# Challenges and Solutions of a Complex Transition-Zone Seismic Survey

*Chen Haolin, Bai Yushan, Gu Haibin*. BGP, CNPC*


## Summary

A transition zone (TZ), also referred to as the trouble zone because its terrain is more complex than either land or marine environment, has become a top challenge for seismic acquisition in special areas.

The challenges are from different areas including source, sensor, geometry, communication, surveying, positioning, and processing. The operational feasibility and efficiency in difficult areas are also key factors affecting acquisitions. However, seismic acquisition in complex TZ areas has become widespread. The reason is twofold. First, there is an increased demand for seismic surveys in such complex areas. Secondly, the development of new technologies has made acquisition in such areas more feasible and efficient than ever before. To meet this challenge, BGP has spent much effort on TZ seismic surveys in recent years and solved many challenging problems in TZ acquisition both in China and abroad. This paper will introduce some special techniques developed by BGP and present representative cases.


## Introduction

TZ terrains are highly diverse and complicated. One major difficulty faced by the conventional land and streamer acquisition equipments is the inability to gain access.

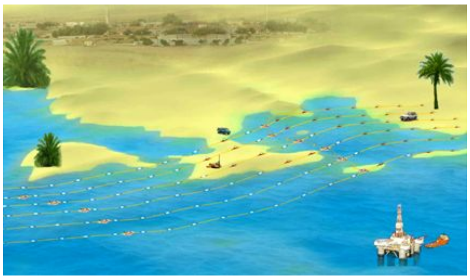

Figure 1. Complex TZ Terrain

The complicated terrains include populous city and town, muddy beach, shallow water island, coral reef, offshore ports, and areas near offshore oilfield infrastructure. These complex surface conditions present several challenging difficulties for seismic operation such as drilling, air-guns, receiver cable deployment, and positioning.

## Challenges

1. Equipment selection

Generally speaking, the TZ surface covers land, tidal zone, and shallow water areas. All these special terrains require appropriate equipment, to ensure a seamless seismic operation. Consequently, selection and allocation of suitable equipment is the most important aspect for TZ acquisition.

2. Quality control

Many systems are combined in TZ seismic acquisition, including recorder, drilling system, air-gun source, and positioning system. The most important aspect is to guarantee the smooth operation of all systems, the quality of air-gun data quality, positioning data, and seismic data. In other words, we must have a system in the field for effective QC.

3. Improving positioning accuracy

Positioning has always been one of the challenging issues in TZ seismic operation. In some areas, the water depth ranges from 2 m to more than 60 m, the surface current and ocean bottom current can move the receivers in any direction in 3D space from their original positions. These deviations in positioning will adversely impact the seismic data and subsequent images. Thus, one of TZ challenges is how to maintain positioning accuracy within the required specifications.

## Solutions

Through more than 30 years of TZ acquisition experience, BGP has developed many techniques and equipment for this application. As a result, we have formed a series of solutions to the aforementioned challenges.

### *1. Seamless acquisition equipment*

**A.** Normally two recorders will be utilized (land and marine) to record seismic data seamlessly and simultaneously in a large TZ project.

Figure 2. Illustration of two recorders working with multiple receivers

**B.** Multiple types of receivers can be deployed in different terrains. They are geophones for land, marsh phones for a tidal zone where water depth is less 1.5 m, and dual sensors for shallow water (up to 50m) (Figure 2.). BGP has developed several types of cable handing equipment for land, tidal-zone, and shallow water areas, such as amphibious vehicles, cable handing boats, and ocean bottom cable (OBC) vessels.

**C.** Three types of sources are used in various terrains for continuous operation. They are vibroseis, explosives and air guns.

BGP has developed various types of air gun boats for different offshore conditions:

(1) Large air gun boats can provide high volume and strong energy. They are normally towed and utilized in deeper water. They can achieve high efficiency production for high density shot-point design.

(2) Medium-sized air gun boats named HAIBAO, have been developed for offshore where water depth is more than 2 m. They are used among obstructions such as ports, oilfield and shallow beach areas.

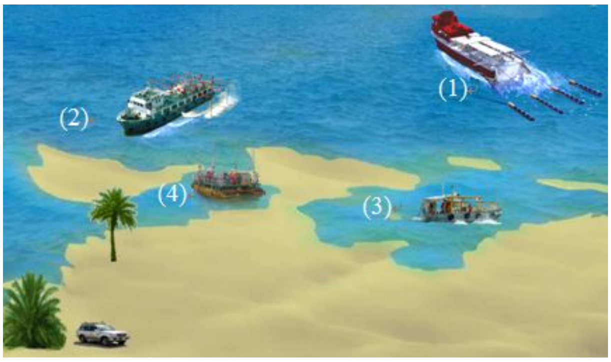


Figure 3. Multiple Air gun systems

(3) A small shallow-water air gun boat has been developed for special areas where water depth is greater than 3 m and normal air-gun boats and drilling boats cannot work (Figure 3). This air gun boat can also be used in small lakes inland.

(4) The mud guns can be deployed in restricted and sensitive areas where dynamite is prohibited.

**D.** Different TZ drilling equipment developed by BGP can be used for different terrain conditions. A hydraulic jack-up drilling boat can work in tidal zones (water depth up to 2.5 m), Hugglund-amphibious drilling vehicles, mud buggies and land drilling vehicles can be utilized in different TZ surfaces. Furthermore, a technique of loading the charge through the drill stem ensures that the charge is loaded to the bottom of the hole.

Figure 4. Multiple drilling equipments

**E.** Multiple positioning & navigation systems are applied in different terrains. DGPS positioning system is applied in vibrators for real time position. Survey data in land and shallow water areas (less than 2 m) is achieved by using the RTK method. Navigation system is used in real time for OBC deployment and air gun shooting in marine surveys.

## *2. Survey design technology*

A high full-fold, wide azimuth, and long offset 3D seismic survey scheme is always the ideal choice in data acquisition, but it is necessary to take TZ terrain, cost effectiveness, and operational feasibility into consideration.

Extensive survey planning in TZ is required to achieve high productivity, and to improve seismic data quality.

A reasonable efficiency analysis is the first step to determine the survey geometry. The drilling for dynamite hole in TZ areas and the use of vibroseis in the city are often difficult and inefficient. Therefore, more receivers and fewer source positions should be considered. High productivity with air gun shooting and the difficulty in OBC deployment dictate that more sources and fewer receiver lines should be used.

In order to balance the efficiency and cost, land and marine surveys always employ different geometries. Figure 5 illustrates typical examples of TZ design for land and city and for offshore shallow-water area, respectively.

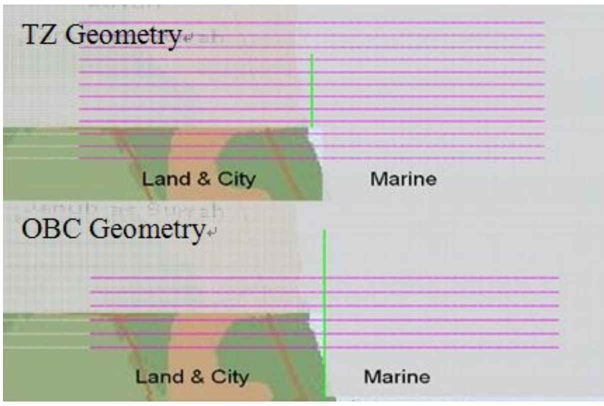


Figure 5. Two geometries

The principle of two geometries is based on the consideration of fewer sources on land and fewer receivers on marine. When the swath rolls in a cross line direction, one half of the receiver lines will be duplicated in the land template and one half of the source lines in the marine template.

In order to achieve the same bin attribute, it is necessary to keep the length and width of two different templates the same.

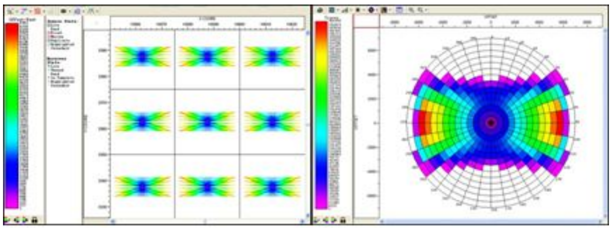

Figure 6. Bin attribute in merge area

In a field operation, normally the selection of geometry template is based on the source type. The two geometries merge together in one swath. The change in bin attribute should be kept even in figure 6.

This design enables that the marine and land crew roll in cross-line direction simultaneously.

### *3. Positioning technology*

OBC receiver positioning control is a delicate technique during the survey. It directly impacts the quality of acquired data and the seismic interpretation result. BGP has many years of experience for cable deployment operation and has developed a series of OBC procedures to meet the challenges in different water depths.

Deployment positioning control:
Before OBC cable deployment, it is important and necessary to collect relevant data, including cable sinking speed, water depth, tide, current direction, weather conditions, and vessel control speed. These data are then merged to calculate the deviation data.

Acoustic Positioning:
The acoustic system is used to check initial cable layout and provide primary positioning results. Acoustic velocity of water in the local area is measured before surveying.

Acoustic transponders are attached to the cables at the defined points for positioning the sensors in the survey.

When OBC deployment is completed, a positioning vessel equipped with an echo sounder travels along both sides of the cables, transmitting a series of predetermined signals to all of the transponders within range. With all data fed back from transponders, the integrated positioning system will automatically calculate the receivers´ locations. Data for layout locations are recorded electronically on board the OBC layout vessels (Figure 7).

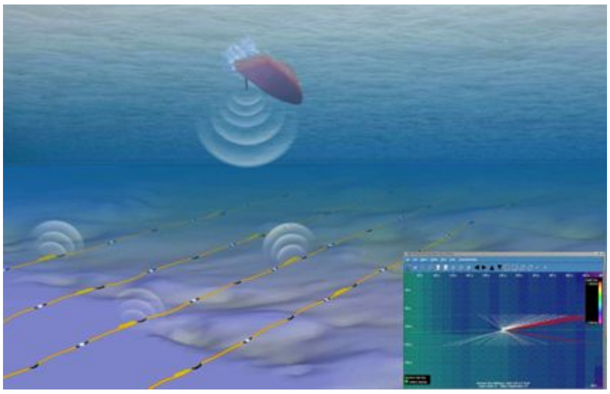

Figure 7. Acoustic repositioning

A full list of drop point to pre-plot position distances can be monitored by the system on the positioning boat in real time. Locating receiver groups is a staged process, including pre-plotting, vessel tracking, and determination of bottom positions by a high - frequency acoustic ping system.

The acoustic positioning system has the real-time positioning and post-processing capability. In addition, the first break repositioning technique is also adopted for receiver positioning.

### *4. Processing technology*

1) The seismic data in TZ areas always have some specific noise due to tide movement, shipping or drilling rig noise, and ghost wave interference. Special processing is required to remove the noise.

Integrated pre-stack noise attenuation
The dominant frequency in primary and high frequency noise can be estimated with the spectrum

decomposition method, and then the high frequency noise can be attenuated in time and offset domains with an auto-adaptive algorithm. The high frequency in primary signals can be preserved effectively (Figure 8).

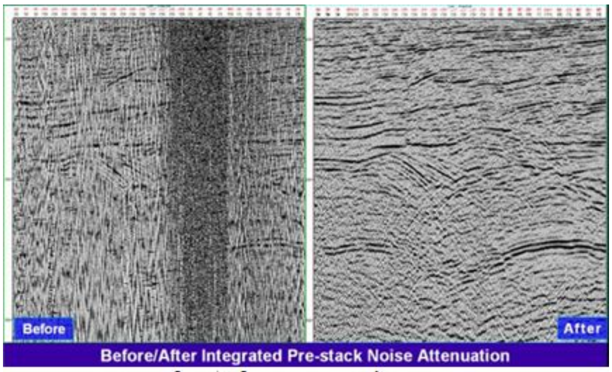


Figure 8. Comparison of seismic image before and after integrated noise attenuation

Because the sea surface is a strong wave impedance interface, the seismic energy may oscillate between sea surface and sea floor, and cause deep notches in seismic spectrum called "water column reverberation". In BGP's OBC operations, two kinds of sensors, hydrophone and geophone are used for the wave field separation in processing.

2) Due to the use of the multiple receivers and sources, seismic data show a variety of characteristics in different terrains. A surface consistent processing is applied to merge the data.

Surface consistent processing

The key techniques to solve the inconsistency issues includes receiver phase correction, wavelet shaping, surface- consistent deconvolution, surface-consistent static correction, and surface -consistent amplitude compensation.

Figure 9 shows the TZ seismic data acquired and processed by BGP in Bohai Bay, China. The surface is complex and the subsurface is dominated by complex structures. With BGP's advanced TZ acquisition and processing techniques mentioned above, we obtained high quality data with clear images.

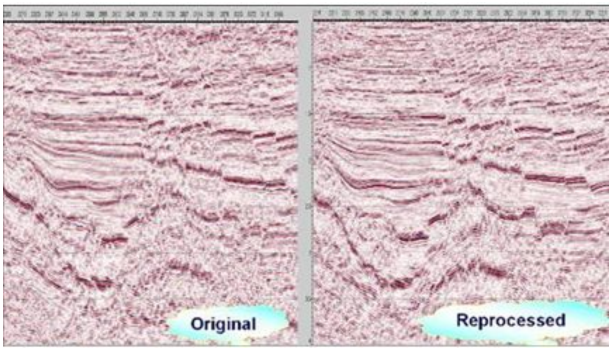


Figure 9. An example illustrating TZ processing.

### *5. TZ capability extended to deep water*

TZ seismic technology has even greater challenges in some special areas. BGP TZ solutions can not only conquer the challenges in the complex transition zone with the water depth 50 m, but also extends to the deep water of more than 1000 m with the help of sea bottom system.

Figure 10 shows the distance of only hundreds meters from beach to offshore, but the water depth increases to hundreds or even a thousand meters. It is very difficult to merge TZ data with streamer data in these areas in a conventional way, because there are two types of completely different acquisition systems with different formats of supporting data and different data storage methods. However, BGP has developed methods to utilize the OBC system to carry out deeper water seismic service for our clients.

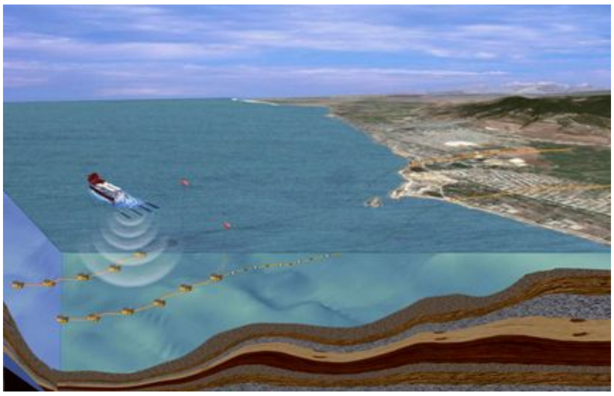

Figure 10. BGP TZ Extends to deep water

## Conclusions

BGP solutions for complex TZ seismic acquisition include multiple components such as integrated air gun systems, navigation systems, and multiple drilling equipments. BGP also possesses advanced techniques covering survey design, field quality control and integrated data processing methods.

All the packages of TZ solutions have been servicing exploration activities worldwide. BGP is well positioned to handle more challenging TZ seismic projects and provide quality exploration results for oil companies in the future.