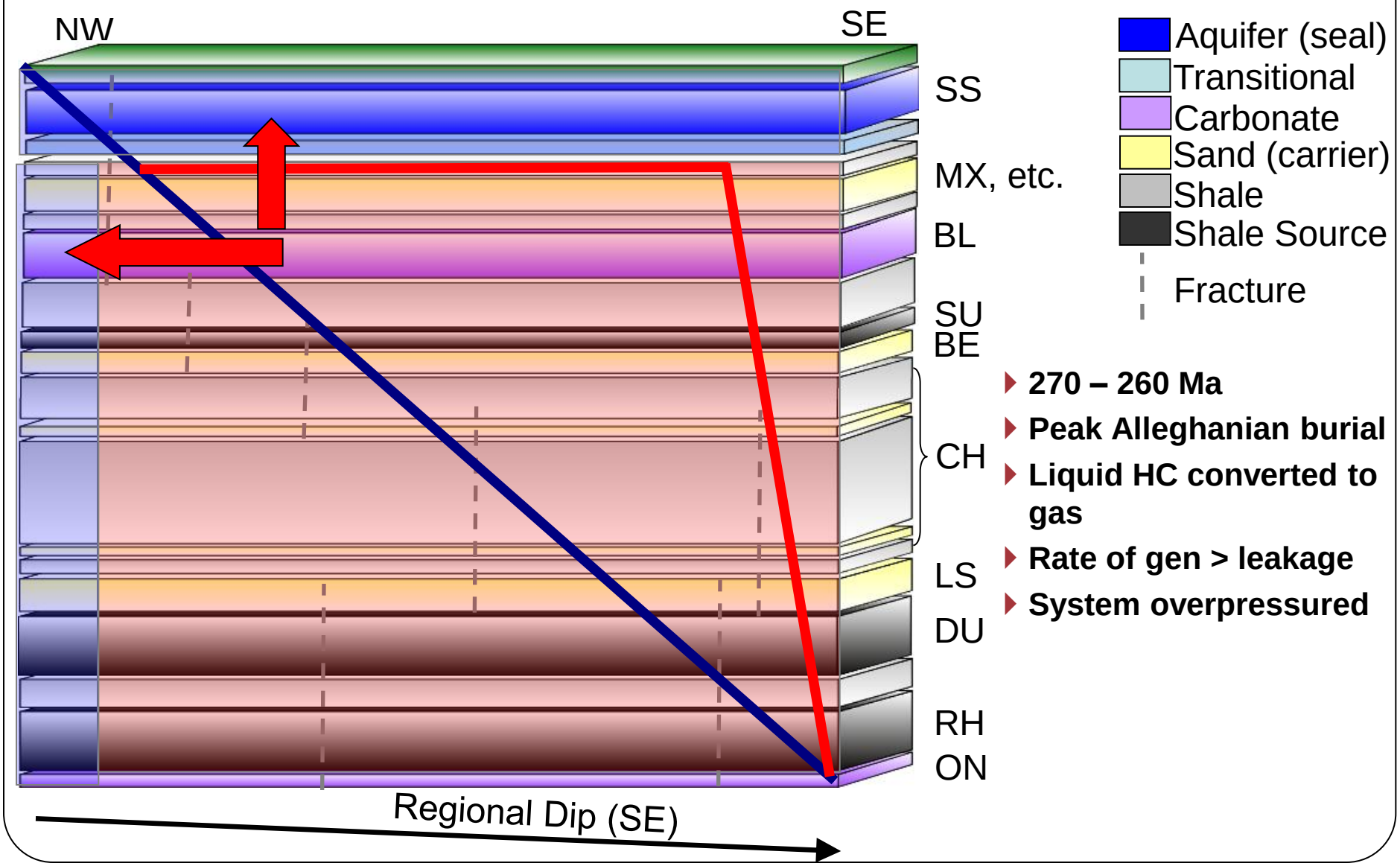
- **310-280 Ma**
- **Alleghanian burial**
- **Liquid HC generation**
- **Water flushed vertically and updip**
- **Rate of gen > leakage**
- **System normal to overpressured**

Working Model (Time 2, Late Genesis)



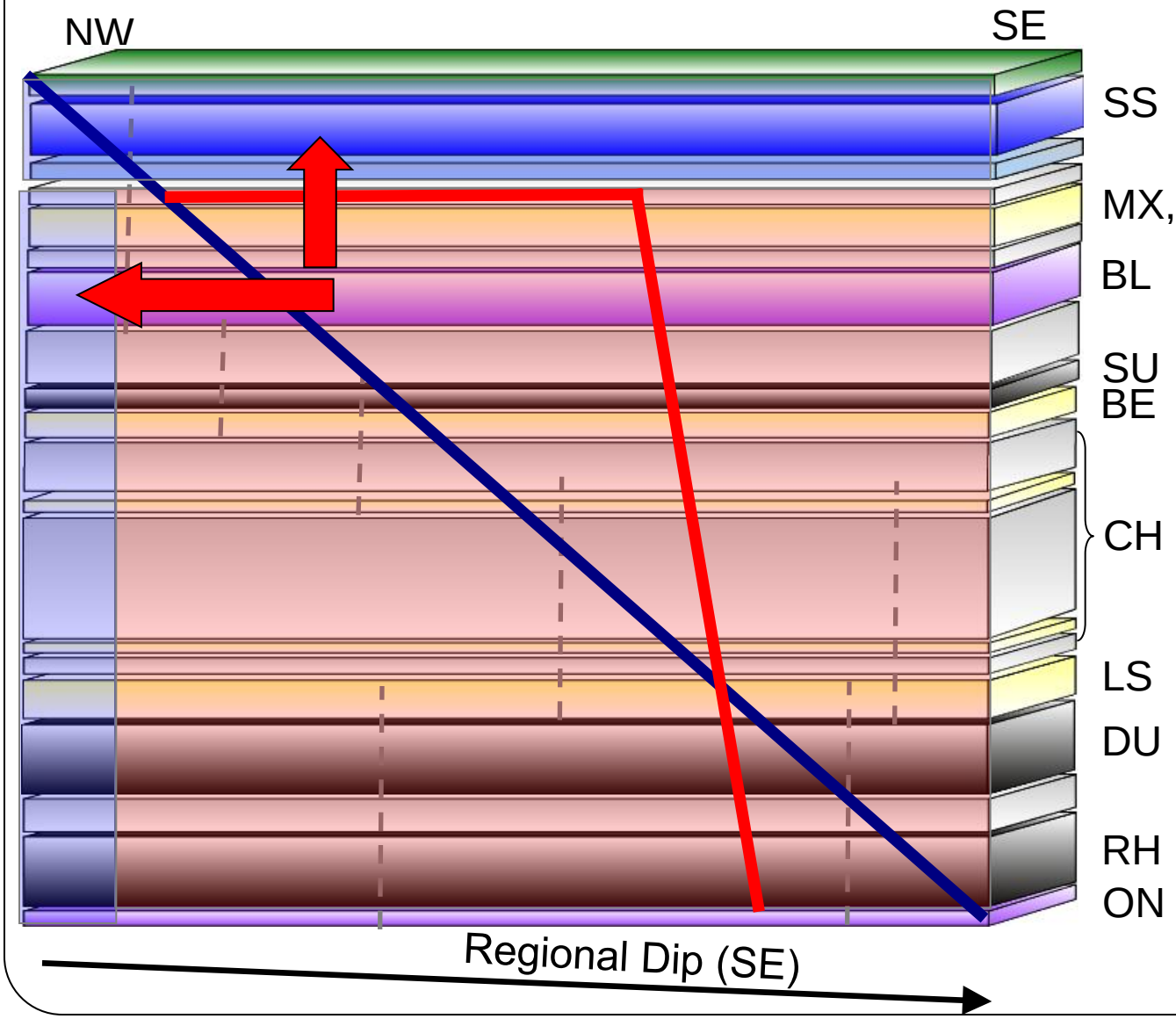
- **280 – 270 Ma**
- **Alleghanian burial**
- **Water flushed vertically and updip**
- **Liquid HC generation**
- **Rate of gen > leakage**
- **System normal to overpressured**

Working Model (Time 3, Thermal Cracking)



- **270 – 260 Ma**
- **Peak Alleghanian burial**
- **Liquid HC converted to gas**
- **Rate of gen > leakage**
- **System overpressured**

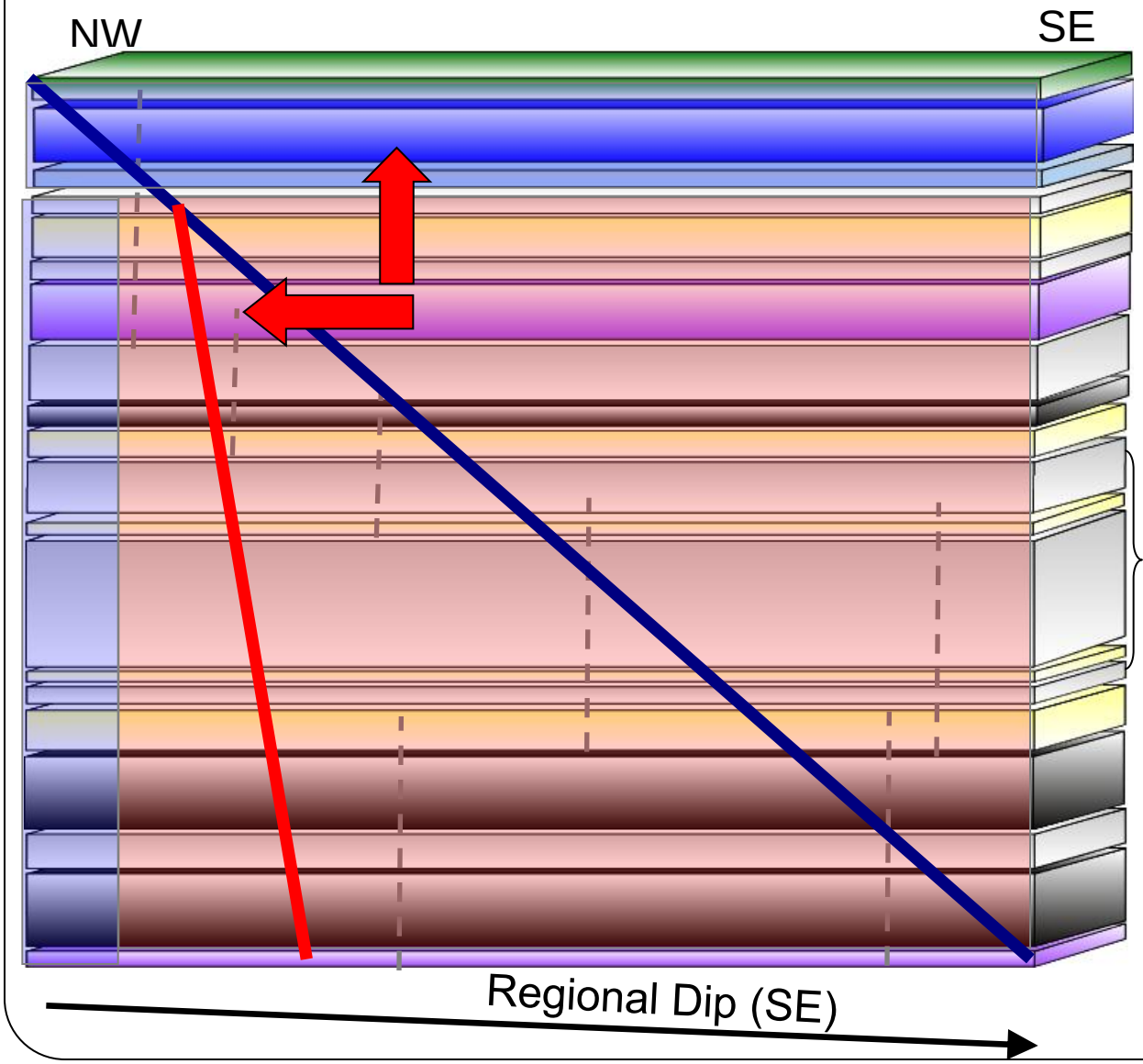
Working Model (Time 4, Transition)



- Aquifer (seal)
- Transitional
- Carbonate
- Sand (carrier)
- Shale
- Shale Source
- Fracture

- **260 - >0 Ma**
- **Start of erosion**
- **Rate of gen < leakage**
- **System under- and overpressured**

Working Model (Time 5, Steady State)



- Aquifer (seal)
- Transitional
- Carbonate
- Sand (carrier)
- Shale
- Shale Source
- Fracture

- **<260 – 0 Ma**
- **Continued erosion (~8000’ in study area)**
- **Continued leakage**
- **Generation halted or slowed**
- **System normal to underpressured**
- **Proposed current state of Dev-Miss system**

Summary

- Numerous data sets have been used to evaluate HC gen/mig/accum and pressure.
- HC migrated in liquid phase initially
- HC converted to gas prior to and during peak burial
- Overlying aquifer acts as seal (water block/capillary trapping)
- System was overpressured during the Permian
- Drop to underpressure due to erosion and leakage

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