Institution: University of Leicester

Unit of Assessment: 7 Earth Systems and Environmental Sciences

a. Context

Geological Science within the Department of Geology is a field of diverse applications of biology, chemistry, physics, and laboratory, analytical and observational science to issues of the Earth and its recent and ancient evolution. Research applications span very deep time early in the Earth's evolution billions of years ago to problems and processes of modern and recent Earth evolution that bear on the Earth's climate, ecosystems, biological evolution, mineral and energy resources, technological innovations of benefit to industry and government, Mans' influence on the Planet in the Anthropocene, and specific aspects of environmental pollution and health.

In the past five years, there has been increasing focus on research with socio-economic impact. The department has extensive and substantial geochemical/mineralogical (ICP-MS, XRF, XRD, SEM and EPMA) and geophysical seismic and borehole characterisation research infrastructure with strong research links with other UK and international research organisations. It has substantial links with the Integrated Ocean (Drilling-) Discovery Programme (IODP). Borehole Research in the department has a long-standing contract with the IODP for core logging and characterisation and downhole logging. This supports a string of research-oriented PDRAs and, as lead of the European Petrophysics Consortium, and in collaboration with Lamont-Doherty Earth Observatory, the Borehole Research subgroup provides petrophysics advice to the IODP. Work with IODP has led to links with multi-national and national companies such as Weatherford, Schlumberger and Geotek, which all provide services, equipment software and training for IODP projects.

Through these links, companies have engaged with, and funded, Leicester researchers in applied research for the oil and gas sector and collaborative efforts in customising core-logging equipment. The non-academic user groups that benefit from the department's impact are growing and include major mining industries (DeBeers of S Africa, Glencore Xstrata), oil companies (BG Group, ConocoPhillips, Cuadrilla, ExxonMobil, SaudiAramco), the UK Ministry of Defence, the Government of the Soloman Islands, UNESCO and other more local organisations.
The public, and young people in particular, are also beneficiaries reached through our public engagement and media work.

b. Approach to impact

The department supports a mixed portfolio of research ranging from theoretical work firmly focussed on geological topics through to applied research aimed directly at resolving current and immediate problems. This approach is designed to encourage the short and long term growth and health of the discipline and foster innovative research.

Support for researchers involved in impact activities

Individual researchers are actively encouraged to apply their own vision, enthusiasm and leadership to pursue research collaborations - and follow-on activity for impact. The department has supported this work through a programme of pump-priming awards (travel, equipment) that allow liaison and collaboration to get started, leading to more substantial competitively awarded research funding. This in-house support is complemented by an institutional approach which supports the transfer of research into commercial activities, with financial assistance and business development advice provided by the Enterprise and Business Development Office (EBDO) and with research impact development and academic practice advice provided by the Research Support Office and Academic Practice Unit.

Over the assessment period, there has been a substantial increase in EBDO support for the College of Science and Engineering (CSE), including the appointment of a new business development manager based in the College, with a team of three, including a contracts manager and a commercialisation manager. The University has also appointed a very experienced Director of EBD, who has led the development of a detailed, user-focussed business plan, prepared in consultation with enterprise leads and includes restructuring and expansion of the central EBDO to support the enterprise and impact priorities in individual Colleges, and enhanced and targeted support for early stage enterprise projects through Proof of Concept and Prospect Funds. At its

inception in 2009, the CSE initiated a business development group. To provide strategic overview for this group, the College has a Business and Industry Advisory Board, with external membership. The business development manager chairs the group, which has provided a forum for development and dissemination of good practice. Researchers are encouraged to make use of both departmental and institutional resources to enable impact.

Collaborative research and industrial funding

Researchers work closely with external organisations from both the public and private sector, winning substantial funding from minerals and energy companies, the IODP (technology support through the European Petrophysics Consortium (EPC) of ECORD), and from governments. The use of Industrial CASE Studentships has enabled a particularly close and productive alignment with industry. Collaborative research has produced applied and technology-oriented research that has been of direct economic and societal benefit to users. For example, the department has a coordinated approach to working with various mining companies (DeBeers, Glencore Xstrata) for mineral deposit research. And Leicester's tradition of biostratigraphical expertise in Lower Palaeozoic faunas has secured strong links in industry, with on-going consultancy projects in Saudi Arabia (with Saudi Aramco) and in Poland (with Chevron).

Strong links with national and global science bodies

The department has a long-standing relationship with the Integrated Ocean (Drilling-) Discovery Programme (IODP), the British Geological Survey and the NERC Isotope Geosciences Laboratory, and this gives the department access to a wide variety of applied projects, many with direct impact. For example, geothermal power work in the Solomon Islands – which aims to provide electricity for the islands' capital city - and research on depleted uranium and its environmental and health aspects (as described in one of the impact case studies) have arisen from direct collaboration with the BGS and its partial funding of PhD students. The department's close relationship with the IODP has led to researchers' world-leading expertise in the fields of downhole logging, core petrophysics and core–log integration. This expertise is highly valued by industries involved in the search for oil and gas. These partnerships are cemented by several cross-appointments - Leng and Parrish are cross-appointed to the British Geological Survey's (BGS) NERC Isotope Geosciences Laboratory where MGeol and PhD students and PDRAs have access to the most advanced isotope research tools and training available. Vinciguerra is cross appointed as Head of Rock Physics at BGS.

Knowledge dissemination and public engagement

The department's palaeobiologists are concerned with understanding how exceptional fossils and fauna are preserved and with reconstructing animals and their habitat in the deep geological past. This work has very broad public appeal, particularly for children and young people. In recognition of the importance to the UK's economy of inspiring interest in science, the department has undertaken a variety of public engagement activities involving direct contact with school children, the public and policymakers at a range of events. With funding from the University, The Palaeontological Association and The Natural Environment Research Council, researchers designed activities and successfully bid for selection at SET for Britain 2011 (Houses of Parliament); The Royal Society Summer Science Exhibition 2011; Big Bang 2012 and Big Bang 2013 (UK Young Scientists and Engineers Fair). Research into pterosaurs has led to major contributions to a BAFTA-award winning film hosted by Sir David Attenborough. Finally, the department has consistently supported the local community of which it is a part by sponsoring and leading the Leicester Literary and Philosophical Society, which hosts free, well-attended scientific lectures many times each year that raise awareness of geological and environmental aspects of our world amongst the general Leicester population.

c. Strategy and plans

Research groups within the department are involved in a more coherent approach to impact than ever before. The department has identified several projects with the potential for impact over the next assessment period. These projects will be supported with the express intention of maximising their potential for societal and economic impact, using the approaches outlined above.

Projects fall into four main areas: (1) mineral resources research with industry and governments; (2) energy related research; (3) palaeobiological research with schools, charities, and media/film,

related to public engagement; (4) environmental pollution and health geochemical research.

Mineral deposit and strategic metal security-of-supply research
Jenkin, Smith, Holwell and numerous collaborators (PhD students, companies, other universities) aim to improve effectiveness of mineral exploration models to more efficiently locate new resources (with Glencore Xstrata involving Fe-Cu-Au deposits), and to improve the recoverability of strategic metals (Pt, Pd, Rh, Ru, Ir, Os, Se and Te) that are by-products of other mining. Working closely with industry, researchers anticipate identifiable research and impact outputs in the next 5 years.

Energy-related research
Borehole research directly relevant to the oil and gas industry has shifted to shale gas research (Davies, Lovell) where the organic constituents and the physical properties of shale are key parameters needed to evaluate the feasibility of shale gas exploration and development. Leicester research is currently providing key new studies of direct interest to industry (PhD projects of Koenitzer, BGS-Leicester funded; Graham, supported by NERC-ExxonMobil; Hartigan, supported by the London Petrophysical Society and BG Group).

Leicester is a major partner in a joint BGS-led BIS initiative proposing to develop an 'Energy Test Bed' to study and monitor areas with accurate physical and chemical baseline information prior to development of shale gas extraction, in order to better monitor its environmental effects. The development of geothermal power in the Solomon Islands has been fostered as a direct result of Leicester research (Smith) into volcanic-related hot springs and vents, and the department is exploring ways in which it can remain involved with the evolving impacts there.

Moorkamp's joint inversion methodology, funded by a consortium of hydrocarbon exploration companies (with negotiations for future work with BGP and China National Petroleum Corporation) is currently being used to identify hydrocarbons beneath basalts for Statoil. Other energy research aims to assist directly a consortium of energy companies that support the Volcanic Margins Research Consortium, of which Walker at Leicester is a key member; its principle aim being to better understand rock physical properties (porosity, lithology, etc.) unattainable by seismic data alone, to improve energy exploration efficiency in continental margin areas.

Palaeobiological research
The impact strategy of the Palaeo3 research group (including Purnell, Siveter, Gabbott, Unwin, Williams, Harvey) is directed broadly at public engagement and educational activities based on research outcomes.

Health-related research
The isotope geochemical research involving depleted uranium and Gulf War Illness conducted by Parrish will continue and is as pertinent as ever given the continuing instability in the Middle East and the potential use of chemical warfare and DU munitions. This research will build on the existing impact case study to test putatively whether DU munitions played a role in Gulf War Illness or whether the exposure to Sarin in 1991 was the prime culprit; this is highly relevant now with the alleged use and potential destruction of chemical weapons stores in Syria.

d. Relationship to case studies.
The UNESCO-related case study which led to the granting of a *World Heritage Site* can be regarded as 'opportunistic' impact. However, once the opportunity arose, the concerted effort by Leicester academics and their Chinese colleagues to protect, preserve and exploit the site for its cultural impact reflects the department's overall commitment to maximising the impact of its research. The case study on research into *Pterosaurs*, the first back-boned animals to evolve powered flight, which underpinned a successful 3D digital product for Sky reflects the department's commitment to public outreach and knowledge dissemination. The *Depleted Uranium* case study, which involved collaboration with the British Geological Survey's (BGS) NERC Isotope Geosciences Laboratory reflects the value of the department's strong links with national and global science bodies.