Sealing Wellbores at the end of their lifecycle to restore subsurface seal integrity and prevent offshore wellbore leakage

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Abstract

As we approach 2020, there are more well bores that require abandonment than well bores waiting to be drilled. The USA alone has ˜1.7 Million well bores with an API number indicating that they are not permanently plugged, therefore will be in need of Plugging and Abandonment (P&A) at some point in the future. Some of these well bores are located in fragile ecosystems, such as the Gulf of Mexico, where it is estimated that 9,000 idle well bores are waiting permanent plugging and abandonment. The numbers of future P&As suggest requirement for an urgent improvement of current technology as many governments are preparing standards that require assurance for zero leakage over thousands of years. This paper/talk will present knowledge gaps we identified during literature review and the data obtained during first two terms of the ongoing project , under NASEM-GRP funding. Extensive literature review points to the following issues: 1) Portland-cement based materials, with their pH ˜13, are geochemically incompatible with the reservoir conditions in the GoM. 2) Weak interfaces between and contamination with drilling fluids in well bore structures present high risk for Hydrocarbon leakage, which currently cannot be mitigated successfully. Placement and accessibility of well bore in offshore environment adds to technological complexity and increases the risk of leakage. 3) Monitoring and verification is currently not available for long-term assessment offshore. Some of our preliminary data suggests the following: 1) Plugging materials are impacted by contamination form drilling fluids and other well bore materials, such as fragment of dehydrated clays, oily rock fragments. 2) Casing corrosion might lead to deterioration of primary well bore cement, which can be difficult to locate and re mediate prior to plugging. 3) Geo-mimicry is a potential path forward in designing and developing barrier materials capable of serving over thousands of years.

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Introduction

- Increasing number of wells ⇒ Compelling need for plugging to prevent leakage of hydrocarbons into the environment
- Issues faced by Portland cement-based materials :
  - Geochemically incompatible with reservoir conditions in GOM.
  - Weak interfaces due to drilling mud contamination pose high risk for Hydrocarbon leakage.
  - Placement and accessibility of well bores in offshore environments adds to the complexity.
  - Insufficient tools for assessment of offshore wellbore plug integrity Increases the need for robust plugging
  - Failure of cement plugs by formation of micro annuli and fractures.
  - Incompatibility between casing and geological formations.
  - Sub surface pressures and temperatures as we as harsh chemical environments

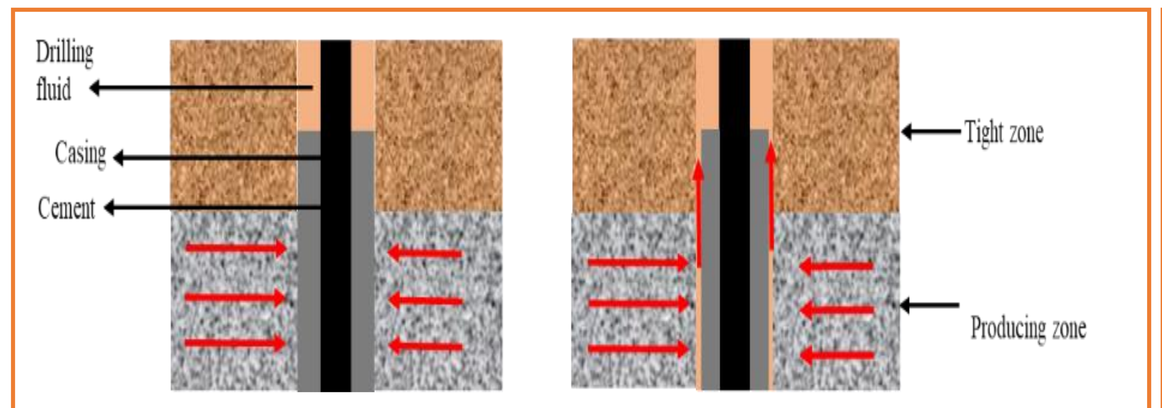

Fig 1. 2D conceptual schematics: Impact of drilling fluid on cement/formation interface. Drilling fluid contamination is one of the challenges that is unavoidable during the cement placement. The contamination always occurs no matter how well the downhole is cleaned

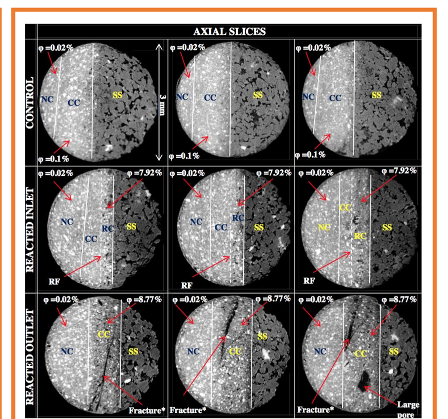

Fig 2. Effect of drilling fluid on the properties of cement by increasing the porosity and generating weaker zone.

- As shown in Fig 2., Micro-CT images of the mini cores drilled from the cement- sandstone interface of the 5% mud contaminated cement-sandstone composite core (inlet and outlet) after 30 days of core-flood and from a control sample.
- The neat cement and contaminated cement in the control sample show no significant porosity difference. The post core-flood mini cores (inlet and outlet) on the other hand reveal presence of lower density cement (dark gray color) close to the sandstone. The black spots in the lower density region indicate increased macro-porosity (Courtesy of Nnamdi Agbasimalo, 2012).

Potential path forward:

- **Achieving Geomimicry by addition of natural minerals as supplementary cementitious materials.**
- **To explore addition of minerals like zeolites which have shown enhancement of properties**

Methodology

- Experimental procedures were designed to understand the chemical stability of zeolites at various conditions.
- Powdered zeolite samples were exposed to high and low pH conditions, high salinity, Oil and a control sample was put in DI water.
- Zeolites were tested after they were in the above conditions at 90^{0}C for 7 days.

Results

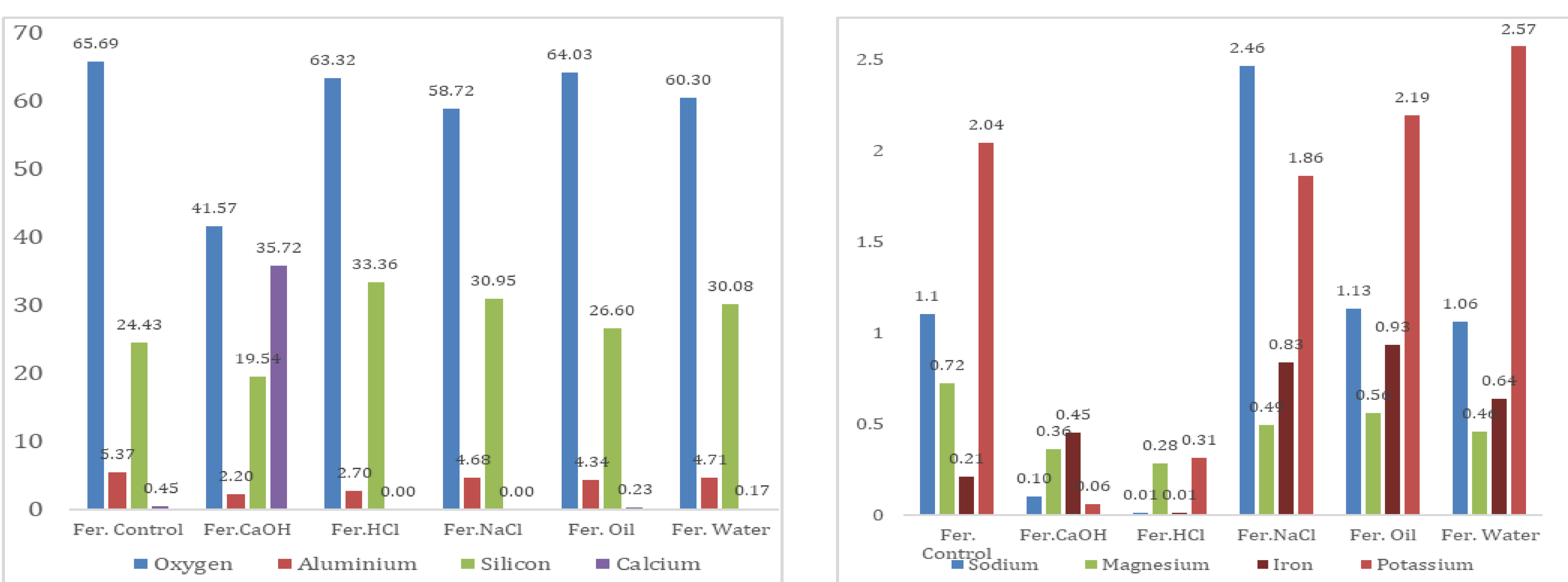

Fig 3: EDS analysis of Atomic percentage variation of various elements in the zeolite on exposure to sub-surface chemical conditions

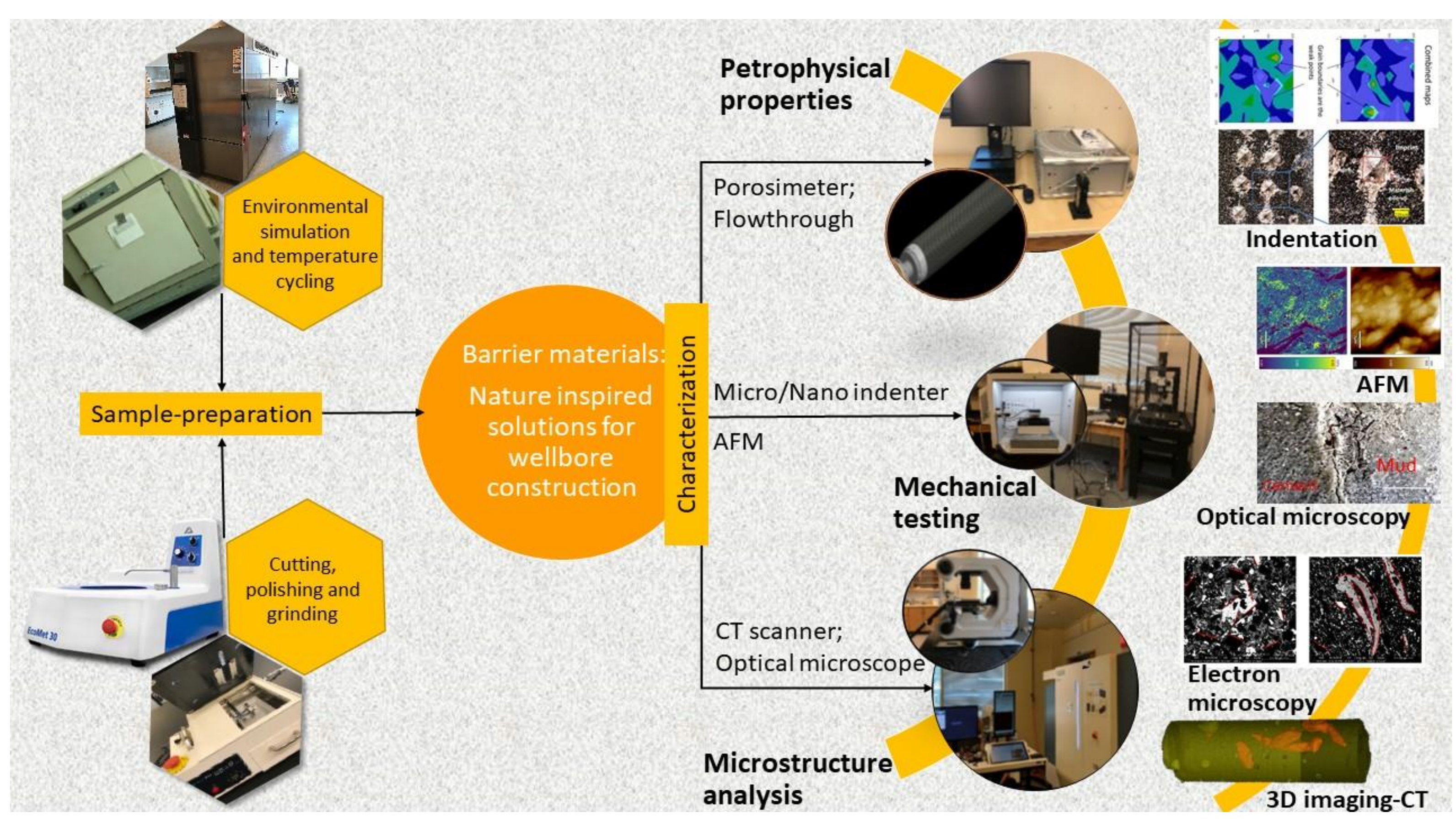

Fig 5: Schematic of the research methodology and analysis techniques used

Fig.4: (a) Plain ferrierite (Control); (b) ferrierite in HCl; (c) ferrierite in CaOH; (d) ferrierite in NaCl; (e) ferrierite in DI Water, (f) ferrierite in oil (g) ferrierite at 10000x (h) ferrierite at 40000x

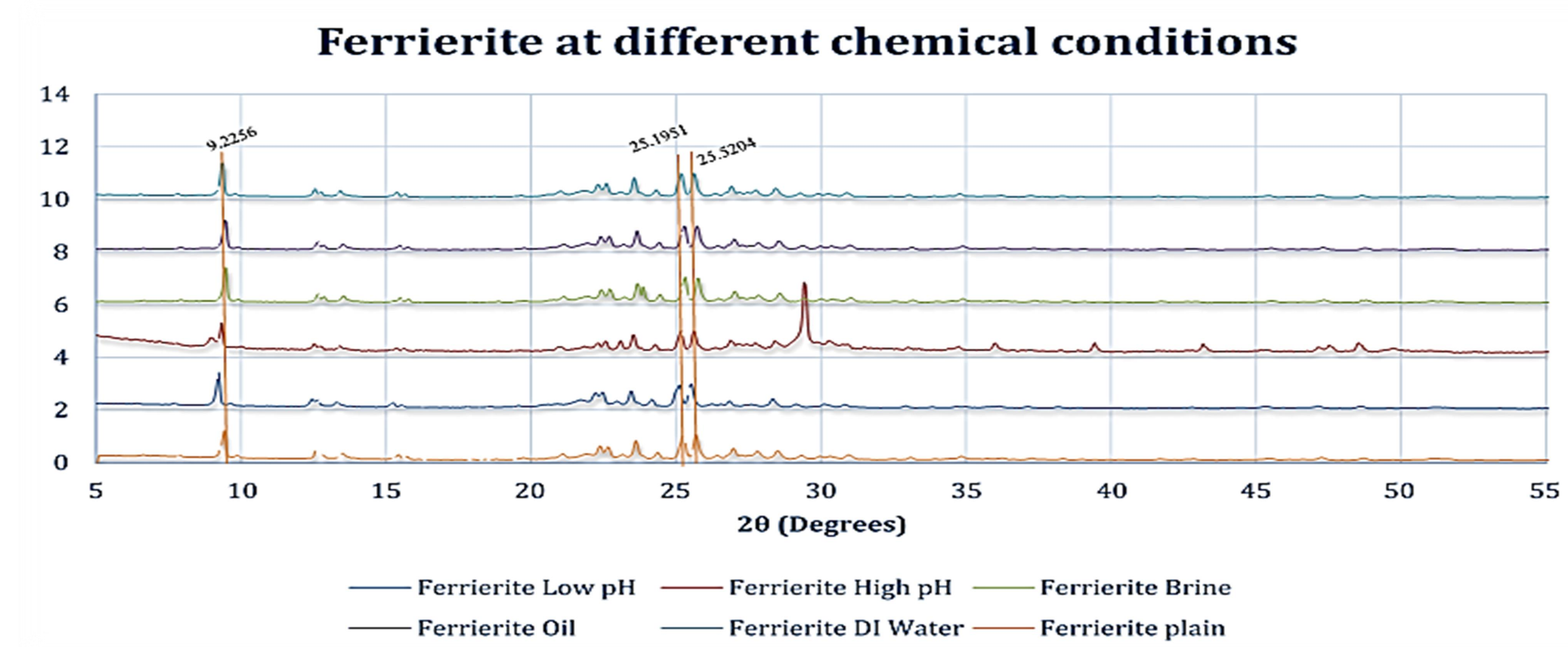

Fig 6: XRD data of ferrierite powder after exposure to various chemical conditions compared with the control sample. Standard ferrierite peaks are highlighted

Discussion

- Elemental analysis shows a slight change surface morphology and surface elemental composition
- XRD Analysis confirms the chemical stability as there is no phase change observed

Conclusion

- Similarity of crystal structure to cement phases is expected to result in a synergistic effect enhancing properties of cement
- Would affect hydration reaction by homogeneously being a part acting like scaffolding or hydration centres
- Future work is planned to make formulations of cement with varying quantities of ferrierite inclusions

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