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QUANTIFYING UNTAPPED HYDROCARBON RESOURCES: A CASE STUDY ON THIN SANDSTONE RESERVOIRS WITH INTEGRATING PETROPHYSICAL ANALYSIS AND SEISMIC INTERPRETATION IN THE LOWER TALANG AKAR FORMATION, SOUTH SUMATRA BASIN

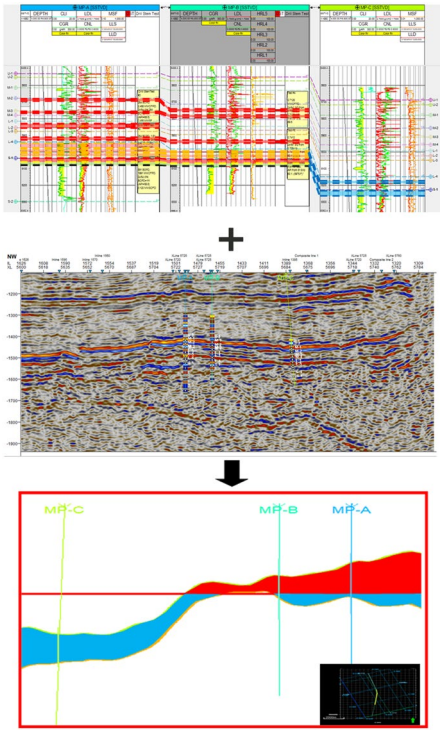
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Graphical abstract



Abstract

This study identifies unproven hydrocarbon reserve zones and estimates gas resources using petrophysical analysis and seismic interpretation in the Lower Talang Akar Formation of the South Sumatra Basin. We utilized 3D PSTM seismic data, well log data from three wells (MP-A, MP-B, and MP-C), and supporting data such as checkshots, mud logs, and DST results. Our petrophysical analysis revealed potential gas-dominated zones in wells MP-A and MP-B, while well MP-C showed no hydrocarbon potential. Based on the petrophysical results, MP-A and MP-B wells have 6 and 5 zones of hydrocarbon potential with fluids dominated by gas. The potential areas have been validated with DST data. In the L-4 marker zone, which based on petrophysical analysis has reservoir potential, validation cannot be carried out due to the absence of DST data, therefore, to see further potential in the L-4 zone, a calculation of hydrocarbon reserves in the L-4 Zone was carried out with the help of seismic data. From this calculation, it is found that the L-4 zone has an estimated gas fluid reserve of 75.1 BSCF based on isopach map parameters, 26.3 BSCF based on sweetness attributes, and 18.8 BSCF based on seismic attributes RMS amplitude.

Keywords: South Sumatra Basin; thin reservoir; petrophysical analysis; seismic attributes; resource estimation.

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1.0 INTRODUCTION

Until now, the world's oil and gas demand has been very high. According to the Energy Institute, from 2012-2022, the world's oil and gas consumption experienced global growth of 0.9% per-year [1]. In reality, the level of oil and gas consumption does not balance with production, which causes hydrocarbon reserves to continue to decline [2]. Even, various sectors review old wells that were previously considered unfit [3]. So, from this problem, it is necessary to increase productivity in oil and gas well fields so that it can restore hydrocarbon reserves.

In the abstract, several abbreviations are mentioned, and we will explain them in this introductory chapter so that the sentences in the abstract are not too long. PSTM stands for Pre-Stack Time Migration, a seismic data processing method that produces seismic cross sections used to obtain an image of the geological structure by moving the position of seismic data recorded on the surface to its original location underground based on wave travel time. Then, DST or Drill Stem Test, an oil and gas well evaluation technique to measure reservoir characteristics through pressure and flow data measured during testing in the well. Then, BSCF stands for Billion Standard Cubic Feet, which is widely used in the oil and gas industry to measure the volume of natural gas. Next, RMS (Root Mean Square) Amplitude is a measure of seismic amplitude intensity in a certain time window calculated by the average square root of the squared amplitude, serves to highlight anomalies such as "brightspots" that indicate hydrocarbon (oil/gas) potential by eliminating polarity and phase distortions, thus allowing direct comparison between amplitude anomalies and facilitating the identification of potential reservoir zones.

In exploiting oil and gas wells, especially in the drilling stage, the rock formations that comprise the well must first be known [4]. Knowing the rock formations that make up the well, the petrophysical components can be known [5]. Geophysical methods such as seismic and well logging methods are required to determine the petrophysical components of the targeted field [6]. These two data are closely interconnected, so by using These, the chances of drilling failures can be minimized [7].

The South Sumatra Basin represents a back-arc basin of Tertiary age, formed by tectonic interactions between the Sunda Shelf and the Asian Continental Plate [8]. Researchers divide the stratigraphic evolution of the South Sumatra Basin into three Megasequences: Syn-Rift, Post-Rift, and Syn-Orogenic, **Figure 1** illustrates the geological map of the South Sumatra Basin, highlighting its structural features [9]. This Tertiary basin has produced significant hydrocarbons in Indonesia [10]. Over a century of exploration has uncovered 1.5 billion barrels of oil and gas [11]. Despite this extensive exploration, geologists consider the basin highly prospective for hydrocarbons, particularly in the Talang Akar Formation [12]. The Talang Akar Formation, a key South Sumatra Basin component, dates from the Late Oligocene to the Early Miocene [13]. Studies continue to highlight the significant hydrocarbon potential of this formation [14].

Due to its favorable geological characteristics, the Lower Talang Akar Formation within this basin remains a potential hydrocarbon source [13, 15]. This formation is stratigraphically positioned in a Late Oligocene to Early Miocene setting, with fluvial and deltaic deposits acting as primary reservoir rocks [15-18]. The stratigraphic column shown in **Figure 2** provides a detailed overview of the depositional environment and lithology of the formation.

Therefore, this study aims to (i) Analyze the petrophysical results and fluid types in MP-A, MP-B, and MP-C wells; and (ii) Determine the potential reservoir zones and hydrocarbon reserves in the Lower Talang Akar formation. This research uses seismic and well logging geophysical methods with supporting data such as checkshot data, mudlog data, and DST data with a petrophysical approach and volumetric-based hydrocarbon reserve calculation. So that later we will get potential hydrocarbon areas and estimated reserves in the area.

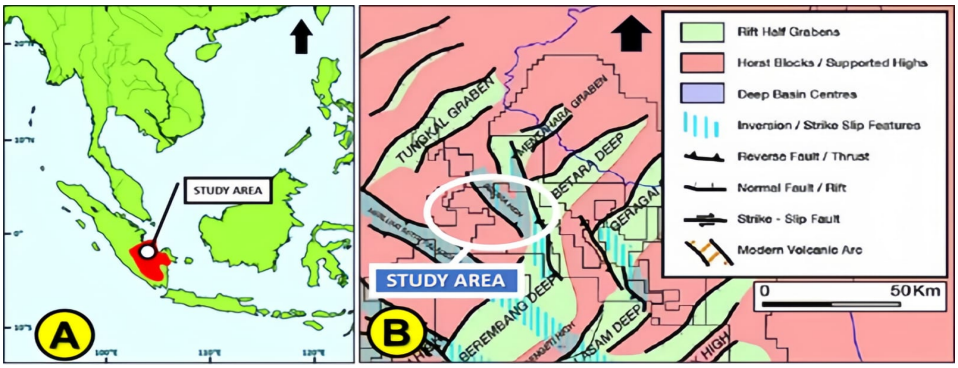


Figure 1 (A) South Sumatra Basin location. (B) Geological map showing the structural features of the South Sumatra Basin (modified from [9]).

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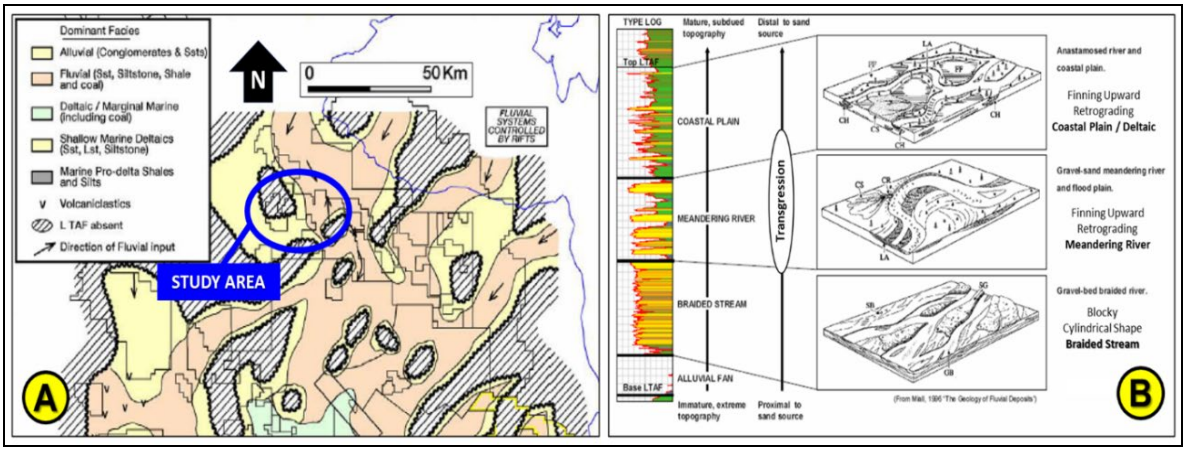


Figure 2 (A) Paleogeography of the Lower Talang Akar formation (B) Lower Talang Akar formation reservoir - Cross section of wireline log data from literature (modified [9])

2.0 METHODOLOGY

This study uses well logging and seismic methods with data from Petrochina International Jabung Ltd covering three wells with marker data, Drill stem test) mudlogs, composite log, and checkshots, then seismic data. The research data is located in the field "S" Jambi Sub-Basin, South Sumatra Basin, Jambi.

The seismic data used is Post Stack Time Migration 3D seismic data and depth 0 - 2100 ms. This seismic data has 331 inline data and 251 xline data.

Figure 3 shows the location of wells relative to seismic lines. Well data is used to provide information on the lithological characteristics of the study area. This study uses 3 well data, namely MP-A, MP-B, and MP-C. These three wells have depth units feet from the height of the Kelly bushing.

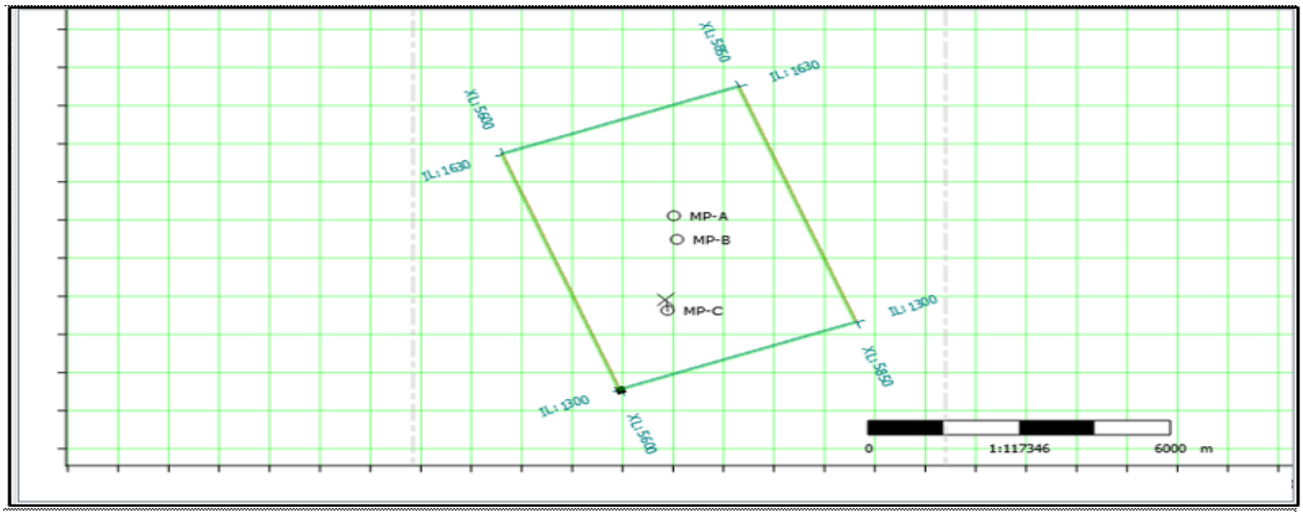


Figure 3 Basemap of the study area including three wells (MP-A, MP-B, and MP-C) and 3D seismic data

2.1 Qualitative Log Interpretation

GR stands for "Gamma Ray," which is a record or measurement of the natural radiation emitted by radioactive elements (Uranium, Thorium, Potassium) in rock formations. Its primary function is to identify rock shale content and distinguish it from other layers such as sand or carbonate in oil and gas or groundwater exploration. PEF log (Photoelectric Factor log) is a type of geophysical log that measures the photoelectric absorption properties of rock formations, useful for determining rock mineralogy, for example dolomite, limestone, or iron minerals) have high PEF values, while sandstone has low PEF values.

Lithological interpretation involves first conducting a literature study of the lithology and depositional environment of the study area. Based on [9], The

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study area has a fluvial and alluvial depositional environment with rocks dominated by shale, sandstone, and siltstone which is in accordance with the results of mudlog, GR and PEF log. Qualitative interpretation the intervals of interest was carried out using the quick look method involving GR, resistivity, and neutron-density crossover log. In GR log, sand lithologies have low gamma ray values, which can be identified as reservoir zones [19]. Resistivity logs are used in determining the type of fill fluid, if the resistivity value has a deflection towards a large value, it indicates the presence of hydrocarbon fluids. The crossover neutron and density log is used to indicate the presence of hydrocarbons.

2.2 Pre-Calculation

The pre-calculation stage includes bad hole identification, coal identification, and temperature gradient calculation. This stage is carried out to minimize errors in interpretation because the presence of coal makes the GR value very low.

2.3 Picking and Calculation Petrophysical Parameter

The equation used to Vshale is the Stieber by considering the age of the Tertiary rocks [20]. Calculation of PHIT and PHIE using neutron and sonic parameters [21]. Based on the lithology, the equation used in the calculation of *Sw* is Archie combined with neutron and sonic values, according to [22] this combined equation is suitable for shaly areas with unknown distribution. In this study permeability calculate by using Schlumberger with consideration of the unavailability of core permeability [23]. The equation in finding the Sw Archi is:

$$Sw^n = a/\emptyset^m \left[(1/R_t - V_{cl}/R_{cl}) \times R_w/(1-V_{cl}\right] \quad (1)$$

Description:
Sw^n = Water saturation from uninvaded zone (archie)
a = Tortuosity factor
Ø = porosity (fractional)
m = cementation factor
Rt = true resistivity (ohm.m)
Vcl = Clay Volume
Rw = Water formation resistivity from formation temperature (ohm.m)
n = saturation exponential

In this study, the clay content in a rock formation is low (Vsh <10%). In well logs, Vsh (Volume of Shale) is a petrophysical parameter that indicates the percentage of shale/clay content in a rock formation, such as sandstone or reservoir. A low Vsh value (<10%, for example) indicates "clean" sand with good reservoir quality, facilitating fluid (oil/gas) movement. Rocks with low clay content (such as clean sandstone) are more suitable for using Archie's Equation to calculate Water Saturation (Sw) because clay contains conductive water.

Clean rocks adhere to Archie's assumption that resistivity is only affected by pore fluids, allowing for more precise Sw calculations using rock resistivity. Archie's Equation is often used because it is a basic and fundamental method for calculating water saturation (Sw) in clean reservoir rocks (without shale). It assumes pores are filled with pure formation water and that conductivity is dominated by water.

2.4 Cut-Off Well Data

PHIE stands for Effective Porosity, which is the volume of interconnected pores in reservoir rocks that can store and flow hydrocarbons (oil, gas) or other fluids, which is measured from log data such as neutron and density logs.

PHIE cut-off is obtained from making a crossplot between PHIE and Permeability, Vshale cut-off is between PHIE and Vshale, and *Sw* cut-off is between Vshale and *Sw* [24].

2.5 Seismic Data Analysis

The equation in finding the tuning thickness is:

$$Tuning\ Thickness = 1/4\ \lambda \quad (2)$$

Where,

$$\lambda = V/f \quad (3)$$

Description:
V = Velocity Average (ft/s)
f = Dominant Frequency (Hz)

The velocity average value is obtained from log data, while the dominant frequency seismic data. Well-to-seismic tie process is carried out with the checkshot data of each well. The checkshot data must first be subjected to a checkshot correction process by calibrating the checkshot data with sonic data. In this study, the wavelets used are deterministic wavelet of MP-A well, statistical wavelet for MP-B and MP-C well obtained after trial and error.

The relationship between checkshot and spatially-vertically changing seismic velocity is that the checkshot survey method measures the travel time of seismic waves (first break) from the source on the surface to the geophone in the borehole (well), producing a crucial time-depth curve for correcting and updating the seismic velocity model, which shows the velocity variation vertically (in the well) and helps to relate seismic time data to depth (time-to-depth conversion) to be more accurate according to the rock conditions in the field, especially in areas with significant velocity changes.

2.6 Structure Interpretation

The structural analysis stage is divided into fault and horizon analysis. The presence of a fault is indicated by the discontinuity in the reflector. Horizon picking was carried out in the L-4 and S-1 marker zones,

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because based on petrophysics the L-4 zone has hydrocarbon potential with indications of gas, but there is no DST data that can validate the presence of hydrocarbons in the area. Horizon picking is performed on seismic data with interval 10, which is then continued to the creation of TSM and DSM until the isopach map.

2.7 Hydrocarbon Volume Calculation

The calculation of hydrocarbon volume is done by the OGIP method with the following equation:

$$OGIP=(43,560 \times V_b \times \emptyset \times Sw \times (N/G)\ )/Bgi \quad (4)$$

Description:
OGIP = Original gas in place (SCF)
43560 = Conversion factor from acre.feet to ft3
V_b = Volume bulk reservoir (acre.feet)
$\emptyset$ = Average effective porosity (fractional)
Sw = Average water saturation (fractional)
N/G = Net sand to gross sand (fractional)
Bgi = Initial gas formation volume factor, BBL/SCF [25]

As for this research, the calculation is carried out by using only fluid contact methods based on petrophysical analysis with isopach maps, sweetness attributes, and RMS amplitude attributes so that the results can be compared later.

To calculate hydrocarbon volume, porosity and water saturation are first calculated for each depth of the well. In calculations using only isopach maps, porosity and saturation are averaged for each well and applied to the calculations on the assumption that the lithology in the area is the same. Meanwhile, in calculations using seismic attributes, the porosity and saturation results for each well are calculated with the help of seismic attributes. Thus, these results are considered sufficient to represent and determine the initial hydrocarbon reserve estimate.

3.0 RESULTS AND DISCUSSION

3.1 Petrophysical Analysis

Based on petrophysical calculations up to net pay, each petrophysical price and possible hydrocarbons are obtained. Furthermore, it can be validated with DST data. The MP-A well and MP-B well have potential zones in 6 zones for the MP-A well and 5 zones in the MP-B well, while the MP-C well after being cut off in the petrophysical analysis does not have hydrocarbon potential in its zones, this is indicated because the MP-C well is in a low area.

Based on **Table 1**, **Table 2**, and **Table 3**, the petrophysical results are in accordance with the DST results in the information column. However, the L-4 zone does not have a DST value, so the presence of hydrocarbons cannot be validated. Therefore, to see the reserves of the L-4 zone, which has a potential zone, further volume calculations are carried out using seismic data.

Prior to the correlation of seismic data processing, a fluid contact analysis of the petrophysical results was conducted. Determination of the fluid contact boundary between the gas zone and the oil zone, oil zone and water zone or gas zone and water zone, respectively referred to as Gas-Oil Contact (GOC), Oil-Water Contact (OWC) and Gas-Water Contact (GWC), needs to be known in an effort to calculate or estimate the volume of oil or gas originally in place (Original Oil In Place or Original Gas In Place). The cut-off value of the L-4 zone top gas boundary is obtained at 5950 ft SSTVD and the L-4 zone bottom fluid contact is at 6030 ft SSTVD **(Figure 4)**. SSTVD stands for True Vertical Depth Sub Sea or sometimes called True Vertical Depth from Sea Level, which indicates the depth of a point in the well vertically from the reference sea level (Mean Sea Level/MSL), not from the ground surface, which is used for more accurate data correlation.

Table 1 MP-A petrophysical and net pay results

Marker	Top MD (ft)	Gross Thick-ness (ft)	Gross Sand (ft)	Net Reservoir		Net Pay			Net Res	Net Pay	N/G	Information (DST Result)	Type of Hydro-carbon
				Average Vsh	Average PHIE	Average Vsh	Average PHIE	Average Sw					
U-1	5582	22	-	-	-	-	-	-	-	-	-	-	-
U-2	5604	63	-	-	-	-	-	-	-	-	-	-	-
M-1	5667	63	27.0	0.112	0.164	-	-	-	-	-	-	-	-
M-2	5730	76	16.5	0.101	0.182	0.093	0.175	0.183	16.5	12.75	0.168	264 BCPD 2.488 MMCFPD	Gas Tested
M-3	5806	26	6.5	0.036	0.210	0.036	0.210	0.154	6.5	9.00	0.346	264 BCPD 2.488 MMCFPD	Gas Tested
M-4	5832	36	1.5	0.225	0.101	-	-	-	1.5	-	-	-	-
L-1	5868	39	22.5	0.093	0.172	0.091	0.178	0.266	22.5	21.50	0.551	264 BCPD 1.161 MMCFPD	Gas Tested
L-2	5907	22	-	-	-	-	-	-	-	-	-	-	-
L-3	5929	63	22.5	0.085	0.190	0.084	0.190	0.211	22.5	25.00	0.397	264 BCPD 1.161	Gas Tested

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Marker	Top MD (ft)	Gross Thick-ness (ft)	Gross Sand (ft)	Net Reservoir		Net Pay			Net Res	Net Pay	N/G	Information (DST Result)	Type of Hydro-carbon
				Average Vsh	Average PHIE	Average Vsh	Average PHIE	Average Sw					
												MMCFPD	
L-4	5992	98	52.0	0.045	0.179	0.041	0.179	0.198	52.0	55.00	0.561	Hydrocarbon Potentially	Gas Indicate
S-1	6090	260	215.5	0.092	0.140	0.082	0.144	0.232	215.5	157.0	0.604	1591 BOPD 0.991 MMCFPD	Oil and Gas Tested
S-2	6350	168.5	-	-	-	-	-	-	-	-	-	-	-

Table 2 MP-B petrophysical and net pay results

Marker	Top MD (ft)	Gross Thick-ness (ft)	Gross Sand (ft)	Net Reservoir		Net Pay			Net Res	Net Pay	N/G	Information (DST Result)	Type of Hydrocarbo n
				Average Vsh	Average PHIE	Average Vsh	Average PHIE	Average Sw					
U-1	5595	23	-	-	-	-	-	-	-	-	-	-	-
U-2	5618	57	5.75	-	-	-	-	-	-	-	-	-	-
M-1	5675	83	24.0	0.281	0.121	-	-	-	-	-	-	-	-
M-2	5758	64	21.0	0.245	0.132	0.234	0.139	0.144	21.00	20.50	0.328	0.7128 MMCFPD	Gas Tested
M-3	5823	29	11.5	0.190	0.145	0.190	0.151	0.122	11.50	11.50	0.397	Hydrocarbon Potentially	Gas Indicated
M-4	5852	40	9.5	-	-	-	-	-	-	-	-	-	
L-1	5892	23	2.5	-	-	-	-	-	-	-	-	-	-
L-2	5915	25	-	-	-	-	-	-	-	-	-	-	-
L-3	5940	87	8.5	0.374	0.098	0.299	0.123	0.187	8.50	12.50	0.098	0.7142 MMCFPD	Gas Tested
L-4	6027	59	16.5	0.254	0.145	0.211	0.155	0.141	16.50	16.00	0.280	Hydrocarbon Potentially	Gas Indicated
S-1	6087	283	84.5	0.230	0.090	0.156	0.129	0.236	84.50	89.50	0.299	Hydrocarbon Potentially	Oil and Gas Indicated

Table 3 MP-C petrophysical and net pay results

Marker	Top MD (ft)	Gross Thick-ness (ft)	Gross Sand (ft)	Net Reservoir		Net Pay			Net Res	Net Pay	N/G	Information (DST Result)	Type of Hydrocarbo n
				Average Vsh	Average PHIE	Average Vsh	Average PHIE	Average Sw					
U-1	5830	31	2.5	0.534	0.140	-	-	-	-	-	-	-	-
U-2	5861	66	19.5	0.501	0.134	-	-	-	-	-	-	-	-
M-1	5927	83	18.0	0.410	0.152	-	-	-	-	-	-	-	-
M-2	6010	58	7.5	0.434	0.149	-	-	-	-	-	-	-	-
M-3	6068	49	14.5	0.380	0.130	-	-	-	-	-	-	-	-
M-4	6117	39	9.5	0.381	0.140	-	-	-	-	-	-	-	-
L-1	6156	32	7	0.432	0.136	-	-	-	-	-	-	-	-
L-2	6188	29	-	-	-	-	-	-	-	-	-	-	-
L-3	6217	104	30.5	0.268	0.152	-	-	-	-	-	-	-	-
L-4	6321	84	11.5	0.356	0.166	-	-	-	-	-	-	-	-
S-1	6405	231.5	136.5	0.487	0.152	-	-	-	-	-	-	-	-

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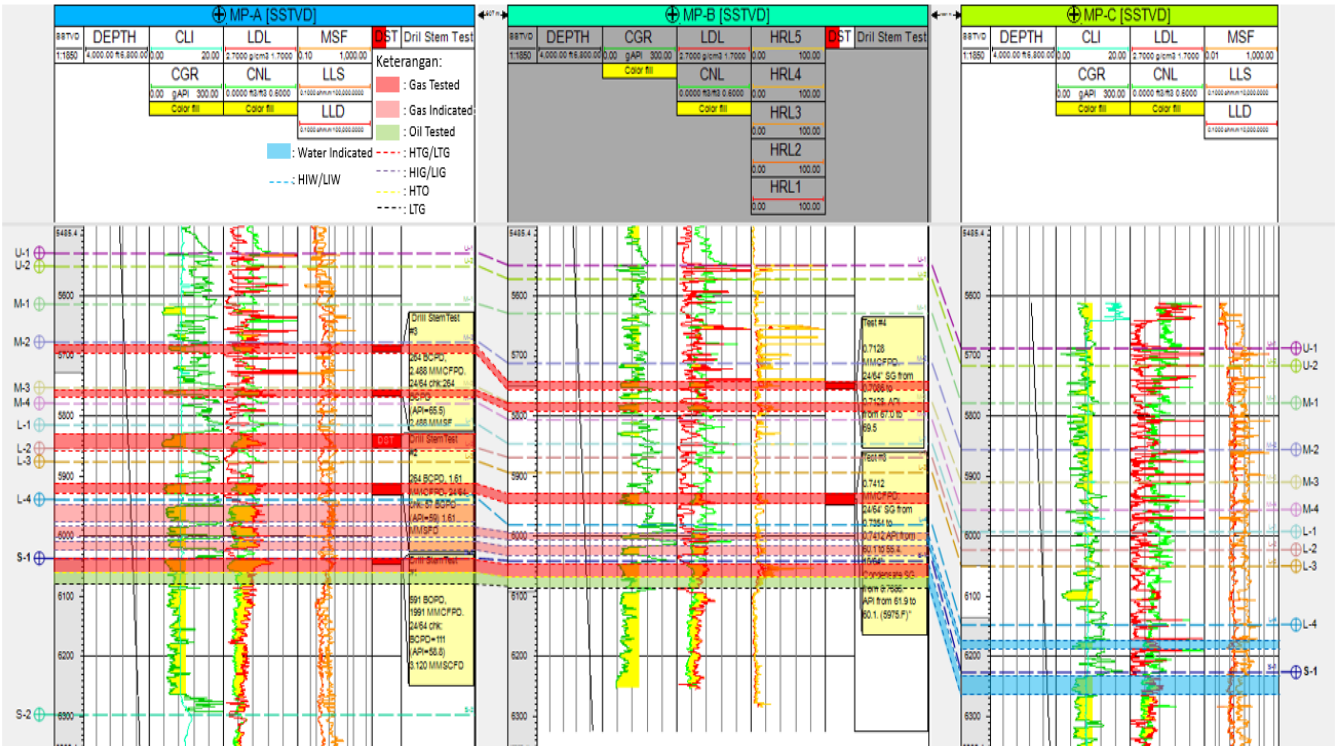


Figure 4 Correlation of structure and fluid contacts obtained from petrophysical results

3.2 Seismic Interpretation and Analysis

The results of the tuning thickness calculation, namely the velocity average value obtained from log data while the dominant frequency is obtained from seismic data. The results of the tuning thickness values are presented in **Table 4.**

Table 4. Calculation of tuning thickness for each well

Interval	MP-A	MP-B	MP-C
U	18.14	3.49	3.49
M	18.14	9.07	4.89
L	25.82	12.55	16.75
S	46.74	23.02	6.38

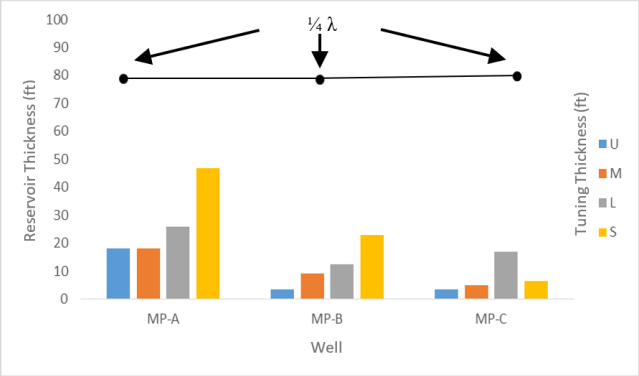


Figure 5 Chart diagram of reservoir thickness and tuning thickness

In the **Figure 5** above, the tuning thickness value has a higher value than the reservoir thickness of each well marker. So it can be concluded that 1 seismic amplitude cannot directly state the boundaries of the upper and lower layers of the reservoir, or one amplitude can consist of several reservoir layers. Although the tuning thickness value cannot represent the reservoir directly and volume calculations are performed, it is possible to calculate hydrocarbon reserves up to probable reserves with the help of petrophysical analysis and seismic attributes. Approach of multi-source data integration, such as combining logs, cores and geophysical analysis, the use of seismic attributes such as sweetness and RMS amplitude attributes can be utilized [26], and petrophysical analysis, including porosity and saturation, can improve accuracy in assessing hydrocarbon potential in thin reservoirs or below tuning thickness [27].

The results of fault analysis that have been carried out on seismic data show that the faults found in the research area are descending faults and shear faults with the direction of Southwest to Northeast, so that the interpretation results show a match with the regional geology of the research area. Meanwhile, horizon picking is carried out in the L-4 and S-1 marker areas through an arbitrary line, resulting in the following results **Figure 6**.

The results of horizon picking on each marker L-4 and S-1 are then carried out a griding process to fill inline and x-line between intervals of 10 for inline and

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10 for x-line. The depth structure map is obtained from the conversion of the time-domain map to the depth domain. This conversion is done using the time-depth curve (TD-curve). To eliminate the deviation of the depth structure map results to the marker, it is necessary to adjust the DSM to the marker. DSM is Depth Structure Map, which is a map of the depth of geological structures interpreted from seismic data for oil or gas exploration. From this result, there will be a slight shift in the contour lines on the map before adjustment and after adjustment to adjust the actual situation on the marker (**Figure 7**).

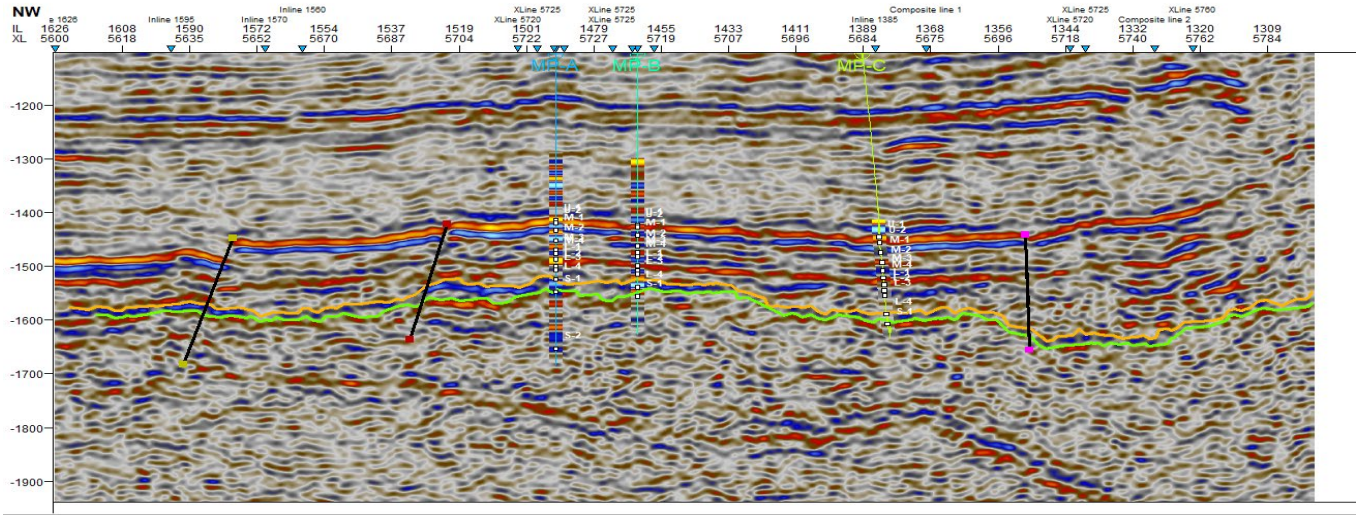


Figure 6 Horizon picking and fault picking results of L-4 and S-1 zones on arbitrary line

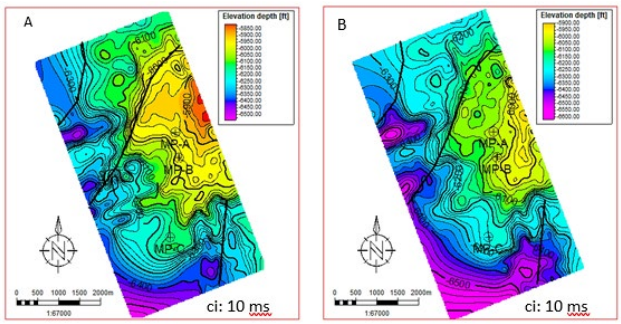


Figure 7 Conversion results from time structure map to depth structure map of markers L-4 (A) and S-1 (B)

The isopach map (**Figure 8**) is the result of DSM with L-4 as the top boundary and S-1 as the bottom boundary. The isopach map created is a TST (True Stratigraphic Thickness) thickness map.

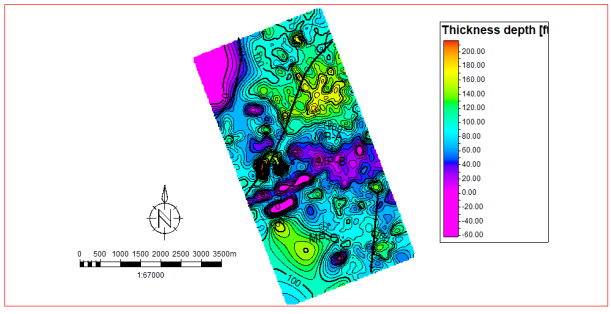


Figure 8 Isopach map obtained from depth structure map L-4 as top and depth structure map S-1 as bottom

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Figure 8 shows that areas with yellow to reddish colors have the thickest thickness, while blue to purple colors have the thinnest thickness. In the process of calculating the volume of hydrocarbons, several methods are carried out, namely using only the isopach map, using the distribution of sand reservoirs using the sweetness attribute, and using the distribution of sand reservoirs using the RMS amplitude attribute. The calculation of hydrocarbon volume using isopach map is done through the calculation of OGIP or Original Gas In Place. Area L-4 in MP-A and MP-B wells after quick look triple combo interpretation and petrophysical analysis indicated that the zone is a gas reservoir zone that has a Lowest Indicated Gas (LIG) value of 6030 ft. Therefore, after obtaining the distribution of gas hydrocarbon zones in the L-4 zone through seismic data, the volumetric calculation of gas hydrocarbons can be carried out.

The area (acre) was calculated using Petrel software. From **Figure 9**, the red color in the map below represents the hydrocarbon area represented in the L-4 DSM map. This area was obtained from the Lowest Indicated Gas (LIG) of the L-4 zone after petrophysical analysis and structural correlation process from wells MP-A, MP-B, and MP-C.

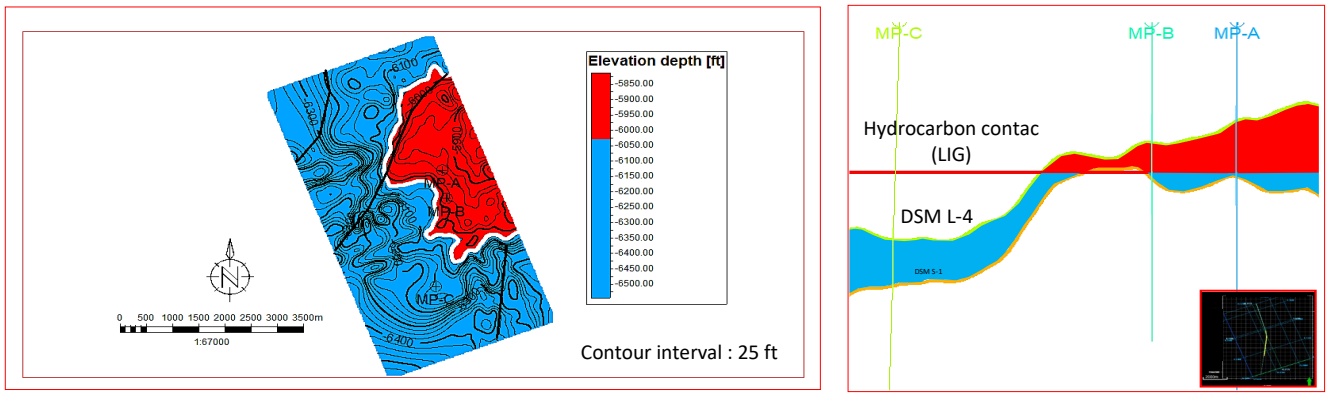


Figure 9 Depth structure map indicating the top structure of the L-4 marker, correlated with hydrocarbon zones inferred from petrophysical data (hydrocarbon indication areas are marked in red)

In the volume calculation process, it is done by first calculating the bulk volume with the help of Petrel software by paying attention to the contact between the L-4 zone and the S-1 zone because this research is focused on calculating the volume of hydrocarbons in the L-4 zone. The resulting hydrocarbon reserves based on the OGIP method using the isopach map are as follows **Table 5.**

Table 5 Estimation of Hydrocarbon Reserves in Zone L-4 of Lower Talang Akar Formation using isopach map only

Formation	Layer	Area (Acre)	Conversion Factor (gas)	Fractional			Volume Bulk (Acre.ft)	Bgi	OGIP (BSCF)
				Porosity	Sw	N/G			
Lower Talang Akar	L-4 (Gas)	1,269.922	43,560	0.162	0.175	0.421	126,900	0.00984	75.1

The sweetness attribute has the advantage of sensitivity to geological changes by utilizing the amplitude in it, this is almost similar to RMS amplitude which utilizes amplitude in distinguishing lithology and hydrocarbons. Therefore, using the sweetness and RMS amplitude attributes, the distribution of sand reservoir thickness and the distribution of petrophysical parameters were first carried out. This process is carried out using linear graphs in order to generate an equation that can be used in the process of spreading these parameters.

When viewed from the curve above (**Figure 10**), it can be concluded that the attribute value is directly proportional to the thickness and porosity of the hydrocarbon zone. This is in accordance with the nature of the amplitude, where the amplitude will be higher if the hydrocarbon saturation is high, the porosity is greater, the pay thickness is thicker.

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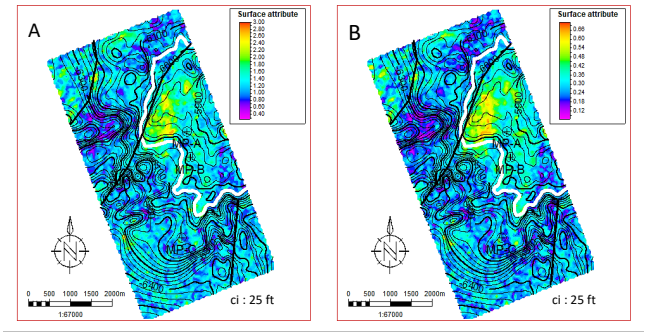


Figure 10 Sweetness attribute distribution map (A) and RMS amplitude attribute distribution map (B)

After obtaining the equation of each graph, the value of the equation is then used to propagate the thickness and porosity parameters on the seismic data, so that later the thickness of the sand reservoir and the porosity value will be obtained (**Figure 11-12**).

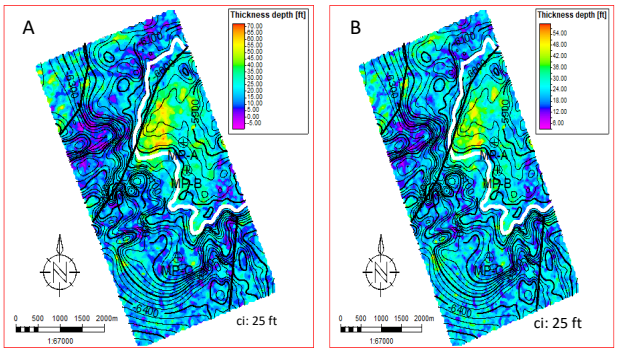


Figure 11 Thickness distribution map of sand attribute sweetness (A) and RMS amplitude (B)

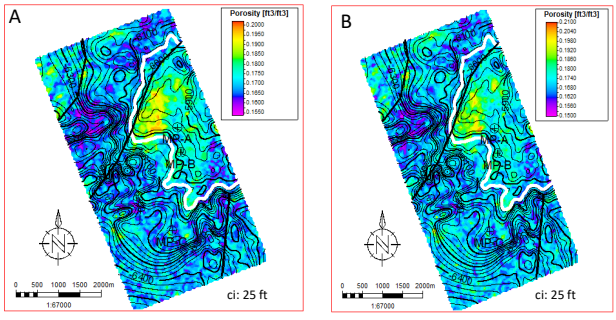


Figure 12 Porosity distribution map of sand attribute sweetness (A) and RMS amplitude (B)

After obtaining the distribution of the porosity value and sand thickness of each attribute, the calculation of HCPV or hydrocarbons in the pore is formulated as follows:

$$HCPV = Area * Net\ Thickness \times Porosity * (1 - Sw) \quad (5)$$

Description:
HCPV : Hydrocarbons Pore Volume
Sw : Water Saturation (fractional) [16]

So, from the results of the above calculations, the results of the HCPV distribution map are as follows **Figure 13**.

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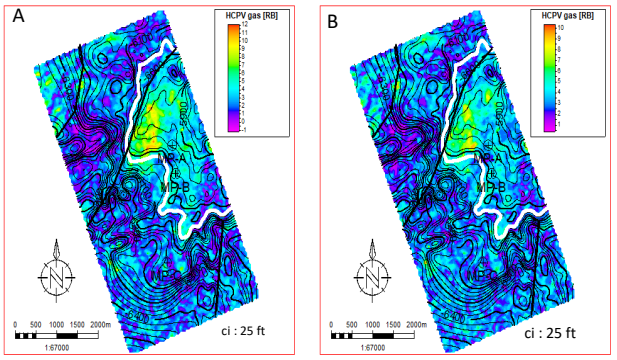


Figure 13 Distribution map of HCPV sand attribute sweetness (A) and RMS amplitude (B)

In this study, the zone that wants to calculate hydrocarbons is a zone that has been demarcated with white or contact hydrocarbon zone, therefore the area that is not inside the white line will be given a value of zero so that it does not participate in the GIIP calculation process, and then the GIIP value calculation is carried out as follows:

GIIP=HCPV*conversion factor(gas) / Bgi (6)

The results are shown in **Table 6**, namely the estimated hydrocarbon reserves of zone L-4.

Table 6 L-4 zone hydrocarbon reserve estimation

Attribute	Layer	Area (Acre)	conversion factor (gas)	Fractional		Thickness (ft)	Bgi (Scf)	GIIP (BSCF)
				Porosity	Sw			
Sweet ness	L-4 (Gas)	1,269.9	43,560	From map	0.18	From map	0.00984	26.3
RMS Amplitude								18.8

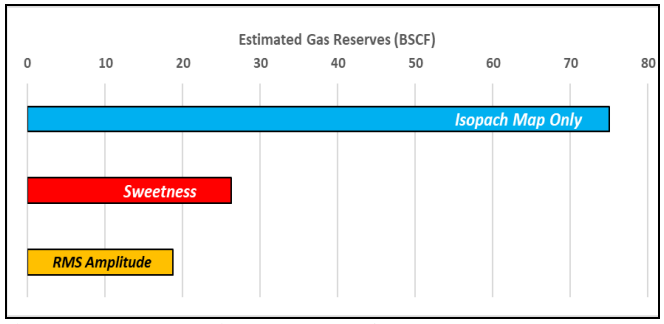


Figure 14 Comparison chart of hydrocarbon reserve estimates

The results of the comparison in the calculation of the L-4 zone gas reserve estimate (**Figure 14**) show a significant difference between the calculation of hydrocarbon contacts or isopach maps alone and the calculation using the sweetness and RMS Amplitude attributes, namely using only contacts has a very optimistic result of 75.1 BSCF compared to using attributes with a range of 18 – 26 BSCF. This is because the OGIP calculation using only contacts has limited parameter values such as porosity taken from the average of 3 wells in the L-4 zone and then assumed that this average value can be used in the entire hydrocarbon zone area, while the use of attributes involves more complex mathematical calculations so that it has a different porosity value at each point of the L-4 hydrocarbon zone area making a more realistic reservoir picture. In addition, the use of attributes only takes into account hydrocarbons in the sand lithology so that the results of the reservoir thickness are more pessimistic than the calculation through the isopach map without attributes which assumes that the entire thickness is a reservoir containing hydrocarbons.

In this study, gas reserves were estimated at 75.1 BSCF using contact only and 18-26 BSCF using seismic attributes combined with petrophysical analysis in the Talang Akar Formation. These results are comparable to those conducted by [28] in Jatibarang Sub-Basin by producing 177.85122 BSCF using seismic interpretation method without attributes and petrophysical analysis. Although without the use of attributes results in more optimistic reserves, the seismic method may be able to provide more realistic reserve estimates laterally.

This study provides novelty in comparing hydrocarbon reserve calculation using petrophysical analysis and seismic interpretation using attributes (sweetness and RMS amplitude) and not using

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attributes in the Talang Akar Formation of the South Sumatra Basin, Indonesia.

4.0 CONCLUSION

Petrophysical analysis of the prospect zones indicates that the reservoir at MP-A exhibits excellent rock quality, with PHIE 0.179 and Sw 0.207. The MP-B well shows slightly lower quality but remains within the economic range, with PHIE 0.139 and Sw 0.166. Zones M-2, M-3, L-1, L-3, and S-1 have been tested via DST, revealing a predominance of gaseous fluids, with some oil presence. The L-4 zone raises particular concern. While petrophysical data suggest strong hydrocarbon potential, no DST test has been performed, leaving the presence of hydrocarbons unconfirmed. Gas reserve estimates for L-4 vary significantly 75.1 BSCF (based on contact), 26.3 BSCF (based on sweetness attribute), 18.8 BSCF (based on RMS amplitude). These wide discrepancies highlight that traditional volumetric methods, relying on well-averaged properties, can lead to both overestimation and underestimation, especially when assuming simplified reservoir property distributions. In the absence of DST data, a seismic attribute-based approach is not only an alternative, but also an attempt to reduce uncertainty and support more informed technical and economic decision-making.

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Conflict of Interest

The authors affirm that they have no conflicts of interest with respect to this paper's publication.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics declaration

Formal ethical approval was not obtained for this study. However, the authors confirm that the research was conducted in accordance with established ethical principles and good research practices, with due consideration given to participant rights, informed consent, confidentiality, and responsible data handling.

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