

The History of the WEHLU (West Edmond Hunton Lime Unit) Play from Conventional to Unconventional*

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Abstract

WEHLU (West Edmond Hunton Lime Unit) has evolved over the years from a conventional field in the 1940's, to a water flood, to a gas flood, to an unconventional horizontal play rescuing orphaned oil. The use of modern logging techniques and improved lift designs has aided in recovering more reserves thought lost in a modern urban drilling environment.

The History of WEHLU from Conventional to Unconventional

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Expanding Our Horizons

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Discovery and History of WEHLU

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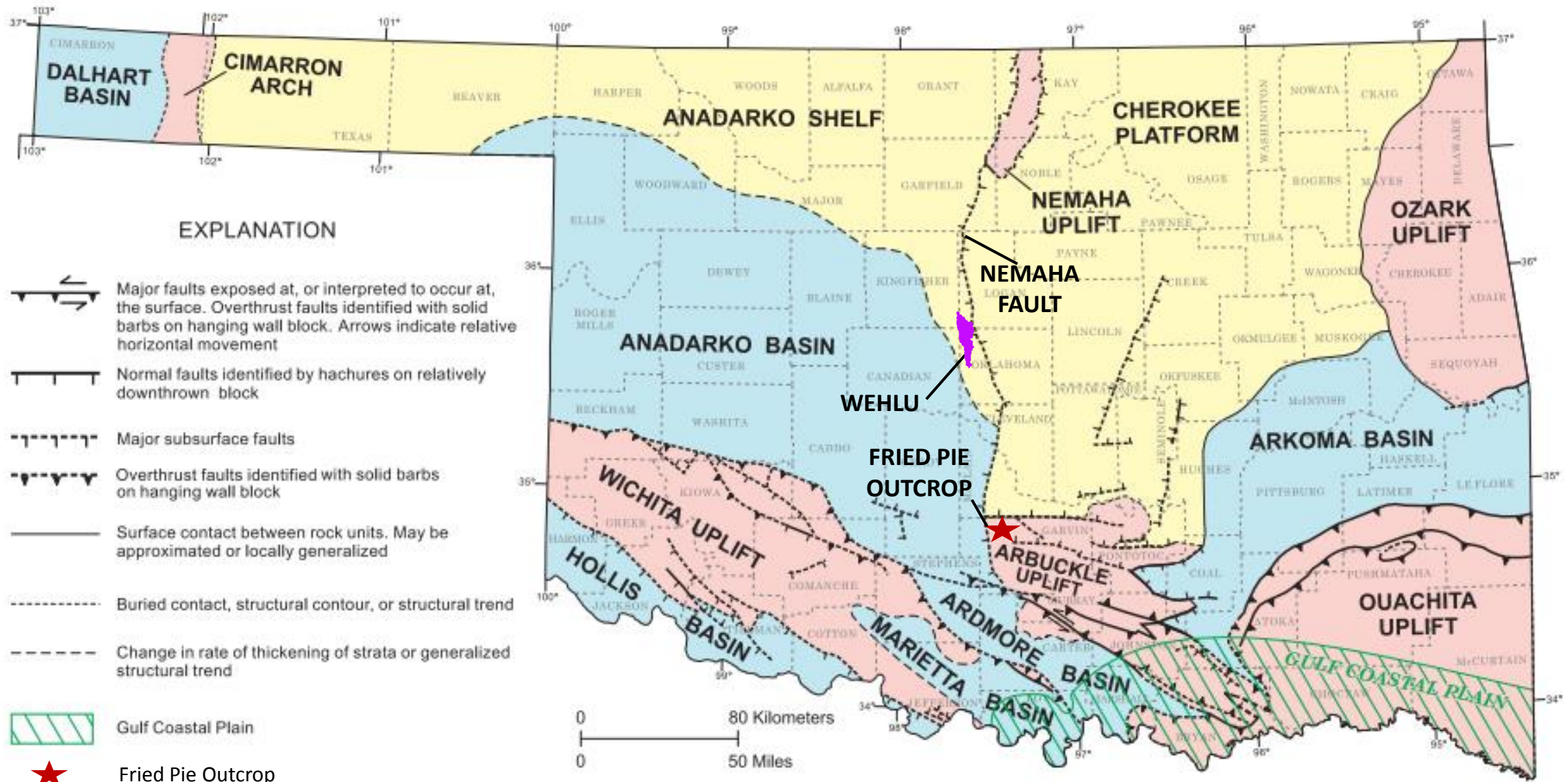
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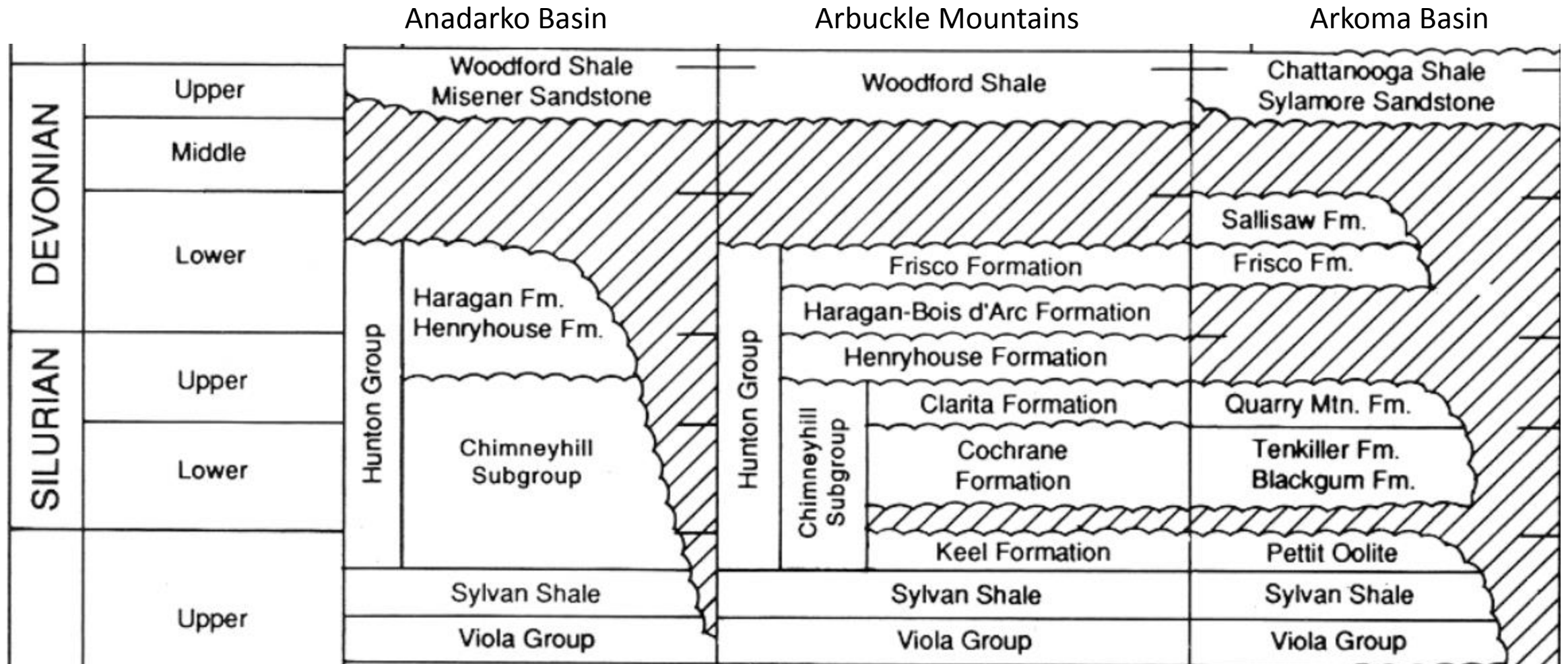
Gastar Work

- Structure maps
- Isopach Maps
- Pilot hole data
- Drilling data, image logs
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- Obrien SWD Work and Log

WEHLU Location And Tectonic Provinces of OK

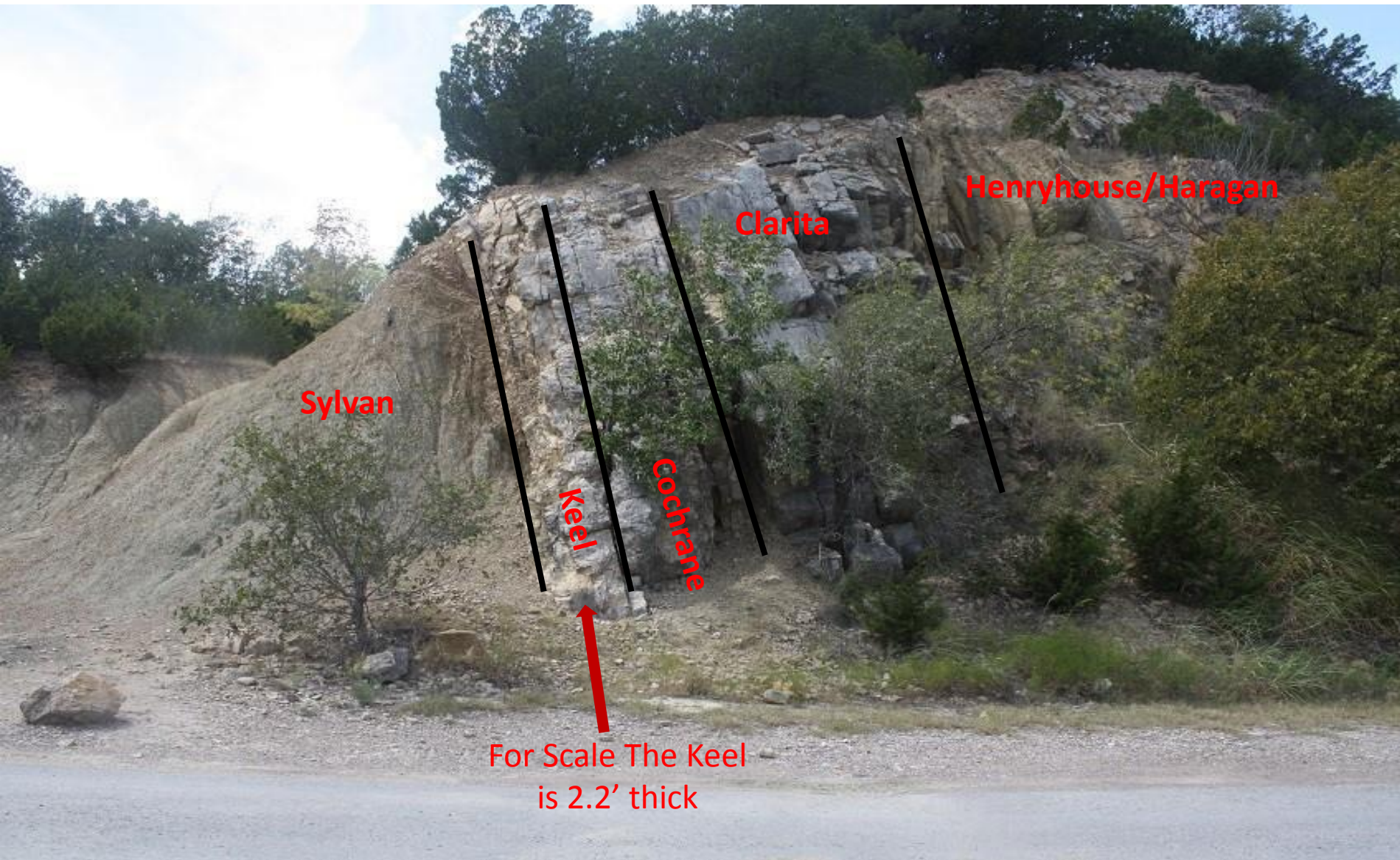


General Stratigraphy



The Famous Fried Pie Outcrop

-Arbuckle Mtns, Southern Oklahoma



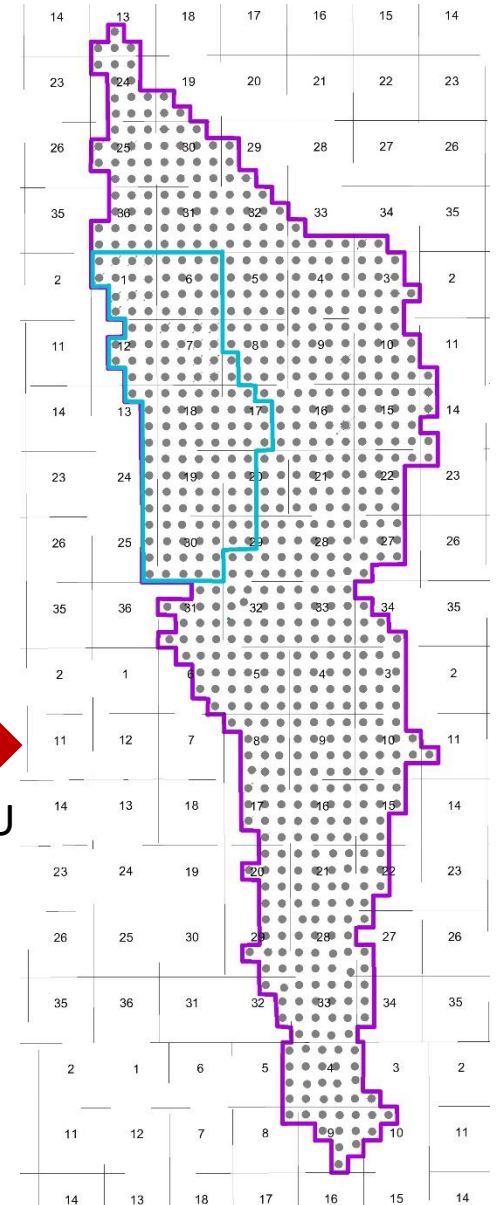
Discovery of WEHLU

- Biggest discovery in Oklahoma since the Oklahoma City field in 1928
- April 5, 1942 by Ace Gutowsky with venture money from Chicago funded a well to 7,350' where he expected to hit the 2nd Wilcox
- Wagner #1 in NW $\frac{1}{4}$, NW $\frac{1}{4}$ SW $\frac{1}{4}$, Section 32, T. 14 N., R. 4 W., Oklahoma County
- The location was picked via “Doodle-bugging” commonly known as dowsing
- Flowed 522 BBL of 41 gravity oil in 24 hrs through a 9/32 choke
- Originally 731 producing wells at an average depth of 6900' on 40 acre spacing by September 15, 1946 “With little prospect for additional wells”(Littlefield et al 1948)
- WEHLU (West Edmond Hunton Lime Unit) is comprised of lands situated in Kingfisher, Oklahoma, Logan, and Canadian Counties, Oklahoma as established under the rules of the Oklahoma Corporation Commission, dated July 29, 1947 by Philips Petroleum
- Peak production was reached in September 1945 at 87,500 bbls/day

- The Unit is comprised of 754 tracts, each 40 acres in size, with a total of 30,160 acres
- Gstar is the operator of WEHLU and purchased ~24,480 gross acres in WEHLU in 2013
- Chesapeake exercised its preferential right on the remaining ~5,680 gross acres
- All leases are held by production (HBP)
- Working interest = 98.3%
- Net revenue interest = 80.5%
- Hunton rights only

Map Showing Original Well Placement

Purple Outline = Gstar Controlled WEHLU
Blue Outline = CHK controlled WEHLU

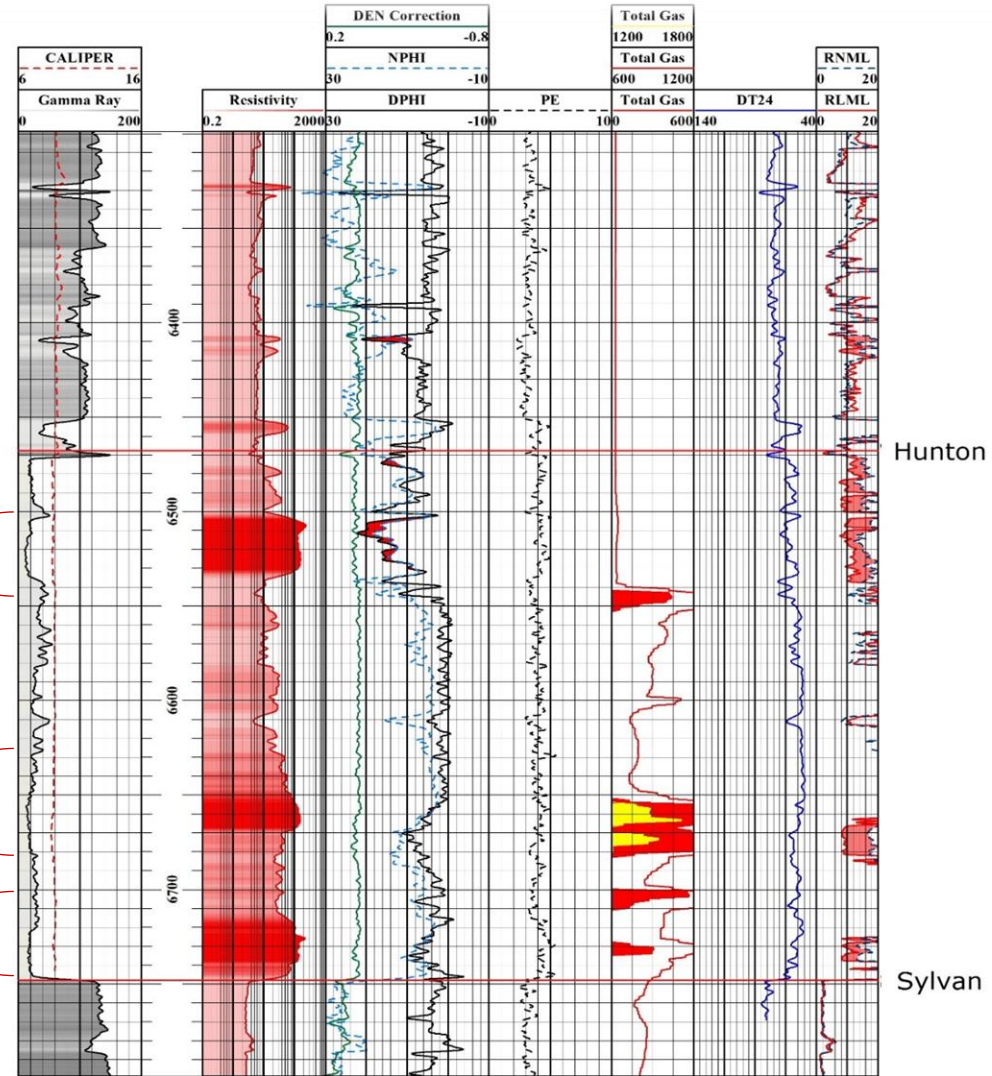


Historical Operators

- Sohio Corporation
- Phillips Petroleum
- WEHLU Producers
- Beta Operating (fka: Red River Energy)
- PetroHawk Energy
- Limerock Resources
- Gastar Exploration Inc.

Easton 22-1 Pilot Hole

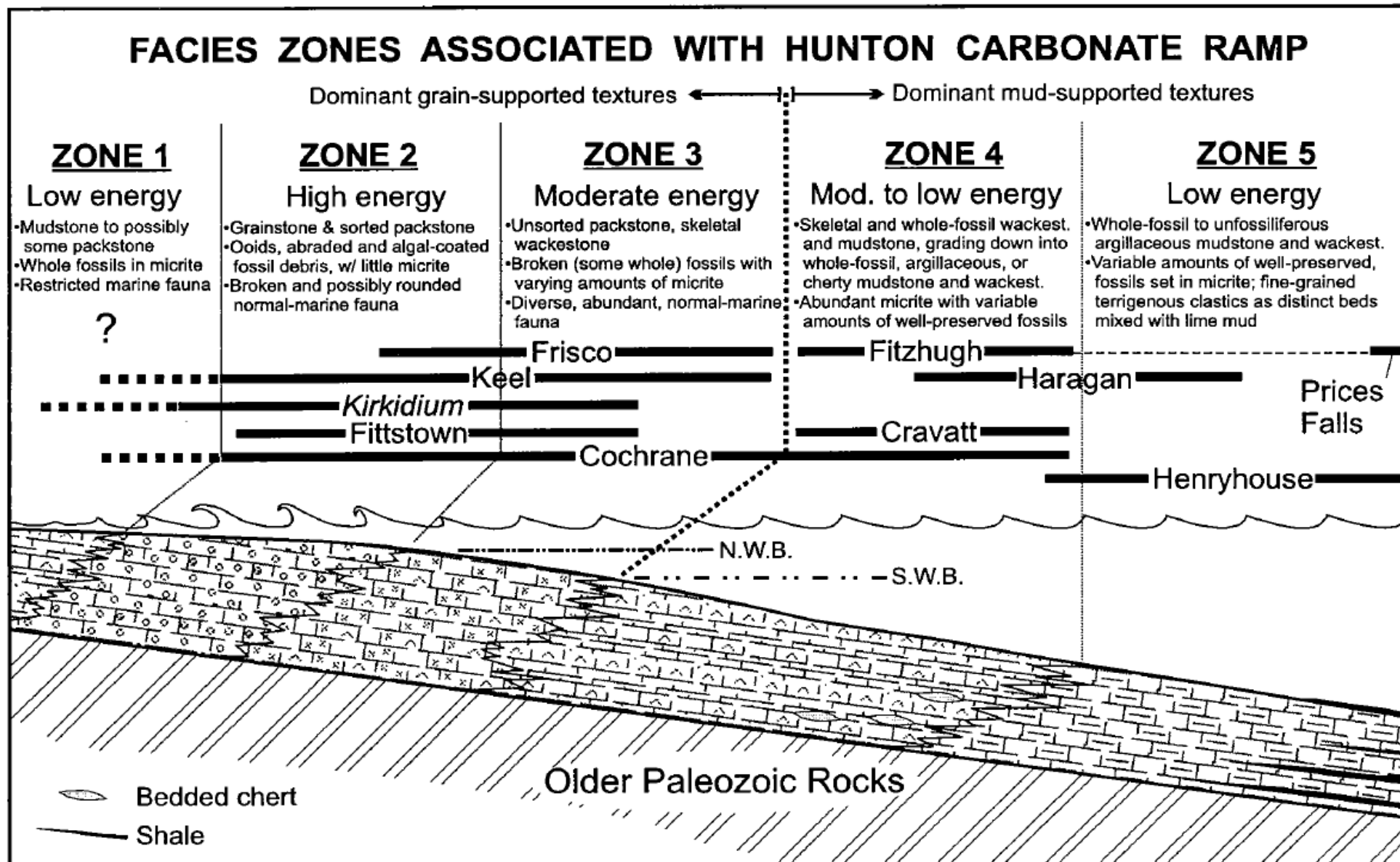
- Good Porosity and Permeability
 - Target Zones
 - Bois d' Arc
 - Middle Hunton
 - Lower Hunton



Paleo-Geographic map



Depositional Model



- Thickness 0-110'
- Limestone and dolomite are the primary rock types
- Slightly argillaceous cherty and dolomitic mudstones and wackestones
 - Part of the shallowing upward sequence started in the Haragan
 - 2 types of chert -tripolitic and vitreous
 - Source of the chert could be due to organic activity or secondarily derived by geochemical alteration
- Sorted and unsorted dolomitic grainstones
 - Represents shoaling and the highest energy environment

- **Clarita**

- **Fitzhugh Member**

- Generally a light gray, skeletal to whole fossil mudstone to wackestone
- Overall uniformly thin, wavy bedded limestone that appears massive on a fresh surface
- Three recognized facies
 - Arthropod micrite facies
 - Ostracode silty-marlstone facies
 - Crinoid sparite facies

- **Price Falls Member**

- Basal Member
- Distinct 1-2' interval of well laminated, dark gray to brown clay shale that grades into a tan-brown weathering argillaceous carbonate mudstone
- Thicker sections are usually composed of terrigenous clastic material
- Thinner sections are usually argillaceous limestone

- **Cochrane**

- Poorly sorted to well sorted glauconitic grainstone and grade laterally and vertically into the skeletal packstone or wackestone
- Contains irregular bedding
- Chert can be present as bedding laminae or as nodules
- Chert nodules are brecciated suggesting possible subaerial exposure
- Presence of glauconite suggests substantial periods of repeated transgressions and regressions creating episodes of erosion and non-depositions

- **Keel**

- Uppermost Ordovician
- Light gray oolitic grainstone to an oolitic skeletal packstone
- Ooids represent 30-60% of rock volume and exhibit well-developed concentric and radial internal structures indicative of those formed in littoral marine zones
- Represents a shoaling-upward carbonate package that formed just below to within the littoral zone of the warm shallow waters of the Late Ordovician sea

Reservoir

NOW

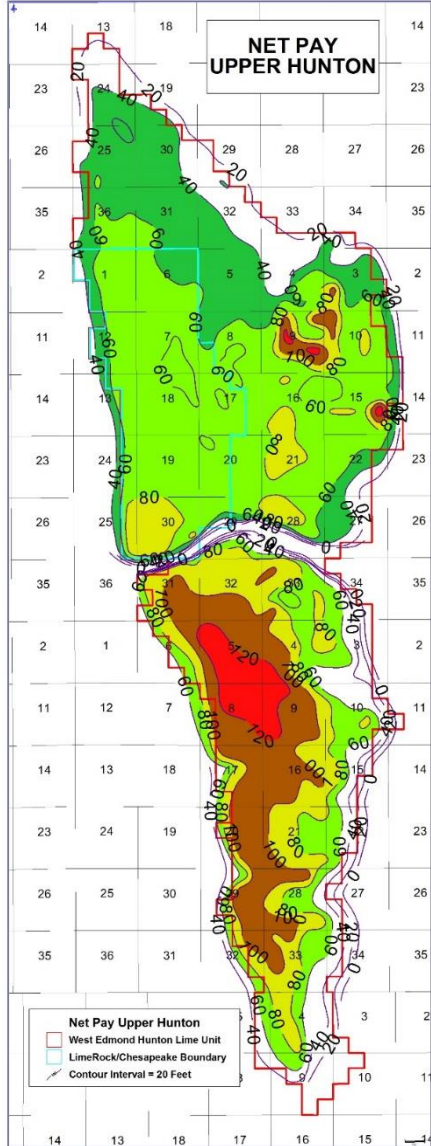
- Original reservoir pressure was 3110-3145psi @ a datum of -5864' SSTVD or 6719' MD
- Oil API was 41^o gravity
- Fluid testing indicated the reservoir was originally undersaturated with the saturation pressure being around 2770-2950 psi
- Solution GOR was 1010 scf/bbl
- Specific gravity of formation water was 1.129
- Gas 1250 BTU/scf
- South half of field has higher GOR than the north possibly due to the fault that cuts through the center of the unit that juxtaposes the Woodford against Bois d' Arc
- Mild water drive system with water encroaching from the west

200-300

39-40

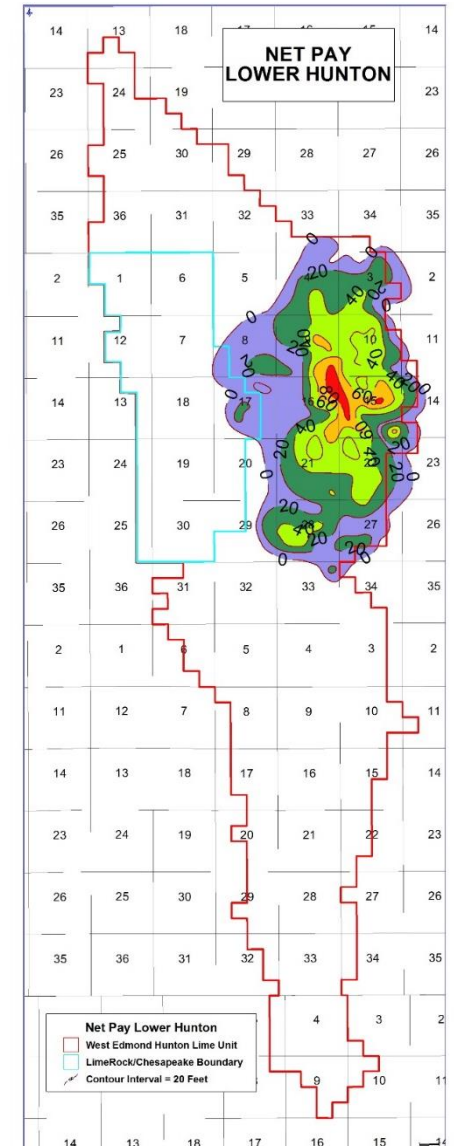
1350

Original Net Pay Maps

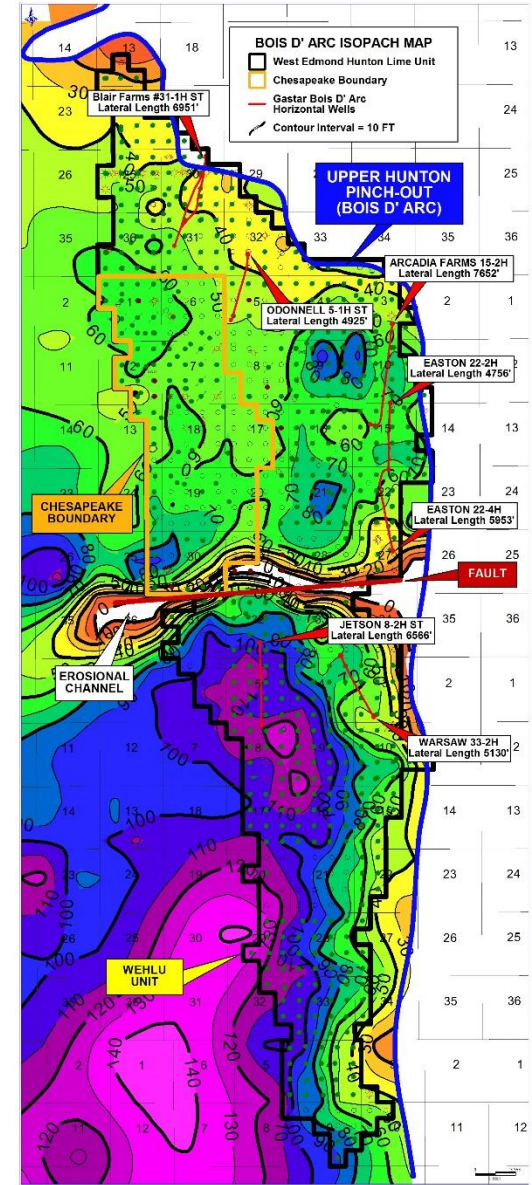
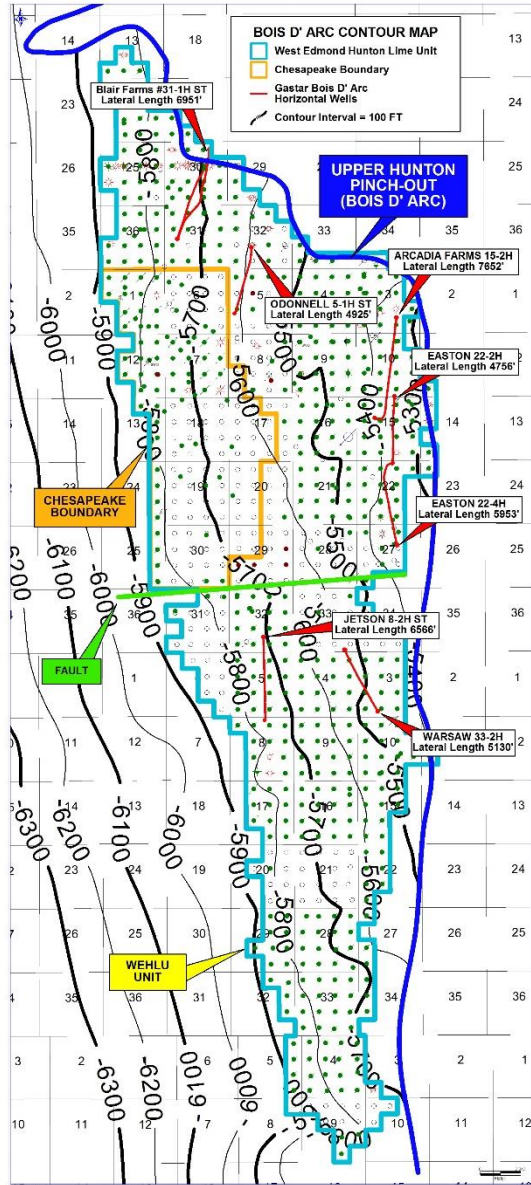


Net pay was calculated using the SP curve

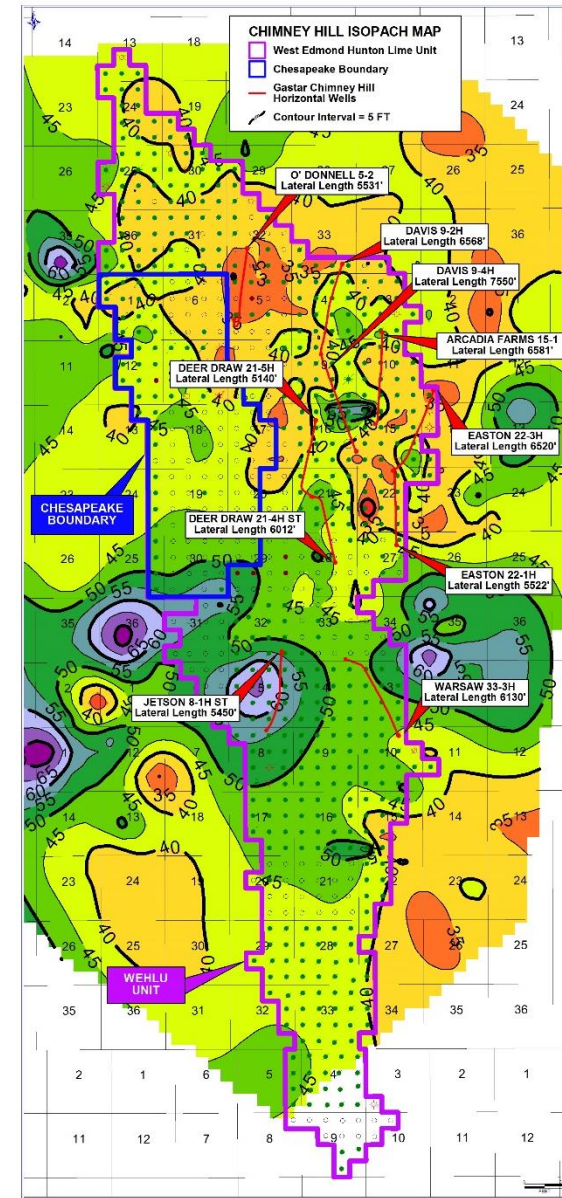
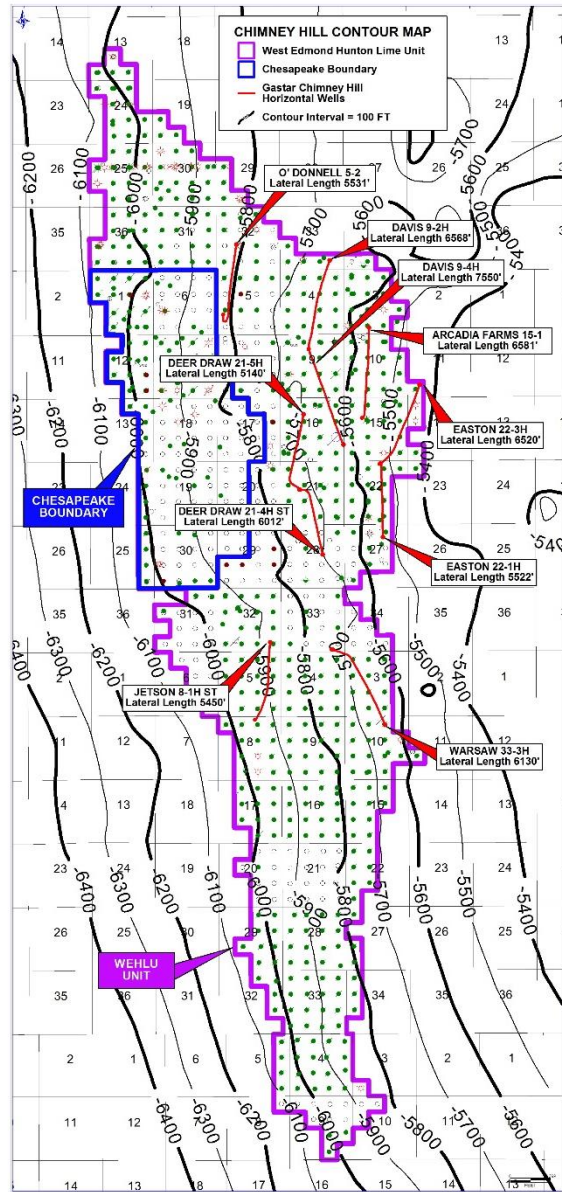
- Bois d' Arc has 2,100,000 acre-feet based on the gross SP anomaly on the electric logs
- Chimney Hill has 212,000 acre-feet
 - It was estimated that the rock was 90% porosity and 10% fractures
 - We now know it is closer to 30/70



Bois D' Arc Contour and Isopach Maps

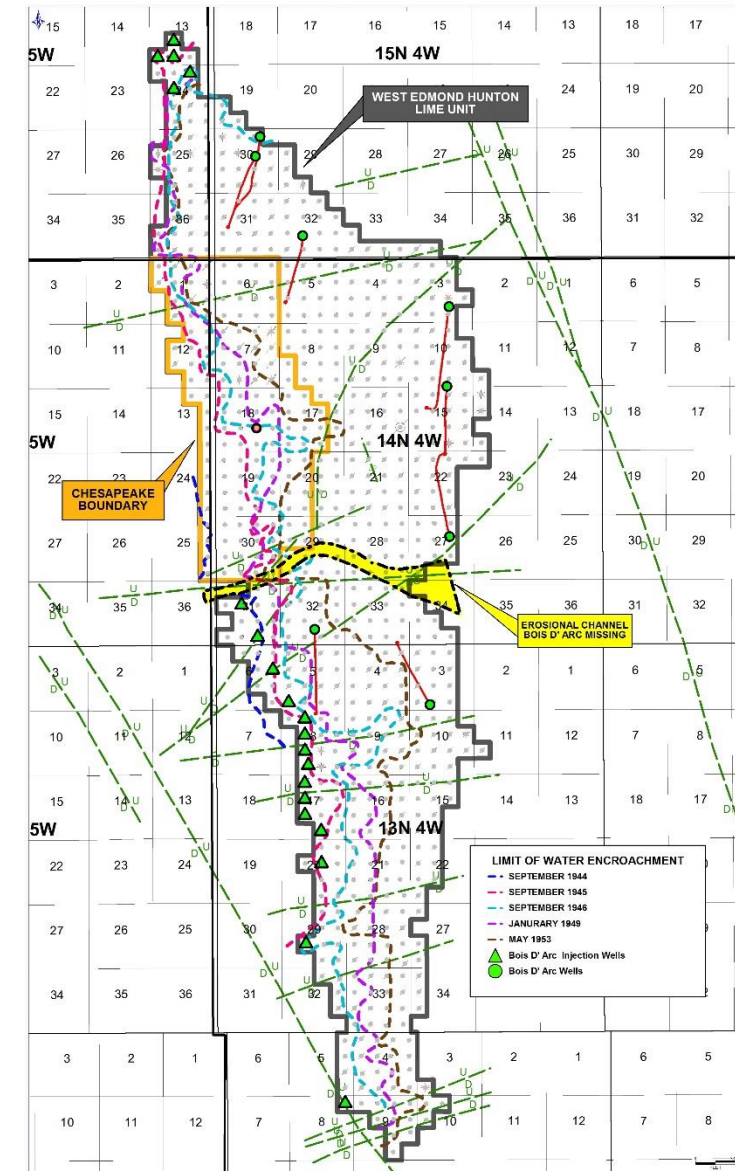


Chimney Hill Contour and Isopach Maps



Bois d' Arc De-Watering

- all water productive wells along the West Side of the field were produced at capacity in an attempt to halt the encroachment of water
- technical success but the lack of adequate disposal facilities made it an economic failure
- discontinued in 1949, a drop in production was noted and the water front rapidly advanced eastward
- 1950, 47 western wells were shut-in as uneconomic due to excessive water production
- 1951 six wells in the area of interest that tested all water were returned to production
- April 1951 one of these, well #290, virtually overnight went from 100% water to 140 bopd and 204 bwpd
- Other wells had less spectacular results but from January 1, 1951 to June 1, 1953, these wells produced a total of 471,000 barrels of oil



Bois d'Arc Waterflood

- Started in July 1949 in 2 west side wells the spread to 13 wells all south of the erosional channel
- Injection initiated at 4,800 B/D and increased to 8,500 B/D
- 9.2 million bbl was injected by April 1953
- Some wells showed an increase in oil production while others watered out
- It is thought the water did not sweep the oil as a normal waterflood is designed to do

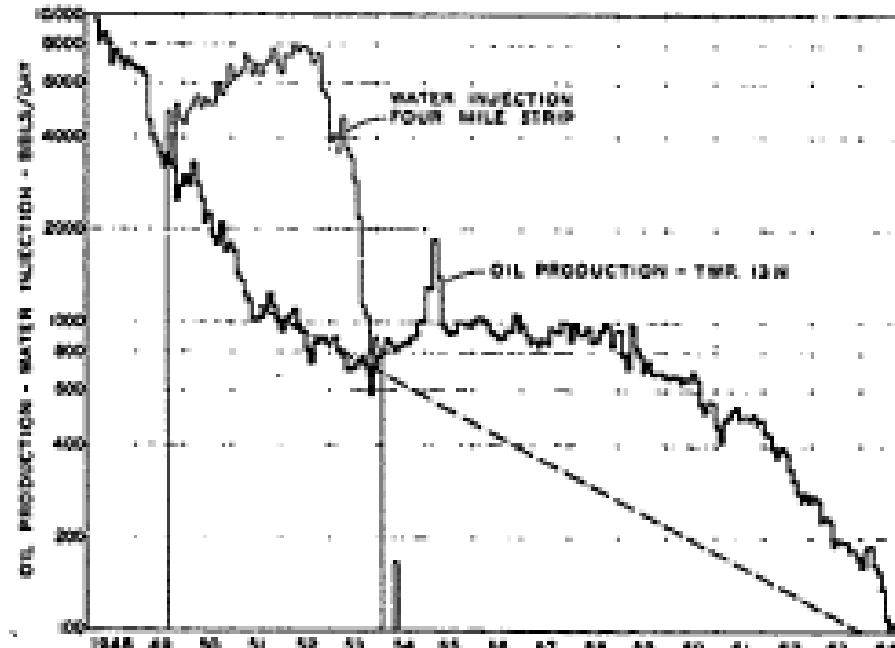
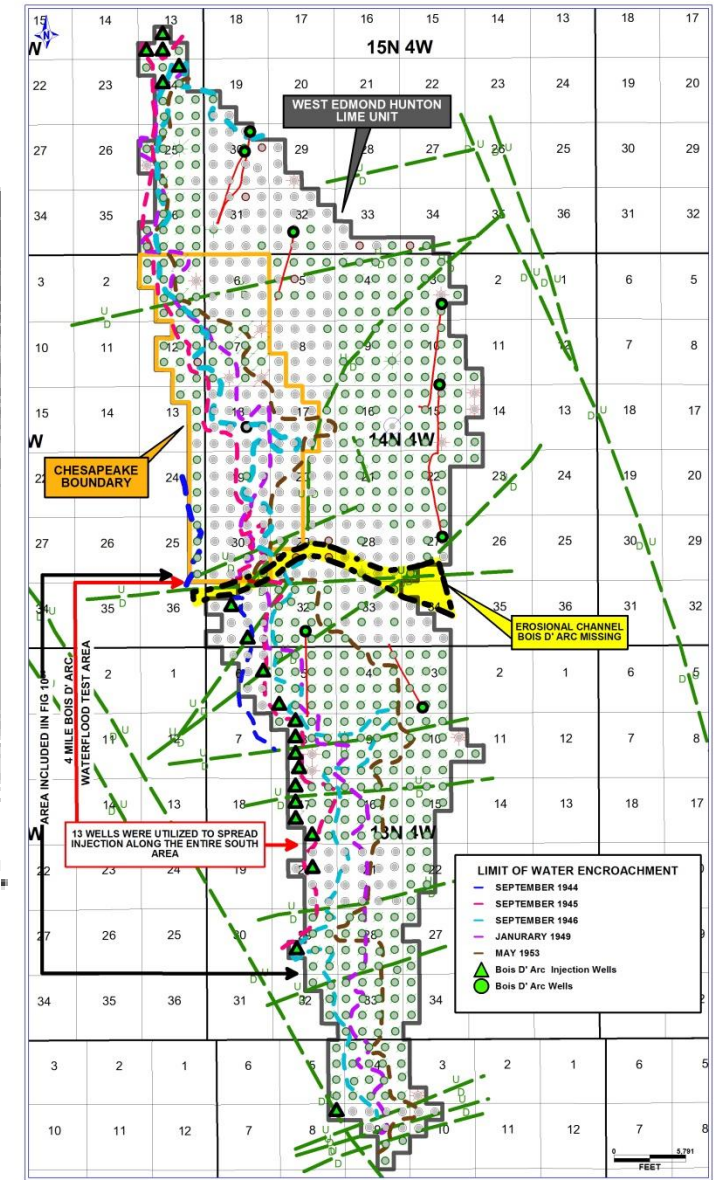
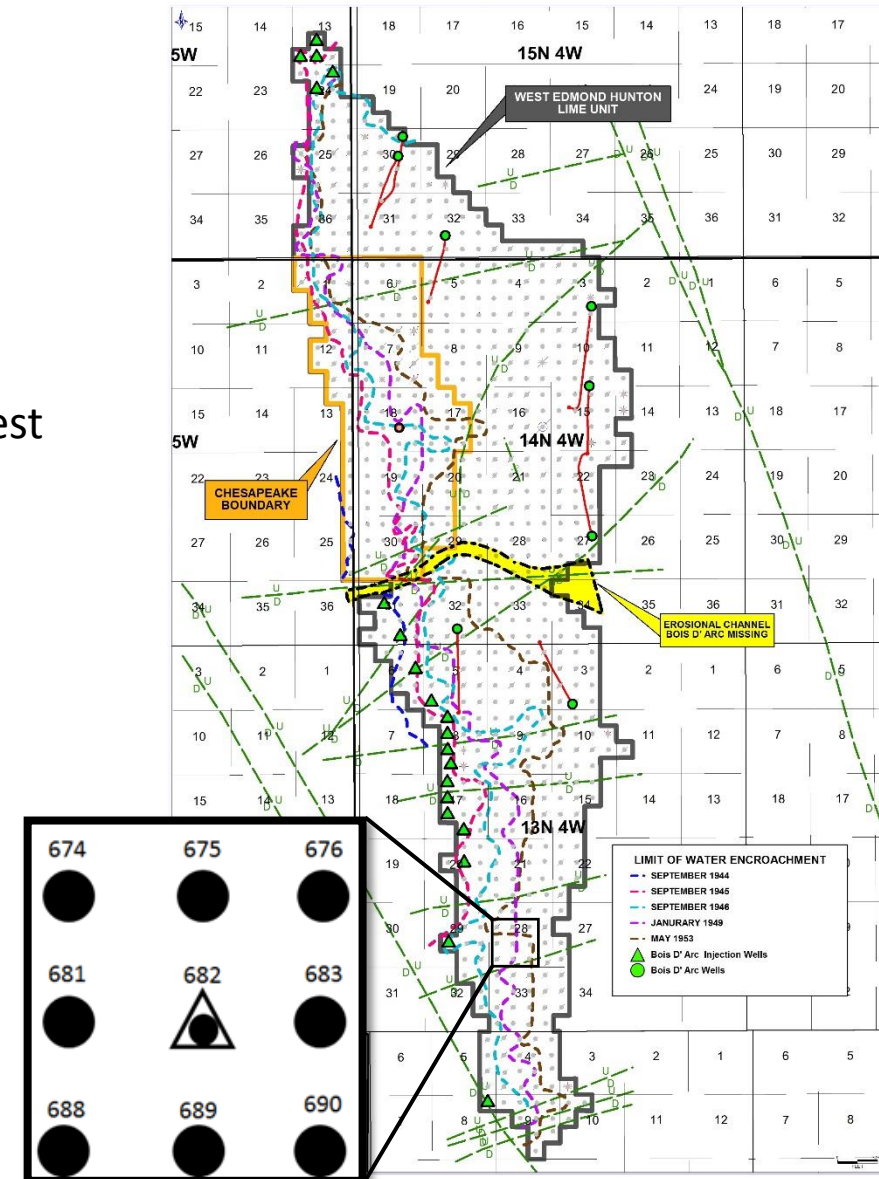


Fig. 10—Bois d'Arc waterflood performance, Twp 13N.



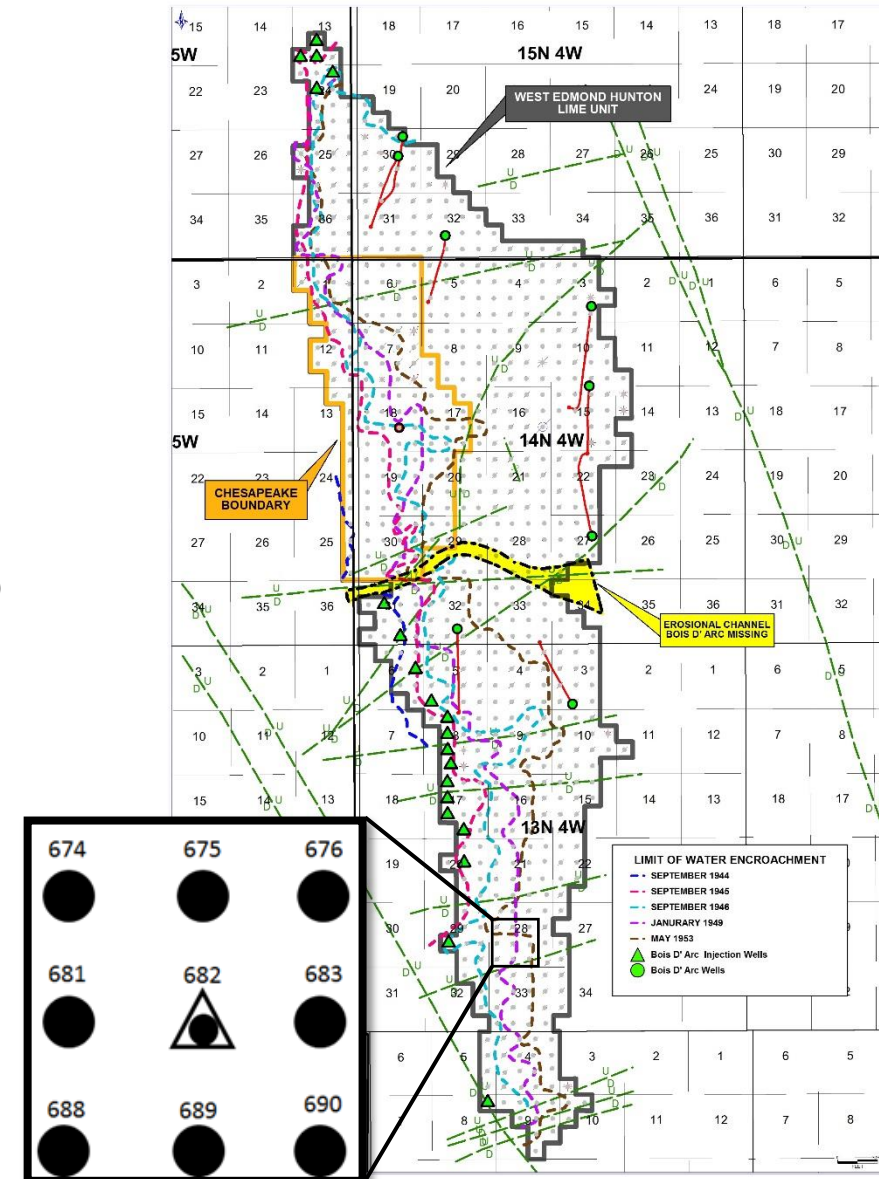
Bois d' Arc Gas Injection - Helium

- Helium was added to injection gas at 1 percent concentration for a week starting April 27. 1948 it was detected in 12 days, and in seven of the nine test wells during the 5-month test
- No helium was detected in any second row offset to the injection wells
- 44 percent of the injected helium was produced



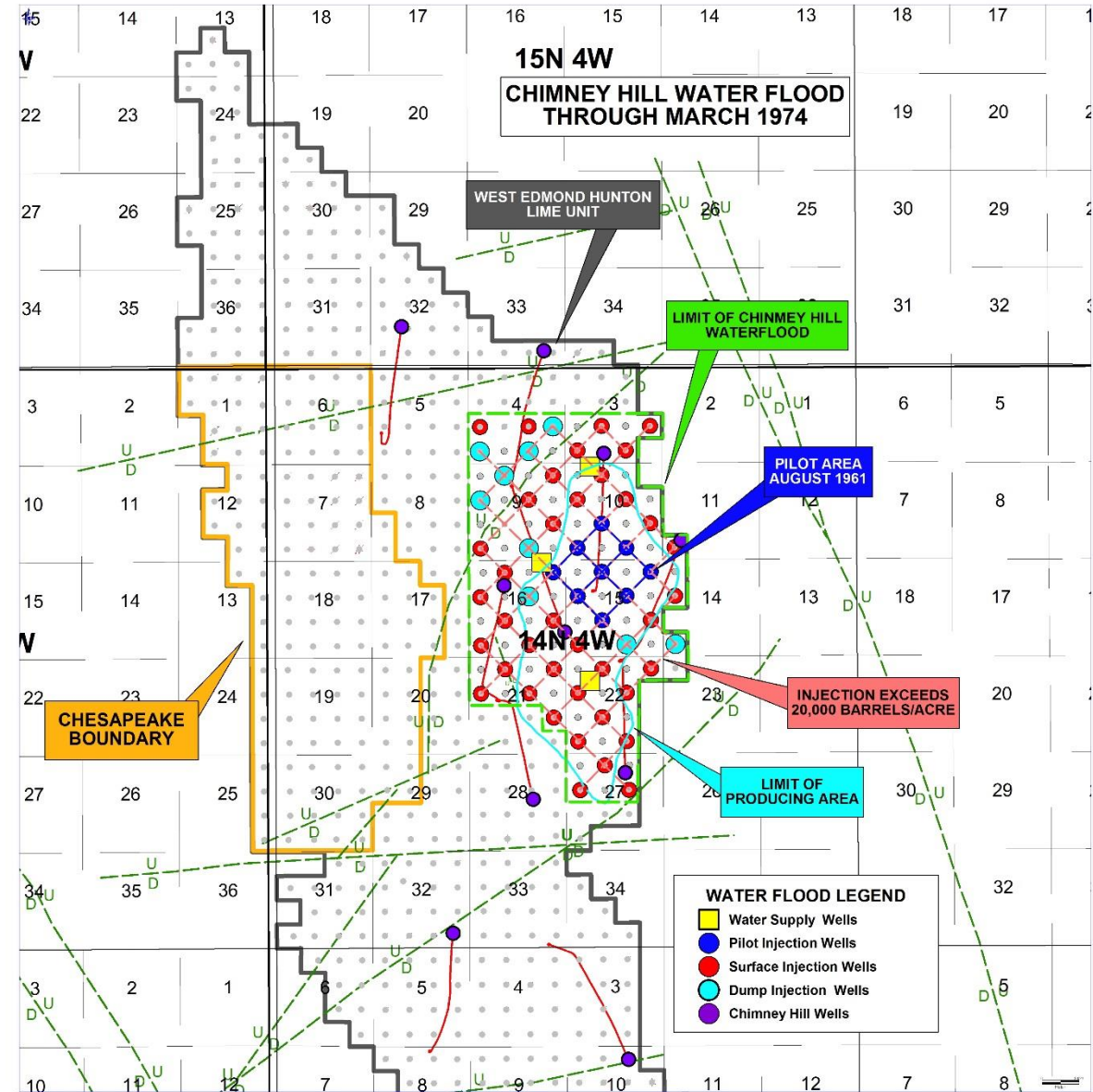
Bois d' Arc Gas Injection- Produced Gas

- Between May 5 and Aug. 11, 1948, 250 MMcf of gas was injected into the Bois d'Arc in Well 682
- Within 2 weeks after gas injection was stopped, GOR of the northeast offset, Well 676, declined from about 21,000 to 11,500 cu ft/bbl
- Within a month the GOR of the east offset, Well 683, declined from 12,000 to 6,700 cu ft/bbl
- 43 percent of the injected gas was channeling to these two wells
- Little or no gas channeling to other off set wells was detected



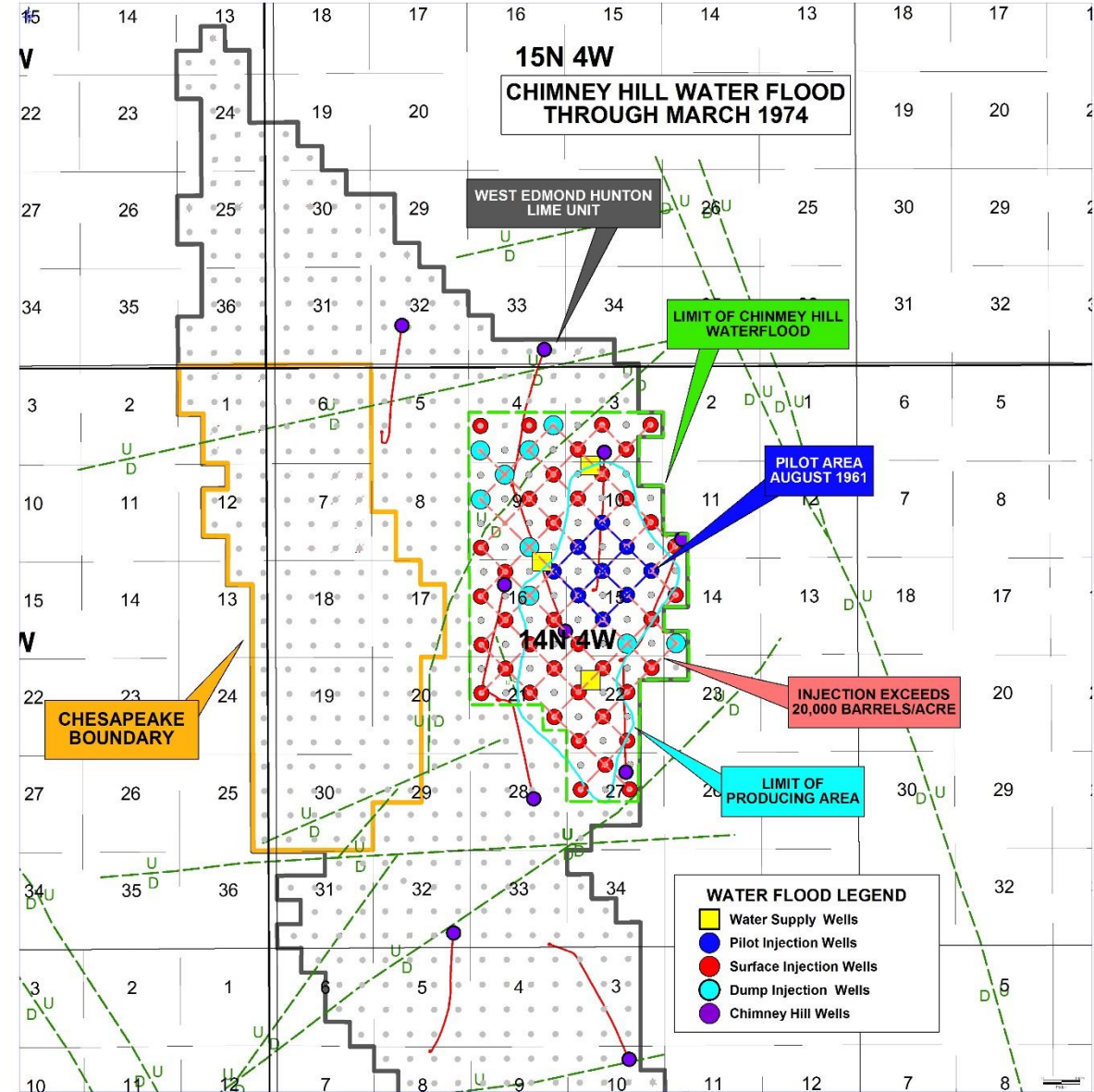
Chimney Hill Water Flood

- Did not exhibit the same direct inter-well communication as the Bois d' Arc
- 1955, a pilot flood was started on the East Side of the field in sections 10, 15 and 16-T14NR4W
- Comprised of nine injectors and four producers laid out in 4 - 5 spots
- Began in December 1955 with the first response seen in September 1959 when an increase in water production was noted
- Increase in oil production because of the flood was seen in October 1960 when well #265, one of the inside producers, went from 16 bopd to 85 bopd and 35% water cut
- 16.6 million barrels of water were use and according to the estimate of reservoir size accepted at the time, this corresponded to the fill-up of 142% of the pore volume



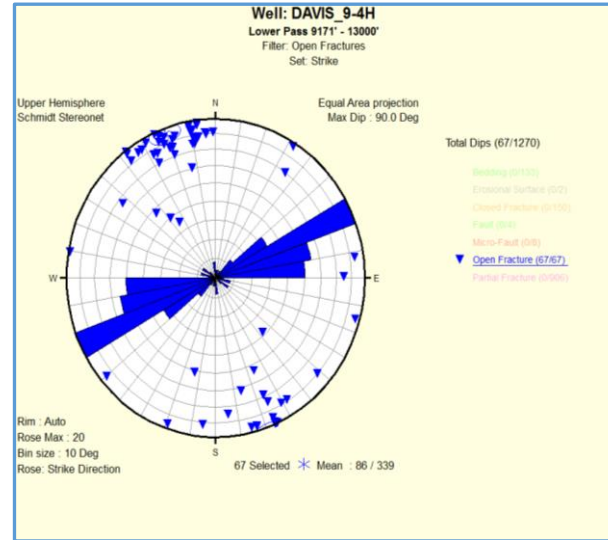
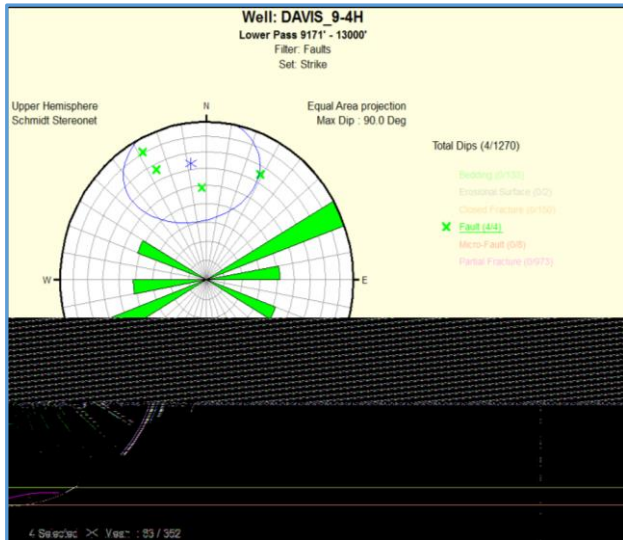
Chimney Hill Water Flood (Cont)

- Water production increased to 600 bpd in 1962 but by setting packers and shutting off the Bois d'Arc, it was reduced to 160 bpd
- shut down in 1974
- the pilot area of four producers and nine injectors had produced 1,781,697 bbl/oil and 3,671,590 bbl/water since 1961 as a result of the waterflood
- Although the response from the pilot continued to exceed expectations, the results of the expanded area were very disappointing with most of the production coming from the original pilot and the wells immediately surrounding it
- As of January 1, 1980, 145,847,042 bbl of water had been injected into the Hunton. Of this total, 126,891,953 barrels was injected into the Chimney Hill. The waterflood included 90,687,287 barrels of supplemental water produced from sources other than the Hunton

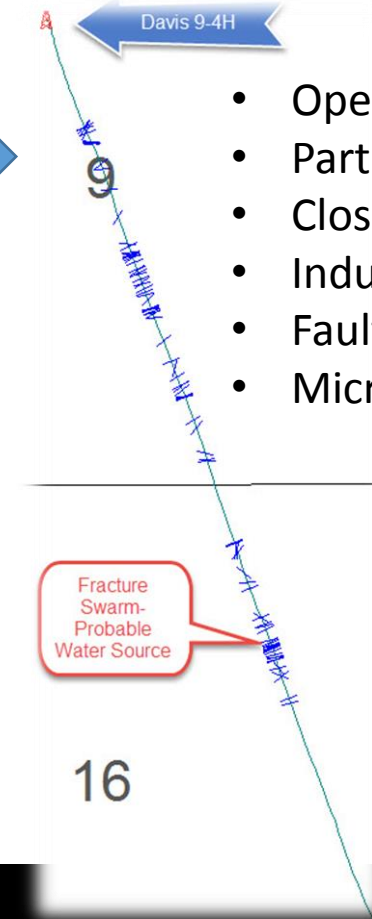


Fractures Identified through logging

Davis 9-4H CH-Fracture mapping utilizing the image logs to try and locate the source of excess produced water and avoid these high density fracture zones in the future.

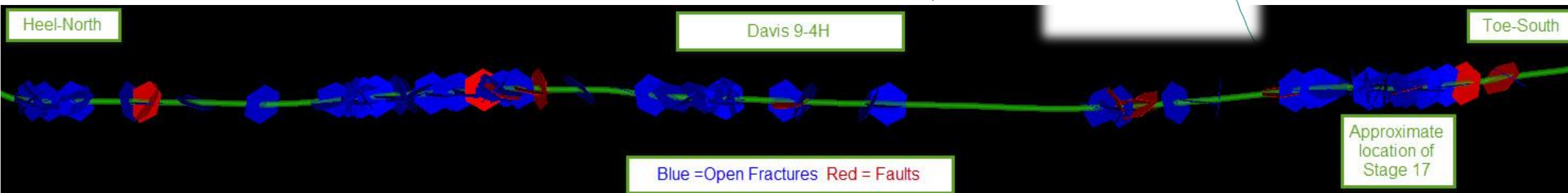


Map View



- Open Fractures=105
- Partial Open Fractures=1385
- Closed Fractures=164
- Induced Fractures=0
- Faults=4
- Micro-Faults=10

3-D Module

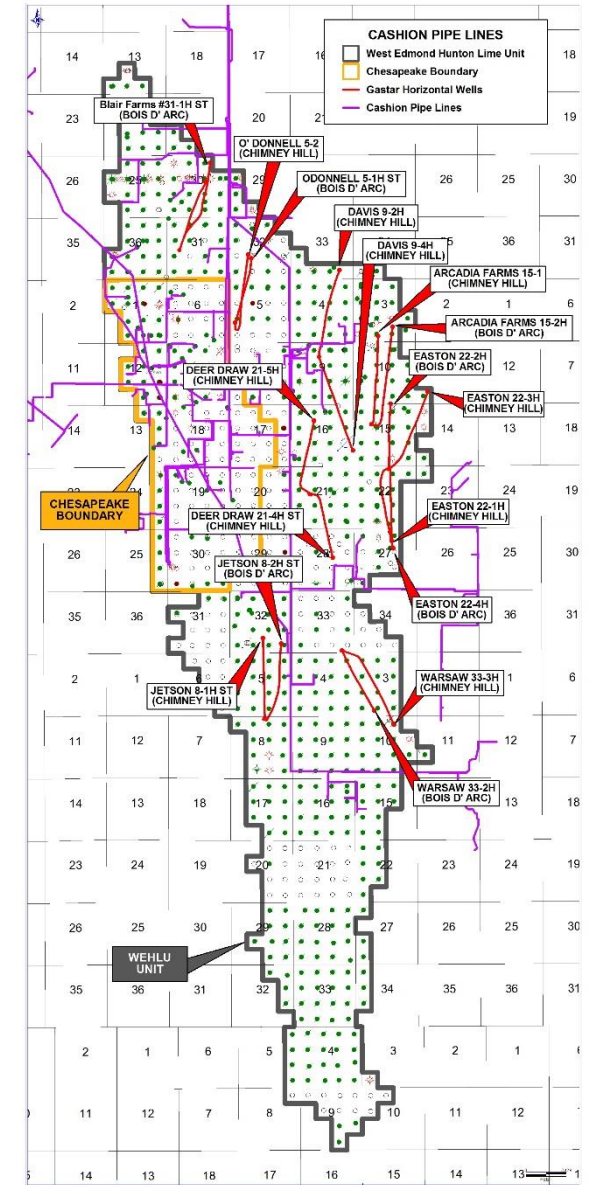


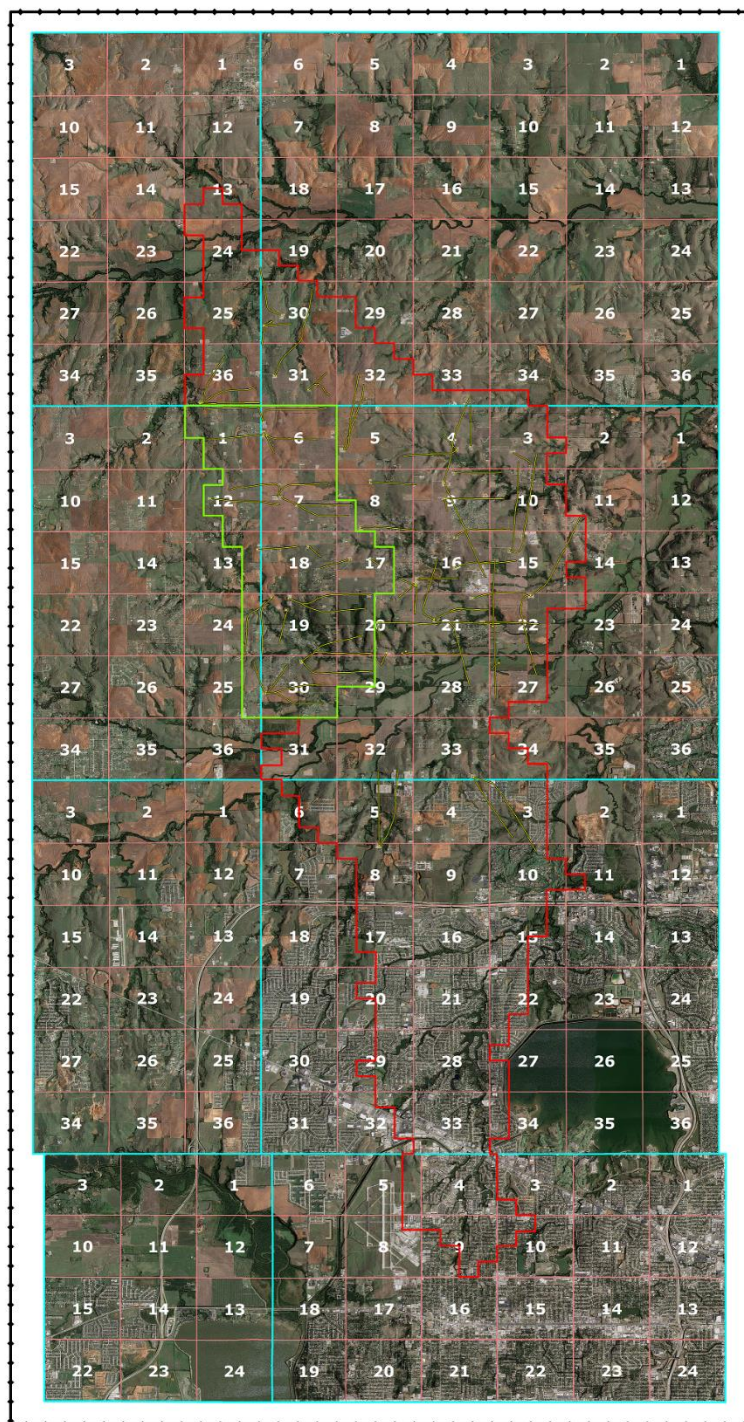
Operational Issues

- Casing failures due to corrosive water in the Tonkawa Formation
- Produced Water and resulting scale and corrosion
- Lost Circulation while drilling
- P & A Wells
- Low bottom hole pressure
- Differential sticking due to the pressure challenges
- Urban Drilling environment
- Power

SWD and Produced Water Issues

- Challenge: OCC is curtailing SWD wells perforated in the Arbuckle Group due to Earthquake activity
 - O'Brien SWD plugged back to the 2nd Wilcox and Viola to get off the OCC watch list
 - Potential to use temporarily abandoned wells for shallow injection
 - Chupa 1-12 SWD-Operated by Chesapeake





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