

# Shadow imaging: attenuation tomography without arrival picking for physical model data from a circular array **David C. Henley**

### ABSTRACT

The CREWES physical modeling system is very versatile, in that it can be used for modeling a large variety of situations, not only for earth imaging, but also for medical and/or engineering applications. Recently, the system has been used to explore the use of circular arrays of transducers immersed in a fluid, to locate and image objects included within the transducer aperture. The first phase of the study uses first arrival waveforms and attempts to use them to provide a low-order estimate of shape and location of objects within the circular aperture. We demonstrate two potential methods, one of which uses anomalous time picks of the arrival wavelets to create 'artificial shadows' of objects, the other of which estimates the attenuation of acoustic energy along each raypath and creates 'attenuation shadows' of the objects. In either case, the shadows are properly oriented in image space and stacked to provide a 'shadow image' of objects within the circular aperture.

### THE EXPERIMENT

Figure 1a shows the geometry used for the physical modeling, with coincident rings of source and receiver positions, while Figure 1b shows the possible raypaths for acoustic transmission, except for apparatus interference.



FIG. 1. a). The concentric transducer arrays for the experiment—72 receiver positions (blue), and 35 source positions (red). b). Possible transmission raypaths for the experiment (about 50% are not allowed because of mechanical equipment constraints.

Figure 2 shows a group of 5 source gathers from a complete survey with an unknown object inside the circular acquisition aperture.

	SOURC	E															
	OFFSET	. 6			7			8				9				10	
	100		2217 262	▶736.0061	1002.95	2676 500	7/12 6222	1905 005	2002 105	100	1950 159	2262 161	2925.218 229	0 6201	1964 022	2275 1	06 20
•	190	1327.83	2317.303	730.0001	1002.35	20/0.009	142.0332	1095.005	2033.105	i ye	1358.135	2303.101	2323.210 223	3.030	1364.023	23/3.10	06 29
0	- अल्ल	mana	REEPINE	<u>ਬਹਾਲ</u> ਾਲ		११३६२१२२	≥unonn	TERENTER	man	सः अग	333777357		manaan	JIEM	10101	121(13)	mm
	利	INUUIII		劉川川			•	<u></u>	•	CT (255.()		)		SUCH	21000		
			ener in the	得建派	ter bir	ect ar	rivals	355 D	irect a	rrivals	5 (公)	Direc	t arrival	S	4X83	10888	8358
	336	进闭济		初月二十	रविकास	( SEAL	100240	5777838	(0KS8)	en son	EH KUT	)KSR833		राधव्ये	¥1580	R.K.K	
	<u>B</u> <u>Ø</u> ]	营长	BUR B	御唐			ジンで開き	482638		84 (RØ)	間上的	EN ED	662622	35318	氢18/8	18816	8889
1	त्रीष्टि		Riderst	<b>新制度</b>			初期目前	<b>基份於於</b> 登	$\mathbf{X}_{\{i\}}$	};; <del>;</del> ;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;	们是出	33 <b>X</b> {	REED	派赵	<b>透</b> 液	( <u>)</u> }{?	8333
-	188	川に開	1111111	<b>HUNHIN</b>	E K	NUQ:	362431	產出出	RUERA	KK 1953	的問題	56355	हाइसाएट्र	1818	以限	NA SE	<b>MSP</b>
	1 H FL		部沿街	MARKED A			322033	《唐朝》	ID RA	33) (R)	の消毒	9(9)33	2040434	1855	<))č78	払わり	8288
S	<u> </u>	08(13)/	國和 383	<b>HATTER</b>		NIN B	KARC	公司管理	ini aki s	<u>]]]                                  </u>	<u>KURNAR</u>	是以出的	15165285	<u>8288</u>	SXIII)	尼当区	41)83
Sec		8951332		883555			1121111	KILIG	EXUNC	K) XQ.	2111(18)	1162/	282332R	3338		が後	8888
	- 3間		別語語		123115717	2651送	21223	952KC?	nnessi	381 Y K	1001111	i de la Colora de la Colora de la Colora de	SILLING		2023	GHK8	5517
2—	- <u></u>	1461134	BREDE	<u>ş(!)(18</u>	121611	1	<u></u>	<u> 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997</u>	$\mathbf{x}$	料意用	ARREN A		83000	到開任	REAL	2218	<u>ikis</u>
			RIFER		NAKE.		(新聞) (1)	1199110	R) 83 (S)	测器		83 <b>1</b> 833	KUBRAD	美語	211113	99200	6425
							HIIT		RESO	28 1111		Karri	renera	111/11	下学业	114214	
				<del>}}}}</del>		KUDSH	- Here Here Here Here Here Here Here Her		REPERTING REPORT	<del>35) 2123</del>	SHALLESS	6(1)经时)		-19959	516 F	義的符	2208
				AUUS.	Dim zo	ne 🐉	新的訊	Dim zo	one 🗄	11 444	5. Dim	zone	SHORE	5303	RUSI	川香	2011
2	253		相關的群	STREET,	0188035	509930	- ALEXAN	31/1/10	n an	新到到	Romme	RUMAR	<u>200000</u>	636	112614	KERD	
3 —	128	REAL	HR (Th)	1888 M		3037	<b>BEAR</b>	<del>\$200.5000</del>	TRACE OF		HARRES .	<u> 22200</u>	HI BRAD		हित्सर	1885 F	<u> SR</u>
	一般的		ister i de la compañía de la	181116		1188	济松们	2568	836383	46 YAN	8493(3)	USSIN	9 KKKK	第四	QQ	18518	10125
	彩机	1){{}}	REALE	引导机		KRABK		<u>ÓMRR</u> E	1821821	) 같은 것 같은	266883	(K&)&K	KIESER	ni so	1311A	19982	6824
	ISB	131111535	TUNKIN	1188890	11253	SHEET)	HINKIN	RECEIPTE	2012000	KK IDD	11:3:8:15	188355	1332387	JUNU	13,03,00	1838	2832
	301			JUNE .		REED	深刻形	<u> </u>	1108833	新之路的	和因为务	528328	RECENT	1111	到均常	18110	NXX 3
4	<u>28</u>	S FERRI		加到北		2(6)8	如那出	254 KIR	WARKS.	27 1990		HUKSSS	KSKNISS	12511	133.800	RISS	(3)(3)
	11223	BREAD	TURAL CONT	THREE		N. ST. C. F. F.	SERECCERS	erress (Tr	restruct	tels and	en cinsula	1227 LOVI	DIFFERENCE	ELENIN	RUSKI	11.11.171	C EXE

FIG. 2. Five source gathers from a complete survey with an unknown object inside the circular acquisition array. Note the prominent 'dim zones' in the first arrival trains that denote energy absorbed by an object between source and receiver transducers.





**UNIVERSITY OF CALGARY** FACULTY OF SCIENCE Department of Geoscience

### PROCESSING



To remove the effects of acquisition geometry, we align all the direct arrivals by applying a 'water' static shift to each trace corresponding to the transit time for acoustic energy along the particular raypath corresponding to the trace, assuming a known water velocity. We refine the alignment using trim statics computed using the entire acquisition set of traces as the learning set. Trace amplitudes are scaled for spherical spreading, using the corresponding raypath lengths, and the traces are deconvolved to equalize amplitudes and phases of the arrivals. Figure 3 shows a group of 3 source gathers after these operations.



FIG. 3. Three source gathers after being aligned with water statics and trim statics, scaled for spherical spreading, and deconvolved. Note that the dim zones are easily seen in these arrivals.

### 1). Artificial shadows from dim zones

In our first attempt at shadow imaging, we examined all 35 source gathers, like those shown in Figure 3, and flagged the edges of the dim zones (requiring arrival picking). Sample values within these zones were set to a constant, while samples outside were zeroed, as in Figure 4.



FIG. 4. Five source gathers showing artificial shadows within the dim zones flagged on the processed and aligned direct arrivals. The gathers in Figure 4 show shadows as a function of source-receiver azimuth. These shadow gathers are tilted and rotated, then stacked, as in Figure 5.



FIG. 5. Trial stack of artificial shadows from dim zones on direct arrivals. Dimensions are unresolved.

2). Shadows from trace attenuation Instead of trying to detect the edges of shadows on aligned direct arrival source gathers, which requires direct arrival picks, we also explored a method in which wavelet magnitude, derived from an envelope function, becomes an analog for inverse energy attenuation, or 'shadow intensity'. Figure 6 shows the reciprocal envelope magnitude (smoothed perigram), normalized by the trace envelope maximum in the vicinity of the direct arrival, for 5 source gathers.



FIG. 6. Normalized reciprocal of smoothed envelope magnitude for 5 source gathers, as a function of source-receiver azimuth. Figure 7 shows all 35 source gathers after conversion to angular beam gathers as a function of offset and depth, then rotated and positioned around an image aperture corresponding to the circular acquisition aperture.



FIG. 7. All 35 source gathers converted to angular beam gathers via the inverse radial trace (RT) transform. The gathers are then positioned around the circumference of an image circle, rotated according to their source position and offset. Header plots show corrections applied as statics to the traces in the gathers.

When the source shadow gathers have been transformed to angular beam gathers, positioned around an image circle, and rotated and otherwise corrected, they may be stacked over image coordinates, as shown in Figure 8.



Trial stack of attenuation shadows

FIG. 8. Stack of attenuation intensity shadows, over image coordinates, of the rotated and adjusted beam gathers in Figure 7. Comparison

## Figures 5 and 7 are not actually comparable because of the attributes they image, but they are 'suggestively similar'.



<i>y</i> `	100	AMP1						
.02924 	23.22636	9 48.13913	73.1078 -4.2	13.91404	10 38.45275	63.24352	88.061<	
								Time (ms)