Planning and Operating a Transition Zone 2D Seismic Survey on Lake Tanganyika*

Doug Roberts[1] and Jeremy P. FitzPatrick[2]

Search and Discovery Article #41765 (2016)
Posted January 25, 2016

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, AAPG/SEG © 2016.

[1]Geophysics Operations, Beach Energy Ltd, Adelaide, SA, Australia (doug.roberts@beachenergy.com.au)
[2]Geotechnical Operations, Woodside Energy Ltd, Perth, WA, Australia

Abstract

Commercial oil discoveries in Lake Albert in the Western Branch of the East African Rift have captured the world's attention and have made remote frontier areas around the African great lakes the focus for oil exploration. Beach Energy (Beach) has operated the Lake Tanganyika South permit in Western Tanzania with Tanzanian Petroleum Development Corporation (TPDC) since 2010 and in mid-2014 Woodside Energy farmed into the acreage. The current 2014 permit work program involved acquiring 1,330 km of 2D marine seismic on the lake to provide infill to the 2,100 km of 2D marine seismic acquired in 2012, as well as acquiring a 107 km land and transition zone (TZ) 2D seismic survey at the lake margin. The TZ part of the program aimed to confirm fault positioning, trap integrity, and sediment thickness for a possible land based exploration drilling location.

The terrain for the land part of the survey area ranged from open low relief hills to flat rice fields between two densely populated villages on the lake edge. The TZ area ranged from shallow lake edge to deeper water lake areas to a depth of over 200 m below the water surface. This variety of terrain necessitated the survey being acquired using a range of seismic sources including mid-range vibrators, dynamite and air guns and recorded into land and swamp geophone cable, rod hydrophones, and ocean bottom nodes.

The planning and operation of this complex land and TZ seismic required reconnaissance trips to review the terrain from a logistics, geophysical, and environmental operations viewpoint and to manage a detailed stakeholder engagement processes.

Location

The Lake Tanganyika South block (Figure 1) is within the western branch of the East African Rift System, formed during the Miocene to present-day rifting of central Africa. This rifting event created all the major lakes within eastern Africa. Lake Tanganyika is over 670 kilometres long and 40 to 80 kilometres wide and is also the second largest body of fresh water by volume and second deepest freshwater lake at 1470 m at its deepest. The Lake Tanganyika South block is approximately 7,123 km^2 and covers the southern portion of the Tanzanian side of Lake Tanganyika.

1984 vintage seismic showed sufficient sediment thickness for hydrocarbon generation and an inter-layered sequence of sands and shale, which could provide source, reservoir and seal for oil and gas.

Prospectively is also enhanced by analogies to large oil discoveries in the similar geological environment of Lake Albert in Uganda and a natural oil seep in north Lake Tanganyika indicates a working petroleum system underneath the lake. No wells have been drilled in the lake to date and due to the water depths it is desirable to commence drilling at an onshore or nearshore location. The previous marine seismic and aerial geophysical surveys indicated that a location near the village of Karema could provide an onshore test of the geology within the lake.

Project Planning

Seismic lines were planned on the basis of connecting to the two lake based marine 2D seismic surveys and also utilising interpretation of results of an airborne high resolution magnetic and gravity gradiometer survey conducted by Beach in 2010, which were evaluated with detailed depth to basement estimation (Figure 2). Interpretation of these data indicated that the Karema area has adequate sediment thickness and was a suitable location where an onshore drilling location could be considered. An onshore well would provide valuable information on the stratigraphy and prospectively of the sediments in the lake before any deeper offshore drilling was programmed. Due to the land locked nature of the lake and non-availability of a floating drilling rig, this onshore drilling location will be an important step in the exploration process.

Field scouting trips were conducted in early September 2014 following a tender process in which the seismic acquisition company BGP was selected to conduct the TZ project. Environmental planning and community consultation procedures were followed to assist in obtaining community support and government approvals for the project. It was aimed to commence recording in late October to avoid the impact of the wet season which commences in November and continues through to May. The central portion of the land area was subject to intense farming mainly in the form of rice fields (Figure 3) which are unused during the later stage of the dry season. As the wet season progresses these areas are cultivated and thus the potential for compensation liability increases. The rice growing areas were recognised as being very vulnerable to the wet season as well as critical for to the economy of the local community. Logistically the area is very remote from the capital Dar es Salaam (over 1000 km) with very poor quality roads most of the way. During the wet season many of the roads become impassable.

The initial plan was to use vibroseis and air guns as the seismic sources. As it turned out due to delays in mobilisation a very late decision was made to provide a dynamite option for wet areas.

Figure 4 summarises the acquisition parameters selected for the project. The airgun array consisted of 8 guns from 40-250 cui with total volume of 960 cui. Two vibroseis units were used in line with a single 16 sec up-sweep ranging from 5-120 Hz. The dynamite shots consisted of single 0.5 kg charges at 6 m depth. The land and marsh geophones were strings of 12 geophones per station.

The source deployment strategy is shown on Figure 5. The source vessel (Haibao) was transported from Kenya to the Tanzanian side of the lake. The 25 m fully demountable vessel was transported to the lake in 8 parts which were assembled at Kigoma, the main port on the lake and 240 km north of the project area. Once constructed, the Haibao transited on the lake to Karema. Three x 26,000 lb Univib vibroseis buggy trucks were transported by road to Karema. Shallow drilling units and dynamite supplies were mobilised to the site. The airgun was only suitable for water depths greater than 2.5 metres so there was a gap on each line from 2.5 m depth to the shoreline which was generally a width of about 100-150 m. On the land portions of the lines, a mobile drilling rig and weight drop unit were used to record 33 uphole locations to a depth of about 50 m.

Figure 6 shows the zone of deployment of the various receiver types. The main recording system for the cable systems was a Sercel 428XL unit. The OBX recorders were self-contained recording units containing a 3 component geophone and a hydrophone. The source vessel Haibao was also utilised for OBX deployment and retrieval for the marine portions of lines.

Operations

Initial mobilisation by BGP to the Karema area commenced on October 10th 2014. There were however a series of delays related to issues of equipment importation into Tanzania from Kenya and Uganda and to the size of loads and road conditions. By early November it was apparent that there would be further delays on mobilising the source vessel (Haibao) and as the wet season was now imminent the decision was made to record the land portions of the lines with Vibroseis (Phase 1) prior to commencing the marine portions of the survey. This then resulted in a 2 km portion of the land lines being reshot (Phase 2) once the marine lines were being recorded. Dynamite operations were also prepared as a contingency at this stage. These variations resulted in a requirement to re-visit the community consultation and approval processes as dynamite had not been included in the original plans. Phase 1 recording commenced on 30th November after geophysical parameter testing. The Phase 2 portion including marine operations commenced on 22nd December and the survey was completed on 9th January 2015. Rainfall became fairly consistent during December and the dynamite contingency became a necessity. Portions of 4 lines and a total of 13.5 km were recorded with the dynamite source in Phase 2.

Figure 7 shows the rice growing areas during the dry season in September and then during the wet season in December.

Figure 8 shows the source station locations colour coded by source type. The dynamite portion was underlain by the Phase 1 vibroseis data. The contours shown are of water depth in the lake and land elevation onshore.

The BGP crew consisted of 22 expatriates and about 150 local villagers who were recruited to work for BGP on the survey. An additional group of up to 50 local people were employed in security and restoration work. Figure 9, Figure 10, and Figure 11 illustrate some of the local activity.

The local BGP camp was placed close to the Karema village and consisted of a mix of tented accommodation (Figure 12) and use of a local council building.

Processing

Figure 13 shows the results of processing the TZ data. There were issues with matching the vibroseis and dynamite data with the dynamite data being surprisingly lower in frequency than the vibroseis data perhaps due to shallow depth of charge. Phase matching filters were created to match the three source types. An issue with the OBX units was also revealed during processing where 30-40% of the units landed upside down on the lake floor and the internal data on attitude was required to correct the geophone data recorded.

Where appropriate the TZ lines were merged with the marine 2D lines and Figure 14 is an example of this merge.

Summary

The Karema transition zone survey recorded 107 km of 2D data over 12 lines. There was 68 km of marine data and 39 km of land data. The mixture of 3 source types and 4 receiver types proved challenging as well as the logistics of mobilisation to the remote village location. The data produced was of a reasonable quality and enabled the selection of a suitable onshore drilling site which will provide a valid test of the lake stratigraphy and prospectively. Further evaluation of the permit will require drilling in deeper water to address a range of identified leads and prospects some with direct hydrocarbon indicators.

Acknowledgement

The contributions and approval for this publication from Beach Energy Limited, Woodside Energy Ltd, and Tanzanian Petroleum Development Corporation is acknowledged.

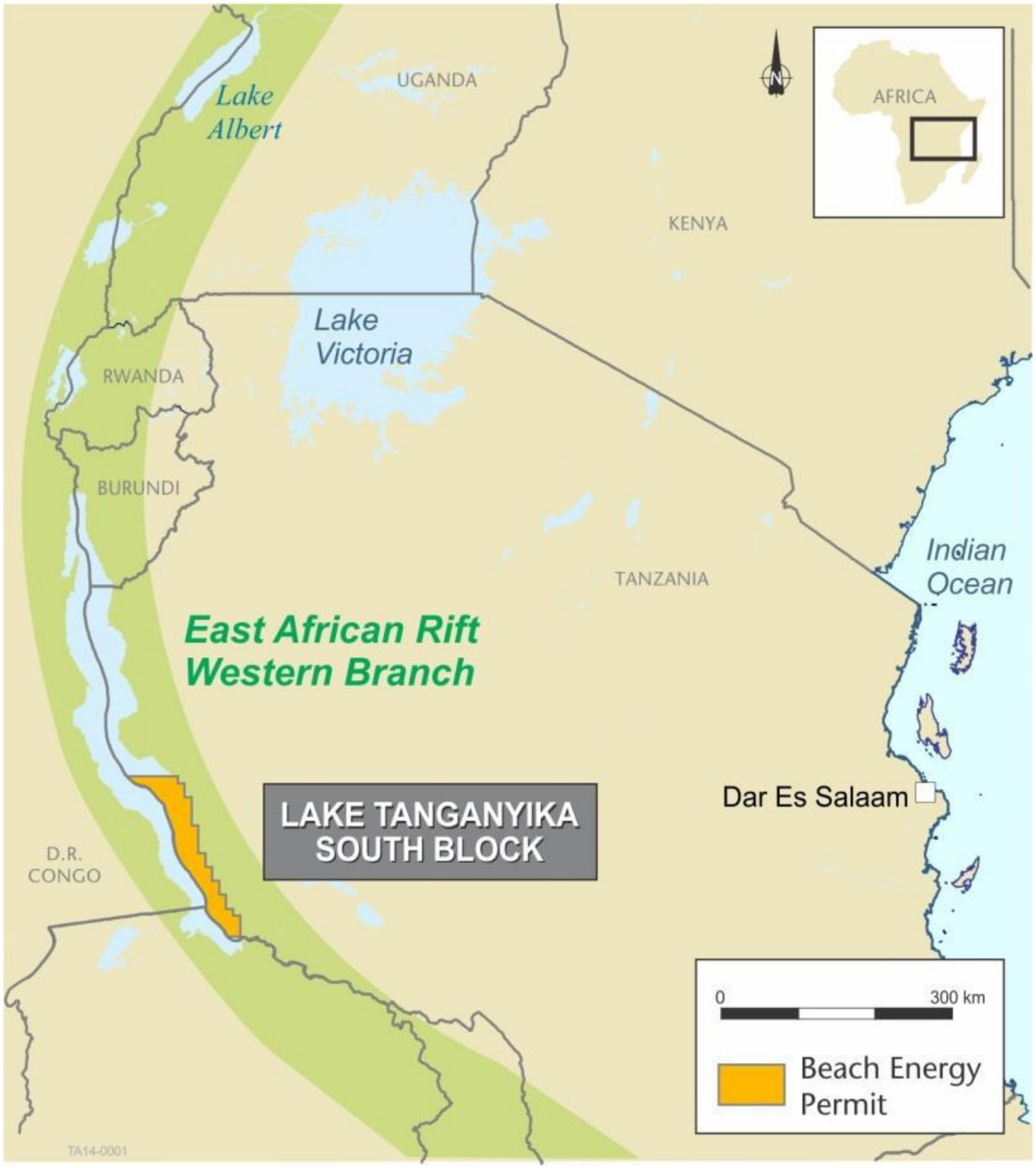

Figure 1. East African Rift

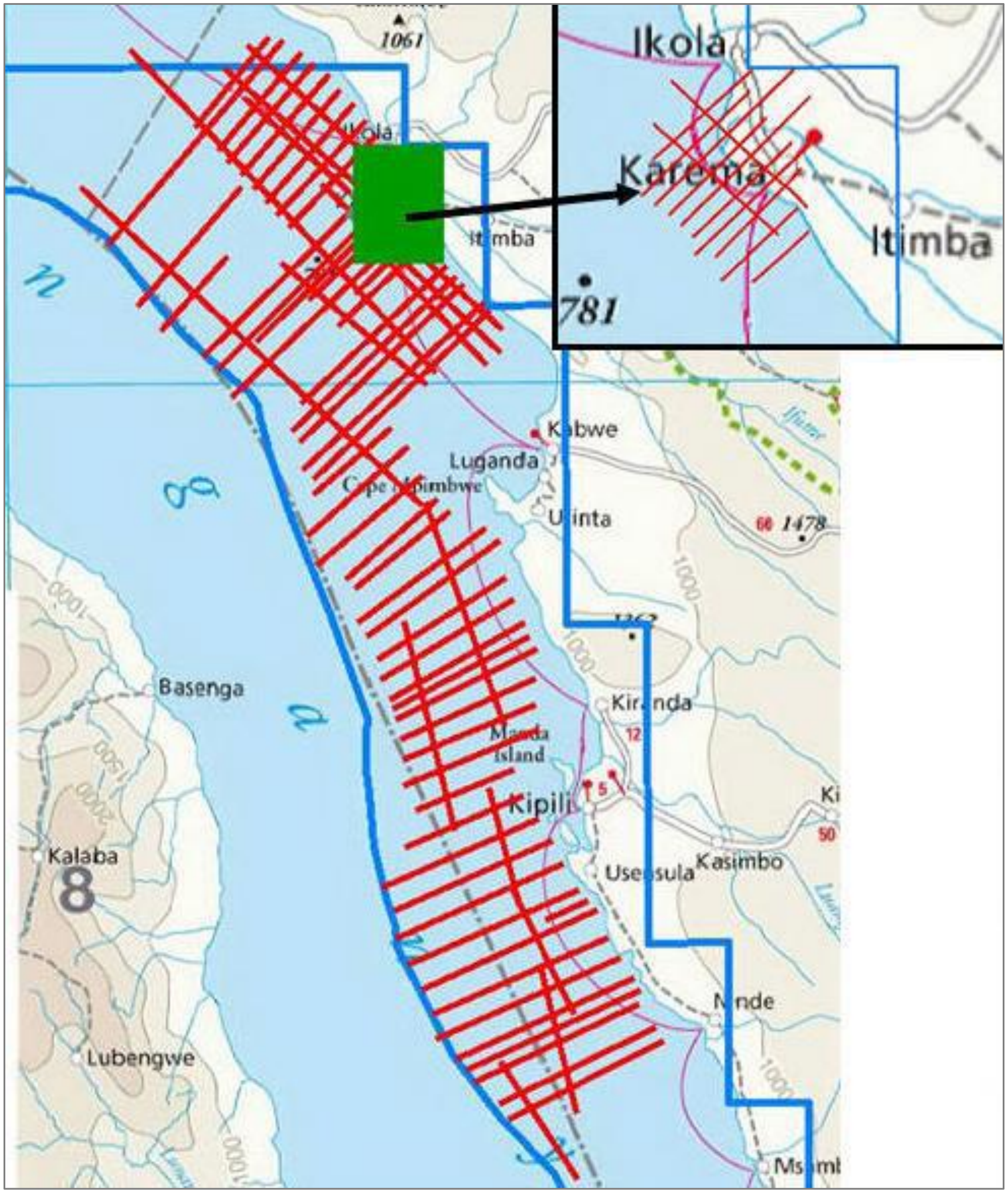

Figure 2. Location of 2014 marine 2D and transition zone 2D lines near Karema

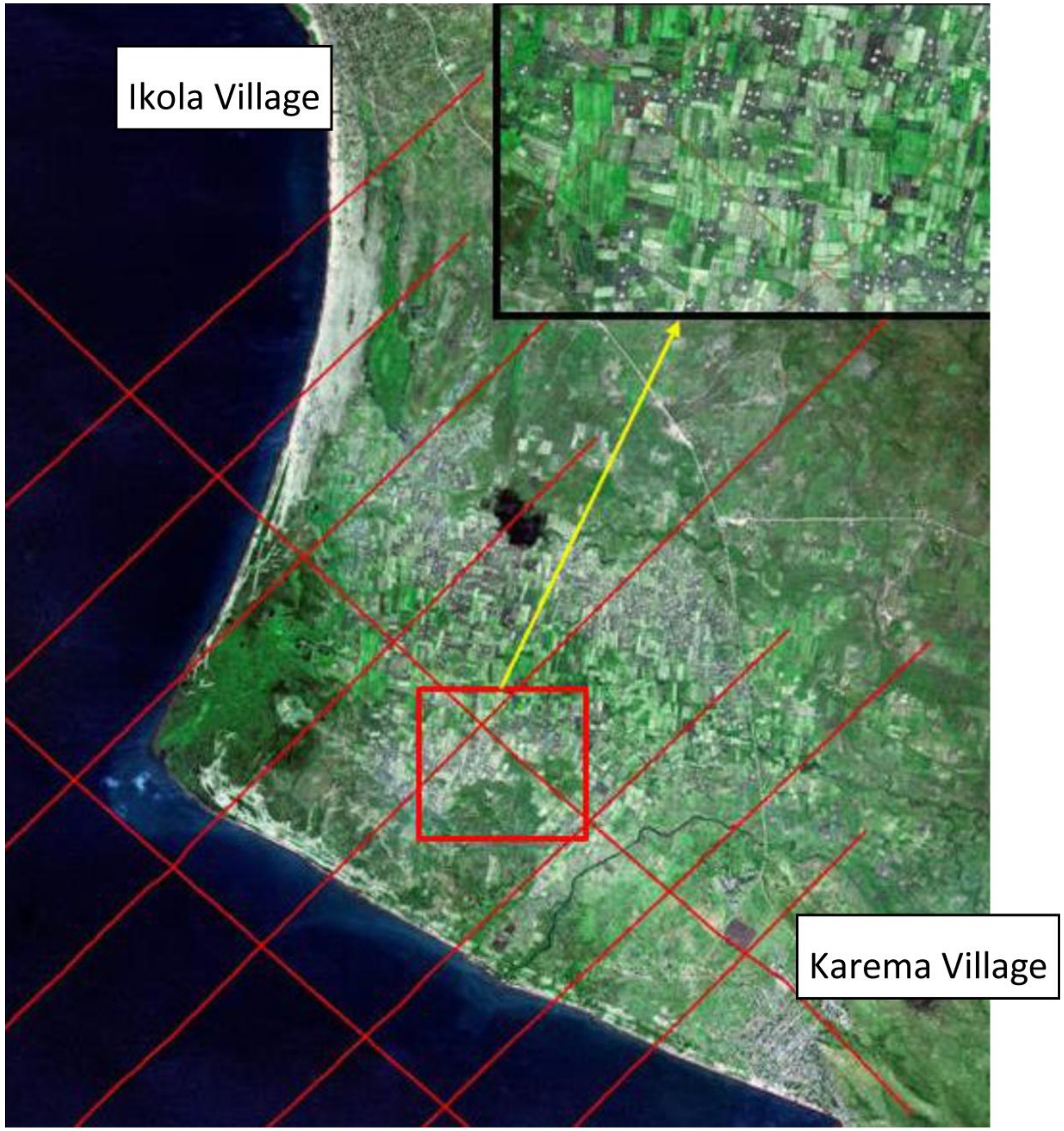

Figure 3. Location of TZ lines on satelite imagery showing villages and rice field locations

2D Transition Zone Survey Acquisition Parameters	
Full Fold	120 Fold(CMP=12.5m)
Spread roll in and roll out	
Source Data	
Source	Airgun/Vibroseis/Dynamite
Source interval	Land 25m; Marine 12.5m
No of Sources	Single or multiple
Receiver Data	
Receiver	Land Geophones/Marsh-Geophones/ Hydrophones/OBX
Receiver interval	Land 25m; Marine 50m
Spread Type	Symmetrical Split Spread
Far offset	2000m
Spread Length	4000m
Recording Length	6S
Sample Rate	2ms

Figure 4. Acquisition parameters

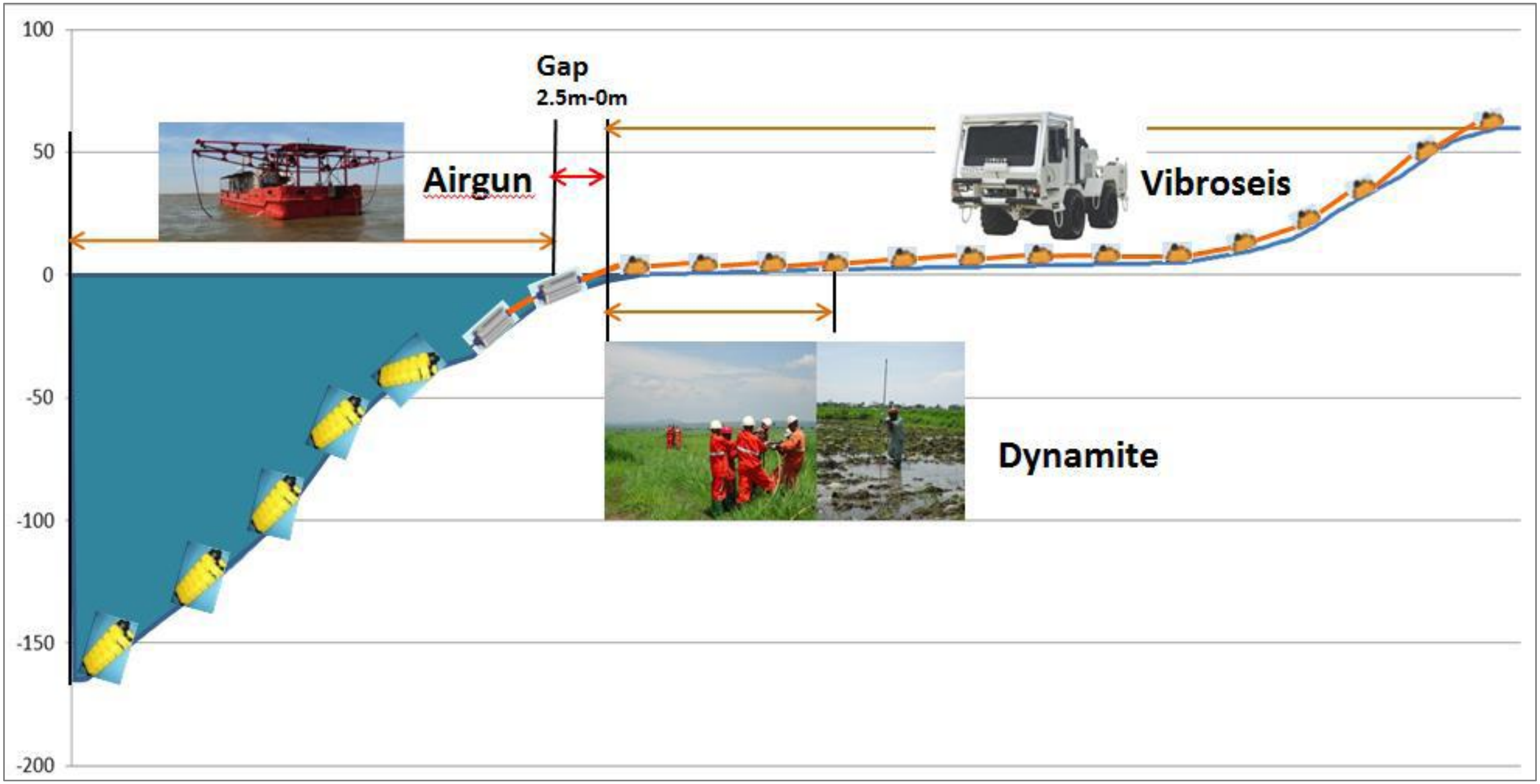

Figure 5. Source deployment

OBX	Rod hydrophone	Marsh phones	Geophones
Water (>=5m)	**Water (>=1m)**	**TZ zone (0-1m)**	**Land**
Geospace 4C Ocean bottom recorder	JSX-1	Strings of 12 x JF20DX-10Hz (6S/2P)	Strings of 12 x JF20DX-10Hz (6S/2P)
			

Figure 6. Receiver deployment (Recording system Sercel 428XL)

Figure 7. Rice fields before (left) and after rain (right)

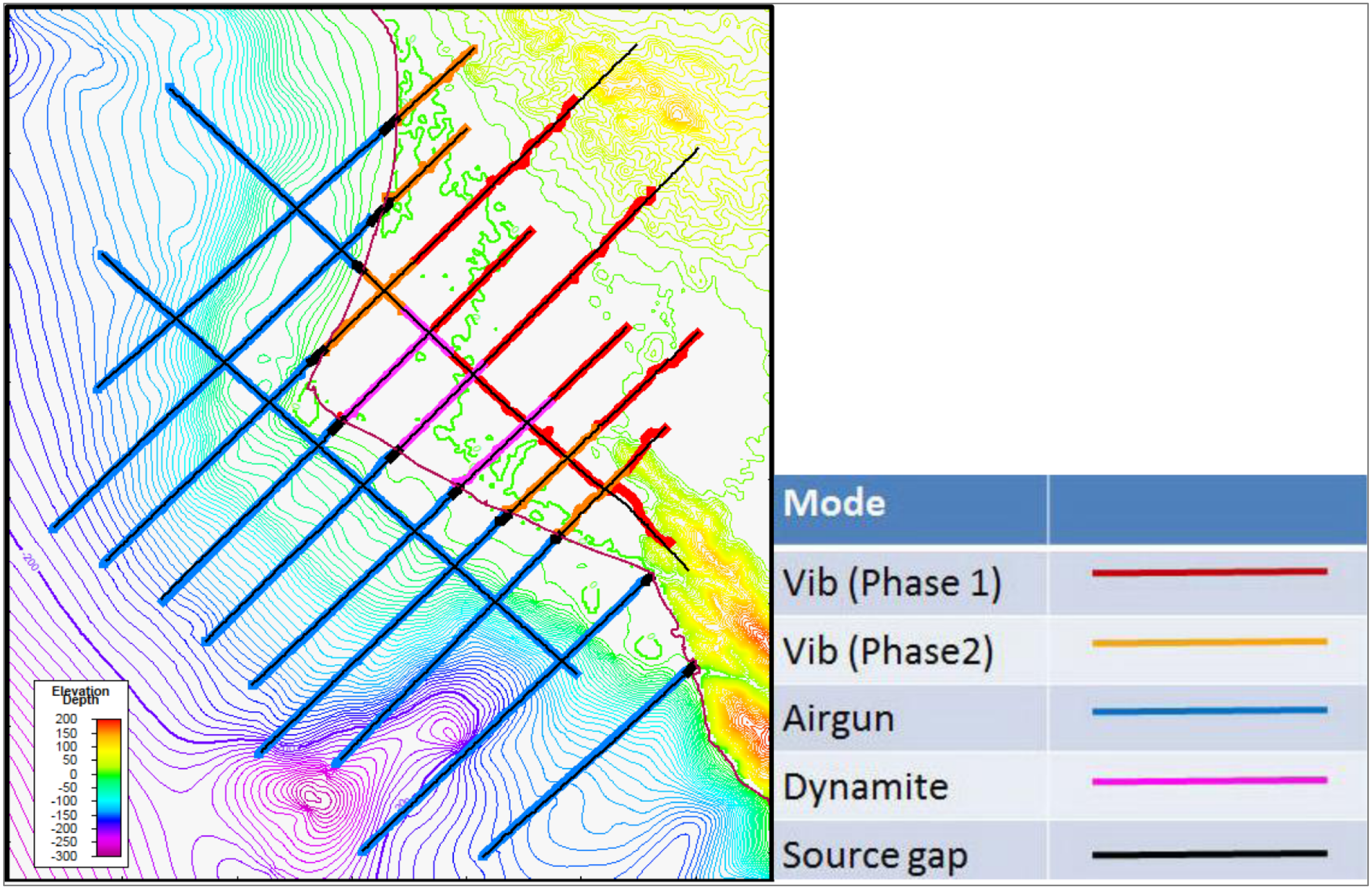

Figure 8. Source deployment

Figure 9. Local employment

Figure 10. Land Operations

Figure 11. Marine operations – Haibao towing Airguns

Figure 12. BGP Camp

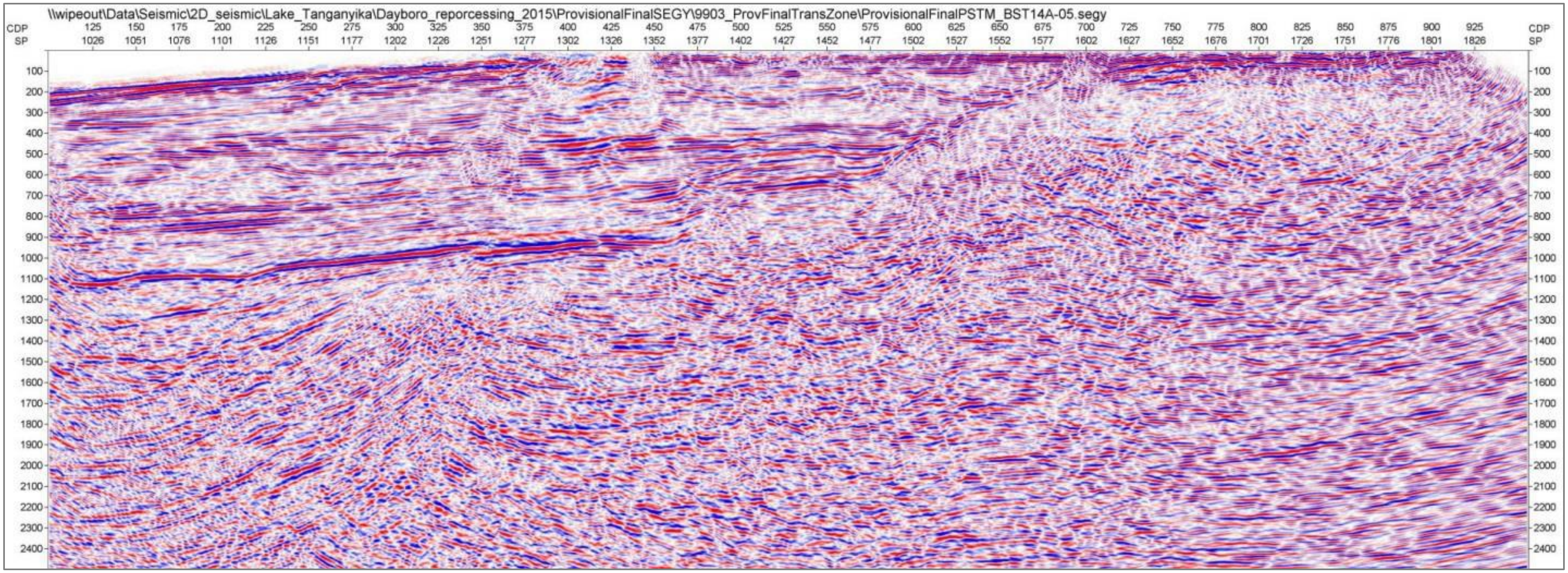

Figure 13. Processed TZ Line 5

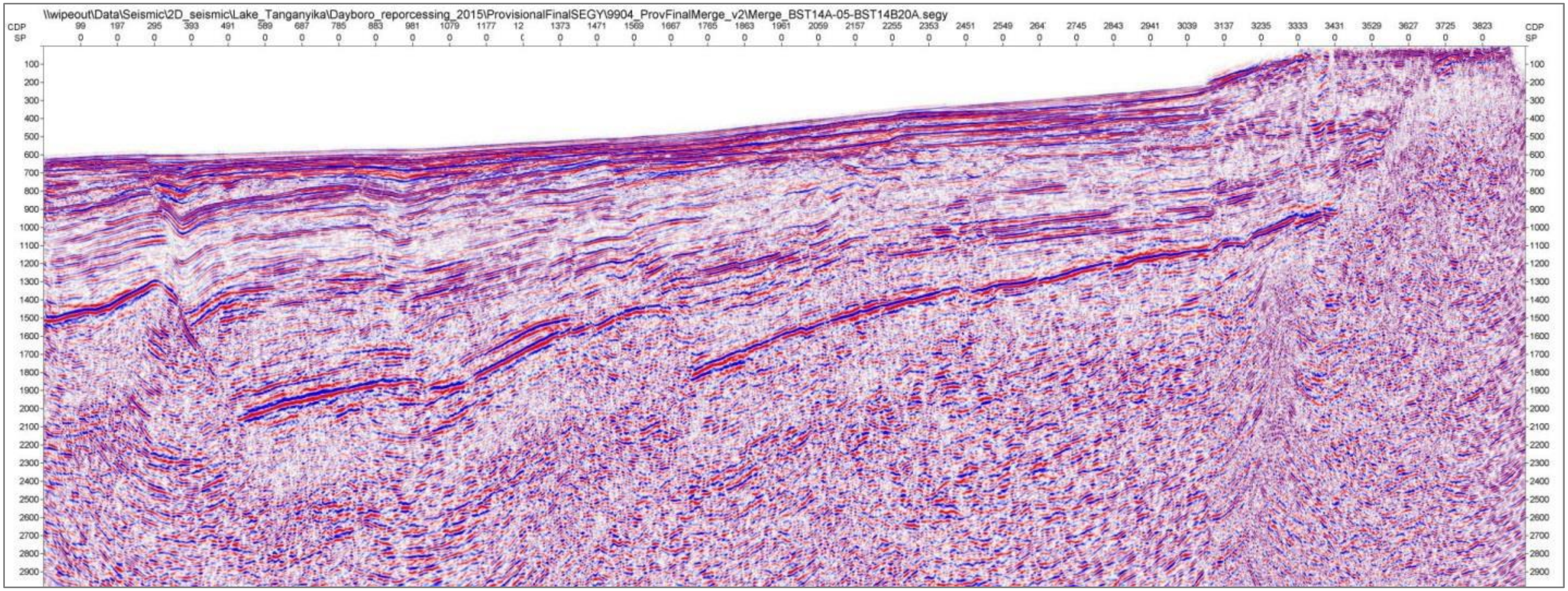

Figure 14. Processed merged line 5 and Marine line 20