

3D Fault Architecture and Coal-Seam Continuity in the Central Sub-basin, Mae Moh Basin, Northern Thailand

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Abstract

The Mae Moh Basin hosts Thailand's largest lignite mine, where planned underground development requires an accurate understanding of fault geometry and coal-seam continuity. This study integrates a newly acquired high-resolution, depth-domain 3D seismic dataset covering approximately 9.6 km² with borehole data to construct a mine-focused 3D structural model of the Central Sub-basin. The Red bed, K, Q, and R horizons were interpreted together with fault surfaces to characterize fault orientation, linkage, vertical extent, dip variation, and their effects on the coal-bearing succession. The interpreted network is dominated by N–S- to NW–SE-striking normal faults. Short, discontinuous fault segments at shallow levels commonly link downward into larger composite surfaces. Major faults exhibit listric geometries, with steep upper segments progressively flattening below the principal coal seams. Fault density and displacement generally increase with depth, resulting in greater structural compartmentalization of the R seam than of the shallower K and Q seams. The K and Q seams remain laterally continuous across much of the survey but are locally offset, deformed, or omitted near major fault zones. In the eastern part of the study area, the no-coal area is associated with linked east-dipping listric faults that structurally omit and juxtapose parts of the coal-bearing succession. The resulting 3D fault model improves the delineation of fault-bounded coal blocks and provides a geological framework for coal-reserve estimation, underground mine planning, targeted drilling, and assessment of fault-related geological uncertainty.

Keywords: Mae Moh Basin; lignite; 3D seismic interpretation; normal fault; extensional tectonics

1. Introduction

Fault architecture strongly controls coal-seam continuity, depth, and compartmentalization in sedimentary basins. Accurate characterization of fault orientation, dip, displacement, and connectivity is therefore essential for coal-reserve estimation and underground mine planning, where unrecognized or incorrectly positioned faults may affect mine layouts and geotechnical risk.

The Cenozoic basins of northern Thailand developed mainly under Late Oligocene–Late Miocene E–W to ENE–WSW extension. Rift development was influenced by inherited NE–SW to ENE–WSW basement fabrics, producing N–S- to NE–SW-trending basins characterized by normal faults, transfer zones, and structurally controlled depocenters (Polachan et al., 1991; Morley and Wonganan, 2000; Rhodes et al., 2000; Morley et al., 2004). The Mae Moh Basin, Lampang Province, is one of these Cenozoic rift basins (Fig. 1). It developed above folded and faulted Triassic rocks of the Lampang Group and hosts the Mae Moh Mine, Thailand's largest lignite-mining operation, managed by the Electricity Generating Authority of Thailand (EGAT) (Morley et al., 2001; Jitmahantakul et al., 2024).

The Central Sub-basin, which contains the principal mineable coal seams, is a structurally complex graben dominated by N–S- to NNE–SSW-trending normal faults and subordinate NE–SW-trending and antithetic structures. Previous studies using boreholes, outcrop mapping, and 2D and 3D seismic data identified segmented and linked normal faults, relay structures, en-echelon fault arrays, domino-style faulting, and bed-parallel slip (Morley and Wonganan, 2000; Morley et al.,

2001, 2004; Simpson and Jitmahantakul, 2021; Jitmahantakul et al., 2024). These structures locally offset, repeat, or remove the economically important Q- and K-zone coal seams and strongly influence their spatial continuity. Earlier 3D seismic work also demonstrated that inherited basement fabrics and multiphase extension-controlled fault geometry and coal-seam distribution within the mine area.

EGAT plans to develop underground mining in the Central Sub-basin, increasing the need for a reliable depth-domain structural model. Underground mine design and coal-reserve calculation require accurate predictions of fault positions at mineable horizons and an understanding of fault segmentation, linkage, dip variation, and displacement. A newly acquired high-resolution 3D seismic dataset, integrated with well data and depth conversion, provides an opportunity to refine the existing interpretation and reduce uncertainty in coal-seam geometry.

This study develops an integrated depth-domain 3D fault model of the planned underground mining area using the new seismic and well dataset. The objectives are to map fault surfaces, characterize their orientation, dip, vertical extent, linkage, and displacement, and to evaluate their relationships with the principal coal seams. The resulting model is compared with previous EGAT and published interpretations and is intended to improve coal-reserve estimation, underground mine planning, and assessment of fault-related geological and geotechnical risks.

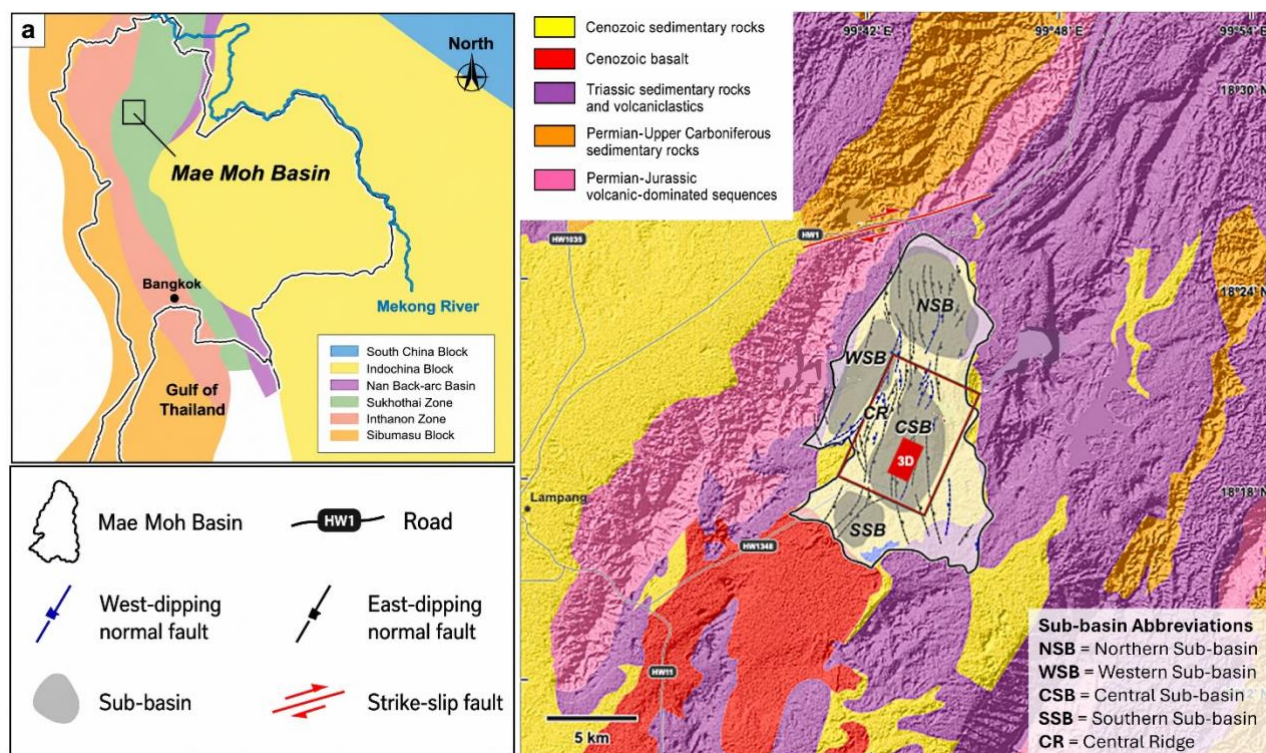


Figure 1. (A) Simplified regional geological map showing the location of the Mae Moh Basin. (B) Geological map of the study area at 1:50,000 scale. The red rectangle indicates the study-area boundary, and the inner rectangles show the extent of the latest EGAT 3D seismic survey. The geological map was prepared by the Department of Mineral Resources and modified after Jitmahantakul et al. (2024).

2. Geological Setting

2.1 Structural Geology

The Mae Moh Basin (Fig. 1) is a Cenozoic intermontane rift basin in Lampang Province, northern Thailand. It is approximately 16 km long and 9 km wide, with a sedimentary fill generally less than 1 km thick. The basin unconformably overlies folded and faulted Triassic sedimentary rocks of the Lampang Group within the Sukhothai Zone and hosts one of Thailand's most important lignite resources (Piyasin, 1971; Chonglakmani, 1972; Ward, 1991; Ratanasthien et al., 2008).

The basin forms part of the fault-controlled Cenozoic basin system of northern Thailand, which developed within a regional

extensional tectonic regime accompanied by strike-slip deformation during the Cenozoic (Morley et al., 2001; Morley & Wang, 2023; Jitmahantakul et al., 2024).

The Mae Moh Basin comprises four sub-basins (Fig. 1): Northern, Western, Central, and Southern (Jitmahantakul et al., 2024). The Western and Central Sub-basins are separated by the NNE-trending Central Ridge, a pre-Cenozoic basement high that influenced basin geometry and sediment distribution. The Central Sub-basin, which contains the principal mining area, is a highly faulted graben with approximately 900 m of sedimentary fill. Its structure is controlled by a series of major east-dipping normal faults that define the basin

architecture and accommodate most of the extensional displacement. These faults are expressed as NE–SW-trending border faults and N–S- to NNE–SSW-trending intra-basin normal faults formed during E–W to ENE–WSW extension. Previous three-dimensional seismic studies have shown that the major faults are laterally linked across the economically significant K and Q coal seams and play a fundamental role in controlling the structural configuration and evolution of the basin (Morley et al., 2001; Simpson & Jitmahantakul, 2021; Jitmahantakul et al., 2024). Synsedimentary fault activity produced growth structures that controlled accommodation and coal-seam distribution, while borehole and seismic data indicate approximately 20% basin-scale extension (Morley et al., 2001; Simpson & Jitmahantakul, 2021; Jitmahantakul et al., 2024; Chenrai, 2025).

Late Miocene–Pliocene tectonic inversion produced broad synclinal folding, localized uplift, and erosion, particularly along the southwestern margin of the Central Ridge. Fault-block rotation, relay structures, and bed-parallel slip further record the basin's multiphase deformation history (Morley et al., 2001, 2011; Jitmahantakul et al., 2024).

2.2 Stratigraphy

The Mae Moh Group (Fig. 2) comprises, from oldest to youngest, the Huai King, Na Khaem, and Huai Luang formations. Together, these units record a transition from early fluvial–alluvial deposition to coal-bearing lacustrine conditions and, finally, renewed fluvial, swamp, and alluvial sedimentation (Corsiri and Crouch, 1985).

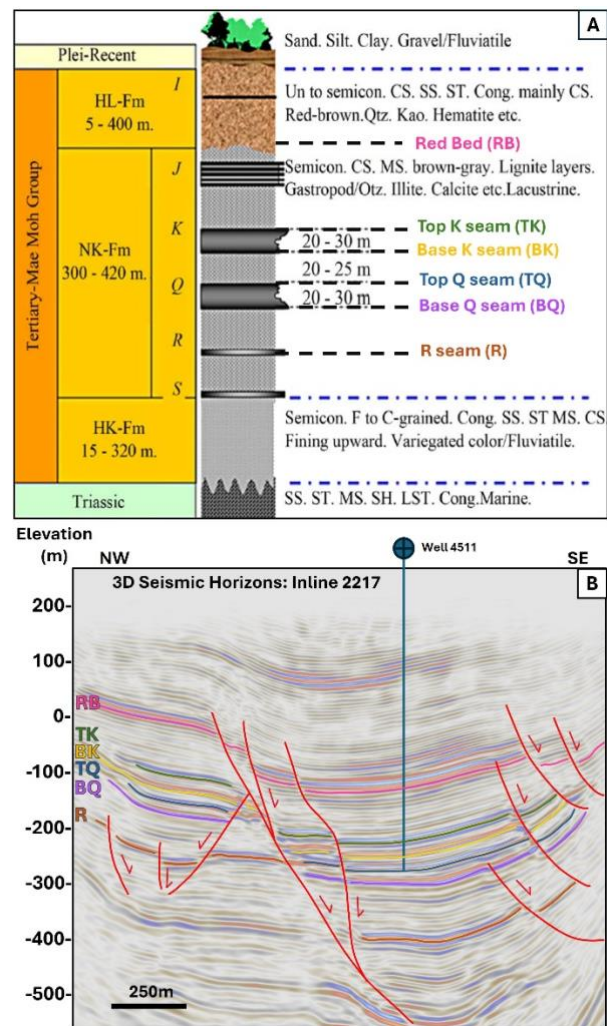


Fig. 2. (A) Simplified stratigraphy of the Mae Moh Group and interpreted horizons in the Mae Moh Mine, including the Red bed (RB), top and base of the K and Q seams (TK, BK, TQ, BQ), and R seam (R) (modified after Zarlin et al., 2012). (B) Interpreted seismic reflection profile (Inline 2217) showing seismic stratigraphic and structural variations of the Mae Moh Group across the study area. Interpreted horizons are color-coded as follows: pink (RB), green (TK), yellow (BK), blue (TQ), purple (BQ), and brown (R). The profile is intersected by several normal faults, including a major east-dipping fault that offsets multiple stratigraphic horizons and represents one of the principal structures

controlling the structural architecture of the Central Sub-basin (Simpson & Jitmahantakul, 2021; Jitmahantakul et al., 2024).

The Huai King Formation, which varies from 15 to 150 m in thickness, is the lowermost unit consisting mainly of a fining-upward sequence of semi-consolidated sediments—including conglomerate, sandstone, siltstone, and claystone—deposited in fluvial and alluvial environments during initial basin development. (Silaratana et al., 2004; Khamhom, 2013; Sangsrichan et al., 2023; Maneepong et al., 2025).

The overlying Na Khaem Formation is the principal coal-bearing unit. It is approximately 300–400 m thick (Jitmahantakul et al., 2024). And it consists predominantly of lacustrine mudstone and claystone, with minor sandstone and multiple lignite seams. The formation is divided into three members. Member III, or the Underburden, contains the thin R and S seams. Member II contains the economically important Q and K coal zones, each commonly 15–30 m thick and separated by claystone interburden. Member I consists mainly of mudstone, claystone, and calcareous siltstone containing the thinner J coal seam (Silaratana et al., 2004).

The Huai Luang Formation, commonly termed the “Red beds,” forms the uppermost unit, which varies in thickness from less than 5 up to 400 m, consisting of semi-consolidated to unconsolidated red-brown claystone, mudstone, siltstone, sandstone, and conglomerate deposited in fluvial, swamp, and alluvial environments during the final stage of basin development (Khamhom, 2013; Jitmahantakul et al., 2024).

3. Datasets and Methods

3.1 Available Data

This study uses a high-resolution 3D seismic dataset acquired by EGAT in February 2025 over approximately 9.6 km² of the Central Sub-basin. The survey comprised 10,543 receiver stations and 9,749 source points at nominal 10 m spacing. Data are referenced to WGS 84/UTM Zone 47N and were processed using an elevation datum of 360 m above mean sea level.

A depth-imaging workflow produced a depth-domain volume that images the coal-bearing succession and deeper structures to approximately 100–300 meters below mean sea level. This avoided a separate post-interpretation time-to-depth conversion and enabled direct analysis of fault and horizon geometry. EGAT borehole data were used to correlate stratigraphic markers and calibrate the seismic interpretation.

3.2 Seismic Horizon Interpretation

Seismic interpretation was conducted in Petrel using the depth-domain 3D volume. Horizon selection and stratigraphic correlation were guided by Simpson and Jitmahantakul (2021) and the 2025 EGAT final operations report (GeneSeis Crew Management, 2025). Horizons were initially interpreted on every tenth inline and crossline, corresponding to a spacing of approximately 100 × 100 m. Interpretation density was increased to every fifth line and, locally, every line (10 × 10 m) in areas of complex deformation or poor reflector continuity.

Horizons were auto-tracked using a correlation threshold of 0.9 and manually reviewed and corrected where necessary. The principal coal seams were identified by their

characteristic high-amplitude reflections, produced by the acoustic-impedance contrast between lignite and the surrounding mudstone. In areas of missing or poor-quality data, Petrel's polygon-interpolation tool was used to construct horizon surfaces from adjacent interpretation control.

3.3 Fault Interpretation and Fault Analysis

Faults were mapped directly from reflector offsets, terminations, and discontinuities on inline, crossline, and arbitrary seismic sections (Fig. 4). Seismic attributes were not used because the major fault surfaces and coal-seam offsets were adequately resolved in the depth-domain volume. Fault correlations were checked against borehole data, previous EGAT interpretations, and published structural models (Simpson and Jitmahantakul, 2021; Jitmahantakul et al., 2024).

The interpreted fault surfaces and horizons, including the Red beds (RB), top and base K seam (TK and BK), top and base Q seam (TQ and BQ), and R seam, were exported to MOVE for structural analysis. The procedure reduced short-wavelength interpretation artifacts while preserving the regional fault geometry. The processed surfaces were used to characterize fault orientation, dip, continuity, segmentation, and spatial relationships with the principal coal seams.

3.4 Data Limitations

The 2025 seismic survey covers only part of the Central Sub-basin; therefore, the resulting interpretation should not be extrapolated to the entire Mae Moh Basin. Seismic quality decreases locally because of low signal-to-noise ratios and interference associated with active mining operations,

reducing reflector continuity and the detectability of small-displacement faults. The depth-domain seismic dataset used in this study was designed to provide reliable structural imaging to the Huai King Formation (approximately 800–1,000 m depth), with the top Triassic basement remaining interpretable across the full-fold survey area (GeneSeis Crew Management, 2025).

Although depth imaging reduces uncertainty associated with time-to-depth conversion, depth accuracy remains dependent on the velocity model and available borehole control. Interpolation, resampling, and smoothing may introduce additional uncertainty in poorly constrained areas. Consequently, subtle faults and poorly imaged fault tips may remain unresolved.

4. Results

The depth-domain 3D seismic volume, calibrated with borehole data, enabled interpretation of the Red bed, top and base K seam, top and base Q seam, and R seam horizons. In the central study area, the K, Q, and R seams occur at approximate depths of 80 m, 110 m, and 200–225 m below mean sea level, respectively (Fig. 2). The horizons are generally laterally continuous but are locally offset, deformed, or absent where intersected by normal faults. The results are presented first in map view, followed by the vertical extent and down-dip geometry of the faults and their effects on the coal-bearing succession.

4.1 Spatial Distribution and Orientation of Faults

The interpreted fault network is dominated by N–S- to NW–SE-striking normal faults, although fault density, continuity, and dip

direction vary across the study area and between stratigraphic levels (Fig. 3).

At the shallow Red bed horizon, fault traces are relatively short, segmented, and discontinuous (Fig. 3). At the K and Q seam levels, these segments become longer and more

continuous, commonly linking to form curved or sigmoidal traces (Fig. 3B, C). The increase in fault connectivity with depth is most evident in the central and eastern parts of the survey, where several segments merge into larger composite fault surfaces (Fig. 3, 4).

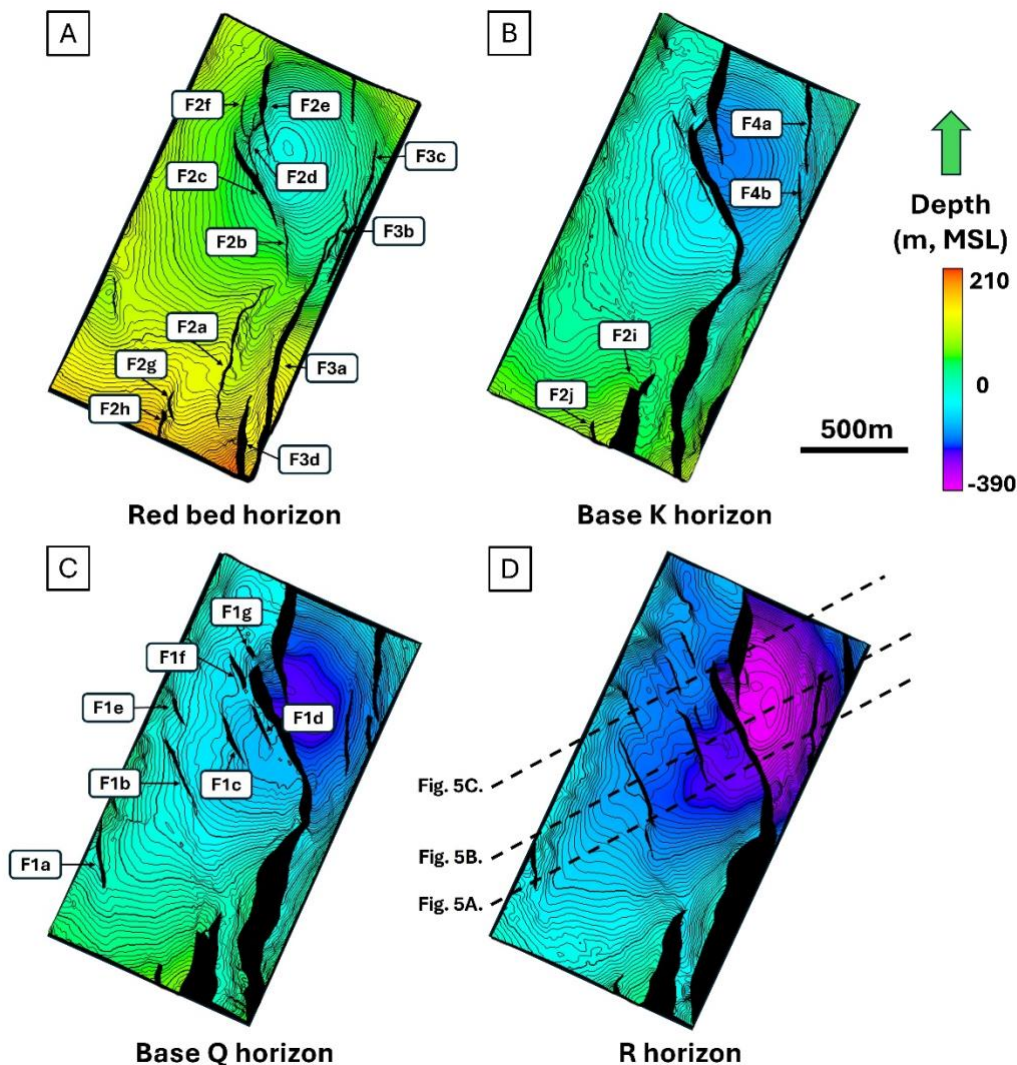


Fig. 3. Depth-structure maps of the interpreted seismic horizons derived from the newly acquired 2025 depth-domain 3D seismic dataset integrated with borehole control. Major stratigraphic - surfaces, including (A) the Red bed, (B) Base K seam, (C) Base Q seam, and (D) R seam horizons,

were interpreted and correlated across the study area. The resulting structural maps reveal fault geometry, including variations, vertical extension and down-dip geometry of the faults. Fault segments F2a–F2c, F3a–F3c, and F4a–F4b follow the nomenclature established by Jitmahantakul et al. (2024), whereas the remaining fault segments were newly interpreted from the 2025 depth-domain 3D seismic dataset.

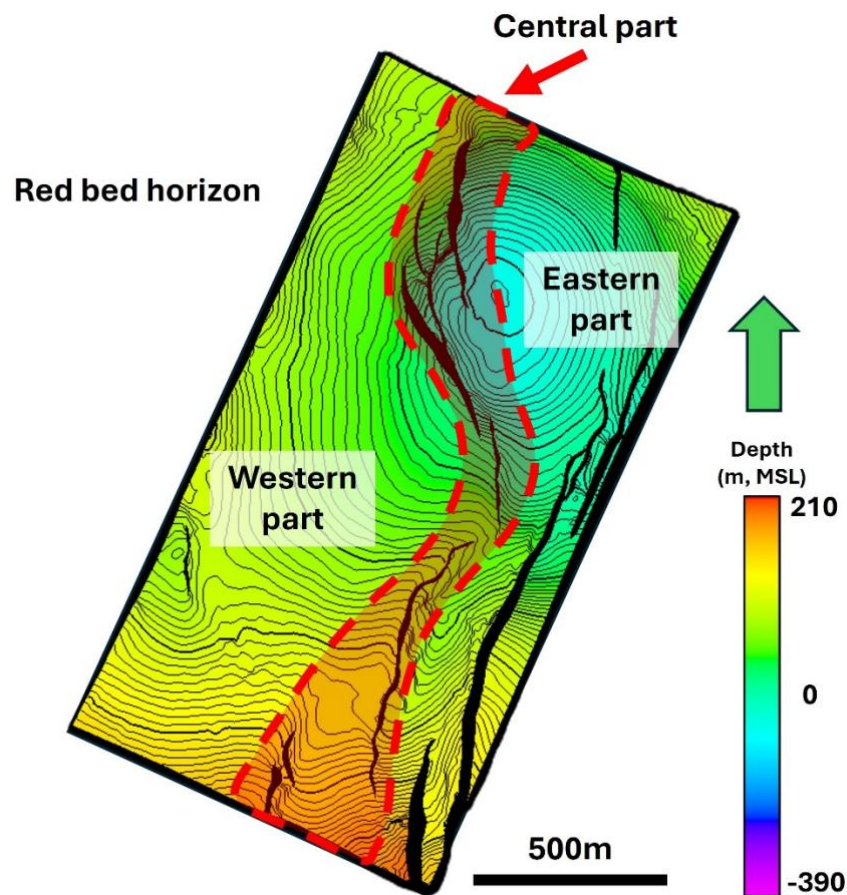


Fig. 4. Subdivision of the study area into Western, Central, and Eastern parts. The zone boundaries (red dashed lines) are defined based on the major fault zone, principally represented by fault segments F2a–F2c, following the structural framework of Jitmahantakul et al. (2024). These zones are used throughout this study to describe spatial variations in fault geometry, structural complexity, and coal-seam continuity.

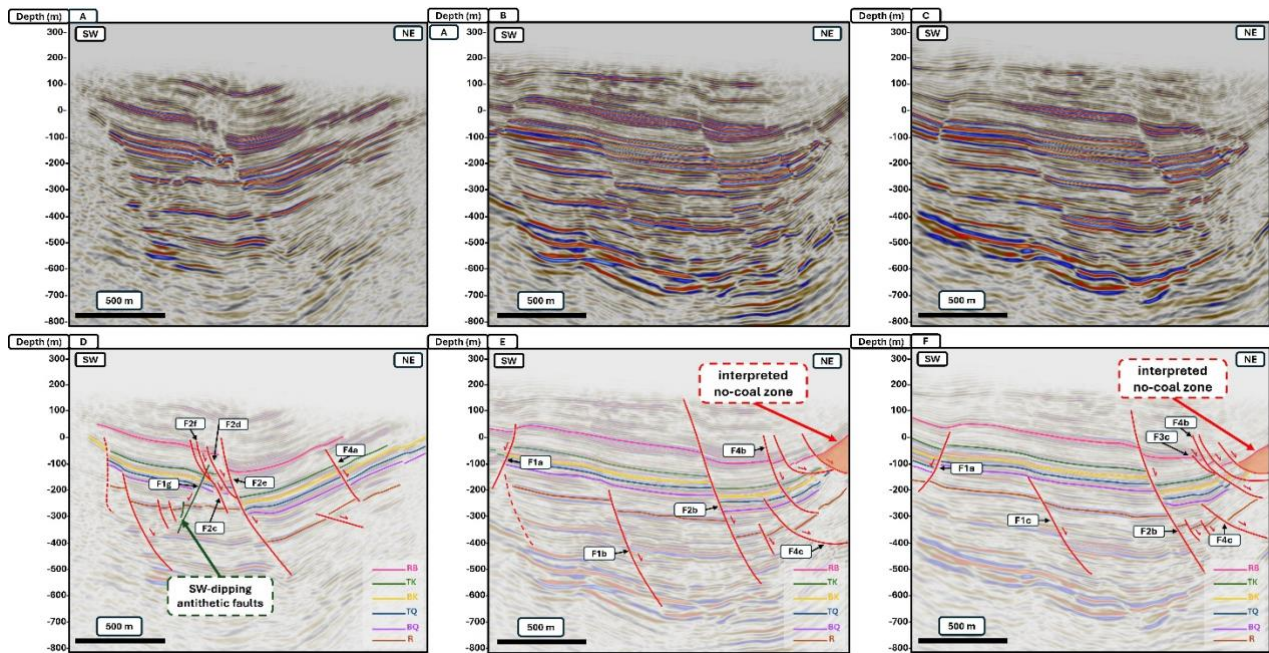


Fig. 5. Representative arbitrary seismic sections extracted from the interpreted 3D seismic volume showing the geometry and structural relationships of the extensional fault systems within the study area. Interpreted coal-bearing horizons (K, Q, and R seams) and fault surfaces are displayed. The sections show large-scale extensional faults, listric normal faults, domino-style normal fault geometries, and conjugate fault systems. Fault displacement increases with depth and is most pronounced within the R seam horizon, while localized coal-seam disruption and no-coal zones are associated with fault linkage and low-angle listric fault development in the eastern part of study area (Fig. 5E).

The eastern part of the study area is characterized by N–S-striking, east-dipping faults (Fig. 3). Several of these faults extend beyond the full-fold seismic coverage, preventing their complete lateral definition. Farther west and at deeper levels, NW–SE-striking faults become more prominent. These structures commonly form en-echelon arrays comprising larger NE-dipping faults and shorter SW-dipping antithetic faults (Fig. 5D).

Fault density and structural complexity are greatest at the R seam level. Here, the NW–SE-striking faults are more continuous and numerous than at the shallower K and Q

horizons. Their intersections with subsidiary antithetic faults subdivide the deeper succession into numerous fault-bounded blocks.

4.2 Vertical Distribution, Fault Limits, and Dip Variation

The faults display marked differences in their vertical extent. The major faults cut the complete interpreted succession from the Red bed horizon to at least the R seam (Fig. 5). Several continue below the deepest mapped horizon. Therefore, their lower tips are not resolved within the seismic volume.

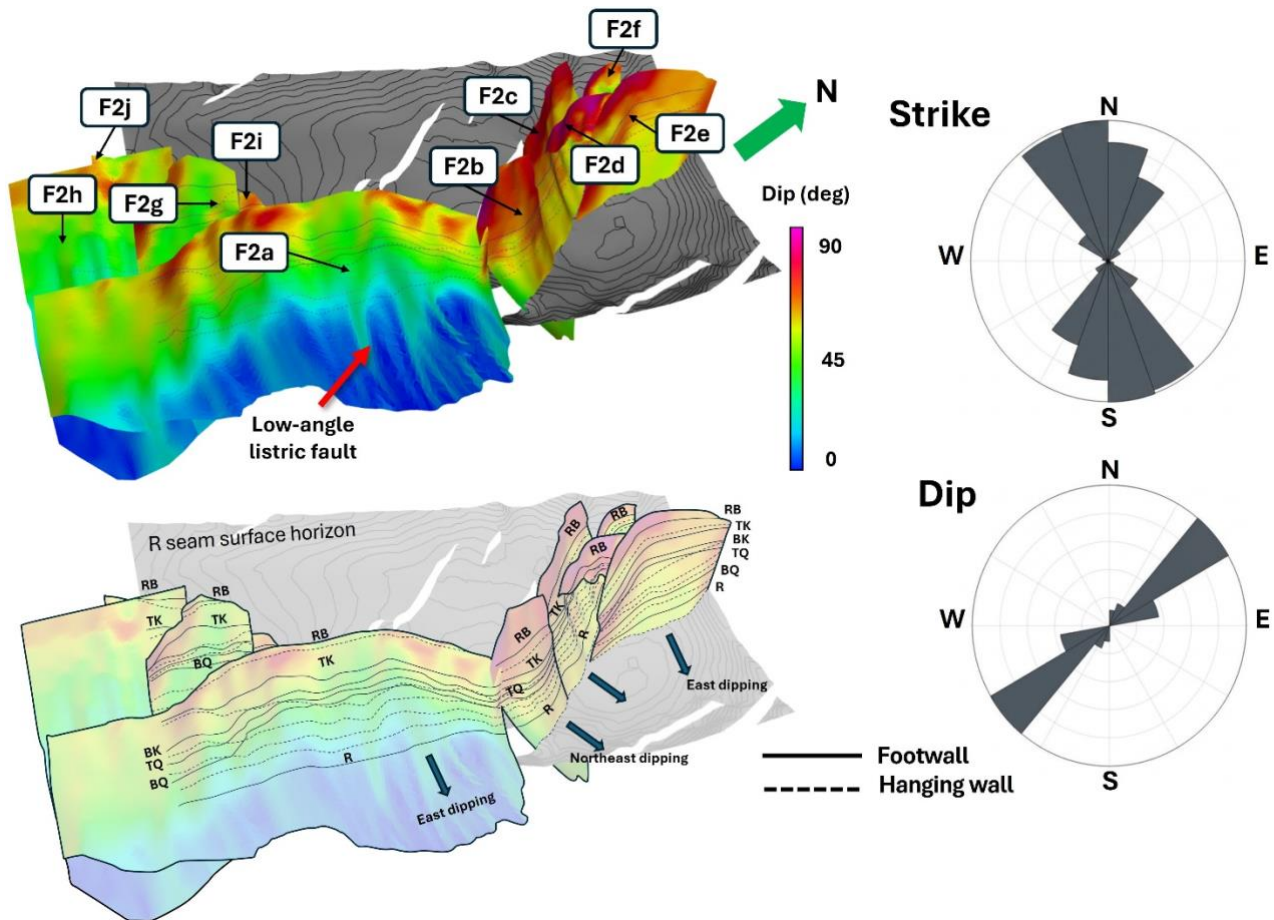


Fig. 6. Fault geometry analysis of the central study area derived from the interpreted 3D fault model. Fault segments are predominantly oriented NW–SE to N–S and exhibit two main geometries: (1) steeply dipping faults in the northern part of the study area, with dip angles $>60^\circ$ (orange - red) within the shallow Red bed horizon that decrease with depth, and (2) east-dipping low-angle listric faults characterized by moderate dip angles ($30 - 60^\circ$) (green - yellow) at shallow levels that progressively flatten to $<30^\circ$ (blue - green) within the deeper R horizon. The interpreted fault architecture demonstrates systematic dip reduction with depth and reflects the extensional structural framework controlling the coal-bearing succession.

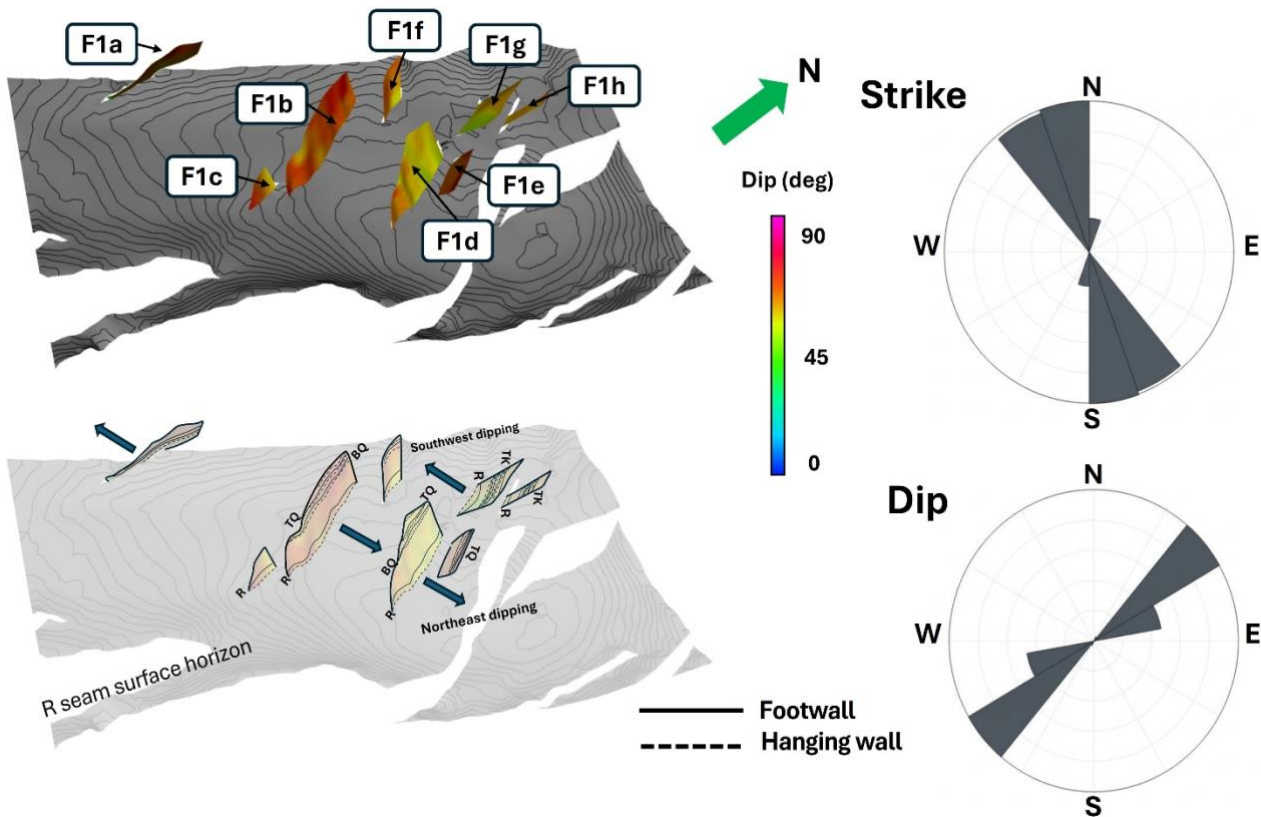


Fig. 7. Fault geometry analysis of the western study area. The interpreted fault network comprises two principal NW–SE-striking fault systems: (1) moderately NE-dipping intra-basin faults, previously described by Jitmahantakul et al. (2024), which form a staircase-like geometry and predominantly affect the deeper R seam horizon, with only minor offsets observed within the K and Q coal seams; and (2) SW-dipping antithetic faults that form conjugate fault pairs with the NE-dipping structures (Fig. 5). These antithetic faults are generally shorter, smaller, and exhibit lower displacement magnitudes than their NE-dipping counterparts. Intersections between both fault systems generate localized zones of increased structural complexity within the western part of the basin. Dip-angle analysis indicates that both fault systems are characterized predominantly by moderate dips of approximately 30°–60° (green - orange), consistent with extensional deformation in the Mae Moh Basin (Jitmahantakul et al., 2024)

At shallow levels, the major faults are represented by separate, steeply dipping segments (Fig. 6). These segments link downward through the K and Q intervals and form more continuous horizons at the R seam level (Fig. 3). Fault displacement generally increases downward and is greatest within the deeper coal-bearing succession.

A second population is concentrated mainly around the R seam. These NW–SE-striking faults produce large offsets at depths of approximately 600–625 m, but their displacement decreases upward (Fig. 5). Minor offsets remain visible at the K and Q horizons, whereas many of the faults are absent or unresolved at the Red bed level (Fig. 3). Their upper tips are therefore interpreted to occur within or above the coal-bearing succession. The associated SW-dipping antithetic faults are generally shorter and have more restricted vertical extents than the larger NE-dipping faults (Fig. 7).

The major faults also show a systematic decrease in dip with depth. Dips are commonly 60°–90° near the Red bed horizon at approximately 400–450 m depth, decrease to 30°–60° around the K seam, and locally become less than 30° below the Base Q horizon (Fig. 6). This downward flattening defines listric fault surfaces. In contrast, many of the smaller synthetic and antithetic faults retain moderate dips of approximately 30°–60° through the deeper succession (Fig. 7).

4.3 Fault Architecture of the No-Coal Area

An interpreted no-coal zone is developed within the eastern part of the survey, where coherent K and Q coal-seam reflections cannot be continuously traced across a zone of linked east-dipping normal faults (Figs. 4E and 7). At the Red bed level, these faults occur as separate segments. Downward, they progressively link or merge into common fault surfaces that intersect the K and Q coal seams (Fig. 5E).

The faults associated with the no-coal area have relatively large displacements and listric geometries. Their dips range from approximately 30° to 60° (green - orange) within the Red bed succession and decrease to less than 30° (blue) below the Base K horizon. This geometry produces substantial vertical separation and juxtaposition of the coal-bearing succession across the fault zone.

The seismic relationships indicate that the local absence of the K and Q seams is associated with structural omission across linked low-angle faults rather than simple thinning of otherwise continuous seams (Fig. 8). Subsidiary antithetic faults further increase deformation within the hanging wall and create additional fault-bounded blocks. Because several master faults continue beyond the eastern edge of the full-fold seismic coverage, the eastern limit of the no-coal area remains incompletely constrained.

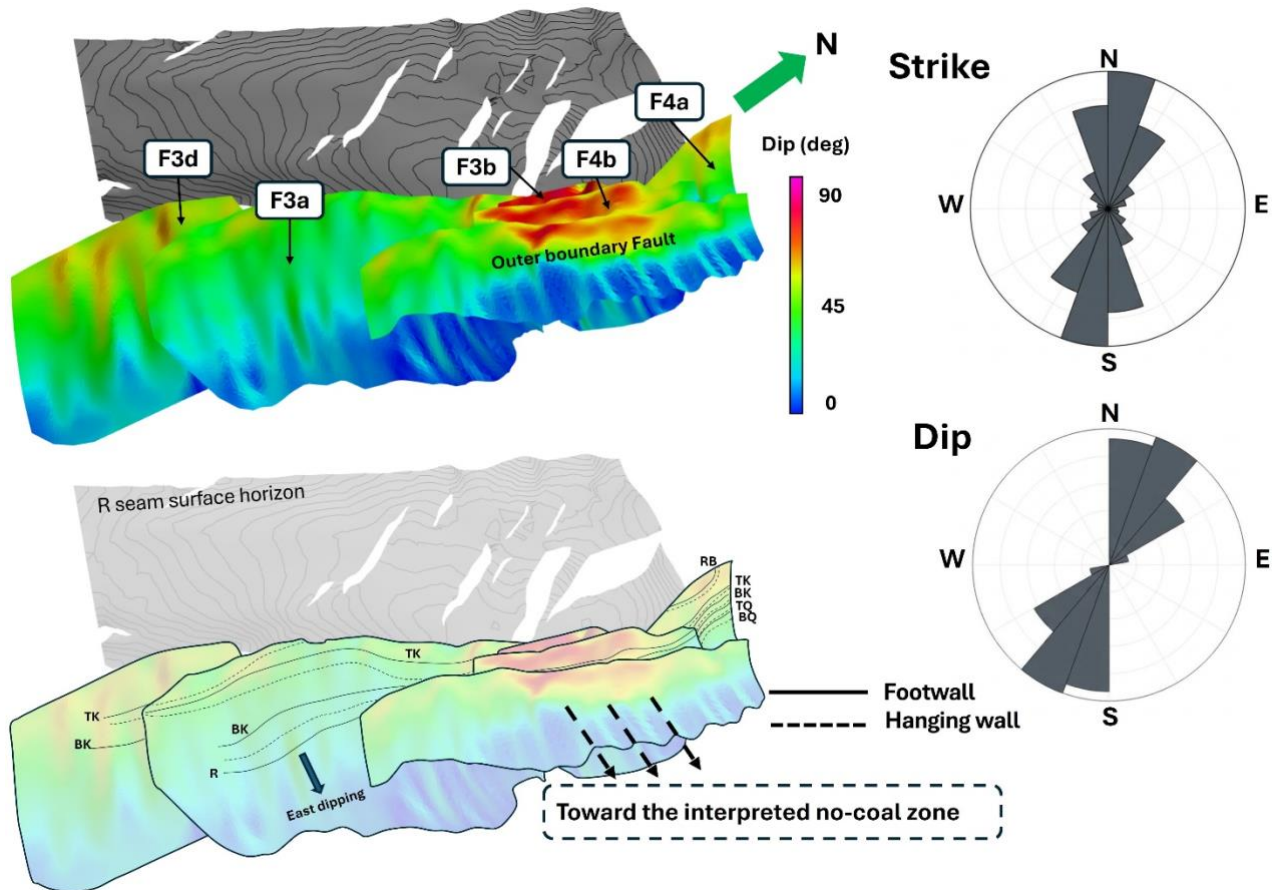


Fig. 8. Fault geometry analysis of the eastern study area. A series of relatively shallow east-dipping faults is identified along the eastern margin of the study area. These faults generally strike N–S and exhibit low- to moderate-angle eastward dips (approximately 30° – 60°). Most interpreted fault traces occur outside the full-fold coverage area of the seismic survey. Fault geometry analysis indicates progressive dip reduction with depth (red to blue), forming low-angle listric fault geometries that flatten within the deeper horizons. Note: The dashed polygon indicates the approximate extent of the interpreted no-coal zone, inferred from the inability to trace coherent K and Q coal-seam reflections across this area in the seismic profiles (Fig. 5E).

5. Discussion

5.1 Development of the fault network

The interpreted faults form a vertically connected and hierarchical network rather than independent structural system. Segmented traces at shallow levels and more continuous surfaces at depth are best explained by fault propagation, overlap, and linkage during

progressive extension. Changes in strike and sigmoidal map geometries probably developed where adjacent segments interacted or where faults propagated above oblique basement structures (Fig. 3). This interpretation is consistent with previous models of segmented normal faulting in the Central Sub-basin,

although direct basement control cannot be demonstrated because the basement is not consistently imaged in the new seismic volume (Simpson and Jitmahantakul, 2021; Jitmahantakul et al., 2024).

The mapped fault orientations are broadly compatible with regional E–W to ENE–WSW extension. However, the new dataset primarily constrains fault geometry rather than regional stress orientation. The influence of inherited basement fabrics should therefore be regarded as a plausible regional control rather than a direct result of this study (Simpson and Jitmahantakul, 2021).

5.2 Vertical fault development and deformation of the coal succession

The greater displacement observed at the deeper R seam, together with the upward reduction in displacement, suggests that many faults initiated early and propagated upward while their activity progressively declined. This interpretation is compatible with syn-rift fault growth, but displacement variation alone does not demonstrate syndepositional movement. Confirmation would require systematic thickening of stratigraphic intervals or growth-strata relationships across individual faults.

The downward flattening of the major faults has important implications for coal-seam geometry. Listric movement can rotate hanging-wall blocks and generate normal drag or rollover deformation, producing gradual changes in seam elevation and dip in addition to abrupt offsets. Consequently, the structurally disturbed zone may extend beyond the mapped fault plane. Reserve models based only on vertical throw or surface fault traces may therefore underestimate the width and complexity of fault-related deformation.

The faults also differ in vertical extent. Through-going faults affect several coal horizons and define the principal structural blocks, whereas faults concentrated near the R seam have less influence on the overlying K and Q seams. Structural complexity and mining significance must therefore be evaluated separately at each target seam rather than inferred from a single horizon map.

Clear reverse reactivation or inversion-related deformation is not recognized within the new survey. This does not contradict evidence for Late Miocene–Pliocene inversion and bed-parallel slip elsewhere in the basin. Such structures may lie outside the survey area or be below seismic resolution. The imaged architecture is therefore interpreted as being dominated by extensional deformation.

5.3 Effects on Coal-Seam Geometry and Continuity

Away from the major fault zones, the K and Q seams remain laterally continuous and can be correlated confidently across the study area. Near the faults, however, they display abrupt changes in elevation, vertical separation, and localized omission. Linked fault segments generate irregular hanging-wall and footwall geometries and divide the seams into fault-bounded compartments with different depths and structural attitudes.

Downward flattening of the listric faults is accompanied by rotation and deformation of their hanging-wall strata. This produces local changes in coal-seam dip, normal drag, and rollover geometries. Subparallel faults locally bound rotated domino-style blocks, whereas intersections between synthetic and antithetic faults form smaller and more structurally complex compartments.

The deeper R seam is more intensely faulted than the K and Q seams, being intersected by a greater number of fault segments and exhibiting larger vertical separations between adjacent fault blocks. Consequently, fault displacement and structural compartmentalization increase with depth, whereas the influence of faulting generally diminishes upward through the K and Q intervals. These relationships indicate that structural complexity increases toward the interpreted no-coal zone, where coherent coal-seam reflections cannot be continuously traced, and within the central and eastern fault-intersection zones (Fig. 3, 5).

6. Conclusion

The newly acquired 2025 depth-domain 3D seismic dataset, integrated with borehole information, provides a mine-focused three-dimensional model of the fault architecture within the Central Sub-basin. The fault network is dominated by N–S- to NW–SE-striking normal faults. Short and discontinuous traces at shallow levels progressively link downward into larger fault surfaces that intersect the principal coal-bearing horizons. Many major faults exhibit listric geometries, with steep upper segments and lower-angle surfaces at depth.

An interpreted no-coal zone is spatially associated with linked east-dipping faults that produce substantial displacement and structural omission of the K and Q seams. Its eastern extent remains uncertain because several controlling faults continue beyond the full-fold seismic coverage. The K and Q seams remain relatively continuous away from the major fault zones but are locally offset and compartmentalized. The deeper R seam is more intensely faulted and exhibits greater vertical separation between adjacent structural blocks.

The resulting 3D structural model improves the definition of fault continuity, vertical extent, linkage, and dip variation within the mineable coal horizons. These structural relationships provide an improved framework for subdividing the coal succession into structurally realistic mining blocks, constraining the extent of the interpreted no-coal zone, and identifying structurally complex areas relevant to underground mine planning and geological risk assessment. Interpretation uncertainty remains near the survey margins, below the deepest interpreted horizon, and in areas where seismic quality is insufficient to resolve small-displacement faults.

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