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Historical Records of Australian Science

Angus McEwan 1937–2018

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ABSTRACT

Dr Angus McEwan FAA FTSE who died on 5 September 2018, aged 81, was a renowned Australian fluid dynamicist, specialising in designing and conducting experimental studies in geophysical fluid dynamics, and providing outstanding leadership of national and international research programs in oceanography and meteorology.

Keywords: climate, fluid dynamics, meteor, mixing, oceanography, turbulence.

Early life

Angus was born in Alloa, a small town on the Forth River in Scotland in July 1937. After migrating to Australia at nine years of age, he left school before Matriculation at age fifteen in order to assist with the family's finances, and he enrolled at Caulfield Technical College to do a diploma in engineering. After six months of national service with the Air Force, Angus took a laboratory assistant job at the Commonwealth Aeronautical Research Laboratories (ARL) and was soon promoted to experimental officer. At ARL, he was working in a research environment alongside research scientists, and it was here that he first decided he'd like a career in science, and to do that he needed more qualifications. With a Commonwealth cadetship and a block exemption, he joined the last two years of a degree course in mechanical engineering at Melbourne University, and graduated with first class honours in 1961. At Melbourne University, Angus' growing interest in aerodynamics and boundary layers was inspired by Peter Joubert, a lecturer in fluid dynamics and later professor. Angus then went on to do a PhD at the University of Cambridge in the Cavendish Laboratory under the supervision of Dr Alan Townsend, one of the many famous fluid dynamicists in Cambridge at that time. It was in that laboratory that he developed a very close and fruitful working association with G. I. Taylor, a legendary figure who was credited with the origins of much of modern fluid mechanics, solid dynamics, meteorology and oceanography. Taylor was renowned for his clever experimentation in the fluids laboratory (Fig. 1).

Returning to Australia from Cambridge in late 1965, Angus went back to ARL for three years as a Research Scientist working on a variety of experiments on supersonic flow and the shape of ablating objects in a hypersonic airstream. His interests changed to experiments on waves, which were a diversion from the core interests of ARL and, with a Queen Elizabeth II Fellowship, he moved in 1971 to the CSIRO Division of Meteorological Physics at Aspendale in Melbourne. When his fellowship ended, he was offered a job there as a research scientist with responsibility for setting up a Geophysical Fluid Dynamics Laboratory (Fig. 2).

Research career

In some ways Angus did not have the normal background for a career in ocean and atmospheric research, where a first degree in mathematics or physics is more common. But his background in engineering, together with his experience during his PhD with both G. I. Taylor and Alan Townsend in Cambridge seemed to align perfectly with his

Fig. 1. Dr Angus McEwan and his 'rotating table' at the CSIRO Aspendale laboratory, around 1980. Fluid experiments are performed on such rotating tables in order to simulate the effects of the rotation of planet earth on fluid motions.

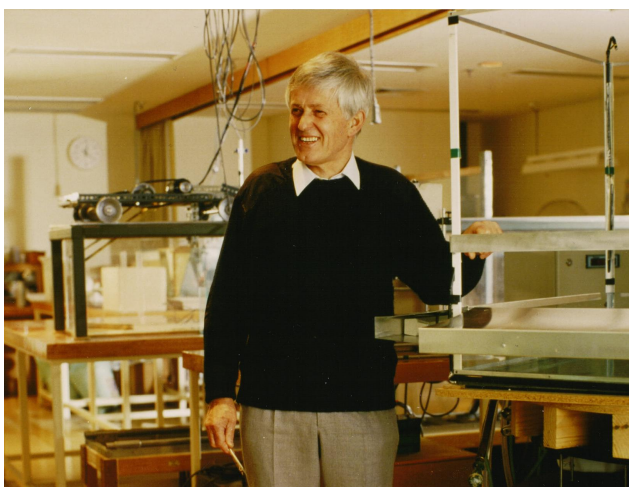

Fig. 2. Dr Angus McEwan during an Open Day at the CSIRO Marine Labs in 1991.

natural talents, because he became the pre-eminent experimentalist in Geophysical Fluid Dynamics of his generation.

Angus was known around the world for the sheer cleverness of how he conceived his scientific experiments. He was very imaginative in the way he constructed his apparatus, the configuration of the fluid, the way it was forced, and the way in which the fluid was visualised or measured. Because he was usually the first person in the world to perform an experiment in that manner, he often came up with results and insights that were highly original and have stood the test of time. In contrast, it is more common to follow an established experimental procedure, exploring many variations, and this approach to the field can flesh out a whole career. This was not Angus' way.

Angus made fundamental research advances in several areas, including non-linear wave interactions, turbulent mixing at both the 1 m and 1000 km scales, and cloud dynamics. All of this impact on the field of Geophysical Fluid Dynamics was made in the rather short fifteen-year period between 1966 and 1981.

The ocean is forced on long time and space scales of days or longer and 100 km or more respectively, and yet the internal waves in the ocean oscillate on time scales of hours and on vertical spatial scales of 1–1000 m. Moreover, the scale at which irreversible turbulent mixing occurs is even smaller, between 1 cm and 1 m. So there was a puzzle; how is it that the ocean is filled with waves that seem to have forgotten the manner in which they were forced, and why do these internal gravity waves exist over continuous and wide ranges of time and space scales? Much of Angus' research bore on this question, and he provided extremely elegant laboratory demonstrations of some of the key processes whereby the internal wave field becomes largely independent of space, even though the wave field is forced discretely in space and time, mainly by the wind blowing on the sea surface and by the ocean flowing over bottom topographic hills.

When Angus moved from ARL to CSIRO in 1969, he began a series of experiments on internal waves. He forced an internal wave in a tank of water that was vertically stratified with fresh water lying above salty water. As well as the dominant wave that he forced, after a while two other internal waves appeared. These parasitic waves were at half the frequency and half the vertical wavelength of the original wave, and they drew their energy from it.[1] These waves in turn could give rise to other waves at even lower frequencies and yet smaller vertical wavelengths. So here was a mechanism, an instability, that would take the energy from the large spatial scales of their generation down to smaller vertical scales where mixing could subsequently occur. This instability mechanism was named the Parametric Sub-harmonic Instability (PSI).

In 1975, Angus published a paper[2] describing an extremely elegant experimental procedure that demonstrated the Parametric Sub-harmonic Instability in its purest form. His previous experiments on this instability were performed in a rectangular fish tank, and now Angus wanted to check that the Parametric Sub-harmonic Instability in a laboratory setting that was not unduly influenced by the end walls of the rectangular tank. To do this he inserted a plastic cylinder horizontally into the rectangular fish tank, being careful to have the same known vertical stratification of the fluid inside the cylinder as in the original experiment. He then moved the whole fish tank (including the interior horizontal cylinder of fluid) horizontally to and fro. The vertical density stratification in the cylinder ensured that an internal wave was set in motion, and to his satisfaction, the parasitic waves grew after a time.

[1] McEwan (1971)
[2] McEwan and Robinson (1975)

Not satisfied with this rather clean demonstration of this new Parametric Sub-harmonic Instability, Angus noticed that there was viscous friction between his working fluid and the inside of the cylinder, which did slightly complicate the interpretation of the results, and he devised a most elegant experimental design to overcome this. Angus mounted the whole tank as a pendulum about a pivot point above the tank, with a large counterweight above this. He then arranged a motor to oscillate the whole counter-weighted tank, as a pendulum, and in his own words 'with careful adjustment of the crank throw and speed, the swing of the assembly could be synchronised precisely with the liquid inside the cylindrical cavity, so that negligible relative movement occurred, and the boundary-forced modes and mixing disappeared.' With this incredibly clever experimental arrangement, Angus achieved a very clear and unequivocal demonstration of the Parametric Sub-harmonic Instability, thus addressing the puzzle of how the spectrum of internal gravity waves in the ocean could be rather universal and continuous as a function of frequency and wavelength. This experimental design was typical of Angus' experiments; they were often this elegant, this bold. Angus' crystal-clear demonstration of this mechanism in the laboratory was a light-bulb moment for the whole field of ocean physics.

In another bold experiment[3] Angus decided to measure the efficiency of mixing in a fluid that is density stratified, with less dense water overlying denser water (typically fresher water overlying salty water). To do this he had to measure the force with which he oscillated a paddle in the tank. This oscillating paddle set a primary internal wave in motion, and by forcing at large amplitude many waves appeared in the tank, some of which were of sufficiently small scale and sufficiently energetic that they would break, much like ocean surface waves break at the beach. But not all of the energy of the waves ends up as vertical mixing of the fluid. Rather, much of it ends up as heat, with the fluid slowly warming over time. In addition, Angus had to take into account the energy that was lost to friction on the side walls of the tank. Notwithstanding these difficulties, he was able to find that the mixing efficiency was 25%. Today there is much on-going research on the topic of mixing efficiency, concentrating on finding and understanding the few locations where the mixing efficiency is not Angus' 25%.

Perhaps the most famous experiment Angus did was with Alan Plumb on simulating the cause of the Quasi-biennial Oscillation.[4] This is a phenomenon that occurs in the equatorial stratosphere (20–35 km high in the atmosphere) where it is observed that the mean flow reverses in sign from west to east and then from east to west in a regular fashion with a period of just over two years. The period is actually close to twenty-eight months. Theoreticians were at a loss to explain why it should display this regular oscillation, spending just a little more than twelve months moving in each direction; what could possibly cause this instability to not behave itself and do its thing with a period of exactly twenty-four months? The height where the speed is maximum descends, while at the same time the strength of the flow increases, until a weak flow of the opposite sign appears at high altitude and strengthens while descending. Angus devised a test of a new theory of Alan Plumb's of this Quasi-biennial Oscillation. The idea was that equal and opposite pairs of internal waves would ascend while moving westward in one case and eastward in the other. Once a mean flow was established, the waves moving in the direction of the flow would deposit their momentum at the lower edge of this flow (by a process known as 'critical layer absorption'), while those moving in the opposite direction would travel through this height and deposit their momentum higher up.

Angus set up an experiment in an annulus of fluid that was stably stratified with less dense fluid overlying denser fluid. The fluid was initially stationary, and it was forced with a pattern of vertical undulations at the bottom, with an annular pattern of forcing of wavenumber eight whereby eight parts of the floor moved upwards while the eight parts in between moved downwards, with the whole pattern repeating in a cycle. This standing-wave pattern of forcing is equivalent to imposing a wave travelling to the east together with an equal wave travelling to the west. The forcing was thus unbiased in that it did not prefer the eastward or the westward direction. The experiment was remarkably successful, with mean flow being induced and reinforced by the 'critical layer absorption', with the flow strengthening as it descended, and then being replaced by a descending and intensifying jet of the opposite sign. This laboratory demonstration provided convincing evidence to the theoretical atmospheric scientists that the QBO was not linked to the annual cycle and could be explained simply by the vertical propagation and dissipation of internal waves.

These are but a few examples of Angus' brilliance in experimental Geophysical Fluid Dynamics; his name will forever be associated with the PSI and QBO processes, and with 'mixing efficiency'.

Impact as chief of CSIRO oceanography

With the pending Law of the Sea Convention, the Fraser federal Government decided to inject new resources into oceanography. This was to be through the establishment of a new CSIRO Division of Oceanography, the building of a new dedicated oceanographic research ship, and the transfer of both the new Division of Oceanography and the

[3] McEwan (1983)
[4] Plumb and McEwan (1978)

Division of Fisheries to Hobart. Angus was appointed Chief of the Division of Oceanography in 1981.

Prior to the formation of the new Division, oceanographic research was seen primarily as support for Fisheries research. There were some great physical oceanographers in the former CSIRO Division of Fisheries and Oceanography—most notably Bruce Hamon, George Cresswell and Stuart Godfrey—but overall, there was limited capability, no dedicated research vessel, and little recognition of the importance of oceanography to a much broader range of issues.

CSIRO's Fisheries and Oceanography had occupied an idyllic location on the waterfront in Cronulla in southern Sydney, and there was no surprise that significant resistance emerged from many of the existing staff to the idea of moving from Cronulla to Hobart.

So immediately on his appointment to his new position, Angus faced three major and simultaneous challenges:

- he had to create a new Division, create an identity and a shared vision of that Division and recruit staff,
- he had to design and get the new laboratories built in Hobart, and
- he had to design and get the new ship built.

Angus decided the Division of Oceanography should start moving to Hobart as soon as possible, with existing staff given time to transfer and new staff recruited directly to Hobart. Angus's enthusiasm and the new investments meant that almost all of the oceanographic research staff eventually welcomed the developments and moved to Hobart. The Hobart staff were initially housed in the Reserve Bank Building in Macquarie Street while the new Marine Laboratories were being designed and built.

At the same time the new ship, the *R. V. Franklin*, Australia's first dedicated oceanographic research ship, was being built in Cairns. Angus developed good and lasting relations both with the German designer and the shipbuilders in Cairns, and as an engineer, he took a huge interest in the building of it and he carefully monitored its progress. One example is that when the shipbuilders were having problems with the spooling of the hydrographic winch, Angus drew on one of his many skills to prepare a few sketches of how to arrange the spooling; and of course, his idea worked. It was a great day for the new Division, and of course for Angus, when the ship sailed into Hobart in 1985. Operating as a National Facility, *Franklin* undertook a wide range of previously impossible scientific investigations all around Australia and put Australia on the international oceanographic map.

Angus also set about recruiting staff from all over the world. He recruited only the best people. There were many international visitors who came to Hobart to see the new lab, to interact with the new research staff, and to establish ongoing collaborations. Oceanographic studies ranged from the smallest scales of ocean turbulence and mixing, studies of local pollutions issues, such as jarosite dumping off southeast Tasmania, the impact of the potential pulp mill in northern Tasmania, the chemical characterisation of the ocean, and the ocean's role in global biogeochemical cycles and in climate variability and change.

Under Angus's guidance the Division was a great place to work. Angus had a vision of the importance of the new CSIRO division to Australia and the world. He encouraged scientists to work on the most challenging scientific problems and he encouraged excellence. Angus was a great mentor and supporter of his staff. Whenever possible he attended seminars and asked probing but friendly questions. He did not prejudge situations and would always listen to reasoned argument, but at the same time he led with authority. His affable, approachable, friendly personality, sociability and sense of humour all helped in this regard. Quoting a more recent Chief of the CSIRO's Ocean's and Atmosphere research unit, 'Angus was regarded by his team of research scientists as a fair and visionary leader. He was open to new ideas and rational argument, and willing to take risks with the science direction'.

The Division was a very friendly and supportive place to work for both staff and visitors. Many staff would turn up each day for morning and afternoon tea, and often Angus was there, mixing with everybody and discussing the full range of issues from science to current affairs. Angus regularly attended happy hours and hosted dinners and parties with staff, their families and visitors. He thought having an active social programme was important in developing morale and fostering camaraderie and developing the culture of the organisation. This camaraderie was evident in 1986 when the Division of Oceanography entered the Sydney-Hobart yacht race with the *Balandra*. Andrew Forbes was skipper and Angus was chief tactician.

The new Division, the new ship and the new laboratories were a magnet for a wide range of eminent scientists from overseas, high profile visitors such as Jacques Cousteau, as well as local dignitaries such as Governor General Sir Ninian and Lady Stephen and various Science Ministers.

In the 1980s, CSIRO divisions were small, and chiefs received little of the training that is common now. Staff can remember a number of instances when confronted with unusual or difficult circumstances Angus said, 'There was nothing about this in the non-existent Chief 101 manual'. Instead of managers, at that time chiefs, and Angus in particular, were primarily leaders and experts in their field and they could guide the development of the science. They had to solve any managerial problems by themselves.

Angus was a very strong and active advocate of the Division of Oceanography, and more broadly of all oceanography. He championed the importance of oceanography for society—the health of the oceans, their role in the climate system, the knowledge required for management of the coastal zone and of marine based resource industries.

He helped run the Marine Science and Technology grants scheme for a number of years and then later ensured oceanography was part of the new CSIRO Climate Change Research Program. In the late 1980s, Angus was influential in the Commonwealth Government's new cooperative research centres program. With guidance from Angus and with Garth Paltridge as leader, a group of scientists put together a bid for the initial Antarctic Cooperative Research Centre. This was one of fifteen successful bids and resulted in a significant expansion of Southern Ocean research in Australia, and in Hobart in particular. This Antarctic Centre was extremely successful and is the only one of the original fifteen centres that still exists today, as the Antarctic Climate and Ecosystems CRC.

Despite his great ability to build consensus and bridge what seemed impossible differences, Angus was no shrinking violet. In those days Chiefs had real power. Angus became chair of the CSIRO College of Chiefs, and in this role, he was a strong advocate for science and CSIRO. This resulted in high profile differences of view with the then Chair of the CSIRO Board, Neville Wran AC. He later was entrusted by the CSIRO board with the task of defending CSIRO when Senator Schott attempted to move the marine divisions out of CSIRO.

So, what is Angus McEwan's legacy from his time as Chief of Oceanography? Most importantly he established the identity of modern oceanography in CSIRO and helped it grow more broadly in Australia. He established the oceanography group in Hobart and created the conditions for it to earn a reputation for outstanding science within CSIRO, nationally and internationally. The culture that he established lasted well after his term as Chief and was important in the survival of ocean and climate research in CSIRO during attempts in 2016 to disband it. He was a much admired and loved Chief by his staff and he was the best Chief that staff ever had.

Influence on the national and international scene

Angus was not just a brilliant research scientist and a much-admired Chief of Division. He was also a major influence for good on Australian and international science and especially on the emergence of a real and lasting partnership between the sciences of the atmosphere and ocean.

At the national level, as Chief of the Division of Oceanography, he played a major role in building effective working relations between CSIRO and the Bureau of Meteorology. When he became entrained into the international oceans policy world of UNESCO's Intergovernmental Oceanographic Commission (IOC) in the 1980s, he worked quietly and constructively to help build an era of inter-agency cooperation between the IOC and the World Meteorological Organization (WMO).

Through the excellence of his research, his unique personal leadership style and his stature in the global ocean community, Angus put CSIRO and Australia at the forefront of many of the major international initiatives in ocean and climate science through the 1980s and 1990s. His contribution to international oceanography through the IOC was honoured with the award, in 2010, of one of the Commission's special 50th Anniversary Medals.

One of Angus' most important IOC roles was in succeeding the legendary Roger Revelle in 1987 as Chairman of the international Committee on Climate Changes and the Ocean which worked with the World Climate Research Programme to ensure the success of the two major 20th century field initiatives in climate research; the 1985–94 Tropical Ocean Global Atmosphere (TOGA) Project and the 1990–8 World Ocean Circulation Experiment (WOCE).

Angus also provided outstanding international leadership in the 1990s development of global environmental observing systems, especially the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). As Chair of the Intergovernmental Committee for GOOS, he took on a special role in promoting GOOS around the world. And as one of four oceanographers on Sir John Houghton's original Joint Scientific and Technical Committee for GCOS, Angus played a unique bridging role between GOOS and GCOS which ensured that ocean observation was fully integrated into the global system which now provides the observational underpinning for the United Nations Framework Convention on Climate Change.

One of the worst crises in international meteorology in the twentieth century was the threatened breakdown of international meteorological data exchange. This was eventually averted through the WMO's historic 1995 'Resolution 40'. But it then fell to the IOC to find ways to ensure the continuing exchange of closely related ocean data, a task for which the IOC turned to Angus and which he successfully delivered to the 2003 IOC Assembly.

Probably the most significant institutional initiative in bringing the international atmospheric and oceanic science communities together was the 1999 establishment of the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM). While many people in the WMO and IOC contributed to the establishment of JCOMM, it is the view of Peter Dexter, who guided it through inter-Secretariat channels, that it would never have been achieved without Angus's persuasive and skilled chairing of a meeting that brought all the disparate and competing sub-bodies of WMO and the IOC together in Sydney in 1998.

In parallel with his many international responsibilities and achievements, Angus played a hugely constructive role on the Australian national science scene.

Even before he became Chief, he served on the Funding Advisory Panel of the Australian Marine Sciences and Technologies Advisory Committee and he represented the Australian Branch of the Royal Meteorological Society on the Organising Committee for the 1979 International

Tropical Cyclone Conference in Perth, even using his artistic skills to design the Conference logo!

Following his appointment as Chief of the Division of Oceanography, he played an extremely influential role on the broader Australian science scene. In the early days of the climate change debate, he found himself representing the Australian Government in the approval process for the science component of the 1990 First Assessment Report of the Intergovernmental Panel on Climate Change. He then served as Deputy Head of the Australian Delegation to the 1993 Intergovernmental Meeting on the World Climate Programme in Geneva and was elected to the key role of Rapporteur on Resourcing of the international Climate Agenda. And, in the same year (1993), he was instrumental, in collaboration with David Karoly, in Hobart's hosting of the American Meteorological Society's Fourth International Conference on Southern Hemisphere Meteorology and Oceanography.

Later in the 1990s, with Roy Green coordinating the Western Australian Government involvement and the Bureau of Meteorology representing the Commonwealth, Angus skilfully brought the various UNESCO players onside for the eventual 1998 establishment of what became the hugely successful Perth Office of the IOC.

Angus was elected to the Australian Academy of Science (AAS) in 1982 and to the Academy of Technological Sciences and Engineering (ATSE) in 1994 and he served both academies with distinction. He chaired several of the AAS discipline and other committees through the 1980s and 1990s, including the International Relations committee, and served on the Academy Council from 1997 to 2000. For ATSE, he helped write the influential 1995 joint academies report on climate change science and he served as lead author for the important International Council of Academies of Engineering and Technological Sciences (CAETS) 2005 Cairns Convocation Statement on 'Oceans and the World's Future'.

From even before the formal establishment of the Australian Meteorological and Oceanographic Society (AMOS) as the successor of the Australian Branch of the Royal Meteorological Society in 1987, Angus was a strong advocate for an Australian professional society which would bring the meteorological and oceanographic communities together. He was awarded the R. H. Clarke Lecture of AMOS in 1989. Following his retirement from CSIRO in 1995, he served as a very active President of AMOS in 1998–9. He presided over the Fifth National Conference of AMOS in Wellington, New Zealand, 9–12 February 1998, and the Sixth National Conference in Canberra, 8–11 February 1999. His Presidency encompassed the publication of a special anniversary issue of BAMOS in August 1998 to celebrate twenty-five years since the establishment of the Australian Branch of the Royal Meteorological Society and, fittingly, another special issue in October 1998 on the International Year of the Ocean.

Angus also served on a number of Australian Research Council (ARC) and other bodies providing research and policy advice well beyond the confines of his own discipline and he became deeply entrained in some of the major national science issues of the 1990s. He did not take kindly to a one-size-fits-all model of research funding and showed great courage and resolve in standing up for the CSIRO role in public good research when it came under attack.

When Angus retired from CSIRO in 1995, there was widespread agreement that ways had to be found to keep him active in the many national and international roles in which he was then contributing so much. The Bureau of Meteorology provided him with a title (Senior Adviser, Oceanography), an office in the Hobart Office of the Bureau and a very small amount of funding support to help keep him active on the international stage. Angus

Fig. 3. Angus McEwan on receiving the Centenary Medal in February 2003.

took on his 'Senior Adviser' role with enthusiasm and there is little doubt that international science, Australia and the Bureau got great value from the final eight-year phase of his distinguished professional career which formally came to a close with his 'final' retirement from the Bureau on 30 June 2003. Angus' commitment and leadership of oceanography was recognised by the Australian Government in 2001 with the award of the Centenary Medal (Fig. 3).

Concluding remarks

In conclusion, Angus McEwan was an outstanding Australian scientist, a great internationalist and a deeply authentic, principled, honourable and loyal human being. He had an air of confidence, while at the same time exuding an endearing calmness. He had an easy-going manner, a great sense of humour and a caring and nurturing side. Many staff members experienced Angus's personal touch many times and he was always ready to support and to encourage all of his staff. As a result, Angus was a much-loved figure on the global oceanographic and meteorological scene. His death in Hobart on 5 September 2018 brought a flood of tributes and affectionate memories from former colleagues in Australia and from many of the great figures of twentieth century oceanography around the world. He is remembered as a special friend, a great boss, a visionary leader, a consummate professional, an astute judge of people and policy, a world-leading scientist, an absolute standout in promoting marine science in Australia and a gentle, endearingly quirky personality with a great sense of fun and unfailing good humour. Australia, and indeed the world, owes a lot to Angus's national and international leadership in oceanography. The bibliography of Dr McEwan's published papers is available online in the Supplementary material.

We extend the deep sympathy of Angus' former professional colleagues to his family and friends and especially to his partner Elizabeth Wood. It is said often but can rarely be said with such sincerity and certainty in our field: 'We will not see his like again.'

Supplementary material

Supplementary material is available online.

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