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Introduction

The Australian Institute of Nuclear Science and Engineering (AINSE) was established in 1958 to provide a mechanism for access to the special facilities at Lucas Heights by universities and other tertiary institutions and to provide a focus for cooperation in the nuclear scientific and engineering fields. Today nuclear science at the Lucas Heights Science and Technology Centre is devoted to supporting activities and research in a wide range of disciplines. These have applications in advanced technology, manufacturing, mining, agriculture, medicine and environmental protection. All are of vital importance to Australia's future.

Many of the techniques and much of the expertise at Lucas Heights cannot be found elsewhere in Australia. AINSE plays an indispensable role in facilitating university researchers with access to major scientific facilities and encouraging a national cooperative research and training effort. This has worked efficiently and cost effectively for the 36 university members and for ANSTO. The universities are saved from duplicating expensive items of equipment and Commonwealth funding can be directed towards one national organisation instead of having several with sub-critical funding.

Mission

AINSE will advance research, education and training in nuclear science and engineering and their applications within Australia by being, in particular, the key link between universities, ANSTO and major nuclear science and engineering and associated facilities.

Objectives

AINSE's objectives are:

1. to provide a mechanism for users in member organisations of AINSE to have access to major nuclear science and engineering and associated facilities at ANSTO and other agreed sites for research purposes

2. to facilitate graduate and undergraduate education and training experience utilising major nuclear science and technology facilities at ANSTO and other agreed sites

3. to encourage collaboration and cooperation between member organisations of AINSE in areas primarily related to nuclear science and engineering and their applications

4. to sustain and support the development of major nuclear science and technology facilities at ANSTO and other agreed sites for shared use by member organisations of AINSE.

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Dr Dennis Mather
Scientific Secretary

President's Report

Professor Ron MacDonald, President, AINSE

At the end of 2000 the Presidency of AINSE passed to Ron Cooper. I have spent the past two years (1999 and 2000) as President and prior to that, several years on the Executive and quite a number of years as a Council Member. Each of those years was rewarding.

AINSE is a special organisation, with its focus on the application of the techniques of nuclear science to a wide range of research projects across many disciplines. It represents most of the universities in Australia, with Auckland University providing an indication of the benefits of an offshore involvement. The areas in that receive research support cross many discipline boundaries with little or no support going to what one might call pure nuclear science. Archaeometry is now a major recipient of support, and biomedical applications are growing. Materials science is also an area to which the techniques associated with accelerator applications can provide valuable research tools. The breadth of the science and the chance to facilitate the involvement of young researchers doing PhDs across these areas is what makes AINSE an attractive organisation to work for. It is also the reason AINSE will continue to exist.

Over the past two years I believe we have been reasonably successful in providing support to researchers in very practical ways. We have managed to develop, with the Australian Research Council (ARC), a working model that allows AINSE to act as the intermediary for the award of grants for research infrastructure. Whilst the model is not one I would label as ideal, it has now been established that the ARC will consider and possibly fund proposals for large equipment and infrastructure provided that individual universities, as well as AINSE and ANSTO, make contributions to the proposed purchase.

The purchase of a new accelerator, which will be housed at ANSTO, is the first example of the model in operation. The universities responded well to a request for the additional funding required to supplement the amount committed by AINSE and ANSTO. This state-of-the-art accelerator mass spectrometer will be available for a wide range of dating applications, using a wide range of active isotopes, to provide support to the equally wide range of Accelerator Mass Spectrometry (AMS) users. The accelerator will also provide support to the ion beam analysis (IBA) community. Along with the existing tandem accelerator, which is already being used for both AMS and IBA, the new accelerator will be able to undertake almost any task requested by an Australian or New Zealand researcher.

One of the most satisfying achievements during the year was the development, with the help of the Executive Committee, of a procedure that allows for an increase (almost a doubling) of the scholarships AINSE could provide for PhD scholars in universities. The example set by these brilliant young scientists in their home universities will provide excellent advertising for AINSE.

The work of AINSE requires continuous and time-consuming input. A part-time President and Executive cannot, on their own, provide this. A hard working and loyal office group is essential to AINSE's continued support of researchers. I wish to extend my personal thanks to AINSE's Scientific Secretary, Dr Dennis Mather, and to the always supportive staff of Irene Parker, Nerissa Phillips and Sandy O'Connor for making my time as President such an easy one. The able and willing support of my colleagues on the Executive is also gratefully acknowledged. I wish the new President, Ron Cooper, all the best for his two-year term. If it is as interesting as mine has been, he will enjoy himself.

I would finish with an earnest request. The one task I did not enjoy carrying out in my capacity as President was making executive excursions to different universities to "show the flag". The visits themselves were very interesting, the laboratory tours and talks were exciting but the promotional bit was in general a waste of time. The audience was usually small and made up of dedicated AINSE grant recipients. The researchers we really wanted to reach were those who would benefit from access through AINSE to nuclear techniques, but who had not yet realised the potential of all that we do in AINSE.

A new presentation focus is planned. This will involve lectures by top researchers who are able to see beyond their own specialised interest area. Well scripted talks aimed at the researcher versed in nuclear techniques, allowing them to explore, by example, possible uses of these techniques, will ensure there is an interest in the facilities to which AINSE can provide access. If this is successful AINSE will grow and its future will be assured. The Council members, however, will need to be behind this new venture and they will have to work hard to ensure the message gets to the targeted group. My parting request to Council members and AINSE researchers generally is to work with the Executive to ensure the success of this new publicity venture. After all, the more satisfied AINSE recipients in a given Institution, the more people to lobby for the institution's payment of the AINSE membership fee.

R J MacDonald

Scientific Secretary's Report

Dr Dennis Mather, Scientific Secretary, AINSE

This year was a significant one for AINSE for a number of reasons. The new accelerator which we have commissioned, at a cost of about $2.7 million, on behalf of the university members and ANSTO, is probably the largest single project ever managed by AINSE. The number of AINSE grants awarded in 2000 increased from those awarded in the previous two years and there were more AINSE postgraduate awards.

During the year AINSE made progress in a number of administrative areas. These are highlighted in the body of my report.

Following the introduction of new procedures for capturing information we can now provide a more accurate picture of the number of days students attend ANSTO in research related activities. This is particularly important because AINSE is the major mechanism by which ANSTO is able to fulfil its training objective under the ANSTO Act. In order to make this function more transparent we now measure both the number of students who do experiments and the total number of days they use the facilities.

The number of university researchers who hold an AINSE grant for the first time might also be used to determine our effectiveness in this measure. Of the 201 grants awarded in 2000 thirty-one or 15% were awarded to researchers who have not previously held an AINSE grant.

We have modified the sign-off procedures for grant holders making it easier to log the use of facilities by grant holders, associate researchers and students. The increase in student days recorded below can be partially attributed to better record keeping. In future we will be making efforts to capture all days on facilities that are provided for AINSE grant work – whether they are paid for or pro bono.

Researchers who do not take up grants continue to be a problem. In order to improve performance we now require, on the application form, details of which month(s) the facilities will be used. Grant holders will then be expected to make bookings during these times. This should allow ANSTO facility operators to plan and schedule AINSE work more effectively.

Council and Committees

The Executive Committee remained unchanged from 1999, and details can be found in section 2 of this report.

On the Council changes included:

- Australian National University - Professor Trevor Ophel passed away in June. He was replaced by Professor John White
- Charles Sturt University - Dr Ken Page was replaced by A/Professor Kevin Robards
- University of Tasmania - Professor Garth Paltridge was replaced by Professor Allan Canty

Chairmanship of the Accelerator Science Specialist Committee passed from the late Professor Trevor Ophel on to Professor Dinesh Sood of RMIT University.

Chairmanship of the Engineering Material Science and Nuclear Technology Specialist Committee will pass from Professor Roger Smart on to Associate Professor Matthew Fewell of New England University.

Finances

AINSE is a non-profit making institute incorporated under the NSW Associations Incorporation Act 1984. In 2000, income of $1,876,077 was made up of $1,237,421 from ANSTO, $638,656 from universities, $585,691 from external grants, $247,310 from interest on investments, and $17,769 from other sources, mainly conference registrations see figure 1.

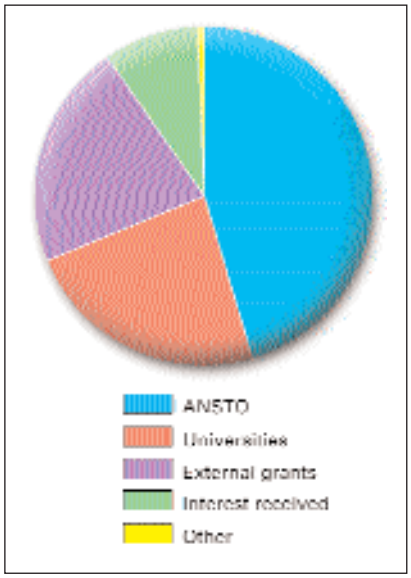


Figure 1. Operating revenue

Membership subscriptions are reviewed annually to determine AINSE support for each university. On average, for the period 1995 to 2000 inclusive, universities received research and training benefits amounting to 3.41 times their subscriptions. For more information on performance indicators see section 2, page 76.

The majority of AINSE funds are used to facilitate travel and access to Lucas Heights for university researchers and their research students, see figure 2. University projects are supported mainly through grants to cover costs associated with operating ANSTO's facilities.

AINSE's operating expenses in 2000 were $2,389,825, leaving a surplus for the year of $337,022. This surplus is due to a variety of things including a shortfall in the take-up of AINSE awards. This is being addressed in a number of ways. The carry-over of grants to the value of about $200,000 until the end of February 2001 was once again facilitated. This enables grant holders to utilise the summer break to use ANSTO facilities. I have already referred to stricter controls on bookings which will be reinforced by provisional awards which can be fitted in as gaps occur.

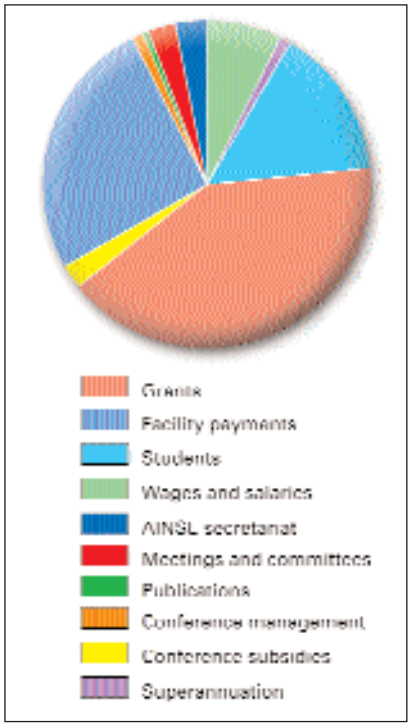


Figure 2. Operating expenses

The Financial Statements for the calendar year 2000 were prepared by ANSTO and audited by Gardner Escott & Co. They are presented in section 2 starting on page 7.

Grants and Postgraduate Research Awards

A total of 201 university projects were awarded in 2000 under the AINSE grant scheme. Fifty-eight projects were carried over from previous years. Figure 3 shows the distribution of AINSE grants awarded in each of the AINSE specialist areas. Highlights in each of these areas are given on pages 8 to 21 and full progress reports for each of the projects can be found on our Home Page.

In this year's report there are three different articles on cement in three different research highlights sections. It is interesting that this ubiquitous material which has been used in the construction industry for so long and has its origin over 2000 years ago is still not fully understood.

In 2000, sixteen of the thirty-one AINSE postgraduate research award holders received an award for the first time. During the year three, PhD theses were received from students who had completed their studies.

The AINSE postgraduate research award holders accessed the facilities for a total of 419 days. In addition, another 93 students gained access to the facilities via grants held by their supervisors for a total of 678 days.

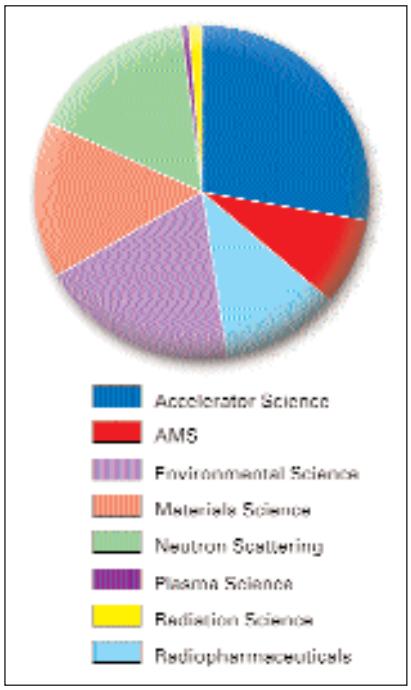


Figure 3. Grants by special area

The AINSE Winter School was held over five days early in July. Each year AINSE provides a scholarship to each of the 36 university members of AINSE, enabling a senior undergraduate student to participate in the program, which includes experiments, lectures and a social program. Feedback from all quarters judged this program to be an outstanding success and it will be continued in 2001. Details of the feedback can be found on our Home Page.

Success in Research Infrastructure and Equipment Fund (RIEF) Program

AINSE acts as a peak body on behalf of its member organisations in applying for and administering major research infrastructure grants. Two RIEF grants awarded for use in 2000, one for membership of ISIS and one for a new accelerator.

ISIS is the most powerful neutron spallation source in the world, located at the Appleton Rutherford Laboratories in the United Kingdom. Membership enables Australian scientists to use small angle neutron scattering techniques covering a wide range of research otherwise not possible within Australia. A summary of the experiments carried out as a result of this grant can be found on page 38 of section 2 of this report.

The RIEF grant provides $255,000 towards the $400,000 membership fee. Six universities contributed $90,000 and ANSTO $25,000. The remainder was made up of AINSE funds.

A proposal for a new 2MV accelerator attracted $1,017,480 of RIEF funds towards the $2.7 million price tag. Twenty-six universities have committed $512,000, ANSTO will contribute $600,000 and AINSE will provide the rest. The order was placed in December 2000 and delivery is expected in July 2002.

Conferences

AINSE is supporting a series of workshops which exchange information about neutron scattering. During 2000 two were held:

- Neutron Radiography and Digital Neutron Imaging at Australia's Replacement Research Reactor held on 30 November and 1 December 2000; and
- Powder Diffraction held on 17 and 18 October 2000.

Another seven are planned for 2001:

- Neutron Reflectometry in May 2001
- Single-Crystal Diffraction
- Small-Angle Neutron Scattering
- Condensed-Matter Physics (inelastic scattering and polarised neutrons)
- Neutrons for Engineering (including residual stresses, in-situ loading experiments, texture)
- Neutrons for Biology
- Neutrons for the Geosciences.

Details will appear on our Home Page.

A SIMS workshop on biological applications has helped consolidate expertise gained in this important new development. Allowed users and potential users to work with ANSTO people in developing this application. One of the experiments is reported in the Environmental Science research highlights section on page 12.

Two very successful conferences were held in December as part of the Australian Institute of Physics Congress at the University of Adelaide: Plasma2000, the 23rd AINSE Plasma Science and Technology Conference and the 18th AINSE Nuclear and Particle Physics Conference.

Rad2000 in November was the largest AINSE conference for the year and attracted an energetic cohort of over 70 radiation scientists to Lucas Heights.

AINSE supported the 3rd Australian Nuclear Association Conference in Canberra from 27 to 29 October 2000, by providing travel subsidies to contributors from member universities.

I am indebted to all members of planning committees for their invaluable contribution to the conferences.

Awards

The AINSE Gold Medal was awarded to Professor James Camakaris from the University of Melbourne at the May meeting of Council at Lucas Heights. He delivered his medal address, entitled The role of the trace element, copper, in human health and disease, at the Council meeting in May 2000.

The Student Gold Medal was awarded to Darren Goossens from Monash University, whose presentation, Magnetism in Two Dimensions, was well received by the Council.

Acknowledgments

I would like to thank Irene Parker, Nerissa Phillips and Tanya Irvine for their support throughout the year and the good will with which they have accepted new challenges. I would also like to extend my thanks to all those from the universities and ANSTO, there must be hundreds, for their help and advice throughout the year. Finally, I owe a special thanks to graphic designer Jeff Evans and editor Jeane Balcombe for their assistance with this report.

Accelerator Science

Research Areas

The Accelerator Science Specialist group promotes accelerator-based ion beam analysis techniques to analyse and characterise surfaces and near-surface structures. The techniques, which are non destructive and highly sensitive, are used in geological studies, characterisation of ancient ceramics and antique metal artefacts, zoological research into lizard physiology, tracing and provenance of obsidian to establish former routes in the South Pacific and investigations into the detailed structure of opto-electronic materials to assist fabrication methods.

ANSTO's 3MV Van de Graaff and 10MV FN-tandem accelerators are essential instruments. The former provides beams of protons and alpha particles, while the tandem beams span a wider range of ions and energies. Most applications involve a combination of nuclear techniques. These may include Proton-Induced X-ray Emission (PIXE) Proton-Induced Gamma-ray Emission (PIGE) Rutherford Back Scattering (RBS), Forward Recoil Analysis and Recoil Time-of-flight spectroscopy.

Selected Research Activities

Beyond the Kara Su

More than a century of archaeological work in Turkey (or Anatolia) has revealed a highly complex and diverse cultural mosaic highlighted by such familiar ruins as those of legendary Troy and grandiose Ephesus. Since 1994, Dr Antonio Sagona and his team from the University of Melbourne have been investigating the ancient mound site of Sos Höyük. It has revealed a virtually continuous cultural sequence, from about 3500 BC (the Late Chalcolithic period) through the Bronze and Iron Ages to approximately 1100 AD when it was incorporated into the silk route. Sos Höyük has added a new chapter in our understanding of ancient Near Eastern highland communities.

Investigating the ancient mound site of Sos Höyük, Anatolia, Turkey.

Kura-Araxes pots from Sos Höyük.

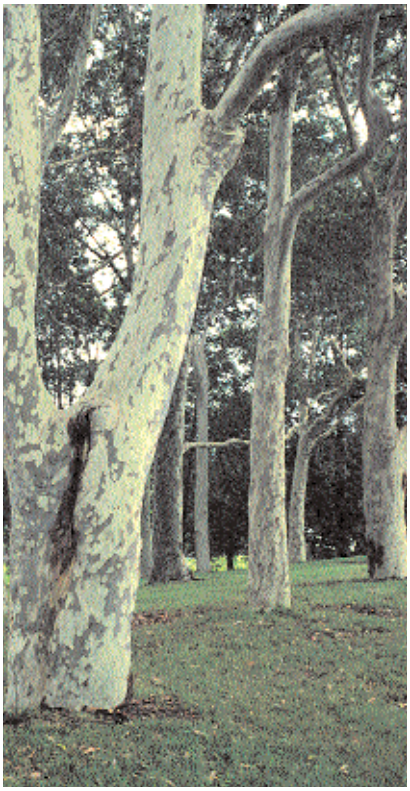
One period of interest covers the entire third millennium and a few centuries beyond, into the second, when Sos Höyük was occupied by peoples of the Kura-Araxes culture complex. These were communities of livestock-breeders and farmers whose homeland was Trans-Caucasus. These transhumant societies, which covered an immense geographic area, stand in sharp cultural contrast to the lowland, urban dwellers of contemporary Mesopotamia. In another period, which falls mostly in the second millennium, deep shaft graves of a type attributed to the Trialeti culture complex were used. These are traditionally associated with the earliest presumed Indo-European speaking communities. Critical evidence from Sos Höyük is leading to an understanding of the whole question of the origin and movement of these communities. Techniques used include the chemical characterisation of obsidian and pottery samples using the 3MV proton milliprobe in collaboration with Dr Rainer Siegele at ANSTO, and the first absolute chronology for the area using AMS carbon-14 dating in collaboration with Dr Ewan Lawson and his team at ANSTO.

Heavy metals in Australian plants

The ecotoxicological risks of metal contamination in soils, streams and groundwater are a major environmental and human health problem in need of affordable and effective remediation solutions. Phytoremediation is a successful, novel alternative technology that is being used to remediate soils that contain bioavailable heavy metals and organic contaminants, without disabling the biological activity and physical structure of the soils. However, little or no research has been done on the potential of Australian plants to take up heavy metals.

Dr D C McPhail and Desmond Menon have used ANSTO's Proton Induced x-ray Emission (PIXE) and Secondary Ion Mass Spectrometry (SIMS) in collaboration with Dr Kathryn Prince and Dr Ivo Orlic from ANSTO to understand how some eucalypts accommodate heavy metal loads by measuring element concentrations and mapping their distribution in plant tissue.

Results from PIXE and SIMS analyses of experimentally grown plants show variability in the overall ability of different plants to hyperaccumulate heavy metals. The results also show that pH and the concentration of heavy metals affects their distribution in the plant tissue, and this varies between plants. For example, lead concentrations decrease systematically along the main veins from the base to the tips of leaves in some plants (e.g. *Eucalyptus globulus* and *E. camaldulensis*) but not in others (e.g. *E. lesouefii*). The combination of PIXE and SIMS analyses is effective and allows us to determine element distributions at different spatial scales, from 1 mm to 5mm to cellular scales of less than 10µm. The results are useful in locating metals and quantifying their concentrations in plant tissue, and in inferring the biochemical pathways and transformations that metals make during their accumulation into plants. This information is critical in developing our understanding of heavy metal hyperaccumulation into plants and developing effective remediation strategies for contaminated soils and sediments.



PIXE/PIGE helps researchers understand how pollutants are leached out of cement

Dr Domenico Caridi and Associate Professor John Casey along with a number of postgraduate students from Victoria University are looking at the leaching of chemical species from cement-stabilised waste. Leaching tests along with physical and micromorphological tests indicate how firmly chemical species are trapped within the cement matrix. This information is essential for a long-term assessment of the behaviour of those wastes where the only acceptable management option currently is cement stabilisation followed by land burial.

The leaching behaviour of arsenic, selenium, lead, copper and zinc from a cement-stabilised industrial waste has been investigated using dynamic leaching. The waste was prepared as spheres moulded in pingpong balls and leached throughout a 12-month period using deionised water. The concentration leached versus time profiles obtained from the tests will aid in understanding the leaching behaviour of the five metals from this particular waste.

Caridi is collaborating with Dr Rainer Siegele from ANSTO who has provided PIXE and PIGE analysis of the cross section of the spheres showed how the concentrations of chemical species changed with the distance from the surface of the spheres. The concentration profile of chemical species along the radius of the sphere and the leaching profiles from the dynamic leach test will provide insight into the movement of chemical species as they escape the cement matrix.

Left: inside the cement sphere the pale rim is related to leaching.
Right: outside surface exfoliating after leaching.

Accelerator Mass Spectrometry

Research Areas

Accelerator Mass Spectrometry (AMS) is an ultrasensitive analytical technique used to identify and count selected isotopes. Isotopic concentrations at the level of 1 part in 10^{15} can be measured in long-lived radioisotopes such as carbon-14, beryllium-10, aluminium-26, calcium-41, chlorine-36 and iodine-129.

Carbon-14 analysis is probably the best known AMS technique. It is used in a wide range of disciplines including archaeology, Quaternary science, global climate change and nuclear safeguards.

Selected Research Activities

Dating Sticknest Rats

Two species of sticknest rats once occupied large areas of semi-arid central Australia. After European settlement one became extinct and the other survived as an isolated population on an offshore island – see picture below. The rats had the habit of building nests of sticks and other plant materials, and the whole mass became cemented together with the viscous urine and faecal materials of the animals. Many of these nests were built in rocky overhangs and as a result they also incorporated the evidence of other animals which inhabited the same areas.

Stuart Pearson and John Dodson at the University of New South Wales began studying the age and contents of a sample of the nests from Western Australia in the early 1990s. They quickly became aware that Lynne McCarthy and Lesley Head from Wollongong University were attempting the same thing from the Flinders Ranges region of South Australia. While the individual groups expanded their activity it became clear that collaboration on developing a methodology for collection, treatment and analysis of samples would benefit all and establish protocols for future workers. A further collaboration has developed with the AMS team at ANSTO who have developed the tricky processes necessary for the preparation of the samples for AMS analysis and the interoperation of the results.

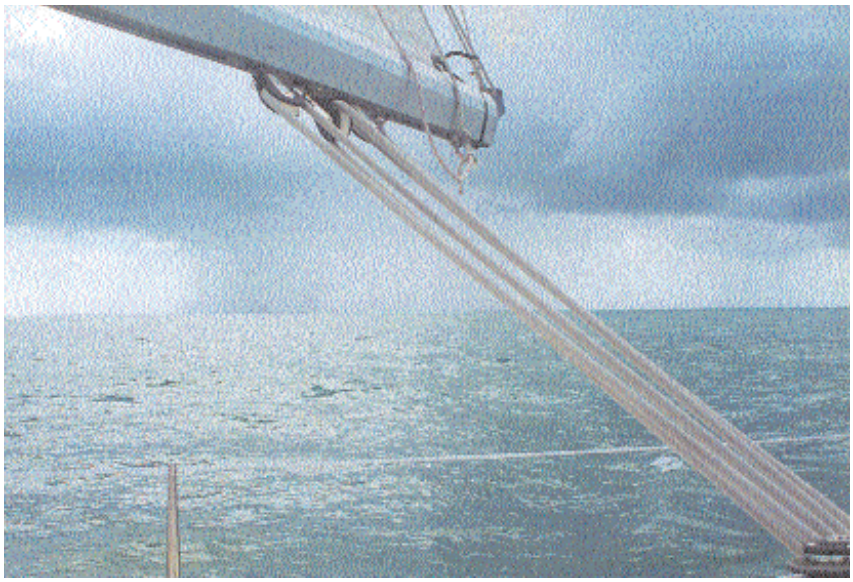
Some nests are up to 10,000 years old, and many were built and occupied by successive generations of sticknest rats for 300 years or so. The contents included wonderful records of fossil pollen, other plant remains, bones, feathers, hair, insect remains and faeces of other animals as well. In short, sticknest rat nests have been shown to reveal abundant and new information of vegetation and climate variability in the interior of Australia, and the bone and insect records have contained species new to science and expanded our knowledge on the former range of some species.

Three century old tomb dated to within 100 years

For the first time in the history of Arabian archaeology AMS dating has been used successfully to determine the date of a collective tomb of so-called 'Umm an-Nar-type'. Circular, stone-built tombs of this sort are common in southeastern Arabia, that is, the area now comprising the Sultanate of Oman and the United Arab Emirates. The tombs had been dated on comparative grounds to about 2500-2000 BC, but there had been little attempt to more precisely date a particular tomb. Now a tomb at Tell Abraq in the United Arab Emirates, excavated by a University of Sydney expedition between 1993 and 1998, has been AMS dated to about 2150-2050 BC. The tomb, which contained the remains of more than 394 individuals, yielded hundreds of objects, including gold jewellery, dozens of ceramic and stone vessels, hundreds of beads, a dozen ivory combs, and much more. This eclectic selection of material includes, besides locally manufactured items, obvious imports from Mesopotamia, Iran, Central Asia and the Indus Valley. The AMS dates from Tell Abraq allow us to fix the chronology of the material with a degree of precision previously unattainable.

Dating the ocean

How old is the ocean? The answer depends on where you look. Carbon-14 forms continuously in the atmosphere and breaks down at a known rate. It is absorbed by living things on land rapidly, but takes time to mix into the ocean. Thus, if you date a living tree, a surface fish, and a deep-water shell they will all give different ages. How different these ages are depends on the ocean's circulation. Today the age of the surface ocean around Australia is about 400 years and that of the deep ocean about 1,400 years. If the ocean's circulation changes we know that the relative ages between those different carbon pools (or reservoirs) will change. This has important implications for studies that use carbon-14 dates for chronology. Each reservoir has a known age which is used to "correct" ages for comparisons. If these ages changed substantially in the past, the relative timing of events could be misconstrued.



Members of the paleoceanographic group from the Antarctic Cooperative Research Centre at the University of Tasmania, Drs Will Howard, Cath Samson, and Liz Sikes (now at the University of Auckland), and Dr Tom Guilderson (Lawrence Livermore Laboratory) have been using dating of deep sea sediments to determine the timing of the change in climate that occurred at the end of the last ice age in the Southern Ocean. In order to do this they have had to determine the ages of the atmosphere and ocean carbon reservoirs in the past. Ash layers in marine cores from off New Zealand were used as stratigraphic markers to show that in the past, when ocean circulation is known to have been different from today, marine reservoir ages increased by two to five fold over what they are today. Surface ocean ages of 2000 years and deep ocean reservoir ages of as much as 5000 years are an order of magnitude more than previously imagined possible. These findings have dramatic implications for our understanding of radiocarbon cycling and ocean dynamics.

Unstable Antarctic ice sheet

Beechwood and marine fossils discovered in the Transantarctic Mountains in Antarctica have been controversially interpreted as originating in marine basins inundated during major waning of the East Antarctic Ice Sheet (EAIS), which challenges the concept of a rigid, unchanging ice sheet. Subsequent Ice Sheet expansion dredged these deposits to high elevations on an uplifting mountain range. Exposure age dating using beryllium-10 and aluminium-26 has been used to establish whether model ages can point to a dynamic or stable Ice Sheet over the past five million years (Ma).

Professor Barrie McKelvey from the University of New England and Dr Rod Brown, University of Melbourne, are carrying out a similar investigation in the Northern Prince Charles Mountains region along Lambert Glacier. The 700km Lambert Glacier is the largest in Antarctica and drains approximately 10% of the ice sheet. Their aim is to reconstruct the Quaternary glacial history of the region and by inference, that of the EAIS. Fifteen samples were collected from bedrock and moraine boulders ranging in altitude from 1300m at the summit of Fisher Massif, to 100m around the northern shore of Radok Lake near the coast. The AMS beryllium-10 and aluminium-26 exposure ages span a broad time range from 2710 ± 420 ka to 10 ± 2 ka. Preliminary conclusions support three age clusters that suggest a receding EAIS at 2.5 Ma, at 1.0 Ma and at 0.10 Ma years ago. The glacially smoothed summits of Fisher (1260m) and McLeod (1200) Massifs emerged above ice at least ~2.5 Ma ago due to a combination of tectonic uplift and a lowering EAIS. The results are consistent with, and introduce, a definitive chronology for a glacial history previously deduced from geomorphic evidence alone. They also support the existence of a dynamic, unstable ice sheet over the past 2.5 Ma.

Fisher Massif projects 1000m above the Lambert Glacier and its peak recorded a minimum beryllium-10 cosmogenic exposure age of 2.5 million years.

Environmental Science

Research Areas

AINSE's environmental science projects utilise four main areas of ANSTO facilities and expertise:

- the Cameca 5f Secondary Ion Mass Spectrometer (SIMS)
- environmental radioactivity, chiefly through lead-210 and caesium-137 dating procedures
- uranium/thorium measurements for Quaternary dating
- Neutron Activation Analysis (NAA).

The SIMS instrument is used to solve a broad range of surface analysis, geological and biological problems. AINSE-supported researchers use it to analyse mineral surfaces and their reactions during benefication, in order to assess the suitability of silicon and other semi-conductor materials for their use in electronic and solar energy applications and to characterise the surfaces of metals and alloys. Biological applications are being developed.

Selected Research Activities

European settlement - changes in marine habitats in SE Tasmania

In populated areas of Australia coastal marine habitats appear to have changed significantly since European settlement. The most obvious impacts on inshore marine habitats are massive sedimentation and nutrification arising from land clearance and runoff, introduction of exotic species, heavy metal and organic pollution, overfishing and habitat alteration from dredges and trawls.

Some impacts on inshore marine habitats in SE Tasmania: increased sedimentation arising from land clearance associated with urbanisation and agriculture; pollution associated with aquaculture, urban and industrial runoff and recreational activities such as boating.

Dr Cath Samson at the University of Tasmania is using the marine sediment record to assess changes in marine benthic habitats in sheltered bays in south-eastern Tasmania over the last 200 years. Past habitat types are determined from molluscs, which are well preserved in the sediment record, combined with sediment characteristics. Measurements of lead-210 and radium-226 at the ANSTO Radiochemistry Laboratory in collaboration with Dr Henk Heijnis establish the timing of sediment and faunal changes in the sediment records. The timing of faunal changes relative to changes in sediment type, fishing practices and introduction of exotic species allow causal mechanisms to be inferred.

Initial results indicate that several areas in south-eastern Tasmania have changed from sand to mud over the last century. In addition, many seagrass communities and scallop beds have been replaced by soft bottom communities. Exotic taxa such as the New Zealand screw shell now dominate the fauna of several soft-bottom areas.

SIMS sorts out preg-robbing ores

A common problem encountered in the gold mining industry is "preg-robbing". This term describes the process by which gold concentration in a slurry decreases when some ores are added to it. It is thought to involve adsorption of the gold on carbon inclusions in the preg-robbing ore, but the exact mechanism and the final form of the gold in these ores is not fully understood.

The gold that the pregs didn't get

The research teams of Dr Stephen Thurgate at Curtin University and Dr Kathryn Prince at ANSTO have used Secondary Ion Mass Spectrometery (SIMS) to look for associations on the surface of the ores between deposited gold and other elements.

Images of gold, carbon and sulfur ions at the surface of the minerals from four different locations showed gold adhering to carbonaceous areas. This is consistent with the view that the major process of preg-robbing is via adsorption onto carbon, in a manner similar to the adsorption of gold onto carbon in the carbon-in-pulp process.

However, the data also showed complex correlations between the distribution of sulfur and adsorbed gold. On some samples there was an anti-correlation between the distribution of sulfur and the distribution of gold. On other samples, gold adsorption occurred in sulfur rich areas. This data requires further understanding and it is likely that the significant entity is the sulfur bound form, since there is a range of naturally-occurring sulfide minerals in these ores.

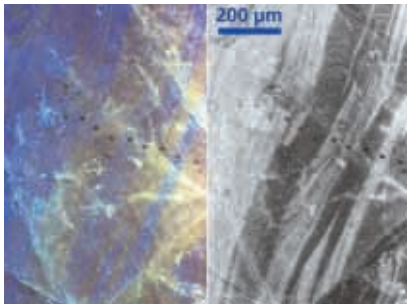
Kalgoorlie's crystal catacombs

Kalgoorlie, Western Australia, sits on one of the richest pieces of real estate in the world. From 1893, when gold was discovered, to 1987 some 1,268 metric tons of gold have been removed, and production is set to continue for many years. Many deposits of similar type and age occur in Western Australia as well as worldwide, but only a few can compete with the Kalgoorlie deposit in size.

Dr Joel Brugger from Monash University is investigating the questions of relative timing between the different types of deposits and regional geological evolution, of the sources of fluids and metals, and of the mechanisms leading to ore deposition. These questions are fundamental for our understanding of this type of deposit, and for improving prospecting models.

Scheelite, is associated with gold at the Mt Charlotte deposit. Scheelite traps small quantities of rare earth elements and strontium in its crystal structure during its growth, and the distribution of these chemical elements has for decades been used as tracers for fluid sources, ore transport and deposition processes.

The study of the Mt Charlotte scheelite using a variety of methods revealed an unexpected complexity, which changes the way we think about trace element geochemistry of hydrothermal minerals. The SIMS at ANSTO provided a vital clue to solving the final puzzle, in revealing the mechanism responsible for the incorporation of rare earth elements in the Mt Charlotte scheelite.



Left: luminescence of a scheelite crystal from Kalgoorlie, colour variations show different rare earth elements. The line of holes (40µm in diameter) corresponds to chemical analyses by laser ablation ICP-MS. Right: Same image after digital enhancement, showing the complexing of the trace element zoning in this scheelite.

Copper tolerant rainbowfish

Since the remediation of the Northern Territory Rum Jungle mine site, metal concentrations, particularly copper, have been reduced in acid mine drainage flowing into the east branch of the Finniss River, nevertheless, copper concentrations remain relatively high, up to 2000 micrograms per litre. Surprisingly several species of fish, particularly the black-banded rainbow fish, *Melanotaenia nigrans*, have been observed in abundance in the creek.

In a laboratory experiment it was found that black-banded rainbowfish from the east branch, where copper levels were high, were over eight times more tolerant to copper compared with an unexposed population from Coomalie Creek, located in an adjacent uncontaminated catchment.

Using the radioisotope copper-64, the biokinetics of newly accumulated copper was traced in exposed and reference fish.

This indicated that the mechanism of tolerance involved blocking the uptake of copper into the gills. This could occur through reduced copper binding affinity at the gill surface, increased mucus secretion by the gills, or altered gill structure, thereby reducing its surface area, or by a combination of the three methods.

To determine if this tolerance to copper was genetically mediated, differences in allozyme frequencies in fish from three populations of black-banded rainbowfish, exposed, reference and captive-bred, were studied using electrophoresis techniques. The differences between the allozyme frequencies of the exposed fish and the reference and captive-bred fish were greater than those between the unexposed and captive-bred fish. This suggests that tolerance to copper may be genetically based.

The implications of these findings include the importance of knowing the origin of fish used in toxicity bioassays to assess the impact of metals on the biota, and in the development of appropriate water quality guidelines for remediated sites. It also provides insights to understanding metal exposure through the food chain.

Engineering, Materials and Nuclear Technology

Research Areas

ANSTO's Materials Assessment group offers an integrated service that concentrates on structural integrity and remaining life assessment. This is complemented by a blend of excellent facilities and broad experience in collaborative research and development and in the assessment of plant integrity, safety and the behaviour of plant with changed operating conditions. Expertise that is related to synroc fabrication, such as sol and powder processing and advanced sintering methods such as hot isostatic pressing is often utilised in collaborative projects with universities and industry.

ANSTO Materials Division's x-ray diffraction, scanning electron microscopy, and transmission electron microscopy facilities are well suited for phase identification, determination of unit cell parameters, studies of phase transformations, imaging of microstructures, and quantitative microanalysis of a variety of solid materials. A field emission transmission electron microscope and imaging filter provides a combination of diffraction techniques, high resolution imaging with a resolution approaching one Angstrom, digital image capture, nanometer scale microanalysis and electron energy loss mapping and spectroscopy. Sample preparation facilities are also available for most applications.

Research into the sol-gel route for bonding silica and alumina at temperatures below 600°C is being undertaken together with work on biocompatible sol-gel matrices for the controlled release of drugs and radiopharmaceuticals. Plasma processing techniques are being developed to modify material surfaces to enhance the value of industrial products.

Ceramic Coatings Improve Corrosion and Wear Resistance

Hard ceramic coatings such as titanium nitride (TiN) are used in areas of engineering where increased wear and corrosion resistance is required. A very thin layer of the coating on the surface of a component, for example twist drills used for drilling holes in wood, metal, and masonry has been known to improve their lifetime by many times. Other potential applications include coatings for critical components in pumps, valves, and impellers, used in the chemical processing industries, where increased corrosion resistance is important. Additionally, the gold coloured appearance of these coatings makes them attractive for decorative purposes. One major drawback with these coatings is that defects, such as pinholes and pits in the coating, may accelerate corrosion of components.

Dr Liam Ward from RMIT University, and Dr Peter Evans from ANSTO have modified the surface of TiN, TiCN and CrN coatings on stainless steel and mild steel by implanting carbon and selected metal species using ANSTO's Metal Vapour Vacuum Arc Ion Source (MEVVA) implanter. This changes the surface properties and reduces the friction coefficient. Wear tests of the modified coatings, carried out at ANSTO, have confirmed some improvement in wear resistance, particularly for coatings implanted with zirconium and molybdenum, caused by changes in the surface properties and reduced friction coefficient. Increased corrosion resistance for implanted coatings compared to unimplanted ones has been confirmed by studies conducted within RMIT and is likely to be associated with the formation of passive layers and/or a reduction in the number of pinholes and other coating defects.

New Prostheses

There are occasions when bone needs to be replaced, due to injury, cancer or even the desire to be taller. While this can be done partially by borrowing bone from other areas of the body, a supply of artificial bone would be very beneficial. The manufacture of artificial bone that the body is happy with is a complex process. Ceramics and metals have been used in the past; however, success has been limited due to the body's rejection of the materials as foreign to the body.

Associate Professor Bruce Milthorpe at the University of New South Wales and his team have made a composite material incorporating the mineral part of bone, hydroxyapatite, and steel reinforcing fibres. The hydroxyapatite is recognised as being "self" by the body and bone grows up to and bonds well to it. The steel reinforcing adds toughness to the hydroxyapatite. On its own, hydroxyapatite is very brittle and would break easily during ordinary day-to-day activities.

The hydroxyapatite and steel components are mixed in the appropriate proportions and sintered in the hot isostatic press at ANSTO to produce a dense final product. This material is then tested for strength and toughness in the laboratory. Its biocompatibility and bone bonding is being tested by cell culture and bone implantation tests at the University of New South Wales.

Why not? - batteries we can recharge forever?

Rechargeable batteries are fast becoming an essential part of everyday life. We all want batteries that are smaller, stay charged longer and have a longer cycle life. Professor Jim Metson at the University of Auckland and his team are interested in finding out what changes occur in the cathodes of lithium ion batteries as they lose their ability to recharge after multiple recycling.

Secondary Ion Mass Spectrometry (SIMS) depth profiling of the thin interfacial layer between some potential cathode materials and the electrolyte has provided clues as to how the cathode grains gradually lose their structure and connectivity – therefore decreasing the capacity of the battery.

The experiment has shown that the cathode material, chromium doped $LiMnO_2$, reacts with the electrolyte $LiPF_6$, forming a thin diffusion barrier which limits both electronic and ionic conductivity across the interface between the solid cathode grains, the matrix in which they are dispersed and the electrolyte.

Cement's Holy Grail

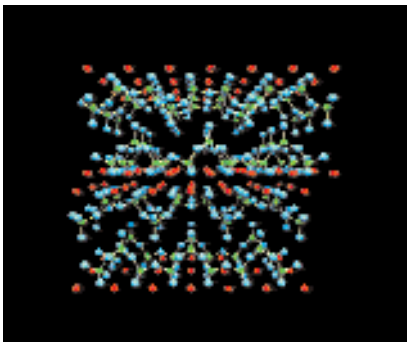
Although cement has been used for over two thousand years, we still know little about the nano-structure of cement pastes. This structure of the amorphous calcium-silicate-hydrate is still the "Holy Grail" of cement chemistry. It has been sought ardently but never found.

One approach has been to heat the paste in a pressure cooker at various temperatures and then use x-ray diffraction to examine the crystalline structures formed, and then extrapolate these structures to permit the best educated guesses regarding the amorphous precursor structure. These problems were being addressed 40 years ago by other researchers.

Associate Professor Abhi Ray of the University of Technology Sydney and Dr Laurie Aldridge of ANSTO have worked on the calcium silicate hydrate structures for a number of years. More recently, their student Danielle Klimesch completed a PhD thesis in 2000 on the effect of inserting aluminium ions into the structure of calcium silicate hydrates formed at elevated temperatures and pressures. By using a combination of techniques including x-ray diffraction and nuclear magnetic resonance spectroscopy she was able to elucidate the sequence of chemical reactions that occur as the paste crystallises.

Danielle's PhD work showed that the traditional chemical understanding was flawed. She published 17 papers in refereed international journals during her PhD study and won the 2000 Chancellor's Award at the University of Technology Sydney.

So while the Holy Grail still eludes us, we are just a little closer to discovering the nanostructure of cement..



Tobermorite, a molecular model for cement paste.

Neutron Scattering

Research Areas

Peer reviewed projects utilised the ANSTO neutron beam instruments including:

- high and medium resolution powder diffractometers
- high and medium resolution single crystal diffractometers
- small angle neutron scattering
- long wavelength polarisation analysis spectrometer.

AINSE continued to manage Australia's partnership with the world's most intense neutron spallation source, ISIS at the Appleton Rutherford Laboratories in the United Kingdom. This facility gives Australian researchers access to a wide range of techniques, which are unavailable in Australia. These include neutron reflectometry, neutron vibration spectroscopy, and muon spin resonance techniques, to name only a few. Australian researchers were awarded 44 days of beam time for projects during 2000. Projects and publications are summarised in section 2, page 40.

AINSE is grateful for the assistance of ARC Research Infrastructure and Equipment funding, which provided most of the money needed for the 2000 subscription to ISIS.

Paper weight

For his PhD from Monash University, Chris Garvey is researching the fundamental science of how the density of paper changes as it hydrates (takes in water) experimenting with a technique that has not been tried before. 'Using the Australian small angle neutron scattering facility AUSANS in collaboration with Dr Robert Knott from ANSTO's Physics Division.

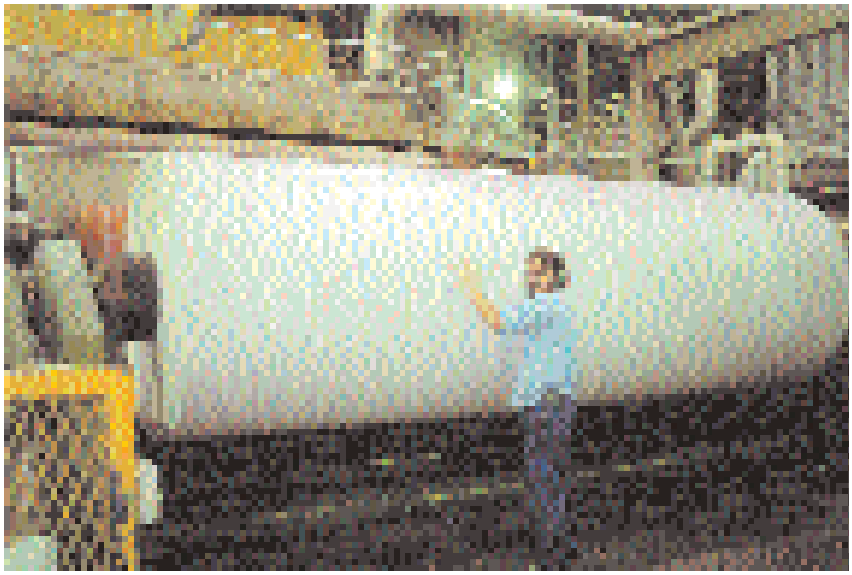


Image coutesy of Australian Paper.

Chris, from the Pulp and Paper Institute in the Department of Chemical Engineering at Monash said 'I aim to understand how the molecules in the paper bind with atmospheric water. Increasing knowledge of the molecular structure of wood and paper may enable us to make modifications to this structure. But it is much more difficult to modify the intrinsic properties of natural materials than say man-made products such as plastics.'

Some staff still keep a small light on in their copy paper cupboard to deal with the frustration of having paper eternally jam in their copying machines and printers. These woes and miseries caused by humidity changes could be a thing of the past due to this collaborative project. Sticking problems are caused by weight gain in paper due to atmospheric water bonding with giant cellulose molecules in paper. 'Water accounts for up to 10 per cent of the mass of paper which expands and contracts with changes in humidity,' Chris said. 'This change in paper size due to the increase in density gives great headaches to the paper packaging industry.

'The AUSANS scattering patterns helps us determine the molecular structure and density of the paper. The density fluctuations within the paper don't change uniformly, but sporadically where the water is absorbed. This changes the volume of the paper as it expands. Armed with this information, we hope to modify the structure of the molecules, preventing the hydration of the cellulose and the fluctuations in the weight of the paper,' he said.

Chris's access to AUSANS has been supported by AINSE grants in the name of his supervisor Dr George Simon of Monash University.

Microstructure of aluminosilicate based binders

Australia's concrete industry is confronted with many challenges as it enters the 21st century. Repair and replacement of aging infrastructure costs Australia millions of dollars every year while cement manufacture itself, is a major contributor to global warming. The search for sustainable alternatives to Portland cement based concretes has arrived, and one such alternative that is more durable, cost-efficient and environmentally friendly are "Geopolymers".

"Geopolymers" are an alternative aluminosilicate binder whose use dates back to ancient Egypt. Just recently they have been rediscovered for their superior durability and strength. Processing of "Geopolymers" however, relies upon waste mineral feedstock that is often highly heterogeneous. This makes the production of a reliable and consistent product a major challenge before commercialisation can be completed.

In collaboration with Dr Robert Knott from ANSTO, John Phair and Professor J S J van Deventer from the Particulate Fluids Processing Centre (PFPC) at the University of Melbourne have set about to explain the processing and material properties of these concretes based on their microstructure. To determine important micro-structural features such as surface area and porosity, Small-Angle Neutron Scattering (SANS) at ANSTO is being utilised to analyse both real and model systems. SANS is a highly useful technique that can analyse solid samples non-destructively and in their natural state - a feat rarely achieved by other techniques.

SANS analysis has also revealed that the aluminosilicate concretes consist of particles of colloidal dimensions, less than 1μm, that interact to form a fractal structure. (see Figure 2) Subsequently, it is possible to analyse the effects of composition based on a fractal structure and provide explanations to why the surface area and porosity vary as they do with composition.

Aluminosilicate fractal cluster whose morphology and structure can be modelled and characterised from data obtained from small angle neutron scattering

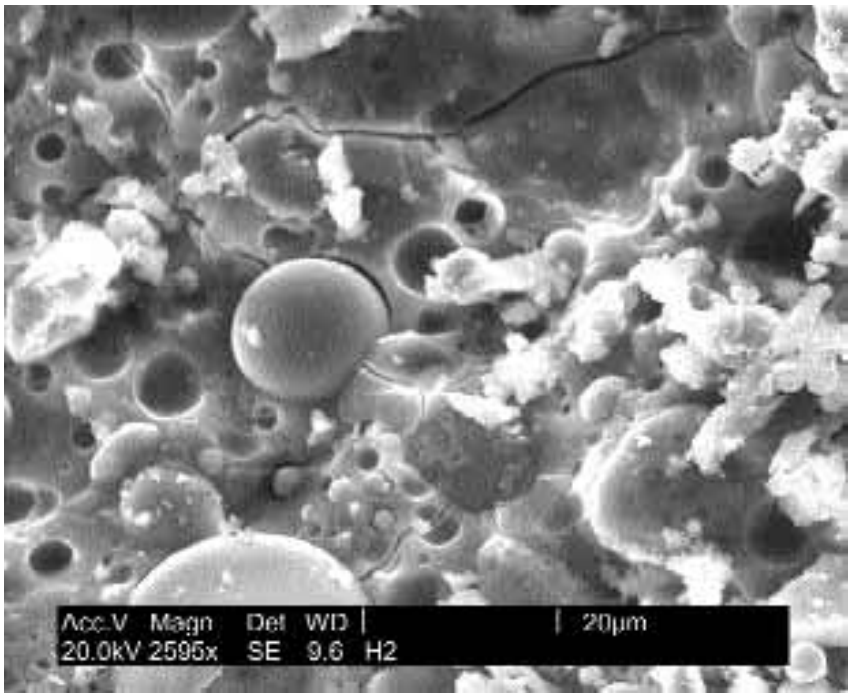


Figure 2. SEM micrograph of porous aluminosilicate paste which must be optimised for aggregate incorporation

Neutron diffraction resolves a long-standing controversy on the crystallography of γ-alumina

γ-alumina is an enormously important material in catalysis technology. Its uses include hydrocarbon conversion (petroleum refining) and as a support for motor vehicle and industrial catalysts. Part of a collaboration between Alcoa of Australia Ltd and the Materials Research Group at Curtin University of Technology focussed on the crystallography of the Bayer process for bauxite processing and relied on cooperation with ANSTO. When bauxite is calcined to produce alumina, the intermediate reaction products include γ-alumina.

Dr Bee K Gan studied the crystallography of γ-alumina formation at ANSTO for her PhD project, using high-temperature neutron diffraction, under the joint supervision of Professors Brian O'Connor and Deyu Li of Curtin University and Dr Shane Kennedy of ANSTO. These measurements revealed subtle features in the data which showed for the first time that γ-alumina comprises a system of co-existing cubic and tetragonal phases, whereas there had been considerable controversy for some 50 years on whether the materials is cubic or tetragonal. This discovery is likely to improve our understanding of the fundamental nature of γ-alumina assisted catalysis.

Also see the report on page 23 on the award winning research of Darren Goossens on neutron powder diffraction analysis of two dimensional magnetic structures.

Radiation Science

Research Areas

Projects facilitated cover a wide range of areas in chemistry, molecular biology, pharmacology, materials science, polymer science, radiotherapy and environmental science.

Facilities

The radiation science projects utilise the following facilities:

- ANSTO's gamma irradiation pond, which provides dose rates from approximately 0.1 to 3.0 kGy/h
- ANSTO's small shielded gamma facility, which provides maximum dose rates of 0.2 and 0.8 kGy/h
- ANSTO's deep level transient spectrometer,
- A Febetron accelerator at Melbourne University, which produces a 3 nanosecond pulsed electron beam with an energy, variable at will, between 200 and 600 keV. The maximum peak current is 7000 A.
- A Dynaray 4 linear accelerator, located at the University of Auckland, which has been converted to deliver electrons in single pulses of up to 180 mA current. Pulse lengths available are 200 ns, 750 ns and 1.5 µs. Beam energy can be varied between 0.5 and 5 MeV.
- A Vickers (Radiation Dynamics) electron linear accelerator at ARPANSA in Melbourne. The accelerator produces an electron beam energy that can be varied continuously between 7 and 21 MeV. Pulse repetition frequencies are available from 3 to 200 pulses per second. A peak pulse current up to 330 mA, depending on the energy, can be reached, corresponding to a dose per pulse at the radiolysis cell of roughly 90 Gy at 12 MeV. The pulse width can be varied from below 100 ns to 4 ms and, up to at least 600 ns.

A nicotine patch can be made with a hydrogel.

Selected Research Activities

Slow release polymers

Contact lenses, wound dressings and 'patches' for slow drug release are based on polymers called hydrogels. A new curing chemistry is being used to synthesise a special class of biocompatible polymer hydrogel through the formation of charge-transfer complexes for use with controlled-release drugs. These charge-transfer complexes are compounds formed by the interaction between electron-rich donor species and electron-poor acceptor species under the influence of a radiation source. Typical examples of donor species are vinyl ethers, while examples of acceptor species are maleic anhydride and maleimides.

Dr Loo Teck Ng and her team at the University of Western Sydney are looking for a combination of acceptor and donor species which, when combined with a high intensity radiation source, will provide a reasonably efficient radiation curable system. UV light radiation is used in place of photo initiators to initiate the polymerisation process. Photoinitiators are costly and will, if unreacted, be embedded as impurities in the hydrogels. Thus, hydrogels obtained using UV initiation are purer, and more economical to produce.

For comparative studies, gamma radiation is utilised for the polymerisation process as well. This irradiation was carried out in ANSTO's gamma pond.

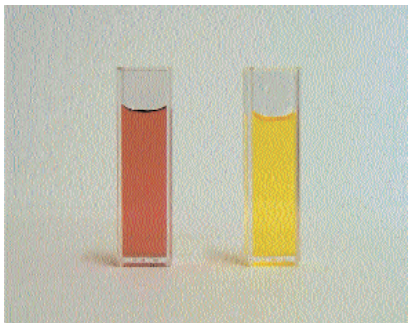
In this preliminary stage a drug such as theophilline, which is prescribed for the treatment of asthma, is used as a model drug. The hydrogel is immersed in water and the rate at which the drug is released is measured using spectrophotometry and high pressure liquid chromatography.

Selection of prodrugs for gene therapy

This project is based on the belief that a group of compounds known as nitro-heterocyclic carbamates might be useful as triggers for prodrugs – drugs that are selectively activated by enzymes to release cytotoxins. The project focusses on the use of prodrugs based on these carbamates, together with the *E. coli* nitroreductase enzyme in gene-directed enzyme prodrug therapy. A team from the University of Auckland headed by Professor Bill Denny is using the Univeristy's pulse radiolysis facility to better understand the fragmentation of these compounds. Three compounds that have suitable reduction potentials and fragmentation rates will be subjected to further studies in cellular conditions prior to studies in tumour-bearing animals.

Chameleon compounds

Compounds containing iron and cobalt can exist in various redox forms, each with a very different colour. If a small electrical potential is applied to a surface coated with one of these compounds, they will change colour, as shown in the picture. This property could be very useful in a wide variety of applications, for example in antiglare coatings for car windscreens or for signs. In some circumstances the compounds provide an alternative to liquid crystals.



Dr Paul Bernhardt and his group at the University of Queensland have discovered a series of such compounds and have been using pulse radiolysis measurements at ARPANSA in Melbourne to characterise the spectral features in a number of different oxidation states of these compounds.

So small they can't be seen Too small to scatter light

Particles less than 20 nm in diameter are called nanoparticles (a nanometer is one millionth of a millimeter). Such particles can be expected to have unique and useful properties such as a large surface area in proportion to the particles' weight; one gram of spherical particles of diameter 20 nm, for example, has a surface area of 300 square meters.

Peter Hidi and David Sangster at the Key Centre for Polymer Colloids, University of Sydney, have succeeded in making latex particles with diameters (mean volume/mass diameter) as small as 15-18 nm from four different monomers – methyl methacrylate, vinyl acetate, methyl acrylate and styrene.

The scientists found that if they irradiate a mixture of monomer and an aqueous solution of a surfactant using a cobalt-60 gamma irradiation source at ANSTO, and incorporate carefully controlled stirring during the irradiation process, small particles form in preference to larger ones. The size of the product particles varies according to the initial surfactant concentration. To make the smallest particles the concentration of the surfactant, sodium dodecyl sulfate, must be greater than 0.1%, but this is not considered a high concentration. A normal latex emulsion is milky and opaque because it is made up of particles large enough to reflect light. The nanolatex is transparent or "water white" because the individual nanoparticles are too small to scatter visible light and hence cannot be seen. A series of preparations, made with successively lower concentrations of surfactant initially present, ranged from transparent through to cloudy, translucent, light dispersion and then heavy dispersion as the particle size increased (see illustration).

The nanolatex is surprisingly stable even after removal of the surfactant, which stabilises the particles against coagulation. During dialysis, the surfactant is removed by allowing the surfactant molecules to pass through the pores of a membrane that retains the nanoparticles. The resulting latex showed no change after three months. If the surfactant is removed slowly and not completely, a transparent gel results. More work is needed to delineate the conditions needed for this gel to form. Since the optical properties of the particles - their inability to scatter light - has been preserved, the gel is thought to be a network of strings of nanoparticles. The adsorbed surfactant remaining on their surface serves to hold water within the network.

Further work is planned to elucidate the reaction mechanisms whereby these interesting materials are formed and to explore their properties and applications.

As the particle size decreases left to right, so does the light scattering. All the samples contain 1% polymer, poly(methylmethacrylate) - the perspex polymer. The surfactant used in their preparation ranged from 0-9 mM.

Radiopharmaceuticals and Neutron Irradiation

Research Areas

Radiopharmaceutical research focuses on the development of radionuclides and radiopharmaceuticals for diagnostic and therapeutic applications in the areas of neurology and cancer. The researchers use in vivo and in vitro evaluations of labelled compounds and carry out clinical trials with promising radiopharmaceuticals.

Radiopharmaceutical sciences consist of:

- radiopharmaceutical chemistry
- macrocycle chemistry
- short-lived positron emission tomography (PET) and single photon emission computed tomography (SPECT) radiopharmaceuticals
- molecular radiopharmaceuticals
- bio-radiopharmaceuticals
- radionuclide development and radiopharmaceutical dosimetry
- radiopharmacology
- molecular design and structure
- rapid radiochemical separations
- monoclonal antibodies
- process control for synthesis and quality control
- hot atom chemistry

Selected Research Activities

Treatment for cardiac arrhythmia

Adenosine is an important regulatory compound that mediates a wide range of physiological effects in the cardiac, nervous and immune systems. Dr Peter Scammells at Deakin University is in the treatment of cardiac arrhythmias by making active compounds that bind to the A1 receptors in the heart– slowing down the heart rate and allowing it to regain it's regular rhythm.

Currently, adenosine is used for this kind of treatment but it is quickly broken down by enzymes and approximately one third of the patients that are treated in this way have a recurrence of the arrhythmia. By binding the adenosine to a ligand it is possible to increase the time it can remain in the body before being broken down.

In this research suitable receptor ligands are prepared at Deakin University and radiolabelled at with iodine-123 at ANSTO for use in Single Photon Emission Computer Tomography (SPECT) studies. These studies will assess the bioavailability and half-life of the ligands. SPECT will also provide information on the density and function of the A1 adenosine receptor.

All that glitters...

The photo above shows the semi-precious gem lapis lazuli. The blue colour is caused by the same species found in blast furnace slag, which unlike the gem, is sometimes buried. It provides a reducing environment, which in concrete favours the retention of radioactive ions preventing them leaching into ground water. A sulfide anion complex causes the blue colour.

Red, yellow and the blue colours are caused by different sulfide anions and can now be explained in terms of specific sulfide anions with two, to four sulfur atoms forming the negatively charged complex. This work used computational chemistry done by Associate Professor Ellak von Nagy-Felsobuki and using ANSTO computing facilities to assign the spectral features to specific polysulfide anions. Further work is being carried out with anions that contain more than four sulfur atoms and relating the infrared spectra the colour of specific ions.

Mineral - lapis lazuli.

Delivering the good samarium

Professors John Webb and Robin Giles of Murdoch University and Harvey Turner of Fremantle Hospital are developing a two stage tumor localisation process to assist in the imaging of tumors. In the first step a monoclonal antibody against a tumour cell antigen (which consists of about 6 amino acid pairs, called hapten) can be injected into a vein from where it will be able to find tumour cells and stick to their surface. In the second step, a chelating agent bound to a hapten molecule is used to carry samarium-153 to the tumour, where it bonds to the hapten and is able to specifically irradiate the tumour.

The samarium-153 is made in ANSTO's HIFAR reactor.

In the current research a number of chelating agents were synthesised which have a different mixture of carboxylate and phosponic groups. The best one for bonding the radioisotopes, and bonding to the hapten was selected; there are two ways of connecting, and the next step is to evaluate which one of these is going to be more stable inside living organisms.

Also see a report on the next page on the award winning work of Dr James Camakaris on the use of copper-64 to advance our understanding of Menkes disease.

AINSE Awards

Gold Medals

1999 AINSE Gold Medal

The 1999 AINSE gold medal for excellence in research was presented to Dr James Camakaris at the Council meeting held on Thursday 25 May Lucas Heights 2000 following his presentation entitled *Use of copper radioisotopes to investigate copper metabolism in normal and mutant cultured cells.*

Radiocopper has been utilised to answer fundamental questions about the role of the trace element copper in health and disease. This is part of a major program of research on copper metabolism being undertaken by Associate Professor Jim Camakaris at the Department of Genetics, University of Melbourne.

Copper is essential for life as it is required by a number of enzymes (biological catalysts) in living cells. However, copper levels need to be tightly regulated as excess copper is potentially highly toxic. There are several acquired and inherited diseases due to either copper deficiency or copper toxicity. The inherited diseases provide "experiments of nature" which allow the normal genes and proteins involved in copper transport to be identified and characterised. Jim Camakaris and his research group (also in collaborative studies with Professor Julian Mercer) have focused on the function of the Menkes (MNK) protein. Mutations in the gene coding for this protein cause a potentially fatal inherited copper deficiency disorder in humans, Menkes disease. Using copper-64, Jim Camakaris and research colleagues have discovered that the Menkes protein functions as a molecular pump that drives copper across biological membranes. This has laid the framework for current studies where mutant forms of the MNK gene have been introduced into cells and the activity of the various mutant proteins is being assessed. This will allow detailed structure-function analysis and will also be important in determining which Menkes patients may benefit from copper therapy. Using radiocopper kinetic studies the researchers found that a normal copy of the MNK gene introduced into Menkes mutant cells can correct the fault in copper metabolism. This is an important and exciting finding in terms of possible future gene therapy.

Dr James Camakaris, from the University of Melbourne, receives the AINSE Gold Medal from Professor Ron MacDonald, AINSE President

The Camakaris group has also commenced studies with a research group in Germany on the role of copper in Alzheimers disease - studies that also depend on the crucial radioisotope of copper, copper-64.

Dr Camakaris was presented with the 1999 AINSE Gold Medal for excellence in research at a plenary meeting of AINSE Council and Specialist Committees on Thursday 25 May held at Lucas Heights.

1999 AINSE Student Gold Medal

The 1999 Student Gold Medal for excellence in research was awarded to Darren Goossens, from Monash University, for excellence in research carried out by a postgraduate student. Darren was awarded the medal on Thursday 25 May Lucas Heights 2000 following his presentation entitled *Magnetism in Two Dimensions*.

Dr Darren Goossens has been a very innovative and successful AINSE Postgraduate Scholar. His PhD thesis on magnetic ordering in $Mn_xZn_{1-x}PS_3$ was recently accepted. The work has been completed at Monash University under the guidance of Dr Trevor Hicks in the Department of Physics. The quality of his work was recognised on 25 May at the presentation, by AINSE president Professor Ron MacDonald, of the AINSE Gold Medal for excellence in research.

Rietveldt analysis of neutron powder patterns, taken on instruments arrached to HIFAR, of two-dimensional magnetic structures were made by Darren. This work involved dealing with the highly asymmetric Bragg peaks that come from two dimensional magnetic order, something which is certainly not routine.

Darren's work on two dimensional magnets, done at Lucas Heights and the Institut Laue-Langevin, has not only involved neutron scattering, he has integrated this work with high and low field magnetic work done at Monash University. While most of the two dimensional magnets, such as those which form the basis of the new high temperature superconductors, are square or rectangular lattices, Darren's material is a honeycomb lattice a type of which very few have been investigated before. His modelling has shown that the order is almost entirely stabilised by the magnetic dipole interaction.

Darren was also responsible for a world first measurement of the low energy states of magnetic rare earth atoms, which discriminated against other processes normally present. The experiment was done, using the energy change of neutrons after scattering, on the LONGPOL polarised neutron spectrometer at Lucas Heights. The measurement showed the superior discrimination of this method for measuring the effects of the surrounding atoms on the electron energies of these magnetic atoms.

Professor Ron MacDonald awarding the 1999 Student Gold Medal to Darren Goossens from Monash University.

Darren is currently a postdoctoral fellow in the Physical and Theoretical Chemistry division of the Research School of Chemistry at ANU, working in the Disordered Materials group headed by Dr Richard Welberry and will soon be taking up a position with the ANSTO neutron Scattering Group. The group uses synchrotron and laboratory-based x-ray experiments to explore the structure of disordered materials including molecular crystals such as benzil ($C_{14}O_2H_{10}$). This involves Monte Carlo modelling of the structure and simulation of the diffuse scattering, followed by an iterative fit to the measured data.

The AINSE Winter School

Nuclear Techniques Applied to Natural Processes

The fourth AINSE Winter School on nuclear techniques applied to natural processes was held at the Lucas Heights Science and Technology Centre from 1 to 5 July 2000 with a great deal of input from ANSTO and university staff.

Introduction

The Winter School was held over a five-day period, from Saturday to Wednesday. Thirty four students participated in the Winter School; they consisted of 16 physics majors, 8 chemistry majors, 5 engineering majors, two environmental science majors, one medical physics, one geology major and one student majoring in archaeology.

A background lecture and experimental session was provided for each of the following topics:

- Neutron Scattering
- Ion Beam Experiments
- Natural Radioactivity
- Radioactivity and the Living World

Marcus Kitchen, Monash University and Minh Le, University of New South Wales.

Samuel Wang, University of Canberra.

- Radiation Chemistry

David Malin from the Anglo Australian Observatory delivered a fascinating after dinner lecture entitled *A Universe of Colour* on Saturday 1 July. This is the fourth time David has given a talk at the Winter School and he once again showed an excellent range of photographs of astronomical and terrestrial objects, including satellite photographs of the Earth at night.

Tony Klein from The University of Melbourne delivered an after dinner lecture entitled *Fun with Neutrons* on Monday 3 July. Tony provided a stimulating summary of his research in the field of neutron scattering.

Lyndon Patterson, La Trobe University.

Selected student comments

The program surpassed any of my expectations, and the overall experience was simply overwhelming.

It gave me a new outlook on industry based research, which I used to dismiss as of no interest.

The staff and demonstrators are to be commended on their enthusiasm, which created a set of stress-free, learning activities in an enjoyable atmosphere.

I found that the gathering of young scientists from universities all around the country, encouraging them to interact, was one of the most enjoyable aspects of the Winter School.

I would like to thank the ANSTO staff, who gave up their time and shared with me their passion for nuclear science.

The benefits of the experience seem to be a well kept secret, and I intend to assist in promoting of AINSE next year to overcome this.

I found the chosen mix of experimental and observational experiences to be of great interest, and will recommend the Winter School highly to future 3rd Year students at RMIT.

I would like to thank you, your staff and all those concerned with the smooth running of the Winter School; it was awesome.

The School has renewed my interest in Physics and shown me where I want to be with my career in the future.

I think that ANSTO would be one of the best organisations to do postgraduate research with. Everyone's a bit shocked at home, because I've been extolling the virtues of nuclear technology, and they didn't think I could be converted.

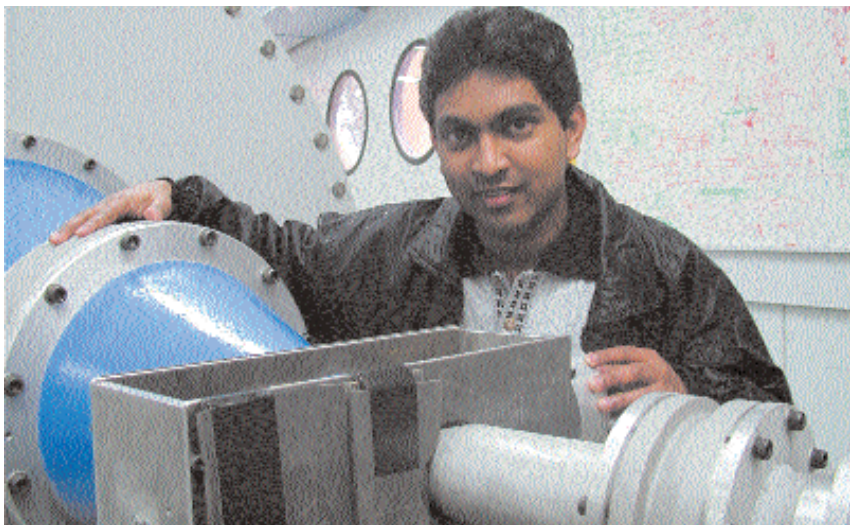
Many experiments in disciplines other than my own was one of the highlights and this accentuated the point that science today is very cross disciplinary.

I loved it! Still extremely excited.

Angie Loh, University of Western Australia.

Tamka Bell, University of Queensland, Tim Ralph, Macquarie University, and Yasmin Antwertinger, Northern Territory University.

Louise Hughes, Newcastle University.



Shyam Bhaskaran, University of Sydney.

Thanks

AINSE is indebted to Professor Helen Garnett, ANSTO's Executive Director, for supporting the Winter School, to the many ANSTO staff members who contributed their time and talent, to Gerald Laurence, Julia James, David Sangster and Ken Doolan from the universities involved, and to the two after-dinner speakers, David Malin and Tony Klein.

2000 Conferences and Workshops

There were 222 participants at the conferences and 105 at the workshop/symposiums. AINSE conferences play a major part in the information exchange process for scientific and technological information, providing a forum for debate and an opportunity for young researchers to present their work. Participants from member organisations are assisted with travel and accommodation expenses and receive a discount on registration fees.

Plasma 2000

Plasma 2000 was held on 10 – 15 December 2000 at University of Adelaide as part of the Australian Institute of Physics Congress. There were 51 participants including 6 from overseas and 12 students; 23 papers and 17 posters were presented. The medal for best student oral presentation was awarded to Mr Andreas Danielsson, The Australian National University, and best poster presentation was awarded to Mr Felix Chueng, Flinders University.

18th Nuclear and Particle Physics Conference

18th Nuclear and Particle Physics Conference was held on 10 – 15 December 2000 at University of Adelaide as part of the Australian Institute of Physics Congress. There were 85 participants including 5 from ANSTO, 6 from overseas and 34 students; 41 papers and 54 posters were presented. The medal for best student oral presentation was awarded to Ms Annette Berriman, The Australian National University, and best poster presentation was awarded to Mr Stewart Wright, University of Adelaide.

David Sangster, AINSE Honorary Fellow, presenting Sheila Devasahayam, The University of Queensland, with best poster award at Radiation 2000.

Radiation 2000

Radiation 2000 was held on 26 – 28 November 2000 at AINSE, Lucas Heights. There were 77 participants including 10 from ANSTO, 8 from overseas and 22 students; 40 papers and 21 posters were presented. The medal for best student oral presentation was awarded to Nadine di Bartolo, and best poster presentation was awarded to Sheila Devasahayam.

2nd AINSE Symposium on Neutron Scattering Powder Diffraction

The 2nd AINSE Symposium on Neutron Scattering Powder Diffraction was held on 22 June 2000 at AINSE, Lucas Heights. There were 47 participants including 14 from ANSTO, 4 from overseas and 15 students; 15 papers and 8 posters were presented.

Neutron Scattering Workshop

The Neutron Scattering Workshop was held on 15 – 17 October 2000 at ANSTO, Lucas Heights. There were 33 participants including 11 from ANSTO, and 5 from overseas; 9 papers were presented and there were 3 open discussion times.

Bio/SIMS Workshop

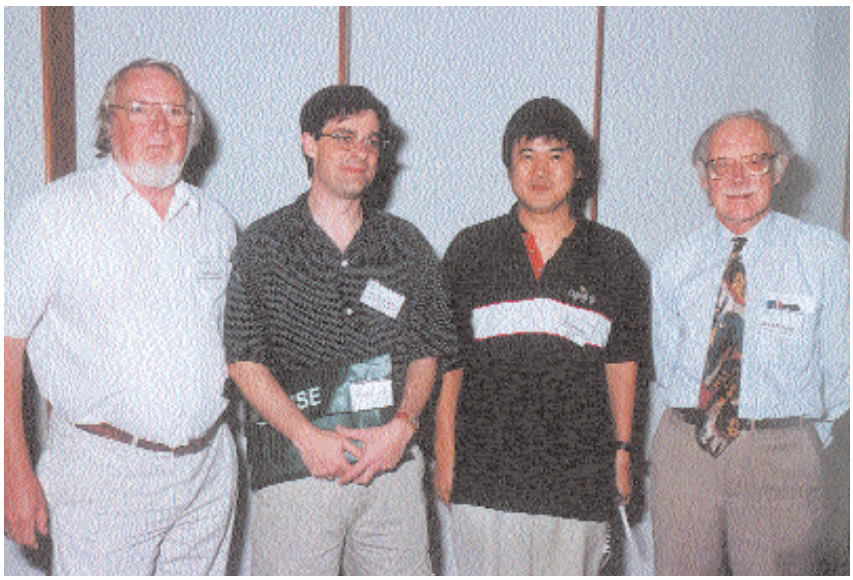
The Bio/SIMS Workshop was held on 28 – 29 November 2000 at AINSE, Lucas Heights. There were 25 participants including 5 from ANSTO and 2 students; 16 papers were presented.

Back row, left to right: Dr Richard Lim (University of Technology Sydney), Assoc Prof Alan Marshall (La Trobe University), Assoc Professor Barry Noller (University of Queensland).

Middle: Mr Desmond Menon (Monash University), Dr Graeme Esslemont (University of Canberra), Mr Rob Russell (ANSTO), Ms Carol Browne (University of Western Sydney), Ms Roslyn Howse (Central Queensland University).

Front: Dr Kathryn Prince (ANSTO), Dr Ross Jeffree (Workshop Convenor, ANSTO) Dr Scott Markich (ANSTO), Professor Rod Simpson (University of New England), Ms Sharyn Kratzman (University of Queensland), Dr Martin Riddle (Australian Antarctic Division International).

David Sangster, AINSE Honorary Fellow, presenting Nadine Di-Bartolo, ANU and ANSTO, with best oral presentation at Radiation 2000.



AINSE Vice President Ron Cooper(l), and conference convenor David Sangster (r) with two of the invited speakers, Michael Huels (University of Sherbrooke, Canada), and Masumi Abe (National Institute of Radiological Sciences, Japan), at Radiation 2000.