

## The Long-Term Evolution of the Corrosion Products formed on Carbon Steel in Simulated Groundwater Solutions as Applied to the Design of Canadian Spent Nuclear Fuel Waste Containers



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It has been proposed that Canada's spent nuclear fuel waste be disposed of 500 m deep in either granitic rock or sedimentary clay deposits. Within the multi-barrier containment system, fuel wastes would be sealed in a metallic container consisting of a carbon steel vessel with or without an outer copper corrosion barrier. If container failure occurs, the surrounding groundwaters will come into contact with the fuel leading to its corrosion and the release of radionuclides. Our project is focused on the long-term evolution of the corrosion of carbon steel under anoxic groundwater conditions and investigates the effects of the moderate to extreme salinity expected at repository depths. A combination of Raman spectroscopy and SEM imaging of the surfaces and on and FIB cross-sections are being used to track the evolution of the corrosion product film over extended periods of time in solutions containing  $\text{Cl}^-$  at concentrations from 0.10 M to 4.77 M.

Steel coupons exposed to  $[\text{Cl}^-]=4.77$  M were shown to develop a  $\text{Fe}_3\text{O}_4$  corrosion film more rapidly than those exposed to  $[\text{Cl}^-]=0.10$  M. This can be observed in the FIB cross-sections where the sample exposed to  $[\text{Cl}^-]=0.10$  M shows a very thin film across the general surface (Fig. a-c) while the sample exposed to  $[\text{Cl}^-]=4.77$  M shows a film on the order of 3  $\mu\text{m}$  thick (Fig. e-f). However, the damage experienced in the  $[\text{Cl}^-]=4.77$  M exposure appears to be more uniform while the sample exposed to  $[\text{Cl}^-]=0.10$  M shows locations in which damage has penetrated into the base metal in the form of either pits (Fig. b) or along single tracks associated with grain boundaries (Fig. d). Clearly the salinity has a significant influence on damage distribution. The bright lamellar structures seen within the oxide film for the sample exposed to  $[\text{Cl}^-]=4.77$  M (Fig. f) were analysed using EDX mapping (Fig. g) which highlights the locations of elemental iron (blue) and carbon (green). The coincidence of both the iron and carbon signals with these bright locations shows the cementite ( $\text{Fe}_3\text{C}$ ) structure of the pearlite grains has been left behind after the preferential conversion of the  $\alpha$ -Fe within the grain structure to  $\text{Fe}_3\text{O}_4$ . This would suggest a galvanic coupling between the  $\alpha$ -Fe and  $\text{Fe}_3\text{C}$  of the pearlite grains.

