

RAY-BINNING ANGLE STACK DOMAIN IN ENHANCING THE ROBUSTNESS OF CONVERTED-WAVE SEISMIC JOINT INVERSION

APLIKASI METODE PENGELOMPOKAN SINAR GELOMBANG-SUDUT DATANG DALAM MEMPERBAIKI KUALITAS PENERAPAN METODE JOINT INVERSION PADA GELOMBANG SEISMIC TERKONVERSI

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ABSTRAK

Aplikasi seismik dengan memanfaatkan gelombang terkonversi P-S telah terbukti sebagai alternatif dalam membantu data seismik konvensional mencitrakan kondisi bawah permukaan terutama untuk kasus medium dengan keberadaan akumulasi gas dekat dengan permukaan. Binning dalam pengolahan data gelombang seismik terkonversi, pada umumnya dilakukan dengan teknik asymptotic conversion point (ACP) dalam domain pasangan source-conversion point-offset. Dalam studi ini, pasangan source-conversion point -offset diusulkan diurutkan dengan menggunakan teknik penyortiran ulang common-ray atau pengelompokan sinar gelombang bersama dengan menerapkan hukum Snellius. Dengan menerapkan teknik ini dihasilkan korespondensi profil sudut dengan sudut datang gelombang P-P. Menyortir kembali sudut gelombang terkonversi ke propagasi gelombang P-P pada titik pencitraan bersama, akan didapatkan sinar gelombang terkonversi pada kisaran sudut yang sama. Sehingga akan membantu dalam meningkatkan kualitas pengelompokan area bersama antara gelombang refleksi P-P dan gelombang terkonversi P-S yang digunakan sebagai input untuk pengolahan data dengan metode Joint Inversion. Hasil penerapan metode ini, telah terbukti dapat menghilangkan bayangan yang muncul sebagai noise pada zona patahan dan iluminasi akibat efek penyerapan energi gelombang keberadaan akumulasi gas dekat permukaan. Hasil akhir dari pencitraan adalah bahwa kualitas seismik gelombang P-P menjadi lebih koheren sesuai dengan kondisi model bawah permukaan dan kualitas hasil joint inversion menjadi lebih bagus dengan kualitas hasil pencitraan V_p/V_s yang jauh lebih bagus.

Kata Kunci: pemodelan full waveform, pengelompokan sinar gelombang-sudut datang, gelombang seismik terkonversi, joint inversion

ABSTRACT

Converted-Wave Seismic has been proven as imaging alternative in aiding conventional seismic data when passing through gas cloud accumulation. However, asymmetrical approximation effect during Converted-Wave Seismic binning still remains in offset domain. PS-Reflection events in offset-domain are mapped using common-ray re-sorting technique by implementing the basic Snell's Law of Mode Conversion. This produces an Angle Profile correspondent with the PP incident angle. Re-sorting the angle

of converted-wave ray path to the PP-Wave propagation within the common imaging point, the Converted-Wave seismic would share similar angle range. Thus, improving the match in PP to PS event as data input preparation for Joint Inversion. Grouping the angle based on AVA Analysis, followed by stacking the Angle Profile into Common-Ray Partial Angle Stack, had proven to eliminate the fault shadow sagging zone and gas absorption illumination area in Converted-Wave Seismic. The final result of PP-Seismic imaging is more coherent with the Converted-Wave Seismic, in term of event alignment and amplitude character. This result lead to more robust PP-PS Joint Inversion, as the coherency between input data is an important key in simultaneous process. The comparison on derived V_P/V_S shows better improvements of subsurface imaging, especially in the near-surface gas masking area of conventional seismic.

Keywords: full waveform modeling, ray-binning angle stack, converted wave seismic, joint inversion.

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I. INTRODUCTION

The presence of shallow depth gas cloud accumulation is generally identified through an area of severely degraded seismic data imaging which often showcasing an amplitude wash-out due to the extreme velocity contrast between the gas saturated zone and beneath area. Latiff (2016) defines several major factors that triggering the seismic imaging degradation bellow the gas could zone, as follow; the gas bearing layer velocity, the depth of reflector, the source – receiver placement during seismic acquisition, and the seismic signals' frequency.

The shallow gas accumulation would then become even more problematic when facing a structurally trapped hydrocarbon reservoir. Appearances of fault shadow illuminating the hydrocarbon bearing layer would further weakening the amplitude and distorting its exact location. Dipping structure appears as distorted reflection in Post-Stack Time Migration (PTM) seismic section. These fault shadow define as the zone of unreliable seismic imaging (Hardwick & Rajesh 2013) which occurs in plane with extreme dipping and complex geologic structures, such as major flower structure in this research.

Facing these challenging geological features, our previous research promotes simultaneous application of both conventional and converted-wave seismic method to reap the superiority of converted-wave seismic imaging. The PP-PS Joint Inversion result showcases a better imaging through gas cloud in term of reservoir delineation and elastic properties estimation, tribute to the converted-wave seismic

data complementing the imaging loss in conventional PP seismic data (Triyoso et al. 2017). The PS Seismic from multi-component seismic surveys have become quite the alternate method when the PP Seismic imaging suffer from poor quality due to gas cloud effect (Stewart et al. 1999, Thomsen et al. 1997). Furthermore, the converted-wave seismic also showcases the ability to identify the unique near surface anomaly, such as gas cloud body, due to a noticeably richer in number of event and appears more high-frequency than the PP seismic image in shallow target area (Triyoso & Oktariena 2018).

As the benefit of Converted-Wave Seismic has been proven, the next concern would be if it is possible to improve the imaging quality of conventional seismic data below the gas cloud. Regardless, our industry still relies on the P-Wave Seismic Survey for subsurface imaging. This research will showcase the alternative imaging technique that can be applied to the PP seismic data so it is possible to use the conventional imaging to create a subsurface profile with enhancement in layering below the gas accumulation zone. When event alignment between PP & PS Seismic data is obtained, the robustness of Joint Inversion will also increase, as the simultaneous nature of its process relies heavily on the coherency of input data.

II. METHODOLOGY

A. Introduction

As previously mentioned, one of the factor in seismic image degradation below the gas cloud is the source – receiver placement during the seismic

acquisition which could be translated into strategic offset or angle. This particular factor would be the key in the following imaging technique reconstruction. To achieve the desired result, several steps are applied during this research as further described below.

B. Full Waveform Modeling

In order to obtain a better understanding in seismic imaging through a gas cloud, a full waveform simulation is conducted using elastic wave on subsurface model derived from real seismic data, based on result of Pre-Stack Depth Migration (PSDM) processing (Triyoso, et. al., 2016). The synthetic shot gather data of the full wave modelling is recorded in vertical and horizontal component which would serve as PP & PS Seismic. The acquisition parameters are not particularly addressed the gas cloud problem or the flower structure condition.

C. Common-Ray Angle Profile Conversion & Re-Sorting

When seismic wave propagating in a solid material, one form of wave energy can be transformed into another form. For example, when a P-Wave is reflected at interface at certain angle, some of the energy can cause particle movement to start a reflected S-Wave. Mode of conversion happens when a seismic wave encounters an interface between materials of different acoustic impedances and the incident angle is not normal to the interface as described in Snell's Law Mode of Conversion (Daley 2001). Certain incident angle value that recorded as PP Seismic are corresponding with a specific con-version angle value that recorded as PS Seismic. However, in Converted-Wave Seismic Data Processing, the Asymptotic Binning would

process all the available offset recorded in seismic data, regardless the conversion angle of horizontal component has its counterpart in vertical component or not. Following Snell's Law, the incident angle of 30 degree would not counterpart with the conversion angle of 30 degree, due to the different in P-Wave and S-Wave Velocity.

This research will re-sorting the PS Seismic according to its PP Seismic counterpart by searching for the pairing of incident – conversion angle that shares Common-Ray Profile through the application of Snell's Law Mode of Conversion. By pairing the right angle, we will have another imaging insight of the gas cloud anomaly. Playing with offset and angle are necessary step to avoid the amplitude deteriorating in sub-layer below the gas accumulation.

D. Common-Ray Partial Angle Stack Grouping via Amplitude versus Angle (AVA) Analysis

Re-sorting the PS Seismic to match its counterpart PP Seismic showcases that there is much more data recorded angle-wise compared to the conventional seismic. While stacking suppresses random noise, one should be cautious to do that in environment of vast lateral change in velocity. Grouping the seismic into an effective range of crucial angle would avoid a loss in extreme dipping event that sometimes only recorded in certain angles. Amplitude Versus Angle Analysis is conducted to obtain the exact angle range in tar-get area, which is Two Way Time (TWT) of 1000 – 1600 msec (Figure 3), for both PP & PS Seismic.

E. PP-PS Joint Inversion

Joint Inversion is a model-based inversion that runs simultaneously, estimating the Z_p , Z_s , and γ

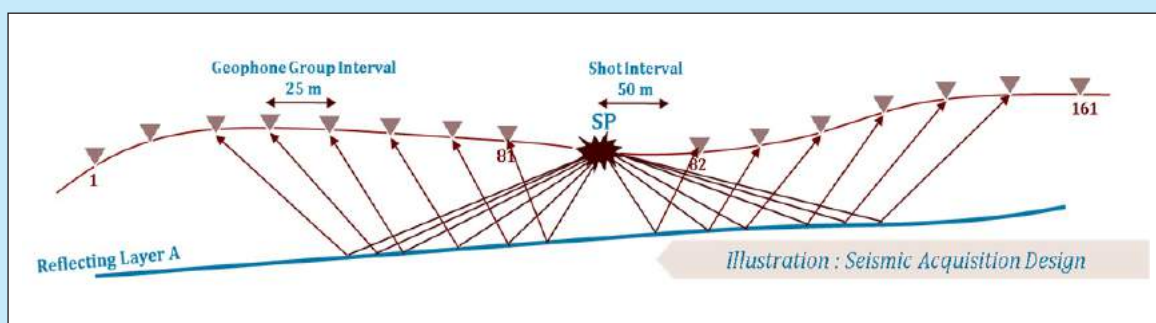


Figure 1
Illustration of seismic acquisition design for this research 2D full waveform seismic modelling. The simulation shoots with split-spread geometry.

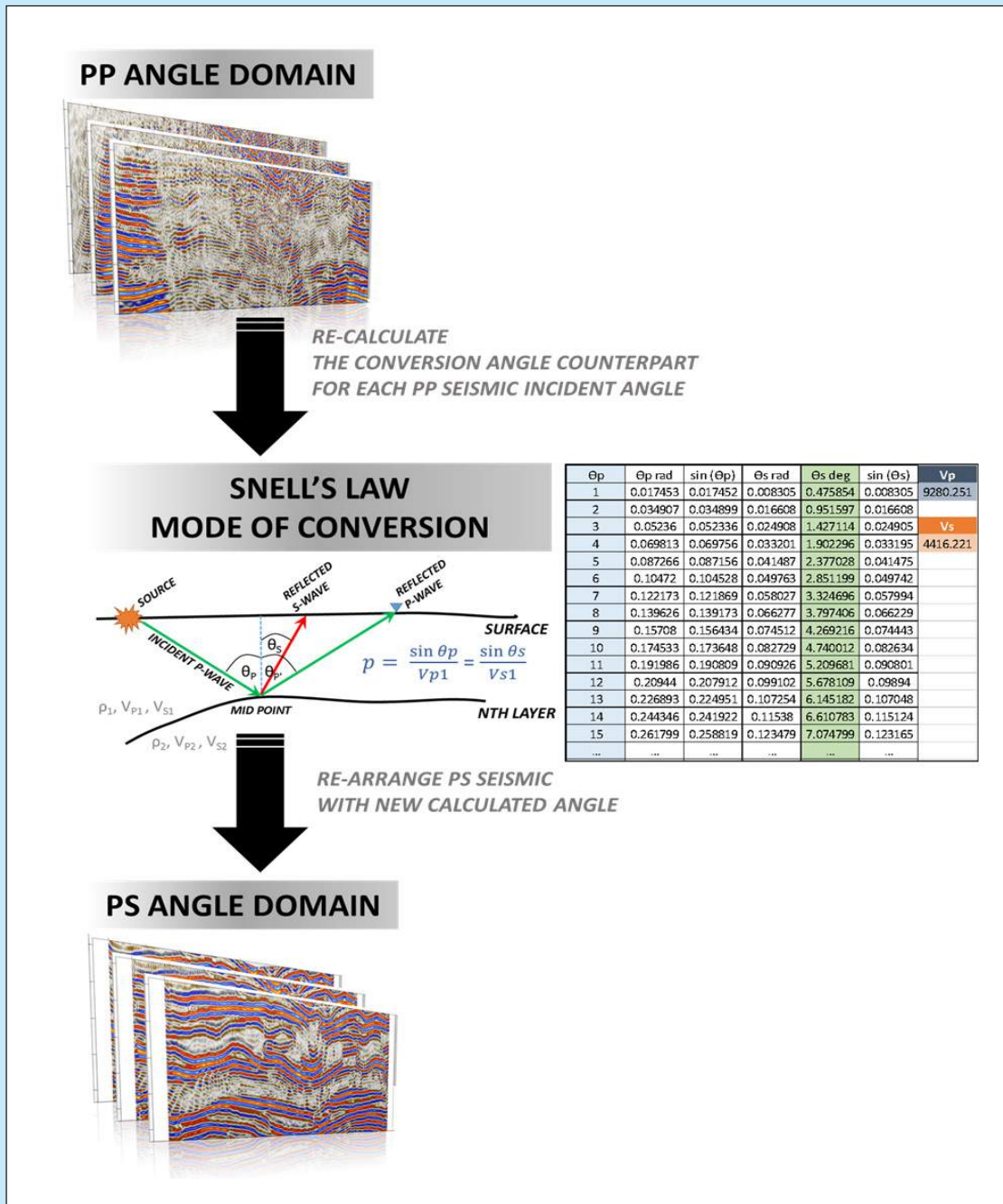


Figure 2
Scheme of re-sorting conversion angle of PS seismic with its incident angle counterpart of PP seismic by applying Snell's law mode of conversion.

that are consistent with the coupling of PP and PS amplitude as input (Stewart 1990, Margrave et. al., 2001). Domain Conversion and Joint Model Building are the core of a precise PP-PS Joint Inversion (Triyoso et al. 2016, 2017). The unique condition of PS Reflectivity which is showcasing a different reflection position and being recorded in different

travel time to thus of PP Seismic Survey makes the process of Joint Inversion between these two datasets somewhat complex but not uneasy. The key to this process is to make sure both data sets as coherent as it could be in term of reflectivity position within the time domain

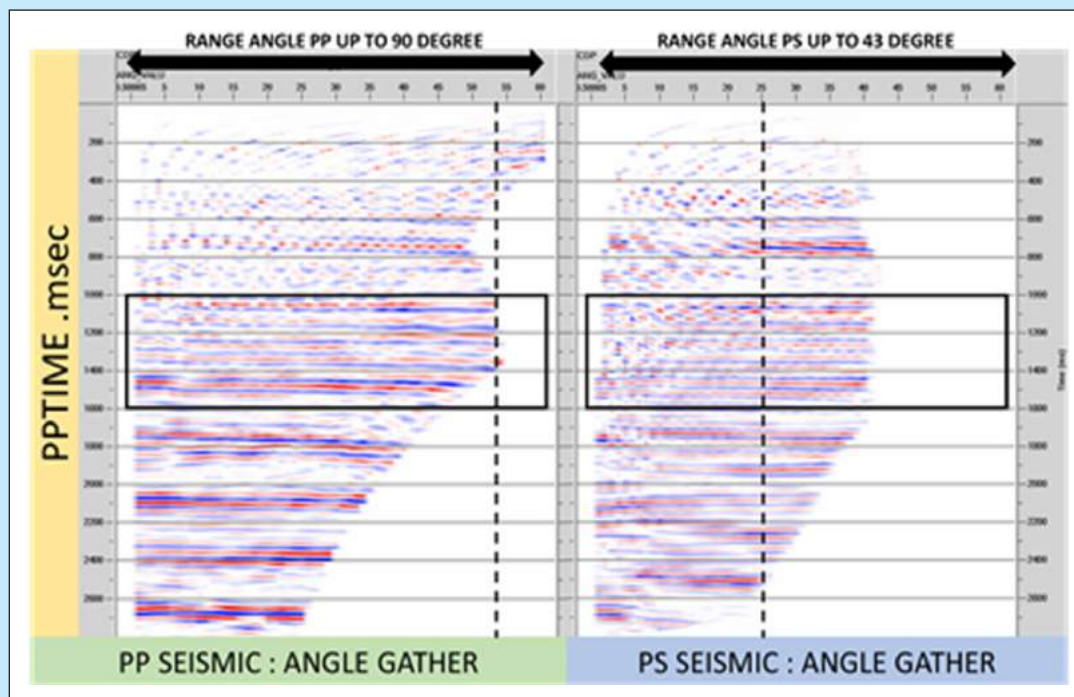


Figure 3
Amplitude versus angle analysis focusing on area inside the black box shows that the effective angle for PP seismic ranged from 0 – 55 degree and the conversion angle of PS seismic counterpart ranged from 0 – 24 degree. However, as shown in the right side area of dashed black line, there are still a lot recorded data left in PS seismic.

III. RESULTS & DISCUSSION

The presence of gas cloud hinders the possibility of reservoir imaging through only P-Wave Seismic data, especially Post-Stack Time Migration (PTM) Seismic since it is not a friendly method to deal with a dipping structure which often only recorded on certain angle of incident. Assuming the incident angle as zero is out of question in dealing with flower structure below gas cloud accumulation where this research took place. With this challenging geologically and complex velocity wise feature, rearranging our point of view regarding offset and incident angle as seismic feature has proven as a necessity.

The result of our previous research relies a lot in Converted-Wave Seismic to guide the P-Wave Seismic Imaging in term of structural aspect. It is a bit concerning how the PP Post-Stack Time Migration Seismic could degrade so much in the presence of near surface gas accumulation as can be seen in Figure 4 below. The illumination area inside white box, which coincidentally where the reservoir zone

located, shows a rather homogeny layering and none of the complex flower structure at all.

In the previous study (Triyoso, et al, 2016, 2017), the PP Seismic is not comparable in term of structural imaging sub-layer below the gas cloud, with the Common-Ray in Angle Domain technique, the resulted PP Seismic has an overall similar structural imaging to the PS Seismic which also reflected how the initial subsurface model is. The gas illumination effect that still very apparent in PP PTM Seismic is completely vanished as can be proven through a richer number of events with a balanced amplitude level inside the white box area in PP Common-Ray Angle Profile. Still, the PS imaging has greater trace continuation due to not affected by the slight velocity lateral different which is caused by hydrocarbon saturation. The PP imaging shows an apparent lateral amplitude change in reservoir zone, particularly the pinching out at the edge of the hydrocarbon saturated area indicated by the low velocity zone inside the black box (Figure 4).

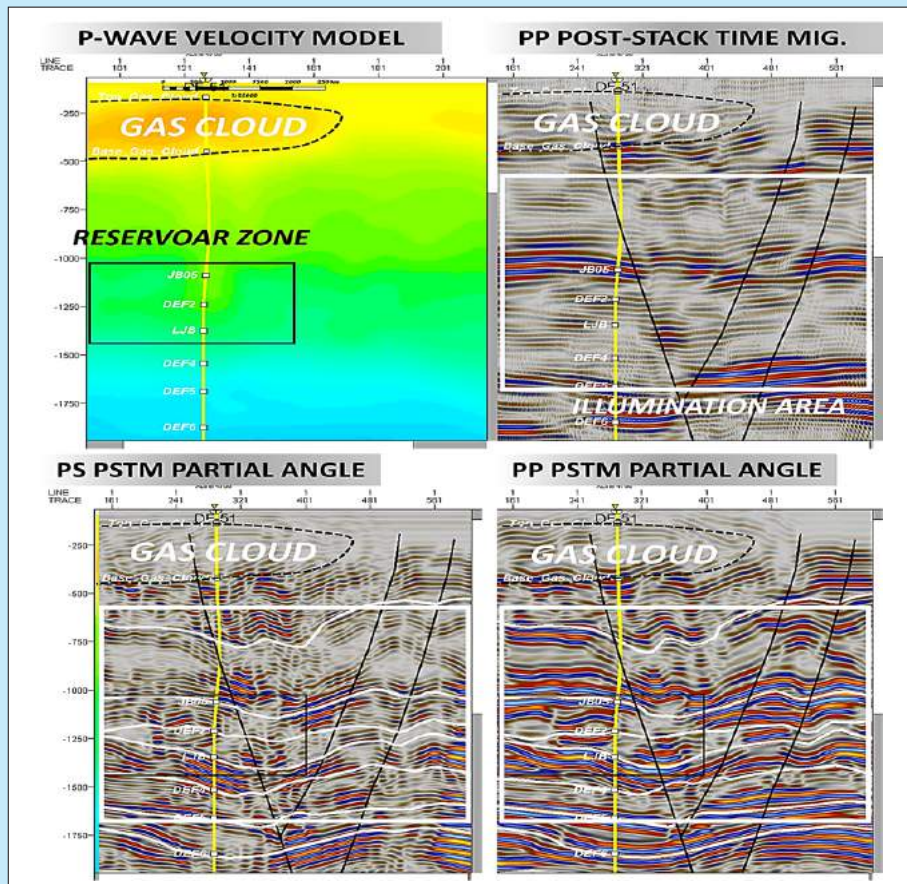


Figure 4
Comparison of initial model, PP PTM, and PP&PS common-ray partial angle stack shows improvement in imaging through a gas cloud.

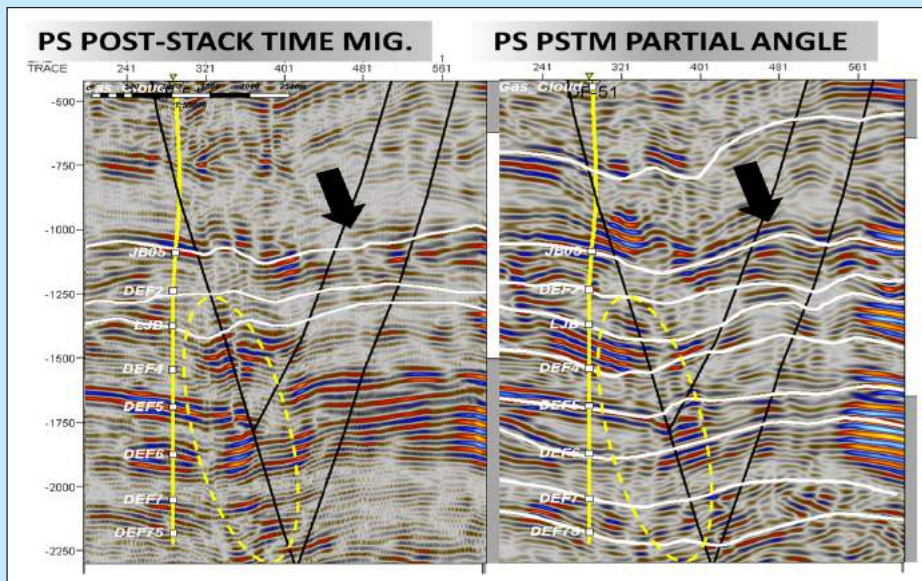


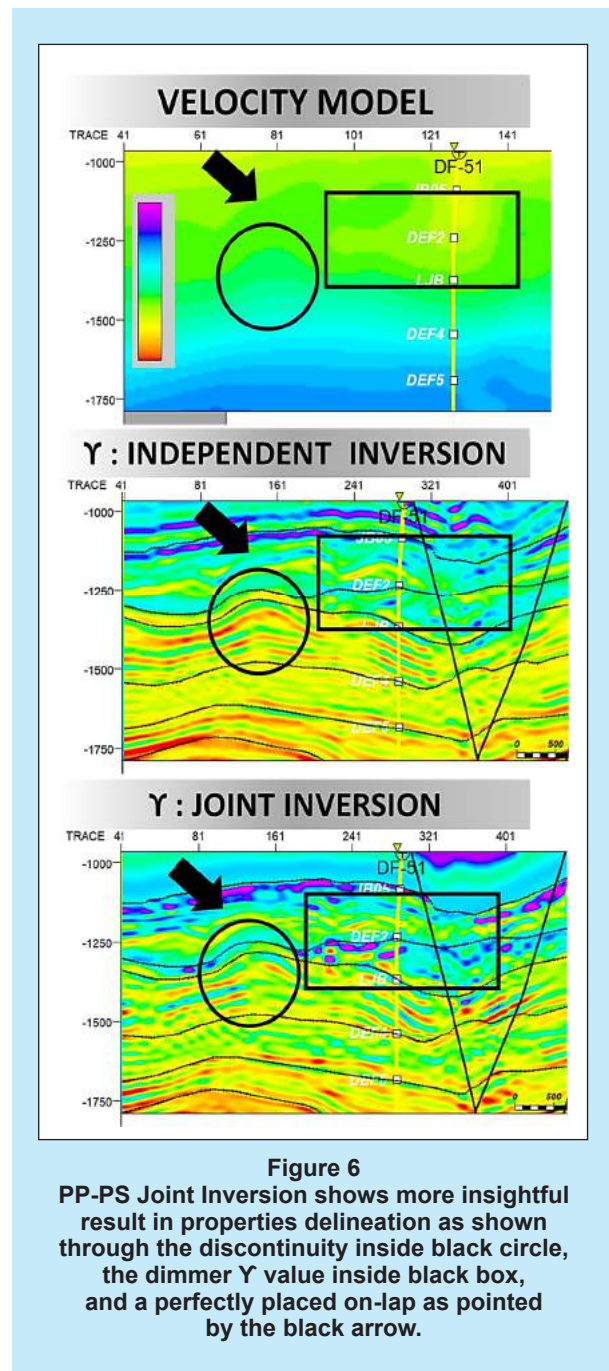
Figure 5
PS common-ray partial angle stack (right) shows no fault shadow inside the yellow dashed circle and as pointed by the black arrow which previously still unclear in PS PTM (left).

By treating the seismic in Angle Domain, this research aware that eliminating the gas cloud is not a choice. Instead, this research focuses in accommodating the subsurface condition below the gas accumulation to its proper treatment. For example, grouping the Angle Domain into Common-Ray then doing a partial stacking instead of full data stacking has a purpose to avoid a loss in dipping event which could be essential in flower structure imaging. In addition, applying Pre-Stack Time Migration (PSTM) instead of PTM is also adding the benefit of eliminating fault shadow as can be seen in Figure 5.

As the PP Seismic imaging now generally similar to the PS Seismic imaging in structural aspect, the Joint Inversion enhances its robustness in term of event alignment stability. This is one of the two crucial aspects in a fruitful simultaneous inversion. Our previous research in near surface condition concludes that Joint Inversion is not applicable in shallow gas cloud identification due to a very apparent contrast in reflector behavior (Triyoso & Oktariena 2018). The algorithm is only effective in a level where the number of event and event alignment are similar. The increasing in the PP Seismic resolution through Common-Ray Angle Domain technique surely derives more stable environment in the algorithm simultaneous processing. Also, with the improvement in PP Seismic imaging, the Joint Inversion does not relies solely on the PS Seismic for structural enhancement. This condition is apparent in the result, where the Gamma γ (V_p/V_s) result of P-Impedance (Z_p) & S-Impedance (Z_s) Independent Inversion is not that different structure wise compared with the γ result of PP & PS Joint Inversion. But, alas, in reservoir characterization wise, the γ result of PP & PS Joint Inversion still showcase a more sensitive result to lateral properties change.

IV. CONCLUSIONS

The advantage of Converted-Wave Seismic in imaging through a gas cloud has been extensive proven. Providing a clearer imaging without the influence of gas illuminating effect, the PS Seismic imaging guides the conventional seismic (PP) imaging that suffers reflected amplitude wash-out sub-layer below the shallow gas cloud. A concern of enhancing the conventional seismic imaging to par with the Converted-Wave Seismic imaging has led this research to retreat and regroup in order to



see the same problematic conventional P-Wave Seismic survey from another side, which is in Angle Domain. Re-sorting the conversion angle based on Snell's Law Mode of Conversion and re-grouping the conventional PP Seismic into its effective angle range are resulting in a PP Seismic imaging that similar in structure to the PS Seismic and a PS Seismic imaging that fault shadow free. Looking through the Common-Ray seismic data in Angle Domain certainly reduces the elimination of dipping structure which usually occurs during the stacking and post-stack migration process. The resulted PP

Seismic is comparable to the PS Seismic, thus, this imaging technique could be a suitable alternative for conventional seismic data that suffers from gas cloud problem. Furthermore, the enhancement in number of event and event alignment between PP & PS Seismic data leads to a more robust PP&PS Joint Inversion.

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