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ABSTRACT

GAS DETECTION AND CAPILLARY SEALING MECHANISM IN THE ANADARKO BASIN, OKLAHOMA, U.S.A: IMPLICATIONS FOR FUTURE EXPLORATION IN EASTERN VENEZUELA, TRINIDAD, GUYANA, SURINAME AND BRAZIL

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The Anadarko Basin located in southwestern Oklahoma (Fig 1) is modeled as a "geopressure" or "overpressure" hydrocarbon province. The overpressure model suggests that sections within the Anadarko Basin contain extensive units of reservoir rock exhibiting abnormal pore-fluid pressures which exceed the hydrostatic (Fig 2, Fig 6). Past research in the Anadarko Basin attempting to explain the origin and dissipation of overpressurized fluids over extended timescales has resulted in the evaluation of two leading hypotheses or models. The first model proposed that the present day abnormally high pore-fluid pressures in the Anadarko Basin were a remnant of Paleozoic compaction disequilibrium preserved for 250 million years. A second hypothesis proposed to account for overpressures in the Anadarko Basin is the hydrocarbon or "gas" generation model. Both hypotheses failed to explain calculations and observations made in the field. In this study, we propose to test a new model based on gas capillary sealing to account for observed geopressure regimes in the present-day Anadarko Basin. We now suggest that the capillary force generated by gas-water interface between fine- and coarse-grained clastic rocks, acts as a zero permeability barrier that prevents the normal escape of excess pore-fluid (Fig 3). This new hypothesis makes two specific predictions, which can be tested. The first is that anomalous pressures are associated with the presence of gas. The second is that ambient fluid (or gas) pressures should undergo rapid changes across capillary barriers. Detecting capillary seals and estimating the magnitude of their pressure sealing in the Anadarko Basin implies two main aspects: (1) measuring the pore throat radius on selected fine-and course-grained rocks and, (2) identifying the presence of the gas layers using a suite of geophysical logs (Gamma Ray, Neutron Porosity, Density Porosity, Caliper and Photoelectric logs) and other recorded data (Fig 4). Mercury Intrusion Porosimetry (MIP) measurements were conducted on 62 fine- and coarse- grained rock samples from the northern overpressure sections of the deep Anadarko Basin. The average pore throat

radius for these fine and coarse rocks was determined to be 4.8 x 10^{-8} and 3.8 x 10^{-7} m, respectively. In the studied area 100 wells containing multiple gas-bearing layers were identified based on interpretation and correlation of geophysical logs from the Roger Mills County, Oklahoma. Further calculation based on previous results indicated that a capillary sealing mechanism in the Anadarko Basin could produce approximately 0.9 x 10^{6} Pa of pressure. This figure represents pressure confined to only a single gas-water interface. The proposed model requires the presence of gas-bearing layers interbedded into shale/sandstone rock interfaces. If we determine that the presence of gas between interfaces is associated with high capillary pressures, then we can infer that a plausible cause of creating and maintaining the overpressures in the Anadarko Basin may be due to the capillary mechanism. Although the examples chosen for interpretation are from a an older sedimentary maintaining overpressure for millions of years, there is no impediment in extending research to younger sedimentary gas basins known to be overpressured. For example, modeling a gas detection system to explore the overpressurized Holocene sandstone gas-bearing layers in the Columbus Basin in Trinidad (Fig 5). Further research understanding of the capillary sealing mechanism in overpressure zones could likely lead to significant contributions in decreasing risks involved in exploring for natural gas in the Anadarko and other sedimentary gas basins around the world. The Eastern offshore sedimentary basins of Venezuela, Guyana, Suriname and Brazil also present exciting opportunity in the exploration for overpressure regimes and hydrocarbon/gas provinces.

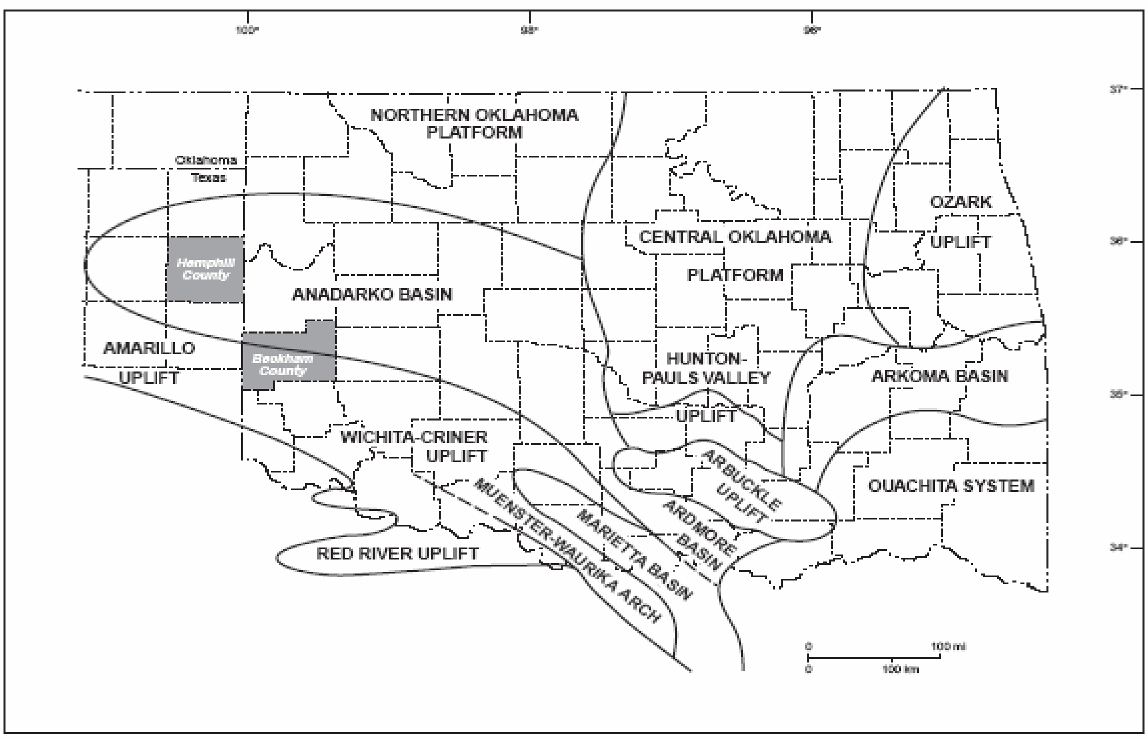

Figure 1.

Tectonic map showing location of the Anadarko Basin and major structural features of Oklahoma.

(after Arbenz, 1956; Al-Shaieb and Shelton, 1977; and Al-Shaieb et al., 1977a, b.)

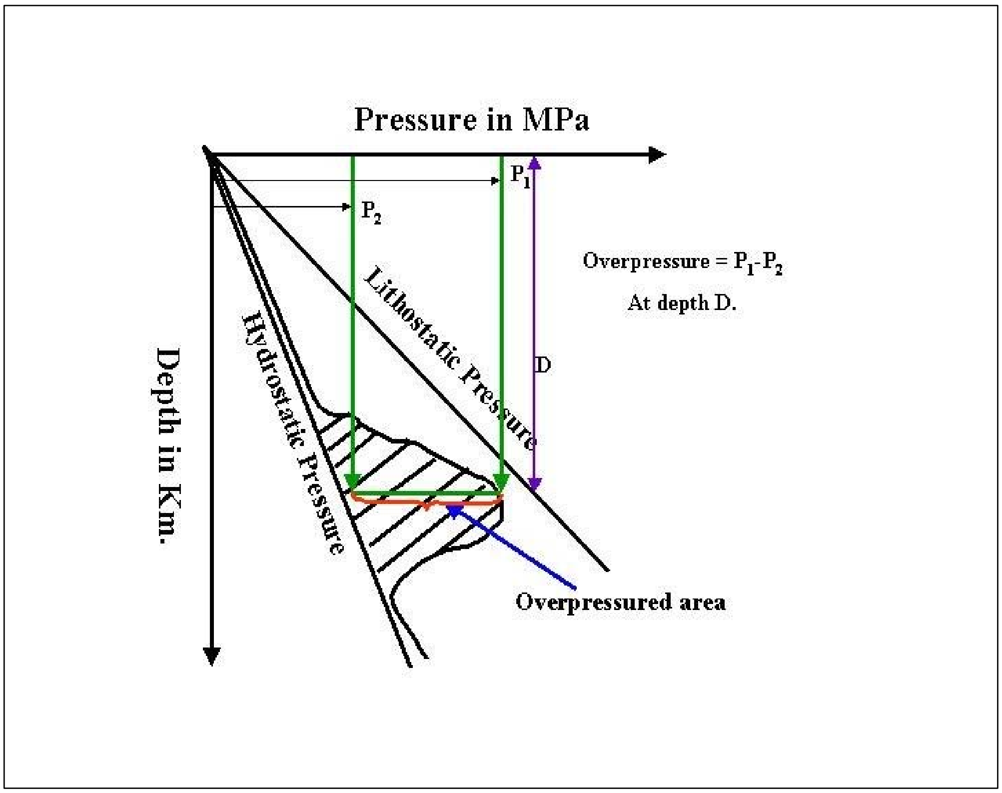

Figure 2

Pressure vs. depth plot. Rocks whose pressures plot between the hydrostatic and lithostatic gradients are termed “overpressured.” Modified from Osborne and Swarbrick (1998). The terms “overpressure,” “abnormal high-pressure” and “geopressure” are commonly applied to describe a geological phenomenon in which anomalous subsurface pressures are higher than the normal pressure. Generally, geopressure regimes can be found at depths greater than 2500m (8200ft) in young and old sedimentary basins throughout the world (Fertl 1976; Hunt 1990; Bigelow 1994, Neuzil, 1995).

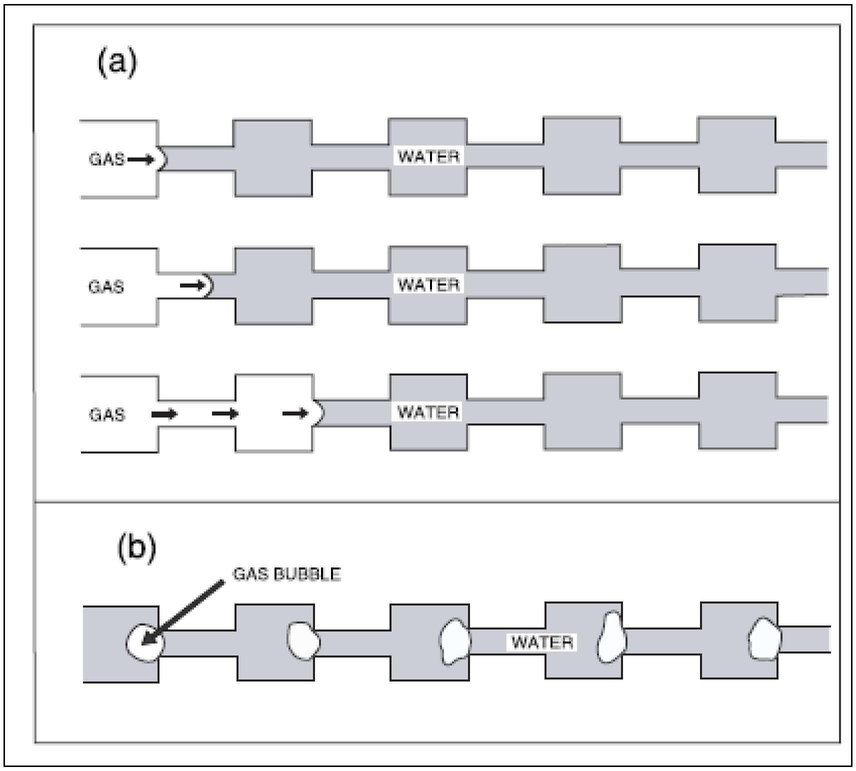

Figure 3: Conceptual models illustrating two types of capillary barriers.

In the first model (Fig 4.1, a) the system is initially water- saturated. Gas invades the system from the left and displaces water from the large pore throat. Once gas pressure is large enough to displace the wetting phase (water) from the smaller pore throat, the entire system will be invaded. In this model, the sealing capacity is equal to the capillary sealing pressure generated in one gas-water interface. In the second model (Fig 4.2, b) a gas bubble is forced out of small-diameter shale pores by capillary pressures and is trapped near the entrance of each pore throat. Capillary forces exist because there is an attractive force between pore walls and water. For water to move through the system, water must be removed from all the pores. The pressure necessary to move water through this system is equal to the sum of all the individual capillary pressures at each interface.

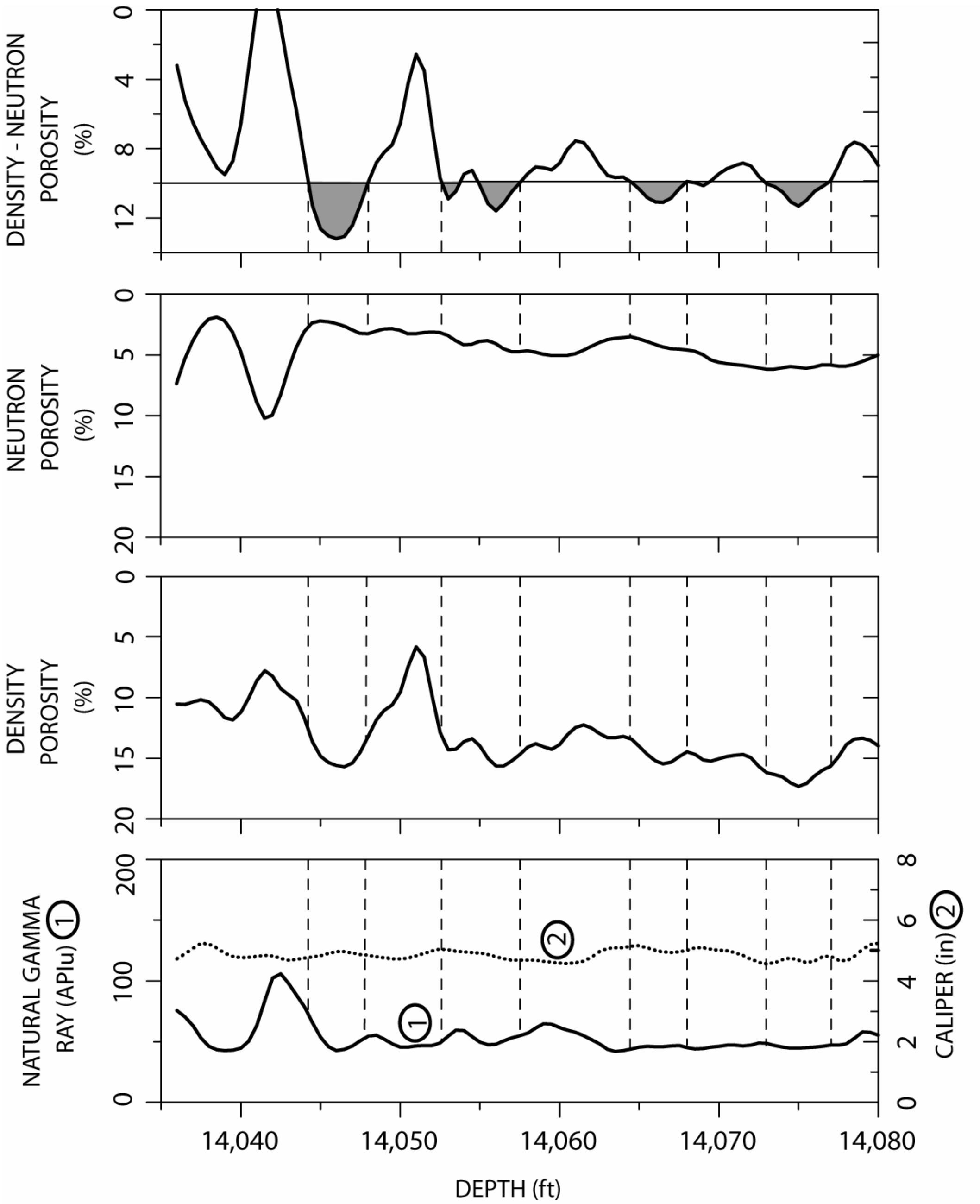

Figure 4.

Well logs from Wesner 2-1 well, Sec. 1, T 12N, R 22W, Roger Mills County, OK

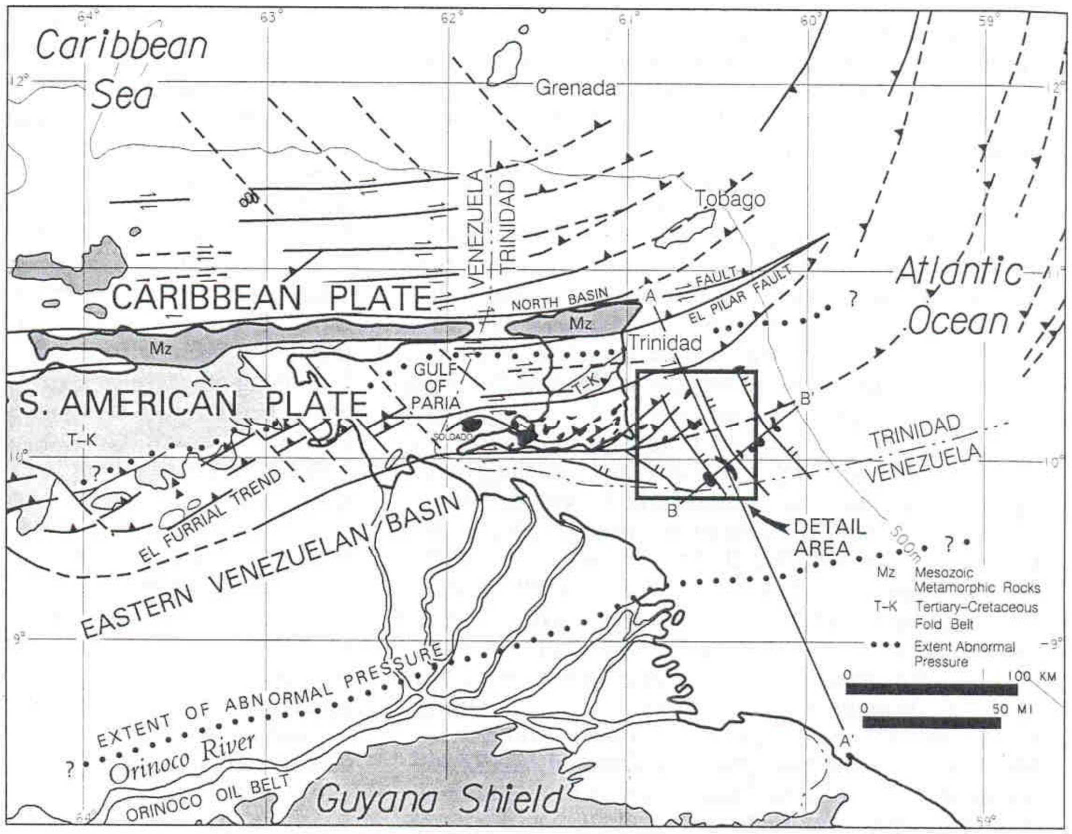

Figure 5

Overpressure region the Southeastern Columbus Basin, Trinidad. After Heppard et al. 1998.

Heppard et al. (1998) suggested that overpressures in sedimentary basins were the result of compaction disequilibrium. They proposed that the abnormal pressures present in the Tertiary to Upper Cretaceous rocks of the Columbus basin resulted from the transfer of overburden stress to the pore system during rapid subsistence and infilling of the foredeep basin during the Miocene and Pliocene Periods.

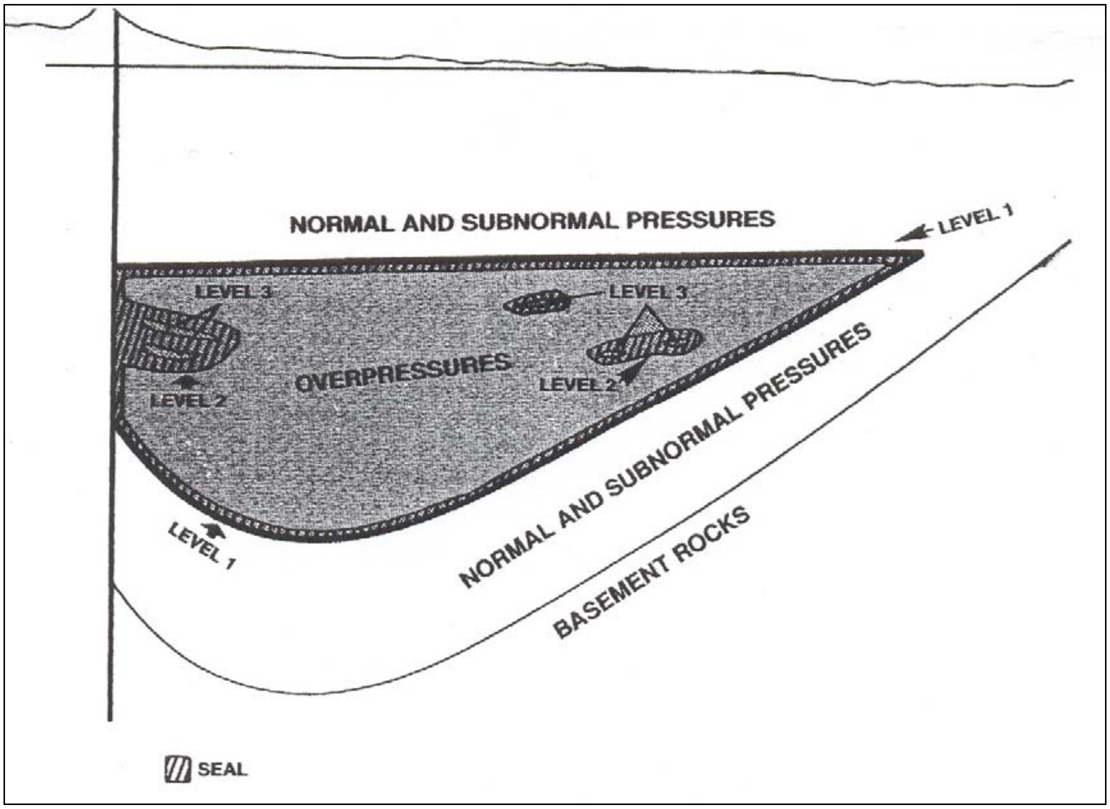

Figure 6

Three levels of distinct overpressurized fluid compartments within the Anadarko Basin. After Al-Shaieb et al. (1994a).The model diagram suggests the existence of three levels of distinct overpressurized fluid compartments within the Anadarko basin. Subsequently, the term "megacompartment complex (MCC)" was introduced to describe the entire volume occupied by pressurized "areas" or "zones" where the fluid pressures exceeded hydrostatic pressure within the Anadarko basin (Fig 3.3) . Cathles (2001) supported this model presented by Al-Shaieb and his co-workers when he described the Anadarko basin as possessing "a complex honeycomb structure of overpressuring." According to Al Shieb t hese overpressure zones generally start at a depth of approx 2.3-3.0 km and extend down to the top of the Woodford Shale, whose depth ranges between 2.5 and 6 km.