Report

on the strategic review of the Institute of Earth Sciences including the Nordic Volcanologic Centre

Introduction

The panel was asked to do a strategic review of the Institute of Earth Sciences (IES) of the University of Iceland, which was formed in July 2004 as merger of the Nordic Volcanological Institute with the Geology and Geophysics section of the Science Institute of the University of Iceland. In preparation for the review panel members were provided with a written document "Structure, research activities and vision“ giving all relevant information on IES. This document outlined the research carried out and gave information on the 6 research groups, which are based on a similar disciplinary background. This document is also structured along these lines.
The review took place from May 15 to May 17 on IES premises in the new building Askja. The program during these days had been proposed by the director and modified according to some suggestions from the panel. The meeting was conducted in a very open and candid atmosphere and all questions the panel raised with the different groups from senior researchers to students were fully answered, leading us to the impression that all members of the new Institute, although coming from different and still recognizable institutional backgrounds, were actively wanted to make the new structure a success.

General remarks

The panel was generally very impressed with the quality of the research at IES. There is no doubt, on the basis of the quality presentations, publication record and data on citations and publication productivity, that much of IES work is of international quality with some work at the cutting edge. The Institute is competitive with many of the major earth science centres in Europe, albeit in a narrower range of fields, as one would be expected of an institute that rightly focuses on Iceland. Despite this regional focus much of the research addresses global and generic issues. The panel was very impressed by the way that many of the scientists at IES have developed and nurtured international collaborations, which has expanded both the scope and influence of their research.

Notwithstanding these good impressions, there is scope for being even stronger and this scope is enhanced by the creation of the IES. Parts of the new IES have a very individualistic culture and the panel perceives that the parts of IES are to some extent stronger than the sum. One could make a football analogy that IES is like a team of very high quality players who have still to get used to playing as a team!

The IES is strongly oriented towards field based observational science with high quality measurement, monitoring and analytical studies characterizing much of the science. While this emphasis is entirely appropriate for an institute devoted to Iceland as a natural

laboratory for many fundamental earth processes, there is scope for strengthening the modeling expertise in the Institute. Although modeling can be partly addressed through international collaboration, it is important that IES develops its in house expertise for a number of reasons: recognition of the importance of modeling in almost all modern earths science; the need to train young scientists in modeling techniques and applications in the graduate programme; the importance of modelers interacting with observational scientists; obtaining ground-truth or reality checks and guiding what is measured; and the longer term objective of having more staff with both kinds of skills.

Physical Geology, Geography and Geophysics

Iceland has rightly been recognised as consistently being at the cutting edge of observational volcanology and several Icelandic eruptions, such as Laki, Surtsey, Krafla and Gjalp are now classic case studies that have advance the science at a fundamental level. This achievement is due to several of the senior scientists at IES and their forebears. This quality work can be expected to continue. Iceland is famous for tephrochronology and the academic descendents of Sigurdur Thorarinsson are continuing to use tephrochronology to unravel volcanic and environmental histories in extraordinary detail. The geophysical work is also cutting edge.The IES offers scope for more integration of different disciplines. In the past for example geochemical, petrological and geophysical studies of volcanoes have been somewhat disconnected. However, the most important advances have been made of late by close teamwork and integration of these disciplines in holistic studies. A key discipline for this integration is the development of models of volcanic flows and magma physics. This is an area that the IES is currently weak in and it would greatly benefit from both developing international collaborations and developing its own in house expertise. There is also much under-exploited potential for modeling volcanic processes. As one example the superb time series data on tephra and tephra composition could be used to develop models of the dynamics of volcanic systems through modeling approaches. Although the geophysics research is superb there is also scope here for more innovation and more advanced modeling. As one example the models of ground deformation still use Mogi models; while still valuable these models are great simplifications and have intrinsic problems (e.g. its very hard to get sensible pressures out of most Mogi models). There is much scope for developing more advanced thermo-mechanical models of crustal and magmatic processes. As another example, the basic model of crustal accretion in Iceland is still largely based on the pioneering work of Palmasson from 30 years ago. With all the new data and major advances in modeling there is a major opportunity to re-examine and advance these ideas. On the geology side the Tertiary geology of Iceland is superb but is relatively neglected as a key source of information on crustal accretion mechanisms.

Geophysical fluid dynamics is now a core discipline in volcanology and the lack of expertise in this area within IES needs to be addressed, while noting that the glaciology group illustrates the kind of integration between flow modeling and geophysical observations that are required.

The IES is well placed to lead major new initiatives in major generic studies of the earth sciences such as large-scale geodynamics of the Iceland system, crustal accretion mechanisms, large-scale geochemical and hydrological cycles, and climate variability in the north Atlantic region. The panel encourages IES to be ambitious and think how they could lead international efforts in such topics. Likewise IES is in a good position to take advantage of its new graduate programme in leading international graduate training in volcanology and related disciplines, taking advantage of the unique status of Iceland as a natural laboratory. Examples include the possibility of EU training Networks for young scientists and perhaps an international school of volcanology.

Glaciology

Iceland, with its many glaciers of various sizes from small to large, provides a natural setting for glaciological research, especially since many of the glaciers sit on top of active volcanic centers, which allows observations of phenomena not to be found elsewhere. The glaciology group has made optimal use of the natural laboratory settings and has gained wide international recognition for cutting edge research which spans the range from basic theory of glacier dynamics to modeling to observations of Jökulhlaups and associated subglacial hydraulics and on to mass balance studies and their climatic implications. It is impressive how much this small and very dedicated group has accomplished in basic glaciological science. Furthermore there is a direct benefit from their work to the Icelandic economy with respect to hydropower and disaster prevention respectively mitigation by the practical application of results from mass balance considerations or prediction of Jökulhlaups.

The group's structural weakness is that there is only one fixed position and that the other four positions in the group depend entirely on soft money. This makes the group vulnerable to a sudden decrease in numbers and a disproportionate decrease in effectiveness. It may even lead to the necessity to abandon crucial long-term field observation programs. The panel considers that it is imperative that glaciological research be continued at least on the same level. IES should strengthen that group proactively. With the retirement of the group leader much accumulated knowledge will disappear and it is therefore recommended that IES starts the search for a suitable successor as soon as possible and have him or her work closely together with Helgi Björnsson for the rest of his active duty. Additionally it would be advisable to allocate one more fixed position to this group.

Deformation-Seismology

IES has a vibrant program in geophysics, reinforced by the fusion of the University of Iceland group with the Nordic Volcanogical Center. The program is currently focused on combining geodetic and seismic data to study the dynamics of the volcanic systems and fracture zones in Iceland and in the north Atlantic. In particular, the combination of GPS and InSAR observations, as well as seismicity, earthquake focal mechanisms and

magnitudes allows detailed studies of dynamic processes at the root of volcanoes, the migration of magma in intrusive episodes in various volcanic systems in Iceland, as well as strain accumulation and post-seismic deformation. IES researchers in this field are productive, have a high rate of publications and apply techniques and methodologies at the cutting edge of modern geodesy. Their work is well recognized and appreciated at the international level.

IES seismologists receive seismic data from the Icelandic Meteorological Office which operates a large network of short period seismic stations across Iceland, as well as a couple of broadband seismic stations and provides catalogs of earthquakes for Iceland and the surrounding regions. Icelandic seismologists from IES and other institutions participated actively in the deployment and subsequent data analysis of two large international seismic experiments deployed in the mid-1990's, the ICEMELT and HOTSPOT experiments, which have yielded important results on the crustal and uppermost mantle structure beneath Iceland, in particular fueling recent debates about the deep structure of the Iceland "hotspot", and whether or not it is rooted in the upper mantle or in the deep lower mantle of the earth.

While information from the present network of short period seismometers is critical for the location of earthquakes in and around Iceland and much can be done with triggered earthquake event data to determine mechanisms and magnitude (for small events), and therefore learn about spatio-temporal patterns of seismicity, stress orientations, and strain release. Several unique circumstances in Iceland call for 1) the collection of continuous, rather than triggered data 2) a more extended network of permanent broadband seismometers.

Continuous data recording, especially with sufficient bandwidth to cover at least the 10 Hz to 10 sec frequency band (preferably even longer period), would allow Icelandic researchers to study such important phenomena as volcanic tremors, as well as study earthquake moment tensors, enabling them to discriminate between "ordinary" tectonic earthquakes and those related to magma motion, thus providing complementary constraints to those provided by geodesy, for the understanding of the dynamics of the volcanic and rift systems in Iceland. In addition, the accumulation of continuous seismic data over decades in other geophysically active areas of the world have recently led to the discovery of intriguing phenomena, such as non-volcanic tremors found deep below the seismogenic zone in subduction zones and recently in a transform-fault regime (along the San Andreas Fault in California), or, at long periods, the earth's "hum" which has been found to originate in the oceans. Powerful methods are being developed to utilize background seismic noise generated by microseisms of oceanic origin to study crustal structure. Because of its unique situation on top of a mid-ocean ridge spreading system, as well as a hotspot volcanic system, such modern seismic observations hold tremendous potential in Iceland, and IES researchers should get involved in defining the directions of evolution of the seismic network instrumentation as well as data collection in Iceland.
Moreover, the now ten years old successful international experiments have clearly demonstrated that, in order to solve the deep plume origin problem, which is of interest to geophysicists and geochemists alike, it is necessary to conduct a wider aperture

broadband and short period seismic experiment that would include a deployment on land and a deployment on the ocean floor around Iceland, and that will last at least a year – to collect data from a sufficient number of earthquakes useful for teleseismic studies. Such an expensive experiment can only be conducted through international collaboration. Through its multiple collaborations and connections in the US and in Europe, IES is ideally positioned to take the lead the next Iceland hotspot project – through careful planning and some diplomacy, icelandic researchers could bring to Iceland existing resources and instrumentation from *both* US and Europe in an experiment of unprecedented scale which would gain them visibility as well as a unique dataset to answer some of the most important questions currently open in understanding how global mantle circulation works. Iceland could perhaps contribute its oceanographic ship and the experiment could be built around that. Some capital investment in field seismic systems for on-land experiments (preferably short period) would help strengthen the Icelandic leadership in future observational projects.While there is an on-going experiment of similar scope in and around Hawaii, the situations of Iceland and Hawaii (the latter in mid-plate rather than at a plate boundary) are sufficiently different to warrant similar approaches, and Iceland would gain from the experience acquired during the Hawaiian experiment.

Quaternary Geology and Sedimentology

The panel was most impressed by the palaeoclimate studies in Icelandic lakes as well as the effective use of tephrochronology to unravel Holocene climate. This work is a significant contribution to regional climate variability in the North Atlantic. There is scope for much more work in the marine environment both for Quaternary environments as well as tectonics. Appointments of a paleoceanographer with expertise in sediment dynamics or biostratigraphy would strengthen these efforts. The panel notes the problems with gaining access to research ships to make bathymetric surveys, to take sediments cores and make seismic profiles. It makes sense for Iceland as an island in general to support marine earth sciences strongly. The Panel recommends that the University of Iceland discusses better ship access at a high level within the government system. These efforts are supported by a stable isotope facility, which is run effectively, and will be further strengthened with the installation of the new mass spectrometer.

Igneous Geochemistry

Icelandic scientists have a long tradition of excellence in igneous geology, petrology and geochemistry. Studies of Iceland rocks have also been and continue to be important in the global context of understanding volcanism. The strengths have tended to be in the traditional areas of the studies aimed at elucidating the deep processes of melting and igneous differentiation. These topics will continue to be important, but modern volcanic petrology has also expanded into studies aimed at elucidating dynamic processes in volcanic systems often through textural and mineralogical studies guided by theoretical or experimental research on kinetics. This latter kind of research has proven to be a

critical part of the integrated case studies of volcanic systems around the World and, in many cases, key work to unravel the interpretation of geophysical data from volcanoes. This kind of research and expertise is largely missing at IES and therefore a weakness. There are retirements coming up in the igneous geochemistry group and so there is an excellent opportunity to bring in new talent and re-configure the emphasis of research.

The facilities for igneous geochemistry at IES are aging and it is important to evaluate what equipment is essential and what work might be better pursued through international collaborations. The panel are of the view that the mass spectrometry to study radiogenic isotopes should be abandoned since the system, which was a prototype, appears not to have worked effectively for over 8 years and the technology no longer competes. Here international collaboration seems a better option for radiogenic isotope studies. IES also needs to consider whether it plans to continue with high-pressure experimental petrology in the long-term; there is a case here too for international collaboration. The microprobe will need replacing soon and this is arguably the most vital equipment for volcanic petrology and mineralogy. The panel recommends that IES develop a clear policy on probe operation, access and data management. The Panel raises the question of whether the IES has almost too much equipment to run effectively. It is essential that analytical kit be well supported by either academic or technical staff dedicated to running equipment effectively. The IES also needs to develop a policy for users of equipment, especially those that are widely used such as the probe.

Aquatic Geochemistry

This is a very high-powered, vigorous and impressive group; the leadership is dynamic; the team is young and energetic and much of the research is world-class. There is a general positive and optimistic attitude in the group, an effective international network, and a good publication record. The quality and competitiveness of the group is reflected by a healthy funding situation, where a large fraction of the funds are from external grants (mostly Icelandic, but also foreign), and companies/agencies. Only about 1/3 of the funding is from the government/NMR. The research is focused on various aspects of water chemistry and speciation in aqueous solutions. Field studies are complemented by experimental studies partly though extensive international collaboration. The group should be further strengthened with new appointments. Their potential to make a greater impact in more process-oriented studies would increase by complementary modeling expertise. The most important competence lacking is within fluid flow / hydrology and reactive transport modeling. A strong and well-integrated modeling component would make this group an extremely exciting research environment, with a great potential to attract both national and foreign students and researchers. Building up such a group is also a very wise investment to secure the future funding situation at IES. Finally, there is a need for a technical appointment of an analyst. This winner should be backed.

Some answers to generic Questions cutting across research groups

1. What are the strengths and weaknesses of the Institute of Earth Sciences (research policy, structural, infrastructural, cultural, environmental)?

Weaknesses include: threat of reduction in funding as a consequence of changes to NORDVULK funding with potential for severe damage to morale and potential; lack of sufficient expertise in modeling studies to complement observational and analytical research; some aging but essential equipment needs replacing; a clearer steer and policy by management is needed to provide access to essential facilities (eg the probe). A key potential weakness to avoid is becoming too insular as a consequence of the new graduate programme. Many of the IES staff were trained aboard and have maintained close connections; the international collaborations are a major strength and IES needs to make sure that Icelandic citizens trained through the graduate student programme have opportunities to work in other institutions.

Strengths
Earth science has a unique position in Icelandic society and culture. From a scientific point of view, Iceland represents a natural laboratory that offers a unique opportunity to study a plethora of *ongoing* geological processes. These factors provide a strong competitive advantage for the Earth sciences. This is directly reflected by the volume of people and funding that previously have been allocated to geo-studies at the University of Iceland The result is a strong research environment with an impressive international impact for a country of only 300 000 inhabitants.

There are several factors that provide opportunities for further improvement of Earth Science in the near future: 1) The merge of the Science Institute with researchers from Department of geology, and the Nordic Volcanological Institute into one unit co-localized in a brand new building with ample space for laboratory facilities, represent new opportunities for better coordinated and focused research; 2) Iceland attracts lots of international students and researchers by its unique geological situation alone; 3) Most researchers at IES have a considerable international network; 4) The age distribution allows considerable renewal of staff within the next 5 year period (provided that the funding level remains the same); 5) The 'volcanic-connection' provides a focus point for all research groups at IES and thus help prevent 'divergence' of the new IES: 6) The current IES' director is popular and respected by a large majority of the IES staff and is thus likely to have the required backing to be able to implement 'strategic decisions'.

Weaknesses
Future success will to a major extent depend on the quality of new staff members. The long and inefficient hiring process at IES is an obstacle in any attempt to attract researchers with a high international 'market value'. Excellent researchers rarely hang around for more than a year waiting for the outcome of internal discussions and voting processes. The lack of a formal interview process is furthermore a mechanism that strongly favors internal candidates and thus may lead to excessive in-breeding in the long run. This is an even bigger problem today (when Iceland produce their own PhD students

in Earth Sciences) than in the past, since the existing staff was mainly educated abroad and thus has an international network.

Despite the relatively ample resources that IES have at their disposal today, the funding is mainly comprised of numerous small-scale projects (1 PhD salary or less). Thus the future situation feels 'uncertain' for many of the researchers, and there was considerable moaning and complaints about lack of resources during the committee's site visit. This represents a challenge for coordinated activities, as too much negative vibes is counterproductive and often frustrating and demoralizing for collaborators and students. The Panel comments here that in general IES has excellent facilities by international standards and appears quite well supported. The complaints are similar to many heard in other well-known institutions in the developed world and a few of the complaints seemed to the panel as overstated.

Scientifically, IES in some of the fields of is research is suffering a bit from a staff with a relatively high average age that despite of having an excellent record in collecting data, have rather limited ability to digest the data in terms of theoretical and modeling approaches. Younger researchers are more modeling focused, but have little senior expertise to direct their activities. Some of the modeling work appeared either to focus on somewhat 'esoteric' problems or were based on too many simplifying assumptions to give very useful information when coupled to observations from the field.

Finally the potential threat of reduction in funding as a consequence of changes to NORDVULK funding may, if it comes true lead to severe damage to morale and potential.

2. Where does the IES have potential to grow (research emphasis, new activities)?

The panel has addressed this question above under the different groups

3. How do we best take advantage of the opportunities offered by the amalgamation of two divisions of the Science Institute, University of Iceland, and the Nordic Volcanologic centre?
and
4. The merging bodies had different governance culture and difference in funding levels. How do we best marry the two into one coherent unit while maintaining a profile for the Nordic Volcanologic Centre?

These two questions are interlinked and are answered together.

The panel suggests that the NORDVULK programme continues to be broadened so that any research on volcanic systems is eligible for support. Volcanology should be viewed in the broadest possible sense. NORDVULKS mission might be stated as "understanding volcanic systems and their effects on the environment" There seem to be clear advantages in making most of the academic staff (any involved in research on volcanic systems)

members of NORDVULK and avoid developing an institution within an institution with its potential for conflicts of loyalty and related tensions. This broadened concept of NORDVULK is a major selling-point to the Nordic Council. There are also major opportunities that arise out of the forthcoming retirements for re-configuring the range of expertise associated with both IES and NORDVULK.

5. How can the IES better take advantage of the Iceland, North Atlantic natural earth science laboratory?

Primarily by IES taking leadership of ambitious and major international efforts in the fields and with focus on Iceland. The panel furthermore thinks that the IES Board's suggestion to form thematic research programs should be followed up. Fixed research groups in traditional disciplines will make the organization rigid and harder to renew. Some research groups will work well, others will not – and this will be hard to change.
Thematic programs should be coordinated by a high-quality researcher with proven management skills. The programs should not be permanent, but only run as long as they are producing high quality science at a satisfactory rate. This will add a 'dynamic' component to the center that will make it easier for the director and the board to make adjustments whenever warranted. It will also represent an additional incentive for the staff to perform. Such a system will also increase the potential to draw in more external research funds, both from the public domain and the industry. This system will also make the branding of NORDVULK easier. It will then be obvious that NORDVULK includes the most existing activities in a dynamic organization, which is a much more favorable image of NORDVULK than a semi-independent research group at IES with almost complete dependence on government (Icelandic or Nordic) subsidies.

Final remarks

The panel considers IES to be an internationally highly visible research institution with ongoing research of very high quality and productivity and with some of it at the forefront of international efforts. This is possible on the one hand because of the ideal regional settting and the easy access to volcanic and related processes and structures and on the other hand because of the very high quality of the leading scientists at IES. This international visibility and esteem also brings great prestige to University of Iceland and to the country itself. Without an in-depth knowledge of other scientific areas specially nurtured at the University the panel feels that IES must certainly be a crown jewel of the University of Iceland.
The panel urges University of Iceland and other relevant Icelandic authorities to continue funding of IES at least at the same level as at present and to fill any gap that may arise in future due to possible funding changes for NORDVULK. The latter has met its Nordic challenge and requirements in the past and IES will in future be even better suited to serve as a focal point for Nordic science through its internal reorganization and restructuring.

The panel furthermore believes that it will be beneficial in the end to give more executive power to the director for faster reaction and better focusing. This should include a stronger role vs. the IES internal board especially with respect to new appointments. Notwithstanding the advice from the IES internal board the director should be advised by a small external scientific advisory board.

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