

Thickness and Extent of Clay Layers in the Pleistocene Tulare Formation near Elk Hills, California: Implications for Water Disposal Operations and Timing of Structural Growth*

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Search and Discovery Article #30496 (2017)**

Posted April 10, 2017

*Adapted from oral presentation given at AAPG Pacific Section and Rocky Mountain Section Joint Meeting, Las Vegas, Nevada, October 2-5, 2016

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Abstract

The lacustrine Amnicola Clay (2.2 Ma) separates the upper and lower members of the Pleistocene Tulare Formation at Elk Hills oilfield, California. The Tulare Clay is found within the upper Tulare Formation below the Corcoran Clay (0.64-0.8 Ma). Logs from 650 wells were used to correlate the Amnicola and Tulare clays across Elk Hills and into adjacent fields to map the structure, thickness and lateral extent of the clays. These maps help bracket the timing of late stage structural and topographic development at Elk Hills. The thickness and continuity of these clays also have important implications for water disposal operations in the Tulare Formation in the map area, as continuous clay layers are more likely to confine the disposed produced waters and keep them from reaching overlying protected aquifers. The structure maps reveal a single northwest-trending anticline in the Elk Hills area. The isochore map shows that the Amnicola Clay is continuous across the Elk Hills area and forms a coherent confining layer across the study area, although it thins over the crest of the anticline. This demonstrates that Elk Hills was covered by the paleo lake approximately 2.2 Ma and most of the recent structural and topographic growth occurred after deposition of the Amnicola Clay. The younger Tulare Clay does not extend over the structural high and forms only a local confining layer. It thickens into the adjacent synclines and is absent over the crests of the anticlines, demonstrating that significant structural and topographic growth occurred at Elk Hills before, or during, deposition of the Tulare Clay (prior to 0.8-0.64 Ma – the age of the overlying Corcoran Clay). Therefore, it appears that late stage structural growth and topographic development of the Elk Hills anticline occurred after 2.2 Ma but began before 0.8-0.64 Ma.

References Cited

Lillis, P.G., and L.B. Magoon, 2007, Petroleum systems of the San Joaquin Basin Province, California - Geochemical Characteristics of oil types, *in* A. Hosford Scheirer, ed., Petroleum systems and geologic assessment of oil and gas in the San Joaquin Basin Province, California: U.S. Geological Survey Professional Paper 1713, Chapter 9, 52 p.

Reid, S.A., 1995, Miocene and Pliocene depositional systems of the southern San Joaquin basin and formation of sandstone reservoirs in the Elk Hills area, California, *in* A.E. Fritsche, ed., Cenozoic paleogeography of the western United States, II: Pacific Section, Society of Economic Paleontologists and Mineralogists, p. 131-150.

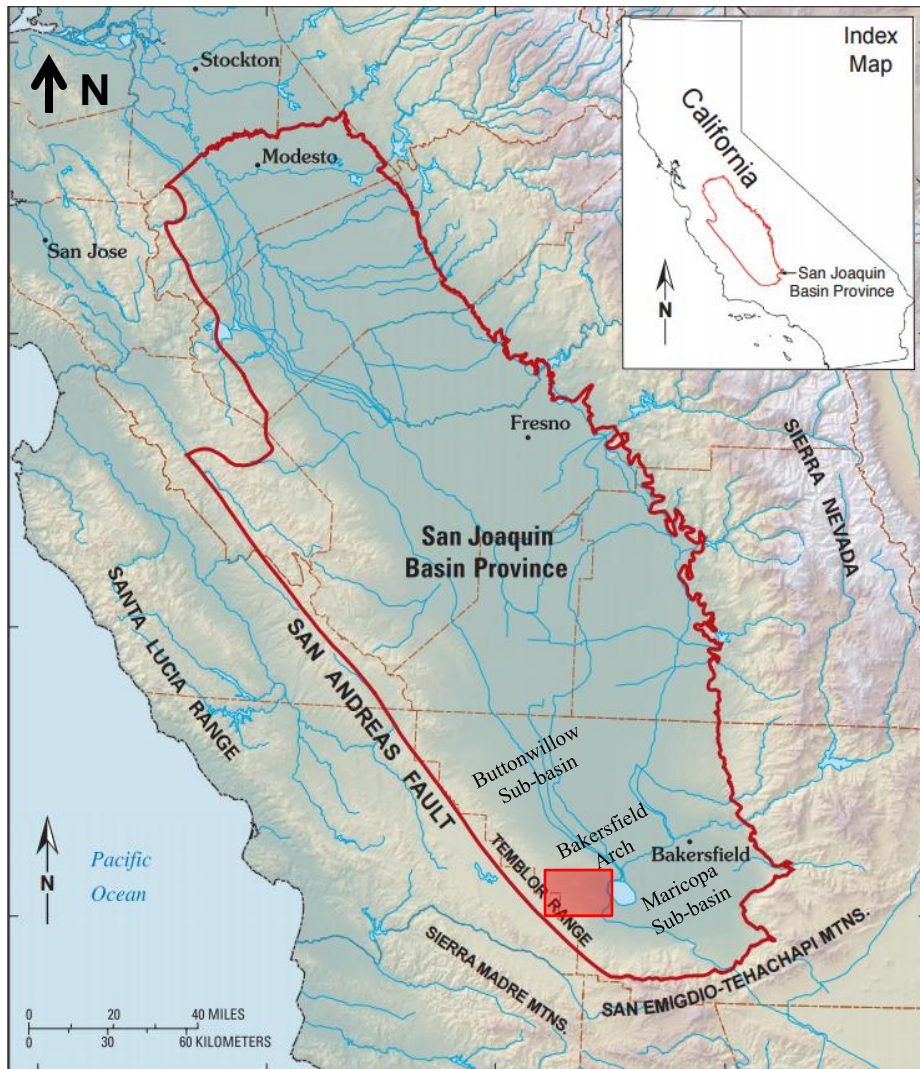
Zumberge, John E., Judy A. Russell, and Stephen A. Reid, 2005, Charging of Elk Hills reservoirs as determined by oil geochemistry: AAPG Bltn., v. 89/10, p. 1347-1371.

**THICKNESS AND EXTENT OF CLAY LAYERS IN THE PLEISTOCENE
TULARE FORMATION NEAR ELK HILLS, CALIFORNIA: IMPLICATIONS FOR
WATER DISPOSAL OPERATIONS AND TIMING OF STRUCTURAL GROWTH**

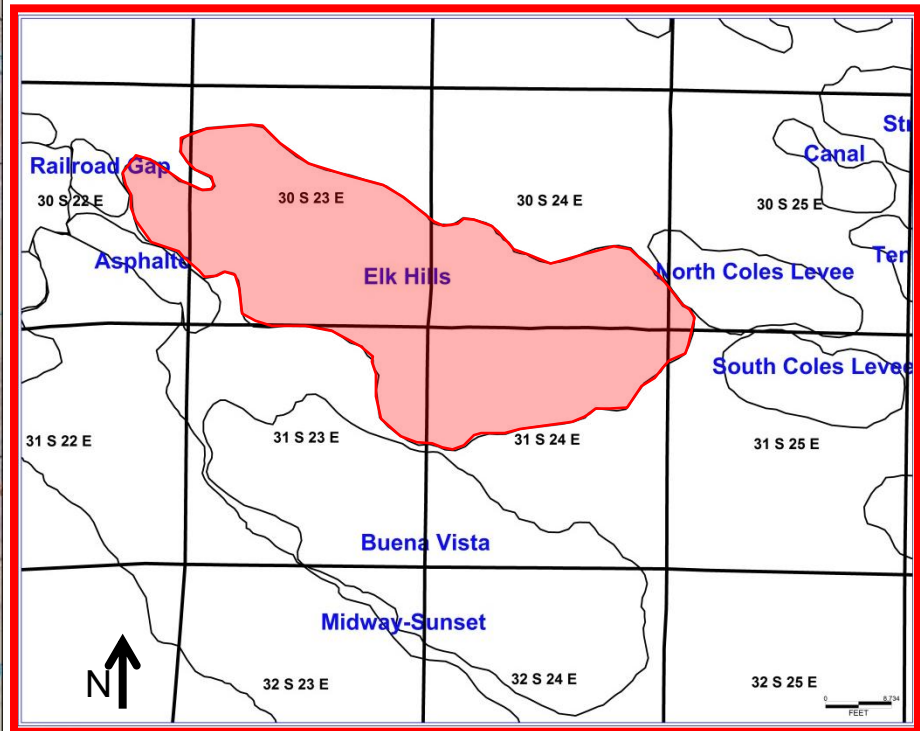
Paul Bowles

Janice Gillespie

STUDY LOCATION

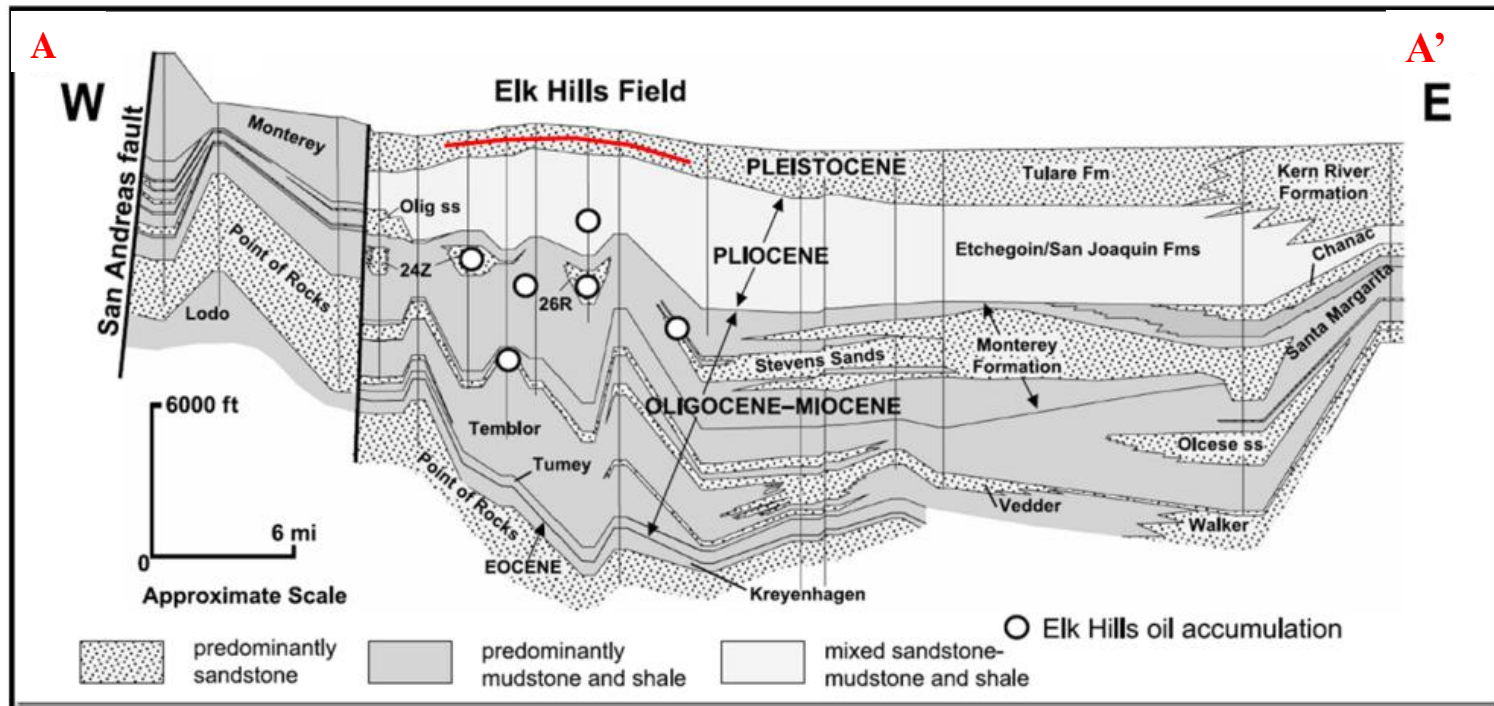
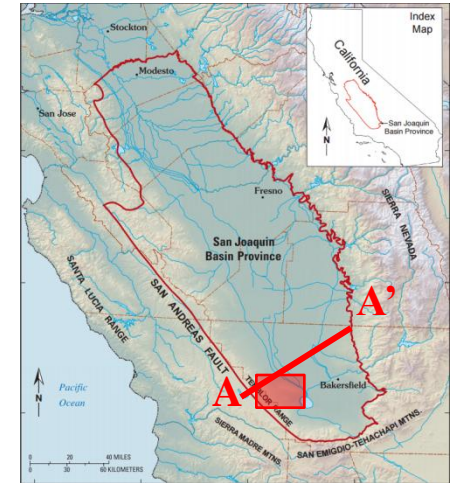


(modified from Lillis and Magoon, 2008)



SOUTHERN SAN JOAQUIN BASIN STRATIGRAPHY

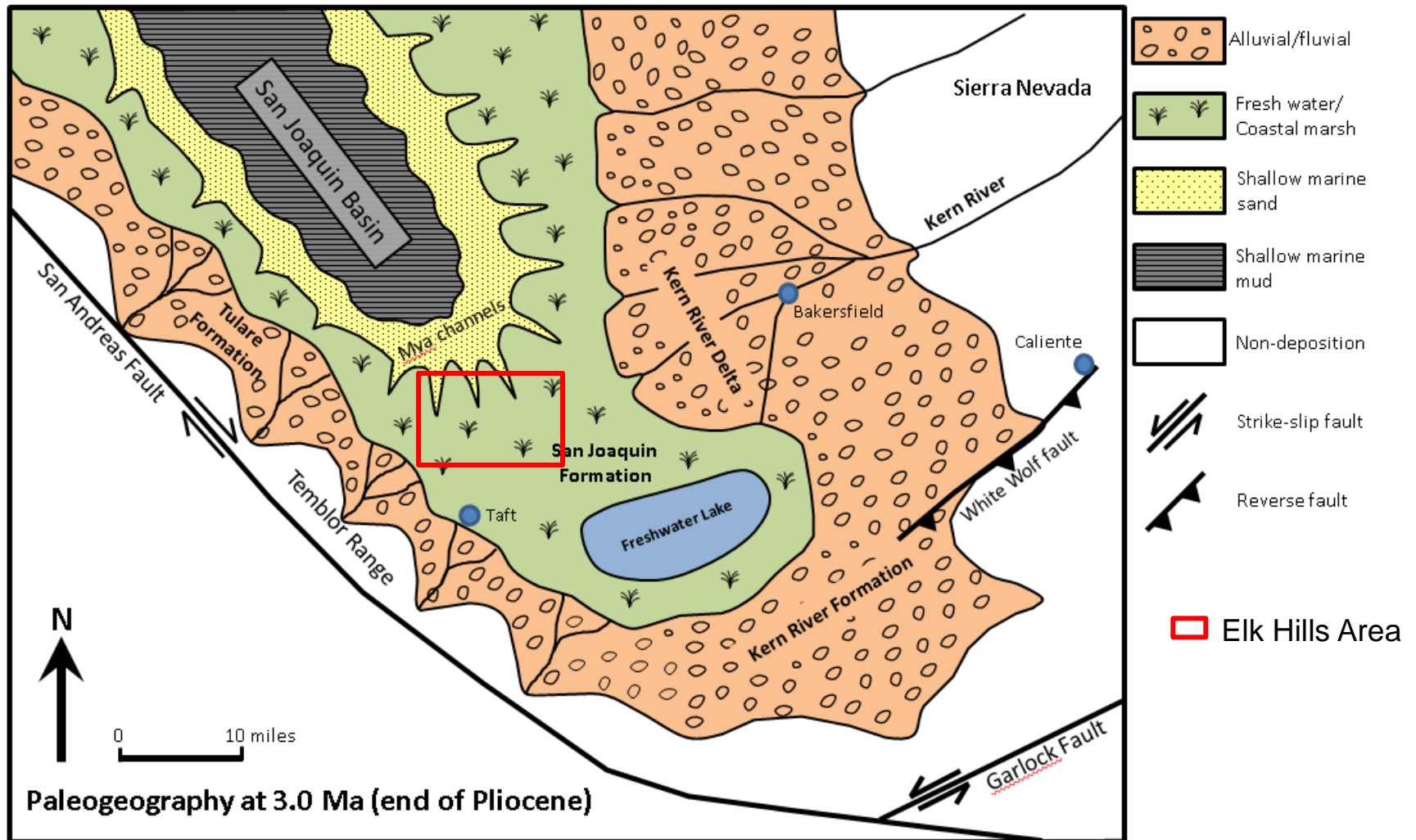
- Miocene Monterey Formation: basin transition to deep water clay, turbidite and diatomite deposits
- Pliocene : transition from marine to freshwater deposits
- Plio-Pleistocene Tulare Formation: alluvial and lacustrine environments



(modified from Zumberge et al., 2005)

(modified from Lillis and Magoon, 2008)

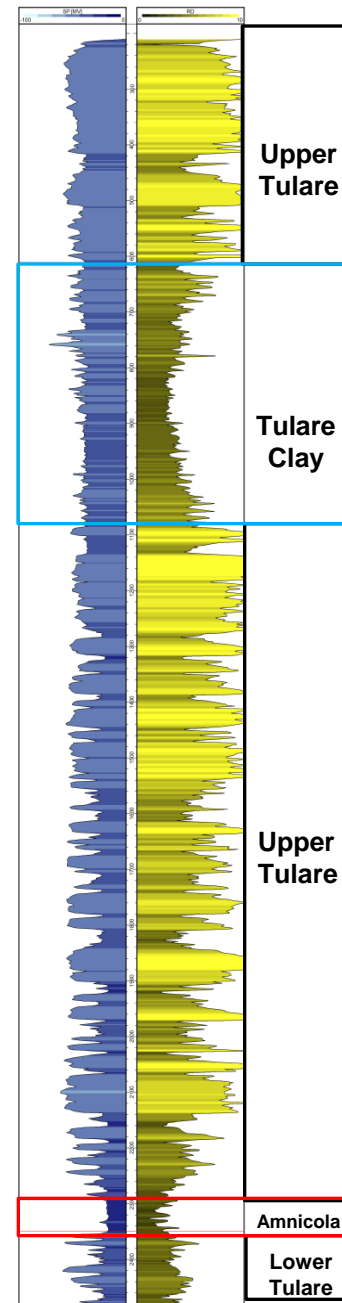
TULARE DEPOSITIONAL ENVIRONMENT



(modified from Reid, 1995)

TULARE & AMNICOLA CLAY

- Upper Tulare Formation clay referred to as the “Tulare Clay”
- Lies below Miller’s (1999) green seismic horizon dated at 0.8-0.64 Ma
- Amnicola Clay is described as an olive gray, partly calcareous/dolomitic, claystone that contains the gastropod *Amnicola*
- Separates the upper and lower sandstone and conglomerate members of the Tulare Formation
- Assumed to correlate to Miller’s (1999) orange seismic horizon dated at 2.2 Ma

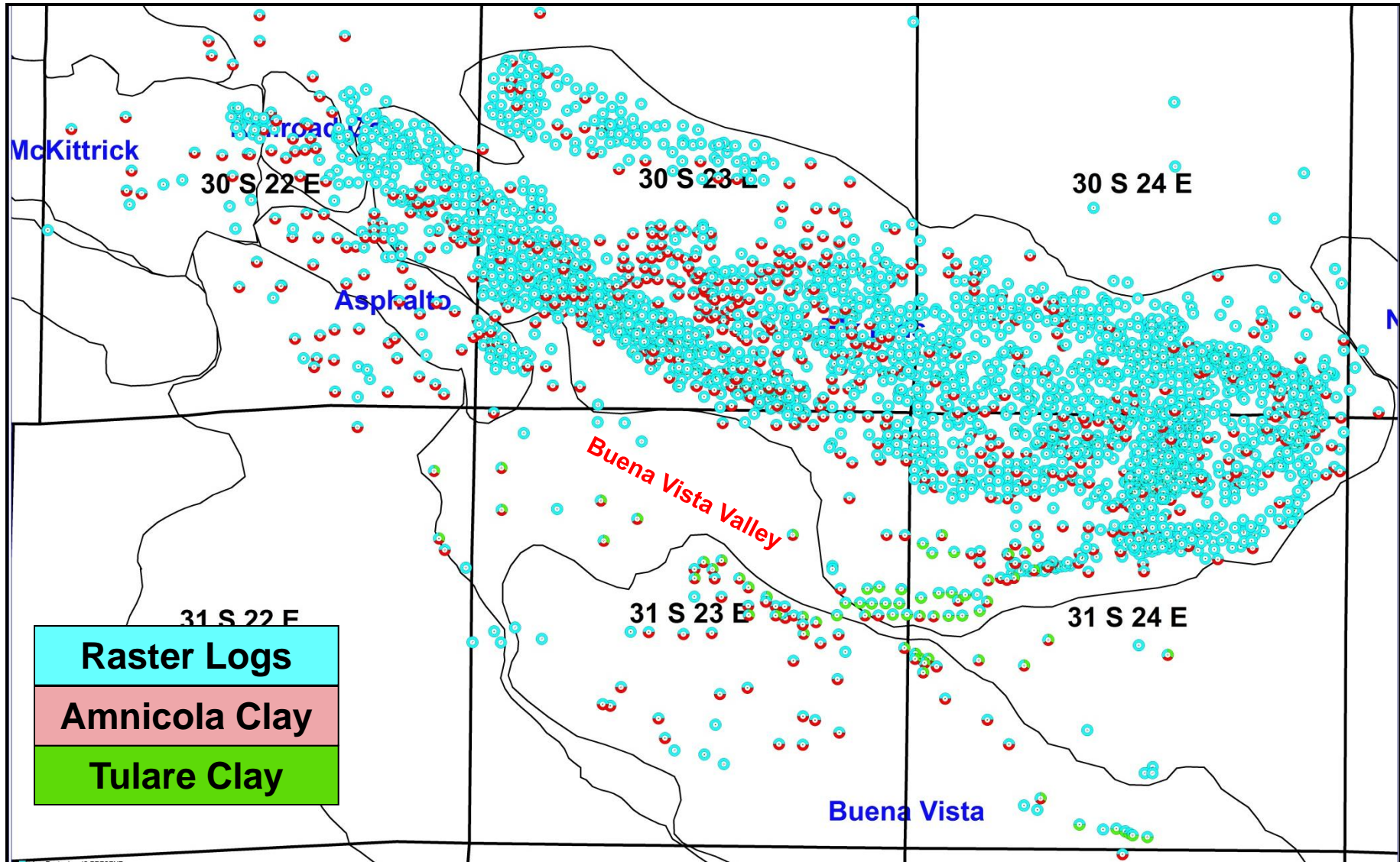


PROJECT OBJECTIVE

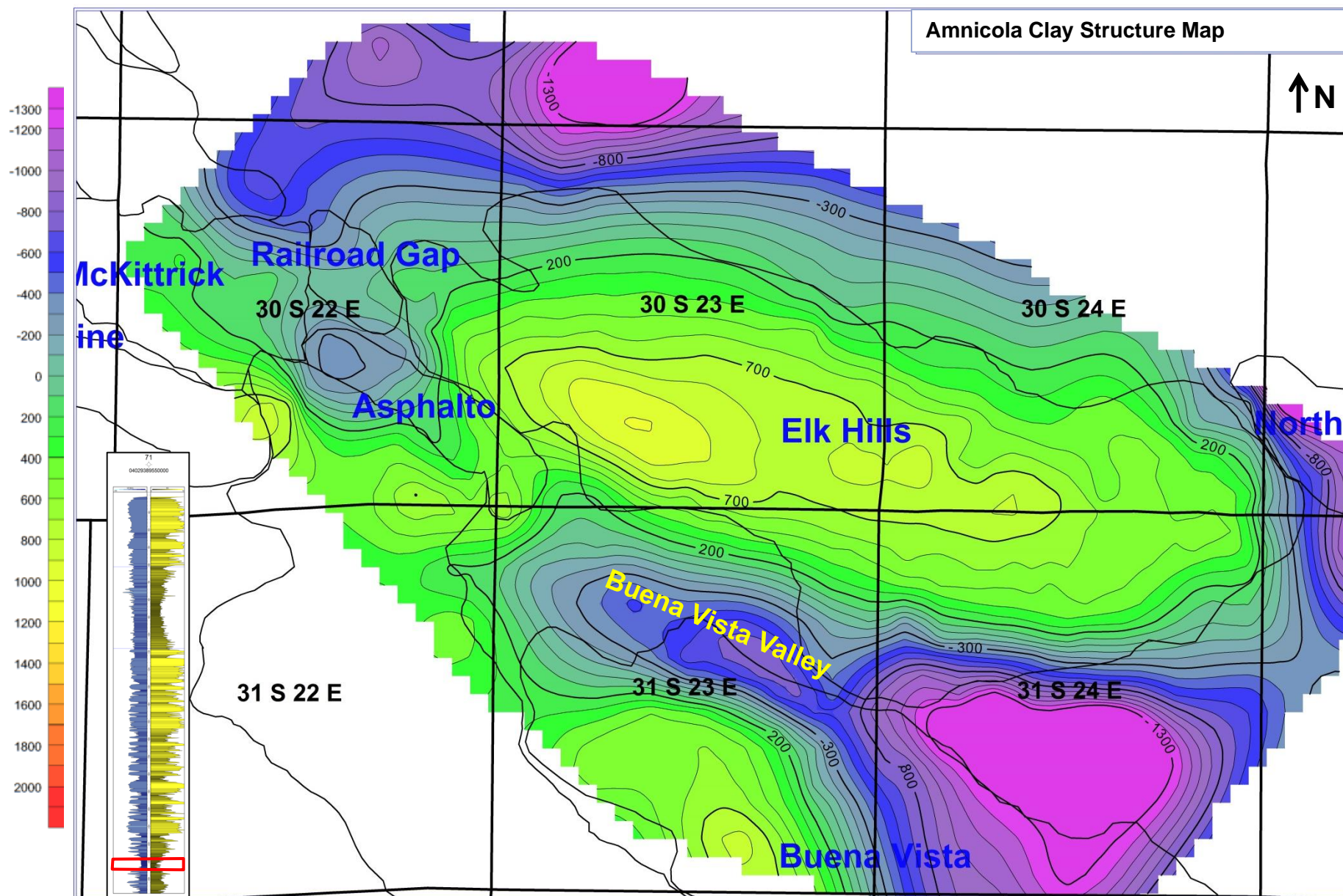
Map the lateral extent and thickness of the Amnicola and Tulare clays in the study area to determine:

- **The relative timing of structural growth of the Elk Hills and other nearby anticlines in the study area with respect to the timing of lacustrine deposition**
- **The ability of the two clay layers to act as confining units between potentially protected aquifers and produced water disposal zones**

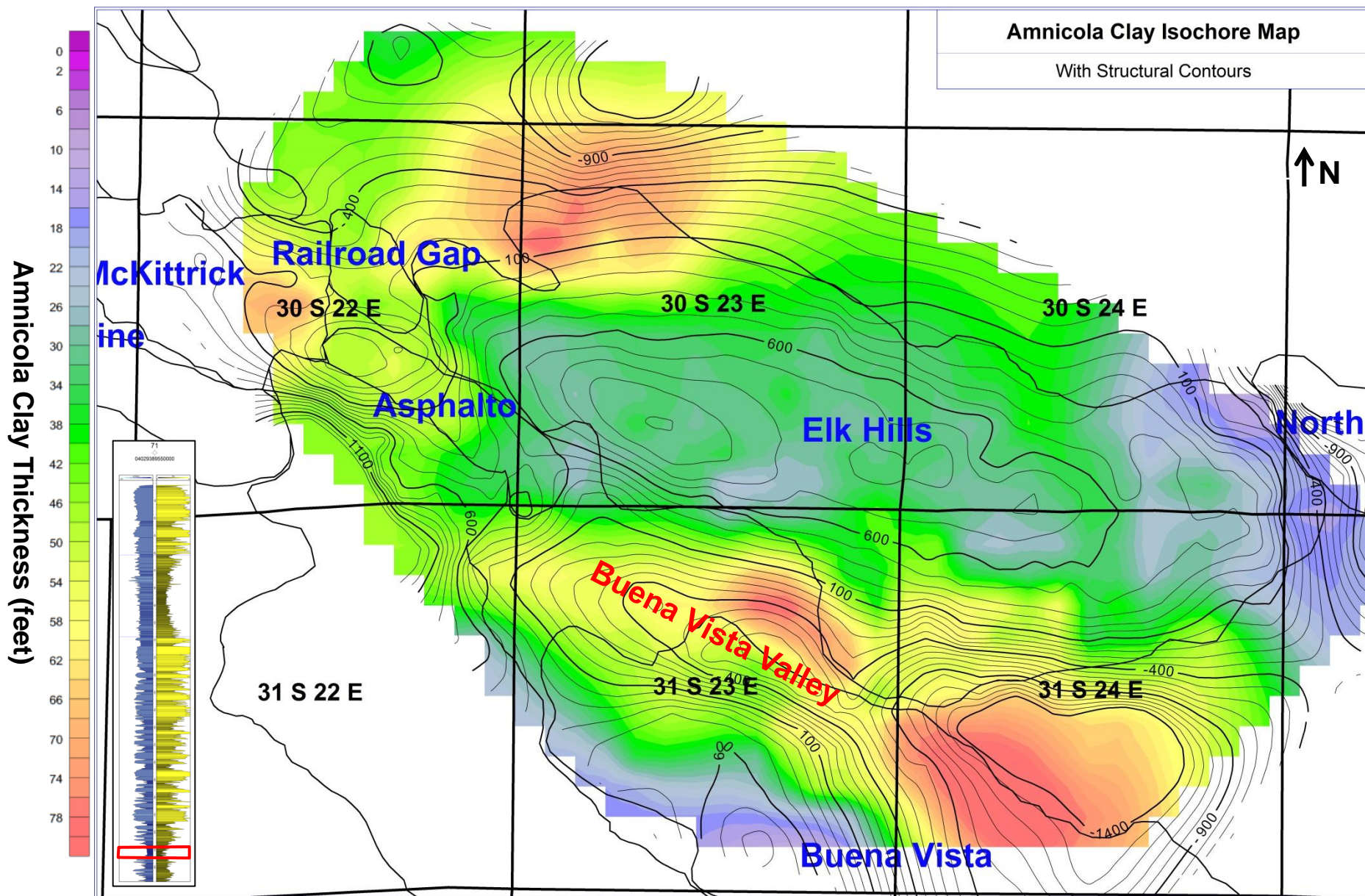
AMNICOLA AND TULARE CLAY MAPPING



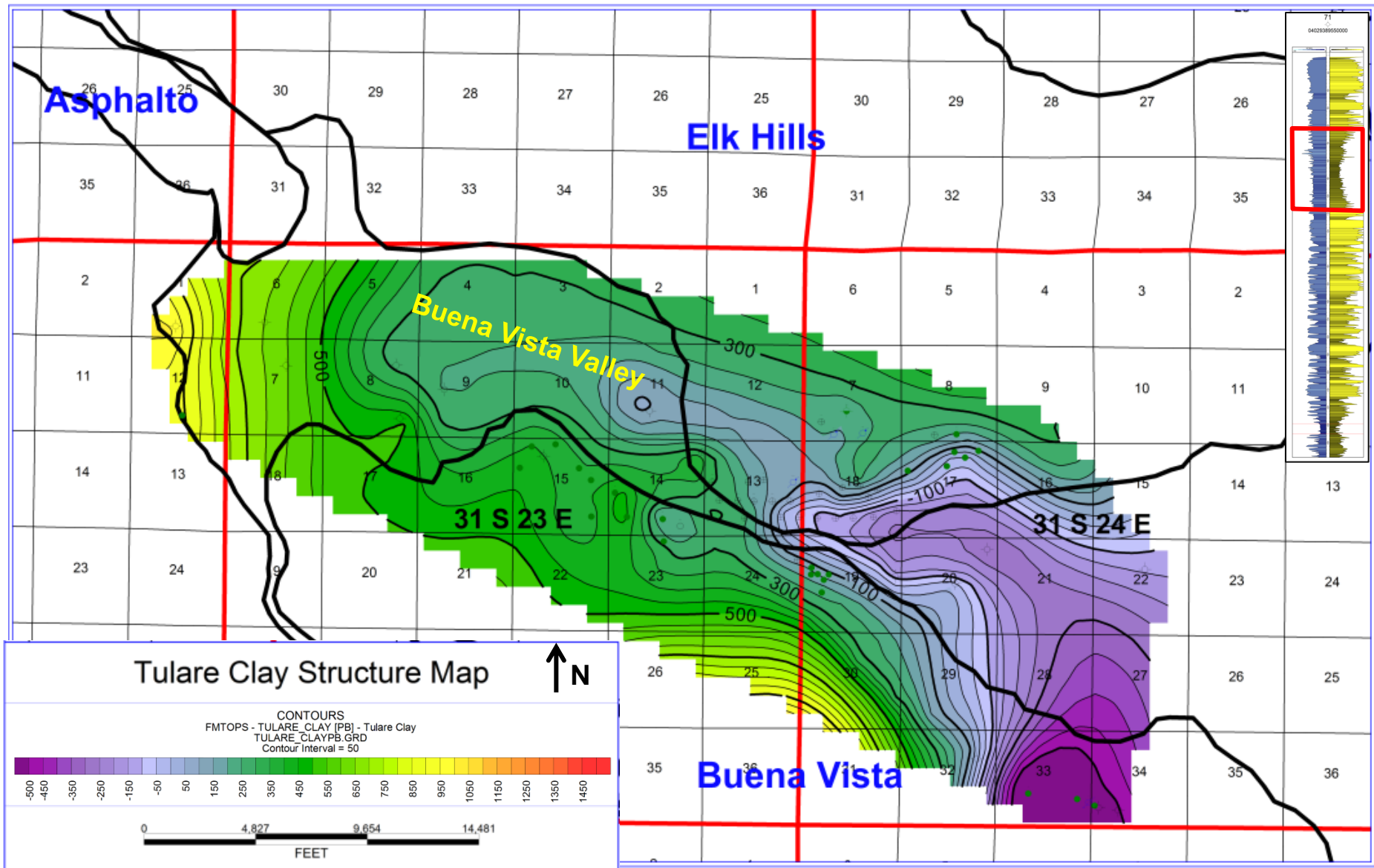
AMNICOLA CLAY STRUCTURE MAP



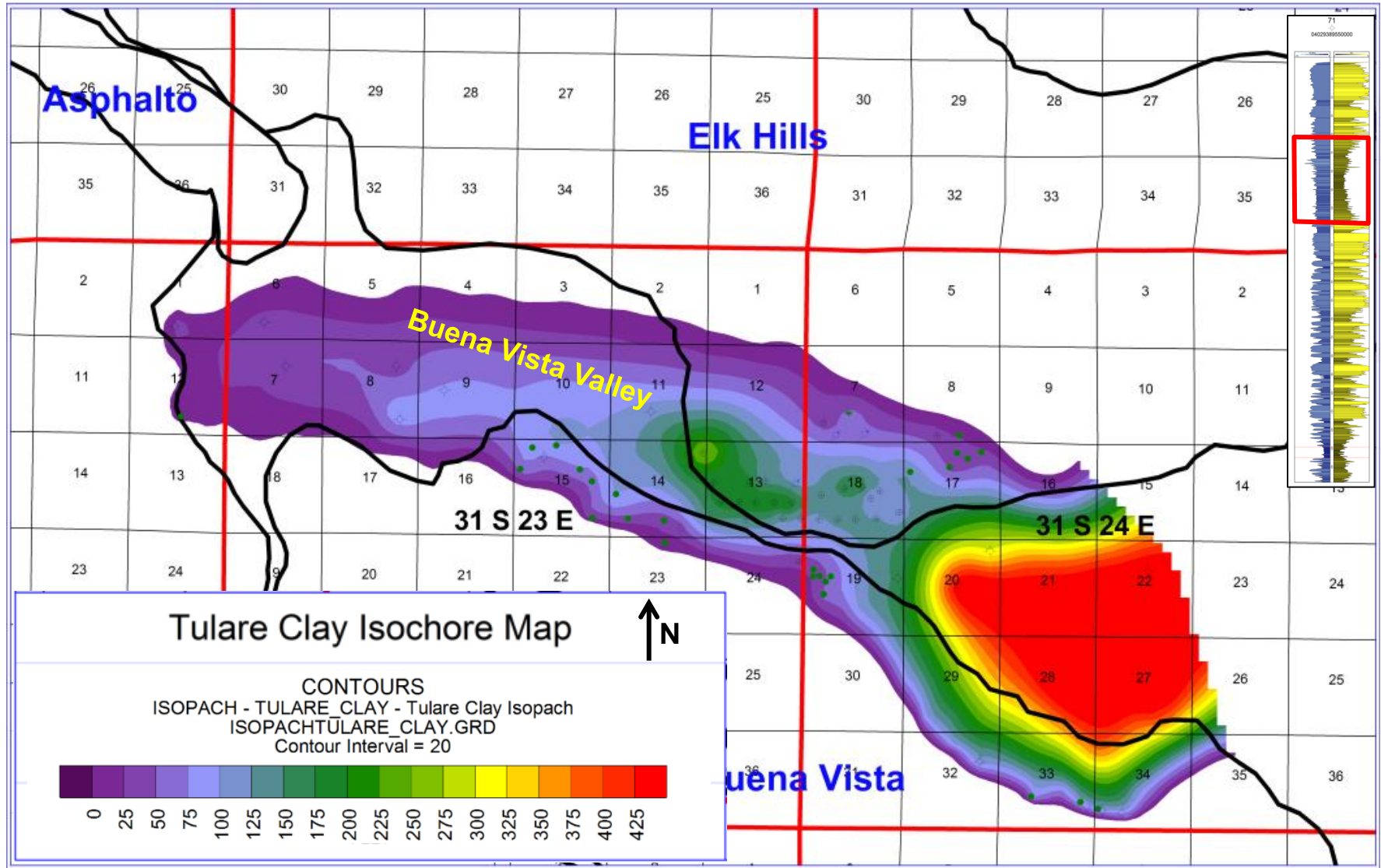
AMNICOLA CLAY ISOCHORE MAP



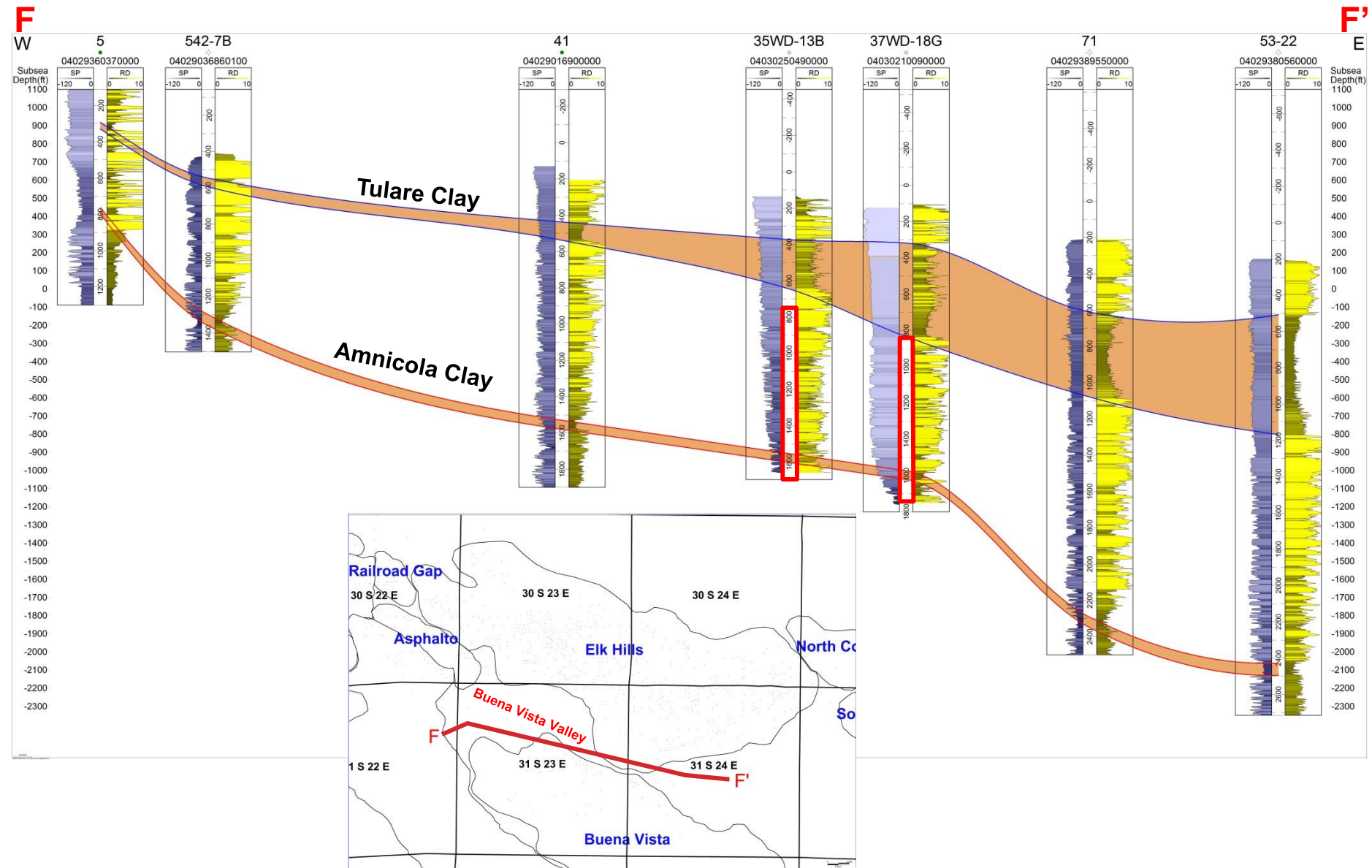
TULARE CLAY STRUCTURE MAP



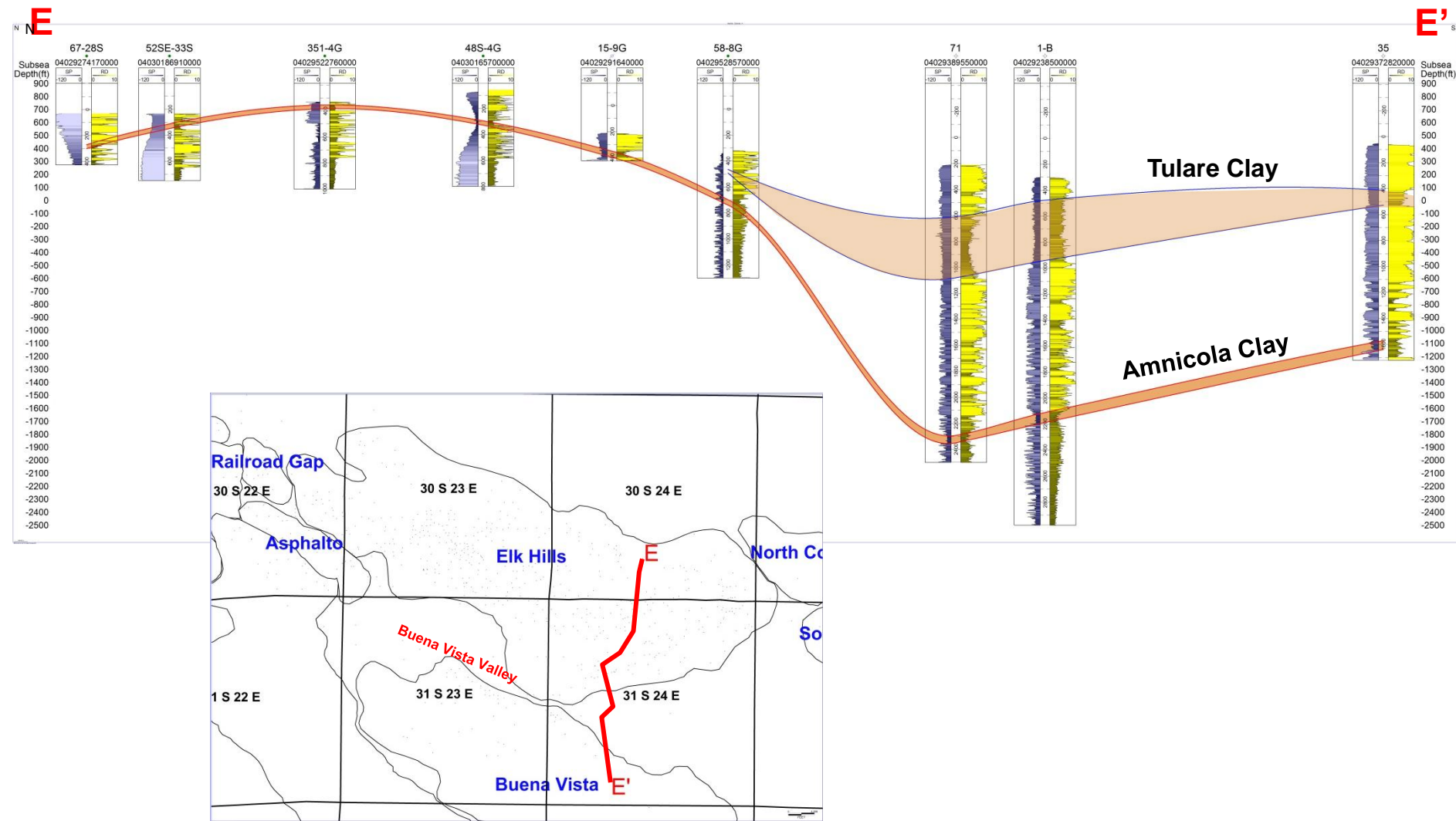
TULARE CLAY ISOCHORE MAP



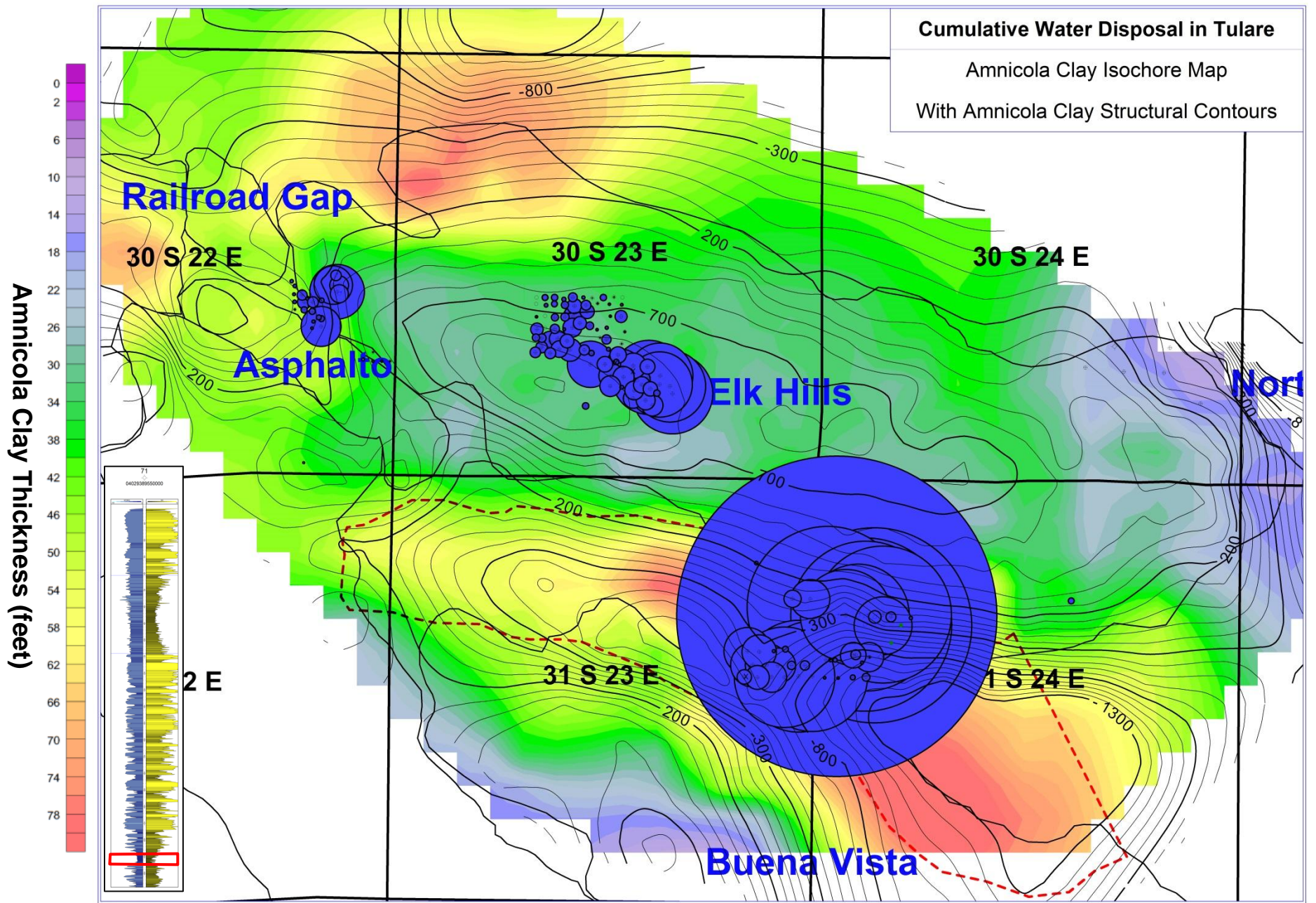
TULARE CLAY WEST-EAST CROSS SECTION



TULARE CLAY NORTH-SOUTH CROSS SECTION



TULARE WATER DISPOSAL WELLS



CONCLUSIONS

- **The Amnicola Clay isochore map shows that the Amnicola Clay thins over the Elk Hills structures but forms a laterally continuous low permeability barrier across the Elk Hills oil field as well as the neighboring Asphalto and Rail Road Gap fields, signifying significant structural growth and related topographic expression was minor at 2.2 Ma**
- **The Tulare Clay isochore map shows that the Tulare Clay is absent over the Elk Hills structure, indicating that significant structural and topographic growth of Elk Hills occurred prior to or immediately after deposition of the Tulare Clay**
- **Based on the evidence provided by the isochore maps and current topography in the area, nearly 1 km of structural and topographic relief has occurred since 2.2 Ma**
- **While the Amnicola Clay provides a continuous confining layer across the study area, the Tulare Clay is only locally confining—particularly within synclinal areas**

ACKNOWLEDGEMENTS

- **Janice Gillespie**
- **Robert Negrini**
- **Ken Frost**
- **Linn Energy**