The International Association for Structural Geology and Tectonics Conference

Accra, Ghana, 22-24 July, 2026

USING AI PREDICTION MODELS FOR CARBON CAPTURE AND STORAGE MONITORING AND RISK ASSESSMENT IN (NEAR) SURFACE AND MARINE MONITORING

Alexander Asonkey

Department of Earth Science, University of Ghana, Legon

Key Findings

- Near-perfect classification — Random Forest achieves F1 = 0.9998 and AUC = 1.000 for AI-based sand–shale lithology classification from wireline logs.
- Robust cross-well generalization — a model trained on one well accurately classifies lithology 1.6 km away, supporting network-scale CCS monitoring without new drilling.
- Gamma Ray is indispensable — removing GR drops accuracy from >99% to ~68%, a key constraint for cased monitoring wells with limited log access.

1 INTRODUCTION

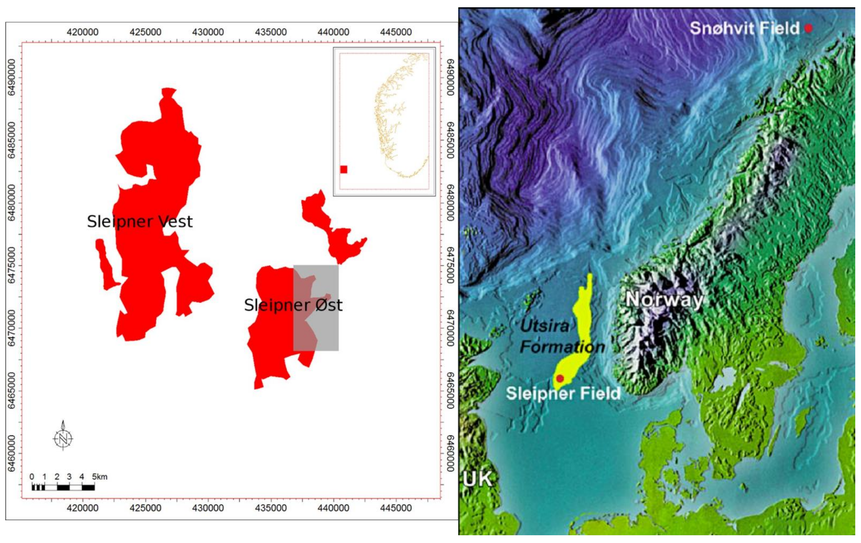
- CCS captures CO_2 at emission sources and stores it in deep geological formations a pathway the IPCC identifies as essential to limiting warming to 1.5–2°C.
- Large-scale injection can trigger induced seismicity, surface deformation, and unintended CO_2 or brine migration.
- Marine sites carry additional risk of benthic/pelagic ecosystem disruption and localized acidification.
- Traditional monitoring (seismic surveys, borehole pressure, geochemical sampling) is costly and slow to catch emerging risks.
- AI methods (Random Forest, Gradient Boosting, CNNs, LSTMs) detect subtle multivariate patterns and flag anomalies in near real time.

2 RESEARCH OBJECTIVES

- Review near-surface and marine CCS monitoring approaches and identify data gaps.
- Develop and validate AI models to detect subsurface risk deformation, gas migration, fluid interactions.
- Assess CCS impact on marine biodiversity, water quality, and seabed integrity.
- Integrate both monitoring streams into one unified risk-assessment framework.

Study Area

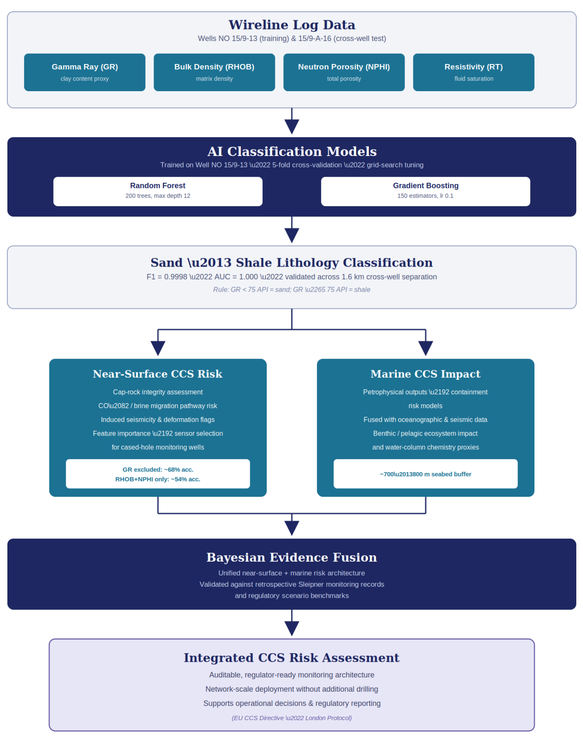
- Sleipner Field, central Norwegian North Sea, ~250 km SW of Stavanger, 80–85 m water depth on the Utsira High.
- Operated by Equinor since 1996 — the world's first commercial-scale offshore geological CCS project.
- CO_2 injected into the Utsira Sand saline aquifer at ~1 Mt/year; cumulative injection exceeds 22 Mt since 1996.
- Reservoir: porosity 35–37%, sealed by >700 m of Nordland Shale caprock.
- Two wells studied deviated well 15/9-A-16 and vertical well NO 15/9-13 separated by ~1.6 km.
- Both wells show consistent, alternating sand–shale stratigraphy matching known Utsira Sand geology, giving a reliable basis for AI lithology classification.



Location of the Sleipner CO_2 storage site in the Norwegian North Sea. Modified after Chadwick et al. (2008) and the Norwegian Offshore Directorate (formerly Norwegian Petroleum Directorate).

3 METHODOLOGY

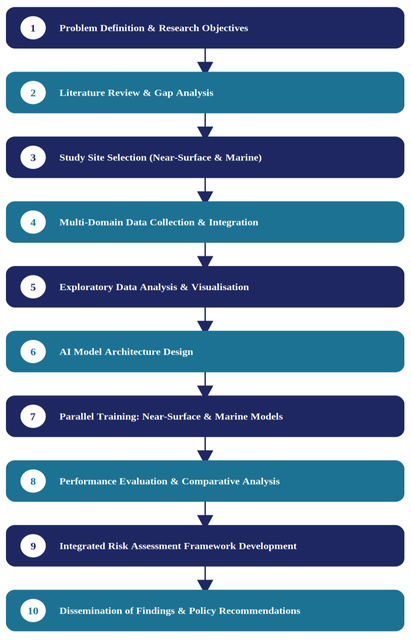
- Logs used: Gamma Ray (GR), Bulk Density (RHOB), Neutron Porosity (NPHI), Resistivity (RT), Sonic (DT).
- Lithology rule: GR < 75 API = sand; GR ≥ 75 API = shale.
- Random Forest (200 trees) and Gradient Boosting trained on Well NO 15/9-13, cross-applied to Well 15/9-A-16.
- Validated with 5-fold cross-validation, grid-search tuning, and a GR-excluded ablation test.
- Marine impact assessed via petrophysical outputs fused with published oceanographic and seismic data through a Bayesian risk model.



AI methodology pipeline: data acquisition through model validation.

0.9998 weighted F1, full model	**1.000** AUC-ROC, full model
~68% accuracy, GR excluded	**~54%** accuracy, RHOB+NPHI only

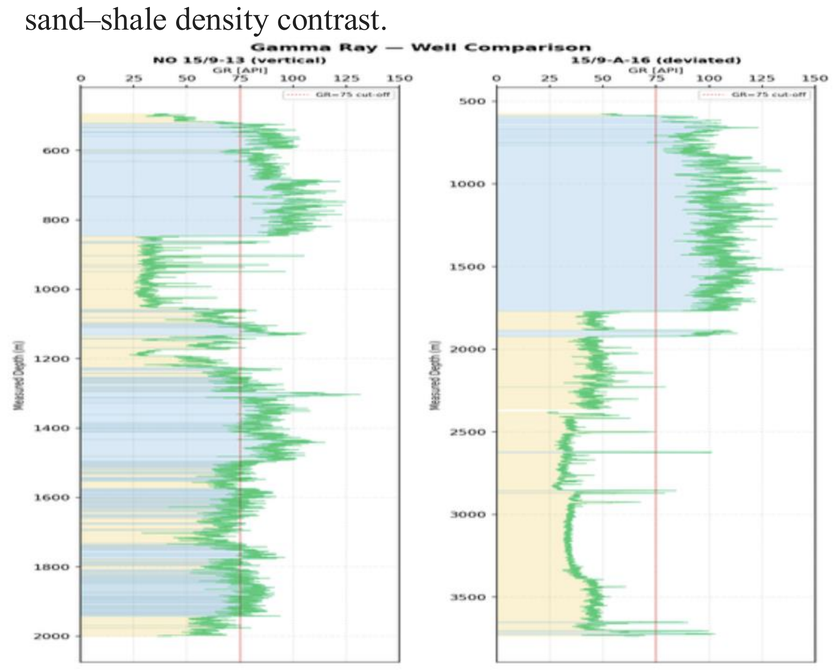
AI Model Classification Summary

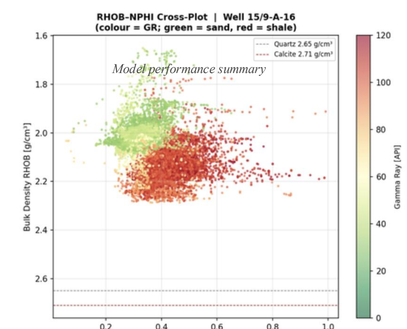


Conceptual framework: CO_2 injection → AI monitoring → CCS risk assessment pathway.

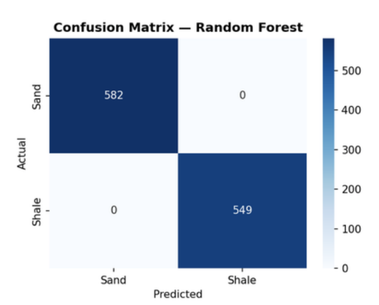
4 RESULTS

Full 4-log model: zero misclassifications across 1,131 hold-out samples. Removing GR sharply reduces accuracy, confirming GR is the single most critical input log. With GR excluded, RHOB emerges as the top feature, reflecting the sand–shale density contrast.

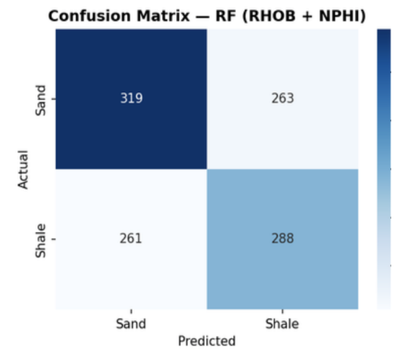




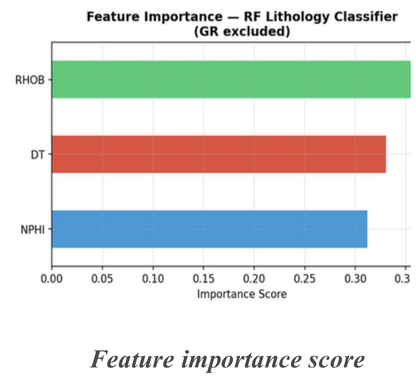
RHOB-NPHI crossplot



Confusion matrix



Confusion matrix



Feature importance score

5 DISCUSSION & CONCLUSION

- The GR–RHOB–NPHI–RT log suite generalizes robustly between wells 1.6 km apart, validating network-scale CCS monitoring without additional drilling.
- The 700–800 m buffer above the reservoir gives a substantial safety margin, consistent with 25+ years of safe, breach-free containment at Sleipner.
- The framework is transferable to other CCS sites and supports auditable regulatory reporting (e.g., EU CCS Directive, London Protocol).
- Future work: multi-class lithofacies, larger inter-well spacing, and 4D time-lapse log integration.

Significance & Scope

Grounded in real wireline log data from two Sleipner wells spanning the Utsira Sand storage formation and its Nordland Shale caprock, demonstrating a generalizable, auditable, regulator-ready AI monitoring framework for CCS deployed at scale.

Contact: aasonkey@st.ug.edu.gh • **Data:** P01ES09584 (Wolff) — NIEHS & EPA framework analogue; see selected references for full source list.

QR Code

Structural Geology in a Changing World: Tectonics, Resources and Sustainable Transitions