

# Interactive Boulder Detection on 2D and 3D seismic datasets



#### **Motivation**

- Detecting boulders in subbottom sediments is critical for de-risking offshore wind farm installations and minimizing their costs.
- High-resolution (HR) and ultra-high-resolution (UHR) seismic is a suitable geophysical method. If the frequency content of the seismic source is fit for the task, the boulders appear on seismic cubes as diffracted events.
- The boulder detection method in RadExPro is based on the detection of diffracted events caused by boulders on seismic data.





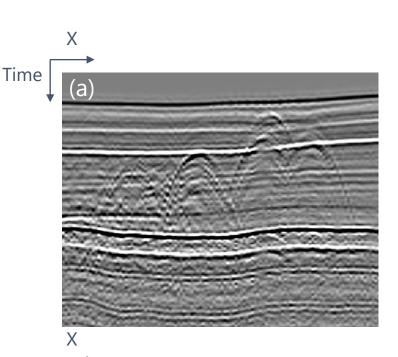
### **Our 3D boulder detection approach**

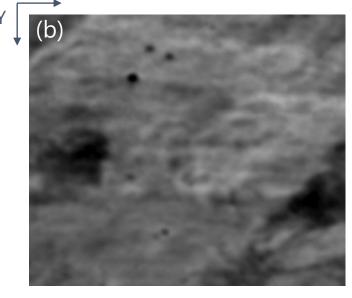


#### **Overview**

- On pre-migration stacked data, boulders appear as hyperbolic events (a).
- After migration, they are focused into local amplitude anomalies, which are particularly easy to notice on time slices (b).
- In RadExPro, we aim to interactively detect these post-migration amplitude anomalies by computing an attribute which highlights the anomalies and applying a threshold to this attribute.
- Our algorithm takes conventional migrated seismic cubes as input, however it can also process separately migrated diffractions, or even input semblance (Schwarz and Krawczyk, 2020) computed using the diffracted wavefield.
- Migration, diffraction images and semblance-like attributes can be computed by existing RadExPro tools.

Schwarz, B., & Krawczyk, C. M. (2020). Coherent diffraction imaging for enhanced fault and fracture network characterization. Solid Earth, 11(5), 1891-1907.

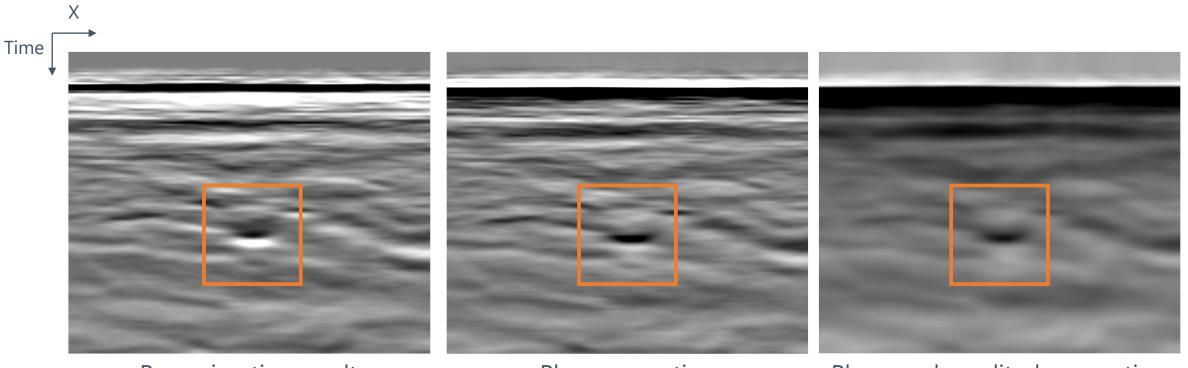






### **Diffraction waveform correction**

As the diffraction waveforms are asymmetric after a typical migration (Denisov, 2017), the module includes phase or phase-and-amplitude corrections of diffraction waveforms.



Raw migration result

Phase correction

Phase and amplitude correction

Denisov M.S. Seismic migration as a tool for true amplitude depth imaging of small objects // Seismic technology, 2017, (4). pp. 51–72. (in Russian)



#### Workflow



#### **Parameter window**

- 1. Input is a migrated seismic cube.
- 2. A suitable waveform correction is chosen ('no correction' is also an option).
- 3. Time limits allow one to run boulder detection only inside the interval of interest (e.g., target subbottom layers).
- 4. The attribute used for thresholding/classification of boulders can be computed internally by an image processing technique, or imported from external software (e.g., can be generated by AI, or diffraction imaging).
- 5. These are default values of interactively set parameters
- 6. Module scheme allows one to save the current work status, exit and return at any point in the future.

Input dataset 🛛 😯			훅	犎	
Correction of input waveform	Phase-only diffraction waveform co	prrection	$\sim$		ľ
Time limits, [ms]	0.0	— 0.0			
Dataset for the boulder detection attribute (positive)			루	₫	
Dataset for the boulder detection attribute (negative)			속	≢	
Attribute computation (defaults)					1
Boulder radius, [m]	2.0				
Attribute (positive) threshold	0.9				
Attribute (negative) threshold	0.9				
Boulder shape filtering (defaults)					6
Aspect ratio	1.0	— 3.0			
🗹 Horizontal size, major axis, [m]	1.0	— 100.0			
Size along time, [ms]	0.2	— 20.0			
Number of 3D cells in a boulder	10	— 400			
Number of 2D cells in a boulder's projection onto the surface	1	— 30			
Module scheme			Object	犎	

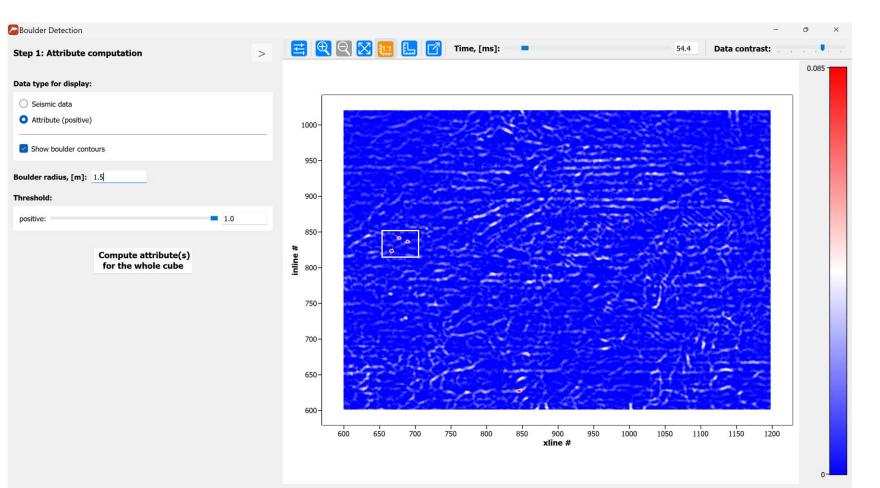


- The module window contains a display of the current time slice (example boulders are highlighted with a white box) and boulder detection parameters.
- First, the user generates an attribute highlighting the boulders, which is then used for thresholding.

Boulder Detection	- 0 X
Step 1: Attribute computation >	🔁 🕄 🔀 🛄 🛄 🗹 Time, [ms]: 🕒 54.4 Data contrast:
Data type for display:	0.17 -
O Seismic data	
Attribute (positive)	1000-
Show boulder contours	950-
Boulder radius, [m]: 2.0	
Fhreshold:	900-
positive: <u>1.0</u>	850-
Compute attribute(s) for the whole cube	* 800- 5 800-
	750-
	700-
	the second se
	650-
	600-
	600 650 700 750 800 850 900 950 1000 1050 1100 1150 1200
	xline #
	-0.17



- The attribute is computed by an image processing technique which highlights objects of a defined size on images.
- One can also import an externally generated attribute.
- One can observe that the boulders have the highest amplitudes on the attribute image.





- With the attribute computed or imported, one can apply a threshold to it.
- The samples with values above the threshold are considered as boulders.

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Seismic data		
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reshold:	900-	
ositive: 0.31	and the second	
	850-	10000
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	650-	To the
	600-	
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		-0.17
		-0.1/-



### Step 2 – Filter and output

Following the thresholding, one switches to step two of the workflow.

- A 3D labeling algorithm numbers all the boulders and computes their spatial properties.
- These properties can then be used to filter out the boulder candidates which do not fit the a priori constraints on the boulder shape.
- Manual editing can also be performed at this stage.
- Finally, the deliverables are exported.

Boulder Detection Step 2: Boulder labeling/filte	ring		<	₫ 🗨	9 🔀	🛄 🕂 🕅	9 9		Time	, [ms]:				54.4	
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<ul> <li>Seismic data</li> </ul>				τ											ľ
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Show boulder contours					600				200				32.	8	
				950-	1						1000		1.1		
Boulder filtering by shape:	1.0	- 2.5	2		1000		2 miles			• •	23				
Horizontal size, major axis, [m]	1.0	- 100.0	2	900-	and a	100	-			1.1.	*		- 11		
Size along time, [ms]	0.02	- 20.0	2	850-				192			A	8			
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Number of 2D cells in a boulder's projection onto the surface	2	- 40	2	inline #	-	100		-			368				
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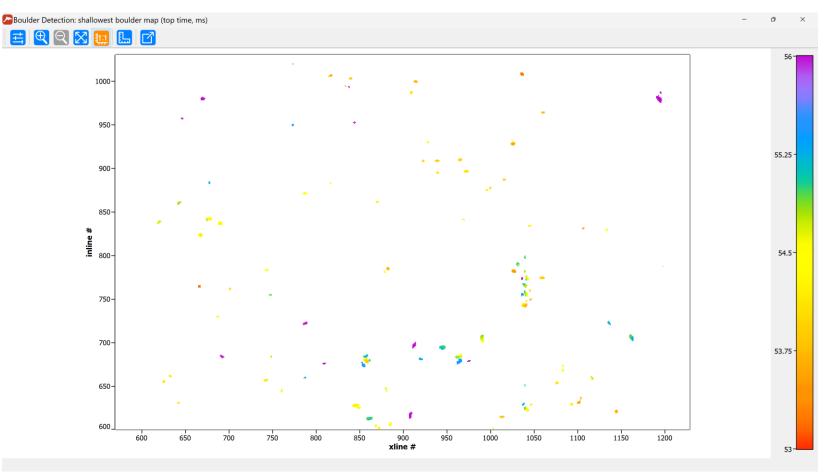


#### Deliverables



#### Boulder map – 3D

As a result, the user obtains a boulder map, where each sample on the surface is colored according to the two-way traveltime to the top of the shallowest boulder at that location.





#### **Boulder table – 3D**

The main deliverable of the module is the boulder table, which contains the locations and properties of all the identified boulders.

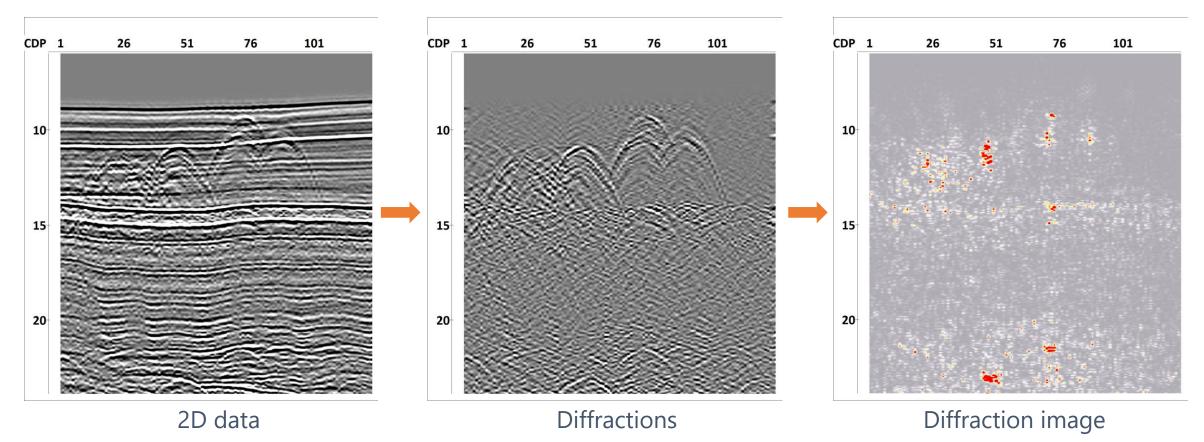
centroid-x-(m)	centroid-y-(m)	centroid-TWT-(ms)	top-TWT-(ms)	bot-TWT-(ms)	TWT-span-(ms)	major-axis-(m)	minor-axis-(m)	aspect-ratio
376.66667	373.72222	54.95	54.9	55.0	0.1	1.65831	0.8165	2.03101
503.23333	518.23333	53.3	53.2	53.4	0.2	2.0702	1.5353	1.3484
390.22881	513.49153	53.65	53.4	53.9	0.5	2.40001	1.72914	1.38798
336.3	431.2	55.15	55.1	55.2	0.1	0.86603	0.86603	1.0
444.1	337.9	55.05	55.0	55.1	0.1	1.5	0.61237	2.44949
327.88462	549.30769	53.55	53.5	53.6	0.1	1.80463	1.57241	1.14769
414.77778	553.16667	53.55	53.5	53.6	0.1	1.73205	0.70711	2.44949
341.46	428.38	55.2	55.1	55.3	0.2	3.33691	1.36906	2.43738
309.75	572.38636	53.7	53.6	53.8	0.2	1.82248	1.78429	1.02141



### **2D modification**

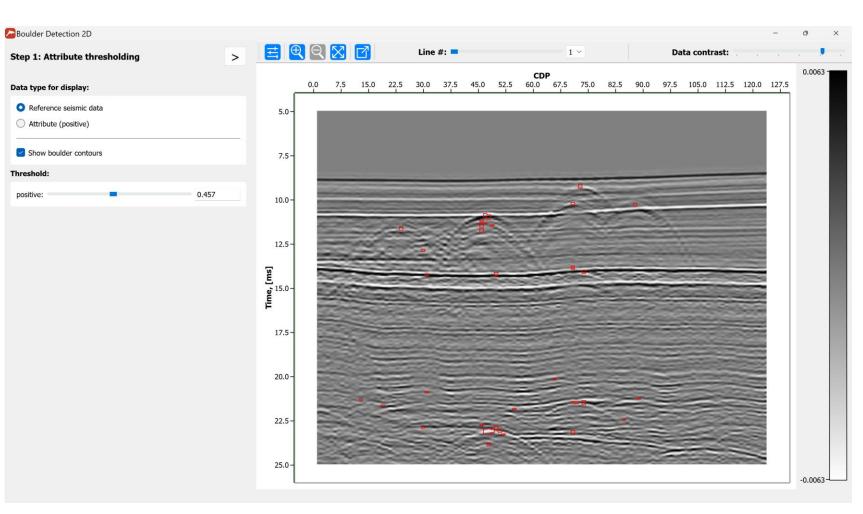


- In 2D, the attribute for boulder detection is computed by diffraction imaging using the capabilities of RadExPro.
- The diffractions are extracted using dip filtering and are then migrated to obtain a diffraction image.





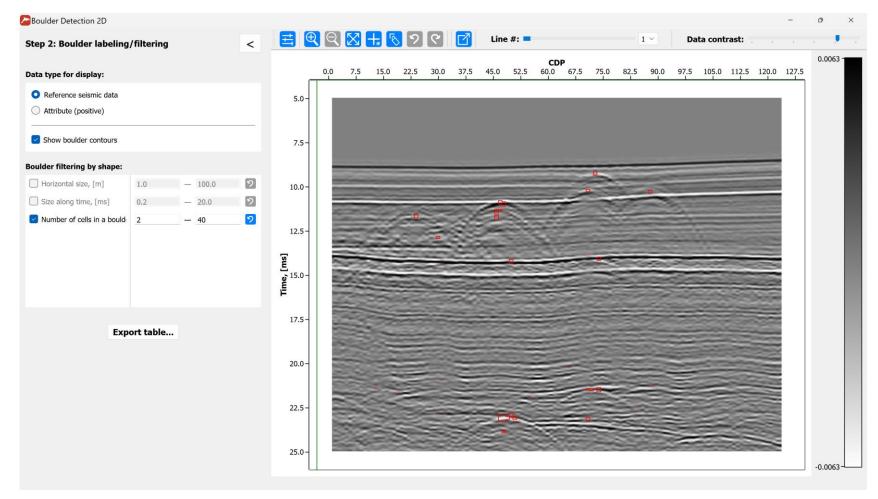
- The obtained diffraction image is input to the interactive module for thresholding.
- In the image on the right, the original dataset is displayed, and the diffraction image is used for thresholding in the background.
- The thresholding is applied exactly like in 3D.





### Step 2 – Filter and output

 Similar to 3D, the user can filter out false positives using a set of filters and output the deliverable – a list of boulders.





#### **Boulder table – 2D**

The main deliverable of the module is the boulder table, which contains the locations and properties of all the identified boulders.

line-number	centroid-CDP-number	centroid-x-(m)	centroid-y-(m)	horizontal-size-(m)	centroid-TWT-(ms)	top-TWT-(ms)	bot-TWT-(ms)	TWT-span-(ms)
1	73	129.2	100.0	0.2	9.2295	9.1035	9.3555	0.252
1	71	128.4	100.0	0.2	10.1745	10.1115	10.2375	0.126
1	71	128.4	100.0	0.2	10.395	10.3005	10.4895	0.189
1	88	135.2	100.0	0.2	10.4895	10.4265	10.5525	0.126
1	47	118.97778	100.0	0.4	10.962	10.8045	11.1195	0.315
1	46	118.4	100.0	0.2	11.403	11.3085	11.4975	0.189
1	24	109.6	100.0	0.2	11.718	11.4975	11.9385	0.441
1	48	119.44	100.0	0.4	11.6865	11.5605	11.8125	0.252
1	74	129.6	100.0	0.2	14.112	14.0175	14.2065	0.189
1	73	129.2	100.0	0.8	21.546	21.5145	21.5775	0.063





#### THANK YOU FOR YOUR ATTENTION!

#### CONTACTS:

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