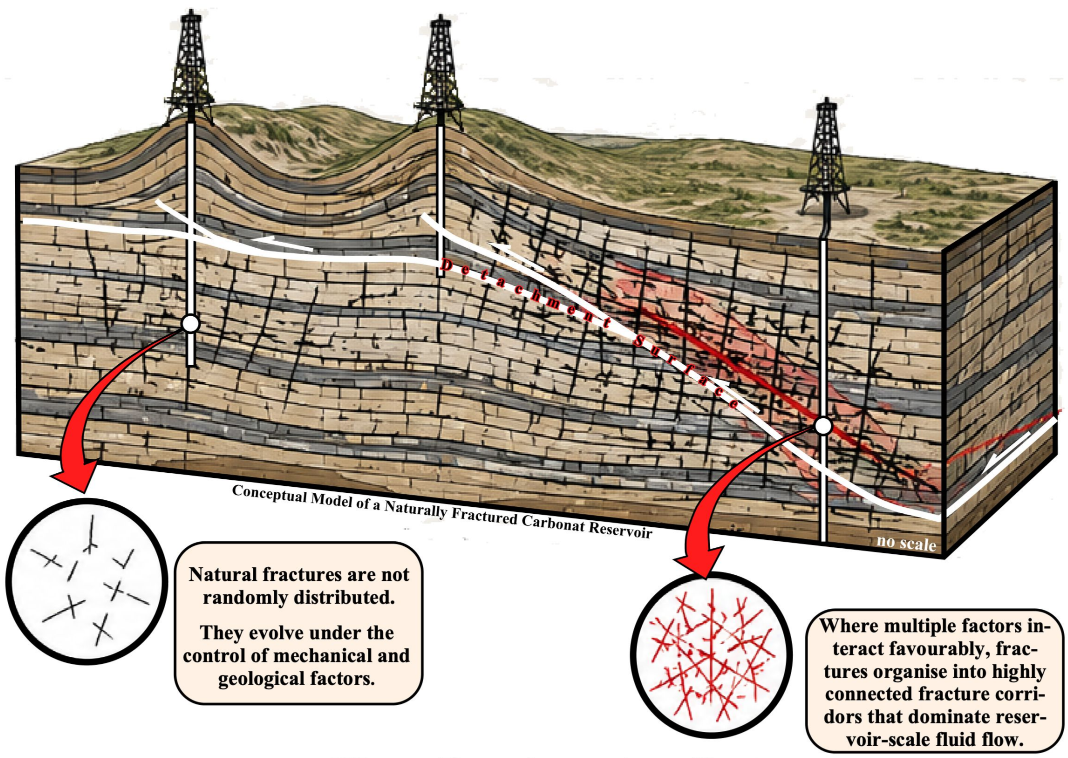
Notes on
Natural Fractured Carbonate Reservoir-Rocks
PART THREE

Aim of this Memorandum

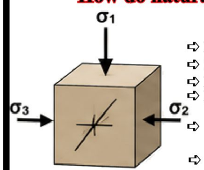
To understand how natural fractures form, why they concentrate, and where they are most likely to occur in several petroleum system, so as to enhance reservoir connectivity, fluid flow, and hydrocarbon recovery.



Three Complementary Parts

Part I- Mechanical Foundation

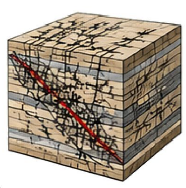
How do natural fractures form?



- ➪ Effecftive stresses
- ➪ Tectonic regimes
- ➪ Faulting ans rock failure
- ➪ Fracture initiation, propagation and termination
- ➪ Conditions for productive reservoir fractures
- ➪ Classification of natural fractures

Part II- Geological Controls

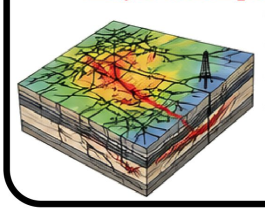
Why do fractures concentrate and evolve into fracture corridors?



- ➪ Lithology
- ➪ Texture
- ➪ Porosity
- ➪ Pore-fluid pressure
- ➪ Bed thickness
- ➪ Structural position
- ➪ Deformation history
- ➪ Fracture corridors and reservoir connectivity

Part III- Application a Petroleum System

Where are fracture corridors most likely to occur in petroleum system?



- ➪ Regional and field-scale structural framework
- ➪ Prediction of fracture corridor location
- ➪ Identification tools and data-sets
- ➪ Impact on well productivity and field development
- ➪ Implications for recovery

Integrating Mechanical Principles and Geological Understanding to Identify Fracture Corridors That Control Reservoir Performance and Hydrocarbon Recovery

Ccramez, August 2026

Caption of the Cover

This conceptual illustration summarises the overall objective and logical organisation of the three-part memorandum — Notes on Natural Fractured Carbonate Reservoir-Rocks—. It illustrates the progressive evolution from isolated natural fractures to highly connected fracture corridors, emphasising that the economic behaviour of naturally fractured carbonate reservoirs depends not simply on the presence of fractures, but on their degree of organisation, connectivity, and hydraulic effectiveness.

The central block diagram represents a conceptual naturally fractured carbonate reservoir developed within a thrust-related anticline, similar to those occurring in the Zagros Fold–Thrust Belt. The left-hand inset illustrates a background fracture population in which fractures remain relatively isolated and contribute only limited reservoir connectivity. The right-hand inset illustrates the development of a fracture corridor, where repeated deformation has produced a highly connected fracture network capable of dominating reservoir-scale fluid flow, pressure communication, well productivity, and ultimately hydrocarbon recovery.

The lower part of the cover summarises the three complementary parts of the study. Part I establishes the mechanical foundations of natural fracturing by explaining the relationships between principal stresses, tectonic regimes, rock failure, and fracture development. Part II examines the principal geological controls governing fracture development, including lithology, texture, porosity, pore-fluid pressure, bed thickness, structural position, and the progressive evolution of fracture corridors.

Part III, the present memorandum, represents the practical application of the concepts developed in the two preceding volumes. Its objective is not to explain how fracture corridors form, but rather to determine where they are most likely to occur within the the case-study petroleum system, to evaluate their influence on reservoir connectivity, pressure communication, well productivity, and hydrocarbon recovery, and to discuss how geological, geophysical, and reservoir-engineering data can be integrated to identify the most prospective fracture-corridor fairways.

The central message of Part III is that successful development of naturally fractured carbonate reservoirs depends not merely on recognising the existence of natural fractures, but on identifying the geometry, continuity, and connectivity of the fracture corridors that ultimately control reservoir-scale fluid flow and field performance.

Author's Note

The author was trained within the traditional field-based petroleum geology tradition, in which direct geological observation, field relationships, well and seismic data, and critical interpretation constituted the primary foundations of geological understanding.

Recognising the increasing importance of digital technologies in modern geoscience, the present memorandum was prepared with the assistance of artificial-intelligence tools, particularly ChatGPT Pro.

Artificial intelligence (AI) was used as a support tool for literature review, conceptual exploration, critical discussion, logical consistency checks, and language refinement. It also served as a means of exploring alternative interpretations and testing the internal coherence of geological hypotheses. However, all geological interpretations, hypotheses, conclusions, recommendations, and any remaining errors are the sole responsibility of the author.

The objective was not to replace geological judgement, professional experience, or critical thinking, but rather to combine the insights derived from conventional geological practice with the analytical and exploratory capabilities offered by emerging AI technologies. In this context, artificial intelligence was employed as a knowledge assistant, while the formulation, evaluation and final acceptance or rejection of all geological ideas remained entirely under the sole responsibility of the author.

Executive Summary

This memorandum represents the third and final part of the trilogy Notes on Natural Fractured Carbonate Reservoir-Rocks. Whereas Part I established the mechanical principles governing the formation and evolution of natural fractures and Part II examined the principal geological controls responsible for their localisation and organisation into fracture corridors, the objective of the present study is to apply these concepts to the case-study petroleum system.

The memorandum does not claim that the distribution of fracture corridors within the study field is already known. On the contrary, it recognises that the existing legacy 3D seismic survey, although highly successful for exploration, was not acquired or processed for fracture-corridor characterisation. Consequently, the proposed fracture-corridor model is presented as the most plausible geological working hypothesis currently compatible with the available geological, structural, well, and seismic information.

Following a Popperian hypothetico-deductive approach, the study integrates multiple independent geological observations, including the structural framework, Oligocene reservoir architecture, mechanical stratigraphy, structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones, to identify those structural domains where fracture corridors are most likely to occur.

The analysis indicates that the relay and transfer zone between the Kurdamir and Topkhana structural culminations represents the highest-priority candidate area for the development of a major fracture-corridor fairway. Nevertheless, this interpretation remains a testable geological hypothesis whose validity must be evaluated through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and a targeted appraisal programme.

The memorandum emphasises that the principal uncertainty affecting future field development is not the existence of hydrocarbons, but the degree of reservoir connectivity controlled by fracture corridors. Consequently, future development decisions, including horizontal well placement, well spacing, production strategy, and reservoir management, should be based upon a substantially improved geological model rather than upon the existing legacy seismic interpretation.

The principal recommendation is therefore clear. Before committing to full-scale development based on the simultaneous production of both oil and gas, rather than prioritising gas production alone, the operator should undertake an inte-grated programme of amplitude-preserving seismic reprocessing, advanced seismic interpretation, fracture-corridor fairway mapping, and targeted appraisal drilling. The objective is not to delay development, but to reduce geological uncertainty sufficiently to optimise the development strategy, preserve reservoir pressure where possible, and maximise the long-term recovery of both oil and gas from the the case-study petroleum system.

Abstract

The distribution of fracture corridors is one of the principal controls on reservoir connectivity, fluid-flow pathways, well productivity, and hydrocarbon recovery in naturally fractured carbonate reservoirs. However, within the the case-study petroleum system the available legacy 3D seismic data do not possess sufficient resolution to identify these features directly.

This memorandum develops a working geological hypothesis for the probable distribution of fracture corridors by integrating independent geological evidence derived from the structural framework, Oligocene reservoir architecture, mechanical stratigraphy, structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones. Rather than attempting to identify fracture corridors directly, the study establishes a probability-based geological model that predicts where fracture corridors are most likely to occur and defines the geological observations required to test those predictions.

The proposed fracture-corridor model is formulated within a Popperian hypothetico-deductive framework and is explicitly presented as a testable geological hypothesis rather than a demonstrated geological fact. Its validity depends upon future amplitude-preserving seismic reprocessing, advanced seismic attributes, geological consistency tests, well calibration, and targeted appraisal drilling.

The study concludes that fracture corridors are expected to develop preferentially where mechanically competent carbonate reservoir units, high structural curvature, fault-damage zones, relay and transfer structures, and persistent deformation zones converge. The structurally complex corridor, separating the northern and southern structural culminations, is interpreted as the highest-priority candidate area for a major fracture-corridor fairway.

The principal recommendation is that field development should be preceded by systematic testing of the proposed fracture-corridor hypothesis. Such an approach is expected to reduce geological uncertainty, improve reservoir characterisation, optimise horizontal well placement, and maximise the long-term recovery of hydrocarbons from the case-study petroleum system.

ملخص

يُعدّ توزيع ممرات التصدع أحد العوامل الرئيسية المؤثرة على ترابط المكامن، ومسارات تدفق السوائل، وإنتاجية الآبار، واستخلاص الهيدروكربونات في مكامن الكربونات المتصدعة طبيعيًا. لا تتمتع بيانات المسح الزلزالي ثلاثي (K/T)، مع ذلك، ضمن نظام كردامير/توبخانة البترولي الأبعاد المتوفرة بدقة كافية لتحديد هذه الخصائص مباشرة.

تُطوّر هذه المذكرة فرضية جيولوجية عملية للتوزيع المحتمل لممرات التصدع، وذلك من خلال دمج أدلة جيولوجية مستقلة مستمدة من الإطار البنيوي، وبنية مكامن الأوليغوسين، والطبقات الميكانيكية، والانحناء البنيوي، ومناطق التصدع والتلف، ومناطق التتابع والتحويل، ومناطق التشوه المستمر. وبدلًا من محاولة تحديد ممرات التصدع مباشرةً، تُؤسس الدراسة نموذجًا جيولوجيًا قائمًا على الاحتمالات، يتنبأ بمواقع ممرات التصدع الأكثر احتمالًا، ويُحدد الملاحظات الجيولوجية اللازمة لاختبار هذه التنبؤات.

يُعدّ توزيع ممرات التصدع أحد العوامل الرئيسية المؤثرة على ترابط المكامن، ومسارات تدفق السوائل، وإنتاجية الآبار، واستخلاص الهيدروكربونات في مكامن الكربونات المتصدعة طبيعيًا. يُصاغ نموذج ممرات التصدع المقترح ضمن إطار استنتاجي افتراضي من منظور بوبر، ويُعرض صراحةً كفرضية جيولوجية قابلة للاختبار، وليس كحقيقة جيولوجية مُثبتة. وتعتمد صحته على إعادة معالجة البيانات الزلزالية مستقبلاً مع الحفاظ على السعة، والخصائص الزلزالية المتقدمة، واختبارات الاتساق الجيولوجي، ومعايرة الآبار، وحفر التقييم المُوجّه.

تخلص الدراسة إلى أنه من المتوقع أن تتطور ممرات التصدع بشكل تفضيلي عند التقاء وحدات خزانات الكربونات ذات الكفاءة الميكانيكية العالية، والانحناء البنيوي العالي، ومناطق التلف الناتج عن الصدوع، وهياكل النقل والتحويل، ومناطق التشوه المستمر. ويُفسَّر الممر ذو التركيب المعقد الذي يفصل بين قمتي كوردامير وتوبخانا على أنه المنطقة المرشحة ذات الأولوية القصوى لممر تصدع رئيسي.

التوصية الرئيسية هي أن يسبق تطوير الحقل اختبار منهجي لفرضية ممرات التصدع المقترحة. ومن المتوقع أن يقلل هذا النهج من عدم اليقين الجيولوجي، ويحسن من توصيف الخزانات، ويحسن من وضع الآبار الأفقية، ويزيد من استخلاص الهيدروكربونات على المدى الطويل من نظام البترول كوردامير/توبخانا.

Main Conclusions

The principal conclusions of the present memorandum are as follows:

1) **Fracture corridors cannot presently be mapped directly within the case-study petroleum system using the existing legacy 3D seismic data.**

2) **The available geological evidence supports the formulation of a scientifically rigorous working hypothesis for the probable distribution of fracture corridors.**

3) **The proposed model is based upon the convergence of multiple independent geological observations, rather than upon any single geological criterion.**

4) **Persistent deformation zones, fault-damage zones, relay and transfer structures, high structural curvature, mechanically competent carbonate reservoir units, and Oligocene depositional architecture constitute the principal geological controls governing fracture-corridor development.**

5) **The structurally complex relay and transfer zone between the northern and southern structural culminations represents the highest-priority candidate area for a major fracture-corridor fairway.**

6) **Reservoir connectivity within the the case-study petroleum system is expected to depend upon the interaction between depositional connectivity and fracture connectivity, rather than upon either mechanism considered independently.**

7) **The proposed fracture-corridor model remains a testable geological hypothesis whose degree of verisimilitude can only be evaluated through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and targeted appraisal drilling.**

8) **The principal geological risk is not that the proposed fracture-corridor model may ultimately prove to be incorrect, but that field development may proceed before its validity has been adequately tested.**

9) **Before committing to full-scale development, the operator should implement an integrated programme of seismic reprocessing, advanced seismic interpretation, fracture-corridor fairway mapping, and targeted appraisal.**

10) **The principal objective of this trilogy is not to claim certainty, but to provide a scientifically rigorous framework for reducing geological uncertainty, improving development decisions, and maximising the long-term recovery of both oil and gas from the Kurdamir/Topkhana petroleum system.**

Table of Contents

1) Introduction

The objective of Part III differs fundamentally from those of the two preceding memoranda.

Part I established the mechanical principles governing the initiation, propagation, and preservation of natural fractures. Part II examined the principal geological controls responsible for the localisation and organisation of fractures into fracture corridors capable of controlling reservoir-scale fluid flow.

The purpose of the present memorandum is not to claim that the distribution of fracture corridors within the case-study petroleum system is already known. Such a claim would be scientifically unjustified because the legacy 3D seismic data currently available were acquired primarily for exploration purposes and were not designed to image the subtle structural and stratigraphic features that commonly control fracture-corridor development.

Consequently, the present study adopts a Popperian hypothetico-deductive approach. Rather than presenting definitive interpretations, it proposes the most plausible geological working hypothesis for the distribution of fracture corridors based upon the mechanical principles established in Part I, the geological controls examined in Part II, and the currently available geological, structural, well, and seismic evidence.

The proposed fracture-corridor model should therefore be regarded as a testable geological hypothesis, not as a demonstrated geological fact. Its degree of verisimilitude can only be evaluated through confrontation with new evidence derived from high-quality seismic reprocessing, advanced seismic attributes, geological consistency tests, and subsequent drilling results.

Accordingly, the objective of Part III is not to provide certainty but to establish a scientifically rigorous framework within which alternative geological hypotheses can be formulated, critically discussed, and progressively tested against empirical evidence.

In this sense, the memorandum does not attempt to predict where fracture corridors must occur, but rather where, according to present geological knowledge, they are most likely to occur and how this hypothesis may be tested before full-scale field development.

This distinction is fundamental because the cost of accepting an incorrect fracture-corridor model during field development may be measured not only in financial losses but also in permanently unrecoverable hydrocarbons. Consequently, reducing geological uncertainty before development is not merely a scientific objective but an essential component of prudent reservoir management.

This is entirely consistent with the philosophy that has underpinned our memoranda from the beginning: theory-laden geology, critical rationalism, and conjectures that must be tested against evidence, not asserted as certainties. We believe that is exactly the tone that policymakers and operator management will find both scientifically rigorous and operationally responsible.

1.1) Purpose of Part III

The purpose of Part III is to apply the mechanical principles developed in Part I and the geological controls examined in Part II to the case-study petroleum system in order to formulate the most plausible geological working hypothesis for the distribution of fracture corridors within the Oligocene carbonate reservoir.

It is important to emphasise that the present memorandum does not attempt to identify the exact location of fracture corridors with certainty. Such an objective would be scientifically unjustified because the legacy 3D seismic data currently available were not acquired, processed, or interpreted for the purpose of fracture-corridor characterisation. Consequently, the geological model proposed herein should be regarded as a testable conjecture, whose degree of verisimilitude can only be evaluated through confrontation with the results of future high-resolution seismic reprocessing, advanced seismic attributes, and subsequent geological and reservoir evidence.

Accordingly, the principal objectives of Part III are to:

- formulate the most plausible geological hypothesis for the distribution of fracture corridors within the case-study petroleum system;
- identify the geological, structural, and stratigraphic factors that are most likely to control their localisation;
- establish a confidence ranking reflecting the relative geological probability of different fracture-corridor fairways;
- define the geological observations, geophysical analyses, and reservoir data required to test, modify, or reject the proposed hypothesis;
- evaluate the possible implications of alternative fracture-corridor scenarios for reservoir connectivity, well productivity, field development, and hydrocarbon recovery.

Throughout this memorandum, the proposed fracture-corridor model is therefore treated as a scientific working hypothesis rather than a demonstrated geological reality. Following the principles of critical rationalism, the objective is not to defend a preferred interpretation, but to formulate the boldest geological hypothesis that remains compatible with the available evidence and that can be subjected to rigorous testing by future seismic reprocessing and subsequent geological observations.

Ultimately, the value of the present memorandum does not lie in claiming certainty, but in providing a coherent predictive geological framework capable of guiding future investigations, reducing geological uncertainty, and supporting better-informed develop-ment decisions for the case-study petroleum system.

> **"In Popperian terms, the objective is not to verify the proposed fracture-corridor model, but to expose it to the most severe geological and geophysical tests capable of revealing its weaknesses or confirming its increasing verisimilitude."**

1.2) Relationship with Parts I and II

The three parts of the present memorandum constitute a single logical progression, in which each part provides the scientific foundation for the next.

Consequently, Part III should not be regarded as an independent study, but rather as the practical application of the mechanical and geological principles developed in the two preceding memoranda.

Part I established the mechanical framework governing the formation and evolution of natural fractures. It introduced the concepts of effective principal stresses, tectonic stress regimes, rock failure, fracture initiation, fracture propagation, and fracture termination, demonstrating that natural fractures constitute the mechanical response of rocks to their evolving stress history.

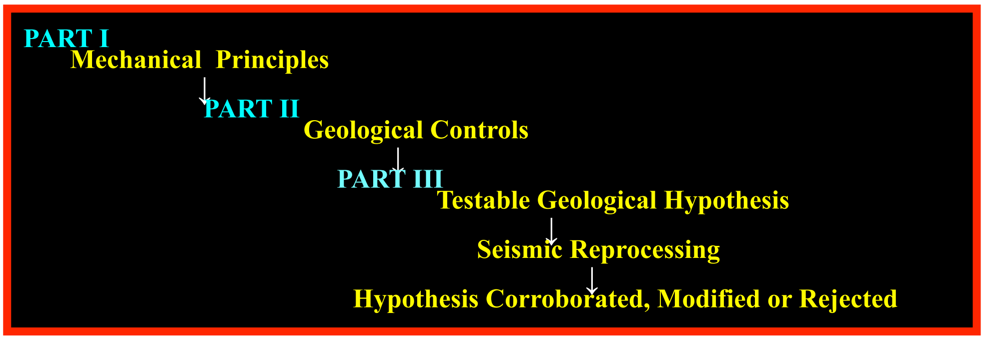
Part II examined the principal geological controls responsible for the spatial distribution and organisation of fractures. It demonstrated that lithology, texture, porosity, pore-fluid pressure, bed thickness, and structural position interact to determine whether isolated fractures evolve into connected fracture networks and, ultimately, into fracture corridors capable of controlling reservoir-scale fluid flow.

Having established how fractures form and why fracture corridors develop, the logical next step is to investigate where these fracture corridors are most likely to occur within the case-study petroleum system.

However, the transition from general geological principles to a specific reservoir model introduces a fundamental increase in geological uncertainty. Whereas the conclusions of Parts I & II are based upon well-established principles of rock mechanics, structural geology, and carbonate reservoir geology, the geological model proposed in Part III necessarily represents a working hypothesis whose degree of verisimilitude depends upon its future confrontation with empirical evidence.

Consequently, Part III should be viewed as the hypothetico-deductive extension of the two preceding memoranda. The geological interpretations proposed herein are not intended to replace future observations but rather to guide them by identifying the most plausible fracture-corridor fairways, defining the observations capable of testing these interpretations, and establishing the geological framework within which alternative hypotheses may be critically evaluated.

In this sense, the three memoranda together illustrate the progression from mechanical understanding, through geological interpretation, to testable prediction. Their common objective is not to eliminate geological uncertainty, but to reduce it progressively through the continuous interaction between theory, observation, and critical testing.



1.3) Why the Legacy 3D Seismic is Insufficient

The principal objective of the legacy 3D seismic survey acquired over the case-study petroleum system was hydrocarbon exploration rather than reservoir cha-

racterisation. Although the seismic volume proved highly successful in identifying the principal structural trap and guiding exploration drilling, it was neither acquired nor processed to resolve the subtle geological features that are most likely to control the distribution of fracture corridors within the Oligocene carbonate re-servoir.

Conventional seismic interpretation is primarily designed to identify major structural elements, including faults, folds, structural culminations, and regional stratigraphic horizons. Such information is generally sufficient for exploration purposes because the principal objective is to demonstrate the existence of a petroleum trap. However, successful field development requires a much more detailed under-standing of reservoir architecture, fracture connectivity, and reservoir-scale fluid-flow pathways.

The principal difficulty arises from a fundamental scale mismatch between the resolution of conventional seismic data and the dimensions of the geological features controlling production. Individual natural fractures, fracture swarms, and many fracture corridors commonly occur at scales well below conventional seismic resolution. Even where fracture corridors influence the seismic response indirectly through subtle changes in discontinuity, curvature, anisotropy, or amplitude behaviour, these signatures are frequently obscured by acquisition limitations, processing assumptions, and seismic noise.

Furthermore, the original seismic-processing workflow was not specifically designed to preserve or enhance the subtle amplitude and azimuthal variations required for modern fracture characterisation. As a result, geological features that may be critical for reservoir development remain only partially resolved or may not be recognisable at all within the existing seismic interpretation.

It is therefore important to recognise that the absence of visible fracture corridors on the legacy seismic does not demonstrate that such corridors are absent from the reservoir. Rather, it reflects the fact that the available seismic data have not yet been optimised for their detection.

Consequently, the present memorandum does not attempt to delineate fracture corridors directly from the existing seismic interpretation. Instead, it combines the mechanical principles established in Part I, the geological controls examined in Part II, and the currently available geological and structural evidence to formulate the most plausible geological working hypothesis for the distribution of fracture corridors within the case-study petroleum system.

The validity of this hypothesis cannot be established solely through geological reasoning. It must be subjected to rigorous testing using a new amplitude-preserving seismic reprocessing workflow, advanced seismic attributes, structural analysis, and subsequent well calibration. Only after this process will it become possible to evaluate which elements of the proposed fracture-corridor model are corroborated, which require modification, and which should be rejected.

Accordingly, the purpose of the legacy 3D seismic in the present memorandum is not to provide definitive answers, but to provide the geological framework from which testable predictions can be derived. The objective of the future seismic reprocessing is therefore not simply to generate a technically improved seismic image, but to confront the proposed geological hypothesis with new empirical evidence capable of increasing—or reducing—its verisimilitude.

1.4) From Geological Theory to Testable Working Hypotheses

Petroleum geology is fundamentally an interpretative science. Unlike laboratory sciences, where hypotheses may often be tested under controlled experimental conditions, geoscientists must infer the three-dimensional architecture of the subsurface from incomplete and indirect observations, including seismic data, well information, cores, well logs, production data, and regional geological knowledge. Consequently, every geological interpretation necessarily contains an element of uncertainty.

This uncertainty should not be regarded as a weakness of petroleum geology but as one of its fundamental characteristics. Geological models are not direct representations of reality; they are working hypotheses constructed to explain the available evidence and to predict geological features that cannot yet be directly observed.

Within the case-study petroleum system, the distribution of fracture corridors represents precisely such a problem. Although the geological and mechanical principles governing fracture-corridor development are reasonably well understood, their actual distribution within the reservoir remains uncertain because the available observations are incomplete and the legacy 3D seismic was not designed to image these subtle geological features directly.

Accordingly, the objective of the present memorandum is not to establish a definitive fracture-corridor model, but to formulate the most plausible geological working hypothesis consistent with the currently available evidence. This hypothesis represents the logical consequence of the mechanical principles developed in Part I, the geological controls established in Part II, and the existing geological, structural, and reservoir information available for tthe study field.

Following the principles of critical rationalism, the scientific value of such a hypothesis does not depend upon claims of certainty, but upon its ability to generate testable predictions. A useful geological hypothesis should indicate where fracture corridors are expected to occur, where they are unlikely to occur, which geological observations should corroborate or contradict the proposed model, and which additional data are required to discriminate between competing interpretations.

The forthcoming seismic reprocessing programme therefore constitutes far more than a technical exercise in data enhancement. It represents the principal opportunity to confront the proposed geological hypothesis with new empirical evidence. Features predicted by the hypothesis should become more clearly expressed if the interpretation is correct, whereas contradictory observations should lead to modification or rejection of the proposed model.

Consequently, geological interpretation should be regarded as a dynamic and iterative process rather than a search for immutable certainty. Each new observation contributes either to increasing the verisimilitude of the current geological model or to revealing its deficiencies and prompting the formulation of improved hypotheses.

From this perspective, the present memorandum should be viewed neither as a definitive interpretation nor as a speculative exercise, but as the formulation of a scientifically testable geological model designed to guide future investigations,

optimise seismic interpretation, reduce geological uncertainty, and support more informed reservoir-development decisions.

The central philosophy underlying Part III may therefore be summarised as follows:

> **The objective is not to prove where fracture corridors exist, but to formulate the most plausible geological hypothesis, derive explicit predictions from it, and subject those predictions to the most rigorous geological and geophysical tests permitted by future observations.**

2) Geological Basis for Predicting Fracture Corridors

The geological model proposed in Part III is based upon the principle that fracture corridors develop where several independent geological factors act together to concentrate deformation over geological time. Therefore, their prediction cannot rely upon a single geological observation but must integrate evidence derived from structural geology, reservoir architecture, mechanical stratigraphy, and the tectonic evolution of the case-study petroleum system.

The following sections examine the principal geological factors that, according to the concepts established in Parts I and II, are most likely to control the localisation of fracture corridors within the Oligocene carbonate reservoir. Each factor represents an independent line of geological evidence that contributes to the construction of a testable working hypothesis for fracture-corridor distribution.

These geological criteria should not be regarded as definitive proof of fracture corridors. Rather, they constitute a set of predictive indicators whose combined interpretation allows the identification of areas having different probabilities for fracture-corridor development. The confidence assigned to the proposed geological model therefore depends upon the degree of convergence between these independent observations and must ultimately be evaluated through seismic reprocessing, advanced seismic attributes, and subsequent geological and reservoir observations.

Accordingly, the following sections progressively assemble the geological evidence required to formulate the most plausible fracture-corridor model currently compatible with the available information. The resulting interpretation is presented as a working geological hypothesis, explicitly intended for future testing rather than as a definitive description of the subsurface.

2.1) Structural Framework of the Case-Study Petroleum System

The structural framework of th case-study petroleum system constitutes the first and perhaps most important line of geological evidence for predicting the distribution of fracture corridors. Since natural fractures develop in response to tectonic deformation, understanding the geometry and tectonic evolution of the structure is a prerequisite for identifying the regions where deformation has most probably been concentrated.

The study structure is interpreted as a thrust-related anticline developed within the Low Folded Zone of the Zagros Fold–Thrust Belt. Rather than representing an isolated structural culmination, it forms part of a larger thin-skinned compressional system detached above a regional décollement horizon. The present-day geometry reflects the cumulative effects of repeated compressional

N.B. — Each section of Chapter 2 develops an independent geological argument contributing to the construction of the final fracture-corridor model proposed for the case-study petroleum system. Consistent with the Popperian philosophy that underlies the present memorandum, no individual section claims to establish geological facts or to demonstrate the existence of fracture corridors. Instead, each concludes with a testable geological working hypothesis, derived from an independent line of geological evidence. The final fracture-corridor model is therefore not based upon a single observation but upon the convergence of multiple independent geological hypotheses. Its degree of verisimilitude will ultimately depend upon its ability to withstand rigorous testing through seismic reprocessing, advanced seismic attributes, well calibration, and subsequent geological and reservoir observations.

deformation, structural inversion, and progressive strain localisation throughout the late tectonic evolution of the basin.

The structure is characterised by two (northern and southern) principal culminations separated by approximately 10–12 km. Although these culminations have commonly been interpreted as distinct structural closures, available geological and drilling evidence suggests that they may represent two culminations developed on the same regional anticlinal structure. This interpretation has important implications for predicting reservoir connectivity and the possible continuity of fracture corridors between the two culminations.

The structural style also suggests that deformation was not distributed uniformly throughout the anticline. Variations in fold geometry, limb dip, fault displacement, and local structural curvature indicate that strain was preferentially concentrated within particular structural domains during folding and thrust propagation. Such domains are expected to have experienced repeated episodes of deformation and therefore constitute the most favourable locations for the development of highly connected fracture systems.

Particularly significant is the interaction between the principal thrust system and associated secondary faults, relay structures, and transfer zones.

These structural elements introduce additional heterogeneity into the deformation pattern and may locally enhance fracture intensity beyond that expected from simple folding alone. The structural architecture suggests that fracture corridors are unlikely to be distributed symmetrically across the anticline but instead concentrated within specific deformation zones.

It is also important to recognise that the present structural geometry represents only the final stage of a long tectonic history. The current anticline records the cumulative effects of multiple deformation episodes that have progressively modified the stress field and repeatedly reactivated pre-existing zones of weakness.

Therefore, the present-day fracture distribution is expected to reflect the integrated tectonic evolution of the structure rather than a single deformation event.

From the perspective of the present memorandum, the structural framework does not identify fracture corridors directly. Rather, it establishes the first-order geological constraints within which fracture corridors are most likely to develop. The structural framework therefore provides the regional context upon which all subsequent geological evidence will be superimposed.

2.1.1) Working Hypothesis

The structural framework of the case-study petroleum system suggests that the probability of fracture-corridor development is highest within structurally complex domains where deformation has been repeatedly concentrated during the tectonic evolution of the field. These domains include the principal fold hinges, fault-damage zones, relay and transfer structures, and other regions of persistent strain localisation. This hypothesis remains provisional and must be evaluated through the inte-gration of the additional geological evidence presented in the following sections and, ultimately, through seismic reprocessing and well calibration.

2.2) Oligocene Reservoir Architecture

The Oligocene reservoir architecture constitutes the second major line of geological evidence for predicting the distribution of fracture corridors within the case-studypetroleum system. Whereas the structural framework defines where tectonic deformation has been concentrated, the depositional architecture determines where mechanically competent reservoir bodies are available to accommodate fracture development.

Previous geological studies indicate that the Oligocene reservoir consists predominantly of a progradational carbonate platform system composed of successive depositional bodies that display significant lateral and vertical heterogeneity. Rather than forming a single homogeneous reservoir unit, the Oligocene succession is interpreted as an assemblage of carbonate reservoir bodies separated by facies transitions and locally by less competent carbonate and marly intervals.

The reservoir architecture is therefore controlled by the distribution of undaforms, clinoforms, and fondoforms, which together record the progressive progradation of the carbonate platform. Within this depositional framework, the principal reservoir facies are interpreted to occur preferentially within the undaform bodies, whereas the associated clinoform foresets and fondoform deposits commonly exhibit lower reservoir quality and may locally behave as mechanical as well as hydraulic barriers.

From the perspective of fracture development, this depositional organisation is particularly important because fracture corridors are unlikely to propagate indiscriminately across contrasting facies. Instead, fracture propagation, fracture persistence, and fracture connectivity are expected to be influenced by changes in mechanical properties, bed continuity, diagenetic evolution, and facies architecture.

The Oligocene depositional framework also introduces an important element of geometrical anisotropy into the reservoir. Because the carbonate bodies were deposited within a progradational system, their lateral continuity, thickness, and orientation vary systematically across the field. Consequently, fracture corridors may preferentially develop within the thicker, more laterally continuous carbo-

nate bodies while becoming attenuated, segmented, or terminated where the reservoir architecture changes abruptly.

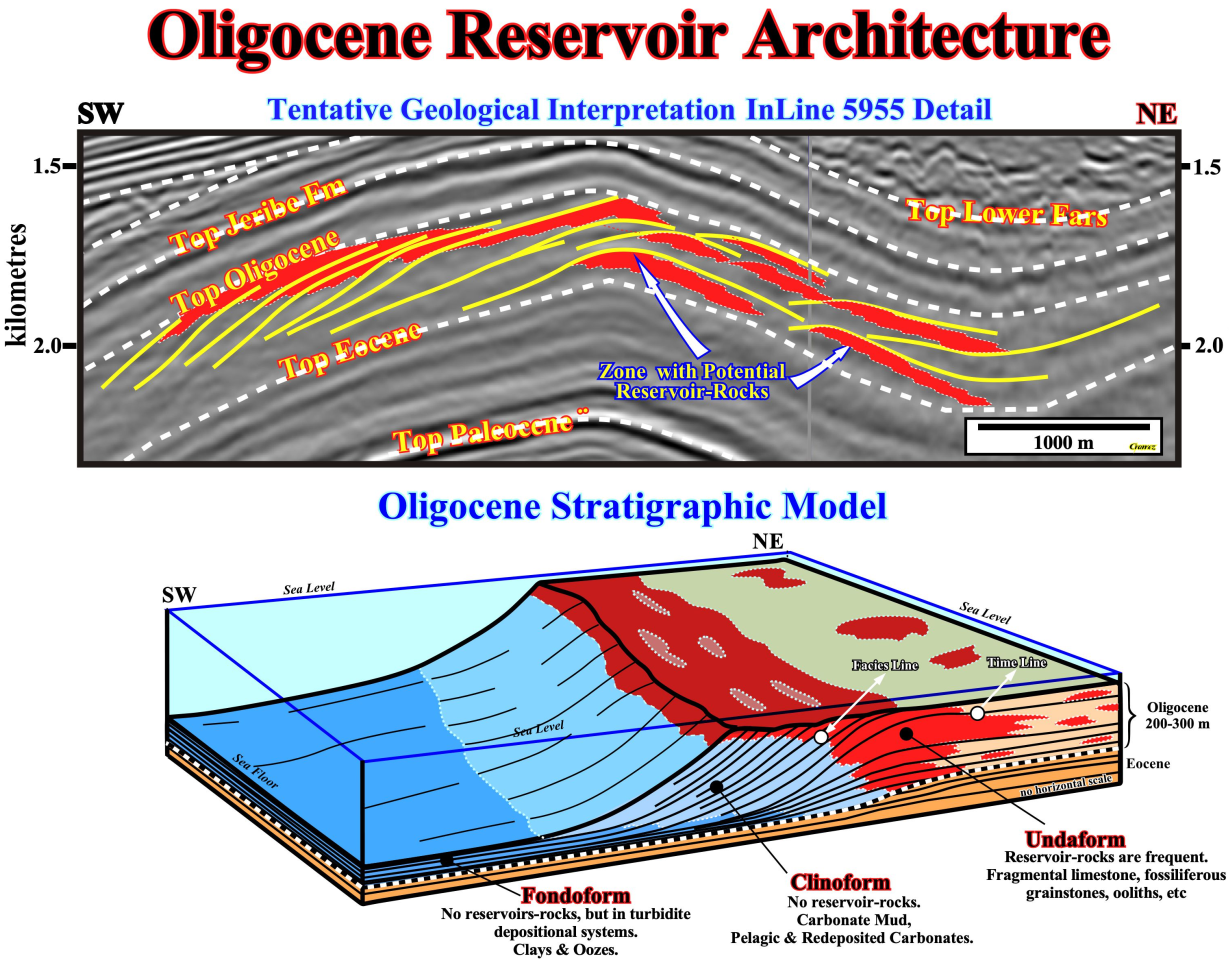


***Figure 1- Oligocene Reservoir Architecture of the Case-Study Petroleum System.** This figure illustrates the interpreted depositional architecture of the Oligocene carbonate reservoir within the case-study petroleum system. The upper panel presents a detailed interpretation of a representative legacy 3D seismic section (Inline 5955), whereas the lower panel provides a conceptual stratigraphic model illustrating the corresponding depositional framework.*

The interpretation suggests that the Oligocene reservoir does not constitute a single homogeneous carbonate unit but rather a progradational carbonate platform system composed of successive undaforms, clinoforms, and fondoforms. These depositional elements record the progressive progradation of the carbonate platform from the southwest towards the northeast, producing systematic variations in facies, reservoir quality, bed continuity, and mechanical properties.

Within this depositional framework, the principal reservoir rocks are interpreted to occur preferentially within the undaform bodies, where fragmental limestones, fossiliferous grainstones, oolitic carbonates, and other relatively competent facies were deposited. In contrast, the associated clinoform foresets and fondoform deposits are interpreted to contain finer-grained carbonates, redeposited sediments, pelagic deposits, and locally marly intervals that commonly exhibit poorer reservoir quality and may locally behave as mechanical as well as hydraulic barriers.

Furthermore, even within the undaform depositional bodies, the porous carbonate reservoir units are interpreted to be locally overlain and laterally sealed by non-porous carbonate facies deposited during the progradation of the platform. Consequently, reservoir continuity is not solely controlled by structure but also by the internal facies architecture of the Oligocene succession. This depositional arrangement introduces an important stratigraphic component to the petroleum trap, whereby porous reservoir bodies may terminate laterally or vertically against tight carbonate *facies, producing local stratigraphic closures superimposed upon the regional structural trap.*

An important consequence of this depositional architecture is that facies lines are not necessarily parallel to time lines. Reservoir bodies therefore display significant lateral and vertical heterogeneity, and their continuity is controlled by depositional geometry rather than by simple stratigraphic thickness. The mechanical properties governing fracture initiation, fracture propagation, and fracture connectivity are also expected to vary systematically throughout the reservoir.

From the perspective of fracture-corridor prediction, this depositional framework provides the geological template upon which subsequent tectonic deformation acted. Fracture corridors are therefore expected to develop preferentially where mechanically competent carbonate reservoir bodies coincide with structurally favourable domains, rather than being distributed uniformly throughout the Oligocene succession.

The figure supports the working hypothesis that effective reservoir connectivity within the case-study petroleum system results from the combined interaction of depositional connectivity and fracture connectivity. Predicting the distribution of fracture corridors requires understanding not only the structural evolution of the field but also the three-dimensional architecture of the Oligocene carbonate reservoir.

Another important implication concerns reservoir connectivity. Even if fracture corridors become well developed, their contribution to reservoir-scale fluid flow will depend upon the continuity of the underlying reservoir bodies. Consequently, the effective connectivity of the petroleum system reflects the interaction between depositional connectivity and fracture connectivity, rather than either factor considered independently.

The geological architecture of the Oligocene reservoir therefore provides the depositional template upon which subsequent tectonic deformation acted. Fracture corridors are consequently interpreted as tectonic features superimposed upon a pre-existing depositional architecture, rather than structures that developed independently of sedimentary facies.

2.2.1) Working Hypothesis

The Oligocene reservoir architecture suggests that fracture corridors are most likely to develop within the thicker, mechanically competent, and laterally continuous carbonate reservoir bodies, particularly where these coincide with structurally favourable domains identified in the preceding section. Conversely, fracture continuity and hydraulic connectivity are expected to decrease across significant facies boundaries, mechanical discontinuities, and non-reservoir intervals.

This hypothesis remains provisional and requires verification through the integration of seismic reprocessing, facies interpretation, well observations, and reservoir-performance data before it can be incorporated into a predictive fracture-corridor model.

2.3) Mechanical Stratigraphy

The mechanical stratigraphy of the case-study petroleum system constitutes the third major line of geological evidence for predicting the distribution of fracture corridors. Whereas the depositional architecture defines the geometry and continuity of the reservoir bodies, the mechanical stratigraphy determines how those bodies respond to tectonic deformation.

Mechanical stratigraphy refers to the vertical and lateral distribution of rock units possessing different mechanical properties, including brittleness, ductility, elastic stiffness, fracture toughness, and deformation style. During tectonic shortening, these mechanical contrasts strongly influence the localisation of strain, the initiation and propagation of fractures, and the development of connected fracture systems.

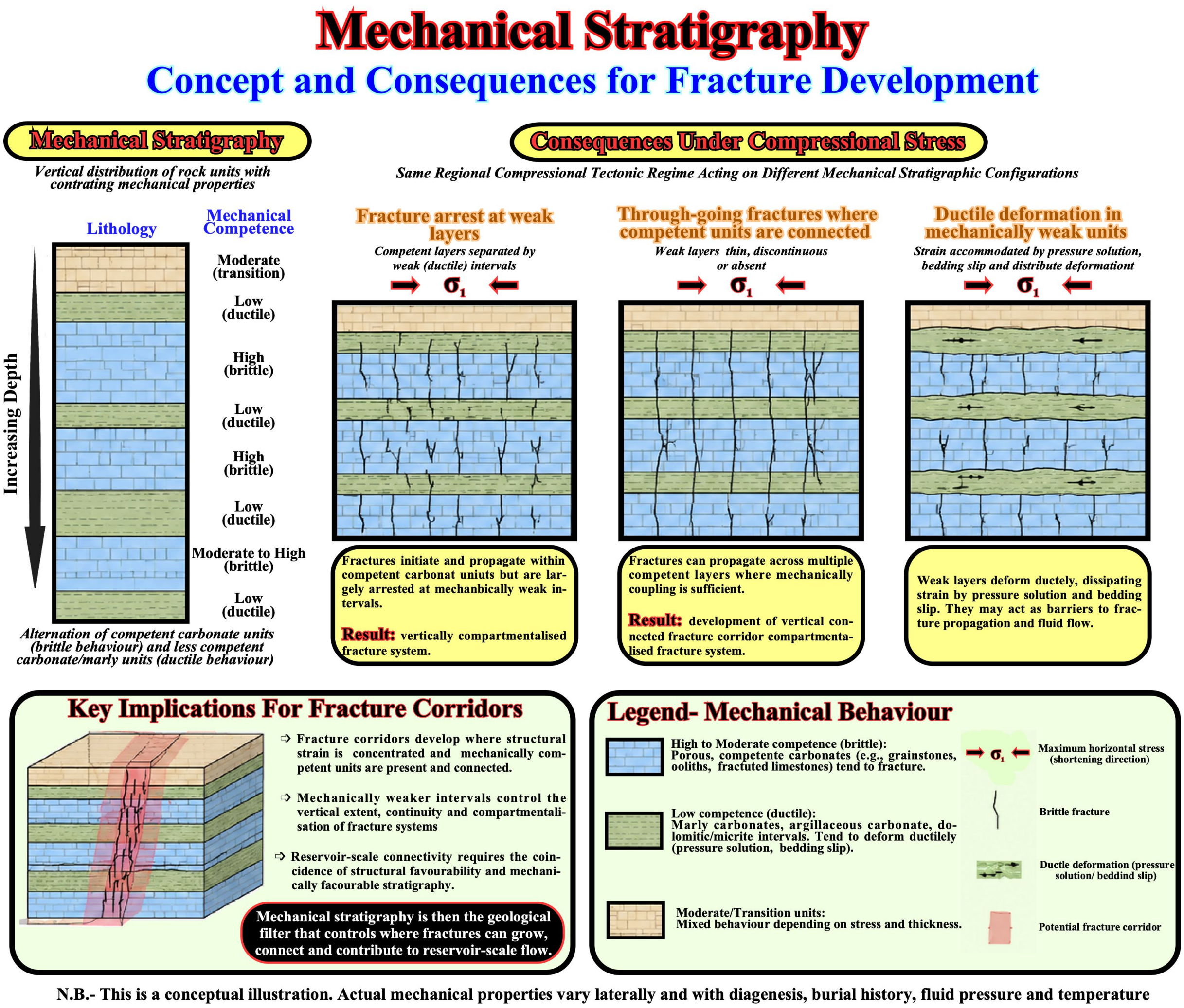


Figure 2- Mechanical Stratigraphy and Its Influence on Fracture Development and Fracture-Corridor Formation. This conceptual model illustrates the fundamental role of mechanical stratigraphy in controlling the initiation, propagation, persistence, and connectivity of natural fractures within carbonate reservoirs. Mechanical stratigraphy refers to the vertical distribution of rock units possessing contrasting mechanical competence, rather than simply contrasting lithologies. Consequently, rocks subjected to the same regional compressional stress regime (σ_1) may develop markedly different fracture systems depending upon their mechanical properties.

The left-hand panel illustrates a simplified mechanical stratigraphic succession composed of alternating mechanically competent carbonate units, which tend to deform by brittle fracturing, and less competent carbonate or marly intervals, which preferentially accommodate deformation through pressure solution, bedding slip, and other ductile mechanisms.

The three central panels illustrate the possible responses of different mechanical stratigraphic configurations subjected to the same regional compressional stress field. Where competent carbonate units are separated by thick mechanically weak intervals, fractures commonly terminate at mechanical boundaries, producing vertically compartmentalised fracture systems. Where mechanically weak intervals are thin, discontinuous, or absent, fractures may propagate across several competent units, producing vertically connected fracture systems capable of evolving into fracture cor-

ridors. Conversely, where deformation is largely accommodated within mechanically weak intervals, brittle fracture development becomes limited and fracture propagation may be significantly inhibited.

The lower panel summarises the principal implications for fracture-corridor prediction. Mechanical stratigraphy acts as a geological filter that controls where fractures are able to initiate, propagate, connect, or terminate. Consequently, fracture corridors are most likely to develop where structurally concentrated deformation coincides with mechanically competent reservoir units that remain sufficiently continuous to permit fracture propagation over reservoir scales.

Within the case-study petroleum system, the concept of mechanical stratigraphy should be interpreted in conjunction with the Oligocene depositional architecture discussed in the preceding section. The mechanical layering responsible for controlling fracture propagation is interpreted to be largely inherited from the original progradational carbonate architecture, subsequently modified by diagenesis and later folded during tectonic shortening. Thus, the mechanical stratigraphy is not an independent geological feature but the tectonically deformed expression of the original depositional framework.

The principal implication for the case-study petroleum system is that fracture propagation, fracture connectivity, and the development of fracture corridors are expected to be controlled jointly by depositional architecture, mechanical stratigraphy, and struc-tural deformation, rather than by any one of these factors considered independently.

Within the Oligocene reservoir interval, the carbonate succession is interpreted to consist of alternating intervals of competent reservoir carbonates and relatively less competent carbonate and marly facies. Although these units may belong to the same depositional sequence, they do not respond identically to tectonic loading. Competent carbonate units tend to accumulate elastic strain and fail by brittle fracturing, whereas less competent intervals preferentially accommodate deformation through distributed strain, pressure solution, bedding slip, or limited ductile deformation.

Consequently, fracture development is expected to be concentrated preferentially within the mechanically competent carbonate bodies identified in the preceding section. These units are likely to contain longer, more persistent, and better-connected fracture systems, while adjacent mechanically weaker intervals may locally terminate fracture propagation or reduce fracture continuity.

Mechanical stratigraphy also exerts a first-order control on the vertical connectivity of the reservoir. Fractures propagating through competent carbonate beds may be arrested when they encounter mechanically weaker horizons, producing vertically compartmentalised fracture systems. Conversely, where competent units remain mechanically coupled over significant thicknesses, fractures may propagate across several depositional bodies and contribute to the development of reservoir-scale fracture corridors.

The influence of mechanical stratigraphy is particularly important because it interacts directly with the structural framework described in the previous section. Structural deformation determines where strain is concentrated, whereas mechanical stratigraphy determines how that strain is accommodated within individual rock units. Fracture corridors therefore develop preferentially where structural localisation coincides with mechanically favourable reservoir intervals.

From a predictive perspective, mechanical stratigraphy provides an essential filter for fracture-corridor interpretation. Even within structurally favourable domains, fracture corridors are expected to develop only where sufficiently

competent carbonate units are present to sustain extensive brittle deformation and maintain fracture connectivity over reservoir scales.

2.3.1) Working Hypothesis

The mechanical stratigraphy of the Oligocene reservoir suggests that fracture corridors are unlikely to develop uniformly throughout the reservoir succession. Instead, they are expected to be preferentially localised within the thicker, mechanically competent carbonate units identified in the undaform depositional bodies, while mechanically weaker carbonate and marly intervals may locally inhibit fracture propagation, reduce vertical connectivity, and compartmentalise the fracture system.

Accordingly, the most probable fracture corridors within the Kurdamir/Topkhana petroleum system are expected to occur where mechanically competent reservoir bodies, favourable depositional architecture, and structurally concentrated deformation coincide. This hypothesis remains provisional and must be tested through seismic reprocessing, well observations, and subsequent reservoir-performance data.

Structural deformation determines where strain is concentrated, whereas mechanical stratigraphy determines how that strain is accommodated within individual rock units.

2.4) Structural Curvature and Strain Localisation

The structural curvature of the case-study petroleum system constitutes the fourth major line of geological evidence for predicting the distribution of fracture cor-ridors. Whereas the structural framework defines the geometry of the anticline and the mechanical stratigraphy determines how individual rock units respond to deformation, structural curvature provides a first-order indication of where tectonic strain has been preferentially concentrated du-ring folding.

Folding is not a process of uniform deformation. Different parts of an anticline experience different magnitudes and styles of strain as the structure evolves. The distribution of natural fractures is expected to reflect the spatial distribution of accumulated strain rather than simply the present-day structural geometry.

The highest strain concentrations commonly develop within fold hinges, where the curvature of the folded strata is greatest. During progressive shortening, these domains accommodate significant bending and extension within the outer arc of the fold while simultaneously experiencing compression within the inner arc. Such deformation creates favourable conditions for the initiation, propagation, and repeated reactivation of natural fracture systems.

Curvature is therefore more than a geometric property of folded strata. It represents an indirect measure of the amount of deformation experienced by different parts of the structure and consequently provides an important predictor of fracture intensity and fracture connectivity. Areas exhibiting high structural curvature are generally expected to have undergone greater cumulative strain and therefore constitute favourable locations for the development of fracture corridors.

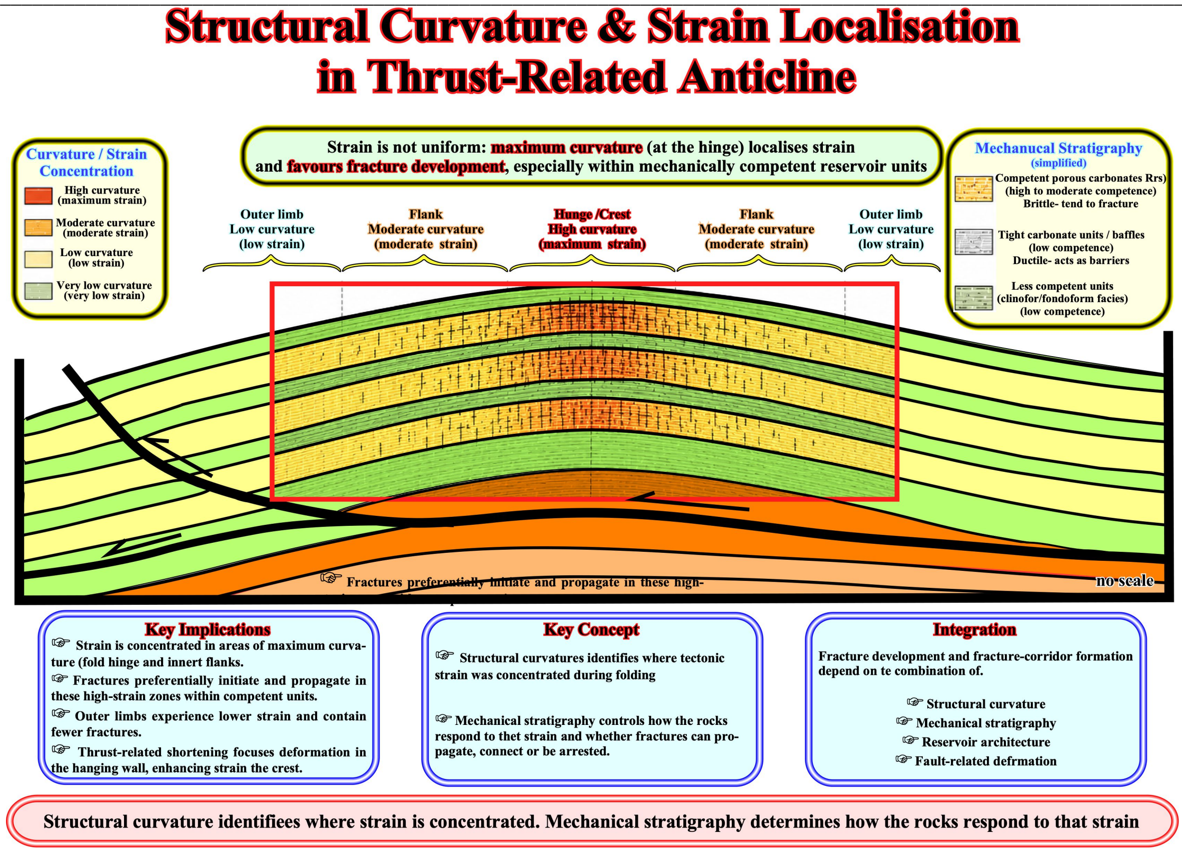


Figure 3- Structural Curvature, Strain Localisation, and Their Influence on Fracture Development in a Thrust-Related Anticline. ***This conceptual model illustrates how structural curvature controls the localisation of tectonic strain during the development of a thrust-related anticline. The structure is interpreted as forming within the hanging wall of a regional thrust fault rooted in a sub-horizontal detachment surface, a structural style characteristic of the case-study petroleum system.***

During progressive tectonic shortening, deformation is not distributed uniformly throughout the fold. Instead, strain localises preferentially within the fold hinge and adjacent inner flanks, where structural curvature reaches its maximum. Conversely, the outer limbs generally experience lower curvature, lower accumulated strain, and consequently a lower probability of extensive brittle fracturing.

The figure also illustrates that structural curvature alone is insufficient to predict fracture development. The mechanical response of the folded strata depends simultaneously on the mechanical stratigraphy inherited from the depositional architecture. Mechanically competent carbonate units preferentially accumulate elastic strain and tend to fracture, whereas less competent carbonate and marly intervals accommodate deformation by pressure solution, bedding slip, and distributed strain. Consequently, structural curvature identifies where deformation is concentrated, whereas mechanical stratigraphy determines how the rocks respond to that deformation.

Within the case-study petroleum system, the interaction between structural curvature, mechanical stratigraphy, reservoir architecture, and fault-related deformation is expected to exert a first-order control on the distribution of fracture corridors. Areas combining high structural curvature with mechanically competent carbonate reservoir units therefore represent the most favourable locations for the development of connected fracture networks capable of enhancing reservoir connectivity, pressure communication, and hydrocarbon productivity.

The figure supports the working hypothesis that fracture corridors are most likely to develop where maximum structural curvature coincides with mechanically favourable reservoir intervals, while structurally less deformed portions of the anticline are expected to contain fewer fractures and poorer hydraulic connectivity.

However, curvature alone does not determine fracture development. Its influence must be considered together with mechanical stratigraphy, reservoir architecture,

and fault-related deformation. High curvature developed within mechanically weak intervals may produce only limited brittle fracturing, whereas moderate curvature affecting mechanically competent carbonate bodies may generate highly connected fracture systems.

In the case-study petroleum system, curvature analysis should therefore be regarded as an essential component of an integrated geological interpretation rather than as an independent fracture predictor. Its principal value lies in identifying those structural domains where deformation was most likely to have been repeatedly concentrated during the tectonic evolution of the anticline.

Another important aspect concerns the cumulative nature of deformation. The present-day geometry of the study anticline represents the final product of multiple tectonic episodes. The present structural curvature reflects not only the latest stage of folding but also the integrated history of progressive shortening and structural growth. Areas exhibiting persistent high curvature are therefore expected to have experienced repeated episodes of strain localisation, increasing the probability of developing well-connected fracture systems.

2.4.1) Working Hypothesis

The distribution of structural curvature within the case-study petroleum system suggests that the probability of fracture-corridor development increases in areas where high curvature coincides with mechanically competent carbonate reservoir units and favourable structural architecture. Fold hinges, zones of maximum curvature, and areas subjected to repeated strain localisation are therefore interpreted as having a higher probability of containing connected fracture networks than structurally less deformed portions of the reservoir.

This hypothesis remains provisional and must be tested by integrating curvature attributes, coherence, ant-tracking, AVAz, structural interpretation, and the results of future amplitude-preserving seismic reprocessing.

Structural curvature identifies where deformation is concentrated, whereas mechanical stratigraphy determines how the rocks respond to that deformation.

2.5) Fault-Damage Zones

The fault-damage zones associated with the principal thrust system constitute the fifth major line of geological evidence for predicting the distribution of fracture corridors within the case-study petroleum system. Whereas structural curvature identifies where deformation has been concentrated during folding, fault-damage zones represent areas where deformation becomes additionally localised in the vicinity of major fault surfaces.

Faults should not be regarded as simple displacement surfaces separating two rock masses. Instead, they are commonly surrounded by damage zones in which the cumulative effects of repeated deformation generate dense networks of joints, shear fractures, small faults, deformation bands, and locally pressure-solution features. These structures commonly extend from a few metres to several hundreds of metres away from the principal fault plane, depending upon the dis-

placement history, lithology, mechanical stratigraphy, and tectonic evolution of the structure.

Within carbonate reservoirs, the mechanical behaviour of fault-damage zones is particularly complex. Some fault zones become extensively fractured and may significantly enhance reservoir permeability and fluid communication. Others undergo intense cementation, pressure solution, or clay smearing, producing zones of reduced permeability that may locally compartmentalise the reservoir. Consequently, the hydraulic behaviour of fault-damage zones cannot be inferred solely from the presence of a fault but must be evaluated in the context of the surrounding geological framework.

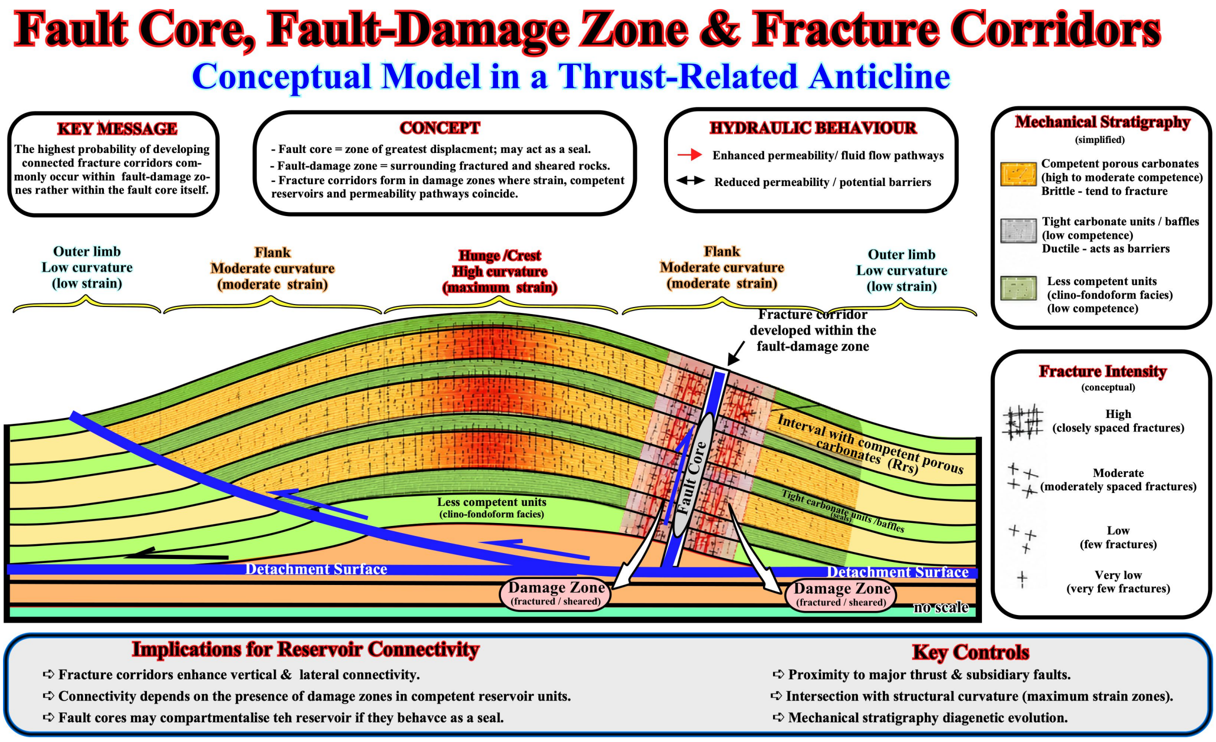


Figure 4- Conceptual Relationship Between Fault Core, Fault-Damage Zone and Fracture-Corridor Development in a Thrust-Related Anticline. This conceptual model illustrates the expected relationship between fault cores, fault-damage zones, mechanical stratigraphy, and the development of fracture corridors within a thrust-related anticline similar to that of the case-study petroleum system. The anticline develops within the hanging wall of a regional thrust fault rooted in a sub-horizontal detachment surface, producing progressive shortening, structural curvature, and localisation of tectonic strain.

The figure distinguishes the narrow fault core, where most of the displacement is accommodated, from the surrounding fault-damage zones, where repeated deformation generates dense networks of joints, shear fractures, and subsidiary faults. Although the fault core may locally behave as a hydraulic barrier because of cataclasis, cementation, or clay smearing, the adjacent damage zones commonly contain the highest density of interconnected fractures and therefore constitute the most favourable locations for the development of fracture corridors.

The distribution of fractures is not controlled by faulting alone. Fracture propagation is strongly influenced by the mechanical stratigraphy inherited from the Oligocene depositional architecture. Mechanically competent porous carbonate units (Rrs) preferentially accumulate elastic strain and tend to fracture, whereas tight carbonate units and less competent clinoform–fondoform facies commonly arrest, deflect, or compartmentalise fracture propagation. Consequently, the fault-damage zone becomes most effective when it intersects thick, laterally continuous, mechanically competent reservoir units.

The figure also emphasises the interaction between structural curvature and fault-related deformation. The highest probability of developing connected fracture corridors occurs where maximum structural curvature, fault-damage zones, and mechanically favourable reservoir intervals coincide. In contrast, structurally less deformed areas or mechanically weaker intervals are expected to contain fewer fractures and poorer hydraulic connectivity.

From a petroleum-geological perspective, the principal implication is that faults themselves should not automatically be regarded as either conductive or sealing features. Their influence on reservoir behaviour depends upon the combined effects of fault-core properties, damage-zone characteristics, mechanical stratigraphy, diagenetic evolution, and reservoir architecture. Consequently, predicting reservoir connectivity within the case-study petroleum system requires identifying not only the principal fault traces but also the geometry and hydraulic behaviour of their associated fault-damage zones.

The figure supports the working hypothesis that the most productive fracture corridors within the case-study petroleum system are likely to occur within fault-damage zones developed in mechanically competent carbonate reservoir units, particularly where these zones coincide with high structural curvature and other regions of persistent strain localisation.

The study anticline is interpreted as a thrust-related structure developed above a regional detachment horizon. The associated thrust fault and subsidiary fault system are therefore expected to be accompanied by fault-damage zones that have experienced repeated episodes of deformation during progressive shortening. These zones are likely to contain fracture densities significantly greater than those observed within the surrounding reservoir and therefore re-present favourable locations for the initiation and development of fracture corridors.

The influence of fault-damage zones should not be considered independently of the geological factors discussed in the preceding sections. Their effectiveness in generating connected fracture systems depends upon the interaction between fault-related strain, mechanical stratigraphy, reservoir architecture, and structural curvature. A fault-damage zone developed within mechanically competent carbonate reservoir units may generate extensive fracture connectivity, whereas an equivalent fault affecting mechanically weak or poorly connected intervals may have a much smaller influence on reservoir-scale fluid flow.

It is also important to distinguish between the fault core and the surrounding damage zone. The fault core commonly accommodates most of the displacement and may locally behave as a sealing element, whereas the surrounding damage zone frequently contains the highest density of interconnected natural fractures. So, the most prospective locations for fracture-corridor development commonly occur adjacent to, rather than directly within, the principal fault surface.

2.5.1)Working Hypothesis

Within the Kurdamir/Topkhana petroleum system, the principal fault-damage zones associated with the thrust system are interpreted as favourable locations for the development of fracture corridors, particularly where they coincide with mechanically competent carbonate reservoir units, high structural curvature, and persistent deformation zones. However, the hydraulic behaviour of individual fault zones may vary considerably according to their diagenetic evolution and deformation history. Therefore, the presence of a fault alone should not be interpreted as evidence of enhanced reservoir connectivity.

This hypothesis must be evaluated through the integration of seismic reprocessing, coherence, curvature, ant-tracking, AVAz, and well observations, which together should permit discrimination between conductive and sealing fault-damage zones.

2.6) Relay and Transfer Zones

The relay and transfer zones associated with the structural framework of the case-study petroleum system constitute the sixth major line of geological evidence for predicting the distribution of fracture corridors. Whereas fault-damage zones concentrate deformation adjacent to individual fault planes, relay and transfer zones localise deformation between neighbouring fault segments as tectonic strain is transferred throughout the evolving structure.

In thrust-related fold systems, fault displacement is rarely accommodated along a single continuous fault surface. Instead, displacement is commonly partitioned between several fault segments that overlap, interact, or terminate against one another. The intervening regions, known as relay zones or transfer zones, accommodate the progressive transfer of displacement from one fault segment to the next and therefore experience complex deformation histories.

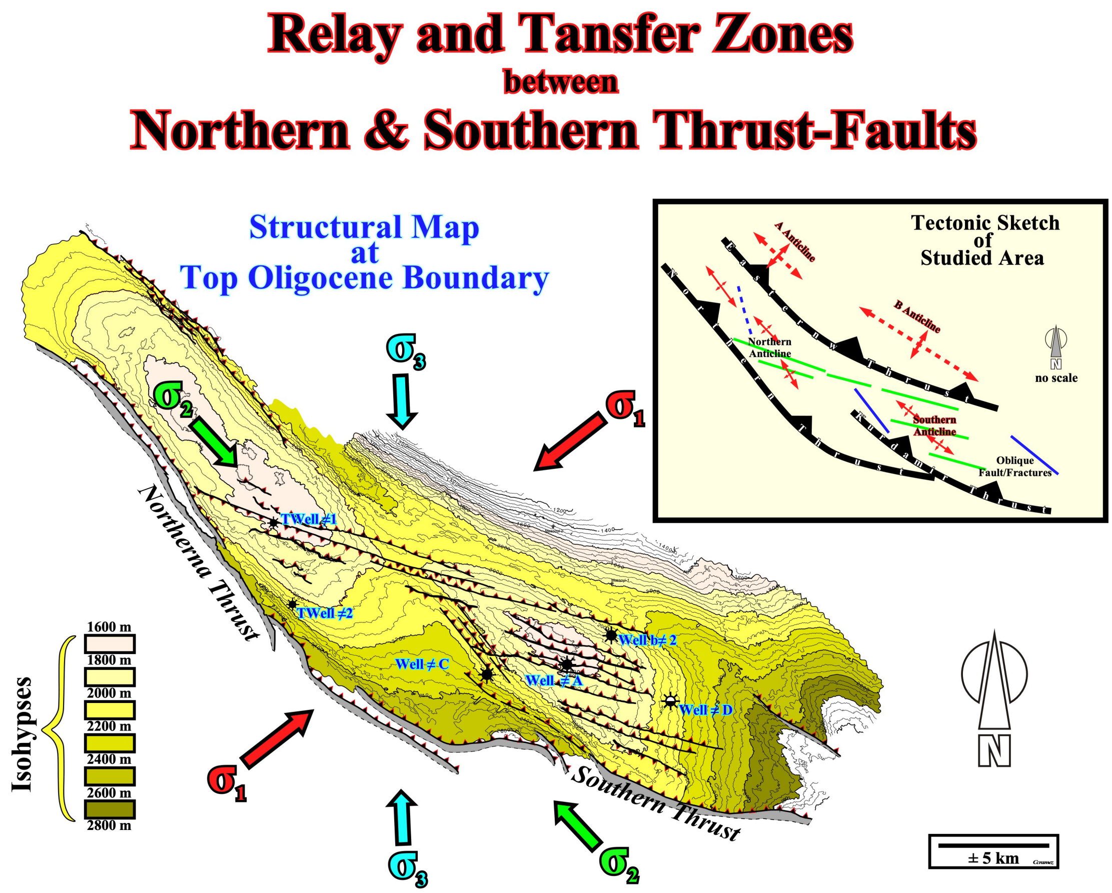


***Figure 5- Relay and Transfer Zones Between the Kurdamir and Topkhana Thrust Systems: A Potential Domain for Fracture-Corridor Development.** This figure presents a conceptual interpretation of the relay and transfer zone developed between the Kurdamir and Topkhana thrust systems, based on the structural map of the Top Oligocene Boundary derived from the legacy 3D seismic interpretation. The inset tectonic sketch illustrates the regional structural framework and the interaction between the principal thrust faults, associated anticlines, and oblique structural discontinuities. The structural map suggests that the northern and southern structural culminations are not isolated anticlines but represent two culminations developed along the same thrust-related structural trend. The area separating these culminations is*

interpreted as a relay and transfer zone, where displacement is progressively transferred between adjacent thrust segments during tectonic shortening. Such structural domains commonly accommodate complex deformation histories involving distributed shortening, subsidiary faulting, fracture development, and repeated strain localisation.

From a mechanical perspective, relay and transfer zones represent regions where tectonic strain is expected to be significantly greater than in the surrounding structure because deformation is shared between interacting fault systems. Consequently, these zones provide favourable conditions for the development of dense, interconnected fracture networks capable of evolving into fracture corridors.

The relay zone located between the Oligocene structural culminations is therefore interpreted as a high-probability target for the occurrence of significant fracture corridors. If this geological interpretation is correct, fracture intensity, fracture connectivity, and reservoir-scale hydraulic communication are expected to be greater within this structural corridor than within adjacent parts of the anticline.

This interpretation should be regarded as a working geological hypothesis rather than a demonstrated geological fact. The legacy 3D seismic data do not possess sufficient resolution to image fracture corridors directly. Instead, the proposed interpretation is derived from the convergence of structural geometry, thrust interaction, relay-zone mechanics, mechanical stratigraphy, and the geological concepts developed in the preceding sections.

The principal implication for the Kcase.study petroleum system is that the relay and transfer zone separating the two structural culminations constitutes one of the most promising geological domains for future investigation. It should therefore represent a priority target for amplitude-preserving seismic reprocessing, coherence, curvature, ant-tracking, AVAz analysis, and subsequent geological interpretation in order to determine whether a major fracture-corridor fairway is present.

Accordingly, the relay and transfer zone between the northern and southern culminations is considered one of the principal candidate areas for a reservoir-scale fracture corridor, whose existence, geometry, and hydraulic significance must be evaluated during the next stage of geological and geophysical investigation.

Because these structural domains accommodate the interaction of neighbouring fault systems, they commonly undergo repeated episodes of brittle deformation, fracturing, small-scale faulting, and strain localisation. Consequently, relay and transfer zones frequently exhibit fracture densities significantly greater than those observed elsewhere within the folded structure.

The geological significance of relay and transfer zones extends beyond fracture density alone. Their complex deformation histories commonly promote the development of interconnected fracture networks, increasing the probability that individual fracture systems evolve into continuous fracture corridors capable of transmitting fluids over reservoir-scale distances.

The effectiveness of relay and transfer zones as fracture-corridor generators depends upon their interaction with the geological factors discussed in the preceding sections. Where these structural domains coincide with mechanically competent carbonate reservoir units, high structural curvature, and favourable reservoir architecture, they constitute particularly favourable locations for the development of highly connected fracture systems. Conversely, where relay zones occur within mechanically weak or poorly connected intervals, their influence on reservoir connectivity may be substantially reduced.

Within the case-study petroleum system, relay and transfer zones are expected to occur at several structural scales. Some are associated with the segmentation of the principal thrust system, whereas others may reflect interactions between

subsidiary faults developed during progressive shortening. Although the precise geometry of these structures cannot yet be resolved confidently using the existing seismic interpretation, their probable locations may be inferred from the overall structural framework and constitute important targets for future seismic reprocessing and attribute analysis.

From a reservoir-development perspective, relay and transfer zones deserve particular attention because they may provide preferential pathways for pressure communication, fluid migration, and well productivity. At the same time, they may also influence reservoir compartmentalisation if fault sealing or local dia-genetic cementation modifies the hydraulic behaviour of the associated fracture systems.

2.6.1) Working Hypothesis

Within the case-study petroleum system, relay and transfer zones are inter-preted as high-probability locations for the development of fracture cor-ridors, particularly where they coincide with fault-damage zones, maxi-mum structural curvature, mechanically competent carbonate reservoir units, and persistent deformation zones. These structural domains are therefore expec-ted to contribute disproportionately to reservoir connectivity and fluid-flow pathways compared with structurally less complex portions of the reservoir.

This hypothesis remains provisional and should be tested through the inte-gration of high-resolution seismic reprocessing, structural interpretation, coherence, curvature, ant-tracking, AVAz, and subsequent well calibration before being incorporated into reservoir-development planning.

The relay and transfer zone between the northern and southern a structural culminations represents the most probable location for a major fracture-corridor fairway within the case-study petroleum system.

2.7) Persistent Deformation Zones

The concept of Persistent Deformation Zones (PDZs) represents the seventh and final line of geological evidence used to predict the distribution of fracture cor-ridors within the case-study petroleum system. Unlike the pre-ceding sections, which examine individual geological factors controlling fracture development, persistent deformation zones integrate the cumulative effects of repeated tectonic deformation throughout the structural evolution of the field.

A Persistent Deformation Zone may be defined as a structural domain that has repeatedly accommodated tectonic strain during successive deformation episodes. Such zones commonly originate from inherited geological discontinuities, including basement structures, mechanical contrasts, or early fault systems, and remain mechanically favourable for deformation during subsequent tectonic events. Consequently, they repeatedly localise folding, faulting, fracturing, and strain accumulation, irrespective of the specific tectonic regime operating at any particular stage of basin evolution.

From the Studied Area:

A Typical Persistent Deformation Zone

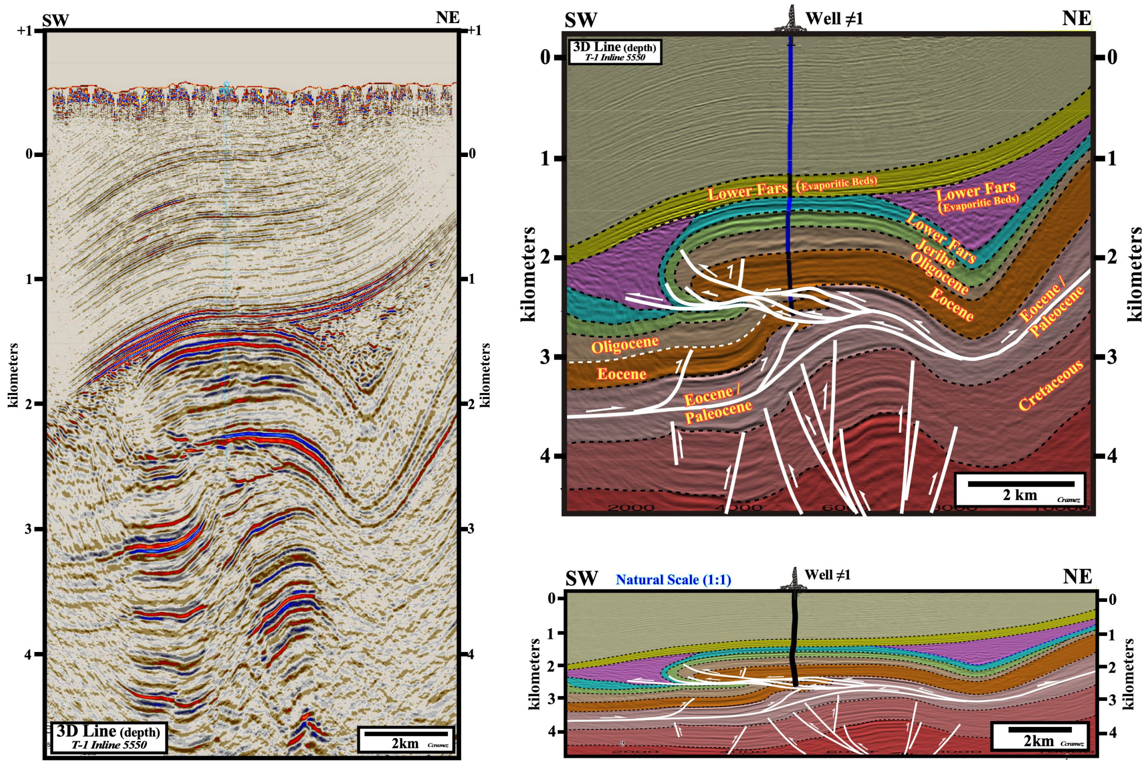


Figure 6- The study Area: A Candidate Persistent Deformation Zone (PDZ).This figure combines a representative legacy 3D seismic section (Inline 5550), its corresponding geological interpretation, and a simplified structural reconstruction to illustrate the cumulative tectonic evolution of the case-study petroleum system. The interpreted seismic section demonstrates that deformation is not confined to the Oligocene reservoir interval but extends downward into the underlying Eocene, Paleocene, and Cretaceous successions, indicating that the entire structural column has been repeatedly affected by tectonic shortening.

A particularly significant observation is that the principal detachment surfaces, although originally subhorizontal, are themselves folded and shortened. This geometry suggests that the present thrust-related anticline is not the product of a single deformation episode but rather the cumulative result of successive tectonic phases associated with the compressional reactivation of the former Mesozoic continental margin during the evolution of the Zagros Fold–Thrust Belt.

The interpreted structural geometry is therefore consistent with the concept of a Persistent Deformation Zone (PDZ), namely a structural corridor that has repeatedly accommodated tectonic strain throughout successive deformation episodes. Within such long-lived deformation corridors, repeated folding, thrusting, fault reactivation, strain localisation, and fracturing progressively increase the probability of developing extensive, interconnected fracture systems.

From the perspective of fracture-corridor prediction, the geological significance of a persistent deformation zone lies not in the occurrence of any single tectonic event, but in the cumulative effects of repeated deformation acting over geological time. Such repeated strain localisation is expected to enhance fracture density, fracture persistence, fracture connectivity, and ultimately the likelihood of developing reservoir-scale fracture corridors.

The figure therefore provides geological evidence that is consistent with the working hypothesis that the case-study petroleum system constitutes a persistent deformation zone. If this interpretation is confirmed by future amplitude-preserving seismic reprocessing, advanced seismic attributes, and well calibration, it would provide a

coherent geological explanation for the expected localisation of the principal fracture-corridor fairways within the field.

Within the case-study petroleum system, the present structural geometry is interpreted as the cumulative result of multiple tectonic episodes associated with the evolution of the Zagros Fold–Thrust Belt. Throughout this prolonged tectonic history, certain structural domains were probably reactivated repeatedly, progressively concentrating deformation and increasing the probability of developing extensive, interconnected fracture systems.

Persistent deformation zones should therefore not be regarded as individual faults or isolated fracture swarms. Rather, they constitute long-lived structural corridors within which several deformation mechanisms have acted repeatedly through geological time. These mechanisms include fold-related strain localisation, fault-damage-zone development, relay and transfer deformation, mechanical stratigraphy, and local diagenetic modification. The cumulative effect of these processes is expected to produce fracture systems that are more extensive, more persistent, and more highly connected than those generated by any single deformation episode.

From the perspective of fracture-corridor prediction, persistent deformation zones provide perhaps the strongest geological indication of where major fracture corridors are most likely to occur. Their significance arises not from any single geological observation but from the repeated convergence of multiple independent deformation processes within the same structural domains.

Within the case-study petroleum system, the probable existence of persistent deformation zones is suggested by the coincidence of the principal thrust systems, fault reactivations (tectonic inversions), structural culminations, relay and transfer zones, high-curvature domains, and the inferred distribution of mechanically favourable Oligocene reservoir units. Although the present seismic data do not permit these zones to be mapped directly, their existence provides a coherent geological explanation for the expected localisation of major fracture corridors.

The concept of persistent deformation zones also explains why fracture corridors are unlikely to be distributed randomly throughout the reservoir. Instead, fracture corridors are expected to represent the geological expression of repeated deformation concentrated within structurally favourable domains over millions of years. Consequently, they should be regarded as the cumulative product of the entire tectonic evolution of the petroleum system rather than the result of a single folding event.

2.7.1) Working Hypothesis

Within the case-studypetroleum system, the principal fracture corridors are interpreted to occur preferentially within persistent deformation zones, where structural curvature, fault-damage zones, relay and transfer zones, mechanically competent reservoir units, and depositional architecture converge. These structural domains therefore represent the highest-probability targets for future fracture-corridor identification and reservoir characterisation.

The available geological and structural evidence suggests that the study area itself constitutes a persistent deformation zone, having undergone repeated episodes of tectonic deformation throughout the evolution of the

Zagros Fold–Thrust Belt. The interpretation of the legacy 3D seismic data is consistent with this hypothesis, indicating that successive phases of folding, thrusting, fault interaction, and strain localisation have repeatedly affected the same structural corridor. If this interpretation is correct, the cumulative effect of these tectonic events is expected to have favoured the progressive development of extensive, interconnected fracture corridors.

This working hypothesis synthesises the independent geological evidence developed throughout Sections 2.1–2.7 and provides the geological foundation for Chapter 3, in which these independent lines of evidence are integrated into a single working fracture-corridor model for the Kurdamir/Topkhana petroleum system.

Consistent with the Popperian philosophy adopted throughout the present memorandum, the proposed geological model is not presented as a demonstrated geological fact, but as the most plausible working hypothesis compatible with the currently available geological, structural, and seismic evidence.

Its degree of verisimilitude can only be evaluated through ampli-tude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and future geological and reservoir observations.

3) Working Hypothesis for the Distribution of Fracture Corridors

The preceding chapters have progressively assembled the principal mechanical and geological evidence governing the development of fracture corridors within the case-study petroleum system. Each geological factor—including the structural framework, Oligocene reservoir architecture, mechanical stratigraphy, structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones—provides an independent line of evidence regarding the probable localisation of fracture corridors.

The purpose of the present chapter is to integrate these independent observations into a single geological working hypothesis for the distribution of fracture corridors within the K/T petroleum system. The resulting interpretation should not be regarded as a definitive geological model, but rather as the most plausible predictive model currently compatible with the available geological, structural, and seismic information.

Accordingly, the fracture-corridor model developed herein does not attempt to identify the exact location of individual fracture corridors. Instead, it identifies structural domains having different probabilities for fracture-corridor development according to the degree of convergence between the geological criteria established in Chapter 2.

The predictive methodology follows a simple principle: the greater the convergence of independent geological evidence, the greater the probability that a significant fracture corridor is present. Conversely, where only a few favourable geological criteria are present, the probability of developing reservoir-scale fracture corridors is expected to be correspondingly lower.

Consequently, the fracture-corridor fairways proposed in this chapter should be regarded as probability corridors rather than directly observed geological objects. Their validity depends upon future testing using amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and subsequent reservoir observations. In keeping with the Popperian philosophy adopted throughout this memorandum, the objective is not to verify a preferred interpretation but to formulate a bold, explicit, and testable geological

hypothesis capable of guiding future geological investigations and redu-cing development uncertainty before full-scale field development.

3.1) Fundamental Geological Assumptions

The working hypothesis proposed in the present memorandum is based upon a series of fundamental geological assumptions derived from the mechanical principles established in Part I, the geological controls discussed in Part II, and the independent geological evidence assembled in Chapter 2 of the present memorandum. These assumptions provide the scientific basis for predicting the most probable distribution of fracture corridors within the case-study petroleum system.

3.1.1) The first assumption,

is that natural fractures are not randomly distributed throughout the reservoir. Instead, they represent the mechanical response of the rock mass to the combined effects of tectonic deformation, mechanical stratigraphy, depositional architecture, and diagenetic evolution.

3.1.2) The second assumption,

is that fracture corridors develop preferentially where several favourable geological factors converge rather than where a single favourable factor is present. Consequently, the probability of developing a major fracture corridor increases with the degree of convergence between in-dependent geological criteria.

3.1.3) The third assumption,

is that the case-study petroleum system constitutes a persistent deformation zone, within which repeated episodes of folding, thrusting, fault interaction, relay-zone deformation, and structural reactivation have progressively concentrated tectonic strain throughout the geological evolution of the field.

3.1.4) The fourth assumption,

is that mechanical stratigraphy, inherited largely from the Oligocene progradational depositional architecture, exerts a first-order control on fracture initiation, fracture propagation, fracture persistence, and fracture connectivity.

Therefore, fracture corridors are expected to develop preferentially within mechanically competent carbonate reservoir units, while less competent intervals commonly act as barriers or baffles to fracture propagation.

3.1.5) The fifth assumption,

is that structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones represent the principal structural mechanisms responsible for strain localisation within the K/T petroleum system. Areas where these mechanisms overlap are expected to constitute the most favourable structural domains for the development of fracture corridors.

3.1.6) The sixth assumption,

is that reservoir connectivity depends upon the interaction between depositional connectivity and fracture connectivity. Consequently, the presence of fractures alone does not guarantee effective hydraulic communication unless those fractures develop within laterally continuous reservoir bodies and become organised into connected fracture networks.

Finally, the present memorandum assumes that the legacy 3D seismic data do not possess sufficient resolution to identify fracture corridors directly. The fracture-corridor distribution proposed herein therefore represents a predictive geological model derived from the convergence of independent geological observations rather than from direct seismic imaging.

These assumptions constitute the conceptual framework upon which the following sections classify the case-study petroleum system into low-, moderate-, and high-probability domains for fracture-corridor development. Their validity remains testable and must ultimately be evaluated through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and subsequent reservoir observations.

3.2) Areas Expected to Have Low Probability

Geological Criterion	Low	Moderate	High
Structural curvature	Low	Moderate	High
Fault-damage zones	Absent	Local	Well developed
Relay/transfer zones	Absent	Posible	Well developed
Mechanical stratigraphy	Weak	Mixed	Competent
Depositional connectivity	Poor	Moderate	High
Persistent deformation	Weak	Moderate	Strong

According to the working geological hypothesis developed in the preceding chapters, certain parts of the case-study petroleum system are expected to have a low probability of containing significant fracture corridors. These domains are characterised by the absence, or only limited occurrence, of the geological conditions considered favourable for the development of extensive, interconnected fracture systems.

Areas assigned to the low-probability category are expected to exhibit one or more of the following geological characteristics:

- ➡ low structural curvature, indicating limited strain localisation during folding;
- ➡ absence of major fault-damage zones, resulting in reduced fault-related brittle deformation;
- ➡ absence of relay and transfer zones, where deformation associated with interacting thrust faults is expected to be minimal;
- ➡ predominance of mechanically weak carbonate or marly intervals, which preferentially accommodate deformation through pressure solution, bedding slip, or distributed strain rather than by brittle fracturing;
- ➡ poor depositional connectivity, where reservoir bodies are laterally discontinuous or separated by sealing or baffle facies;
- ➡ little evidence for repeated tectonic reactivation or long-term persistent deformation.

Within such structural domains, natural fractures may still occur because fracturing is an inevitable consequence of regional tectonic shortening. However, these fractures are expected to remain relatively isolated, short, and poorly connected, reducing the probability that they evolve into reservoir-scale fracture corridors capable of significantly enhancing fluid flow.

Consequently, areas classified as having low fracture-corridor probability are expected to exhibit relatively poor reservoir connectivity, limited pressure communication, and generally lower productivity than structurally more favourable parts of the field. Nevertheless, these domains should not be interpreted as entirely unfavourable for hydrocarbon accumulation or production. Local geological variations, diagenetic effects, or previously unrecognised structural features may locally improve fracture development.

The classification proposed here is therefore relative rather than absolute. It indicates only that, based on the current geological evidence, these structural domains appear less favourable for the development of significant fracture corridors than the moderate- and high-probability areas discussed in the following sections.

3.2.1) Working Hypothesis

Within the case-study petroleum system, areas characterised by low structural curvature, limited fault interaction, mechanically weak stratigraphy, and poor depositional connectivity are interpreted as having the lowest probability of containing extensive fracture corridors. Although isolated natural fractures are expected to occur throughout the reservoir, these domains are unlikely to contain the highly connected fracture systems required to dominate reservoir-scale fluid flow and hydraulic communication.

This interpretation remains a testable geological hypothesis that must be evaluated through amplitude-preserving seismic reprocessing, advanced seismic attributes, and future geological and reservoir observations.

Rather than simply describing the three probability classes, use the same evaluation criteria in all three sections. For example:

That way, the reader sees that the high-probability areas are not selected arbitrarily. They simply represent the locations where all six independent geological criteria converge. This is completely consistent with the hypothesis-driven approach of Part III and will make the transition to the Tentative Fracture-Corridor Fairway Map much more compelling.

3.3) Areas Expected to Have Moderate Probability

According to the working geological hypothesis, areas assigned a moderate probability for fracture-corridor development occupy an intermediate position between the structurally unfavourable domains described in the preceding section and the high-probability areas discussed later in this chapter. These domains satisfy several of the geological criteria considered favourable for fracture-corridor development, but not all of them simultaneously.

Moderate-probability areas are therefore expected to occur where tectonic deformation has been sufficiently intense to generate significant natural fracturing, yet where the degree of strain localisation, mechanical continuity, or structural

interaction is less pronounced than within the principal fracture-corridor fairways.

Such structural domains commonly exhibit one or more of the following geological characteristics:

- ➡ moderate structural curvature, indicating appreciable but not maximum strain localisation;
- ➡ proximity to fault-damage zones without direct coincidence with their most intensely deformed sectors;
- ➡ possible influence of relay or transfer structures, although deformation may be less concentrated than within the principal relay zones;
- ➡ presence of mechanically competent carbonate reservoir units, but with limited lateral continuity or partial separation by mechanically weaker intervals;
- ➡ moderate depositional connectivity, resulting from the geometry of the Oligocene carbonate bodies;
- ➡ geological evidence suggesting repeated tectonic activity, although less persistent than within the principal persistent deformation zones.

Within these areas, fracture systems are expected to be more abundant and better connected than in the low-probability domains. Nevertheless, fracture corridors, if present, are likely to be less continuous, more segmented, and more variable in their hydraulic behaviour than those predicted for the highest-probability structural domains.

From a reservoir perspective, moderate-probability areas may locally contain productive fracture systems capable of enhancing fluid flow, pressure communication, and well productivity. However, the spatial continuity of these fracture systems is expected to be more uncertain, and reservoir connectivity may vary significantly over relatively short distances because of local variations in mechanical stratigraphy, depositional architecture, and diagenetic evolution.

Consequently, these areas should be regarded as intermediate-priority targets for future investigation. They represent structural domains where the existence of significant fracture corridors cannot presently be either confirmed or excluded using the available geological and seismic information. They therefore constitute some of the principal objectives of the planned amplitude-preserving seismic reprocessing and subsequent attribute analysis.

3.3.1) Working Hypothesis

Within the Kurdamir/Topkhana petroleum system, areas exhibiting moderate structural curvature, partial fault interaction, locally favourable mechanical stratigraphy, and moderate depositional continuity are interpreted as having a moderate probability of containing significant fracture corridors. These domains may locally develop connected fracture systems, but their geometry, continuity, and hydraulic effectiveness remain uncertain until tested by high-resolution seismic reprocessing, advanced seismic attributes, and future well calibration.

Accordingly, moderate-probability areas should be regarded as candidate fracture-corridor domains, whose geological significance will depend upon the degree to which the independent geological criteria developed throughout Chapter 2 are corroborated by future geophysical observations.

3.4) Areas Expected to Have High Probability

According to the working geological hypothesis, the high-probability domains represent those parts of the case-study petroleum system where the greatest number of favourable geological conditions converge. These structural domains therefore constitute the most likely locations for the development of major fracture corridors capable of controlling reservoir-scale fluid flow, pressure communication, and hydrocarbon productivity.

Unlike the low- and moderate-probability domains discussed in the preceding sections, the areas assigned a high probability are characterised by the simultaneous occurrence of several independent geological factors known to promote fracture initiation, fracture propagation, fracture persistence, and fracture connectivity.

The principal geological criteria defining these domains include:

- ➡ high structural curvature, indicating maximum tectonic strain localisation during folding;
- ➡ proximity to major fault-damage zones, where repeated brittle deformation has generated dense fracture systems;
- ➡ occurrence within relay and transfer zones, where displacement is transferred between interacting thrust faults;
- ➡ presence of mechanically competent carbonate reservoir units, capable of sustaining extensive brittle deformation;
- ➡ favourable Oligocene depositional architecture, providing laterally continuous reservoir bodies;
- ➡ location within persistent deformation zones, where successive tectonic events have repeatedly concentrated strain throughout the geological evolution of the field.

The simultaneous convergence of these geological criteria is expected to produce the most favourable conditions for the development of large, persistent, and hydraulically connected fracture systems. Such fracture systems have the greatest potential to evolve into major fracture corridors capable of linking individual reservoir compartments and establishing efficient reservoir-scale fluid-flow pathways.

Within these structural domains, fracture density alone is not the principal geological objective. Rather, the critical characteristic is the development of fracture connectivity over reservoir scales. Consequently, these areas are expected to exhibit the highest probability of enhanced pressure communication, well productivity, drainage efficiency, and ultimately hydrocarbon recovery.

Based upon the geological evidence developed throughout Chapter 2, the structurally complex zone extending between the northern and southern structural culminations represents one of the most promising candidates for such a high-probability domain. The interpreted interaction between the Western Thrust, the Southern Thrust, associated relay and transfer zones, and the inferred persistent

deformation corridor suggests that this structural belt has experienced repeated strain localisation during successive tectonic episodes.

Nevertheless, this interpretation should not be regarded as a demonstrated geological fact. It represents the most plausible geological prediction currently compatible with the available geological and seismic evidence and must therefore be subjected to rigorous testing through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and future reservoir observations.

3.4.1) Working Hypothesis

The highest probability of developing significant fracture corridors within the case-study petroleum system is interpreted to occur where persistent deformation, high structural curvature, fault-damage zones, relay and transfer structures, mechanically competent carbonate reservoir units, and favourable depositional architecture converge within the same structural domain.

According to the present geological model, the structural corridor extending between the northern and southern culminations represents the most probable fracture-corridor fairway presently identifiable from the available geological evidence. However, this interpretation remains a testable working hypothesis whose degree of verisimilitude must ultimately be evaluated through future seismic reprocessing, advanced seismic interpretation, and reservoir calibration.

3.5) Tentative Fracture-Corridor Fairway Map

The Tentative Fracture-Corridor Fairway Map presented in this section represents the graphical synthesis of the working geological hypothesis developed throughout the present memorandum. It integrates the independent geological evidence discussed in Chapter 2 together with the probability assessment established in Sections 3.2–3.4 in order to identify the structural domains where fracture corridors are considered most likely, possible, or unlikely to occur.

It is essential to emphasise that the proposed fairways are not interpreted fracture corridors directly observed on the legacy 3D seismic data. Rather, they represent the most plausible geological prediction currently compatible with the available structural, stratigraphic, mechanical, and reservoir information. Consequently, the map should be regarded as a predictive geological model rather than a definitive geological interpretation.

The proposed fairways are based upon the convergence of several independent geological criteria, including:

- ➡ **structural framework;**
- ➡ **Oligocene reservoir architecture;**
- ➡ **mechanical stratigraphy;**
- ➡ **structural curvature;**
- ➡ **fault-damage zones;**
- ➡ **relay and transfer zones;**
- ➡ **persistent deformation zones.**

Conceptual Example of a Fracture Corridor Fairway Map

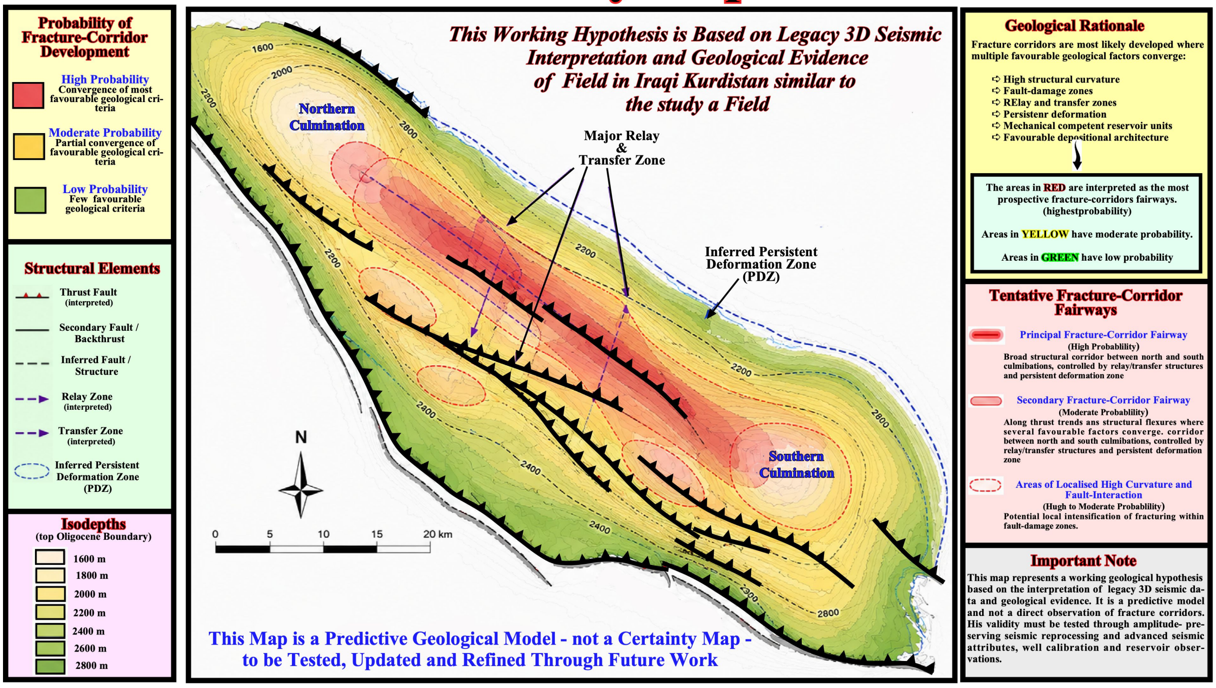


Figure 7- Conceptual Example of a Tentative Fracture-Corridor Fairway Map. This figure illustrates the type of integrated geological product that should result from the interpretation of the reprocessed legacy 3D seismic data. It is presented solely as a conceptual example to demonstrate how multiple geological and geophysical observations may be integrated into a Tentative Fracture-Corridor Fairway Map capable of supporting reservoir characterisation and field-development planning.

The map combines the principal geological factors discussed throughout the present memorandum, including structural framework, mechanical stratigraphy, structural curvature, fault-damage zones, relay and transfer zones, persistent deformation zones, and reservoir architecture, in order to identify structural domains having different probabilities for fracture-corridor development. Rather than attempting to locate individual fractures, the objective is to delineate broad fracture-corridor fairways where interconnected fracture systems are considered most likely to occur.

The coloured fairways shown on the map should not be interpreted as mapped fracture corridors. They represent working geological hypotheses based upon the convergence of independent geological criteria. Following the completion of amplitude-preserving seismic reprocessing, these tentative fairways should be tested, refined, modified, or, where necessary, rejected through the interpretation of advanced seismic attributes (including coherence, curvature, ant-tracking, and AVAz), together with well calibration, dynamic reservoir information, and subsequent geological interpretation.

Accordingly, the principal purpose of the map is methodological rather than interpretative. It illustrates the type of decision-support document that the operator geoscience team should be able to prepare after completion of the seismic reprocessing programme. Such a map would provide management with a clear geological assessment of the most probable fracture-corridor fairways, the associated levels of geological confidence, and the principal areas requiring further appraisal before full-scale field development.

Consistent with the Popperian philosophy adopted throughout this memorandum, the final fracture-corridor fairway map should be regarded as a testable geological model, whose scientific value lies not in claiming certainty but in providing explicit geological predictions that can be evaluated against future seismic interpretation, drilling results, and reservoir performance.

Areas where these geological criteria converge most strongly are interpreted as the highest-probability fracture-corridor fairways, whereas areas exhibiting fewer favourable criteria are assigned moderate or low geological probability.

Particular attention is drawn to the structural corridor extending between the northern and southern Oligocene structural culminations. The convergence of high structural curvature, interacting thrust systems, relay and transfer deformation, mechanically competent carbonate reservoir units, and the inferred persistent deformation zone suggests that this domain represents the most favourable geological environment for the development of a major fracture-corridor fairway. However, this interpretation remains a working hypothesis whose validity must be established through future geological and geophysical investigations.

The principal objective of the proposed fairway map is therefore not to provide certainty, but to guide future investigations by identifying those structural domains where amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and subsequent reservoir studies should be concentrated. In this sense, the map constitutes a predictive exploration and development tool, designed to reduce geological uncertainty before major field-development decisions are undertaken.

3.5.1) Working Hypothesis

The Tentative Fracture-Corridor Fairway Map represents the current best geological prediction of the probable distribution of fracture corridors within the scale-study petroleum system. The proposed fairways are interpreted from the convergence of multiple independent geological cri-teria and should therefore be regarded as probability fairways rather than demonstrated geological objects.

Consistent with the Popperian philosophy adopted throughout the present memorandum, the proposed fairway map is explicitly formulated to be tested. Future amplitude-preserving seismic reprocessing, advanced seismic attributes, well observations, and reservoir-performance data should either corroborate, modify, or reject the present interpretation.

Consequently, the scientific value of the proposed fairway map lies not in claiming certainty, but in providing a clear, explicit, and testable geological hypothesis capable of guiding future exploration, appraisal, and development of the case-study petroleum system.

3.6) Confidence Ranking

The Tentative Fracture-Corridor Fairway Map presented in the preceding section represents the best geological working hypothesis that can presently be formulated from the available geological, structural, well, and legacy 3D seismic data. However, the degree of confidence associated with the different elements of the proposed model is not uniform because each component is supported by different quantities and qualities of geological evidence.

Accordingly, the present interpretation should be regarded as a confidence-ranked geological model rather than a definitive geological description of the subsurface. Some geological elements are supported by extensive observational

evidence and can therefore be assigned relatively high confidence, whereas others remain largely interpretative and require additional investigation.

The principal geological components of the present model may be ranked as follows:

High Confidence

- ➡ **Regional compressional tectonic framework.**
- ➡ **Existence of the northern and Tsouthern structural culminations.**
- ➡ **Presence of the principal thrust systems.**
- ➡ **General Oligocene reservoir architecture.**
- ➡ **Interpretation of the case-study petroleum system as a thrust -related anticline.**

These geological elements are supported by regional geology, well control, and the interpretation of the available seismic data.

Moderate Confidence

- ➡ **Distribution of mechanical stratigraphy.**
- ➡ **Location of major relay and transfer zones.**
- ➡ **Identification of persistent deformation zones.**
- ➡ **Relative distribution of high- and moderate-strain domains.**
- ➡ **Predicted variation in fracture intensity across the structure.**

These interpretations are consistent with the available geological evidence but remain partly dependent upon conceptual geological models and indirect structural interpretation.

Low Confidence

- ➡ **Exact location of individual fracture corridors.**
- ➡ **Detailed geometry and width of fracture-corridor fairways.**
- ➡ **Hydraulic behaviour of individual fault-damage zones.**
- ➡ **Degree of fracture connectivity between the northern and southern culminations.**
- ➡ **Relative contribution of different fracture corridors to reservoir-scale fluid flow.**

These geological elements cannot be established reliably from the existing legacy 3D seismic data and therefore remain the principal objectives of the proposed seismic reprocessing programme.

The most important conclusion arising from this confidence assessment is that the principal geological uncertainties are precisely those that most strongly influence future field development. Consequently, the objective of the proposed amplitude-preserving seismic reprocessing is not to improve the regional structural interpretation—which is already reasonably well established—but rather to reduce uncertainty concerning the geometry, continuity, and hydraulic significance of the inferred fracture corridors.

The confidence ranking presented here therefore provides the principal justification for the next phase of investigation. Rather than attempting to confirm

preconceived interpretations, the proposed seismic reprocessing should systematically evaluate those aspects of the geological model that currently possess the lowest confidence while having the greatest impact on reservoir development.

3.6.1) Final Working Hypothesis

The fracture-corridor model proposed in the present memorandum represents the most plausible geological interpretation currently compatible with the available geological, structural, well, and seismic evidence. It should therefore be regarded as a working geological hypothesis, not as a demonstrated geological fact.

The proposed model has been developed through the convergence of multiple independent geological observations and is fully consistent with the mechanical principles presented in Part I, the geological controls discussed in Part II, and the structural analysis developed in the present memorandum. Nevertheless, its scientific value depends entirely upon its ability to withstand future testing.

Accordingly, the next objective is not to defend the present model, but to challenge it through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, and subsequent reservoir observations. Those elements of the model that are corroborated should be retained with increased confidence, whereas those contradicted by new evidence should be modified or rejected.

In this sense, the present memorandum should not be regarded as the conclusion of the geological investigation, but as the scientific framework upon which the next stage of geological and geophysical work should be based.

4) How the Hypothesis Can Be Tested

The fracture-corridor model proposed in the preceding chapter represents the best geological working hypothesis currently compatible with the available geological, structural, well, and seismic information. However, the scientific value of any geological hypothesis does not depend upon its apparent plausibility, but upon its capacity to generate explicit predictions that can subsequently be confronted with empirical evidence.

Accordingly, the principal objective of the next stage of investigation is not to confirm the proposed fracture-corridor model, but to subject it to rigorous geological and geophysical testing. Only those aspects of the model that withstand confrontation with new observations should be retained with increased confidence. Conversely, any component inconsistent with future observations must be modified or rejected in favour of a better geological explanation.

Within the case-study petroleum system, the proposed hypothesis predicts that fracture corridors should preferentially occur within structural domains where several independent geological criteria converge, including persistent deformation zones, relay and transfer zones, fault-damage zones, high structural curvature, mechanically competent carbonate reservoir units, and favourable reservoir architecture. If these predictions are correct, they should become progressively more evident following amplitude-preserving seismic reprocessing and the application of modern seismic interpretation techniques.

Testing the hypothesis therefore requires an integrated geological workflow in which seismic reprocessing, advanced seismic attributes, geological consistency tests, and well calibration are used together rather than independently. Each method provides an additional and independent line of evidence capable of either strengthening or weakening confidence in the proposed fracture-corridor model.

It is equally important to recognise that more than one geological model may initially explain the available observations. Consequently, alternative geological interpretations should be considered throughout the investigation and critically compared against the new evidence. The preferred interpretation should ultimately be the one that explains the greatest number of independent observations while requiring the fewest unsupported assumptions.

The following sections therefore describe the principal methods by which the proposed fracture-corridor hypothesis may be evaluated before major field-development decisions are undertaken. Collectively, these investigations are intended to reduce geological uncertainty, improve reservoir characterisation, and establish a more reliable basis for future appraisal and development of the case-study petroleum system.

4.1) Seismic Reprocessing

The first and most important step in testing the proposed fracture-corridor hypothesis is the amplitude-preserving reprocessing of the existing legacy 3D seismic survey. Because the original seismic data were acquired and processed primarily for exploration purposes, they were never intended to resolve the subtle structural and stratigraphic features that commonly control the distribution of fracture corridors within naturally fractured carbonate reservoirs.

Consequently, the objective of seismic reprocessing is not simply to improve image quality. Rather, it is to maximise the geological information contained within the existing seismic data so that the predictions developed in the present memorandum may be critically evaluated against a substantially improved seismic image.

The proposed fracture-corridor model predicts that deformation has been preferentially concentrated within specific structural domains, particularly those associated with persistent deformation zones, relay and transfer zones, fault-damage zones, high structural curvature, and mechanically competent Oligocene reservoir units. If this geological interpretation is correct, seismic reprocessing should improve the imaging of these structural domains and provide indirect evidence supporting, modifying, or contradicting the proposed model.

Particular emphasis should be placed upon preserving relative seismic amplitudes, azimuthal information, and the continuity of subtle structural features. These characteristics form the basis for subsequent interpretation using coherence, curvature, ant-tracking, AVAz, and other advanced seismic attributes capable of detecting structural discontinuities associated with fracture development.

It is important to recognise that seismic reprocessing is not expected to image individual fractures directly. The dimensions of most natural fractures remain well below conventional seismic resolution. Instead, the objective is to identify the larger geological expressions associated with fracture corridors, including discontinuity corridors, persistent deformation zones, fault-damage zones, relay structures, structural curvature anomalies, and azimuthal anisotropy.

The success of the proposed investigation should therefore not be measured by the direct identification of fractures, but by the degree to which the reprocessed seismic data either corroborate or contradict the predicted structural framework upon which the fracture-corridor model is based.

From a scientific perspective, seismic reprocessing constitutes the first empirical test of the geological hypothesis proposed in the present memorandum. If the improved seismic image confirms the predicted structural domains, confidence in the fracture-corridor model will increase. Conversely, if the reprocessed data contradict the proposed geological interpretation, the model must be modified or replaced by a more satisfactory explanation.

Accordingly, seismic reprocessing should not be regarded simply as a geophysical exercise, but as the principal geological experiment through which the present working hypothesis can be objectively evaluated before major field-development decisions are undertaken.

4.2) Seismic Attributes

The first and most important step in testing the proposed fracture-corridor hypothesis is the amplitude-preserving reprocessing of the existing legacy 3D seismic survey. Because the original seismic data were acquired and processed primarily for exploration purposes, they were never intended to resolve the subtle structural and stratigraphic features that commonly control the distribution of fracture corridors within naturally fractured carbonate reservoirs.

Consequently, the objective of seismic reprocessing is not simply to improve image quality. Rather, it is to maximise the geological information contained within the existing seismic data so that the predictions developed in the present notes may be critically evaluated against a substantially improved seismic image.

The proposed fracture-corridor model predicts that deformation has been preferentially concentrated within specific structural domains, particularly those associated with persistent deformation zones, relay and transfer zones, fault-damage zones, high structural curvature, and mechanically competent Oligocene reservoir units. If this geological interpretation is correct, seismic reprocessing should improve the imaging of these structural domains and provide indirect evidence supporting, modifying, or contradicting the proposed model.

Particular emphasis should be placed upon preserving relative seismic amplitudes, azimuthal information, and the continuity of subtle structural features. These characteristics form the basis for subsequent interpretation using coherence, curvature, ant-tracking, AVAz, and other advanced seismic attributes capable of detecting structural discontinuities associated with fracture development.

It is important to recognise that seismic reprocessing is not expected to image individual fractures directly. The dimensions of most natural fractures remain well below conventional seismic resolution. Instead, the objective is to identify the larger geological expressions associated with fracture corridors, including discontinuity corridors, persistent deformation zones, fault-damage zones, relay structures, structural curvature anomalies, and azimuthal anisotropy.

The success of the proposed investigation should therefore not be measured by the direct identification of fractures, but by the degree to which the reprocessed

seismic data either corroborate or contradict the predicted structural framework upon which the fracture-corridor model is based.

From a scientific perspective, seismic reprocessing constitutes the first empirical test of the geological hypothesis proposed in the present memorandum. If the improved seismic image confirms the predicted structural domains, confidence in the fracture-corridor model will increase. Converse-ly, if the reprocessed data contradict the proposed geological interpretation, the model must be modified or replaced by a more satisfactory explanation.

Accordingly, seismic reprocessing should not be regarded simply as a geophysical exercise, but as the principal geological experiment through which the present working hypothesis can be objectively evaluated before major field-development decisions are undertaken.

4.3) Geological Consistency Tests

The interpretation of fracture corridors should not rely exclusively upon seismic attributes or structural interpretation. Even if seismic reprocessing reveals discontinuity corridors, azimuthal anomalies, or curvature lineaments consistent with fracture development, these features should be accepted only if they are also geologically consistent with the overall tectonic and stratigraphic evolution of the case-study petroleum system.

Accordingly, the proposed fracture-corridor model should be subjected to a series of geological consistency tests designed to evaluate whether the interpreted fracture corridors satisfy the independent geological criteria established throughout the present memorandum.

a) The first consistency test concerns the structural framework.
The interpreted fracture corridors should coincide preferentially with structural domains where tectonic strain is expected to have been concentrated, including fold hinges, fault-damage zones, relay and transfer zones, and other areas of persistent deformation.

b) The second test concerns the Oligocene reservoir architecture.
Proposed fracture corridors should occur preferentially within laterally continuous carbonate reservoir intervals, rather than extending indiscriminately across mechanically or stratigraphically unfavourable facies. Their distribution should therefore remain compatible with the depositional architecture of the Oligocene carbonate platform.

c) The third test concerns mechanical stratigraphy.
Fracture corridors should preferentially develop within mechanically competent carbonate reservoir units, while becoming attenuated, segmented, or terminated where mechanically weak carbonate or marly intervals dominate the succession.

d) The fourth test concerns structural continuity.
Individual fracture corridors should display geometries compatible with the regional structural framework and should not terminate arbitrarily or exhibit orientations inconsistent with the interpreted tectonic evolution of the field.

e) The fifth test concerns regional tectonic coherence.

The proposed fracture corridors should remain compatible with the regional compressional stress regime, the geometry of the principal thrust systems, and the progressive tectonic evolution of the Zagros Fold–Thrust Belt.

f) The sixth test concerns reservoir behaviour.

Wherever possible, the predicted fracture corridors should be evaluated against available geological and dynamic observations, including well productivity, pressure communication, fluid contacts, production performance, and other independent reservoir data. Agreement between the predicted fracture-corridor distribution and observed reservoir behaviour would increase confidence in the geological model.

These geological consistency tests should not be regarded as independent confirmation of the proposed hypothesis. Rather, they constitute successive opportunities to identify inconsistencies requiring revision of the geological model. The objective is therefore not to defend the preferred interpretation, but to identify those aspects of the model that remain incompatible with the available geological evidence.

Accordingly, the fracture-corridor model should be progressively refined until it provides the simplest geological explanation capable of satisfying the greatest number of independent observations while introducing the fewest unsupported assumptions.

4.3.1) Working Hypothesis

The proposed fracture-corridor model should be regarded as geologically acceptable only if it remains consistent with the structural framework, reservoir architecture, mechanical stratigraphy, regional tectonic evolution, and available reservoir observations. Any interpreted fracture corridor that fails one or more of these geological consistency tests should be regarded as provisional and revised in the light of additional geological or geophysical evidence.

Consequently, the confidence assigned to the final fracture-corridor fairway map should depend not upon the strength of any single observation, but upon the convergence and mutual consistency of all available geological evidence.

4.4) Well Calibration

No geological interpretation, however sophisticated, can be regarded as reliable unless it is calibrated against direct observations. Consequently, the proposed fracture-corridor model should ultimately be evaluated through well calibration, which constitutes the principal link between the interpreted seismic response and the actual geological characteristics of the reservoir.

Within the case-study petroleum system, the available exploration and appraisal wells provide the only direct observations of the Oligocene reservoir, including lithology, reservoir facies, fracture occurrence, well productivity, pressure behaviour, fluid contacts, and production performance. These observations therefore represent the fundamental reference against which the geological interpretation must be evaluated.

The first stage of well calibration consists of comparing the predicted fracture-corridor fairways with the observed behaviour of existing wells. If the proposed model is correct, wells located within or adjacent to the predicted high-probability fracture-corridor domains should, on average, exhibit geological or dynamic characteristics different from wells located outside these domains.

Particular attention should be given to observations that may reflect enhanced fracture connectivity, including:

A) drill-stem test (DST) and extended well test (EWT) productivity;

B) production rates and productivity indices;

C) pressure communication between wells;

D) pressure-transient behaviour;

E) mud losses during drilling;

F) wellbore instability associated with intense natural fracturing;

G) image logs (FMI, XRMI or equivalent), where available;

H) core observations describing fracture density, orientation, aperture, and mineralisation;

I) production logging and flow profiling, where available.

Agreement between the predicted fracture-corridor distribution and these independent observations would increase confidence in the proposed geological model. Conversely, systematic discrepancies should lead to re-evaluation of the interpretation and, where necessary, modification of the fracture-corridor fairway map.

Well calibration should not be interpreted as a process of confirming a preferred geological model. Following the principles of the philosophy of science, it represents an opportunity to evaluate the explanatory power of the proposed model against direct geological observations.

The objective is therefore not only to identify those aspects of the interpretation that are corroborated by well evidence, but, more importantly, to identify those that are inconsistent with the observations and therefore require revision, refinement, or, where necessary, rejection. In this way, each new well contributes not only to reservoir evaluation but also to the progressive improvement of the geological model and the reduction of geological uncertainty.

It is also important to recognise that existing wells provide only point observations within a very large three-dimensional reservoir. Consequently, individual wells cannot by themselves prove or disprove the existence of fracture corridors. Their principal value lies in providing independent geological constraints that, when integrated with reprocessed seismic data, advanced seismic attributes, and structural interpretation, contribute to a more reliable geological model.

4.4.1) Working Hypothesis

If the proposed fracture-corridor model is geologically correct, the existing and future wells drilled within the case-study petroleum system should exhibit systematic geological and reservoir characteristics compatible with the predicted distribution of fracture corridors. Wells located within high-probability fracture-corridor fairways are expected, on average, to display greater fracture intensity, fracture connectivity, pressure communication, and reservoir productivity than wells located outside these structural domains.

Accordingly, well calibration constitutes the final and most direct geological test of the proposed fracture-corridor hypothesis before its incorporation into reservoir-development planning.

4.5) Alternative Geological Interpretations

The fracture-corridor model proposed in the present memorandum should not be regarded as the only possible geological interpretation of the case-study petroleum system. Like every geological model, it represents an at-tempt to explain the available observations in a coherent and internally consistent manner. Consequently, alternative geological interpretations should be consi-dered throughout the investigation and critically compared with the proposed working hypothesis.

Several geological models may initially appear compatible with the available seismic, structural, and well information. For example, variations in well productivity may be interpreted as resulting from differences in matrix reservoir quality, diagenetic heterogeneity, fault comparmentalisation, reservoir thickness, fluid distribution, or fracture connectivity. Likewise, structural discontinuities observed on seismic data may represent faults, fracture corridors, stratigraphic discontinuities, or combinations of these geological features.

The objective of geological interpretation is therefore not to defend a preferred model, but to determine which interpretation provides the simplest, most coherent, and most comprehensive explanation of the available evidence while introducing the fewest unsupported assumptions.

The proposed fracture-corridor model offers one possible explanation for several geological observations within the case-study petroleum system, including the variability of well productivity, differences in reservoir connectivity, the apparent communication between structural culminations, and the structural complexity revealed by the legacy 3D seismic interpretation. However, these observations may also be explained, wholly or in part, by alternative geological mechanisms.

Consequently, the proposed model should be evaluated not only against new geological observations but also against competing interpretations. The preferred geological explanation should be the one that best satisfies the following criteria:

a) consistency with the regional tectonic framework;

b) compatibility with the Oligocene reservoir architecture;

c) agreement with the mechanical stratigraphy;

d) consistency with structural geometry and fault architecture;

e) compatibility with well observations and reservoir behaviour;

f) ability to explain the greatest number of independent geological observations while requiring the fewest additional assumptions.

The forthcoming amplitude-preserving seismic reprocessing, together with the interpretation of advanced seismic attributes and continued well calibration, will provide the principal means of discriminating between these alternative

geological models. Some interpretations may gain support, whereas others may require modification or complete rejection.

Accordingly, the present fracture-corridor model should not be regarded as a final geological interpretation, but as the best working hypothesis currently compatible with the available evidence. Its scientific merit lies not in claiming certainty, but in providing explicit geological predictions that can be critically evaluated against future observations.

4.5.1) Final Working Hypothesis

At the present stage of knowledge, the interpretation that fracture corridors preferentially develop within persistent deformation zones, where structural curvature, fault-damage zones, relay and transfer structures, mechanically competent reservoir units, and favourable depositional architecture converge, provides the most coherent geological explanation of the available evidence for the case-study petroleum system.

Nevertheless, this interpretation remains provisional. It should continue to be challenged by alternative geological models and subjected to rigorous testing using reprocessed seismic data, advanced seismic attributes, well calibration, and future reservoir observations.

Only through this continuous process of comparison, testing, and revision can confidence in the geological model progressively increase and geological uncertainty be reduced before major field-development decisions are undertaken.

In petroleum geology, the best geological model is not the one that is most confidently asserted, but the one that survives the most rigorous comparison with alternative interpretations and the most severe confrontation with new geological evidence.

The last sentence beautifully combines Karl Popper's critical rationalism, Occam's razor, and practical petroleum geology.

5) Development Implications

The principal objective of the preceding chapters has been to formulate a testable geological working hypothesis for the distribution of fracture corridors within the case-study petroleum system. Regardless of whether the proposed hypothesis is ultimately corroborated, modified, or rejected, its principal value lies in its implications for field development.

Natural fractures do not merely influence reservoir permeability; they control reservoir connectivity, pressure communication, fluid-flow pathways, well productivity, drainage efficiency, and ultimately hydrocarbon recovery. Consequently, uncertainty regarding the distribution of fracture corridors translates directly into uncertainty regarding development planning, well placement, production performance, and economic recovery.

The purpose of the present chapter is therefore not to present a definitive development plan, but to examine how the proposed fracture-corridor model should influence future appraisal and development decisions. Particular attention is given to reservoir connectivity, horizontal

well placement, appraisal strategy, development risk, and the decision-making process that should precede full-scale field development.

Throughout this chapter, the proposed recommendations should be regarded as conditional upon the outcome of the amplitude-preserving seismic reprocessing and subsequent geological interpretation. If future observations modify the fracture-corridor model, the corresponding development strategy should also be revised. In this sense, geological interpretation and field development should be viewed as parts of the same iterative decision-making process.

5.1) Reservoir Connectivity

Among all the geological uncertainties affecting the case-study petroleum system, reservoir connectivity is probably the most critical because it directly influences well productivity, pressure communication, drainage efficiency, field development strategy, and ultimately hydrocarbon recovery. Consequently, understanding reservoir connectivity constitutes the principal objective of the fracture-corridor model proposed throughout the present memorandum.

In conventional reservoirs, connectivity is controlled primarily by the continuity of the porous and permeable reservoir rock. In naturally fractured carbonate reservoirs, however, connectivity depends upon the interaction between depositional architecture and fracture connectivity. Reservoir bodies may be laterally continuous but hydraulically compartmentalised if fracture systems remain poorly connected. Conversely, fracture corridors may establish efficient hydraulic communication between reservoir compartments that would otherwise remain only weakly connected.

The geological interpretation developed in the preceding chapters suggests that the Oligocene reservoir of the case-study petroleum system should not be regarded as a single homogeneous reservoir. Instead, it is interpreted as a complex assemblage of carbonate reservoir bodies, internal stratigraphic baffles, mechanical discontinuities, and fracture corridors, all of which contribute to the overall pattern of reservoir connectivity.

If the proposed fracture-corridor hypothesis is correct, reservoir connectivity is expected to be highly anisotropic. Fluid flow should preferentially occur along the principal fracture-corridor fairways, whereas areas located outside these corridors may communicate only poorly despite possessing similar reservoir properties. Consequently, the reservoir is expected to behave as a system of preferential hydraulic pathways rather than as a uniformly connected porous medium.

A particularly important geological question concerns the degree of hydraulic communication between the northern and southern structural culminations. If a significant fracture-corridor fairway exists within the interpreted relay and transfer zone, the two culminations may form part of a larger hydraulically connected reservoir system. Conversely, if fracture connectivity across this structural domain proves to be limited, the two culminations may behave as partially or completely compartmentalised reservoir units despite belonging to the same regional anticline.

The existence or absence of such reservoir-scale connectivity has major implications for pressure support, well interference, fluid migration, production fore-

casting, and the overall development strategy. Consequently, the question is not merely geological but directly influences reservoir management and economic decision-making.

The proposed fracture-corridor model therefore provides a geological framework for evaluating reservoir connectivity before large-scale development begins. Nevertheless, the model remains a working geological hypothesis whose validity must be tested through amplitude-preserving seismic reprocessing, advanced seismic attributes, well calibration, pressure-interference testing, and future production data.

5.1.1) Development Implications

If the proposed fracture-corridor model is corroborated, reservoir connectivity should become one of the principal criteria governing future field development. Horizontal wells should preferentially intersect the predicted fracture-corridor fairways, appraisal wells should be designed to test communication between structurally distinct reservoir compartments, and dynamic reservoir studies should focus on quantifying the hydraulic continuity of the inferred fracture network.

Conversely, if future investigations demonstrate that reservoir connectivity is significantly lower than predicted, the geological model and corresponding development strategy should be revised before full-scale field development proceeds.

Accordingly, the principal objective is not simply to determine whether fractures are present, but to establish whether they form reservoir-scale connected flow systems capable of controlling the long-term behaviour of the case-study petroleum system.

5.2) Horizontal Well Placement

The proposed fracture-corridor model has important implications for the placement of future horizontal wells within the case-study petroleum system.

In naturally fractured carbonate reservoirs, production performance depends not only on the quality of the reservoir rock, but also on the degree to which the well intersects connected fracture systems capable of providing efficient hydraulic communication over reservoir scales.

Conventional development strategies generally place wells near the structural crest of an anticline in order to maximise hydrocarbon column and minimise the risk of early water production.

Although this approach remains appropriate for many conventional reservoirs, it may not fully optimise production in naturally fractured carbonate systems where fracture corridors constitute the principal pathways for fluid flow.

If the geological hypothesis developed in the present memorandum is correct, the most productive horizontal wells will not necessarily be those located simply at the highest structural positions, but those that intersect the principal fracture-corridor fairways predicted from the integrated geological model - geological connectivity becomes as important as structural position when selecting drilling targets.

The orientation of horizontal wells should also be considered carefully. In general, maximum intersection with natural fractures is achieved when the well trajectory is oriented approximately perpendicular to the dominant fracture trend. However, the optimum trajectory should ultimately be determined from the orientation of the interpreted fracture corridors, the local stress field, drilling constraints, and the objectives of the development programme.

The proposed fracture-corridor fairways should therefore be regarded as preferred drilling corridors rather than precise well locations. Their principal function is to identify structural domains where horizontal wells have the greatest probability of intersecting extensive, interconnected fracture systems capable of enhancing reservoir connectivity, pressure communication, and well productivity.

It is important to recognise that the present fracture-corridor model remains hypothetical. Consequently, horizontal well placement should not be finalised until the proposed fairways have been evaluated through amplitude-preserving seismic reprocessing, advanced seismic attributes, and detailed structural interpretation. Premature well placement based solely on the legacy seismic interpretation may significantly increase geological and economic risk.

A phased appraisal strategy is therefore recommended. Initial horizontal wells should be designed not only to produce hydrocarbons but also to test the predicted fracture-corridor model. Information obtained from image logs, production logging, pressure interference tests, and production performance should then be used to refine the geological model before subsequent development wells are drilled.

5.2.1) Development Implications

If the proposed fracture-corridor model is corroborated, future horizontal wells should be preferentially located so as to intersect the highest-probability fracture-corridor fairways, particularly those associated with persistent deformation zones, relay and transfer zones, fault-damage zones, and mechanically competent carbonate reservoir units.

Such a strategy should maximise the probability of intersecting highly connected fracture systems and thereby improve well productivity, reservoir drainage, and ultimate hydrocarbon recovery.

Conversely, if future seismic interpretation or well calibration indicates that the predicted fracture corridors differ from those proposed herein, the drilling programme should be modified accordingly. Horizontal well placement should therefore remain an adaptive geological decision, continuously updated as new geological and reservoir information becomes available.

5.3) Appraisal Strategy

The principal objective of the proposed appraisal strategy is to reduce the geological uncertainties associated with the distribution, continuity, and hydraulic behaviour of the inferred fracture corridors before major development decisions are undertaken. Because the present fracture-corridor model represents a working geological hypothesis, the appraisal programme should be designed not merely to collect additional data but to test the validity of that hypothesis.

A successful appraisal strategy should therefore follow a progressive sequence in which each stage reduces geological uncertainty and provides the information required to decide whether the proposed fracture-corridor model should be retained, modified, or rejected.

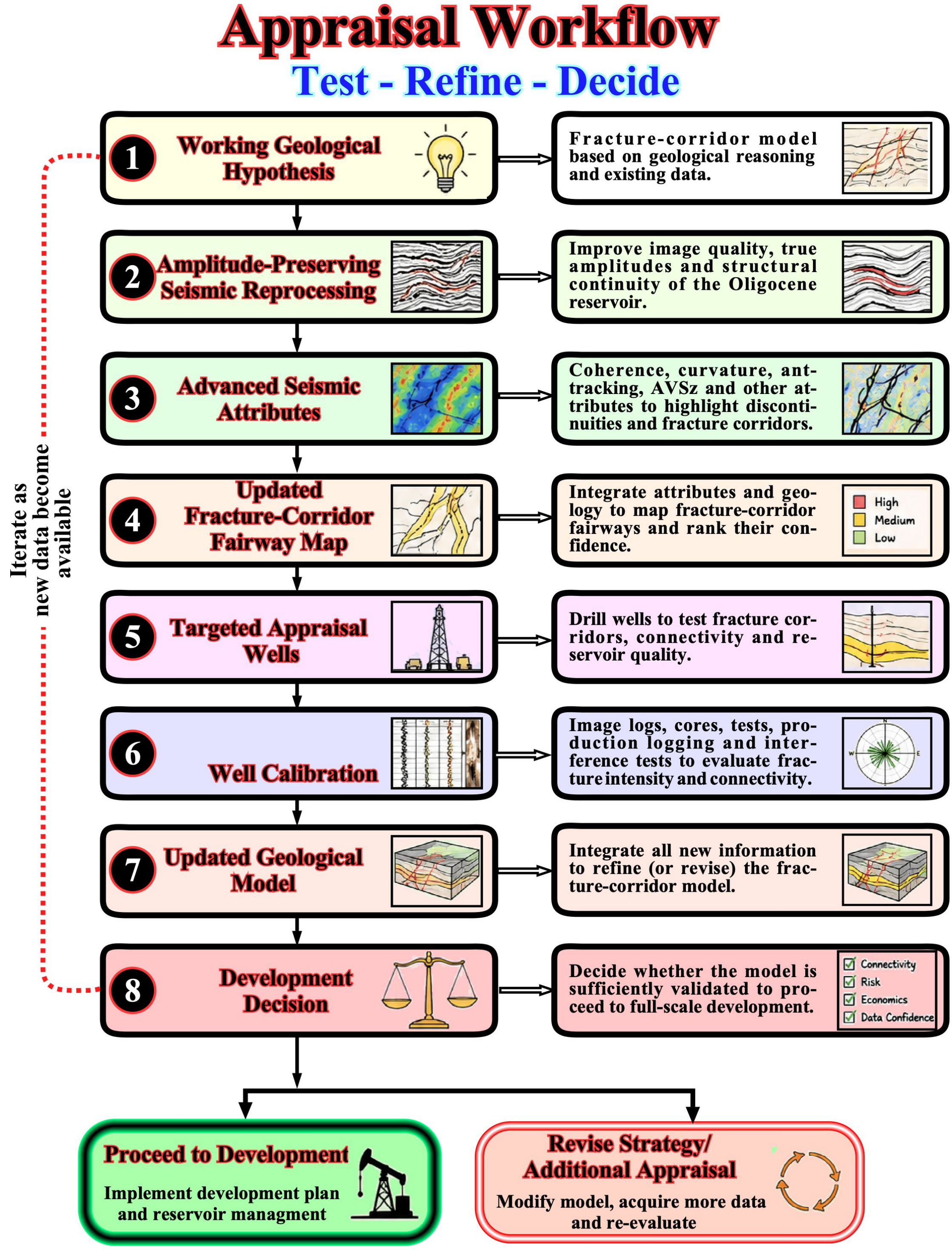


Figure 8- Proposed Appraisal Workflow for Testing the Fracture-Corridor Hypothesis Prior to Field Development. This figure illustrates the recommended hypothesis-driven appraisal workflow proposed for the case-study petroleum system. The workflow demonstrates how a preliminary working geological hypothesis concerning the distribution of fracture corridors should be progressively evaluated, refined, and ultimately translated into a field-development decision.

The process begins with the formulation of a working fracture-corridor model based upon the available geological, structural, well, and legacy 3D seismic information. This initial hypothesis is subsequently tested through amplitude-preserving seismic *reprocessing, followed by the interpretation of advanced seismic attributes capable of identifying structural discontinuities associated with fracture development.*

The resulting geological interpretation is then integrated into an updated fracture-corridor fairway map, which forms the basis for a targeted appraisal programme designed to evaluate the predicted fracture corridors through appraisal wells, image logs, core observations, formation tests, production logging, and pressure-interference testing. These independent observations provide the geological calibration necessary to update and refine the fracture-corridor model.

The workflow emphasises that geological interpretation is an iterative process. New geological and geophysical observations may either corroborate or contradict the proposed model, requiring progressive refinement of the geological interpretation before major development decisions are taken. Consequently, each stage of the appraisal programme contributes to reducing geological uncertainty and increasing confidence in the reservoir model.

The final development decision should therefore be based not upon the initial hypothesis itself, but upon the degree to which that hypothesis has been corroborated by independent geological, geophysical, and reservoir evidence. If the available evidence provides sufficient confidence in the proposed fracture-corridor model, field development may proceed. Conversely, if significant uncertainties remain, the geological model should be revised and the appraisal programme extended before major development investments are committed.

The figure summarises the central philosophy of the present memorandum: field development should be preceded by a structured scientific programme designed to test, refine, and progressively improve the geological model. In this way, the objective is not to eliminate geological uncertainty completely, but to reduce it to a level compatible with sound technical decisions, prudent reservoir management, and efficient hydrocarbon recovery.

The recommended first stage is the amplitude-preserving reprocessing of the legacy 3D seismic survey. This represents the principal opportunity to improve the structural image of the Oligocene reservoir and to identify the subtle geological features associated with fracture corridors, including fault-damage zones, relay and transfer zones, persistent deformation zones, and areas of high structural curvature.

The second stage consists of the integrated interpretation of advanced seismic attributes, including coherence, curvature, ant-tracking, AVAz, and other discontinuity-sensitive techniques. These independent datasets should then be integrated with the geological framework developed in the present memorandum to produce a revised fracture-corridor fairway map and an updated confidence ranking.

The third stage involves targeted appraisal drilling designed specifically to evaluate the proposed fracture-corridor model. Appraisal wells should not merely confirm the presence of hydrocarbons but should also acquire geological and dynamic information capable of evaluating fracture intensity, fracture connectivity, reservoir continuity, and pressure communication. Wherever possible, the programme should include image logs, cores, formation testing, production logging, and pressure-interference testing.

The fourth stage consists of integrating all available geological, geophysical, petrophysical, and reservoir-engineering information into an updated geological model. The fracture-corridor hypothesis should then be re-evaluated in the light of the new observations, and the proposed development strategy modified where necessary.

Only after completion of these appraisal stages should the field progress to full-scale development. At that point, horizontal well placement, production strategy, and reservoir management will be based upon a substantially improved understanding of the distribution and hydraulic significance of the fracture corridors.

5.3.1) Development Implications

The proposed appraisal strategy is fundamentally hypothesis-driven. Each stage of the programme is designed to reduce geological uncertainty by testing the fracture-corridor model rather than by simply acquiring additional information. Consequently, the appraisal programme should be regarded as a scientific investigation as well as a reservoir-development activity.

Successful implementation of this strategy is expected to reduce uncertainty concerning reservoir connectivity, improve the placement of future horizontal wells, optimise field-development planning, and ultimately increase hydrocarbon recovery while reducing technical and economic risk.

5.4) Development Risk

The principal objective of the present memorandum is to reduce development risk by improving the geological understanding of the case-study petroleum system before full-scale field development begins. Geological uncertainty cannot be eliminated entirely; however, it can be reduced sufficiently to permit more reliable engineering decisions and more efficient reservoir management.

At the present stage of knowledge, the greatest uncertainties do not concern the existence of hydrocarbons or the overall structural geometry of the field. Instead, they concern the distribution, continuity, and hydraulic significance of the inferred fracture corridors, which are expected to exert a first-order control on reservoir connectivity, pressure communication, well productivity, and ultimately hydrocarbon recovery.

If these geological uncertainties are not adequately resolved before development, there is a significant risk that major engineering decisions

- **horizontal well placement,**
- **well spacing,**
- **completion strategy,**
- **production forecasting, and**
- **field-development planning**

may be based upon an incorrect geological model. Such decisions could result in reduced recovery efficiency, unnecessary drilling costs, premature water or gas breakthrough, ineffective reservoir drainage, and, in the worst case, the permanent loss of recoverable hydrocarbons.

Conversely, reducing geological uncertainty before development provides substantial operational benefits. A better understanding of fracture-corridor distribution and reservoir connectivity should improve drilling efficiency, optimise well placement, enhance production forecasting, reduce the likelihood of

unsuccessful wells, and increase confidence in long-term reservoir-management decisions.

It is important to recognise that the proposed fracture-corridor model is not intended to increase geological complexity but to reduce development uncertainty by identifying those aspects of the reservoir that most strongly influence field performance.

The recommended programme of amplitude-preserving seismic reprocessing, advanced seismic interpretation, well calibration, and geological consistency testing therefore represents an investment in reducing uncertainty before substantially larger financial commitments are made during field development.

From a decision-making perspective, the principal risk is not that the proposed fracture-corridor hypothesis may ultimately prove to be incorrect. The principal risk is that field development may proceed without first determining whether the hypothesis is correct. If subsequent investigations demonstrate that the model requires modification, such revisions can readily be incorporated before major development investments are committed.

By contrast, correcting an inappropriate development strategy after large numbers of wells have been drilled is likely to be considerably more expensive and, in some cases, impossible.

5.4.1) Development Implications

The recommended development strategy is therefore based upon the principle that geological uncertainty should be reduced before engineering uncertainty is managed.

Consequently, the proposed programme of seismic reprocessing, advanced seismic attributes, targeted appraisal drilling, and well calibration should be regarded not as optional geological studies but as essential components of a risk-reduction strategy designed to maximise the technical and economic success of future field development.

Accordingly, the principal objective is not to eliminate geological uncertainty, but to reduce it to a level at which major field-development decisions can be made with an acceptable degree of technical confidence and economic risk.

The principal risk is not that the proposed fracture-corridor hypothesis may ultimately prove to be incorrect. The principal risk is that field development may proceed without first determining whether the hypothesis is correct.

This sentence perfectly captures the purpose of this memorandum. It shifts the discussion from

> **"Is the model right?" to "Have we acquired enough evidence to justify a multi-billion-dollar development decision?"**

That is exactly the perspective that management should adopt, which reinforces our central recommendation: test the geology first, then commit to development.

5.5) Decision Tree

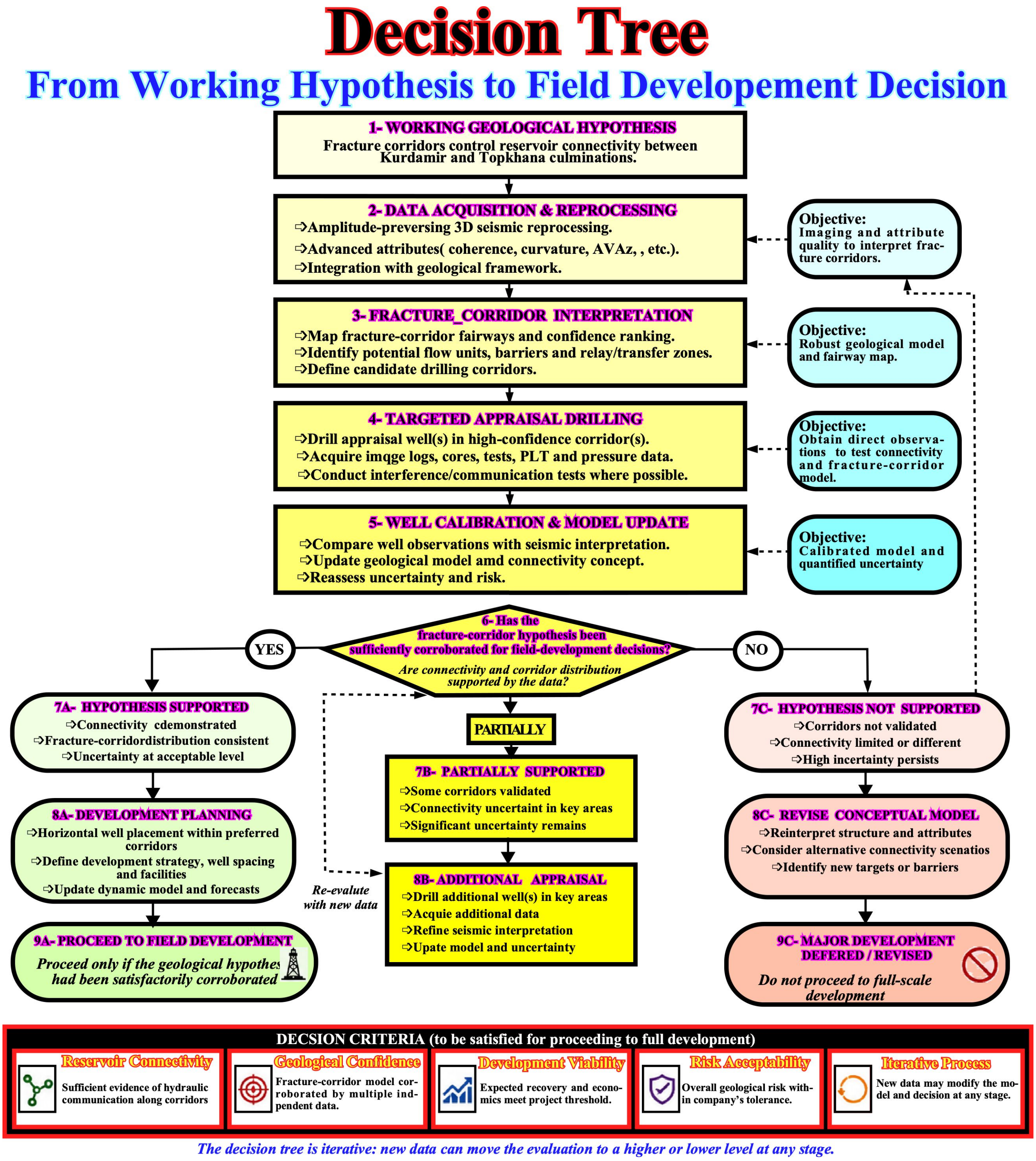


Figure 8- Decision Tree for Testing the Fracture-Corridor Hypothesis and Supporting Field-Development Decisions. This figure presents a hypothesis-driven decision tree illustrating the recommended sequence of geological, geophysical, and reservoir-engineering activities leading from the formulation of a working fracture-corridor hypothesis to a final field-development decision. The workflow emphasises that development should proceed only after the proposed geological model has been rigorously tested and progressively refined through the acquisition of independent geological evidence.

The decision process begins with the formulation of a working geological hypothesis, followed by amplitude-preserving seismic reprocessing, interpretation of advanced seismic attributes, preparation of an updated fracture-corridor fairway map, targeted appraisal drilling, and well calibration. At each stage, new information is incorporated into an updated geological model, progressively reducing uncertainty concerning the distribution and hydraulic significance of the inferred fracture corridors.

A key feature of the decision tree is the explicit evaluation of whether the fracture-corridor hypothesis has been sufficiently corroborated by the available evidence. Three possible outcomes are recognised. If the hypothesis is satisfactorily corroborated, the project proceeds to development planning and ultimately full-scale field development. If the evidence provides only partial support, additional appraisal and model refinement are recommended before a final decision is made. If the hypothesis is not supported, the geological model should be revised and alternative geological interpretations evaluated before any major development commitment is undertaken.

The figure also identifies the principal decision criteria that should be satisfied before development proceeds, including reservoir connectivity, geological confidence, development viability, risk acceptability, and the recognition that the entire process remains iterative. New geological, geophysical, or reservoir data may require the geological model and the corresponding development strategy to be updated at any stage.

The decision tree summarises the central philosophy of the present memorandum: the objective is not to confirm a preferred geological interpretation, but to reduce geological uncertainty to a level compatible with sound engineering decisions and responsible reservoir management. Consequently, field development should proceed only after the proposed fracture-corridor hypothesis has been satisfactorily corroborated by multiple independent lines of geological, geophysical, and reservoir evidence.

6) Conclusions

The present memorandum has developed a working geological hypothesis for the probable distribution of fracture corridors within the case-study petroleum system. This hypothesis was not derived from a single geological observation but from the progressive integration of multiple independent lines of geological evidence, including the structural framework, Oligocene reservoir architecture, mechanical stratigraphy, structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones.

Consistent with the Popperian philosophy adopted throughout this work, the proposed fracture-corridor model is explicitly presented as a testable geological hypothesis rather than a demonstrated geological fact. Its principal value lies not in claiming certainty, but in providing a coherent scientific framework capable of guiding future geological investigations and reducing development uncertainty before full-scale field development.

The following sections summarise the principal geological findings, identify the remaining uncertainties, define the essential information still required before development, and present the final recommendations arising from the present study.

6.1) Main Geological Findings

The principal geological findings of the present memorandum may be summarised as follows:

- ➡ **The case-study petroleum system is interpreted as a structurally complex thrust-related anticlin edeveloped within the Zagros Fold–Thrust Belt.**
- ➡ **The Oligocene reservoir is interpreted as a heterogeneous progradational carbonate system, composed of laterally variable reservoir bodies rather than a single homogeneous carbonate unit.**
- ➡ **The mechanical stratigraphy of the reservoir is interpreted to be largely inherited from the original depositional architecture, and subsequently modified by tectonic shortening and diagenesis.**

- ➡ Structural curvature, fault-damage zones, relay and transfer zones, and persistent deformation zones constitute the principal geological mechanisms responsible for strain localisation.
- ➡ Significant fracture corridors are expected to develop preferentially where these geological controls converge within mechanically competent carbonate reservoir units.
- ➡ The structurally complex domain located between the northern and southern structural culminations represents the highest-priority candidate area for the occurrence of a major fracture-corridor fairway.
- ➡ Reservoir connectivity is interpreted to depend upon the combined effects of depositional continuity and fracture connectivity, rather than upon either factor considered independently.
- ➡ The proposed fracture-corridor model provides the most coherent geological explanation currently compatible with the available geological, structural, well, and seismic evidence, but remains a working geological hypothesis requiring further testing.

6.2) Remaining Uncertainties

Despite the progress achieved, several important geological uncertainties remain unresolved. The principal uncertainties include:

- ➡ the precise location, geometry, and continuity of the fracture corridors;
- ➡ the hydraulic behaviour of individual fault-damage zones;
- ➡ the degree of reservoir connectivity between the northern and southern culminations;
- ➡ the relative importance of matrix flow and fracture-controlled flow;
- ➡ the influence of diagenesis on fracture permeability and connectivity;
- ➡ the dynamic behaviour of the reservoir during production.

These uncertainties cannot be resolved satisfactorily using the currently available legacy 3D seismic interpretation and therefore require additional geological and geophysical investigation.

6.3) Data Required Before Development

Before major development decisions are undertaken, the following information should be acquired or generated:

- ➡ Amplitude-preserving seismic reprocessing of the legacy 3D survey.
- ➡ An updated velocity model.
- ➡ Interpretation of coherence, curvature, ant-tracking, AVAz, and other advanced seismic attributes.
- ➡ An integrated fracture-corridor fairway map with associated - ranking.
- ➡ An updated geological model incorporating the new seismic interpretation.

- ➡ Targeted appraisal wells designed to evaluate the proposed fracture corridors.
- ➡ Image logs, cores, pressure-interference tests, and other well-calibration data.
- ➡ Updated reservoir simulation integrating the revised geological model.

Collectively, these datasets constitute the minimum geological and geophysical information required before committing to full-scale field development.

6.4) Final Recommendations

Taking into account that the principal objective of operator should be to maximise the recovery of both oil and gas from the cos-study petroleum system, rather than focusing primarily on the early production of the gas caps, the present memorandum does not recommend immediate full-scale development based solely upon the interpretation of the existing legacy 3D seismic data.

Instead, it recommends that field development should be preceded by amplitude-preserving seismic reprocessing, integrated geological interpretation, construction and testing of a fracture-corridor fairway model, and a targeted appraisal programme designed to reduce the principal geological uncertainties affecting reservoir connectivity, horizontal well placement, and ultimately hydrocarbon recovery.

Only after these investigations have satisfactorily corroborated the proposed geological model should full-scale field development be undertaken.

Accordingly, the following programme is recommended:

A) Carry out amplitude-preserving seismic reprocessing of the existing legacy 3D survey.

B) Perform an integrated geological interpretation using advanced seismic attributes.

C) Construct and evaluate an updated fracture-corridor fairway model.

D) Implement a targeted appraisal programme designed specifically to test the proposed geological hypothesis.

E) Proceed to full-scale field development only after the geological model has been satisfactorily corroborated by independent geological, geophysical, petrophysical, and reservoir evidence.

The principal recommendation arising from the three memoranda is straightforward. Before committing to full-scale development of the case-study petroleum system, the proposed fracture-corridor hypothesis should be rigorously tested through amplitude-preserving seismic reprocessing, advanced seismic interpretation, and a targeted appraisal programme. The objective is not to delay development, but to ensure that development proceeds on the basis of the most reliable geological model achievable.

In naturally fractured carbonate reservoirs, reducing geological uncertainty before development is not merely good scientific practice; it is an essential

prerequisite for responsible reservoir management, efficient field development, and the maximisation of long-term hydrocarbon recovery.

Ultimately, the scientific value of the proposed fracture-corridor model will not depend upon whether every element of the hypothesis proves to be correct, but upon its ability to stimulate critical testing, improve geological understanding, reduce development uncertainty, and support better-informed engineering and management decisions.

The present trilogy should therefore be regarded not as the conclusion of the geological investigation, but as the beginning of a new phase in which geological hypotheses are transformed into geological knowledge through systematic testing, critical evaluation, and progressive refinement. Only after this process has been completed should full-scale development of the case-study petroleum system be undertaken.