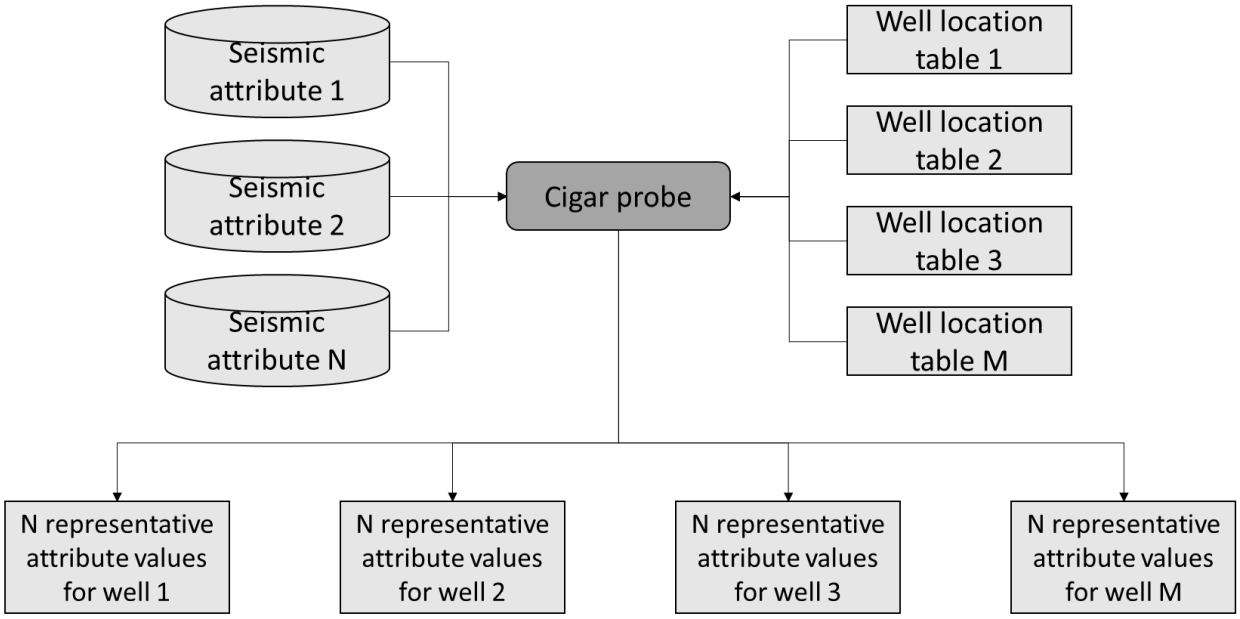
CORRELATING PRODUCTION OR INJECTION VOLUMES TO VOLUMETRIC ATTRIBUTES – PROGRAM cigar_probe

Contents

Computation flow chart

Program **cigar_probe** uses a suite of seismic amplitude volumes and a table containing the location and volume of fluid produced or injected at several wells. The output of the cigar probe is one representative value per well per attribute.



Attribute Correlation: Program **cigar_probe**

Given *N* seismic attribute volumes and *M* well location files (as detailed later in this documentation) **cigar_probe** will generate *N* statistically representative values of each attribute for each one of the *M* wells within the survey. To do so, the tool also requires two constraining surfaces between which the representative value will be computed.

Theory

cigar_probe assumes that each perforation acts as a point sink (for fluid production) or point source (for fluid injection). The Green's function of a point fluid source in a 3D homogeneous body is 1/R. Assuming a linear system, the production (or injection) volume from a well is a linear sum of that from each of the perforation locations.

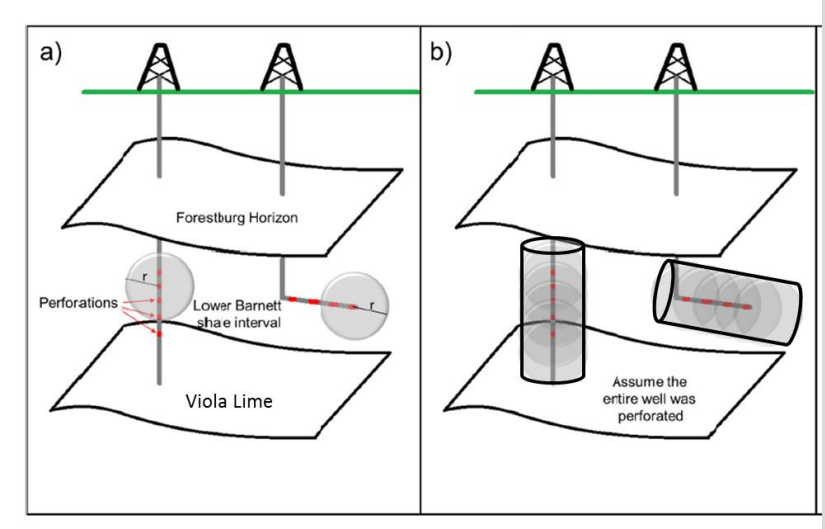


Figure 1. Illustration of the cigar probe. (a) A vertical and horizontal well in the Lower Barnett Shale with a single perforation whose impulse response, or Green's function is *1/R*. (b) For multiple perforations, the flow is simply the integration of multiple impulse responses giving the shape of a cigar. The impulse response is set to be zero outside the target formation in this example, corresponding to the upper and lower fracture barriers.

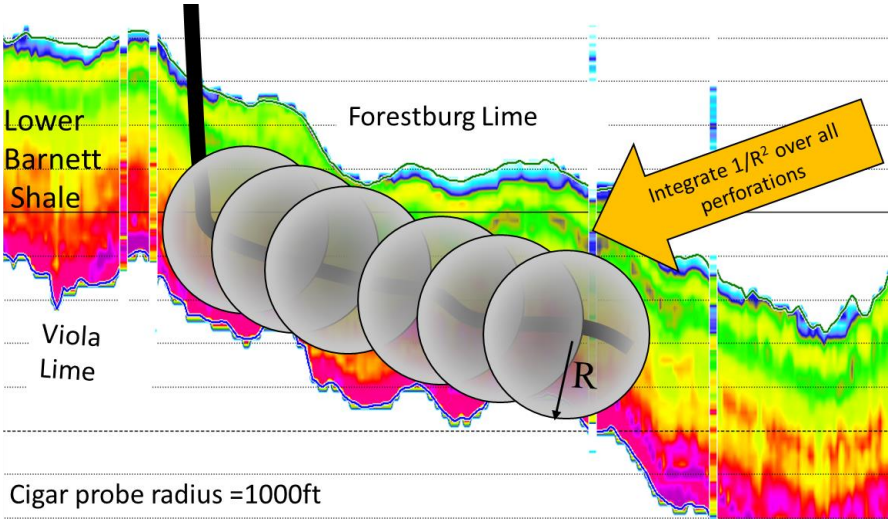
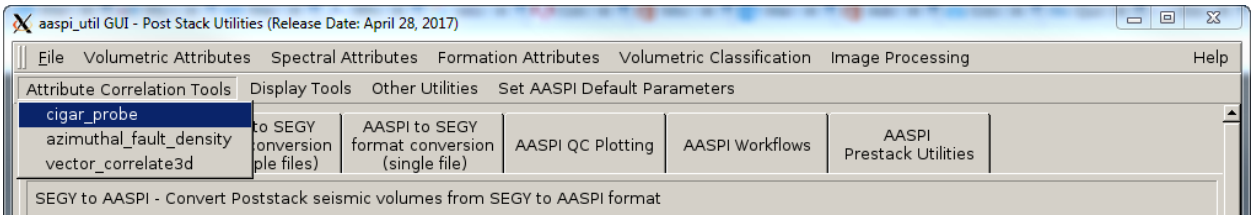


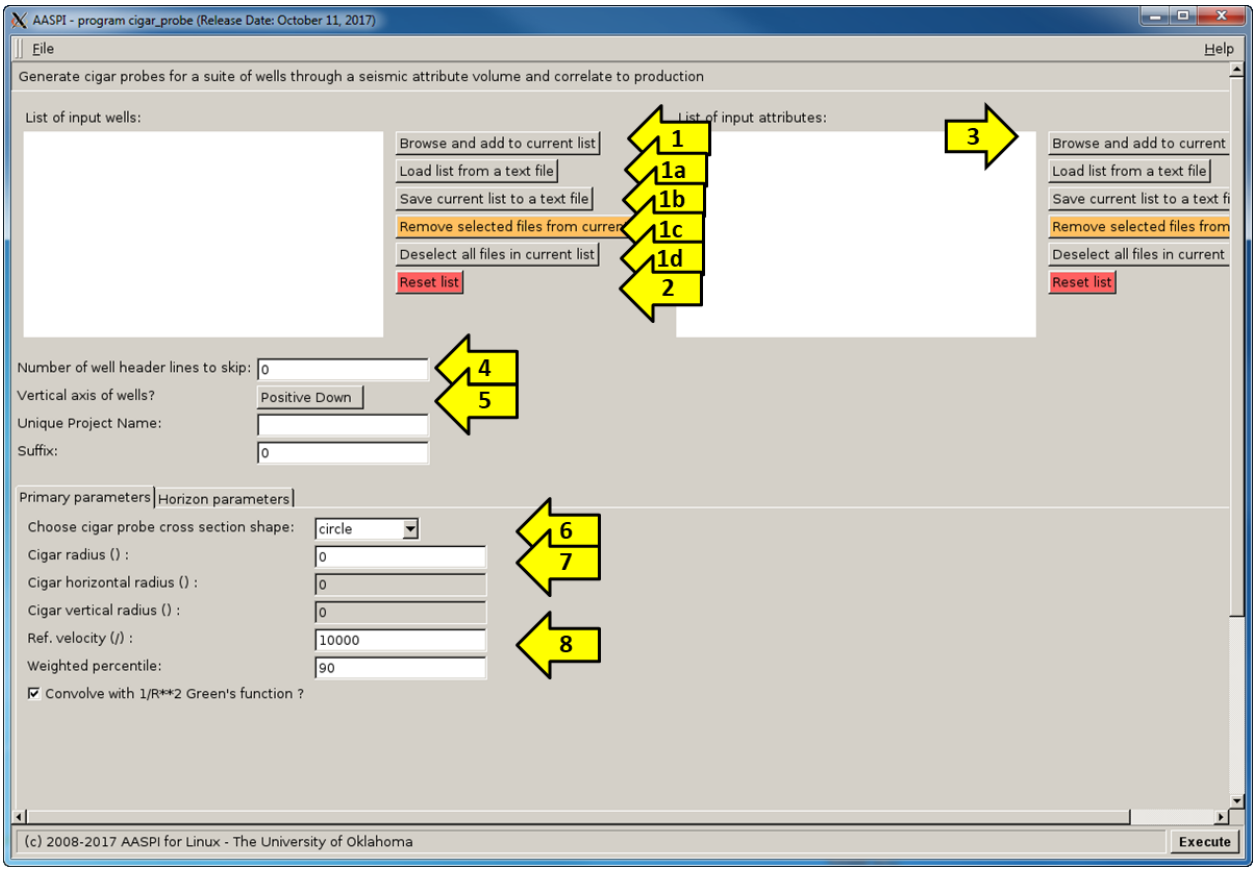
Figure 2. Another illustration for cigar probe through TOC volume (After Verma et al., 2016).

Parameter description

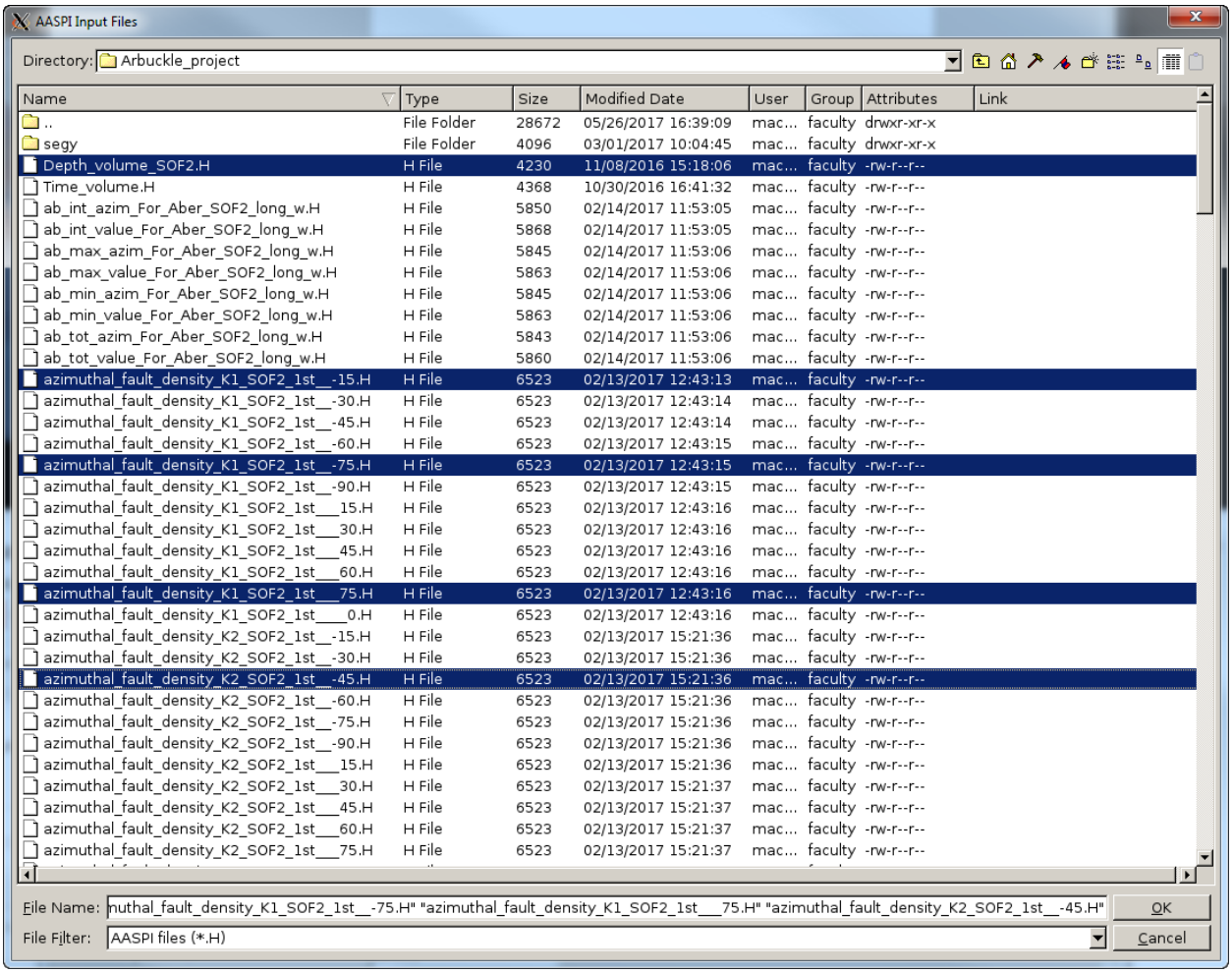
At the top of the **aaspi_util** GUI, click the "*Attribute Correlation Tools*" tab, and select **cigar_probe** on the drop-down menu:



The following GUI will appear (see next page):



Tabs (1) and (3) allow you to browse the current folder and select all the seismic attributes to correlate with production or injection parameters, along with the well paths for such operations. Multiple attributes may be selected. The format for well paths is discussed in the next section. You may also (1a) load a list to a text file or (1c) save a list to a text file.



Reset List (2) allows you to reset the list of input attributes in case a mistake was made in the selection process. The program is smart enough to recognize whether an attribute is selected twice; in this case, one of the duplicated attributes will be discarded. (4) Specifies the number of header lines to skip in the well files and (5) the positive orientation of the well depth. (6) Type of cigar probe cross section (ellipsoidal or circular). (7) Radius of influence for cigar probe. If the option for an ellipsoidal cross section is selected, the horizontal and vertical radius of the cigar will need to be specified.

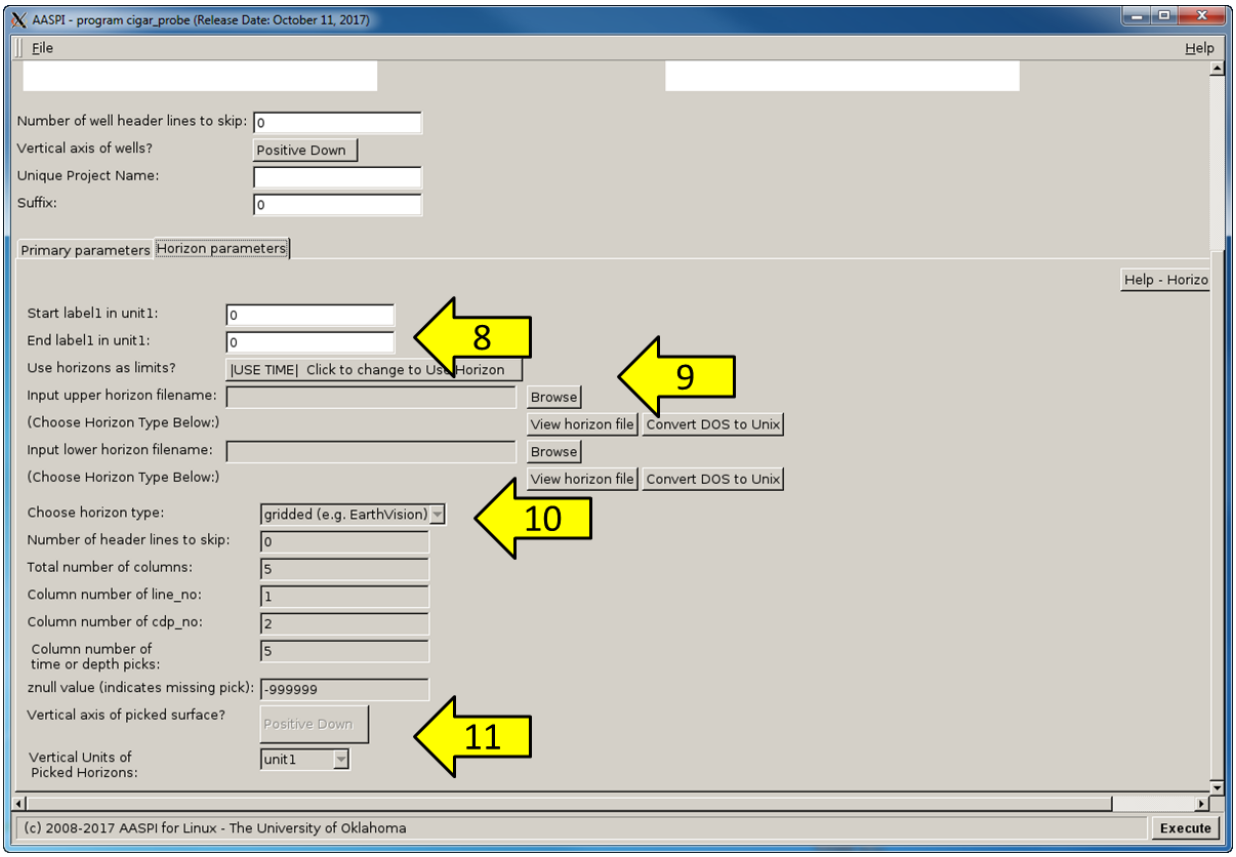
(8) This option is only available for time seismic volumes for vertical unit conversion purposes.

If the seismic is in depth units, the unit matching between the well and the seismic will be automatic.

If the seismic is in time units, the formula is as follow:

Vertical Unit Conversion Factor = 0.5*Reference Velocity (accounting for the two-way travel time of seismic rays).

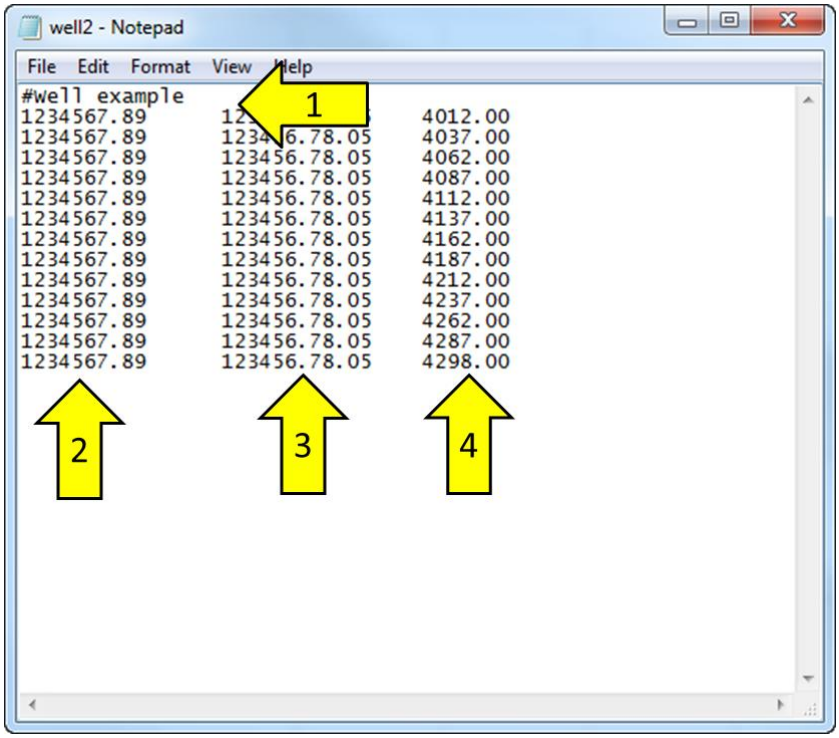
If both seismic and wells are in time, then we need to set the reference velocity to be 2x the vertical unit conversion factor. For example, if seismic data are in second and wells are in millisecond, then we need a vertical unit conversion factor of 1000 (1s = 1000 ms), and thus the reference velocity should be set to 2000.



On the Horizon parameter tab, (8) refers to time or depth slice constrains the user may want to impose for the limits of the cigar. The target top surface and the target bottom surface are selected in (9). (10) accounts for the format of the horizon file imported and (11) for the orientation of positive values in it.

Input well file format

The input file should be in following format



(1) Is for the well name and (2), (3) and (4) for the x, y and z coordinates of the well respectively. The z coordinates refer to the coordinate of points along the well path. By default, well's z axis is assumed to be in feet. However, if it's converted to time, please make sure to set the correct reference velocity mentioned in the "Primary Parameters" tab so that we can match seismic and well's vertical units.

Input surface format (earth-vision)

```
# Type: scattered data
# Version: 6
# Description: No description
# Format: free
# Field: 1 x
# Field: 2 y
# Field: 3 z feet
# Field: 4 column
# Field: 5 row
# Projection: Local Rectangular
# Units: feet
# End:
# Information from grid:
# Grid_size: 780 x 526
# Grid_space: 2019950.000000,2058900.000000,518750.00000
# Scattered data: Not_available
# Z_field: z
# Vertical_faults: Not_available
# History: No history
# Z_units: feet
2020400.000000 518800.000000 7016.443848 10 2
2020450.000000 518800.000000 7014.488281 11 2
2020500.000000 518800.000000 7015.145020 12 2
2020550.000000 518800.000000 7018.464844 13 2
2020600.000000 518800.000000 7018.161621 14 2
2020650.000000 518800.000000 7016.391602 15 2
2020700.000000 518800.000000 7015.364746 16 2
2020750.000000 518800.000000 7014.772461 17 2
```

Output files

The number of files generated by the program is the number of wells input plus 4. For example, if 5 wells are used for the cigar probe analysis, then 9 files are generated as output. The first N files (with N the number of wells) are all the extracted seismic values along the wellbore, and will look similar to the next figure. The explanation for the meaning of each column can be found within the file in the upper section.

cigar_statistics_weighted_percentile_test_0.txt | cigar_value_well_test_for_cigar.txt

```
# Column 1: Inline No.
# Column 2: Crossline No.
# Column 3: Vertical Sample No.
# Column 4: X Coordinate
# Column 5: Y Coordinate
# Column 6: Z Coordinate
# Column 7: Distance from current point to well path
# Column 8: Weight of current point in cigar statistical calculation (inversely proportional to the distance from current point to well path)
# Column 9: depth_volume
# Column 10: energy_ratio_similarity_depth_volume_Arbuckle
      1638      1360       212     2314800.00      397466.00     4738.048      396.444      0.1811936E-06     -0.2877334E+04      0.9954978E+00
      1638      1360       213     2314800.00      397466.00     4760.406      396.466      0.1429789E-06     -0.5833118E+04      0.9965609E+00
      1638      1360       214     2314800.00      397466.00     4782.764      396.505      0.1039102E-06      0.1056746E+04      0.9973944E+00
      1638      1360       215     2314800.00      397466.00     4805.123      396.562      0.6401115E-07      0.6331425E+04      0.9979280E+00
      1638      1360       216     2314800.00      397466.00     4827.480      396.635      0.2327306E-07      0.1959354E+04      0.9980052E+00
      1638      1360       217     2314800.00      397466.00     4849.838      396.561      0.3412051E-06     -0.2681192E+04      0.9975127E+00
      1638      1360       218     2314800.00      397466.00     4872.196      396.504      0.3068685E-06     -0.9755228E+03      0.9962043E+00
      1638      1360       219     2314800.00      397466.00     4894.554      396.465      0.2716474E-06      0.5294808E+02      0.9934805E+00
      1638      1360       220     2314800.00      397466.00     4916.912      396.444      0.2355496E-06     -0.1885390E+04      0.9883053E+00
      1638      1360       221     2314800.00      397466.00     4939.270      396.440      0.1985832E-06     -0.4977718E+03      0.9811493E+00
      1638      1360       222     2314800.00      397466.00     4961.628      396.453      0.1607582E-06      0.2281746E+04      0.9722609E+00
      1638      1360       223     2314800.00      397466.00     4983.986      396.485      0.1220806E-06      0.1604787E+03      0.9796135E+00
      1638      1360       224     2314800.00      397466.00     5006.344      396.534      0.8255938E-07     -0.2344542E+04      0.9812972E+00
      1638      1360       225     2314800.00      397466.00     5028.702      396.600      0.4220465E-07      0.3604128E+03      0.9803625E+00
      1638      1360       226     2314800.00      397466.00     5051.060      396.593      0.1031822E-08      0.2651979E+04      0.9785124E+00
      1638      1360       227     2314800.00      397466.00     5073.418      396.528      0.3228565E-06      0.4982486E+03      0.9780436E+00
      1638      1360       228     2314800.00      397466.00     5095.776      396.481      0.2880429E-06     -0.7226664E+03      0.9794598E+00
      1638      1360       229     2314800.00      397466.00     5118.134      396.451      0.2523493E-06      0.5152006E+03      0.9810932E+00
      1638      1360       230     2314800.00      397466.00     5140.492      396.439      0.2157913E-06     -0.4156162E+03      0.9811605E+00
      1638      1360       231     2314800.00      397466.00     5162.851      396.445      0.1783692E-06     -0.2331593E+04      0.9783596E+00
      1638      1360       232     2314800.00      397466.00     5185.208      396.468      0.1400840E-06     -0.1060132E+04      0.9751233E+00
      1638      1360       233     2314800.00      397466.00     5207.566      396.509      0.1009521E-06      0.9696045E+03      0.9747285E+00
      1638      1360       234     2314800.00      397466.00     5229.924      396.567      0.6098298E-07      0.6158895E+03      0.9747632E+00
      1638      1360       235     2314800.00      397466.00     5252.282      396.629      0.2018305E-07      0.1946801E+03      0.9770235E+00
      1638      1360       236     2314800.00      397466.00     5274.640      396.556      0.3386599E-06      0.8317620E+03      0.9834874E+00
      1638      1360       237     2314800.00      397466.00     5296.998      396.501      0.3042574E-06      0.7286709E+03      0.9874280E+00
```

The remaining four files will be corresponding to the statistical analysis performed for the correlations. The user can then use these results and find correlations using other software, like Microsoft Excel. The statistical results are as follows: weighted median; weighted average; weighted percentile and cross correlation.

statistics_weighted_percentile_test_0.txt | cigar_value_well_test_for_cigar.txt | cigar_statistics_weighted_average_test_0.txt

```
# Row 1: well file name = well2
# Row 2: well file name = well_test_for_cigar
# Column 1: attribute file name = depth_volume
# Column 2: attribute file name = energy_ratio_similarity_depth_volume_Arbuckle
       0.2043130E+03        0.9576283E+00
      -0.6092163E+02        0.9840460E+00
```

References

Verma, S., T. Zhao, K. J. Marfurt, and D. Devegowda, 2016, Estimation of total organic carbon and brittleness volume: Interpretation, **4**, T373-T385.