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Determining the Optimum Drilling Spots using Geomodeling for Multilayered Reservoirs, Taranaki Basin, New Zealand

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Abstract

The Taranaki Basin, the largest petroliferous basin in New Zealand, has a spatial closure of 150 km^2 and a 3D seismic coverage of 1500 km^2. The largest gas field in the STB is the Maui Gas Field. Seismic interpretation is the primary focus of this study, followed by structural-facies-petrophysical, potential well locations, and static volumetric estimates.Marginal marine (MM) is interpreted to be the most dominant facies association in the Mangahewa facies model, accounting for 64% of the depositional facies associated with this environment, according to two major reservoirs of the field, the Mangahewa and Farewell Formation. The combination of structural, facies and petrophysical factors creates a novel set of volumetric uncertainty scenarios for the gas field.

Keywords *Geomodeling; Multilayered reservoirs; Geo-body modeling; Facies modeling; Volumetric uncertainty.*

1. Introduction

The Maui Gas field is the area of interest for this study. (Fig.1). The Paleocene to Eocene succession, which primarily produces gas-condensate from the Mangahewa and Farewell Formation, is the primary focus of the study [1-2].

The main objective of this study was to test our algorithm in the examined field by creating a logical, geo-cellular, spatially distributed facies architectural model of the two possible reservoirs (Mangahewa and Farewell Formations). A previously built structural model's gridded horizons, which serve as the model's foundation grid, are used for study. In order to model all potential facies of the reservoirs, Sequential Indicator Simulation (SIS) with object-based facies Paleo-trend modelling interpretation is the main algorithm used. This method is combined with quantitative parameters that are motivated by the geomorphology of the channels and sand body geometries in Taranaki and other siliciclastic basins throughout the world. This combined approach is novel as it has not been used before in any facies related modeling and the outcome is very favorable [3], with the possibility of improving the development/production scenario of the target reservoirs. In order to test the range of volumetric estimations associated with various petrophysical factors, static simulations are carried out with probability functions and reservoir drive scenarios (P10-P50-P90) [4].

2. Technical workflow

The Figure 2 illustrates the workflow for this study, which is the combination of seismic, a velocity model, a gridded framework, a facies probability, geobody detection, and petrophysics.

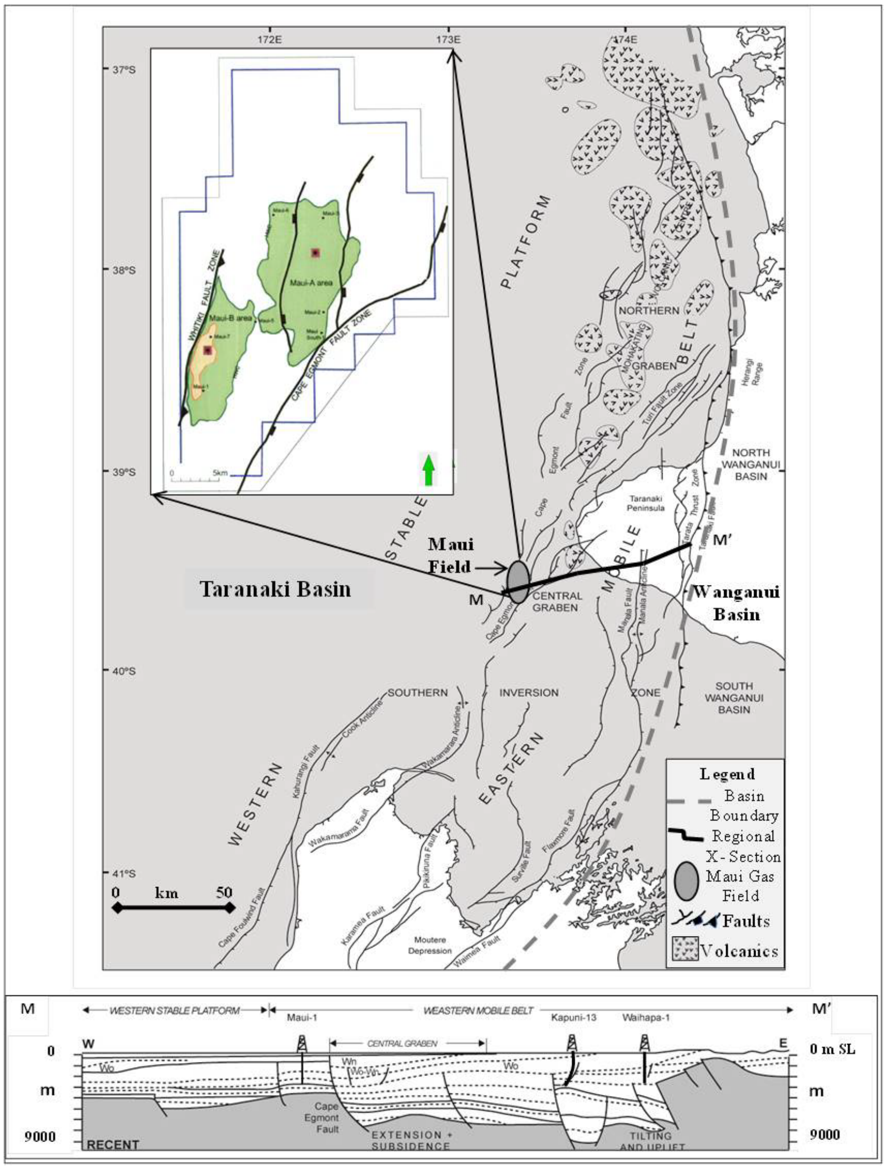


Figure 1. Maui gas field and its surroundings in the Taranaki Basin

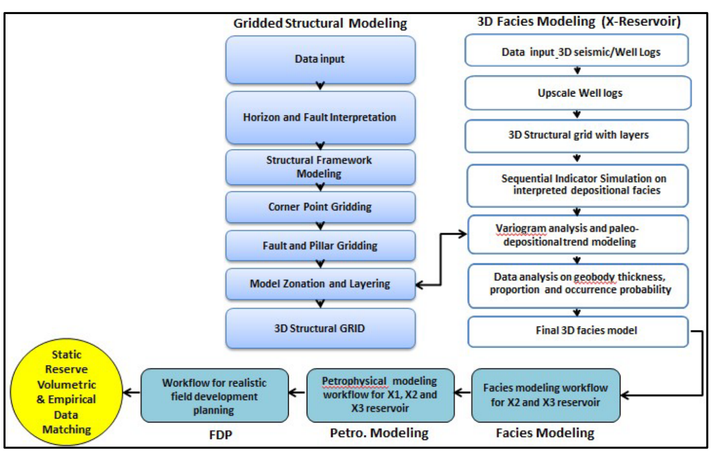


Figure 2. Specialized G&G workflow for the Maui field geomodeling

3. Analyses and interpretation

3.1. Structural modeling

The interpretation of structures within the Maui Gas revealed that there exists a combination of normal and reverse faults, mainly striking north to South and Nth East to Sth West, compartmentalized within eleven (11) defined zones within the structural model. Multiple seismic sections show evidence of fault inversion and multiple events of faulting during deformation. The Late Cretaceous to Palaeocene rifting phase, the Late Eocene to Miocene contractional faulting phase, and the Plio-Pleistocene contractional (Maui, South) and normal (Maui North) faulting are the three main episodes of faulting that have been identified [3,5].

With the exception of the zone between the second regional unconformity and the Moki Formation, all stratigraphic units that were deposited between 15 and 7 Ma displayed decreasing thickness [3,6]. Stratigraphic units dipping to the west as monoclines with dip angles of 15-20^0 dip angles, which are higher than those in the field's central and northern regions. The study also created a 2D restoration model to understand the Maui structure's structural mechanics (Fig.3). The lithospheric plate's stretching and thinning are depicted in the model. Along the Maui structure, it might have started the early stages of extensional deformation. The north central part of the structure may then experience subsequent extensive normal faulting as a result [7-8].

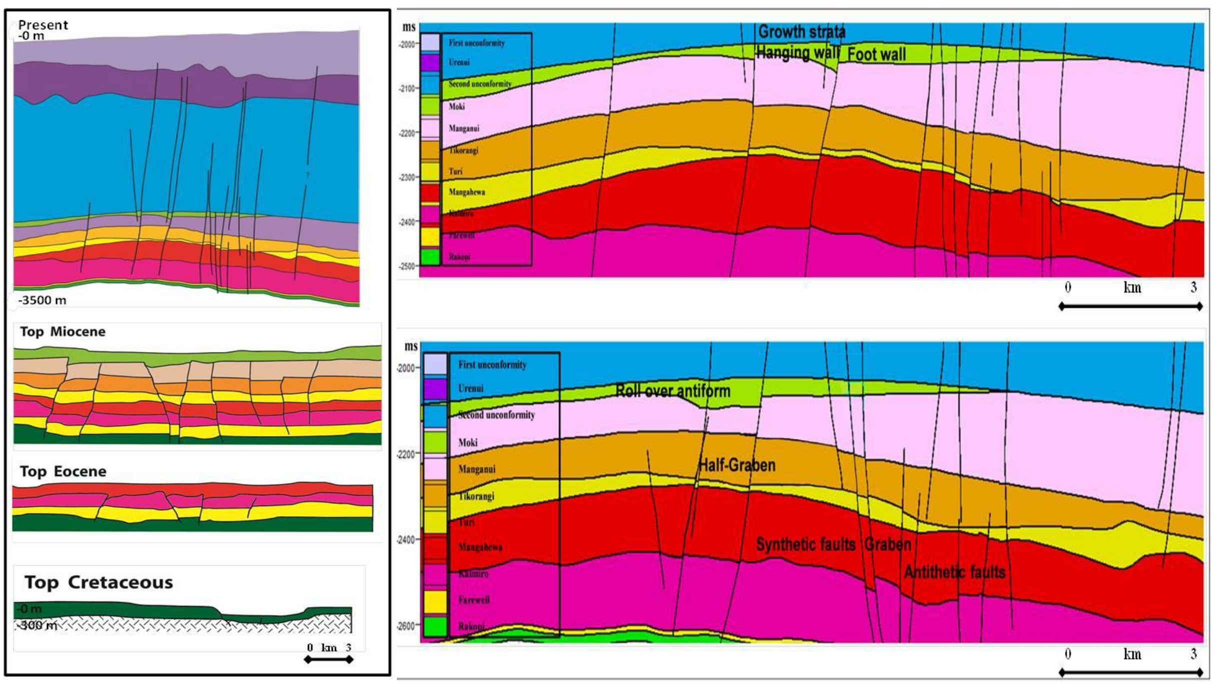


Figure 3. Based on a restoration model of cross section A-A', the structural evolution of the Maui Gas Field is shown on the left. Exaggeration vertically = 3

In the modelled succession, Listric faults were interpreted to be contained within it, some of which formed rollover anticlines and accompanying displacements within the block (Fig.3). With respect to the master normal fault, the thickness of these syn-extensional sedimentary layers increased with the angle of dip and rollover top. Due to the extensional processes of the Maui structure, a number of secondary synthetic and antithetic faults were able to lengthen the hanging wall rollover arc over the major normal fault in the absence of flexural slip [9-10]. (Fig.3).

Table 1. Formations' Regional dip angles as determined by the structural model

Horizons	Northern Area Regional dip* (degrees°)	Southern Area Regional dip* (degrees°)
Regional first unconformity	10	13
Urenui Formation	9	16
Regional second unconformity	13	15
Moki Formation	12	17
Manganui Formation	12	15
Tikorangi Formation	14	17
Turi Formation	8	18
Mangahewa Formation	11	14
Kaimiro Formation	9	20
Farewell Formation	12	16
Rakopi Formation	12	17
Basement Complex	8	15

In the northern and southern parts of the Maui structure, respectively, the average regional dip of the beds was estimated to be 10 to 15^0 and 15 to 20^0 (Table 1).

The field's estimated hydrocarbon column, which was mostly drilled on the central southern portion of the Maui structure, was between 250m and 450m. The northern and southern sections of the gas field's wells were separated [3,11].

The initial structural framework and well location observations were focused on the gaps between objects and the intended radius of the wells being drilled. The study discovered that the model supports the drilling of new wells in largely flawless areas of the field after carefully examining the field's current wells. While keeping the best Gas/Oil-Water Contact (G/OWC) in view, this is the southern part [11-12]. Wells drilled in the southern section, which spanned from 700 m to 5 km, made it possible to look into potential additional drilling sites as long as the field's reservoir drawdown pressure was sufficient to generate natural drive. Mangahewa and Kaimiro Formations, having same GWC; with the SSTVD value of -3100m the southern section of the field has been indicated to be the most productive and was less faulted (Fig.4).

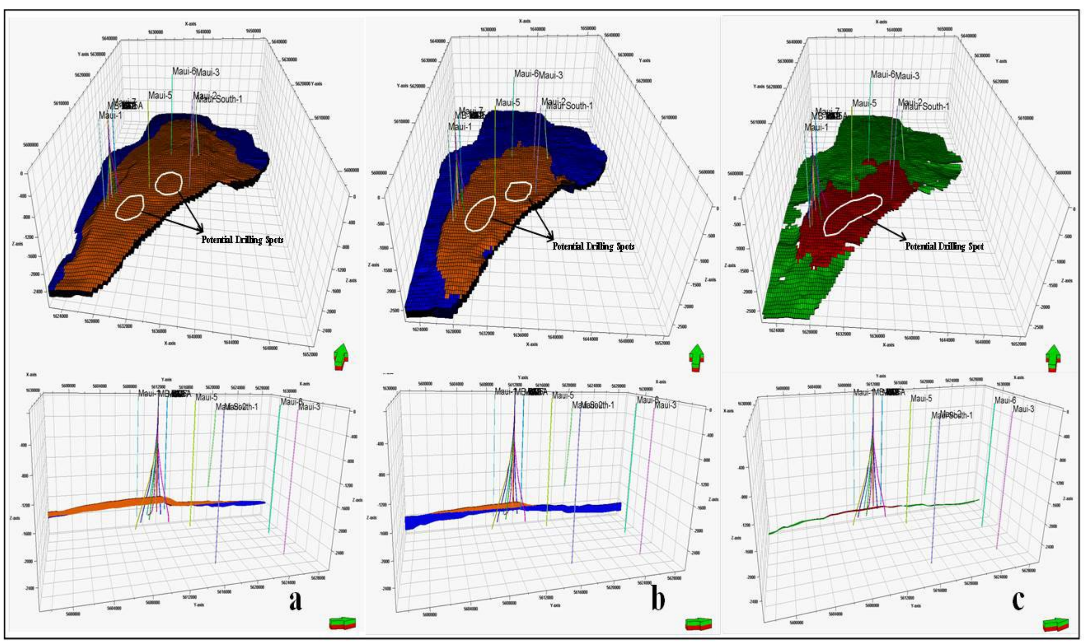


Figure 4. Gas-Water Contact of Mangahewa (a), Kaimiro (b) and oil-gas contact of Farewell Formation (c)

3.2. Facies modeling

Mangahewa Formation: - Three (3) facies associations (Marginal Marine, Shallow Marine, and Offshore) and eighteen (18) depositional facies were identified and interpreted. The examined core logs also revealed two (2) mudstone-dominated lithofacies, four (4) siltstone-dominated lithofacies, and six (6) lithofacies with sandstone as the dominant rock type. It should be mentioned that lithofacies analysis was one of the key markers for depositional facies interpretation, which ultimately aided the study in creating a logical basis for a 3D facies model of the formation [4-5].

According to the study's findings, the southern region exhibited greater quality reservoir facies associations (sand flat with deltaic sand dominated mouth bar) which were prospective [13-15]. However, the east central region showed less possibility for future drilling campaigns because to the presence of mixed flat to estuarine sand facies as well as local pressure regime and structural ambiguity (Fig.5).

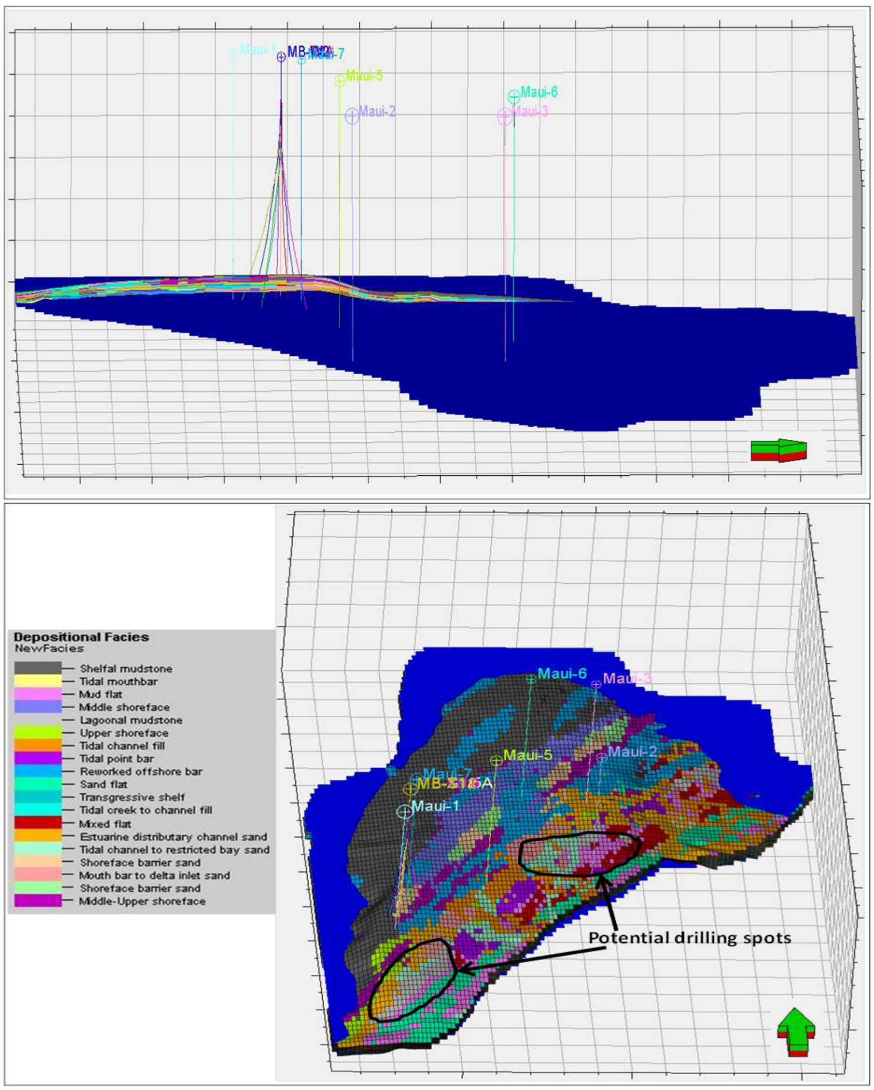
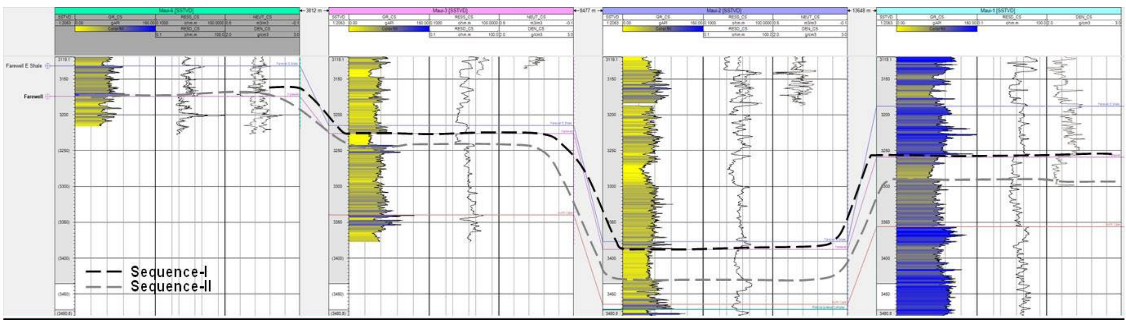


Figure 5. Facies model scenarios with the Gas-Water Contact of the Mangahewa Formation (Top)

The interpreted gas-water contact for the Mangahewa reservoir is depicted as a blue layer. The Facies are interpreted by the model in terms of their ability to create above contact. Facies and potential drilling sites are related (Bottom). A black circle designates the Late Eocene Paleo-shoreline. The circled areas indicate potential drilling locations for field extension. When selecting locations, the Mangahewa reservoir's sand-rich geobodies and the lack of previously drilled wells are also taken into account.

Farewell Formation: - Within the Farewell Formation, three (3) depositional facies (Meandering, Braided, and Floodplain facies) were found and interpreted. Due to the lack of physical samples or core cuttings during the course of the study, all potential reservoir subzones and subsequent geobodies within the Farewell Formation were interpreted using well log response and object-based simulations. A sequence stratigraphic framework for the formation was also established in addition to the 3D depofacies model. (Fig.6).



Formation	Sequence Stratigraphy	Facies Association
Farewell Formation	Sequence II	Amalgamated, stacked braided fluvial channel sandstones intercalated with floodplain/overbank deposits
	Sequence I	Menadering channel sandstone deposits, associated with mouth bar sands, levee and floodplain deposits.

Figure 6. Stratigraphy of the Farewell Formation's sequence

According to the interpretation of the well logs, this formation can be separated into two significant unconformities-based, regional-scale depositional sequences. Meandering deposits' sedimentation is linked to Sequence I, whereas braided channel sands' sedimentation is linked to Sequence II.

Sandstone made up 45% of the entire volume fraction, with shale making up the remaining 55%. The geometries of channel sand bars were, as expected, not recreated by indicator-based simulation since it used variograms (a two-point statistics) to incorporate the spatial correlation of the reservoir lithologies (Fig.7). However, the general distribution of sandstone honored all the constraints. Discontinuous sandstones and shales made up the majority of the lower parts of the facies model (layers 115–120) of the indicator-based model [16-18]. In contrast, in the top half of the facies model, stacked and more continuous sandstone and interbedded shale intervals were more prevalent. As a result, the upper portion was classified as potentially braided stacking channel sands. Sand deposits in a multistory meandering channel made up the lower portion. Throughout the modelled interval, smaller and more irregular sand bodies were seen [5].

3.3. Volumetric uncertainty

Out of 100 simulation runs, #Run No. 17 can be considered to be the best appropriate combination for the volumetric estimation of the Mangahewa Formation, according to the study's cut-offs. According to this particular Run Number, the Mangahewa Formation had an estimated recoverable amount of 1.54 Tcf of gas when 71% recovery factor (RF) for P50 was taken into account. However, when using the same recovery factor, P10 and P90 values are 1.79 Tcf and 1.03 Tcf, respectively [12]. It was found that #Run No.20 produced the best probability estimate of 820 Bcf gas (71% RF) for the Farwell Formation in the case of P50. P10 calculated 954 Bcf and P90 calculated 419 Bcf, respectively. In addition to producing 2.2 Tcf [P50], the Mangahewa and Farewell Formations also left with 80 Bcf (P90) of gas. Based on statistics, the current study confirms that, when taking P50 probability into account, the recoverable reserve growth of 103 Bcf of gas is achievable (Fig.8).

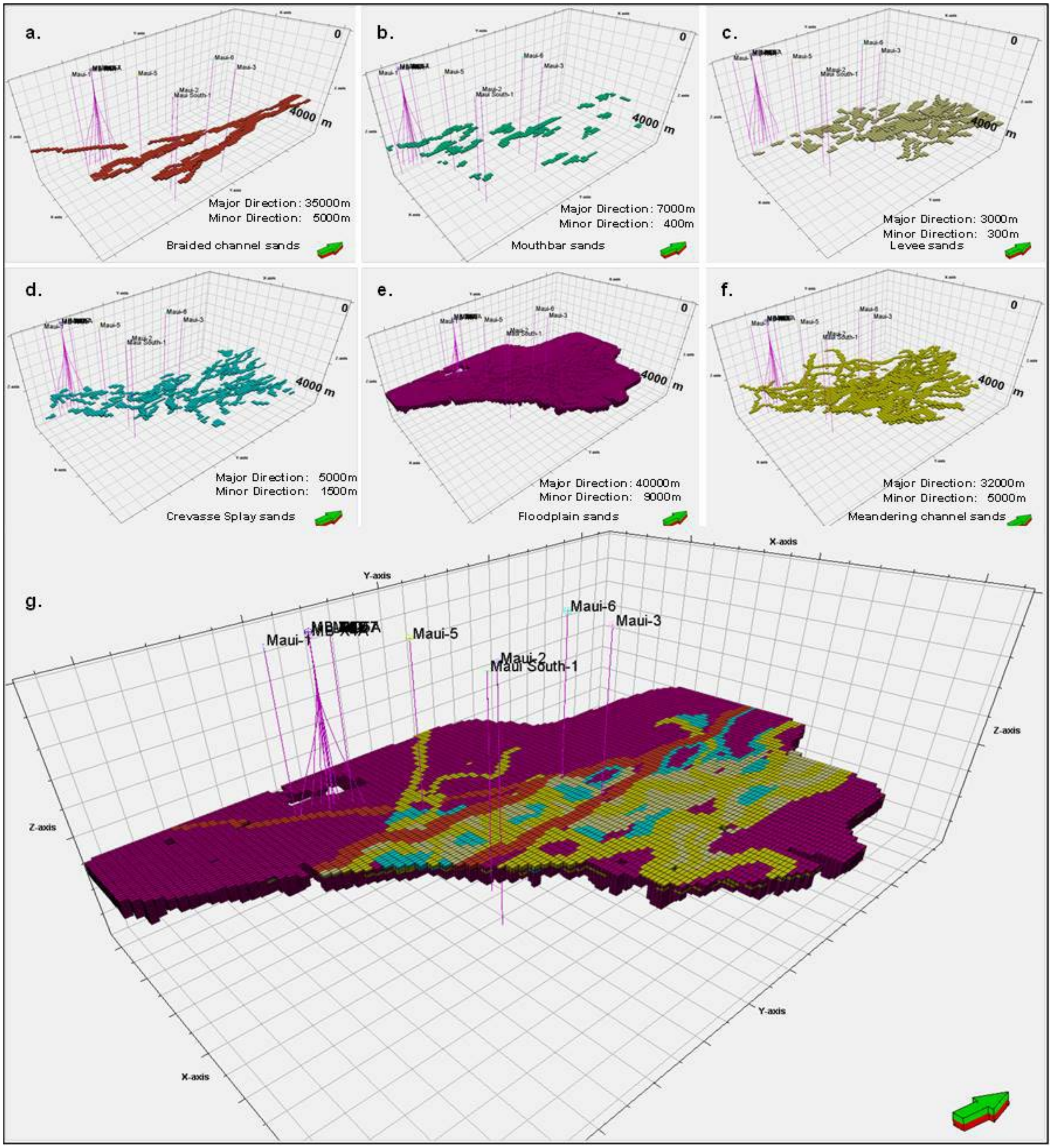


Figure 7. Object geometries (a-f) of the interpreted geobodies of the Farewell Formation. Each geo-body represents its spatial distribution within the formation along the X-Y-Z axis of the modeled grid. Braided channel sands to meandering channel deposits have been modeled for the analysis

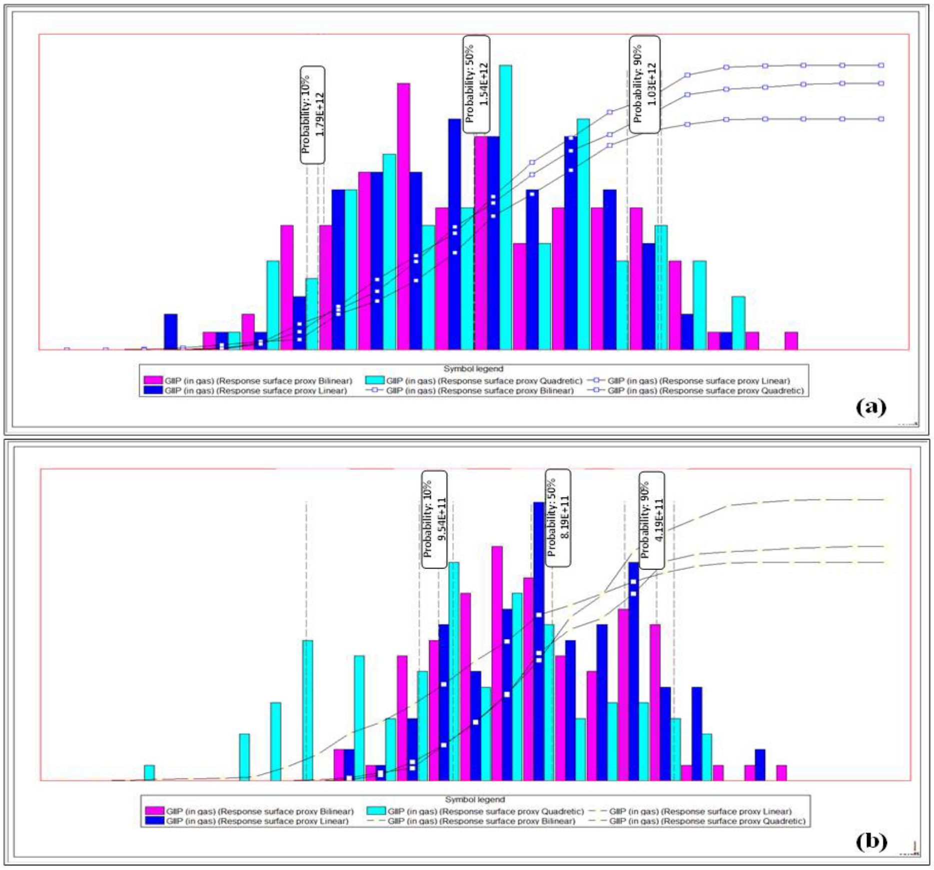


Figure 8. Static reserve estimation of (a) Mangahewa and (b) Farewell Formations. The figures show P10, P50 and P90 probabilistic reserves for both the reservoirs

4. Conclusion

Petrophysical analyses were combined with structural, facies, and geobody modelling of the Mangahewa and Farewell Formations to carry out petrophysical modelling and generate quantitative volumetric for the reservoirs under study.

The final recoverable GIIPs for both formations are ~1.54 Tcf and 820 Bcf respectively, in the case of P50, according to volumetric estimation, which incorporates all relevant parameters using Monte Carlo Simulation (MCS). In comparison to earlier work in this field, the probable reserve growth for the combined Mangahewa and Farewell Formations is 103 Bcf of gas.

The conclusion of this study and its suggested workflow, which combines the three main modelling processes of structural, facies modelling, and volumetric uncertainty analyses, was therefore recommended for use in the development of fields like Maui. This study is crucial for the exploration and development of related hydrocarbon fields in the future.

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