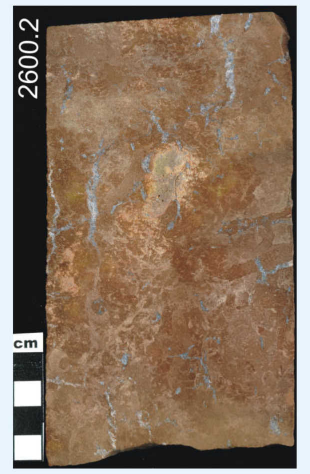
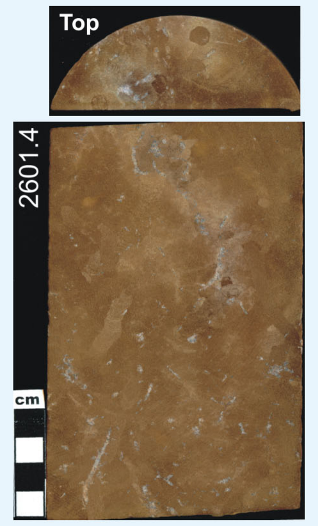
Biostabilization of eolian sediment

Samples from Cross H Cattle well

Root traces filled with anhydrite in burrowed, vfg sandstone. Note gray iron depletion zone enveloping rooted areas and darkened red band of hematite accumulation from surface water gleying.



Root traces filled with anhydrite and calcite cement rimmed rhizoliths in coarse siltstone. Network of fine root traces is well preserved; moderately burrowed.



Root traces filled with anhydrite in burrowed, vfg sandstone. Top view shows cylindrical form of root traces as well as cross section of burrow.

Stabilization Mechanism

We propose that the coarser eolian sediments were stabilized by vegetative cover and assisted by grain packing of burrowing organisms, probably insects. This allowed for aggradation of eolian siliciclastic sediments.

Evidence

- Root traces in coarse siltstones and sandstones
- Sufficient quantity to suggest vegetative cover
- Sandstone is heavily burrowed wherever it is preserved
- Plants and burrowing animals coexisted (cross-cutting relationships)

Mechanisms at play in accumulation of continental siliciclastics

1. Accumulation related to accommodation below sea level accounts for a small portion of the interval (tidal flat, marsh, salina and ephemeral lake deposits).
2. There is no evidence that siliciclastics are fluvial (alluvial) with accommodation produced by a rising equilibrium gradient over a low relief surface.
3. Though there is evidence of established water tables, the coarser eolian siliciclastics are not interpreted to have been stabilized by a rising water table associated with a rising sea level. Minor lake deposits may have been deposited because of rising water table from increasingly humid climates, or from sea-level rise.
4. Some of the coarser siliciclastics (interpreted as eolian) were stabilized by a rising water table associated with increased rainfall.
5. The majority of the coarse siliciclastics are eolian and accumulation was made possible through biostabilization by plants and animals.

Relative importance of mechanisms

Accumulation through accommodation below sea level (tidal flat, marsh, salina and ephemeral lake deposits) is approximately equal in thickness in updip and marginally downdip settings. Most of the coarser siliciclastics (very fine-grained sandstones and coarse-grained siltstones) were stabilized by plants and burrowing animals. These sediments account for approximately 50% of the volume at mid-shelf and 80% at the updip margin of the field where eolianites dominate.

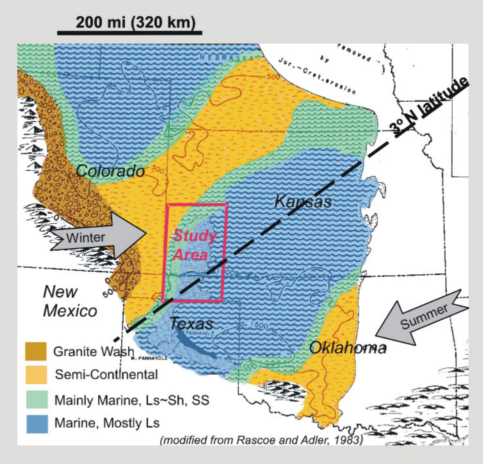
Factors influencing sediment supply, deposition, accommodation and stabilization

Climate

- Arid during glacial periods (low sea level) (Rankey,1997; Soreghan, 2002)
- More humid during interglacial periods (high sea level)
- Monsoonal precipitation patterns (dry winters, wetter summers)
- Prevailing winds from present-day west during winter and east during summer (Parrish and Patterson, 1988)

Geometry of shelf and forced sea level changes

- Extremely low relief, 30 meters from updip margin to position of steepened slope downdip; estimated by considering Wolfcamp isopach, position of marine carbonate pinchout and a faunal depth indicator (fusulinids)
- Rapid absolute sea level changes (forced) due to glacial cycles.



Late Wolfcamp Paleogeography
(Rascoe and Adler, 1983)
Prevailing winds from Parish and Peterson, 1988
Wolfcamp latitude from Scotese, 2001

Proximity to probable siliciclastic source (Ancestral Rocky Mountains)

- 250 kilometers to western margin
- 330 kilometers to steepened slope marginal to the Anadarko Basin

End members of the cycles

Interglacial (low sea level)

- Continental conditions on the Kansas shelf
- Relatively high siliciclastic sediment supply
- Cg silts and vfg sands available from source due to arid conditions
- Monsoonal patterns (dry winters and wetter summers) and prevailing winds (present-day westerly in winter and easterly in summer) were synchronized for optimal sediment supply by wind and optimal biostabilization of eolian sediments.
- Wetter months supported at least intermittent vegetative cover, support for burrowing animals, soil moisture, intermittent mobile water (gleying) and high water tables

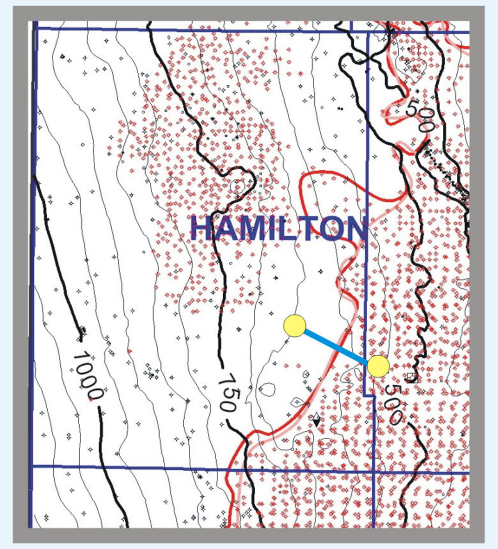
Glacial (high sea level)

- Marine conditions on Kansas shelf except in areas above updip margin
- Relatively low siliciclastic sediment supply
- Cg silts and vfg sands stabilized closer to source during more humid conditions
- Only fg silts and clay in low volumes were delivered to the Kansas shelf

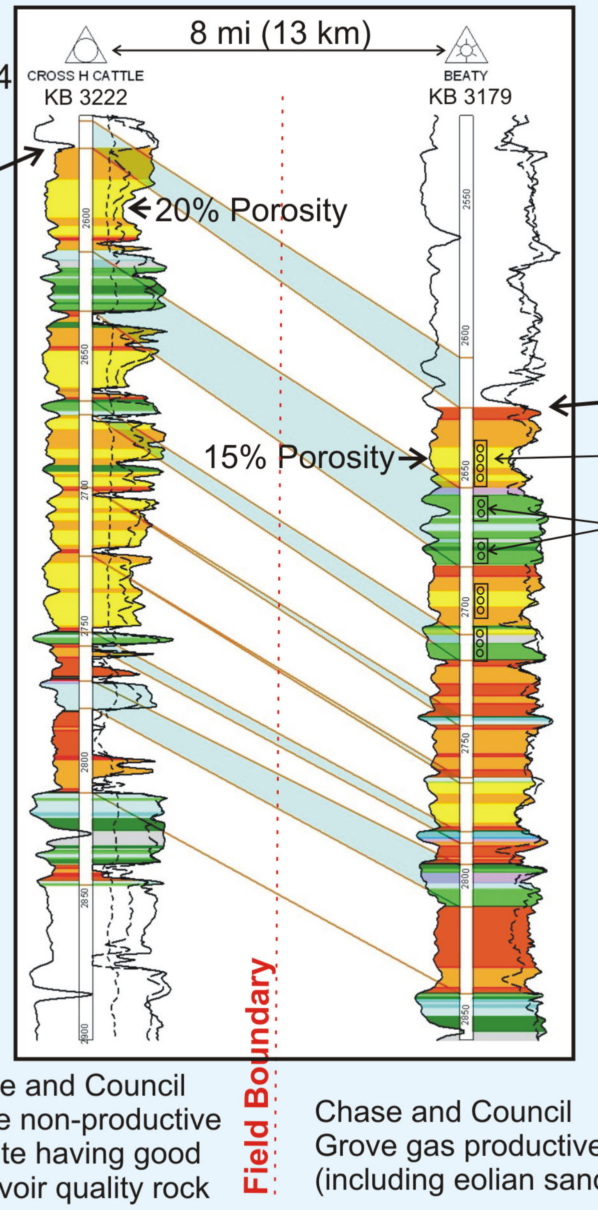
Continental redbeds may not be lateral seal for Hugoton and Panoma Fields

Two cored wells straddling the Panoma Field boundary show that though the margin is coincident with thinning or absence of the marine carbonates, continuous eolian sandstones with relatively high reservoir quality straddle the field boundary. These sands are gas pays in the field but in an updip position outside the field are non-productive and water bearing.

Council Grove structure (CI=50') shows continuous regional dip of approximately 10 feet per mile in 2-well cross section area.



Structural X-Section

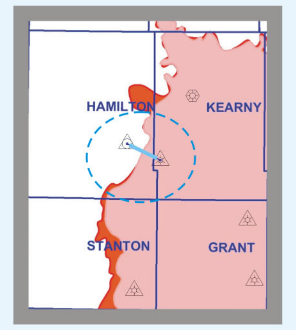


Gas Well
Perforations 2640-2718'
Acidized and fraced
AOF 8.4 mmcfpd (1974)
Cum. Prod. 1.5 BCF

Chase and Council Grove non-productive despite having good reservoir quality rock

Chase and Council Grove gas productive (including eolian sands)

Potential "pay" eolian sands in the Cross H Cattle well are nearly 100 feet updip from their positioni the Beaty well yet are not productive. Dip is regional and there are no indications of faults separating the two wells.



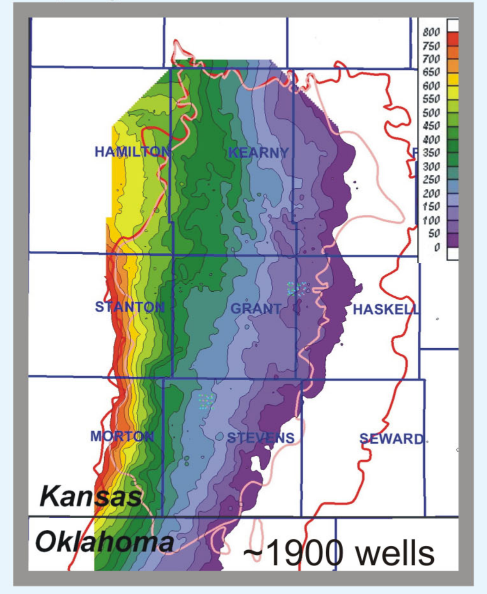
Gas Trapping Mechanism Questions Unresolved

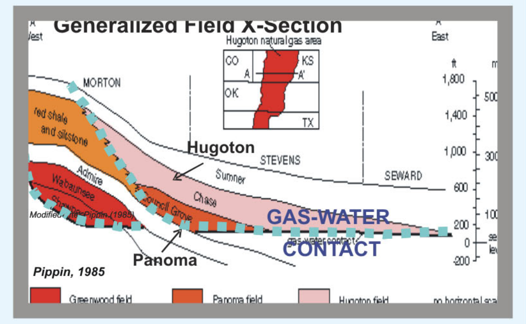
Earlier workers recognized that the Hugoton Gas-Water (G/W) contact is not constant and rises dramatically on the west edge of the field. Dubois and others (2004) suggested that the Chase and Council Grove have a common G/W contact *and* free water level (FWL) throughout most of the field and that the FWL is continuously sloped.

To explain the trap and sloped G/W contact, Hubbert (1953) invoked a hydraulic gradient connected to the Rocky Mountain front range and a permeability barrier at the field margin. Pippin (1970) cited Hubbert's work along with updip facies changes, and Olson (1997) invoked fault bounded compartments with separate, flat G/W contacts and updip facies changes for explaining the geometry.

Our work suggests that facies changes are not the trapping mechanisms in the continental sandstone reservoirs. Further work is needed to demonstrate that there are no physical barriers such as faults or capillary pressure differences that cause the phenomenon that we have observed.

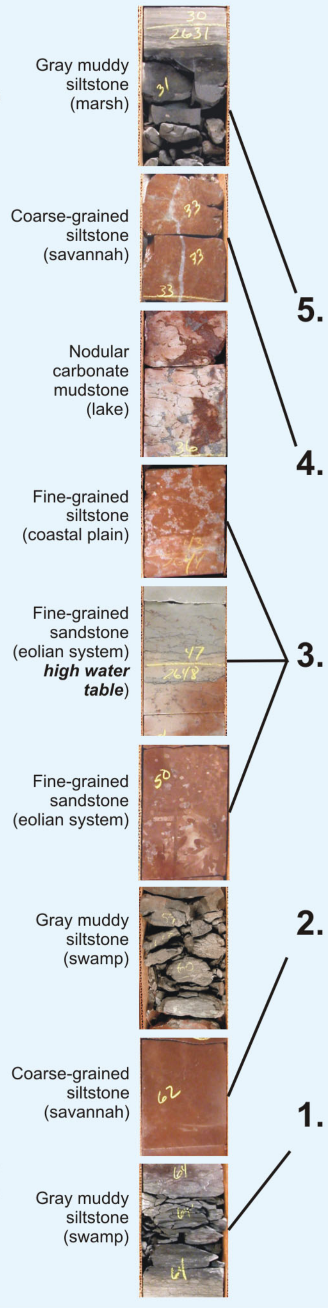
"Structure" on base of CGRV perforations, surrogate for sloping, contiuous G/W contact





Pippin's G/W contact

Accommodation and stabilization model for Council Grove continental sediments



5. **Muddy fine-grained siltstones deposited during a rising sea level** in shallow ponds marginal to the advancing shoreline. Low sediment volume due to relatively humid climate conditions resulted in thin deposits.

4. **Finer siliciclastics were again delivered by wind**, as in (2), above, and similar climatic and stabilization conditions prevailed as glaciers began to recede and sea level rose. Accommodation for modest amount of fine sediment may have been created by water tables tied to a rising sea level or increasing rainfall.

3. **Coarser siliciclastics delivered by wind** (air fall, silt-sized loess and saltated eolian sand) and stabilized by plants, animals and water tables associated with climate at low and rising sea-level position (glacial). High seasonal (winter) sediment supply due to more arid conditions and less stabilization a source. Sandstone deposition at updip margin represents the farthest east that saltating sands reached before being stabilized.

2. **Fg silts delivered by wind and stabilized by plants, animals and soil processes** in arid coastal plain setting during continued sea level fall. Silts may coarsen westward towards source. Low sediment volume due to relatively humid climate conditions or distance from source resulted in thin deposits.

1. **Muddy fg siltstones deposited during a falling sea leve**l in shallow ponds marginal to receding shoreline. Low sediment volume due to relatively humid climate conditions and dropping base level resulted in thin deposits.

Conclusions:

- Much continental siliciclastic accumulation in the Council Grove results from biostabilization (plant and animal-induced) rather than by accommodation related to sea-level rise
- Continental siliciclastics of eolian origin built relief that reduced accommodation for marine carbonates at the updip field margins
- Continental siliciclastics are not a lateral seal for the Panoma Field even though the field margin is coincident with pinchout of marine carbonates
- There is a predictable succession of continental lithofacies controlled by the interaction of climate, glaciation/deglaciation and sea level

Acknowledgements:

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