Institution: University of Aberdeen

Unit of Assessment: 7 (Earth Systems & Environmental Sciences)

a. Context

Beneficiaries of research emanating from this Unit of Assessment (UoA) include the oil & gas industry and their service companies together with NGO's and policy makers, especially within the environmental sector. We support these communities by direct interaction and by disseminating relevant primary research derived from deep time and present day Earth systems. This research provides beneficiaries with context for surface and subsurface models, reducing risk and bias and for informing decision-making.

The Unit includes three research groups, each facing different end-user communities. For the **Tectonics & Geophysics** and the **Basin Fill** research groups the principal end-user of our research is the oil & gas industry. Application of our research has improved understanding of basin structure, hydrocarbon reservoir locations, geometries, heterogeneities, volumes and possible behaviours during production. Immediate impacts of our research include promoting exploration drilling, increasing estimates of reservoir volumes, and reducing operator risk and costs during development and production. Three of our case studies demonstrate these significant impacts. We do not rely on passive dissemination of our research, but have developed knowledge exchange pathways and feedback mechanisms through active industry participation events and especially via our innovative exploHUB and Turnstone interfaces. These present hydrocarbon industry staff and decision makers with the wide spectrum of our research that facilitates discussion on research direction and maximization of impact.

Our **Earth Surface Processes** research is being applied to inform policy and public decision-making. Our hydrology research impacts on river management and fisheries industries (e.g. Environment Agency, Scottish Environment Protection Agency, Marine Scotland, Tay District Fisheries Board). Our process-based cryosphere research tackles key uncertainties in the feedback between climatic and environmental change and the ecosystem that has broad societal significance by informing scientific and public debate on the environmental impacts of climate change, and decisions on environmental policy (e.g. through the Intergovernmental Panel for Climate Change, European Space Agency, Scottish Government on Coastal Flooding). This research provides one of our case studies, influencing climate model development in the British Antarctic Survey, the European Space Agency and NASA.

b. Approach to impact

Members of all three research groups contribute to the development of best practice in maximising non-academic impact. Our approaches differ with relevance to the target end-users. Since 2012 this has been facilitated and developed by the co-ordinator for Public Engagement with Research (Bond), appointed as part of an RCUK Catalyst grant, to sustain existing collaborations and attract new partners effectively.

• *Engaging directly with the oil & gas industry to promote the application of research*

Our Joint Industry Project (JIP) research addresses immediate business needs, commonly using industry data, with knowledge exchange and wide-picture integration as explicit deliverables (see Case Study 1-3). This results not only in economic impact on the hydrocarbon field scale, but also on basin-wide global industry policy-making (e.g. Brazilian government 'special participation' scheme). Impact is embedded via in-house and field-based workshops, multi-sponsor meetings and subscription-based web-pages to disseminate research outputs, reports, and to provide discussion forums. These interactions resolve business-related technical challenges, the wide context of our research impacting on industry practitioners by highlighting new opportunities and approaches. Broader engagement with industrial end-users happens via presentations at a wide-range of industry-focussed exhibitions and conferences. We co-publish our research with companies who share their software with us (e.g. ffA for *SVI Pro* and Midland Valley for *Move*), and they receive annual reports and case studies from us which are used in further software development and marketing.

• *Knowledge exchange through advanced professional training and outreach*

ExploHUB and Turnstone programmes specifically target industry employees using the outcomes of research to inform professional development. Field-based and in-house workshops that form the

Turnstone programme are typically attended by 30 delegates from a range of oil & gas companies (including Badleys, BG, BP, Bridge Energy, Cairn Energy, Chevron, ConocoPhillips, Dana, Maersk, Midland Valley, Schlumberger, Senergy, Shell, Sinopec, Task, Total, Tullow; together with the Department of Energy and Climate Change). This initiative links our expertise and research within the fields of structural geology and tectonics to the oil and gas sector, addressing issues in exploration and production. This activity is led by **Bond** (since May 2010). Professional MSc-level training in hydrocarbon exploration is transferred through the exploHUB initiative (Director – Archer). In three years of operation this has benefitted 17 staff from 8 companies around the world (PEMEX, Schlumberger, Premier Oil, Sterling Resources, GNPC (Ghana), Saudi Aramco, Senergy, and Dana Petroleum). By exposing current and future explorationists to modern techniques and our leading research, exploHUB directly disseminates our research to industry, enabling informed exploration decision-making through reduction of subsurface uncertainty.

We foster long-term links with industry internationally through our leading MSc programmes (Integrated Petroleum Geoscience and Oil and Gas Enterprise Management), with project work chiefly carried out within companies. The majority of our PhDs are funded by industry, spending time embedded within the sponsoring company. This alumni base provides key networks for future research and knowledge exchange with industry and government (UK and overseas).

Seismic data is of value in research, within both the Basin Fill and the Tectonics & Geophysics groups, and increasingly with studies of Quaternary glaciations recorded offshore. A significant pathway for achieving impact is the Virtual Seismic Atlas (www.seismicatlas.org; Director - **Butler**), an open-access community initiative that is used by thousands of scientists (accessed on more than 3 million occasions over three years) from around the world both within industry and academia, with links to original research outputs and training materials.

• *Supporting policy-makers*

Our involvement with ClimateXChange creates a direct pathway to policy development. The research has been directed by the Scottish Government through call-down questions, and co-constructed with government policy teams. In the past year we have provided research-based evidence and advice on the uncertainties and risks of climate change, including written evidence to the House of Commons Science and Technology Committee on public understanding and its policy implications'; we have analysed stakeholder perceptions of climate change impact on Scottish trunk roads; and quantitatively assessed the uncertainties in expert opinion on carbon abatement curves. Through Tetzlaff's involvement in the NERC Arctic programme there are direct linkages with the Hadley Centre at the UK Met office. The modelling of soil C, N and GHG fluxes will ensure that new understanding generated by the project will be incorporated into models (JULES, ECOSSE) used by the Met Office providing evidence for policy development. Nationally, we were involved in the establishment for the Scottish Government's Centre for Research Expertise on Waters (CREW). Also hydrology research is closely linked with the Freshwater Laboratory of Marine Scotland Science (MSS) providing advice on the relationships between hydrology and ecosystem response for determination of environmental standards for Water Framework Directive and assisting in the future development of ecologically based assessment tools. Our work on sustainable water management is a prerequisite to assessing how catchments will be affected by environmental change and given the needs of the EU Water Framework Directive, UK regulatory organisations such as the Environment Agency, Scottish Environment Protection Agency, English Nature and Scottish Natural Heritage benefit from the work regarding management of uplands catchments. By way of example, the invasion of signal crayfish from North America into NE Scotland represents a serious threat to biodiversity. **Tetzlaff**'s research, in partnership with Scottish Natural Heritage and Nairn Lossie Fisheries Trust, is helping to overcome the scientific and institutional barriers to action in the face of uncertainty on effectiveness, financial costs, and collateral damage of intervention. This helps to provide the partners with effective management tools to tackle this alien species.

• *Engaging with the public to promote understanding of our research*

Impact within the public dissemination of science is exemplified by **Butler**'s research on NW Highlands geology (spanning 25 years). These have led to on-camera contributions during the REF period to two broadcast television series: the BBC's "Men of Rock" (broadcast 2011), and ARTE (France)/Discovery Canada "Dance of the Continents" (first broadcast July 2012). His work is also used, in collaboration with the British Geological Survey, to underpin the status of the NW

Highlands Geopark, and by Scottish Natural Heritage in establishing the network of SSSI's relating to the Moine Thrust Belt (Geological Conservation Review: Mendum et al. 2009). The research also led directly to the development and marketing of a new brand of whisky (Mull a'Mhoine: www.mull-a-mhoine.com) by Aceo Ltd, principally to the German market. Our cryosphere research output ultimately has impact on policy makers concerned with the potential impacts of climate change on global sea level rise. For example, scientific output from the Greenland Ice Sheet (Mair) and Antarctica (**Bingham**) is being used by international ice sheet modeling communities (e.g. the EU-funded "Ice2Sea" research consortium) to reduce the uncertainty surrounding ice sheet boundary conditions and processes and improve constraints on future model-based predictions of ice sheet response to climate change. This research has achieved significant wider societal impact through media interest (e.g. **Bingham**'s Antarctic research in 2012 was reported in >200 international media outlets, including the BBC Website, BBC World and BBC Scotland Radio, Scientific American, Time Magazine and NERC Planet Earth Online); and through a series of public outreach activities. These include contributions to Our Dynamic Earth in October 2011 (**Mair**), Café Light in November 2011 (**Mair**), and the British Science Festival in September 2012.

c. Strategy and plans

We will maintain a diverse strategy to maximize the impact of our research. Research developed within JIPs, with the oil & gas sector will continue to be a core activity within the Unit. Results and expertise will be exchanged with sponsors through a combination of group and company-specific workshops, seminars and working sessions. This has proven a successful strategy (Case Studies 1-3) that we expect to continue - influencing exploration direction and targets. We share research with the broader oil & gas sector through presentations and exhibitions at industry-focused conferences, especially engaging with industry-led seminars in the Aberdeen area (e.g. Petroleum Exploration Society of Great Britain). Staff and postgraduate researchers will continue to interact with companies on an individual or small-group basis. Longer-term relationships with the energy industry build through our alumni base arising from our degree programmes (and their exceptional employment records which rank Geology at Aberdeen 2nd in the UK for employability). We will continue to develop novel CPD programmes deriving from our research, to better connect with and influence our end-users. This includes the dual programme development of exploHUB and Masters training with the oil industry service provider, Senergy. Such partnerships lever considerable penetration into the oil & gas industry, greatly increasing the reach of our impact. We are a key partner in the SFC funded, multi-institutional Oil & Gas Innovation Centre across Scotland that will provide direct interaction with industry, thereby further increasing our reach into this diverse sector, together with governmental policy-makers. This will also involve regular themed workshops and seminars to reach new companies, together with placing our scientists within company teams. We will continue to assist government in policy development through participation in multi-institutional initiatives such as ClimateXChange and CREW. These engagements also open pathways to develop impact for other policy-relevant research, including early notice of consultations and calls for evidence. We will continue to foster and grow our media and public-facing activities(e.g. Cafés Scientifiques, exhibitions, geoconservation initiatives), assisted by the University's communication office and public engagement grants.

d. Relationship to case studies

We have selected four case studies that illustrate our different approaches to impact. They do not cover the whole range of our research impact, but highlight some of our main pathways and the application of Aberdeen research by end-users. In Case Study 1 we show how fundamental research on the stratigraphy of large igneous provinces assists frontier oil and gas development by virtue of conducting research in close partnership with industrial end-users, explicitly linked to their commercial assets. Likewise in Case Study 2, industry-funded research is transferred to clients by sharing results through company-specific training and field workshops, using outcrop analogues. Turbidites research outlined in Case Study 3 also uses field training and workshops to transfer results and expertise, further enhanced by core-workshops, short-course and in-house coaching of oil industry professionals. These researchers facing the oil & gas sector also feed into our own professional training programmes, which continue to reach out to wider parts of the industry. The end-user community for the cryosphere research that underpins Case Study 4 is reached through media and other public engagement activities, forming part of broader campaigns to raise awareness of climate change, and informing non-academic international groups (British Antarctic Survey, European Space Agency) exploring the future of global ice sheets.