Sealing wellbores at the end of their lifecycle to restore sub surface seal integrity and prevent offshore wellbore leakage

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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

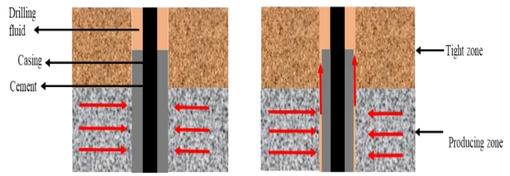

Fig 1. 2D conceptual schematics: Impact of drilling fluid on cement/formation interface. Drilling fluid contamination is one of the challenges that is unavoidable during the cement placement. The contamination always occurs no matter how well the downhole is cleaned

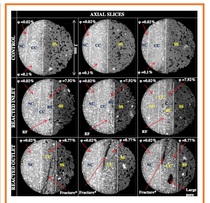

Fig 2. Effect of drilling fluid on the properties of cement by increasing the porosity and generating weaker zone.

- 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

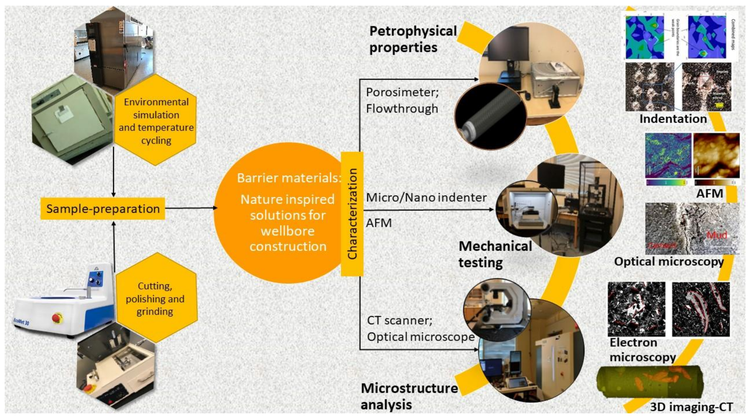

Fig 5: Schematic of the research methodology and analysis techniques used

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

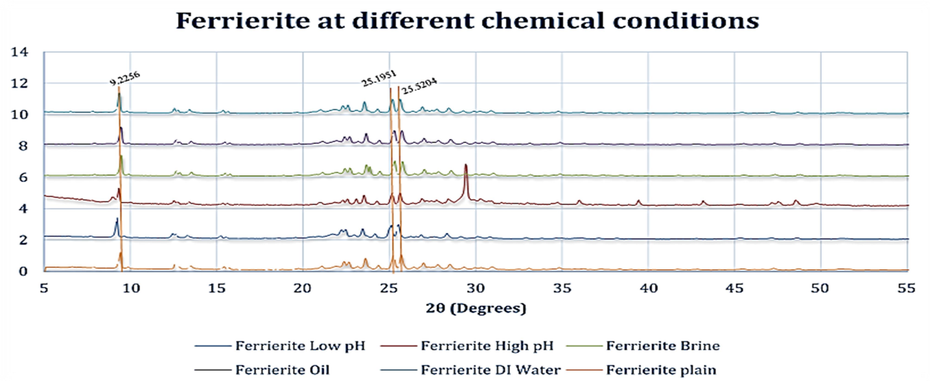

Fig 6: XRD data of ferrierite powder after exposure to various chemical conditions compared with the control sample. Standard ferrierite peaks are highlighted

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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References

- Agbasimalo N, Radonjic M. Experimental Study of the Impact of Drilling Fluid Contamination on the Integrity of Cement-Formation Interface. ASME. International Conference on Offshore Mechanics and Arctic Engineering, Volume 6: Materials Technology; Polar and Arctic Sciences and Technology; Petroleum Technology Symposium ():879-885. Doi:10.1115/OMAE2012-84237.
- Christian, W. W., Chatterji, J., & Ostroot, G. W. (1976, November 1). Gas Leakage in Primary Cementing - A Field Study and Laboratory Investigation. SPE. doi:10.2118/5517-PA