

# **The Geology of the Arbuckle Group in the Midcontinent: Sequence Stratigraphy, Reservoir Development, and the Potential for Hydrocarbon Exploration\***

**Richard D. Fritz<sup>1</sup>, Patrick Medlock<sup>2</sup>, Michael J. Kuykendall<sup>3</sup>, and James Lee Wilson<sup>4</sup> (Deceased)**

Search and Discovery Article #30266 (2013)

Posted May 13, 2013

\*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013

<sup>1</sup>SM Energy, Tulsa, Oklahoma, USA ([rfritz@sm-energy.com](mailto:rfritz@sm-energy.com))

<sup>2</sup>Consultant, Austin, Texas, USA

<sup>3</sup>Newfield Exploration, Tulsa, Oklahoma, USA

<sup>4</sup>Consultant, New Braunfels, Texas, USA

## **Introduction**

The Arbuckle Group of the Midcontinent comprises the mid-southern part of the “Great American Carbonate Bank” (GACB) and consists mostly of carbonates with a few laterally consistent sandstones. The Arbuckle Group is found in the Anadarko, Ardmore, and Arkoma Basins and surrounding environs in the Texas panhandle, Oklahoma, and Arkansas ([Figure 1](#)). These basins represented a significant downwarp associated with early rifting in the area now located in the southern one-half of both Oklahoma and Arkansas.

The Arbuckle and Timbered Hills groups in Oklahoma, the equivalent strata in the Ozark Mountains, the combined Wilberns Formation and Ellenburger Group of Texas, the El Paso Group of southwestern Texas, and the Knox Group of the southeastern United States comprise or partially comprise the Sauk III supersequence, which began to form with the late Dresbachian – early Franconian transgression and ended with a major regression in the early Middle Ordovician (Whiterockian; [Figure 2](#)).

## **Depositional Facies, Diagenesis, Geologic History, and Reservoir Development**

The Arbuckle is a cyclic carbonate that is dominated by intertidal and shallow subtidal facies ([Figure 3](#)). In some areas, supratidal or deeper subtidal facies are observed. The depositional model is an extensive, dominantly regressive tidal flat with persistent peritidal facies across much of the GACB. These peritidal cycles shallow-upward with significant variation in thickness from as thin as 4 ft (1 m) to more than 110 ft (>34 m) thick ([Figure 4](#)). Large-scale regional changes in relative sea level may have had a large influence on the type of cycles and sequences that formed during Arbuckle deposition. Arbuckle strata, especially within third-order sequence boundaries, are correlatable across the basin.

Within the sequence boundaries, cycles can be further grouped into packages of sequences that are composed mostly of either intertidally dominated or subtidally dominated cycles ([Figure 5](#)). Detailed local to regional correlation of the facies bundles can be made with gamma-ray and resistivity logs; however, facies are commonly obscured by strong diagenetic overprint, which makes detailed correlation difficult.

Reservoirs in the Arbuckle are complex, and porosity is controlled by original depositional fabric, diagenesis, paleokarst, and fracture overprint. Upper subtidal and lower intertidal facies typically have the depositional fabric most conducive to reservoir development. Diagenetic changes are a continuum that begins with early diagenesis, including hypersaline-evaporative conditions, vadose and phreatic conditions, and followed by deep phreatic to late thermal diagenesis. Evidence that porosity formed during multiple diagenetic phases exists. Dolomitization and precipitation events also occurred throughout various levels of the profile. Dolomite is the most abundant mineral, and it can be subdivided into (1) early (syngenetic to penecontemporaneous) hypersaline dolomite, (2) shallow-burial mixed-water (phreatic) dolomite, and (3) deeper-burial to thermal (baroque and xenotopic) dolomite ([Figure 6](#)).

The super-Arbuckle unconformity is recognized as evidence of a eustatic sea-level drop and has been used to mark the boundary between the Sauk and Tippecanoe depositional megasequences. The Arbuckle Group contains multiple unconformities at major sequence boundaries ([Figure 7](#)). Paleokarst is especially prevalent beneath the super-Arbuckle unconformity, in particular along major sequence boundaries with related unconformity surfaces. Paleokarstic features in the Arbuckle Group have been identified in outcrop in the Arbuckle Mountains of southern Oklahoma and in the southern Ozark uplift in northeastern Oklahoma. Numerous cores and logs indicate collapse breccias that are interpreted to have formed in response to karst conditions.

The Arbuckle Group is an important petroleum reservoir in the Midcontinent, and it has great potential, especially for natural gas. Three key oil and gas fields are found on Oklahoma: West Mayfield in the Anadarko Basin, Cottonwood Creek in southern Oklahoma, and Wilburton in the Arkoma Basin. Exploration is enhanced by understanding the complex relationships of depositional process, stratigraphic relationships, paragenesis, and structural overprint. Reservoir development is typically along sequence boundaries, especially where facies have strong diagenetic overprints from dolomitization and dissolution associated with paleokarstic events. No major source rocks below or within the Arbuckle Group are observed; so the best reservoirs are structurally related to strong fracture overprints and juxtaposed with source rocks, or are along migration pathways ([Figure 8](#)).

A generalized sequence of Arbuckle reservoir development can be delineated ([Figure 9](#)). (1) deposition and early syngenetic dolomitization primarily in the Arkoma and Anadarko basins, a type of dolomitization that was apparently inhibited in southern Oklahoma because of abrupt subsidence providing greater circulation of marine waters and thereby restricting movement of saturated brines; (2) syndepositional karst development along sequence and/or parasequence boundaries, especially at the top of subtidally dominated sequence boundaries of third-order cycles; (3) subsequent rejuvenation of karst and porosity development during later lowstand events in intra-Simpson to pre-Woodford hiatuses; (4) fracture development by extensional tectonics; (5) burial by Mississippian and Lower Pennsylvanian sediments; (6) fracturing and erosion by Early Pennsylvanian tectonics with overthrust in the Arkoma Basin and strike-slip- related upthrust in southern Oklahoma and the Wichita

uplift along the southern boundary of the Anadarko Basin; (7) deep phreatic or meteoric hydrothermal karstification along both old and new hydrologic pathways; (8) hydrocarbon migration predominantly from Devonian, Mississippian, and Pennsylvanian shales; (9) further fracturing during Late Pennsylvanian tectonics; and (10) both construction and destruction of hydrothermal porosity in the Arbuckle reservoir. This sequence is in the order of most likely occurrence; however, many of the processes would have developed over a wide range of time.

### **Conclusion**

The conclusion is that exploration in peritidal carbonates such as the Arbuckle Group should not only involve seismic structural analysis but should also include close examination of sequence boundaries and their relationship to reservoir development. Sequence boundaries within lower zones in the Arbuckle Group should also be examined for untapped production.

### **References Cited**

Bertagne, A.J., C. Vuillermoz, and T.C. Leising, 1991, Seismic exploration for Cambrian-Ordovician objectives, Wilburton area, southeastern Oklahoma: Oklahoma Geological Survey Bulletin Circular 92, p. 66-70.

Ethington, R.L., J.E. Repetski, and J.R. Derby, 2012, Ordovician of the Sauk megasequence in the Ozark region of northern Arkansas and parts of Missouri and adjacent states, *in* J.R. Derby, R.D. Fritz, S.A. Longacre, W.A. Morgan, and C.A. Sternbach, eds., The great American carbonate bank: The geology and economic resources of the Cambrian-Ordovician Sauk megasequence of Laurentia: AAPG Memoir 98, p. 275-300.

Pratt, B.R., and N.P. James, 1986, The St. George Group (Lower Ordovician) of western Newfoundland: Tidal-flat island model for carbonate sedimentation in shallow epeiric seas: *Sedimentology*, v. 33, p. 313-344, doi:10.1111/j.1365-3091.1986.tb00540.x.

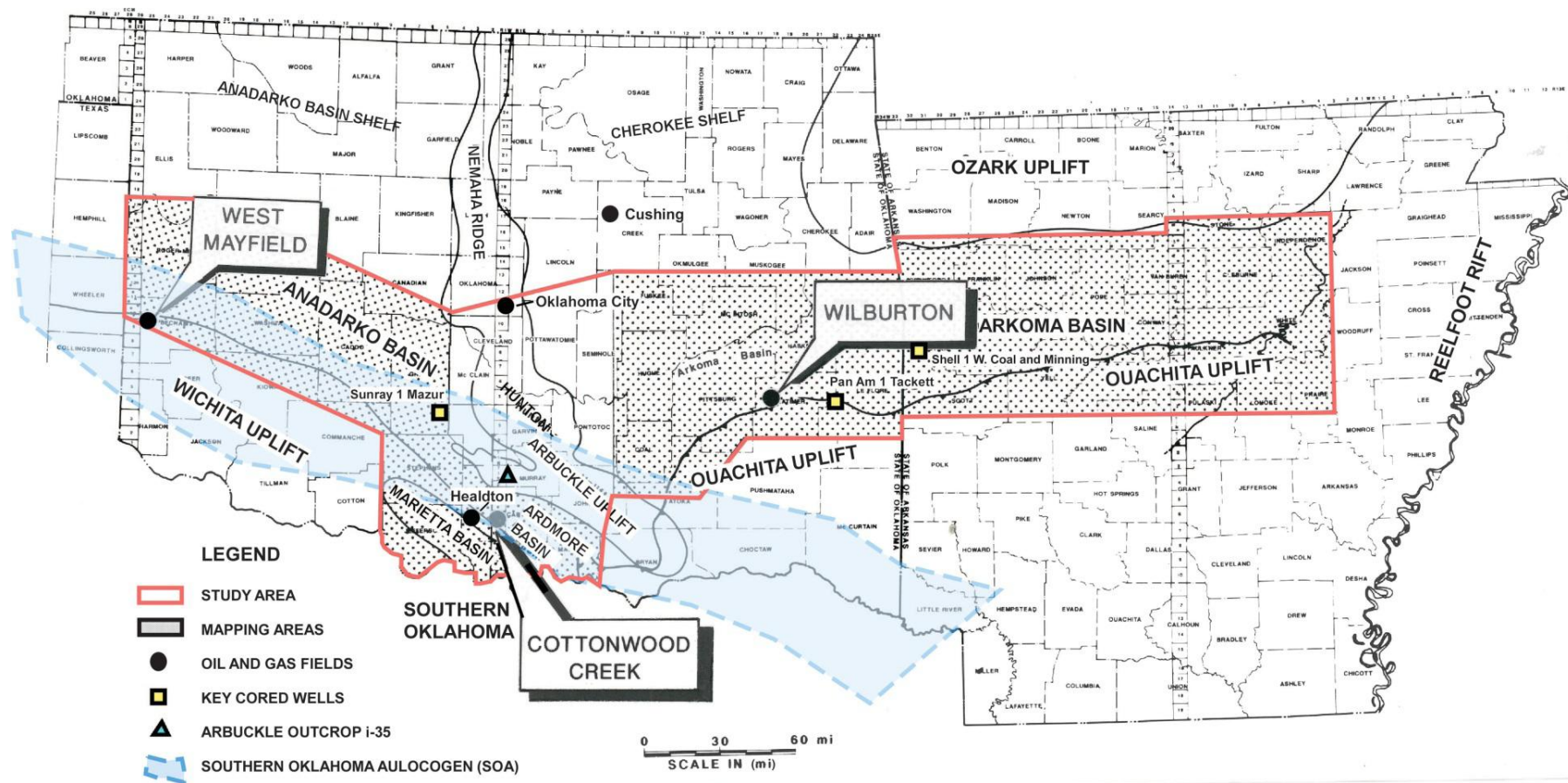


Figure 1. Index map of the study of the Arbuckle Group of the Midcontinent. 30 mi (48.3 km).

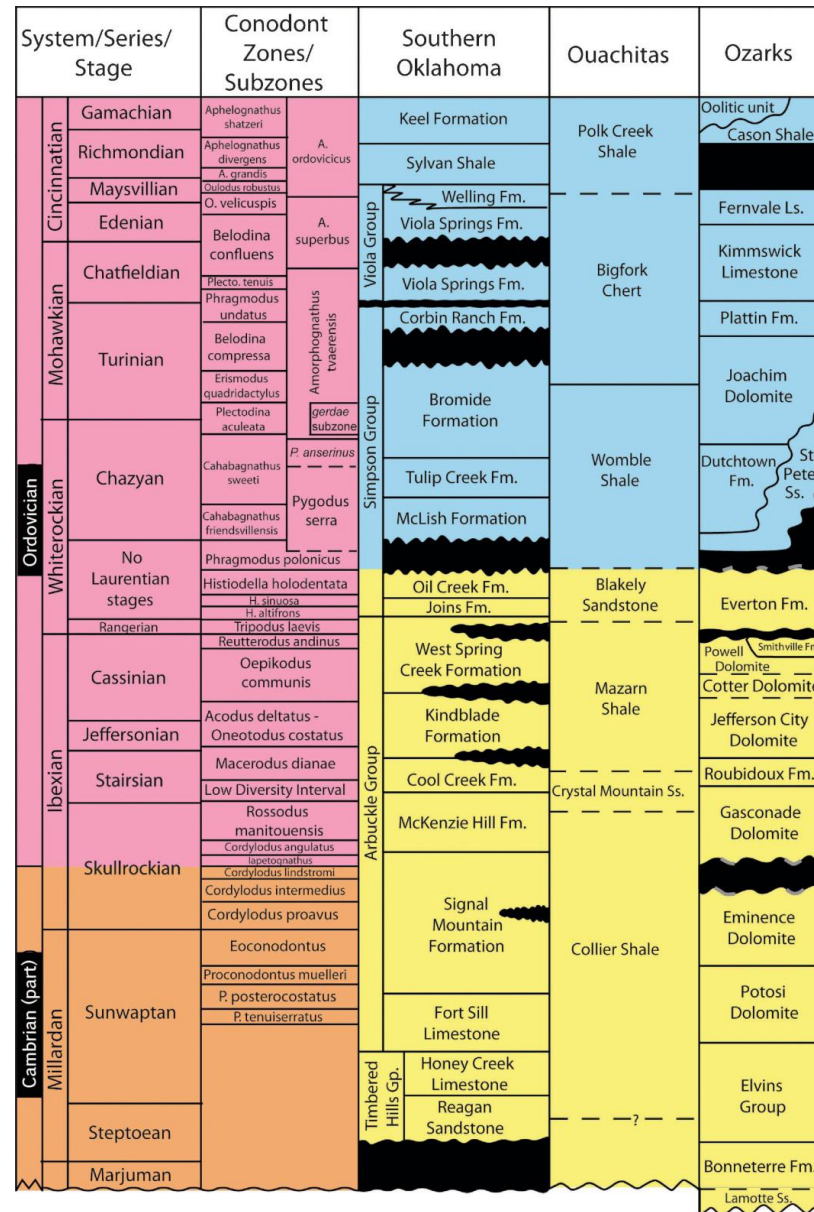


Figure 2. Stratigraphic correlation chart showing biostratigraphic relationships in the Arbuckle Group (Ethington et al., 2012, used with permission of AAPG).



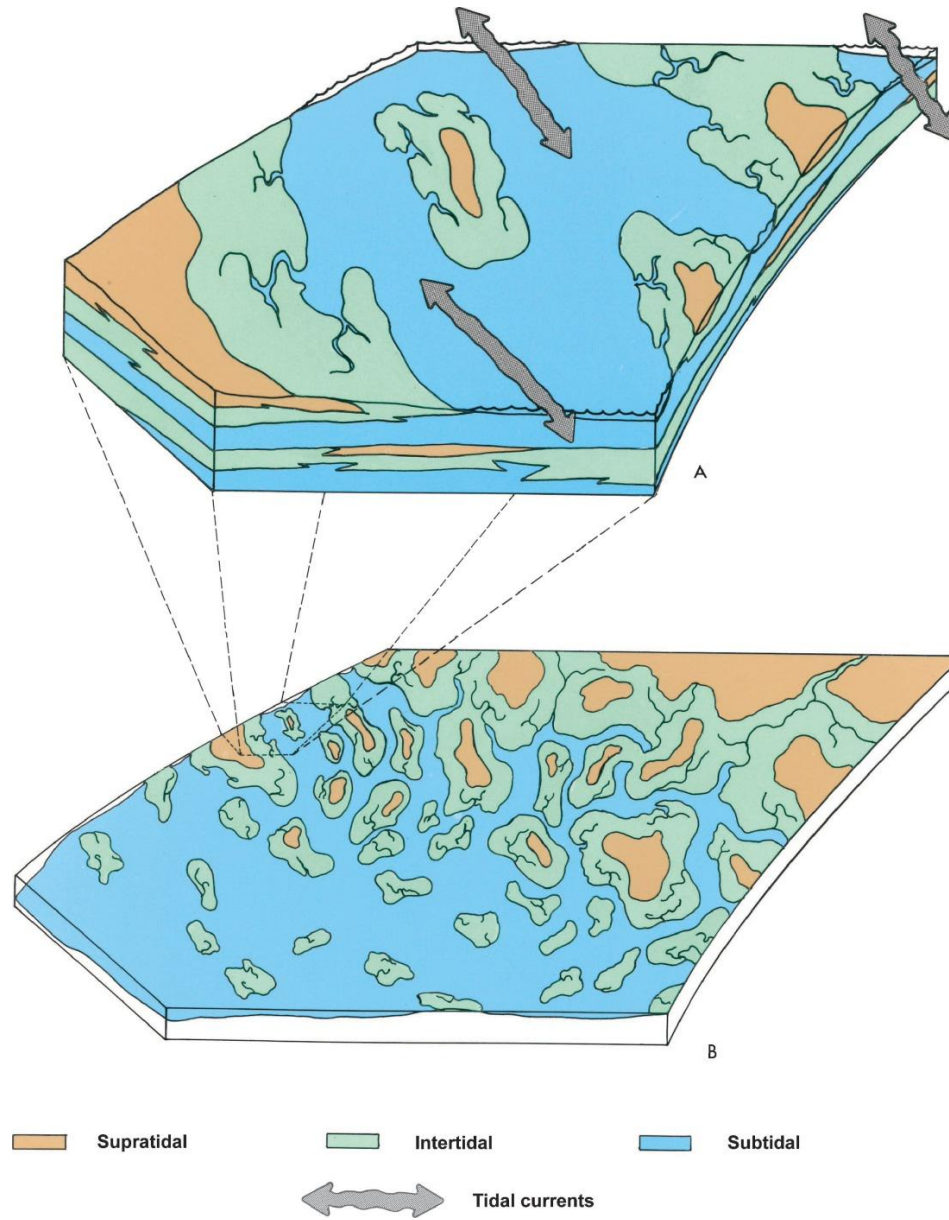


Figure 3. Block diagrams showing (A) regional depositional setting (approximate scale in hundreds of miles) and (B) hypothetical depositional model showing tidal currents (modified from Pratt and James, 1986).

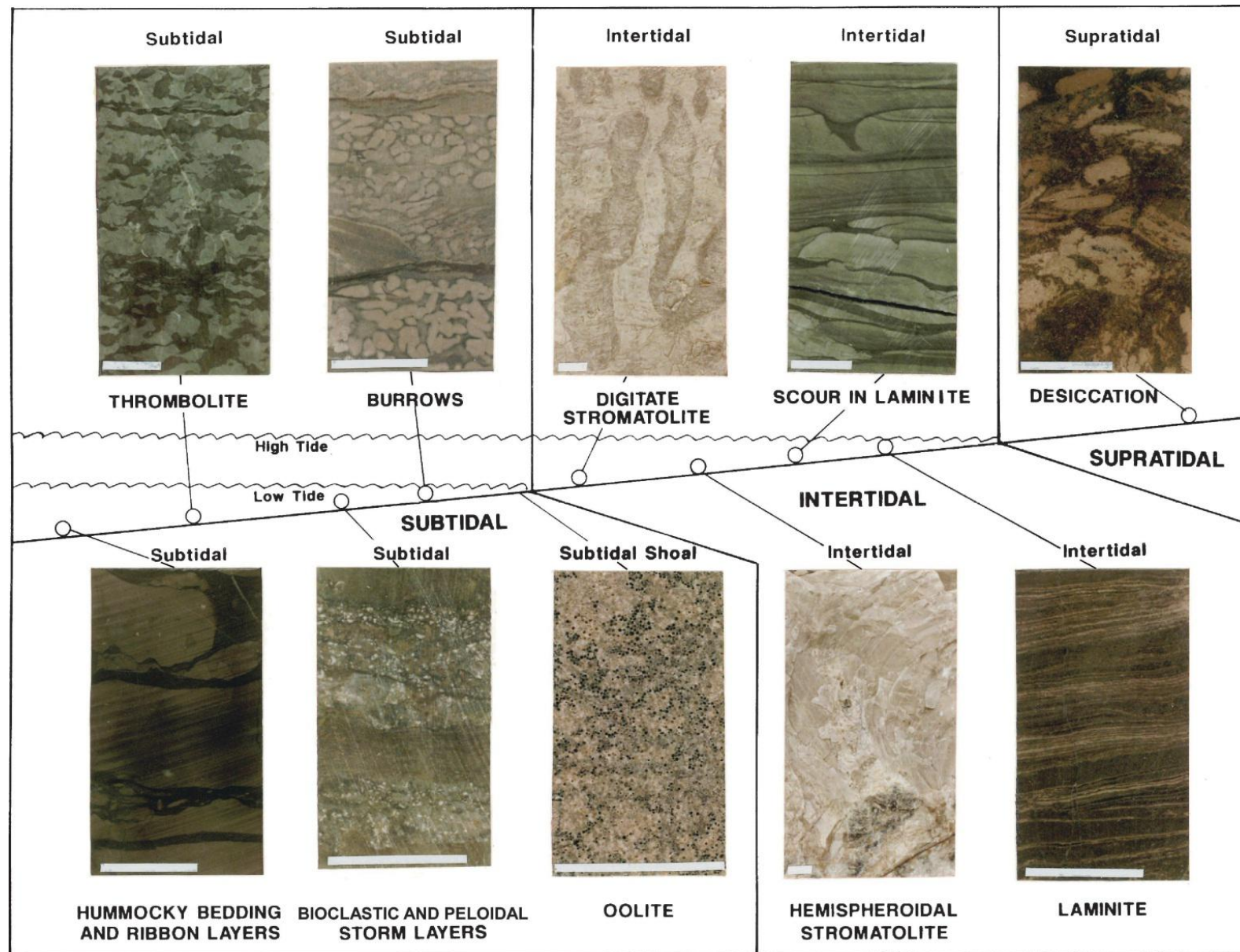


Figure 4. Schematic diagram showing photographs of facies types to depositional environment.

**FOSTER 1 Mabee**

**Sec.15-13N-25E**

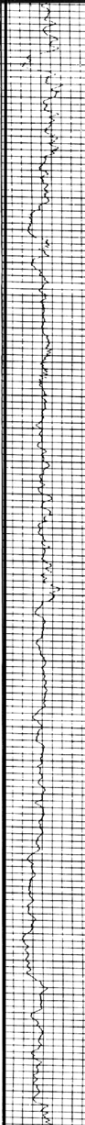
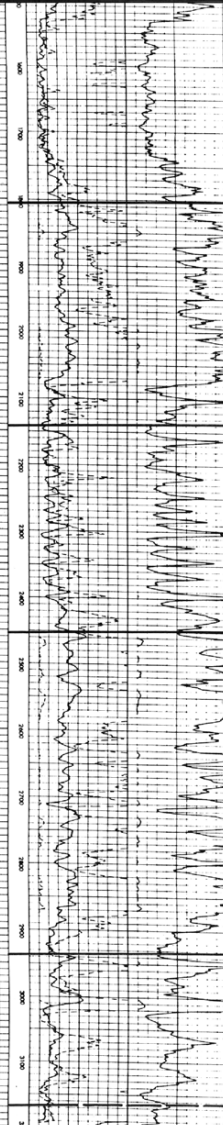
SP	RESISTIVITY	CHARACTERISTICS	NOMENCLATURE	ARBuckle GROUP
		Mostly thin, intertidally dominated cycles: sandstone and shale common	<b>ZONE F</b> West Spring Creek	
		Thick, subtidally dominated cycles; clean with high resistivity	<b>ZONE E</b> Kindblade	
		Thin normal to intertidally dominated cycles	<b>ZONE D</b> Cool Creek	
		Thick, subtidally dominated cycles; fairly clean with high resistivity; some thick sandstones	<b>ZONE C</b> McKenzie Hill	
		Thick, subtidally dominated cycles at top; thin, intertidally dominated cycles at base; thick sandstone common	<b>ZONE B</b> Signal Mountain	
		Thick, subtidally dominated cycles; high resistivity	<b>ZONE A</b> Fort Sill	

Figure 5. Correlation logs for the Arkoma Basin showing division of sequence compared to formation names. SP = spontaneous potential; 100 ft (30.5 m).



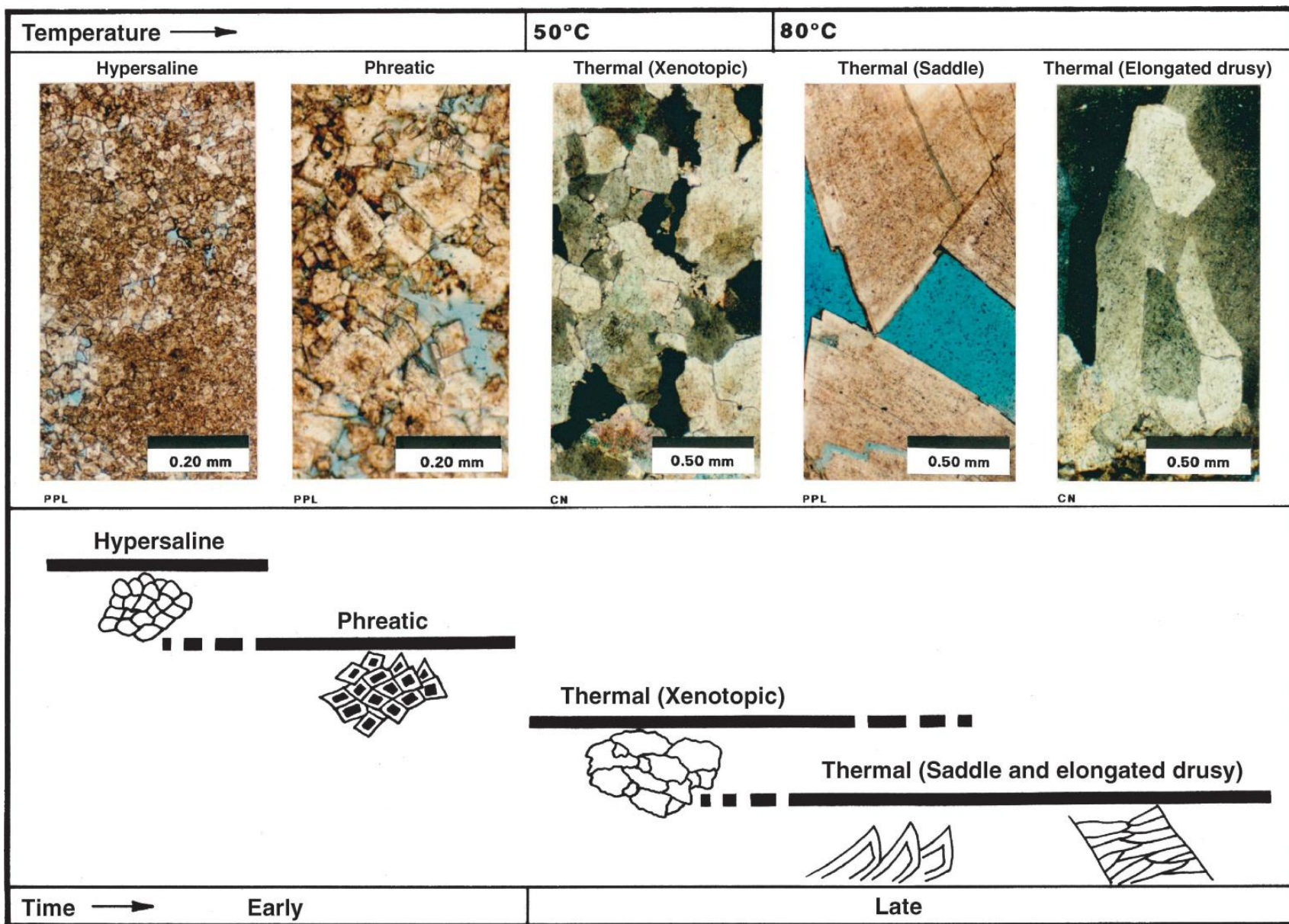


Figure 6. Types and sequences of Arbuckle dolomite development. PPL = plane-polarized light; CN = crossed nicols.

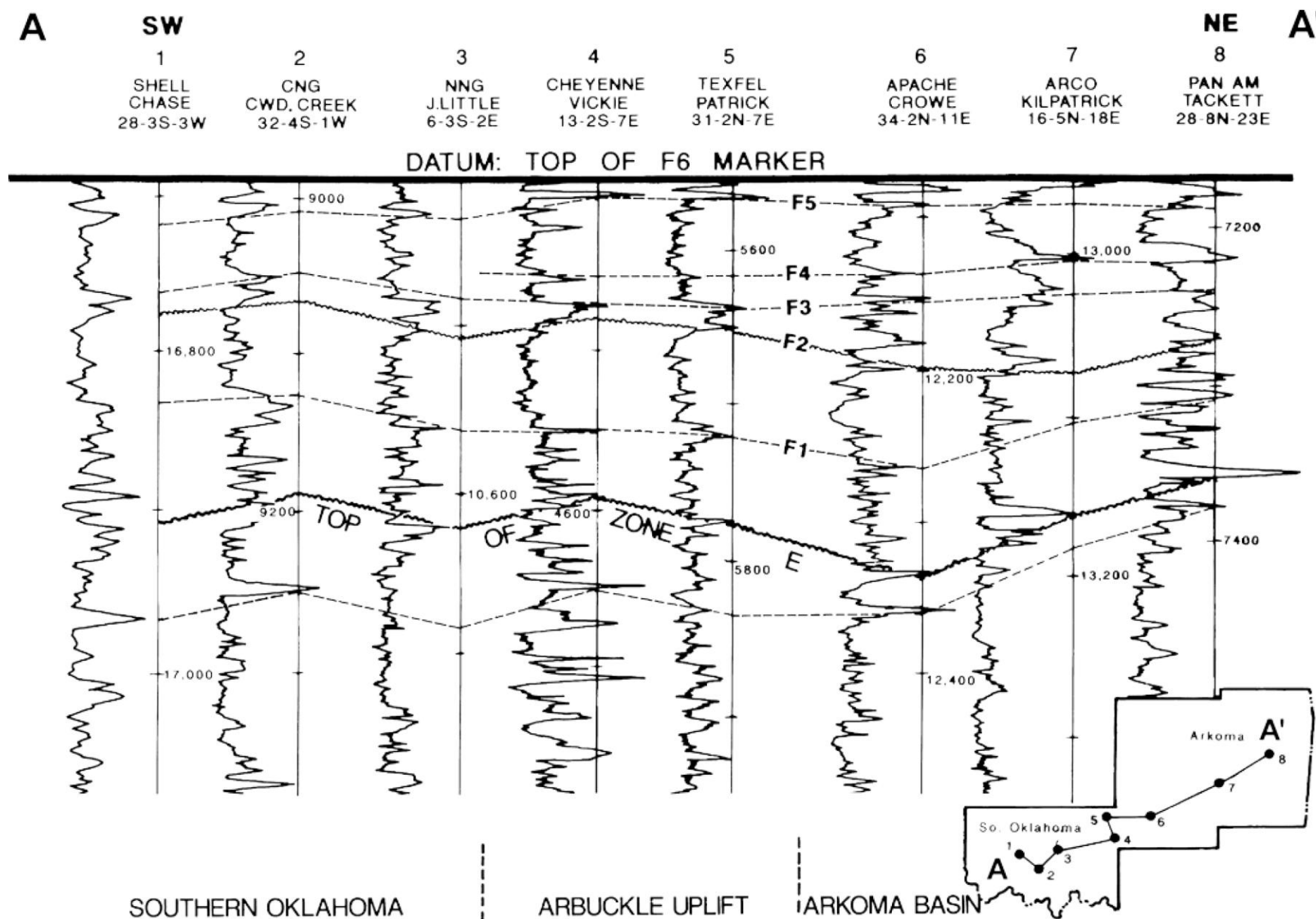


Figure 7. Regional southwest to northeast stratigraphic cross section from southern Oklahoma to the Arkoma Basin showing marker beds (dotted lines) in zones E and F (log signatures are gamma-ray responses). 200 ft (61 m).

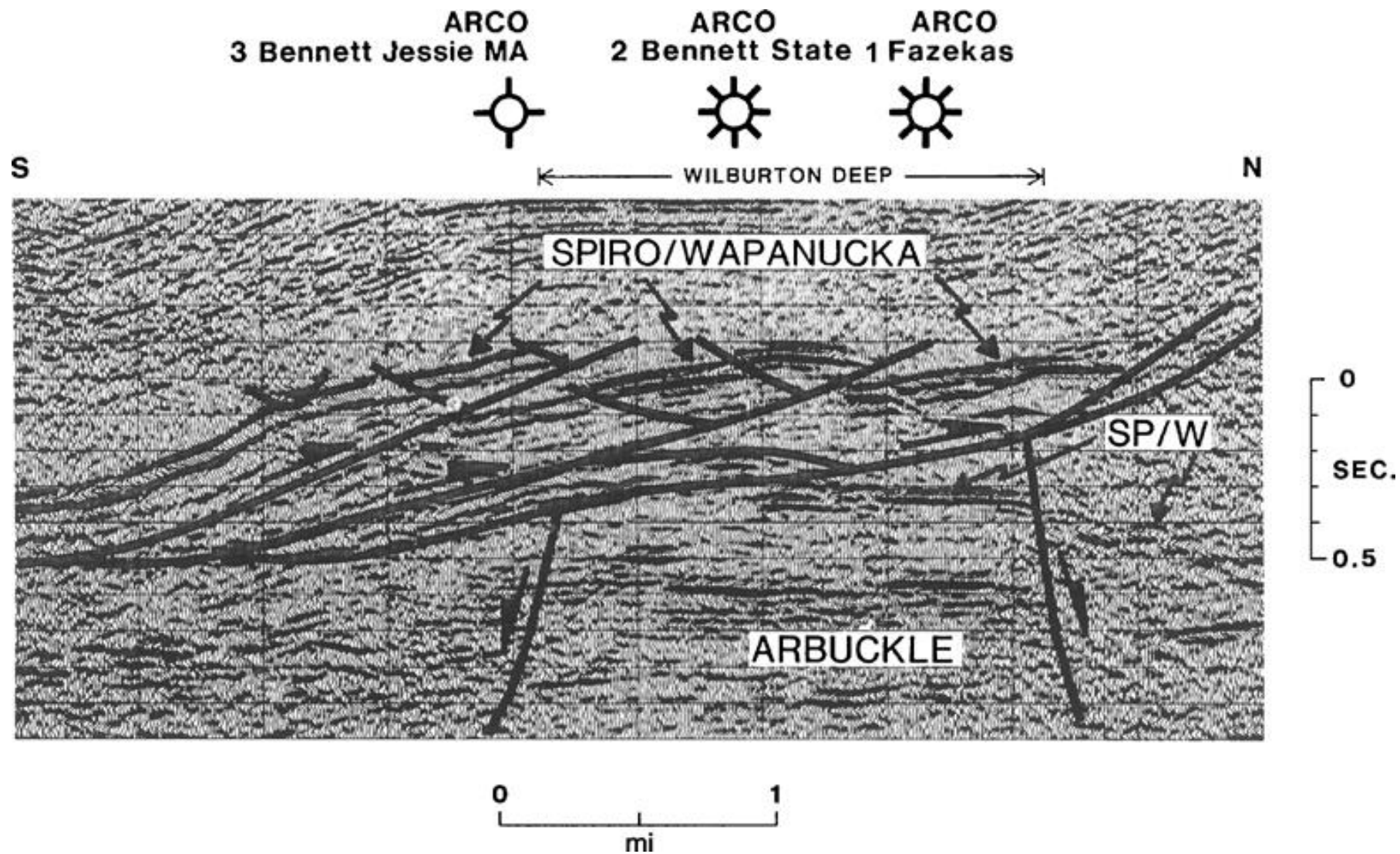


Figure 8. Seismic line showing the expression of the Wilburton field. Early production was from thrust Spiro-Wapanucka (SP/W) structures. Note the juxtaposition of Arbuckle rocks and younger beds that contain source rocks. (Bertagne et al., 1991, used with permission of the Oklahoma Geological Survey). 1 mi (1.6 km).



# Arbuckle Reservoir Cycle

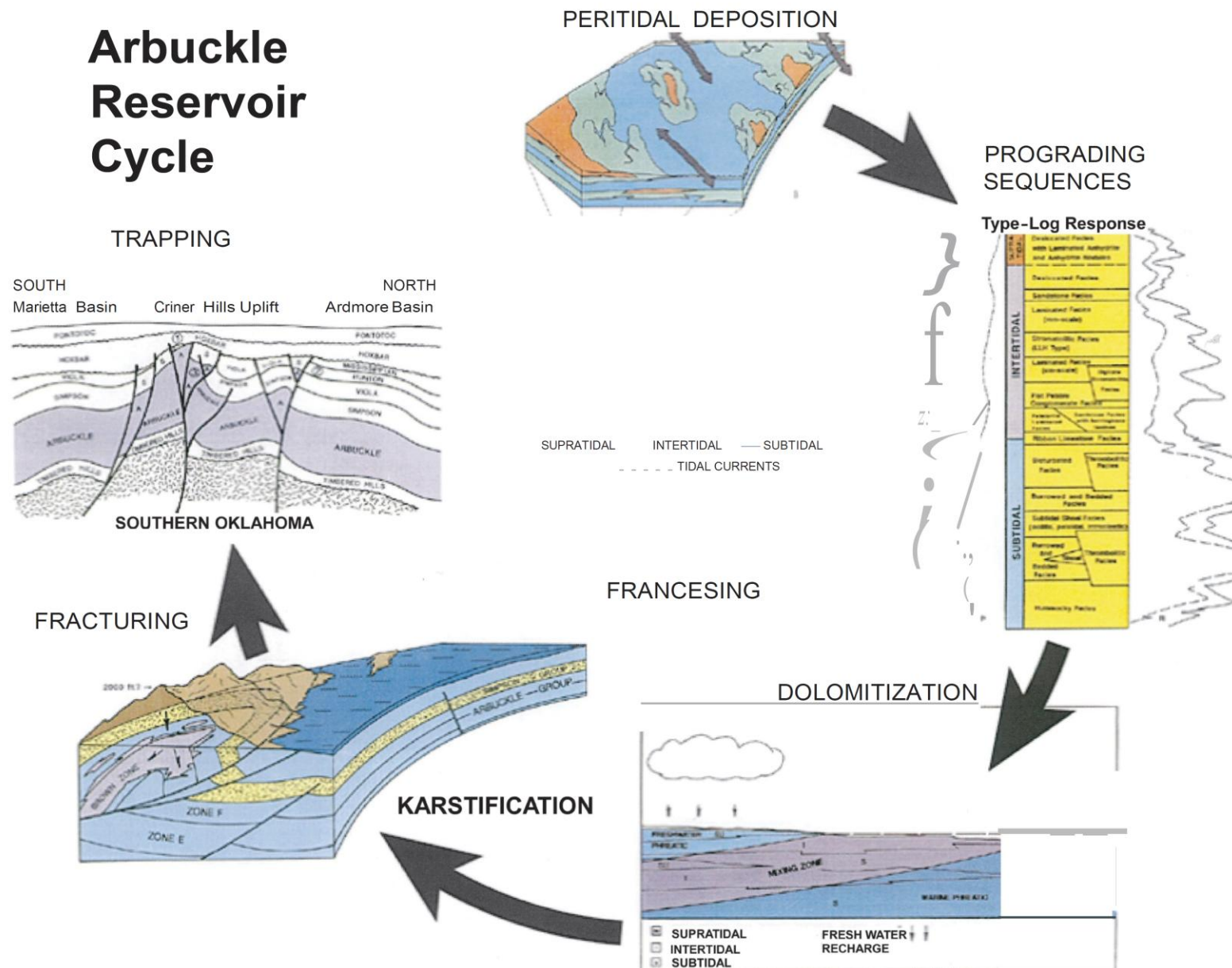


Figure 9. Diagram showing various stages of Arbuckle reservoir development and trapping.