Contrasting Styles and Common Controls on Middle Mississippian and Upper Pennsylvanian Carbonate Platforms in the Upper Midcontinent, U.S.A.

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Importance/Implications

A goal of this poster is to demonstrate the importance of continuing reactivation of structural elements in shelf-shelf margin areas throughout the Paleozoic that impacted deposition and diagenesis and resultant reservoir properties. Continued recognition of the impact of these reactivated structures during Paleozoic deposition is improving our understanding and prediction of hydrocarbon pay in these reservoirs.

1. Structural reactivation is apparently common and leads to stacked pays at field scale and the coincidence of hydrocarbon plays.

2. True stratigraphic traps of economically producible hydrocarbons are probably fewer than believed and accordingly structural constraints set limits and additional guidelines for future resource play development and resource assessment.

3. Reservoir prediction necessarily involves factoring in complexities of linked structure, sedimentation, diagenesis, and post-depositional preservation of pore space.

4. Structural controls on reservoirs at all scales will be better modeled when strata are quantitatively characterized as mechanical units.

The relative roles of processes including deposition, diagenesis, and structure probably need to be refined to improve prediction of ever-decreasing field size in spite of the use of more efficient and effective technologies. Moreover, refined geologic models are necessary to keep up with technology.

Summary

Middle Mississippian Osagean

- Middle Mississippian Osagean shelf and shelf margin lithofacies dominated by heterozoan carbonates including sponge-spicule rich facies and early formation of chert
- Chert increases southward from nodules in shallow, restricted inner shelf areas to extensive, thick chert beds deposited on an open marine shelf margin
- Decameter-scale sequences are commonly delineated by glauconite beds and subaerial exposure
- Early to post-Mississippian subaerial exposure diagenesis resulted in additional sponge spicule dissolution, vuggy porosity in moldic-rich rocks, and autobrecciation

Middle and Upper Pennsylvanian carbonates

- Abundant photozoan carbonates
- Dominated by decameter-scale, unconformity-bounded sequences
- Deposited on a shallow inclined ramp and shelf margin
- Widespread oolite and grainstone shoals were commonly deposited
- Punctuated, high-frequency forced regressions where early subaerial exposure resulted in pervasive moldic lithofacies and paleosol development

Block Fault Movement

- Mississippian and Pennsylvanian carbonate settings were affected by block fault movement at a scale of 1-10's of km
- Deformation closely linked to reactivation of basement lineaments
- Block faulting influenced locations of shelf edges and caused segmentation of the ramp/shelf profile
- Distinct localized differences in lithofacies, thicknesses, and stratal architecture across segments
- Preferentially preserved, locus areas for thick accumulations of sponge spiculite and oolite reservoir deposits
- Topographic highs that were subjected to subaerial exposure
- Later meteoric water influx and possible basinal fluid migration are also closely associated with lineaments.
- Reactivation often leads to stacked pays at field scale and plays at regional level

Integrated geological, petrophysical, and geophysical studies are providing a clearer picture of the complex creation of hydrocarbon plays and the variable reservoir properties of each system.

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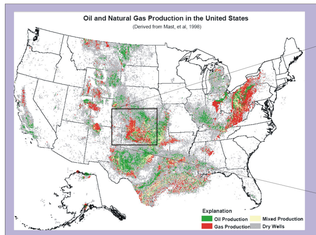
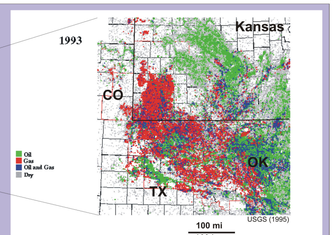
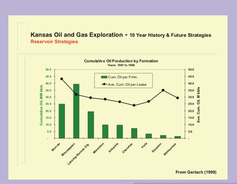
PETROLEUM GEOLOGY

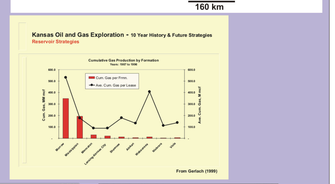
Northern Midcontinent - very mature oil and gas producing province

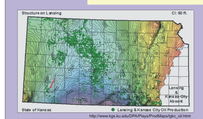
- 145 years production, over 350,000 wells drilled in Kansas.
- New technology and resurgence in product prices have revitalized the region
- Mississippian and Pennsylvanian reservoirs offer opportunities to recomplete existing wells and drill new wells.
- A dominant portion of cumulative oil and gas produced in the past decade in Kansas from Mississippian and Pennsylvanian carbonate reservoirs
- High productivity from numerous stacked zones and compartmentalization due to general stratigraphic trapping
- Horizons may contain remaining economic hydrocarbons due to the subtle stratigraphic nature of traps.



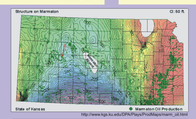




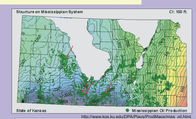




Structure map on top of the Lansing Group showing distribution of oil production from Upper Pennsylvanian Lansing and Kansas City Groups, predominantly cyclic, stacked carbonates. Production is focused on the Central Kansas Uplift. Arrows delineate field examples used in this paper.



Structure map on the top of the Marmaton Group showing the distribution of oil production from Middle Pennsylvanian Marmaton Group reservoirs. Production is widespread throughout much of Kansas. Arrows indicate field examples that are illustrated in this paper.



Structure map of the top of the Mississippian limestones showing oil production that surrounds the Central Kansas Uplift and the Nemaha Uplift, sites where the Mississippian carbonates were removed by erosion due to pre-Pennsylvanian lowstand in eustatic sea level that coincided with tectonic uplift of the shelf.

Stratigraphy

Well log depicting the stratigraphy of the intervals (highlighted) examined in this study that extends from the Upper Pennsylvanian Heebner Shale to the base of the Mississippian System

Generated using free interactive geo-engineering modeling software called *GEMINI* (www.kgs.ku.edu/GEMINI)

GEOLOGIC SETTING AND CONTROLS ON DEPOSITION

Paleogeography & Tectonic Setting

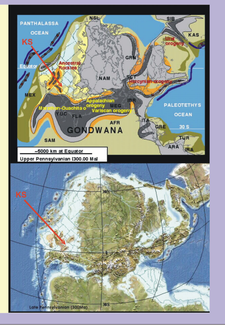
Mississippian Paleogeography

- Broad, low latitude Mississippian shelf
- Subtropical to tropical
- Convergent plate margin between Laurussia and Gondwana with significant potential sources of silica in island arcs; older and contemporaneous novaculites?

Map source: Blakey, Global Earth History Website

Late Pennsylvanian Paleogeography

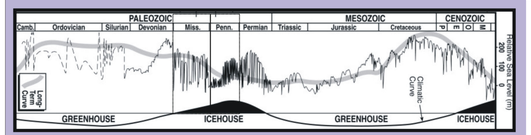
- Broad, low latitude Pennsylvanian shelf
- Subtropical to tropical
- Convergent plate margin between Laurussia and Gondwana
- Photozoan-dominated ramp in Midcontinent U.S.A.



Map source: Blakey, Global Earth History Website

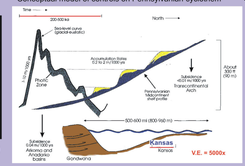
Sea-level History

Phanerozoic Sea Level Curve

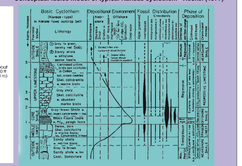


After Longman, M.W., and M.D. Sonnenfeld (1996)

Conceptual model of controls on Pennsylvanian cyclothem



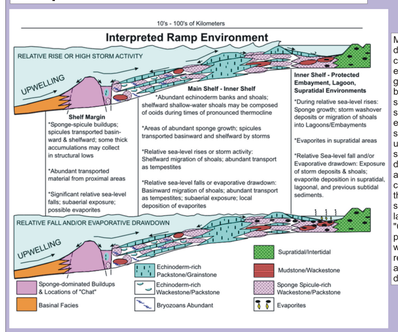
Conceptual facies model of typical Kansas cyclothem - Heckel (1977)



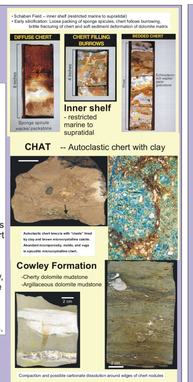
Onset of icehouse conditions started in lower Mississippian and continued through Pennsylvanian resulting in high-frequency sea-level oscillations.

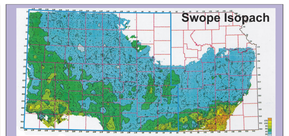
Higher frequency cycles are evident in the Mississippian, believed to be in part related to an episode of glacial eustacy. The Pennsylvanian is prominently punctuated by high frequency and high magnitude, 4th order cycles, expressed by the carbonate-dominated "Kansas Cyclothem" of Heckel (1977). The interaction of subsidence and sea-level changes and stillstands led to complex stacking patterns and shoal development affecting the resultant geometries of these reservoirs across the upper Midcontinent shelf.

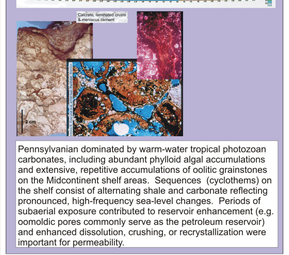
Depositional Environment



Mississippian (Osagean) dominated by heterozoan carbonates (e.g. echinoderms, bryozoa, gastropods, foraminifera, brachiopods, ostracods, solitary corals) and siliceous sponges, likely as a result of excess nutrients and silica supplied to the shelf through upwelling (see cartoon cross section). Facies are dolomitic, cherty dolomitic, and chert. The shelf margin is characterized by bedded chert thought to represent original sponge buildups that were later weathered to form the "Chat" reservoir facies (vuggy, porous, commonly permeable weathered chert). Favorable reservoir character in shelfal areas results from early dissolution and dolomitization.







Pennsylvanian dominated by warm-water tropical photozoan carbonates, including abundant phylloid algal accumulations and extensive, repetitive accumulations of oolitic grainstones on the Midcontinent shelf areas. Sequences (cyclothems) on the shelf consist of alternating shale and carbonate reflecting pronounced, high-frequency sea-level changes. Periods of subaerial exposure contributed to reservoir enhancement (e.g. oomoldic pores commonly serve as the petroleum reservoir) and enhanced dissolution, crushing, or recrystallization were important for permeability.

LEAD-IN TO REST OF POSTER

Mississippian and Pennsylvanian reservoir strata in the Midcontinent have been studied extensively, and the above documented controls are fairly well understood and have aided in production of these intervals. However, there are patterns, questions, and production problems that are still not fully understood. In addition to the above controls on reservoir character of these strata, our ongoing studies are indicate that local structures (e.g. faults, fractures, lineaments) that segmented these broad shelf and shelf-margin areas, and that were variously re-activated throughout the Paleozoic, are important elements that controlled depositional patterns, paleotopography, weathering intensity, and movement of fluids. The contribution of re-activated (and syn-depositional) structural elements to reservoir character are as critical as commonly thought of processes such as sea-level history and post-depositional tectonism.

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