Three-Dimensional Organization of Low Angle Fault Planes and Fractures in Alberta - A View of Problems in Wells, Sweet-Spots and Migration Paths*

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Abstract

Multidisciplinary 3D integration can unravel structural elements not described before and can explain various types of unexplained anomalies. The present paper is essentially based on the large amount of public domain data available for the Western Canadian Sedimentary Basin; this includes drilling problems, production anomalies, and abnormal gas occurrences as well as more typical geological data such as cuttings and core descriptions or wireline log data.

Commonly, anomalies aligned on a map are interpreted as linked to subvertical faults or fracture systems. On the other hand, apparently random anomalies remain unexplained as they cannot be linked to any other anomaly or structural feature. Three-dimensional exploration statistical tools can reveal the existence of planar relationships between these individual instances. Many low angle structural planes with less than one degree angle connect many interesting features that can be understood in the structural context of the areas involved.

A 3D study of the southern part of the Peace River Area reveal two main planes connecting many large hydrocarbon producers, these two planes account for 56% of the hydrocarbon production covering a very large acreage (after filtering the very deep Devonian that were too rare and too scattered).

Drilling data is too commonly neglected in a structural analysis; it can be used with some caution because many problems can have been caused by operator mistakes or by consequences of previously solved problems (e.g. too high mud-weight following a gas kick inducing a loss circulation problem). The sheer amount of data available from drilling compensates for this kind of uncertainty. One example from West
Central Alberta will show that some 40 planes connecting drilling problems coherently plot on a Schmidt diagram with great circles at 90 degrees from each other.

One example of abnormal porosity spikes delivers a near perfect low angle plane that is totally in line with today’s compressional stress regime orientation. Other examples will show the use of gas composition anomalies such as H$_2$S and a case of abnormal red stain in cuttings that shed new light on the structural history of the Peace River area. Combining data of different kinds brings down the uncertainty linked to the proposed planar relationships.
Multidisciplinary 3-D integration can unravel structural elements not described before and can explain various types of unexplained anomalies. The present paper is essentially based on the large amount of public domain data available for the Western Canadian Sedimentary Basin; this includes drilling problems, production anomalies, abnormal gas occurrences as well as more typical geological data such as cuttings and core descriptions.

Commonly, anomalies aligned on a map are interpreted as linked to subvertical faults or fracture systems. On the other hand, apparently random anomalies remain unexplained as they cannot be linked to any other anomaly or structural feature. Three-dimensional exploration statistical tools can reveal the existence of planar relationships between these individual instances. Low angle structural planes commonly with less than one degree angle connect many interesting features that can be understood in the structural context of the areas involved.

A local 3-D study within the Peace River Area reveals two main planes connecting many large hydrocarbon producers, these two planes account for 56% of the hydrocarbon production covering a very large acreage (after filtering the very deep Devonian that were too rare and too scattered).

Drilling data is too commonly neglected in a structural analysis, it can be used with some caution because many problems can have been caused by operator mistakes or by consequences of previously solved problems (e.g. too high mud-weight following a gas kick inducing a loss circulation problem). The sheer amount of data available from drilling compensates for this kind of uncertainty. One example from West Central Alberta will show that some 40 planes connecting drilling problems coherently plot on a Schmidt diagram with a direct link to great circles at 90 degrees from each other.

Other examples will show the use of gas composition anomalies such as H2S. Combining data of different kind brings down the uncertainty linked to the proposed planar relationships.

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Abstract

Keywords

Cross-formational approach
Anomaly approach
3-D exploratory statistics
Big hydrocarbon producers

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High pressure and blow-out low angle planes

North-South projection of all blow out problems in wells

Blow-outs aligned on planes

Zoomed and rotated projection of blow out problems in wells

Major regional blowout plane

Maps of two major very low angle near N-S planes

Map of low angle high pressure plane TWP 74

All high pressure problems in wells

Perfect North-South Projection

Zoomed projection of all high pressure problems

Extremely well defined very low angle N-S plane
Planar alignments of lost circulation events

Graphical summary of intersections of lost circulation planes with the top of the Upper Cretaceous Leapark Formation

- Note that only for vertical planes (e.g., plane 10) the map will be the same when dealing with other formations.
- The aim of the map is to give a feel for where to expect problems and to give the direction of the intersections.

Dimension of all interpreted lost circulation planes

Why are the two great circles at 90° to each other?

The planes not on the two great circles are aligned with the main regional riedel shear directions known in the area.

Three stereoplot views of all of the lost circulation and blow out planes.

Geographic position of some planes

Lower hemisphere projection

Anomaly approach
Cross-formational approach
3-D exploratory statistics
H2S Anomalies aligned on low angle planes

Example 1

Projection and map view of a shallow H2S very low angle plane

Slope = 100 meters in 35 km
0.2 degree dip

Note the very horizontal distribution of H2S crossing stratigraphy from the Swan Hill of Kaybob to the Leduc of Pine Creek

Example 2

H2S low angle plane

Note that the direction of the plane of projection is the direction of today's stress.
Low Angle Hydrocarbon Migration in West Central Alberta

A very large majority of Devonian hydrocarbon pools is aligned on one preferential low angle plane dipping 0.9° to the SW (North 215°)

3-D views of a mega migration low angle plane

View optimized for Top Nisku

View optimized for planar oil pools alignment

View optimized for multi-layer display

Depths are at top producing intervals, not at the depth of the production perforations

Simplified stratigraphic chart

Schematic cross-section of some Devonian strata

Hydrocarbon producing pools

- Wabamun Fm
- Wintario Gp
- Blueridge Mbr
- Nisku Fm
- Cynthia Mbr
- Wolf Lake Mbr
- Zeta Lake Mbr

Plane dip = N215 /0.9°

Top of Nisku surface (convergent gridding) and all of the Devonian hydrocarbon producers

Top of Wabamun surface (convergent gridding) Based on all tops from more than 3000 wells

Hydrocarbon migration plane (1st order polynomial)

All of the Devonian hydrocarbon producers in map area (cut-off dec 31 2003)
Hydrocarbon Migration along Low Angle Planes

in Peace River Area

Planar alignments on 3-D volume

Slicing the dice for 3-D statistics

Planes crossing formations

Map view of 3-D volume and projection orientation

Contour map of Big Prod 2 Plane and intersections with two formations

3-D views of Big Prod 2 Plane

Cumulative Production

Proportion of rock volume

3-D exploratory statistics clearly indicates that hydrocarbon in the study area is not randomly distributed

Pools located on 2 low angle planes account for 56% of the hydrocarbon produced in the selected volume