AVO Screening in Frontier Basins: An Example from the Gulf of Papua, Papua New Guinea*

Amanda Davies[1], Cyrille Reiser[2], Bob Burmaz[3], and Rod Reed[3]

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[1]Petroleum Geo-Services Asia Pacific Pte Ltd., 111 Somerset Road, TripleOne Somerset, Singapore, 239899 (amanda.davies@pgs.com)
[2]Petroleum GeoServices, Petroleum Geo-Services, 4 The Heights, Brooklands, Weybridge, Surrey, KT13 0NY, UK
[3]PGS Australia Pty Ltd., Level 4, IBM Centre, 1060 Hay Street, West Perth, 6005, Australia

Abstract

There has been a recent resurgence of interest in the gas potential of the Gulf of Papua enhanced by ExxonMobil's recent announcement of the development of new LNG facilities on the East Coast of the Gulf. New 2-D and MC3D surveys have been acquired over the area in recent times. The most recent being PGS's Solwara MultiClient 3D survey.

Although most of the discoveries in Papua New Guinea are from the highland areas the Gulf is a proven hydrocarbon province with gas/condensate accumulations previously discovered in several reef build-ups. Exploration in the Gulf has mainly been near-shore and exploration has then concentrated on Miocene biohermal reef build-ups on pre-Mesozoic highs. Gas accumulations have been discovered along this reef trend, namely the Pasca and Pandora Fields.

During the Late Miocene to Early Pliocene clastic sediment input resulted from compression and uplift of the hinterland. Sediments from the Papuan Fold Belt produced clastic dominated deltas into the Gulf area. These are thought mainly to be deposited in the topographic lows or low relief structures and may have bypassed the rapidly growing compressional highs. Although this play is untested offshore there is good evidence that these sandy facies exist and could contain hydrocarbons.

On the first phase of acquisition tests was carried out using an efficient screening workflow called "Prospect Scanner" developed to highlight areas of Amplitude-Versus-Offset (AVO) effect in large 3-D seismic datasets. It uses pre-stack seismic gathers to extract AVO attributes, such as compressional and shear reflectivities, which are then recursively inverted to derive acoustic and shear

impedance volumes. These are then loaded into conventional interpretation package for further understanding of the lithology-fluid anomaly. Using idealized cross-plot derived from well data the relationship between Vp/Vs ratio and the Ip values give a good indication of the fluid and lithology of the tested interval.

The lead analysed shows a Vp/Vs anomaly shows ponding geometry which fits to structure down dip and relies on a pinchout at the crest of the structure. The Vp/Vs vs Ip cross-plot shows clustering of the sand anomaly and good separation from the majority of the plot. These points correspond to the idealized location for a gas sand in the crossplot.

Past concerns regarding lateral prediction of reservoir presence and quality associated with the basin floor fans can be addressed through this workflow.

Introduction

There has been a resurgence of interest in the gas potential of the Gulf of Papua, offshore Papua New Guinea enhanced by ExxonMobil's recent announcement of the development of new LNG facilities on the East Coast of the Gulf. Petroleum Geo-Services Asia Pacific has completed the acquisition and processing of a significant MultiClient 3D (MC3D) seismic survey project, which totals approximately 6000 km^2 over operated permits PPL234, PPL312, and PPL244 (Figure 1). The exploration targets in these blocks are slope and basin floor fan sands and carbonate build-ups (pinnacle reefs) with target depths between 1500–3000 m. The Gulf of Papua ranges in water depth from 0–2000 m.

The Solwara MC3D survey is only the second 3-D seismic survey to be recorded in this area (the first 3-D was acquired by PGS in 2008). The survey area includes part of the route for the planned ExxonMobil operated PNG LNG Project which will take gas from a number of large fields in the highlands to an LNG plant near Port Moresby, thus high-grading access to infrastructure for any future gas discoveries in the area. The gas will be sourced from onshore prolific areas of the Southern Highlands of PNG where gas fields such as Hides, Angore, and Juha gas fields are located. Associated gas from the Kutubu, Agogo, Moran, and Gobe Main oil fields will also contribute to the project.

The Gulf of Papua

Although most of the discoveries in Papua New Guinea are from the Papuan Fold Belt highland areas, the Gulf of Papua is a proven hydrocarbon province with gas/condensate accumulations previously discovered in several reef build-ups. Exploration in the Gulf has mainly been onshore and near-shore. The first well drilled in the basin in 1913 was onshore targeting a surface mapped anticline of the Aure Thrust Belt - an extension of the Papuan Fold Belt (see Figure 1) - and reported oil shows. Most of the onshore exploration has targeted these easily mapped thrust structures. In 1967 the first offshore well was drilled targeting a Miocene-Pliocene reef on the shelf edge and encountered gas condensate. Exploration has since concentrated on Miocene biohermal reef build-ups on pre-Mesozoic highs. Gas accumulations have been discovered along this reef trend in Pasca, Pandora, and Uramu (offshore) and Elk/Antelope (onshore). Vintage seismic in the offshore basin is generally poor in quality, with short lines and shallow record lengths. In 2006 Fugro and Searcher acquired an extensive long-offset non-exclusive 2-D seismic survey in the eastern part of the basin, focusing on the extension of the Aure Thrust Belt offshore and into the Coral Sea.

The offshore Gulf of Papua has a complex tectonic history. Research is still on-going as to the age of the basin and the origin of the pre-rift sediments. There have been multiple phases of compression, extension, and reactivation from the Triassic to present creating a variety of structures and play types. The current compressional regime was set up in the Middle Oligocene when the Melanesian Arc and the Australian Craton started to collide (Pigram et al, 1990). Pre-existing structural highs in the foreland were reactivated and formed ridges for reef growth and by the Middle Miocene an extensive carbonate platform had developed. The growth of this platform ceased in the Middle to Late Miocene due to a regional sea level fall. During the Late Miocene a major sea level rise led to the complete drowning of the reef. It was initially buried by shales and as the compression and uplift of the hinterland continued into the Early Pliocene, clastic sediment input resulted (Evgueni et al, 2010). Sediments from the Papuan Fold Belt produced fluvial dominated deltas into the Gulf area. The course grained sands associated with these deltas are thought mainly to be deposited in the topographic lows or low relief structures and may have bypassed the rapidly growing compressional highs (Jablonski et al, 2006). Although this play is untested offshore there is good evidence that these sandy facies exist and could contain hydrocarbons.

The Data - Solwara MC3D

The main area of focus for the Solwara MC3D seismic data processing was the very shallow and the very deep intervals. Careful processing has been performed over this area with the main aim of enhancing the Pre-Stack Time Migrated (PSTM) gathers and preserving the Amplitude-Versus-Offset (AVO) behaviour. The shallowest data down to one to 1.5 seconds exhibits a combination of carbonate layers, isolated carbonate fragments, trapped gas, and gas chimneys, all of which contribute to strong and rapid changes in amplitude. Particular attention was required to the conditioning of the shallow data in order to minimize any acquisition footprint and at the same time honour the real amplitude variations. As for the deeper portion of the volume, the dominant Miocene carbonate layer was an obvious target for imaging, particularly with the prominent pinnacles such as Pasca. However, an additional goal was to image the dipping structures below the main carbonate layer which are often missing on vintage 2-D.

The Solwara MC3D survey is designed to tie the many play and prospect elements found in the Gulf of Papua. The 3-D dataset ties the Pasca gas field (Figure 2), together with the wells at nearby Pasca-C and extends along the Miocene reef trend to the northeast, covering the Flinders Prospect (Pliocene basin floor fan) and finally into the offshore extension of the Aure Thrust Belt. In the past the

Miocene carbonate platform was interpreted to be overlying a shallow basement. With this modern dataset, seismic imaging below the platform is possible and Jurassic and Triassic play types are evident along with potential Permian syn-rift sediments.

The Method - Prospect Scanner

The Flinders Prospect located in PL244 permit is one example of a Pliocene basin floor fan prospect that exists in this region. It has multi Tcf potential with an associated AVO amplitude anomaly. Although the first phase of acquisition and processing did not cover this particular prospect, testing was carried out on the dataset to screen the volume for other, similar, anomalies using a proprietary workflow: Prospect Scanner. Prospect Scanner is an efficient AVO screening workflow developed to highlight areas of AVO anomalies in large 3-D seismic datasets. It was used to highlight whether similar fans existed in the 3-D that were not apparent on the vintage 2-D. The workflow uses PSTM seismic gathers to extract AVO attributes, such as compressional and shear reflectivities by AVO curve fitting - (Shuey (1985) 2 or 3 term depending of the maximum angle available on the dataset) - which are then inverted to derive relative acoustic impedance (Ip) and relative shear impedance (Is) volumes. The compressional to shear velocity ratio (Vp/Vs) is simply derived from the Ip and Is estimation. The advantage of this workflow is that it does not require any well calibration so a low frequency model is not required. Available wells, if there are any within the survey, would be used to validate the results and/or to have a clear idea of the seismic phase of the seismic data. Those relative elastic attribute data volumes (acoustic impedance, shear impedance, and Vp/Vs ratio) are then loaded into a conventional interpretation/visualisation package for further understanding of the lithology-fluid anomaly distribution in 3-D. As this workflow is not calibrated to well information the interpretation of the elastic attributes are done using general elastic response for the clastic sediments encountered into the volume. We should expect for instance having the gas sand reservoirs with low Vp/Vs ratio and low acoustic impedance (Figure 3). The relationship between Vp/Vs ratio and the Ip values give a good indication of the fluid and lithology distribution of the tested interval in 3-D.

Results

Out of this first phase of the results an amplitude lead, similar to the Flinders Prospect, which is evident on the full-stack seismic volume was chosen for detailed analysis. It displays a strong Vp/Vs response indicting the anomaly is fluid related. The lead exhibits a ponding geometry which fits to the structure down dip and relies on a pinch-out at the crest (Figure 3a). Channels sands are evident along the Miocene carbonate ridge, sourced from the shelf break and feeding the ponded sand body. The Ip vs Vp/Vs cross-plot shows clustering of the sand anomaly (pink) and with a good separation from the majority of the plot (Figure 3b). The points highlighted could potentially be a gas sand reservoir (Figure 3c). Further calibration of this elastic response could be revisited when additional information becomes available (i.e. well logs).

Conclusions

Multiple risks have been mitigated through the acquisition of this 3-D dataset, and the prospectivity of the Pliocene play has been high-graded. Past concerns regarding lateral prediction of the Pliocene reservoir sands and the quality associated with the basin floor fans can now be addressed. The use of Prospect Scanner to derive relative elastic properties from seismic data provides stratigraphic seismic attributes for the identification and discrimination of fluid and lithology facies. The process is useful for the efficient regional 3-D AVO screening of pre-stack seismic attributes for field discovery and prospect delineation over large 3-D datasets.

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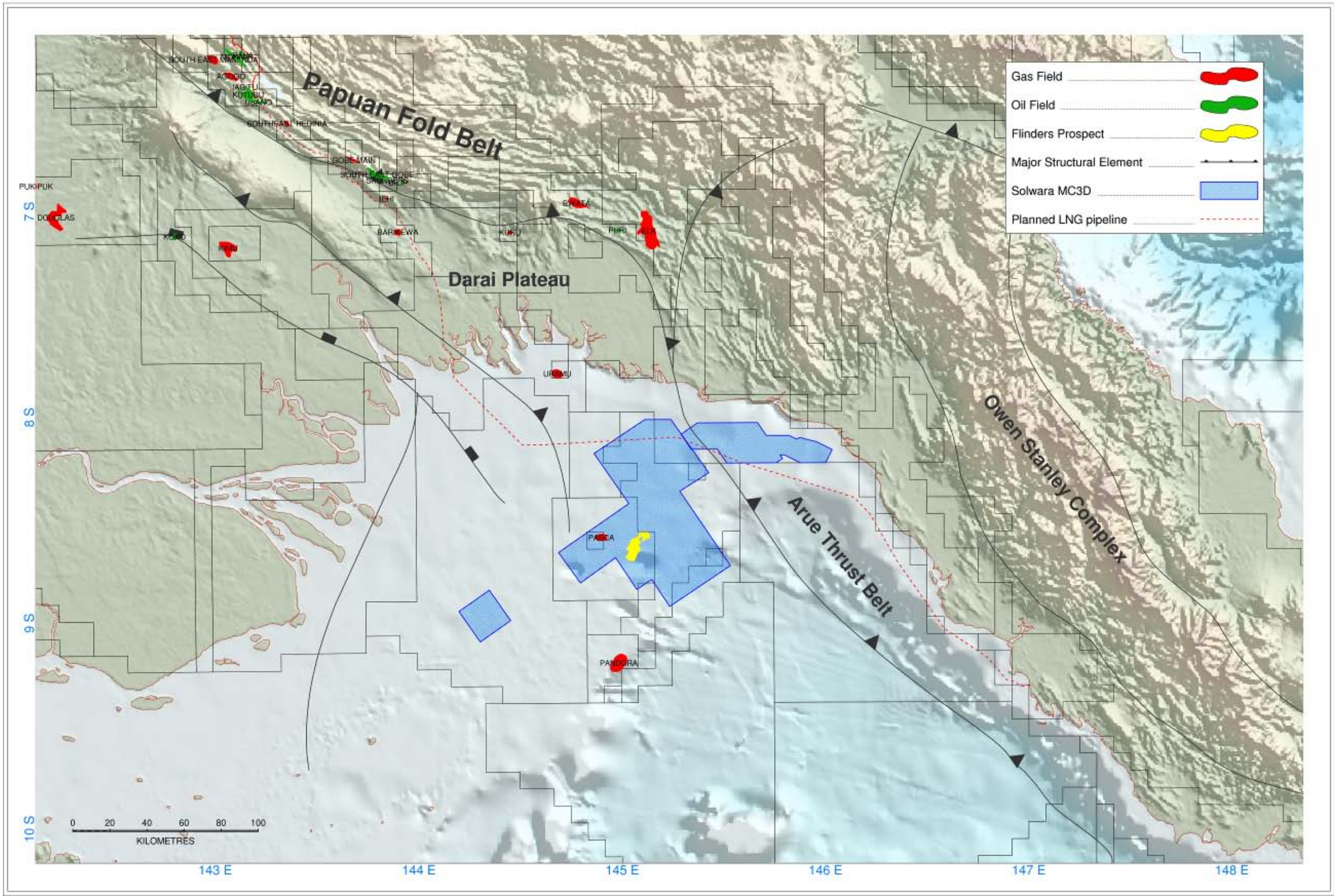

Figure 1. Solwara MC3D location in the Gulf of Papua showing major structural elements and oil and gas fields.

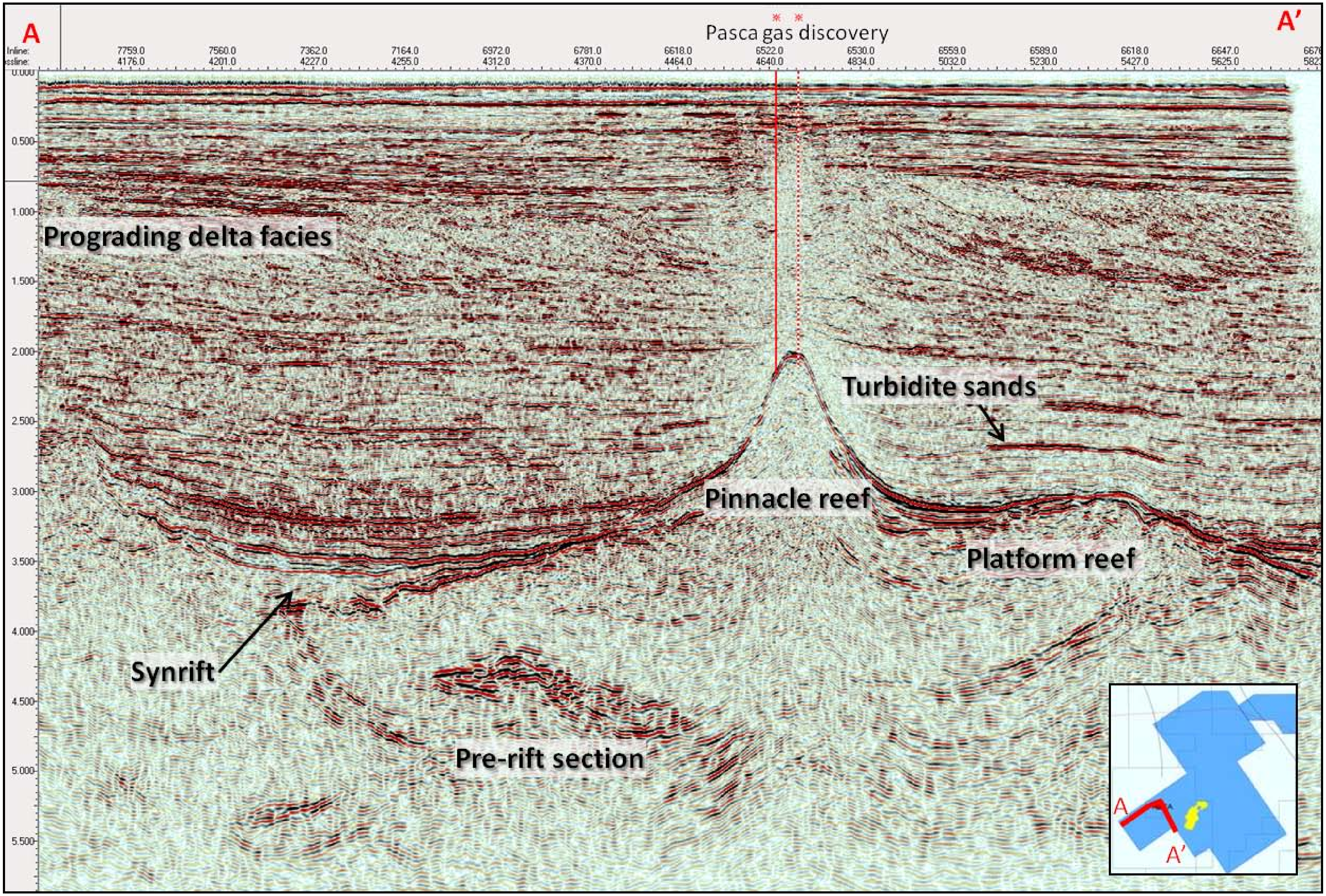

Figure 2. Arbitrary seismic cross-section showing main play elements in the Gulf of Papua. Previous seismic has failed to image beneath the platform carbonates and this area was previously thought to have shallow basement.

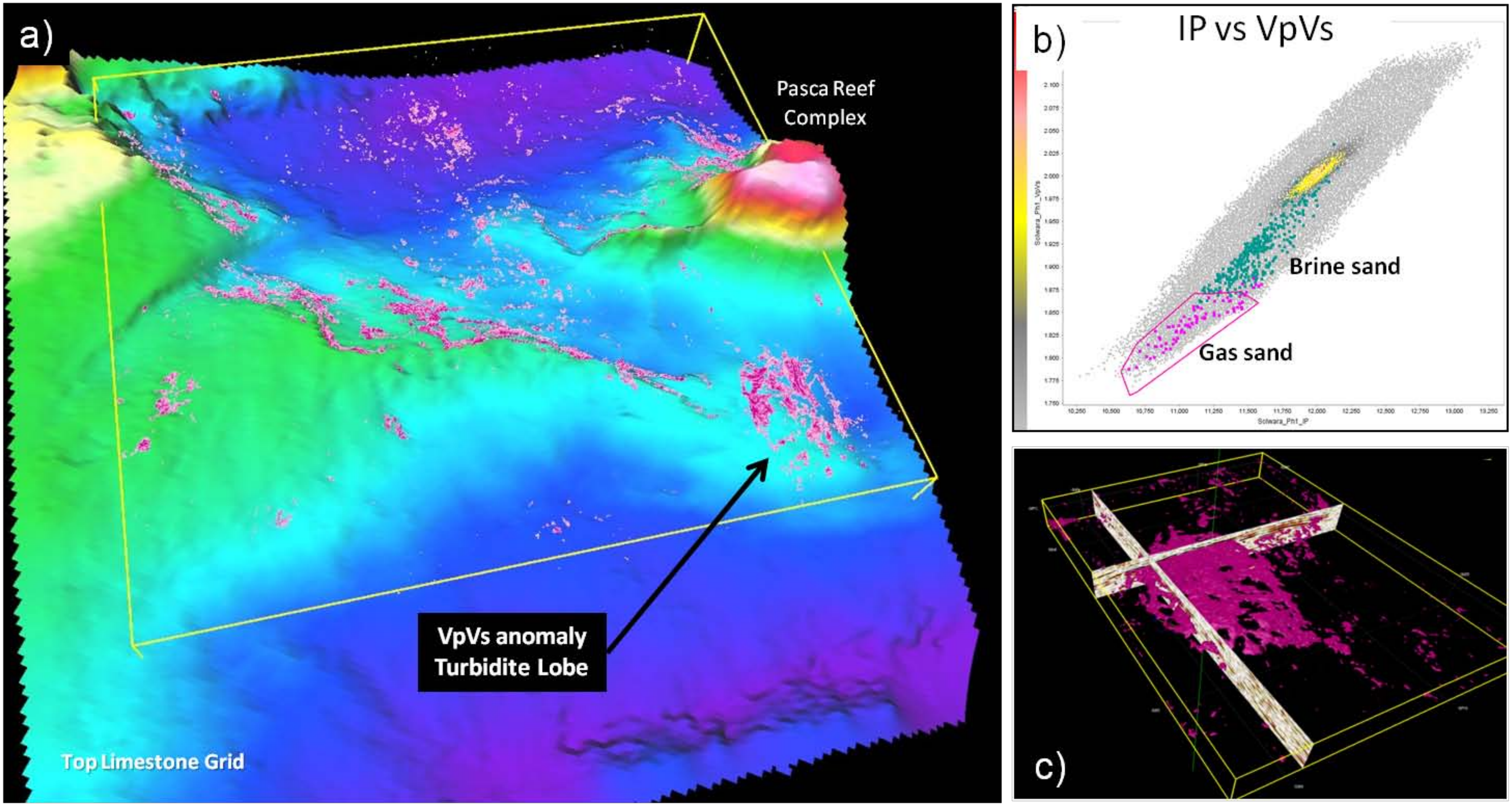

Figure 3. a) Prospect Scanner Vp/Vs volume rendered to show channel sands and ponding geometry of a prospective turbidite lobe. b) Cross-plot of Ip and Vp/Vs showing clustering in the 'idealised' location for gas sands. c) Points in the clusters gas sand above correspond to the same location/geometry of the turbidite lobe.