Institution: University of Birmingham

Unit of Assessment: UoA7 – Earth Systems and Environmental Sciences

a. Overview

Our Earth Systems and Environmental Sciences (ESES, UoA7) research is embedded within the School of Geography, Earth & Environmental Sciences (GEES), which is one of four Schools in the College of Life & Environmental Sciences. Although our research provides a continuous spectrum across the School, for REF purposes we are dividing it to demonstrate strength in different disciplines. Hence GEES research is also being submitted to UoA17 (Geography and Environmental Studies); the division of staff FTE between the School's four research themes are shown below:

Theme	UoA 7	UoA17
1. Environmental Health Sciences	10.2	3
2. Geosystems	11	2
3. Water Sciences	6	8
4. Society, Econ & Environ and Centre for Urban & Regional Studies	0	16
Eligible staff not submitted	1	1

The rationale for division of staff between UoAs is to fit best the descriptors of the assessment sub-panels and the communities addressed by the research. Hence, Geosystems staff who work only on modern or Quaternary environments are submitted to UoA17, whereas staff who work both on Quaternary and deep time systems are submitted to UoA7. Water Sciences research on surface water and the hyporheic zone is submitted to UoA17 and groundwater to UoA7. Environmental Health Sciences work on applied meteorology and climatology is submitted to UoA17, but work related to air pollution is submitted to UoA7.

b. Research strategy

In the School we take an integrated approach to environmental change on modern and geological timescales: investigating the driving forces and feedbacks that link the marine and terrestrial realms, the lithosphere, atmosphere, cryosphere and carbon and hydrological cycles. GEES exists to create world-class research, to translate that research into societal impact, and to foster the next generations of Earth and environmental scientists through excellent teaching and doctoral supervision. The vision behind GEES as a School is to create and sustain an exemplar of how different, cognate disciplines can work synergistically to enhance both research and teaching.

In 2008, we submitted 17.5 FTE in four distinct groups (Environmental Health, Hydrogeology, Palaeobiology & Palaeoenvironments and Subsurface Structure & Properties) to the ESES sub-panel. The panel feedback indicated broadly similar quality of group outputs and was positive about the research environment, the one criticism being a lack of evidence of synergy between the groups. Across the School, the wider issue was that of removal of structural barriers and, hence, positive enhancement of **multi- and interdisciplinary working**. Therefore, we replaced 3 Earth science, 1 environmental science, and 6 geography research groups with the 4 over-arching themes (see table, above).

A key driver for our research strategy has been to nurture disciplinary leadership whilst continually challenging disciplinary mind-sets with perspectives from cognate disciplines. Consequently, our research environment balances staff-centred mentoring and incentives with research initiatives linked to global drivers and cutting across themes, across Schools, and across Colleges in the University. A good example of integrated research is our contribution to the study of urban environments as illustrated by the impact case studies of Tellam et al., Harrison, and Cai et al. as well as a great many of our submitted outputs. Combining social science, natural science and engineering approaches, we seek to provide a distinctive perspective on sustainable urban regeneration and designing resilient cities as the planet moves into a future dominated by urban living.

Our strategy in the current period has been guided by the University's strategic plan (2010-15), *Shaping our Future* the relevant parts of which emphasize:

I) *Enhance research power.* We have striven to enhance research *quality* by our recruitment strategy, investment in infrastructure, nurturing of international partnerships and staff mentoring. *Quantity* of research has also demonstrably increased significantly as evidenced by grant income data (see d, ii below) and by overall growth in staff numbers, publications and citations (see section e i, below).

II) *Sustain financial strength and use it purposefully*. The School has remained in a strong financial position throughout the period (above 100% full economic cost recovery), has increased its staffing overall, and invested significantly in infrastructure (see d i, below).

III) *Enhance performance and status as an engaged University*. We welcome the increased emphasis on impact in REF2014 and provide detailed evidence for our activities in REF3.

IV) *Be destination of choice* [for students and staff]. We have attracted many EU and other overseas research students, e.g., through the highly competitive Marie Curie ITNs and increasing numbers of staff from overseas. We have been to the fore in building strategic links with Brazil, India and China on behalf of the university. Examples include engaging municipal stakeholders in Guangzhou, China (Bloss, Cai); participation in oil-and-gas and biodiversity themed workshops in Brazil (Dunkley Jones, Reston, MacKenzie); and research collaborations in India, supported through a highly competitive UK-India Education and Research Initiative award (Harrison) and a Royal Society exchange grant (Bloss).

These strategic choices have implications for each ESES research theme. In the **Geosystems** theme, we have taken advantage of retirements, departures and new initiatives to build a new and dynamic research group, attracting: a Reader in molecular palaeoclimatology (Bendle); a senior lecturer in geodynamics (Jones); two Birmingham fellows (Dunkley Jones and Butler) in palaeobiology; and two NERC fellows (Watt and Hastie) and a lecturer (Stevenson) in petrology and structural geology. Combined with an increasing focus of Fairchild and Boomer on deep-time studies, we have developed distinctive strengths that we nurture in our strategic planning. Our foci are now i) plant and vertebrate palaeobiology and evolution, ii) combined deep Earth, sedimentological, biogeochemical and palaeontological approaches to early Cenozoic environments, iii) crustal structure and magmatism at rifted and convergent margins and iv) novel proxies for the environment (e.g. sulphate, phosphate isotopes) and geologic fabric (magnetic anisotropy) from Quaternary to deep time. Cross-theme research includes work on colloidal contributions to rock geochemistry and migration through aquifers and the capture of atmospheric chemistry in geological materials. The group has been supported by infrastructural investments (see d, i below) and numerous NERC grants, supplemented by EPSRC, industrial and European funding. We have deployed our expertise in micropalaeontology to establish a Masters programme, which has been well supported by students and the petroleum industry, and which is adding to our research reputation in this field. We will make two joint appointments with the British Geological Survey in micropalaeontology in 2014.

The strength of the long-established hydrogeology activity, within the **Water Sciences** theme, continues to lie in the prediction of the transport and fate of contaminants in groundwaters at scales relevant to decision-making, thus facilitating the protection of the environment and human health. A range of important advances have been made, e.g. in the transport of colloidal material including viruses in groundwater, organic contaminant migration, urban water resources, recharge, reactive solute transport, fracture flow systems and in applications of bacterial bioremediation to nuclear waste stabilization (the latter in collaboration with Biosciences). Connections to stakeholders are strong (e.g. the Tellam et al. impact case study) and have been further strengthened by the return of Herbert from 10 years in consultancy. His return has facilitated access to the nuclear decommissioning and “fracking” sectors and quickly generated 2 RCUK grants. A notable development which reflects the success of the integrated water science theme has been a focus on the linkage between surface and subsurface waters initially via a hyporheic zone network and subsequent EU-funded field and modelling studies, and then the recruitment of Krause (UoA17) who is leading a new Marie Curie ITN involving Rivett. Overall the activity is supported by a diverse portfolio of RCUK, European, industrial, and government agency funding. We continue to provide the leading centre of excellence in training in groundwater science, with annual recruitment of 20-30 Masters students who contribute to the group’s research. A second

Masters on Nuclear Decommissioning is now in place jointly with the School of Physics.

The **Environmental Health Sciences** theme has developed very strongly during the return period with a doubling of staff returned overall. The theme now contains three large groups of ESES researchers. Harrad leads a group of 15 researchers, at the census date, who focus on persistent organic pollutants and are primarily funded by European sources in collaboration with industrial partners. Specific strengths of the group are: the assessment of human exposure to consumer chemicals; the environmental fate and behaviour of persistent brominated organic pollutants; and sources, pathways and effects of human exposure to flame retardant chemicals. Very strong growth of the aquatic chemistry activity under Lead continues under the leadership of Valsami-Jones. Research is now focused specifically on environmental nanoscience and includes the NERC FENAC analytical facility (see d, i). Together with Lynch and Lead, Valsami-Jones works on the fate and toxicity of manufactured nanomaterials in the environment. The ecotoxicological work is collaborative with the School of Biosciences and Water Sciences and is strongly engaged with European funders (e.g. the FP7 NanoMILE project, coordinated by Valsami-Jones, total value €10M with €1.3M to Birmingham) as well as RCUK. The third area is in air pollution and atmospheric chemistry. Six members of the theme contribute to this activity compared with two in 2008.Urban air quality and exposure to air pollution continue to be central concerns (e.g., the €2.3M ERC FASTER project led by Harrison and involving Cai and MacKenzie), but chemistry-climate aspects of the troposphere (including global oxidising capacity and ocean fertilisation) and the stratosphere (including geoengineering) are emerging (supported by multiple NERC grants, infrastructure investment and access to international facilities (section d, i, below)). Novel instrumentation (e.g. NERC-funded development of resonance fluorescence for atmospheric halogen atoms) and platforms (e.g., 3 NERC-funded projects using unmanned aerial vehicles) are becoming increasingly important in this work and will form a strategic focus of future work.

c. People, including:

i.Staffing strategy and staff development

Sustaining and enhancing research strengths have formed the basis of the unit's recruitment policy. Success in nurturing disciplinary leadership is exemplified by 4 internal promotions to Chairs or Readerships in the census period. External Professorial appointments have been made in environmental nanoscience and in atmospheric chemistry, with Senior Lecturer/ Readers appointed in molecular palaeoclimatology and groundwater. When recruiting, we have been able to attract outstanding new staff fit to, and building upon, a coherent research environment in which research facilities can be fully exploited.

Our staff are in demand internationally. Turnover has been modest, but primarily to senior positions: e.g., Director of the Geotechnical & Hydrogeological Engineering Research Group at Monash University (Mackay), Deputy Chief Geologist of the BG Group (Turner), Director of the Oxford University Museum of Natural History (Smith). While Lead continues to contribute to our research strength in environmental nanotechnology, he has also been appointed to an endowed Chair at the University of South Carolina. These positions have been replaced and the activity has also expanded significantly since 2008.

Much of the expansion has been through the attraction of early career scientists as Fellows. In the period we have hosted 5 Marie Curie Fellows, 4 Research Council Fellows, 1 Royal Society Fellow; also Delgado-Saborit received the 2011 Walter A. Rosenblith New Investigator Award of the American Health Effects Institute, funding her research for 3 years. Two of the NERC Fellows have been appointed to proleptic lectureships in petrology and two more form part of our cohort of 4 Birmingham Fellows. **Birmingham Fellowships** are an innovative university initiative to bring internationally-prominent early-career staff to Birmingham and we have been disproportionately successful in winning such awards. The scheme offers a permanent academic post after a 5-year research-intensive position. The 4 UoA7 Birmingham Fellows significantly deepen our existing strengths in environmental nanoscience, atmospheric chemistry, macro- and micro- palaeontology, and palaeoenvironments. Our micropalaeontology Fellow (Dunkley Jones) strengthens our interactions with the hydrocarbon industry, including through the new MSc in Applied & Petroleum Micropaleontology and through participation in the new (2014 -) NERC Doctoral Training Partnership in Oil & Gas.

We have secured succession-planning through recruitment and development of staff in-place.

Recruitment at all academic levels in environmental nanoscience has allowed us, without a drop in research funding, to accommodate Lead — previously our second highest grant earner — reducing to 0.2 FTE in order to take up a position in North America. Harrison, our leading atmospheric scientist, will continue through most of the next census period, not least to lead the 5-year FASTER project on nanoparticle emissions from vehicles, but the vitality and sustainability in this area is evidenced by the threefold increase in submitted staff, each with a significant portfolio of funding.

A Visiting Scholars scheme provides for extended visits for international researchers (e.g. 20 visitors in 2012; 10 in the first 6 months of 2013). Since new immigration processes began in January 2013, the School has been processing about 4 visitor applications per month, of which about two thirds are to work with UoA7 staff.

Our early-career contract researchers each have the same Personal Development Review (PDR) process as established academic staff. The University was awarded the HR Excellence in Research accreditation in September 2011 and fully implemented its Concordat action plan in September 2013. Organisation-level process, policies and activities include an integrated leadership development programme for researchers / academics at all levels and recurrent central funding to maintain development provision for researchers. College-level activities include a College Post-doc & Early Career Development and Training committee, mentoring schemes, and specific local induction. Researchers take full advantage of professional development provided by the university's People & Organisational Development unit.

All staff members reflect on their professional development via the PDR scheme, which consists of annual formal meetings that are more frequent when more support is needed. PDR has been successful in improving career trajectories. To further the career prospects of women scientists in academia, the university was awarded Bronze on the Athena SWAN programme, in March 2012. In November 2013, GEES submitted an application for a Bronze award; staff members also undertake compulsory online training to be aware of, and take account of, all diversity and equality issues. To ensure equitable and transparent treatment of staff across the School, a workload model has been implemented (2013). GEES management aims to ensure that the voices of all staff are heard. Junior academics are represented on the School Executive Board and the School Research Committee. A "Have Your Say" staff satisfaction survey is run every other year to allow staff at all levels to comment on the university in general and on their particular situation within the institution as a whole.

ii. Research students

Research student numbers are steady, success we attribute to the attractiveness of our research to funded overseas students, our responsiveness to applicants, and success at drawing down external funding for doctoral training, especially CASE open competitions and EC Marie Curie Initial Training Networks, of which we have led 4 in the census period. The College match-funds studentships from centres of doctoral training to grow the doctoral student population within strong training cohorts.

The university supports training of doctoral students with increasing levels of disciplinary specificity at university Graduate School level, at College level, within the School and within individual research clusters. Doctoral researchers undertake a Development Needs Analysis, to assess immediate and more long-term training requirements across Vitae's Researcher Development Framework (RDF): that is, with respect to personal effectiveness, research governance, the impact agenda, as well as with respect to discipline-specific knowledge.

The university Graduate School provides a one-stop-shop for generic skills training. More discipline-focused training is provided through national programmes such as the National Centre for Atmospheric Science Summer Schools on Atmospheric Measurement and on Earth System Modelling, through study visits and secondments. Doctoral researchers in the persistent organic pollutants group have undertaken 15 study visits in the census period and the group has hosted 15 study visits involving partnerships with China, Japan, Canada and Australia. NERC have recently funded MacKenzie to deliver a national Summer School on use of unmanned aerials vehicles for Earth and environmental sciences and the Geosystems group to provide a 1-week short-course in oil field micropalaeontology and biostratigraphy. There has been a progressive enhancement of doctoral skills training during the period. Looking ahead, the restructuring of RCUK studentships

into Centres of Doctoral Training puts a much clearer focus on the training element of PhD studentships. UoA7 staff (Bendle, Fairchild) lead the NERC CENTA Doctoral Training Partnership, which will advance the provision of doctoral training across 5 Higher Education Institutes and 2 NERC research centres in the midlands over the next 5 years.

Funding and training is provided for doctoral researchers to design and deliver conferences that bring internationally-leading researchers to campus. The doctoral students come together to discuss their own research at annual symposia. We also have at least 3 seminars per week on UoA7 topics - well over 100 per year. By having seminar series at theme, School and College level, we attract speakers from postdoctoral to senior professorial level.

The university adheres to all precepts of the Quality Assurance Agency for Higher Education; doctoral research progress is monitored through regular supervisory meetings with progression committees at 6 monthly intervals. Continuing professional development (CPD) in doctoral supervision is already provided at College level in the university, and will be significantly strengthened in the future. From 2013/14, reflective practice-based CPD will be a requirement of doctoral supervision in GEES. All doctoral students have at least 2 internal supervisors, ensuring stability and broadening intellectual engagement for the students.

Doctoral research is often the springboard for multidisciplinary working, bringing together supervisors with different backgrounds (e.g. our hydrogeology staff members have six different disciplinary backgrounds and their PhD students are even more diverse). Joint PhD studentships across the Universitas 21 group provide opportunities for students to gain significant experience of different research cultures within their PhD studies. Examples of doctoral researcher success stories include a business/maths graduate who co-authored a very widely cited Earth science paper during her PhD, subsequently worked as a post-doc in engineering, and now lectures geography at University of Leicester. Another UoA7 doctoral researcher, with an environmental science background, now lectures chemistry in New Zealand having applied nanoscience techniques to cave environments for the first time.

d. Income, infrastructure and facilities

i. Infrastructure and facilities

A great deal of our research is based on fieldwork and laboratory experiment, equipment for which is refreshed continuously through grant awards, university investment (£1.4M in census period), and innovative equipment sharing. Since 2012, university investment in research infrastructure is directed primarily through its Dynamic Investment Fund, which has funded the state-of-the-art Birmingham Molecular Climatology Laboratory (BMC) to new Reader appointment, Bendle. The BMC specialises in organic geochemistry to unravel Cenozoic and Holocene climate. The suite includes a GC-FID and –MS, GC-IR-MS and LC-APCI-TOF-MS, i.e., the full range of molecular and isotopic techniques for organic geochemistry, and will be applied to study Cenzoic Greenhouse worlds, basin evolution and hydrocarbon prospects, and contemporary atmospheric transport of organic tracers and pollutants.

Environmental Health Sciences operates from state-of-the-art laboratories for the analysis of gaseous, particulate and dissolved pollutants in field and laboratory. The field-deployable aerosol time-of-flight mass spectrometer for particulates is one of only two operational in the UK. Laboratory instrumentation for characterisation of organic compounds includes five GC-MS instruments — one with a thermal desorption facility, and one with negative ion chemical ionization — and a LC/MS-MS system; capability has been considerably strengthened by the acquisition of a GC x GC-ToFMS instrument, one of only two in the country for atmospheric aerosol samples. Field equipment includes flight-ready ambient greenhouse gas analysis by cavity ring-down spectroscopy for use in manned and unmanned aerial measurement programmes. Laboratory systems for atmospheric chemistry research include laser photolysis, time-resolved absorption and fluorescence spectroscopy, aerosol flow tubes and cavity-enhanced absorption spectroscopy.

The Facility for Environmental Nanoscience Analysis and Characterisation (FENAC) was set-up to produce reliable synthesis, labelling and characterisation of nanoparticles under realistic conditions and in a variety of potentially complex media for the better understanding of biological and environmental impacts of manufactured nanoparticles. In recognition of the quality of this work, FENAC became a NERC facility in 2009, allowing consolidation and expansion of the laboratory. A

unique range of analytical equipment is available, comprising two atomic force microscopes, a near-field scanning optical microscope, voltammetry instrumentation, and fractionation equipment including various field-flow fractionators, cross-flow ultrafiltration, and gravitational split-flow thin fractionation instruments; many other analytical facilities on campus (e.g. electron microscopy) are available through FENAC. A new award (NERC, 2013) to FENAC has been matched by the university to provide a new ICP-MS instrument for single-particle elemental analysis.

The Stable-Isotope Laboratory provides mass spectrometric analysis of stable isotopes in environmental media, and has proved important in attracting Birmingham Fellows and other new staff. A university-funded upgrade in 2009 has enabled high temperature pyrolysis of organic and inorganic compounds. SRIF and university investments (£0.6M) have been made in new ICP-OES (complementing one existing and one new ICP-MS instrument), GC-MS and organic carbon instrumentation. Our other Earth Science laboratories include chemical analysis; flow-systems; palaeontology preparation; rock magnetics including state-of-the-art anisotropic magnetic susceptibility equipment; rock-sectioning; microbiology, and an optical and fluorescence microscopy suite. Two, on-campus, borehole arrays support groundwater research; a broad suite of hydrogeological and geophysics field equipment is maintained.

The nationally recognised, designated and accredited Lapworth Museum (AHRC core-funded), supported by a Director, Academic Keeper, curator and assistant curators, is a major resource for the Palaeobiology group. Investment in the museum totals £0.6M during the census period (AHRC, SRIF, Microsoft and HLF) and Heritage Lottery funding is in place to develop a £2.4M expansion project (see REF 3a). The SRIF-funded Shotton Room acts as an interface between the School's substantial paper-based map and archive collections and digital mapping/GIS facilities. The SRIF3-funded Subsurface Imaging Lab, with full 3D seismic processing, modelling, interpretation/ visualisation capability, supports research into tectonic processes. Specialist computing clusters are supplemented by upgrades to the Birmingham Environment for Academic Research (BlueBEAR) in December 2012 to provide an IBM iDataplex HPC cluster with 800 Sandy Bridge based computer cores complete with large memory servers and a GPU-assisted compute node. This supports work on modelling atmospheric pollution and 3D reconstructions in palaeobiology. An internal IT consortium (5 computer officers) supports PCs and networking, with a full-time technician in the School and 0.5 FTE Unix/Linux support. Research support staff (13.5 FTE posts in the School), provide support for laboratory management, rock sectioning, chemical analysis, stable isotope analysis, hydrogeological investigations and field sites, and technical drawing.

Instrument sharing is an important element of securing a high-quality research environment in the current fiscal climate. Internally, we have built strong sharing agreements with the university Molecular Physics group (for soft-ionisation mass spectrometry), the Mechanical Engineering department (for engine test-beds) and with Biosciences (for 'omics). We regularly use excellent facilities in the Centre for Electron Microscopy, micro-CT equipment in Dentistry, and the University / Hewlett Packard Visualization and Spatial Technology Centre. Regionally, the unit benefits from the M5 scientific equipment-sharing initiative (http://www.m5universities.ac.uk/) which provides staff with access to scientific equipment from across the Midlands via a searchable database. Nationally, we use the Diamond synchrotron source (4 projects in the return period), the STFC Rutherford-Appleton Laboratory central laser facility (2 projects), the NERC Ion Microprobe facility (5 projects) and aircraft and ship research platforms. Internationally, the unit makes full use of European research facilities, including 4 experimental campaigns at the large outdoor Euphore smog chamber (http://euphore.es/) and use of the European Synchrotron Radiation Facility. Access to state-of-the-art instrumentation for the detection and quantification of brominated persistent organic chemicals (gas and liquid chromatography interfaced with orbitrap mass spectrometry) has recently been provided by Thermo Scientific (Bremen) GmbH through a European Industrial Doctorate programme led by Harrad.

A significant infrastructural aspect of our research environment is provided by our contribution to the National Centre for Atmospheric Science (NCAS). The School hosts a node of this distributed NERC Research Centre. As well as directly funding research at Birmingham, this facilitates collaboration with other leading Universities in atmospheric science and provides access to the advanced instrumentation supported by NCAS.

In addition, GEES is co-leading (with the School of Biosciences) the £20M Birmingham Institute of

Forest Research (BIFoR). BIFoR will address two fundamental environmental challenges (the impact of climate and other drivers of change on woodlands, and the resilience of trees to invasive pests and diseases) in the context of a new world-class field experimental facility. The inaugural Director of BIFoR (Mackenzie) is from our UoA7 team.

ii. Research funding portfolio

We recognise the importance of diversity of research funding streams. Research income has grown year-on-year throughout the census period, from £1.5M in 2008/09 to £2.4M in 2012/13 (see REF 1a). A sharp increase to more than £7M of newly announced awards within the last year guarantees a significant increase in income in the coming REF period. UK Research Councils provide the largest single funding stream (68 % over the return period). Of the UK Research Councils, funding is drawn mostly from NERC but with important contributions coming from MRC, EPSRC, and BBSRC.

The unit has been successful in drawing down funding from the EU and the ERC (£2.6M, 16 % of total research income over the return period and with several large awards announced in 2013). Highlights include the NanoMILE and FASTER grants and 4 Marie Curie Initial Training Networks described above. From this strong base, and with the help of the university's European research support team, we are well positioned to respond to Horizon 2020.

Much value accrues to the School through in-kind contributions from industrial and commercial stakeholders, more than through consultancy per se (4 % of income in return period). School strategy is to develop lasting partnerships based on in-kind exchange, and to spin-out successful commercial activities where possible.

We provide substantial research evidence to central government, particularly Defra and its regulatory arm, the Environment Agency (generating 9 % of total research income over the return period), concentrated on air quality but with other contributions in environmental nanoscience, persistent organic pollutants, and groundwater. Funding for use of national and international facilities has risen steadily through the period and totals £0.8M.

e. Collaboration or contribution to the discipline or research base

i. Overview

We focus on high-quality science outputs. Citation analysis of publications from 2007 onwards show University of Birmingham's environmental science to be in the top few percent of a basket of 30 comparable international institutions (analysis conducted by the university's Planning Office). Translating research results, and engaging to define the research agenda, involves close collaboration with a wide range of stakeholders, discussed briefly in turn, below.
We take significant roles in relevant international organizations, for instance leading proposals for and taking part (Bendle, Dunkley Jones, Harrington, Jones, Reston, Watt) in Integrated Ocean Drilling Program and other international marine geological cruises, and Cryogenian Subcommission of the International Commission on Stratigraphy (Fairchild).

Regulatory and policy Stakeholders. We provide science to inform policy — for example, on environmental pollution to Defra and other UK government bodies (see the Tellam et al. and Harrison impact case studies), on nano materials to the Food Safety Authority of Ireland and the European Food Standards Authority (Lynch), on air pollution to the World Health Organization (Harrison), on Persistent Organic Pollutants to the UN Environment Programme's Stockholm Convention (see Harrad impact case study), and on sustainability to Birmingham City Council through its Smart Commission (MacKenzie). MacKenzie is also one of 3 University of Birmingham Commissioners on the university's Policy Commission on Future Urban Living, which is Chaired by Lord Shipley of Gosforth and is due to deliver its findings at an open meeting in parliament in January 2014.

Industrial partners (e.g., Shell, BP International, PetroBras, ExxonMobil, BHP Billiton and OMV (UK) Ltd). Engagement with industry is a two-way partnership: industry typically can provide data beyond the capability of any academic institution (e.g., the hydrocarbon industry may make available data that cost £100Ms to collect), whereas we can provide the expertise to interpret that data, both to the benefit of industry, but also to address blue skies research issues. Examples

include: site remediation associated with nuclear decommissioning (our expertise here is aided by a new appointment (Herbert) and the launch of a new MSc programme); and work with the water industry (see the Tellam et al. impact case study). There are rapidly developing collaborations with the hydrocarbon industry aided by the launch of the new micropalaeontology MSc programme, exploiting both new (Dunkley Jones) and existing (Boomer, Harrington) research strengths in the School. A Business Engagement Partner is provided by the College to facilitate links to industrial partners at all scales. A newly funded ERDF-funded initiative to the College is aimed at developing links with regional SMEs (see REF 3a). Indicative of our stakeholder engagement is the list the CASE/industrial doctorate partners since 2008: AEA Technology; Aston Reinvestment Trust; Birmingham City Council; Centre for Environment, Environment Agency; Environmental Simulations International; Fisheries & Aquaculture Science; Food Standards Agency; Health Protection Agency; Kore Technology; Macaulay Institute; Malvern Instruments; National Physical Laboratory (2); Natural History Museum; Sellafield Ltd, Severn-Trent water Ltd, South Staffordshire Partnership; Tata Steel; Thermo Scientific; Unilever; and Waterra In-situ.

Accrediting bodies for taught programmes (Institute of Air Quality Management, Chartered Institute of Environmental Health, Institute of Occupational Safety and Health, The Geological Society, Royal Meteorological Society and the Institute of Environmental Science). A major means of engagement with industry and the professions is through our portfolio of 7 taught Masters programmes. These are designed to provide the training required by the profession and by industry for entry into the profession, and are also partly funded (e.g. studentships from the Micropalaeontological Society and the Petroleum Exploration Society of Great Britain for the Applied and Petroleum Micropalaeontology MSc) and taught by external lecturers from industry, providing links with industry that can and do lead to research collaborations. There has been a significant increase in similar interactions at undergraduate level through enhanced careers teaching and though an industrial placement module.

Leading professional good citizenship, we serve many professional bodies: the **Royal Society** (Dunkley Jones, International Exchanges Committee), the **Geological Society of London** (Rivett, Member of Council and Professional Committee; Tellam, Member of the Council, Science Committee and Election Committee; Fairchild, member of the Research Grants Committee; Valsami-Jones, Environment Network coordinator; Dunkley Jones, member Joint Committee for Palaeontology), the **Royal Society of Chemistry** (Bloss, Environmental Chemistry Group Chair 2012-14; Member, Energy, Sustainability and Environment (ESED) Division Council, 2012-14; Renshaw, Honorary secretary Radiochemistry Group), the **International Association of Hydrogeologists** (Rivett, Chair of British Chapter), the **Society of Vertebrate Paleontology** (Butler), the **Palaeontographical Society** (Dunkley Jones, Committee member), **Mineralogical Society** (Valsami-Jones, Treasurer, Environmental Mineralogy Special Interest Group), and the **International Society of Exposure Science** (Delgado-Saborit, Member of the Students and New Researchers Committee).

We serve the UK research councils, taking a variety of senior positions such as Theme Leader for NERC's Environment Pollution and Human Health theme (Harrison) and membership of the NERC Pool of Chairs (MacKenzie). Seven other staff members have served on NERC panels during the period. Two of us serve on the UoA7 REF panel (Fairchild and Harrison). Contributions to international science peer-review include Chairing the Earth and Environmental Science peer-review panel of the European Synchrotron Radiation Facility (Fairchild) and panel membership of the Ex-Post Impact Assessment of European Union's 6th Framework Programme (MacKenzie). We contribute significantly to the wider community of scholars through editorial work. 4 full editorships have been held in the census period (*Rev. Geophysics* (2005-2010, Fairchild); *Environ. Technol.* and *Issues in Environ. Sci. Technol*. (Harrison); and *Micropalaeontological Society Special Pubs*. (Dunkley Jones)). 20 editorial-board positions are held, along with 12 Associate Editorships (*Acta Palaeobotanica, Atmos. Environ., Atmos.-Ocean, Atmos. Phys. Chem., Atmos. Sci. Lett., J. Geol. Soc. Lon., Groundwater, Mineralogical Mag., J. Palaeogeography, Palaeontologica Electronica, Paläontologische Zeitschrift, Zootaxa*). Additionally, we have guest-edited 9 special issues/sections for international journals.

ii. Interdisciplinarity

Interdisciplinary research is fostered across the university by the Institute for Advanced Studies (IAS). 1-day IAS workshops establish the critical mass in a given research area. A full programme, lasting 3 to 6 months and involving extensive visits from external colleagues with complementary expertise, is then developed. Recent UoA7-relevant topics for Institute workshops have been "Hydrohazards", "the Biophilic City", and "Climate Change: Arctic and Alpine Environments". There will be significant contributions from across UoA7 staff to the inaugural IAS theme "Saving Humans", which will run through 2013 and 2014.

iii. Individual contributions not mentioned above

Conference organising:

Naturally, we are active in convening sessions at all the major broad meetings such as the annual AGU San Francisco and EGU Vienna meetings in addition to a wide range of meetings with a disciplinary focus. Examples of conferences convened by our staff, including several held at Birmingham are: Environmental effects of nanoparticles and nanomaterials (annually 2008-2013), 28th international symposium on halogenated persistent organic pollutants (2008), First International workshop on cave monitoring (2009), William Smith meeting Environment, Pollution & Human Health (2009), Palaeontological Association annual meeting (2009), Lyell meeting (2009, 2012), Bionan (2009), Tectonic studies group annual meeting (2010), Climate Change – the karst record (KR6, 2011), What's new in groundwater (2011), Fermor meeting on the Neoproterozoic (2012) and Ineson meeting – Groundwater and energy (2012). In addition, we belong to many scientific committees for conference organisation.

Prizes:

EGU Arne Richter Award for Outstanding Young Scientist (Watt, 2014)
Micropalaeontological Society Alan Higgins Award (Dunkley Jones, 2012)
Fitzroy prize of the Royal Meteorological Society (Harrison, 2012)
Lord Stafford Award for Innovation for Environmental Sustainability (Cai et al., 2012)
Hodson Award of Palaeontological Association (Butler, 2011)
Emerging Investigator in special issue of *Journal Environ. Monitoring* (Delgado-Saborit, 2011)
2 x Geological Society London President's Award (Stevenson, 2009; Dunkley Jones, 2010)
Long Range Initiative Innovative Science Award (Delgado-Saborit, 2010).
Micropalaeontological Society Charles Downie Award (Dunkley Jones, 2010)
J. Geological Society Young Author award (Stevenson, 2008)
Ramsey Medal (Stevenson, 2008)

Other indicators of esteem:

Adjunct Distinguished Professor, King Abdulaziz University, Saudi Arabia (Harrison, 2011—)
Hon. Researcher, Evolutionary Studies Inst, University of the Witwatersrand, (Butler, 2013—)
Member, GeoBio-Center, Ludwig-Maximilians-Universität München, Munich (Butler, 2011—)
Executive Committee member, the Paleobiology Database (Butler, only UK member, 2013 —)
Director at Large of AASP The Palynological Society in the USA (Harrington).