Subsurface Sandstone Investigation

This plan integrates core data, well logs, and geochemistry to characterize sandstone and define its depositional and reservoir potential.

Topic

Investigation on sedimentology, diagenetic, and petrographic characteristics of sandstone to determine the depositional environment and reservoir potential: requiring a systematic, integrated approach for subsurface: depositional environment and reservoir properties.

Phase 1: Available Data Acquisition and Context Establishment (feasibility)

1. Literature Review in general and Regional Context in particular : what type of literature review

- **Review regarding the subsurface available data , seismic and well logging drilling reports to establish a general lithologic column, with synopsis on tectonic setting, and environmental depositional.**
- **Establish a theoretical model for potential sandstone depositional systems or environment (e.g., shelf, delta, fluvial-channel belts) based on data acquisition**.

2. Subsurface Data Preparation

- all available **core data** (e.g., photographs, descriptions, sample depths) to the wireline log data..

Phase 2: Core and Log Analysis (Facies & Environment)

Core Sedimentologic Logging and borhole Imager : lithologic facies analysis and description, Sedimentary structures analysis including Grain size sorting with : Lithofacies: Sedimentary Structures:

- **Log Analysis:** Define **Electrofacies** by grouping log responses (e.g., Gamma Ray (GR), Neutron Porosity (NPHI), Density (RHOB), Spontaneous Potential (SP)).
- **Facies Association and Depositional Environment Interpretation**

- **Depositional Model:** Interpret the overall **depositional environment** by analyzing the **vertical stacking patterns** and lateral distribution (via cross-sections) of the Facies Associations across the study area.

3: Petrographic and Diagenetic Analysis

Petrographic Analysis (Thin Sections)

- **Sampling:** Select representative samples from each key Facies Association for thin section preparation.
- **Modal Analysis:** Perform **point counting to quantify (see the available model)**

- **Framework Grains:** Quartz, Feldspar, Lithic Fragments. This informs **provenance** and tectonic setting (e.g., QFL plots).
- **Matrix and Cements:** Quantify the volume and type of matrix (clays) and **authigenic cements** (e.g., quartz overgrowths, calcite, iron oxides).
- **Porosity:** Differentiate and quantify primary (intergranular) versus **secondary (dissolution)** porosity.

- **Textural Analysis:** Quantify grain sorting, roundness, and packing—properties related to transport energy and original depositional setting.

Diagenetic Sequence and Mineralogy

- **Paragenesis:** with the **diagenetic events** (compaction, cementation, dissolution, replacement) based on petrographic analysis
- **Microscopy :** Use Scanning Electron Microscopy with Energy Dispersive X-ray) on select samples to:

- Visually assess **pore-throat geometry** and the morphology of diagenetic clay minerals (e.g., pore-filling kaolinite, pore-lining illite) which significantly affect permeability and porosity.

- **Mineral Identification (XRD):** Use X-ray Diffraction (XRD), especially the **clay mineral assemblage** as key products of diagenesis.

Geochemical Analysis

Stable Isotopes: Analyze C and O isotopes in carbonate cements to infer the **source and temperature of diagenetic fluids** (e.g., meteoric water, burial fluids).

- **Fluid Inclusion Analysis:** Determine the **temperature and salinity of fluids** that precipitated quartz or carbonate cements, providing a direct measurement of the burial history and thermal regime.

Phase 4: Synthesis

- **Diagenesis-Environment:** Define the **original depositional environment** leading to the subsequent diagenetic pathway
- **Reservoir Quality Assessment:** Determine the relative impact of depositional characteristics versus diagenetic modification on the final **porosity and permeability** (reservoir quality).

Investigation on Sandstone (Subsurface)

This plan outlines the systematic, integrated approach using <u>core data, well logs, and geochemistry to determine the depositional environment and reservoir properties</u> of subsurface sandstone.

Step	Focus	Key Deliverables
1. Regional Review	Tectonic setting, stratigraphy, and existing reports (drilling, seismic, logging).	**Conceptual Model** of potential sandstone depositional systems (e.g., delta, shelf, fluvial).
2. Subsurface Data Preparation.	Ensure data availability quality and alignment.	**Core-Log Depth Match** (core photos/descriptions to wireline logs) and **Log Normalization**.
Step	Focus	**Key Deliverables**
3. Sedimentologic Logging	Detailed core/BHI analysis (lithofacies, grain size, sedimentary structures, bioturbation).	**Detailed Lithofacies Descriptions (input for environmental interpretation).**
4. Log Analysis	Group frequent log responses (NPHI}RHOB)and interpret curve shapes.	**Electrofacies defined and Calibrated to specific core Lithofacies.**
5. Environment Interpretation	Analyze the vertical and lateral succession of Facies/Electrofacies.	**Facies Associations and a Depositional Model (e.g., shoreface succession).**

Step	**Focus**	**Technique**	**Key Deliverables**
6. Petrography	Composition, texture, and cement/porosity	**Thin Section Point Counting** on representative samples.	**Modal Analysis** (QFL for provenance) and quantification of **Primary/Secondary**

Step	Focus		Key Deliverables
	quantification.		**Porosity**.
7. Diagenetic Sequence	Determine the sequence of post-depositional events.	**Optical Petrography** (cross-cutting relationships).	**Paragenetic Sequence** (e.g., compaction quartz cement dissolution).
8. Mineralogy & Fabric	Identify fine-grained minerals and pore geometry.	**SEM-EDS** (clay morphology, pore-throat) and **XRD** (clay mineral assemblage).	
9. Geochemistry	Infer fluid source and temperature.	**Stable Isotopes** on cements; **Fluid Inclusion Analysis** (salinity, temperature etc…)	Diagenetic fluid history and maximum burial temperature.

Step	Focus	Result
10. Diagenesis-Environment Link	Integrate petrography and geochemistry with depositional setting.	Define how the **original depositional environment controlled diagenesis** (e.g., initial grain sorting/mineralogy).
11. Reservoir Quality Assessment	Determine the relative control of depositional vs. diagenetic processes on the final rock quality.	Quantification of the impact on **Porosity and Permeability** (reservoir properties).

Or

1 Foundation and Context Establishment (Feasibility)

This phase ensures all necessary data is collected and a preliminary geological framework is established.

Step	Focus	Action/Technique	Key Deliverable
1. Regional Review	Tectonic, stratigraphic, and environmental context.	Review **available seismic interpretation**, **well logging data**, and **drilling reports** to establish a general lithologic column.	**Conceptual Depositional Model** (e.g., shelf, delta, fluvial-channel belts).
2. Subsurface Data Prep.	Data alignment and quality control.	Perform **Log Normalization** and critical **Core-Log Depth Matching** (aligning core photographs/descriptions with wireline logs).	Aligned, normalized, and usable subsurface dataset.

Phase 2: Depositional Environment Analysis (Sedimentology)

This phase uses macroscopic data (core/logs) to define rock units and environmental interpretations.

Step	Focus	Action/Technique	Key Deliverable
3. Core Facies Analysis	Detailed rock description and process identification.	**Core Sedimentologic Logging** and **Borehole Imager** analysis: describe lithofacies, grain size, sorting, and key **Sedimentary Structures**	**Detailed Lithofacies Descriptions** and **Vertical Stacking Patterns**.

Step	Focus	Action/Technique	Key Deliverable
4. Electrofacies Definition	Bridge core data to uncored intervals.	Define **Electrofacies** by grouping recurring log responses (e.g.GR NPHI)(RHOB) **Calibrate** Electrofacies to core Lithofacies.	**Facies Associations** defined across all logged wells.
5. Depositional Modeling	**Interpret large-scale environment.**	Analyze the vertical succession and **lateral distribution** (via cross-sections) of Facies Associations.	**Depositional Model** of the sandstone environment.

Phase 3: Diagenetic and Reservoir Characterization (Petrography & Geochemistry)

This phase investigates the microscopic controls on mineralogy and porosity evolution.

Step	Focus	Action/Technique	Key Deliverable
6. Petrographic Analysis	Composition, texture, and cement/porosity quantification.	**Sampling** of representative Facies Associations. Perform **Modal Analysis (Point Counting)** to quantify **Framework Grains** (QFL for provenance), **Cements** (quartz overgrowths, calcite), and **Primary/Secondary Porosity**.	Sandstone classification, **Textural Analysis**, and initial porosity assessment.
7. Diagenetic Sequence	Temporal ordering of alterations.	Establish **Paragenesis** based on cross-cutting relationships observed in thin sections.	**Temporal Sequence of Diagenetic Events** (compaction $\rightarrow$ cementation $\rightarrow$ dissolution $\rightarrow$ replacement).
8. Advanced Mineralogy	Identify fine-grained components.	Use **SEM-EDS** to assess **pore-throat geometry** and the morphology of **diagenetic clay minerals** (e.g., kaolinite, illite). Use **XRD** to quantify the overall mineralogy and clay assemblage.	Morphology of pore-filling materials and precise clay identity.
9.	Diagenetic fluid	Analyze C and O **Stable Isotopes** in cements. Conduct	Constraints on **diagenetic fluid source**

Step	Focus	Action/Technique	Key Deliverable
Geochemistry	history.	**Fluid Inclusion Analysis** (temperature and salinity) on quartz/carbonate cements.	**and temperature** (burial history).

Phase 4: Synthesis and Conclusion

This final phase integrates all results to answer the essential questions of the investigation •

10. Diagenesis-Environment Link: Define the critical control exerted by the **original depositional environment** (e.g., grain sorting, mineralogy) on the **subsequent diagenetic pathway** (e.g., cement type and distribution).

11 Reservoir Quality Assessment: Determine the relative impact of **depositional characteristics** versus **diagenetic modification** on the final **porosity and permeability (reservoir quality)**.