

# The usefulness of a 320-row CT scanner in the oil industry

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Alberta Innovates-Technology Futures (Tech Futures) is part of an integrated provincial system that works to further research and innovation in Alberta, Canada. The priority of the corporation is to accelerate the development and growth of new and existing industries in agriculture, forestry, energy, environment, and health. To help meet research needs in Alberta, Reservoir and Geosciences at Tech Futures acquired an Aquilion ONE™ CT scanner.

As a world leader in energy technology and innovation, Reservoir and Geosciences works with companies to enhance the recovery of unconventional oil. The goal is to help oil producers engage in sustainable development of Alberta's resources through technologies that reduce costs, improve recovery, and decrease environmental impact. Research in this area is facilitated by the Aquilion ONE, which was purchased primarily as support for applied R&D in petroleum recovery and advanced materials. This article describes the use of CT with Aquilion ONE for research at Tech Futures.

## Computed Tomography at Tech Futures

Through computed tomography, non-destructive examination of internal structure is accomplished and high-resolution 3D images of items like geological core samples and sand packs are created. A wide variety of reconstruction algorithms and post-processing options are used at Tech Futures to suit the material being scanned and the imaging needs of the customer. Accurate extraction of quantitative information from advanced image processing, along with 2D and 3D reconstructions, is often paramount. Quantitative information is delivered to clients by way of customized calibrations for each object or experiment scanned. Targeted noise-reduction techniques provide methods to acquire the best resolution possible. Specifically, this involves repeat scans and averaging data whenever possible to reduce noise. Further discrimination of materials can be done through dual energy scanning, which exploits subtle differences in attenuation spectra.

Tech Futures' current strategy is to design CT experiments conducive to the energy level and geometry of the Aquilion ONE. Low-attenuation vessels and materials suitable for X-ray use are considered in the experimental design stage. The speed of the scanner, for both the acquisition



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and reconstruction of data, makes it possible to track processes that change on a scale of minutes. This is invaluable for fluid flow experiments in cores and sand packs.

Efforts are also made to carefully register experiments when repeat scans are taken in order to successfully subtract images and uncover small changes in density. Orbital sync has been a useful tool in securing registration. This function ensures that the source and detector are located in precisely the same starting position for each repeat scan allowing the images to be either subtracted for discrimination of tiny density changes or averaged for noise reduction.

Radiation dose reduction is not critical to scans carried out at Tech Futures since subjects are not living. In fact, objects or experiments are scanned repeatedly at the highest available settings in order to extract the best quantitative information. Often, protocols are designed so objects are scanned in short lengths, with multiple volumes necessary to cover the desired length. This technique permits the highest allowable dose to penetrate objects much denser than the human body.



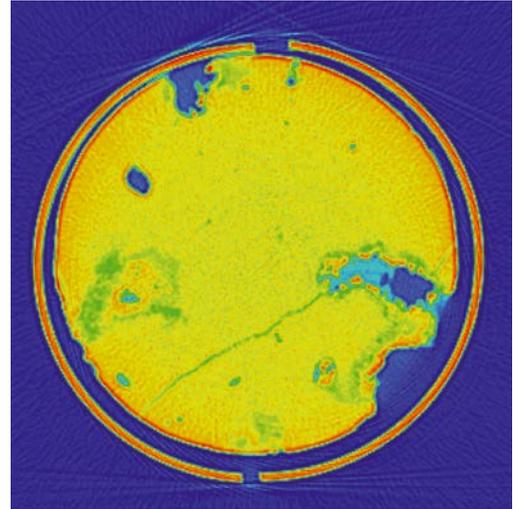
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*Oil Recovery from Rock: Digital Rocks*

One application for advanced imaging with Tech Futures' scanner is digital rocks, which is an emerging concept in characterizing reservoirs by obtaining physical properties directly from images of rocks. The technology combines CT at different scales (mm to micron resolution) with X-ray and scanning-electron microscopy (SEM) to create images of the internal structure of the pore spaces as well as minerals and organic matter within them. Such data can be very useful in studying pore architecture and physics of the processes happening during enhanced oil recovery (EOR). It is especially important for unconventional resources like shale, carbonate, tight gas, and coal seam gas. One of the most interesting aspects at this time is characterizing bitumen-bearing carbonates, especially fracture characterization.

Figure 2: Axial image of Alberta Carbonate Core

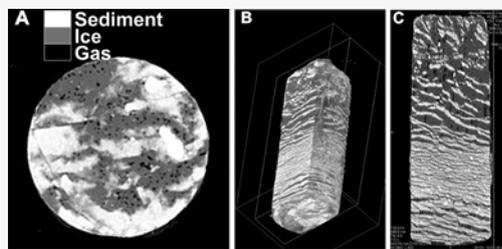


Digital rocks enables Tech Futures to engage in a unique up-scaling effort of merging micro and macro imaging to observe a wide range of fluids, conditions, and detailed behaviour in EOR processes. The advantage of the technique is the considerable cost savings over securing individual laboratory analysis for each desired property. The procedure involves first obtaining full core mm-scale resolution scans with the Aquilion ONE scanner to identify sites representative of a range of image properties. This is followed by micro CT scans (approximately 10 micron resolution), available from various outsourced

labs, which are suitable for sand packs or other very small samples. Imaging with sufficient resolution to resolve individual pores in a sand pack or a core is inevitably restricted to a very small volume. Simulation software is used to upscale the results of pore scale multi-phase flow simulations to obtain flow properties at each site and look for correlations between flow properties and image properties. Properties are then mapped back onto the macro CT scan using the correlations and core scale flow simulations are performed with the results to make predictions for recovery from the oil reservoir.

**Aquilion ONE assists in measuring PERMAFROST**

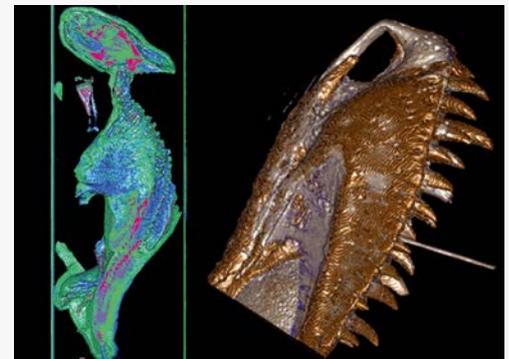
Water is trapped as ice in the permafrost of the world's arctic regions. If the Earth is warming, the amount of water in the permafrost should decrease as the ice melts. How can we measure the ice in permafrost? The Aquilion ONE at Alberta Innovates - Technology Futures, is doing just such measurements. Permafrost cores are scanned and 3D volume rendered images are produced depicting ice and sediment. Quantitative measurements can also be made to determine the percentage of ice in each core. By imaging cores from the same region over many years, the change in the amount of ice can be measured.



Three images from CT data. (A) Axial slice; (B) 3D reconstruction; (C) Longitudinal slice. Soil is white, ice is gray and gas is black. Calmels, F., Froese D.G., and Clavano, W. Cryostratigraphic record of permafrost degradation and recovery following historic (1898-1992) surface disturbances in the Klondike region, central Yukon Territory. Can. J. Earth Sci. 49: 938-952

**225 to 65 million years in the making**

Dinosaurs first appeared 225 million years ago and died out 65 million years ago. Today most dinosaur fossils are found by doing fieldwork, but also during excavations for tunnels, buildings and drilling for oil wells. The Aquilion ONE at AlbertaInnovates-TechnologyFuturescansthese fossils to provide detailed information to paleontologists on the structures of the animals. Below are two examples of dinosaur fossils scanned with Aquilion ONE.



3D Image of a Juvenile Snout (Antorbital Region) of a Tyrannosaurus Ceratopsian

*Specimens are from the collections of the University of Alberta, Laboratory of Vertebrate Paleontology*

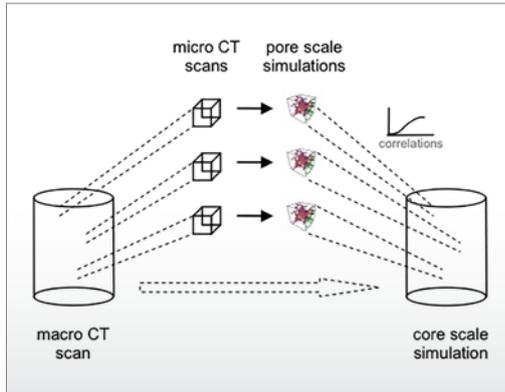


Figure 3: Merging macro and micro scanning to observe a range of conditions to determine the behaviour of enhanced oil recovery.

### Oil Recovery from Sand: Imaging Sand Packs

Other Reservoir and Geosciences applications of the Tech Futures scanner include calculating porosities and saturations in sand packs, tracking solute in sand packs, testing solute uptake in oil, studying turbulent flow in water as well as laminar flow in oil, monitoring sand failure or production, and investigating the waterflood process used in oil recovery at the scale of sand grain pores.

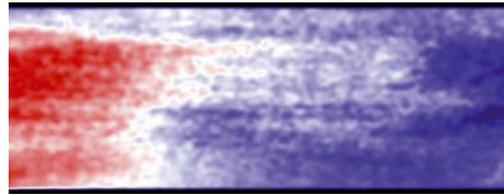


Figure 4: A sagittal section through a waterflood experiment in a cylindrical sand pack. Flow is from left to right. Blue indicates "unswept" regions with oil saturations of about 90%. Red indicates where water has displaced about 25% of the oil. This "synthetic radiograph" was obtained by averaging a number of sagittal slices near the axis of a cylindrical pack, to reduce noise and improve the spatial resolution.

### Conclusion

The use of CT to image and quantify materials greatly assists scientists in determining potential sites for commercial oil extraction in unconventional materials such as carbonates and oil sands. This is a very interesting and different application of CT from its usual medical uses.

## Local Service seals the deal



### Core experiments on the Aquilion ONE

Research is facilitated by the Aquilion ONE, which was purchased in 2013, primarily as support for applied R&D in petroleum recovery and advanced materials. This CT system was an upgrade to an Aquilion 64, which had been installed in the Edmonton facility in 2007.

The decision to purchase the original Aquilion 64 in 2007 was based partly on its ability to monitor dynamic processes. Another deciding factor was the presence of a local service base, which enables Tech Futures to obtain same-day service calls to address instrument problems. While the energy range of the

medical scanner is lower than that of the industrial CT scanner Reservoir and Geosciences used previously, the trade-off of higher energies and longer scan times for greater speed and local service was deemed favourable.

The speed of the scanner, for both the acquisition and reconstruction of data, makes it possible to track processes that change on a scale of minutes. This is invaluable to fluid flow experiments in cores and sand packs. The wide area coverage allows cores to be scanned in fewer sections and enhances the measurements of dynamic processes.



### Flow Experiments on the Aquilion 64