Institution: Durham University

Unit of Assessment: Earth Systems and Environmental Sciences (UoA 7)

a. Context

Earth Systems and Environmental Sciences research is carried out by Durham Earth Sciences (DES). We have developed areas of user-inspired research that are linked to the Geoenergy, Resources & Waste, Climate & Environmental Change and Geohazards research themes described in REF5. This research is important to stakeholders in the petroleum, geoenergy, mining and insurance industries, as well as government, NGOs and the general public. The *impacts* detailed in our four Case Studies are *economic* (e.g. creation of commercial advantage, creating and hosting businesses, reduction of financial risk) and in *policy* (e.g. debate, decisions over policy). All our current Case Studies fall under the well-established Geoenergy research theme. Our growing research portfolio in climate and geohazards means that we anticipate significant new impacts in areas of *environment, policy* and *healthcare* by REF 2020 (see Section c).

b. Approach to impact

Forums and Processes: Our proactive approach to impact derives from our stated aims during RAE 2008 to diversify our sources of research funding and develop a more outward-facing research portfolio (REF 5, Section d). We have developed a number of forums and processes designed to engage internal and external stakeholders in order to maximise the opportunities to create impact. These mechanisms influence every stage of research from initial planning through to final delivery, and are managed by the Head of Department, Director of the CeREES Centre for Geoenergy, Director of Research and Departmental KE Champion. Specific examples include:

i] Strategic academic hires: DES was one of the first in Europe to appoint a Chair in Geoenergy, Carbon Capture and Storage. The employment of **Gluyas** in this industry-funded position – with his distinguished career in the commercial sector - was explicitly intended to increase impact. It is meant to ensure that Durham research is in the vanguard of work on energy security and clean energy supply both at national and global scales. Other hires have been made in subject areas that lend themselves to new sources of commercial and (non-NERC) RCUK funding with high impacts, e.g. **Greenwell**, **Mathias** and **Aplin**, all of whom have strong industry-relevant research portfolios. The appointment of **Brown** to an industry-funded lectureship also strengthened our research based in volcanic margins and volcanic hazards.

ii] Promoting academic involvement with industry and placements: The Department strongly encourages staff (and research students) to spend time working in placement positions, including those available to academics through the Royal Society Industrial Fellowships scheme (4 held since 2008; **McCaffrey, Selby, Imber, Greenwell**). **Holdsworth** was the first UK Earth Scientist to be awarded a NERC Knowledge Exchange Fellowship (2009-12). He acted as a knowledge broker between the NERC-facing research in Durham University, its associated spin out companies (see Section v] below) and other parts of the private sector. This helped DES researchers (e.g. **Goulty, Jones, Hobbs, Davies, Gluyas, Mathias**) to identify and develop opportunities for co-financed, cross-disciplinary research with industry, e.g. 3 new research consortia in DES (total value £3.8M), a new business (Geoenergy Durham Ltd), a Knowledge Transfer Partnership (with ERC Equipoise Ltd) (award of £0.144M) and 6 CASE studentships. A specific web portal for knowledge exchange and impact was also created: http://www.dur.ac.uk/research.office/knowledge_exchange/

iii] Durham [University] Earth Sciences Advisory Board (DESAB): Meeting biannually, DESAB comprises ten individuals, including Durham academics, senior individuals from the petroleum and mineral industries, representatives from other governmental bodies, NGOs and staff from leading regional universities, e.g. Newcastle. DESAB drives and helps define the impact agenda, broadening the knowledge base of the Department's staff and acting as an external sounding board for new research (and research-led teaching) ideas and initiatives.

iv] CeREES Centre for Geoenergy: An early outcome from DESAB was the creation in 2006 of a geoenergy-focussed research centre based in DES, the Centre for Research on Earth Energy Systems (CeREES). It forms an externally-facing research portal where academic and industry collaborators design international research projects and programmes that aim to answer fundamental Earth Science questions as well as generating incremental and step changes in our understanding of Earth processes as they apply to geoenergy systems. In 2006, CeREES created the Geoenergy Scholarship Programme which trains postgraduates – mainly at PhD level - for the energy industry (see REF5, Section c). To date 77% of graduating research students have taken up employment with industry (e.g. Statoil, BP, Hess, Badley Ashton, Shell, Total, DONG,

Chemostrat) with the remainder continuing their careers in academia. Our CeREES graduates are an important legacy helping to forge new links and strengthen our external networks in the future

v] *Creation and hosting of spin-out companies:* DES has provided space and infrastructure support to three early-stage spin-out companies: **Ikon GeoPressure** (formerly GeoPressure Technology Ltd (created 1998); **Geospatial Research Ltd** (created 2004); and **Geoenergy Durham Ltd** (created 2010). The first two are now located off-campus in Durham City with 40 highly skilled (graduate-level) employees. All the spin-outs derived from successful DES research projects that involved significant collaboration with international industry partners (e.g. see High Pressure Geological Reservoirs and Structurally Complex Hydrocarbon Reservoirs case studies).

vi] *Consultancy and partnerships with spin-outs:* Departmental expertise and infrastructure provide significant impact to external organisations. Since 2008, DES staff have had individual consultancy contracts with over 50 international and national industrial and other end-user companies including: ConocoPhillips, BP, Chevron, USGS, BHP Billiton Petroleum, Rio Tinto, Office of Nuclear Regulation, Neftex, Bureau of Economic Geology, National Grid Carbon.

We have used novel partnerships with our associated spin-out companies to engage more effectively with external public/private sector organisations. The spin-out offers a range of consultancy-type services, and by engaging with the external organisation(s), can help University researchers to network more effectively and leverage both data and funding. This ultimately leads to new knowledge over longer, less business-critical timescales. The spin-out benefits by creating wealth and employment, while the University gains access to often large, expensive datasets leading to research outputs and impact. One example of this symbiotic relationship has been the key role played by Ikon GeoPressure in setting-up and delivering the multi-sponsor GeoPOP 3 consortium. Another was £4k of consultancy work for the Crown Estates carried out by Geoenergy Durham that led to further investment (c. £0.16M) in a project based in DES to determine the way in which the UKCS will be licensed for carbon storage.

vii] *Research consortia:* In partnership with 20 multinational and national commercial companies, the Department has successfully launched three externally-funded research consortia since 2008 (Volcanic Margins, GeoPOP3, ReFINE). The total value of these consortia to DES will be £3.8M. Each consortium has its own advisory board with representatives from the international stakeholder companies together with academics from Durham and other Universities (e.g. Newcastle, Birmingham, Glasgow, Leicester). Some consortia have a strong research focus (e.g. GeoPOP3), while others are additionally concerned with informing policy (e.g. ReFINE). Others involve elements of training, e.g. using field trips and workshops, the Volcanic Margins consortium has trained 90 industry professionals in aspects of applied volcanology, structural geology and geophysics. This enables industry geoscientists to make improved, informed technical decisions in what is otherwise an unfamiliar geological setting and it has helped companies better understand the risks associated with exploration in volcanic margin settings.

viii] *University Research Institutes:* Our established expertise in geoenergy forms a key element of the Durham Energy Institute (DEI) research portfolio, whilst our emerging strengths in geohazards fall naturally under the remit of the Institute for Hazard, Risk and Resilience (IHRR).

Created in 2009 and directed by **Davies** until 2012, DEI encompasses over 100 research staff in 12 departments, covering social sciences, geoenergy, renewables, and fusion materials for energy and energy conversion. Research impacts are broadened by including anthropologists and social scientists in projects to address issues such as energy security and energy supply. Through DEI, DES researchers have taken part in the Party conferences, provided advice to the shadow energy team and advice to the Government Committee on Climate Change. DEI representatives are members of PRASEG (Parliamentary Renewable and Sustainable Energy Group) and PGES (Parliamentary Group for Energy Studies), the cross party group for UK politicians and senior industry stakeholders that exists to promote sustainable energy issues in Parliament.

Launched in 2007, the IHRR - which **Horwell** co-directs - aims to develop and support world-leading hazard- and risk-related research, knowledge exchange and research impact. IHRR brings together a multidisciplinary group of academic researchers, practitioners, policy makers and local communities using networking, research generator events, online media and public lectures. It also provides support and accommodation for visiting external collaborators (e.g. Northwestern University Prof Stein 2013 visit to discuss seismic risk issues around fracking).

Institutional support for Impact: Our internal impact processes align with and inform the broader university strategy led by our Dean of Knowledge Exchange (**Davies**) and Dean of Technology

Transfer (**Tanner**, winner of the Queen's Award for Enterprise Promotion, 2012). DES works closely with University professional support departments including Marketing and Communications, Durham Alumni Relations Office, Durham Business and Innovation Service (DBIS) and the Research Office (RO). DBIS helped, for example, in the creation and launching of our spin-out companies, whilst the RO have provided legal advice and management accounting during the setting up of our three multi-company funded research consortia.

c) Strategy and plans:

Strategy: The development of externally-facing research partnerships is a core part of the Durham University Research Strategy 2010-20 (http://www.dur.ac.uk/research/strategy/).

DES has two particular strategies explicitly intended to strengthen research and enhance impact:

i] *Stimulating and embedding industry and stakeholder involvement in research activities*: External stakeholders (e.g. BP, BG, Shell, DONG, Statoil) are key members of the strategic advisory boards for the Department (DESAB), CeREES, the research consortia, DEI and IHRR. All host regular seminars, workshops and fieldtrips collaboratively with external visitors and staff/students. External stakeholders also act as partners/supervisors in all collaborative research and PhD projects.

ii] *Encouraging inward investment in Durham University by external stakeholder organisations:* Impact is best encouraged by attracting external research funding into the University. From industry alone during the period 2008-2013, the Department and CeREES have been awarded over £6.3M, funding research projects, consortia, PDRAs, PhD studentships and 3 new academic staff positions (**Gluyas** [Ikon-DONG], **Selby** [Total] and **Brown** [Volcanic Margins]). Large volumes of commercial data have been used for research, creating new scientific knowledge and impacts.

Plans: Looking toward REF2020, we plan to use initiatives and mechanisms such as those offered by the BP Research Hub (see REF5, Section bv) in order to: a] engender an environment in which research is undertaken that has world-leading impact; b] support the development and optimisation of partnerships with the most influential national and international businesses, research councils, spin-out companies, non-governmental organisations and public sector bodies with mutually beneficial research agendas; c] explicitly identify impact opportunities as they develop within research projects; and d] collate quantitative and qualitative information about the impact that our research generates in preparation for REF 2020.

We anticipate a range of research impacts maturing by REF 2020. Our increasing involvement in cross-disciplinary research into geohazards and climate has meant that some of our most recent projects are of societal importance in areas related to hazards, risk and improvements to the quality of life. They include (with [*impact areas*]): 1) Project GO: an EU NEST FP6 consortium led by **Hobbs** using industry seismic reflection data to study ocean mixing processes, a major control on global climates [*environment*]. 2) HURRICANE: An ERC project led by **Baldini** using geochemical signatures in cave stalagmites to develop a high-resolution Atlantic hurricane activity record for at least 500 years. It will significantly improve our ability to predict hurricanes and will also shed important new light on whether anthropogenic climate change is leading to increased hurricane activity [*environment, policy*]. 3) Ash particles and Human Health: **Horwell** is studying the impact of ash particles on human health. She also directs the International Volcanic Health Hazard Network (IVHHN) [*environment, healthcare*]. 4) Active faults and seismicity: **McCaffrey** is using Terrestrial Laser Scanning techniques to separate co-seismic and afterslip components of fault movement from the L'Aquila earthquake in Italy. **DePaola** is using low to high velocity rotary shear experiments to study the frictional properties of natural seismogenic fault zones hosted in carbonates of central Italy and Israel. The results of both these NERC-funded projects can be used to model and better predict the behaviour of mature seismogenic faults [*environment*].

d. Relationship to case studies

Our case studies are related to the well-established Geoenergy research theme, underpinned by research excellence in geochemistry, petroleum geosciences, structural geology and volcanology. Each illustrates a spectrum of interactions related to research developed collaboratively with industry partners to address mutual fields of interest. All four case studies emerged from the provision of specialist expertise and the application of new techniques and approaches designed to address problems initially of academic focus, e.g. virtual outcrops, Re-Os geochronology, geological overpressure. Two case studies (High Pressure Geological Reservoirs and Structurally Complex Hydrocarbon Reservoirs) also involve close research partnerships with Durham-based spin-out companies (Ikon GeoPressure and Geospatial Research Ltd, respectively).