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Interconnected geoscience for international development

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Spending in international aid programmes from governments and other agencies represents a >> \$100Bn US investment annually. International development and global environmental management greatly benefit from the application of high quality/ appropriate geoscience and related expertise. Barriers exist, particularly between research-intensive geoscience organisations and development agencies, that inhibit the greater application of geoscience within development. Key barriers include differing world-views, performance rewards, and values. This paper argues that geoscience can rapidly evolve in its importance and application to complex regional/global, development and environmental challenges. Changes in ethos, performance rewards, attitudes, and culture, will drive an increase in relevance. Case studies are presented, from Afghanistan, and Solomon Islands, to illustrate how geoscience approaches can be applied, within complex multi-faceted development contexts, with consequent outcomes and challenges. Lessons can be learned from such case studies that inform interconnected approaches. A conceptual model is presented of 'interconnected geoscience', defined as: 'a philosophy that combines geoscience expertise with an equivalent expertise/consciousness in the understanding of developmental situations, conditions, and context, including the integration of diverse world views/wisdom and values, placing development-goals at the heart of the interconnected-approach'.

Introduction

This paper argues that it is vital for global development to inextricably link and closely involve geoscientists (alongside natural scientists and engineers) in development programmes. The paper cites examples where geoscience has made a key contribution to development and argues that the future of geoscience within international development requires approaches that increase multi-disciplinary and interconnected philosophies. There are barriers to the successful integration of geoscience within international development. These barriers are most acute between geoscientists in research-intensive institutions and development-outcome oriented development organisations. Differing promotional reward systems and world views within aca-

demical science and professional development environments can inhibit close collaboration. A range of approaches can be adopted that encourage geoscientists to develop more interconnected approaches towards global development. The paper defines terms related to international development, examines inhibitors to geoscience-development collaboration, presents lessons learned from case studies, and proposes an interconnected geoscience concept for international development.

Geoscience and International Development

International Development: Terms and Concepts

Terms related to international development and the categorisation of countries or regions (economically, socially, in 'development' terms) are politically and culturally sensitive. The term *international development* itself is considered to be inappropriate in some quarters. Horner (2019) argues that the blurring of the 'Global North' (e.g. N. America, Europe, East Asia) and 'Global South' (e.g. sub-Saharan Africa, lower-income parts of Asia) economic classifications, the rapid development of countries such as China, Korea, Singapore, and Taiwan, growing inequalities within the 'Global North', and the rise of global agendas such as climate change and environmental capacity, make the term 'international development' redundant. Older definitions of 'international development' often involved the giving of the richer part of the world to a more vulnerable poorer world, on terms that best-suit the richer world. The term *Global Development* is increasingly being used, recognising increasing world inter-connectedness. Other workers such as Ghosh (2019) argue that whilst the global share of wealth of regions such as North America has fallen from 42% in 1968 to 25% in 2016, the consequent economic gap has largely been filled by China and East Asia, with other regions staying level. Ghosh (2019) further argues that the ratio of privilege/non-privilege between the wealthiest and poorest countries remains a key issue to be resolved and that global aid and trade remains controlled by richer countries/regions. Development discussions can revolve around power and wealth discrepancies between different parts of the world, past and present colonial/imperial politics and drivers, changing levels and metrics of development with time, the increased recognition of global connections, and so forth. For pragmatic purposes, this paper suggests a definition for 'international development' as:

'activities aimed at reducing levels of inequality and variable

opportunity (in their totality) between the economically richer and poorer nations of the world and the two-way-sharing/transfer of technology, geoscience, skills, and experience, between higher and lower income countries'.

In 2015 the United Nations General Assembly passed Resolution A/70/L.1 'Transforming Our World: the 2030 Agenda for Sustainable Development' which spelled out an agenda for sustainable development to 2030 and the definition of 17 sustainable development goals (United Nations, 2015). The term *International Development* in some quarters is being partly recast as activities that promote, embody, and actualise the intent of the Sustainable Development Goals, (e.g. World Bank, 2016). Historically, the terms 'Developed' and 'Developing' or similar have been used as prefixes to describe countries belonging to the economically richer and poorer world. In a similar fashion to 'international development' terms such as 'Developed' 'Developing' 'Under Developed' and 'Third World' are becoming increasingly unfashionable. The United Nations defines countries as 'Developed', 'Economies in transition' and 'Developing Economies' with further subdivisions for 'Fuel-exporting countries', 'Least Developed Countries' 'Heavily Indebted Poor Countries', 'Small Island Developing States', and 'Landlocked Developing Countries', (United Nations, 2019). The three basic UN country classifications (Developed/In Transition/Developing) reflect economic country conditions using aggregated statistical data such as Gross National Income. In 2016 the World Bank (WB) decided to drop the terms *Developed* and *Developing* as prefixes that define the relative economic status of countries (World Bank, 2016). The WB still maintains a database and classification system that separates low-middle income countries (LMIC) from Upper-Middle Income Countries (UMIC). The WB uses their International Development Assistance (IDA) term for countries classified as 'the worlds economically poorest' countries using a range of systematic and consistent aggregated economic data. This paper adopts the WB terminology using 'IDA-WB' to signify the lowest income countries, and the term 'HIC' (high income countries) to signify the richer countries. HIC countries are, mostly, those countries who operate international aid assistance schemes to the IDA-WB countries. This paper deals with aspects of geoscience, science, and engineering international aid activities funded largely by the HIC countries, and taking place largely in IDA-WB countries.

Language, Monetary Value, and Funders of Development

The language of international development practice is often framed within the context of poverty alleviation, food security, water and sanitation, disaster and risk, empowerment of oppressed minorities, institutional strengthening, job and wealth creation, and so forth. Development programmes are mostly designed, in consultation with aid-recipients, by aid agencies, such as USAID, the World Bank, EU-AID, UK-DfID, China International Development Cooperation Agency, KOICA (Korea), and JICA (Japan). Aid Agencies are mostly arms of individual national governments, mainly from the richer countries, or multi-national agencies, and philanthropic foundations. In 2014, the OECD (Organisation for Economic Cooperation and Development) countries spent c. \$US 135Bn, approximately equivalent to the GDP of Kuwait, the 58th richest country, in 2018 on international aid, (IMF, 2018). This was close to the highest ever (2013) record (OECD, 2015, Guardian, 2015). Although OECD countries recommend spending at least 0.7% of their

Gross National Income on international aid, only five countries (Sweden, Luxembourg, Norway, Denmark and UK) achieved this in 2014 (OECD, 2015, Guardian, 2015). Aid is a significant part of global development. It is important that all relevant key actors deliver the most appropriate service to maximise the probability of programme success. For a range of reasons, geoscientists and natural scientists can struggle to interact effectively with aid programme culture and ethos. This paper explores reasons why this situation exists, and suggests a conceptual model that may be of generic and practical use for maximising the inputs of natural scientists and technical 'experts' within aid programmes.

Culture Challenges between Research-Centric Geoscientists and Development Practitioners

There are challenges, between traditional science and development cultures. The culture challenge is, arguably, most closely linked to drivers for career development on the part of the geoscientist or engineer, and how these only occasionally align with the outcome-focused needs of most development practitioners/organisations. These differing approaches can act as an inhibitor to the involvement of geoscientists in development programmes. An examination of literature by authors such as (Joynson and Leyser, 2015, Segal, 2008, Mazzocchii, 2006, Vierger, 2013, Öhrstrom et al., 2018, DfID, 2014, Choi et al., 2005, and HamidiMotlagh et al., 2018) argue that a range of challenges are present that complicate close and integrated working between development practitioners and scientists. Joynson and Leyser (2015) surveyed almost 1000 bioscientists and concluded that whilst individuals have values that include a desire to work for greater societal good, institutional work cultures inhibited wider applications of knowledge. Segal (2008) presents strong evidence for two disciplines within one academic institution (the Open University, UK) struggling to work together and to view one another with equal respect. A wide range of literature (e.g. Choi et al., 2005, DFID, 2014, Öhrstrom et al., 2018, Mazor et al., 2018, and Weichselgartner and Kasperson, 2010) argues that: 1) academic research may not always produce what policy makers or development practitioners want/need; 2) products/services may be in the wrong form; 3) outputs may not achieve the intended developmental outcome; 4) or products are not so easily accessed by the wider non-scientific community. Reynaud (2005) sums the conundrum of rich country scientists interested in working with the less privileged world by stating '*I should probably concentrate on my scientific work, as my future depends on it, and I should leave it to others to help developing countries*'. Key issues and arguments based on the author's experience and the quoted literature are expanded below. The professional-practitioner development culture has a focus embedded primarily in developmental outcomes, seeking improvement in environmental and/or socio-economic conditions for focus communities/governments. Measures of success of geoscience aid-projects are outcome-focused, with project management viewed as a prime skill sought with respect to the awarding of aid-related contracts. The experience of the author, as Director, Geoscience Division, Pacific Community, (formerly SOPAC), working and negotiating with numerous aid organisations, (e.g. WB, European Union, USAID, New Zealand Aid (NZAID), Australian Aid, Korean Aid, JICA, and others), within the Pacific Islands region, 2013-2017, included project design discussions that

focused upon: improvements in governance; institutional strengthening; Pacific Islander upskilling; policy improvements; community inclusion; increased Pacific Islander employability; and increased resilience, e.g. for disaster and risk applications. In the Pacific context, practitioner-development cultures are policy-focused, and are comfortable with policy-related language. Peer review journal publication, whilst welcome, is not usually regarded as a prime, or even secondary, project output. The traditional geoscientist (or natural scientist/engineer) working within a university or high-impact-research-centre setting has a focus on science and research, which will deliver her/him institutional key performance indicators. Typical university and research centre performance indicators are the attraction of high-kudos competitive academic research grants, and the publication of numerous high-impact scientific publications. Universities and research centres are highly competitive in their culture, (e.g. Joynson and Leyser, 2015), and look to maximise metrics/achievements in the quality and number of peer review publications, the quality and amount of attracted research grants, and peer-esteem. These metrics influence appointments, promotions, and work status.

Bridging the Gap between Science, Geoscience, and Development

It is possible to bridge the cultural divide between development and science and some individuals skilfully manage to do so (e.g. Öhrstrom et al., 2018, DfID, 2014, Cronin et al., 2004). Steffen et al., (2018), debate further, that, addressing the management of global holistic issues such as climate change, requires ‘*collective human action, entailing the stewardship of the entire Earth System*’. Such an approach, this paper argues, requires geoscientists/scientists to work in collaboration, in new interconnected ways, with social scientists, and society, alongside the *most affected communities*. This allows the scientific mind to further-understand the impacts and challenges of changing human behaviours, and the development context of scientific application. The IPCC (International Panel on Climate Change) is an example of a body that brings science to bear in a multi-disciplinary manner to a global challenge. The IPCC drafts numerous advisory/policy papers that speak to the wider non-science, non-specialist audience (e.g. IPCC, 2014). The UK’s Natural Environment Research Council, offers grants in international climate change adaptation, including linkages with European research funding programmes, and the UK international aid programme (NERC, 2019). The objective of schemes such as this is to encourage richer-world scientists to focus increasingly on IDA-WB countries. Within geoscience, the mining industry recognised the need for holistic science-technology-community sustainable development approaches, and published a thematic sustainable development volume entitled *Breaking New Ground*, (MMSD, 2002). This initiative brought together industry, academic geoscientists, social scientists, development practitioners, and mining affected communities. Examples of changing mining company attitudes resulting from this initiative are: increased pre-mining stakeholder dialogue; the recognition of local-benefits accrual; and the development of a cadre of socially-minded professionals within the mining industry (Pettersson and Tawake, 2016, 2018, Pettersson, 2008, Tolia and Pettersson, 2005). There remain numerous detractors of the mining industry, an industry that will often attract controversy, who argue that profit is, and will remain, the key mining driver, and

that local people within the IDA-WB countries will always receive less than they should from a range of benefits (Pettersson, 2008, Pettersson and Tawake, 2018, Phillips, 2017, Pigrau, 2013). Organisations such as AGID (Association of Geoscientists for International Development) and, more recently, *Geology for Global Development* are examples of voluntary organisations promoting linkages between geoscientists throughout the world, for development goals. These organisations have activated interchange and skills sharing activities (active projects, conferences and workshops) partnering geoscientists between IDA-WB and HIC countries. Two case studies are presented below that illustrate approaches and challenges for geoscience within development. Lessons learned from these case studies and discussions above are cited as potential elements of the ‘interconnected geoscience’ concept.

Case Study 1: Geoscience Support to Solomon Islands, 1970s to 1990s

The British Geological Survey, (BGS), were involved in a c. 20 year institutional strengthening programme within Solomon Islands (SI), SW Pacific region. Aspects of this work are published in (Pettersson and Tawake, 2018, Pettersson et al., 2008, Tolia and Pettersson, 2005) and presented in Table 1. The style of development programme was typical of a number of UK geoscience aid programmes during the 1970-1990s period, in many parts of the ‘Developing World’. Residential BGS geologists and related staff were seconded on a residential basis to Solomon Islands. A job awaited the seconded individual within BGS, post-project. Some geologists spent their careers moving from one international project to another. The SI Geoscience Project was designed to strengthen the Geological Survey of SI, and associated government departments, from a human, physical, and data/resources perspective. The core physical outputs were geological maps and reports from unmapped territory within SI. These outputs were primarily used to assess mineral and energy economic potential but had multiple additional applications such as for hydrogeology, disaster and risk, environmental geoscience and rural/urban development. There were numerous positive outcomes of this intensive and prolonged effort, including: the generation of new geological data; an increased understanding of the geo-tectonic evolution of SI; the development of new facilities and equipment; the sharing of skills and upskilling of numerous national and expatriate staff; and; positive contributions to the national economy and capability. Numerous national staff gained an increased career potential that resulted in the appointment of individuals to medium-high level government positions, and within the private sector. A good number of national staff gained degree and postgraduate level qualifications they may have otherwise struggled to obtain. The generation of data led to an increased interest from exploration and mining countries and resulting inward investment/ job-generation. This style of aid intervention is an example of a donor-centric aid model. Whilst the donor respects and negotiates with the aid-recipient, the aid recipient has an inferior power status relative to the donor, and may have limited options for influencing decisions. The SI project was dependent upon a cadre of available geoscientists who are willing to live within the host country for 2-8 year long periods, and an institution such as BGS, who, at the time, were capable of accommodating long-term staff deployments. Some of these conditions became increasingly difficult

with time. BGS staff, at this time, were specifically trained in development issues, and understood that the core output of their work was development-focused. Work contributions/outputs were recognised as key performance indicators by BGS, and staff career progression was rewarded by successful international performance indicators. Whilst the objective of the programme was to localise capability/staff positions and exit non-national staff once this had been achieved, it proved to be a 20-year process. Inevitably, there were monetary, status, and power asymmetries between expatriate and local staff, which required careful management, although many life-long career and personal friendships were formed. The biggest challenge has been the sustainability of geoscience capability in the longer term, post-aid-programme. Small states such as SI, can struggle to prioritise a national geoscience capability.

Case Study 2: Institutional Strengthening of the Afghanistan Geological Survey

In 2002 the British Geological Survey (BGS) was approached by the-then Afghanistan Minister of Mines and Industry, Mr Juma'a Mohammed Mohammadi. Mohammadi had been the Afghan Minister for water and power in the 1970s, imprisoned for two years under the Communist administration (1978-1980), and subsequently working with the WB prior to his appointment to the 2002 post-Taliban administration (Petterson, 2010). Mohammadi had gained incisive learning in combining scientists within development programmes. From 2003, the author, and BGS colleagues, worked closely with Afghan colleagues in designing a technical assistance programme for the revitalisation of the Afghanistan Geological Survey (AGS), and progressing a range of development challenges (Petterson, 2010, Ellison, 2010). Kabul had been shattered by decades of war. The AGS building was severely damaged,

and reflected the poor state of many Afghan government institutions at the time. A team of Afghanistan Government advisors was assembled to work with BGS geoscientists, from inception. To meet DfID (UK Department for International Development) aid philosophy and funding criteria, the project had to demonstrate that it could address aspects of dire national need. There was suspicion within some DfID circles that a geoscience-oriented programme within the Afghan post-conflict context was inappropriate/low-priority. This situation is a prime example of geoscientists being challenged to prove their relevance to development programmes. After project initiation, around 40 BGS and other national staff (geoscientists, knowledge-management experts, ICT experts and trainers, language trainers, translators, and so forth) travelled regularly on a fly-in, fly-out basis, to Kabul, over a 4-5 year period. It was inappropriate to adopt a residential approach as the security situation mitigated against this. Highest-level development aims were the project foundation (e.g. post-conflict country rebuilding, institutional strengthening, development of a peace economy, job-generation, introduction of E-technologies). A primary practical aim was the translating of Afghanistan's mineral wealth potential, through mining, into national development, facilitated by world-standard open and transparent policy processes. AGS was structurally positioned within the Ministry of Mines and Industry, but also had close relevance to several other Ministries, (e.g. energy, transport, water, infrastructure, finance, employment). This is a practical example of the inter-connectedness of geoscience through partnership and collaboration. Enhancement of good governance was at the core of the project. Developmental goals were addressed through a geoscience lens. This was challenging for geoscientists more comfortable with science-focused approaches. Scientific programme themes included the synthesis and modelling of geological data for metallogenic prospectivity purposes, the design of a range of geological, mineralogical, and geochemical laboratories,

Table 1. Summary of characteristics for the Solomon Islands Geoscience Programme. Read downwards, column by column

Development Approach	Purpose	Geoscience Outcomes	Development Outcomes	Development Challenges
Residential team of expatriate geoscientists in-country, 1970s to 1990s.	Institutional strengthening, creation of a nationally sustainable Geoscience capability	Baseline data of the geology of Solomon Islands	Upskilling of a large number of national staff in technical, administrative and organisational areas	Although the recipient government, in theory, prioritised aid and activities, the aid donor country was dominant re decision making.
Numbers of in-country expatriate staff varied from 10 to 1 over time	Skills strengthening of both national and Expatriate staff	Numerous geological maps and reports	Upskilling and increased awareness of Expatriate staff	The presence of residential expatriate staff, overall, was considered to be a significant benefit by SI government and staff.
Expatriates teamed up with local Solomon Islander counterparts	Identification of national economic opportunities	Exploration geochemical data	Increased Human Resource capacity. Tens of staff gained new skill, experience and capability	Sustaining an expatriate residential presence for decadal periods is expensive and increasingly difficult to achieve.
Shared learning mainly through practical activities. Predominantly a 'teacher-student' style relationship	Building of modern office and laboratory facilities	Advice to government re mineral and energy potential, environmental and planning issues.	Creation of data, maps, reports, library, and enhanced experience base. Professional links made across government and international organisations.	Whilst many national staff were upskilled and benefitted through improved public sector opportunities, many staff were lost to opportunities beyond the public sector and consequent gaps required recruiting/reskilling solutions.
Some Solomon Islanders received formal academic qualifications from international universities	Application of geoscience for national development outcomes	Application of geoscience to disaster and risk, and the environment. Networking with a range of Ministries	Improved decision making capability for economic, environmental, energy, water, and disaster/risk issues	The ability to sustain a comprehensive or fit-for-purpose geoscience facility within a small island state is challenging in the longer term.

geological and mineral mapping of the Kabul region, and assistance to the gemmological/industrial mineral industry. Science leadership approaches were collaborative and inclusive. The AGS Senior Leadership Team and Government Ministers co-led and co-designed workshops, training/mentoring programmes, and related activities. Soft-skill development became a key to the achievement of project goals and meeting the aspirations of AGS officers. In particular, training in English Language and ICT skills were in high demand. The rebuilding and refurbishment of the AGS building was a high priority, requiring a high-budget intervention. The BGS-DfID project worked with the Afghan government developing linkages to other aid programmes, active within Kabul at the time, that eventually led to the total renewal of the AGS building, and the consequent much-improved spirit of AGS staff. One major setback were the tragic deaths of Minister Mohammadi, and his advisory team, in an aeroplane-crash, in Pakistan, in 2003 (BBC, 2003). Whilst a great tragedy, the team who remained were determined to move the project forwards. Readers are directed to (Ellison, 2010, Greenbaum and Petterson, 2005, ESCAP, 1995, and Mining Journal, 2006) for further details of project outcomes. The project was deemed to be 'successful', scoring highly in internal (confidential) DfID project reviews. The programme helped the planning of a 3-year British Council funded programme that linked 4 universities (Leicester, UK, Charles University, Prague, Czech Republic, Peshawar, Pakistan, and Kabul). This professional linkage programme led to inter-group professional and strategic explorations, and staff-interchange for geoscience and engineering Faculties. Geoscientists and engineers engaged in activities such as exchange visits, workshops, leadership programmes, PhD research programmes, and an 18 month one to one mentoring scheme. The Afghanistan programme developed a model for success-

ful integration of geoscientists and technical experts within international development programmes. Key principles learned included: 1) begin with agreed development goals, as the project foundation, and stress the inter-connectedness between geoscience, development, partnerships, and context; 2) geoscientists to work closely with the aid recipient leadership team and the funding agency, from the earliest stages, co-designing the project together; 3) design of appropriate scientific work themes and programmes to meet development goals; 4) inclusive involvement of AGS staff throughout the entire programme; 5) adapting to changing needs with time; 6) properly preparing geoscientists for Afghanistan deployment; 7) working respectfully within the values and parameters of Afghan culture; and; 8) where possible, maintaining an overall permanent presence in-country. Once the trust links are matured, it is possible to continue elements of the programme through a more remote, centre-centre link, with intermittent face to face contact, as occurred with the British Council-University linkage programme. A summary of aspects of this project is presented in Table 2.

An Interconnected Geoscience Approach

Building the Principles of Interconnected Geoscience

The case studies from Afghanistan and Solomon Islands present three main tactical approaches to geoscience and international development: deployment of residential teams over 10-20 years in-country; deployment of teams on a fly-in, fly-out basis, whilst retaining a permanent presence in-country for c. 5years; developing networks of geoscientists over a 3-year period with intermittent physical contact.

Table 2. Summary of characteristics for the Medium Term Afghanistan Geoscience Project. Read downwards, column by column

Development Approach	Purpose	Geoscience Outcomes	Development Outcomes	Development Challenges
Team of 40 geoscientists. Short-medium term fly-in, fly-out basis. Experts drafted from a number of countries and organisations.	Institutional Strengthening. Re-creation of a nationally sustainable geoscience capability	Intense interaction over a 4-5 year period between a large multidisciplinary UK + other nationals geoscience team and hundreds of Afghan geoscience officers.	Comprehensive project developed. Jointly designed by a collaborative Afghan-UK development team	Safety was paramount and a real constraint on activities. Post-conflict environments require specialised approaches and understanding. Trust takes time to develop.
Highly diversified skill base including geoscience, knowledge management, language translation, ICT, English language teaching, leadership and management development.	New human resource skill modelling, mixing experience with new blood and new development goals	Bespoke geoscience, e-science, ICT, English language, and field skills training. Management/leadership mentoring.	High demand from Afghan officers for ICT/English training met which significantly increased capability	Approaches were highly development and national-need focused. Long period of war led to acute deskilling and a generation gap in skills and institutional memory.
High level links with Ministers, Permanent Secretaries and Directors. V. close collaborative approach	Creation of a minerals for national development programme	Data and geo-package developed for the world's second largest unworked copper deposit (Aynak). High activity related to industrial and gem minerals and industry.	Sustainable Development policies developed and drafted	Outcomes were practical addressing acute and basic skill needs, loss of knowledge and data, and national recovery
Project goals inextricably linked to defined national development objectives. These evolved with time and including cross-Ministerial collaboration and negotiation	Redevelopment of buildings and laboratories. Introduction of ICT and English Language classes	Geoscience awareness raised in discussions with a wide range of ministries, including energy, education, mining, industry, and development	Restructuring of Afghan Survey and related government organisation undertaken for new post-Soviet country needs	Leadership and management approaches were in high demand. They required sensitive interactions.
Post-Geological Survey project light-touch international collaboration project between 4 universities in UK, Afghanistan, Pakistan and Czech Republic	Skills, experience, and knowledge sharing between Afghan Universities and international academics	Medium-longer term geoscience and engineering collaborations developed between staff from various universities, including new research/PhD projects.	Open discussion on role of geoscience in universities undertaken through a series of collaborative workshops	Bringing together of close national universities (Peshawar/Kabul) with UK/Czech universities was novel and popular.

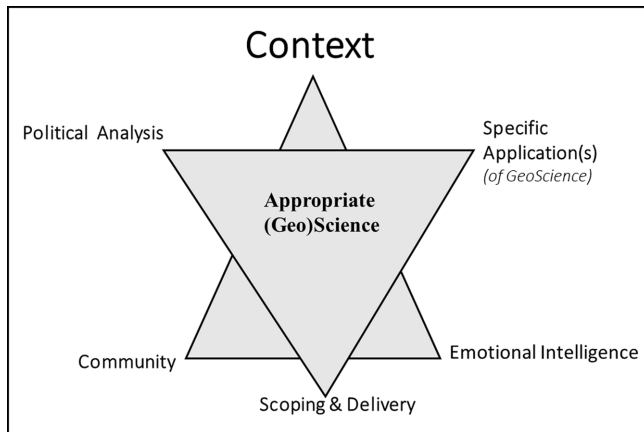


Figure 1. Applying the Geoscience conceptual model. The key principle is that geoscience + context = appropriate application for international development. Appropriate (and excellent) geoscience is at the heart of the concept. Understanding the context of a developmental situation is essential to the design and successful application of geoscience. A contextual understanding will involve mapping the politics of the situation (e.g. geopolitics, agendas of organisations, governments, communities and funders). Impacted communities should be involved from project inception and included within the project-body. The understanding of people and their values (emotional intelligence) encourages appropriate project activities. All of these analyses inform the types of geoscience required and project design/delivery specifications.

The case studies demonstrate that geoscience application must be appropriate to, and in cognisance with, development goals, policy drivers and local conditions and culture. Fig. 1 illustrates elements that assist the successful integration of geoscientists within development programmes. A guiding principle is that *science alone* rarely solves complex development problems. A key to successful integration is for geoscience to be added to situational context. *Geoscience plus context* forms the basis for the successful integration of science within development programmes. The principle that *science plus context* finds support in the literature. Gill and Bullough (2017) propose that three global development frameworks (the Sustainable Development Goals, the Sendai Framework for Disaster and Risk Reduction, and the Paris Agreement on Climate Change) are clear examples of context in the form of a better-defined science-policy-practice principle that geoscientists must be mindful of to maximise their application of development-focused geoscience. Gill and Bullough (2017) provide examples of geoscientists who have produced work, for example in the field of disaster and risk, that are tailored towards developmental applications. Stewart and Gill (2017) suggest that if geoscientists are serious in making their work relevant to a wider development context, they must 'broaden their constituency' and 'explicitly integrate sustainability' into their work. In other words, geoscience *alone* will be far less useful without context to global development challenges. Fig. 1 presents a number of higher and lower level consideration themes for integration. These include: context and challenges; world views; political-community analysis; inclusion of communities/recipients/project staff/donors; and project design/scoping and delivery. This methodology improves the probability of success, and sharpens geoscientific application. Additionally, individual geoscientists, who may be unused to

this way of working, will require appropriate training and awareness raising.

Conceptual Model of Interconnected Geoscience

Geoscience, in combination with context, community, and appropriate programme design, are the roots of interconnected geoscience. The concept can be further refined and developed. A definition of an interconnected geoscientist (or engineer/technical expert) is *someone who has a deep expertise in a relevant geoscience area and an equivalent deep expertise/consciousness in understanding the developmental situation and conditions s/he is working in, including the 'world view' of people affected by the geoscience intervention*. Fig. 2 summarises the conceptual model for an 'interconnected geoscientist'. At the centre is geoscience with an interconnected philosophy. This model does not intend to 'dumb down' or reduce the importance of geoscience, which is fundamental to excellent development solutions. The word 'interconnected' is added to emphasise the importance of more holistic approaches. Developmental setting/conditions are the foundation: these will guide how the geoscience is to be optimally applied. Projects are devised with development goals in mind and outputs/services tailored to meet the needs of policy makers and practitioners. Local affected communities must be at the heart of project outcome design. An interconnected approach places importance on issues such as inclusivity, environment and local focus, indigenous and non-conformist world-views, valuing and incorporating traditional knowledge, the possibilities of citizen-science and geoscientist-community-connections/relations. The interconnected approach adopts the equal and respectful inclusive approach from the earliest stages of programme conception and development. Interconnected geoscience approaches, provide a conceptual model for the possibilities of science + social science + community + local world views, to feed into policy and communal acceptance of policy. An interconnected geoscience approach stands a better chance of addressing complex, regional and global development issues, including planetary health and global climate change. The approach improves the probability of practitioners using research results, and researchers undertaking research that addresses the highest level needs of development. The geoscience-policy-practice interface could become more seamless with outputs addressing the needs of all participants. Elements of the approach discussed here are present in the literature. Stewart (2016) argues for a 'sustainable-geoscience' approach integrated within geoscience education, communication, and professional development, with the development of conscious links to social science, policy makers, and planners. Gill and Bullough (2017) emphasise the ethical dimension to geoscience engagement: geoscientists have a 'professional and social responsibility', and should 'be equipped' to address the demands of government, industry and society. A range of organisations including universities, learned societies, professional bodies, and chartered programmes can be further-developed to encourage an ethos similar to the interconnected model, (Gill and Bullough, 2017). Di Capua et al., (2017) produced a statement of 'Geoethics' with ten fundamental values, including those addressing knowledge sharing at all levels, working in a spirit of cooperation and reciprocity, and respecting the sustainable development of communities, all of which are within the heart of the interconnected geoscience concept. Steffen et al. (2018) advocate for an approach that links climate sci-

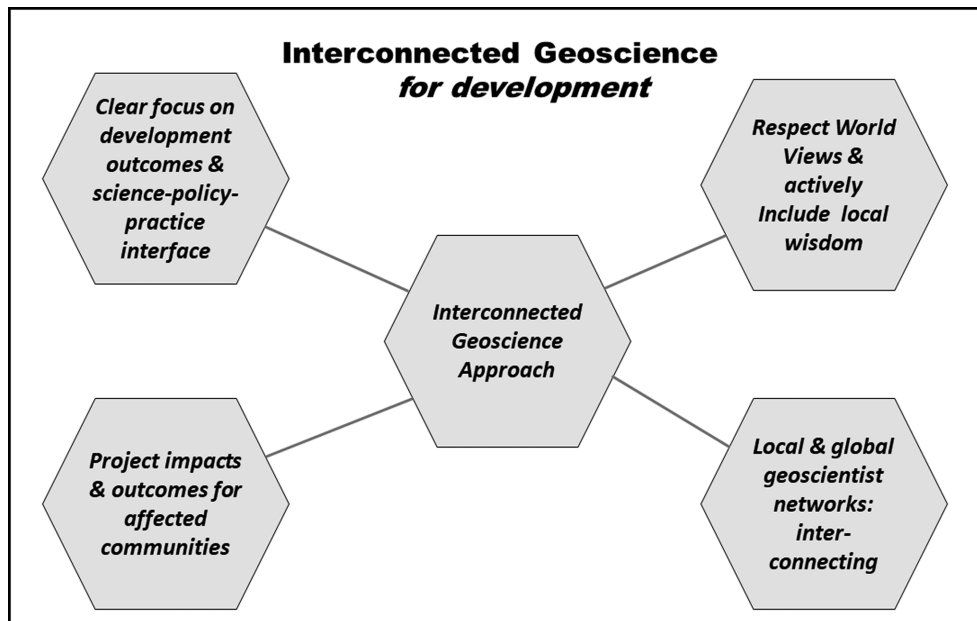


Figure 2. A conceptual model for 'interconnected science'. Excellent and innovative science is at the centre of the model. Stand-alone reductionist science has limited impacts within international development. It rapidly becomes a powerful tool when combined with other existential factors. Situational context is vital, alongside inclusivity, and a genuine respect for local world-views and values. Issues such as wellbeing, and holistic/planetary environmental impacts, should be considered, where appropriate. To change mind-sets, new performance reward models for the concept of 'interconnected science' must be adopted, and the value of this work recognised, even within highly prestigious research-intensive scientific research universities and institutes. See text for details.

ence and social science to policy and action, with a global outcome of changing existing socio-economic models, and human behaviours. Some areas of geoscience practice are at a more mature stage than others with respect to an interconnected approach. Disaster and risk is one area where geoscientists have a significant track record in working closely with social scientists, policy makers, practitioners and disaster first-responders (e.g. Pacific Community, 2015). The 2015 cyclone Pam disaster (which impacted on two thirds of Vanuatu's economy) elicited a strong interconnected response involving geoscientists working alongside national and regional disaster management offices, national governments, NGOs, armed services, first responders, health professionals, diplomats and the international aid community. Geoscience was applied in a real-time fashion, working within multidisciplinary teams, and with representatives of the policy, practice and geoscience to provide an interconnected service. Weichdelgartner and Kaspersen (2010) examined a range of project outcomes within disaster and risk, examining barriers between practice and science and suggested that stronger interconnections can be made by academic scientists becoming less 'silo' oriented, and adopting behaviours that are within the core of the 'interconnected geoscience' model such as involvement of a wide range of stakeholders, and working closely with communities/end-users of science. The adoption of international frameworks in disaster and risk such as the Hyogo Framework and successor Sendai frameworks present aspirational goals that encourage more interconnected approaches (Gill and Bullough, 2017).

Roles of IDA-WB Country Geoscientists and Mainstreaming Interconnected Geoscience

As discussed in early sections of this paper, economic and political

power asymmetries can skew debate in international development. The voice of the richest and most powerful is often the loudest and most influential. For the concept of interconnected geoscience to be successful the role of the IDA-WB country geoscientists is critical. How can geoscientists from the poorer countries influence the development agenda and become as important as geoscientists from the richer countries? There are a spectrum of possibilities. In c. one generation countries such as India, Malaysia, South Korea, and China have changed roles from aid recipient to aid donor. These countries are now highly influential in developing new agendas in international development, and seeking different ways to interact with the IDA-WB countries. China has promoted and helped create the 'Asian Infrastructure Development Bank' (Firzli, 2015) which funds development programmes. India is becoming less supportive of being an aid recipient and has an active international aid scheme of its own. The South Korean government worked closely with the author across a number of projects within the Pacific region from 2013-2019, and has an extensive aid programme in the Pacific and elsewhere through KOICA. The newer rich countries are bringing their own world-views, and geoscientists/experts into a whole range of international programmes and gaining increasing influence in global development (Horner, 2019). It is now a multi-polar world, and geoscientists will access international development through numerous gateways. At the other end of the spectrum the poorest IDA-WB geoscientists will continue to find influence in international development debates challenging. There are mechanisms for poorer-country geoscientists to become more involved in influencing development agendas and the role of geoscience. Case studies presented in this paper suggest models of engagement such as: 1) ensuring that programme planning, from inception, is collaborative, on an equal power basis, with the 'recipient' country geoscientists being the key

architect of programme planning; 2) IDA-WB geoscientists must occupy the main decision making positions within development programmes in-country, with a strong influence on the management of foreign geoscientists and programme focus; 3) development programmes must all include funding for knowledge and experience sharing between all geoscientists, allowing poorer-country geoscientists to travel and spend time in richer-country institutions; 4) inter-institutional global network projects with limited face to face time, should be used as enablers for regular geoscientist interaction and for the poorer country geoscientists to present at international events that influence geoscience and development debates. Organisations such as AGID and GfGD are role models set up for addressing poorer-country geoscientists aspirations/needs and promoting cross-world dialogue and skills sharing. This approach should be adopted increasingly by Learned and Professional geoscience societies with a percentage of funding set aside for international development activities. Regional bodies such as ASEAN (Association of South East Asian Nations), the Pacific Community, CCOP (Coordinating Committee for Geoscience Programmes in East and SE Asia), the OAS (Organisation of American States), SADC (South African Developing Countries), SAARC (South Asian Association for Regional Cooperation), CARICOM (Caribbean Community) as well as UN bodies such as UNESCO and UNDP all have vital roles to play in encouraging/enabling the professional/scientific voice of geoscientist from the less privileged world. Geological Survey Organisations and global geoscience meetings/conventions (e.g. IUGS) all play critical roles in international development, and providing improved platforms for geoscientists from the poorer world.

The time is here, more than ever before, to mainstream 'interconnected geoscience'. Interconnected geoscience should become the default approach to addressing geoscience and development. The paper has discussed international platforms such as the Sendai agreement and the Sustainable Development Goals which are a strong driver for holistic engagement for development. Similarly, the Paris Agreement on Climate Change; development of a more diverse set of 'donor countries'; creation of a multi-polar world for development; adoption of the Cape Town agreement on Geoethics, and; increased recognition that many developmental, resource, and environmental challenges, are beyond national boundaries are added drivers for multi-disciplinary approaches. More can always be done. One area this paper suggests work is urgently required on, is the issue of staff reward systems, and organisational performance indicators. These systems can over-emphasise behaviours that oppose the 'interconnected geoscience' ethos. New systems that value outputs for positive development and interconnected geoscience behaviours could, in one go, revolutionise engagement and rapidly reduce barriers in the geoscience-policy-practitioner interface. This paper agrees with Stewart (2017) that different emphases in education, at school and university levels, encouraging the interconnected model in all geoscience themes, would influence the minds of the next generation. Funding agencies are powerful forces in mainstreaming new approaches, as they have proven with issues such as gender, ethnic diversity, and climate change. Finally, international meetings that have a focus on geoscience and development can consciously give space to interconnected-geoscience related themes, and insist that geoscientists from IDA-WB countries take a lead in session design, session chairing, and keynote addresses.

Conclusions

International aid programmes and development represent large investments in the future welfare of countries and communities, particularly within the poorer world. Some \$135 US Billion are invested, annually, by governments in international aid. Philanthropic organisations contribute an additional investment. Development is multi-faceted and complex. Geoscience, and related technical expertise, are essential in optimising the lasting impact and success of development programmes. Career and performance indicators at research-intensive universities/organisations are largely unsympathetic to the needs of development programmes.

The application of geoscience to development issues would benefit from the encouragement of an interconnected geoscience ethos approach. This approach involves geoscientists working at the heart of development with an increased understanding of global development, differing world-views, development-context, traditional knowledge, and so forth. A conceptual model is presented, as a basis, for the development of interconnected geoscience for development.

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References

- BBC., 2003, Plane crash kills Afghan Minister. Monday 24th February 2003. http://news.bbc.co.uk/2/hi/south_asia/2793135.stm [accessed 10th October 2018].
- Choi, B.C.K., Pang, T., Lin, V., Puska, P., Sherman, G., Goddard, M., Ackland, M.J., Sainsbury, P., Stachenko, S., Morrison, H., and Clotney, C., 2005, Can scientists and policy makers work together? *Journal of Epidemiology and Community Health*, v.59. doi: 10.1136/jech.2004.031765.
- Cronin, S.J., Petterson, M.G., Taylor, P.W., and Biliki, R., 2004, Maximising multi-stakeholder participation in government and community volcanic hazard management programs. A case study from Savo, Solomon Islands. *Natural Hazards*, v. 33, pp. 105–136.
- DFID., 2014, What is the evidence on the impact of research on international development? Crown Copyright. Department for International Development, London, 72p.
- Di Capua G., Peppoloni S. and Bobrowsky P.T., 2017, The Cape Town Statement on Geoethics. *Annals of Geophysics*, v.60, doi: 10.4401/ag-7553.
- Ellison, R., 2010, Report on the BGS work in Afghanistan 2004-2008. British Geological Survey, international programme, Open Report, OR/11/038.
- ESCAP., 1995, Geology and Mineral Resources of Afghanistan. Atlas of the mineral resources of the ESCAP region. United Nations, New York, v.11, 85p.
- Firzli, M., 2015, China's AIIB, America's pivot to Asia and the Geopolitics of Infrastructure Investments. *Revue Analyse Financiere*. Q4, No 257. www.academia.edu/19535167/China_s_AIIB_America_s_Pivot_to_Asia_and_the_Geopolitics_of_Infrastructure_Investments [accessed 3rd

- July 2019].
- Ghosh, J., 2019, A Brave New World, or the Same Old Story with New Characters? *Development and Change*, v. 50, doi: 10.1111/dech.12485
- Gill, J.C., and Bullough, F., 2017, Geoscience Engagement in Global Development Frameworks. *Annals of Geophysics*, v. 60, doi: 10.4401/ag-7460.
- Guardian., 2015, Foreign aid close to record peak after donors spend \$135Bn in 2014. <https://www.theguardian.com/global-development/2015/apr/08/foreign-aid-spending-2014-least-developed-countries>, [accessed 27th September, 2018].
- Greenbaum, D., and Petterson, M.G., 2005, A fresh start in Afghanistan. *British Geological Survey. Earthwise*, v. 22, pp 4–8.
- HamidiMotlagh, R., Babee, A., Meleki, D., and A. Isaai, M.T., 2018, Innovation policy, scientific research, and economic performance: the case of Iran. *Development Policy Review*, doi:10.1111/dpr.12423.
- Horner, R., 2019, Towards a new paradigm of global development? Beyond the limits of international development. *Progress in Human Geography*, doi:10.1177/030932519836158.
- IMF., 2018, World Economic Outlook. <https://www.imf.org/external/pubs/ft/weo/2018/01/weodata/index.aspx> [accessed 27th September, 2018].
- IPCC., 2014, Climate Change. 2014. Synthesis Report. Contribution of Working Groups 1,2 and 3 to the fifth assessment report of the Intergovernmental Panel on Climate Change. Pachauri R.K., and Meyers, L.A. (Eds). IPCC, Geneva, Switzerland, 151p.
- Joynson C., and Leyser, O., 2015, The culture of scientific research. *F1000 Research*, v. 4, doi:10.12688/f1000research.6163.1
- OECD., 2015, Development aid stable in 2014 but flows to poorest countries still falling. <https://www.oecd.org/dac/stats/> [accessed 27th September, 2018].
- Mazor, T., Doropoulos, C., Schwarzmueller, F., Gladish, D.W., Kumaran, N., Merkel, K., Moreno, D.M., and Gagic, V., 2018, Global mismatch of policy and research on drivers of biodiversity loss. *Nature Ecology and Evolution*, v.2, doi.org/10.1038/s41559-018-0563-x
- Mazzocchi, F., 2006, Western science and traditional knowledge. *European Molecular Biology Organisation*, v.7, No 5, pp. 463–466.
- Mining Journal., 2006, Afghanistan: Mining and minerals Overview. Special Publication. Mining Communications Ltd, Albert House, Singer Street, London, UK. 12 p.
- MMSD (Mining, Minerals and Sustainable Development)., 2002, *Breaking New Ground*. ISBN 1 85383 907 8. Earthscan for IIED and WBCSD, London, 440 p.
- NERC., 2019, International partnerships. <https://nerc.ukri.org/research/partnerships/international> [accessed 18th July 2019].
- Öhrstrom, L., Wiederud, P., Youssef, M.A., and Yaghi, O., 2018, Global engagement in science: the University's fourth mission? *Science and Diplomacy*, v. 7, No 2. <http://www.sciencediplomacy.org/perspective/2018/global-engagement-in-science-universitys-fourth-mission> [accessed July 20th 2019].
- Pacific Community., 2015, Cyclone Pam response (Vanuatu, South Pacific). <https://www.spc.int/updates/blog/2015/03/cyclone-pam-response> [accessed 18th July 2019].
- Petterson, M.G., 2008, Minerals sustainability, emerging economies, the developing world and the 'truth' behind the rhetoric. *Estonian Journal of Earth Sciences*, v. 56(3), doi: 10.3176/earth.2008.2.01
- Petterson, M.G., Tolia, D., Cronin, S.J., and Addison, R., 2008, Communicating geoscience to indigenous people: examples from the Solomon Islands. In: Liverman, D., Pereira, C.P.G., and Marker, B. (Eds). *Communicating Environmental Geoscience*. Special Publication of the Geological Society of London, No 308, pp. 141–161.
- Petterson, M.G., and Tawake, A.K., 2016, Toward inclusive development of the Pacific region using geoscience. In Wessel, G.R., and Greenberg, J.K., (Eds). *Geoscience for the public good and global development: toward a sustainable future*. Geological Society of America, Special Paper, 520, pp. 459–478.
- Petterson, M.G., and Tawake, A., 2018, The Cook Islands (South Pacific) experience in governance of seabed manganese nodule mining. *Ocean and Coastal Governance*, v. 167, doi:10.1016/j.ocecoaman.2018.09.010.
- Petterson, M.G., 2010, My eureka moment: Rocks and hard places. *Times Higher Education*. <https://www.timeshighereducation.com/features/my-eureka-moment-rocks-and-hard-places/410298.article> [accessed 15th October, 2018].
- Phillips, N., 2017, Power and inequality in the global political economy. *International Affairs*, v.93(2), pp. 429–444.
- Pigrau, A., 2013, The environmental and social impacts of Shell's operations in Nigeria. *Generalitat de Catalunya*, Issue 18. <http://www.icip-perla-pau.cat/e-review/issue-18-november-203> [accessed 18th July 2019].
- Reynaud, E.G., 2005, Natural scientists for a better world. *European Molecular Biology Organisation*, v. 6, No 2, pp. 103–107.
- Segal, J., 2008, Natural scientists and software engineers.: a tale of two cultures. *Proceedings of the 20th Annual Meeting of the Psychology of Programming Interest Group*. Lancaster University, Lancaster. UK.
- Steffen, W., Rockstrom, J., Richardson, K., and 13 others., 2018, Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences (PNAS)*, doi: 10.1073/pnas.1810141115
- Stewart, I.S., 2016, Sustainable geoscience. *Nature Geoscience*, v. 9(4), pp.262.
- Stewart, I., S., and Gill, J.C., 2017, Social geology – integrating sustainability concepts into Earth sciences. *Proceedings of the Geologists Association*, doi.org/10.1016/j.pgeola.2017.01.002
- Tolia, D.H., and Petterson, M.G., 2005, The Gold Ridge Mine, Guadalcanal, Solomon Islands' first gold mine: a case study in stakeholder consultation. In: Marker, B.R., Petterson, M.G., McEvoy, F., and Stephenson, M.H. *Geological Society London Special Publications*, 250(1), pp.149–159, doi: 10.1144/GSL.SP.2005.250.01.15
- United Nations., 2015, Resolution A/RES/70/1. Transforming our world: the 2030 Agenda for Sustainable Development. Records of the Seventieth session of the General Assembly of the United Nations, Agenda items 15 and 116, 21 October, 2015, 35p.
- United Nations., 2019, World Economic Situation Prospects. eISBN: 978-92-1-047611-9, 246p.
- Viergever, R.F., 2013, The mismatch between the health research and development (RandD) that is needed and the R and D that is undertaken: an overview of the problem, the causes, and the solutions. *Global Health Action*, v. 6, doi: 10.3402/gha.v6iO.22450
- Weischelgartner, J., and Kasperon, R., 2010, Barriers in the science-policy-practice-interface: Toward a knowledge-action-system in global environmental change research. *Global Environmental Change*, v. 20, pp. 266–277. doi 10.1016/j.gloenvcha.2009.11.006
- World Bank., 2016, World Development Indicators. International Bank for Reconstruction and Development, ISBN 978-1-4648-0684-1, doi:10.1596/978-1-4648-0683-4.



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