MINIMAL-IMPACT SEISMIC ACQUISITION: SUCCESSFUL IMAGING USING AN ACCELERATED WEIGHT DROP SYSTEM

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INTRODUCTION

Under a joint agreement with the Cambodian National Petroleum Authority, PGS has commenced the first onshore seismic survey in the Kingdom of Cambodia. The aim of this seismic exploration program is to improve understanding of the hydrocarbon prospectivity of the Tonle Sap and Kompong Som Basins.

The current area of operation is focused on the Tonle Sap Basin – with seismic lines extending from Battambang in the north to approximately 50km SE of Pursat in the south (Figure 1). The reconnaissance 2D seismic exploration program has been designed around structural trends and a depth-to-basement model derived from high-resolution aerogravity and aeromagnetic data available in the Tonle Sap Basin. At the time of writing, some 700 km of 2D seismic data have been acquired. The main geophysical and geological objectives of this seismic acquisition program have been to:

- verify the presence of the gravity lows and the depth-to-basement model
- verify the presence of a potential petroleum system; and
- obtain a better understanding of the structural evolution of the basins

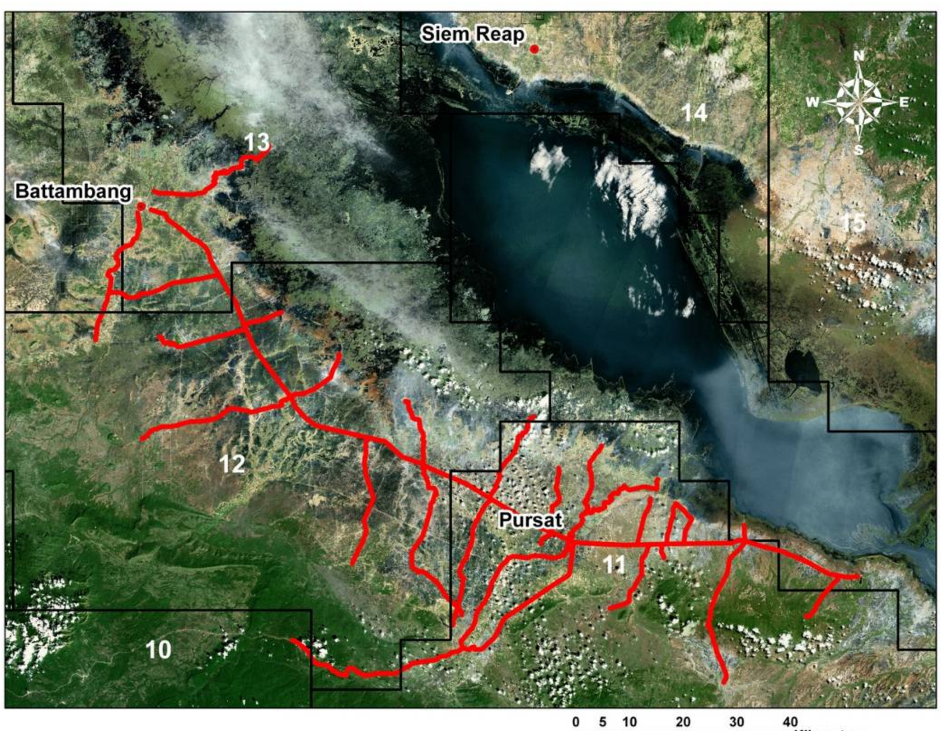

Figure 1: Location of 2D seismic lines for the Tonle Sap Basin reconnaissance seismic exploration program, 2008.

The actual Tonle Sap or Great Lake of Cambodia is a combined lake and river system surrounded by a vast wetland that is an ecological hotspot and a designated UNESCO biosphere. Conducting a seismic exploration program in the vicinity of such a globally significant environment has required careful planning and implementation. Further challenges have been presented by the number of mines and unexploded ordinance (UXO) in the survey area, and the fact that the 2D seismic lines pass through numerous local communities and culturally sensitive areas. In light of the importance of minimising the footprint of the survey on the local ecosystem, avoiding damage to buildings and infrastructure, and handling the logistics of moving through busy communities, an accelerated weight drop system was deemed the most appropriate seismic source. This paper summarises the testing that has helped optimise seismic acquisition and processing to meet the objectives of this reconnaissance survey.

ACQUISTION USING AN ACCELERATED WEIGHT DROP SYSTEM

The accelerated weight drop (AWD) system is a vehicle-mounted, gas-charged accelerated weight drop energy source. A large hardened-steel hammer of 635 kg (1400 lb) has been used to impact a ground-coupled base plate. The AWD uses nitrogen as the accelerating force for the hammer mass, exerting a pressure of 562 kg/cm^2 (8000 psi) on to the hammer.

The AWD system has historically been used for seismic exploration surveys focused on shallow to intermediate geological targets, with clear images recoverable down to TWTs of approximately 2.5-2.8s. This lies well within the target range expected in the Tonle Sap Basin.

To expedite acquisition in the presence of UXO and reduce disturbance to vegetation, the 2D seismic lines have been largely confined to pre-existing roads and tracks. Along main thoroughfares the AWD system can be used mounted on the back of a truck. For minor tracks and rough terrain, more efficient acquisition is possible with the AWD system mounted onto a Morooka (Figure 2).

Figure 2 Truck mounted accelerated weight drop system (left), and Morooka mounted accelerated weight drop system (right). The Morooka's manoeuvrability makes it better for maintaining acquisition production rates along narrow tracks and over rough terrain.

Peak particle velocity (PPV) tests were conducted prior to acquisition to evaluate the distance production thump points should be kept from sensitive structures and objects. These tests involved dropping thumps at offsets of 60 m, 50 m, 40 m, 30 m, 20 m, 10 m, 7.5 m, 5 m, and 2.5 m from a seismograph station. As seen in Figure 3, the PPV starts to rapidly increase for offsets less than 7.5 m. For one test, conducted on a well-compacted road, the PPV exceeded the generally accepted 12.7 mm/s limit at 7.5 m. Consequently, a 10 m clearance distance has been imposed for operation of the AWD system. Where people tend to gather in structures like temples, hospitals, schools etc, a 50 m safety distance has been adopted.

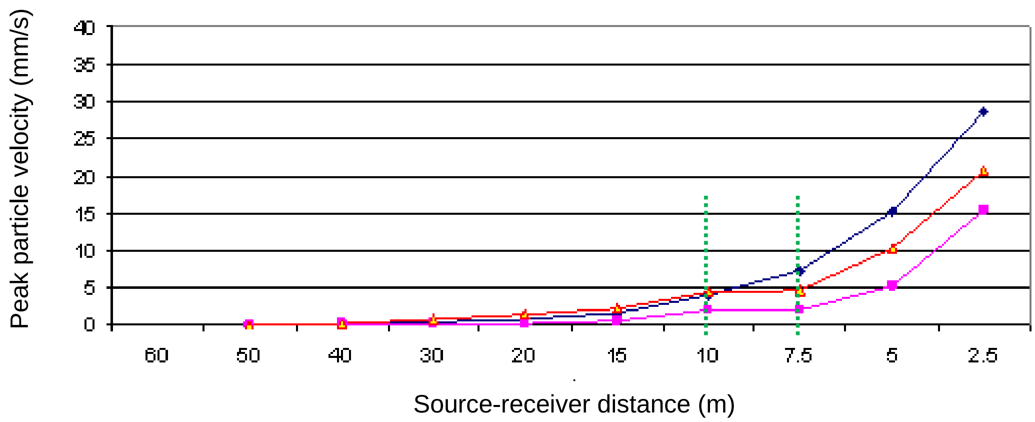

Figure 3 Radial (blue), transverse (red) and vertical (pink) components of the peak particle velocity for a representative PPV test site. The peak particle velocity becomes significant for offsets less than approximately 7.5m.

Acquisition Parameters

A number of acquisition parameters were recognised as critical for optimising cost versus outcomes for the 2D reconnaissance seismic program. Each of these was examined during the early phases of acquisition.

Most significant to the acquisition program has been tailoring the number of weight drops at each source point. For the well-compacted roads and tracks along which the AWD system has been operating in the Tonle Sap Basin, we have found no significant difference in signal and noise strength and character between the shot records acquired using the first thump compared to shot records acquired from a second, third, fourth or fifth thump. This is in contrast to previous experiments conducted in different field conditions. Consequently, we are able to make use of the first drop at each source point.

Our acquisition is more cost- and time-efficient if receiver effort is increased in lieu of reducing the source effort. While the signal-to-noise ratio is improved with each additional thump used at each source point (Figure 4), careful consideration has been given to how much additional regional-scale geological detail is revealed with each extra drop of the AWD system. So, while initially four thumps per station was considered a good compromise between daily production rates and the data signal-to-noise ratio, we subsequently found we could recover the same geological detail by reducing the number of thumps at each source point and compensating with an increase in the fold of the data. Figure 5 shows an example of this effect – we can maintain an acceptable level of geological detail when we reduce the number of thumps per station to one, when we double our receiver effort (i.e. increase fold from 140 to 280). Table 1 summarises our preferred 2D seismic acquisition parameters.

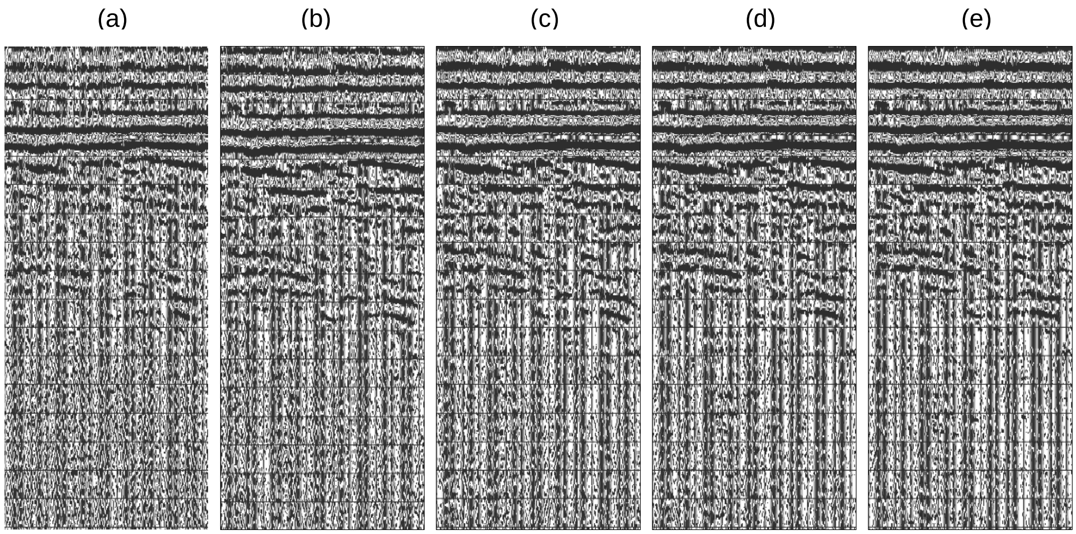

Figure 4 A small portion (~1km) of a field brute stack generated using (a) one thump per source point; (b) two thumps per source point; (c) three thumps per source point; (d) four thumps per source point; (e) five thumps per source point. These data were acquired with 25 m receiver spacing and 25 m source spacing. Nominal fold is 140. Timing lines are 100 ms. As expected, the signal-to-noise ratio improves as the number of thumps per source point increases.

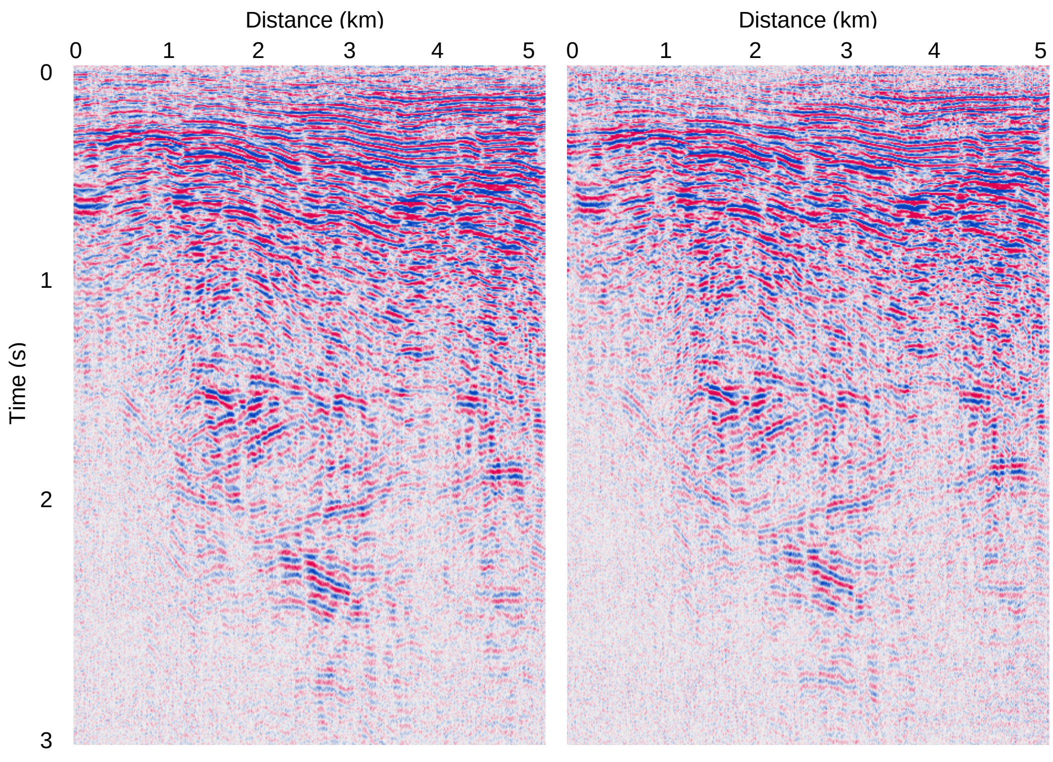

Figure 5 (a) Un-migrated stack derived from seismic data acquired using two thumps per source point and a nominal fold of 140; and (b) un-migrated stack derived from seismic data acquired using one thump per source point and a nominal fold of 280. The regional-scale geological detail that can be extracted from both sections is comparable.

Table 1 Summary of recording parameters for the Tonle Sap Basin reconnaissance 2D seismic program.

Record Length	6 seconds
Sample Interval	2 milliseconds
Number of live channels	560 + 1 aux
Recording spread	Split spread
Receiver group interval	12.5 m
Phones per group	6
Maximum offset	3493.75 m
Minimum offset	6.25 m
Source interval	12.5 m
Number of thumps per source point	1
Nominal fold	280

DATA PROCESSING

The focus of data processing has necessarily been on reducing random and coherent noise. One pitfall of acquiring seismic data along established roads and tracks, and through local communities, is the amount of non-seismic noise that contaminates the seismic shot records. Our optimum pre-stack processing flow includes trace editing to remove data collected by receivers close to strong noise sources, time-frequency domain sub-spectral balancing and *f-k* filtering. We have used a wide hand-picked mute to maximise fold along target reflectors, and applied *fx*-deconvolution and eigenvector filtering following post-stack migration to further reduce the impact of non-seismic noise on the 2D seismic sections. Figure 6 shows a final migrated section for one of the potentially prospective areas in the Tonle Sap Basin.

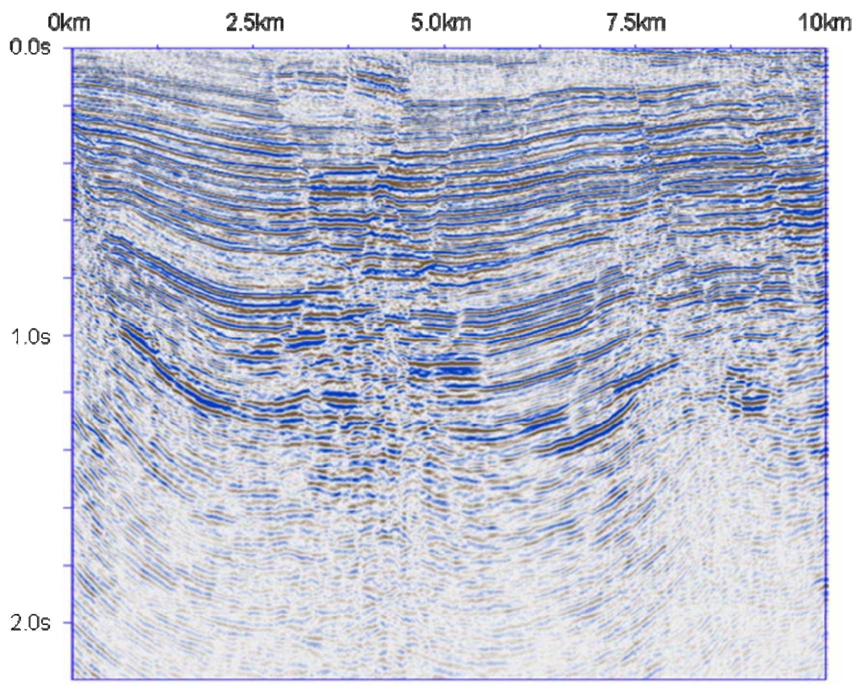

Figure 6 Final migrated stack from the Tonle Sap Basin reconnaissance seismic survey. These data highlight the variable basement depth and complex structural features that occur across the Tonle Sap Basin.

CONCLUSIONS

A minimal impact philosophy with respect to both the natural and local community environments is helping PGS successfully undertake the first onshore seismic survey in the Kingdom of Cambodia. An accelerated weight drop system is helping the onshore crew move quickly and efficiently along established roads and tracks, through local communities and culturally sensitive areas, and across any rough terrain with reduced risk from UXO and no disturbance to existing infrastructure. Careful selection of acquisition parameters and a concerted effort on noise reduction during processing has helped maximise acquisition production rates while also ensuring the geological and geophysical objectives of the reconnaissance 2D seismic survey are met. The resultant seismic data have verified the gravity lows and revealed complex structures, sedimentary depocentres, and the highly variable basement (at depths up to 3.5 – 4.0 km) across the Tonle Sap Basin. The interpretation of these 2D seismic profiles will be used to constrain subsequent re-interpretation of the locally-available gravity and magnetic data to help prioritise subsequent hydrocarbon exploration initiatives.

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