Extended Abstract:

Geophysics and Geohazards: Defining subsea engineering risk

Title: Enhanced coastal geotechnics with integrated marine seismic reflection and multi-source, extended array refraction.

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Abstract:

Strong world demand for energy, mineral resources and agricultural products is underpinning new construction and upgrades at many Australian ports, particularly in Western Australia (WA) . These have required extensive near-shore marine geophysical investigations in shallow waters, typically less than 20m deep directed mainly at port entrance channels, pipeline routes and supporting facilities such as jetties and wharfs. The technologies have usually employed continuous seismic profiling (CSP) with surface-tow boomer sources and single-ended, continuous underwater seismic refraction (CUSR) with near-bottom towed equipment and air-gun sources (Whiteley & Stewart, 2008).

The near-shore marine environment of WA is challenging for both shallow reflection and refraction methods. This area is essentially a Pleistocene dune platform, sometimes overlain by Holocene sediments, that has been submerged and dissected (Bird, 2008). It contains re-worked calcareous marine and terrestrial sediments with “hard” cap rocks, variably cemented “hard” calcarenites,

limestones, sandstones and conglomerates of variable thickness and lateral extent. These materials lie on an irregular surface of much older, but also highly variable, bedrock units. Generally these “hard” layers, their seismic velocity, as indicative of their excavatability and strength are of most importance to dredging and piling contractors together with the depth to bedrock.

Figure 1 shows a sample of near-shore boomer CSP data from the Pilbara region , WA. This is about 1.4km length and extends to about 16m sub-bottom depth. Four simplified, geotechnical logs for boreholes about 400m apart are also shown on this CSP section. Drilling within these conditions is also difficult with sometimes significant core losses so the location of the interfaces between the various geotechnical units can often be uncertain.

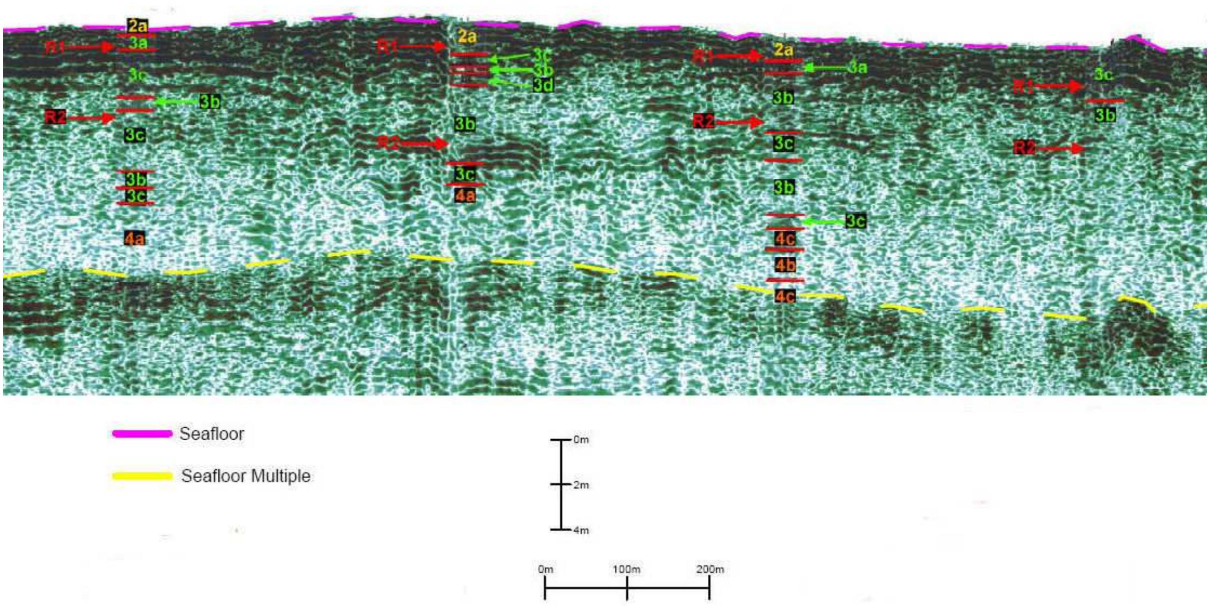

Figure 1 Sample of near-shore boomer CSP data and borehole logs from the Pilbara region, WA

From the sea floor, unit 2a represents the relatively thin Recent Marine sediments, mainly sands, gravels and silts. Units 3a to 3c represent the calcareous shallow marine sediments. The “hard” cap rocks (3a) and the “hard” siliceous calcarenite, calcareous sandstones and conglomerates (3c) were encountered at differing depths in the boreholes and there is no easy way to correlate these units between these boreholes. The underlying units (4a to 4c) represent the older terrestrial sediments, mainly calcareous clays, gravels (4a and b) and claystone (4c).

There is also no detailed correlation between the CSP record and these geotechnical units, however, there are general correlations, as is typical of this region. Two CSP reflectors (R1 and R2) are marked where they occur at the boreholes. R1 approximately represents the base of recent marine sediments near the sea floor but does not clearly distinguish the thin cap rock (3a) and calcarenite (3c). R2 occurs within the shallow marine sediments and shows some correlation with the deeper “hard” calcarenite (3c) unit in three of the boreholes. Laboratory testing of calcarenite samples from this area indicated seismic velocities in excess of 3000 m/s could be expected.

Taken together the CSP and borehole data suggest a seismic velocity reversal (or inversion) beneath the “hard” layers that could pose some interpretation difficulties with interpretation of CUSR data from this region (Whiteley and Greenhalgh , 1979).

To date much of the near shore CUSR data in WA and elsewhere around Australia has been collected with relatively short hydrophone arrays(< 50m) and a single near-array source. This data is usually interpreted with intercept time methods assuming a horizontal, plane-layered earth model with a uniform velocity in each layer and velocities increasing with depth.

In order to investigate the performance of this system in more realistic situations a multilayered synthetic model was constructed using typical seismic velocities for the region with a relatively thin high velocity “hard” layer of limited lateral extent as shown in Figure 2a. Single- ended, CUSR first arrival times were computed through this model to a 50m source-receiver array with detectors at 2m intervals and a 10m source interval using Polvin and Lecomte’s (1991) finite difference solutions to the 2D seismic eikonal equation.

This data was then interpreted using the intercept-time method and the smoothed intercept-time interpretation is shown in Figure 2b. This interpretation shows a more extensive high velocity region that has been migrated laterally in the source direction and is a considerable variance with the original model.

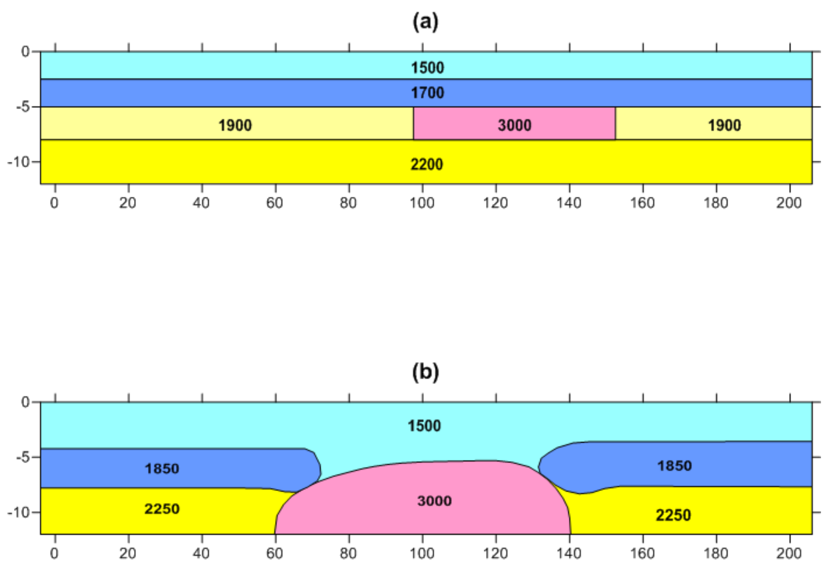

Figure 2 Synthetic seismic model and intercept time interpretation

2a. Synthetic seismic model

2b. Smoothed intercept time interpretation

These limitations can be largely overcome and improved resolution in these conditions can be achieved employing a longer seismic array and multiple offset sources together with improved tomographic interpretation methods.   Figure 3a shows the same synthetic model in Figure 2a that has been extended to include a deeper higher velocity layers (2500 and 4500 m/s).   First arrival travel-times were again computed through this model for a 100m receiver array with sources at 0m and 50m offsets and inverted using Wavepath Eikonal Tomography (WET, Schuster and Quintus-Bosz, 1993) and RAYFRACT(R) Vers. 3.1 software (Intelligent Resources, 2010) from an initial velocity gradient model. This produces a seismic image that is continuous rather than discrete as assumed with the intercept time method and is increasingly used in near-surface seismic refraction on land (Whiteley and Eccleston, 2006) .

The seismic image obtained is shown on Figure 3a. This bears a strong resemblance to the discrete model. Both the lateral extent and depth to the top of the high velocity lens are closely defined in this image.   The base is less well defined in Figure 3a but is more clearly observed on the seismic ray density diagram in Figure 3b that is produced by the software.   This shows the concentration of seismic rays in the high velocity lens and within the deepest "hard" bedrock refractor.

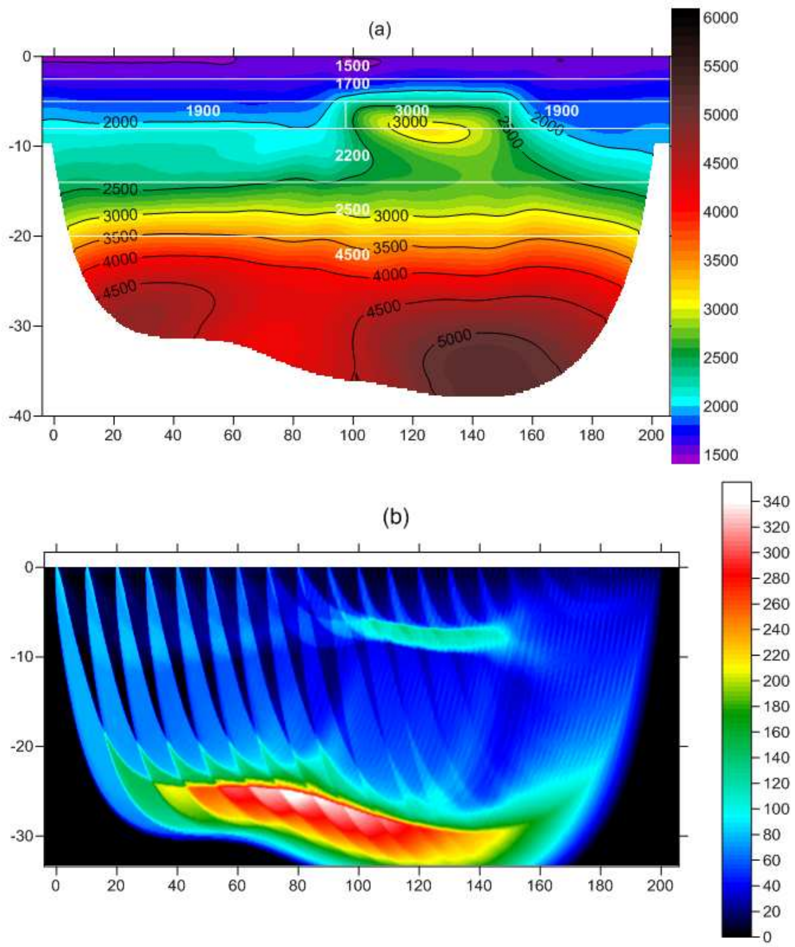

Figure 3 WET Interpretation and seismic ray density model

3a. WET interpretation

3b. Seismic ray density

Figure 4 shows the CSP section from Figure 1 on which the approximate extent of the cap and calcarenite layers have been marked using both the CSP and borehole information. The CUSR tomographic image along part of this line obtained with the improved system and approximately scaled to the CSP record is also shown. The cap and calcarenite layers near sea floor are not evident in this image suggesting that they are also less cemented but the higher velocity deeper calcarenite layer that is truncated laterally is clearly observed.

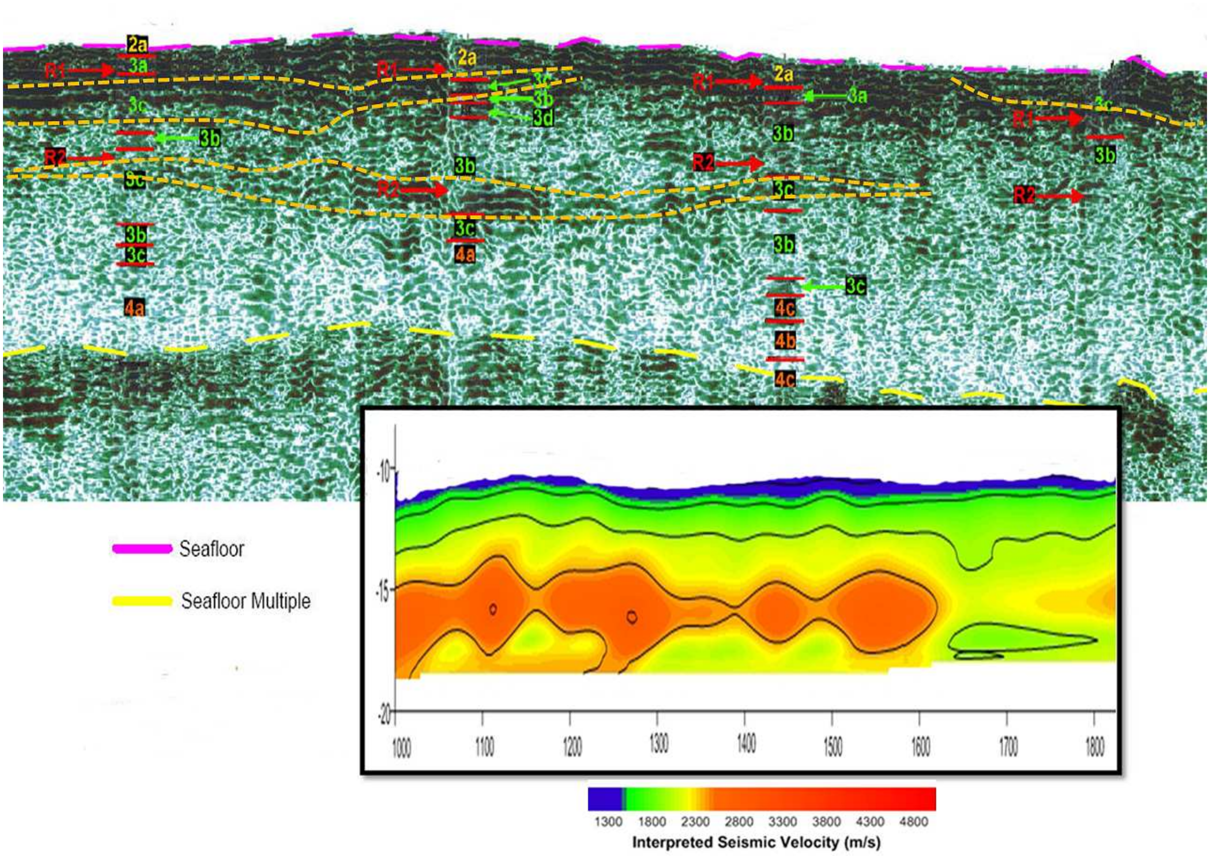

Figure 4 Interpreted CSP and CUSR sections

This study demonstrates that application of this improved CUSR system and its integration with CSP and offshore drilling offers enhanced geotechnical modelling and reduces engineering risks in near-shore deeper dredging and construction in complex near-shore regions such as those in Western Australia .

References:

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Figure Captions:

Figure 1 Sample of near-shore boomer CSP data and borehole logs from the Pilbara region , WA

Figure 2 Synthetic seismic model and intercept time interpretation

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2b. Smoothed intercept time interpretation

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