

CORRELATING PRODUCTION OR INJECTION VOLUMES TO VOLUMETRIC ATTRIBUTES – PROGRAM cigar_probe

Contents

Computation flow chart	. 1
Theory	. 2
Parameter description	. 3
Input well file format	. 6
Input surface format (earth-vision)	. 8
Output files	. 8
References	. 9

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.



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:

3	🖌 aaspi_util GUI - Post Stack Utiliti	es (Release Da	ate: April 28, 2017)							
	<u>F</u> ile Volumetric Attributes	Spectral	Attributes Formatio	on Attributes Vol	umetric Classification	Image Processing	Help			
	Attribute Correlation Tools Display Tools Other Utilities Set AASPI Default Parameters									
	cigar_probe azimuthal_fault_density vector_correlate3d	to SEGY onversion ple files)	AASPI to SEGY format conversion (single file)	AASPI QC Plottin	g AASPI Workflows	AASPI Prestack Utilities	<u> </u>			
	SEGY to AASPI - Convert Poststack seismic volumes from SEGY to AASPI format									

The following GUI will appear (see next page):

X AASPI - program cigar_probe (Release Date: October 11, 2017)	
]] <u>F</u> ile	Help
Generate cigar probes for a suite of wells through a seismic attribute volume and correlate to production	-
List of input wells: Browse and add to current list Load list from a text file Save current list to a text file Remove selected files from current Deselect all files in current list Reset list Vertical axis of wells? Unique Project Name: Suffix: 0	Browse and add to current Load list from a text file Save current list to a text fi Remove selected files from Deselect all files in current Reset list
Primary parameters Horizon parameters Choose cigar probe cross section shape: Cigar radius (): 0 Cigar horizontal radius (): 0 Cigar vertical radius (): 0 Ref. velocity (/): 10000 8 Weighted percentile: 90 V Convolve with 1/R**2 Green's function ?	
(c) 2008-2017 AASPI for Linux - The University of Oklahoma	Execute

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.

🗙 AASPI Input Files										×
Directory: 🔁 Arbuckle_project							💌 🖻 🛣	7.16	di 111 - 1	• 🕅 🖄
Name	7 Туре	Size	Modified Date	User	Group	Attributes	Link			
🛅	File Folder	28672	05/26/2017 16:39:09	mac	faculty	drwxr-xr-x				
🗀 segy	File Folder	4096	03/01/2017 10:04:45	mac	faculty	drwxr-xr-x				
Depth_volume_SOF2.H	H File	4230	11/08/2016 15:18:06	mac	faculty	-rw-rr				
Time_volume.H	H File	4368	10/30/2016 16:41:32	mac	faculty	-rw-rr				
ab_int_azim_For_Aber_SOF2_long_w.H	H File	5850	02/14/2017 11:53:05	mac	faculty	-rw-rr				
ab_int_value_For_Aber_SOF2_long_w.H	H File	5868	02/14/2017 11:53:05	mac	faculty	-rw-rr				
] ab_max_azim_For_Aber_SOF2_long_w.H	H File	5845	02/14/2017 11:53:06	mac	faculty	-rw-rr				
ab_max_value_For_Aber_SOF2_long_w.H	H File	5863	02/14/2017 11:53:06	mac	faculty	-rw-rr				
] ab_min_azim_For_Aber_SOF2_long_w.H	H File	5845	02/14/2017 11:53:06	mac	faculty	-rw-rr				
ab_min_value_For_Aber_SOF2_long_w.H	H File	5863	02/14/2017 11:53:06	mac	faculty	-rw-rr				
ab_tot_azim_For_Aber_SOF2_long_w.H	H File	5843	02/14/2017 11:53:06	mac	faculty	-rw-rr				
ab_tot_value_For_Aber_SOF2_long_w.H	H File	5860	02/14/2017 11:53:06	mac	faculty	-rw-rr				
azimuthal_fault_density_K1_SOF2_1st15.H	H File	6523	02/13/2017 12:43:13	mac	faculty	-rw-rr				
azimuthal_fault_density_K1_SOF2_1st30.H	H File	6523	02/13/2017 12:43:14	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st45.H	H File	6523	02/13/2017 12:43:14	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st60.H	H File	6523	02/13/2017 12:43:15	mac	faculty	-rw-rr				
azimuthal_fault_density_K1_SOF2_1st75.H	H File	6523	02/13/2017 12:43:15	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st90.H	H File	6523	02/13/2017 12:43:15	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st15.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st30.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st45.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
] azimuthal_fault_density_K1_SOF2_1st60.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
azimuthal_fault_density_K1_SOF2_1st75.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
azimuthal_fault_density_K1_SOF2_1st0.H	H File	6523	02/13/2017 12:43:16	mac	faculty	-rw-rr				
] azimuthal_fault_density_K2_SOF2_1st15.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
] azimuthal_fault_density_K2_SOF2_1st30.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st45.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
] azimuthal_fault_density_K2_SOF2_1st60.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
] azimuthal_fault_density_K2_SOF2_1st75.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st90.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st15.H	H File	6523	02/13/2017 15:21:36	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st30.H	H File	6523	02/13/2017 15:21:37	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st45.H	H File	6523	02/13/2017 15:21:37	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st60.H	H File	6523	02/13/2017 15:21:37	mac	faculty	-rw-rr				
azimuthal_fault_density_K2_SOF2_1st75.H	H File	6523	02/13/2017 15:21:37	mac	faculty	-rw-rr				-
• • • • • • • • • • • • • • • • • • •										
Eile Name: nuthal fault density K1 SOF2 1st -7	5.H" "azimuthal	fault den	sity K1 SOF2 1st 75.	H" "azin	nuthal fa	ult density	K2 SOF2	1st -45	5.H"	<u>0</u> K
File Filter: AASPI files (*.H)		-				_ /-			▼	ancel

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.

🗙 AASPI - program cigar_probe (Release Date: October 11, 2017)	
ji Eile	Help
	<u>ب</u>
the second se	
Number of well header lines to skip: 0	
Vertical axis of wells? Positive Down	
Unique Project Name:	
Suffix: 0	
ning and the Harizon parameters	
Primary parameters moneon parameters	<u></u> []
	Help - Horizo
Start label1 in unit1: 0	
End label1 in unit1: 0	
Use horizons as limits? USE TIME Click to change to Use Horizon	
Input upper horizon filename: Browse	
(Choose Horizon Type Below:) View horizon file Convert DOS to Unix	
Input lower horizon filename: Browse	
(Choose Horizon Type Below:) View horizon file Convert DOS to Unix	
Choose horizon type: gridded (e.g. Earth/vision)	
Number of header lines to skip:	
Total number of columns: 5	
Column number of line_no:	
Column number of cdp_no: 2	
Column number of 5 time or depth picks:	
znull value (indicates missing pick): -999999	
Vertical axis of picked surface? Positive Down	
Vertical Units of Picked Horizons:	
•	v
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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

well2 - Notepad			
File Edit Format	View Help		
#well example 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89 1234567.89	12 1234 6.78.05 123456.78.05 12366.78.05	4012.00 4037.00 4062.00 4112.00 4117.00 4162.00 4127.00 4227.00 4227.00 4287.00 4298.00 4298.00	
L			

(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)

```
1
    # Type: scattered data
 2
    # Version: 6
    # Description: No description
 3
    # Format: free
 4
 5
    # Field: 1 x
 6
    # Field: 2 y
    # Field: 3 z feet
 7
    # Field: 4 column
 8
 9
    # Field: 5 row
    # Projection: Local Rectangular
10
    # Units: feet
11
12
    # End:
    # Information from grid:
13
14
    # Grid size: 780 x 526
    # Grid space: 2019950.000000,2058900.000000,518750.00000
15
16
    # Scattered data: Not available
    # Z field: z
17
    # Vertical faults: Not available
18
19
    # History: No history
20
    # Z units: feet
    2020400.000000 518800.000000 7016.443848 10 2
21
    2020450.000000 518800.000000 7014.488281 11 2
22
    2020500.000000 518800.000000 7015.145020 12 2
23
    2020550.000000 518800.000000 7018.464844 13 2
24
25
    2020600.000000 518800.000000 7018.161621 14 2
26 2020650.000000 518800.000000 7016.391602 15 2
27
    2020700.000000 518800.000000 7015.364746 16 2
28 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.

😑 ciga	r_statistics	s_weighted	_percentile_test_0.txt	🗵 🔚 cigar_v	value_well_test_for_cigar.t	xt 🗵							
1	# Co:	lumn 1:	Inline No.										
2	# Co:	lumn 2:	Crossline No										
3	# Co:	lumn 3:	Vertical Sam	ple No.									
4	# Co:	lumn 4:	X Coordinate	•									
5	# Co:	lumn 5:	Y Coordinate	•									
6	# Co:	lumn 6:	Z Coordinate	2									
7	# Co:	lumn 7:	Distance fro	om current	point to well	path							
8	8 # Column 8: Weight of current point in cigar statistical calculation (inversely proportional to the distance from current point to well path)												
9	# Co:	lumn 9:	depth_volume	:									
10	# Co:	lumn 10	: energy_rati	o_similar	city_depth_volum	e_Arbuckle							
11		1638	1360	212	2314800.00	397466.00	4738.048	396.444	0.1811936E-06	-0.2877334E+04	0.9954978E+00		
12		1638	1360	213	2314800.00	397466.00	4760.406	396.466	0.1429789E-06	-0.5833118E+04	0.9965609E+00		
13		1638	1360	214	2314800.00	397466.00	4782.764	396.505	0.1039102E-06	0.1056746E+04	0.9973944E+00		
14		1638	1360	215	2314800.00	397466.00	4805.123	396.562	0.6401115E-07	0.6331425E+04	0.9979280E+00		
15		1638	1360	216	2314800.00	397466.00	4827.480	396.635	0.2327306E-07	0.1959354E+04	0.9980052E+00		
16		1638	1360	217	2314800.00	397466.00	4849.838	396.561	0.3412051E-06	-0.2681192E+04	0.9975127E+00		
17		1638	1360	218	2314800.00	397466.00	4872.196	396.504	0.3068685E-06	-0.9755228E+03	0.9962043E+00		
18		1638	1360	219	2314800.00	397466.00	4894.554	396.465	0.2716474E-06	0.5294808E+02	0.9934805E+00		
19		1638	1360	220	2314800.00	397466.00	4916.912	396.444	0.2355496E-06	-0.1885390E+04	0.9883053E+00		
20		1638	1360	221	2314800.00	397466.00	4939.270	396.440	0.1985832E-06	-0.4977718E+03	0.9811493E+00		
21		1638	1360	222	2314800.00	397466.00	4961.628	396.453	0.1607582E-06	0.2281746E+04	0.9722609E+00		
22		1638	1360	223	2314800.00	397466.00	4983.986	396.485	0.1220806E-06	0.1604787E+03	0.9796135E+00		
23		1638	1360	224	2314800.00	397466.00	5006.344	396.534	0.8255938E-07	-0.2344542E+04	0.9812972E+00		
24		1638	1360	225	2314800.00	397466.00	5028.702	396.600	0.4220465E-07	0.3604128E+03	0.9803625E+00		
25		1638	1360	226	2314800.00	397466.00	5051.060	396.593	0.1031822E-08	0.2651979E+04	0.9785124E+00		
26		1638	1360	227	2314800.00	397466.00	5073.418	396.528	0.3228565E-06	0.4982486E+03	0.9780436E+00		
27		1638	1360	228	2314800.00	397466.00	5095.776	396.481	0.2880429E-06	-0.7226664E+03	0.9794598E+00		
28		1638	1360	229	2314800.00	397466.00	5118.134	396.451	0.2523493E-06	0.5152006E+03	0.9810932E+00		
29		1638	1360	230	2314800.00	397466.00	5140.492	396.439	0.2157913E-06	-0.4156162E+03	0.9811605E+00		
30		1638	1360	231	2314800.00	397466.00	5162.851	396.445	0.1783692E-06	-0.2331593E+04	0.9783596E+00		
31		1638	1360	232	2314800.00	397466.00	5185.208	396.468	0.1400840E-06	-0.1060132E+04	0.9751233E+00		
32		1638	1360	233	2314800.00	397466.00	5207.566	396.509	0.1009521E-06	0.9696045E+03	0.9747285E+00		
33		1638	1360	234	2314800.00	397466.00	5229.924	396.567	0.6098298E-07	0.6158895E+03	0.9747632E+00		
34		1638	1360	235	2314800.00	397466.00	5252.282	396.629	0.2018305E-07	0.1946801E+03	0.9770235E+00		
35		1638	1360	236	2314800.00	397466.00	5274.640	396.556	0.3386599E-06	0.8317620E+03	0.9834874E+00		
36		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.

```
tatistics_weighted_percentile_test_0txt I cigar_value_well_test_for_cigar.txt I cigar_statistics_weighted_average_test_0.txt I cigar_statistics_cigar_statistics_weighted_average_test_0.txt I cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_statistics_cigar_s
```

References

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