

Importance of low angle migration paths in Alberta – Detection and 3-D visualization

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Introduction

The importance of low angle migration paths will be demonstrated via a series of examples covering oil, gas or water migration.

All of the examples used are based exclusively on public domain data released by the Alberta Board; they include problems in wells, gas compositions, pressures, cumulative hydrocarbon productions (as of December 2003) and formation tops. One example will however invoke proprietary data of cutting descriptions graciously released by Canstrat.

The low angle planes

The first example relates to some present day hydrocarbon migration paths along a south plunging low angle fault plane system (Figs.1 and 2). The plane is characterized by high to very high pressures; it is extremely large and has been identified from western Saskatchewan to Eastern British Columbia. Whereas the plane is laterally extensive and can be interpreted as a low angle fault system, the plane crosses stratigraphy (Fig.3) and can be subdivided into various distinct segments, some of which do not exhibit any high pressure. The fracture plane probably does exist in these two segments devoid of gas kicks but the lack of traps and possibly the lack of gas generation today imply a lack of gas kicks. The plane is plunging at an angle of 0.6 degrees to the south (N180).

The existence of migration planes can be revealed by specific staining of cuttings. Thus dead oil stain can indicate hydrocarbon migration paths or iron stain can indicate water migration paths. One example of these low angle migrations of iron rich water will be examined using Canstrat cuttings descriptions. The stratigraphy of the stained units can narrow down the age of a migration.

In one area of West Central Alberta, abnormal occurrences of H₂S gas in Cardium, Dunvegan and Paddy Cadotte at shallow depths are perfectly aligned on a low angle plane(Figs. 4 and 5). The absence of recorded high H₂S concentration in other wells on that plane seems to confirm that the H₂S comes from deeper horizons and got trapped locally on the low angle plane.

Extremely high pressure planes south of the Peace River Area. Seven occurrences of extremely high pressure kicks have been analyzed in a 3-D volume. The 3-D position of the events has been studied

and revealed the existence of two parallel planes, one with four points, the other one with three. This second plane is validated by the parallelism with the first plane despite having only three points.

Our study of hydrocarbon production in a large 3-D volume in the Peace River Area has revealed the existence of major low angle planes of migration that account for a very large part of the production to date (as of December 2003). Statistics were performed on the volume excluding the Devonian strata because of the too localized and too limited penetration. The fields located on two migration planes have thus produced 31.4% and 24.9% of the total of hydrocarbon produced (Figs. 6 to 11); this is respectively 81 and 64 times more than the average of all of the other layers. Note that the two volumes are differently rotated to maximize the fit with the proposed migration planes. Figure 7 shows that these planes are crossing stratigraphy.

Conclusions

Exploration tools dealing with 3-D multidisciplinary data have proved to be very valuable in deciphering some of the hidden structural elements that control the hydrocarbon distribution and migration paths in Alberta. All of the findings presented here could not have been achieved without the easily accessible public domain data base available to all of us geoscientists. The western Alberta Basin may still have some surprises left for us.

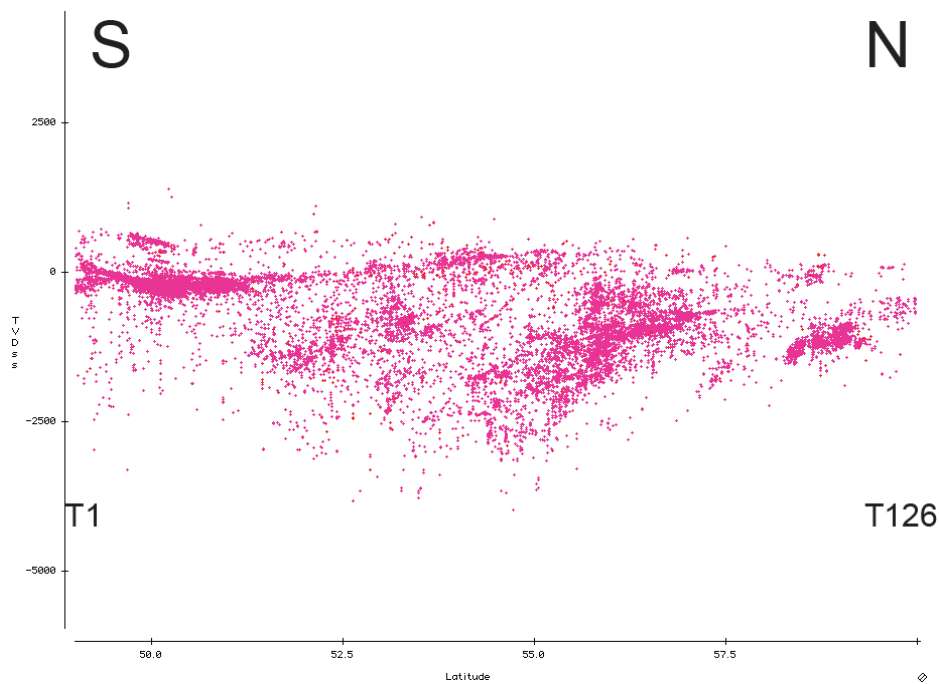


Fig.1 North-South Projection of High pressure gas kicks reported to the Alberta Energy Board

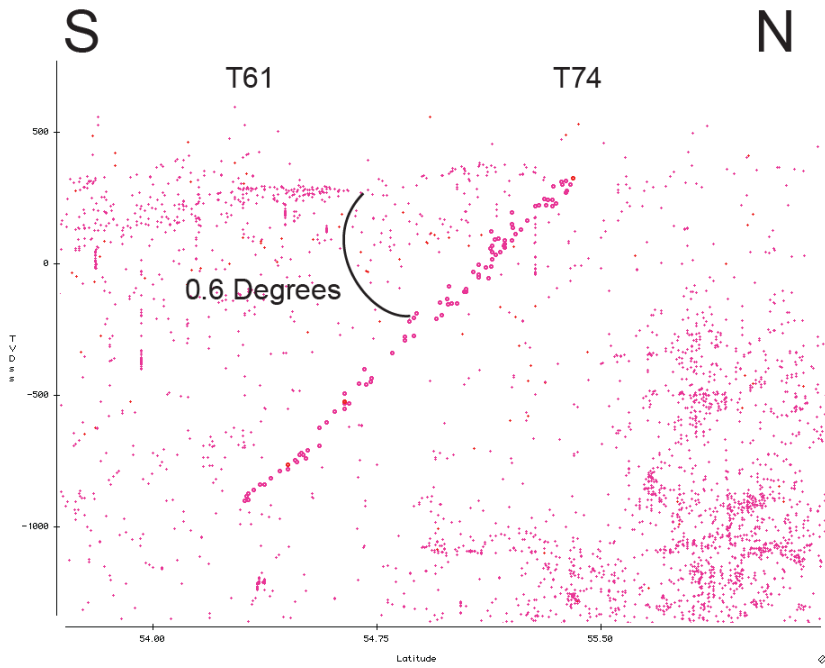


Fig. 2 Zoomed view of the low angle fault plane (migration) with a 0.6 degree dip to the south

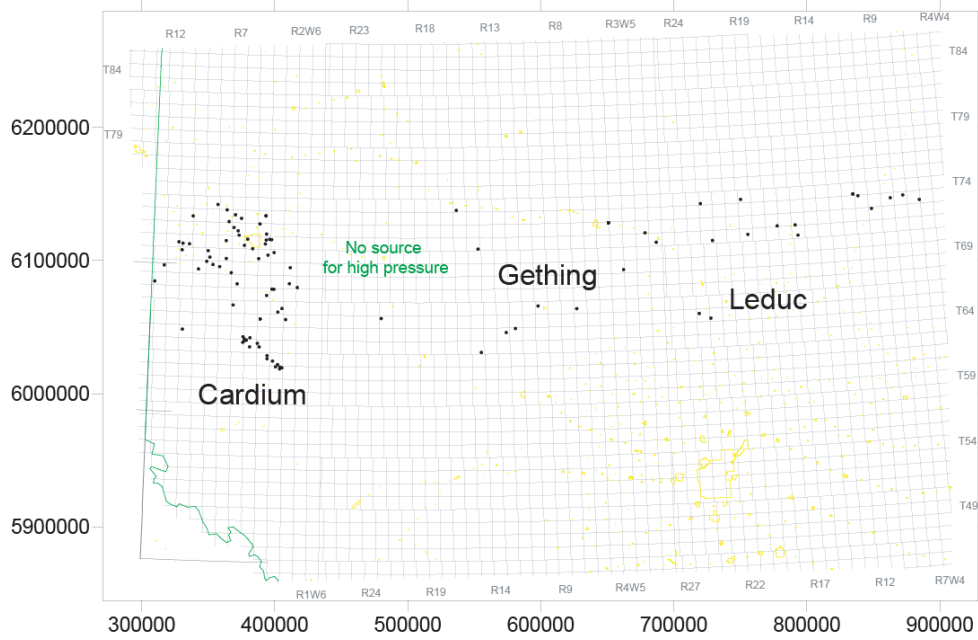


Fig. 3 Location of the 101 wells with high pressure gas kicks on a shallow south dipping plane, The selected formations cited are only indicative of some of the stratigraphic units involved

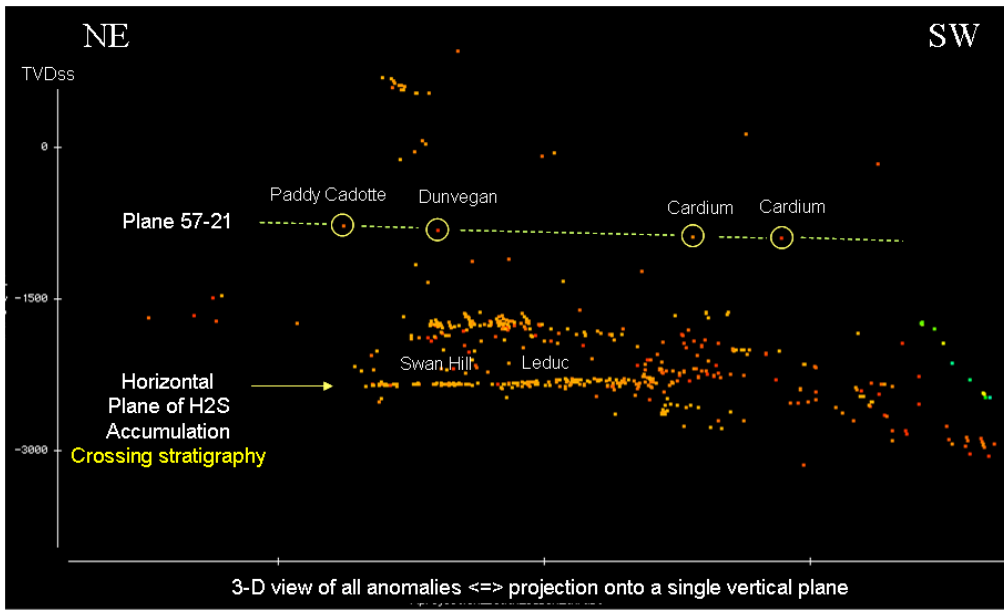


Fig.4 Projection 3-D of high H₂S occurrences in West Central Alberta showing the alignment of some shallow H₂S anomalies on a single plane

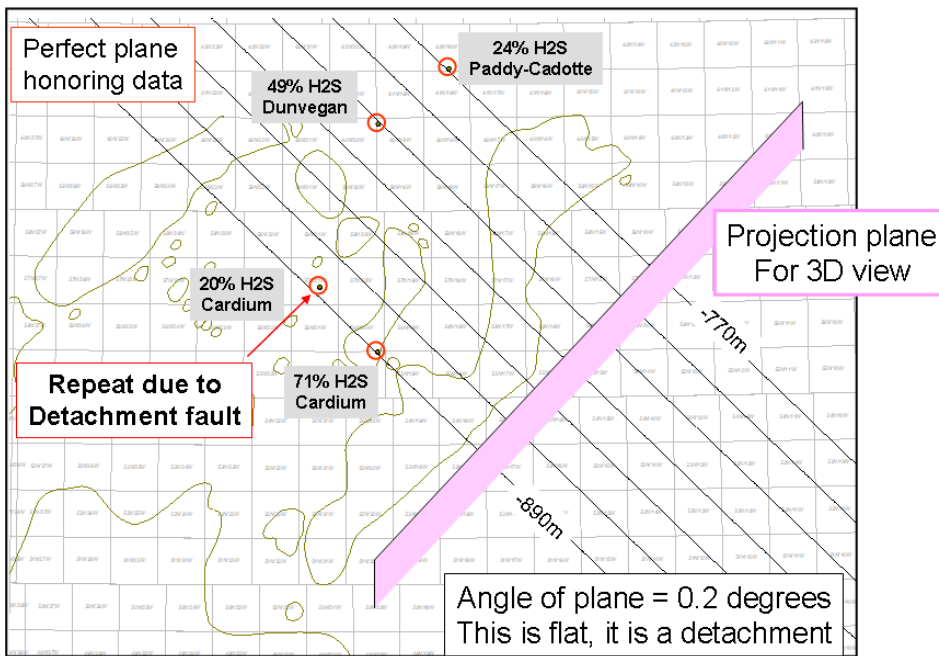


Fig.5 Contour map of the anomalous H₂S plane – note that the values reported are the highest recorded in any of the gas samples analyzed

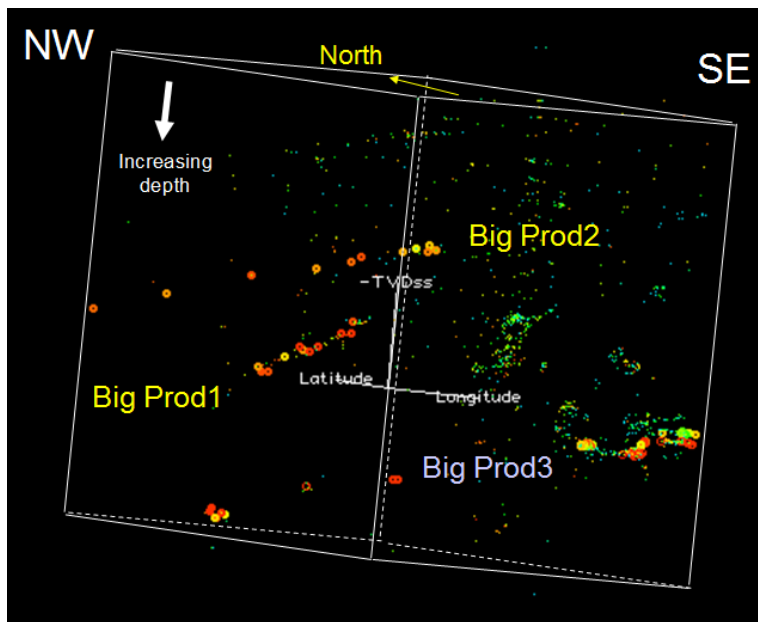


Fig.6 Projection 3-D of hydrocarbon production in a large volume taken from the Peace River Area – three major planes migration planes

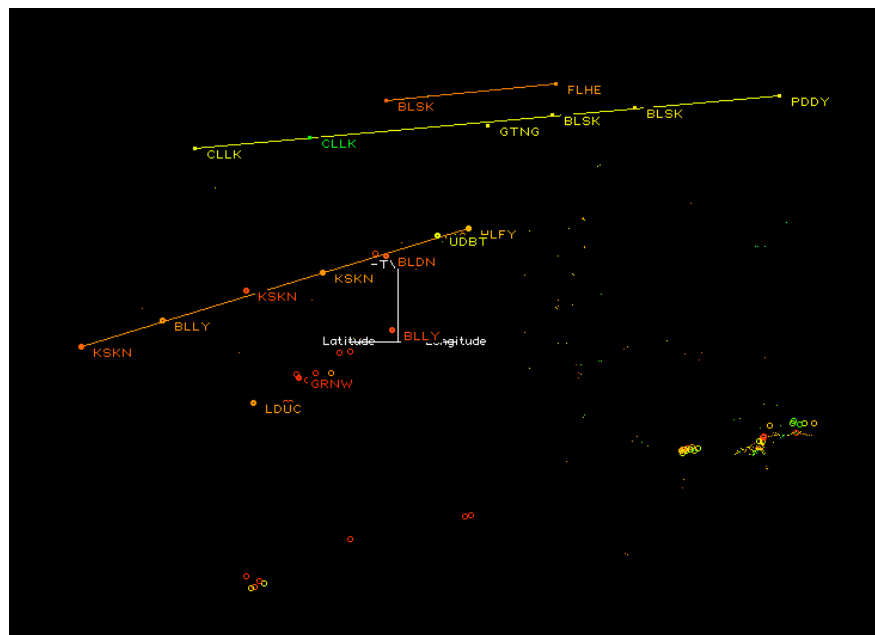
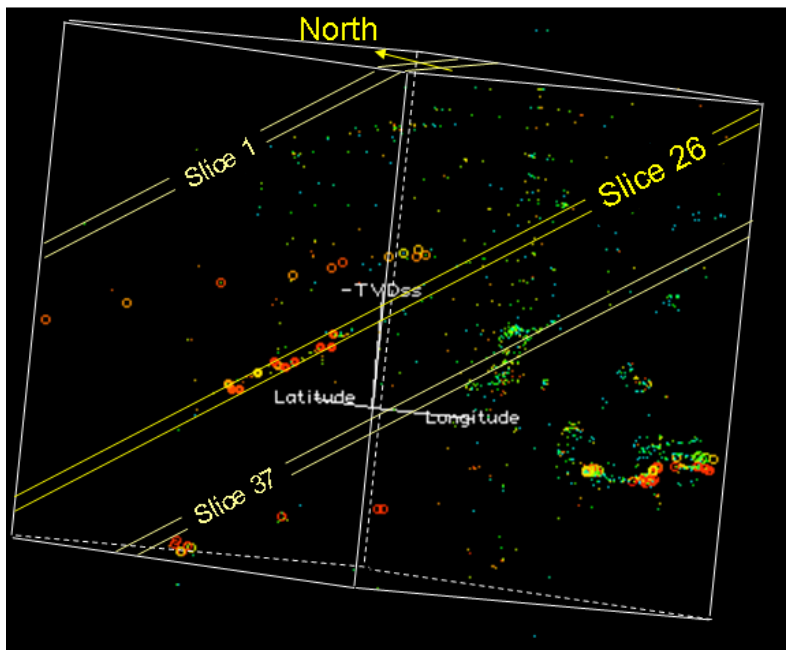


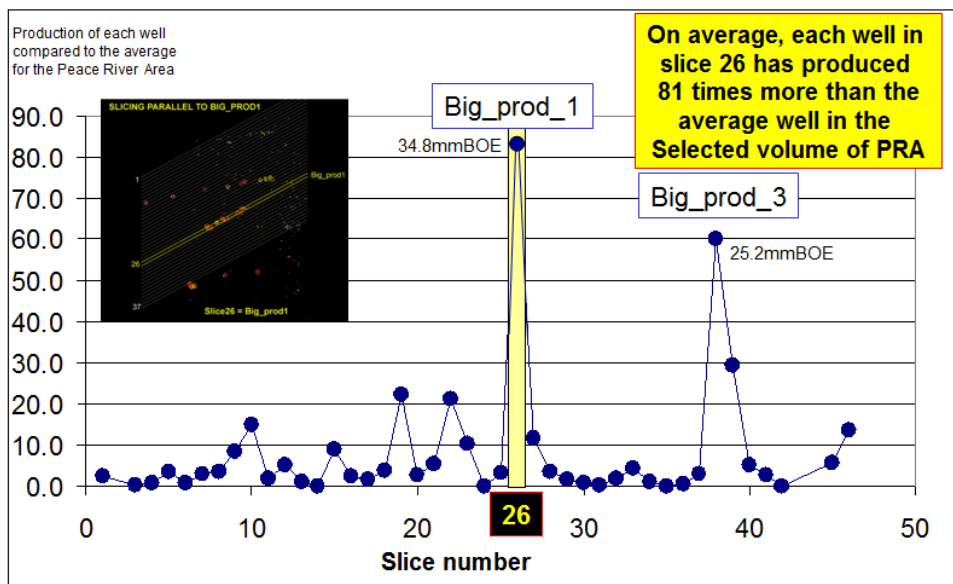
Fig.7 Low angle planes linking major producing wells and some of the associated formation names. These underline the cross-formational aspect of these structural elements



Slice 26
Has produced
31.45 % of
the total production
From
slice 1 to slice 37

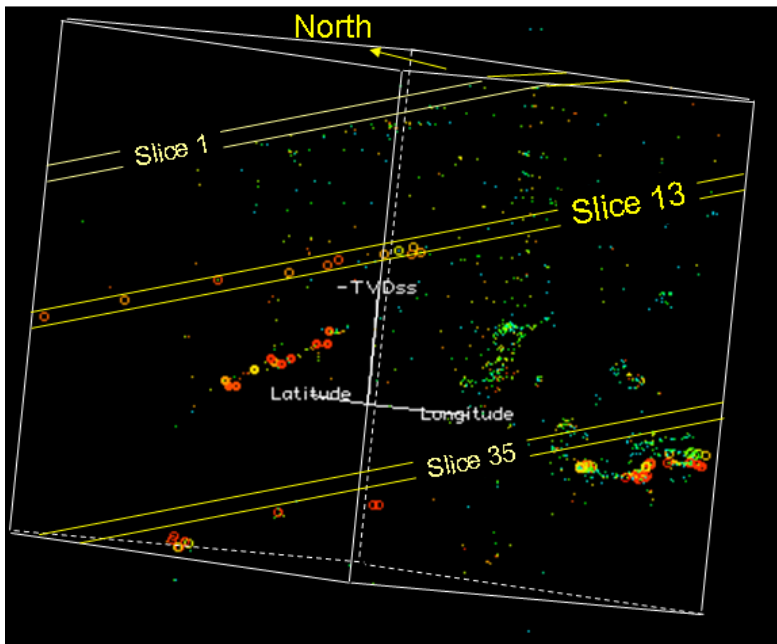
Slice 26 = 1/37th of the
whole earth volume
i.e. 2.7 %

Fig.8 Volume 3-D oriented for a statistical analysis linked to Big_Prod_1 plane



Vertical axis is cumulative production as a function of average pool size
Horizontal axis: slice ID as 3-D volume is broken up in slice **parallel to production plane 1**

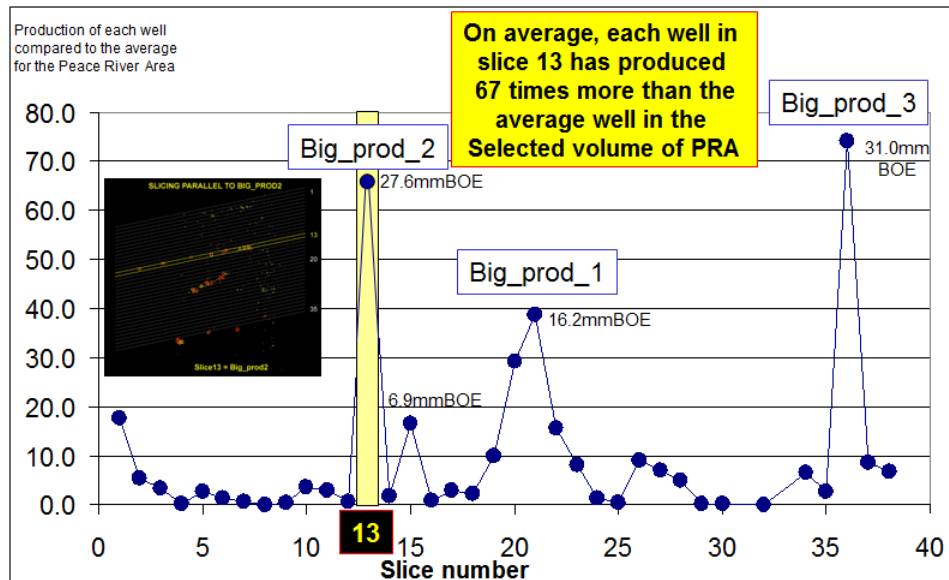
Fig.9 Cumulative production of equal volume slices parallel to the Big_prod_1 plane



Slice 13
Has produced
24.95 % of
the total production
From
slice 1 to slice 35

Slice 13 = 1/35th of the
whole earth volume
i.e. 2.85 %

Fig.10 Volume 3-D oriented for a statistical analysis linked to Big_Prod_2 plane



Vertical axis is cumulative production as a function of average pool size
Horizontal axis: slice ID as 3-D volume is broken up in slice parallel to production plane 2

Fig.11 Cumulative production of equal volume slices parallel to the Big_prod_2 plane