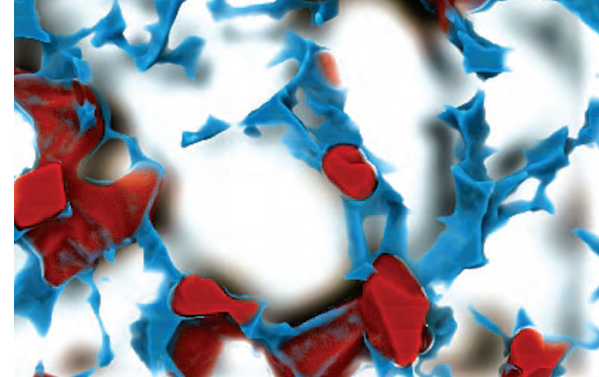
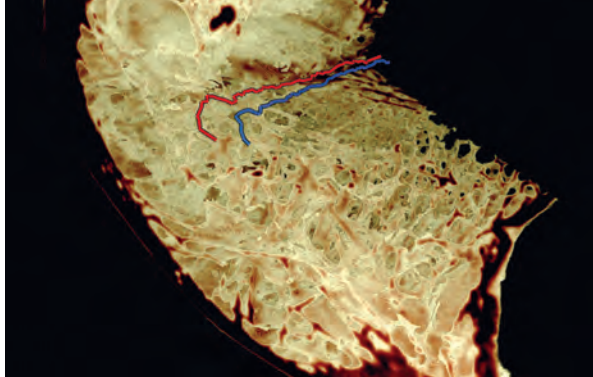


# DETECTING HIDDEN STRENGTHS AND WEAKNESSES

SEEING INSIDE MATERIALS AT A RANGE OF SCALES REVEALS NEW WONDERS AND OPPORTUNITIES

It is the exquisite structure of human bone, down to the smallest scale, that lends it its exceptional strength—or reveals its secret frailties. How strong or weak a material may be, how porous or impermeable, are now coming to light for the first time through the art of three-dimensional X-ray computer tomography (CT).



At the Australian National University Applied Mathematics Department a world-leading facility is using the NCI supercomputer to probe the hitherto-unseen heart of materials at scales ranging from centimetres to nanometres, teasing out their secret strengths, weaknesses, flaws and capabilities. From osteoporitic bone and novel medical implants to rock strata harbouring oil or saline groundwater, from novel packaging to the super-light, super-strong industrial materials of tomorrow, the ability to 'see' inside substances has become a critical tool.

"Looking inside things at these scales is fascinating," says Professor Mark Knackstedt who heads the ANU's Digital Materials group. "You start to appreciate that strength or flexibility depends not just on structure at one level, but across a whole hierarchy of scales down to the very smallest. You gain a whole new insight into why things behave the way they do—and also to appreciate why they fail."

He instances bone density, long regarded as a major risk factor for people suffering osteoporosis. However bone density alone as a measure can mislead: a bone may look dense and be strong in one plane, yet weak in another—one of the reasons patients sustain unexpected fractures from sideways falls. By exploring the structure of bone in three dimensions and across a range of scales, a much clearer picture emerges of what it can withstand and what may cause failure: future injuries may be predicted—and avoided.

Similarly with advanced medical implants: these devices, now made of polymers or ceramics, have to have both the structural integrity to support skin, bone, body mass, muscle or organ but also the porosity that enables the patient's own cells to naturally colonise them, fusing the implant into the body itself. To design the elegant scaffolding required for this to occur requires a deep insight into structure and understanding of their mechanical and transport properties.

As the world approaches 'peak oil'—forecast by the International Energy Agency to occur within ten years—insight into the microscopic fracturing of rock strata that harbour the elusive substance is essential to tracking down accessible reserves. Here too, CT is lending a hand in the search by delineating the essential oil-storing qualities of the rock in three dimensions and at a range of scales, Mark says. In another application the ability to safely store CO<sub>2</sub> underground requires understanding of the pore structure in rocks.

"The same applies to salinity and to groundwater—another precious resource which is in increasingly scarce supply. Understanding how salt and contaminants migrate through soils is crucial to protecting groundwater quality. It can also help us to predict and head off the emergence of dry-land salinity."

3D CT prospects the cutting edge of futuristic materials design: for these to perform optimally, their designers must have fingertip control over their internal microstructure. "While the engineering potential of advanced materials is considerable," Mark says, "our ability to optimise structures is sometimes a bit hit-or-miss, since there is rarely a good grasp of local structure in these materials. By imaging and understanding the microstructure of advanced foamed materials, tissue engineered constructs, controlled release substances and biocomposites tailored to specific end-uses, we can accelerate and enhance their development."

Envisioning such structures in three dimensions, and integrating the knowledge across hierarchies of scales, devours vast amounts of computational power and it is no accident the Digital Materials facility is located close to the NCI National Facility, linked by vast data pipes, Mark says. A single 3D image may contain 8 billion voxels (cubic pixels)—producing exceptional clarity, but also many gigabytes of data. The computer code alone used in the project runs to 400,000 lines.

"A typical CT dataset may consist of tens of gigabytes. To date we have collected 2000 datasets involved in this project and this will eventually add up to around 100 terabytes (trillion bytes) of information. As we are now completing duplicate scanning facilities, this pace will quicken. You simply couldn't store or process that on any other computer in Australia," Mark says.

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