3D Horizon/Fault Interpretation Exercise Using Seismic Micro-Technology's PC based 2d/3dPAK Seismic Interpretation Software

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based on procedural steps developed by Mike Enomoto of Seismic MicroTechnology Inc. Houston, TX.

Fault/Horizon Interpretation Using
Seismic Micro-Technology's 2d/3dPAK

This manual is based on a set of procedural steps provided by Mike Enomoto of Seismic Micro-Technology, Inc. for the 2d/3dPAK Users Group meeting hosted by Appalachian Region Resource Center on June 23rd of 1997.

NOTE: Left clicking the mouse is used to start, continue and end an activity. Right clicking is ONLY used for displaying the pop-up menu.

This fault/horizon interpretation exercise was presented at the June 23rd 1997 Users Group meeting hosted by the Appalachian Region Petroleum Technology Resource Council's Resource Center on the campus of West Virginia University. Questions about the steps and procedures listed below can be directed to SMT technical staff in their Houston office at (713) 464 6188.

Data for the following exercise was provided by Seismic Micro-Technology. In this exercise, the B46 formation top is selected from any well and then tied around to the remaining wells. The entire 3D grid is interpreted. It is recommended that major faults be interpreted at the outset, since this will prevent autopicking of select reflection events across fault planes.

Procedures:
When you open a project under Kingdom, the basic windows layout will contain a 3D basemap (right) and project tree (left) (Figure 1).

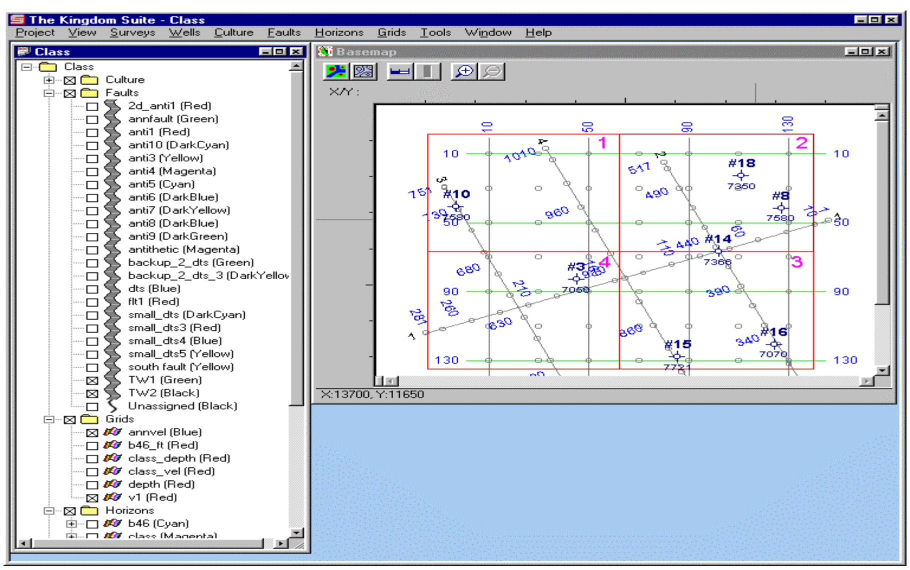

Figure 1: Basic window layout showing project tree and 3D grid basemap.

1. ***Left click on the 3D grid (Figure 1) to activate it.*** In this example, position the cursor on line 110. Right click and select ***Display Line 110***. The seismic line will now appear as shown below in Figure 2.

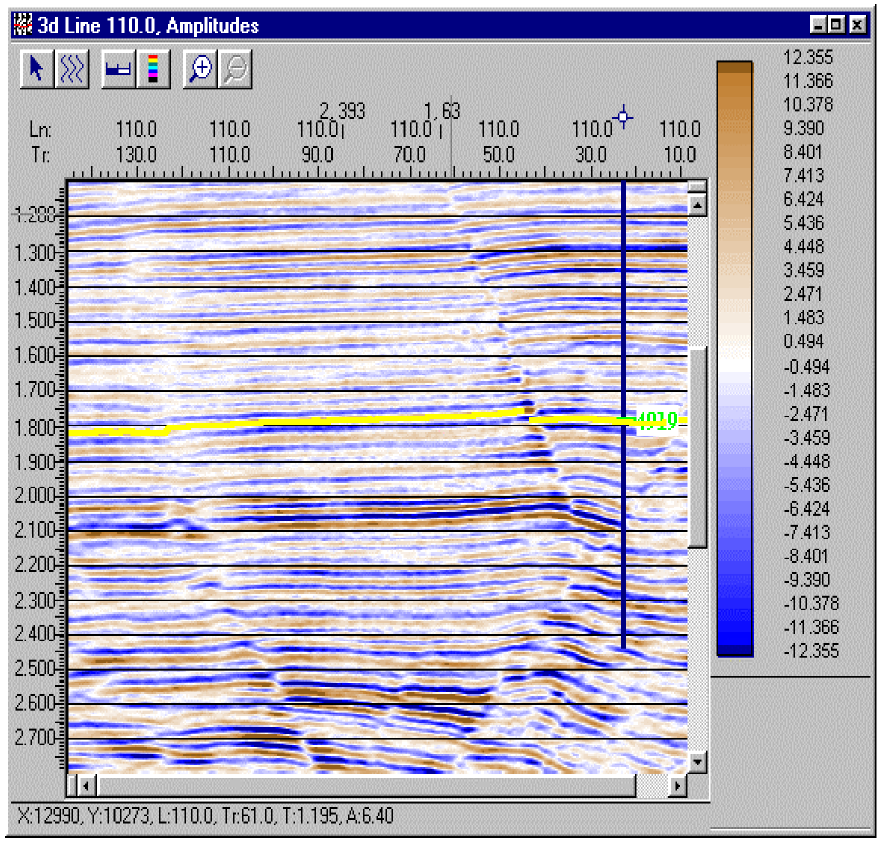

Figure 2: Display of 3D line 110.

2. ***If you prefer another colorbar***, left click on View and Colors. Click on File and Open and select a different colorbar. In most cases, the name of the colorbar describes the colors and the number of colors in the colorbar. For example, the default colorbar, brwbl50.clm, is a blue-white-brown colorbar with 50 colors. Close the color editor once you are satisfied with a colorbar.
3. If you are accustomed to ***wiggle trace overlay***, left click on View and Type of Plot and select Wiggle Variable Area. You may need to change the scale in order to display properly. The variable area wiggle trace display will appear as shown below (Figure 3). Note the other display formats for future reference.

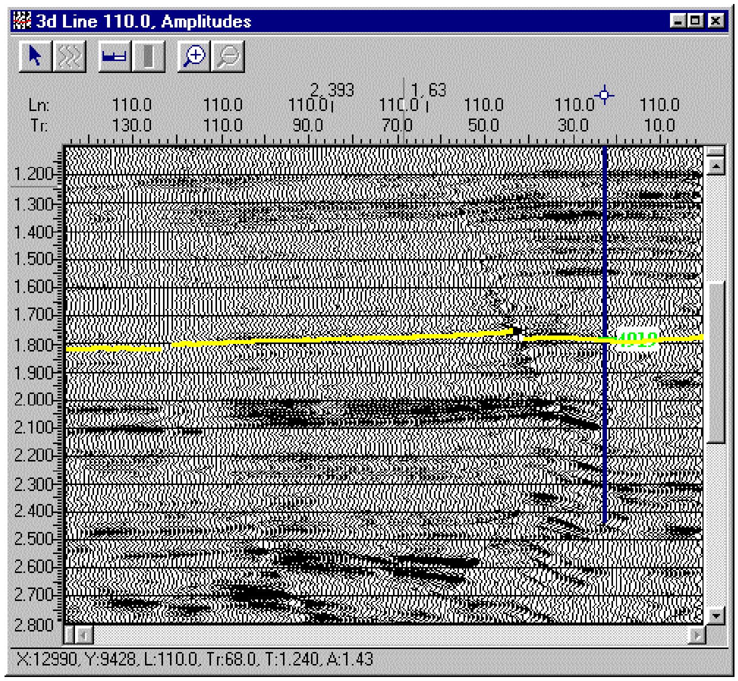

Figure 3: Variable area wiggle trace display format of Line 110.

4. ***To change the display scales***, left click on View and Set Display Scales or click on the scale bar at the top of the seismic line display window. Try 5 traces per inch and 10 inches per second to provide a closeup (Figure 4) view of waveform character in the vicinity of the well shown above (Figure 3). Use the scroll bars to position yourself within the line.

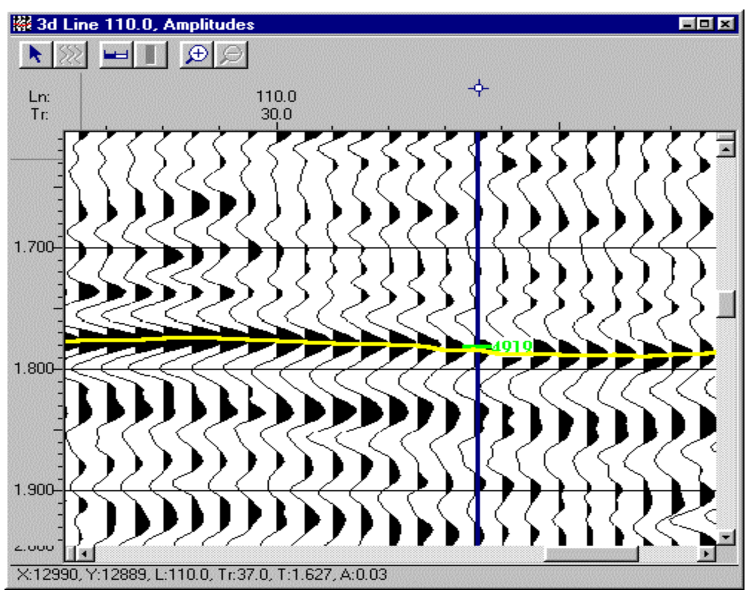

Figure 4: Closeup view obtained using 5 traces per inch and 10 inches/seconds.

5. You can ***orient yourself*** to geographical directions by moving the cursor on the seismic window (Figures 3 or 4) and watch the cursor movement on the map. If the direction is backwards hit the R key on the keyboard to reverse the line direction.

6. The colorbar may or may not be displayed on the seismic window. To ***display colorbar***, left click on **View** and **Toolbars** and then **Color Bar**. A check indicates “on”.

7, On the seismic line, several faults are prominently displayed. Many are easily correlatable, others are not. Now would be a good time **to *assign a name*** to at least two of the major faults, the down to the south and the antithetic. The others may be picked as assigned or unassigned. **To assign the faults**, right click on the seismic window and select **Fault Management**. From there, select the **Create** tab and enter a name and color for the antithetic fault. Left click on **Apply**. Enter a name and color for the major fault and then either OK or Apply. Create new faults if desired, You're now in the fault picking mode with the last created fault active.

8. ***Display the fault toolbar*** to allow for quicker selection of the faults you wish to pick. To do this left click on **View and Toolbars** and then **Faults.** All the displayed faults are present, including Unassigned. Hot keys are available: “d” is digitize, “a” is assign, and 's' is de-assign.

9. ***To start picking your fault***, left click on the one of the fault names. To begin digitizing hit the D key and then left click on the fault break that courses through the seismic data. A rubber band should appear as you go from point to point. Continue left clicking on the break until you either need to scroll vertically or horizontally. At this point, double click to end the segment. Use the scroll bar to move the display so that more of the fault is visible. The fault should have square dots representing the digitized points. If so, left click on the last point and then continue until you can no longer pick this fault. Double click to end. If no square dots are present, the fault is not active and simply requires a left click anywhere on the fault to activate.

If you enter a point you don’t like, ***you can back up or delete the last by hitting the* Esc *key***

10. Left click on the other fault displayed in the **Faults** menu to activate it and then hit the “D" key to begin digitization. Begin picking the second fault. If you choose to pick some of the other

faults on the Faults Toolbar, simply activate the appropriate named or unassigned fault, hit the “D” key and start picking. The two faults you just picked should appear as shown in the montage below (Figure 5). The number of points used to digitize the fault will vary from interpreter to interpreter.

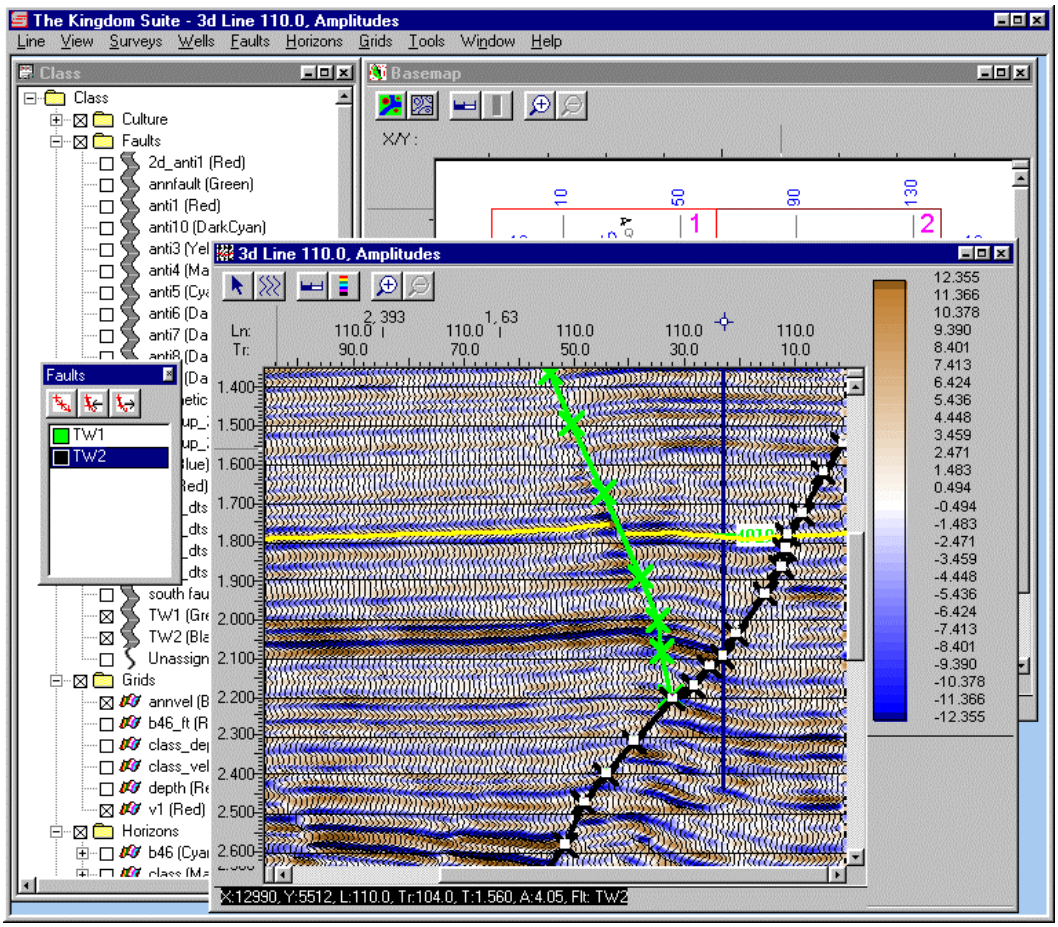

Figure 5: Project tree (back left) and basemap (right) lie in the background behind seismic Line 110 (right) and the Faults menu (small window at left). Faults just digitized on the northern end of the line appear as shown above.

11. If you want ***to edit some of your picks***, the fault is active so long as the square dots are present. Note that the black fault in the above display is currently active. ***To move poin****ts*, activate the fault and then left click and hold on the digitized fault point. As you move the mouse, the digitized point will also move. If you move more than one point you may have to use the Esc key to undo the rubber band.

12. If you would like ***to move the entire fault line***, first activate the fault and then hold the Ctrl key and then left click and hold on any part of the fault line. Move the line to wherever you like and then release the mouse button and Ctrl key.

13. ***To delete a fault segment***, make it active and then hit the delete key on your keyboard.

14. ***To add points***, left click on an existing point, add the appropriate intervening points, and double click on another existing point.

15. ***To remove consecutive points***, left click on an existing point, skip the 'bad' points and double click on an existing point.

16. If you'd like *to* ***change faults*** on the display. left click on the fault to activate. or select from the Faults Menu. If the new fault has no existing digital points, you must hit 'D' on either the keyboard or Faults Menu. **DO NOT HIT THE "D" KEY IF EDITING A FAULT.**

17. ***To assign an unnamed fault***, activate the fault name, activate the unassigned fault line and then hit the A key.

18. ***To de-assign a named fault*** activate the fault line and then hit the S key.

19. Once the faults have been picked on this line, you can begin picking the faults on a grid of lines extending through the entire 3D data base. ***To set the grid spacing***, left click on **Line** and **Set Line Skip Increment**. Set the increment to 20 and then **OK**. Now whenever the right arrow on the keyboard is hit. the line displayed will increase by 20. If the left arrow is hit. the display will decrement by 20. If a cross line is displayed, the up and down arrow keys will work likewise.

20. Go to line 130 and pick the faults.

21. Once an assigned fault has been picked on at least two lines, a fault surface is automatically created. ***To view fault surfaces in map view*** go to the Project Tree and double click on the appropriate fault icon. This makes that fault surface the active subset and opens a new map window where the fault may be displayed as either a *fault plane* or *lines*. ***To toggle from planes to lines***, go to **View, Fault Display Mode** and select either **Fault Surface** or **Fault Segment**.

Map and line views are shown in the montage below (Figure 6).

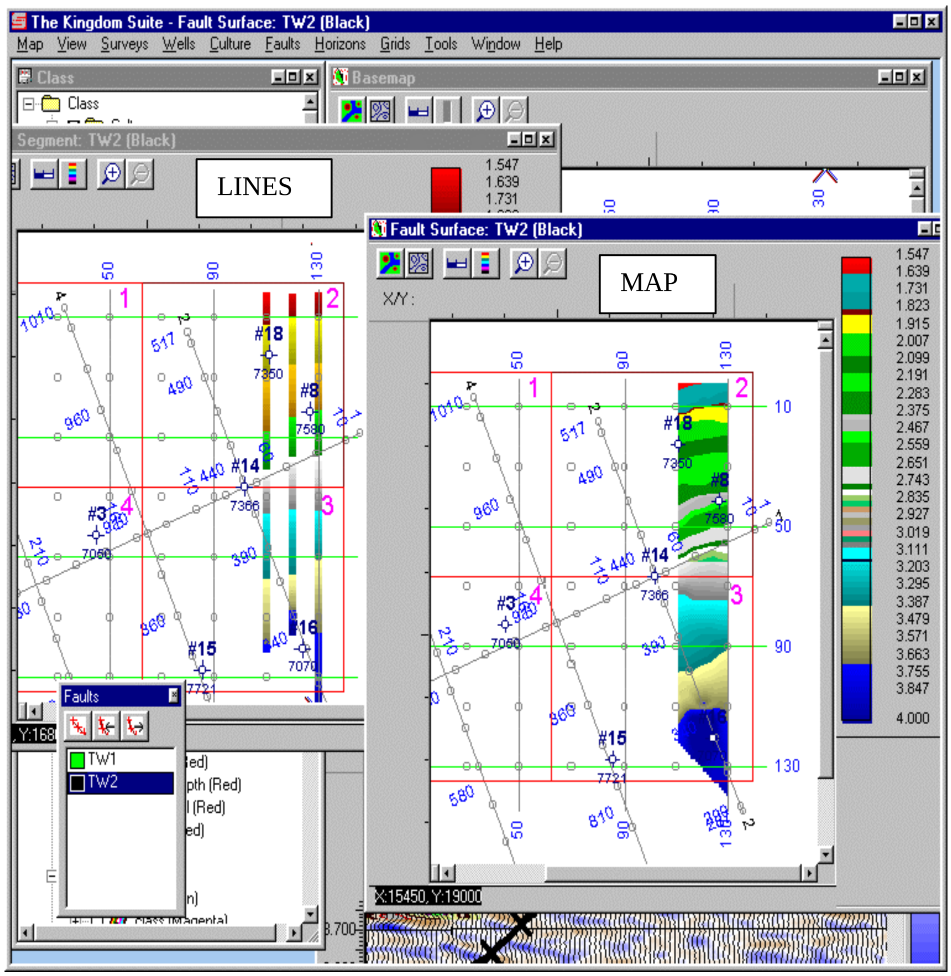

Figure 6: The large synthetic fault dipping to the south is displayed in both line and map views. Color coded two-way travel times appear in the color bar at right.

22. ***Display the fault surface in seismic view*** so that any miscorrelation can be quickly seen. To do this, go to a seismic window and right click, go to **Fault Management**, and **Display**. Verify that **Both** is selected for **Display Type**. If "Both" is selected, two lines are visible in seismic view, the straight line connecting the digitized points and the interpolated fault surface.

23. ***Complete fault picking:*** Continue over to the east end of the survey to Line 145. Then return to line 90 and continue to the west. To go to line 90, *left click on Line and then Select or left click on the arrow button* in the seismic display window which brings up the same window. Type in 90 and be sure the *line* button is on and that the 3d survey is displayed. Hit OK. If you would like to **view the faults in strike direction** or on an arbitrary line, *right click* on the desired cross line in the base map window and then display. **To display line with an arbitrary orientation through the survey**, right click on a map window, select *Digitize Arbitrary Line*, left click on the starting point, continue left clicking on each bend in the line and then double click to end.

Note: **To bring up a fresh basemap** click on *Window* and *New Map Display*.

At this point, your fault surfaces will be correlated across the entire survey area. The north-dipping fault surface, for example, will appear as shown below (Figure 7).

24. Continue picking faults, in the western direction.

You can **edit interpolated fault picks** by first selecting the desired fault as the active fault in the Fault Management Window, and then hitting the D key to digitize. If you wish to correct a portion of the interpolated picks simply begin picking points through the desired region. Double click to complete digitization. Your picks will replace the interpolated picks.

If a fault has been extended too far, you can delete a portion of the interpolated fault line by digitizing the extended portion, and double clicking to replace the interpolated line with your picks. Then click on the bad pick and drag the rubber band to the first good pick and double click. All points beyond the last pick will be deleted.

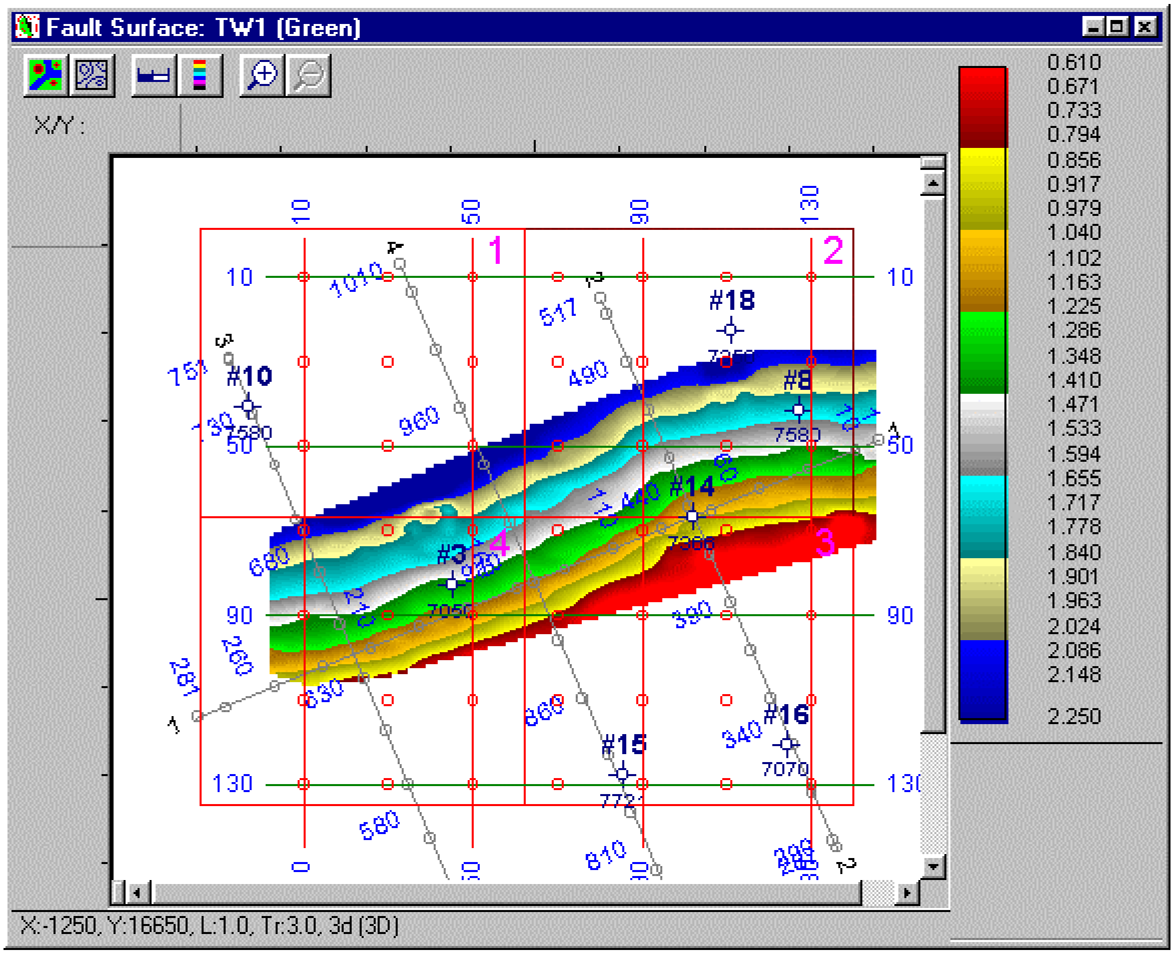

Figure 7: Contour display of north-dipping fault surface.

25. Once you are satisfied with your fault interpretation you can **begin picking horizons.**

26. As mentioned earlier, the seismic data will be tied to a well using the B46 formation top. **Display line 110**. *Scroll until the well is visible* and the B46 top is displayed around 1.8 seconds. If the B46 top is not displayed, left click on *Wells* and *Wellbore Display Options*, Left click an *Plot Formation Tops* and OK. The B46 should be displayed and correlated along a peak (Figure 8).

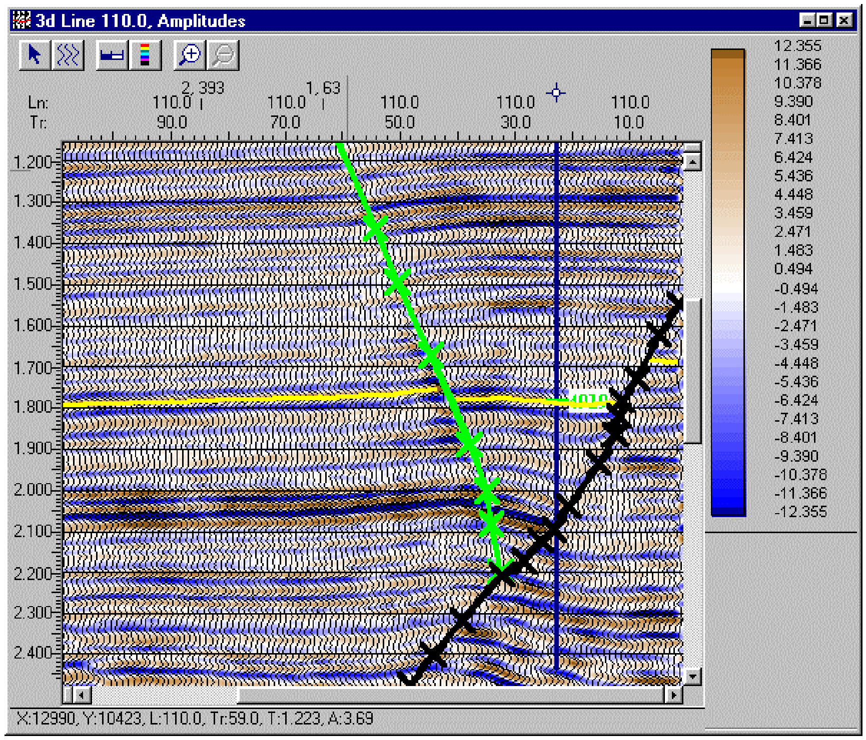

Figure 8: Horizon B46 tied to well on Line 110.

27**. Horizons are created** in much the same way as faults. Anywhere on the seismic line, right click and select *Horizon Management*. Select the *Create* tab and then *enter B46* for the horizon name and then select a color. Hit OK. The B46 horizon is now active.

28. **Display the horizon** in map view by double clicking on the icon next to the B46 Horizon. Since no picks have been made, no horizon is visible.

29. **Horizon Picking:** Right click on a seismic line and select *Picking Parameters*. Make sure that *Stop at Displayed Fault Surface Intersections* is enabled. This feature, when enabled, works with the Autopick-2D Hunt mode. Picking will stop either whenever data goes away or the horizon encounters a fault surface.

30. Display the Horizon Toolbar by left clicking on View, Toolbars, and Horizon bar. Note that the active horizon is highlighted in the toolbar. Hot keys are available, M = manual

picking. F = Fill made, H = 2d Hunt. P = Erase. P = Peak, and T = Trough. Hot keys are not available for zero crossings.

31. Note the shape of the cursor and the status bar. The cursor is now a '+' with either a E, M, F, or H next to it. Change the picking mode to either F or H, and change the phase to peak. Pick the event as far as you can, jump the fault if desired. Note that the map display is updated immediately after picking.

32. Once the inline has been picked, place the cursor on crossline 70 on the seismic display, right click and display the line. A small tick mark is visible where the two lines intersect. You may also see a vertical red line. This red line is a line overlay and can be disabled by left clicking on *View* and selecting *Line Overlays*. A check mark indicates 'on'. If you chose the **Hunt mode**, *left click once on the tick mark* and the entire horizon between fault segments is completed.. Increment through your data using the arrow keys and continue picking this horizon, You should end up with picked grid of lines for the B46 horizon (Figure 9)

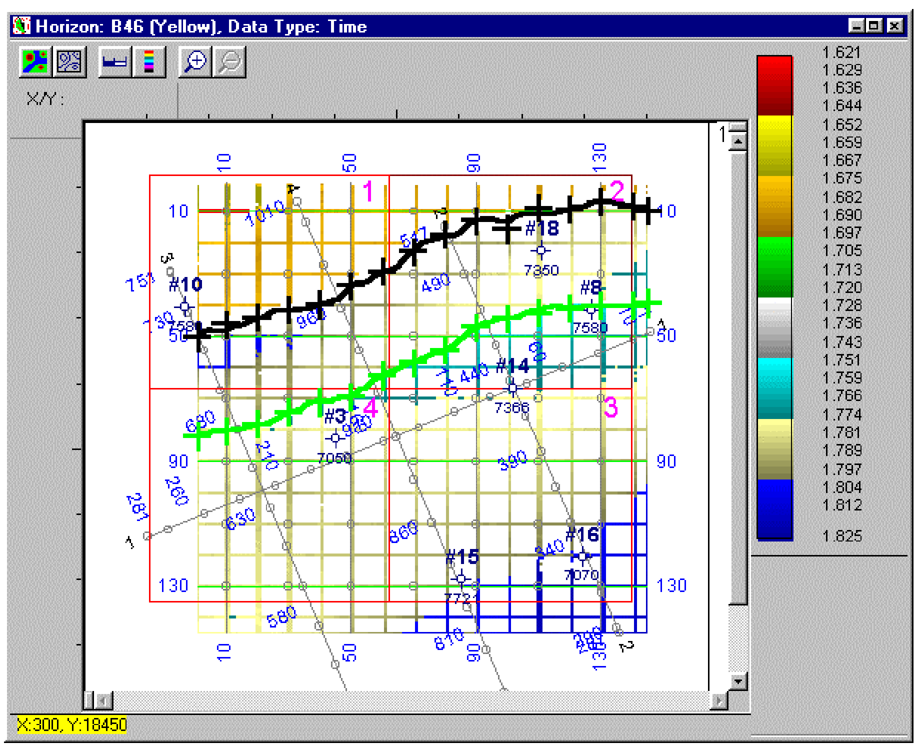

Figure 9: Horizon picks are shown on the grid of in-lines and cross lines. Travel times are color coded. Fault intersections are correlated through the area.

33. With this grid, the **horizon is now ready for the autopicker**. Since the horizon now consists of seed points, *protect these picks by copying the horizon*. Using the *Horizon Management dialog* box, select the *Copy* tab, type the new horizon name, select the seed horizon, and assign a new color (Figure 10). *Apply*. *OK*. **Now if the autopicker runs amok, the original picks are unaffected.**

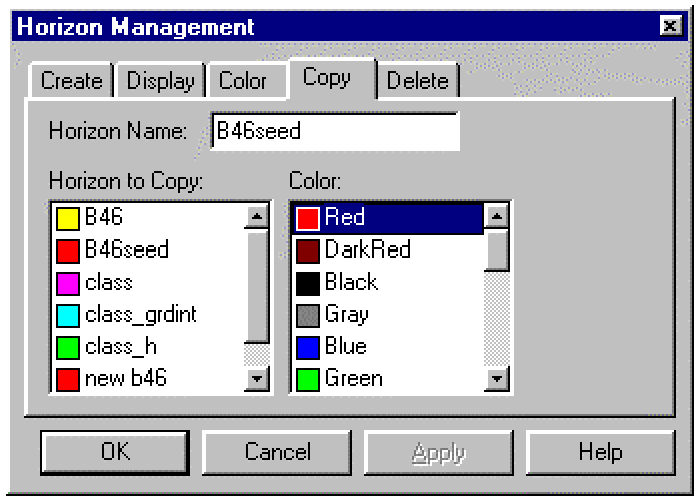

Figure 10: Horizon Management window showing definition of the seed horizon (B46seed) used for autopicking extensions of the horizon through the 3D data volume. Your original picks remain unaffected in horizon file B46.

34. **Display the copied horizon** (B46seed). *Go to the Project Tree* and find the copied horizon. *Drag the horizon* to the current map display. **Draw fault polygons around the fault gaps** by *right clicking* on the map, and then selecting *Digitize Fault Polygons*. Begin left clicking a series of points which define the fault gaps. Double click on the final point.

You may find it useful to zoom in on the faults to observe the gaps as shown in Figure 11. The fault polygon is drawn to outline the gap (Figure 11),

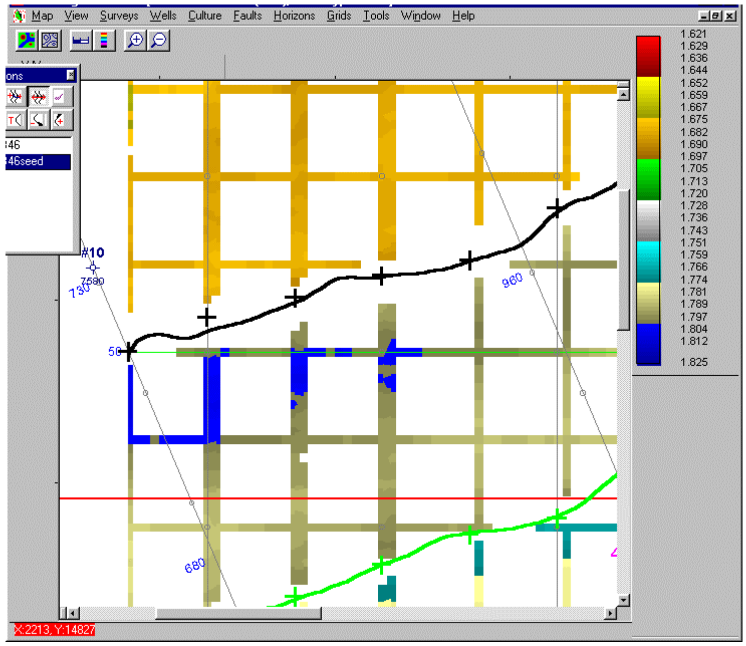

Figure 11: Fault gaps in horizon B46 appear in closeup view of the basemap.

It may help to zoom in and draw polygons around visable segments in closeup view. Double click to close the polygon surrounding a restricted segment of the total fault. Then use the slide bars to reposition your viewing area farther along the fault. Continue digitizing the polygon beginning at the end of the previous polygon. When the rubber band is returned to the adjoining point on the opposing side of the fault, double click on that point. One continuous polygon will appear. Your fault polygons may appear as shown in Figure 12 below.

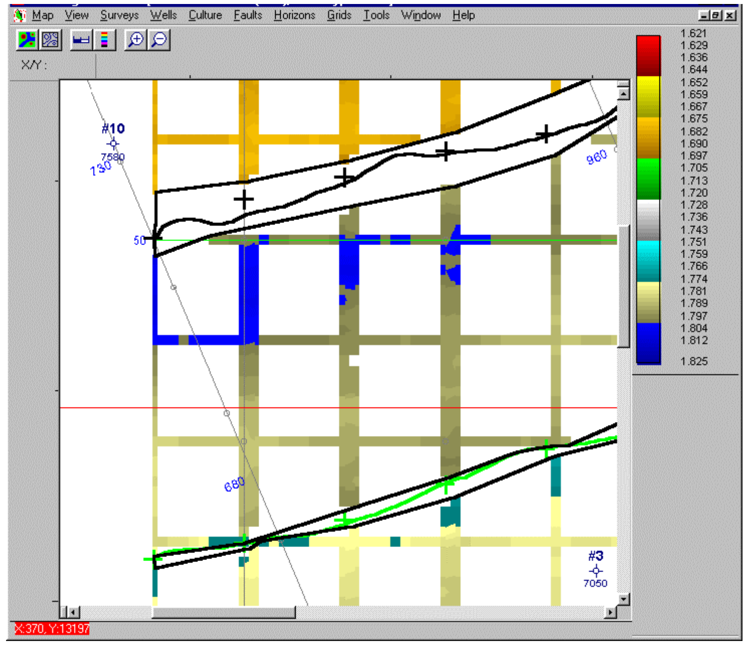

Figure 12: Closeup view of fault polygons drawn around the fault gaps.

35. Left click on Horizons on the Command line and select Polygon 3D Hunt. Using the left mouse button, draw a polygon around one of the fault blocks. Double click to end. Autopicking begins Immediately after double clicking. Continue this process using a series of polygons. Not recommended is one giant polygon. Instead, create a series of smaller polygons.

You will have trouble correlating across the high side of the northern-most fault particularly in the northeast quadrant.

Note that you can bring up a seismic line and go to regions of the data where the Polygon Hunt operations are having trouble. You can manually interpret the data in these regions directly on the seismic lines. When you do this, the active seismic line will show up as a red line. If you want to bring up a line nearby you need only left click on the red line and drag it to the location where you need an interpretation.

Your completed horizon interpretation will look something like the one shown below (Figure 13).

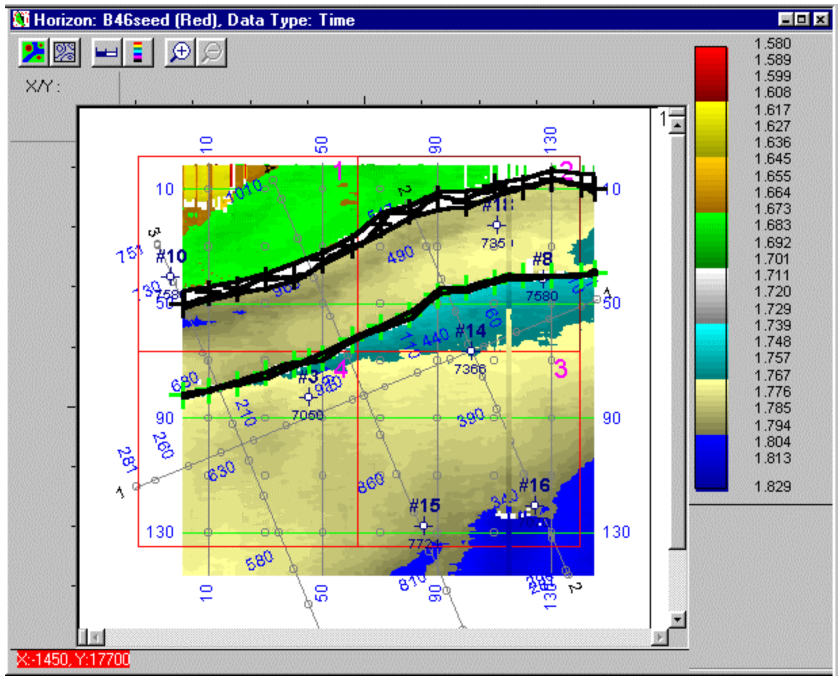

Figure 13: Two-way travel time map to top of the B46 reflector generated from interpretation and automatic computer interpolation between picks.

36. **If you don't like how 3D Hunt worked** in particular area, left click on Horizons and select *Polygon 3D Erase*. Draw a polygon around the area of interest similar to 3D Hunt. *You will he given the option to erase your seed picks with the default. Set to do not erase.* Hit Yes and the polygonal area is wiped clean. Repick a tighter grid if necessary and rerun 3D Hunt.

37. Once the map is completed, **display the amplitudes**. Go to the *Project Tree* and *left click on the '+'* sign next to the B46 horizon line. This opens the horizon showing you the additional surfaces available (Figure 14). *Drag the amplitudes from the Project Tree to the map window*.

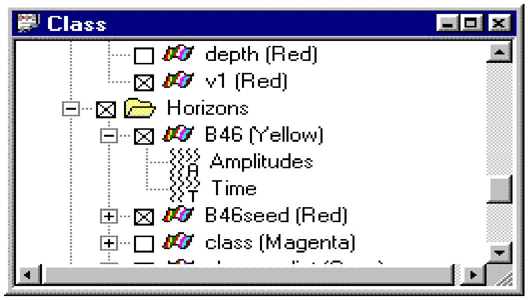

Figure 14: View of Project Tree window, Clicking the + sign at left on an individual window opens a drop down list of other data available for that horizon. In this case displays of amplitude and time are listed.

Dragging the amplitudes from the Project Tree list to the base map will cause reflection event amplitude to be displayed. Remember we undertook autopicking on B46seed(Red) (Figure 14). If you drag amplitudes from B46(Yellow) you will see amplitudes displayed only along interpreted lines in the grid. Horizon travel times are shown in Figure 13, Horizon amplitudes are shown below (Figure 15).

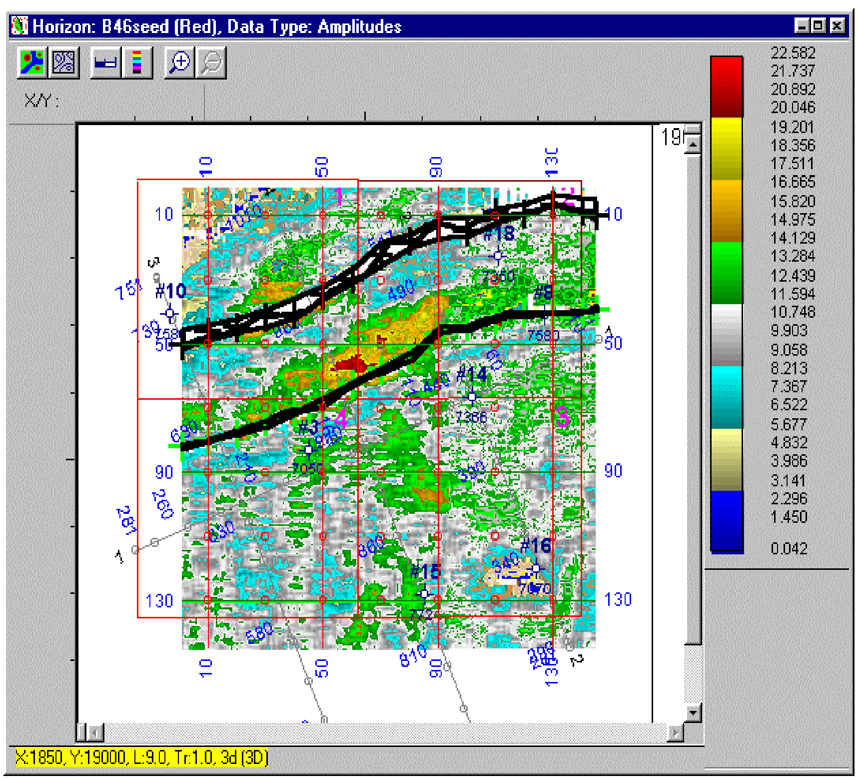

Figure 14: Horizon amplitudes for B46Seed.

38. Generate a **time-structure contour map** by selecting *Map* and *Select Contour Overlay*. Select the horizon and data type (Time). Click on OK. If you would like to change contour line parameters click on Parameters to the right in the Horizon window (Figure 15).

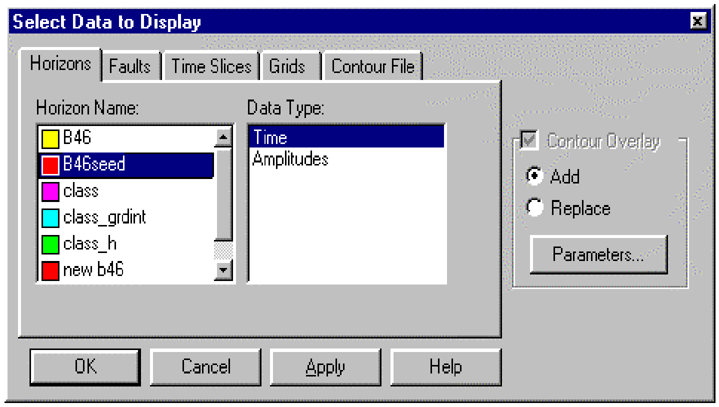

Figure 15: Contour overlay horizon selection menu. Not Parameter Button.

Change the parameters and then see what the effect is. You can check the effect of various parameter selections by leaving the contour overlay window active and selecting *Apply*. Your result may appear similar to that shown below (Figure 16).

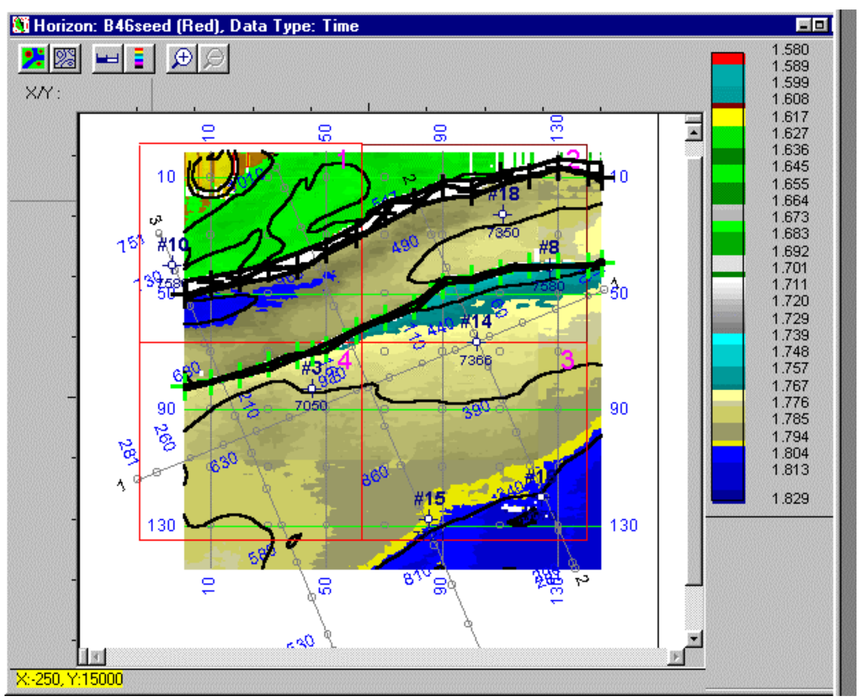

Figure 16: Contour Overlay on B46Seed.

39. To **create a depth map**, *select Tools* from the main Menu Bar and then *Depth* from the drop down list. Under *Depth* there are several selections. Click on *Compute Average Velocity Map*. For *Type*, select *Horizon.* The program computes the average velocity at each well using *one of three options (Apparent, Time Grid or Formation Top)* (Figure 17).

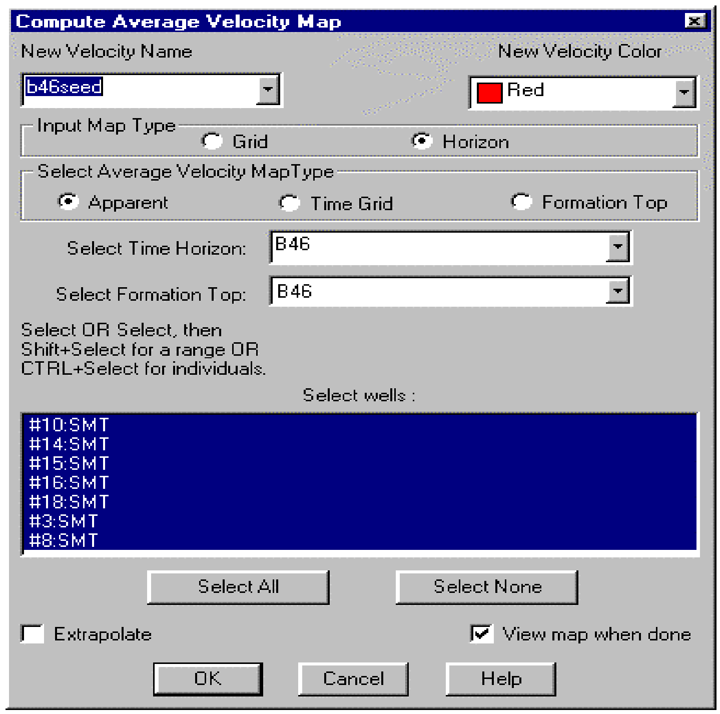

Figure 17: Method used to compute the *Average Velocity Map* of a selected horizon is selected in this menu

1) The **Apparent** method uses the horizon time and formation top depth. You must provide a velocity file name (Figure 17) and gridding parameters can be tailored to individual needs (Figure 18). Time and depth pairs are then combined to form an average velocity grid.

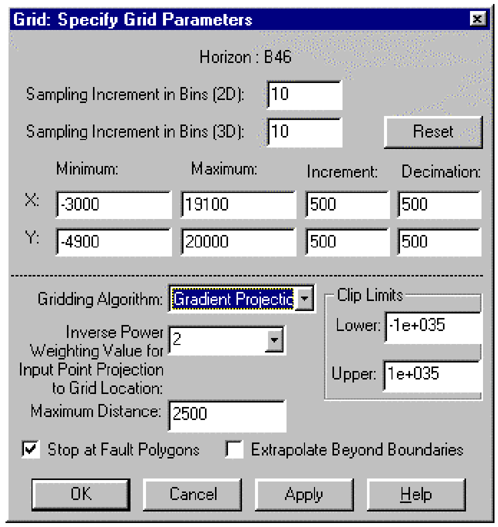

Figure 18: Gridding parameters selections menu.

Average velocity in this approach is computed by dividing horizon depth by half the horizon time. Whether you extrapolate (Figure 19) or not (Figure 20) will yield two different results. Extrapolation will make use of wells without velocity information.

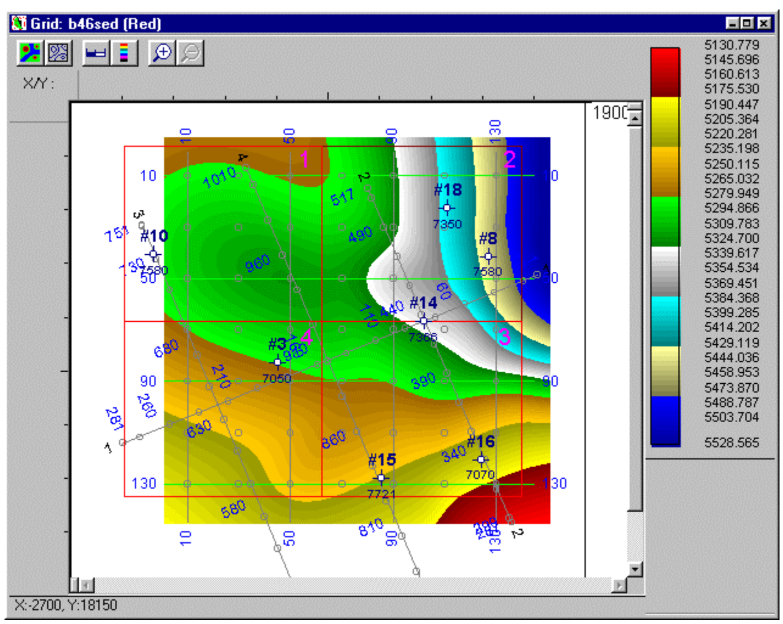

Figure 19: Depth map formed by extrapolation .

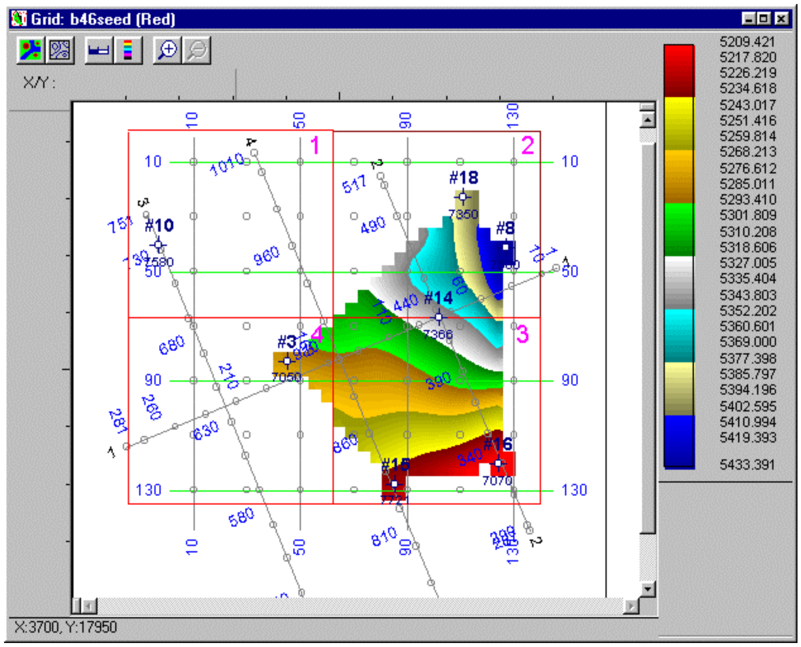

Figure 20: Depth conversion of B46 horizon without extrapolation.

2) The **Time Grid** method uses the horizon time picks, converts it to depth using the well time/depth function and then generates a velocity grid. Depth conversion (Figure 21) yields a map only slightly different in this case from

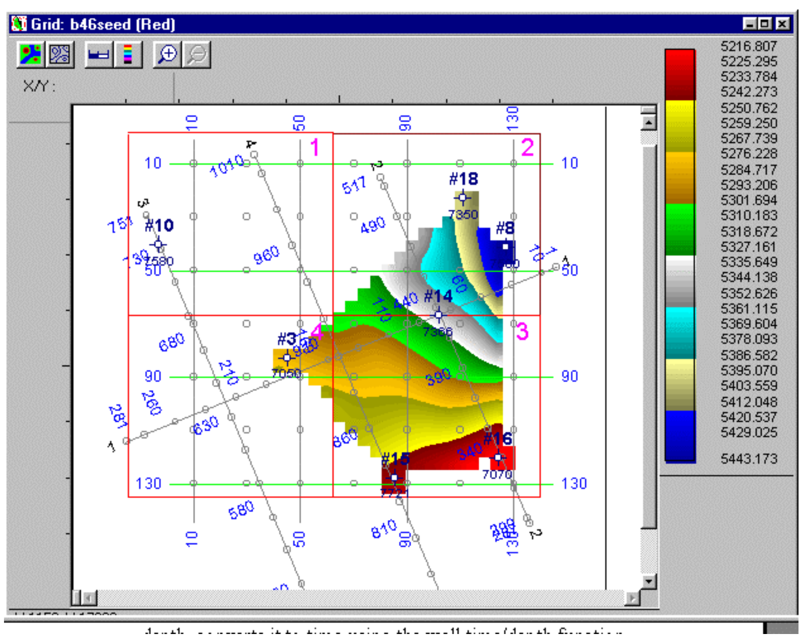

Figure 21: Depth conversion from *Time Gridding* (no extrapolation).

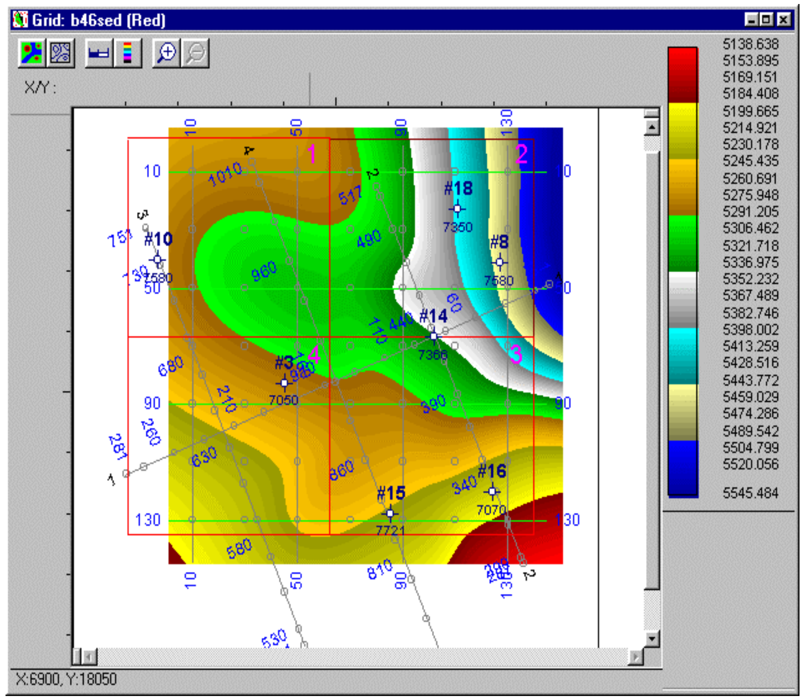

Figure 22: Depth conversion from *time gridding* with extrapolation.

Comparison of Figures 19 and 22 reveal notable but minor differences in this example.

3) The **Formation Top** method starts with the formation top depth, converts it to time using the well time/depth function and then generates a velocity grid. If the horizon and formation top do not tie, three different velocities can be generated. Use the default grid parameters as a first pass for each velocity map. Depths obtained from this approach (Figure 23 and 24) reveal subtle differences.

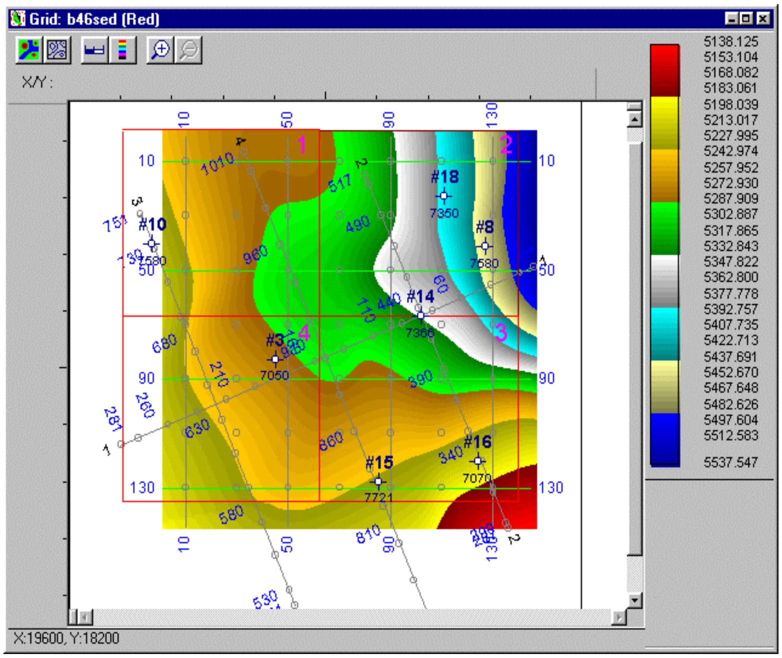

Figure 23: Depth conversion obtained from *Formation Top* method with extrapolation to the borders of the survey.

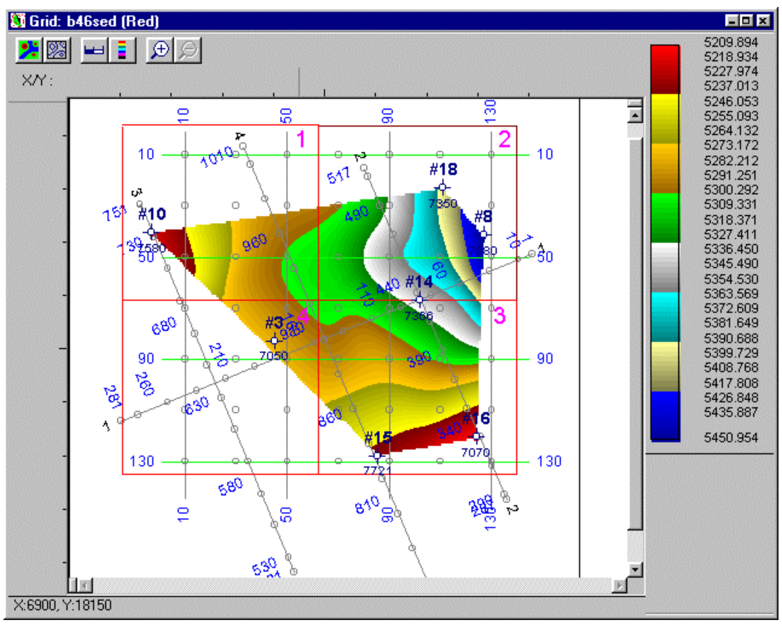

Figure 24: *Formation Top* conversion without extrapolation yields this depth map, which has been extended to incorporate well #10 along one of the 2D lines external to the 3D survey.

40. **Contour the depth map and display the amplitudes under the contours.** Remember that you can contour your maps using the **Map Select Contour Overlay** options. Contours of depth to the B46 horizon are shown below (Figure 25).

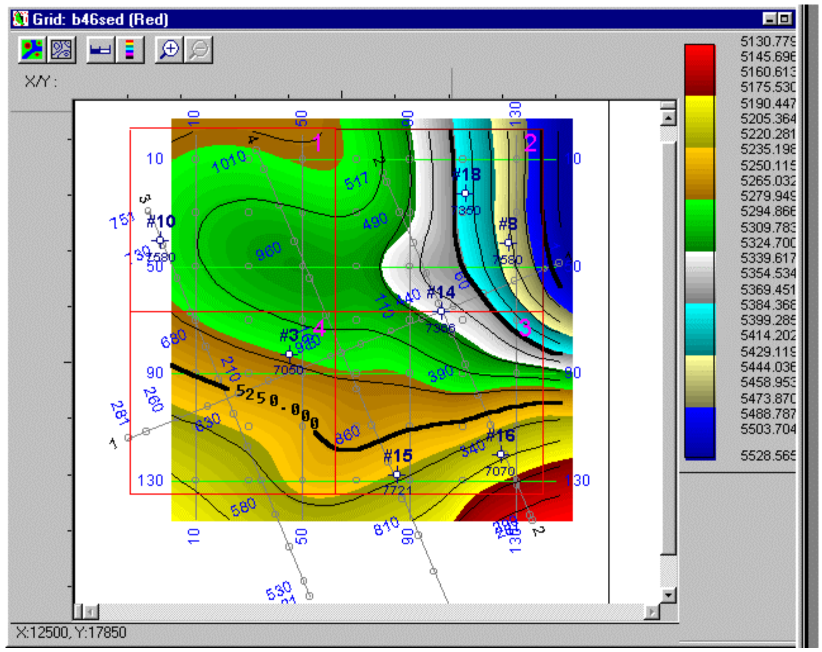

Figure 25: Depths obtained form time-gridding (Figure 22) have been contoured for the B46 horizon.

Amplitude of the B46 reflection event can then be followed along the structure by dragging the amplitudes from the **project menu** onto the map (see montage Figure 26), Note the association of amplitude anomalies with the faults in this example.

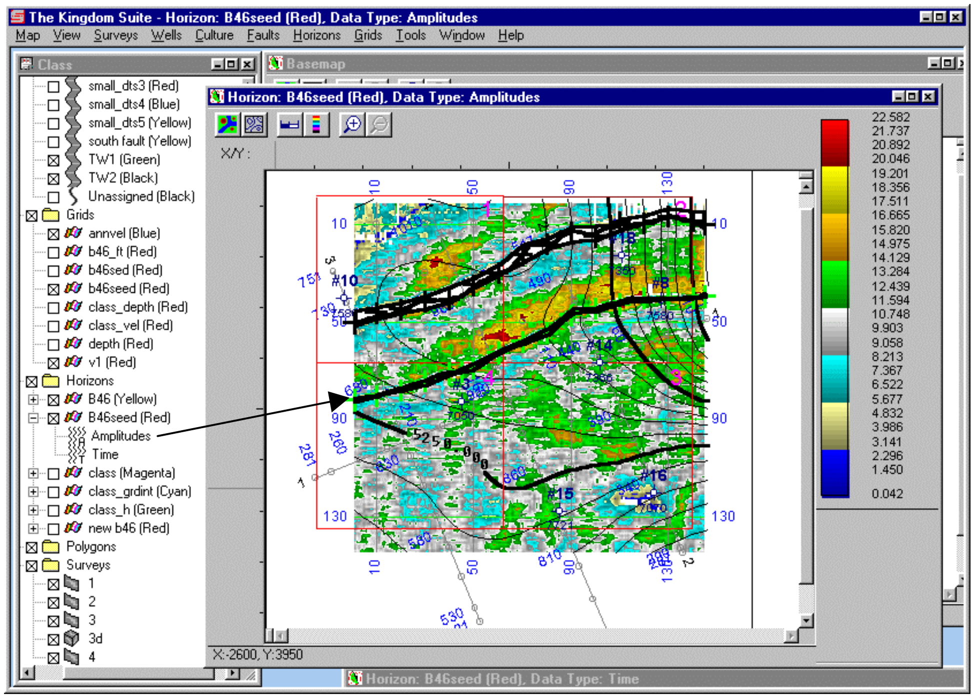

Figure 26: Reflection event amplitude compared to depth contours for the B46 Horizon.