CSEM's
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Probing Earth's deep structure

Dr Nick Rawlinson has been setting up seismic arrays all over south east Australia for many years now. Each array picks up vibrations, seismic waves, travelling through the planet from distant earthquakes. The signal detected by each sensor is compared with the signals picked up by the other sensors in the array, and the resulting data set is then mathematically transformed to yield a picture of the planet below.


A seismic station caught in a bush fire in Tasmania.

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THE AUSTRALIAN NATIONAL UNIVERSITY

Imagine living in the middle of outback Australia and a person comes up to your front door unannounced and says he'd like to place a box in your backyard to measure earthquakes in Japan. You'd probably be wondering if this guy has been in the sun too long. And yet this is a task that Dr Nick Rawlinson has performed many times in recent years and he's never been knocked back.

"In the process of gaining permission to set up seismic recording stations on private land I must have knocked on 300 doors," says Dr Rawlinson. "Most people we meet are only too happy to let us onto their land once we've explained our purpose. Some are initially suspicious - one lady even answered the door with a knife in her hand. But they all come around when we explain we're monitoring earthquakes. Actually, I don't immediately tell them the main earthquakes we're monitoring are from distant countries like Japan and Taiwan, and they're probably thinking we're working on local earthquakes."

Deep science

Indeed, most people think seismology is just the study of earthquakes, whereas in truth it is a much broader subject, and includes using the energy of earthquakes to probe the deep structure of the earth below – down hundreds of kilometres. There are other ways of looking at deep structure including gravity- and magnetic-mapping but these technologies are best for looking at shallow structures in the top ten kilometres or so. Seismic imaging is the premier technique when it comes to probing the deep earth.

Dr Rawlinson is a seismologist based in the Research School of Earth Sciences, Australia's leading institution when it comes to the seismic monitoring of our region's deep geology. For most of the last ten years he's been deploying seismic arrays across south east Australia in order to better understand what lies underneath.

"We're currently establishing an array of 36 seismometers around south western NSW," says Dr Rawlinson. "They'll be positioned across the Hay Plains and beyond.

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Travelling all over the countryside. Dr Nick Rawlinson sets up another seismic recorder.

Probing Earth's deep structrure

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Each station is about 40 to 50 km apart, and they're going to sit out there for around seven months.

"These stations will record the seismic waves from large earthquakes occurring at the margins of distant tectonic plates in places like Japan, Taiwan, Fiji and New Guinea. Large earthquakes from these regions dissipate huge amounts of energy in the form of seismic waves which can be easily detected by our seismic stations.

"The idea is that you use these big distant earthquakes to illuminate the structure underneath the array," explains Dr Rawlinson. "It's similar to going to the hospital and having a CAT scan where you have all these X-rays going through your body at different angles.

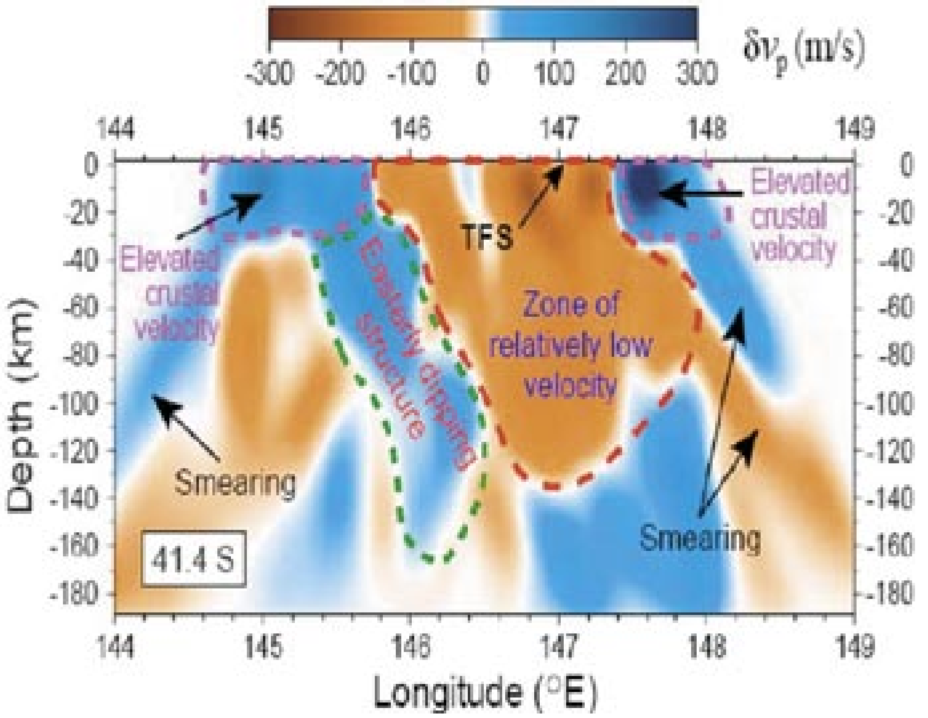
"In seismology we use a lot of seismic recorders spread out in an array. Energy from big distant earthquakes penetrates quite deeply into the planet and comes up underneath the array. As these seismic waves approach the surface, their paths cross in many directions, which is similar to the X-rays going through the body, and we can use that to image the variations in structure beneath the array."

Seismic imaging

The basic relationship used to extract structural information from the seismic data is that the travel time of seismic energy from an earthquake to a receiver is a function of the speed at which the wave travels. Seismic wave speeds vary principally with depth in the Earth, but more subtle lateral changes caused by structures such as subduction zones also influence the travel time of seismic waves.

Dr Rawlinson's group use a seismic imaging technique known as teleseismic traveltime tomography to produce three dimensional maps of seismic wavespeed variation in the Earth using information from many earthquakes recorded by the multiple stations which comprise an array.

"We exploit travel-time information carried by many crisscrossing seismic waves that travel from a large number of earthquakes to many receivers located on the surface," says Dr Rawlinson. "This allows us to build up three-dimensional images of seismic wavespeed variation in the Earth."



An example of a tomographic image produced by a seismic array in northern Tasmania in 2002. It shows an East-West cross-section through northern Tasmania. The "smearing" labels point to those parts of the model which are not well resolved by the seismic dataset. TFS stands for Tamar Fracture System, which turns out to be a near-surface rather than crustal scale feature.

An example of a tomographic image from a seismic array set up in northern Tasmania in 2002 is pictured in the upper right of this page. Blue colours indicate where seismic wavespeeds are higher than normal; brown areas indicate where seismic wavespeeds are lower than normal. Shallow regions of elevated wavespeed (or "velocity") may reflect those parts of the crust which have an oceanic crustal origin. The easterly dipping structure may represent remnants of a past subduction zone which formed over 500 million years ago.

What's in the box

The seismic sensor itself is a small device (about the size of a soft drink can) which is buried about 40 cm beneath the surface. This detects the ground motion caused by an earthquake. That information is conveyed to the recorder box, via a connecting cable, as variations in voltage.

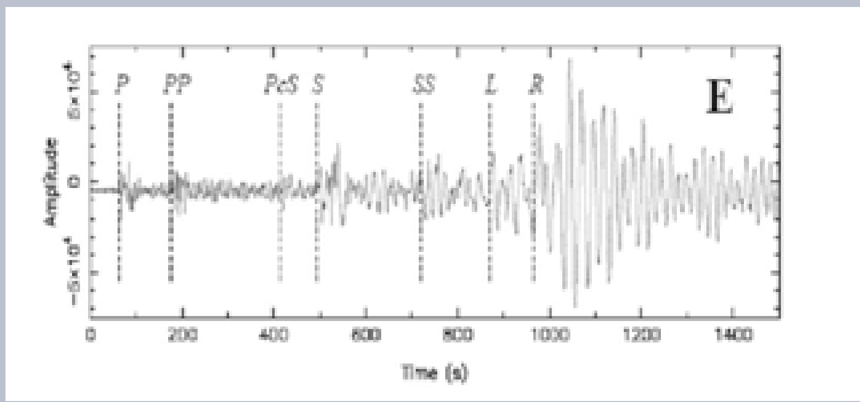
The recorder box contains an analogue-to-digital converter which turns the incoming signal into a binary format which is then recorded onto a compact flash card (exactly the same as used by many digital cameras). In order to use the data the seismologists need to know exactly when the seismic energy from an earthquake arrives at one sensor relative to the signal being picked up at other stations. This requires accurate timing information to within several milliseconds. The internal clock in the recorder unit tends to drift by several milliseconds an hour, which means that it loses accuracy over time. To remedy this, a GPS antenna is placed in each box which gets very accurate timing information from orbiting satellites, and allows the recording stations to regularly correct the internal clock.

Each recorder unit is powered by six 6-volt lantern batteries which last for several months. All up each recorder uses about 80 milli watts of power.

Dr Rawlinson tests the recorder boxes before heading out into the field.

Anatomy of a seismic wave

Pictured below is the typical seismic trace from a large distant earthquake. The smaller amplitude, higher frequency waves near the beginning of the trace represent body wave arrivals, which travel through the volume of the Earth before returning to the surface. There are two types of body waves: P (which arrive first) and S (which arrive later). P waves are compressional waves (similar to acoustic waves in the atmosphere) while S waves are shear waves. S-waves cannot propagate through a fluid, and hence cannot travel through the outer core of the Earth, which is liquid iron. The later arriving, large amplitude waves labelled L and R, are surface waves, which travel along the surface of the Earth. It is this type of wave which causes most of the destruction in a large earthquake.



From images such as this seismologists are able to make inferences about the structural (eg, is there a dipping subduction slab present or not), compositional (eg, is the material granite or sediment) and physical (eg, is the rock hotter than normal or not) properties of the Earth.

Under south east Australia

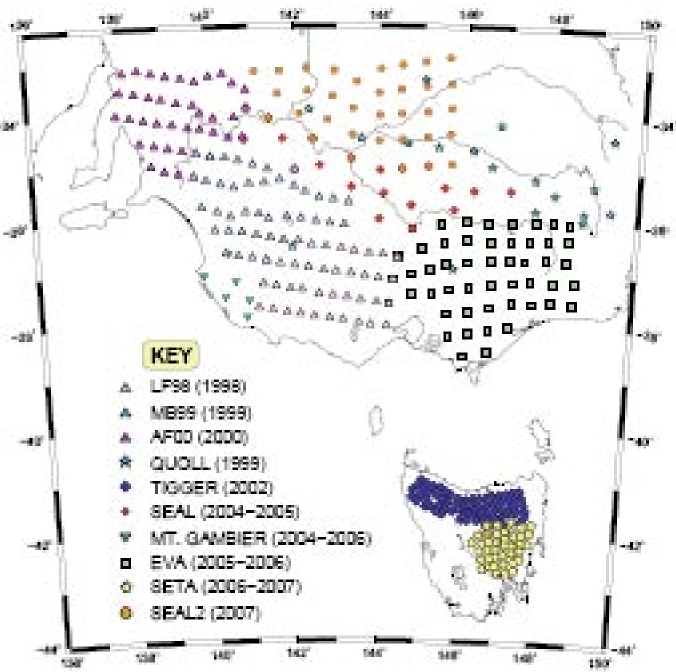
The recording stations that Dr Rawlinson and colleagues set up consist of a seismometer, buried about half a metre in the ground, and a recording box (see the box: What's in the box). Arrays of these instruments often cover an area of ten thousand square kilometres or more and have been set up across south east Australia to determine the deep structure that lies under our continent.

"These arrays have been part of a very systematic approach undertaken by RSES to mapping under Australia," explains Dr Rawlinson. "The lithosphere in this part of Australia goes down some 100 km."

The lithosphere is the rigid part of the plate that moves across the mantle underneath. It's the crust plus the uppermost mantle. (The lithosphere is a mechanical definition as opposed to a compositional one.)

"While we believe that much of south east Australia was created by subduction accretion, the process of one tectonic plate colliding with and descending beneath another plate, there are still many unanswered questions about the deeper structure of south east Australia," says Dr Rawlinson. "Our work sheds light on this. It's fundamental research that's explaining how this region has evolved over time.

"A problem with understanding the structure of the older parts of eastern Australia is that a lot of it is covered by younger sediments or volcanics, particularly in Western Victoria. It's very hard to see older rocks under the younger rocks. Seismic imaging can help us because it can look below this shallow surface material to the building blocks of the lithosphere beneath."



The locations of various seismic arrays that Dr Rawlinson has helped establish over the past decade.

Setting up an array

"The rough location of each station in an array is determined in advance of the field trip," says Dr Rawlinson."I then consult the maps and try to place specific sites close to roads or tracks so we don't have to walk far carrying heavy equipment.

"When we actually get onto a private property we then make a decision as to the best position to place the recorder. We have to be careful with cattle and sheep. Cattle will often destroy a recorder. Sheep you can normally keep at bay by surrounding the recorder with fallen timber. You also have to keep out of crop fields. So, that normally restricts us to fence lines and sidings.

"Sometimes we're working in very rough terrain like in eastern Victoria and it's difficult finding your way to the area you need to reach. Other problems include the risk of bushfires sweeping through an area and taking out equipment."

"It can be extremely hot work and even though the sensor only has to be buried 40cm down, sometimes the ground is as hard as concrete and you need a crow bar to break through.

"While establishing these arrays can be a very laborious task, it's also one of the interesting aspects of this work – you meet different people in parts of Australia that most Australian's never get to see.

"And the data yielded by these arrays allows us to probe the very base of our continent."

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Reworking an ancient craft

The Gold and Silversmithing Workshop

Gold and silversmithing are ancient crafts based on working with gold and silver to produce items of jewelry and objects of art. However, according to Johannes Kuhnen, Head of the Gold and Silversmithing Workshop at the ANU School of Art, the modern practice of silversmithing requires a working knowledge of a dazzling array of other materials – metals and non-metals. He believes the Gold and Silversmithing Workshop is ideally suited to prepare aspiring silversmiths to work with this diversity of materials and that materials research has an important role to play in this rapidly evolving practice.

"We're quite different from the other workshops because of the diversity of materials that we work with," says Mr Kuhnen. "Traditionally gold and silversmithing was working with a bit of base metal: gold, silver, occasionally platinum and a gemstone or two. But that's all gone – those materials are too expensive, they're not available so we can't actually train them.

"The contemporary jewelry movement has introduced from the 1960s onwards such a vast array of new materials into this practice that we're usually struggling to keep up with them. Now we're using titanium alloys, aluminium alloys, nickel alloys, steel, you name it. Okay, some say all metals are the same but the joining and fabrication techniques for each are vastly different.

"And that's just the metals. We're also using plastics and a wide range of natural products to complement things, so we're suddenly dealing with different substances and different processes and often very different working properties.

"Students are also now looking at electronic compounds incorporating sound and light into wearable objects or table wear. So, for example, the latest generation of LEDs are also commonly being used in this workshop.

"Because of this diversity of materials you need to change your working practices. Traditionally you'd simply be using a saw, a couple of bars, and a few forms to work on. These days, however, you need to understand and use a much wider range of techniques and tools. We're using many more machine tools, for example. We're also seeing influences from different cultural zones, for example, the Japanese copper alloys which combine copper, silver and gold in their traditional alloys to get specific colours.

"Because there's always something new to work with I'm forever encouraging our students to experiment. That is exactly why I think students should be looking at general science and technology areas so they can compare what's about, and see what's new. A scientist might develop a new material or substance for a very different purpose, but it might have some useful additional qualities that can be used in our area."

Johannes Kuhnen with a lidded container by Robert Foster 1984 (made with anodised aluminium and polyester resin). It was the first work to be anodised in the Canberra workshop.

The Gold and Silversmith Workshop - gold and silver is just where it begins.

Johannes Kuhnen is internationally renowned for his work with anodised aluminium in jewellery and hollow ware. And, just as he encourages his students to do, he developed his knowledge of the anodising technique himself.

"In the mid 70s I was one of the first people who used anodised aluminium. I did the anodising myself in a small studio in Germany to introduce a different range of colours in jewelry," he explains. "I had several motives for this. At that time the gold price had gone up sky high, and I had the belief that jewelry should be available to the masses. Making anodised aluminium was a way of being viable because my friends couldn't afford big diamonds and gold.

"And it has really taken off since I've come to Australia in the early 80s. And when I was appointed here at the Workshop at the end of 1984 one of the first things I did was set up an anodising facility, which is still a distinguishing feature for the workshop. Not many workshops have them."

The Gold and Silversmithing Workshop distinguishes itself in a number of other areas, too. It's the first Australian art and design school studio to house a rapid prototyping facility. Based on the fused deposition process, the facility allows the development of large prototypes, forming tools and master patterns.

In addition to this, the Workshop has facilities for most metalworking techniques including hot and cold forming, the machining of metals and plastics as well as advanced welding facilities. Finishing techniques such as polishing, bead blasting and electroplating are also provided for.

Each student is allocated an individual work space and is expected to be fully involved in Workshop activities such as equipment and tool maintenance. The small student numbers in Gold and Silversmithing ensures a highly effective and intense working environment. As with the other workshops at the School of Arts, students are selected on a port folio presentation and judged on their experience.

More info: http://www.anu.edu.au/ITA/CSA/gold&silver/index.html

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Students at work practising a Korean Inlay technique.

Multi-point annealing

at The Glass Workshop

In December 2006 The Glass Workshop in the School of Arts received from ANU a Major Equipment Grant for $130,000 to build a next generation of glass facility. The facility, currently under construction, will comprise a sets of large kilns that will be configured for multi point annealing, a new hot glass furnace (designed by renowned designer Fred Metz), pot furnace and pick up kilns.

"The research we hope to undertake in this new facility aims to provide practical information on multi-point annealing for artists working in glass," says Richard Whiteley, Head of the Glass Workshop. "The facility also aims to allow students in Canberra to push the limits of the material and develop new creative works in glass.

"We're proposing to build a set of four large-scale kilns featuring the facility of multi-point annealing support and zone temperature control so that heat of individual kiln chambers can be controlled separately as required.

"A better understanding of thermal dynamics within kilns will give researchers real information as opposed to the blunt instrument of single point annealing. Through the sensitivity of equipment, these kilns will allow senior students and staff the ability to cross over between forming processes with much more certainty and success.

"To assist in the project Professor David Ellis from the Department of Earth and Marine Sciences has been offering advice and support with approaches to setting up the technical side of the research. The Glass department at the Monash University will also send staff and students to Canberra to assist in exploring new works.

"We have established an excellent reputation for our artistic outcomes. Additionally, many of our senior students have a strong technical research component as part of their practice. We have identified this as an area that needs more collective research to assist the whole sector move forward."

The facility will be built in stages with most of the facility up and running by July 2007.

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Richard Whiteley holds up a transparent glass book, an artwork by Workshop student Sue Kesteven. The book is made by fusing together several glass elements and poses many challenges when it comes to annealing. The new multi-point annealing facility being constructed in the Workshop will greatly assist in creating complex objects like this.

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Split on 2006 CSEM Prizes

As has been the case in recent years, we received an excellent crop of entries to the 2006 CSEM Prizes. But this time around the judges felt that both the 'science' and the 'applications' award should be shared between two equally deserving students.

"We're seeing some amazing materials science and engineering being carried out by our young enthusiastic undergraduates," said Dr Zbigniew Stachurski, Director of CSEM. "The CSEM Prizes is one small way of acknowledging the quality of their efforts and rewarding the most outstanding among them.

"The judges of last year's entries felt that there were two deserving winners in each category. So, for the first time, we've decided to share both the 'Application of Materials' and the 'Science of Materials' awards."

In the Science of Materials category the winners are John Antony (Dept. of Chemistry) for his work on hemp hybrid thermoplastic composites and Erin Davies (Dept. of Engineering) for her investigation of the structural and thermal properties of electrospun nanofibres.

In the Application of Materials category, the winners are Eileen Proctor (Gold and Silversmithing Workshop) for her work comparing the properties of five new silver alloys and Henry Wilson (Wood Workshop) for his development of the Forces of Nature table.

CSEM would like to congratulate all winners who each receive a certificate and $1000.

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Editor of Materials Monthly, David Salt, presents Eileen Proctor with her winning CSEM Prize for Application of Materials for her work on new silver alloys.

Under an Aussie sun

Last year the Industry-Academic Cooperation Foundation at Chungju National University in South Korea signed an Agreement of Cooperation with CSEM in an effort to enhance the exchange of students and ideas between the two universities. One of the first interactions arising out of that agreement has been an English language teaching course at ANU over the summer break.

Second and third year science and engineering students from several Korean universities stayed at Bruce Hall during January and were given intensive English tuition. What made the experience so special was that the students were also taken on tours of some of our university's unique research and technology facilities such as the Big Dish (pictured above).

The hope is that programs such as this will make ANU well known to some of Korea's best and brightest students and build many bridges over time.

"The feedback we've received is that the students really enjoyed themselves, and they did well in their English studies," says Dr Zbigniew Stachurski, Director of CSEM. "It's been noted that there have been remarkable improvements in their English and we're now planning similar programs for the future."

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