PSHorizontal Detachments, Planes of Weaknesses and Layer-Parallel Shortening in Shale: Potential Impact on Unconventional Shale Development*

Jean-Yves Chatellier[1]

Search and Discovery Article #41653 (2015)**
Posted July 20, 2015

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Pittsburgh, PA, May 26-29, 2013.

[1]Tecto Sedi Integrated Inc. Calgary, presently with Talisman Energy Inc., Calgary, Alberta (jeanch@usa.net)

Abstract

Shale units are commonly the place of predilection for horizontal detachments. Their occurrence during geological time or induced by human operations is reviewed. Their expression and our understanding of the mechanisms involved will be addressed using a series of examples from Canada, South America and South-East Asia.

Analogues include outcrops from the La Borracha Island (Venezuela), Miri anticline (Sarawak), Quito Road Cut, and cored shales from the Santa Barbara and Lama fields (Venezuela), as well as from the Utica shale from Quebec.

Horizontal detachments can disrupt and misalign faults and fractures by displacing, even slightly, the rock units or layers located above and below the detachment. These displacements may have effects on sealing capacity, migration paths, fracture density, fracture orientation and fraccability. Each of these issues is reviewed with examples.

Thus in Alberta, some oil is locally produced from the Kiskatinaw Formation among otherwise gas-producing fields. These anomalies are associated with detachments within the Golata Shale that displace normal faults and create pathways for oil from the Exshaw Shale.

Diagenesis associated with pressure solution and slickensides may include quartz- cement precipitation in rocks units surrounding horizontal detachments; these highly cemented zones, especially in hybrid shales, can create hydraulic frac barriers.

High-density tensile fractures are commonly associated with layer-parallel shortening along shale-bed interface. These fractures may influence the frac placement and will have some bearing on the gas deliverability of the stimulated zone.

Pre-existing shear fractures located in the neighbourhood of some planes of weaknesses may be reactivated and create horses or duplex structures that may have some bearing on a well completion (productivity, stability…). Such mechanisms are best observed and illustrated in cores and with image logs.
Pore-pressure increase associated with hydraulic fracturing can change the local stress regime and initiate horizontal frac propagation along specific bedding planes. These bed boundaries in shale behave as micro-detachments that may have positive or negative effects on stimulated well productivity.

Selected Reference

Chatellier, J-Y., P. Flek, M. Molgat, I. Anderson, K. Ferworn, N. Lazreg, L. Ko, and S. Ko, 2013, Overpressure in shale gas: When geochemistry and reservoir engineering data meet and agree, *in* J-Y. Chatellier and D.M. Jarvie, editors, Critical Assessment of Shale Resource Plays: AAPG Memoir 103, p. 45-70.

Horizontal Detachments, Planes of Weaknesses and Layer-Parallel Shortening in Shale

Potential Impact on Unconventional Shale Development

TALISMAN ENERGY

T.S.I.

Abstract

Shale units are commonly the place of predilection for horizontal detachments. Their occurrence during geological time or induced by human operations is reviewed. Their expression and our understanding of the mechanisms involved will be addressed using a series of examples from Canada, South America and South-East Asia.

Analogues include outcrops from the La Borracha Island (Venezuela), Miri anticline (Sarawak), Quito Road Cut and cored shales from the Santa Barbara and Lama fields (Venezuela), as well as from the Utica shale from Quebec.

Horizontal detachments can disrupt and misalign faults and fractures by displacing, even slightly, the rock units or layers located above and below the detachment. These displacements may have **effects on sealing capacity, migration paths, fracture density, fracture orientation and fraccability.** Each of these issues reviewed with examples.

Thus in Alberta, some oil is locally produced from the Kiskatinaw Formation among otherwise gas-producing fields. These anomalies are associated with detachments within the Golata Shale that displace normal faults and create pathways for oil from the Exshaw Shale.

Diagenesis associated with pressure solution and slickensides may include **quartz cement** precipitation in rocks units surrounding horizontal detachments; these highly cemented zones, especially in hybrid shales,can create hydraulic frac barriers.

High-density **tensile fractures** are commonly associated with layer-parallel shortening along shale-bed interface. These fractures may influence the frac placement and will have some bearing on the gas **deliverability** of the stimulated zone.

Pre-existing shear fractures located in the neighbourhood of some planes of weaknesses may be reactivated and create **horses or duplex structures** that may have some bearing on a well completion (productivity, stability…). Such mechanisms are best observed and illustrated in cores and with image logs.

Pore pressure increase associated with hydraulic fracturing can change the local stress regime and initiate horizontal frac propagation along specific bedding planes. These bed boundaries in shale behave as **micro-detachments** that may have positive or negative effects on stimulated well productivity.

Keywords

- Fault locking mechanism
- Fracture porosity
- Cataclasis and pressure anomalies
- Overpressure

Jean-Yves Chatellier *

Tecto Sedi Integrated Inc. Calgary

jchatellier@usa.net

* Presently with Talisman Energy Inc.

Acknowledgments:

Thanks to Talisman Energy Inc. for permission to present the material shown on this poster

TALISMAN ENERGY

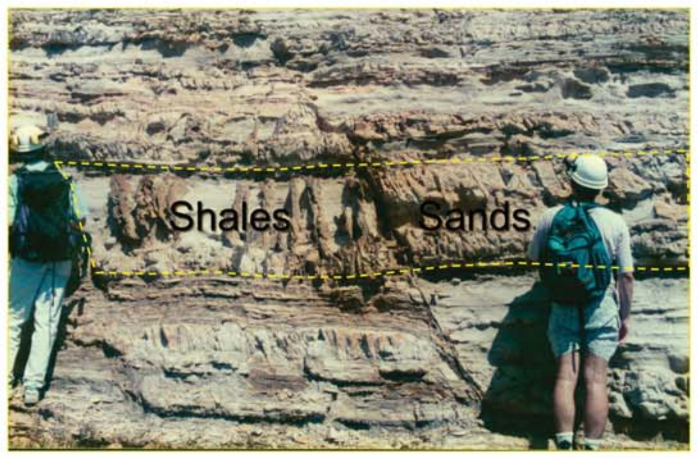
T.S.I.

Illustrations of some processes leading to detachment creation

Fault locking, proto-detachment and tensile fractures
Example from the Miri anticline, Sarawak

Synsedimentary normal faulting

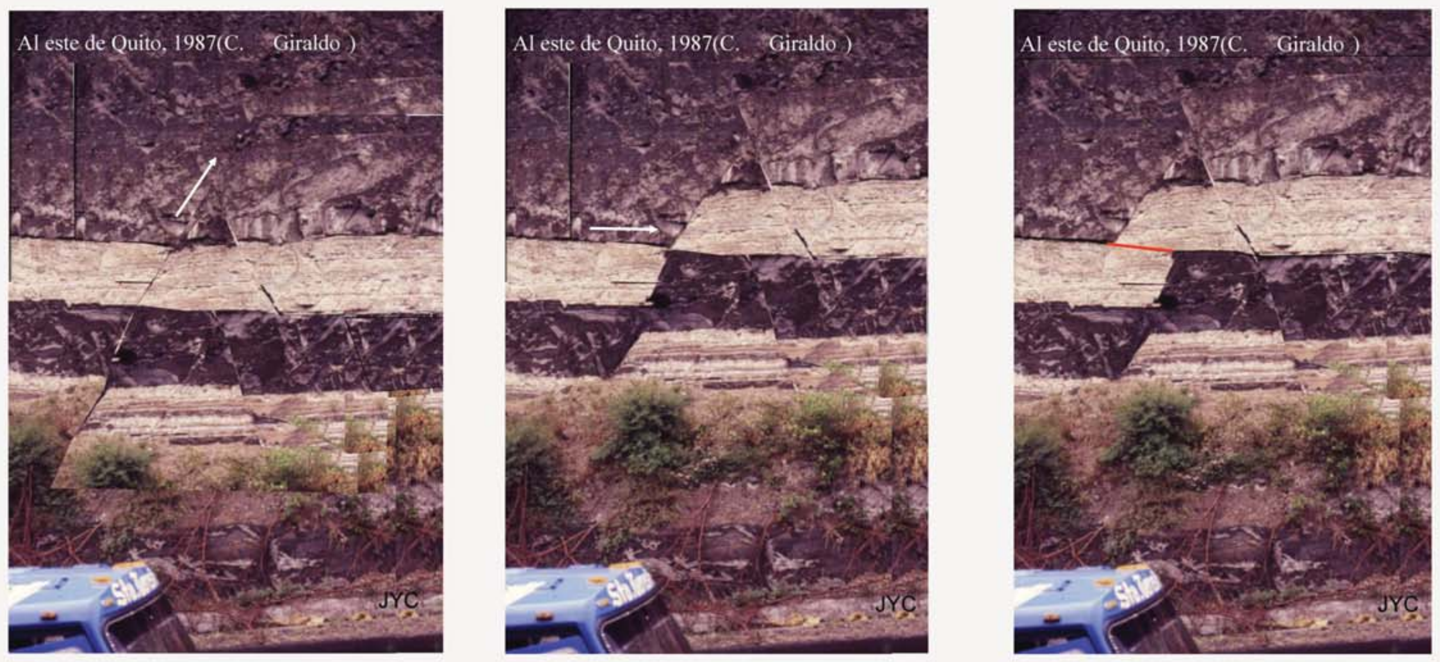
Proto-detachments



Tensile fractures bounded by horizontal surfaces

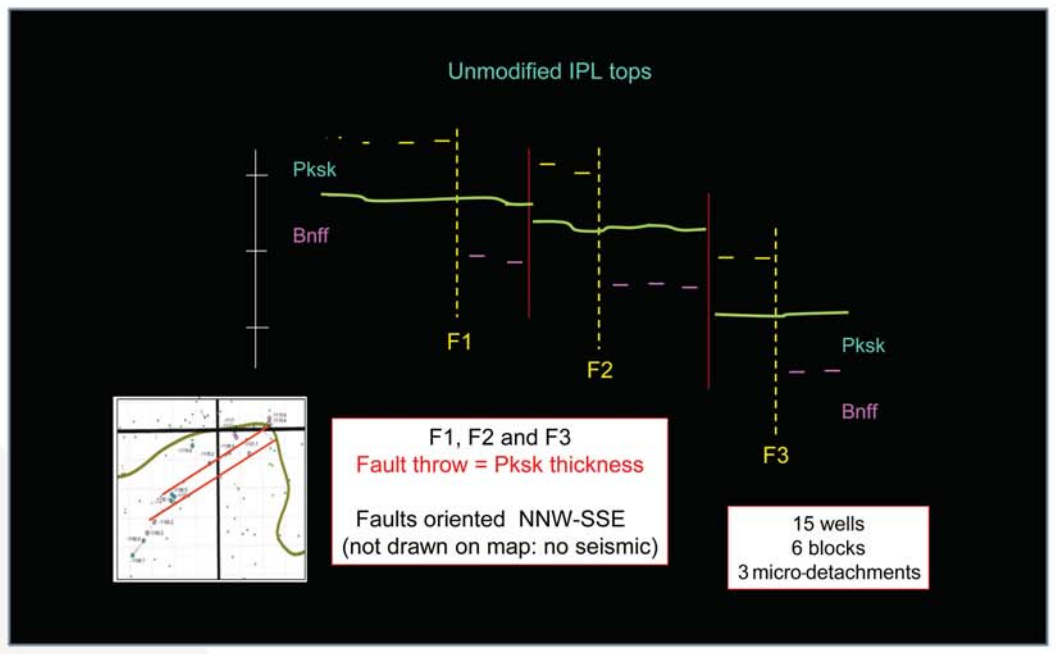
Normal faulting followed by proto-detachment; detachment at the level of the ankle of the geoscientist on the right

Fault locking and detachments
Outcrop from Quito Ecuador



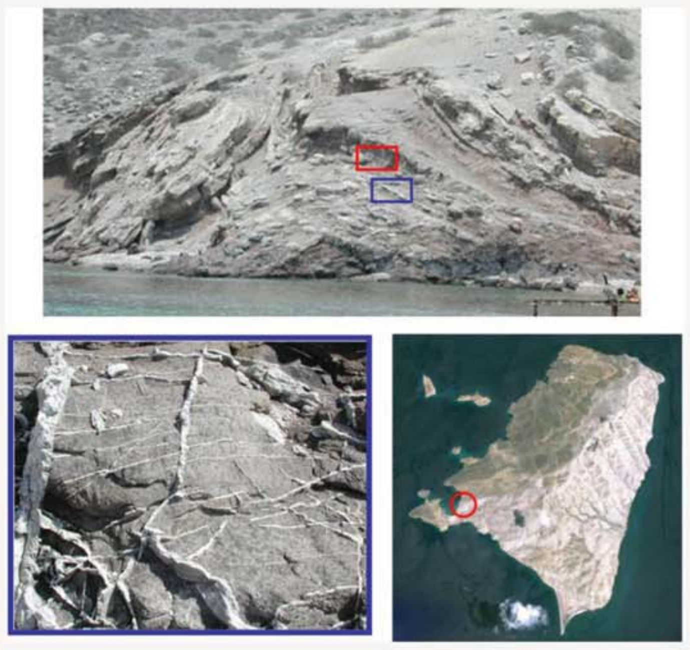
Normal faulting followed by fault locking then by detachment

Fault locking and detachments
Windfall , Alberta, Canada



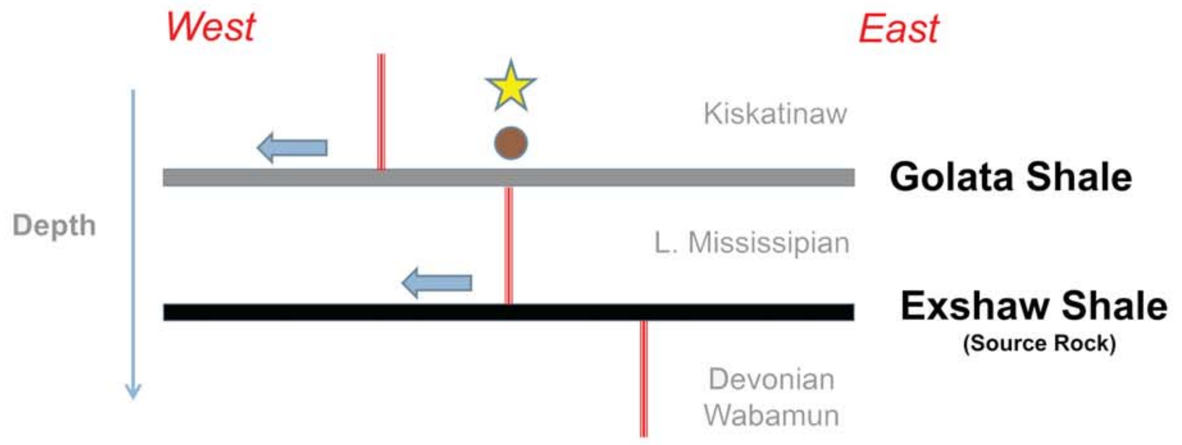
Normal faulting followed by detachment

Expression of detachments and tensile fractures in shales
Outcrop on island of La Borracha Venezuela



Various expressions of detachments in Alberta's Paleozoic

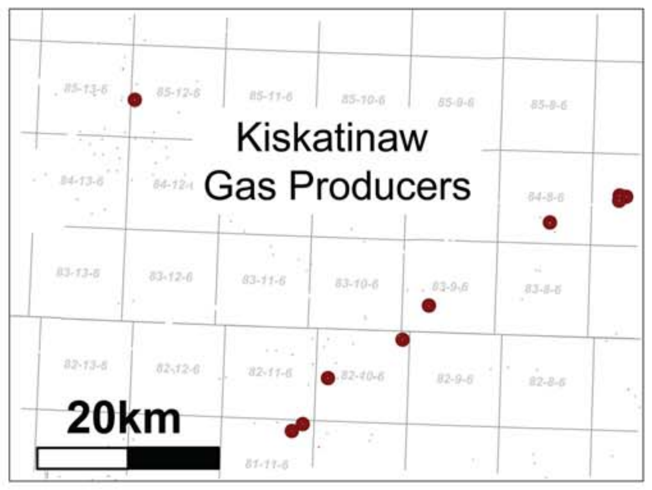
Oil producing Kiskatinaw in otherwise Gas province



Horizontal detachments along the Exshaw and Golata Shale have isolated the normal fault (in red)

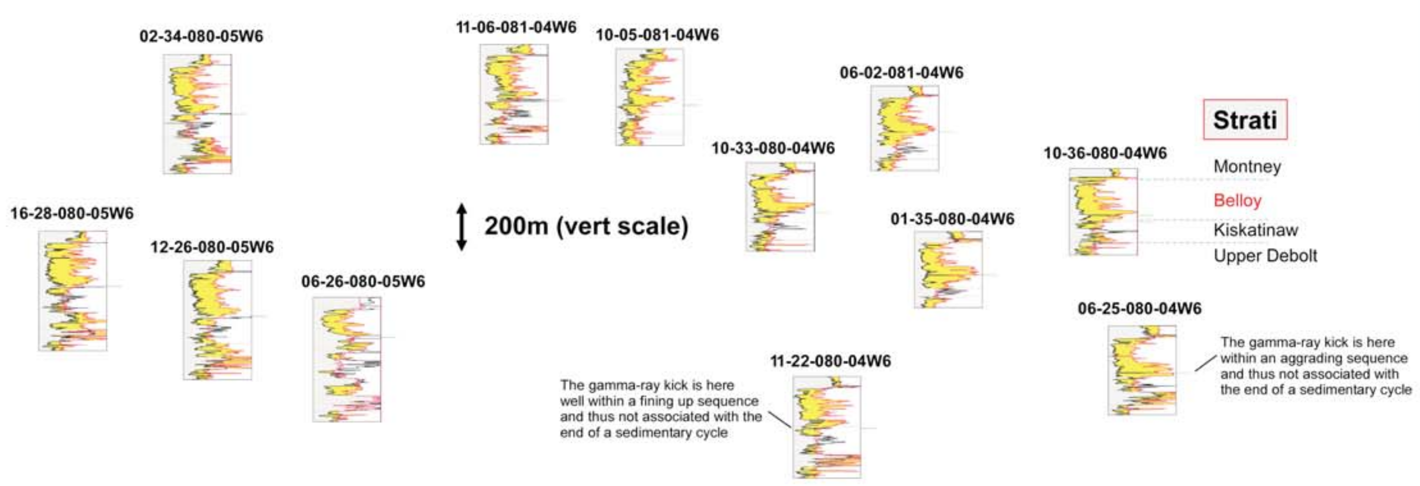
The open fracture network associated with the fault is in communication with the oil generating Exshaw Shale.

Normal vertical migration from the Exshaw shale brings liquid hydrocarbon in the otherwise gas-bearing Kiskatinaw. Production derived pressure drawdown can facilitate this vertical migration.

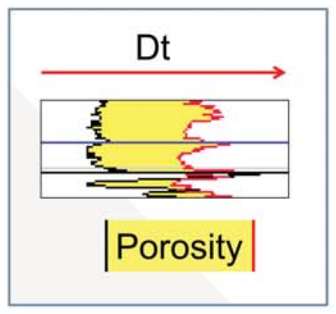


Increased fracture porosity above detachments

Detachment at base Belloy

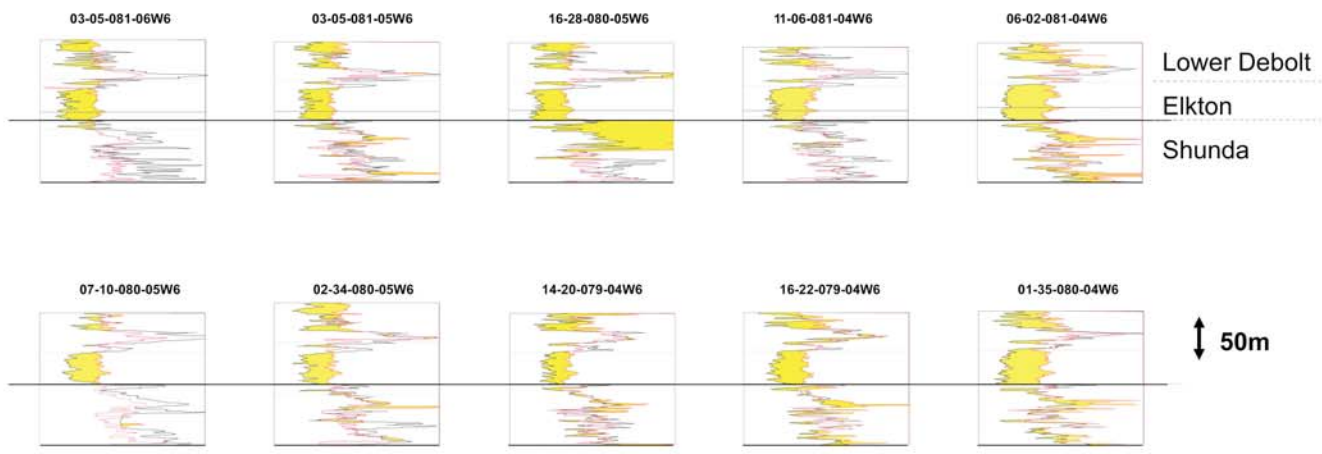


The base of the Belloy interpreted by IHS geologists seems to have been used as a shear plane which would have induced heavy tensile fracturing in the lithologies just above it. Two shear planes are common occurrences.



Legend

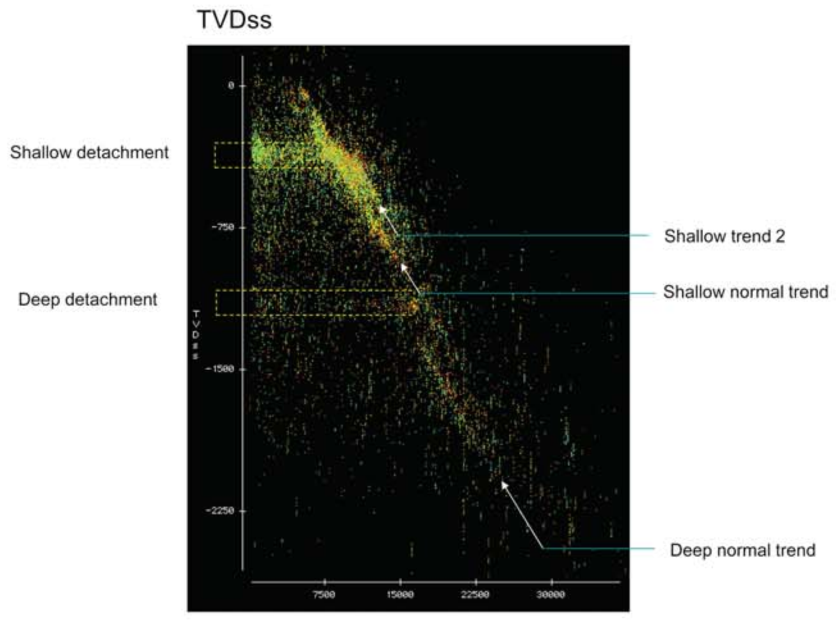
Detachment at base Elkton

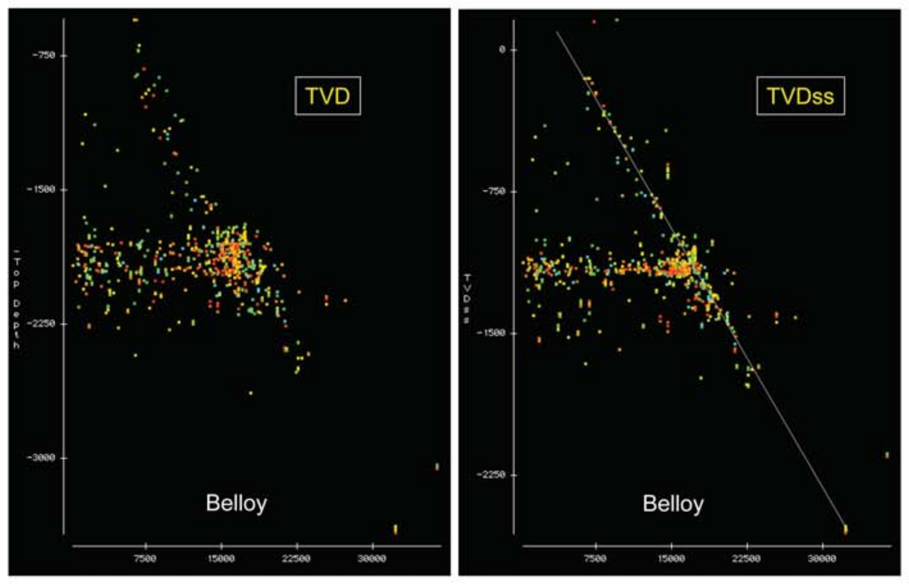


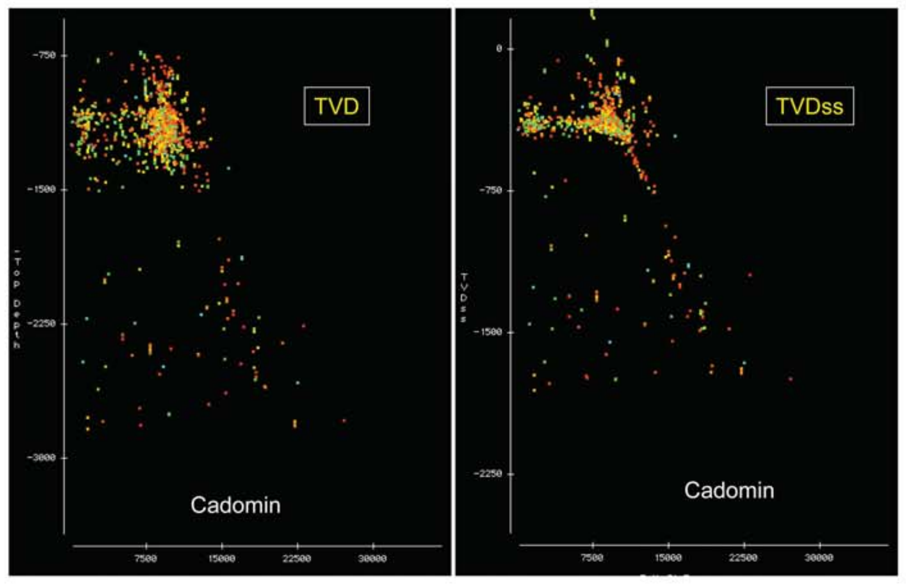
Enhanced fracture porosity above a detachment is very common; these two have been selected essentially because of log availability. Many other formations exhibit similar patterns.

Porosity destruction associated with detachments

Eastern British Columbia – Western Alberta



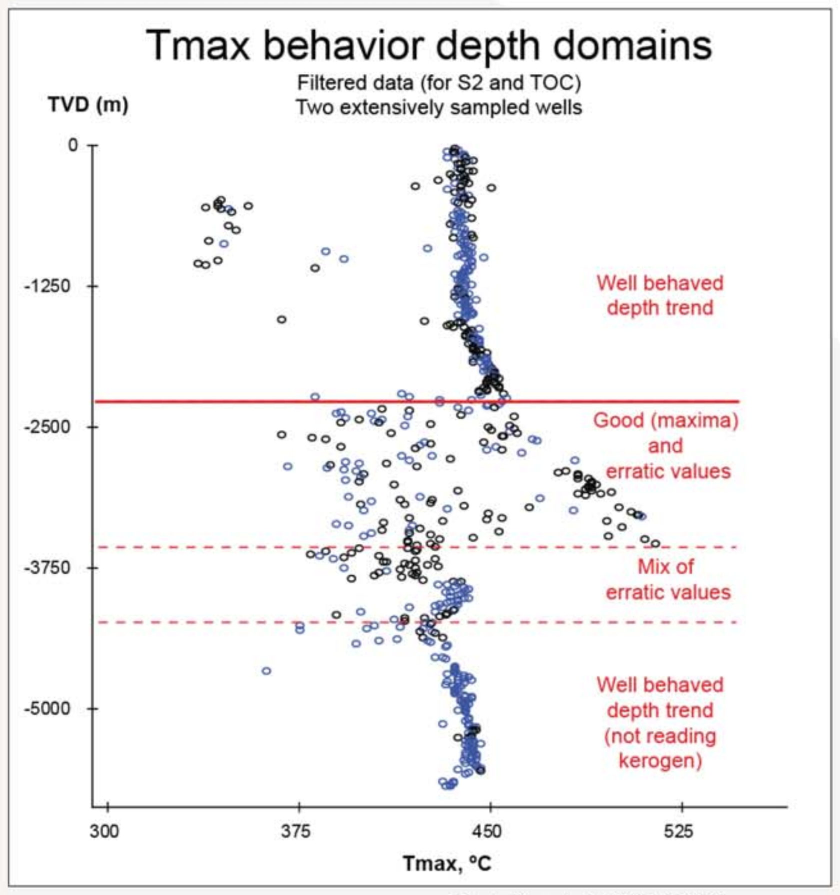




Alignment of the abnormal shut-in pressures using TVDss as reference, supports the idea of horizontal detachment at those levels

Detachments and hydrocarbon-generated overpressure

Oil-cracking derived overpressure

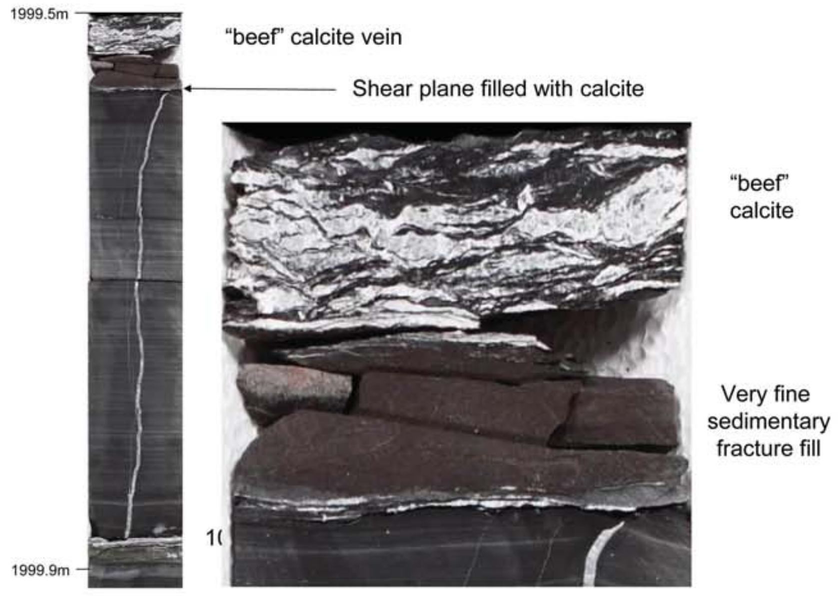


Chatellier et al. 2010, 2013

1.1%Ro

Beef Calcite Generation

Beef Calcite in Utica Shale associated with oil cracking

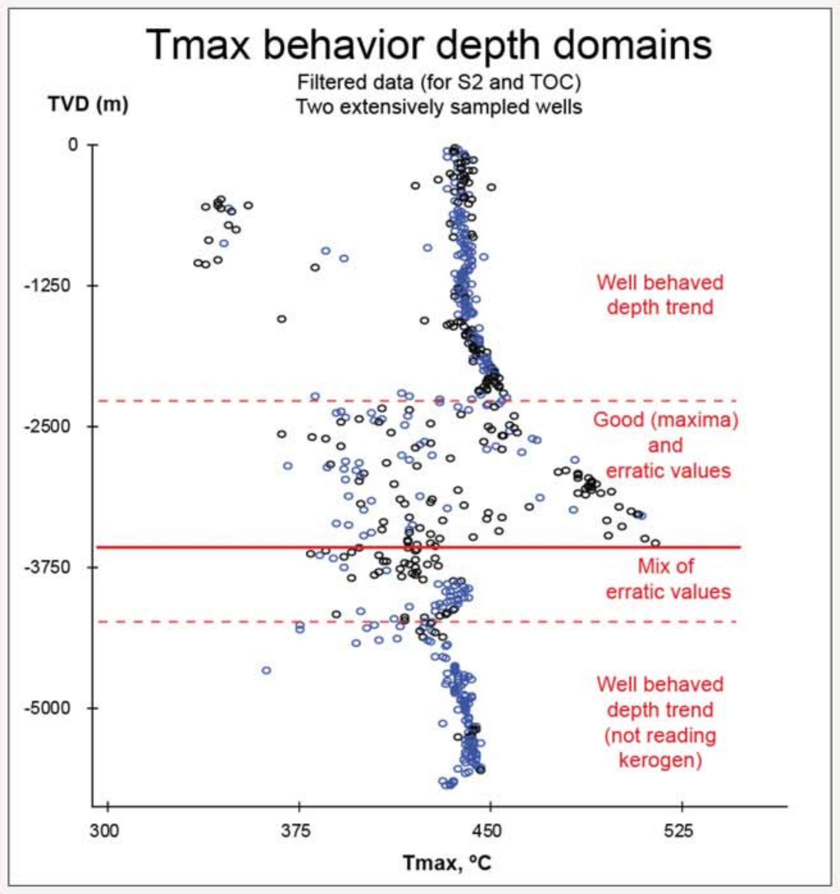


Typical habitus of beef calcite (expansion seams) above calcite filled shear fractures.
Note similar and characteristic XRF signatures of all of these calcite veins (beef, shear or tensile)

Oil cracking and beef-calcite precipitation is post-thrusting in the St Lawrence Lowlands.
The horizontal calcite layers cross-cut a fold.
Note XRF specific Sr signature in beef calcite.

At the time of oil cracking overpressure is generated that can induce detachments and displacement

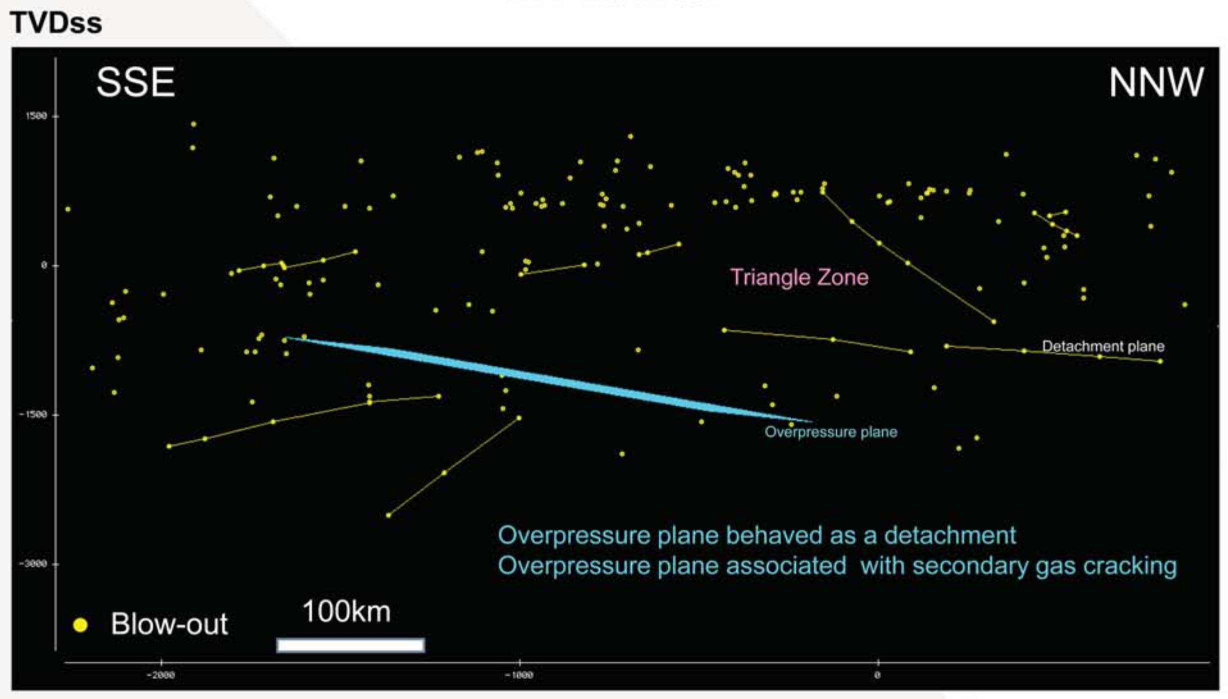
Secondary gas-cracking derived overpressure



Chatellier et al. 2010, 2013

1.5%Ro = overpressure plane

Zoomed and rotated projection of blow-out problems in wells In Alberta



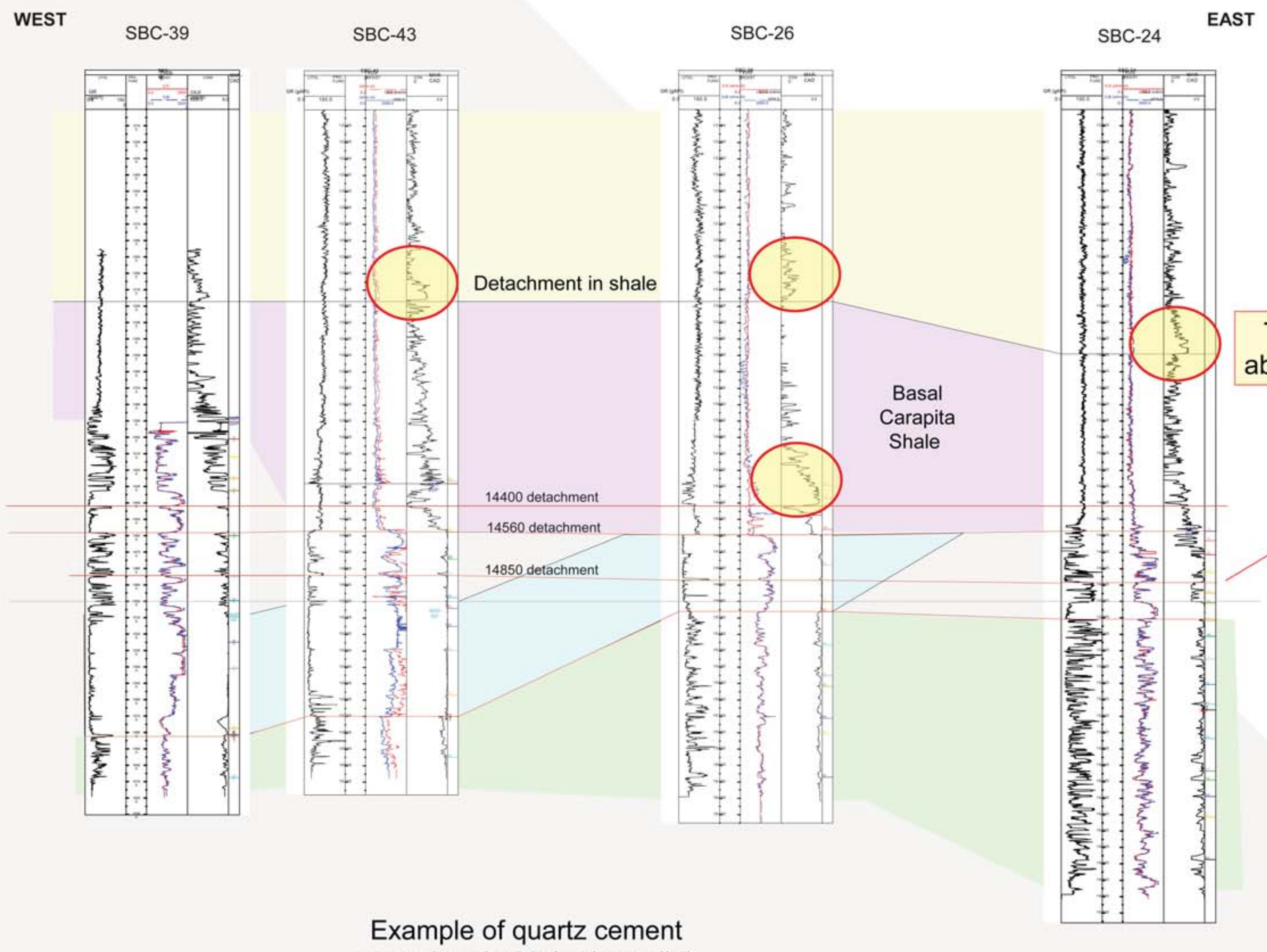
3-D Projection

In many basins major detachments have been recognized/generated at the level of the secondary cracking interface

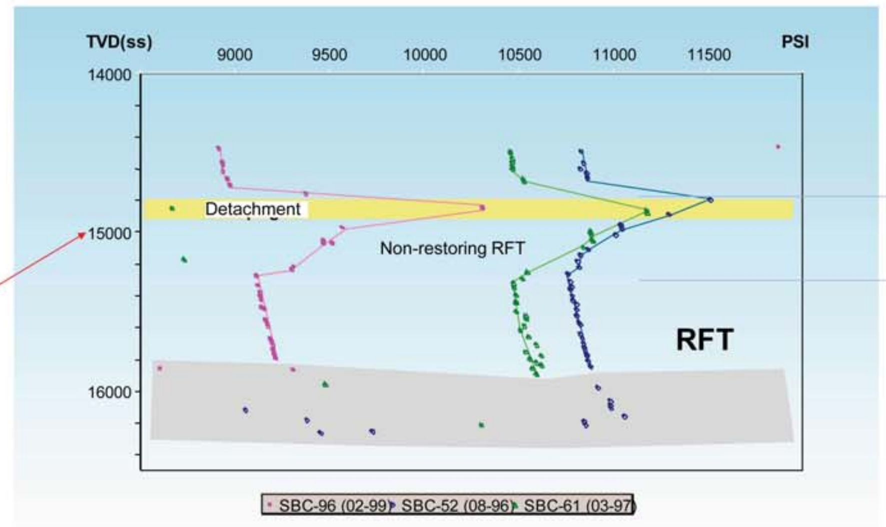
Pittsburgh AAPG Convention 2013

Processes associated with detachment planes

Expression of detachments in shale and sandstone sequences



RFT pressures from 3 wells a few kilometers to the NW of the cross-section

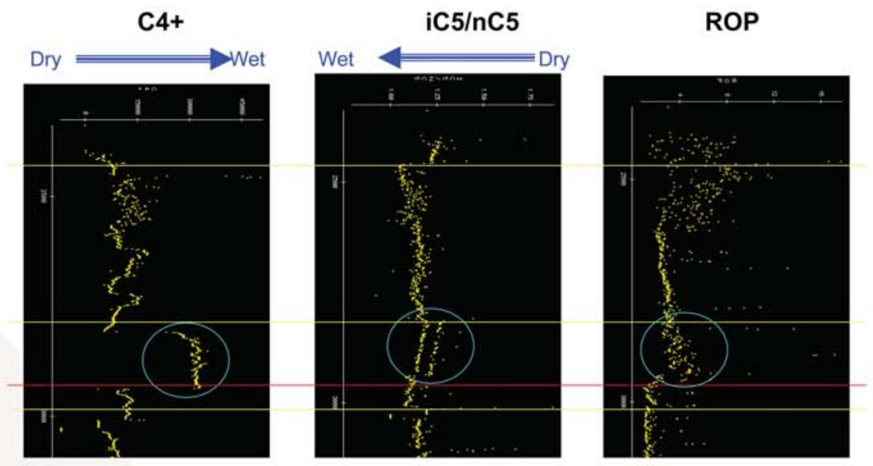


400-foot-thick zone with shear and slickensides in shale below detachment

Example of quartz cement associated with bed-parallel gliding prior to oil migration

Slickensides in shale

Expression in drilling parameters



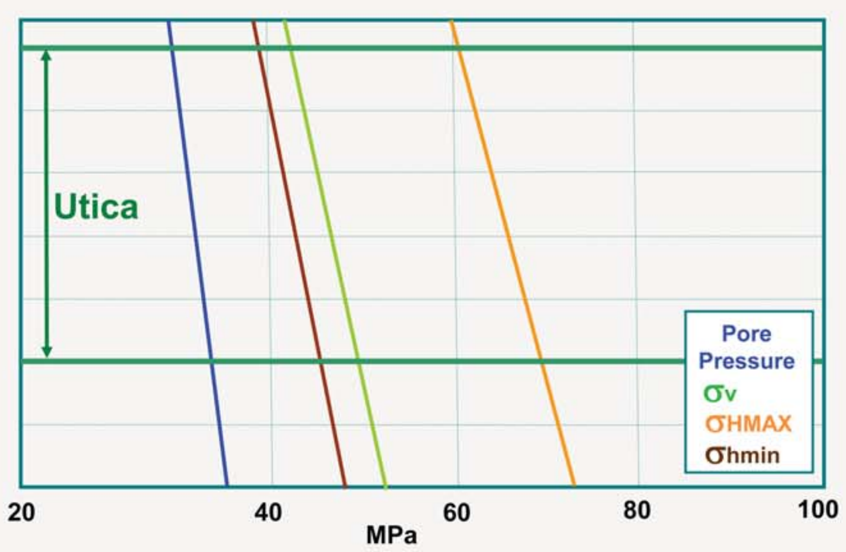
Wetter gasses | **Bimodality:** Fracture + matrix contribution | **Erratic and Increasing ROP**

Detachment

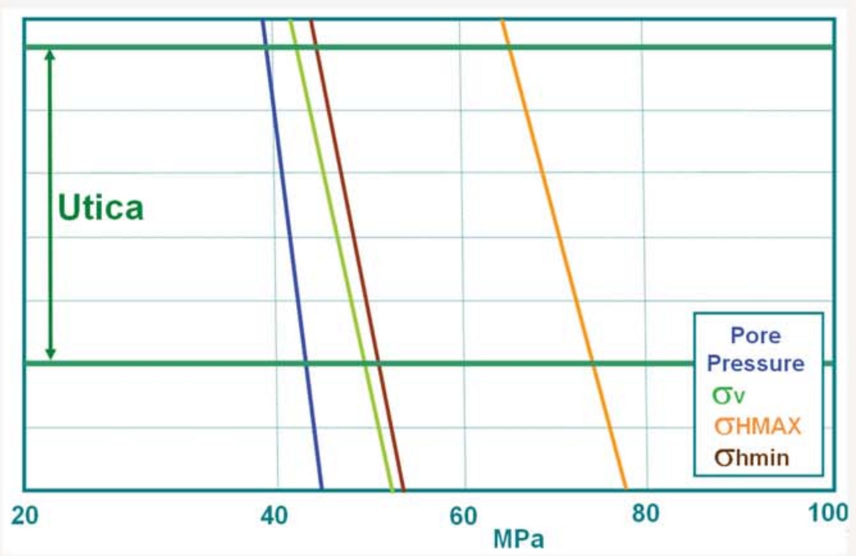
The abrupt change in ROP Is interpreted as the expression of a detachment

The effect of pore-pressure increase on the stress regime

Wrench Regime
Pre-completion stress state
More vertical fracturing
σHmax > σv > σhmin



Thrust Regime
Hydraulic fracturing stress state
More horizontal fracturing
σHmax > σhmin > σv



The increase in pore pressure associated with oil cracking can modify the local stress state. Thus it can move from strike-slip to compression, in which case the vertical stress is minimum and an open bed-parallel fracture can be created. The failure of the Mohr-Coulomb envelope is when the vertical stress is minimum.

The exact same mechanism can be generated by a hydraulic frac as the fluid injected will increase the pore pressure

Conclusions

- Shale units are commonly the place of predilection for horizontal detachments.
- Horizontal detachments can disrupt and misalign faults and fractures by displacing, even slightly, the rock units or layers located above and below the detachment. These displacements may have effects on sealing capacity, migration paths, fracture density, fracture orientation and on fraccability.
- Some hydrocarbon anomalies, such as the oil locally produced from the Kiskatinaw Formation among otherwise gas producing fields, are linked to detachments. These anomalies are associated with detachments within the Golata Shale that displace normal faults and create pathways for oil from the Exshaw Shale.
- Diagenesis associated with pressure solution and slickensides includes quartz-cement precipitation in rocks units surrounding horizontal detachments; these highly cemented zones, especially in hybrid shales, can create hydraulic frac barriers.
- High density tensile fractures are commonly associated with layer-parallel shortening along shale-bed interface. These fractures may influence the frac placement and will have some bearing on the gas deliverability of the stimulated zone.
- Pore-pressure increase associated with hydraulic fracturing can change the local stress regime and initiate horizontal frac propagation along specific bedding planes. These bed boundaries in shale behave as micro-detachments that may have positive or negative effects on a stimulated well productivity.

Acknowledgments:

Thanks to Talisman Energy Inc. for permission to present the material from this poster