Future of Tunu Field Development: A Breakthrough of Gas Sand Identification Using Automated Seismic Assessment*

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Abstract

Tunu is a giant gas field located below the present-day Mahakam Delta, East Kalimantan, Indonesia. Since launched in 1990, more than 1100 development wells have been drilled with the cumulative production of >9 Tcf. The field is divided into two intervals, Tunu Shallow Zone (TSZ) with a depth of 500-1500 mSS and Tunu Main Zone (TMZ) between 2500-5000 mSS. TSZ corresponds to Pliocene fluviodeltaic series where the gas reservoirs have limited surface extensions and are scattered all over the field. Main lithologies in the interval are shale, sand, and coal layers. The first TSZ development phase was launched in 2008. Recently more attention has been given to TSZ where most of the new wells are being drilled. The zone currently contributes 40% of the Tunu Field production.

The TSZ development relies heavily on the use of seismic to assess and identify gas sand reservoirs as drilling targets. Three seismic surveys (3D95, CT3D, and NWT3D) are available for this purpose. The main challenge for conventional use of seismic is differentiating the gas sands from the coal layers. In TSZ, gas sands are characterized by an established seismic workflow that comprises of analysis on prestack domain: angle-substacks, CDP gathers, amplitude versus angle (AVA), and inversion/litho-seismic cube.

From the 1-D modeling and drilled wells results, the water sands do not create an amplitude anomaly on seismic, due to their relatively similar petro-elastic behavior vs. surrounding shale. This means that any observed anomaly will correspond only to either gas sands or coal. In the Full stack seismic, the gas and coal layers are non-distinguishable. Both lithologies have equally low acoustic impedance, and thus give similar response on the Full and Near angle stack data (Figure 1). It is starting from the Far and Very Far that their reflection coefficients differ. Coal tends to be weaker (become closer to 0 reflectivity) and blend to the surrounding shale's response, whereas gas sands' reflections stay strong with the tendency of brightening towards the Very Far angle. This difference of the AVA gradient is also confirmed while extracting the amplitude value in the pre-stack gathers.

To date, more than 150 seismic-driven wells have been drilled with a success ratio of 82% in finding the targeted reservoirs, hence making the workflow reliable. However, assessing each seismic anomaly to determine potential gas sands in the area of 1350 sq km would be a lengthy procedure. This triggered the need of a quicker approach that can mimic and automate the seismic workflow in the most efficient manner. A geomodel was therefore built to have an exhaustive and comprehensive view of all potential gas sands in the TSZ.

Automation of Seismic Assessenmt Methodology

Structural Model and Attributes Extraction

The geomodel construction started with structural horizons layering which is called isoproportional layer. The horizons were adjusted to several maximum flooding surfaces correlated on hundreds of wells as the references. The isoproportional layer is basically a structural layer which is created by dividing the seismic surveys into several vertical proportional layers. The layer thickness is dependent on seismic resolution in order to optimize the preservation of the bright negative anomalies that represent the gas related seismic anomalies.

The field structural framework is considered as simple layer cake, where detail correlation on geological markers was used to tie the structural framework. The horizontal cell geometry is adapted to the size of the seismic bin (to preserve the seismic resolution) and the average cell height is adapted to the isoproportional layer thickness to capture the variation of seismic amplitude, vertically (Figure 3; step 1).

Seismic attributes were extracted and inputted into the structural grid for each interval in the previously defined isoproportional layer. Some of the most important attributes are minimum (negative/trough) amplitude corresponds to the presence of gas reservoirs (bright anomalies) and type of lithology, and the other one is Root Mean Square (RMS) corresponds to seismic background amplitude and gas reservoir thickness.

Geobody Creation

In TSZ development, the extension of gas reservoir (reservoir area) is defined by bright anomalies up to a specific “cut-off” value where the probability to find gas outside that value is low. The reservoir geometry which is shown afterwards by this cut-off limit certainly needs to be confirmed by detailed gather analysis, consistency of reservoir geometry in all seismic sub-stacks, and a rational geological shape (Figure 2a). The easy and rapid way to define cut-off would have been to use a unique amplitude cut-off (single value) and apply it into the entire field. However, this method is only valid when applied in seismic with constant amplitude distribution. In the Tunu Shallow case, the amplitude variation appears in all seismic surveys. There are local contrasts of amplitude and gradation of seismic energy from one side to another. Consequently the cut-off should be varied with the seismic quality, laterally and vertically. Applying single cut-off into this kind of seismic would have delivered irrational anomaly shape and reduce or boost up the area of the considered gas reservoir anomaly. Therefore independent cutoffs are required to accurately distinguish all seismic anomalies. It was then decided to develop an automatic 3D cut-off methodology to accelerate the process (Figure 3; step 2).

The main principle to build the automatic independent cut-off is that the cut-off value will be dependent on seismic quality, represented by the local background amplitude. RMS is an attribute that is sensitive to the energy of the seismic, thus it is selected to capture the background amplitude variations. Based on a feasibility analysis of several anomalies (~300 samples), it appears that a good correlation exists between background amplitudes and the cut-off values defined manually. From this correlation, the cutoff law is generated and applied into RMS attribute which have been assigned into the cell grids (full field scale). The product is a 3D cut-off (cube) consisting of individual cut-offs respecting the local variation of amplitude and background energy level. The cut-off cube is applied to filter the low value of the minimum amplitude attribute, thus only bright anomalies above the cut-off were preserved. The result illustrates a full field inventory of potential anomalies, represented by ~25,000 geobodies, which need to be further assessed since those geobodies are not only gas bearing sands.

Geobody Classification

Each anomaly is then classified as gas or coal category through detailed assessment of their AVA response, which would be time consuming if done manually. In order to tackle this drawback, a quantification of amplitude behavior is done by generating and comparing the ratio between Far angle stack amplitude and Very Far angle stack amplitude for a given anomaly. This approach has a relatively similar concept to the gather analysis. Lithology classification is defined empirically by detailed analysis of the threshold ratio (VFar/Far amplitude ratio) on some representative anomaly samples (~600 samples). Most of gas sand samples show a high ratio while coal samples generally present low ratios. Some gas with coal risk samples were mixed in between those two ratios. Despite these minor overlaps of gas with coal risk, most of the gas sand and coal samples are well separated.

Practically, two limits of the ratio are defined to classify the geobodies into three categories: low ratio geobodies are categorized as “Coal”, high ratio geobodies are categorized as “Gas”, and intermediate ratio geobodies are categorized as “Gas possible” (Figure 3; step 3). In order to validate the approach and reliability of the result, a probability of success for “Gas” and “Gas Possible” was estimated by comparing the geobodies which were already penetrated by wells. The success ratio of “Gas” category is 80%, which is close to success rate of the drilled wells in finding targeted reservoirs (~80%) and this demonstrates the robustness of the methodology. Success ratio is lower for “Gas possible” (50%-60%) but it is still high enough to pay attention to this category. Through this classification, half of the TSZ geobodies exhibit typical gas reservoir response.

Resource Estimation

Once the “Gas” and “Gas possible” geobodies are distinguished from “Coal”, the final step is to properly assess the resource of each reservoir. Reservoir area can be directly measured from the size of the geobodies, while net pay is calculated as a function of amplitude (Figure 2b).

TSZ gas accumulations have very limited net pay (average ~7 m), which is below the seismic resolution (15-20 m). The fact that all seismic anomalies are in the tuning domain, however, has an advantage since there is a correlation between amplitude strength and gas bearing thickness. This correlation had been calibrated on drilled seismic anomalies. Considering that the net pay is a function of amplitude, the net pay prediction in the model can be automatically derived from the extracted minimum amplitude. Other parameters that might affect the amplitude-net pay relation are the petrophysical properties of the gas sand reservoir and the interference from other lithology with low impedance response (generally coal). Those parameters are also integrated to enhance the accuracy of the prediction.

Petrophysical parameters (porosity and saturation), gas formation volume factor and recovery factor are derived from empirical laws calibrated on existing data. By having all parameters for the calculation, the resources of TSZ can be estimated simultaneously from all potential geobodies. The stacked resources are being used to highlight the most interesting location with the highest resource accumulation in TSZ (Figure 3; step 4).

Integration of Subsurface Targets, Drilling Envelope, and Surface Facilities

The geobody inventory allows the integration of subsurface targets, well trajectory initiation, and surface facilities constraints, which is essential to maximize the well's economic (Figure 3; step 5). To simulate the drilling constraint, a cone filter was built using distance versus depth function representing a maximum well departure allowed by drilling envelope (50 degree maximum inclination and 3 degree/30 m maximum dog-leg severity).

First type of cone filter is built from existing platforms, which is performed to capture all potential drilling candidates reachable from the existing wellheads. All geobodies that have been penetrated by Tunu wells are marked to keep only the potential undrilled developable targets; drilled and produced geobodies will be updated regularly as new wells will be drilled. This type of cone filter is very useful to define main priorities for the next well candidates since the well will be more economic and no additional cost for laying a new pipeline.

Second type of cone is built from the actual bathymetry survey map to integrate rig access restriction on land area. The purpose is to identify and estimate the accumulation of all geobody resources that reachable from an accessible possible surface location with current drilling envelope. The filter is created by classifying the bathymetry map into several water depth categories and then eliminates the possibility to put the platform outside the designated depth range. This will help to foresee the possibility to drill targets that cannot be accessed from existing platform and to spot the prospective new well head location. The final output is a collection of geobodies that can be reached from a corresponding platform, either the existing platform or the new location.

Conclusions

Automation of seismic assessment in TSZ has been effectively accelerating the well preparation processes. Several high stakes well proposals have been initiated by using this geobody inventory/ geomodel, especially in areas with relatively weaker and subtle seismic anomalies, unidentified by conventional interpretation technique. Excellent results are delivered by latest drilling status, which verify the reliability of this geomodel methodology. An additional contribution of the geomodel for future development scheme is it might provide complete outline for the next well candidate: number of wells accessible from existing facility, better time allocation for drilling sequence, and also a global view of remaining resources of TSZ. Today, up to 1400 anomalies are classified as potential drilling targets. With the recent downturn of gas prices, this geomodel is considered a key in identifying economical wells to support TSZ development.

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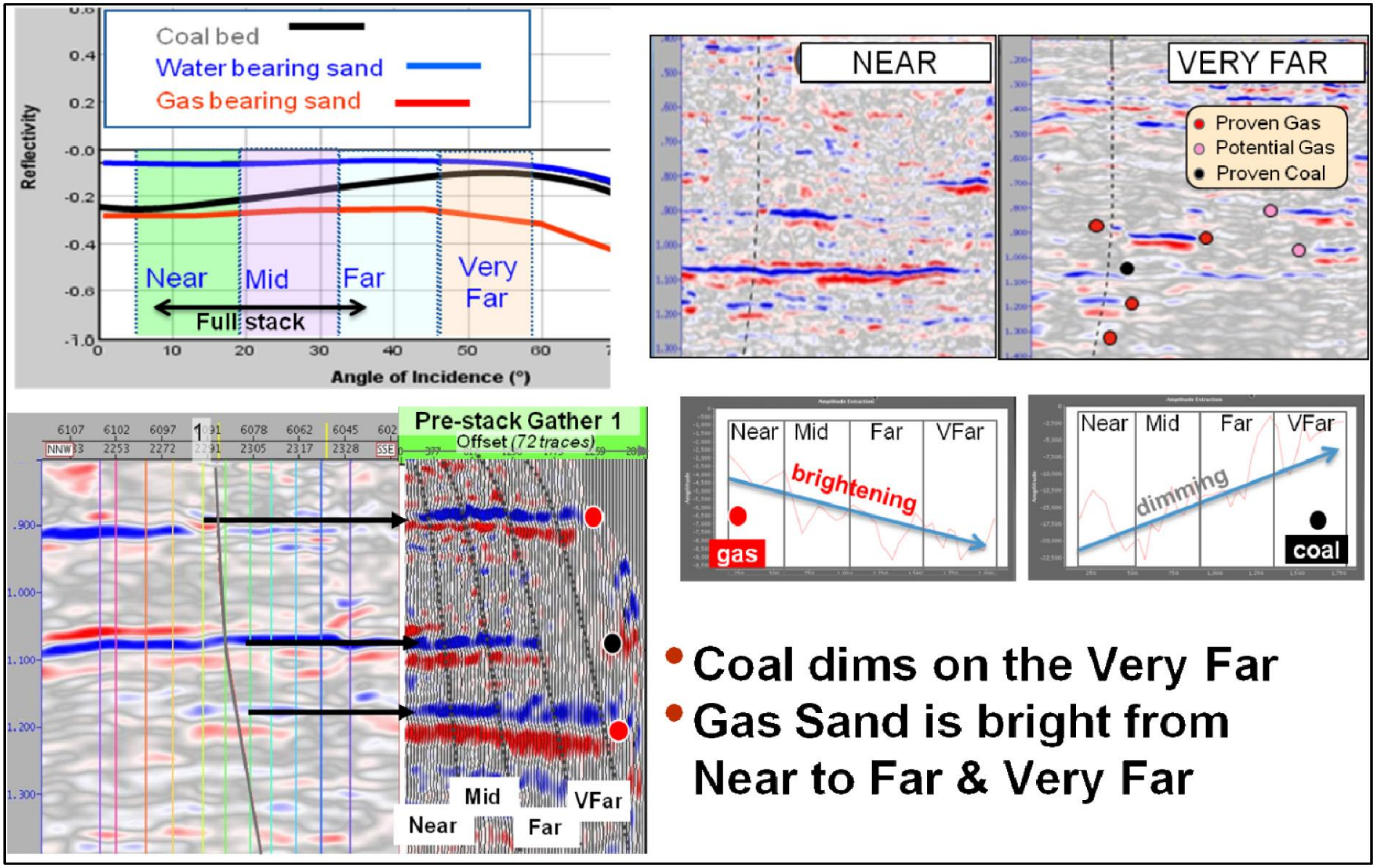

Figure 1. Identification of gas sands in Tuna Shallow Zone (TSZ). Use of prestack seismic is fundamental to distinguish gas sand from coal.

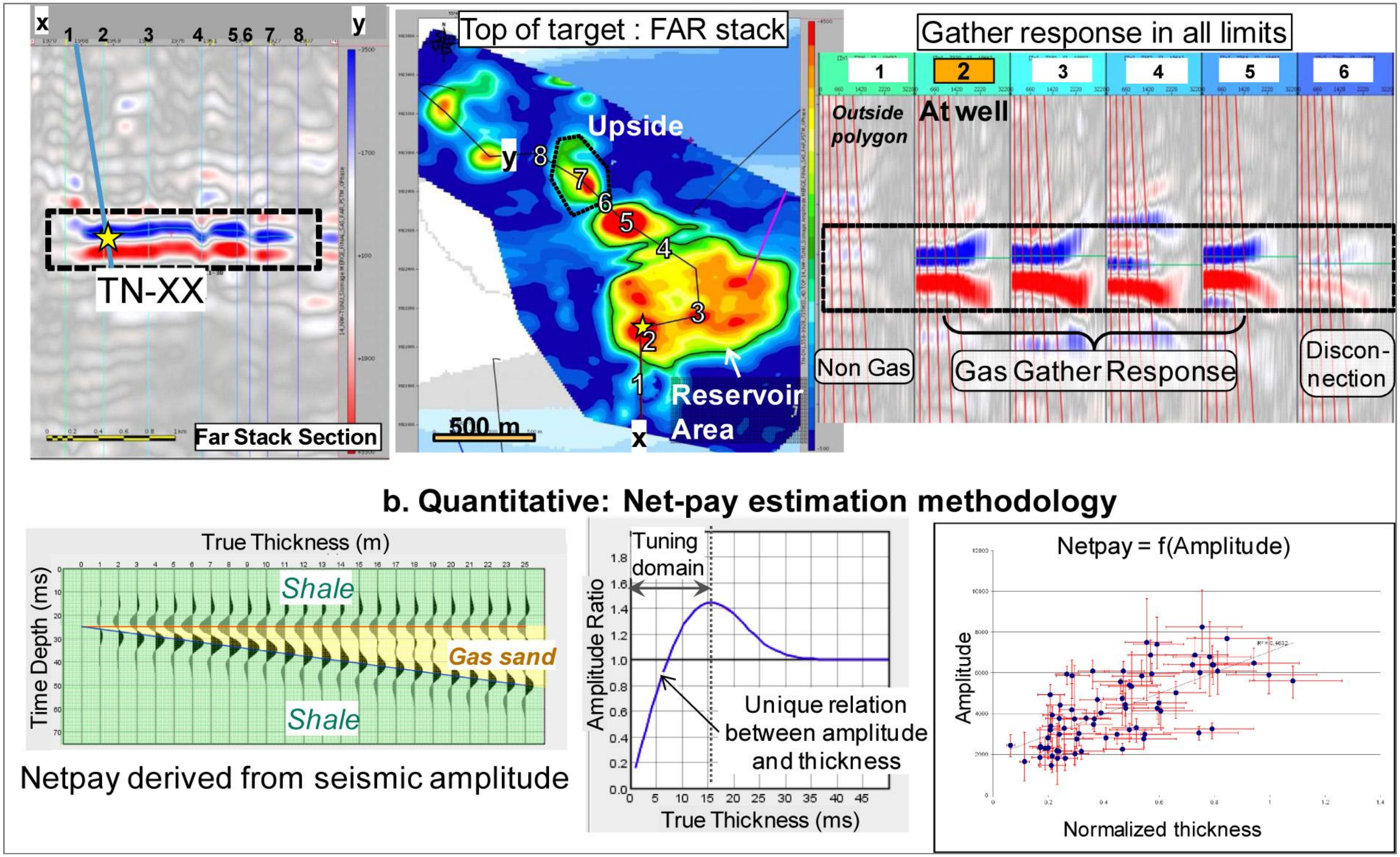

Figure 2. TSZ seismic methodology best practice. (a) Gas anomaly identification and definition of reservoir Area, (b) Netpay estimation from seismic amplitude.

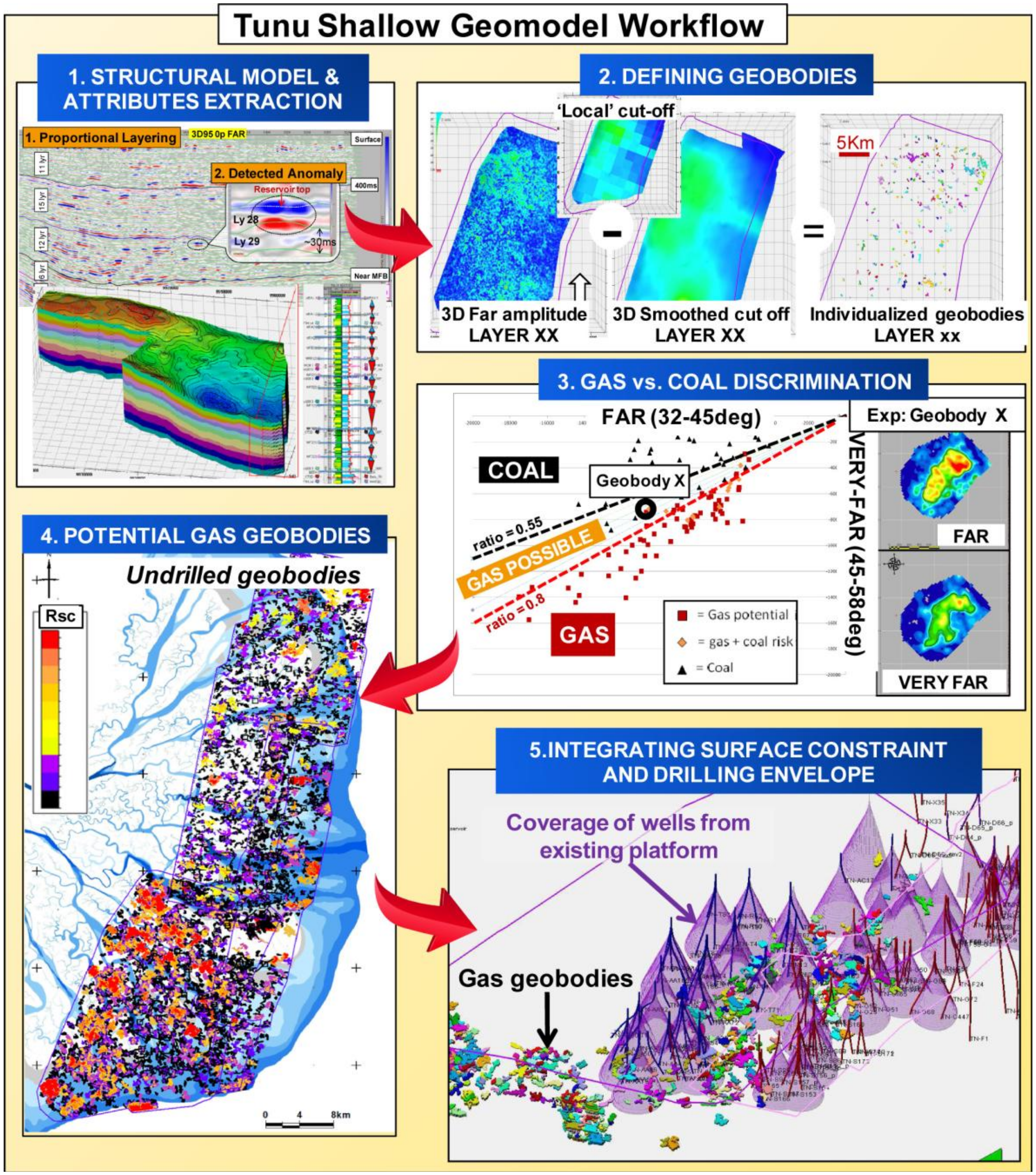

Figure 3. Automation of Tunu Shallow methodology to define seismic anomalies, discard coal, and assess gas sand volumetrics for future drilling targets.