Seismic Noise Test: Bayou Corne, LA, USA

A Report from

Louisiana State University, Baton Rouge

to

Louisiana Department of Natural Resources

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Date: October 24, 2012

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Introduction

In the vicinity of Bayou Corne, Assumption Parish, Louisiana low-intensity earthquakes (Figure 1), many probably unfelt, during the month of June and July culminated on August 3, 2012 in the formation of a small lake about 100 m in diameter (Horton and Leith, 2012) During this activity, unusual amounts of natural thermogenic gas (Philp, 2012) were observed escaping from local bodies of water and it is suspected that much gas remains trapped at depth within sands of the local aquifer.

The shallowest portions of the Mississippi Alluvial Aquifer (~ 100') are now likely locations for free gas. At these shallow depths, free gas is expected migrate to the higher portion of the most porous sandy units. We conducted seismic noise tests at Bayou Corne, Louisiana to show that the near-surface sediment bodies may be mapped using shear-wave seismic techniques.

In particular, shear-wave seismic methods which detect contrasts in density and shear modulus between sedimentary layers have greater resolution than the faster pure acoustic waves. Other sediment properties such as porosity, permeability or gas content are normally inferred by passing seismic lines over wells where these properties have been measured independently.

Seismic Methods

Over a two-day period (Sept. 22 and 23) we collected both vertical-component (40-Hz) and horizontal-component (4.5 Hz and 30 Hz) seismic data using conventional hammer-and-plate seismic sources to generate vertical-component seismic arrivals (P and SV) and SH waves.   One site (Site 1) is located west of Bayou Corne (Triche property) and another east of Bayou Corne, north of the sinkhole and immediately north of route 70 (Site 2).   At both sites we employed a pseudo-walkaway acquisition geometry with a maximum source-receiver offset of 192 m. (Table 1). Data collected with 4.5 Hz and 30 Hz geophones proved nearly identical for the purpose of this study.

Table 1.

Seismic source	Seismic sensor	Target signal type
Hammer and plate	40-Hz vertical-component	Seismic ground roll and refraction
I-beam and hammer	30-Hz horizontal-component sensor	Shear waves: refraction, reflection and surface waves
I-beam and hammer	4.5 Hz horizontal-component	Shear waves: refraction, reflection and surface waves

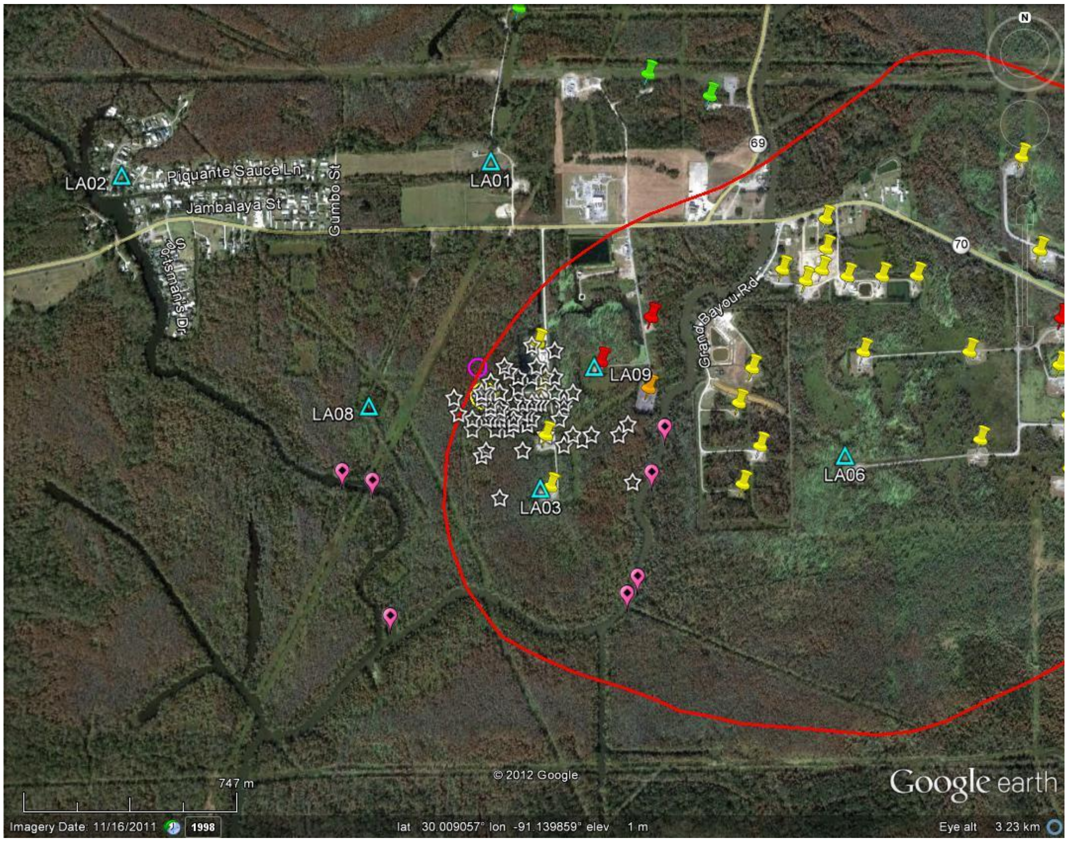


Figure 1 Earthquakes epicenters (white stars) between 7/24 and 8/02. The red pins are location of LPG storage cavity, orange pins are locations of gas storage cavities, yellow pins are location of brine cavity, and green pins are salt water disposal wells. The sinkhole is located at the magenta-colored circle, with the Geiser#3 cavity just to the south of it (yellow circle beneath earthquake symbols). (From Horton and Leith, 2012)

Seismic Processing and Analysis

Because amplitude-versus-offset information in reflected signals may contain valuable information of gas content at depth we carefully frequency band-pass and gain the data before displaying and interpreting the data. In all plots shown in both Appendices (A&B) and in the main text (Figure 3), only standard seismic SEGY-format changes were made on the headers that incorporated field geometry.

Data display at least 2 key seismic reflector- and refractor-events (Figure 2) whose shape we attempt to best-match by forward-tracing rays (Cerveny, 2001) through a simple, one-dimensional velocity-depth model that uses either constant-velocity and gradient-velocity layers. In other words, both refraction events as well as reflection events were incorporated into each velocity-depth model. Velocity-depth models (estimated errors of 2-10%) are developed for V_P (sound velocity) and V_S (horizontal-shear-wave velocity) versus depth at Site 1 (Figure 4) and Site 2 (Figure 5). Conventional semblance velocity analysis (Taner and Kohler, 1969) help verify velocity trends by estimating interval velocity values from all reflection events (Figures 4A, 5A and Appendices B and C).

Figure 2 Location of seismic noise tests. Site 1 lies on the Triche property immediately west and south of Bayou Corne, Site 2, north of route 70 and west of Bayou Corne lies on the Dugas-Le Blanc property.

In the compressional-wave data (P waves or sound data) we can interpret only one possible and extremely shallow reflector ("WT", Figures 4B and 5B) but no other reflectors that correspond to the prominent reflectors seen in the shear-wave data. In similar alluvial organic-rich facies, shallow P-wave reflections are not well developed (Lorenzo et al., 2006)

Results and Recommendations:

Shear-wave data indicate the tops of two prominent reflector boundaries. These key reflectors were selected because they are the most notable events—they are high-amplitude, laterally continuous events and overlap refracted arrivals. The shallower boundary (“A”) lies at 7-10 m below the surface and the deeper boundary (“B”) at ~40-50 m below the land surface. Reflector B emanates at a shallower depth (~42 m) east of Bayou Corne than west of Bayou Corne (~47 m).

Structure contour maps show that the top of aquifer sands (DNR, 2012) lie at 34 m below sea level. As such, reflector B appears to lie deeper than the top of the aquifer sands by ~10 m, after adjusting for land elevation of ~2 m above sea level at Bayou Corne. Seismic data (Figures 3) show other candidate reflectors that may correlate to the top of the aquifer but these are not as prominent but may extend laterally for tens of meters beneath the surface. Corresponding compressional-wave reflectors are not seen in the data because organic-rich sediments within these alluvial facies possibly small amounts of gas or air (<2%) which highly sound waves. In contrast, shear-waves are far less sensitive to the presence of biogenic gas can and do highlight sediment interfaces of varying strengths and density contrasts.

The results of these noise tests show that buried alluvial sand and clay layers produce prominent reflectors at depths as shallow as 10 m and are seismically detectable using S-wave techniques. Using standard continuous reflection seismic profiling (CMP method) these reflector bodies have a great potential for generating seismic cross-sections of the shallow earth structure at depths between 10 and 40 m and deeper. As with standard practice in the oil and gas industry, continuous seismic images are very useful for extrapolating geological information between logged and tested wells.

Figure 3. Shear wave data (Dugas-Le Blanc property; Site 2) show strong reflector (A) at ~10 m depth (shallow/earlier arrow) and another (B) at ~42 m depth (later arrow). Refracted arrivals and Love waves appear as "linear" events across the pseudo-array. Reflectors display a strong hyperbolic shape from close to far distances. Data are displayed at a constant rms amplitude and using an "all-pass" filter. Maximum source-receiver offset is 192 m. Data were collected using 4.5 Hz horizontal-component geophones.

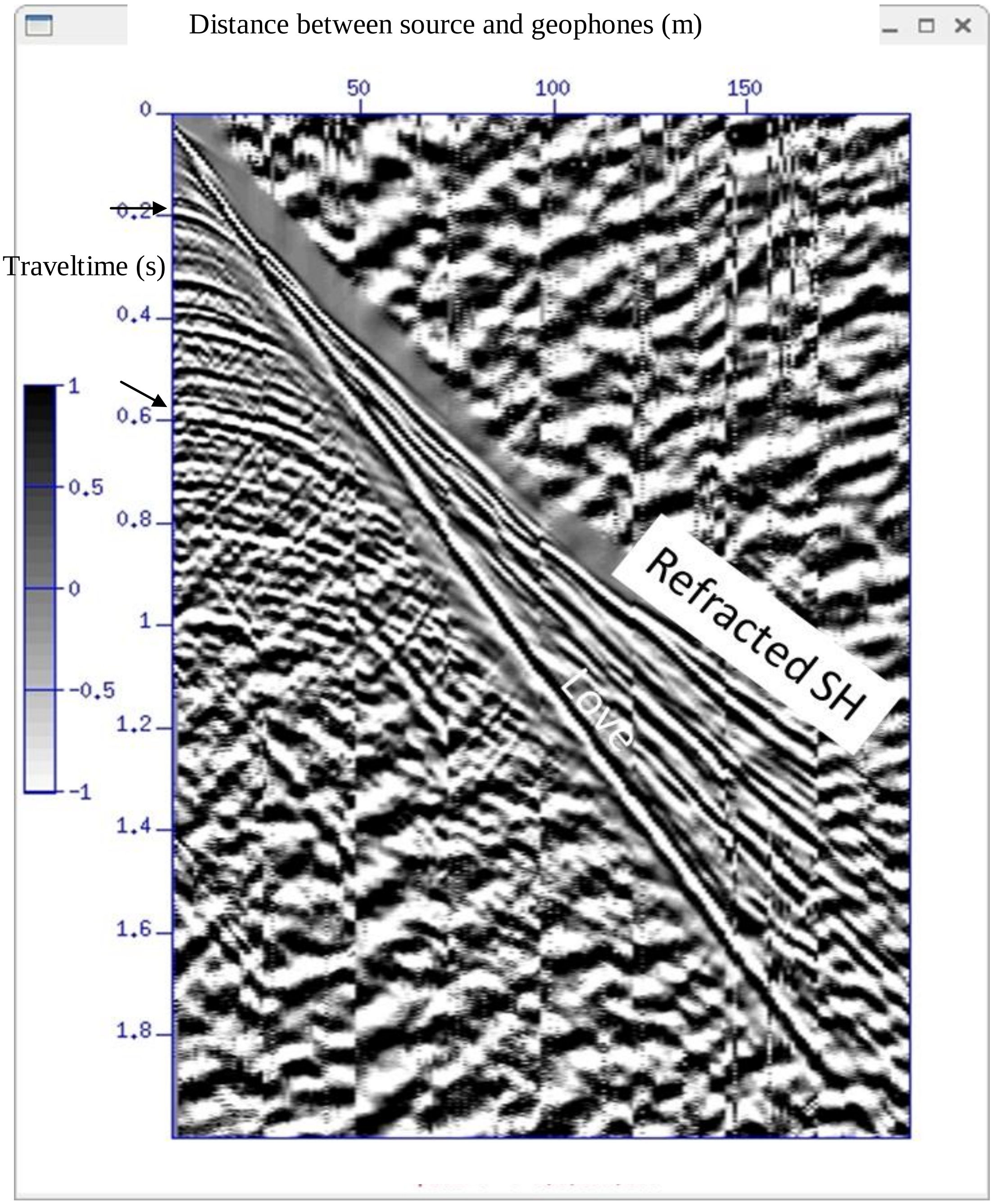
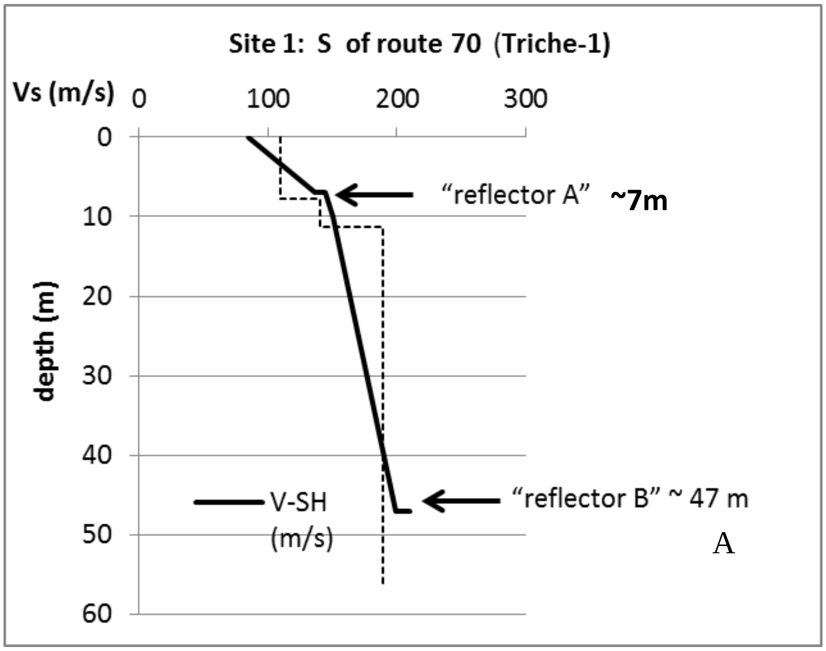


Figure 4: A&B Velocity values (Triche property; Site1) derived using semblance velocity analysis (dashed line) help confirm best-matched forward ray-trace models (continuous bold lines) for both shear-wave data (A) and compressional/sound wave data (B) WT marks the interpreted top of the water table.



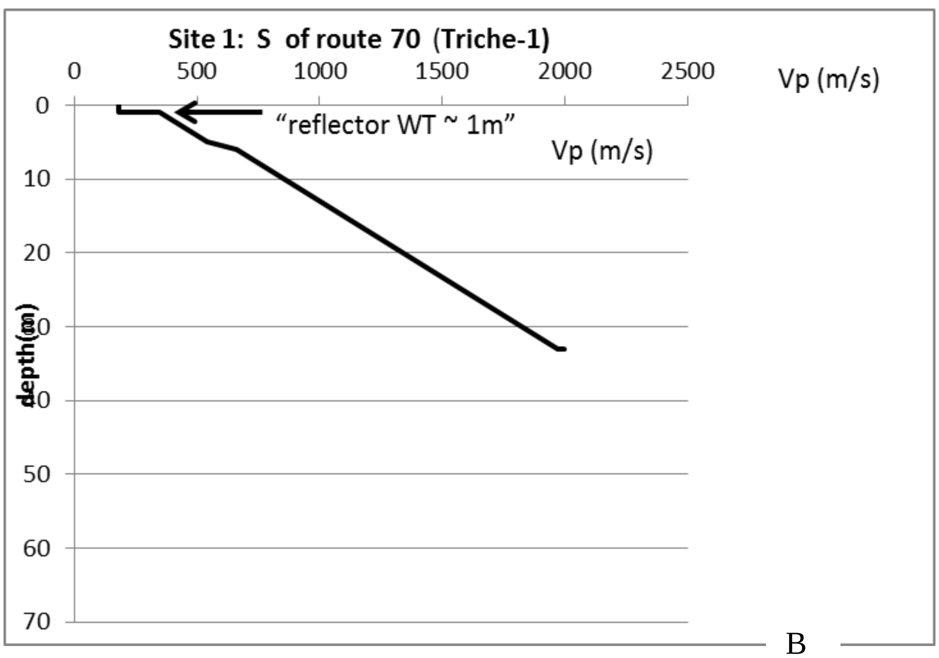
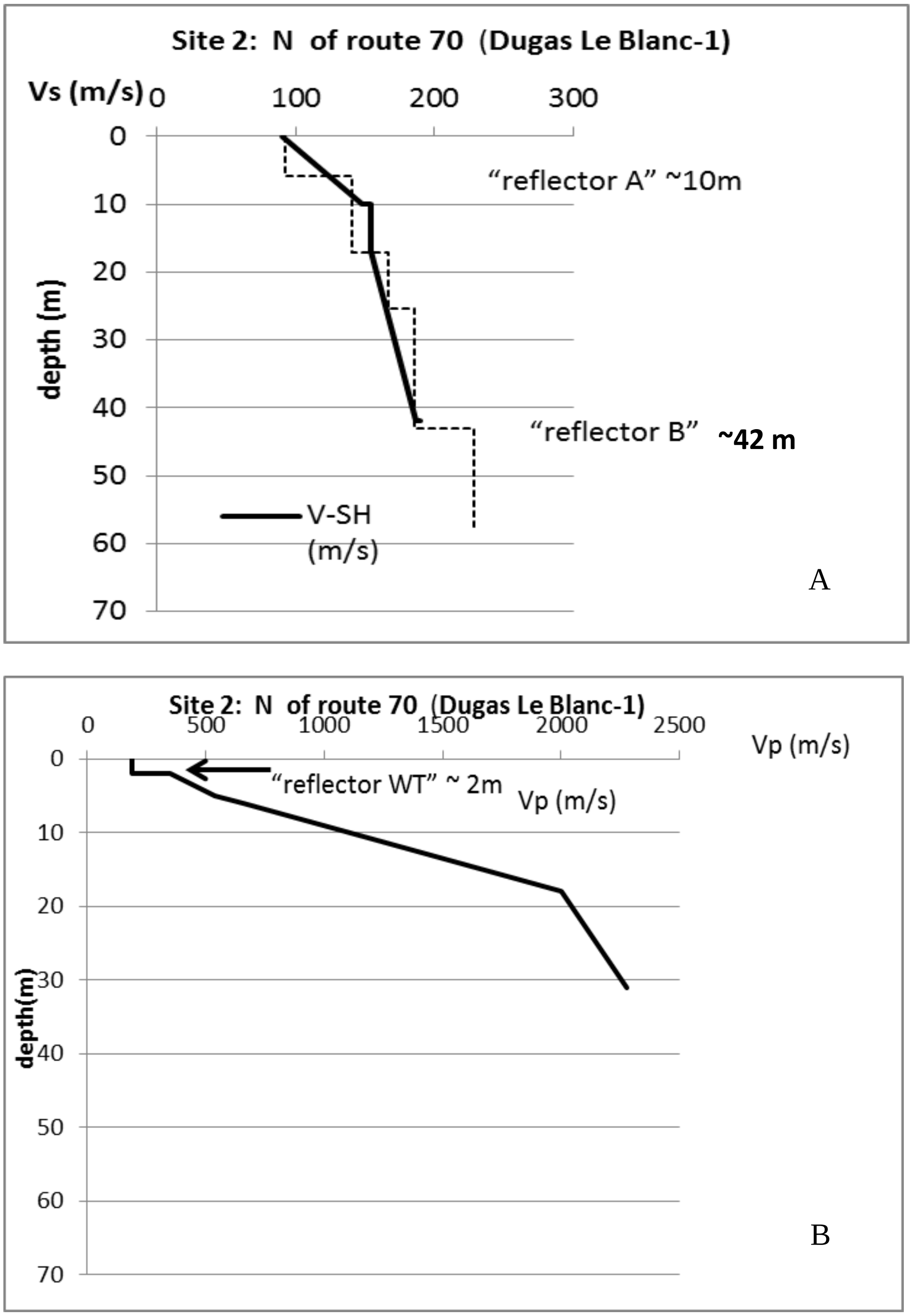


Figure 5 A&B Velocity values (Dugas-Le Blanc property; Site 2) derived using semblance velocity analysis (dashed line) help confirm best-matched forward ray-trace models (continuous bold lines) for both shear-wave data (A) and compressional/sound wave data (B). WT marks the interpreted top of the water table.



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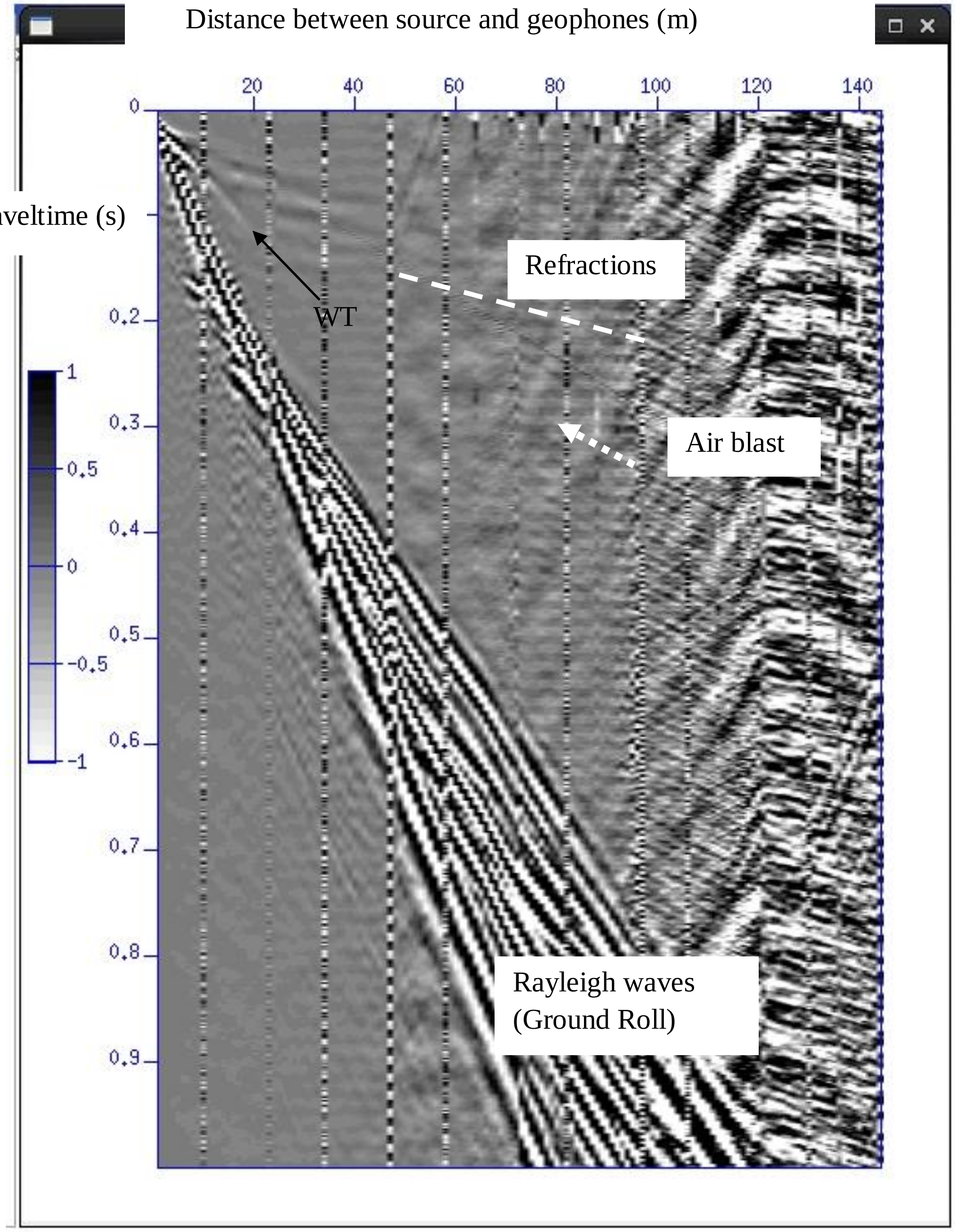
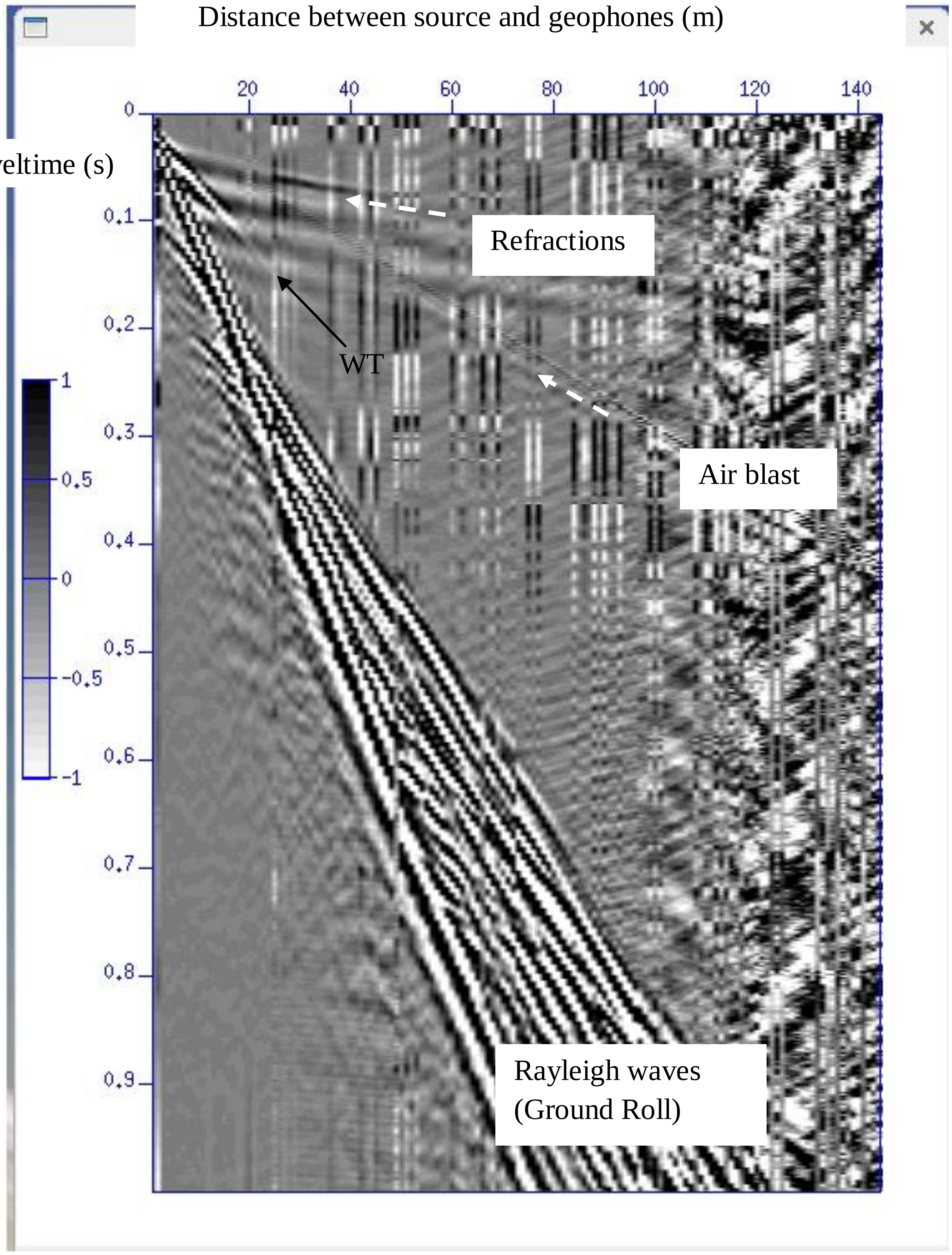
Appendix A-1 Compressional-wave seismic data

Compressional-wave data collected using 40-Hz vertical component geophones at the Triche property: Site # 1. Possible shallow event is interpreted as the **WT** reflector.



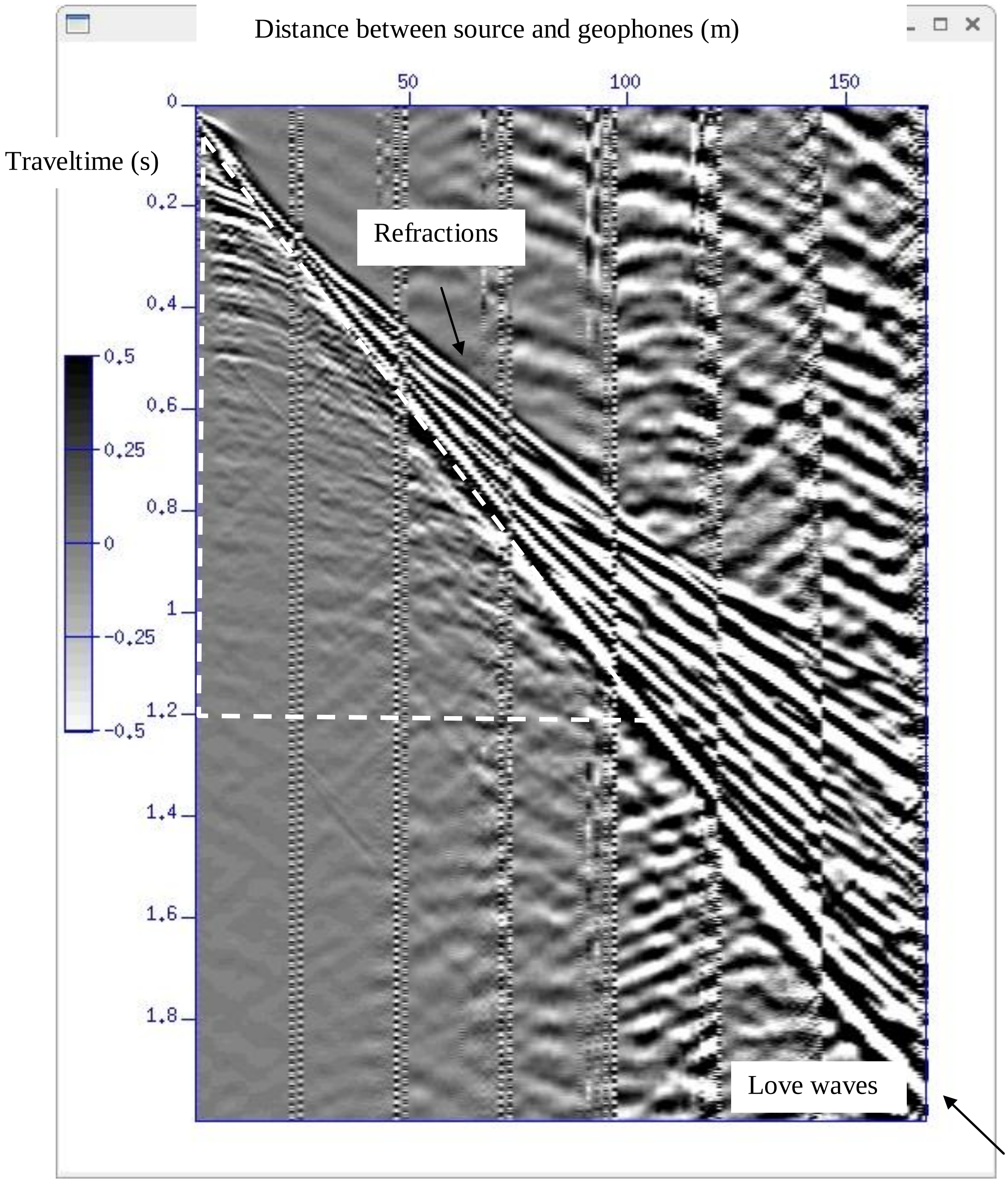
Appendix A-2- Compressional-wave seismic data (Dugas-Le Blanc property: Site 2)

Curved reflector at (0.1s) lies below area of interest. Possible shallow event is interpreted as the **WT** reflector.



Appendix A-3- Shear-wave seismic data (Triche property: Site # 1)

Concave-down reflectors are prominent in a small triangular area beneath Love waves and SH-refraction events.



Appendix B- Velocity-depth values for the best-matched cases in seismic noise test data set at Site 1 (Triche property).

	Site 1 Triche property	South of route 70 West of Bayou Corne			Vinterval (m/s)			
V-SH (m/s)	depth (m)	VP(m/s)	depth (m)		V-SH (m/s)	TWTT (s)	layer thick-ness (m)	depth (m)
85	0	180	0		110	0	0	0
136	7	180	1		110	0.141	7.755	7.755
144	7	350	1		140	0.141		7.755
150	10	540	5		140	0.191	3.5	11.255
150	10	540	5		189	0.191		11.255
199	47	660	6		189	0.67	45.266	56.521
210	47	660	6					
		1971	33					
		2000	33					

Appendix C- Velocity-depth values for the best-matched cases in seismic noise test data set at Site 2 (Dugas-Le Blanc property).

Site 2 Dugas-Le Blanc property		N of route 70	
V-SH (m/s)	depth (m)	VP(m/s)	depth (m)
90	0	190	0
148	10	190	2
154	10	350	2
154	17	540	5
154	17	540	5
187	42	660	6
190	42	660	6
		2000	18
		2000	18
		2280	31

Vinterval (m/s)			
V-SH (m/s)	TWTT (s)	layer thick-ness (m)	depth (m)
92	0	0	0
92	0.126	5.796	5.796
141	0.126		5.796
141	0.195	4.8645	10.6605
141	0.195		10.6605
141	0.286	6.4155	17.076
167	0.286		17.076
167	0.385	8.2665	25.3425
186	0.385		25.3425
186	0.576	17.763	43.1055
228	0.576		43.1055
228	0.704	14.592	57.6975