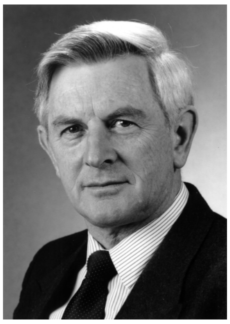
INTRODUCTION — 2000 IN REVIEW



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Director, RSES

The Research School of Earth Sciences (RSES) has a national charter to achieve excellence in basic and strategic research in earth sciences, emphasising the sub-disciplines of geophysics and geochemistry and their interfaces with geology. The School fulfills training responsibilities at both graduate and postdoctoral levels that are enhanced by being able to offer facilities and equipment for research which are unique within Australia. RSES is increasing its focus on issues which have long-term relevance to Australian needs or which exploit the unique geographic location of Australia. Through 2000, RSES has accordingly expanded its research and research training in the fields of global change and environmental processes while continuing its traditional national roles in basic research in geophysics and geochemistry, particularly in the subdisciplines of seismology, experimental high pressure and temperature studies, isotope geochemistry and geochronology.

My term as Director finishes in 2001. The process of selection of a new Director was completed late in 2000 with the appointment of Professor Mark Harrison, Professor and Chair, Department of Earth and Space Sciences, Institute of Geophysics and Planetary Physics, University of California, Los Angeles. Professor Harrison will take up the post in mid-2001 and, during the transition period, will be a frequent visitor to RSES. Professor Harrison completed his PhD in noble gas geochemistry and geochronology at RSES in 1981 and since that time has held academic and research positions at ANU and State University of New York at Albany before moving to University of California, Los Angeles in 1989. His term as Director will begin in the midst of significant change for RSES and for the Institute of Advanced Studies (IAS) as a whole. As noted in the 1999 Annual Report, the IAS will enter the Australian Research Council (ARC) and Department of Education and Youth Affairs (DETYA)-funded research system which supports all other Australian universities. (Currently, the IAS is funded by DETYA through a separate block grant.) The ARC and DETYA research funding system has itself undergone significant change both in the organisation of ARC research funding panels and programs, and in DETYA programs to fund research infrastructure.

From 2002, RSES will, over a four-year transition, lose ~20% of its block grant recurrent funding and must compete to potentially regain or increase its research funding via ARC programs. These include Discovery Grants, Linkage Grants, Research Fellowships, Centres of Excellence, and Research Infrastructure, Equipment and Facilities Grants. ARC will also introduce new Federation Fellowships at Professorial salary levels that are competitive with US or European salaries,. RSES Groups have been divided into four 'cohorts' for staged entry into the ARC funding system and the first cohort will encompass seismology and petrophysics, environmental geochemistry, geochronology and ore-genesis research. The first cohort will lodge applications for research grants in 2001 for funding that would commence from 2002.

With the publication during 2000 of several reports on research and innovation in Australia which emphasised the relative decline in university funding for teaching and research, the flight from science and engineering by secondary and tertiary students, and the loss of morale or departure from Australia of active leading researchers, the Commonwealth Government announced a future funding scenario whereby significant additional funds would be awarded to the ARC for competitive allocation to the university sector. Although only a small proportion of these new funds will become available in the 2002 calendar year, larger increases planned for 2003-2006 offer the prospect of real future growth in scientific research. For RSES, and for a new Director coming to RSES, this prospect of additional funding for new, well-conceived and relevant research objectives presents exciting opportunities. The ensuing report of RSES activities demonstrates that current research is high quality, so sound arguments can be made for retention of current activities and for strong growth of key areas. Thus, the opportunities for growth and, more importantly, to initiate new fields of research rests with RSES successfully competing in the ARC programs and for other external funds.

In the changes to funding of research and research training which have followed the 1999 White Paper, "*Knowledge and Innovation*", there is an increasing emphasis on research training and on timely completion of higher degrees. RSES offers a stimulating research environment which is second to none in its staffing and facilities. However, in the absence of an in-house undergraduate stream and as a consequence of the failure of Government policies to encourage students to leave their undergraduate university for a new intellectual environment, RSES is not currently recruiting desirable numbers of new graduate students. RSES has experienced growth in the numbers of students undertaking research in environmental earth sciences and on issues related to global change and human impacts on the physical environment. However, few prospective students seek to undertake basic or strategic research in RSES's traditional strengths in solid earth geophysics, and mainstream chemistry and physics of earth materials. That is unfortunate because these basic science fields underpin exploration for and development of minerals and energy resources. They also provide fundamental insight into catastrophic events such earthquakes and volcanism that is essential for planning and risk assessment. Although current employment demand in the mineral industry is depressed, there is clearly both ongoing and long-term need for earth science graduates with geophysics and geochemistry training.

RSES is exploring ways in which its strengths, in geophysics in particular, may be used in the wider higher education system, possibly by encouraging MSc enrolment as an alternative to the Honours year. A number of factors point to the desirability of shifting from the traditional Honours with research project emphasis, to a fourth year of advanced coursework, followed by a research-oriented fifth year in the chosen sub-discipline, i.e. BSc followed by MSc. This is the pattern in most European universities, and in North America. This change would acknowledge that the breadth and depth of knowledge and experience necessary for recruitment as earth science professionals cannot be taught or learned in only three years of tertiary coursework. While the independence, self-discipline and self-reliance which are core elements of the Australian 'Honours year' remain great strengths, Australian students are often only well-grounded in selected sub-disciplines of earth science and lack essential career skills in geophysics, mathematics or chemistry. With changes to DETYA funding of advanced training and of research, RSES will explore opportunities to partner with Departments of Geology and Physics at ANU and with other universities in the effective delivery of MSc level courses and research training as part of a general move towards five-year training for professional scientific careers.

The current RSES Strategic Plan, published in the 1999 Annual Report, has an integrating theme of "*Earth Dynamics and Global Change*". The 2000 Annual Report, confirms this new focus. For example, in the "*Earth Dynamics*" context the Environmental Processes Group explores the dynamics of soil production, transport and erosion in Australian landscapes by means of cosmogenic beryllium isotope (^{10}Be) abundances and also via optically stimulated luminescence (OSL). This research is essential to scientific understanding of Australian soils and weathering profiles and thus to the major economic issues of land management in agricultural and forestry regimes. In another example, palaeomagnetic facilities at the Australian Geological Survey Organisation (AGSO)-ANU jointly operated Black Mountain Palaeomagnetic Laboratory were deployed to study weathering profiles in the Kalgoorlie district of Western Australia. This work, part of the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME) program within RSES, revealed that Tertiary, Jurassic and Palaeozoic weathering imprints — hundreds of millions of years old — are still preserved within the weathering profiles of the area. The OSL technique, in contrast, reveals rapid changes in other terrains. It has successfully established uplift rates over the past 100,000 years in the Kanto Plain in Japan. This information is crucial to a collaborative pilot study with Japanese colleagues, whereby the various sites under assessment for geologic and tectonic suitability for safe disposal of waste materials. The rapidity of uplift and erosion in active mountain-building regions has also been confirmed by Ar-Ar dating techniques, which have unravelled the temperature/time history of rocks in the Victoria Range, South Island of New Zealand. A further technique, also used by the Geochronology and Isotope Geochemistry Group, deploys the Sensitive High Resolution Ion Microprobe (SHRIMP) to analyse the lead, thorium and uranium isotopes occurring as trace components in the mineral titanite (sphene) in high pressure metamorphic rocks. In the context of the mineral assemblages and petrography of certain eclogite facies calc-silicate rocks, this technique showed that these Alpine rocks had been uplifted at remarkably rapid rates of 1.5 to 3.4 cm/year during the most active phase of buoyant rise. The examples summarised demonstrate the variety of complementary techniques which are being applied within RSES to obtain factual information on the evolution, uplift and erosion (exposure) of the Earth's surface. A further and very innovative part of the RSES work on "*Earth Dynamics*" is modelling by the Geodynamics Group of interactions between solid-earth deformations and surface processes. In 2000, earlier foundations have been extended to modelling landscape development in glaciated mountain belts and to modelling of accretionary prisms — moreover the latter has now been extended from two-dimensional to three-dimensional scales. A further contribution to the theme of "*Earth Dynamics and Global Change*" came from the Geodynamics Group who complemented the aforementioned observational work on soil formation and transport with theoretical models of soil transport processes.

The most direct information on the dynamics of the solid earth is derived from precise geodetic measurements. In the Geodynamics Group, observations using the mobile Global Positioning System (GPS) receivers have been directed to our near neighbour, Papua New Guinea, via a collaboration with the University of Technology at Lae and with the Rabaul Volcano Observatory. A major earthquake (magnitude 8) occurred in New Ireland followed by numerous aftershocks only a few weeks after setting up GPS sites spanning the active boundary between the Pacific Plate and the South Bismarck Microplate. The opportunities and rationale for further intensive studies of this area will therefore be kept under review, because there are opportunities to advance basic research in global geodynamics, in parallel with monitoring a tectonically-active and geologically-complex region in Australia's neighbourhood. Disincentives include the costs and logistical difficulties of research in this remote tropical region. However, this type of research is crucial to the recognition and monitoring of major natural hazards such as earthquakes, volcanic eruptions and tsunamis (tidal waves). The RSES Seismology Group has already (1999 report) undertaken the RELACS project to locate anomalies related to magma chambers beneath Rabaul caldera. On a broader scale the global seismic tomography experiments of the Group (see this and previous annual reports) have painted a dynamic three-dimensional map of the Southwest Pacific region that extends more than a thousand kilometres into the Earth's deep interior.

This year's annual report from the Seismology Group also illustrates the links between development of theory and modelling, and the application of real-earth observational data. Recording and collecting that data present major challenges, because we have to deploy staff and infrastructure in inhospitable and previously inaccessible locations. However, a collaborative experiment between the New Zealand Institute of Geological and Nuclear Sciences and the RSES enabled use of seismometers from RSES and the Major National Research Facility (ANSIR) for a successful summer program in the Trans-Antarctic Mountains. The same instruments were later deployed in the Western Australian craton in a project designed to delineate, using seismic tomography techniques, deep crustal and upper mantle structures beneath the major crustal divisions of Western Australia.

The "*Earth Dynamics"* theme also encompasses the work of the Geophysical Fluid Dynamics Group where the emphasis is on fluid and liquid behaviour rather than that of the solid earth. The applications are widespread, ranging from ocean/atsmosphere interactions and ocean circulation patterns, to the structure and dynamics of mantle plumes and diapirs on both Earth and Venus. In 2000, the Geophysical Fluids Dynamics Group commenced operations in purpose-built laboratories in a new building of RSES, where they have recommissioned the 'Geophysical Flows Rotating Table', together with improved facilities for their ongoing emphasis on experimental fluid dynamics research.

Turning from the "*Earth Dynamics*" aspect of the School's research theme to "*Global Change*", a major unifying theme evident in the 2000 Annual Report is the development and applications of complementary and overlapping techniques of numerical age determinations on a variety of geological and anthropological materials. With strong social, political and scientific interests in understanding Earth behaviour in various systems on decadal to millennial time scales, the Annual Report documents both advances in methods for age determinations of these geologically-young materials, and applications of those techniques to the understanding of rates and processes of Global Change. In collaboration with the Research School of Physical Sciences & Engineering (RSPhysSE), which houses the Tandem Accelerator, the carbon-14 method of age determination combined with our new techniques of low-blank radiocarbon extraction, has facilitated the reliable dating of materials 40,000 to 60,000 years old (Environmental Processes Group). Further refinement of this technique should permit dating of materials older than 60,000 years. Accordingly, it will become increasingly important to cross-calibrate the carbon-14 timescale against measurements obtained by independent in-house techniques such as electron spin resonance, optically stimulated luminescence and U-Th dating. This is one of the many examples whereby interaction between RSES research groups is mutually beneficial. Its ultimate applications include measuring sea level change, deciphering palaeo-climatic records, documenting major volcanic events, and most importantly, delineating archaeological parameters that in turn shed light on the early indigenous occupation of Australia.

The socio-economic impact of potentially catastrophic climate change in response to greenhouse gas emissions is of widespread concern. Predicting future climates requires understanding of past climate change. A substantial component of RSES effort is therefore directed towards understanding both the magnitude and rapidity of spontaneous natural climatic fluctuations. Certain corals may retain records of annual cycles of sea-surface temperature and salinity that are relevant in this context (Environmental Geochemistry and Geochronology and Environmental Processes Groups). In 2000, work on modern and mid-Holocene (to 8000 years before present) sediments from islands offshore from the Sepik River in Papua New Guinea has revealed evidence for rapid regional climate change from drier to moist conditions around 5700 years ago. Rapid climate shifts in the recent past are of particular interest in documenting natural climate variability and potentially valuable for identifying precursor signals for, and causes of, such changes. Collaborative work with Indonesian colleagues is documenting past behaviour of the "Indian Ocean dipole", a climate oscillation associated with ocean through-flow between the Western Pacific Warm Pool and Indian Ocean. Major sea-surface cooling in 1994/95 and 1997/98 is tentatively correlated with severe rainfall and drought cycles in the region, and with partial loss of reef ecosystems. Past climatic impacts on coral reef systems (particularly the Great Barrier Reef) have been documented from trace-element abundance patterns in the "growth rings" of corals. These measurements were made with our laser-ablation ICP-MS system. Other in-house analytical facilities have likewise proved invaluable, including mass spectrometric measurements of oxygen isotopes, and trace elements to monitor flood-plumes, land-sourced groundwater and nutrient fluxes. These projects are laying the basis for distinction between natural variability and changes related to human occupation and land-use in Australia, with particular emphasis on developing a predictive capacity to warn of damage to the coastal and island reef systems of our region.

In addition to the integrative theme of "*Earth Dynamics and Global Change*", RSES research can be subdivided into four programs:

a) Origin and Evolution of the Earth — Mantle, Crust and Hydrosphere
b) Structure and Deformation of the Crust and Mantle
c) Fluids, Melts and Mineralisation
d) Climates, Landforms and Ocean/Atmosphere Dynamics.

The body of this report highlights contributions to these programs, grouped according to RSES organisational structure around sub-disciplines and major facilities (including technical support).

Significant additions to RSES analytical capacities include the commissioning of a new TRITON thermal ionization mass spectrometer, and a NEPTUNE ICP-multicollector mass spectrometer, with laser-ablation sampling, which arrived in late 2000. Following applications to the ARC's Research Infrastructure, Equipment and Facilities Program (RIEF) and the ANU Major Equipment Committee, RSES will, in 2001, acquire a new electron microprobe (Petrochemistry and Experimental Petrology Group) and a new electron spin resonance spectrometer (Environmental Geochemistry and Geochronology Group). These successful applications were joint initiatives that have included partner universities and ACT-based science organisations. The Australian Geological Survey Organisation (AGSO) deserves special recognition for its support for the RIEF proposal to purchase a new electron microprobe to replace the 17-year old instrument that is still in use.

Our close scientific collaboration with AGSO in the field of geochronology is evident in the inclusion in this Report of selected research contributions from AGSO staff co-located with RSES facilities, who are part of both scientific communities on a day-to-day basis. AGSO and RSES jointly operate the Major National Research Facility for advanced seismology research — ANSIR. Deployments of ANSIR instruments is determined by the ANSIR Board and Director and, experience to date suggests that this will provide an effective means of facilitating internationally competitive seismology research by Australian CRCs, universities, AGSO, CSIRO and industry — the last through organisations such as the Australian Mineral Industry Research Association (AMIRA).

As noted in the 1999 Annual Report, RSES sought growth funding from the Institute Planning Committee (IPC) for a new initiative expressed in the unifying theme "*Earth Dynamics and Global Change*". RSES also led a consortium approach to the IPC for growth funding in the area of "*Global Change and Environmental Research*". This proposal rests on the merits and strengths of current collaborations and historical links in relevant fields with RSPhysSE, Pacific and Asian Studies (RSPAS) and Biological Sciences (RSBS), and with the Centre for Resource and Environmental Studies (CRES). The IPC allocated $1.2 million in 2001 and $1.5 million per annum from 2002 onwards to an IAS-focussed program that includes RSES, RSPAS, RSPhysSE and CRES. On the basis of this growth funding RSES has advertised positions in the Environmental Geochemistry and Geochronology Group and in the Geodynamics Group. It is also intended to advertise joint positions with RSPhysSE to further develop Accelerator Mass Spectrometer and Thermal Ionization Mass Spectrometer applications of dating geologically young materials; and with RSPAS to ensure access and productivity in age determinations for anthropological and archaeological research, and to pursue links to human impacts on, and responses to, climate change. The RSES work on carbon measurements in soils and its links to the carbon cycle and climate change aspects of greenhouse science research are significant factors which have developed into collaborations and a joint appointment located in RSES between RSES and RSBS, including CRC Carbon Accounting. The establishment of jointly funded positions between RSES and three other Research Schools, in addition to the two very successful joint positions in Ore Genesis research between Department of Geology and RSES, are symptomatic of the growing importance of cross-disciplinary research. Indeed, it highlights the multidisciplinary nature of most environmental research, particularly that of global socio-economic significance.

RSES has continued to collaborate with ANUTECH and its subsidiary scientific instrument manufacturing company Australian Scientific Instruments (ASI), in the commercialisation of ANU intellectual property sourced within RSES. The marketing and construction by ASI of the 'Paterson' high pressure gas apparatus for petrophysics research has continued successfully, and three 'Geophysical Flows Rotating Tables', prototyped within RSES, have been delivered to North American universities. However, the major project for ASI remains the manufacture of SHRIMP, with most of 2000 being devoted to the construction of a SHRIMP-II for the Ministry of Land and Resources in Beijing, China. RSES has continued developmental work on a multicollector analytical system for installation on SHRIMP II and has made significant modifications to the prototype SHRIMP-RG as steps towards improved beam intensity at high mass resolution.

The ability to design and construct prototype scientific instruments for laboratory or field observations and experiments remains at the core of RSES research. This is particularly noteworthy because workshop facilities and technical support staff have undergone major contraction in Australian universities as a whole. RSES is particularly appreciative of the motivations, creativity and expertise of its technical staff. In addition to supporting RSES research, workshop and technical staff have been invaluable in collaborations with ASI, and in technology transfer related to commercialisation of ANU intellectual property.

A further important facet of RSES is the practical and important task of encouraging and appropriately managing the access to RSES research facilities by external researchers and agencies, including both Australian and overseas visitors. In part, this is effected through special contractual arrangements for shared scientific purposes, as between RSES and AGSO for geochronological research, and in the operation of ANSIR and the jointly-operated palaeomagnetic laboratory. Access to our geochemical facilities is also available through Precise Radiogenic Isotope services (PRISE) which, through 2000, has been formally part of ANUTECH. With changes to both the DETYA and ARC funding of RSES and to the operation of ANUTECH, PRISE staff will formally become ANU academic staff with the special designation of PRISE Fellows. The operation, management and funding of PRISE will continue as previously, reflecting the successful business model which has evolved through experience. During 2000, PRISE has offered expertise and enhanced access to Argon/Argon dating techniques and to the acquisition of ICPMS and laser-ablation ICPMS trace-element and isotopic data. Increasing demand for age-determination, and the need to measure geochemical tracers for environmental and archaeological research may see a case developed for expanding PRISE expertise to these fields, in addition to its current capacities. The PRISE section of the 2000 Report documents the importance of PRISE in hosting numerous international and Australian visitors to RSES, particularly for SHRIMP analyses. It also summarises the personal research contributions of PRISE staff. Although there are times when instrument repair or development, or pressures resulting from commitments to AGSO and PRISE visitors result in interruptions or delays to RSES programs, the perceived responsibilities of RSES to provide external access to unique facilities and the demonstrable high usage rates (efficiency) of the facilities under multiple usage are counterbalancing aspects of the PRISE unit. Most importantly, PRISE demonstrates the enhancement of the intellectual vigour, experience and scientific breadth that follows when the continuum of basic to applied research can be focussed and supported around a particular set of facilities and sub-disciplines.

The RSES Advisory Committee did not meet during 2000, but were informed and consulted on the submissions to the IPC. Delays in the appointment of the incoming Director, the pressures of busy timetables and uncertainties around the entry of ANU's Institute of Advanced Studies into the ARC funding system conspired against calling the Committee together. A meeting is planned for 2001 to meet the incoming Director and to review ARC-related issues of funding and research priorities.

With respect to staffing matters, Dr J. Braun was promoted to Level D (Senior Fellow) during 2000 and the gender imbalance in RSES was alleviated by appointments of Dr A. Reading in Seismology, Dr D. Rubatto in Geochronology and Isotope Geochemistry and Dr C. Meriaux in Geophysical Fluid Dynamics. RSES Administration has been ably led by Ms B. Payne (Executive Officer) and Ms T. Gallagher (Assistant Executive Officer). Change to an external contractor for cleaning services reflected economic pressures and was ably managed by Ms Payne and Mr E. Ward (Buildings & Facilities Officer).

Due to the generosity of Emeritus Professor and Mrs Paterson in establishing an endowment fund matched by the University's Endowment for Excellence, the University has established the Mervyn and Katalin Paterson Fellowship. This Fellowship will be awarded annually on a competitive basis to a postgraduate research student in RSES to assist the student to make a more extended overseas visit — for example, to attend an international summer school, gain laboratory experience with an overseas group or to attend a major international conference with field excursions or specialist workshops attached. The first award will be made in 2001. RSES expresses its thanks to Professor and Mrs Paterson for their generosity in making this award possible.

In the body of the Report which follows, selected aspects of RSES research are presented within the Research Group structure, together with details of theses completed, publications and research collaborations both within Australia, and internationally.