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By Philip H. Nelson and
Nicholas J. Gianoutsos

Evolution of overpressured and underpressured oil and gas reservoirs, Anadarko Basin of Oklahoma, Texas, and Kansas—Overview

Abstract

The deep Anadarko Basin is overpressured from Mississippian strata to the base of Missourian strata, as previously documented by Al-Shaieb and others (1994).

Departures of resistivity logs from a normal compaction gradient indicate that overpressure previously extended north of the present-day overpressured zone. These indicators of paleopressure, which are strongest in the deep basin, are mapped to the Kansas-Oklahoma border in shales of Desmoinesian age. The broad area of paleopressure has contracted to the deep basin, and today the overpressured deep basin, as determined from drillstem tests, is bounded on the north by strata with near normal pressures (hydrostatic), grading to the northwest to pressures that are less than hydrostatic (underpressured). Thus the pressure regime in the northwest portion of the Anadarko Basin has evolved from paleo-overpressure to present-day underpressure.

Sheet 2

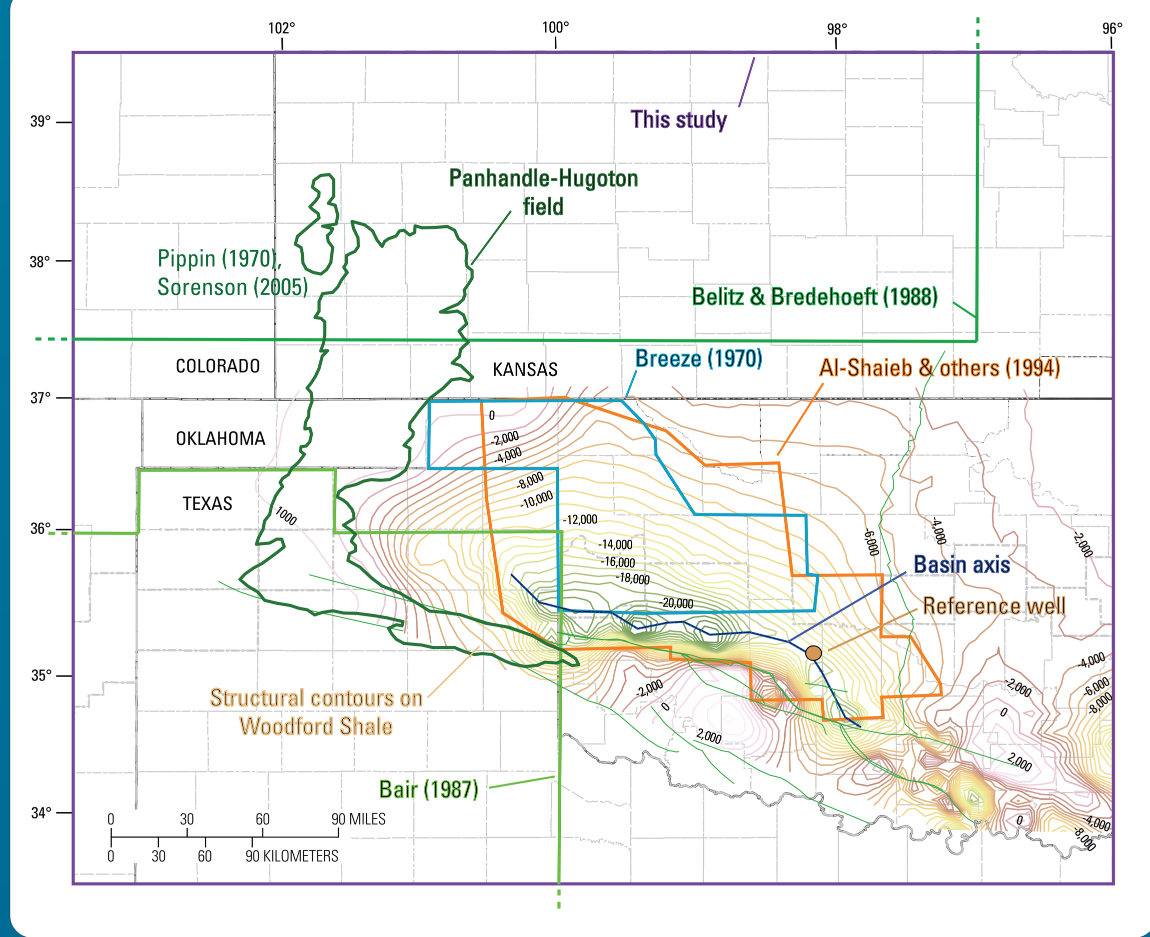
Using pressure data from drillstem tests, we constructed cross sections and potentiometric maps that illustrate the extent and nature of present-day underpressuring. Downcutting and exposure of Lower Permian and Pennsylvanian strata along, and east of, the Nemaha fault zone in central Oklahoma form the discharge locus where pressure reaches near atmospheric. From east to west, hydraulic head increases by several hundred feet in each rock formation, whereas elevation increases by thousands of feet. The resulting underpressuring of the aquifer-supported oil and gas fields, which also increases from east to west, is a consequence of the vertical separation between surface elevation and hydraulic head. A 1,000-ft thick cap of Permian evaporites and shales isolates the underlying strata from the surface, preventing re-establishment of a normal hydrostatic gradient.

Sheet 3

Thus, the present-day pressure regime of oil and gas reservoirs, overpressured in the deep basin and underpressured on the northwest flank of the basin, is the result of two distinct geologic events—rapid burial and uplift/erosion—widely separated in time.

1 Previous work on pressure

Five previous investigations fall within our study area. We especially relied upon the work of Al-Shaieb and others (1994) that defined the overpressured megacompartments in the deep basin, and the paper by Sorenson (2005) that explains the origin and underpressuring of the Panhandle-Hugoton gas field.



2 Pressure-depth plots reveal underpressure, normal pressure, and overpressure

Explanation.
All pressure data from a 30 x 30 square mile area are plotted on a pressure-depth plot (see Key). Large areas are needed to capture sufficient data to define trends. Data falling to the left of the hydrostatic gradient reveal "underpressure" (blue squares); data falling on the hydrostat reveal "normal pressure" (green squares) and data falling to the right of the hydrostat reveal "overpressure" (red squares).

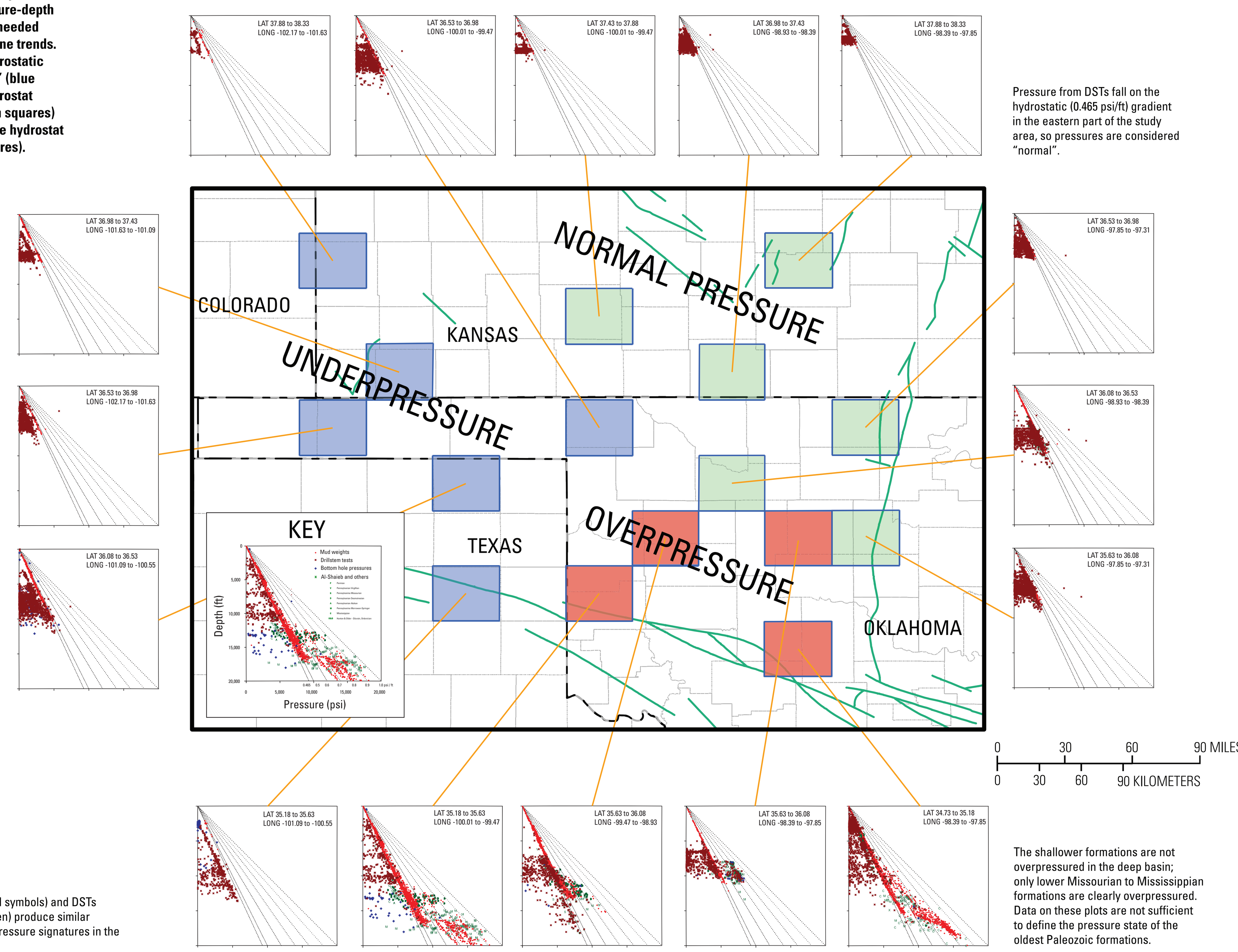
Separation between the hydrostatic gradient and pressure from drillstem tests (DSTs) shows that underpressuring is greatest along the western margin of the study area. Underpressuring decreases from west to east.

Pressures from many DSTs are lower than formation pressure, because the test was not successful or because of drawdown during production. However, the right-hand edge of DST pressures are considered valid.

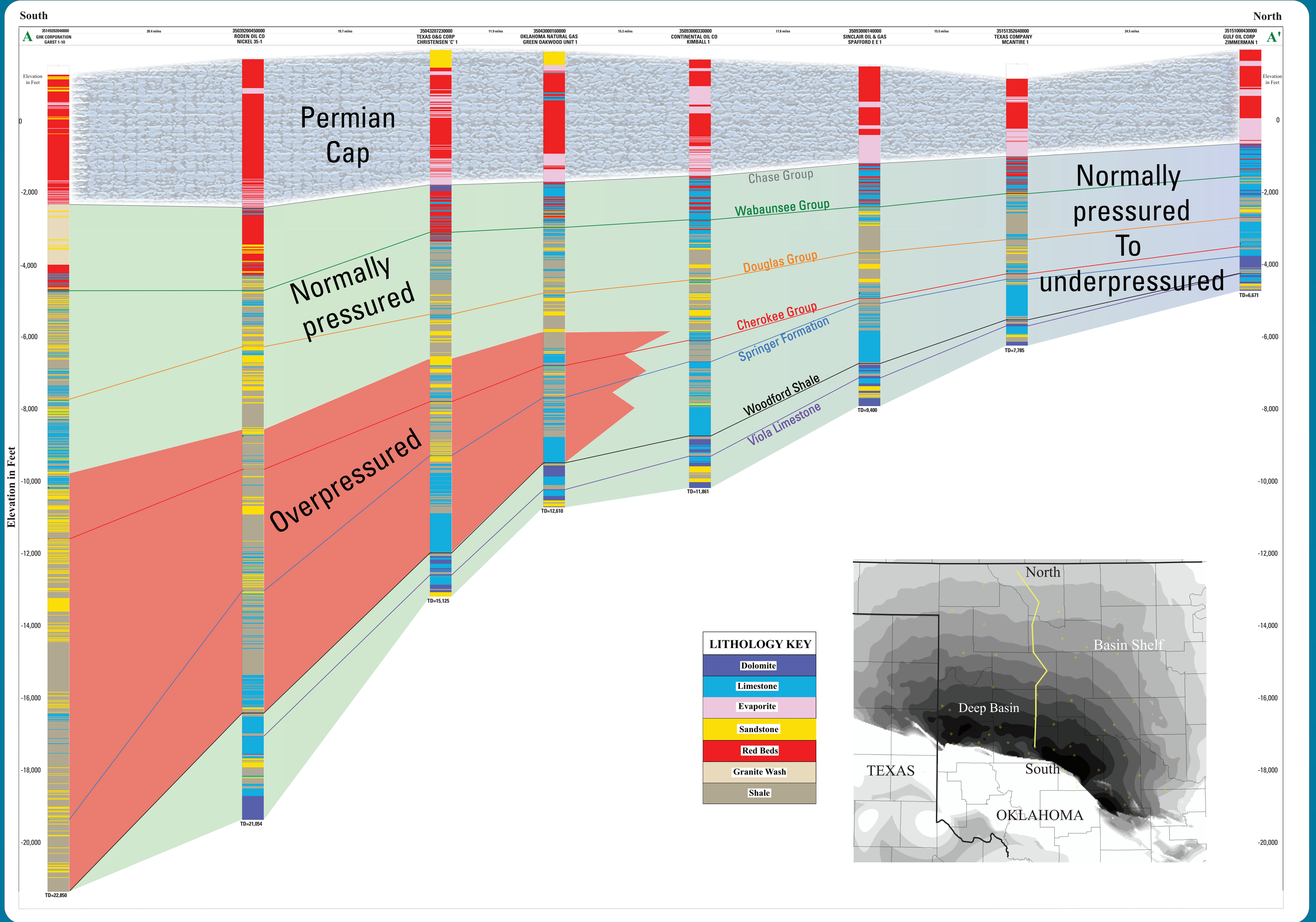
Pressure from DSTs fall on the hydrostatic (0.465 psi/ft) gradient in the eastern part of the study area, so pressures are considered "normal".

The shallower formations are not overpressured in the deep basin; only lower Missourian to Mississippian formations are clearly overpressured. Data on these plots are not sufficient to define the pressure state of the oldest Paleozoic formations.

Mud weight (red symbols) and DSTs (brown and green) produce similar maximum overpressure signatures in the deep basin.



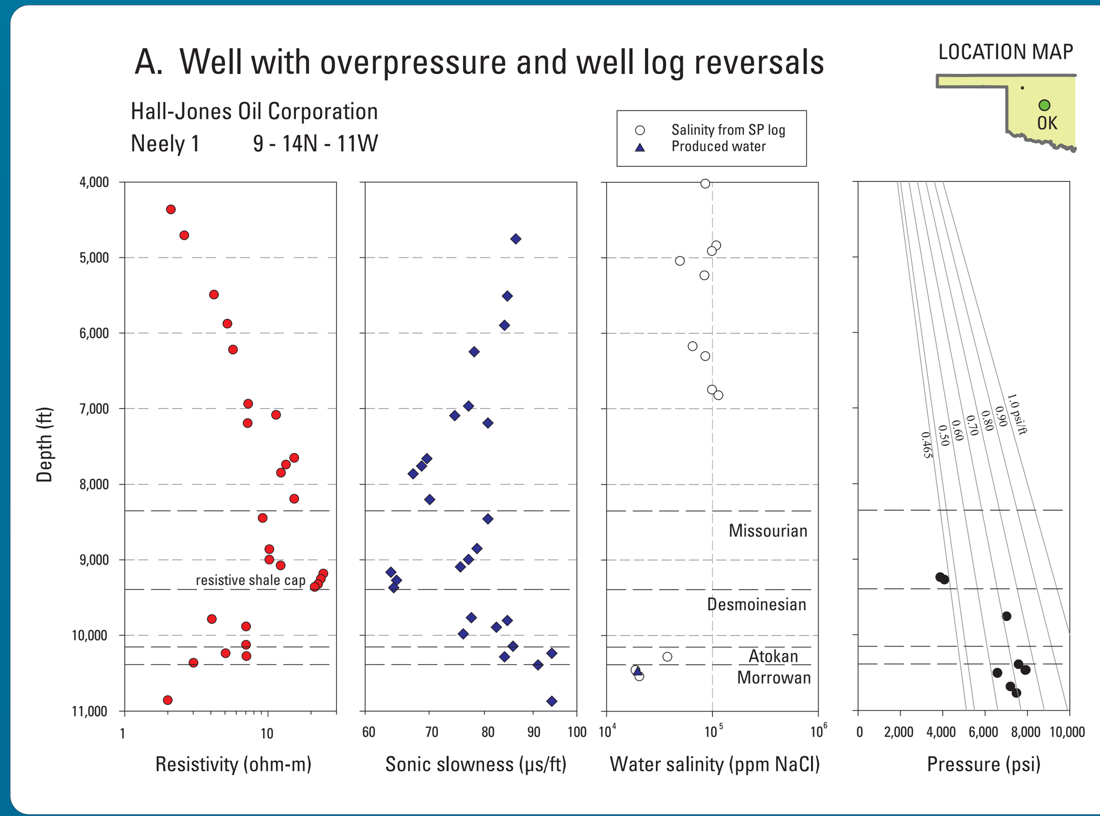
3 The pressure domains: the overpressured deep basin, the normally pressured area, the underpressured area, and the Permian cap

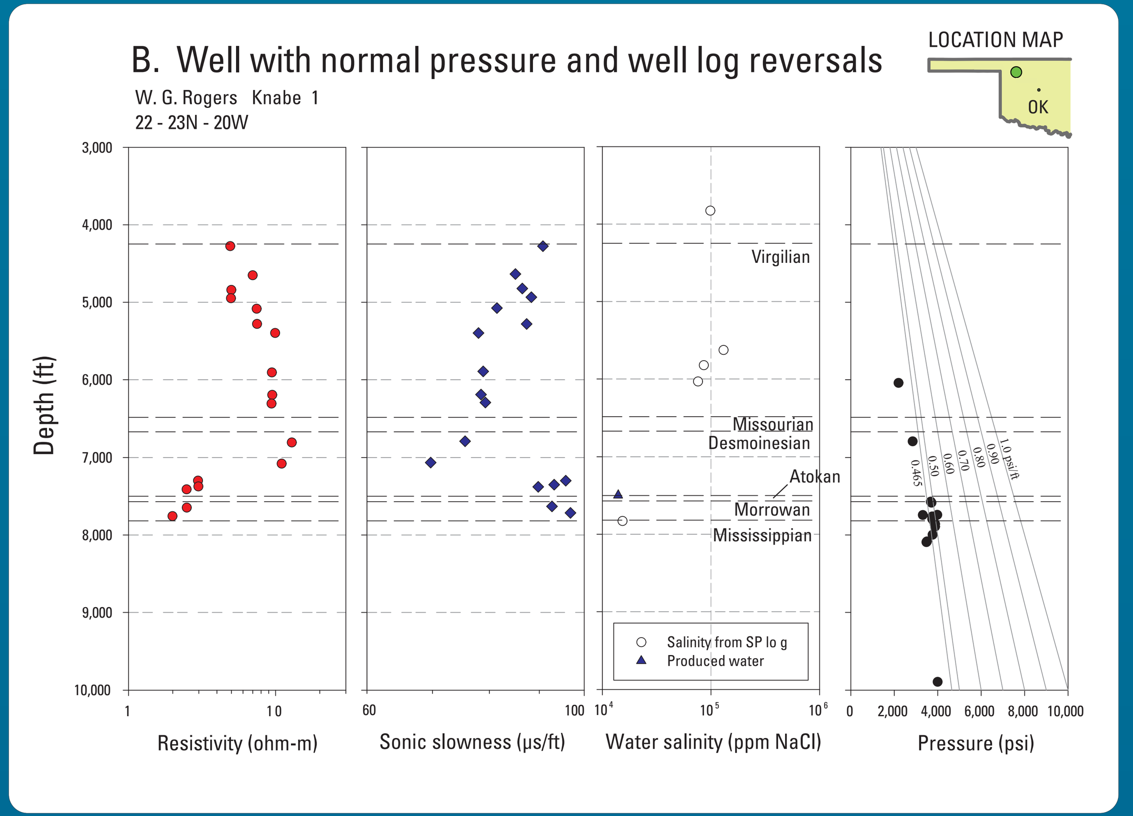


This cross section shows the overpressured zone in the deep basin (red), surrounded by strata in which the pre-production pressure-depth ratios were normal to underpressured (light green). The top of the section is capped by impermeable mudstones, salts, and anhydrites of Permian age. The lithology logs, from Gallardo (1989), also show the shale-sandstone-limestone sequences of Pennsylvanian age and the underlying carbonate sequences of Mississippian and older ages.

4 Paleopressure indicators documented by A.F. Breeze

While investigating the cause of underpressure in Morrowan sandstones in the northwestern Anadarko Basin, Breeze (1970) noticed that sonic and resistivity logs showed reversals in trends in wells that were overpressured (A) and wells that were normally pressured (B). From this, he decided that the conditions producing the well log reversals differed from present-day conditions, stating "It is therefore concluded that the entire area was once subject to a similar history of deposition that left undercompacted shales as evidence." Sheet 2 of this poster follows the same line of reasoning.





Sources of data

1. Mud weights from IHS Energy (2009), converted to equivalent pressure.
2. Bottom-hole pressures from IHS Energy (2009).
3. Drillstem tests from IHS Energy (2009).
4. Pressure data from various sources compiled by Oklahoma State University (OSU), courtesy of Jim Puckette (personal commun., 2008).

Acknowledgments

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