Reservoir Pressures Suggest Communication between Hugoton and Panoma Fields and Provide Insights on the Nature of the Connections

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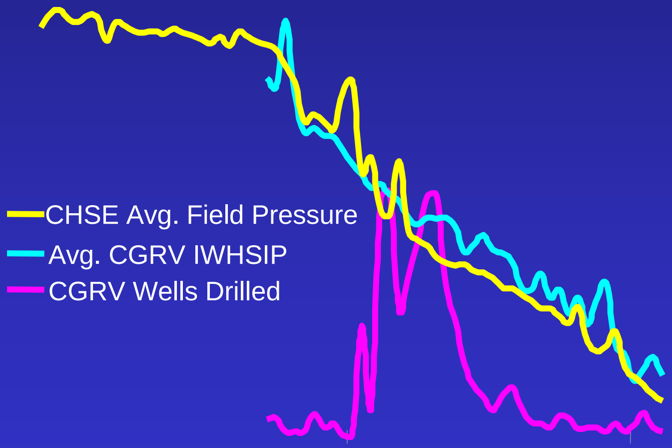
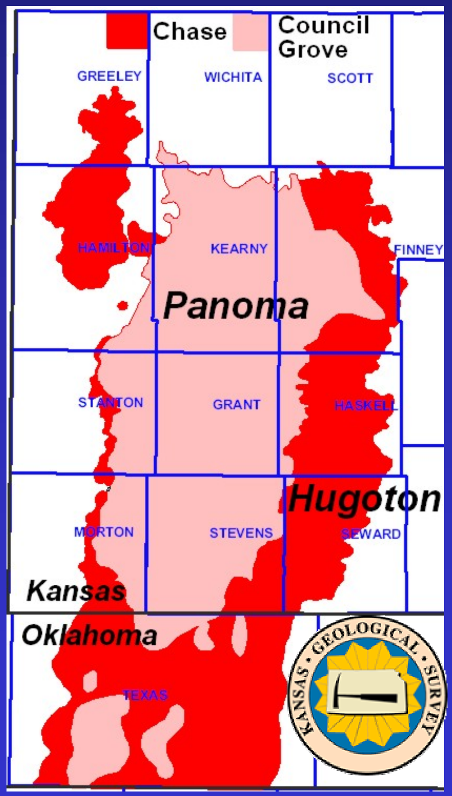
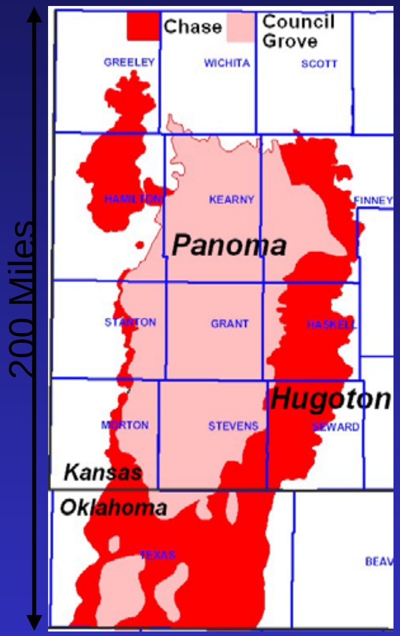




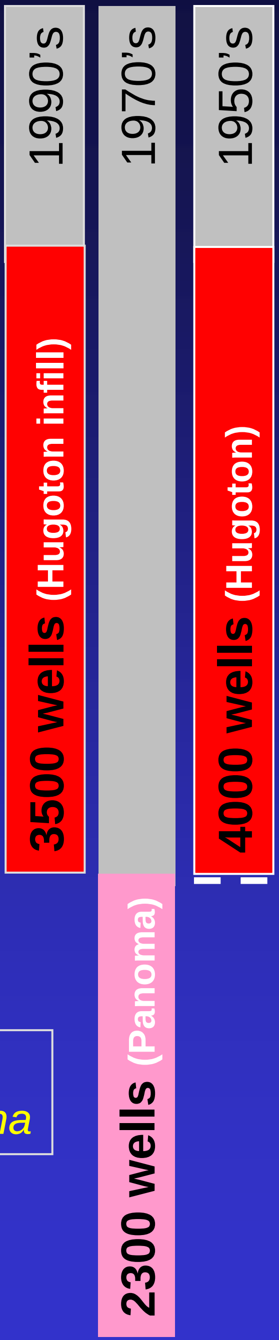
Midcontinent AAPG, Oklahoma City
September 13, 2005

http://www.kgs.ku.edu/HAMP/index.html

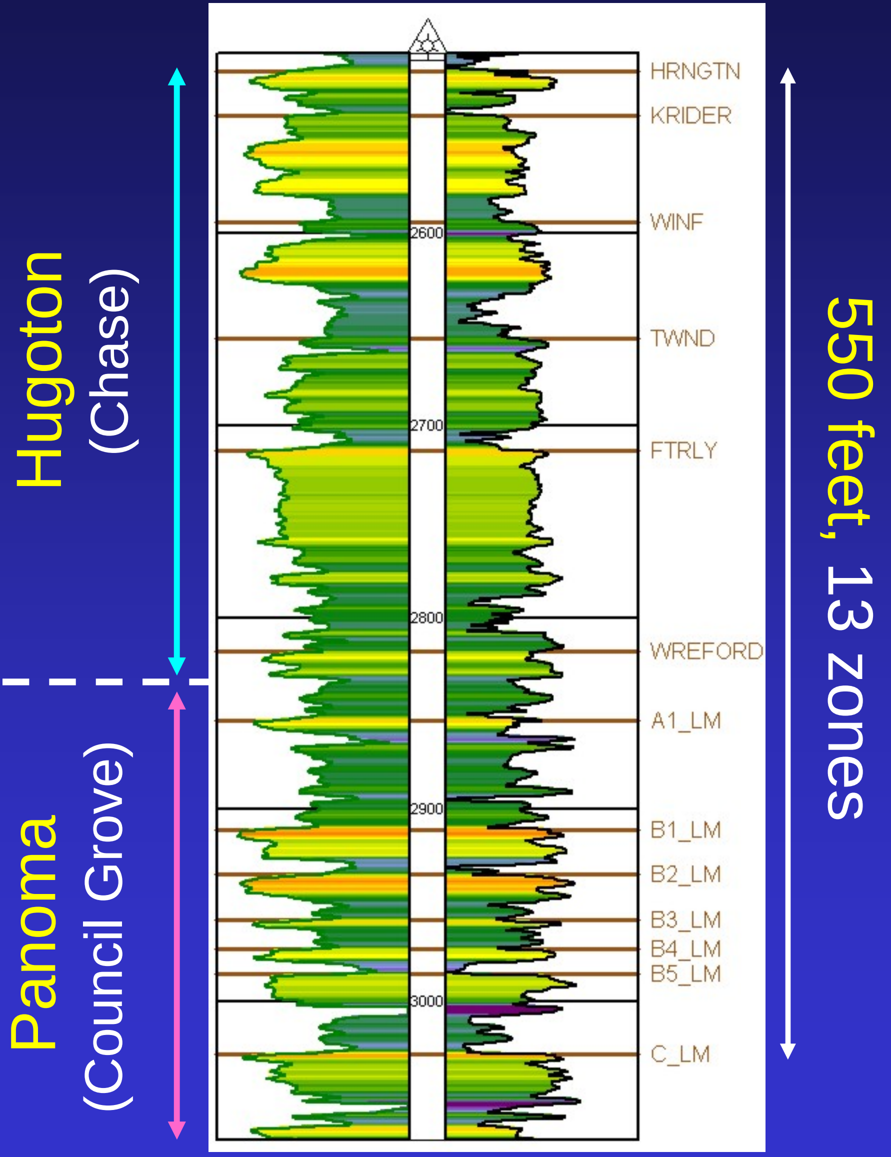
Kansas Development History



No Hugoton infill wells in Oklahoma



Thinly layered, alternating carbonate and siltstone reservoir in 13 marine-nonmarine sedimentary cycles

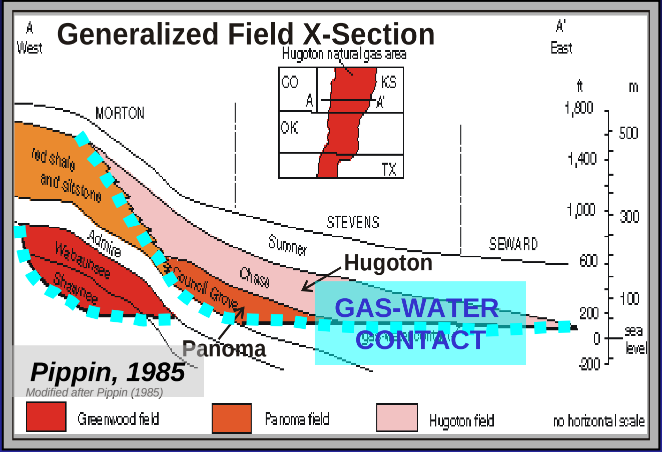


Hugoton (Chase) – Panoma (Council Grove) connection question

Stacked reservoirs systems are recognized as separate fields and regulated separately.

However, several authors have suggested that they at least filled as one reservoir system:

- Pippin (1985) shows a common gas/water contact
- Sorensen model (2005) implies a common reservoirs system during gas migration

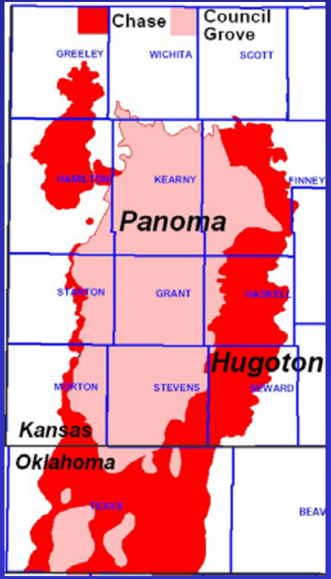


Pippin, 1985

Modified after Pippin (1985)

Panoma (below) is only productive in highest portion of field.

Gas column is continuous between Chase and Council Grove in Panoma area

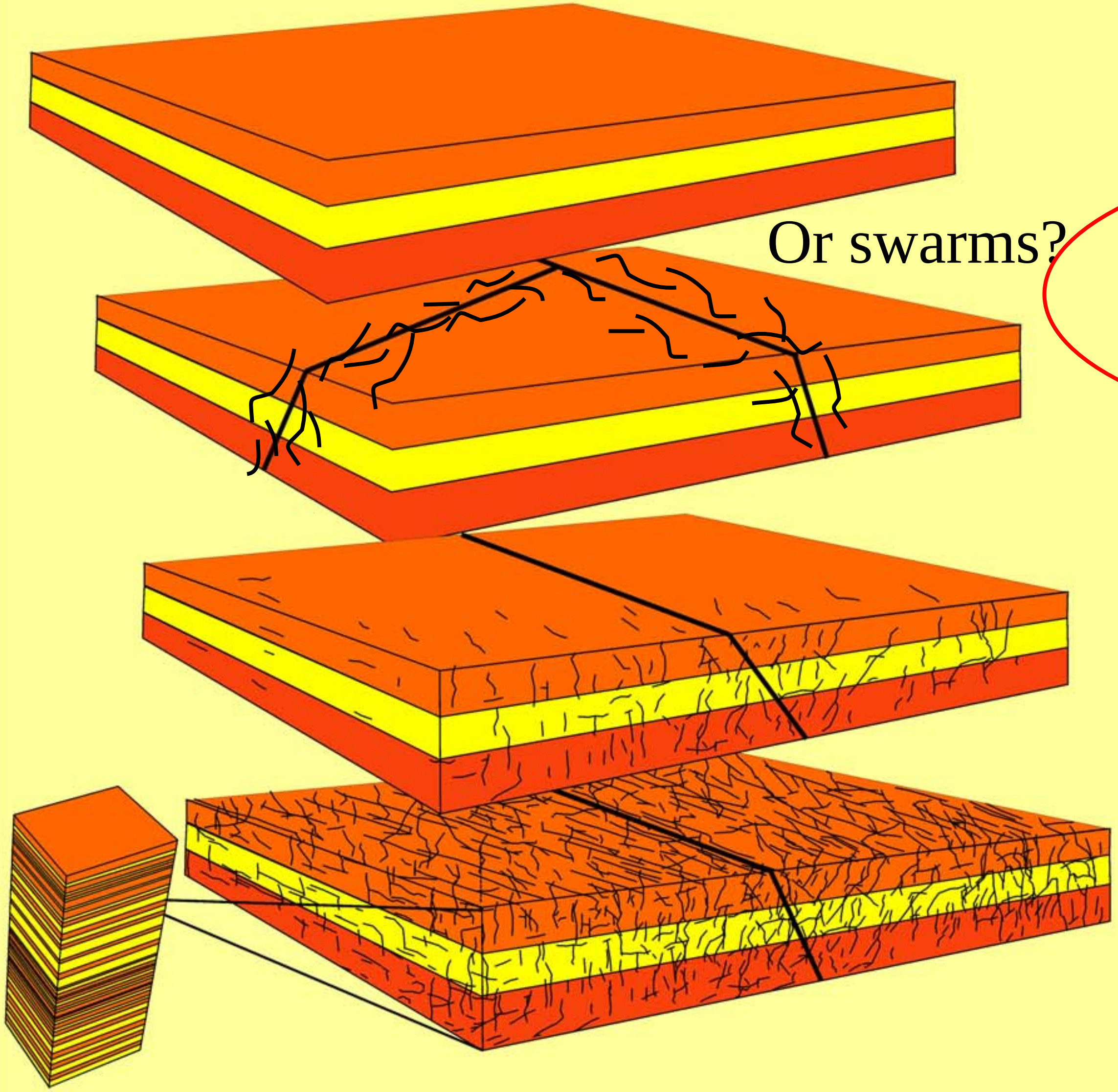


Note: colors are reversed in Pippin x-section

Conflicting observations

Hugoton and Panoma pressures generally track one another	Suggesting vertical communication
Both are layered reservoirs with differential depletion (pressure)	Suggesting little or no vertical communication
Rocks separating Chase from Council Grove (Speiser Shale) are same as those separating pay zones within either the two groups	Chase is no more sealed from (or communicated with) Council Grove than is the Towanda sealed from the Ft. Riley, for example.
DST calculated permeability in science wells approximate core matrix permeability	Rules out pervasive, closely spaced naturally fractured reservoir, at least at locality

Four Basic Permeability Models


Or swarms?

Matrix-driven: well performance and field pressure history consistent with matrix properties

Local matrix/Large-scale fractures: well performance consistent with matrix properties, field pressure history indicates large-scale communication

Local matrix/random small-scale fracture/large-scale fractures: well performance consistent with matrix properties in some beds and fracture influence in others, field pressure history indicates large-scale communication

Fracture-driven: well performance and field pressure history inconsistent with matrix properties, field pressure history indicates large-scale communication

Possible conduits *(if in communication)*

1. Naturally occurring, large scale, regional system of large fractures or swarms of smaller fractures
2. Artificial, hydraulic fracture treatments introduced during well completions
3. Both

Another bit of relevant info:

- Permeability of silts between the carbonate and sandstones ~ 10^{-5} to 10^{-7} md
- Sufficient for gas migration over centuries
- Not for equilbration over years to decades.

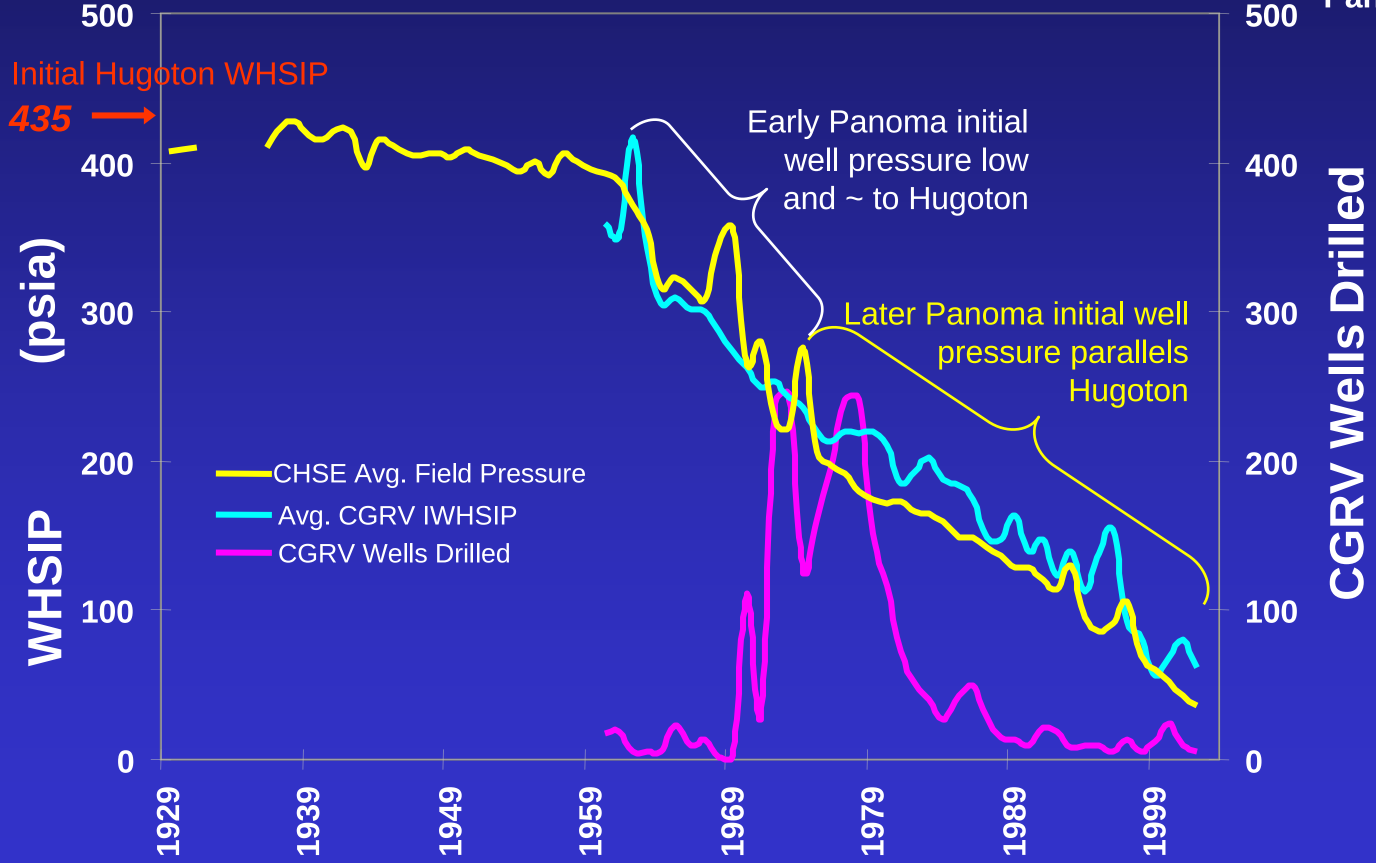
Evidence for communication is strong, but the jury is still out on the nature/cause for communication

Pressure data available

Main types	Utility	Shortfall
1. 72 hour well head shut in pressure (WHSIP) Extensive in Kansas and Oklahoma.	Connectivity within and “between” reservoirs at various scales	Commingled, equals lowest pressured zone
2. Long term (equilibrated) buildup Abundant locally, absent otherwise.	Implications on ultimate recovery and field life	Dense data but only in one area
3. Pressure by zone (layer) through time Modest amount of data.	Critical for estimating remaining GIP and simulation	Minimal scattered data

Similar pressure histories suggest Hugoton and Panoma Fields are connected in Kansas

	Disc. Yr	Major Prod. Yr
Hugoton	1928	1944
Panoma	1958	1970

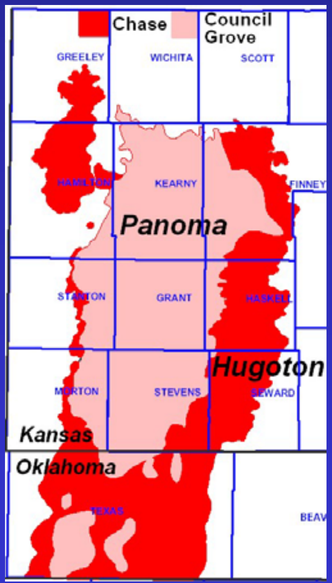


Initial Hugoton WHSIP

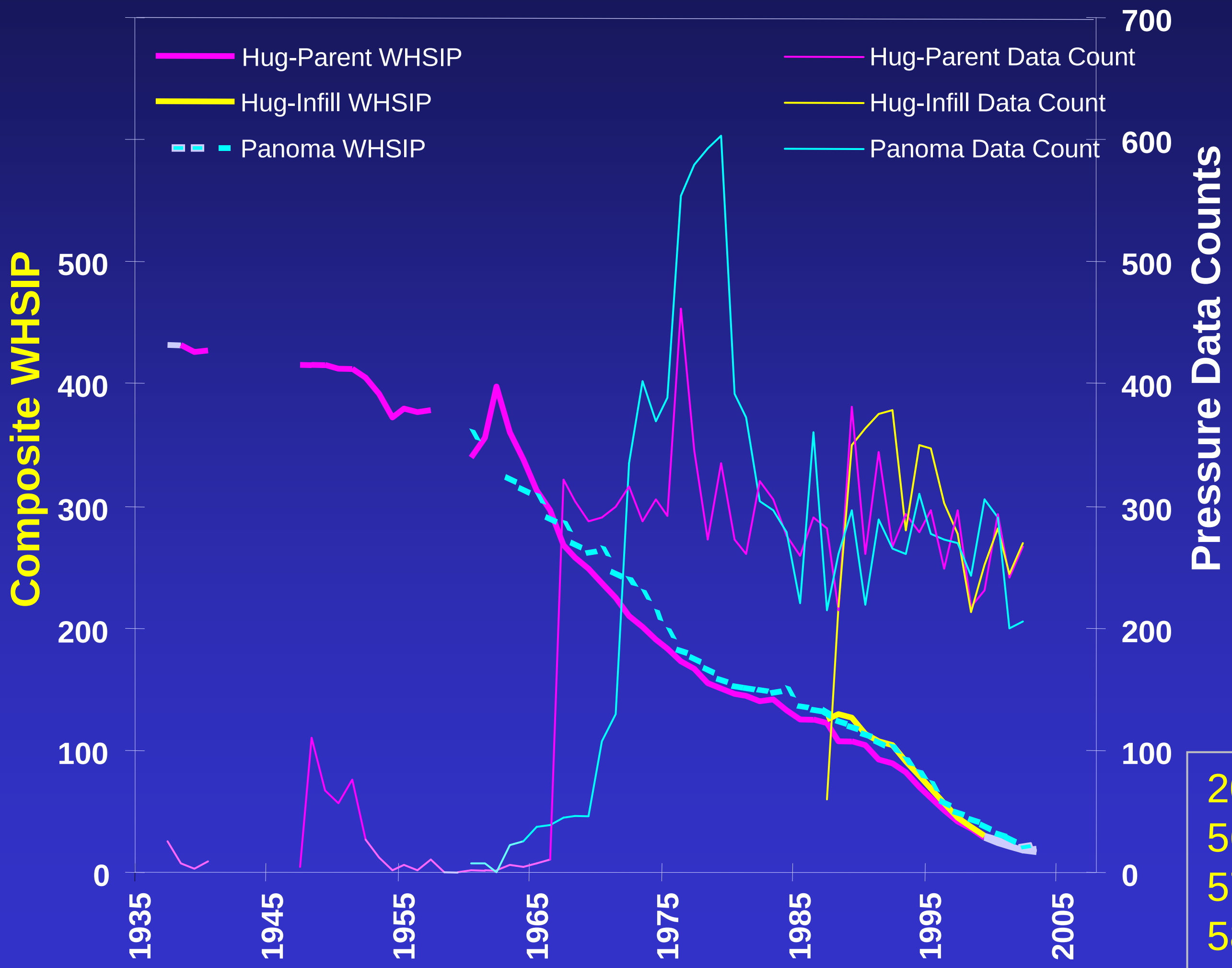
435

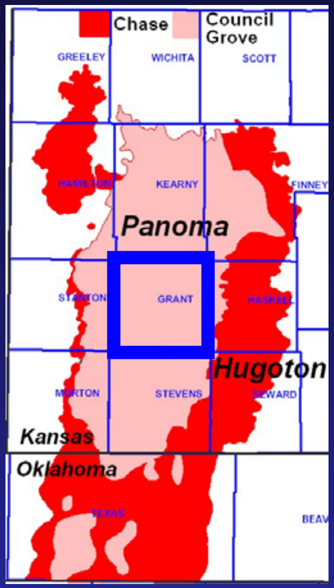
Early Panoma initial well pressure low and ~ to Hugoton

Later Panoma initial well pressure parallels Hugoton



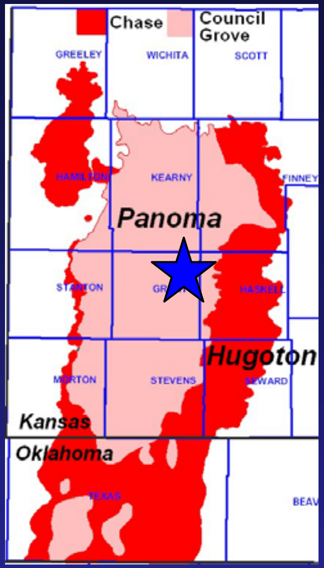
Hugoton & Panoma Composite WHSIP
Grant County, Kansas



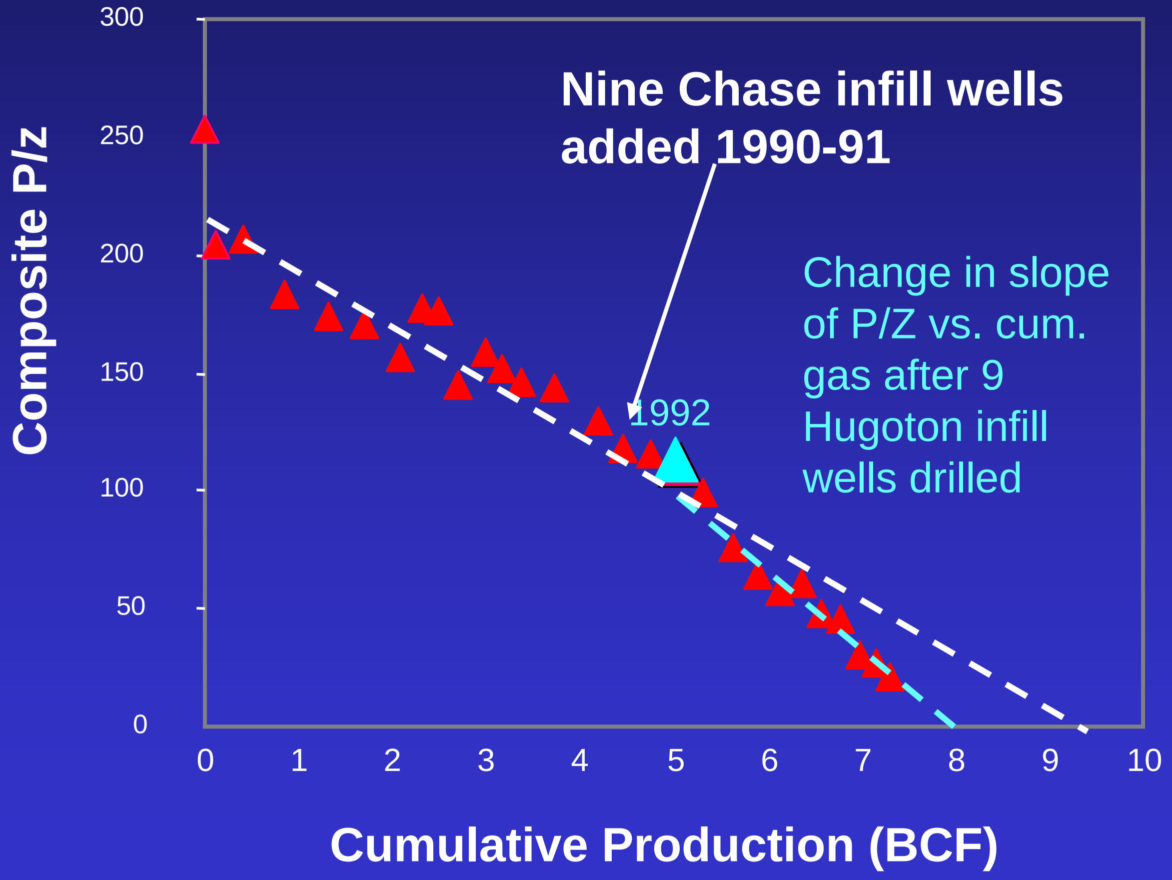


2004 Well Count
562 Hugoton Parent Wells
573 Panoma Wells
587 Hugoton Infill or
or Replacement Wells

Interference with Panoma by Hugoton Infill wells?



Composite Pressure of Nine Panoma Wells



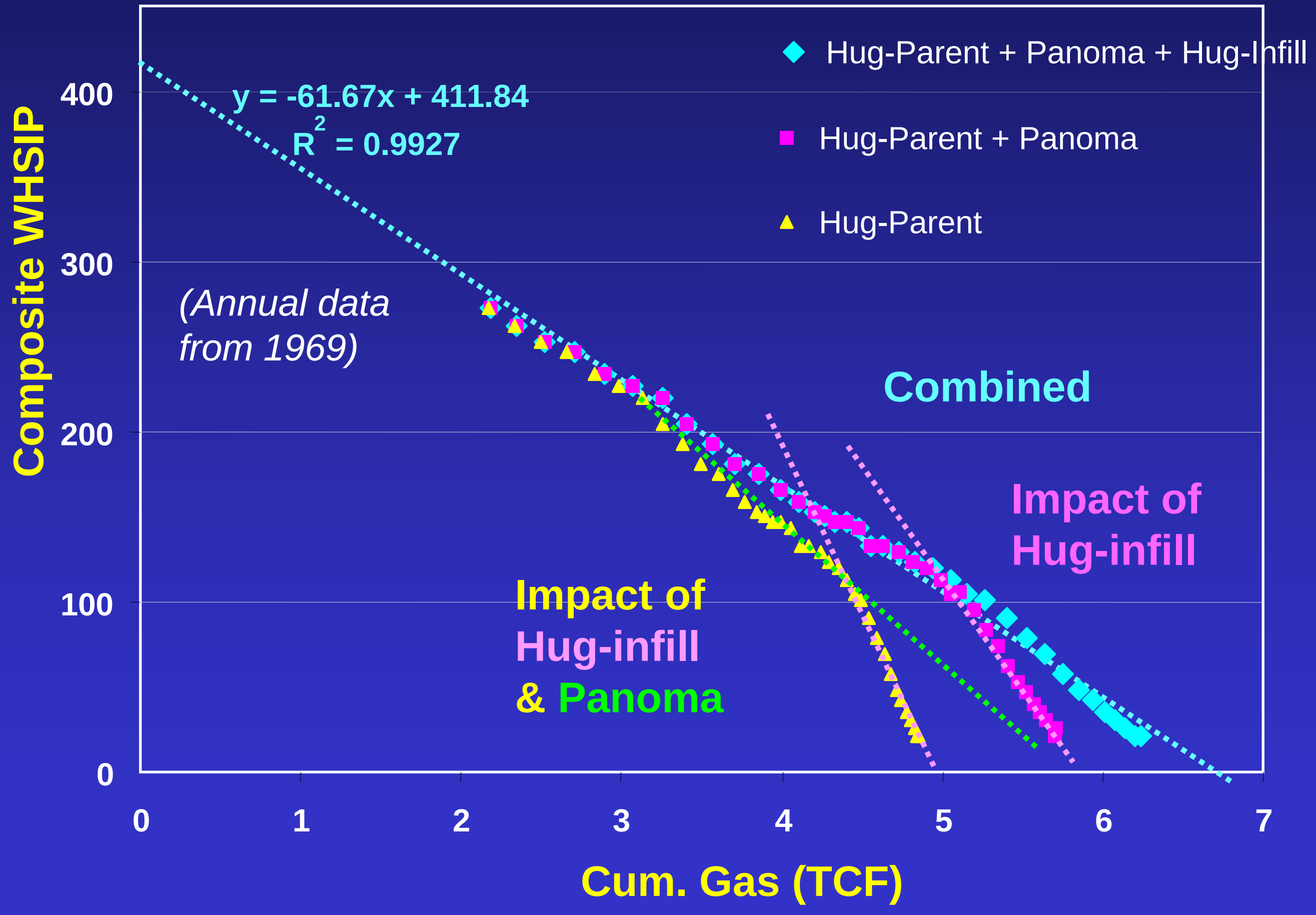
Nine Chase infill wells added 1990-91

Change in slope of P/Z vs. cum. gas after 9 Hugoton infill wells drilled

Change in slope in the P/Z vs. cumulative gas indicates a possibility of interference after 1992, roughly coincident with the addition of nine Hugoton infill wells.

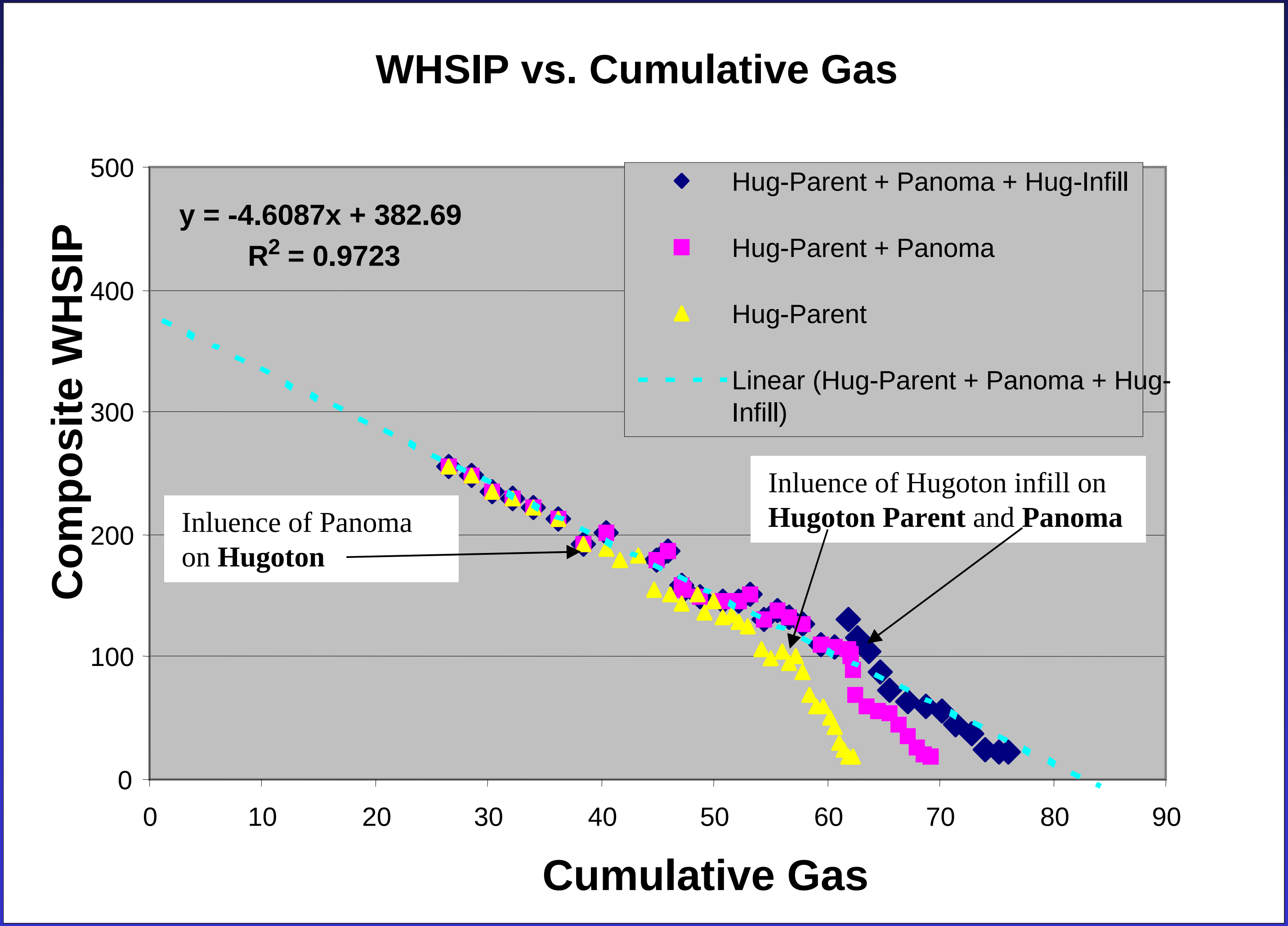
Data is from wells in 9 contiguous units

Hugoton & Panoma Composite WHSIP vs. Cum Gas
Grant County, Kansas



Change in slopes probably indicates interference by succesive generations of wells added

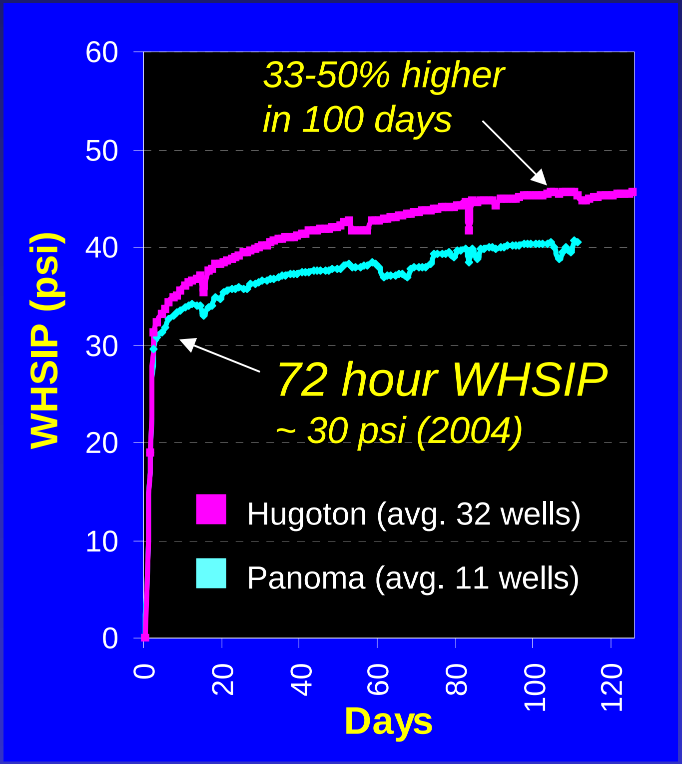
WHSIP vs. Cumulative Gas
(same 9 section area as before)



Pattern of interference observed at many scales (well, multiwell, and county)

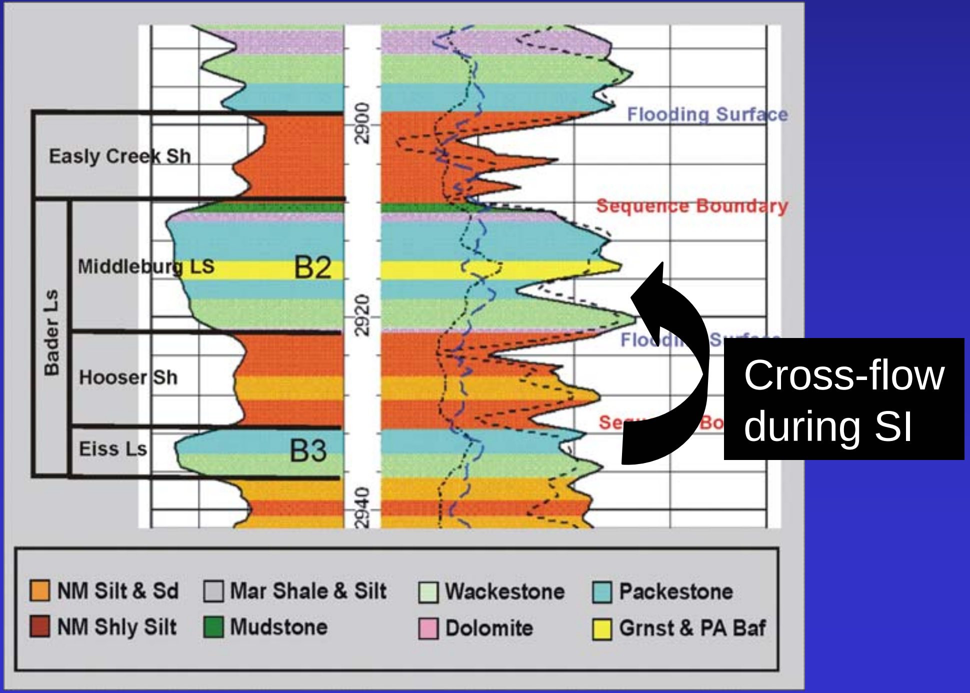
WHSIP does not accurately reflect BHP for all layers, but may to be proportional to overall depletion

WHSIP does not equilibrate



72 Hour WHSIP is readily available but is misleading

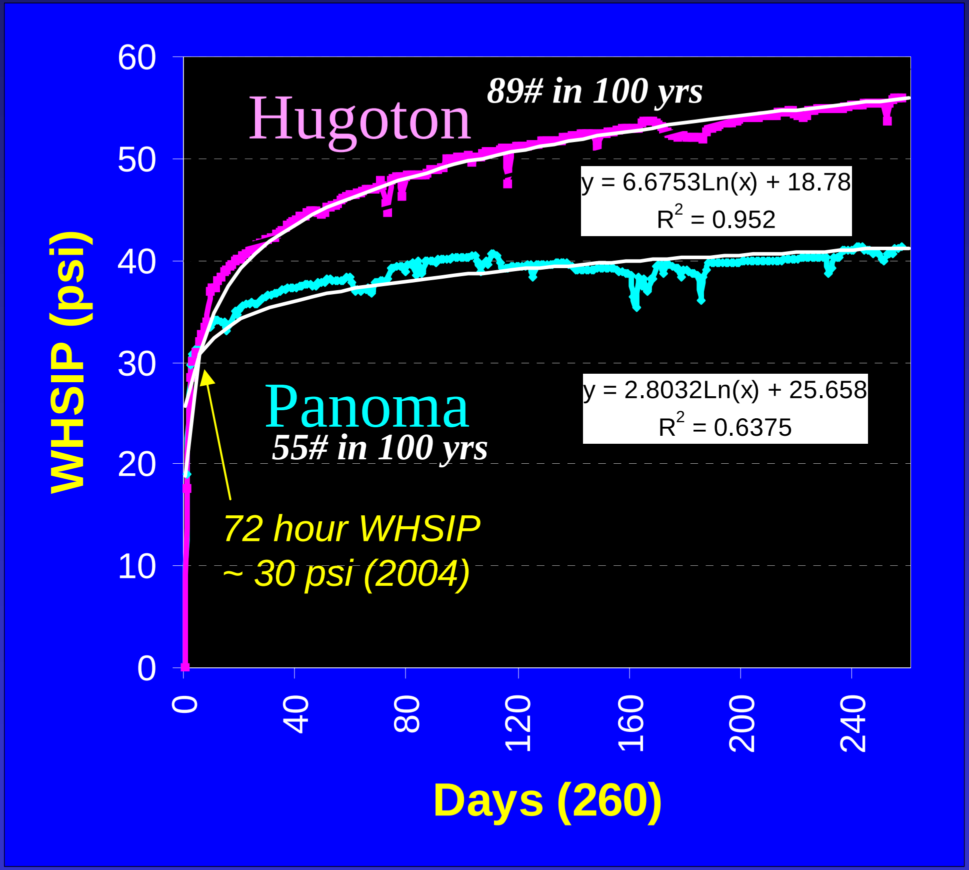
- Pressure ~= that of highest permeability zone (lowest pressure)
- Insufficient time to equilibrate



Cross-flow during SI

Hugoton and Panoma composite long term WHSIP

It is probably a stretch, but Chase wells in data set project to 89 psi in 100 years vs. 30 psi in 72 hours



Though it is certain that 72 hour WHSIP cannot be used to project remaining GIP, it remains a useful metric in evaluating communication and relative depletion.

First 100 days: 11Hugoton and 32 Panoma wells
101-260 days: 7 Hugoton and 24 Panoma wells7

DST and XPT SIP by zones illustrates differential depletion

Foam drilled well (1994)

CHASE	SIP
Herrington	120
Krider	88
Winfield SS	105
Winfield LS	121
Towanda	187
U. Fort Riley	230
L. Fort Riley	>400.
Florence	398
Wreford	372
COUNCILGROVE	
ALM	400
B1LM	350
B2LM	131
B3LM	368
B4LM	215
B5LM	160

104

156

(DST's)

New Well (2005)

6 mi. north

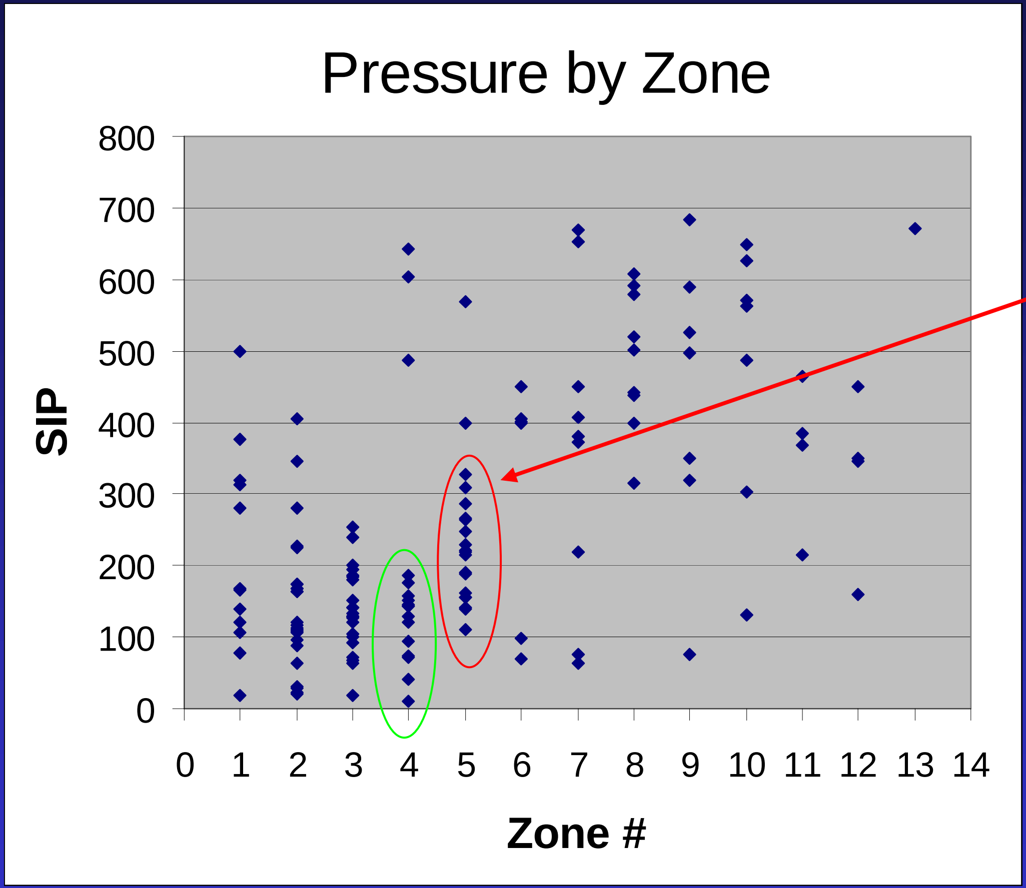
	Avg SIP	Individual SIP
Herrington	19	19
Krider SS	21	21
Krider DOL	30	23 30 29
Winfield SS	141	141
Winfield LS	217	240 194
Towanda	165	169 180 151 144
U. Fort Riley	192	179 189 199 187 193
L. Fort Riley	265	252 277
Wreford	219	200 237
B3_LM	386	386 385
B5_LM	348	370 340 342 353 343 339

Depleted

Targets?

(XPT's)

Pressure by Zone



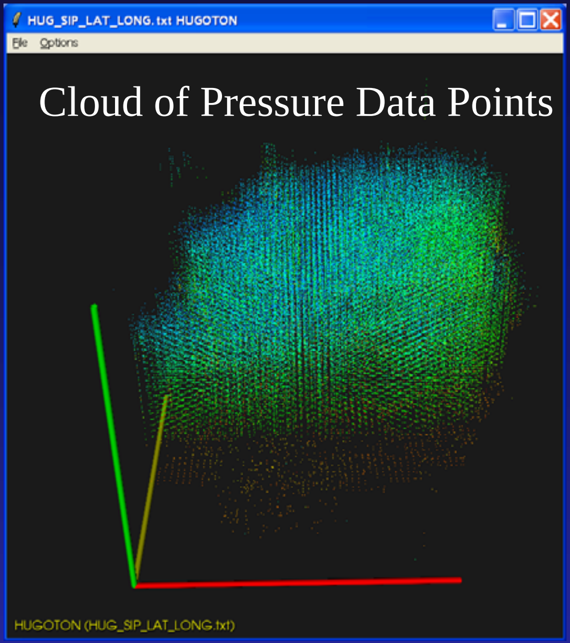
	Formation
1	**Herrington**
2	**Krider**
3	**Winfield**
4	**Towanda**
5	**Ft Riley**
6	**Florence**
7	**Wreford**
8	**A1_LM**
9	**B1_LM**
10	**B2_LM**
11	**B3_LM**
12	**B5_LM**
13	**D_LM**

Data is from 25 wells taken between 1977-2005, all areas of field (Kansas and Oklahoma)

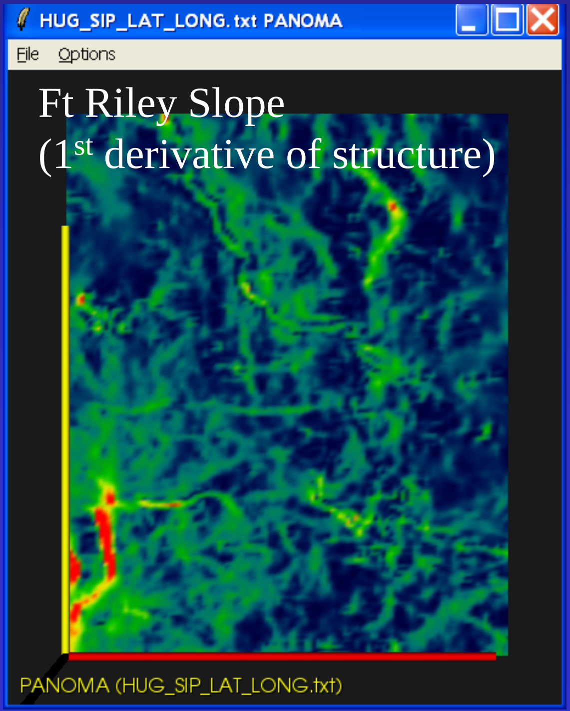
Variability within zone due to
- Geographic location (facies & k)
- Below G/W contact
- Time

4D View of Panoma WHSIP through time in Kansas

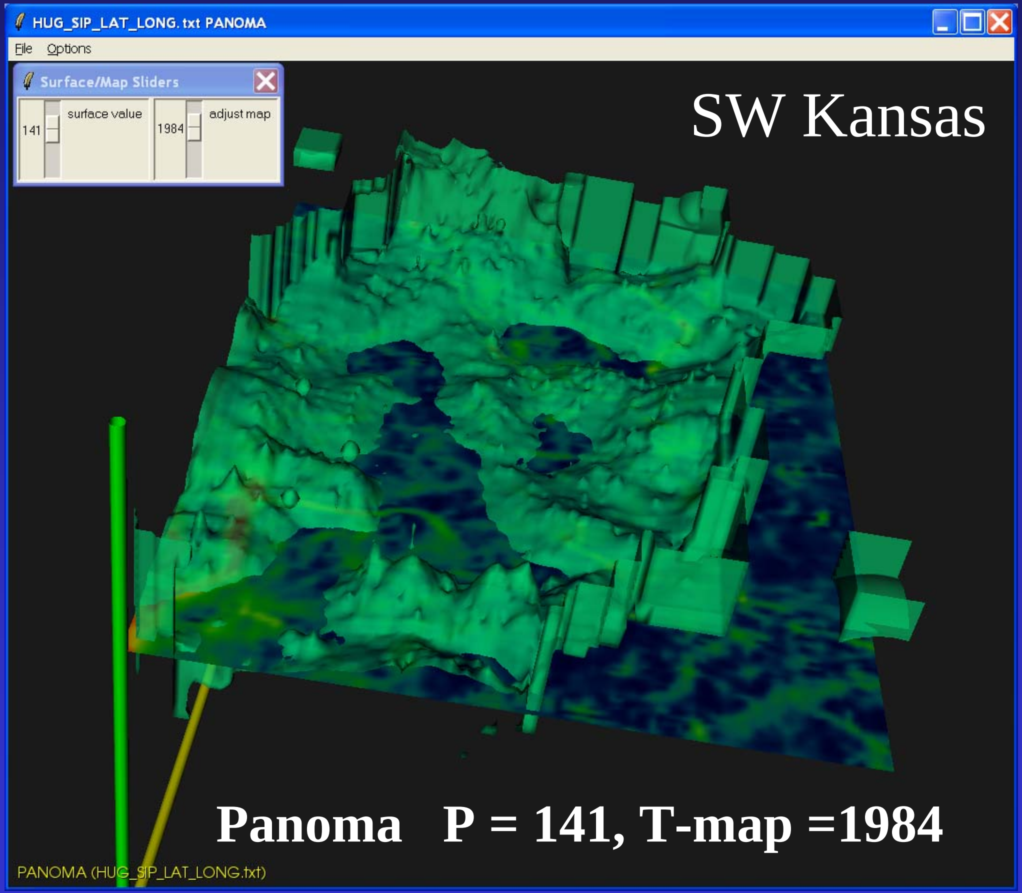
X(ew), Y(ns), Z(time) Color(p)



Cloud of Pressure Data Points



Ft Riley Slope
(1st derivative of structure)



surface value 141

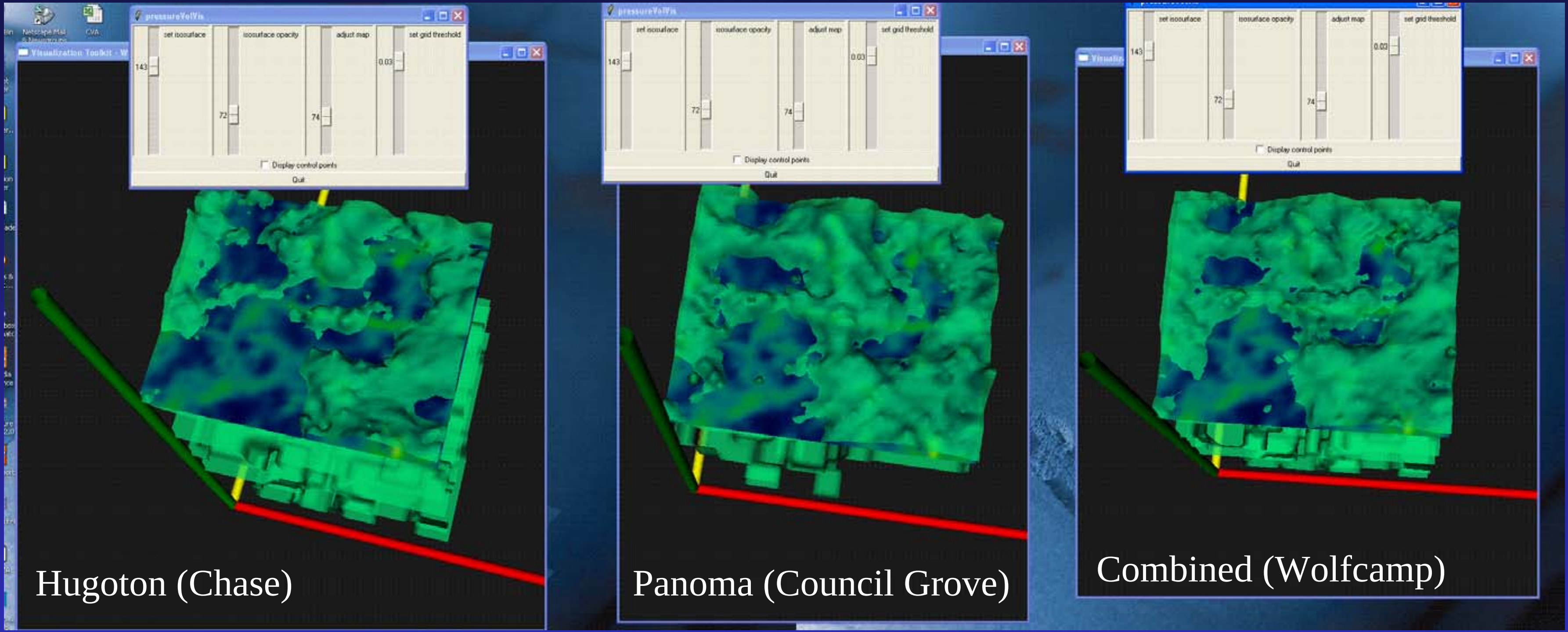
adjust map 1984

SW Kansas

Panoma P = 141, T-map =1984

Surface passes through the “cloud” at 141 psi.
Peaks are later in years.

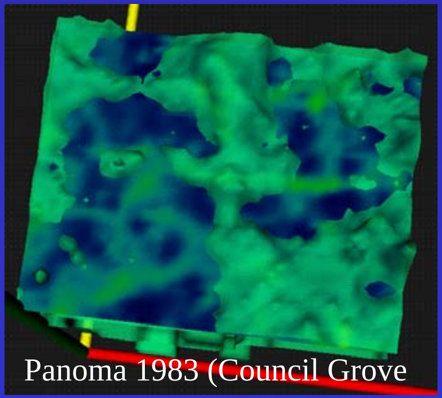
Hugoton and Panoma WHSIP and Ft. Riley dip



Ft. Riley dip map at 1981 on time axis
WHSIP isobar surface = 143#

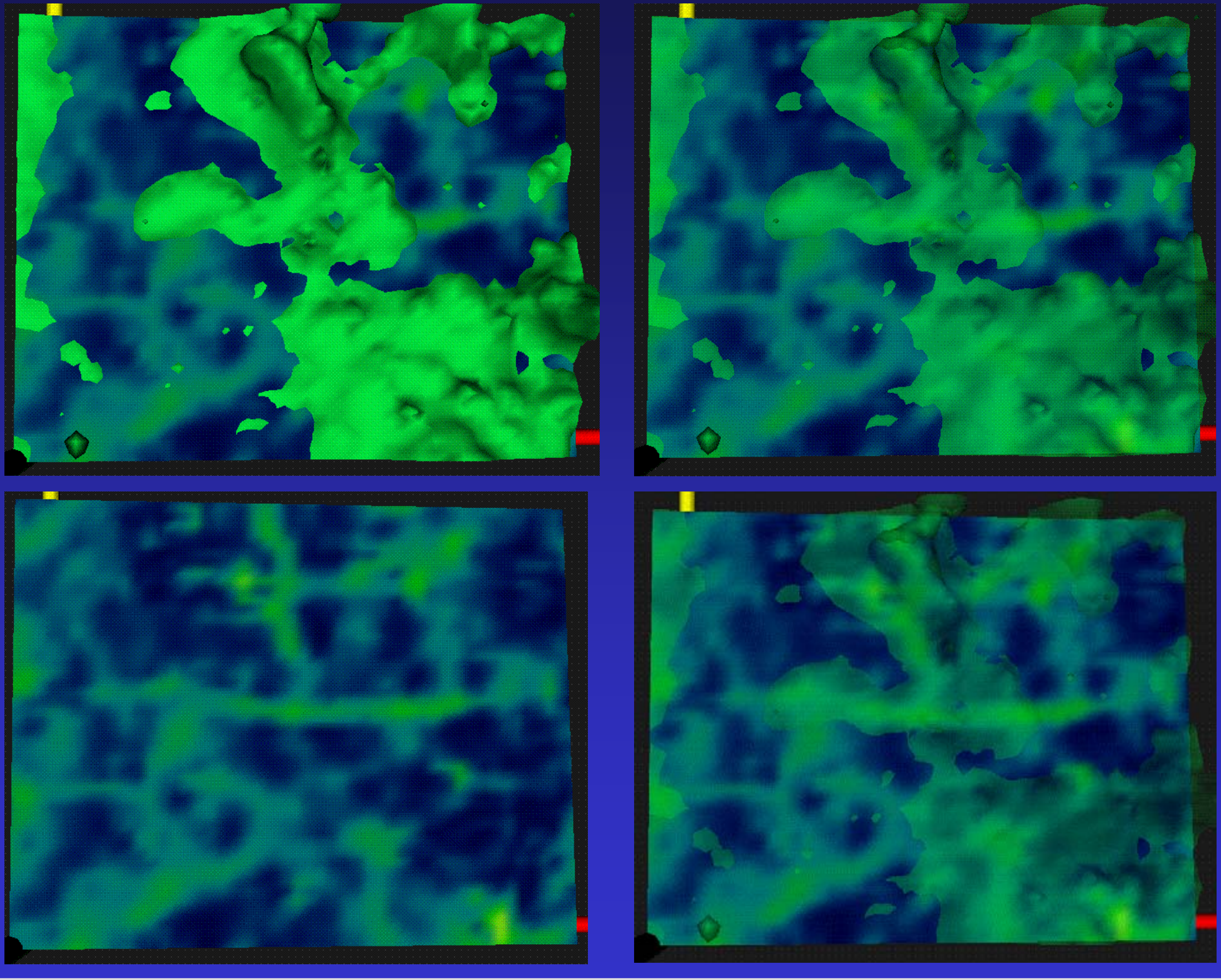
X axis (red) points East, Y (yellow) is North, and Z is time increasing up

Hugoton and Panoma isobar pressure surfaces are very similar, having similar correlation to the Ft. Riley dip map, however, the Panoma 143# isobar surface lags the Hugoton by approximately two years.



Relationship of Panoma Isobar Surface to Ft. Riley Dip Surface, Grant County Kansas

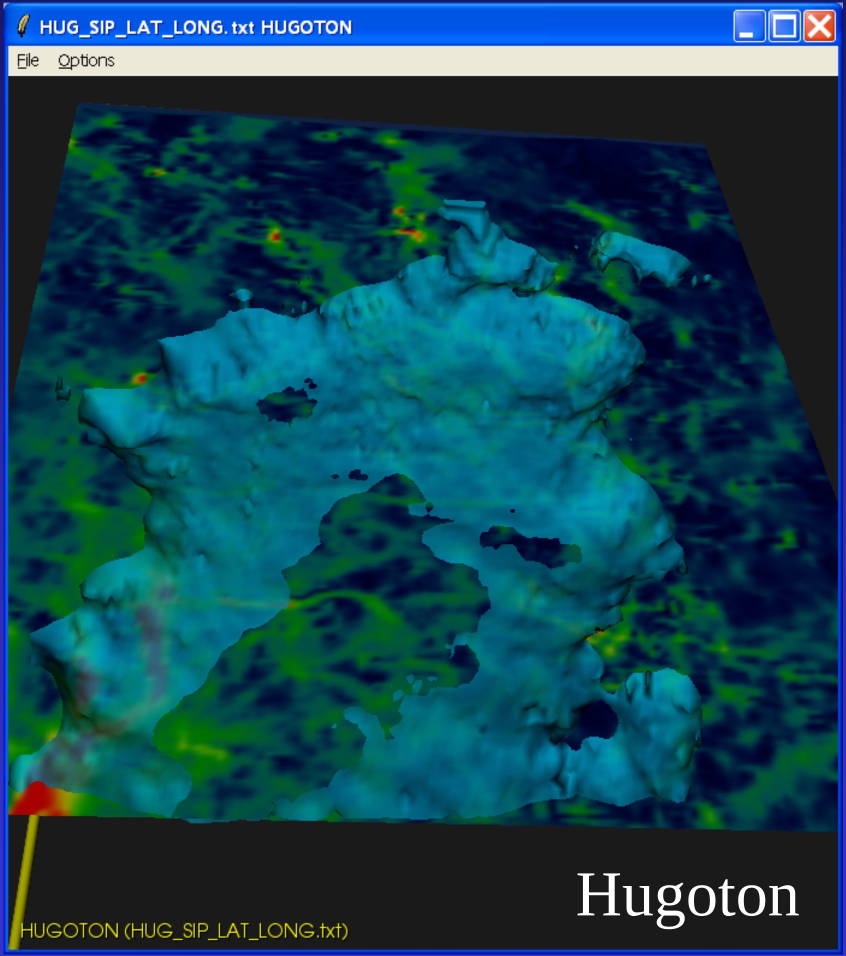
Map view of Panoma 170# isobar surface with Z axis being time. Ft. Riley dip map is placed at T = 1976 and is an opaque plane that slices the 3D Panoma 170# surface. The four images have different opacity settings for the 170# surface (100% to 0% clockwise) allowing one to see the correlation with the Ft. Riley dip map.

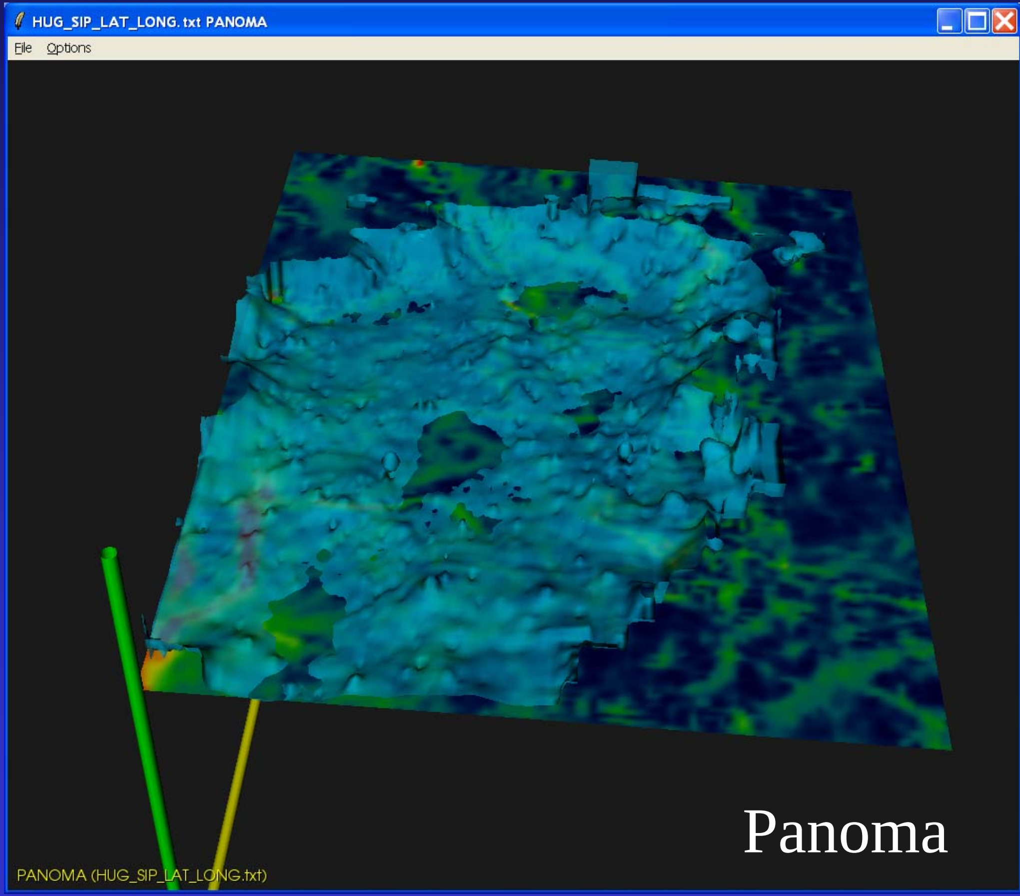


Areas with high rates of dip may be areas where joints and fractures provide more effective communication between layers and thus higher WHSIP as gas is fed from higher pressure layers.

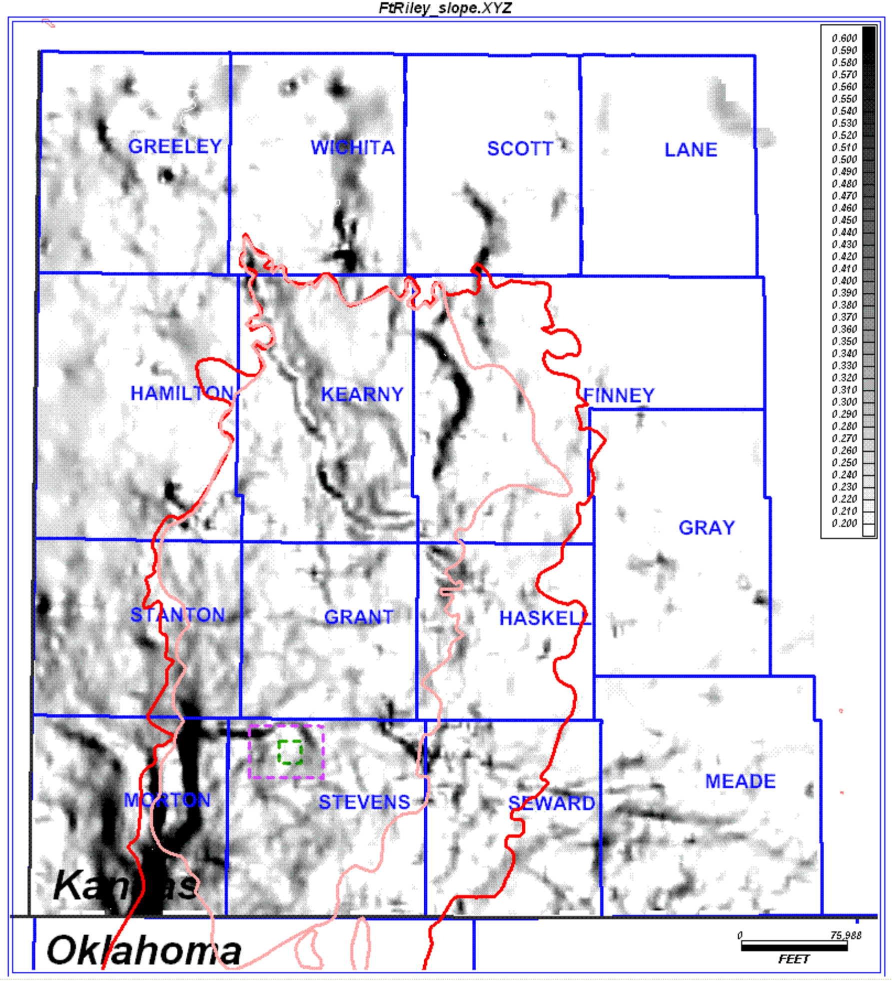
Later in life

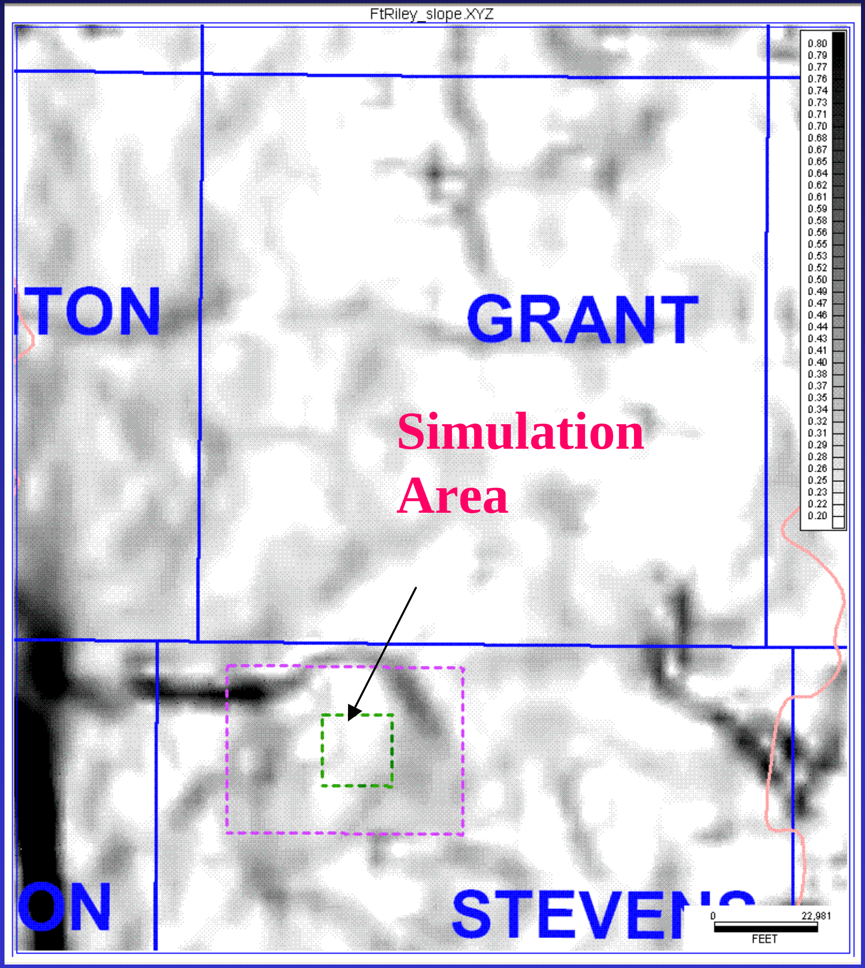
P = 60, T-map = 1996





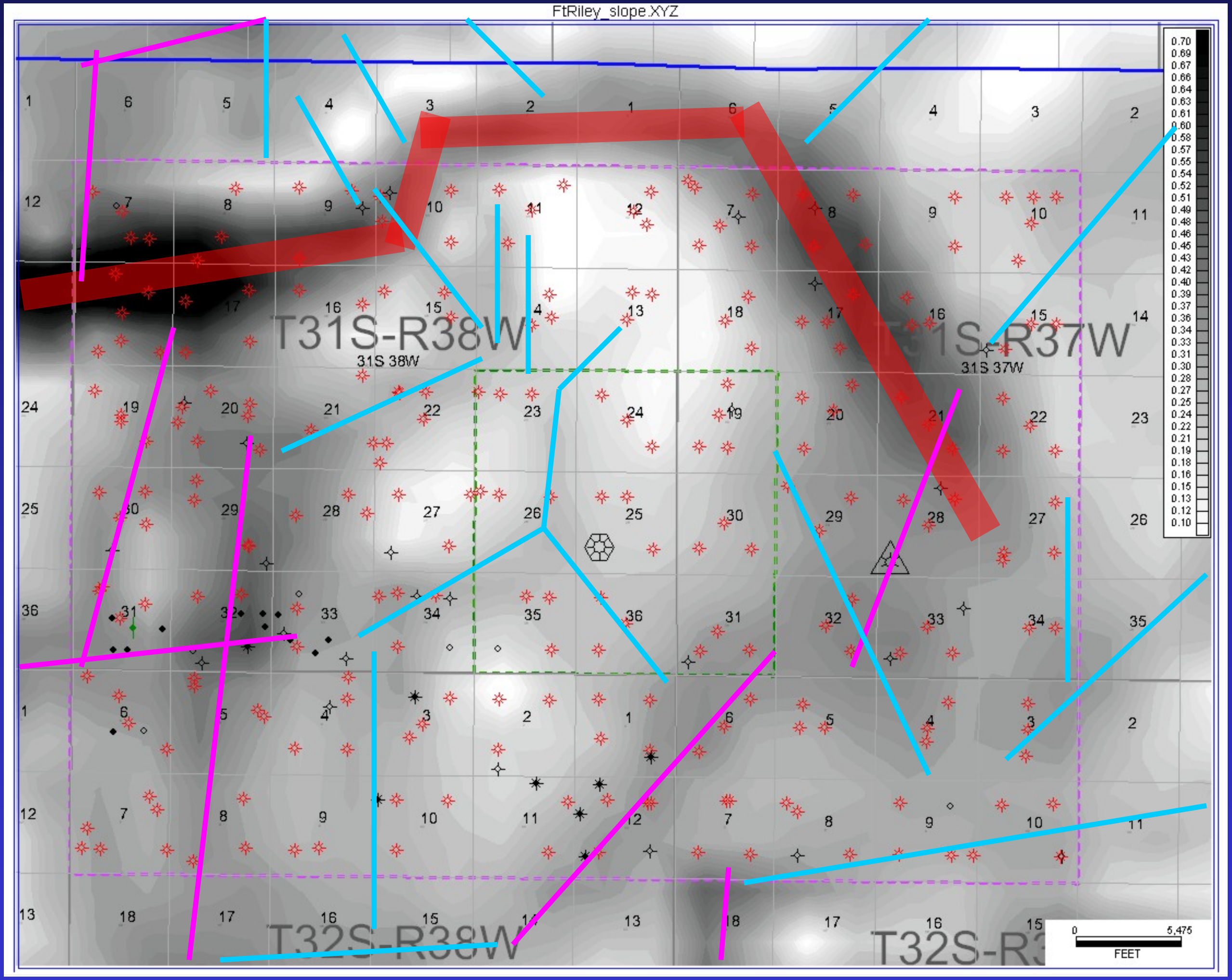
Ft Riley Structure1st Derivative Hugoton-Panoma Area





Simulation Area

Lineaments in Ft Riley Structure 1st Derivative Map, Flower Model Area



Possible conduits for vertical communication between layers and between Hugoton and Panoma?

Fractures in Chase and Council Grove

Silverdale Member, Ft Riley LS, southeast Kansas

Joint frequency and geometry in core suggest that if regular (square) they may occur in 10-15 foot patterns in SW Kansas

Trends in pressure through time

1. Hugoton and Panoma show similar patterns
2. Slightly higher pressures correlate well with basement related fractures
3. Pressures often times are not inversely proportional to cumulative gas production

1. Behaving as one reservoir system (or separate behaving exactly the same)
2. Recurrent movement could cause higher frequency of open joints (swarms) that provide better communication within low perm zones, thus higher WHSIP
3. Better communication of tighter zones may lead to slightly better production

Additional work may provide better understanding of reservoir communication and guidance on prospective sites for "alternative plumbing"

Conclusions

Hugoton and Panoma Fields in Kansas appear to have behaved as one large reservoir rather than two separate systems during production, *though effects of proration could have had an artificial influence*

Lines of evidence:

- Similar pressure histories, temporally and spatially
- Interference by successive generations of wells

Possible causes:

- Natural large scale fractures or swarms of smaller fractures, possibly coincident with basement
- Hydraulic fractures during well completion
- Both

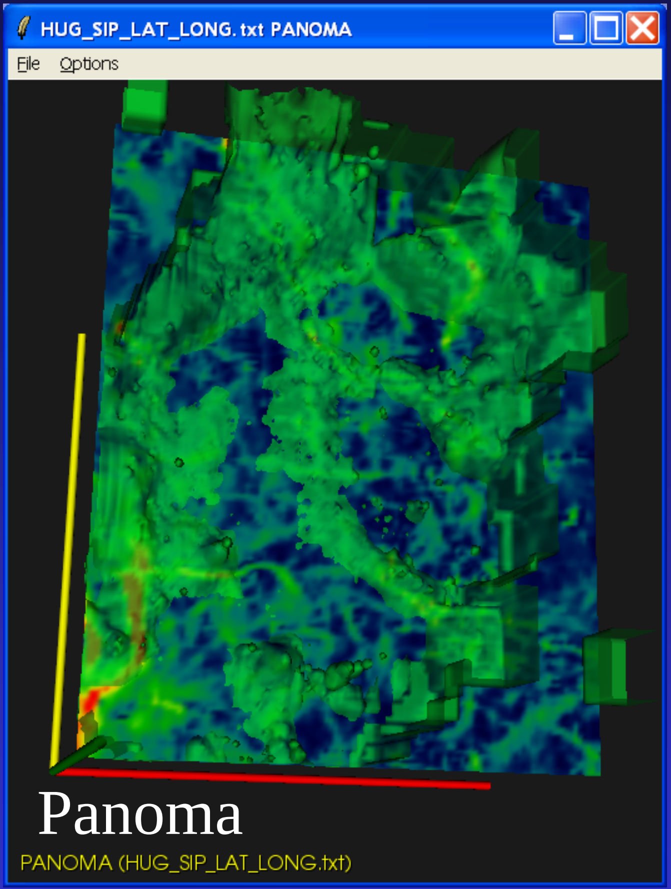
The conclusions and insights presented are preliminary and are based upon work that is still in progress. They are the opinions of the authors and not necessarily those of the sponsors of the Hugoton project.

Acknowledgements

We thank our industry partners for their support of the Hugoton Asset Management Project and their permission to share the results of the study.

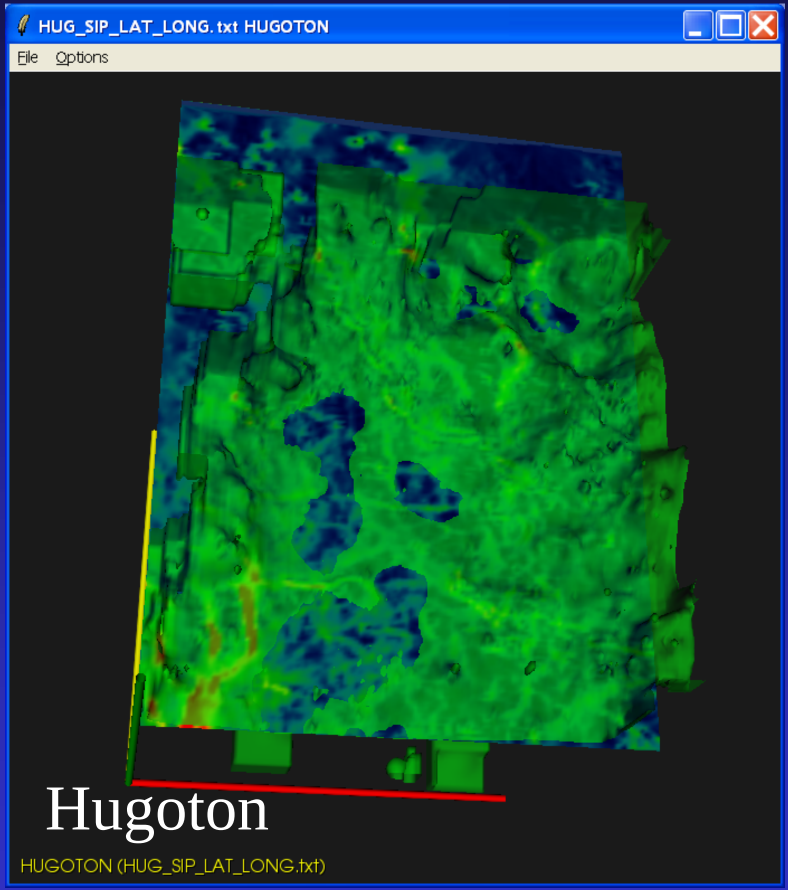
Anadarko Petroleum Corporation
BP America Production Company
Cimarex Energy Co.
ConocoPhillips Company
E.O.G. Resources Inc.
Medicine Bow Energy Corporation
Osborn Heirs Company
OXY USA, Inc.
Pioneer Natural Resources USA, Inc.

Compare Panoma and Hugoton



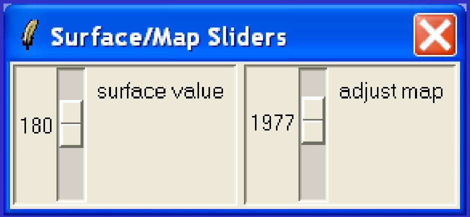
Panoma

PANOMA (HUG_SIP_LAT_LONG.txt)



Hugoton

HUGOTON (HUG_SIP_LAT_LONG.txt)



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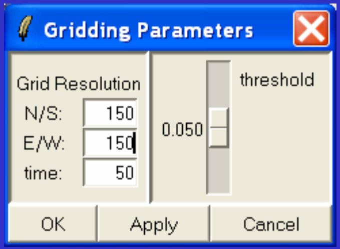
adjust map: 1977



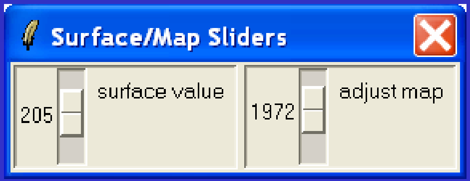
Grid Resolution

N/S: 150

E/W: 150

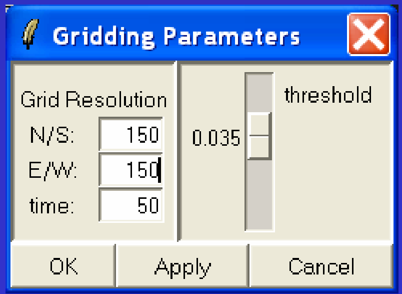
time: 50

threshold: 0.050



surface value: 205

adjust map: 1972



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time: 50

threshold: 0.035