A New Technique for Building *In Situ* Sub-Surface Hydrologic Barriers: NBT

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Abstract

Research currently being undertaken through ANSTO, the Australian Nuclear Science and Technology Organization, and consultant Earth Systems is the development of a new technique for building in-situ sub-surface hydrologic barriers called Neutral Barrier Technology or NBT. NBT aims to control fluid flow in a wide variety of permeable rock or unconsolidated sediments. NBT enables the *in situ* formation of sub-surface containment structures or barriers to impede the migration of specific water flows (polluted or otherwise) into the wider environment. The technique involves selectively sealing microscopic inter-pore channels that permit the passage of water through soil, sand, and porous rock with mineral carbonates such as calcite. Applications envisaged for the mining industry include:

- as guides to reactive barriers,
- for the construction or enhancement of water or gas exclusion covers for waste dumps,
- as groundwater intercept barriers,
- restricting inflow of water into mine workings, and
- plugging leaks in tailings dams or other water impoundments.

Unlike existing technologies, Neutral Barriers can be installed in sub-surface settings with no earthworks and negligible disruption.

Introduction

Bench-top experiments over the last three years have created numerous barriers with a broad variety of geometries, and clarified barrier construction techniques. Some configurations have demonstrated up to a 1,000-fold reduction in hydraulic conductivity across a barrier. Under particular conditions only the throats of the pore spaces are filled with carbonate mineral precipitates, which dramatically reduces reagent consumption and therefore the cost of each square meter of barrier. This means that combined with the ability of the technique to naturally seek out the most permeable zones, large areas of barrier can be constructed with minimal reagent consumption. Some major advantages of the NBT compared to existing containment technologies are likely to be:

- the relatively low cost of barrier formation,
- the potential for constructing barriers at far greater depths without any excavation, and
- the self-seeking characteristic of barrier formation means that detailed definition of the permeable zone or leak is not required.

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Analogue
There are natural examples of highly effective "Neutral Barriers". Reservoirs of liquid hydrocarbons trapped in the pore spaces of geologic formations need to be pierced by drillholes to release the oil because natural capping formations prevent its migration. In many situations, these cap rocks are comprised of highly porous sandstones that have been naturally cemented by interstitial calcite minerals generated by the interaction between carbon dioxide rich gases evolved from the hydrocarbons, and calcium-rich groundwater. The commercial development of NBT is an attempt to harness the successful aspects of these natural systems for a variety of environmental applications.

Applications
Potential applications of this new technique are numerous, and all carry the possibility of environmental benefit. From mundane problems such as sealing leaks in dams and minimizing the impact of groundwater and surface water on building foundations, to more exotic issues such as containing groundwater pollution plumes, controlling coal-bed gas emissions and fighting underground coal seam fires, NBT appears to have a range of potential applications.

There are predicted to be numerous NBT applications in the field of waste containment. Solid and liquid wastes in municipal, industrial and hazardous landfills could be isolated from groundwater or surface water interaction with limestone pore-filling barriers that can be retrospectively and essentially non-invasively installed at most sites. This approach has particular application to old landfill sites, which were not fitted with state-of-the-art lining techniques, which are in common use today.

NBT offers the potential to control fluid flow in aquifers. Appropriately located barriers could prevent local interaction between surface and groundwater, or isolate two different types of groundwater (eg. fresh and saline). NBT offers the possibility of manipulating groundwater levels to assist agricultural practices or minimize pollution in near surface settings caused by an altered water table (eg. acid sulphate soils).

Other contaminated sites containing wastes or polluted water could benefit from this approach. Minimizing the formation of contaminated leachate by reducing rainwater infiltration, or preventing the release of pollution into aquifers by sealing off migration pathways could be achieved by sub-surface Neutral Barrier formation.

Neutral Barrier Characteristics
The technique involves selectively sealing the microscopic pathways that permit the passage of water through soil, sand, and porous rock with mineral carbonates such as calcite. By manipulating the interaction between two of the lowest cost chemicals available, lime and carbon dioxide, calcite can be induced to precipitate in the pore spaces. Under particular conditions only the throats of the pores are filled with calcite to lower the permeability, thereby promising low application costs. Lime is injected as a saturated solution into appropriate porous rocks and soils, and the carbon dioxide as a gas. Minute quantities of calcite (Figure 1), strategically located in small voids within various geologic materials, has the capacity to block and redirect water flow.

Comparison with other Sub-Surface Barrier Technologies

Compared to techniques that have already been developed, many would regard this method as a microscopic grouting technique. There are, however, few similarities with conventional grouting systems. Grouting techniques fill all of the available pore space using concrete, bentonite slurries, or polymers, which leads to relatively high reagent costs per square metre of constructed barrier. Grouts also suffer from an inability to flow very far from the injection site, and then require another close spaced overlapping injection well to pump in new material. NBT relies on the manipulation of a reagent-mixing zone, causing calcite precipitation away from the injection site. Primarily, NBT is predicted to be far more cost effective, flexible and more broadly applicable. Furthermore, the effects of traditional grouting techniques cannot be readily reversed, unlike microscopic calcite barriers, which should be able to be removed by increasing carbon dioxide gas pressures.

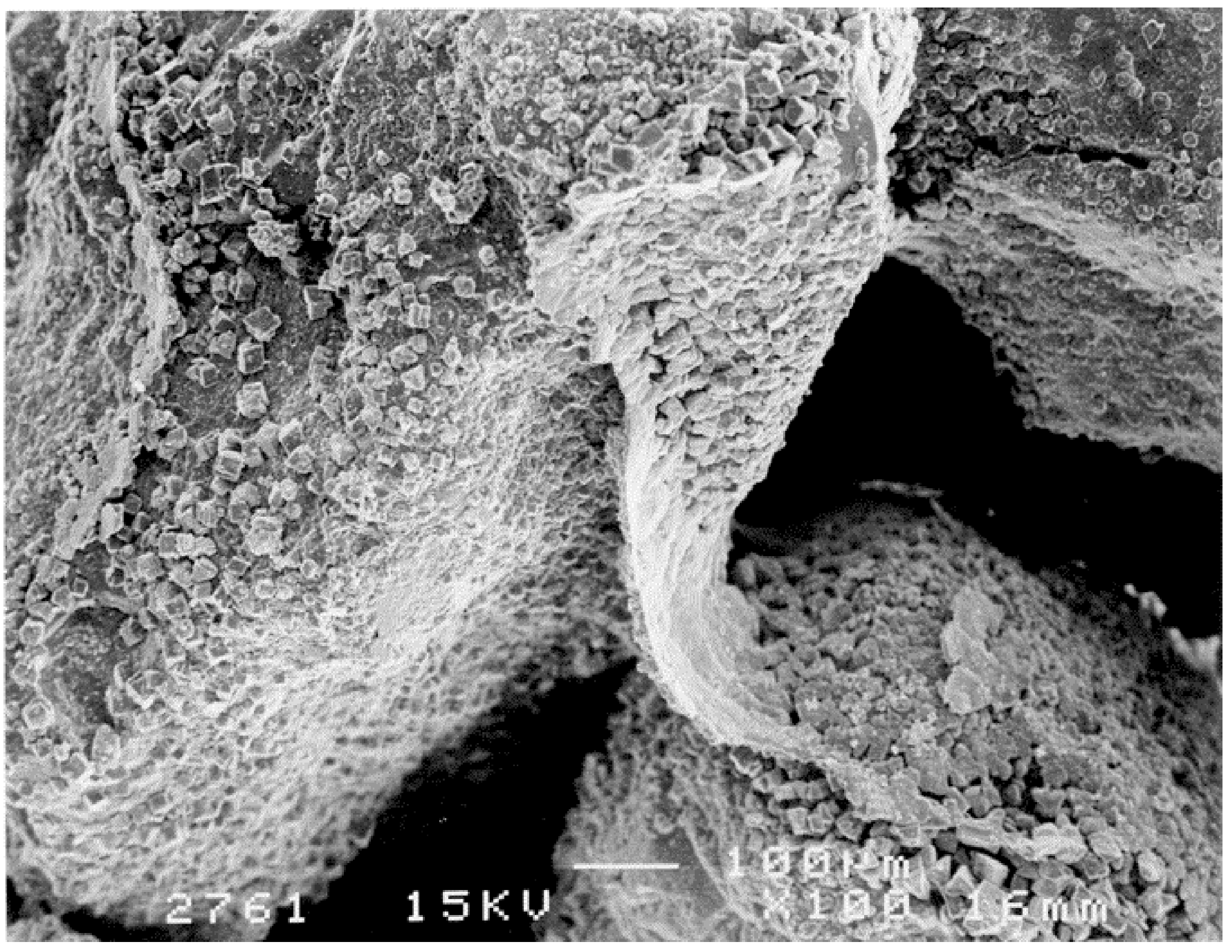

Figure 1 A Neutral Barrier: image from a Scanning Electron Microscope showing calcite layers over the surface of grains of quartz in unconsolidated sand. The calcite has formed continuous layers between adjacent sand grains, which lowers permeability without the need for complete pore filling.