Abnormally High Geothermal Gradients in the Cherokee Basin, Southeastern Kansas, USA

K. David Newell and Daniel F. Merriam

Kansas Geological Survey, University of Kansas, Lawrence, KS 66047-2736, dnewell@kgs.ku.edu; 785-864-2183

ABSTRACT

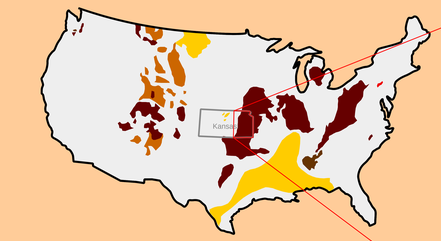
The Cherokee Basin in southeastern Kansas is a shallow northward extension of the Arkoma Basin in Oklahoma. It is an asymmetric cratonic basin where strata on its eastern flank dip gently west-northwestward at a rate of 4 m per km. The maximum sedimentary thickness is about 1100 m. The western flank is steeply dipping and faulted due to late-Mississippian--early-Pennsylvanian structural movement associated with the south-southwestward plunging Nemaha Uplift.

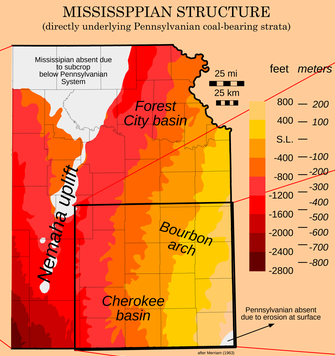
Approximately 2200 temperature logs were obtained by drilling for coalbed methane (CBM) in the Cherokee Basin in the last 15 years. These wells were mostly air-drilled and targeted several thin coal seams in the Pennsylvanian Series at depths from 250 to 375 m. Each well was drilled in about 1 day and formation waters would then quickly fill the hole before logging. TDs are usually in Mississippian limestones lying unconformably underneath the Pennsylvanian siliciclastics. The temperature profile in the well logs markedly increases at the basal Pennsylvanian unconformity, then gradually increases in to deeper strata. This suggests that relatively thick Pennsylvanian shales have low thermal conductivity, and thus act as a thermal blanket.

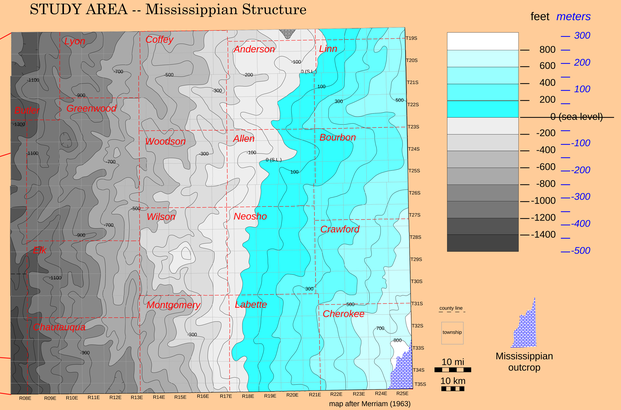
Thermal mapping based on the temperature logs define regions, 750-1000 sq.-km in area, that have, for example, 30 deg C fm. T at 300 m depth, which translates to geothermal gradients of ~50 deg C/km. The source of the anomalous heat is conjectured to be radioactivity in the Precambrian crystalline basement complex and possibly northward movement of heated water out of the Arkoma Basin. The temperature anomalies are also manifest by higher ranks of coal in southeastern Kansas as compared to lower-rank coals at similar depth in the Forest City Basin in northeastern Kansas.

The close spacing of the temperature logs (as many as 100 per 36-sq.-mile [93-sq.-km] township) allows for detailed temperature mapping. Formation temperatures derived from the temperature logs are also less variable than that derived by bottom-hole temperatures from earlier oil and gas drilling, hence these thermal anomalies have gone largely undetected until the region was intensely explored for CBM. The thermal anomalies likely extend in to southwestern Missouri and northeastern Oklahoma.

GEOLOGIC SETTING







Kansas is in the stable Midcontinent of the United States. In eastern Kansas, Paleozoic sedimentary rocks, approximately 2000 to 2500 ft thick (600 - 750 m) overlie Precambrian cratonic basement. Eastern Kansas is underlain by two shallow basins -- the Forest City Basin in the northeastern part of the state and the Cherokee Basin in the southeast.

The Cherokee and Forest City basins have shallow eastern flanks with strata that onlap the Ozark dome in south-central Missouri. The western flanks of these basins are steep and faulted against the Nemaha uplift. Dips of Pennsylvanian and Mississippian strata on the eastern flanks of both basins are very shallow -- on the order of 20 ft per mile (~4 m per km).

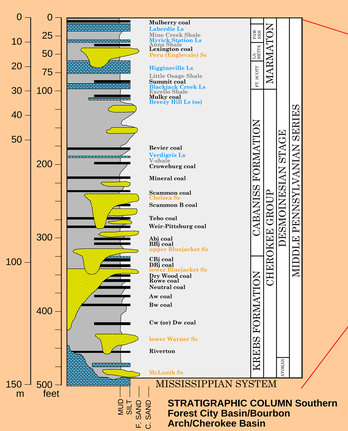
STRATIGRAPHY

Gently westward-dipping Pennsylvanian strata crop out at the surface in eastern Kansas. Coal-bearing Desmoinesian strata (Cherokee and Krebs Gps.) on the eastern flank of the basin are overlain by Missourian and Virgilian-age cyclothemic strata (Lansing-Kansas City and Shawnee Gps.) farther west.

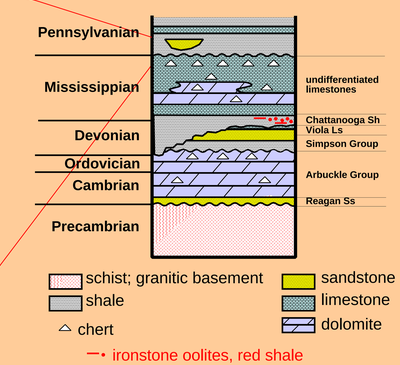
The coal has been the target for coalbed methane (CBM) development since 1998. The coal beds are between 800 and 1600 ft depth (250-500 m) and have cumulatively produced over 350 BCF of natural gas from approximately 7000 wells.

Most CBM wells TD in Mississippian limestone that unconformably underlies the coal-bearing strata. Disposal wells drill 200 to 400 ft (60-120 m) deeper into the top of the Cambrian-Ordovician Arbuckle Group, a regional salt-water aquifer composed mostly of vuggy and fractured dolomite.

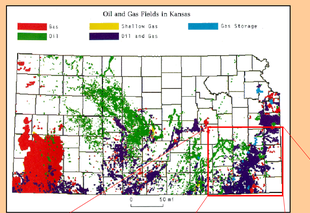
The Arbuckle Group is 700 to 1100 ft (200 - 325 m) thick. It lies on Precambrian basement, with only a few feet of intervening Cambrian Reagan Sandstone being locally present.

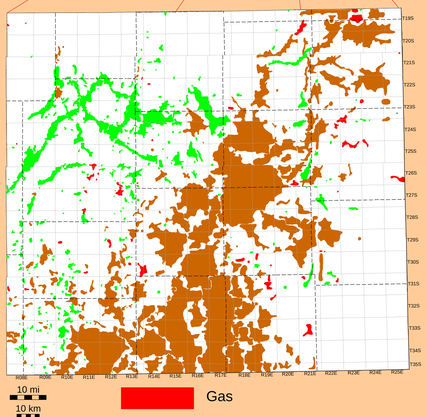


STRATIGRAPHIC COLUMN Southern Forest City Basin/Bourbon Arch/Cherokee Basin



OIL AND GAS PRODUCTION





Most oil and gas fields in the Cherokee Basin in southeastern Kansas were discovered prior to 1920. As such, it is a venerable producing area now dominated by stripper production. Coalbed methane (CBM) exploration and production (see next panel) in the last 15 years has revitalized the region. Pennsylvanian sheet and channel sandstones account for most of the production oil and gas production, but Mississippian limestones and Cambrian-Ordovician Arbuckle Dolomite account for localized production in the western parts of the study area.