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APPLICATION OF SURFACE CONSISTENT AMPLITUDE CORRECTION (SCAC) IN THE "HRNR" FIELD

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Abstract. This research aims to enhance the quality of 3D onshore seismic data and understand subsurface structures in a study area. We implemented the Surface Consistent Amplitude Correction (SCAC) method in seismic data processing. This study's results demonstrate that using SCAC significantly improves the quality of seismic data amplitudes, especially in eliminating previously disruptive noise in the analysis. Following the application of SCAC, seismic data amplitudes become clearer and stronger. The interpretation of the enhanced seismic data with SCAC revealed the presence of a significant geological structure, namely a reverse fault, which has significant implications for subsurface understanding. The location of this reverse fault was identified at inline 190 within the CMP range of 60 to 120, with time domain depths ranging from 150 ms to 1250 ms in the southwestern part of the cross-section. This research highlights that SCAC plays a key role in enhancing seismic data resolution and enables the identification of reverse faults that were previously challenging to discern. These findings make a crucial contribution to understanding subsurface geology in the study area and hold significant potential in the context of natural resource exploration. This study firmly establishes that SCAC is an effective tool in improving seismic data quality and revealing important geological structures, especially reverse faults, which can be a primary focus in subsurface geological studies in this research area.

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INTRODUCTION

Seismic reflection processing typically consists of several steps or sequences, and one of the conventional seismic processing stages is deconvolution and migration. Deconvolution is a stage that applies deconvolution functions to seismic data to improve resolution by carefully removing system frequencies (Sheriff and Geldart, 1995). Conversely, migration is a stage in seismic processing that aims to restore dipping reflectors to their original time positions and eliminate diffraction effects resulting from specific structures, thereby enhancing spatial resolution and the subsurface seismic image quality (Yilmaz, 2000).

Conventional and unconventional seismic processing methods are employed in seismic reflection processing. Conventional seismic reflection processing typically focuses on denoising or noise removal from seismic data without specific approaches in its application. In contrast, unconventional processing methods follow steps similar to conventional processing but incorporate additional enhancements to improve seismic data quality without excessively removing existing seismic signals, thereby minimizing data loss during processing. Standard modules used in unconventional seismic data processing include Surface Consistent Amplitude Correction, Surface Consistent Deconvolution, Coherent Noise Attenuation, Wild Amplitude Attenuation, and several others. This study applies an unconventional method by adding Surface Consistent Amplitude Correction (SCAC). The purpose of implementing the Surface Consistent Amplitude Correction (SCAC) module is to maintain the consistency of seismic data amplitudes and enhance seismic data resolution for more accurate subsurface interpretation. Additionally, the unconventional method applied in this study aims to preserve more amplitudes, typically lost due to Spherical Divergence effects (Sheriff & Geldart, 1995).

The field research "HRNR" is conducted to assess the impact of Surface Consistent Amplitude Correction on the quality of seismic data and subsurface structural analysis. The initial step involves implementing Surface Consistent Amplitude Correction in the seismic data. The results of this implementation will be evaluated by considering improvements in resolution and the level of detail in the geological structure images that can be obtained from the "EPS-107" seismic data. Thus, this research aims to understand the effects and the success of Surface Consistent Amplitude Correction in enhancing the quality of seismic data and improving the existing structural patterns in the research area.

Geology

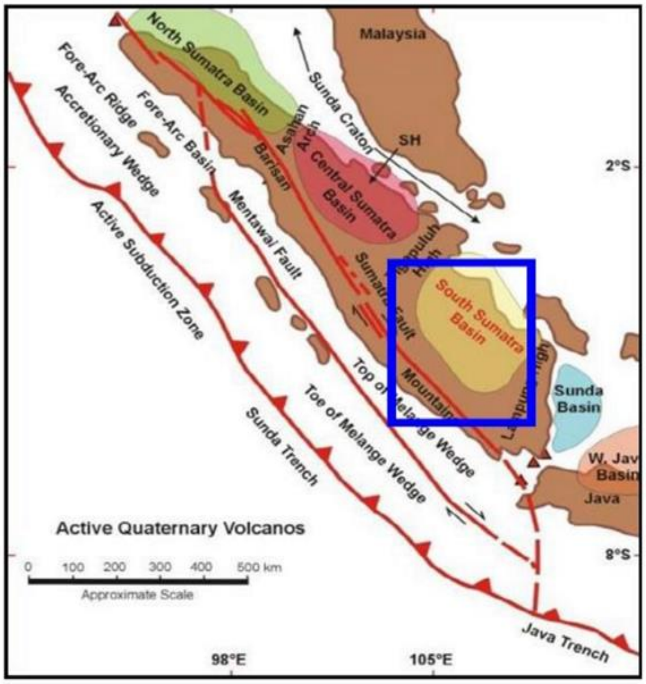


Figure 1. The Geographical Location of The South Sumatra Basin (De Coster, 1974).

The South Sumatra Basin depicted in Figure 1 is a Tertiary basin located in the southwestern part of Sumatra. The Semangko Fault and the Bukit Barisan Range are to the southwest, the Sunda Shelf is to the northeast, the Lampung Highlands is to the southeast, and the Twelve Mountains and Thirty Mountains are to the northwest bound this region. This basin is formed as a result of the interaction between the Sunda Shelf (as a part of the Asian continental plate) and the Indian Ocean plate, covering an area of approximately 330 x 510 km2, and falls into the category of foreland or back-arc basins. The South Sumatra Basin is also recognized as one of the most prolific hydrocarbon-producing basins off the eastern coast of Sumatra in Indonesia (Blake, 1989; Wisnu & Nazirman, 1997; Panggabean & Santy, 2012).

Stratigraphy

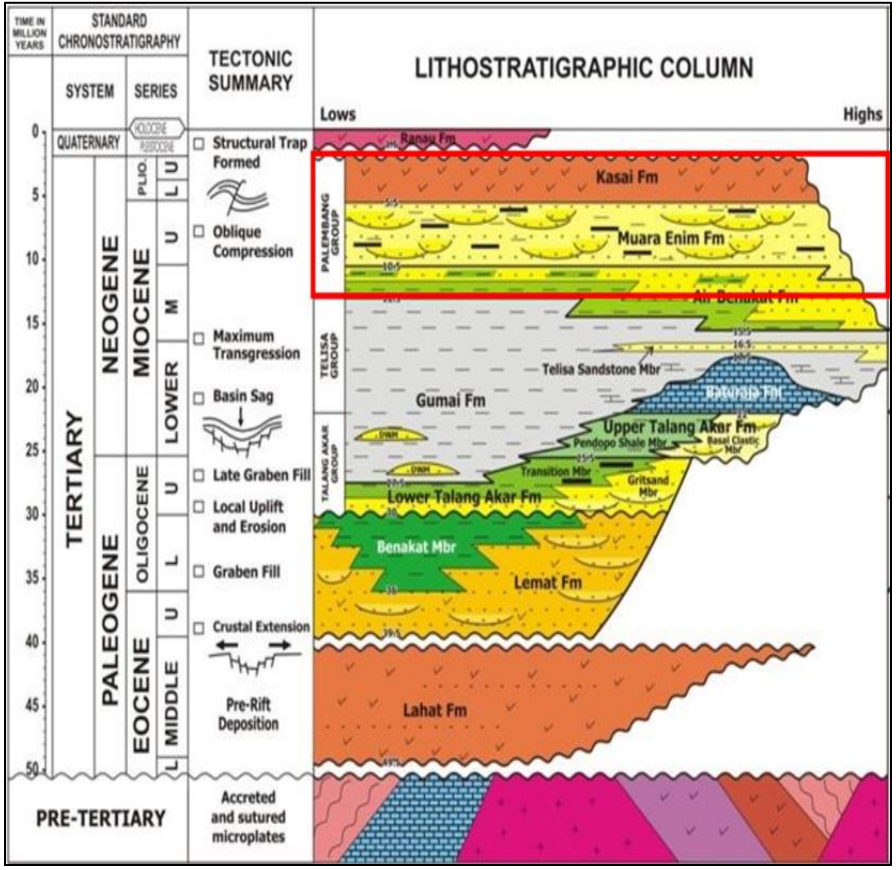


Figure 2. Regional Stratigraphic Column of the South Sumatra Basin (Kamal et al., 2005)

The HRNR Field has a geological stratigraphy comprising three distinct formations, as indicated in Figure 2, marked in red boxes. These stratigraphic units represent sedimentary sequences deposited during different geological time intervals, each characterized by its unique rock layers and characteristics (Kamal et al., 2005). The division of these formations is as follows:

1. Upper Palembang Formation (Kasai):

   The Lower Palembang Formation represents rock layers deposited during the initial phase of a regression cycle in the HRNR Field. The composition of this formation includes glauconitic sandstone, claystone, shale, and carbonate-bearing sandstone. This indicates lithological variations encompassing both clastic and carbonate sediments. The formation dates back to the Middle Miocene and was formed in a shallow marine environment. Depositional processes occurred in shallow waters, suggesting that the marine environment at that time was relatively close to sea level. This formation provides valuable insights into the paleoenvironment and sea-level changes during the Middle Miocene in the HRNR Field (Kamal et al., 2005).
2. Middle Palembang Formation (Muara Enim):

   The Middle Palembang Formation, or Muara Enim Formation, consists of sandstone, claystone, and coal layers in the HRNR Field. In the southern part of the basin, the lower boundary of this formation is marked by coal layers often used as markers. Its thickness varies from approximately 1500 to 2500 feet (about 450 to 750 meters). This formation ranges in age from Late Miocene to Pliocene and was deposited in shallow marine, delta plain, and non-marine environments (Kamal et al., 2005).
3. Lower Palembang Formation (Air Benakat):

   The Kasai Formation is the youngest geological formation in the South Sumatra Basin. It was formed during the orogenic period in the Plio-Pleistocene timeframe. The formation process occurred through erosion from the Barisan and Tiga Puluh Mountains. The Kasai Formation consists of tuffaceous sandstone, clay, shale, and thin coal layers. While the exact age of this formation cannot be precisely determined, it is believed to have a Plio-Pleistocene age. Deposition of this formation occurred in a terrestrial environment (Kamal et al., 2005).

RESEARCH METHODOLOGY

Pre-Processing

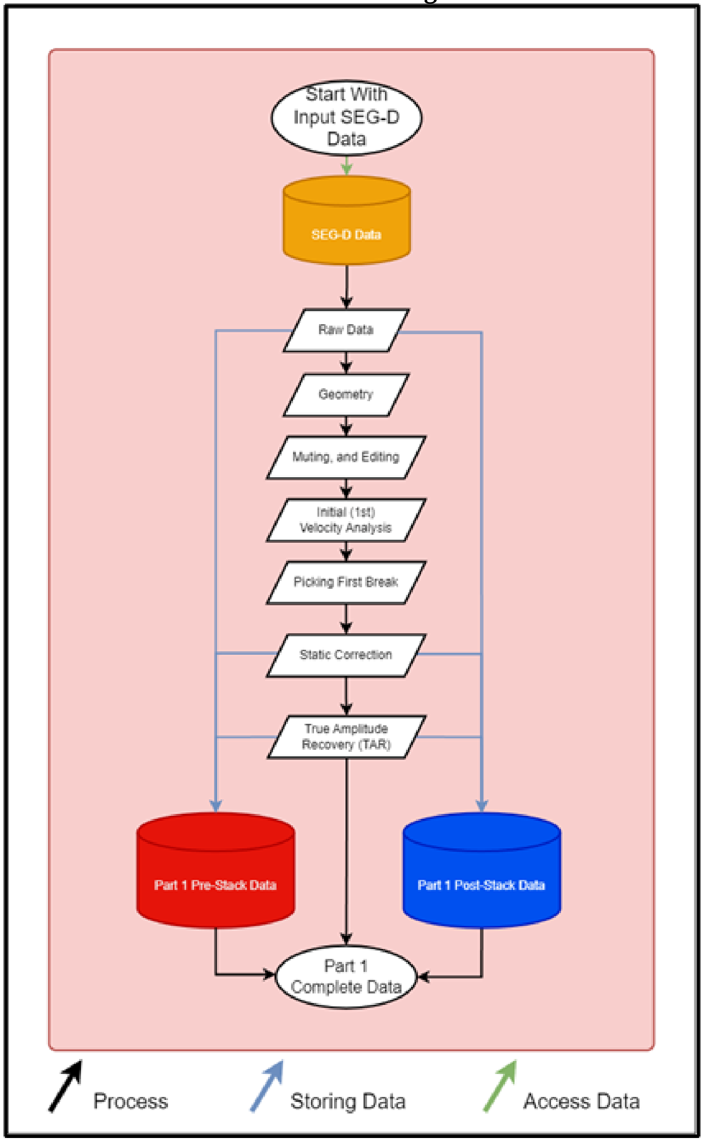


Figure 3. Pre-Processing Stage

The first stage is the pre-processing stage in Figure 3. This stage aims to prepare seismic data before further analysis is conducted. These steps include initial noise removal and correction for amplitude imbalances in the data. By preparing this data, the quality of the seismic recordings to be processed in the next stage becomes better and more accurate. The data required at this stage is the raw or secondary data in the research area, resulting in pre-processed data.

Processing

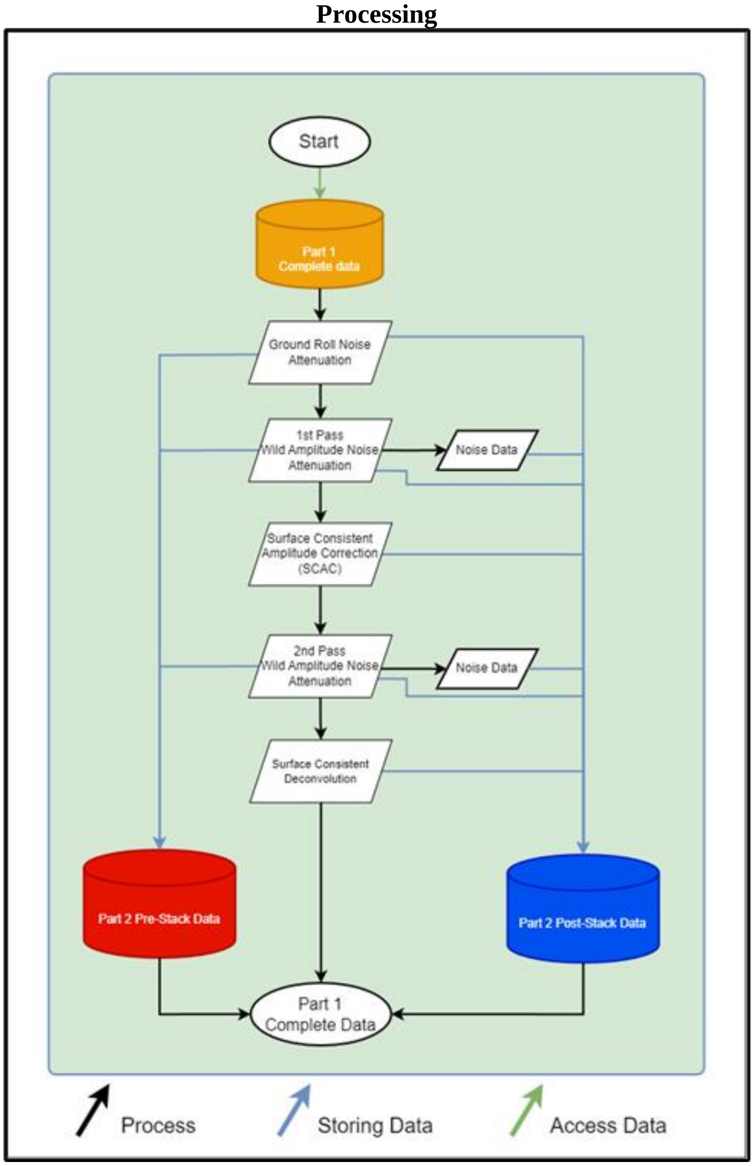


Figure 4. Processing Stage

The second stage is the processing stage in Figure 4. In this stage, the primary focus is removing the noise in the initial seismic data. This processing is done without amplitude compensation. The result is cleaner seismic data free from disturbances that may have occurred during acquisition. By reducing seismic noise in this stage, subsurface information can be more clearly revealed. In the Processing stage, the input data used is the data that has undergone pre-processing, which will then undergo denoising or the removal of seismic data noise present in the research area, resulting in seismic data ready for the post-processing stage.

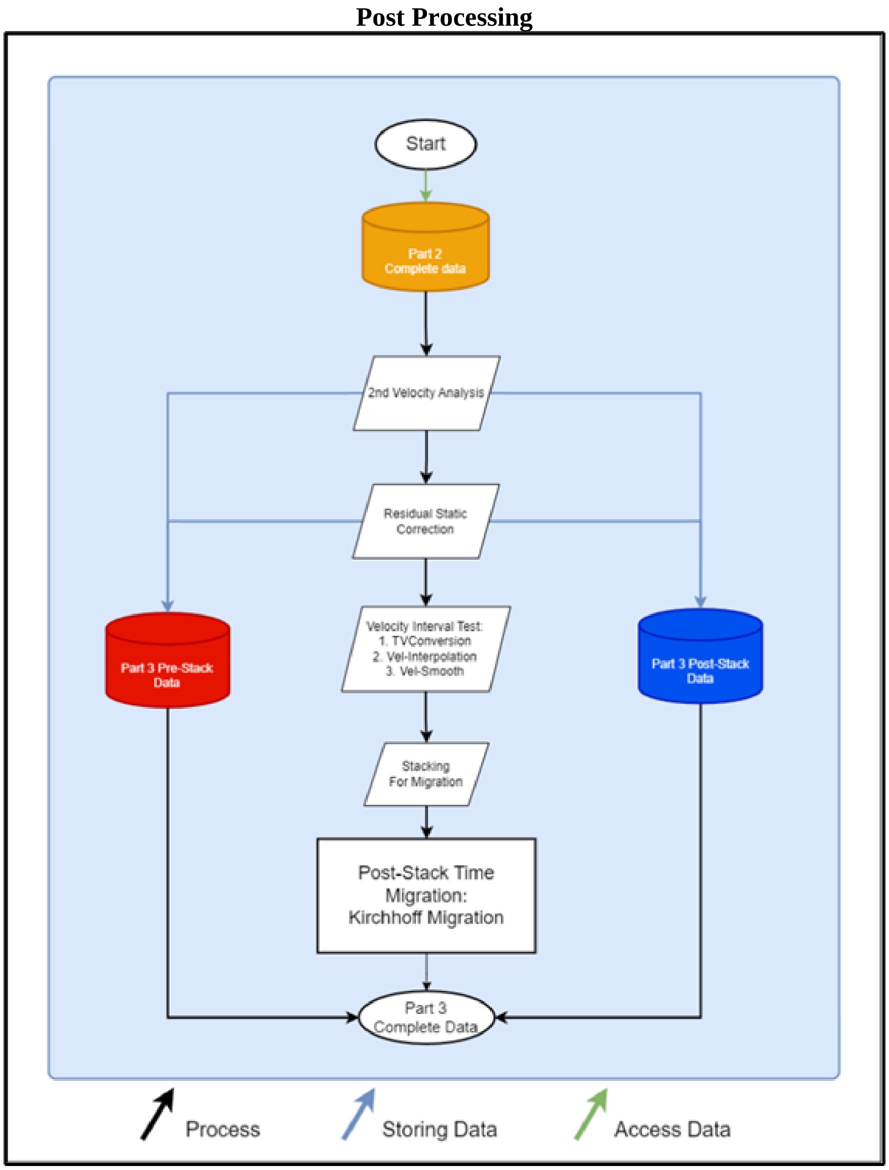


Figure 5. Post-Processing Stage

The third stage, the post-processing stage in Figure 5, involves advanced processes in removing seismic noise. This time, it is done with consideration for amplitude compensation. The goal is to optimize seismic data by highlighting residual seismic noise. The input for the post-processing stage is seismic data that has already undergone denoising or the removal of seismic noise such as ground roll noise, wild noise, and other unwanted noise sources. In this stage, the seismic data may still be ambiguous due to factors from the earlier deconvolution, so residual static correction is needed to restore the amplitude positions to their original state. Subsequently, migration is applied to the seismic data to reposition the reflector points within the seismic data, resulting in both preserved and unpreserved amplitudes.

Interpretation

The interpretation of seismic data involves two main approaches: qualitative and quantitative interpretation in Figure 5. In qualitative interpretation, the emphasis is placed on observing amplitude patterns within the data. Through this analysis, the primary goal is to explain how these amplitude patterns can indicate the presence of geological formation boundaries and faults. For example, when we observe wave patterns that show zones with higher reflection levels in Seismic Reflection data, this can be interpreted as a sign of the presence of specific rock layers, such as sand or limestone, with different geological properties (Sheriff, R. E., & Geldart, L. P., 1995).

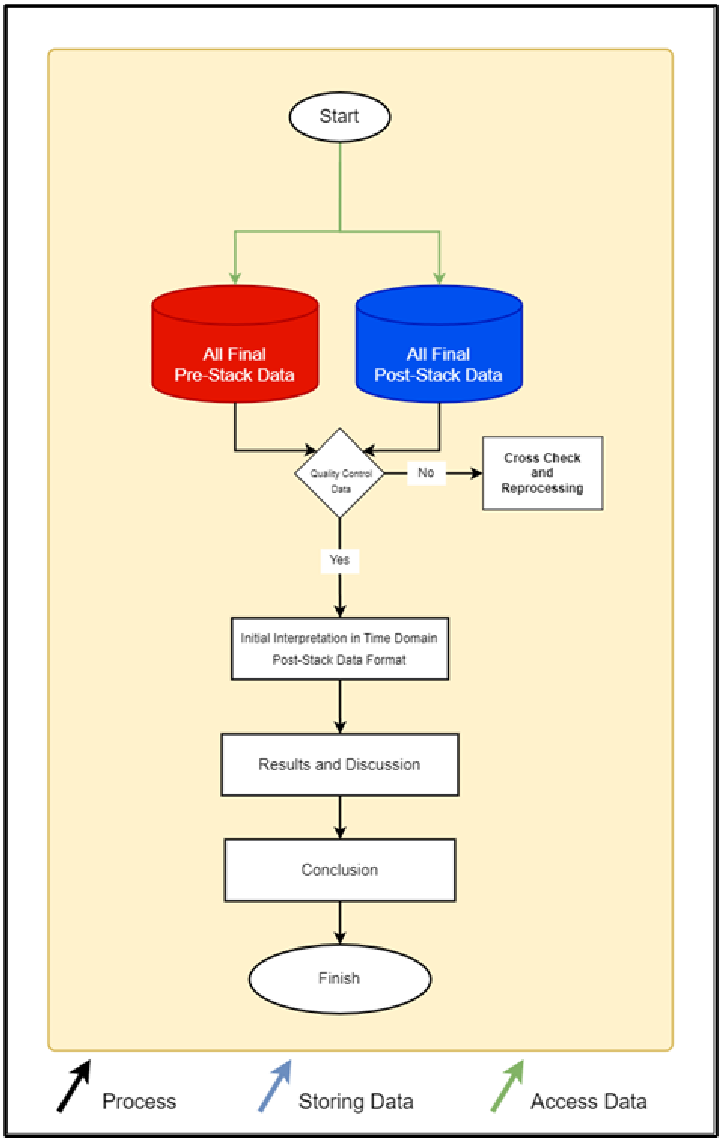


Figure 6. Interpretation Stage

The interpretation of seismic data involves two main approaches: qualitative interpretation and quantitative interpretation, as shown in Figure 6. In qualitative interpretation, the emphasis is placed on observing amplitude patterns within the data. Through this analysis, the primary goal is to explain how these amplitude patterns can indicate the presence of geological formation boundaries and faults. For example, when we observe wave patterns that show zones with higher reflection levels in Seismic Reflection data, this can be interpreted as a sign of the presence of specific rock layers, such as sand or limestone, with different geological properties (Sheriff, R. E., & Geldart, L. P., 1995).

RESULT AND DISCUSSION

Results of Applying Surface Consistent Amplitude Correction (SCAC)

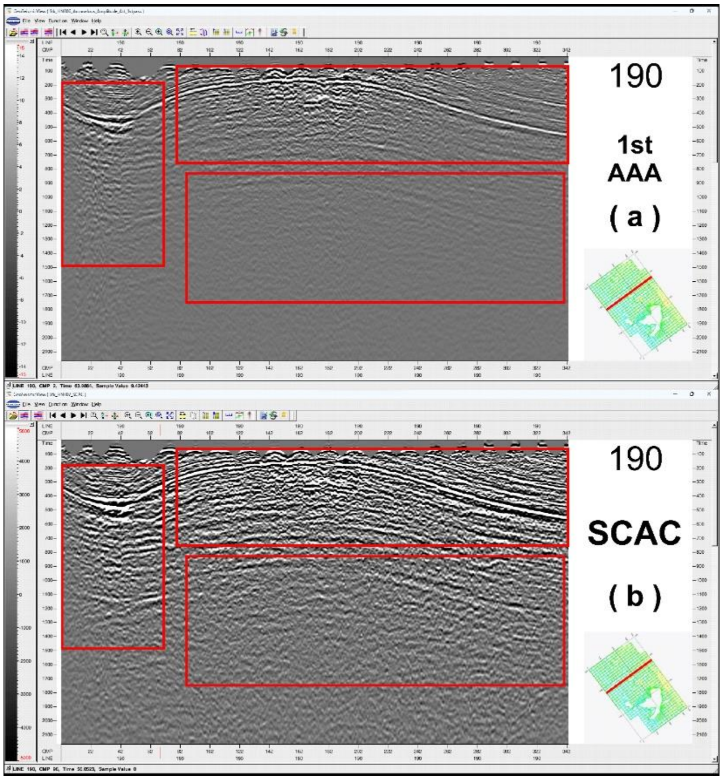


Figure 7. Results of Applying Surface Consistent Amplitude Correction (SCAC)

Table 1. Comparison Between Non-SCAC and SCAC

Comparison	**Non-SCAC**	**SCAC**
Seismic Data	Only visible down to a depth of time 600 Clearly visible down to a depth of time 2100	Clearly visible down to a depth of time 2100
Noise	Only slightly visible (wild noise) due to lower resolution factors More visible (wild noise) due to higher resolution factors compared to non-SCAC	More visible (wild noise) due to higher resolution factors compared to non-SCAC
Vertical Resolution	The boundary between the Muara Enim formation and the Benakat water is not clearly visible boundary between the Muara Enim formation and the Benakat water	The clearly visible boundary between the Muara Enim formation and the Benakat water
Horizontal Resolution	The boundary layer between the Muara Enim formation and the Benakat water appears to vanish and lacks continuity The disappearing boundary layer between the Muara Enim formation and the Benakat water becomes visible and exhibits continuity	The disappearing boundary layer between the Muara Enim formation and the Benakat water becomes visible and exhibits continuity

Structure Pattern	Appears not to be a fault body, but rather appears as cracks due to unclear vertical and horizontal resolution factors Cracks that appear as faults in non-SCAC show vertical displacement (upthrust) due to unclear vertical and horizontal resolution factors.	Amplitudes that appear as cracks in non-SCAC show vertical displacement (upthrust) due to unclear vertical and horizontal resolution factors.

In Figure 7, part (a) depicts a portion of seismic data on inline 190 before the application of surface consistent amplitude correction. Therefore, part (b) illustrates the seismic section on inline 190 after applying surface consistent amplitude correction to the seismic data. In the red boxes, CMP 1 to 68 at a time depth of 180 ms to 1480 ms, CMP 80 to 342 at a time depth of 50 ms to 750 ms, and CMP 85 to CMP 342 at a time depth of 800 ms to 1750 ms show that the amplitudes, which initially appeared weak in Figure (7a), become stronger Figure (7b). This enhancement or strengthening aids in analyzing and improving the noise distribution in the seismic data within the research area, which was not eliminated during the 1st AAA stage and can be further cleaned in the 2nd AAA stage. There can be multiple interpretations during the surface consistent amplitude correction stage, marked by the red boxes on CMP 1 to 68. In part (a), inline 190 appears to be a basin. Still, after the migration stage, as shown in Figure 8, which is the result of the interpretation of the cross-section, it is indicated that the portion from CMP 1 to 68 is suspected to be a part of a reverse fault, commonly referred to as an uplifted fault, located beneath the surface. The analysis based on Figure 5 can be summarized in Table 1.

Results of Applying Migration

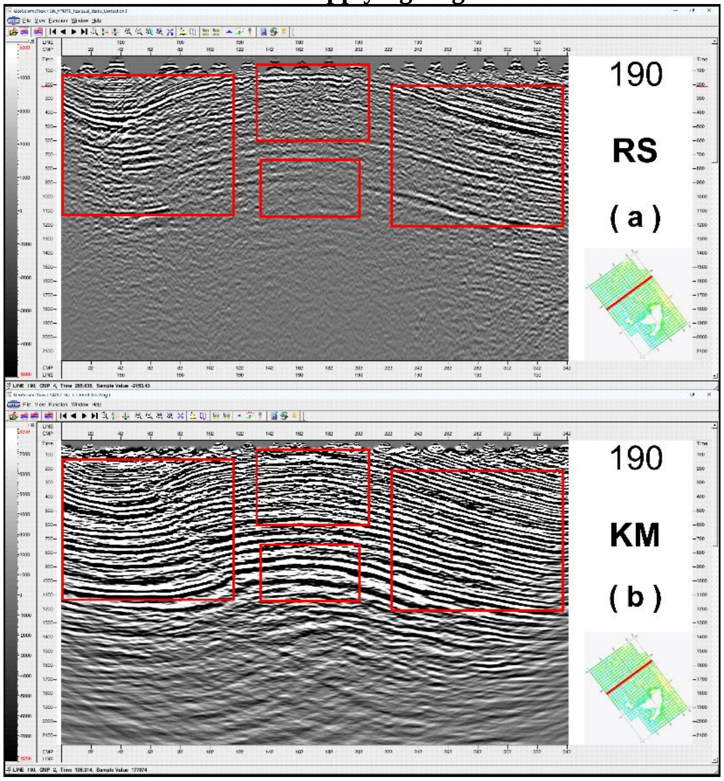
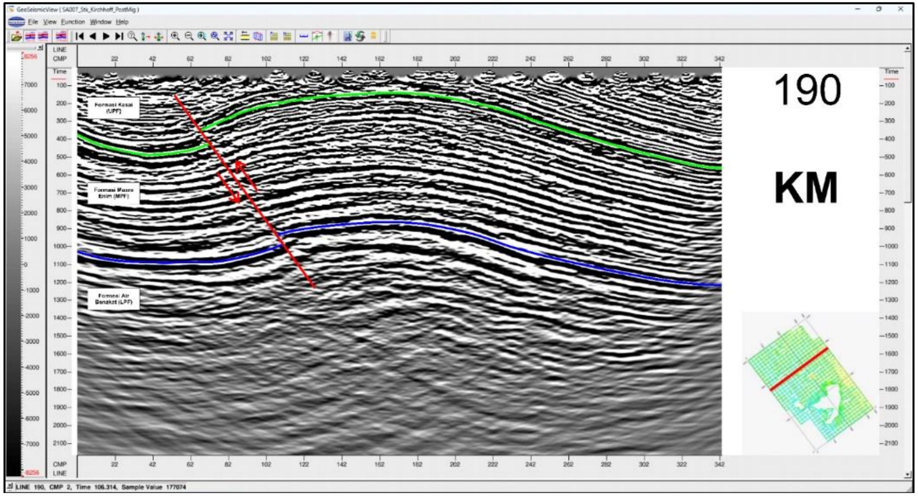


Figure 8. Inline 190 (a) Residual Static Correction Vs (b) Migration.

Referring to Figure 6, there are cross-sections for inline 190 (left) and a cross-line section (right), consisting of (a) a section that has not yet been subjected to the Migration module or has already undergone Residual Static Correction module, and (b) a section resulting from the application of seismic Migration. In the red boxes, significant changes in amplitude patterns can be observed as a result of the Migration application, specifically in CMP 1 to 118 at a time depth of 130 to 1130 ms, CMP 130 to 208 at a time depth of 50 to 600 ms, and CMP 133 to 202 at a time depth of

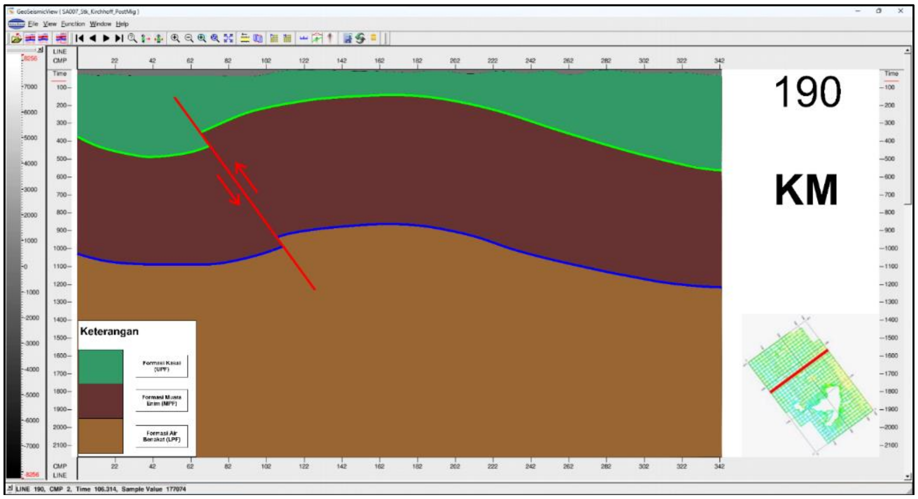
700 to 1112 ms. These changes indicate clear shifts in the locations of seismic wave reflector points, making the cross-sections generated during the migration stage ready for interpretation in the time domain.

Results of Interpretation



LINE 190, CMP 2, Time 106.314, Sample Value 177074

Figure 9. Interpretation of Inline 190 Cross-Section.



LINE 190, CMP 2, Time 106.314, Sample Value 177074

Figure 10. Inline 190 (a) Subsurface Model of Inline 190 Cross-Section.

In Figure 7 and 8, we can observe the interpretation of the seismic cross-section in line 190. This interpretation is based on local stratigraphic knowledge in the research area, which consists of three formations in ascending order: the Kasai Formation, the Muara Enim Formation, and the Air Benakat Formation. This interpretation provides a deeper understanding of the subsurface structure in the research area. Based on the interpretation in the time domain, the green horizon is interpreted as the boundary between the Kasai Formation and the Muara Enim Formation, while the blue horizon is interpreted as the boundary between the Muara Enim Formation and the Air Benakat Formation. Based on this information, the research area meets the criteria for a petroleum system.

The Kasai Formation is interpreted as the caprock or sealing rock in this study, as the rocks in the Kasai Formation tend to have relatively low permeability, making them suitable for a caprock. Next is the Muara Enim Formation, which is interpreted as the reservoir in this study because it exhibits sufficient porosity, particularly due to the presence of sandstone in this formation. The Air Benakat Formation is interpreted as the source rock in this study due to the organic content within this formation.

One significant finding in this interpretation is the presence of a reverse or uplifted fault in the research area. This fault is located in the CMP range of 60 to 120 on the cross-section and has a time depth ranging from 150 ms to 1250 ms in the southwestern part of the cross-section. This reverse fault indicates past geological movement in the research area. Specifically, a reverse fault is a type of fault that experiences vertical movement where one block of rock is pushed upward and over another block. The interim formation model can be seen in Figure 8

CONCLUSION

Based on the research objectives, several significant conclusions can be drawn from the results of this study. Firstly, Surface Consistent Amplitude Correction (SCAC) has a noteworthy impact on seismic data quality. Secondly, its influence on subsurface structural analysis is pivotal, particularly in detecting reverse faults, which signify significant past tectonic activity and have important implications for fluid storage and movement within rock formations. Thirdly, the effective application of SCAC hinges on the thoughtful selection of appropriate parameters and settings. Finally, SCAC successfully enhances the resolution and detail of geological structure images in seismic data, facilitating interpretation by making horizons, formation boundaries, and reverse faults more discernible.

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