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 production (as of December 2003), and formation tops. One example,however, will 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-dipping, low-angle fault plane system (Figures 1 and 2). The plane is characterized by high to very high pressures; it is extremely widespread; it 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 (Figure 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 dipping 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. Our example of these low-angle migrations of iron-rich water resulted from examining Canstrat cuttings descriptions. The stratigraphy of the stained units can narrow the age of a migration.

In one area of West Central Alberta, abnormal occurrences of H_2S gas in Cardium, Dunvegan, and Paddy Cadotte at shallow depths are perfectly aligned with a low-angle plane(Figures 4 and 5). The absence of recorded high H_2S concentration in other wells on that plane seems to confirm that the H_2S comes from deeper horizons and was trapped locally on the low angle plane.

Extremely high pressure planes are present south of the Peace River Area. Seven occurrences of extremely high pressure kicks have been analyzed in a 3-D volume. Study of the 3-D position of the events 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 as of December 2003. Statistics were performed on the volume, excluding the Devonian strata because of the data are too localized and penetration too limited. The fields located on two migration planes have produced, respectively, 31.4% and 24.9% of the total hydrocarbon production (Figures 6, 7, 8, 9, 10, and 11); this is 81 and 64 times, respectively, 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 cross 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 the findings presented here could not have been achieved without the easily accessible public-domain data base available to all geoscientists. The western Alberta Basin may still have some surprises left for us.

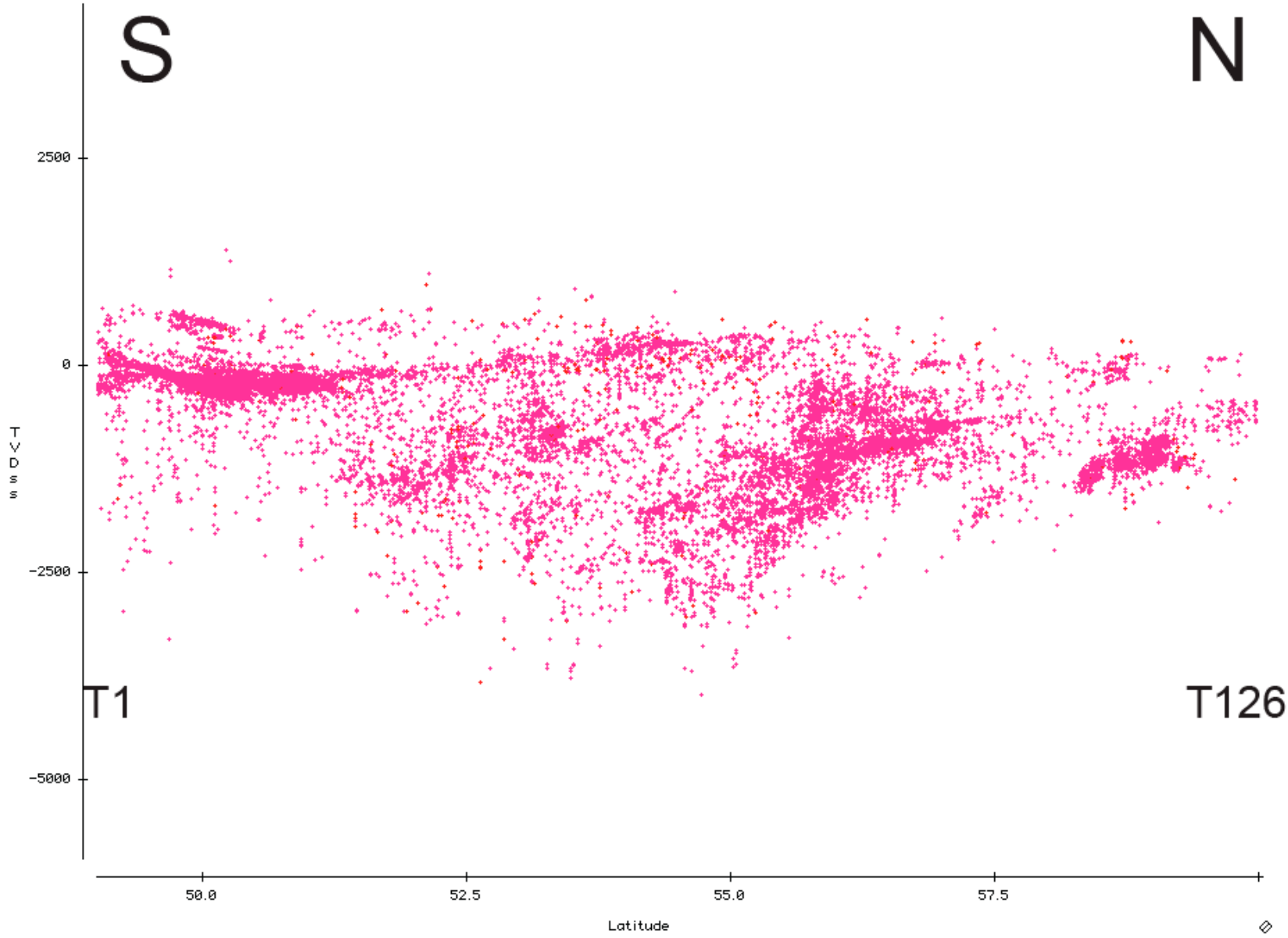


Figure 1. North-south projection of high-pressure gas kicks reported to the Alberta Energy Board.

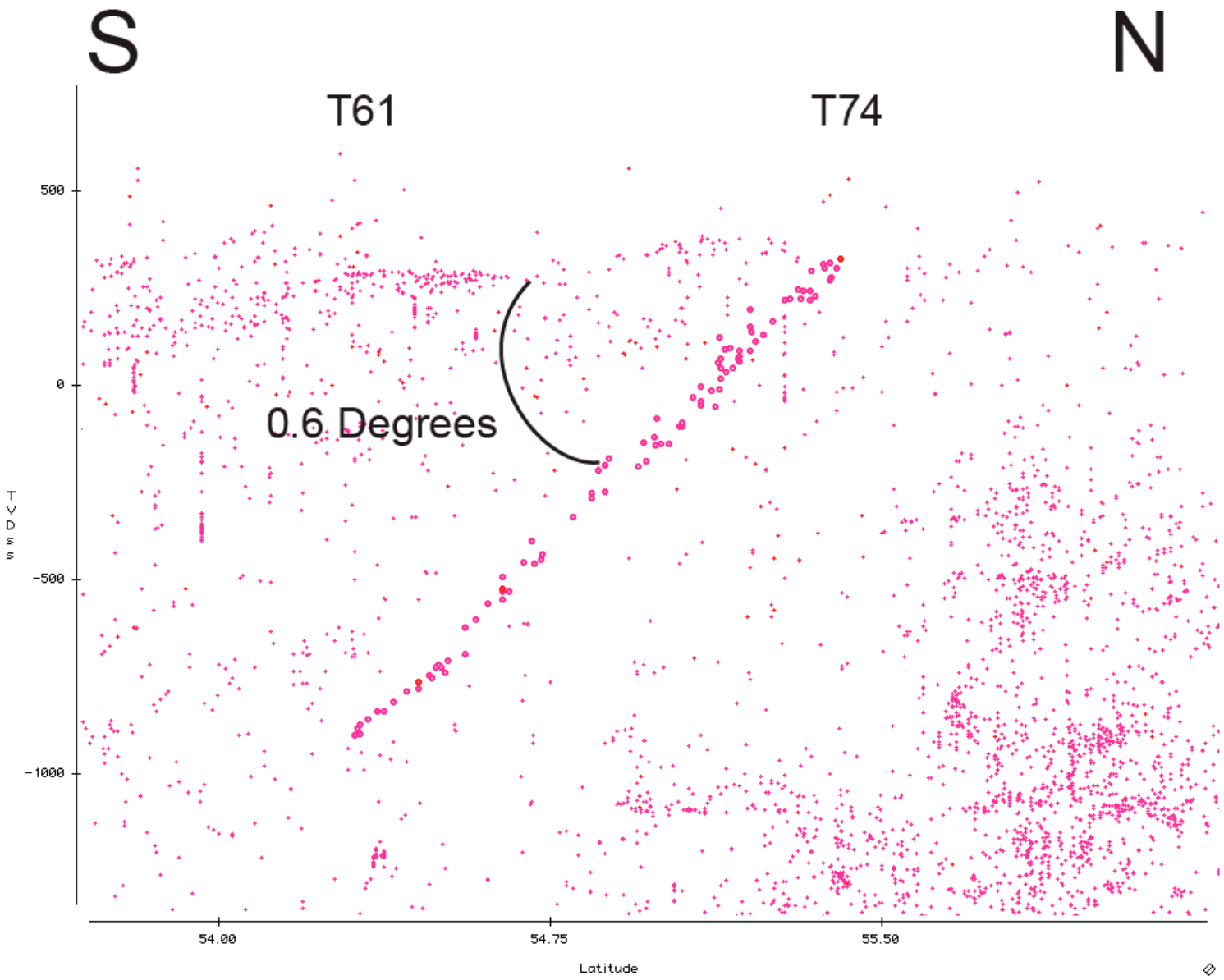


Figure 2. Zoomed view of the low-angle fault plane (migration) with 0.6 degree dip to the south.

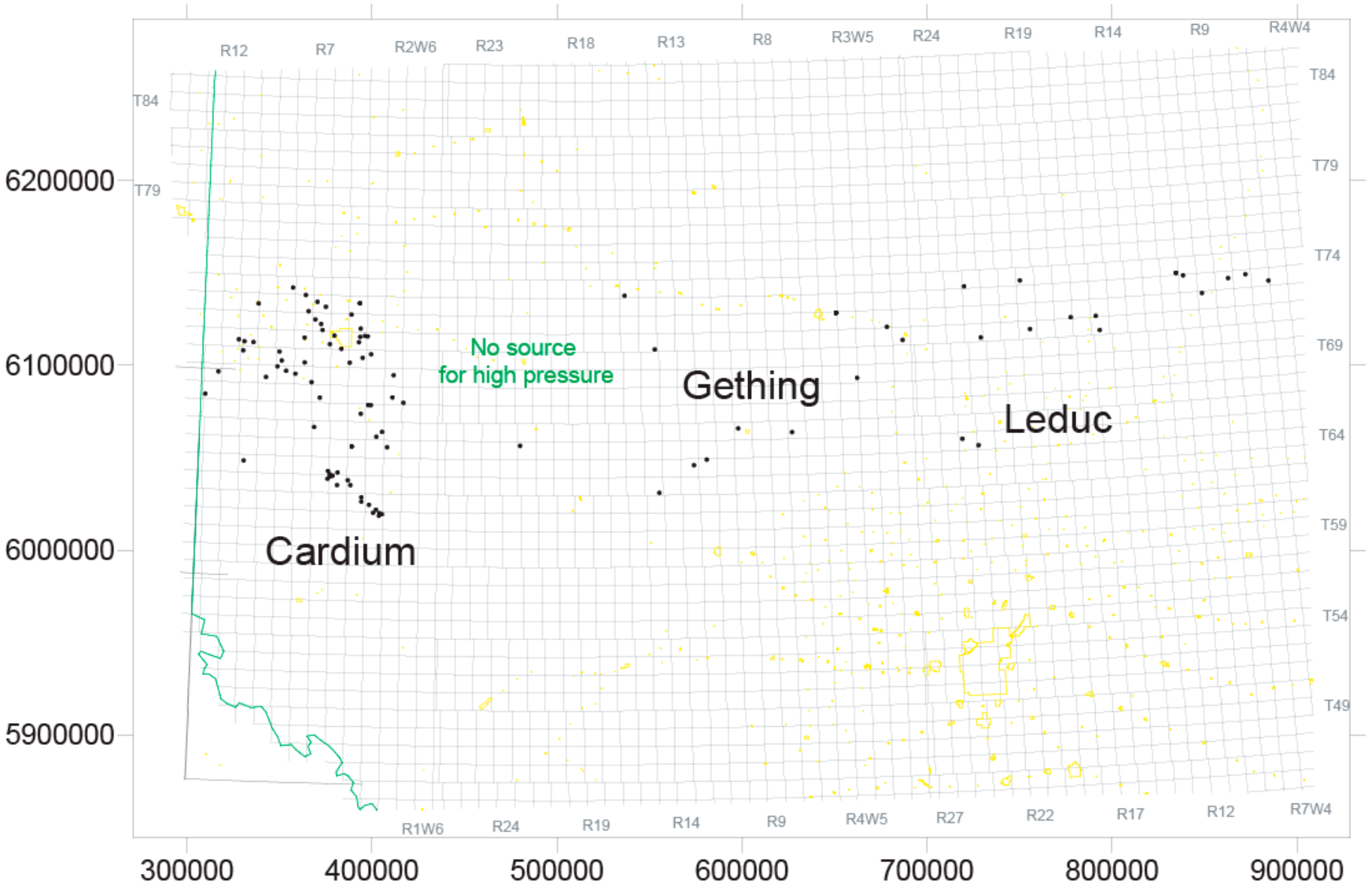


Figure 3. Location of the 101 wells with high-pressure gas kicks on a shallow south-dipping plane, The selected formations cited are only indicative of some of the stratigraphic units involved.

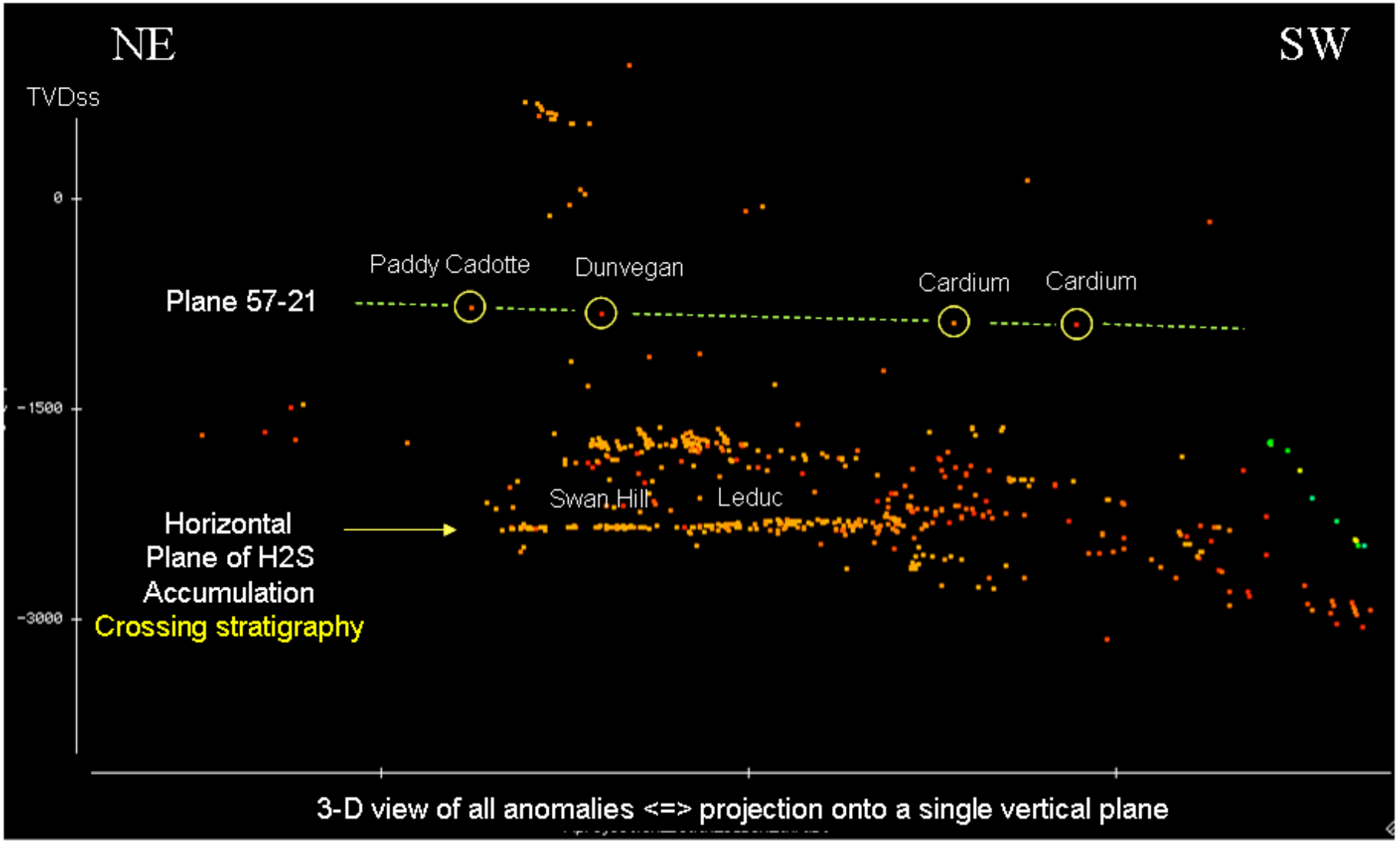


Figure 4. Projection of high H_2S occurrences in West Central Alberta, showing on a single vertical plane the alignment of some shallow H_2S anomalies on a single plane.

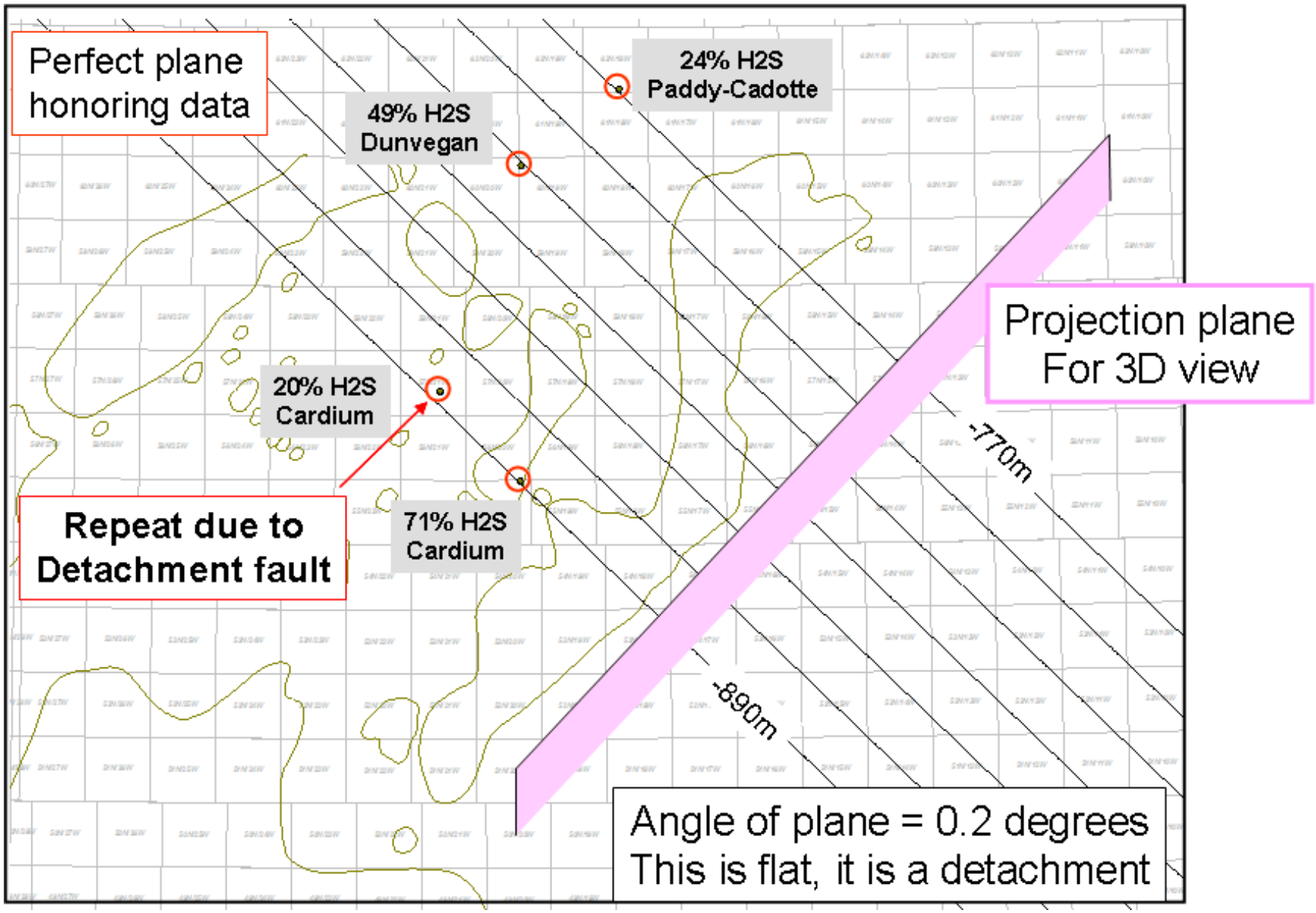


Figure 5. Contour map of the anomalous H_2S plane. Note that the values reported are the highest recorded in any of the gas samples analyzed.

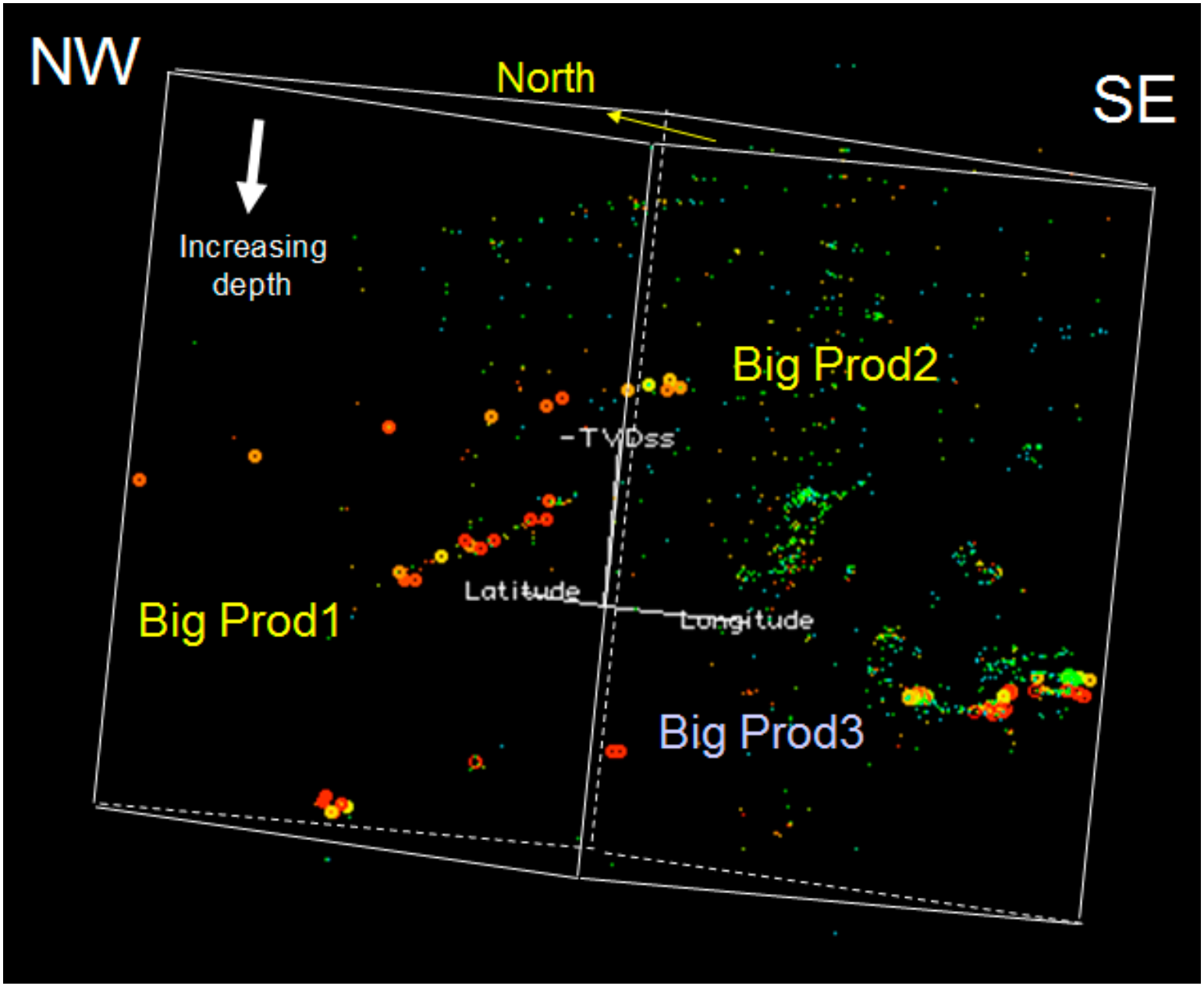


Figure 6. 3-D projection hydrocarbon production in a large volume taken from the Peace River Area, with three major planes migration planes (Big Prod1, Big Prod2, Big Prod3).

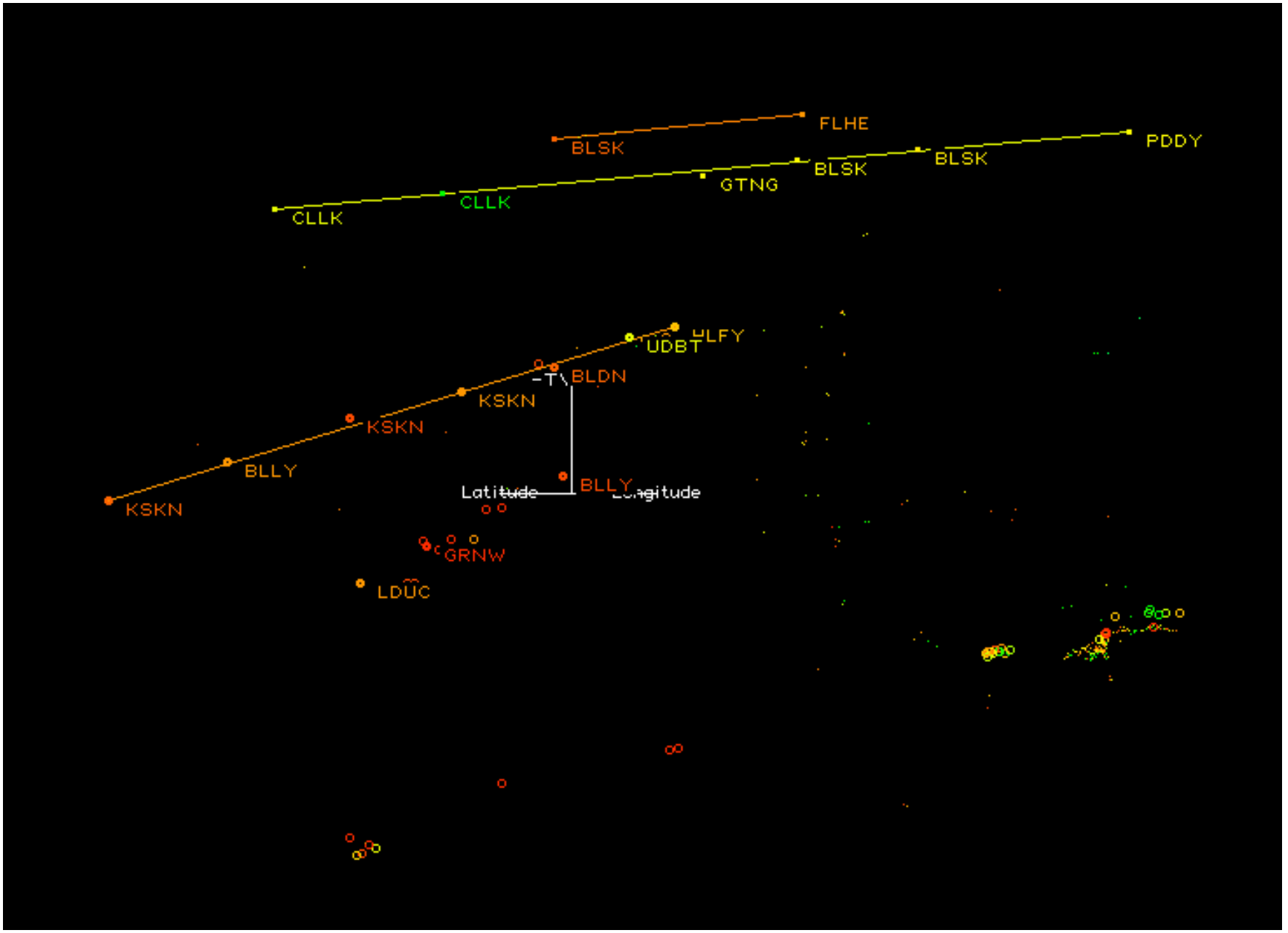
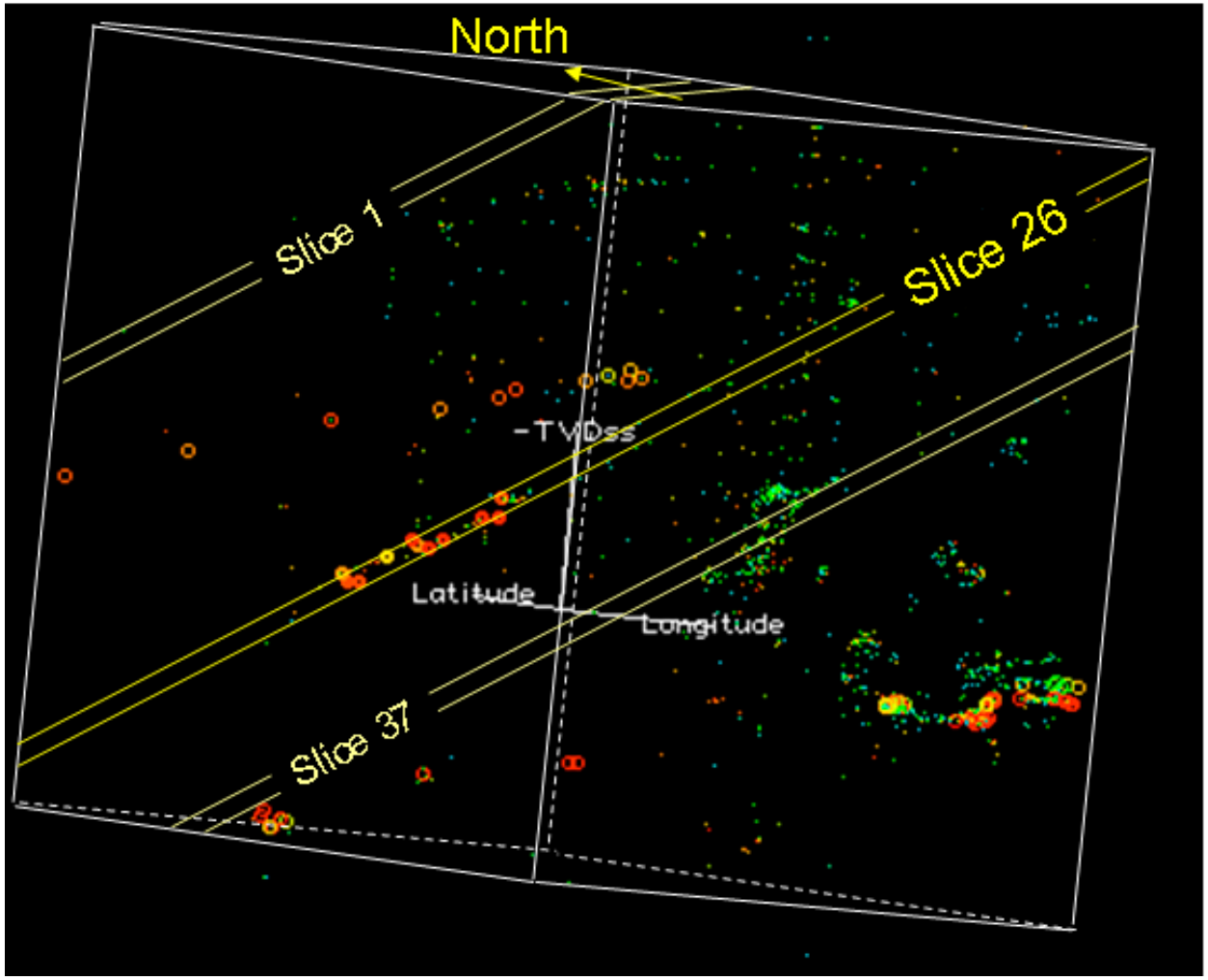


Figure 7. Low-angle planes linking major producing wells and some of the associated formation names. These underline the cross-formational aspect of these structural elements.



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 %

Figure 8. 3-D volume oriented for a statistical analysis linked to Big_Prod_1 plane.

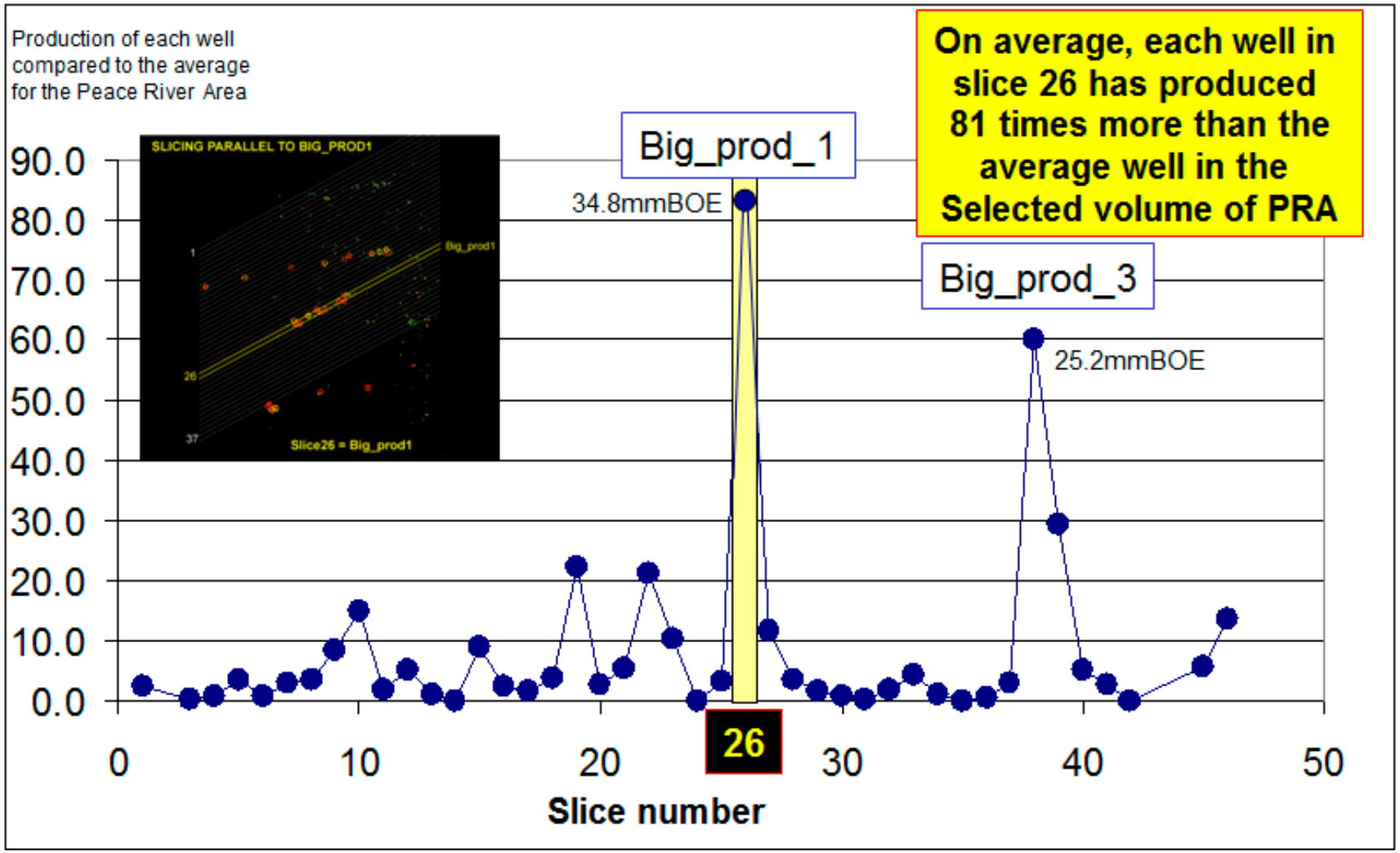
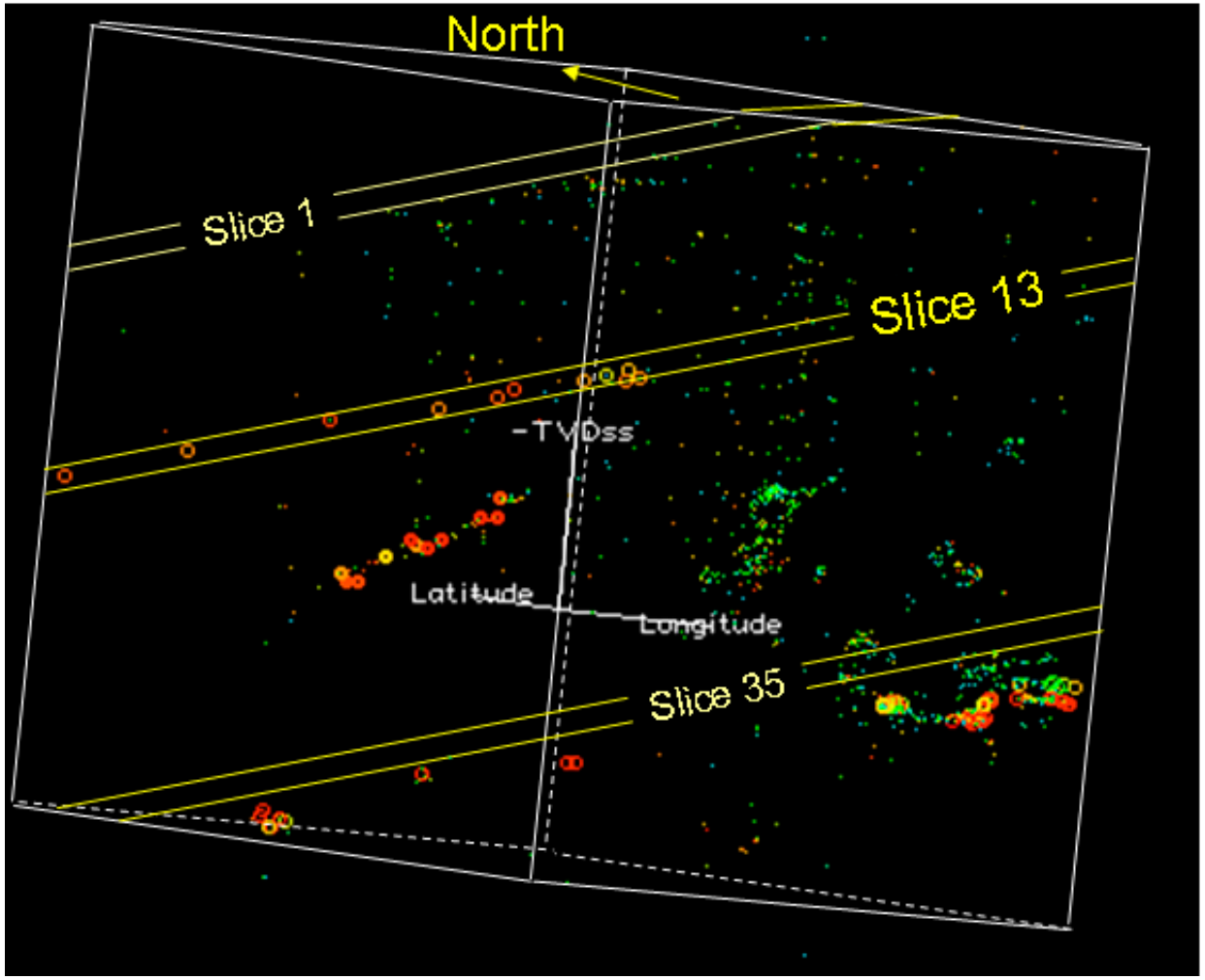


Figure 9 Cumulative production of equal volume slices parallel to the Big_Prod_1 plane.



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 %

Figure 10. 3-D volume oriented for a statistical analysis linked to Big_Prod_2 plane.

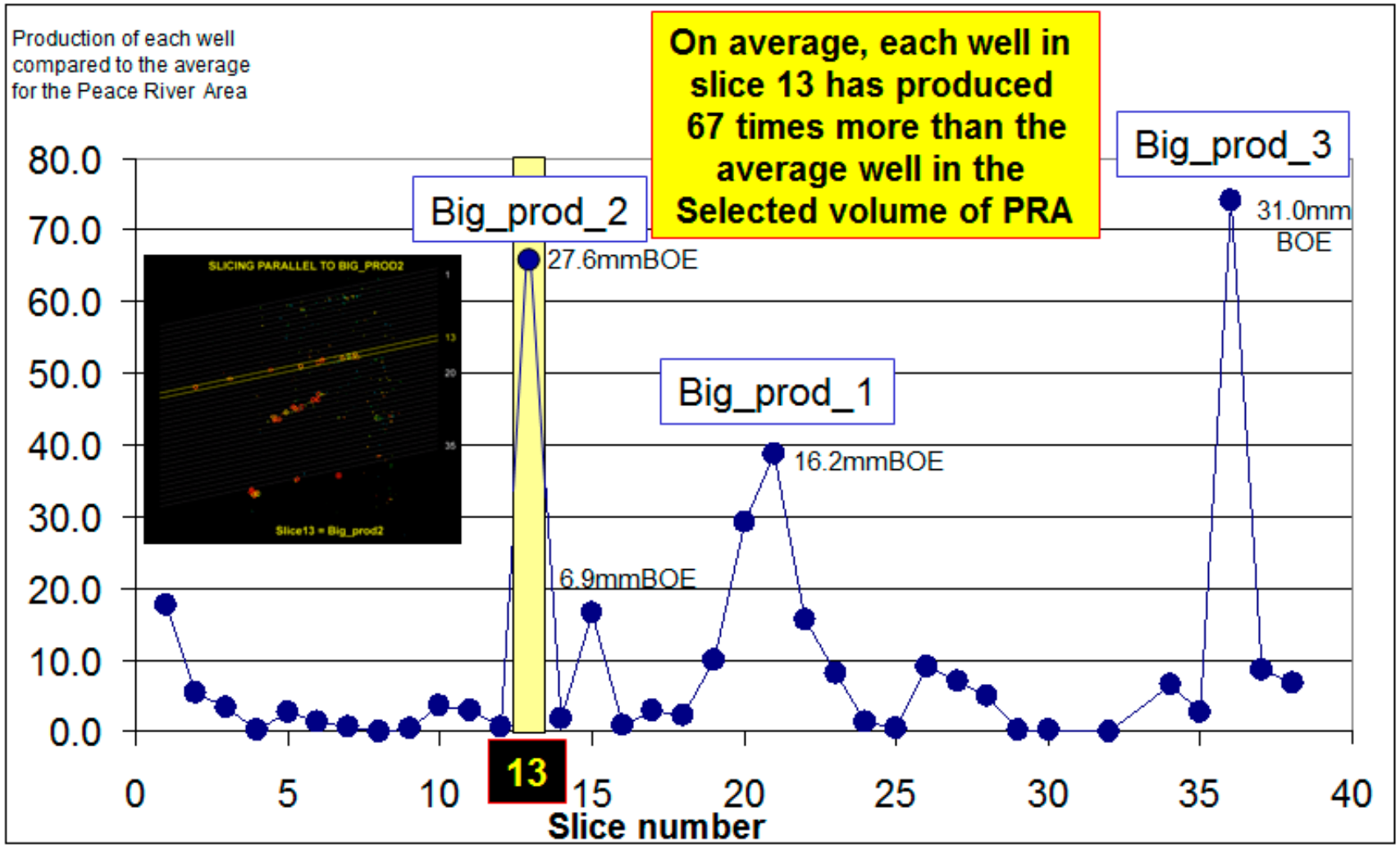


Figure 11. Cumulative production of equal volume slices parallel to the Big_Prod_2 plane.