Earthquakes Alignments Linked to Hydrocarbon Sweet-spots in the Western Canadian Sedimentary Basin

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Abstract

Alternating fault activity can be demonstrated using 4D views of earthquakes in areas where seismic events are frequent. Examples studied and published by the authors includes the December 26th 2004 Aceh earthquake that led to the infamous tsunami and the New Madrid Seismic Zone in the central part of the USA known for formation of Reelfoot Lake in 1812.

For this subsequent study, the Canadian government data available and used encompasses 11,800 earthquakes in Western Canada, 1,024 of which are located in Alberta.

The general picture in British Columbia is that of many major west-plunging and south-plunging seismic planes. In Eastern BC, our 3-D earthquake analysis shows a series of large seismic trends of similar strikes but variable dips, these are sub-parallel to hydrocarbon trends from the Rocky Mountain Foothills farther to the East.

In Alberta, the limited number of earthquakes recorded does not allow identification of any major plane encompassing many seismic events. However, 2D and 3D analyses covering Alberta, BC and part of Montana unravelled deep seated patterns of direct interest to the oil industry: many anomalous producers are perfectly aligned with seismicity trends.

Thus, in Alberta a different series of rules and methods had to be applied to decipher patterns of interest. Rule 1: as earthquakes are commonly located at the crossing between faults, each earthquake site can be used to define two separate fault trends. Rule 2: regular spacing between faults can be used as a guide to define the structural grain in the Alberta Plains.

A map-based approach and some outstanding results are outlined with three selected structural directions common in Alberta, North 93, North 9 and North 72 degrees. The former corresponds to deep seated faults commonly reactivated in left-lateral strike-slip mode, the other...
two directions are respectively the antithetic and synthetic Riedel shears. Examples of Hydrocarbon sweet spots linked to such earthquake trends will be taken from Paleozoic carbonate and Cretaceous sandstone fields.

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Western Canada Earthquake Distribution

Incredible alignments of earthquakes on preferential N-S and W-E planes. Majority of planes plunging South or West.

Large number of earthquakes. Some of them very deep > 225km. Dipping nearly perfectly to the South.

Observations near surface:
Unusual high concentration of CO2, N2, H2S and Dolomite.
Earthquakes and Big Hydrocarbon producing trends

Earthquakes planes on a map
- Two large elongated earthquake planes
- Two nice earthquake planes (another story)
- Earthquake cluster
- Planes unrelated to planes 1 or 2

Earthquake planes in 3-D projection
- Projection (nearly West East)
- Map view
Here are two earthquake planes with very similar strikes.
Trend 2a is further South in Montana; At the map scale it belongs to trend 2

Hydrocarbon pools in 3-D
- 3-D view of hydrocarbon producers in the WCSB
- Colour = quantity produced
- Cut-off date = Dec 31 2003

Seismic trends 1 and 2 have been merged to a series of en-echelon Producing pools
This was done in a 3-D volume by changing the vertical scale of the earthquakes by a factor 100
i.e. 75km = 750m
150km = 1500m

Extracted 3D view of merged data sets
Very similar strikes, slight difference in dip angles

The best vertical alignment of hydrocarbon pools is parallel to the newly identified earthquakes planes
It is estimated that the cumulative production along that trend is more than 125 times the Alberta average per rock volume

Alberta hydrocarbon production slices
- 1.32 Billion BOE
- 26 times the average prod
- Alberta total prod = 21 Billion BOE
- 50 million BOE per slice
- Average prod for 400 slices = 0.05 Billion BOE
Last update Dec 31st 2003
Earthquake and deep seated strike slip faults

All started with the North 9 degrees lineaments

Banff Formation
Devonian Fairholme (lineament 2)

Aeromag confirms that direction (lineament 1)

Three associated deep seated structural elements

Three associated deep seated structural elements

Antithetic riedel
Synthetic riedel
Strike-slip Fault

The earthquake trends are mimicking the patterns shown by abnormal production behavior; they are linked to the deep seated fault system

Paleozoic producers
Yellow to red bubbles

Water breakthrough (shale gas)
Earthquakes
Paleozoic
Cum BOE
Super parax LHR

Paleozoic producers

Deep seated strike slip fault
Incredible opportunity for some of the best seismic

Synthetic riedel shear
relatively high-risk in map area

Antithetic riedel shear
Great opportunity
Earthquakes and Cardium Pools Orientation

Observations

Cardium Producers

Cardium producers are commonly aligned on NW-SE trends
With one exception one trend is WNW-ESE

Earthquakes

There are five important earthquakes in the study area
All between 2.8 and 3.5 on Richter scale
Perfect alignment along two parallel trends

Problems

Cardium Producers

Note the alignment of the southern earthquake trend with the anomalous Cardium producer trend

Devonian Producers

Large and very large Devonian oil producers in the study area

Lessons

Perfect alignment of the Northern Earthquake trend and three very large Devonian oil producers in the study area

The Blueridge pool to the East needs the seismic trend to make some sense

Regular pattern of earthquakes and its relationship with Paleozoic hydrocarbon production

Merged data sets
Conclusions

The great majority of all of the earthquakes recorded in recent years are aligned on known trends of big hydrocarbon producing anomalies.

Their geographic distribution and the relative geometry of the observed trends are best explained by a simple sets of deep seated faults that are reminescent of strike slip faults and their Riedel shears.

Merged data sets

The mega scale earthquake planes in Western Alberta and Eastern British Columbia are parallel to a mega scale hydrocarbon trend.

Deep seated structural features are linked to many hydrocarbon sweet-spots in Western Canada.

Mega earthquake planes

1.32 billion barrels trend

We would like to thank the seven companies that accepted to be members of a consortium on the multidisciplinary 3-D analysis of the Western Canadian Basin (Tecto Sedi Integrated 2003).

References

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