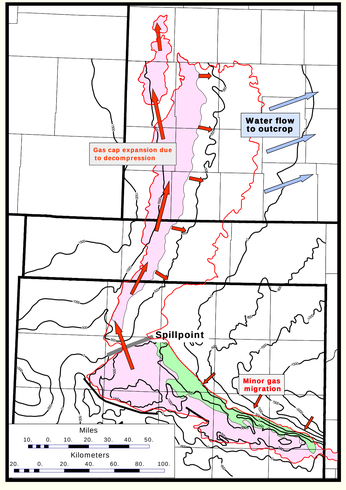
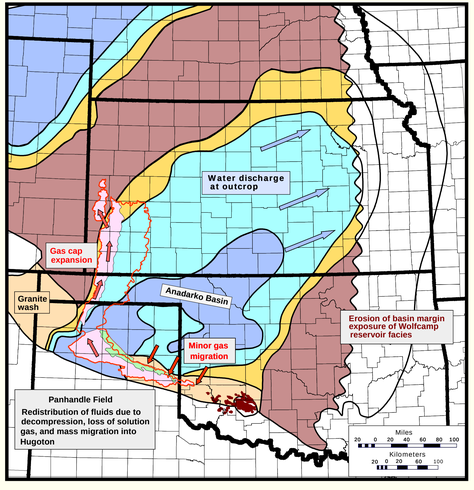
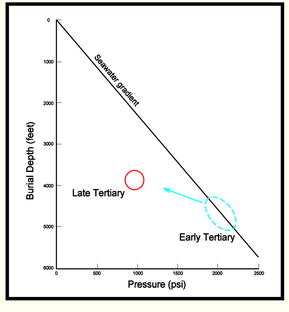
Anadarko Petroleum Corporation

LATE TERTIARY







LATE TERTIARY

Continued erosion along the margin of the Permian depositional basin in eastern Kansas began to expose the Wolfcampian reservoir carbonates.

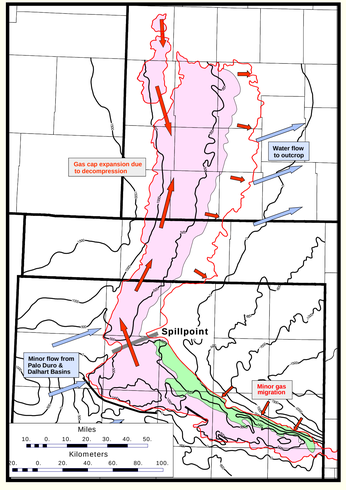
The regional Wolfcampian aquifer system was "uncorked", allowing water discharge at outcrop elevations much lower than the hydraulic head.

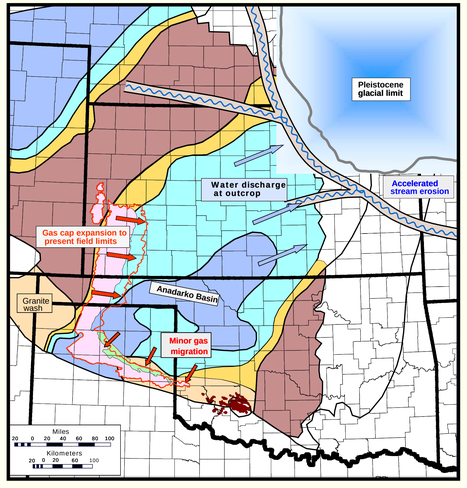
As water discharged from the system in eastern Kansas, the regional aquifer pressure dropped below 1000 psi, and the decompression caused a proportionate expansion of the Panhandle Field gas volume.

The Panhandle Field gas cap expanded beyond the spillpoint, flowed northward, and began to rapidly fill the Hugoton and associated gas fields.

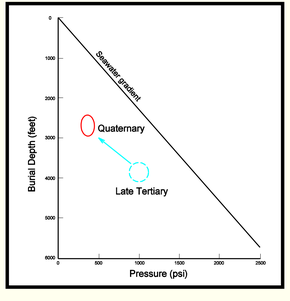
As the pressure continued to drop, the regional aquifer's dissolved gas would have been liberated and pushed to the updip reservoir limits by the expanding gas front, providing the source of the nitrogen-rich, low-BTU gas found along the northern and western margins of Hugoton.

QUATERNARY





Glacial geology after Frye & Leonard (1952)



QUATERNARY

Continental glaciers reached the Permian outcrops in northeastern Kansas, and, coupled with radically increased water flow in local streams and rivers, caused accelerated erosion rates and outcrop exposure for Wolfcampian reservoir carbonates

The regional Wolfcampian aquifer reached a normal hydraulic pressure gradient relative to discharge areas, at outcrops with surface elevations of 950-1000 feet

As the Panhandle-Hugoton reservoir pressure dropped to its discovery value of 435 psi @ subsea depths of +100 feet, the gas cap continued to expand in proportion, displacing approximately 500,000,000,000 barrels of aquifer water and filling Hugoton and other field areas to their current limits

CONCLUSIONS

Accumulation of hydrocarbons in Amarillo Uplift drape structures of the Panhandle Field began during the Permian, and continued throughout the Mesozoic. Primary migration was southward from the deep Anadarko Basin, up bounding faults and Permian-Pennsylvanian alluvial fans.

Prior to the Early Tertiary Laramide orogeny, the Wolfcampian reservoir pressure was normal relative to burial depth (1500-2500 psi at 4-6000 feet). The giant structural traps of the Panhandle Field were large enough to hold, at that pressure, all of the gas now found in Midcontinent Permian reservoirs.

Following Laramide uplift and tilting, erosion in eastern Kansas exposed Wolfcampian carbonates, allowing communication of the regional aquifer with the surface. Much of this erosion took place during the Quaternary, when the present outcrop belt was near the southern limit of continental glaciation.

The Panhandle-Hugoton Field reservoir pressure is now controlled by aquifer discharge to outcrops of Wolfcampian reservoir carbonates in eastern Kansas, at elevations much lower than the surface elevations in the vicinity of the producing field. The discovery reservoir pressure (435 psi at +100 feet subsea) was normal relative to the outcrop discharge elevation of 950-1000 feet.

The 3 to 5-fold post-Laramide drop in reservoir pressure caused a proportional increase in gas volume. The gas expanded until it crossed the structural spillpoint from the Panhandle Field, and displaced more than 500,000,000,000 barrels of water as it filled the giant stratigraphic traps of the Hugoton Embayment.

Hubbert (1953, 1967) recognized the symptoms of dynamic fluid movement in the form of tilted fluid contacts and hydraulic head gradients, and attributed them to west-to-east hydrodynamic water flow, despite the absence of a significant updip aquifer. The Panhandle and Hugoton Fields do in fact have a dynamic component, but the driving force is the volumetric expansion of a supergiant gas accumulation and discharge of the displaced water at the reservoir outcrop.

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