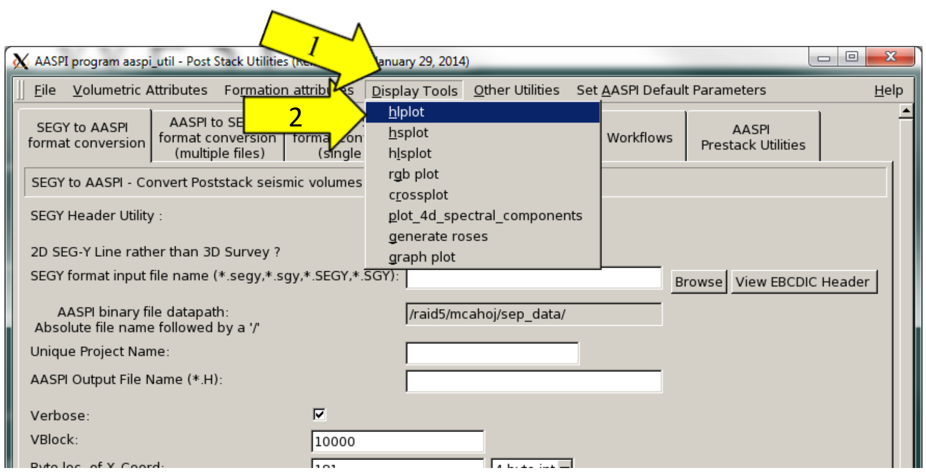
MULTIATTRIBUTE DISPLAY: PROGRAMS hlplot, hsplot, hlsplot, rgbplot, and crossplot

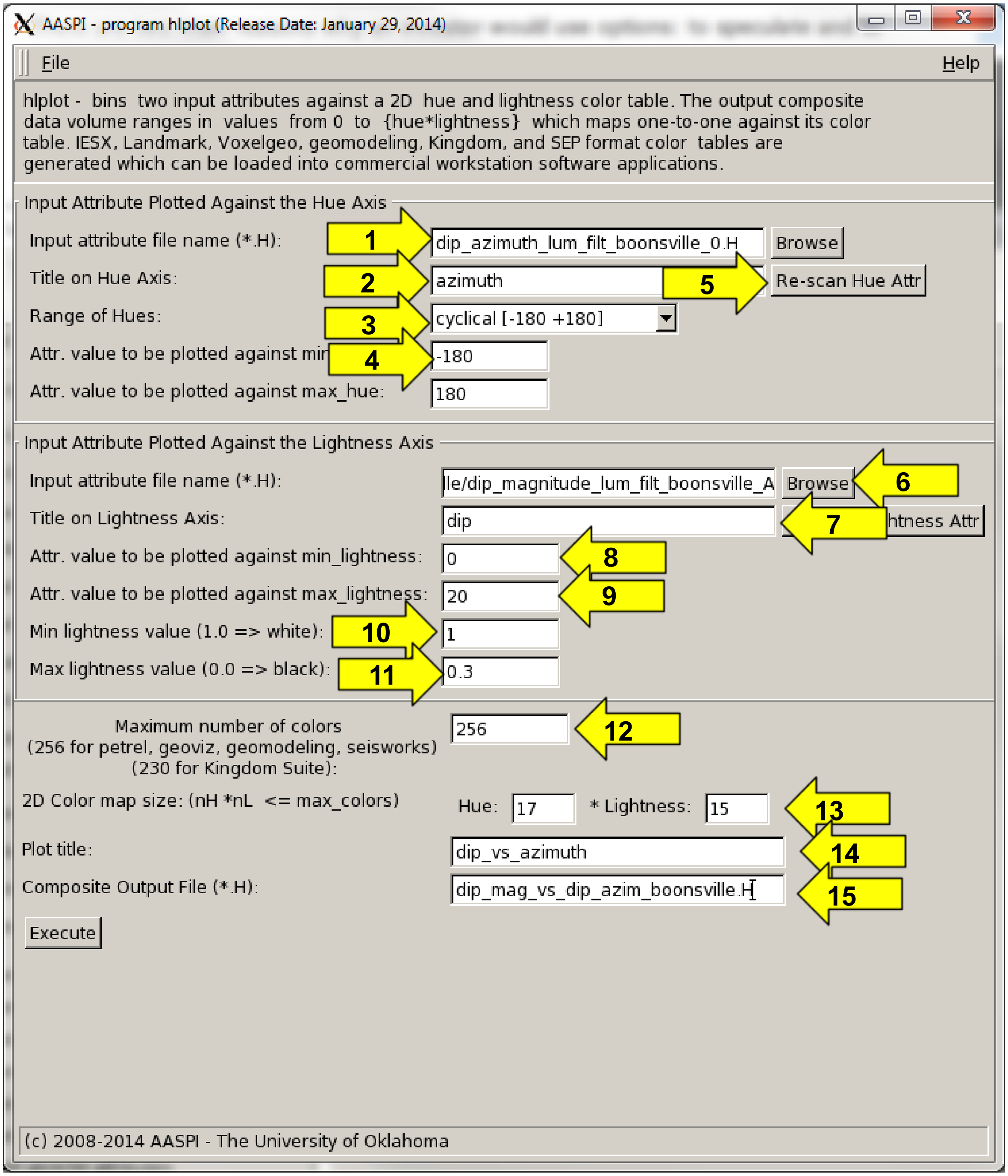
Multiattribute display of dip magnitude modulating dip azimuth – Programs hlplot and hsplot

In section 6, pages 12-13, we used transparency (in PowerPoint!) to blend the dip magnitude and dip azimuth volumes to generate a composite image. A much better composite image can be generated by modulating the dip azimuth by the dip magnitude rather than by blending the two images. To do so, return to the **aaspi_util** GUI and select (1) *Display tools* and then (2) *hlplot*:



Program **hlplot** plots one attribute against hue (H) and a second attribute against lightness (L). You should have a GUI that looks like this:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

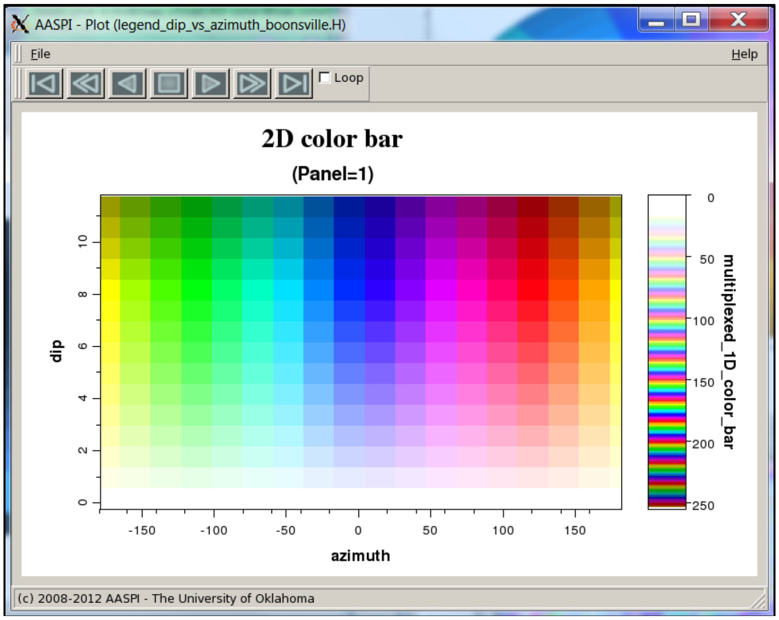


In this example I browse and select (1) the file *dip_azimuth_lum_filt_boonsville_0.H* as the file to be plotted against Hue. The current GUI is somewhat more clever than previous releases and will trigger off the substring “dip_azimuth” in the file name such that (2) the string *azimuth* appears for the *Title on Hue Axis,* (3) the string *cyclical (-180 +180)* color bar will appear as appropriate color bar, and (4) the *Attr value to be plotted against min_hue* (in this case, -180.0 degrees) and the

Attr value to be plotted against max_hue (+180.0 degrees) are read from the values of *min_amplitude* and *max_amplitude* from the input file entered after arrow 1. All of these default values can be altered, though for azimuth attributes these values are almost always the optimum ones. If you mistype the range of minimum and maximum values, or if for some reason they are not in your *.H input file you can always (5) *Rescan Hue Attr* to recompute the largest possible range in the data.

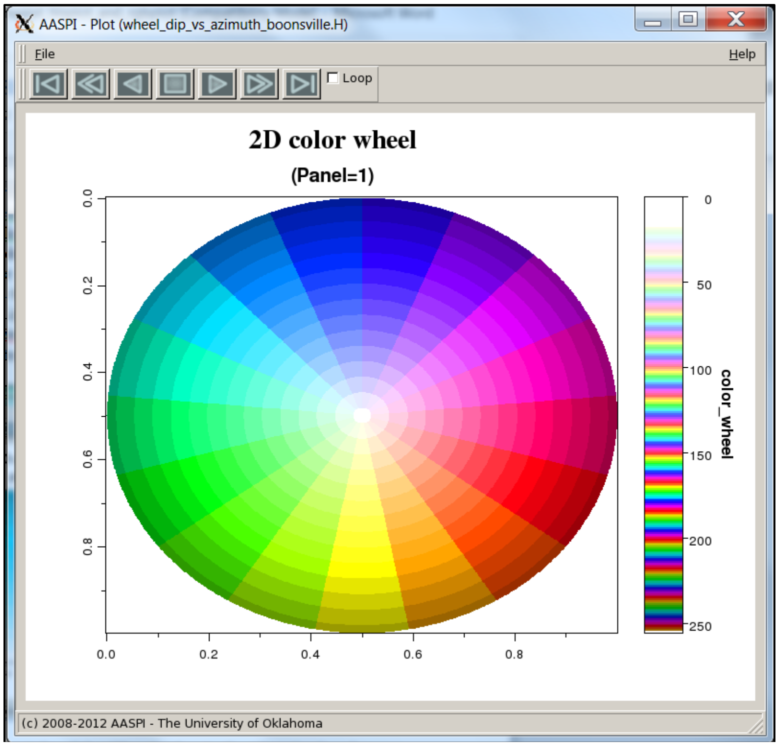
The *Lightness* section is similar. The current GUI is again, somewhat more intelligent than our first releases, such that when (6) I click the *Browse* button, only files that most commonly couple with those after arrow 1 will appear. Since I have previously entered a file name beginning with "dip_azimuth" the GUI will present a list of those beginning with "dip_magnitude". In this case I choose *dip_magnitude_lum_filt_boonsville_0.H* as the file to be plotted against Lightness. The (7) *Title on Lightness Axis* defaults to be "dip_magnitude", the (8) *Attr. value to be plotted against min_ Lightness* defaults at "0" and the (9) *Attr. Value to be plotted against max_ Lightness* defaults to be "12" where the latter two values were stored as "min_amplitude" and "max_amplitude" in the input *.H file. However, our previous dip magnitude images showed a maximum dip magnitude of about 5 degrees, so (9) in the *Attr. Value to be plotted against max_ Lightness* box type in 5. The *Minimum and Maximum Lightness Value* (10) and (11) respectively, allow you to define the lightness value to plot the attribute against, with a minimum lightness of 1.0, representing white, and a maximum lightness of 0.0, representing black. Leave the (12) Maximum number of colors to be 256 since most workstation software will not allow you to import files with more than 256 colors. If this is the case, (13) keep the number of Hue and Lightness bins at 17 and 15. Finally, (15) type in a name for your output file *dip_mag_vs_dip_azim_boonsville.H* and click *Execute*. The following four images will appear when the job completes:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

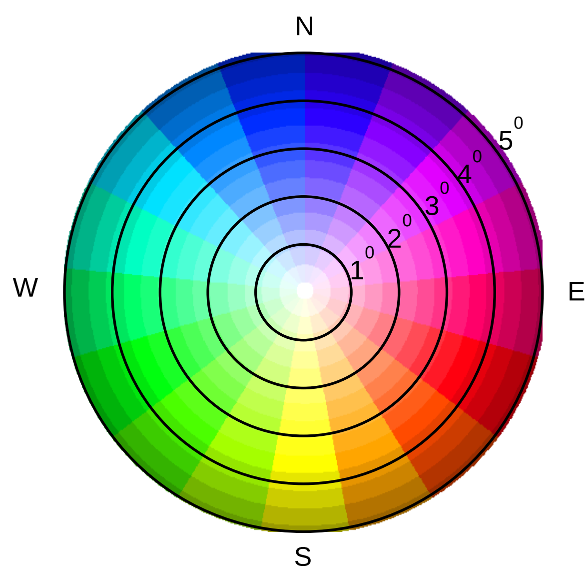


The first image is a 2D color bar. On the right of the 2D color bar is the 1D color bar that you will load into your interpretation workstation. Note that it has been multiplexed (or wrapped) horizontally. White corresponds to low dip magnitude, and solid color to high dip magnitude, with pastel colors in between. Note that an azimuth of 0^0 (North) appears as blue, while azimuths of both -180^0 and $+180^0$ (South) appear as yellow. The GUI recognizes this to be a cyclic 2D color bar or color wheel and also provides the following image:

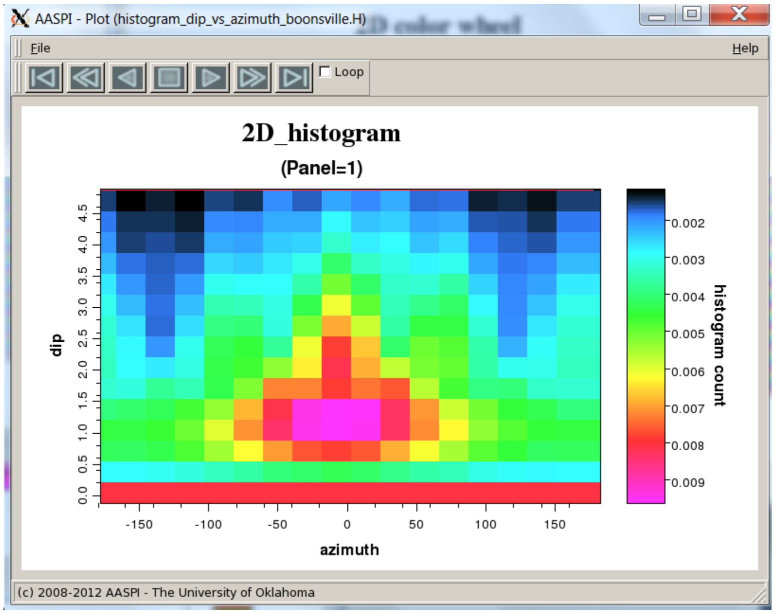
Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

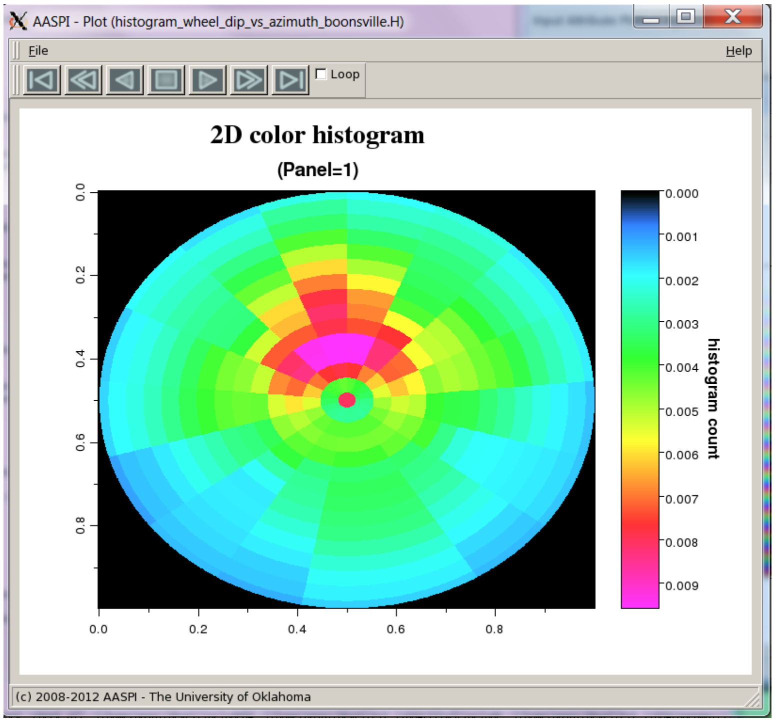


The color wheel is plotted using the **aaspi_plot** utility which is designed to display seismic amplitude and attribute data. I've annotated the image in PowerPoint to give a more explicit definition of the color wheel:



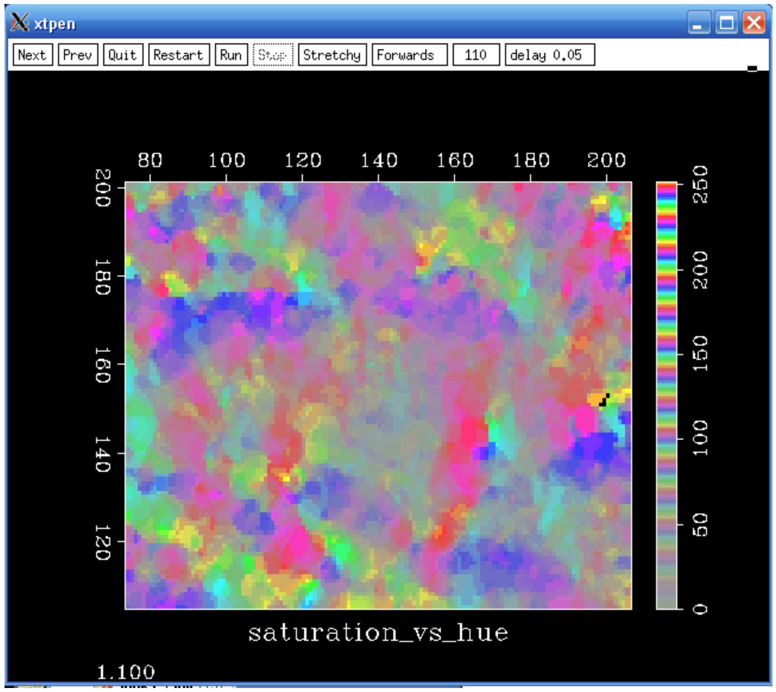
Flat (horizontal) events with a dip magnitude of 0^0 are plotted against white. Events with a dip magnitude of 50 and dip azimuth of 0^0 (North) appear as blue, 60^0 as magenta, 120^0 as red, 180^0 (South) as yellow, 240^0 as green, 300^0 as cyan, and 360^0 as blue. Less strongly dipping events appear as pastel colors.





The third image is a 2D histogram:

The second image will be an animation of time slices of the output data mapped to the 2D color bar. Strong dips are displayed as pure colors and weak dips as gray.



A list of the files generated by program hsplot gives the following:

```
-rw-r--r--  1 kmarfurt aaspi    276 Sep 20 21:10 wheel_dip_mag_vs_dip_azim_hsplot_boonsville_0.H
-rw-r--r--  1 kmarfurt aaspi    303 Sep 20 21:10 legend_dip_mag_vs_dip_azim_hsplot_boonsville_0.H
-rw-r--r--  1 kmarfurt aaspi   8275 Sep 20 21:10 hsplot_18_14_h360..voxelgeo
-rw-r--r--  1 kmarfurt aaspi   7680 Sep 20 21:10 hsplot_18_14_h360..sep
-rw-r--r--  1 kmarfurt aaspi   9917 Sep 20 21:10 hsplot_18_14_h360..landmark
-rw-r--r--  1 kmarfurt aaspi   7756 Sep 20 21:10 hsplot_18_14_h360..iesx
-rw-r--r--  1 kmarfurt aaspi  22562 Sep 20 21:10 hsplot_18_14_h360..gpc
-rw-r--r--  1 kmarfurt aaspi   5033 Sep 20 21:10 hsplot_18_14_h360..geomodeling
-rw-r--r--  1 kmarfurt aaspi     62 Sep 20 21:10 hsplot_18_14_h360..CLM
-rw-r--r--  1 kmarfurt aaspi   5632 Sep 20 21:10 hsplot_18_14_h360..alut
-rw-r--r--  1 kmarfurt aaspi   7168 Sep 20 21:10 hsplot_18_14_h360..aaspicolor
-rw-r--r--  1 kmarfurt aaspi   1789 Sep 20 21:10 dip_mag_vs_dip_azim_hsplot_boonsville_0.H@@
-rw-r--r--  1 kmarfurt aaspi   3459 Sep 20 21:10 dip_mag_vs_dip_azim_hsplot_boonsville_0.H
-rw-r--r--  1 kmarfurt aaspi  26842 Sep 20 21:10 hsplot_18_14_h360..out
[kmarfurt@opal boonsville]$
```

The files *wheel_dip_mag_vs_dip_azim_hsplot_boonsville_1.H* and *legend_dip_mag_vs_dip_azim_hsplot_boonsville_1.H* correspond to the 2D color wheel and 2D rectangular legend plotted above. The file *dip_mag_vs_dip_azim_hsplot_boonsville_1.H* corresponds to the seismic attribute displayed above. If you type *Attr <dip_mag_vs_dip_azim_hsplot_boonsville_1.H* you obtain :

```
[kmarfurt@opal boonsville]$ Attr < dip_mag_vs_dip_azim_hsplot_boonsville_0.H
********************************************
rms = 106.813
mean value = 83.6001
norm value = 343149
maximum value = 255 at 2 1 1
minimum value = 0 at 1 1 1
number of nonzero samples = 9380260
total number of samples = 10320800
```

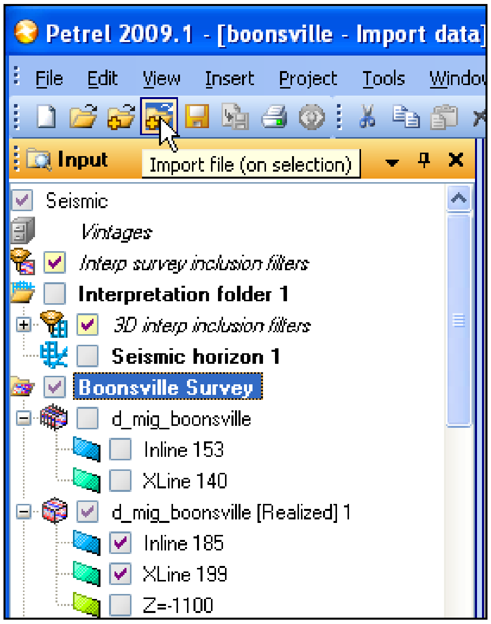
where you will note the ‘seismic data’ range between 0 and 255. Although each sample is stored as a floating point number, they are actually integers that correspond to color lookup tables. The file *hsplot_18_14_h360.alut* is one of these color lookup tables that is in Petrel format. The AASPI software outputs color tables in many of the commonly used formats. The limitation is that the commercial software needs to have a well-defined format (e.g. with documentation, or else a simple ascii file) and the ability to import a color table from a file.

Loading and displaying multiattribute plots in Petrel

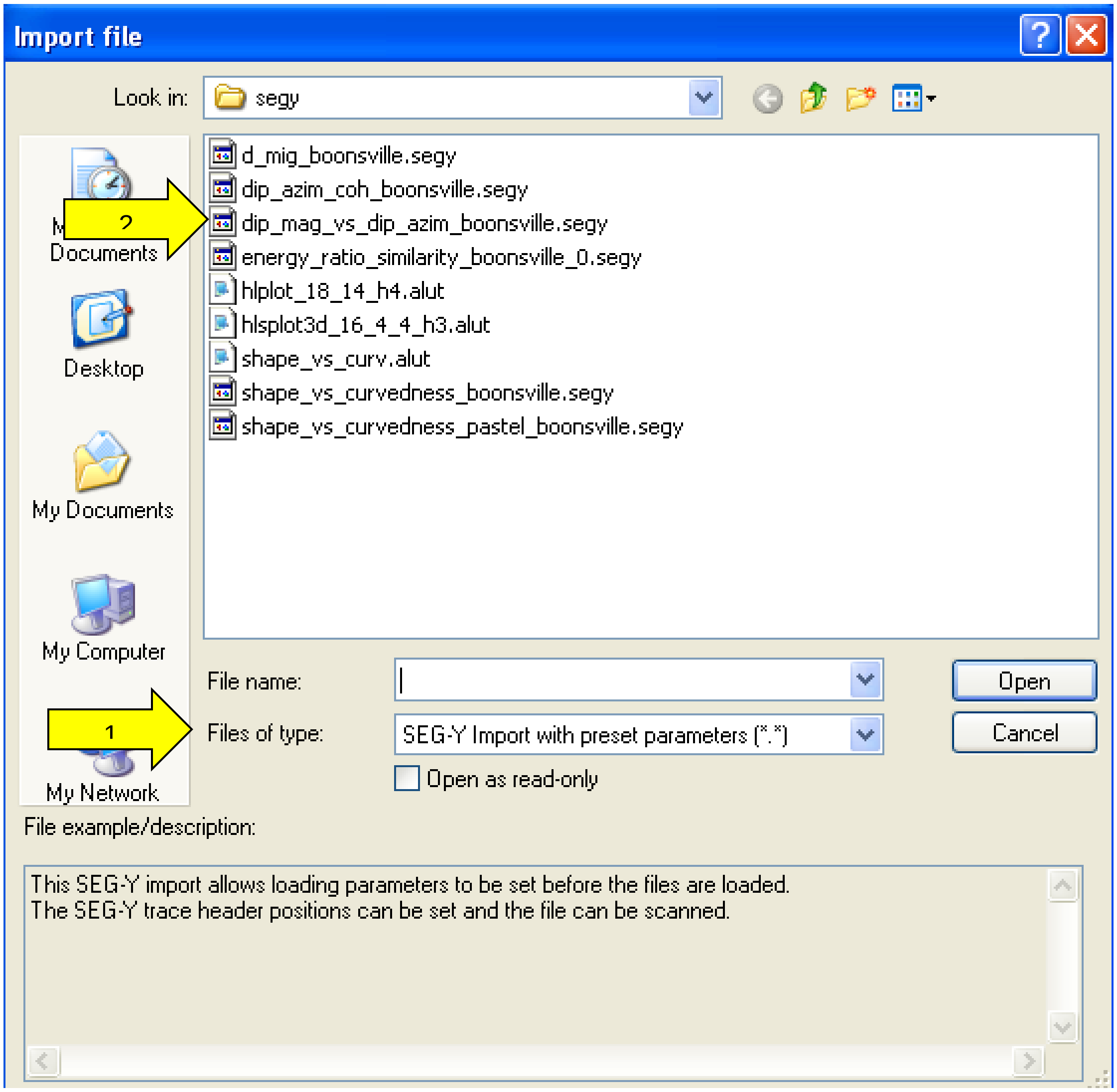
Schlumberger has been gracious enough to provide OU with licenses for education and research, hence the example on how to load a composite attribute volume into Petrel. Loading such volumes in Voxelgeo, Kingdom Suite, Landmark, Geoprobe, IESX, and Geomodeling are similar. Unfortunately, a few packages (e.g. Geographix) do not allow loading an ascii color bar from a file.

The first step is to convert the SEP-format file dip_mag_vs_dip_azim.H to a SEGY-format file dip_mag_vs_dip_azim.segy using the *Sep2Segy (single)* tab in **aaspi_util**. Then, depending on how your disk drives are mounted and shared, you will need to copy this data from your Linux system to your PC where you run PetreOnce the data have been converted and copied, launch Petrel, open your Boonsville project, and add the new SEGY file into the project by highlighting the survey name and clicking the *Import File (on selection)* icon:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

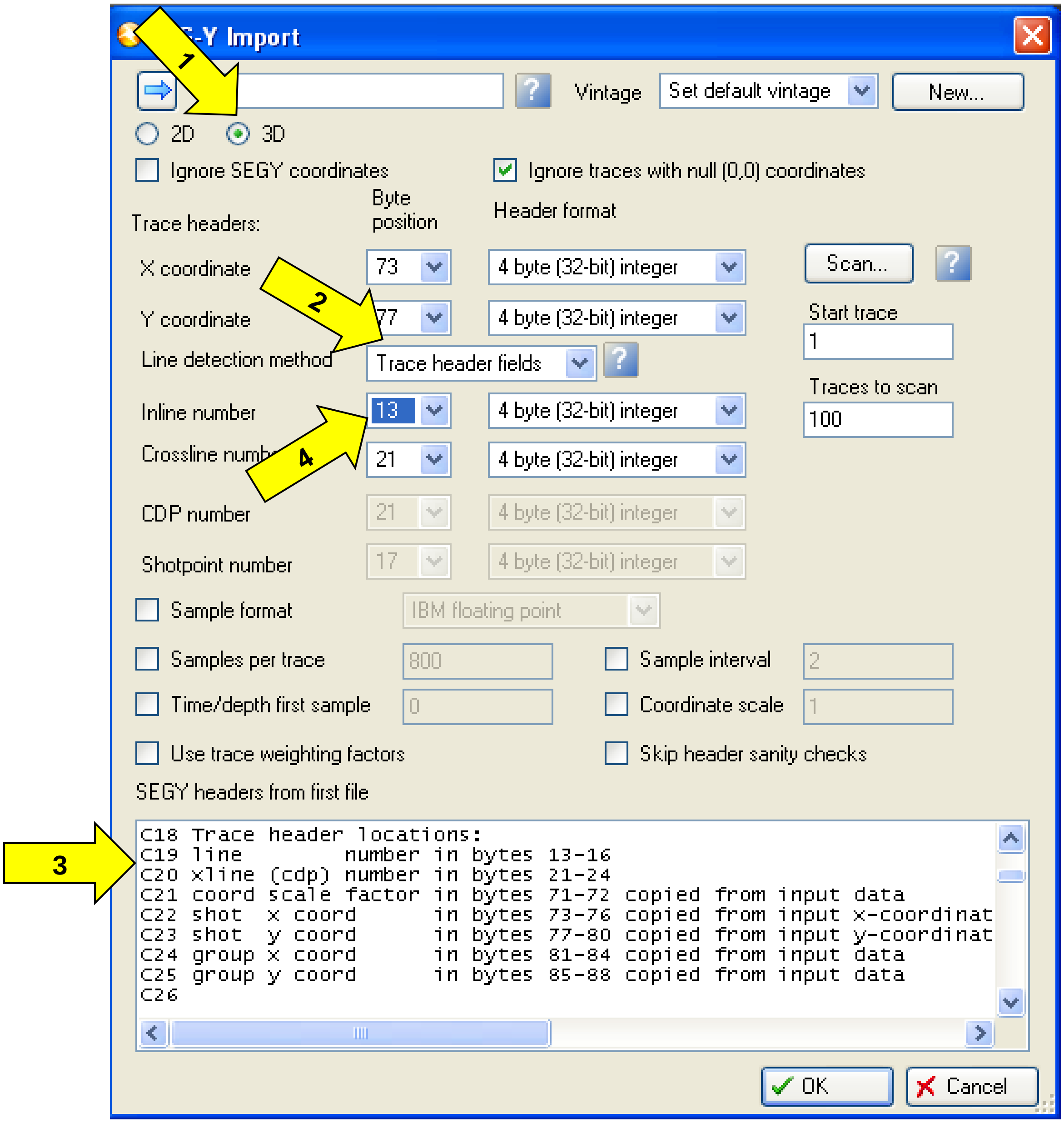


The following window should pop up:



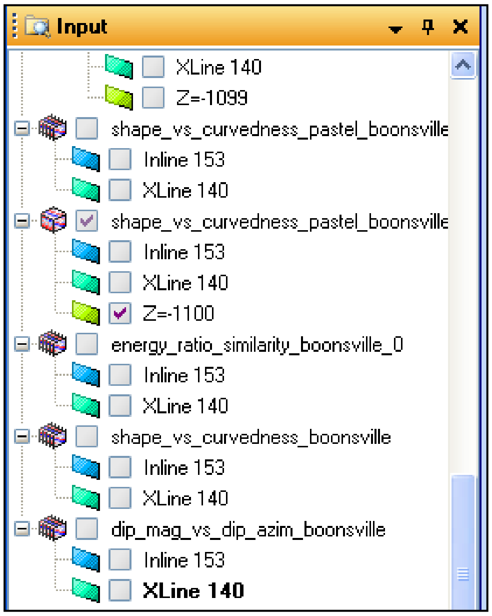
First, choose to load (1) *SEG-Y import with present parameters (*.*)*, since the header values for the AASPI volumes may be different from your default settings. (The Petrel loading utilityis fairly clever, but let's just do this for clarity). Then (2) select *dip_mag_vs_dip_azim_boonsville.segy* as the file to be loaded.

Click Open and the following panel pops up:

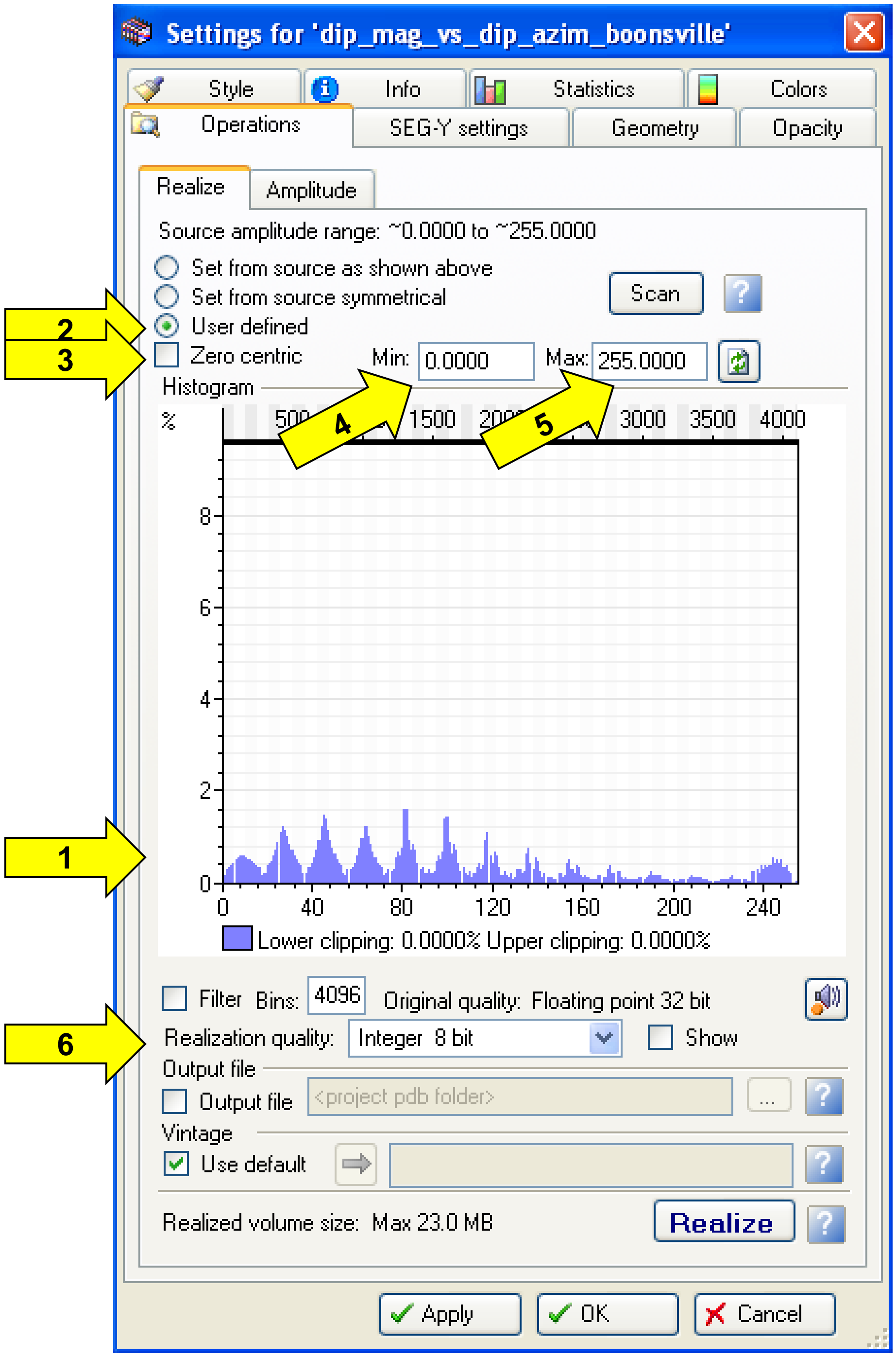


First, select (1) *3D* since you will wish to load a 3D seismic volume. Then (2) select *Trace header fields* as the *Line detection method*. Next, scroll down under *SEGY headers from first file* and note that the (3) *Inline number* is in bytes 13-16 and the *Crossline number* in bytes 21-24. The value of 21 is the 1977 SEG-Y standard for CDP number and is usually set as the default crossline number for interpretation systems. However, most interpretation systems were started before the 2003 SEG-Y standard for 3D seismic data was adopted, such that finding the inline number takes some detective work. For all the AASPI volumes, the inline number will be in bytes 13-16. Enter (4) the value of 13 for the *Inline number* byte location.

Click OK and the data begins to load. The file will then be under your *Input* tab:

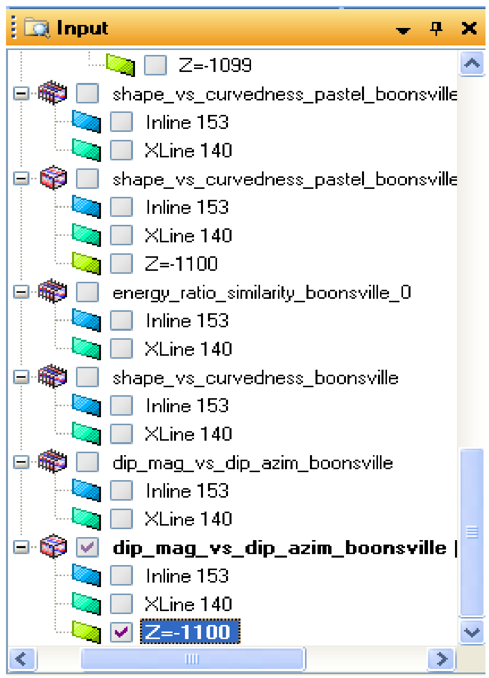


Double click the last file in the list *dip_mag_vs_dip_azim_boonsville* to open the *Settings* pop-up window:

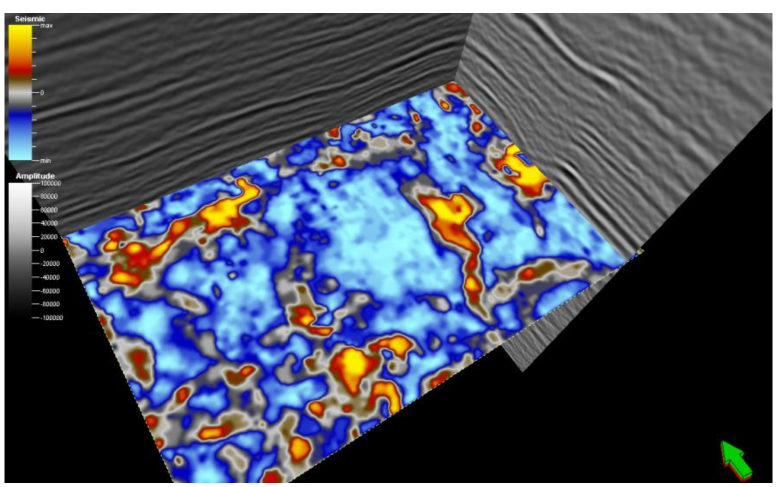


Under the *Operations* tab, you will note that (1) the histogram is neither Gaussian (like seismic amplitude) nor log-normal (like RMS amplitude and envelope). Rather, what you see is the histogram of the dual attribute data multiplexed into a single composite attribute histogram. Next, select (2) *User defined* and unselect (3) *Zero centric*. The composite attributes will range from 0 to 255. In order to map accurately against the 2D color bar, explicitly set (4) *Min* to be 0.0 and (5) *Max* to be 255.0. Since the data range between 0 and 255, choose the (6) *Realization quality* to be *Integer 8 bit*. Finally, click Realize and close the window when to exit when done.

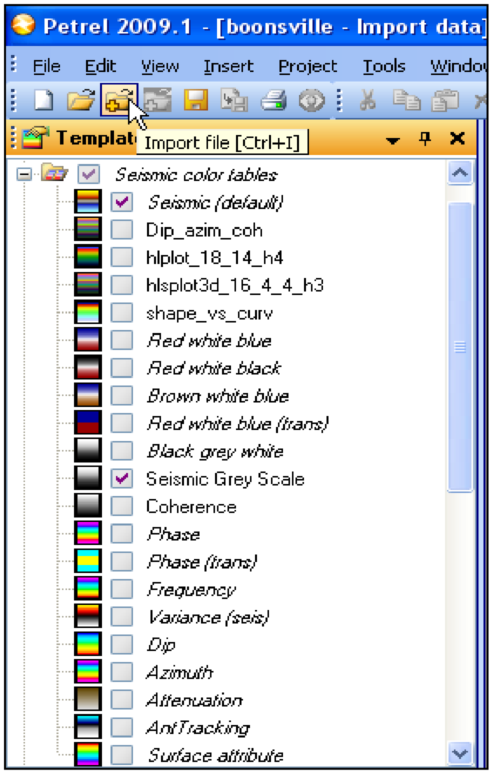
Your Input tab should have the Realized data under it:



Choosing the plot the time slice at t=-1100 ms (for those of you not familiar with Petrel, it has the time and depth axes as positive UP) you should get the following display:

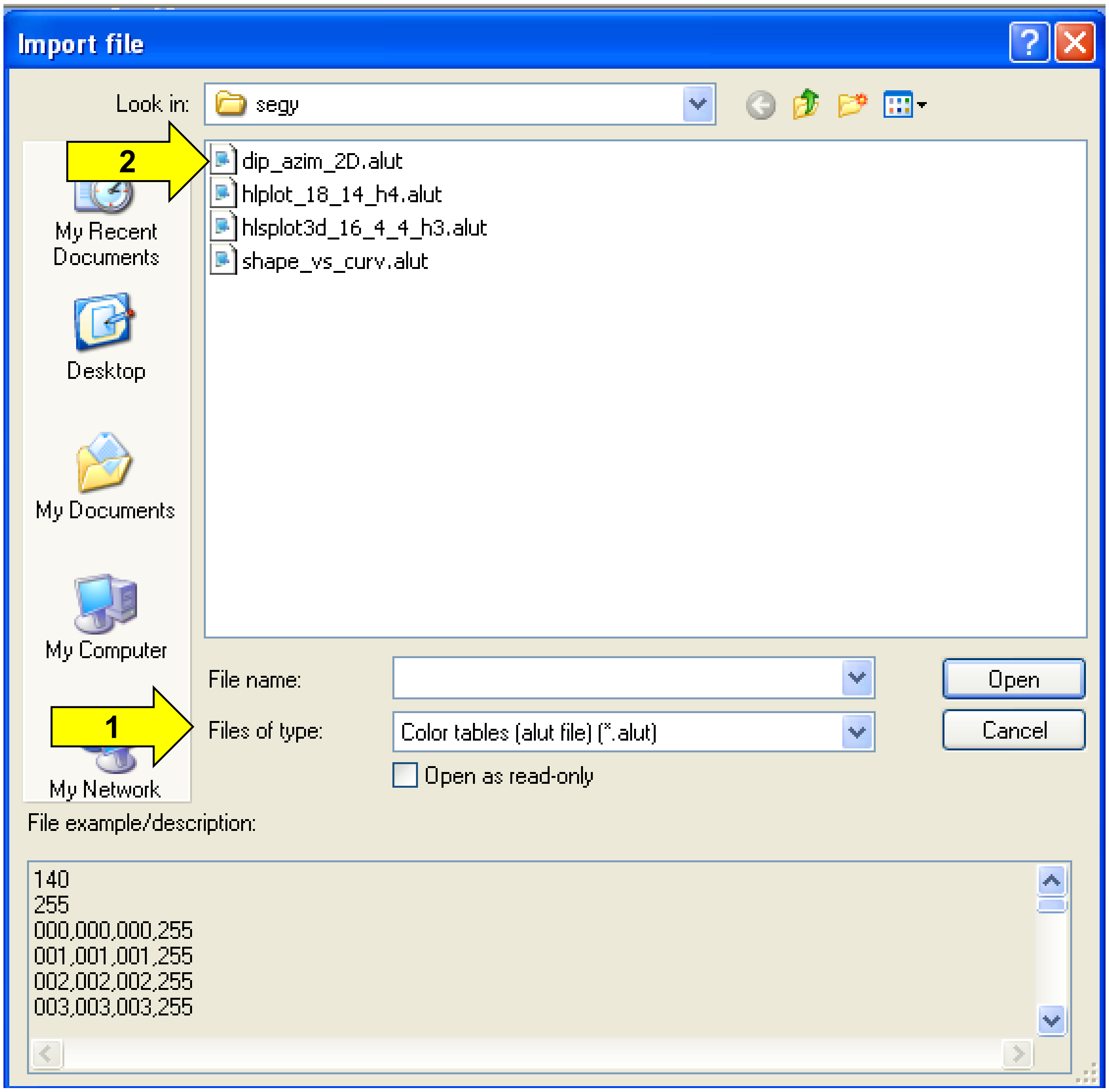


Petrel assigns the default Seismic color bar. You will need to import the 2D color bar generated by program **hlplot**. To do so, first copy the file *hsplot_18_14_360.alut* down from your Linux workstation. Rename it to be something that makes sense, such as *dip_azim_2D.alut*. Then highlight your *Templates* tab and click the import icon:



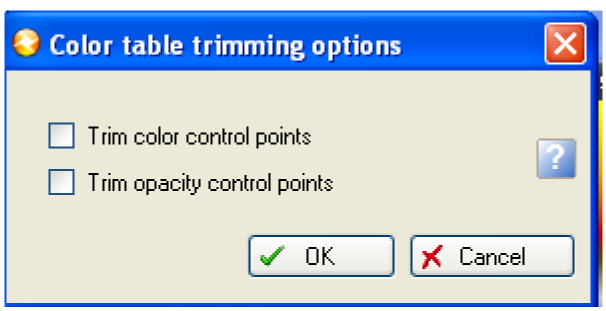
The following window opens:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**



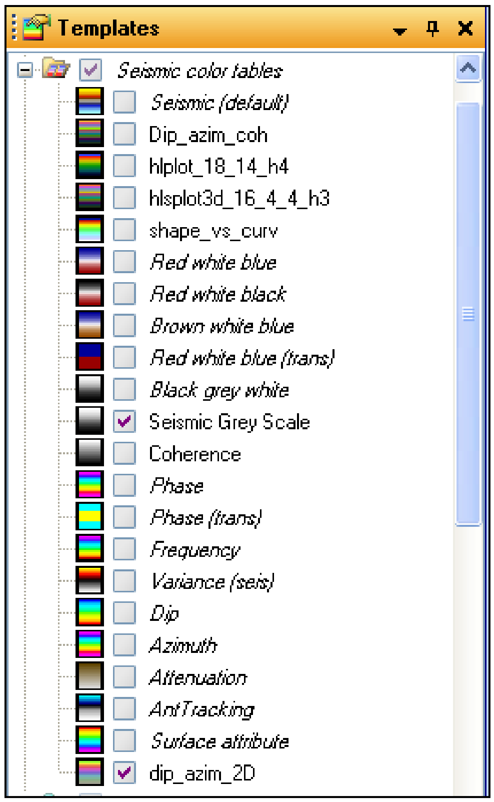
First, (1) select *Files of type* to be *Color tables (alut file) (*.alut)* . Then (2) select the file *dip_azim_2D.alut* and click *Open.*

The following pop-up window appears:



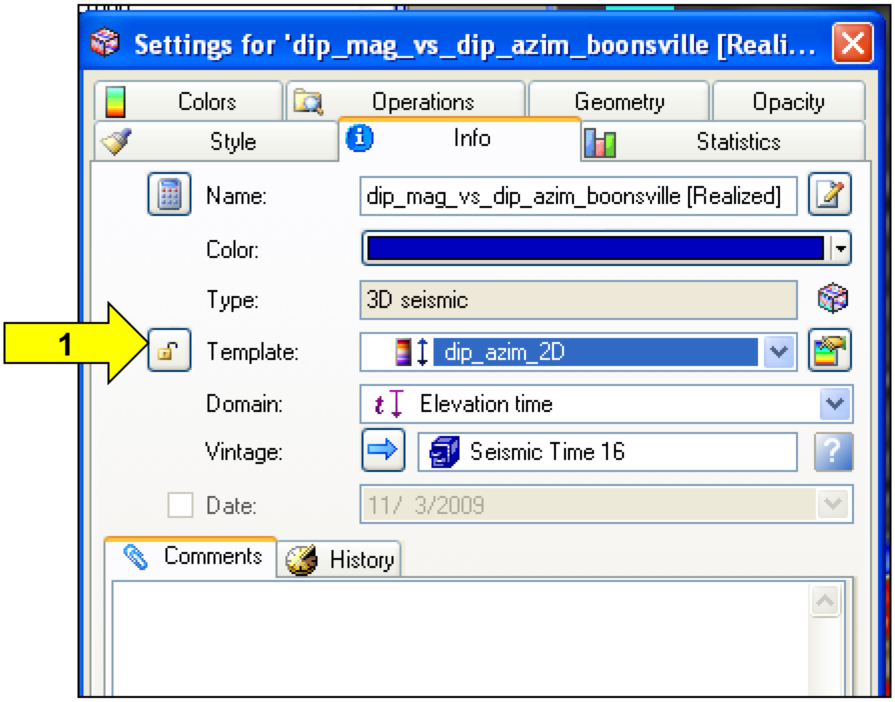
Petrel will want to Trim your color and opacity control points. It is extremely important that you unselect this default option or your color mapping will not work! Once unselected, click OK.

The new color bar will appear at the bottom of your *Seismic color tables* in the *Templates* tab:

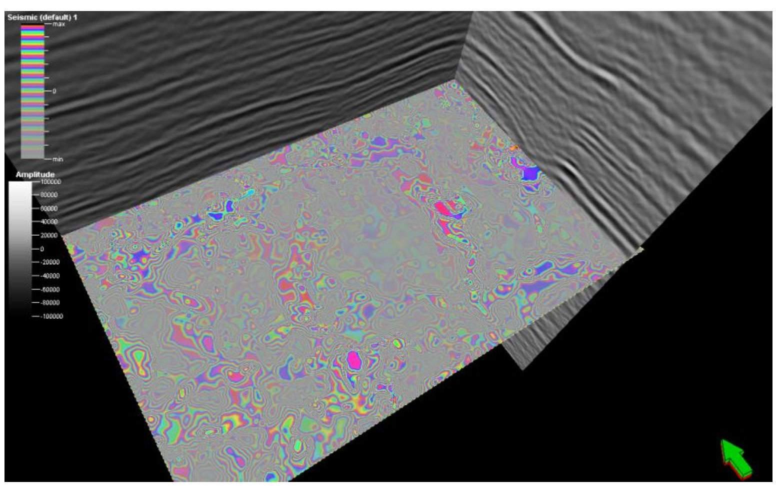


Return to the Input tab and double-click the realized data volume dip_mag_vs_dip_azim_boonsville (Realized) to open the Setting tab:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

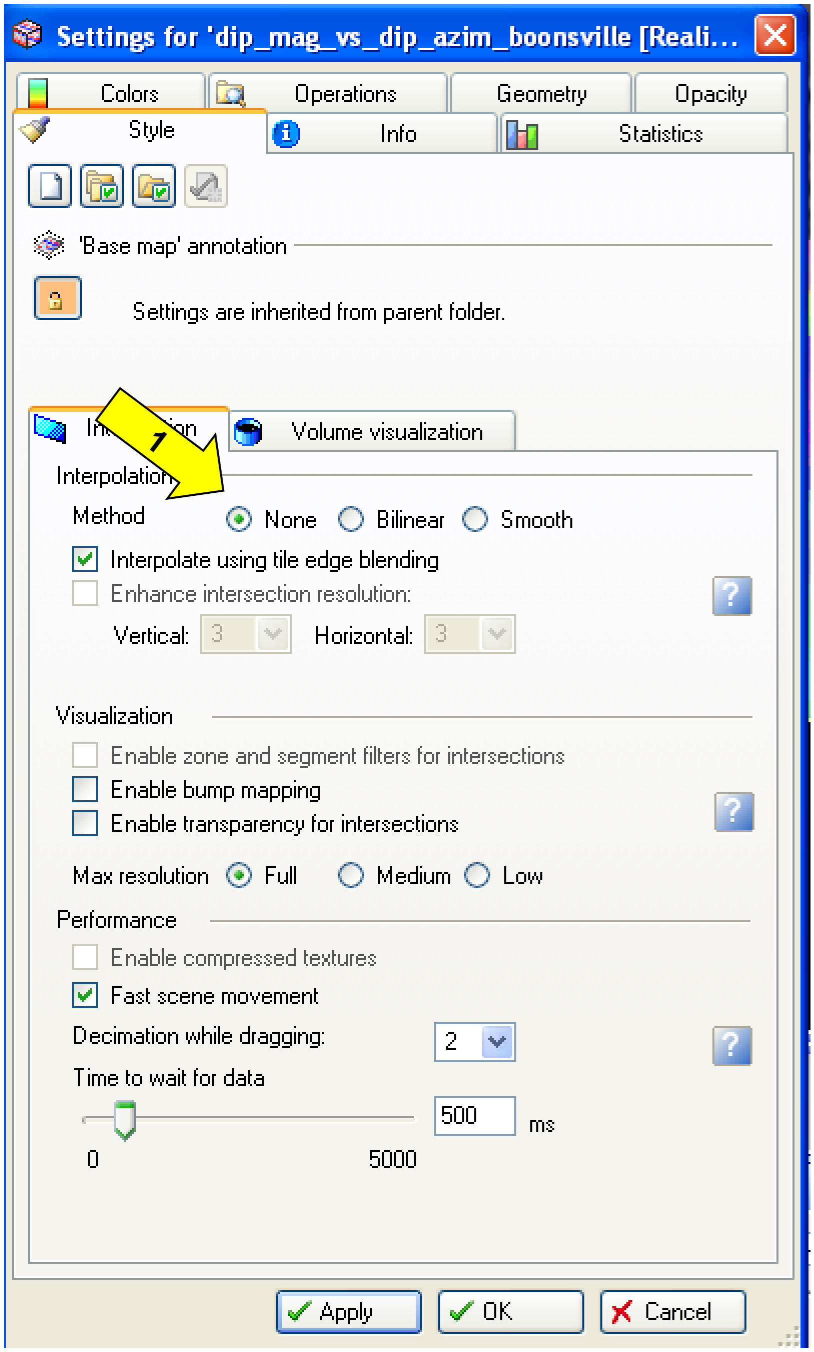


Under the *Info* tab, (1) select your new color bar, *dip_azim_2D*. Click Apply and your seismic attribute time slice may look like the following:



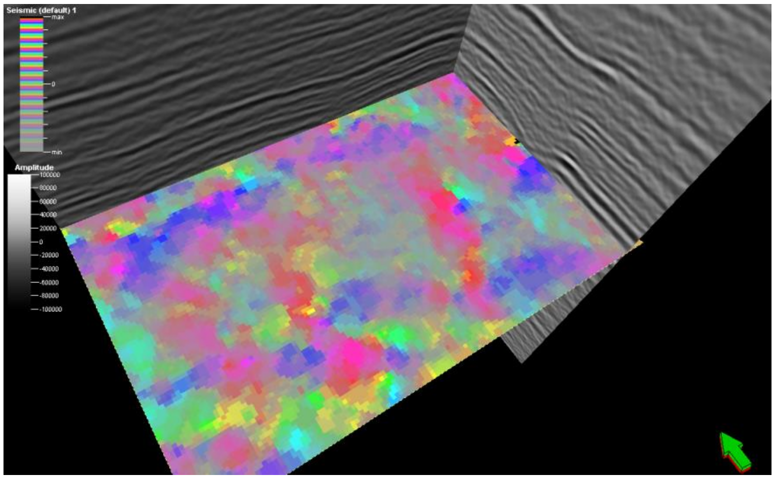
The problem here is that Petrel is interpolating colors. Go back to the *Settings* tab and under the *Style* tab, click (1) *None* as the *Interpolation Method*. You will encounter this problem when using any discontinuous color bar. In addition to multiattribute images, these may occur with discrete classifications (e.g. if you import classes from Stratimagic) or discrete color tables from facies inversion (e.g. green for shale, yellow for sandstone, blue for limestone).

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

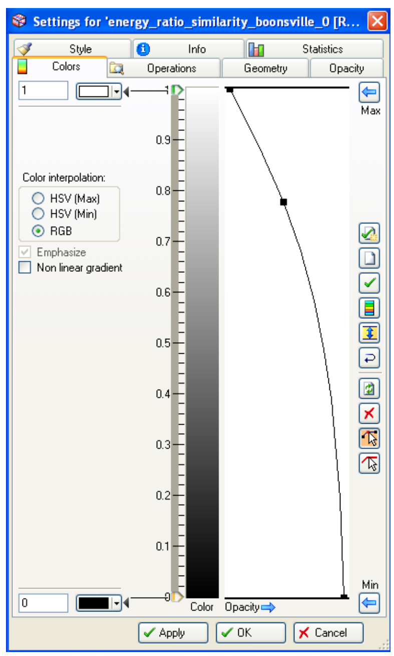


The new image looks like this:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

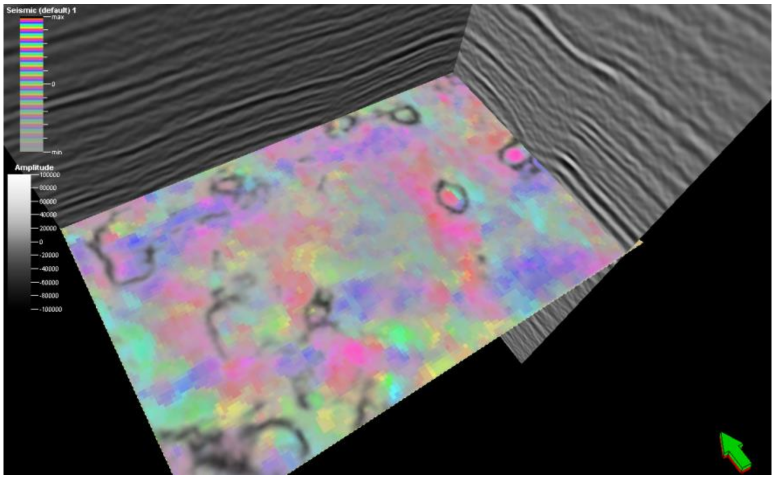


Later, using program **similarity3d**, you will generate various coherence images. You will wish to set your transparency for energy-ratio similarity to be transparent for coherent regions, and black for incoherent regions:



Co-rendering the energy ratio similarity image with the composite dip magnitude vs. dip azimuth image results in the following:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

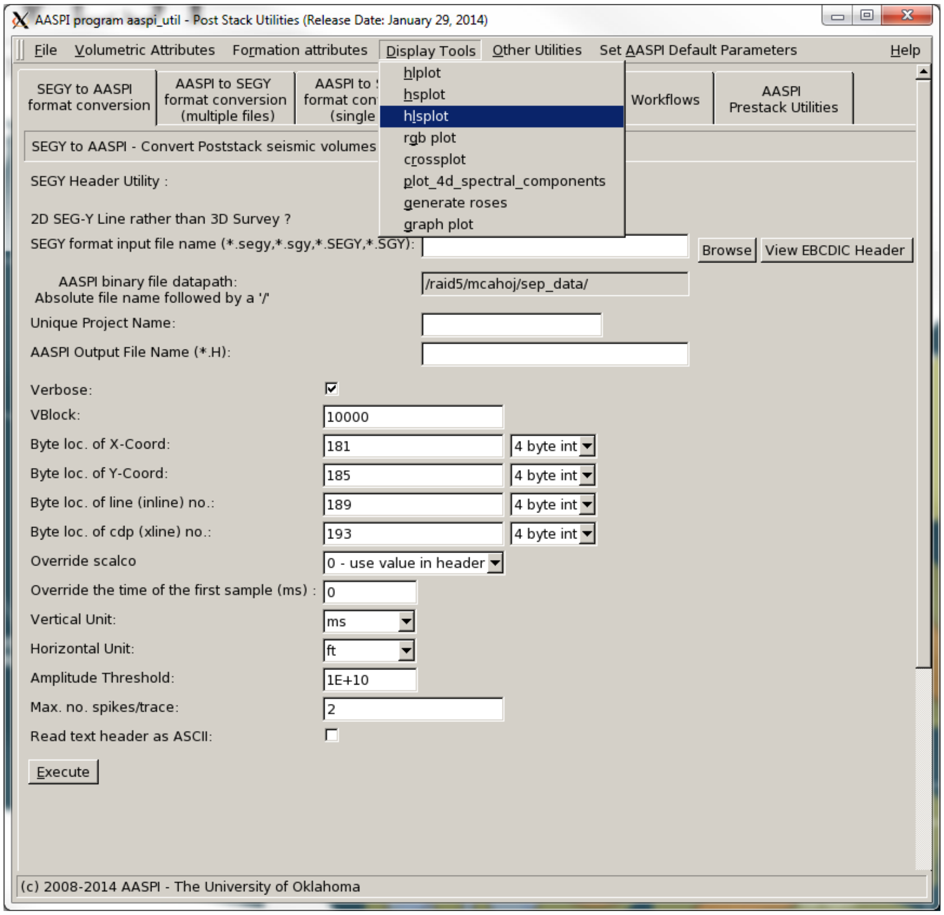


Careful examination indicates that the color-encoded dip magnitude vs. dip azimuth images shows the reflectors dipping into the circular karst collapse features.

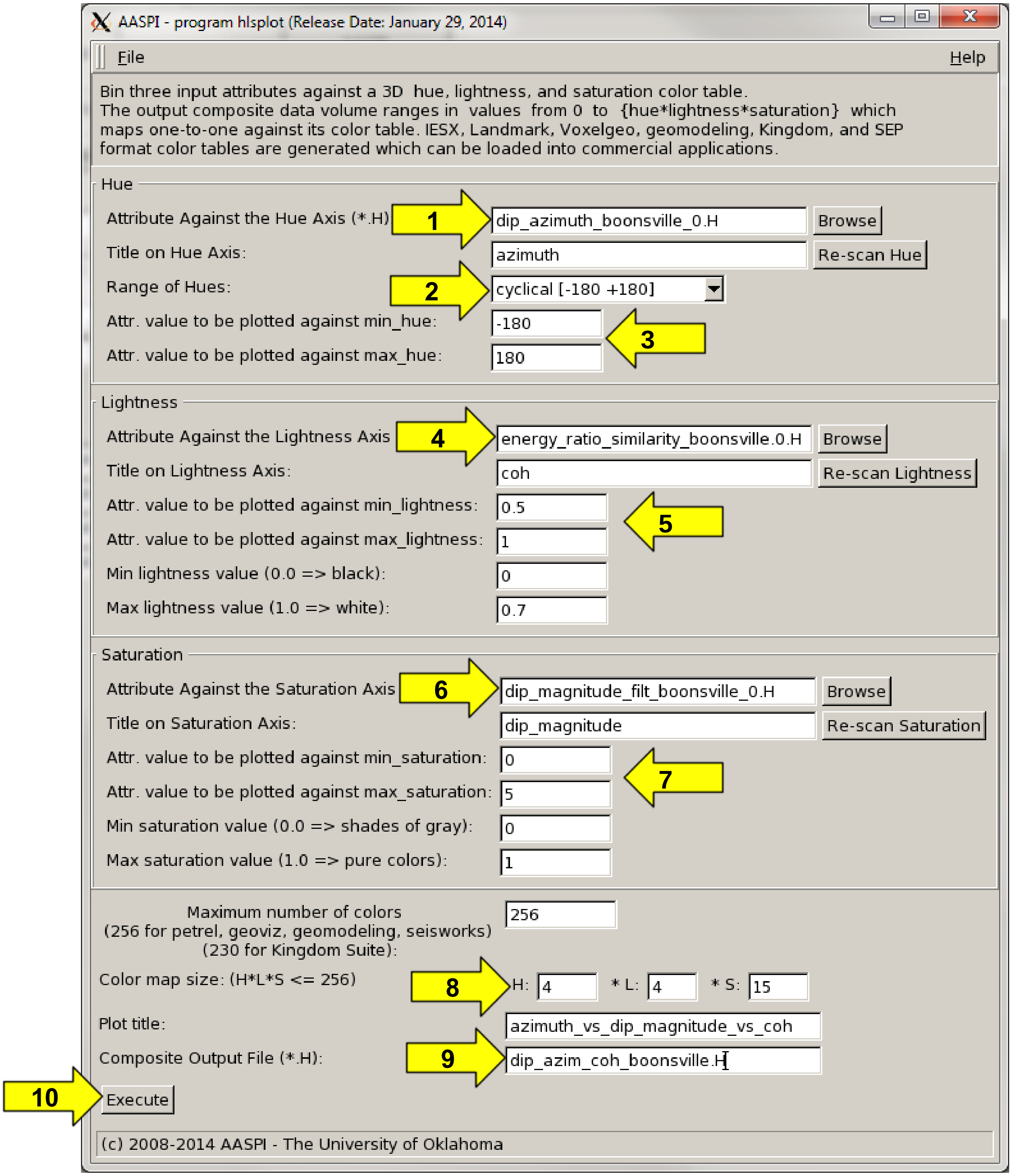
Plotting dip vs. azimuth vs. coherence – Program hlsplot

Earlier, we showed how we can plot dip magnitude against saturation and dip azimuth against hue to obtain a multiattribute image whereby one attribute modulated another. We can carry this construct one step further and plot coherence against lightness. To do so, return to the **aaspi_util** GUI and select *Display Tools* and select *hlsplot* as shown below:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**



The following GUI will appear:



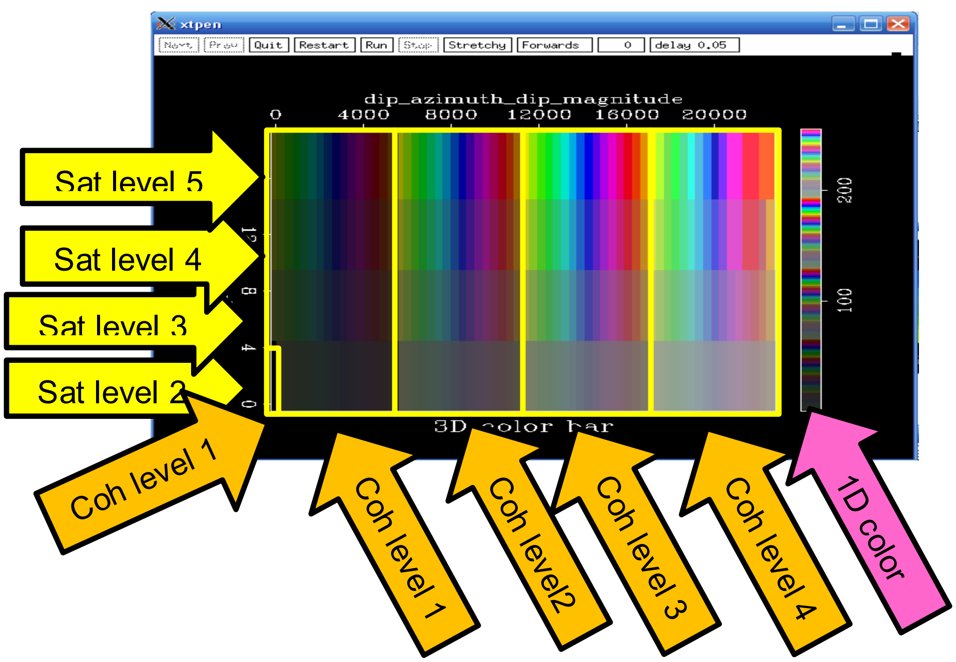
The appearance of the **hlsplot** GUI is similar to that for program **hsplot,** except that now you will need to define three rather than two files. (1) For *The Attribute Against Hue (*.H)* select dip_azimuth_median_filt_boonsville_0.H. The dip azimuth should be plotted against a cyclical color bar. We want yellow to map against 180^0

and blue to map against 0^0 and so (2) choose cyclical (-180 +180) for *Range of Hue*. The dip azimuth ranges from *-180^0 to +180^0*, so (3) enter -180 and +180 under the *Attr. value to be plotted against min_hue and max_hue* boxes.

Enter (4) *energy_ratio_similarity_boonsville_0.H* (coherence) as the *Attribute Against Lightness (*.H)*. The range of this attribute varies from 0.0 to 1.0, but very few values fall below 0.5. Let's clip the range to be displayed and (5) type 0.5 and 1.0 in the *Attr. value to be plotted against min_lightness and max_lightness* boxes.

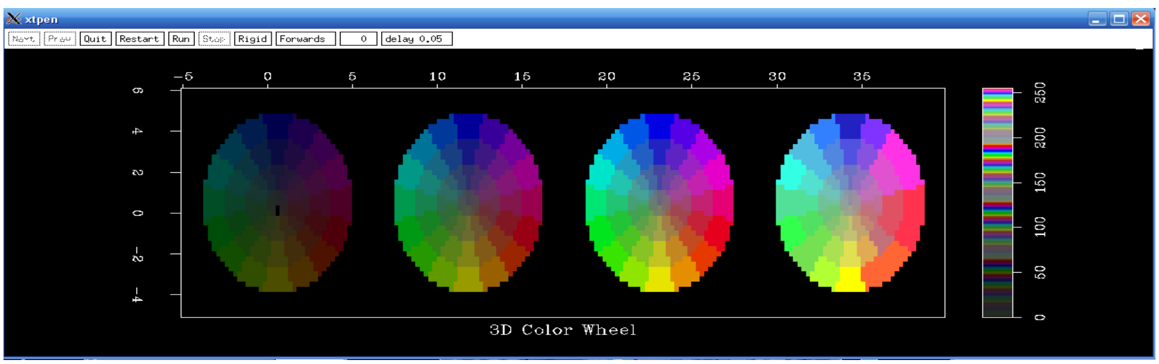
Enter (6) dip_magnitude_filt_boonsville_0.H as the *Attribute Against Saturation (*.H).* The range of this attribute varies from 0.0 to 15, but as with our hsplot earlier, (7) type 0.0 and 5.0 in the *Attr. value to be plotted against min_saturation and max_saturation* boxes.

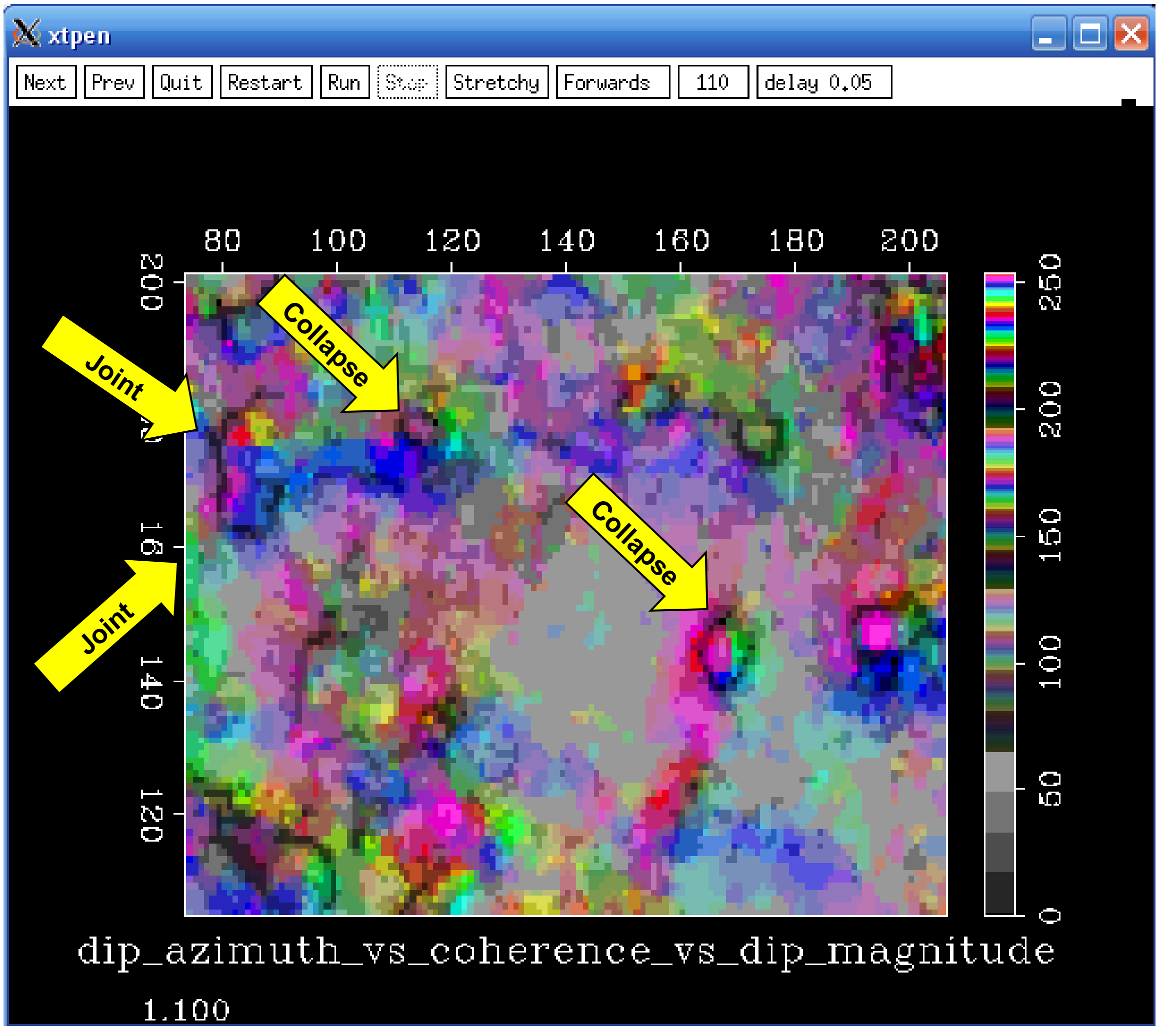
As of September 2009, most interpretation workstations only allow importation of 256 colors (several allow more internally). Therefore under *Color map size: (H*L*S <=256)* leave the defaults (8) of 4, 4, and 15. The last parameter to enter is (9) the *Composite Output File (*.H)* where you will enter *dip_azim_coh_boonsville.H*. With all the parameters selected, (10) click *Execute.*



As with program **hsplot,** a color legend appears. The one above has been also annotated in PowerPoint. Although we specified four levels of coherence, the program cheats a little bit, and steals one of the darker unsaturated colors from the first level and makes it black (annotated as *Coh level 1*). For the coherence ranges we specified, this color corresponds to values of coherence <0.5 . The next four levels correspond to coherence values that range between 0.500- 0.625, 0.625-0.750, 0.750-0.875, and 0.875-1.000. The lightnesses of these five levels are *L= 0.00, 0.15, 0.30, 0.45*, and *0.50*. Blocks of constant saturation (dip magnitude for this example) progress horizontally. Within each block the hue (dip azimuth for this example) progresses horizontally as well. A color wheel should also appear:

The four lightness levels are shown below. Each color wheel corresponds to a range of dip from 0^0 to 5^0, at increasing levels of coherence. The black level of coherence (c < 0.5) is not displayed.





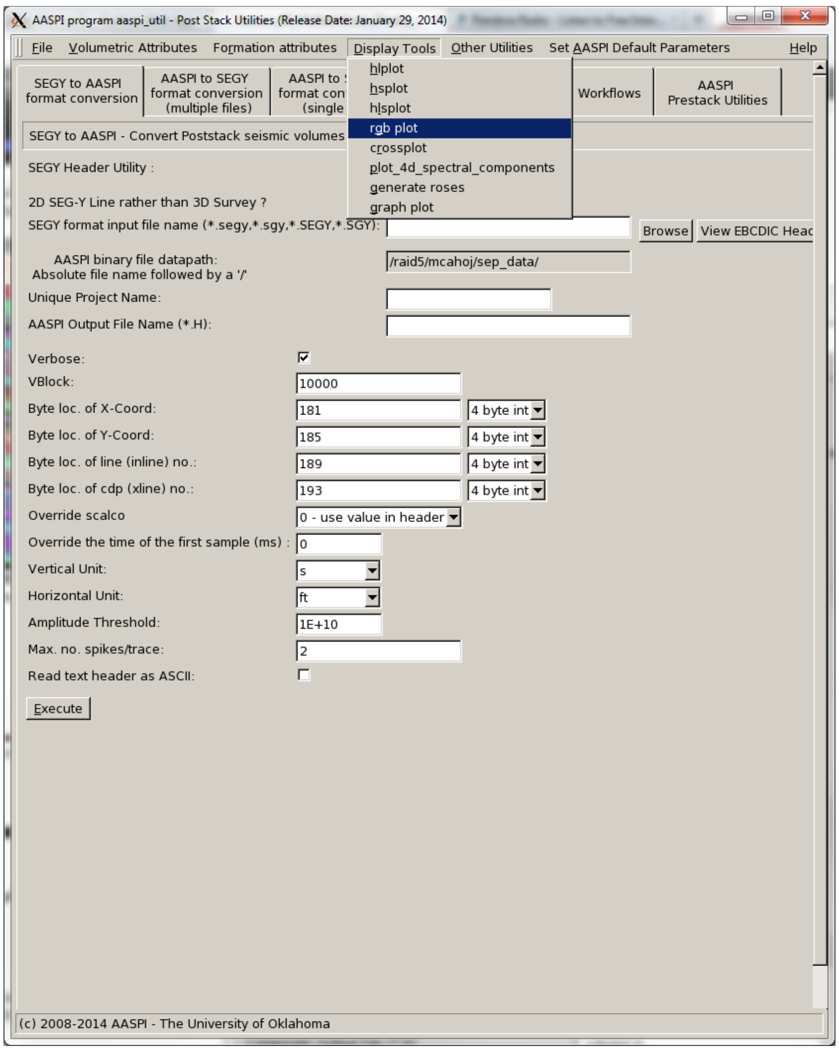
The resulting image is overall less pastel than the image generated using program **hsplot**. The less-coherent areas become darker, with the least coherent areas being black. Several collapse features can easily be identified. The areas marked 'joints' are less clear. However, subsequent curvature calculations will sharpen these areas where there is a lateral change in dip magnitude and dip azimuth.

The 3D volume has integer values ranging from 0-255 stored as floating point numbers. When loaded into commercial workstation software, these data should be loaded with a user-defined range between 0 and 255. The corresponding color table (ending in *.alut, *.iesx, *.geoprobe, etc.) should be loaded and mapped one-to-one against the data volume. Stretching and squeezing the color bar will destroy the one-to-one mapping and should not be used.

Plotting attributes against red, green, and blue – program rgbplot

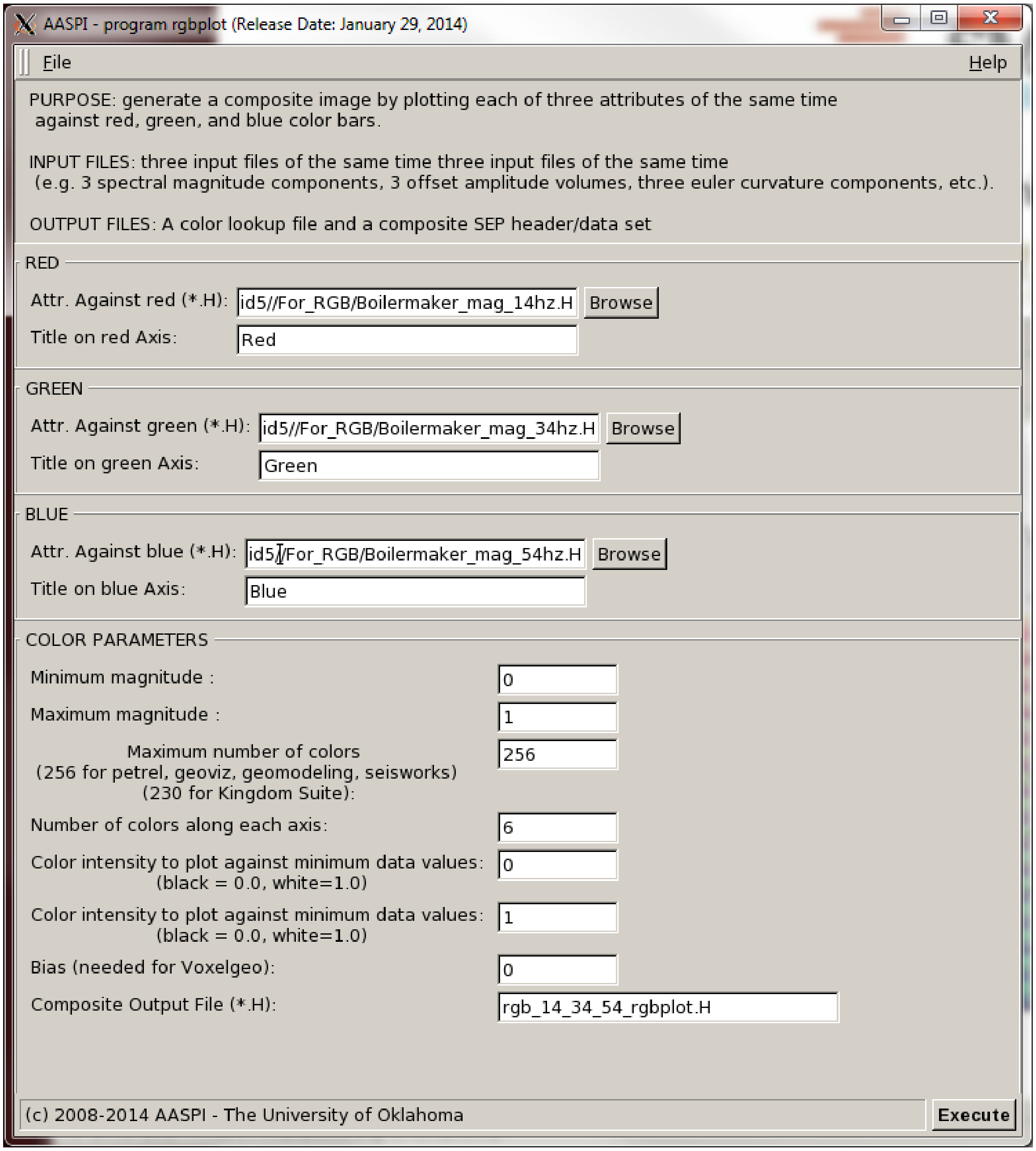
Program **rgbplot** quite simply plots one attribute against red, a second against green, and a third against blue. At present, the SEP programs Grey and Stube only allow 256 colors, which provide an insufficient number of bins (only 6) along each axis. Our future C++ graphics utilities will have 32-bit vs. 8-bit color. If you have greater than 8-bit color, the output of this program should work just fine.

To invoke program **rgbplot**, click Displays, then **rgbplot** on the **aaspi_util** GUI:



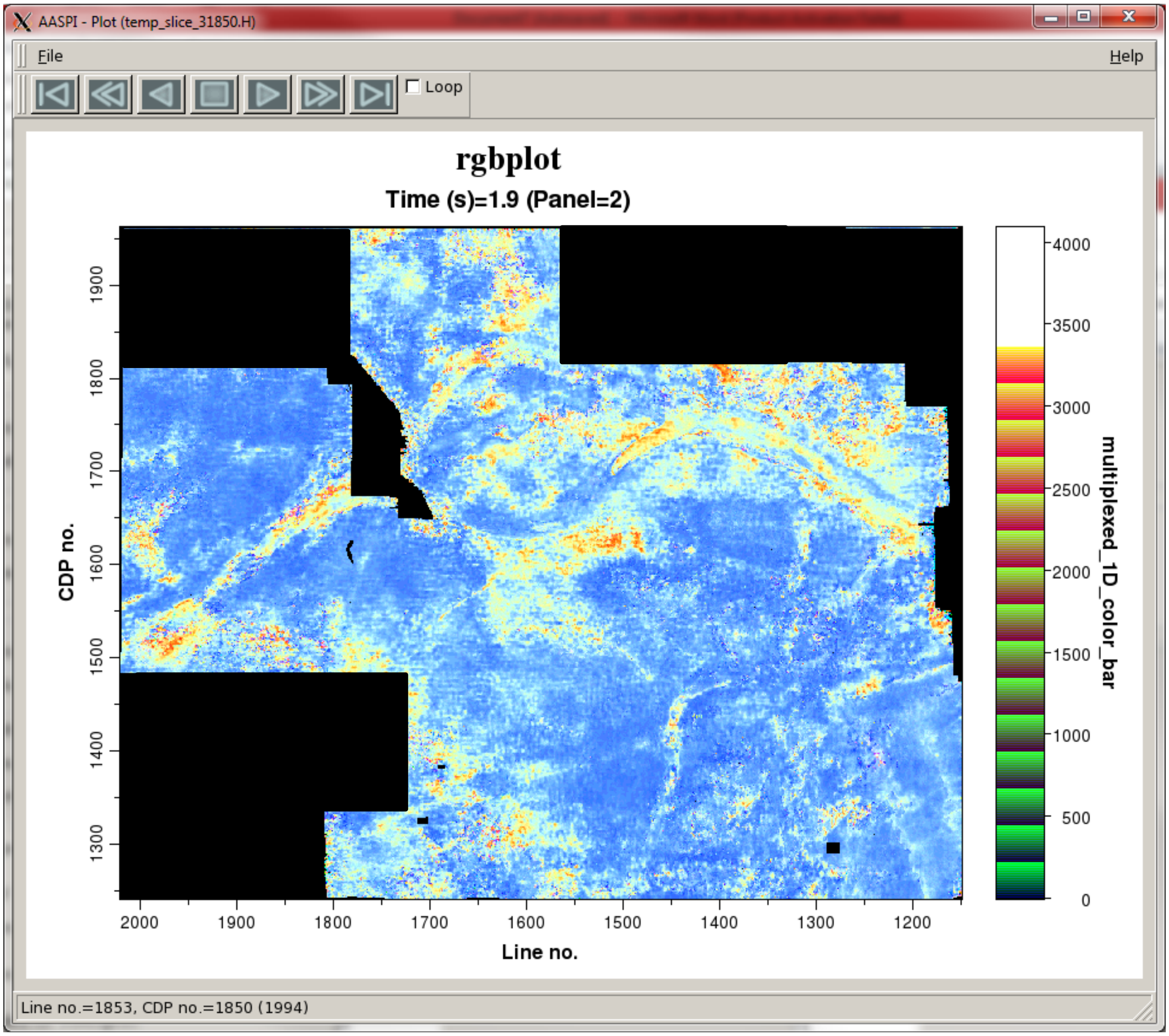
The following GUI appears:

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**



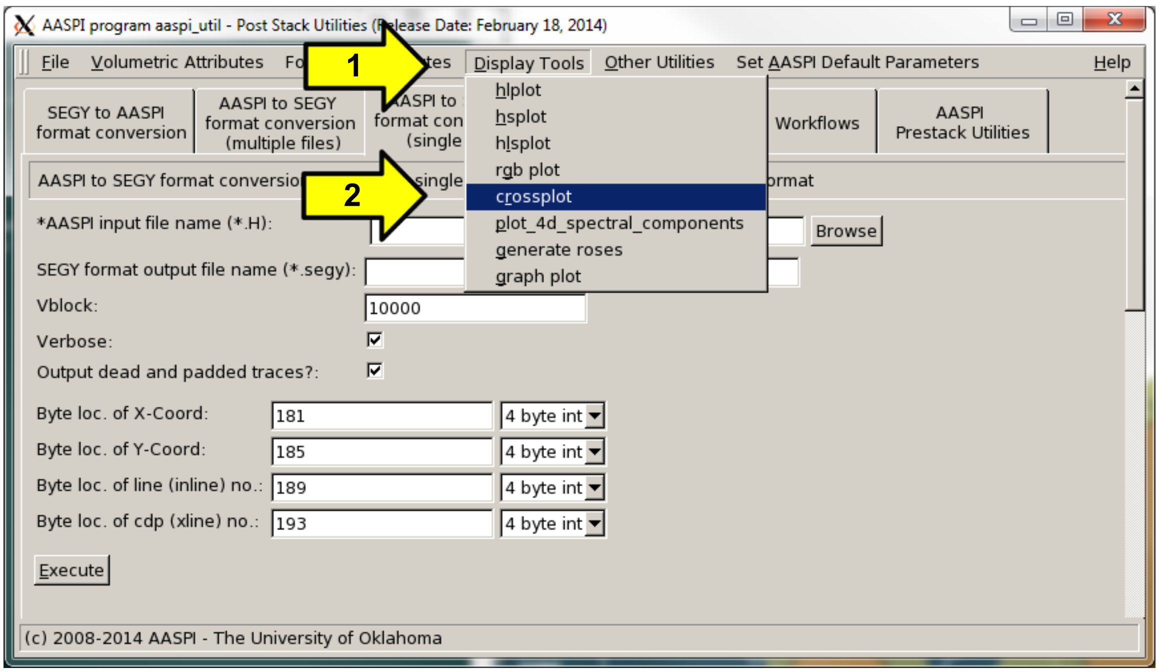
I choose the three input attributes which are the 14, 34, and 54 Hz spectral components generated by program **spec_cmp** for the Boilermaker data volume. Because of the 8-bit color limitation, the following image is less than satisfactory, although we can see some channels tuned in at lower frequencies that appear as orange.

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

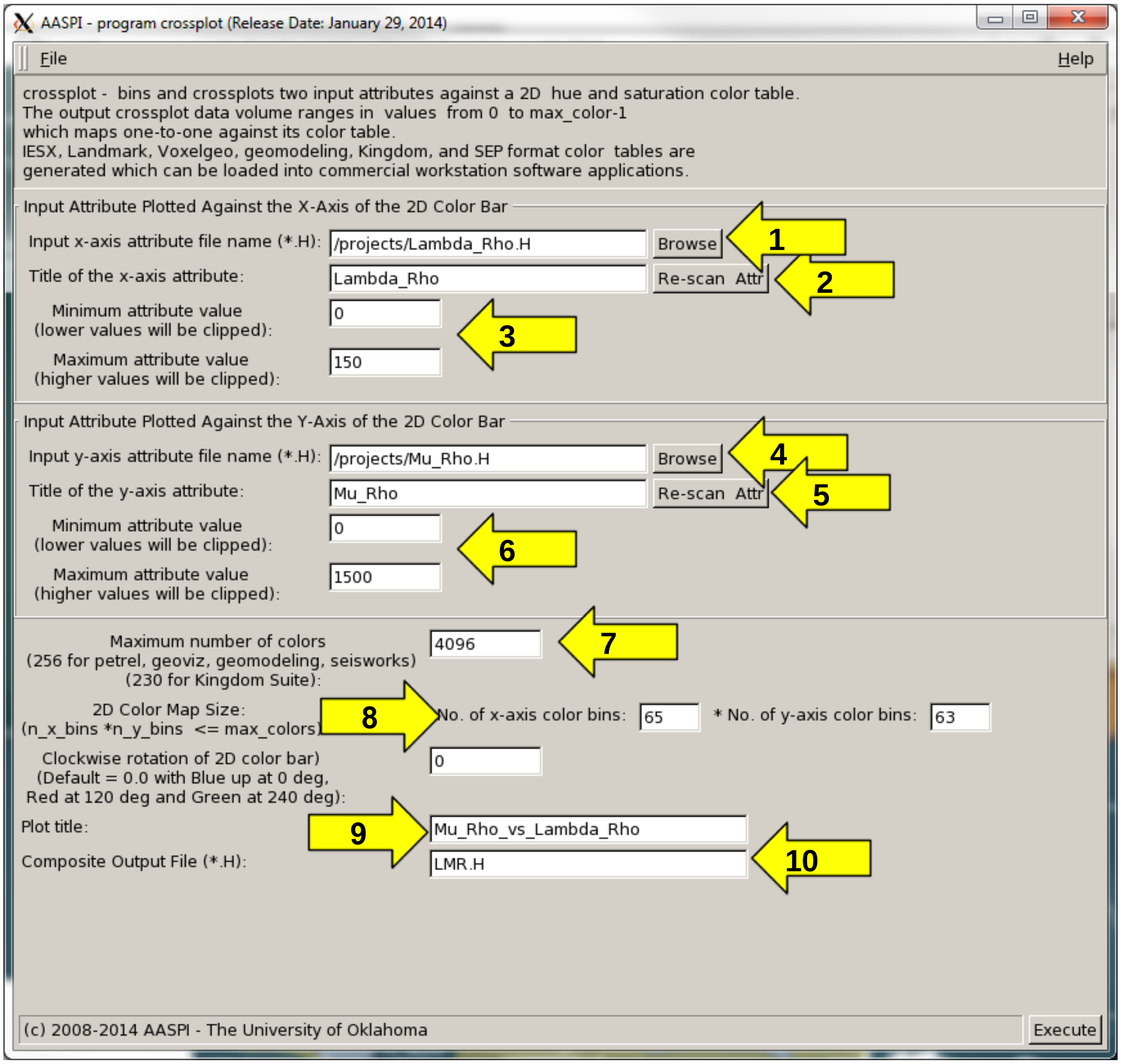


Crossplotting two attributes against a 2D color bar – program crossplot

This is a new utility included in AASPI as of late 2012 to address issues in mapping lambda -rho vs. mu–rho for pre-stack inversion volumes. To initiate **crossplot** return to the **aaspi_util** window click 1) *Display tools* then scroll down to 2) *crossplot*.



The **crossplot** window shown below will appear. In this example we input (1) the file *Lambda_Rho.H* in the *x-axis attribute* and (5) the file *Mu_Rho.H* in the *y-axis attribute*. If the range of values does not automatically appear click (2) and (5) *Re-scan Attr* to rescan the range of values in the two data volumes. Often you will wish to hand type these values (3) and (6) to clip the range of the data displayed. The maximum number of colors chosen depends on your interpretation software package. Most are limited to 256 colors. In this case (7), we have used 4096 colors. (8) *2D Color Map Size* allows you to adjust the number of color bins denoted to the x and y- axis. Finally, add a (9) *plot title* and a *composite output file* name (10).



After clicking the execute button three plots will appear. The first one shows the 2D color bar, with Lambda_Rho on x-axis and Mu_Rho on the y-axis. The second plot shows the 2D histogram, which plots the probability density Lambda_Rho vs.Mu_Rho against the x-and y-axis. The third plot shows time slices through the 3D crossplotted volume. This can be converted into SEGY and then be loaded into your interpretation software.

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

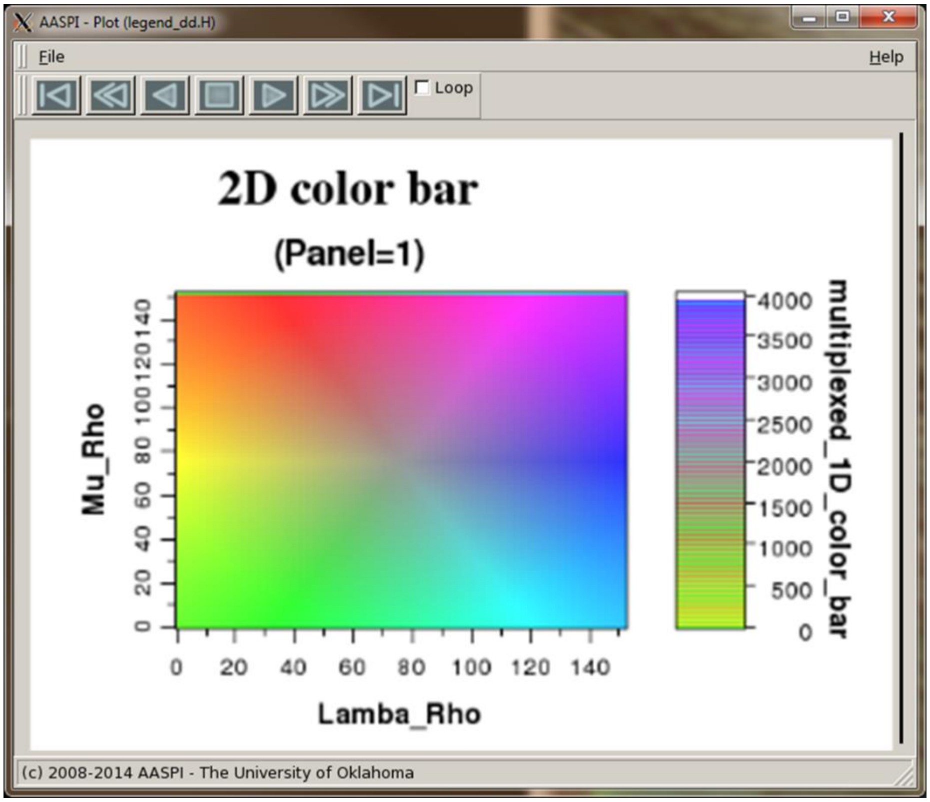


Figure 1. The 2D color bar.

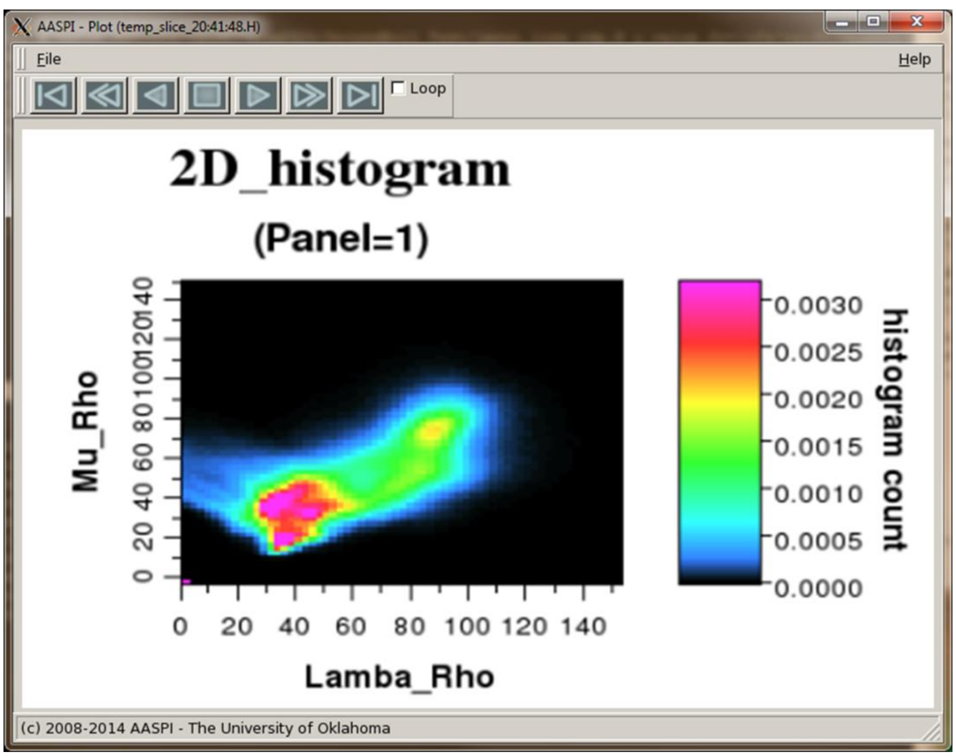


Figure 2. A 2D histogram using the default scaling parameters.

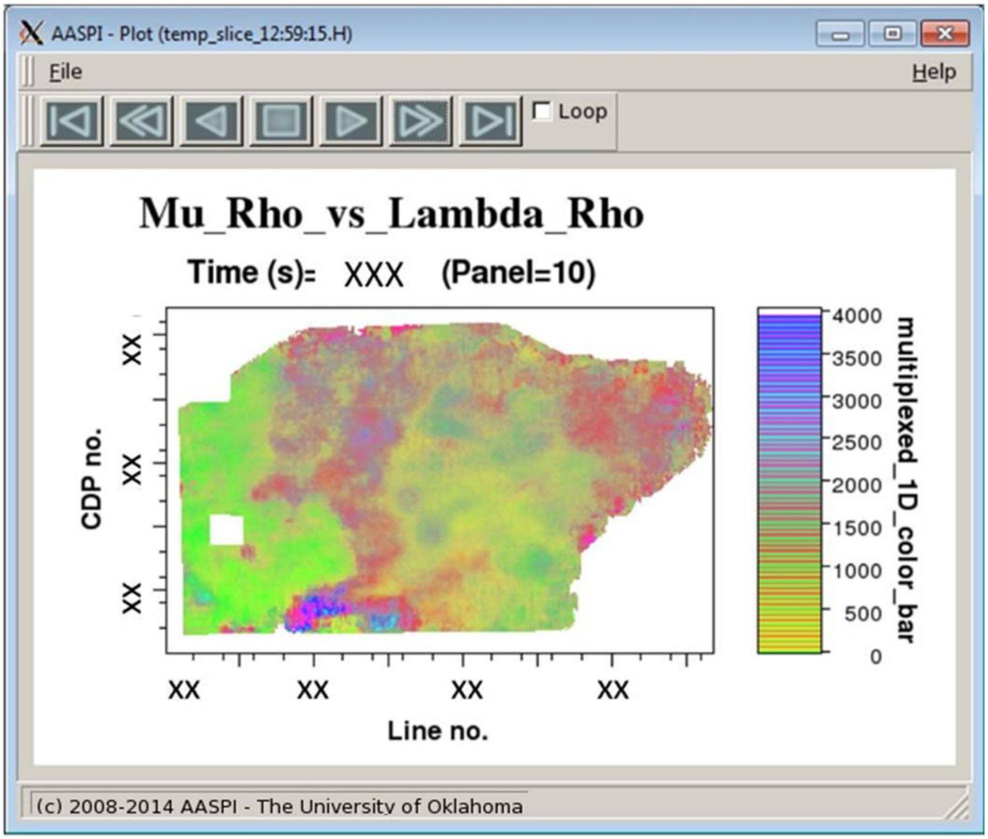


Figure 3. A stratal slice of the Lower Barnett shown as a crossplotted volume of Lambda -Rho vs. Mu-Rho.

By changing the range of the 2D histogram, we can enhance different features of interest. In the example below from Perez (2013) the quartz -rich facies are towards the upper left, the clay-rich towards the lower left, and the calcite-rich facies towards the upper right. Figure 4 shows the same data as shown in Figures 2 and Figure 3 after modifying the ranges to more accurately the data. Quartz-rich facies appear as yellow and red, clay-rich as green, and calcite-rich as magenta, blue, and purple, providing an estimate of lithology and geomechanical behavior.

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

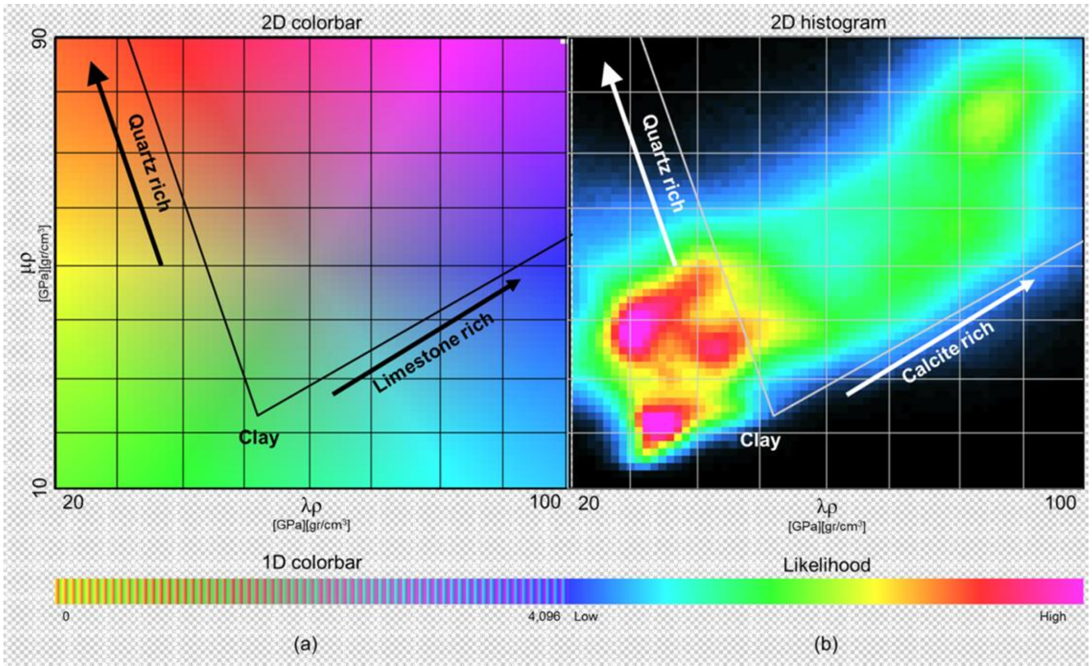


Figure 4. The same data as shown in Figures 2 and 3, but now adjusted to provide better dynamic range of the data.

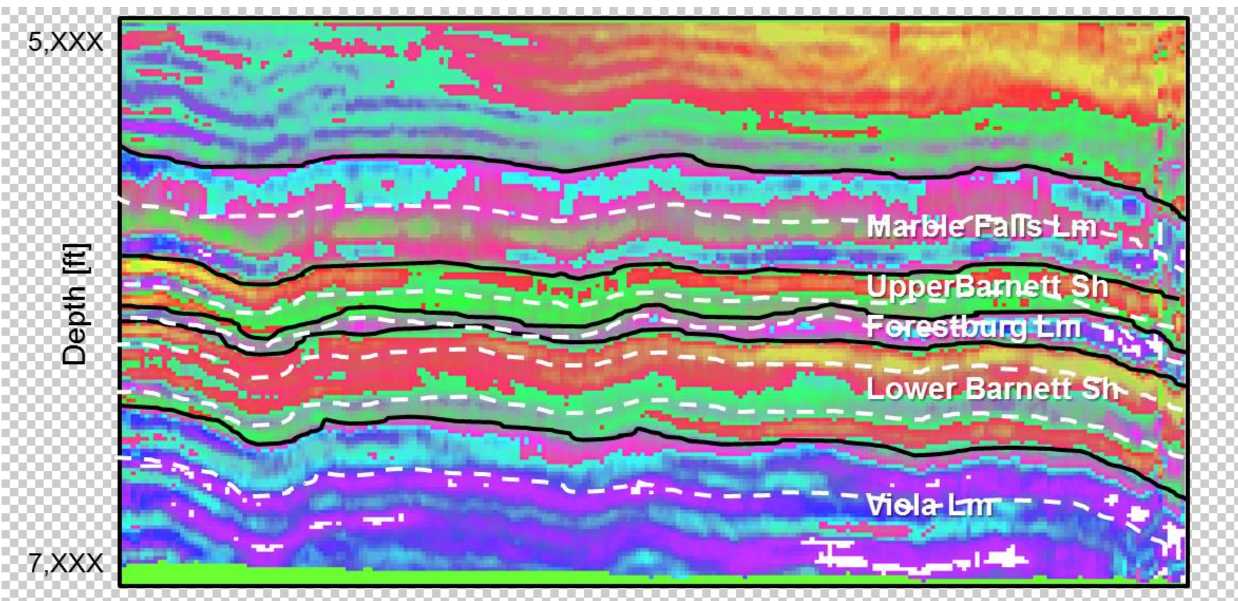


Figure 5. A vertical slice through the crossplotted volume. Quartz-rich facies appear as red and orange, clay -rich as green, and calcite-rich as cyan, blue, and purple. (After Perez, 2013).

Display tools: Programs **hlplot, hsplot, hlsplot**, **rgbplot and crossplot**

References

Perez, R., 2013, Brittleness estimation from seismic measurements in unconventional reservoirs: Application to the Barnett, Ph.D. dissertation, The University of Oklahoma.