Multiscale Geologic and Petrophysical Modeling of the Giant Hugoton Gas Field (Permian), Kansas and Oklahoma

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Hugoton Asset Management Project:

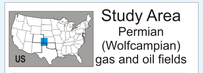
Collaborative, multi-disciplinary study of Hugoton field, supported by ten industry partners

Purpose:

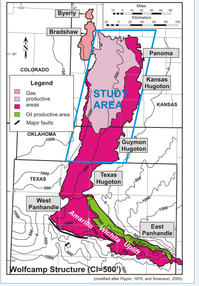
- **Develop comprehensive, field-wide geologic and engineering models**
- **Quantify, locate and characterize remaining gas**
- **Tools for improved reservoir management**

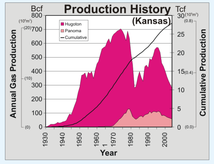
Field History:

- Largest gas field in North America. EUR 75 TCF (2.1 trillion m^3), Sorenson, 2005.
- Discovered 1922. Development after 1940 (Chase). Council Grove "discovered" 1958. Kansas Hugoton infill (Chase).
- Gas reserves: 34 TCF (963 billion m^3) of original 50 TCF (1416 billion m^3) produced Kansas/Oklahoma. Current annual ~300 BCF/yr.
- Chase (Hugoton) and Council Grove (Panoma) considered separate fields for regulatory purposes in Kansas. Maximum continuous gas column of 500 ft (165 m).
- Shallow: Top 2100-2800 ft deep (640-850 m). Productive range +100 ft (+30 m) to +1250 ft (+380 m) on (sloping gas/water contact and free water level).
- Initial wellhead SIP 437 psi (3013 kPa), Hemsell (1939).
- Dry gas, pressure depletion reservoir.
- 12,000 wells, 6200 mi^2 (16,000 km^3). 2.8 BCF per well.
- Wells per 640 acres: Kansas Hugoton-2, Panoma-1; Oklahoma Hugoton-1.



Study Area
Permian (Wolfcampian) gas and oil fields





Significance (beyond Hugoton)

- Importance of core lithofacies and associated properties where log-derived Sw is problematic.
- Benefits of pooling proprietary geologic and engineering data in settings with split ownership.
- Effective management techniques for vast and varied data.
- Example of high-resolution, full-field scale modeling of giant reservoir systems in a data-rich environment (108 Million cells, 26,000 km^2).
- Detailed three-dimensional view of thirteen stacked shoaling upward cycles on a gentle ramp in a cratonic setting.
- Analog for similar thinly layered reservoirs (e.g.: Permian basins, U.S.; Khuff Formation, Gwahar and North fields, Arabian Gulf).
- Insight and defined opportunities in differentially depleted, thinly layered reservoir systems.

Focus:

Definition and integration

- Core-defined lithofacies
- Core-derived petrophysical properties
- Wireline log response
- Estimation of reservoir properties

To characterize a giant reservoir system at the core-well-, and field-scale.

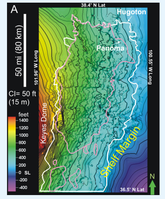
Core-defined lithofacies are to "train" neural networks to predict lithofacies at wells without core.

Geologic Setting

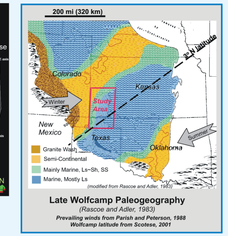
Hugoton and Panoma Fields are situated in the Hugoton Embayment, the shallow shelf portion of the Anadarko basin, and asymmetric foreland basin associated with the Ouchita-Marathon Orogeny.

By Wolfcamp time the Pennsylvanian-aged Anadarko was nearly completely filled and slopes on the Kansas shelf were extremely low.

Glacially driven eustatic sea level changes resulted in fourth order marine-continental (carbonate-siliciclastic) sedimentary cycles on the Kansas shelf during Wolfcamp.



(A) Present day structure on top of the Wolfcampian reservoir (top of Chase) is mostly a function of eastward tilt during the Laramide orogeny. Note the "shelf margin" or area of steepened slope at southeast margin of Hugoton field outline.
(B) 3-D view of the same area.Top of the Chase and base of Council Grove.



Isopach of the Wolfcampian from top of Chase to base of Grenola Limestone (Council Grove Group). Rate of thickening increases by a factor of ten at the "shelf margin." Dubois and Goldstein (2005) estimated the maximum relief across the Kansas portion of the shelf during Council Grove deposition to have been 100 feet (30 m) with a slope of approximately 1 ft/mi (0.2 m/km).

Stratigraphy

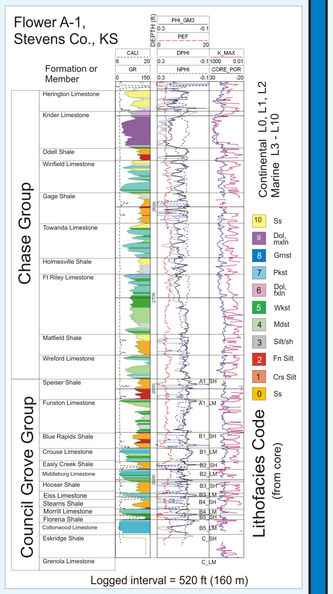
Twelve of the thirteen gas productive marine-continental (carbonate-siliciclastic) sedimentary cycles are illustrated (Grenola Ls, C_LM is not logged). Stratigraphic names that include "Limestone" are marine half cycles, when combined with an adjacent continental half-cycle, form a complete sedimentary cycle. In this paper, Hugoton is the combined Hugoton (Chase) and Panoma (Council Grove) in Kansas and Guymon-Hugoton (Chase) in Oklahoma.

Wireline log abbreviations:

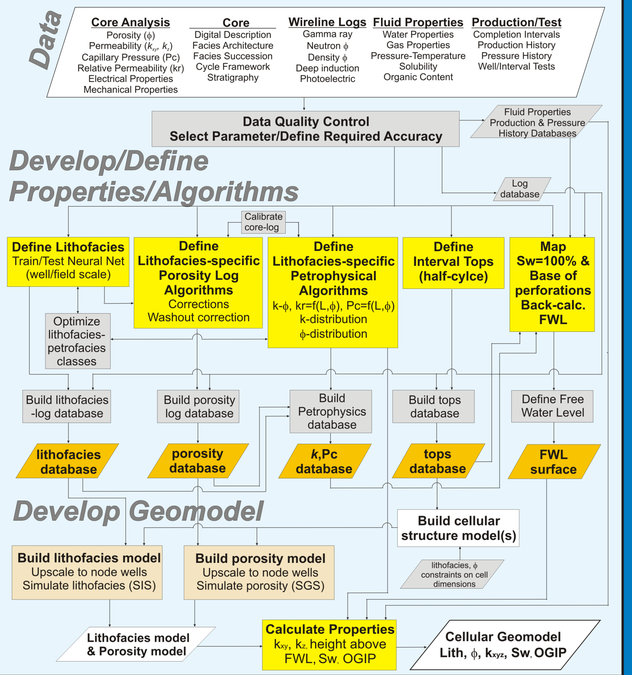
CALI	caliper
GR	gamma ray
PHI_GM3	corrected porosity
PEF	photoelectric effect
DPHI	density porosity
NPHI	neutron porosity
K_MAX	core permeability
CORE_POR	core porosity

SYSTEM	SERIES	GROUP	Kansas fields	Oklahoma field
Permian	Leonardian	Sumner		
	Wolfcampian	Chase	Hugoton-Panoma Byerly Bradshaw	Guymon-Hugoton
		Council Grove		
Pennsylvanian	Virgilian	Admire	Greenwood	
		Wabaunsee		
		Shawnee		

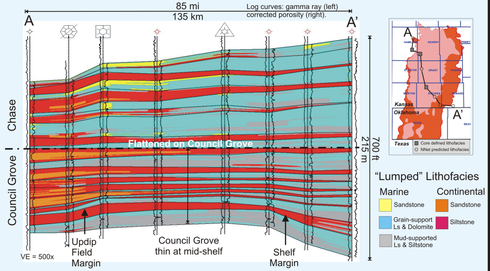
(compiled from Zeller, 1968; Pippin, 1970; Barrs et al., 1994; Merriam, 2006)



Model Development Workflow



Wolfcamp Stratigraphic cross-section

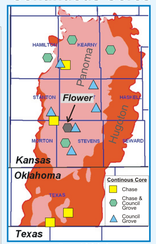


- Thickness of marine and continental units are nearly reciprocal.
- Marine sandstone prevalent in Chase near west updip margin.
- Council Grove is thinnest at a mid-field (mid-shelf) position.

Data

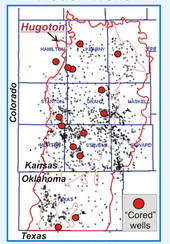
Cycle Framework:
Intervals were defined within a simple cyclic rather than a sequence stratigraphic framework. Existing formation or member tops are half-cycle boundaries between marine and continental intervals represent a sequence boundary and flooding surface. Since the transgressive system tract (flooding surface to maximum flooding) is relatively thin and consistent in the majority of the cycles, little is gained by correlation of an additional surface for sequence stratigraphic classification.

Continuous Cores



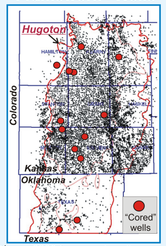
14 core wells: 4200 feet (1280 m) core-defined lithofacies and petrophysical properties related to lithofacies.

"Node" Wells



1364 node wells: Lithofacies at ½-foot (0.15 m) by neural networks or core and corrected log porosity. Formation/ member level (½-cycle) tops set.

"Framework" Wells



9200 framework wells: Tops set for 7 key horizons.