SERVICES & FACILITIES ANNUAL REPORT - FY April 2017 to March 2018

SERVICE	FUNDING	AGREEMENT	ESTABLISHED as S&F	TERM
Geophysical Equipment Facility (GEF)	Contract to	Univs of Edinburgh, Leicester, Durham & Southampton	1974 OBIF added in 2007	N/A

TYPE OF SERVICE PROVIDED:

The Geophysical Equipment Facility (GEF) is an essential and unique facility supporting high-quality, peer-reviewed projects across a broad spectrum of earth and environmental sciences by provision of internationally-recognised, state-of-the-art geophysical instrumentation for marine and land-based field experiments. It enables researchers to undertake world-class research utilising geophysical observations. Its diverse customer base undertakes research into active tectonics and crustal, mantle and deep earth structure, science-based archaeology, glaciology, climate change, sedimentology, volcano monitoring and magma chamber imaging, environmental hazards and geothermal resource mapping; categories which are encompassed in the NERC's strategic themes.

The Facility provides researchers, council, NERC institute staff and NERC studentship holders, with the planning, training, scientific and technical support necessary to meet the objectives of their proposed research projects. The onshore instrumentation is provided to users through a **free at the point of delivery** service, the marine instrumentation on a **pay as you go** basis.

Key advantages –

- *High quality science is ensured through a peer-reviewed application process. 35 projects of highly graded science were supported by the GEFE & GEFL in 2017-18, with OBIF supporting 3 major marine experiments.*
- *A cost-effective, responsive, centralised equipment base and a small, skilled group of well-qualified electronic engineers and scientists provides advice, loans, scheduling, training, maintenance and data management. The availability of high quality training enables fieldwork to be conducted by previously inexperienced operators, frequently PhD students.*

An ability to evaluate, tender for and acquire new instrumentation as a need is identified, thus maintaining provision of research quality state-of-the-art instrumentation to the community. The ability of the Facility to provide large quantities of geophysical equipment for major deployments, beyond that possible by most individual institutions, allows UK scientists to conduct and participate in experiments on a global scale. There is, therefore, a clear need for the continued provision of a community equipment facility.

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

We aim to provide a first-class service to UK researchers and this year has seen 100% of borrowers select the top grade for customer satisfaction, as recorded by our project questionnaire.

SCORES AT LAST REVIEW (each out of 5)			Date of Last Review:	N/A
Need	Uniqueness	Quality of Service	Quality of Science & Training	Average
N/A	N/A	N/A	N/A	N/A

CAPACITY of HOST ENTITY FUNDED by S&F	Staff & Status	Next Review (March)	Contract Ends (31 March)
100% (OBIF 50%)	GEF Edinburgh - UoE: Manager, Deputy, 2 Engineers (100%) (1 post vacant) GEF Leicester - UoL: 3 seismologists (100%), (1 post vacant), Computing officer (20%) OBIF - UoD: 2 engineers (50%), UoS 2 engineers (50%)	TBC	

FINANCIAL DETAILS: CURRENT FY						
Total Resource Allocation £k	Unit Cost £k			Capital Expend £k	Income £k	Full Cash Cost £k
	Unit 1	Unit 2	Unit 3			
GEFE-251.93 GEFL- 249.35 OBIF-363.75	£7 per unit of equipment per week	OBIF - PAYG specific to each service		GEFE - GEFL- OBIF -		GEFE-329.12 GEFL-319.46 OBIF-416.71

FINANCIAL COMMITMENT (by year until end of current agreement) £k				
2017-18	2018-19			

STEERING COMMITTEE	Independent Members	Meetings per annum	Other S&F Overseen
NGGFSC	10	2	BIGF, SGF

APPLICATIONS: DISTRIBUTION OF GRADES (current FY — 2017/18)													
	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**R***	**Pilot**
NERC Grant projects*			1		1								
Other academic			2	4									
Students			7										
TOTAL			10	4	1								

APPLICATIONS: DISTRIBUTION OF GRADES (per annum average previous 3 financial years —2014/2015, 2015/2016 & 2016/2017)													
	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**R***	**Pilot**
NERC Grant projects*		0.67	3.33	2.00							0.33		
Other academic			1.33	3.00							0.67		
Students			2.33	3.33	0.67						0.33		
TOTAL		0.67	7.00	8.33	0.67						1.33		

PROJECTS COMPLETED (current FY – 2017/18)												
	10 (α5)	**9**	**8 (α4)**	**7**	**6 (α3)**	**5 (α2)**	**4**	**3 (α1)**	**2**	**1 (β)**	**0 (Reject)**	**Pilot**
NERC Grant projects*		1	2		1							
Other Academic			1	3								
Students			6	2								

Project Funding Type (current FY – 2017/18) (select one category for each project)										
Grand Total	**Infrastructure**					**PAYG**				
	Supplement to NERC Grant *	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**	**NERC Grant***	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**
35	13	8	8		6					

Project Funding Type (per annum average previous 3 financial years - 2014/2015, 2015/2016 & 2016/2017)										
Grand Total	**Infrastructure**					**PAYG**				
	Supplement to NERC Grant *	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**	**NERC Grant***	**PhD Student NERC**	**PhD Student Other**	**NERC Centre**	**Other**
35	12	7.33	5.33		10.33					

User type (current FY – 2017/18) (include each person named on application form)				
Academic	**NERC Centre**	**NERC Fellows**	**PhD Students**	**Commercial**
121	**12**		**28**	

User type (per annum average previous 3 financial years - 2014/2015, 2015/2016 & 2016/2017)				
Academic	**NERC Centre**	**NERC Fellows**	**PhD Students**	**Commercial**
112.33	**9.33**		**27**	

OUTPUT & PERFORMANCE MEASURES (current year)

Publications (by science area & type) (calendar year 2017)

SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
0.57	**31.74**	**14.07**	**1.40**	**5.24**	**7.91**	**5.07**	**66**	**36**	**23**	**7**

Distribution of Projects (by science areas) (FY 2017/18)

Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
35	**0**	**17.17**	**1.17**	**0**	**4.16**	**8.17**	**4.33**

OUTPUT & PERFORMANCE MEASURES (per annum average previous 3 years)

Publications (by science area & type) (Calendar years 2014, 2015 &2016)

SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
0.45	36.55	10.67	1.25	4.56	14.66	6.56	**74.7**	33.35	36	5.35

Distribution of Projects (by science areas) (FY 2014/2015, 2015/2016 & 2016/2017)

Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
35	0.05	19.88	1.33	**0.66**	2.66	6.6	**3.82**

Distribution of Projects by NERC strategic priority (current FY 2017/18)

Grand Total	**Climate System**	**Biodiversity**	**Earth System Science**	**Sustainable Use of Natural Resources**	**Natural Hazards**	**Environment, Pollution & Human Health**	**Technologies**
35	**2.83**	**0.50**	**16.67**	**3.50**	**7.67**	**0.33**	**3.50**

**Either Discovery Science (Responsive Mode) or Strategic Science (Directed Programme) grants*

NOTE: All metrics should be presented as whole or part of whole number NOT as a %

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2017/18):

The GEF has provided instrumentation and support to 35 projects worldwide during the financial year 2017/18. Projects of grade 7 and above accounted for over 97% of those supported. The remaining projects supported PhD students.

GEF Edinburgh supported 19 loans utilising GNSS receivers, GPR, Geomagnetic and TLS systems. A total of 31 people were trained by GEF Edinburgh staff both in Edinburgh and at borrower's institutions. In addition, support was provided post-fieldwork including geo-referencing and processing of TLS data and post-processing GNSS data. The list of principal investigators includes 8 new users of the Facility.

GEF Edinburgh staff participated in a backpack TLS demonstration in Scotland whilst also providing GEF equipment for comparison purposes. The backpack scanning system has now been added to the list of possible future purchases after impressing during field trials.

GEF-Leicester supported 16 projects of which the highlight was a very large NERC funded project in New Zealand. 6 days of training for a total 19 people were undertaken at Leicester or at PI's institutions. On-site field support was provided for 2 projects and out of hours support was provided for another 3 projects. Post fieldwork support of data analysis was provided for 7 projects. Temporary staff were employed to assist with the rapid turn-around of instruments required for the New Zealand project and on projects developing an automated test rig with GEF-Edinburgh and automation of database entry and paperwork for shipping.

During FY 2017/18 OBIF (GEF-Durham, GEF-Southampton) supported three major experiments which contributed to a NERC Discovery Science Large Grant and a Highlight Topic Large Grant:

(1) Controlled-source electromagnetic experiment at Scanner pockmark in the North Sea (CHIMNEY). This is investigating a major fluid escape structure as an analogue to systems that may become active during large-scale carbon capture and storage. CSEM is being used to measure the filling of pore-spaces and fractures within the experiments, being very sensitive to the difference in conductivity between sea-water and gas saturation within the pores. During this experiment we deployed for the first time vertical dipole electrodes that were requested by the PI after the project had been approved, and also an experimental tilt and orientation sensor.

(2) Active source seismic experiment offshore Lesser Antilles (VoiLA project). This experiment is investigating the links between hydration of the subducting plate from the Atlantic and the extent and nature of volcanism in the arc. Three deployments of OBS totalling 67 sites were carried out. In addition, we provided our prototype vertical hydrophone array (developed initially for the OSCAR experiment in 2015/16, and not available at the time of the original proposal) to enable the far-field signature of the airgun source to be measured. Despite the use of a relatively limited seismic source array, clear P-wave and S-wave arrivals are present in the data to 250km offset.

(3) Multi-frequency active source seismic experiment at Scanner pockmark (CHIMNEY). This experiment was to investigate seismic properties of an active fluid escape structure, and in particular to determine frequency-dependence of anisotropy to characterise fracture networks. Seismic sources included Bolt airguns (7-50 Hz), GI guns (30-200 Hz), surface-towed sparkers (100-2000 Hz) and a deep-towed sparker (400-2000 Hz), requiring the full 4 kHz capability of our instruments on 4 channels. The experiment used one deployment of 25 instruments to meet the main science objectives; for other operational reasons a mid-cruise port call was required and following this we were able to carry out an additional deployment of 7 instruments using our spare consumables, to significantly enhance the science that was possible. The high sampling rates meant that within a deployment of 10 days more than 1TB of raw data were recorded, with almost 200000 shots. Nevertheless, fully processed and QC'ed record sections were handed over to the PI before the cruise ended.

These services (programmed without reference to OBIF) were back-to-back, and to some degree overlapping, with some of the instruments deployed five times without an opportunity to return them for shore-based refurbishment. Two of our staff spent more time at sea than National Marine Facilities allow within a year, including flying directly from one experiment to the next, and being away from home for more than 70 days continuously. The seismic experiments were the first large-scale deployment of our new LJ1 logger, which provides access to modern storage up to (currently) 256GB per instrument, removing a significant vulnerability due to storage shortcomings that emerged in a bought-in design. We were able to respond rapidly to new requests from PIs due to our in-house engineering facility, enhancing the delivery significantly. In addition, we supported critical tasks such as determination of accurate absolute shot instants that are not delivered by National Marine Facilities.
In summary, this operational period has seen 324 engineer days away from base successfully delivering 113 deployments (99 seismic, 14 EM), 1 prototype vertical array deployment and 1 prototype broadband platform development trial. In data terms, 438 individual datasets with 97.5% data recording, totalling 3 Tbytes in volume that was fully processed to standard form, QC'ed, archived and provided to the PI before reaching port.

SCIENCE HIGHLIGHTS. ***To focus on economic and societal impacts and benefits where possible*:**

1. A high frequency Pulse EKKO 1000 GPR system was deployed to Nepal by Dr Hamish Pritchard of the British Antarctic Survey to measure debris thickness on Lirung Glacier **(McCarthy, M., Pritchard, H., Willis, I. and King, E., 2017, Ground-penetrating radar measurements of debris thickness on Lirung Glacier, Nepal, *Journal of Glaciology*, p1-13, doi: 10.1017/jog.2017.18, GEF Loan 1014)**.

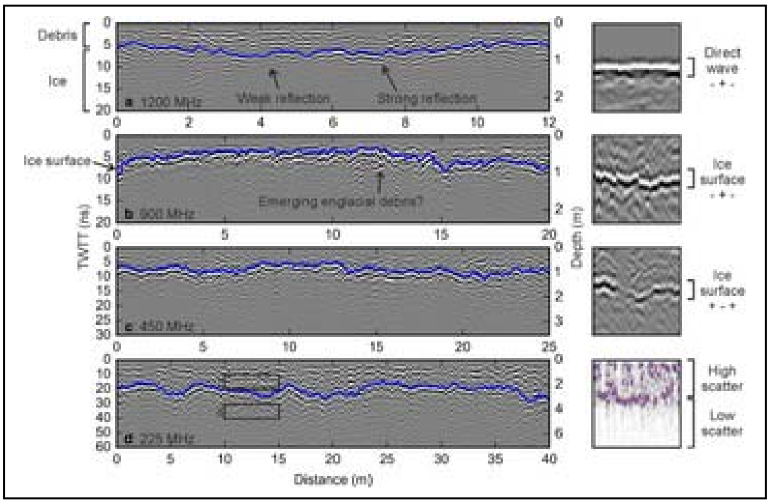

Fig. 1. Left: ice surface reflection picks (blue) on example reflection profiles in which the ice surface was successfully imaged. (a) T13, 1200 MHz. (b) P1, 900 MHz. (c) P20, 450 MHz. (d) P27, 225 MHz. Depth scales do not take system geometry into account and are therefore approximate. Right: direct wave and ice surface wavelets and the radar facies of debris and ice.

GPR data was collected with 225, 450, 900 and 1200MHz antennas, varying the operating frequency until the ice surface had been successfully imaged. 29 reflection profiles along 15 transects were collected together with 9 CMPs. To validate the GPR measurements, 34 pits were dug, ranging from 0.16 to 0.58m deep through the debris to the ice surface.

A strong, continuous reflection occurred below the direct wave in 16 of the 29 reflection profiles collected. Above this reflection is a high-scatter radar facies and below it is a low-scatter radar facies. The strong, continuous reflection is interpreted as the ice surface (Figure 1).

Debris thickness measurements made by GPR agreed well with those made by digging pits to the ice surface (RMSE=0.04m and correlation coefficient r=0.91).

The results confirm that GPR is a useful tool for mapping debris thickness of Himalayan glaciers and provide an insight into debris thickness variability and the nature of the ice surface during the survey period on Lirung Glacier.

2. Equipment supplied by both GEF Edinburgh and GEF Leicester provided data used to determine the crustal structure of active deformation zones in Africa **(Ebinger, C.J., Keir, D., Bastow, I.D., Whaler, K., Hammond, J.O.S., Ayele, A., Miller, M.S., Tiberi, C. and Hautot, S., 2017, Crustal structure of active deformation zones in Africa: Implications for global crustal processes, *Tectonics*, doi: 10.1002/2017TC004526).**

The Cenozoic East African rift (EAR), Cameroon Volcanic Line (CVL), and Atlas Mountains formed on the slow-moving African continent, which last experienced orogeny during the Pan-African. We synthesize primarily geophysical data to evaluate the role of magmatism in shaping Africa's crust. In young magmatic rift zones, melt and volatiles migrate from the asthenosphere to gas-rich magma reservoirs at the Moho, altering crustal composition and reducing strength. Within the southernmost Eastern rift, the crust comprises ~20% new magmatic material ponded in the lower crust and intruded as sills and dikes at shallower depths. In the Main Ethiopian Rift, intrusions comprise 30% of the crust below axial zones of dike-dominated extension. In the incipient rupture zones of the Afar rift, magma intrusions fed from crustal magma chambers beneath segment centers create new columns of mafic crust, as along slow-spreading ridges. Our comparisons suggest that transitional crust, including seaward dipping sequences, is created as progressively smaller screens of continental crust are heated and weakened by magma intrusion into 15–20 km thick crust. In the 30 Ma Recent CVL, which lacks a hot spot age progression, extensional forces are small, inhibiting the creation and rise of magma into the crust. In the Atlas orogen, localized magmatism follows the strike of the Atlas Mountains from the Canary Islands hot spot toward the Alboran Sea. CVL and Atlas magmatism has had minimal impact on crustal structure. Our syntheses show that magma and volatiles are migrating from the asthenosphere through the plates, modifying rheology, and contributing significantly to global carbon and water fluxes.

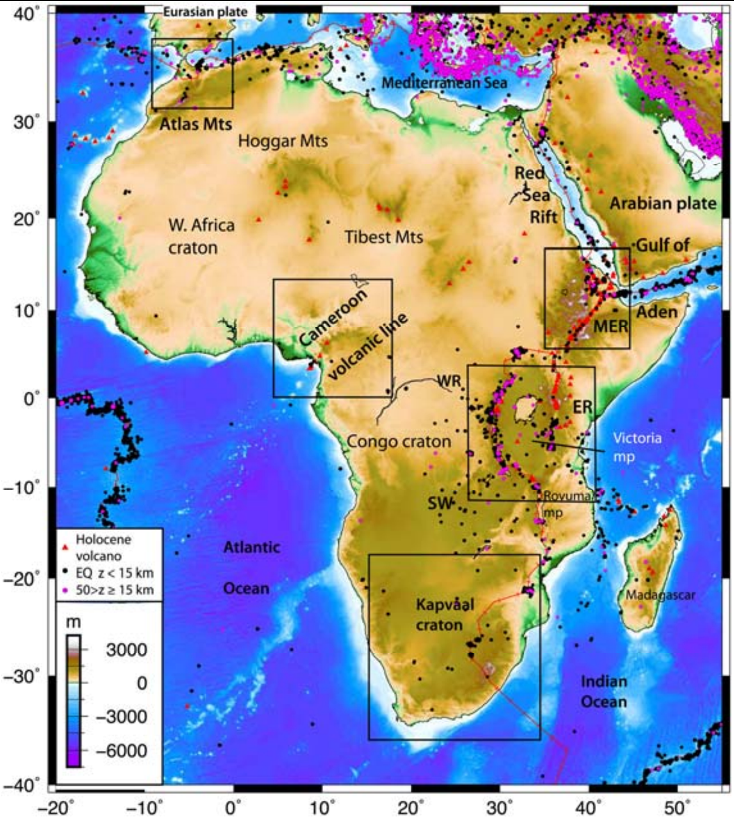

Fig 2. Topography of Africa with major plates, and 1976–2016 seismicity from the NEIC catalogue, and Holocene to Recent volcanoes from the Global Volcanism Program (http://volcano.si.edu/). ER = Eastern rift, WR = Western rift, SW = Southwestern arm, Rovuma mp = Rovuma microplate, Victoria mp = Victoria microplate. Large Archaean cratons with deep roots labeled; small Tanzania craton lies between the ER and WR. Lower crustal earthquakes with depths greater than 15 km are highlighted in magenta.

3. Ocean bottom instruments supplied by OBIF were deployed to record wide-angle (WA) and multichannel seismic (MCS) data across the Louisville Ridge Seamount Chain (LRSC) and Kermadec forearc (**Funnell, M., Peirce, C. and Robinson, A., 2017, Structural variability of the Tonga-Kermadec forearc characterized using robustly constrained geophysical data, *Geophysical Journal International*, 210(3), p1681-1702, doi: 10.1093/gji/ggx260**).

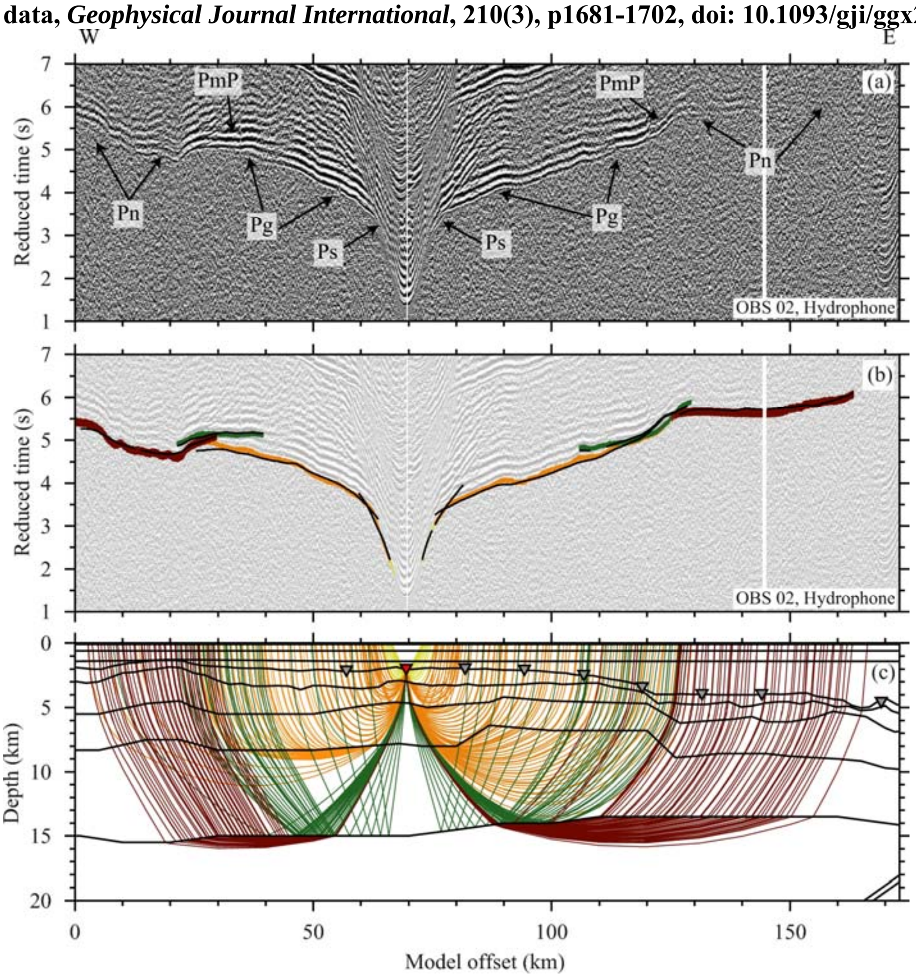

Fig 3. Kermadec forearc. (a) Hydrophone data from OBS 02 plotted with a reduction velocity of 8 km s^{-1}, with major phases labelled. (b) Picked phases (yellow—P_s; orange—P_g; green—P_mP; brown—P_n). Colour bar height indicates pick uncertainty, and black lines represent modelled arrival traveltimes. (c) Calculated ray paths for each picked phase through the final forward model. The location of OBS 02 is indicated by the red inverted triangle.

Subducting bathymetric anomalies enhance erosion of the overriding forearc crust. The deformation associated with this process is superimposed on pre-existing variable crustal and sedimentary structures developed as a subduction system evolves. Recent attempts to determine the effect and timescale of Louisville Ridge seamount subduction on the Tonga-Kermadec forearc have been limited by simplistic models of inherited overriding crustal structure that neglect along-strike variability.

Synthesis of new robustly tested seismic velocity and density models with existing data sets from the region, highlight along-strike variations in the structure of the Tonga-Kermadec subducting and overriding plates. As the subducting plate undergoes bend-faulting and hydration throughout the trench-outer rise region, observed oceanic upper- and mid-crustal velocities are reduced by ∼1.0 km s^{-1} and upper mantle velocities by ∼0.5 km s^{-1}. In the vicinity of the Louisville Ridge Seamount Chain (LRSC), the trench shallows by 4 km and normal fault throw is reduced by >1 km, suggesting that the subduction of seamounts reduces plate deformation. We find that the extinct Eocene frontal arc, defined by a high velocity (7.0–7.4 km s^{-1}) and density (3.2 g cm^{-3}) lower-crustal anomaly, increases in thickness by ∼6 km, from 12 to >18 km, over 300 km laterally along the Tonga-Kermadec forearc. Coincident variations in bathymetry and free-air gravity anomaly indicate a regional trend of northward-increasing crustal thickness that predates LRSC subduction, and highlight the present-day extent of the Eocene arc between 32°S and ∼18°S. Within this framework of existing forearc crustal structure, the subduction of seamounts of the LRSC promotes erosion of the overriding crust, forming steep, gravitationally unstable, lower-trench slopes. Trench-slope stability is most likely re-established by the collapse of the mid-trench slope and the trenchward side of the extinct Eocene arc, which, within the framework of forearc characterization, implies seamount subduction commenced at ∼22°S.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

GEFE: A number of NERC projects have now been approved that will require MT equipment capable of operating on ice. The Facility has requested capital for new systems capable of supporting these projects. The Facility is keen to expand on its range of terrestrial laser scanners to include the very latest technology which is why a backpack mounted system has been suggested for purchase. This makes use of inertial measurements coupled with GNSS, multiple cameras and multiple laser scanners to capture 3D point clouds whilst moving through the landscape. The GEF see great potential in mapping previously difficult landscapes such as under forest canopies at much greater speeds. It is also considered a priority to obtain a new high-frequency radar with multi-channel capability to replace our existing elderly system and enhance the capability of the Facility.

GEFL: The real terms freeze in funding for the Facility over the last 5 years and the ongoing uncertainty over the duration of Facility contracts has had a particularly adverse effect on staffing levels at GEF-L. A consequence of this is the total amount of equipment for loan and the level of support available to the community is going to have to be reduced and expectations carefully managed. Following an intensive period of activity supporting a large number of loans, including a series of urgent loans to areas affected by devastating earthquakes, the facility has a large amount of equipment on test or in repair. Steps are being taken to get this equipment back into service as soon as possible. Funding is being sought for an upgrade to the current equipment test facilities to enable larger numbers of instruments to be tested and returned to service. Longer turn-around times are being introduced to better manage demand, particularly as projects are increasingly ambitious and are requesting larger numbers of instruments. In addition, training programmes are being reviewed and changes to the loan terms and conditions made in order to reduce a recent increase in equipment being returned either damaged or in need of repair. Through these measures a limited number of instruments not required for scheduled projects is being built up to enable the Facility to once again support urgent loan requests with modest amounts of equipment. The data processing and data management system which has been at the heart of ensuring the data is publicly available via the IRIS data management centre is due for renewal. This access to the data for use by researchers internationally, beyond the projects for which it was collected, has very considerably added to its value and the international profile of the Facility.

OBIF: A number of key enhancements are in progress. First is a new A2D board which will reduce power consumption and increase flexibility for a broader range of sensor types. Second is to enhance our electromagnetic recording capability with new electric field preamplifiers and magnetic field sensors. Third is to take a number of prototype auxiliary sensors (e.g., platform orientation, GPS timing systems) and make them fully production-ready.