Meek, Reed H., XTO Energy, Fort Worth, TX ; Jeffrey R. Levine, Consultant Geologist Richardson, TX

Delineation of Four "Type Producing Areas" (TPAs) in the Fruitland Coal Bed Gas Field, New Mexico and Colorado, Using Production History Data

The Fruitland Coal gas field is a continuous-type hydrocarbon accumulation covering more than 3,300 mi^2 in the San Juan Basin. Cumulative hydrocarbon production through 2004 was >11.4 tcf (gas) and >239,000 bbl (oil) from more than 5517 wells. Cumulative production from individual wells is highly variable: <1 mmcf to >43,000 mmcf (gas); 0 to 21,000 bbl (oil), and 0 to 7 million bbl (water). Individual well peak gas rates range from <100 MCFGD to >20,000 MCFGD. Four NW-SE trending "type producing areas" (TPAs) can be delineated within the field, based upon similarities in reservoir characteristics and production behavior, which are broadly consistent within each TPA, but change dramatically across three internal field boundaries which separate the TPAs (figure 1). Production parameters useful for delineating the TPAs and their boundaries include cumulative gas production (figure 1), peak gas producing rate, current gas producing rate, cumulative water production, gas to water ratio, composition of produced gas (figure 2) , and cumulative oil production (figure 7).

Within each TPA, wells tend to exhibit certain distinctive characteristics in their production behavior through time, as illustrated in the "Type Production History Curves" that have been developed using selected wells from each of the four areas (figures 3-6). Some key characteristics of the type curves and production from each TPA are:
TPA1: Initial Production: 150 MCFGD, 25 BWPD, Peak gas rate: 350 MCFGD, reached after 7 years of incline; Cum after 12 years: 1 BCFG, 37 mbbl (water); Gas/water ratio: >20; Gas quality: 900-1100 Btu.
TPA2: IP: 200 MCFGD, 0.2 BWPD; Gas rate declines rapidly then stabilizes at 75 MCFGD, low gas and water rates throughout well life; Cum after 12 years: 270 MMCFG, 1 mbbl (water); G/W ratio:>200. Gas quality: 1100-1300 Btu; low CO_2, some oil production. Many of these wells produce no water. Most of the wells (80%) reporting oil production are in this area.
TPA3: (a.k.a. "The High Rate Fairway") IP:1000 MCFGD, 275 BWPD; Gas rate inclines quickly, reaching a peak rate of 3700 MCFGD within 1 year; Water rate declines to 30 BWPD within 3 years; Cum after 12 years: 13 BCFG, 227 mbbl (water); G/W ratio: 20-200; Gas quality: 650-900 Btu, >10% CO_2.
TPA4: IP: 200 MCFGD, 250 BWPD; Peak gas rate of 700 MCFGD is attained after 12 years of incline; Cum after 12 years: 2.2 BCF, 845 mbbl (water); G/W ratio: <20; Gas quality: 900-1100 Btu.

Using these type profiles, each of the wells in the Fruitland Coal gas field was classified into one of these four type categories, based on its individual production history. A color-coded map showing the distribution of wells in each category aids in the delineation of the TPA boundaries (Figure 8). Companies operating gas production wells in the field have used different drilling, completion, and operation methods to optimize production, dependent upon the reservoir characteristics of the portion of the field in which the well is located.

Variations in production behavior can be linked to underlying geological controls, especially thermal maturity, coal thickness, organic petrology, and hydrodynamics. These variables affect many of the primary characteristics of the reservoir, such as hydrocarbon (oil and gas) content and composition, fluid pressure, isotherm shape, water saturation, and cleat permeability. Interpretation of these interrelationships is complex, as the effects of multiple controls may be overprinted at any given location. Thermal maturity clearly has the greatest impact on reservoir quality. Coal rank increases from south to north, ranging from 0.45 $R_{o,vit}$ (subA) in TPA1 to 1.6 $R_{o,vit}$ (mv) in TPA4. The highest gas production rates occur within TPA3 (a.k.a. "The High Rate Fairway"). The sinuous, but sharp southern boundary of TPA3 (B2/3) is associated with a coal rank transition occurring around 0.75 – 0.80% $R_{o,vit}$. South of B2/3 (within TPA2) the reservoir is underpressured, permeability and production rates are low, and wells produce wet gases (rich in C_{2+}) with little or no water. Most of the wells that report oil production from the Fruitland Coal are

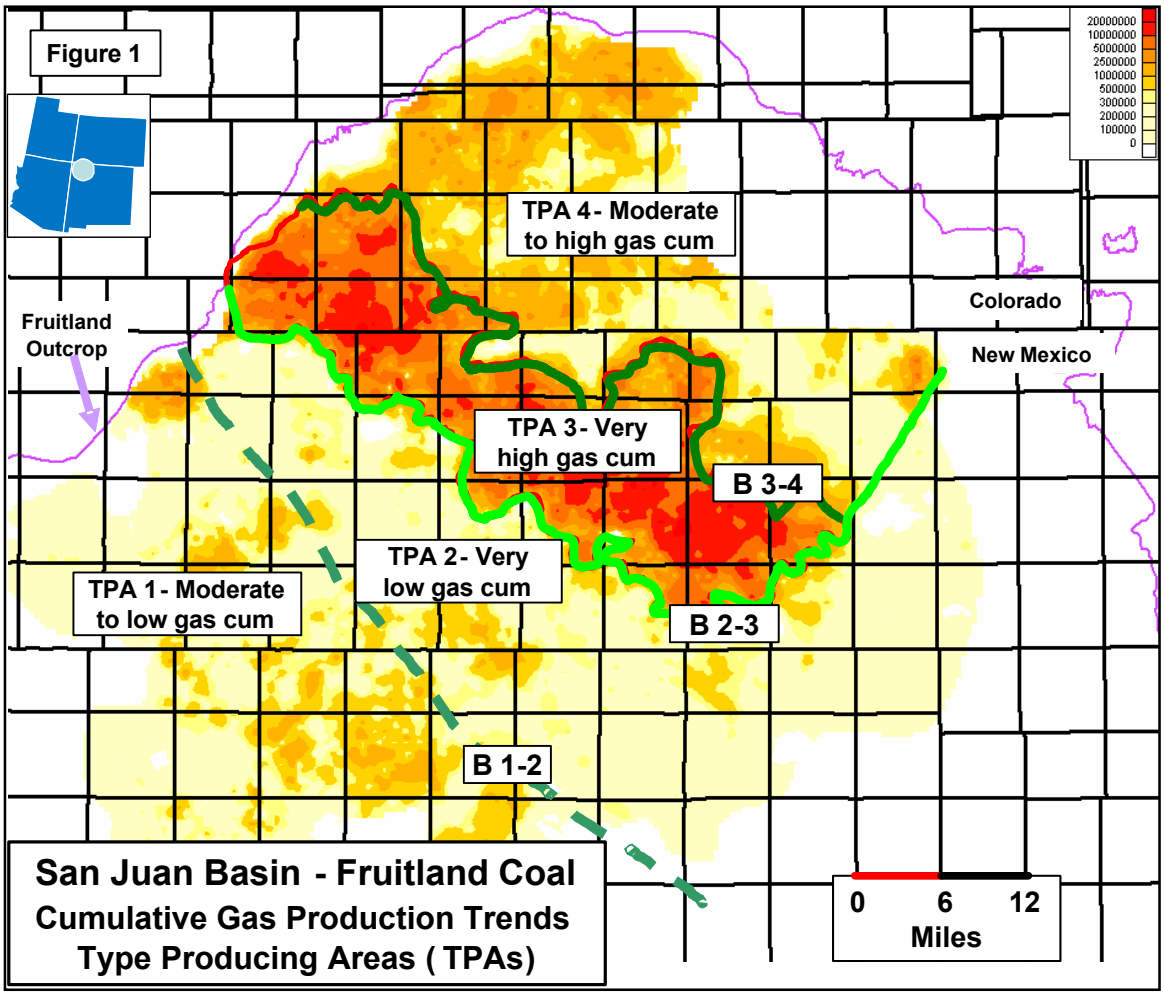
also located in this area (figure 7). North of B2/3 (within TPA3) the reservoir is overpressured (although now depleted in many areas), permeability is high, and wells produce dry CH_4 together with up to10% (or more) CO_2, and large volumes of water. Peak gas rates increase 10-100X across the B2/3 boundary. Overpressuring within TPA3 has been interpreted as a relict of thermal maturation and hydrocarbon generation (Meek et. al., 1993).

Boundary B1/2 may also be related to maturity, but if so, the effect is more subtle. The location of B1/2 is less sharp than B2/3, but is roughly coincident with a 0.60% $R_{o,vit}$ contour, which corresponds approximately to the entry of coal into the window of oil expulsion. The presence of a distinct oil phase in the fracture network in TPA2 may impede the flow of gas and water to the production well, which could account for the generally low gas production rates. Moreover, occluded oil in the organic matrix suppresses the methane sorption capacity, which decreases gas content (Levine, 1991). Gas and water production rates tend to be significantly higher in TPA1 than TPA2 indicating higher permeability.

Coal thickness trends and the stratigraphic pinchout of major coal seams in the lower Fruitland have a strong impact on B3/4. A protracted stillstand of the Pictured Cliffs shoreline in the predominantly regressive facies sequence resulted in a vertical aggradation of the beach and marginal marine sands (Pictured Cliffs Fm.) and associated back-barrier peat-forming environments (Fruitland Fm.) near B3/4 (Fassett, 2001). Toward the southwest, on the landward side of B3/4, the net coal isopach reaches its greatest value in the basin, ~80-100 feet. Northeast of B3/4, the net coal isopach thins dramatically, due to the seaward pinchout of several major coal seams in the lower part of the Fruitland Formation. Stratigraphic pinchout of the lower Fruitland Coals is interpreted as the primary control on the B3/4 boundary.

The influence of hydrogeology is greatest in TPA4, but is minor elsewhere. Wells in TPA4 have very low gas to water ratios, many being less than 1 (mcf of gas per bbl water). Some of the wells near the coal outcrop have produced over 6 million barrels of water and have g/w ratios as low as 0.2. The proximity of these wells to the outcrop and their very long dewatering times indicates that there is a probable connection of the coal gas reservoir to the outcrop where meteoric recharge is taking place. Published water chemistry data support a meteoric recharge model for coals in TPA4 (Kaiser et al, 1990). Wells in TPA3 dewater relatively quickly and, based on production history data, appear to be hydrologically isolated from TPA4. B3/4 is inferred to be a hydrodynamic boundary that isolates the lower Fruitland coals in TPA3 from the coals in the northern part of the field and therefore from connection to the recharging aquifer.

Structural geology has little discernable influence on reservoir behavior in the Fruitland Coal Field, except along the northwestern basin margin, where beds are dipping at high angles toward the basin center. Previously published interpretations that gas production rates are influenced by tectonically induced fracture trends, hingelines, or other structural features are difficult to substantiate. Although other authors have implied that regional production trends may be influenced by structural features none have convincingly made the case. Stratigraphic variations, including coal rank related variations, and coal thickness trends created during deposition appear to be the primary controls on the regional scale production trends.



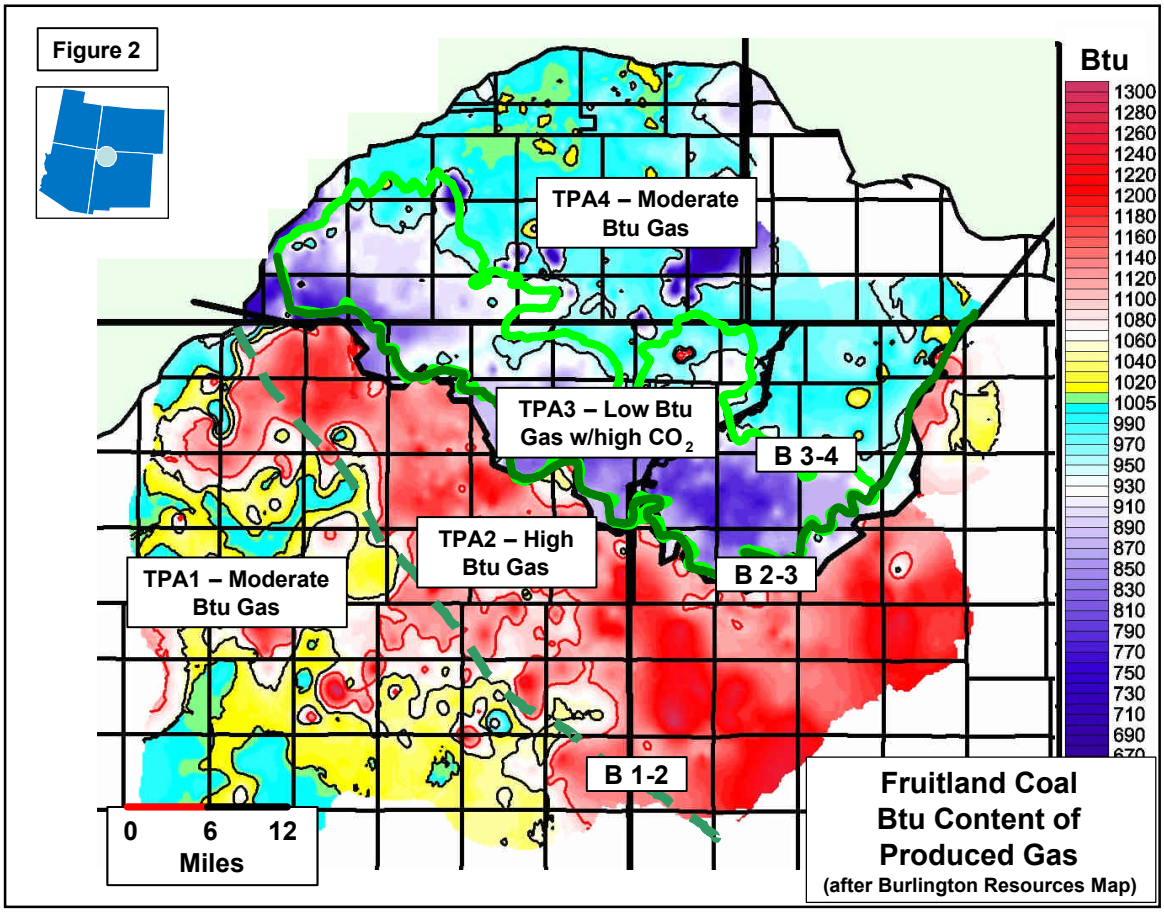


Figure 3

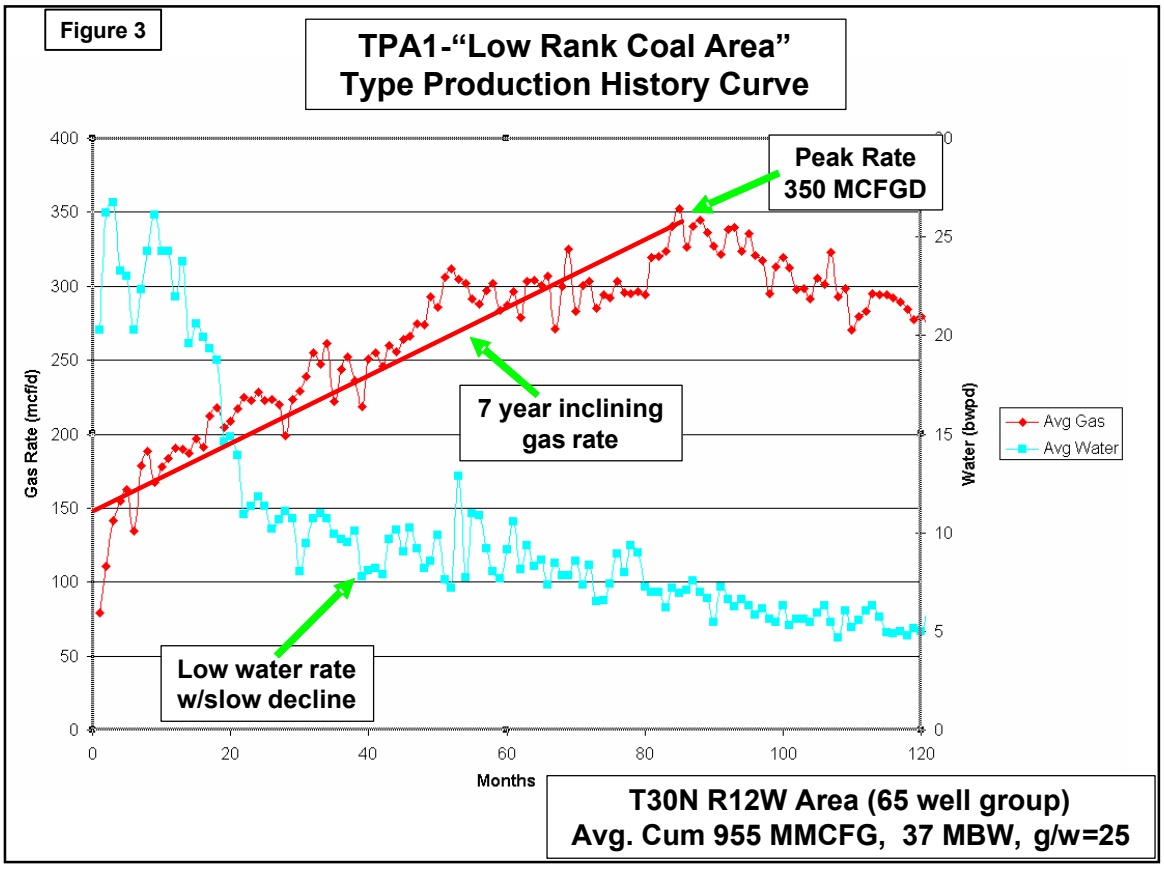


Figure 4

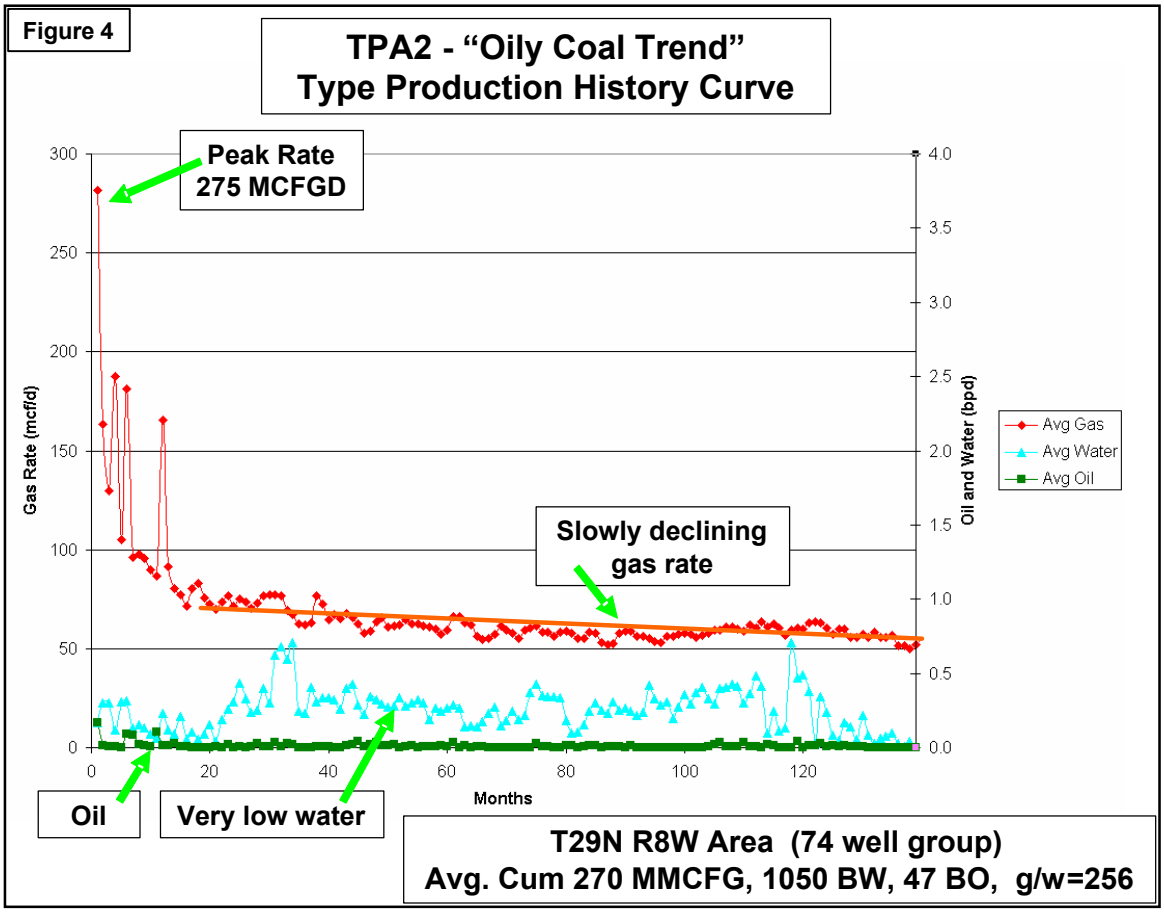


Figure 5

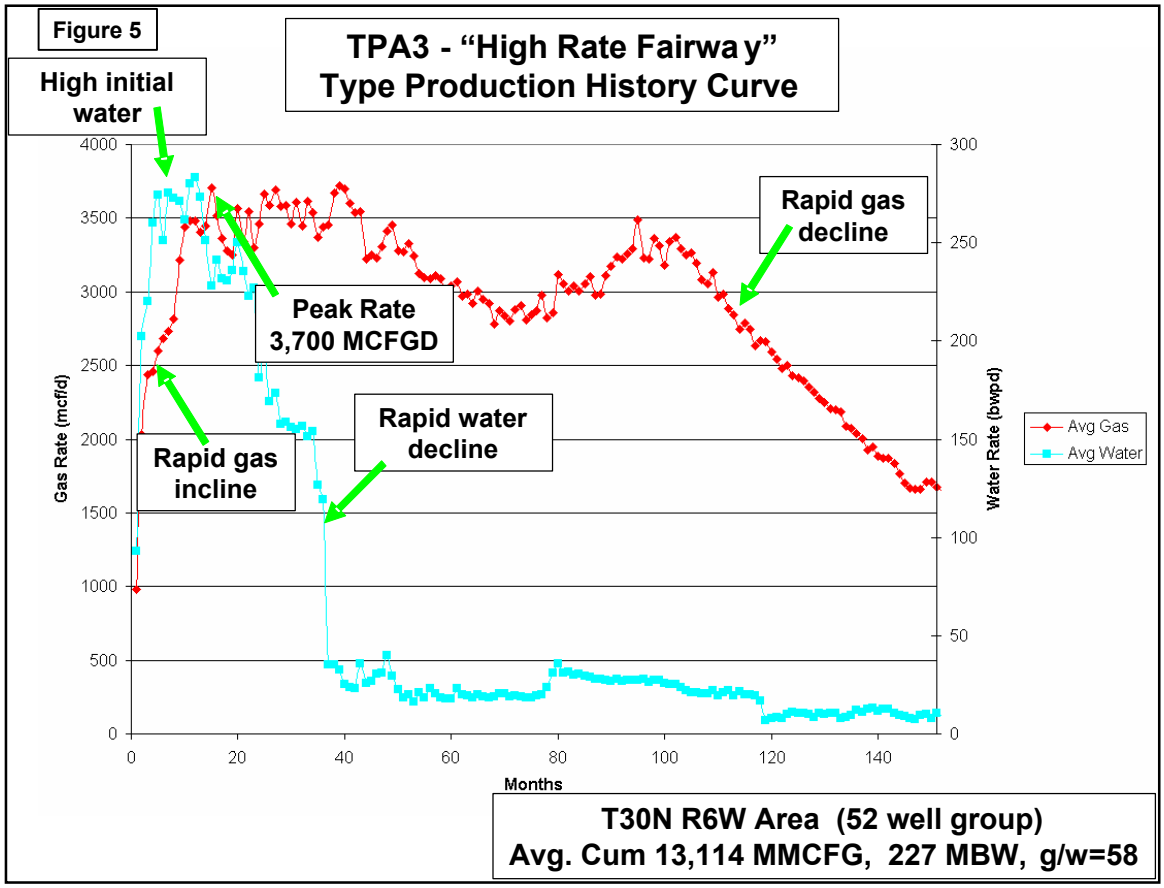


Figure 6