Institution: University of Oxford

Unit of Assessment: UoA7 (Earth Systems and Environmental Sciences)

a. Context

The UoA actively seeks to translate fundamental research to practical deployment in industry and the policy arena, and to communicate our discoveries to diverse audiences. Resulting impact is achieved in four main areas:

i. The search for natural resources: Research helps understand the formation, distribution and recovery of resources including minerals, water and, particularly, hydrocarbons. This work has economic impact in the industrial sector, including oil companies where it helps identify exploitable resources. It is also of interest to authorities setting resource policy: identifying future resource availability and the hazards associated with extraction.

ii. Assessing geological hazards: Fundamental research in tectonics and volcanology provides insight into the risks posed to society by earthquakes and eruptions. This work has impact via the insurance industry, and significant public-policy impact (e.g. building zoning and structural requirements; flight permissions during volcanic eruption).

iii. Informing environmental policy: Research provides information about changes in the natural environment caused by human activities, and the risks these changes pose to society and the economy. This research is relevant to policymakers in governments as they consider environmental legislation and climate adaptation strategies. It also has economic impact, helping decision makers in industry to plan future strategy.

iv. Public understanding of the Earth: People have a high level of curiosity about the planet we inhabit: from the fascination of school-children in dinosaurs and volcanoes; to widespread public concern about environmental change; and to fundamental questions such as how our planet formed, or life initiated. UoA research reflects this broad thirst for knowledge about the natural environment. Communication of research helps educate and inform public appreciation of our planet, allowing wider understanding of its hazards, benefits and sensitivity to change.

b. Approach to impact

There is recognition across the UoA that important societal challenges demand earth-sciences research, and that dialogue and engagement with stake-holders is critical. The UoA ensures that impact results from its research through the following policies:

i. Communication and collaboration with the resource industry: Close professional links between those in relevant companies and UoA researchers ensure that we learn about the research challenges facing these industries, and that we communicate our innovative research findings. Visiting Professorships provide formal links between industry and the UoA, with two senior oil-company executives in such posts (Daly, BP; Levell, Shell). Another Visiting Professorship is to an academic (Robb) with a long-standing reputation for working with mining companies in frontier regions. Graduating students from Oxford University are sought after by industry and can go on to occupy senior positions in resource companies. An active DoES alumni network (maintained by a full-time Alumni Officer) ensures that we stay in close contact with such graduates throughout their careers, providing a large number of industrial contacts, and a conduit for knowledge exchange. UoA researchers also attend industry conferences (e.g. AAPG), sit on advisory bodies with industry professionals, conduct corporate peer-reviews (e.g. Cartwright), and run training courses for petroleum companies (e.g. Jenkyns for BP and Petrobras). There is also exchange of personnel, with student internships, and company representatives visiting Oxford University and joining field-trips. Such communication ensures that new research findings benefit industry, as demonstrated by widespread use by the petroleum industry of models of oceanic anoxic events, developed in Oxford University, to improve success in exploration. Communication also results in collaborative research to address key questions challenging industry. Research grants from oil companies since 2008 (from Shell, BP, Exxon, Total, Petrobras, Anadarko, Conoco Philips, Chevron Texaco, and Statoil) represent 16% of total research funding to the UoA during this period, and there has been significant in-kind funding (≈£7M) by donation of software. This collaborative research has provided new knowledge to aid the resource industry, including that related to the development and structure of hydrocarbon-hosting sedimentary basins, and new

chemical tracers.

ii. Policy advice to governments and other stakeholders: We seek opportunities to inform environmental policy. One strategy by which we increase such impact is through provision of space and support to those with explicit roles in knowledge exchange (KE). The DoES hosted, for example, the Environmental Sustainability Knowledge Transfer Network (ES-KTN) during the entire REF period. This unit, funded by the UK Government (BIS) employs 6 full-time KE specialists with expertise in environmental sectors (e.g. water, soil; energy; CO_2 sequestration). It advises research councils (NERC, EPSRC, BBSRC) on policy, and DECC, Defra, DFID, FCO and UKTI on environmental challenges and opportunities. The proximity of the ES-KTN increases the impact of UoA research, with examples being advice to DECC on negative-carbon-emission technologies (Renforth, Kruger), and on soil carbon and heavy-metal pollution to a broad range of environmental and energy companies via ES-KTN workshops. Individual knowledge-exchange experts hosted by the UoA include Holmes and Gardner. Holmes works to improve the use of science in environmental policy making and regulation. He has been funded by the EA, the Environment Research Funders Forum, and the LWEC Partnership. His proximity to research conducted in the UoA increases its policy impact (such as to Defra's mercury contamination policy), and the general use of environmental science in policy (e.g. tinyurl.com/mj2jheb). Gardner has a joint Oxford University/NERC appointment and works as a KE co-ordinator to ensure that environmental policy is accurately informed by the latest research. He helps to connect UoA researchers with those seeking policy advice. Researchers also seek such contact through service on boards and committees, attendance at policy meetings, and through collaborative research. Examples of resulting impact in the UK include Mather's advice to the Cabinet Office on future eruptions following the Iceland ash disruption, and the use of Woodhouse's research by AWE to support the nuclear weapons moratorium. Outside the UK, research to map active faults and measure slip rates (England, Parsons, Walker) has influenced the way that governments assess earthquake hazard in countries including Greece, Iran and Khazakstan. Palaeontological research has influenced the UN on the establishment of world-heritage sites in China (Siveter) and Canada (Brasier); volcanic research influenced the WHO on the hazards of volcanic ash (Pyle); and work on radionuclide contamination influenced IAEA policy (Porcelli).

iii. Knowledge exchange activities funded by Research Councils: The UoA makes extensive use of Research Council opportunities for KE. We employ two Research Facilitators (one dedicated to Earth Sciences, the other to Climate) who have KE as a specific aspect of their job descriptions. They play a leading role in developing the impact statements required for research council grant applications, helping researchers identify impact goals and mechanisms and identifying specific end-users in industry or government. They help to support a general policy of seeking communication early in the planning of research projects so that end-users can actively shape research goals rather than be merely passive recipients. Research in the iGlass Sea-Level Consortium, for instance, was directed specifically at addressing the H++ scenario for maximum future sea-level rise, giving it increased policy relevance for the EA and insurance companies. UoA researchers play a significant role in two NERC/ESRC-funded consortia focused on increasing societal resilience to geohazard: Earthquakes Without Frontiers (ewf.nerc.ac.uk; England, Holmes, Parsons, Elliot) which addresses earthquake hazard; and STREVA (streva.ac.uk; Pyle, Mather), which seeks to reduce the negative consequences of volcanic activity (see REF5).

iv. Innovative museum engagement: The OU-MNH is one of the leading natural history museums in the UK and is dedicated to education of the general public in the natural sciences. This education builds directly on the substantial collections housed by the museum, and on the research conducted by the UoA, particularly in palaeobiology and mineralogy (frequently involving scientists from the UoA in outreach activities). The museum's learning team works closely with academic departments and has been a nationally respected provider of informal science learning since it was established in 1998. The team provides a comprehensive service to schools, from early years to KS5. All facilitated sessions are taught by specialist education officers, with tailored programmes offering active learning opportunities using a wide range of museum specimens. Numbers of visiting school pupils have continued to rise steadily (by 52% since 2008) and, in 2012, 27,454 UK pupils visited in 769 groups. Facilitated sessions are frequently fully booked a term in advance, with a very large number of repeat visitors. Overall, visitors to the museum have increased from 418,098 in 2007-08 to 557,644 in 2011-12, a 33% increase over the REF period.

Learning is also supported by online resources (www.oum.ox.ac.uk/educate/index.htm), with the museum website visited 1.5M times during 2011/12. OU-MNH has received major national awards for museum learning, including the inaugural Clore Award for Museum Learning in 2011. Oxford University's museums, libraries and archives were awarded the Queen's Anniversary Prize in 2009 in recognition of their outstanding quality and their high public benefit.

v. Diverse science communication to a broad range of audiences: All returned UoA researchers (and many post-doctoral scientists and students) have taken part in the public communication of science during the REF period. This communication ranges across the full range of media and is actively encouraged by the culture of the UoA and by requests from media, schools, and industry. Oral presentations range broadly in audience, from frequent talks to schools, interest groups and science festivals around the country, to presentation at the World Economic Forum Davos meeting (tinyurl.com/llcrtus). Successful popular science books (Searle and Brasier) communicate the science of mountain building and the evolution of life to general audiences (the latter is shortlisted as the best popular biology book by the Society of Biology). UoA scientists were instrumental in the funding, shooting, and release of the feature film, *Thin Ice* (thiniceclimate.org/), which communicates the life and work of climate scientists to a wide audience, and was aired at more than 200 venues across 120 countries on Earth Day in 2013. Shorter films reach a still wider audience on the web, such as those presenting information about specific research projects in the UoA (e.g. GEOTRACES; www.youtube.com/watch?v=_XUpMooEthQ; Bouman, Henderson). And the innovative *OxfordSparks* series which provides entertaining animations, and associated educational resources, to engage otherwise non-scientific audiences in new scientific discovery. A UoA researcher (Pyle) played a leading role in this initiative – chairing the Steering Group and developing one of the first animations (www.oxfordsparks.net/animations/volcano). Oxford University's iTunesU site helps bring such online resources to wider audiences, as does active engagement by the DoES with social media, such as Twitter (there are 20 active DoES staff Twitter accounts promoting science). UoA scientists are regularly asked to comment across all media on topical aspects of the earth and environmental sciences. For example, Pyle was interviewed on Al Jazeera and the World Service about volcanic unrest in Greece and Chile; and Parsons interviewed by the BBC on understanding fault movement (bbc.in/BBCNews76).

vi. Institutional support for impact: The UoA is part of a research university with significant institutional infrastructure to support communication with industry, the public and policy-setting organisations. The UoA makes significant use of this infrastructure to augment its own support for impact. Dedicated science writers in the University Press Office manage press releases and media coverage, with notable recent examples related to melting of Siberian permafrost (Vaks), and the evolution and morphology of fossil fish (Friedman). A dedicated team of Business Development Managers provides contacts to new industry, and organises events to showcase research and learn about industrial research challenges. Interdisciplinary organisations within the University also provide significant opportunities for impact, particularly the Oxford Martin School (OMS; www.oxfordmartin.ox.ac.uk/), which showcases leading Oxford University research to influential audiences. Four UoA faculty have been involved in OMS, including Henderson who launched the Oxford Geoengineering Programme within the school in 2010. This programme (www.oxfordmartin.ox.ac.uk/institutes/geoengineering/) has since become a major voice in the debate about the ethics, governance, and practicality of geoengineering. Staff are encouraged to pursue activities that lead to impact by institutional policies: public outreach activities are included in workload assessment when setting teaching and administrative loads; and contracts allow 30 days for consulting or other impact activities.

c. Strategy and plans

The UoA is pursuing mechanisms to further increase the impact of our research:

i. The Earth Resources Initiative: The UoA significantly strengthened its links to the petroleum industry in the last two years by appointment of a new Shell-funded Professor of Geoscience (Cartwright) and two visiting professors from the industry (Daly, Levell). Cartwright is a leading academic petroleum geoscientist with an international reputation across the industry and a wide range of active contacts in oil companies. We will build on these appointments to pursue collaborative research on questions important for the industry. This Earth Resource Initiative (ERI) will seek to bring together a core group of industrial partners, guided by a joint industry/university

advisory board, to identify and fund fundamental research relevant to critical problems for the industry. The expertise already in the UoA, and further developed by the ERI, will ensure that UoA staff are known as experts in fields such as fracking, shale gas, and CO_2 sequestration, and are consulted by diverse stakeholders, including those in government.

ii. Increase industrial graduate sponsorship: Successful research and impact has been achieved by company sponsorship of graduate students, with close company involvement ensuring that the research is industrially relevant. We will increase the number and range of such sponsorships. This will be set in the context of Doctoral Training Partnerships, following the University of Oxford's successful bids to NERC for 24 studentships per year through that scheme. That bid, and our involvement in a recently funded multi-institute NERC DTP in Oil and Gas, included confirmed links to industry, with commitments to fund studentships from organisations such as Aramco, BP, and BGS. We will seek further studentships from companies in relevant sectors. In the petroleum sector, we will contribute to a training programme with other UK institutes with complementary expertise, to provide broad, industrially relevant training and networking.

iii. Improved communication of new research findings: The DoES will increase staff resources dedicated to communication of its research to the public. Improved web content (and continued use of social-media) will reflect our own research findings and provide an overview of important environmental and resource questions. In 2014, OU-MNH will create a large, new display space to showcase contemporary geo- and bioscience research in Oxford within its public displays. This 150 m^2 area will combine video with graphics-rich displays and the content will be developed jointly by museum specialists and UoA scientists. Each six-month display will be visited, on average, by 250,000 people and online resources to support and disseminate these displays will remain accessible after the exhibitions. The award-winning museum education team will develop integrated learning programmes in collaboration with scientists. This approach will provide a much wider audience with insight into both cutting-edge research and contemporary debates, and provide staff and students with new opportunities to develop their communication skills to a variety of audiences and stakeholder groups.

iv. Increased partnership activity: Oxford Networks for the Environment (ONE) was launched in 2013 to link interdisciplinary work on climate, energy and water, and to communicate Oxford University's research findings in these areas to the wider world (e.g. www.climate.ox.ac.uk/). The UoA will work with partners elsewhere in the university to ensure that ONE effectively communicates environmental research to stakeholders. Oxford University's strength across a broad range of subjects means there is much to gain from linking activities in various departments through ONE, including forging strong links to social scientists as a route to greater policy impact. Impact will also be achieved through the Universities entry into the Met Office Academic Partnership (MOAP). MOAP is a mechanism to focus research on key challenges in weather and climate science, leading to greater impact for relevant research areas, including physical oceanography, ocean biogeochemistry, and atmospheric chemistry. The UoA plays an integral role in the MOAP and is represented on its steering group (Johnson).

d. Relationship to case studies

Close links to the resource industry (Section Bi) enabled fundamental research on oceanic anoxic events to influence oil-company exploration policy (Case Study UoA7-01). These links have led to productive ongoing fundamental research and continued impact, and to expansion of partnership with the sector by funding of research, appointment of the new Shell Professor, and hosting of Visiting Professors.

Three other case studies illustrate the success of our approach in influencing policy makers (Section Bii). Impact on Hg policy (Case Study UoA7-03) arose from hosting of KE professionals in the UoA (Holmes from the EA, Howard within the ES-KTN), while impact on the Comprehensive Test Ban Treaty (Case Study UoA7-4) and on UN World Heritage (Case Study UoA7-5) arose from personal contacts between UoA researchers and relevant agency personnel.

Our selected case studies demonstrate the wide range of impact arising from our research: from provision of fundamental understanding to inform a major industry, to more specific research in close collaboration with a small-medium-enterprise, and from research to guide public policy, to that impacting the public understanding of science.