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SECED Special Issue: Reporting from the 2019 SECED Conference

Earthquake risk and engineering towards a resilient world

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Editorial Introduction

Damian Grant
SECED Newsletter Editor
Arup, London, UK

In this issue of the SECED newsletter, we turn our thoughts back to those halcyon, pre-pandemic days of September 2019, when many of us met with people outside our household in groups of more than six to discuss the latest exciting research and practice of earthquake engineering and structural dynamics. The 2019 SECED Conference was hosted in Greenwich, and once again attracted submissions and attendees from all over the world. In the weeks after the conference, we collected some fresh feedback from attendees, which we present to you in this special issue of the SECED newsletter. Thanks to those who contributed their thoughts.

In other news, I would very much like to thank Konstantinos Gkatzogias, who recently stepped down from his role as sub-editor of the SECED newsletter – a role he had held since 2017. Dr Gkatzogias did the lion's share of newsletter preparation, and also improved a lot of our processes behind the scenes. I'm also grateful to Manuela Daví who takes over as sub-editor from this issue.

As usual, we welcome any new content from SECED members and non-members alike. Please contact me or Manuela if you would like to contribute.

Photo of the keynote lecturers at the Painted Hall of the Old Royal Naval College. From left to right: Tiziana Rossetto, Jack Baker, Ziggy Lubkowsky, Dina D'Ayala, Ioannis Anastasopoulos, Sinan Akkar and Ahmed Elghazouli. Eleni Chatsi was not present in the photo (© SECED).

Reporting from the SECED 2019 Conference

Damian Grant
SECED Newsletter Editor
Arup, London, UK

As with SECED's 2015 conference, I was pleasantly surprised by the success of the 2019 edition in Greenwich. Again in common with last time, by far the highlight for me and many other attendees was the dinner in the stunning Painted Hall of the Old Royal Naval College. If only the conversation from my table-mates wasn't so stimulating, I could've spent more time absorbing the details of "London's Sistine Chapel".

Another highlight for me was getting to introduce the second keynote presentation of the conference, Professor Jack Baker from Stanford University, and therefore securing a front row seat for his talk. What followed was an absolute *tour de force* on the state of the art performance based earthquake engineering (PBEE) and its extension beyond individual buildings to 1000s of buildings across several city blocks. This is a necessity for the kind of seismic performance questions that local authorities are now asking, particularly in places like San Francisco. One of the examples Professor Baker covered was in modelling the possibility of safety cordons being in place around damaged buildings, and the impact this has on the functional recovery of neighbouring buildings. He has also collaborated with Stephane Hallegatte from the World Bank to model regional economic recovery using results from his simulations. The economic models quantify, for example, the negative impact of an earthquake on many sectors of the local economy, partly offset by the boom in the construction industry as reconstruction and repairs take place.

Also in common with 2015's conference, oral presentations took place over quite a few parallel sessions. When studying the programme and deciding how to plan out the two days, this can be a source of frustration (for all but those with very narrow interests). But, on the day, the slightly longer timeslots per speaker that this allows seems to work really well for speaker, audience and session chair. The least satisfying role of the session chair is having to hurry a speaker towards a conclusion, and I was grateful that every single one of the presentations in my sessions both stuck to time, and generally left some time for questions and discussion. As for the presentations I missed, I've followed up on many of the papers in the conference proceedings, and have found a few gems that I wish I'd seen presented.

In such an eclectic conference, it's hard to draw any overarching themes and directions that the industry is travelling in. Given the way conversations seem to be going in the engineering industry right now, it was perhaps surprising that many of the buzz topics around digital technologies, data science and machine learning were not more of a focus. The keynote presentations all gave us a snapshot of the state of the art (or sometimes just beyond), but perhaps Professor Eleni Chatzi's keynote, "Towards self-aware infrastructure" pointed closest to the direction of travel I see in my own clients' demands. She described a continuum between normal, "inanimate" structures, and "animate", self-regulating, autonomous ones. Typical structural health monitoring sits somewhere close to the inanimate on this scale, whereas current developments in her research team are mostly focused on how continuous data collection is used to inform maintenance or operation of the structure. A pertinent example Professor Chatzi gave was on using sensor data from earthquakes to predict vulnerability to aftershocks and to aid in "smart tagging".

Congratulations to Tiziana Rossetto for chairing such a successful conference, and thanks to the rest of the conference organising committee. Bring on SECED 2023!

Sarah Tallet-Williams
SECED YMSC Vicepresident
Jacobs, London, UK

Young members at the SECED Conference. The inspiration for the Young Members' Subcommittee came from the 2015 SECED conference. Several of my classmates and I were overwhelmed with the number of other young people at the conference we had never met, but who were also working in earthquake engineering and structural dynamics in the UK. It was amazing, therefore, to see a 66% increase in young members attending the 2019 conference, many more of whom I had the pleasure of knowing through Young Members events. This increase can be attributed to the support from the main SECED committee, both in the creation of the Young Members' Subcommittee as well as providing affordable student rates and accommodation for those not located in London.

The technical contribution of work from the Young Members was impressive.

We are very grateful to Jacobs for sponsoring the Young Members' best presentation award, deservedly won by Elena Elettore. I am looking forward to seeing her present the paper again at the Young Members' AGM in October. In attending the Soil Structure Interaction session, I was also lucky enough to see Hazib Abdulrazaq present his work, a different aspect of which won the Norsar poster prize.

This conference's legacy was that much of the new Young Members' Subcommittee was made up of those who had attended. It has been wonderful to be able to go to the events they have organised this year, particularly being able to keep in touch online during the current difficult circumstances. I am very much looking forward to the next conference, though it does become questionable whether at that stage I will still count as young.

Vitor Silva

Seismic Risk Coordinator at the Global Earthquake Model (GEM) Foundation, Pavia, Italy

SECED 2019: Now Greenwich is not only known for the meridian line and the Cutty Sark. There are conferences with great presentations but too large to properly appreciate every session, and conferences where it is easier to interact with fellow researchers, but fall short on the number of impressive presentations. And then there are the SECED conferences, bringing the best of both worlds. It is great to have a platform where experts from the industry are not afraid of the formulae and theories of the academics, and likewise, researchers have the opportunity (and courage!) to interact with the ones that are putting all the models into practice.

The 2019 SECED conference had all of this and more: previews of the upcoming revised Eurocodes, demonstrations of how machine learning technology is changing structural monitoring practice, recent advancements in loss assessment, vulnerability for infrastructure and structures with accumulated damage and physics-based seismic hazard modelling. On top of all of this, let us all make a minute of silence for all of those that were unfortunate to miss the phenomenal dinner at the Painted Hall at the Old Royal Naval College, a night to remember. There are many things we should look forward in 2023: electric cars with better mileage, NASA's new space telescope, the 36th postponement of Brexit, and of course, the next SECED conference.

Robin Spence

Cambridge Architectural Research Ltd

I have been attending SECED Conferences since the Bristol Conference of 1988, and have (I think) presented papers at all of them. This time, not presenting a paper, but as joint chair of one of the sessions, I was freed to pay closer attention to the scale and range of what was presented. Choosing to attend just one of 7 parallel sessions in each time slot presented invidious choices, and I was unable to hear many papers of great interest to me. But those I did attend, the 6 keynote papers and the papers in the 4 presentation sessions, taught me a lot about that current state of our field, and also impressed me with the scale of what is being done, in this country and globally. I was particularly impressed with the keynote presentation by Jack Baker, showing how scenario impacts are being modelled in California as a contribution to the efforts of the Cities of San Francisco and Los Angeles to approach earthquake risk from a new resilience perspective. I was also struck by the value of the work being done by Arup and others through World Bank Partnerships on improving the seismic safety of schools in several vulnerable countries. And it was valuable to learn how EEFIT is thriving, and continues to be able to mount highly professional post-earthquake field missions, as well as having now a properly funded research programme to support these field missions.
The standard of presentations was commendably high, and it was particularly gratifying to see so many current PhD students at the podium, making very polished presentations.

Of course it is the personal contacts made in the

Photo from the auditorium during one of the keynote lectures held at the SECED Conference (© SECED).

break-out sessions, over lunch and dinner, that make a conference, and this one was second to none in the number of email follow-ups to conversations which resulted. The setting and the wonderful Painted Hall was a brilliant backdrop to the proceedings. My only suggestion for improvement would be that the poster sessions should have been more integrated spatially with the tea and lunch-break venues. One eminent colleague from Portugal, who came solely to present a poster, was dismayed at the small number of delegates who made their way to view the posters, and was wondering if it had all been worthwhile – particularly when he almost missed his flight from Stansted because trains on both the DLR and Stansted Express were suspended! But all in all it was a great success and many congratulations to the organisers, and thanks for their hard work in putting it together.

Photo of the Painted Hall at the Old Royal Naval College during the SECED Conference dinner (© SECED).

Chris Browitt and Alice Walker

ABConsulting, Edinburgh, UK

The induced seismicity session at the SECED 2019 Conference. We (Alice Walker and Chris Browitt) had the good fortune to convene and jointly chair the Induced seismicity session at the SECED 2019 Conference, comprising 11 orals and a poster, together with a strong audience of delegates who contributed throughout the day with their questions and thoughts from both engineering and seismological perspectives. We are in Damian's category of having "narrow interests" but still missed several presentations we wished to attend; perhaps a 3-day conference would help to some degree (a thought for the young engineers likely to be involved next time).

Our induced seismicity presentations were complementary and covered the spectrum from history, through case histories, current activities in geothermal, shale gas and conventional gas exploitation, new models for Traffic Light Systems (TLS) to replace the discredited one (in our opinion) in current UK use, to economic, political and social damage impacts, and, finally, to the concept of the "Comfort Level Earthquake" (CLE). The last appears, at first sight, to be in conflict with itself but is, in fact, very real. Our personal experiences, over several decades, of speaking with residents who felt coal-mining induced earthquakes, shows that, with hindsight, all but a few of the many hundreds of such events were in the "comfort level" category.

We only wish that we had thought of the term at the time rather than being presented with it by Ihsan Bal, of Hanze University, at this conference. Our congratulations to him – the task we now have in the UK is to have it accepted as a reality in relation to shale gas fracking, a point that was brought out in our discussion session at the end of the day. That is not to say the CLE will not be exceeded at times, such as with the magnitude 2.9ML event on 26 August, this year, in Lancashire, as described by Brian Baptie in his talk. That resulted in many reports of plaster cracking (although not authenticated) and certainly would have caused alarm in some people.

The history of induced seismic event in the UK (Browitt and Walker, 2019) took us back to a lead mining event in Lanarkshire (1749) and a coal mining one at Long Benton Colliery, near Newcastle, in 1765. These are the earliest such events that Roger Musson has found in his historical searches. The main focus, however, was on coal mining earthquakes in Midlothian and Stoke in the 1970s with local, modern BGS seismic monitoring to prove the links to the hand-of-man. Our understanding was then consolidated in the 1980s and 1990s over the whole country when mining activity was still widespread and when seismic monitoring became nationwide.

Brian Baptie and Richard Luckett (Baptie and Luckett, 2019) summarised the seismicity and monitoring of the current fracking activity in Lancashire where shale gas is being targeted at a depth of 2,300m. They showed a clear correlation of small events (mostly below 0.5ML) with short periods of stimulation by fluid injection but with a small number of "trailing events" that followed. The magnitude 2.9ML event, noted above, was one of these; for this, details were presented although are not in the submitted paper as that pre-dated the event.

Gemma Cremen and others (Cremen et al., 2019), presented their results of a study to compare the relative value of four candidate ground motion prediction equations (GMPEs) for application in the UK, with particular focus on the Lancashire region. Detailed analysis of their performance resulted in the equation developed by Douglas et. al. (2013), from data generated at geothermal sites, being the most suitable although it would still overestimate the hazard, particularly at long return periods. This is a valuable result that will guide those assessing seismic hazard at other proposed fracking sites in the UK.

With considerable media and public focus on the first shale gas fracking site in the UK, in Lancashire, a series of small felt earthquakes in Surrey, within a few km of oil field production and development wells, has also raised questions about their origin. Stephen Hicks, and others, (Hicks et al., 2019) have been investigating these with seismic data collected by BGS in the area. In this well-argued presentation, Hicks concluded that the E-W Newdigate fault was the causative structure, and that it is unlikely the oilfield operations could have triggered seismicity on it. That is, the events are tectonic. Continuing this theme of possible fault reactivation during fracking operations, James Verdon, and others, (Verdon et al., 2019) examined a database of 18,000 microseismic events associated with a multi-well site in Alberta. He reported that high resolution monitoring and mapping of the events led them to conclude that pre-existing fracture networks can provide corridors, through otherwise low permeability shales, permitting elevated pore fluid pressures to transfer to a pre-stressed natural fault; in this case, at a distance of 600m.

In an attempt to understand how likely significant damage will occur from induced earthquakes with magnitudes of 4.0 or more, Cecilia Nievas, and others (Nievas et al., 2019), have compiled a global database of shallow, potentially damaging earthquakes around this magnitude threshold (described in her poster). With several caveats, in presenting her analysis orally, she concluded that the percentage of such earthquakes causing damage was less that 3% for induced ones, and less that 2% for tectonic ones.

Our afternoon session started with Peter Ledingham and Andrew Jupe (Ledingham and Jude, 2019) reporting on a new project to develop a geothermal system in the heat-producing granites of SW England. It follows on from a Hot Dry Rock research programme conducted through the 1980s that resulted in a greater understanding of reservoir development and permeability enhancement. That programme produced considerable induced seismicity but with only one earthquake being felt (2.0ML). In this new project, two wells have been drilled to intersect a fault structure at 2.5 and 4.5km depth where it is anticipated there will be sufficient permeability to permit flow between them without any rock fracturing. In this case, induced seismicity is expected to be at a low level that will be tested by the seismic monitoring system installed. Cornwall Council has set operational guidelines based on the use of measured peak ground velocity (PGV) rather than event magnitude which, in our opinion, is a more sensible and practical approach than that adopted in the traffic light system in Lancashire – why predict how the ground might move when you can measure it directly! Peter Ledingham reported, also, that they have already engaged in a strong outreach programme in the local community; another most welcome step. The Public perception of an earthquake is, generally, the destruction they see on TV, not these minor induced tremors we have in the UK.

Continuing the theme of finding an appropriate traffic light system, both Tom Ader and Stefan Wiemer (Ader, 2019 and Wiemer, 2019) detailed their schemes. Tom described the approach developed for a geothermal site in Finland with a 6.1km deep stimulation well sited near Helsinki. Measured surface PGV values, similar to those used in Cornwall, were used to trigger TLS thresholds but with the addition of a magnitude/GMPE probabilistic prediction of PGV threshold exceedance operating in parallel. This resulted in the red (stop) alert being triggered at either

a measured PGV of > 7.5mm/s or a magnitude of 2.1ML at a depth of 6km. Stefan Wiemer argued that current TLSs are too simplistic and do not take into account the full range of possible scenarios and the uncertainty of the process. Advanced, or Adaptive Traffic Light Systems (ATLS), being developed by his group in Switzerland, aim to overcome the problem. They depend on a quantitative risk assessment, are fully probabilistic with new data being continuously integrated to update geomechanical and seismicity forecasting models, coupled with information on exposure and vulnerability of nearby structures. These concepts have been tested retrospectively and will be demonstrated in a commercial scale application in Iceland.

Our final two papers focused on damaging and induced earthquakes in the Groningen gas field of the Netherlands where the existing building stock has not been designed for seismic loading. Vasilis Sarhosis, and others, (Sarhosis et al., 2019) have addressed the issue of establishing the condition of an unreinforced masonry building subjected to several potentially damaging induced seismic events and, therefore, experiencing the cumulative impacts. Only the residual damage can be observed and assessed whereas other cracks may have opened and closed. They have developed a numerical model to achieve this.

Ihsan Bal, and others, (Bal et al., 2019) have addressed the problem of disputes arising in relation to damage claims in the Groningen region where it can be argued that buildings had already suffered damage before an earthquake owing to their vulnerability in relation to the soft soils, water table oscillations, and general deterioration in these conditions. He explained their proposed CLE concept to address these issues; particularly the inherent difficulties of correlating damage with small recursive events. The idea is to combine the CLE with a risk-based annual compensation per-house scheme which would be higher in the heart of the gas field reducing to zero with distance from it. This would not exclude specific additional claims for damage caused by earthquakes exceeding the CLE. We await responses from the government and operators to this proposed scheme which has the potential to take out some of the complexities and public anxieties of the current claims process.

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Editor's note: On 29th January 2020, SECED and the Institution of Civil Engineers (ICE) jointly hosted an evening event at the Institution of Civil Engineers. Professor Prodromos Psarropoulos (ISCARSAH-UK) gave a presentation and he kindly provided this summary of his talk.

Soil–Structure Interaction and Optimum Seismic Design of Onshore and Offshore Energy Projects

Prodromos Psarropoulos
Structural and Geotechnical Engineer, BEng, MEng, MSc, PhD
Laboratory of Structural Mechanics and Engineering Structures, School of Rural and Surveying Engineering
National Technical University of Athens, Greece

Since our modern society demands increased availability and reliability of energy supply, together with improved environmental standards, the structural design of any onshore or offshore energy project, including energy lifelines (i.e. pipelines and cables), can be very demanding, depending on the circumstances. It is evident that in the case of long lifelines that traverse remote regions with extreme terrain and/or seabed, the design may be more challenging due to the variety of geotechnical conditions and the potential geohazards along the routing. Furthermore, in areas characterized by moderate or high seismicity the design of energy projects may be more complicated due to the various types of seismic loading. Seismic loading may be either dynamic due to the inertial forces developed on the mass of the structure(s) and/or quasi-static due to the permanent ground displacements (PGDs) caused by various earthquake-related geohazards, such as active-fault ruptures at the ground surface, soil liquefaction phenomena (i.e. settlements or lateral spreading) and/or earthquake-triggered slope instabilities (i.e. landslides). The presentation which took place on the 29th of January 2020 highlighted, through case studies (e.g. see Figure 1 and 2) such interesting issues of geotechnical earthquake engineering, from a structural and a geotechnical perspective.

Figure 1: Oil tanks connected with a marine jetty in Cyprus (courtesy: VTT Vasiliko Ltd).

The first part of the presentation focused on the impact of local site conditions (i.e. soil stratigraphy, bedrock geomorphology, and/or surface topography) on the ground surface motion that can dominate the dynamic structural response. Records and analyses in the past have shown that local site conditions in combination with the potential soil nonlinearity modify (a) the amplitude, (b) the frequency content, (c) the duration, and (d) the spatial variability of the seismic motion at the ground surface or at the seabed.

In the second part of the presentation emphasis was given on the quantitative assessment of the earthquake-related geohazards and the realistic estimation of the PGDs which will actually determine the soil–structure interaction and the structural distress. Actually, there exist four options regarding the seismic design of extensive energy lifelines:

1. The first is the avoidance of the potentially problematic areas. This option requires rerouting or in some cases tunnelling; these solutions are not always feasible due to various technical and/or environmental constraints, or even time limitations.
2. The second option is the application of various geotechnical mitigation measures aiming to avoid the occurrence of the potential earthquake-related geohazard (e.g. stabilization of a slope in order to avoid an earthquake-triggered landslide). However, the geotechnical mitigation measures may incur a substantial cost, depending on the type and the extent of the geohazard.
3. The third option is the crossing through potentially problematic areas with "isolation" techniques, provided that the isolated lifeline (i.e. pipeline or cable) has been checked that it is capable of accommodating the expected PGDs.
4. Finally, the fourth option, which is more cost-effective, is based on the modern seismic philosophy, according to which repairable damages to any structure are allowed, provided that the non-collapse requirement has been fulfilled.

The fourth option is crossing through the potentially problematic area(s) without any mitigation or isolation measure, provided that the lifeline has been checked that it is capable of accommodating the expected PGDs.

Therefore, provided that reliable data exist to enable rigorous assessment of the PGDs and of the subsequent structural distress, it is possible to make a clear distinction between (a) problematic areas (in terms of PGDs) that are non-critical (in terms of lifeline distress – usually strain) and a lifeline can cross them with safety, and (b) problematic areas that are in parallel critical, and therefore a lifeline cannot cross. Basic prerequisites for the fourth option are the following: (a) specifications and supervision during the construction phase in order to achieve in practice the high-strain capacity, and (b) monitoring of the geohazard(s) and the pipeline distress simultaneously during the operation phase. Monitoring is required as after the (strong) design earthquake damages must be identified and repaired as fast as possible since an aftershock may cause the collapse of the damaged structure.

Based on the aforementioned, the third part of the presentation was devoted to remote monitoring (i.e. sensing) and early-warning systems. There are at least six reasons why real-time remote sensing is directly or indirectly related to the risk assessment and management of an energy project:

1. Human errors and/or negligence during the design, construction and/or operation phase cannot be excluded. Additionally, national and international standards and norms have limitations and they are getting improved every 10 to 20 years, a time period which is shorter than the usual lifetime of an oil and gas facility.
2. All input data of the design have a certain degree of uncertainty, especially when geodata are concerned. Furthermore, the implications of climate change make this uncertainty even higher. For example heavy rainfalls increase the risk of landsliding not only under static conditions, but under seismic conditions as well.
3. Seismic design relies on seismological studies which are based on probabilistic analysis and statistical interpretation of data.
4. Some projects are located in remote isolated areas with limited accessibility. These areas may be high mountains with snow during many months of each year or deep waters of the order of kilometers, making thus the accessibility (and any potential repair) extremely difficult.
5. As modern seismic design allows certain damage levels, a relatively small aftershock may cause the collapse of a damaged structure if the structural damages of the mainshock have not been identified and repaired quickly.
6. Finally, an early-response system (such as a smart block valve that connects two or more components of a facility) may decrease the loss of new or old facilities, and therefore the total risk. It is evident that the application of an early-response system could separate the various components of the facility in case of an emergency.

By monitoring in parallel of (a) the acceleration levels (i.e. the triggering), (b) the PGDs, and (c) the structural response (i.e. strain), remote sensing can substantially contribute to the reduction of the risk of various energy projects that are subjected to natural hazards. It may be very effective in the case of extensive (i.e. long) lifelines that are crossing remote areas characterized by potential earthquake–related geohazards.

Finally, it should be emphasized that simplistic provisions of national and international seismic norms cannot cover sufficiently all issues of geohazard assessment and seismic design of energy projects, especially offshore. The optimum seismic design of an energy project requires, apart from geoscientists familiar with qualitative geohazard assessment, engineers capable of performing (a) quantitative geohazard assessment (based on reliable data), (b) realistic soil–structure interaction analyses, and (c) the design of various geotechnical and/or structural mitigation measures (if required).

Figure 2: Trans-Adriatic-Pipeline (TAP) high-pressure gas pipeline in Albania during the construction phase (courtesy: Spiecapac)

Leighton Buzzard, Bedfordshire Earthquakes

David Galloway
British Geological Survey BGS, Edinburgh, UK

An earthquake, with a magnitude of 3.5 ML, occurred on 8 September 2020, at 08:45 UTC, with a location near the town of Leighton Buzzard, Bedfordshire. Seismograms of the ground displacement from the earthquake as recorded by BGS seismograph stations at West Acre, Norfolk (WACR), Monmouth, Monmouthshire (MONM), Michaelchurch, Herefordshire (MCH), Herstmonceux, East Sussex (HMNX), Tregeiriog, Clwyd (FOEL) and Elham, Kent (ELSH) are shown in Figure 1. The BGS received over 1,950 reports, via online macroseismic questionnaires, of the earthquake being felt. Most reports were from towns, villages and hamlets in the counties of Bedfordshire, Buckinghamshire and Hertfordshire, with the majority coming from within around 25 km of the epicentre. Typical reports described, "the house had one dramatic shake", "all the windows rattled", "there was a heavy vibration", "felt like the whole house was shaking" and "it was like a large explosion". A maximum intensity of 6 European Macroseismic Scale (EMS) was assigned for this event (Figure 2).

A further five events were detected in the same area during September 2020. The first of these occurred on 13 September, at 23:20 UTC, with a magnitude of 2.1 ML, and was felt, with a maximum intensity of 3 EMS, in an area within around 5 km of the epicentre. Another two occurred on 14 and 15 September, at 06:11 UTC and 03:28 UTC, with magnitudes of 1.3 ML and 1.1 ML, respectively. Neither of these were reported felt. On 22 September, at 08:32 UTC, a magnitude 3.0 ML event occurred. The BGS received some 500 reports, via online macroseismic questionnaires, of it being felt. Most reports were from towns, villages and hamlets within around 20 km of the epicentre. A maximum intensity of 4 EMS was assigned for this event. Later that day, at 12:39 UTC, a magnitude 2.1 ML event occurred and was felt, with a maximum intensity of 3 EMS, in an area within around 5 km of the epicentre.

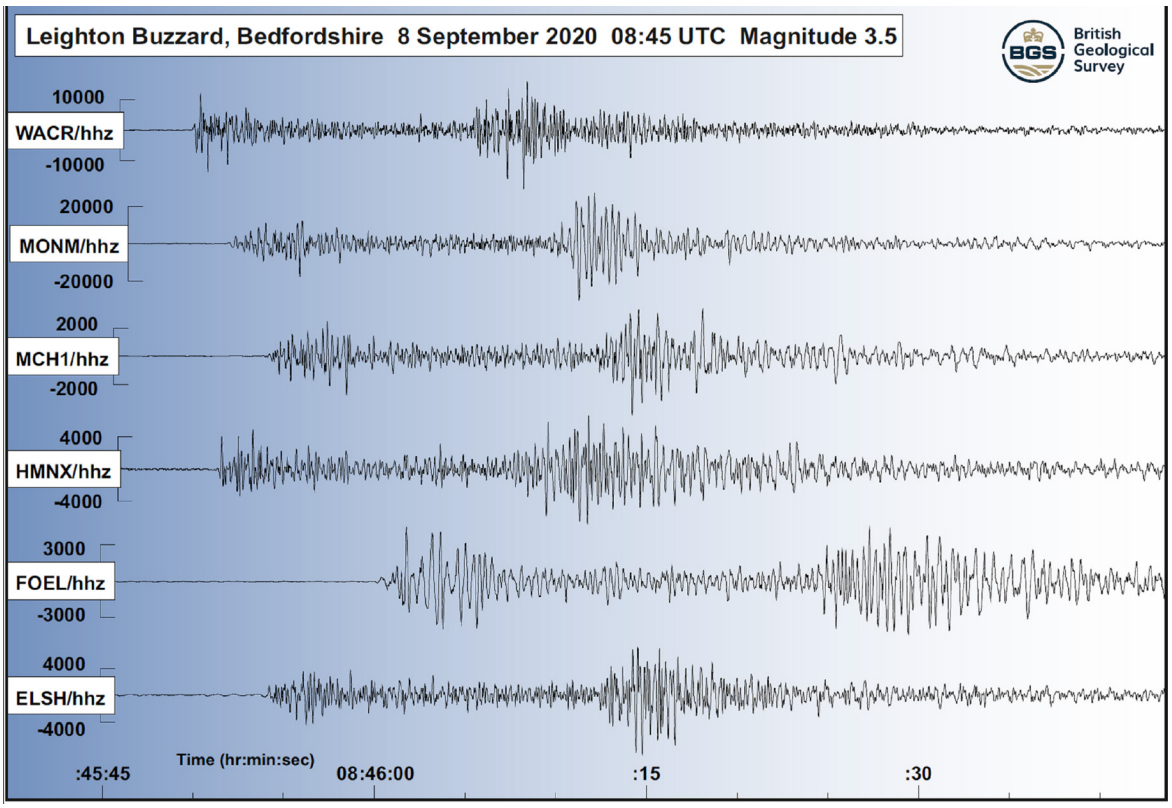

Figure 1: Seismograms of the ground displace,emt from the magnitude 3.5 ML Leighton Buzzard earthquake 2020, recorded by BGS seismograph stations.

There is relatively little significant historical seismicity in this locality. An earthquake with a magnitude of 2.0 ML was recorded near Dunstable on 15 July 2010 and one with a magnitude of 2.2 ML occurred near Brackley, 30 km west of Leighton Buzzard, on 4 April 2020. Neither of these were reported felt. The closest event, with a similar magnitude (3.4 ML), was near Oxford on 6 November 1764, and was widely felt in Oxfordshire, Wiltshire and Berkshire.

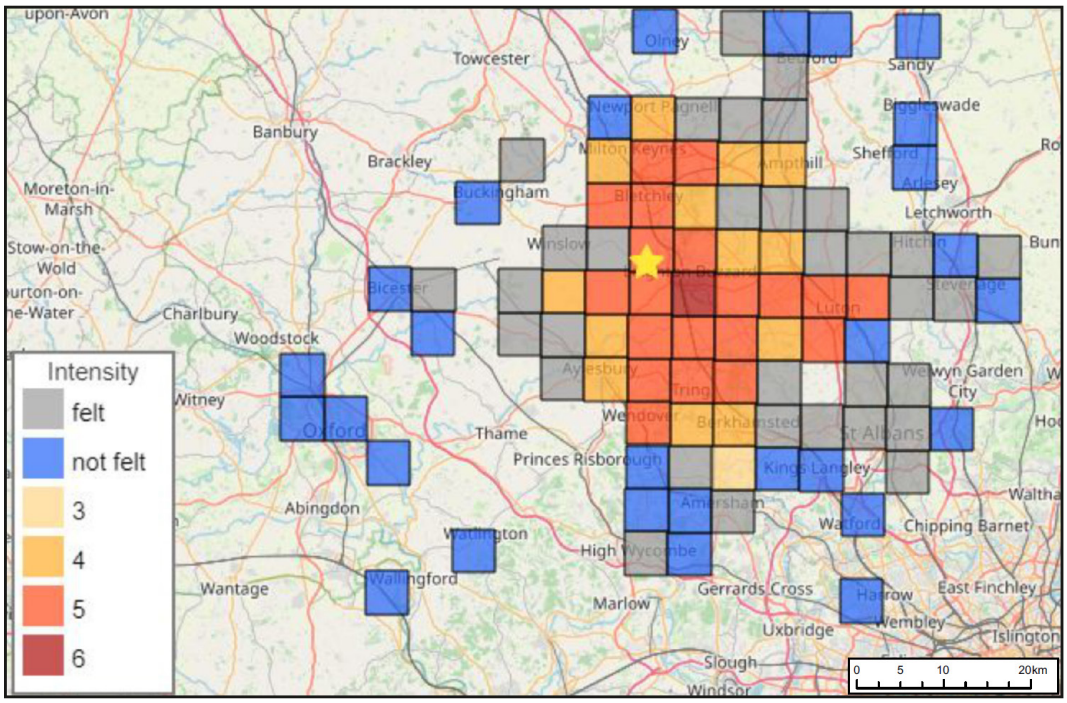

Figure 2: Macroseismic intensities (EMS) for the magnitude 3.5 ML Leighton Buzzard, Bedfordshire earthquake on 8 September 2020. The yellow star shows the epicentre. Intensities are calculated in 5 km grid squares from over 1,950 reports from people who felt the earthquake. A minimum of five observations are needed in any grid square to calculate a value of intensity, otherwise the value is calculated as 'felt' but no intensity is calculated (grey squares). Blue squares indicate that any reports from these locations suggested that the earthquake was 'not felt'.

SECED Newsletter

The SECED Newsletter is published quarterly. Previous issues of the SECED Newsletter are available online. All contributions of relevance to the members of the Society are welcome.

Manuscripts should be sent by email. Diagrams, pictures and text should be attached in separate electronic files. Hand-drawn diagrams should be scanned in high resolution so as to be suitable for digital reproduction. Photographs should likewise be submitted in high resolution. Colour images are welcome.

Articles published in the SECED Newsletter are not peer-reviewed; the views and opinions within published articles represent those of the Authors and do not necessarily reflect the official policy or position of SECED.

Please contact the Editor of the Newsletter, Damian Grant, for further details. This edition of the Newsletter was co-edited by Manuela Daví.

Notable Earthquakes
September 2019 – June 2020

Reported by British Geological Survey

Issued by: Davie Galloway, British Geological Survey, October 2020.
Non British Earthquake Data supplied by: United States Geological Survey.

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2019	01	SEP	15:54	20.36S	178.57W	591			6.6	FIJI ISLANDS REGION
2019	02	SEP	05:13	51.16N	0.24W	2	1.1			NEWDIGATE, SURREY
Felt Newdigate (2 EMS).										
2019	05	SEP	15:39	53.03N	4.11W	14	1.5			BEDDGELERT, GWYNEDD
Felt Llanberis, Groeslon and Carmel (3 EMS).										
2019	07	SEP	22:42	29.53N	104.93E	10			5.0	SICHUAN, CHINA
One person killed, 63 others injured, over 130 houses destroyed and over 5,000 others damaged in Neijiang.										
2019	11	SEP	15:12	55.73N	3.16W	7	2.0			EDDLESTON, BORDERS
Felt Lyne Station (2 EMS)										
2019	24	SEP	11:01	33.08N	73.79E	10			5.6	AZAD KASHMIR, PAKISTAN
At least 39 people killed, over 740 others injured and some 4,500 homes, 140 public buildings, four bridges and several roads destroyed or damaged in the region.										
2019	24	SEP	13:38	57.03N	1.94E	10	4.2			CENTRAL NORTH SEA
Felt on a Production/Utilities/Quarters (PUQ) platform in the Elgin/Franklin gas and oil field (3 EMS).										
2019	25	SEP	23:46	3.45S	128.37E	12			6.5	MALUKU, INDONESIA
At least 41 people killed, over 1,500 injured and around 6,300 houses, 500 public buildings and a bridge damaged on Seram Island, Maluku.										
2019	26	SEP	00:11	52.84N	2.62W	7	1.9			HODNET, SHROPSHIRE
2019	29	SEP	15:57	35.48S	73.16W	11			6.7	MAULE, CHILE
One person killed in Concepcion.										
2019	02	OCT	19:22	52.80N	0.89W	5	2.4			MELTON MOWBRAY, LEICS
Felt Melton Mowbray, Asfordby Hill, Mountsorrel, Sileby, Wymondham, Syston, Frisby on the Wreake, Queniborough, East Goscote, Somerby, Groby, Loughborough, Waltham on the Wolds and Leicester (Leicestershire), in Oakham, Cottesmere, Empingham, Langham, Egleton and Uppingham (Rutland) and in Nottingham and Stapleford (Nottinghamshire) (4 EMS).										
2019	05	OCT	10:17	52.74N	2.38W	7	1.6			NEWPORT, SHROPSHIRE
2019	05	OCT	15:35	53.18N	0.94E	5	2.0			SOUTHERN NORTH SEA
2019	12	OCT	13:33	56.09N	5.19W	7	1.6			BARNACARRY, ARGYLL/BUTE
2019	14	OCT	16:51	52.57N	2.91W	14	2.4			BISHOP'S CASTLE, SHROPSHIRE
Felt Shrewsbury, Church Stretton, Pontesbury, Westbury, Minsterley, Bayston Hill, Cross Houses, Ford, Bicton Heath, Annscroft, Condover, Much Wenlock, Cardington, All Stretton, Bridgnorth, Lydbury, Craven Arms, Dorrington, The Bog, Longden, Hanwood and Wem (Shropshire) in Ellerdine (Telford & Wrekin) and in Knighton and Church Stoke (Powys) (3 EMS).										

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2019	16	OCT	11:37	6.72N	125.01E	16			6.4	MINDANAO, PHILIPPINES
Seven people killed, over 200 others injured and around 3,200 buildings and seven bridges damaged in the epicentral area										
2019	29	OCT	01:04	6.76N	125.01E	15			6.6	MINDANAO, PHILIPPINES
At least 23 people killed, over 560 others injured and around 40,000 buildings and 30 roads and bridges damaged in the epicentral area. Several landslides and liquefaction also occurred in the region										
2019	31	OCT	01:11	6.91N	125.18E	10			6.5	MINDANAO, PHILIPPINES
Casualties and damage are included with the event above (29 October at 01:04 UTC).										
2019	04	NOV	22:43	18.58S	175.27W	10			6.6	TONGA ISLANDS REGION
2019	07	NOV	22:47	37.80N	47.58E	20			5.9	NORTHWEST IRAN
At least six people killed, over 580 others injured and some 400 houses either destroyed or heavily damaged in East Azerbaijan Province.										
2019	08	NOV	10:44	21.95S	179.51W	577			6.5	FIJI ISLANDS REGION
2019	08	NOV	16:12	53.75N	1.85W	5	2.3			HALIFAX, WEST YORKSHIRE
Felt Mixenden (2 EMS).										
2019	13	NOV	17:40	56.66N	5.18W	7	1.9			BALLACHUISH, HIGHLAND
Felt Ballachulish, North Ballachulish, Fasnacloich, Kinlochleven, Glencoe, Duror, Lettermore and Fort William (3 EMS).										
2019	13	NOV	17:47	56.67N	5.16W	7	1.7			BALLACHUISH, HIGHLAND
Felt Ballachulish, North Ballachulish, Fasnacloich, Kinlochleven, Glencoe, Duror, Lettermore and Fort William (3 EMS).										
2019	14	NOV	16:17	1.62N	126.42E	33			7.1	MOLUCCA SEA
Three people injured and 36 buildings damaged on Pulau Mayu. A tsunami was observed with the following wave heights: 10 cm at Bitung, 9 cm at Jailolo and 6 cm at Ternate.										
2019	17	NOV	22:31	56.41N	5.69W	3	2.1			MULL, ARGYLL & BUTE
Felt Croggan, Gruline, Tobermory, Aros, Pennyghael, Craigure and Garmony (on the Isle of Mull), in Clachan and Achnacroish (on the Isle of Lismore) and in Seil and Clachan-Seil (on the Isle of Seil) (3 EMS).										
2019	26	NOV	02:54	41.51N	19.53W	22			6.4	ALBANIA
At least 51 people killed, over 2,000 others injured and around 2,360 buildings either destroyed or badly damaged. The majority of the casualties and damage occurred in the counties of Durres and Tirana.										
2019	05	DEC	22:49	51.12N	2.98W	4	3.2			BRIDGWATER, SOMESET
Felt Somerset, North Somerset, Bath and NE Somerset, City of Bristol, South Gloucestershire, Dorset, Devon and South Wales. (5 EMS).										
2019	08	DEC	22:59	52.97N	4.23E	3	2.9			SOUTHERN NORTH SEA
This is a known induced event, as confirmed by KNMI Data Centre (Netherlands) and ROB (Belgium).										
2019	15	DEC	06:11	6.70N	125.17E	18			6.8	MINDANAO, PHILIPPINES
At least 13 people killed, 210 others injured and over 45,000 houses, 750 public buildings and several roads and bridges damaged in southern Mindanao.										
2019	15	DEC	21:19	53.64N	4.93W	7	2.1			IRISH SEA
2019	15	DEC	21:19	53.64N	4.93W	7	2.1			IRISH SEA
2019	18	DEC	03:52	53.94N	1.77W	14	1.7			ILKLEY, WEST YORKSHIRE

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2019	28	DEC	10:39	57.09N	5.73W	7	2.0			KNOYDART, HIGHLAND
2020	01	JAN	17:28	51.60N	3.52W	5	1.5			OGMORE VALE, BRIDGEND
2020	03	JAN	03:09	49.91N	4.39W	8	1.8			ENGLISH CHANNEL
2020	05	JAN	16:57	51.60N	3.51W	5	1.5			OGMORE VALE, BRIDGEND
2020	06	JAN	02:35	51.60N	3.52W	4	1.8			OGMORE VALE, BRIDGEND
2020	07	JAN	08:24	17.87N	66.83W	9			6.4	PUERTO RICO
One person killed, eight others injured in Ponce. Widespread damage and landslides blocked roads in SW Puerto Rico and power and water outages occurred throughout the island. Damage estimated at $US 3.1 billion.										
2020	07	JAN	10:36	57.14N	5.48W	6	2.3			ARNISDALE, HIGHLAND
Felt Arnisdale (2 EMS).										
2020	15	JAN	20:27	54.35N	0.57W	24	1.9			FLYINGDALES, N. YORKSHIRE
2020	23	JAN	05:57	54.59N	1.31W	4	3.1			STOCKTON, COUNTY DURHAM
Felt Stockton-on-Tees, Billingham, Norton, Middlesbrough, Wolviston, Thornaby, Hartlepool and surrounding towns, villages and hamlets (5 EMS).										
2020	24	JAN	17:55	38.43N	39.06E	10			6.7	ELAZIG, TURKEY
At least 41 people killed, over 1,600 others injured and over 1,370 buildings, including many public buildings, were either destroyed or heavily damaged in the provinces of Elazig and Malatya.										
2020	28	JAN	19:10	19.42N	78.76W	14			7.7	CARIBBEAN SEA
A tsunami with a maximum wave height of 11 cm reported in George Town, Cayman Islands.										
2020	31	JAN	11:53	52.27N	0.83W	7	2.2			NORTHAMPTON, NORTHANTS
Felt Kettering (2 EMS).										
2020	01	FEB	01:19	53.31N	3.16E	10	2.7			SOUTHERN NORTH SEA
2020	01	FEB	01:20	53.31N	3.16E	10	2.9			SOUTHERN NORTH SEA
2020	03	FEB	00:36	55.80N	6.36W	7	1.7			ISLAY, ARGYLL & BUTE
Felt Islay (2 EMS).										
2020	07	FEB	15:04	53.34N	2.52E	10	2.4			SOUTHERN NORTH SEA
2020	13	FEB	08:44	56.46N	5.37W	7	1.2			CONNEL, ARGYLL & BUTE
Felt Barcaldine (2 EMS).										
2020	13	FEB	10:33	45.62N	148.96E	143			7.0	KURIL ISLANDS
2020	20	FEB	13:50	55.82N	6.35W	7	1.6			ISLAY, ARGYLL & BUTE
2020	22	FEB	18:43	55.68N	3.00E	11	4.0			CENTRAL NORTH SEA
2020	23	FEB	05:53	38.45N	44.42E	10			5.8	IRAN / TURKEY BORDER
Ten people killed, 66 others injured and over 1,000 buildings damaged in Van, Turkey and at least 75 people injured and 43 villages affected in the Qotur area, Iran.										
2020	23	FEB	16:00	38.50N	44.37E	10			6.0	IRAN / TURKEY BORDER
Nine people killed, 50 others injured and many houses damaged in Van, Turkey and over 70 people injured and many houses collapsed in Iran.										

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2020	14	MAR	04:19	52.14N	2.33W	5	1.7			MALVERN, WORCESTERSHIRE
2020	15	MAR	05:11	60.24N	1.95E	10	2.0			NORTHERN NORTH SEA
2020	16	MAR	22:01	56.75N	5.87W	7	1.5			KENTRA, HIGHLAND
Felt Kentra, Acharacle, Glenborrodale, Resipole, Mingarry, Gobsheallach, Kilchoan and Salen (3 EMS).										
2020	22	MAR	05:24	45.91N	15.97E	10			5.3	CROATIA
One person killed, 26 others injured, several buildings collapsed and considerable damage to other buildings and homes in the Zagreb district.										
2020	24	MAR	17:19	51.98N	2.89W	16	2.3			PONTRILAS, HEREFORDSHIRE
2020	25	MAR	02:49	48.96N	157.70E	57			7.5	KURIL ISLANDS
2020	27	MAR	03:25	53.35N	4.00E	10	2.8			SOUTHERN NORTH SEA
2020	31	MAR	23:52	44.47N	115.12W	12			6.5	IDAHO, USA
2020	04	APR	15:28	52.01N	1.13W	4	2.2			BRACKLEY, NORTHANTS
2020	06	APR	21:27	56.29N	6.26W	8	1.4			MULL, ARGYLL & BUTE
Felt Mull (2 EMS).										
2020	16	APR	12:07	57.65N	5.64W	2	1.6			SHIELDAIG, HIGHLAND
2020	17	APR	13:01	53.05N	2.14W	2	1.7			BAGNALL, STAFFORDSHIRE
2020	18	APR	08:25	27.13N	140.14E	453			6.6	BONIN ISLANDS, JAPAN
2020	23	APR	05:30	53.03N	2.16E	10	3.3			SOUTHERN NORTH SEA
2020	01	MAY	03:52	56.41N	5.76W	2	1.4			MULL, ARGYLL & BUTE
Felt Mull (3 EMS).										
2020	02	MAY	12:51	34.18N	25.71E	10			6.5	OFFSHORE CRETE, GREECE
A tsunami with a maximum wave height of 20 cm reported in Ierapetra.										
2020	06	MAY	05:12	52.36N	3.14W	8	1.5			KNIGHTON, POWYS
2020	06	MAY	13:53	6.78S	129.79E	96			6.8	BANDA SEA
2020	12	MAY	22:41	12.07S	166.65E	107			6.6	SOLOMON ISLANDS
2020	12	MAY	22:41	12.07S	166.65E	107			6.6	SOLOMON ISLANDS
Felt Croggan, Gruline, Aros, Knock and Craignure (Isle of Mull), in Clachan and Achnacroish (Isle of Lismore), on the Isle of Seil, on the Isle of Kerrera, on Easdale Island and in Kilmelford, Kilmore and Oban (3 EMS).										
2020	15	MAY	01:32	55.09N	0.51W	9	1.6			CENTRAL NORTH SEA
2020	15	MAY	11:03	38.17N	117.85W	3			6.5	NEVADA, USA
2020	18	MAY	13:48	27.27N	103.29E	10			5.1	YUNNAN, CHINA
Four people killed, 28 others injured and several homes destroyed or damaged in Qiaojia County.										
2020	24	MAY	17:36	51.90N	0.94W	8	1.6			QUAINTON, BUCKINGHAMSHIRE
2020	03	JUN	07:35	23.27S	68.47W	112			6.8	ANTOFAGASTA, CHILE
2020	04	JUN	12:48	52.56N	1.90W	8	2.1			WALSALL, WEST MIDLANDS
Felt Walsall and Great Wyrley, Staffordshire (3 EMS).										

Year	Day	Mon	Time UTC	Lat	Lon	Dep km	Magnitude ML	Mb	Mw	Location
2020	06	JUN	14:22	56.39N	4.01W	3	2.2			COMRIE, PERTH & KINROSS
Felt Comrie, Crieff, St Fillans and surrounding villages in the PH6 and PH7 postcode areas (4 EMS).										
2020	13	JUN	15:51	28.86N	128.27E	165			6.6	RYUKYU ISLANDS, JAPAN
2020	18	JUN	12:49	33.29S	177.86W	10			7.4	KERMADEC ISLANDS
2020	23	JUN	15:29	15.89N	96.01W	20			7.4	OAXACA, MEXICO

Forthcoming Events

Evening Lectures

Don't look up, look down! Kathmandu, UNESCO, Archaeology and learning from the 2015 Gorkha Earthquake

Robin Coningham

25 November 2020 (6:00 pm) , online event

Synopsis

The earthquake which struck Nepal in 2015 (the Gorkha Earthquake) was a humanitarian disaster. Not only did it inflict tragic loss of life and livelihoods, it also destroyed parts of Kathmandu's unique UNESCO World Heritage site. These monuments were not just ornate structures but living monuments playing central roles in the daily lives of thousands. Their rehabilitation was of economic importance as they represent a major source of tourist income and employment. Unfortunately, the social and political desire to rapidly reconstruct resulted in the swift removal of many traditionally constructed foundations and their replacement with modern materials without assessments of whether these contributed to the collapse of an individual monument. These actions, combined with the wholesale removal and dumping of mixed modern and historic debris, contributed to a second, equally destructive, cultural catastrophe – irreversible damage to Kathmandu's medieval archaeology.

This talk outlines the impact of the earthquake before drawing attention to the series of damaging interventions by first responders, architects and engineers – activities which cumulatively contributed to Kathmandu's second cultural catastrophe. It also describes the process by which a team mobilized by UNESCO and the Government of Nepal explored the potential of post-disaster archaeological interventions. This ranged from using geophysical survey to create risk maps of subsurface archaeological deposits for urban planners to undertaking a major post-disaster excavation in the debris of the Kasthamandap. Encountering hitherto unknown medieval construction techniques and sequences, this new knowledge has directly contributed to its reconstruction. The talk will conclude by reviewing the lessons learned from the cultural impacts of the Gorkha Earthquake and the remaining challenges facing heritage managers.

Robin Coningham

Robin Coningham is Professor of Early Medieval Archaeology at Durham and holds UNESCO's 2014 Chair in Archaeological Ethics and Practice in Cultural Heritage. He has worked across South Asia refining chronologies and investigating the region's urbanization, the genesis of Indian Ocean trade and the archaeology of Buddhism. He is committed to heritage protection and has joined over 30 UNESCO missions across the South Asian region. Since 2011, he has co-directed UNESCO's archaeological fieldwork within the Greater Lumbini Area of Nepal, including excavations at Lumbini, the birthplace of the Buddha. He was mobilized by UNESCO and the Government of Nepal in 2015 to co-direct post-earthquake archaeological interventions, which were followed by AHRC-GCRF and British Academy-GCRF Cities and Infrastructure Programme sponsored research and dissemination involving archaeologists, architects and engineers. He has published over 100 academic papers and chapters, as well as 10 books, including Archaeology, Heritage Protection and Community Engagement in South Asia in 2019. Robin is a member of UK's National Academies Resilient Futures Steering Group and was a member of AHRC's GCRF Strategic Advisory Group.

Further information

This evening meeting will be chaired by Sean Wilkinson (Newcastle University). Non-members of the society are welcome to attend. Attendance at the meeting is free. The meeting will take place online via Microsoft Teams.

For up-to-date details and further information on events organised by SECED, visit the SECED website or contact Shelly-Ann Russell (020 7665 2147, societyevents@ice.org.uk)