Institution: Cardiff University

Unit of Assessment: UoA7

a. Context

The School of Earth and Ocean Sciences has long-standing recognition for conducting internationally excellent research, including in marine and petroleum geology, metal deposits, climate change, and environmental hazards and integrated management, which have direct and significant global impacts. The outputs from our research, therefore, are fundamental to many challenges in society, including economic, environmental and societal impacts. The established School strategy for frontier research includes a vibrant and innovative environment, which encourages, facilitates and optimizes applied research potential. Mostly funded by the UK Research Councils and EU (67%), the School also attracts significant additional support from commercial, agency and Government funding worth £2.9M over the assessment period. Our links with a range of end-users drives a strategy that generates impacts from our research, enables access to unique samples and data, and encourages links between researchers and stakeholders. Key beneficiaries include the petroleum exploration and metal mining industries, coastal engineers, managers and practitioners in coastal and marine resource management.

We have strong relationships with the geographically close Welsh Government (e.g. Climate Change Knowledge Exchange Advisor Secondment), National Museum of Wales and BGS Wales, and are involved in the leadership of the Climate Change Consortium for Wales (C3W), Sustainable Places Research Institute, and the Severn Estuary Partnership. We are active participants in the Low Carbon Research Institute, Tyndall Centre for Climate Change Research, and National Oceanography Centre Association. Our academics actively engage in mass media outreach of science to the public through television, radio, and newspaper interviews, including such diverse topics as human evolution and climate change, Icelandic volcanic ash and human health, the deep biosphere, and the evolution of the first forests in the Palaeozoic.

b. Approach to impact

Impact is embedded in the culture of the School; including recognition of impact activities in workload credit and post-graduate researcher funding. Formally, it is the remit of the Research Committee, which has representatives from each Research Group in the School, along with our 'Impacts Officer' (Dr T. Jones) and two 'Innovation and Engagement Officers (I&E)' (Dr S. Oberst and L. Beaman, C3W) to facilitate delivery of our impacts agenda. Indeed, the School's recent academic appointments in economic geology reflect a vigorous policy of supporting impact-based activity. We strongly encourage an interdisciplinary focus within the School which can often facilitate excellent research with impacts. We have an Impacts Panel of external experts, with diverse backgrounds and experience, to further advise on impact strategy and potential impact of current and future research initiatives.

Relationship with end-users. Working closely with our end-users is the key to translating our research into impacts. Our research outputs impact on a broad range of these end-users from multi-national industry (petroleum, metal exploration, and geoenvironmental) through to international organisations informing global environmental policies (e.g. Intergovernmental Panel for Climate Change). The School provides research-led advice and guidance on the often complex and contradictory interactions and objectives of the industrial and environmental sectors. An important key to successful impact is the School's investment through our I&E Officers; the establishment of long-term strategic partnerships, as evidenced by the Caprocks Consortium (petroleum industry) and the Severn Estuary Partnership (SEP, environmental management); and our Impacts Panel of representative research users.

Wider contribution and public engagement. Taking action to avoid potentially calamitous

climate change in the future requires the support and understanding from the widest possible number of participants and end-users. The Palaeoclimate and Climate Systems Research Group, largely through its involvement in C3W (Cardiff Institutional Director, Professor I. Hall), has undertaken extensive innovative activities to promote climate science awareness. Examples include collaborations with (i) the Beacons Project to develop an education resource pack for teachers and pupils of Key Stage 4 – exploring how changes in the climate change could impact citizens of Wales, (ii) the National Museum Wales in an exhibition entitled "Exploring our World" (iii) filmmaker Hywel George (Plastic Buddha Productions) who accompanied Dr H. Coxall and Professor P. Pearson in the field in Tanzania in 2008 and 2009 to make a documentary about their climate research (Climate Detectives), (iv) IPCC 5th Assessment of Climate Change Science -a Welsh Perspective, Cardiff Bay, 29th October 2013.

Research involving the School's Applied Environmental Geoscience Research Sub-Group has lead to mitigation of the serious health and environmental risks posed by municipal waste landfills, with toxic emissions being linked to various cancers, respiratory disease, congenital birth defects, low birth weight rates and still births. The research outputs has been successfully applied to sixteen landfills during the assessment period, including Nant-y-Gwyddon where links with birth defects provoked international opposition. Cardiff's research was instrumental in decisions concerning gas and leachate management, and ensuring a safer environment for the local community.

The Marine and Coastal Environment Sub-Group have significantly influenced professional practice at UK and international level. The impacts include developing tools to engage communities and inform practitioners in managing coastal environments. Performance indicators have been identified for the formal reporting of environmental trends in the European port sector, and developing the World's only recognized port-specific Environmental Management Standard. The Group also leads the SEP.

Identification of impacts and agility of approach. We strongly encouraged an 'agile approach' for research that might lead to impacts; including helping individual staff identify impact opportunities, which could be well outside their normal research field. For example, Dr Tim Jones, who specialises in geology and human health, undertook a contract (with School of Bioscience colleagues) with the University's IP commercialisation partner 'Fusion IP' to investigate the efficiency of a device developed to clear airborne particles of 'key-hole' surgical smoke. Generated by energy-based cutting instruments the smoke obscures the surgeon's view of the operation, lengthening operation times and having adverse health effects on the operating team inhaling the fumes.

Enabling staff to achieve impact and rewarding that achievement. Innovation and engagement activity is strongly encouraged. A senior academic (Professor D. Edwards) maintains overall responsibility, supported by two I&E Officers. The school engages with the community, through public lectures and events, and with schools across South-mid Wales and W-SW England. A portal for schools outreach is under development on the university website. The School considers that time spent on I&E activities constitutes an important workload model component and is acknowledged in the formal annual appraisal. These activities are recorded on a School database. The School's coastal research vessel, *R.V. Guiding Light,* is a high-profile component of the School's I&E activities (http://cplan.subsite.cf.ac.uk/cplan/sites/default/files/CCS-GuidingLightFloatingClassroom.pdf). Each year, with the support of the Reardon Smith Nautical Trust, the School engages with a wide range of institutions and organisations in order to bring the importance of the oceans (and local marine environment) to a wider audience and to work with professional bodies that offer research and career collaborations.

c. Strategy and plans

Research impact is an important component within the School's strategic plan. The plan documents the expectation that researchers engage in internal and external interdisciplinary research, and knowledge exchange, produce the highest quality research and explore potential impacts of their results. The School's strategy recognises the fundamental importance of excellent research outputs to end-users, beneficiaries and the wider community, as well as to academia. This is evidenced by, for example, our long-term and highly successful collaborations with the SEP and Natural Resources Wales. We also recognise the increasing importance of innovation and entrepreneurism for the long-term health and vigour of the School's future research profile. Engagement with industrial and commercial partners is encouraged and supported, fostering knowledge transfer, and the provision of expert advice and consultation. Industrial collaborations have included matching funds arrangements for research students, and the support of 'spin-out' activities (e.g. TerraDat, Cardiff). Academics are encouraged to obtain commercial funding for their research and act as consultants by a flexible approach to profit sharing, which enhances future research. In addition the School provides targeted financial support for staff engaged in impactive research through a Staff Development Fund.

Recent academic staff appointments have taken into account the importance of impactive research, with support for applied research areas including economic geology and marine coastal hazards. These appointments will support and strengthen our existing Research Groups generating commercial impacts in mineral exploration, and societal and environmental impacts in coastal management. Additional future positions are planned in petroleum geology that will continue to support the impact agenda.

The School has well-established and long-term relationships with many geoenvironmental and exploration companies through our internationally renowned MSc. in Applied Environmental Geology and BSc/MESci in Exploration and Resource Geology. This network was initially built to provide industrial placements and sponsorships, and includes local and UK SMEs as well as multinational companies (e.g. SRK Consulting Ltd; Shell, BP). Building on past successes the commercial network is constantly expanding and improving, and provides exciting potential to generate future high-impact activities, including funded studentships, knowledge transfer, analytical facilities development, consultancy, and access to unique samples and data sets etc.

d. Relationship to case studies

The understanding of the mechanisms and behaviour of polygonal faults (Case Study 1) is on-going research, and crucial findings have been made that impact strongly on the hydrocarbons industry. This is evidenced by the industry's continued logistical, provision of seismic data, and financial support to the Caprocks Consortium. This Case Study is an exemplar of how important high-Impact research was recognised within the School and the appropriate logistics and teaching support to researchers was put in place to facilitate its successful development. On Earth the intense heat, fracturing and inward collapse caused by large extra-terrestrial impacts may lead to the eventual development of enormous mineral or hydrocarbon deposits, such as platinum mineralization. Case Study (2) shows the School's and individual researcher's ability to identify complimentary research pathways, and adapt accordingly. Dr Hazel Pritchard researches PGE mineralisation in mafic igneous rock deposits, and Dr Iain MacDonald has researched ancient terrestrial impact sites. A critical component of this research has been the state-of-the-art geochemical analyses facilities in the School, including the laser-ablation ICP-MS. This demonstrates the Schools understanding of the need to facilitate and fund long-term specialised equipment. This is further evidenced by the School's recent investment in a new analytical scanning electron microscope.