The sea level record of Guantanamo Bay, Cuba, sheds light on rates of Late Quaternary uplift along the North America-Caribbean plate boundary

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The tectonic setting of the North America-Caribbean plate boundary has been studied intensively, but the complex boundary west of Haiti is not well understood. There, movement is accommodated primarily by the Oriente fault zone, a zone of distributed faulting paralleling Cuba's southern coast (Fig. 1). The fault zone is considered to be in transpression. If so, there should be a measurable component of vertical movement. Guantanamo Bay, southern Cuba, is north of this transpressive fault zone and would be expected to display evidence of this uplift. We tested this by studying emergent reef terrace deposits around the bay.

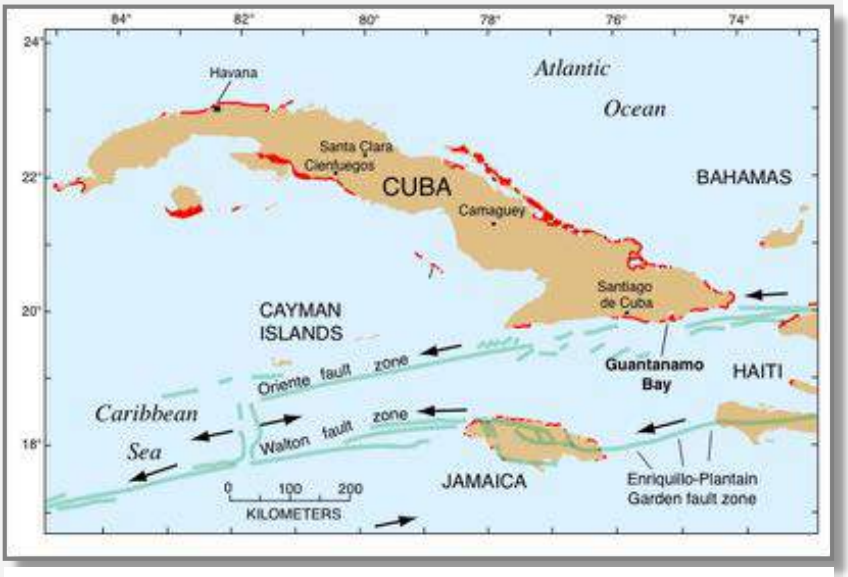

Figure 1. *Map of Cuba, adjacent islands, and active faults near the southeastern part of the island. Red areas in Cuba show extent of the Jaimanitas Formation; red areas shown on other islands are emergent coral reef terraces dating to, or thought to date to, the last interglacial period.*

The lowest-elevation marine terrace of Cuba (Fig. 2) is considered to be broadly of the same age along its length and is a constructional coral reef terrace, not an erosional landform. The reef of which this terrace is composed is referred to as the Jaimanitas Formation. U-series dating of corals in the Jaimanitas formation near Havana indicates that this fossil reef could date to the last interglacial period, ~120 ka.

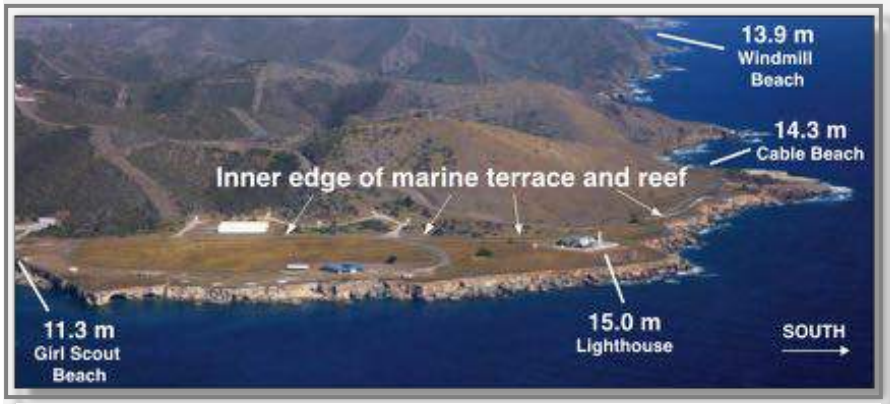

Figure 2. *Oblique aerial photograph of the eastern, windward part of Guantanamo Bay, showing the reef terrace geomorphology .*

In the Guantanamo Bay area, Oscar E. Meinzer did a remarkable job of mapping what is now recognized as the Jaimanitas Formation in 1915, on horseback and without the aid of aerial photographs. We field checked all units mapped as fossil coral reef deposits by Meinzer and, with few exceptions, we found his mapping to be accurate.

We described and measured sections exposing the Jaimanitas Formation at several localities around Guantanamo Bay; well-preserved corals were sampled for U-series dating. We took elevations of all localities studied using direct measurement by tape and hand level and/or by differential GPS measurements (Fig. 3).

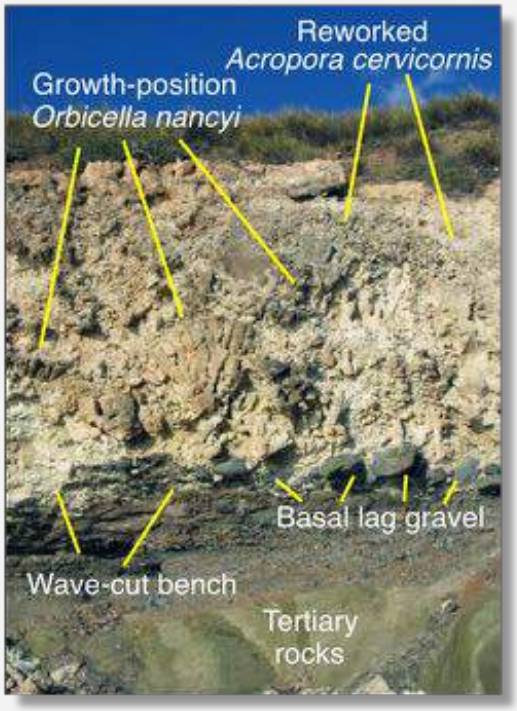

Figure 3. *Cliff exposure at Girl Scout Beach, showing, from bottom to top, Tertiary sedimentary rocks, wave-cut bench, basal marine lag gravels, growth-position corals, and reworked corals.*

Meinzer reported two coral reef terraces in the Guantanamo Bay area. The older terrace occurs about 40 m above sea level north of the modern runway on the leeward (western) side of the bay. All corals we examined from this fossil reef were recrystallized and thus not collected for any analytical work.

Much of the U.S. Naval base is built directly on the younger terrace and associated emergent fossil reef of the Jaimanitas Formation. Within the Jaimanitas Formation we recognize both an exposed, outer-coast facies and a protected, inner-bay facies. Reef elevations in the protected, inner part of the bay are ~11-12 m and outer-coast, wave-cut benches are as high as ~14 m. Uranium-series analyses of corals yield ages ranging from ~133 ka to ~119 ka, correlating this reef to the peak of the last interglacial period, marine isotope stage (MIS) 5.5.

Knowing the age and elevation of the lowest terrace, we need to know paleo-sea level at the time of terrace formation in order to estimate the rate of uplift. Paleo-sea level can be obtained from studies of emergent terraces in tectonically stable areas. Commonly, paleo-sea level at the peak of the last interglacial period is thought to have been 2-10 m higher than at present, but do not include corrections for glacial isostatic adjustment (GIA), which generate variations on this average eustatic value from coast to coast. We considered a range of eustatic sea level estimates and GIA corrections, and calculated uplift rates using paleo-sea levels of +4.2 m to 11 m (relative to present) and last-interglacial end times of ~120 ka to 115 ka. Our results indicate that under virtually any scenario, uplift rates in the Guantanamo Bay area are fairly low, with late Quaternary uplift rates of 0.20 to 0.11 m/ka. It is clear from the results that some measureable amount of uplift has occurred here since the last interglacial period. However, on the eastern and southern coasts of Cuba (east and west of Guantanamo Bay), there are flights of multiple marine terraces at higher elevations that could record a higher rate of uplift, implying that Guantanamo Bay may be regionally anomalous.

In an effort to foster interaction on this topic between Cuban and American geologists, USGS geologists will host visiting Cuban geologists to examine last interglacial reefs and other deposits in the Florida Keys and Miami area this coming May, 2018.

For references and the full report on this study, see:

Muhs, D.R., Schweig, E.S., Simmons, K.R., Halley, R.B. (2017) Late Quaternary uplift along the North America-Caribbean plate boundary: Evidence from the sea level record of Guantanamo Bay. *Quaternary Science Reviews* 178, 54-76. https://doi.org/10.1016/j.quascirev.2017.10.024

Student Research Projects

Micromorphology and biomarker analysis from deglacial loess-paleosol sequences of central Alaska: A paleoenvironmental framework for human occupation of eastern Beringia

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For several decades, archaeologists, geologists, and ecologists, among others, have worked to provide paleoenvironmental context for human colonization of subarctic lowlands in eastern Beringia (modern Alaska and the Yukon) during the Late Glacial period (~15–10k cal. B.P.). Eastern Beringia contains some of the earliest archaeological sites in North America and has long been considered key to understanding the initial entry of humans into the Americas. This high-latitude region also experienced sweeping climatic and environmental change during the Late Glacial. Such climatic variability likely had great impact on the timing, routes, and mechanisms of human settlement of the far north, yet there is limited terrestrial data to test this idea (Dilley, 1998; Reuther, 2013; Reuther et al., 2016).

Loess-paleosol sequences in Shaw Creek Flats (SCF) of central Alaska contain well-preserved soils and organic compounds (e.g., plant leaf waxes, bacterially-derived compounds) that can be used as terrestrial proxies for Late Glacial landscape and climatic change. These same deposits also contain well-stratified, multi-component records of archaeological occupation from the deglacial period (~15–10k cal. B.P.) to the Holocene. These sequences are therefore ideal archives for testing the hypothesis that climatic variability had an impact on human paleoecology. Micromorphology blocks and bulk soil and sediment samples were collected from five of the earliest archaeological localities in SCF: Swan Point (Fig. 1), Mead, Camp section (proxy for Broken Mammoth), Rosa-Keystone Dune, and the Cook site, many of which contain occupations dated to ~14.5–13k cal. B.P. For regional comparison, samples were also collected from Hurricane Bluff, a Holocene archaeological site from the neighboring Delta River Valley.

Although these sites share broad stratigraphic characteristics, they also exhibit significant variability in pedogenesis and site formation processes. For example, deglacial soils at the Mead site contain abundant calcite and iron oxide hypocoatings, often localized around root pores, while the Camp and Cook sites show fewer signs of pedogenesis.

Figure 1. *Stratigraphic section at Swan Point archaeological site, showing transition from deglacial sands and silts (gray sediments) to Holocene soils (reddish horizon). Bulk samples were collected from this sequence for micromorphology and biomarker analysis.*

Additionally, the six sites differ in the extent of cryoturbation. Evidence of freeze-thaw is common in the Swan Point samples and present in Mead samples, while no signs of freeze/thaw are observed from the other sites. Micromorphology also demonstrates clear differences in organic matter types and degradation at the Camp and Cook sites, which could provide an explanation for differing biomarker signals seen in these sequences.

Plant leaf wax (n-alkane) hydrogen (δD) isotope values indicate variability during the Late Glacial and Early Holocene, interpreted as fluctuations in aridity and/or temperature. Overall, δD values become more positive over time, perhaps indicating a strong temperature influence on the signal. The distribution of bacterially-derived branched glycerol dialkyl glycerol tetraethers (brGDGT; Fig. 2), a proxy for mean annual air temperature (MAAT), indicates an expected trend of increasing MAAT over time and slight deglacial variability, although some sites show contrasting signals. These proxies have the potential to provide more quantitative information about moisture availability and temperature change since the Last Glacial, yet more interpretation is needed to parse out the signals.

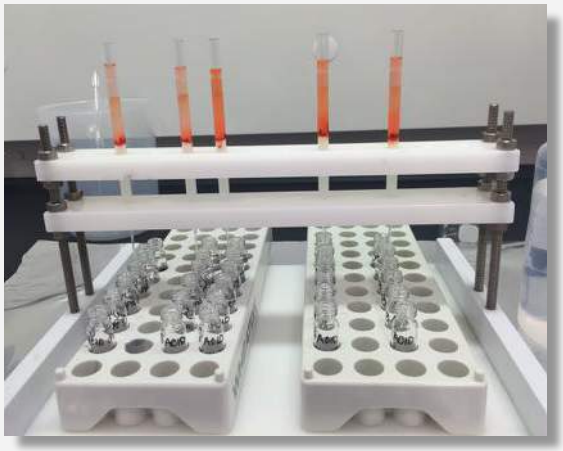

Figure 2. *Samples are processed in the University of Arizona Organic Geochemistry Laboratory to extract organic compounds of interest. Here, samples are run through silica gel hybrid columns to separate n-alkane plant leaf waxes, GDGTs, and plant fatty acids.*

Nevertheless, this work provides an initial attempt to evaluate the role that biomarker analysis can play in these high-latitude, loess-paleosol settings.

Overall, this research contributes to a larger research program focused on human ecology since the deglacial, known as the Quartz Lake/Shaw Creek Flats Multidisciplinary Project (Reuther et al., 2014). Micromorphology and biomarker proxies add new data to existing paleoenvironmental records, improving the paleoenvironmental framework for human colonization and occupation of this region. Numerous researchers cite climatic change as a major influence on human subsistence, settlement, and behavior during early colonization and occupation of SCF; this doctoral project offers new data to help test this relationship.

References

Dilley, T.E. (1998) Late Quaternary loess stratigraphy, soils, and environment of the Shaw Creek Flats Paleoindian sites, Tanana Valley, Alaska. Ph.D dissertation, Tucson, University of Arizona, 296 p.

Reuther, J.D. (2013) Late glacial and early Holocene geoarchaeology and terrestrial paleoecology in the lowlands of the Middle Tanana Valley, subarctic Alaska. Ph.D. dissertation, Tucson, Arizona, University of Arizona, 662 p.

Reuther, J.D., Holmes, C.E., Lanoë, F., Kielhofer, J., Plaskett, D. (2014) The 2014 results of the Western Shaw Creek Flats archaeology and geoarchaeology project. Museum Technical Series Report #2015-01, Fairbanks, University of Alaska Museum of the North and University of Alaska Fairbanks, 27 p.

Reuther, J.D., Potter, B.A., Holmes, C.E., Feathers, J.K., Lanoë, F., Kielhofer, J. (2016) The Rosa-Keystone Dunes Field: The geoarchaeology and paleoecology of a late Quaternary stabilized dune field in Eastern Beringia. *The Holocene* 26, 1939-1953.

How will the sediment yield of global rivers respond to climate change?

By Alexander Prescott, PhD candidate, Department of Geosciences, The University of Arizona
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The transfer of regolith from hillslopes through fluvial networks and ultimately to depositional basins reduces mountains to alluvium. This process holds important consequences for the sustainability of human agriculture, the water quality of drinking supplies, and the continued utility of engineered structures. Understanding the spatial variability in the response of sediment transport processes to future climate change is a requisite for local and national planning.

Although many models have been created to estimate the sediment load produced by a river basin, these generally use basin-averaged parameters that do not capture the wide array of intrabasin processes involved in determining the ultimate fate of sediment. My research uses a geomorphic source-to-sink numerical model to provide insight on future global changes in sediment yield by testing the following principal hypothesis: the sediment yield response of river basins will depend on the local probabilistic hydrologic response, the corresponding response of vegetation to climate change, and the initial state of vegetation throughout the basin. We expect that vegetation changes will impart the largest changes on sediment yield, particularly at latitudes associated with poleward expansion of the descending limb of Hadley Cell circulation (due to desertification) and at high-latitudes where the greatest absolute changes in climate are expected to occur.

Testing of the research hypothesis first requires improvements to the sediment flux model, initially published by my advisor (Dr. Jon D. Pelletier) in 2012. These include incorporation of probabilistic river hydrology, a new vegetation transfer function, and an improved representation of the routing network. Calibration and validation uses three independent datasets for hydrologic distribution prediction and sediment routing: long-time USGS records of daily discharge, a global database of river width and depth, and a global database of pre-industrial riverine sediment yields. Results from the most recent Coupled Model Intercomparison Project will then be used to project changes in steady-state annual sediment yield.

In addition, I have updated the sediment flux model with a higher global spatial resolution (30 arc-seconds) and with techniques to optimize runtime. Calibration tests run on the University of Arizona high performance computing clusters, while internal model code implements simple parallel processing.

Honduras on a volunteer trip with Global Water Brigades, helping install clean water infrastructure in a small mountain community.

Also pictured: fellow volunteer Emily Adams.

Attending computing workshops at the University of Arizona and the University of Wisconsin-Madison (through the Open Science Grid) have vastly improved my skills in this area, and I have made it a habit to promote these opportunities to my fellow graduate students. The methods amplify our research abilities!

Initial analysis suggests that modeled riverine sediment fluxes are most sensitive to perturbations in vegetative cover due to: i) the assumed exponential inverse relation between vegetation and rate of denudation; and ii) the large uncertainties that exist in future projections of vegetation cover. This model can also hindcast sediment fluxes to help shed light on geologically recent sedimentation events, e.g., the proposed link between glacial-interglacial cycling and increased erosion rates. Next year, I will work with Dr. Andy Cohen and the Hominin Site and Paleolakes Drilling Project research team to develop a landscape evolution model of East African rift valley springs. These may have served an important role in human development as a consistent source of water over periodic wet/dry climate cycles.

An *example output of the sediment flux model, showing the Chao Phraya River in Thailand. This is an example of one of the best model predictions relative to observed data. The model predicts the annual sediment yield for every 30 arc-second grid cell across the globe.*

New Publications

Williams, J.W., Grimm, E.C., Blois, J.L., Charles, D.F., Davis, E.B., Goring, S.J., Graham, R.W., Smith, A.J., Anderson, M., Arroyo-Cabrales, J., Ashworth, A.C., Betancourt, J.L., Bills, B.W., Booth, R.K., Buckland, P.I., Curry, B.B., Giesecke, T., Jackson, S.T., Latorre, C., Nichols, J., Purdum, T., Roth, R.E., Stryker, M., Takahara, H. (2018) The Neotoma Paleoecology Database, a multiproxy, international, community-curated data resource. *Quaternary Research* 89, 156-177.

Wolbach, W.S., Ballard, J.P., Mayewski, P.A., Adedeji, V., Bunch, T.E., Firestone, R.B., French, T.A., Howard, G.A., Israde-Alcántara, I., Johnson, J.R., Kimbel, D., Kinzie, C.R., Kurbatov, A., Kletetschka, G., LeCompte, M.A., Mahaney, W.C., Melott, A.L., Maiorana-Boutilier, A., Mitra, S., Moore, C.R., Napier, W.M., Parlier, J., Tankersley, K.B., Thomas, B.C., Wittke, J.H., West, A., Kennett, J.P. (2018a) Extraordinary biomass-burning episode and impact winter triggered by the Younger Dryas cosmic impact ~12,800 years ago. 1. Ice cores and glaciers. *The Journal of Geology* 126, 165-184.

Wolbach, W.S., Ballard, J.P., Mayewski, P.A., Parnell, A.C., Cahill, N., Adedeji, V., Bunch, T.E., Domínguez-Vázquez, G., Erlandson, J.M., Firestone, R.B., French, T.A., Howard, G., Israde-Alcántara, I., Johnson, J.R., Kimbel, D., Kinzie, C.R., Kurbatov, A., Kletetschka, G., LeCompte, M.A., Mahaney, W.C., Melott, A.L., Mitra, S., Maiorana-Boutilier, A., Moore, C.R., Napier, W.M., Parlier, J., Tankersley, K.B., Thomas, B.C., Wittke, J.H., West, A., Kennett, J.P. (2018b) Extraordinary biomass-burning episode and impact winter triggered by the Younger Dryas cosmic impact ~12,800 years ago. 2. Lake, marine, and terrestrial Sediments. *The Journal of Geology* 126, 185-205.

Fellowships

CLARE HALL CAMBRIDGE

Sir Nick Shackleton Visiting Fellowship

Nick Shackleton wanted to ensure that research into palaeoclimatology should be continued both at Clare Hall and in the Cambridge Quaternary community, which is why a Fund was established to enable a Visiting Fellow at Clare Hall to research palaeoclimatology for a period of up to one year.

Applicants for this fellowship should apply via the Visiting Fellows page of our website (link below), where you will find information about Visiting Fellowships at Clare Hall and a link to the online application system. When completing an application the applicants should make clear that they are interested specifically in the Shackleton Fellowship.

https://www.clarehall.cam.ac.uk/visiting-and-research-fellows

The Visiting Fellowship competition is a rolling program. The **deadline** by which completed applications must be received to be considered at the next meeting of the Governing Body is **3 April for 18 April 2018** and **15 May for 30 May 2018**.

Workshops

III **International Field Workshop**

Mesozoic and Cenozoic paleobiogeocenoses of the Northern hemisphere

Date: July 8 - 31 (Module 1), August 5 - 29 (Module 2)

Location: Tomsk State University, Russia

Target Group: international students, researchers and professors

Application Deadline: June 1, 2018 (Module 1); July 1, 2018 (Module 2)

Topic: paleontological, stratigraphic, and paleogeographic methods of field research

Module 1. The undrained lake basin of the Baraba lowland (Novosibirsk province). The territory of research includes Volchia Griva, one of the largest mammoth fauna site comprising Paleolithic artifacts, and Pleistocene geological sections of the Om' River and Lake Chany.

Module 2. The Chulym River basin (Krasnoyarsk territory). The territory of research includes dinosaur and mammoth fauna sites, important Mesozoic and Pleistocene geological sections of the Chulym River and its tributaries.

For more information please contact:
Prof., Dr. of Sci. Sergey V. Leshchinskiy sl@ggf.tsu.ru

Conference Announcements

CANQUA/AMQUA 2018

Joint meeting of the Canadian and American Quaternary Associations

Crossing borders in the Quaternary

Carleton University, 7-11 August 2018

Sessions

S1. The Quaternary record of aeolian systems in mid- to high-latitudes

S2. Island biogeography in a changing world: an interdisciplinary roadmap from the Quaternary

S3. Empirically testing paleoglaciological hypotheses and models

S4. Syntheses of human-environment Interactions during the Holocene

S5. Mapping the Quaternary – Advances and applications of surficial geology map ping

S6. Reducing the "Time to Science": data management in the Quaternary sciences (lightning session 5 min talks)

S7. Improving understanding of Quaternary Environments through multi-proxy, net work, or statistical advances

S8. The relict permafrost environment

S9. Changes in the wildfire regime and impact on ecosystem structure and function

S10. High-resolution records of the Common Era

S11. New perspectives on the use of karst basins for paleoenvironmental research: implications for paleoclimatology, paleontology, and archaeology

S12. Geohazard processes and impacts: landslides, floods, earthquakes, permafrost and others

S13. The application of Quaternary science to societal issues in the 21st century

S14. General contributions

Registration and abstract submission will close 7 May 2018
https://www.quaternary2018.com/

INQUA 2019
DUBLIN
IRELAND

XX INQUA
Congress 2019
25th – 31st July 2019
Dublin, Ireland

www.inqua2019.org

Quaternary Research in Ireland and the Irish Quaternary Association (IQUA)

Ireland's famously beautiful landscape contains a wealth of evidence for a dynamic Quaternary history. Widespread glacial landforms, varied coastlines, extensive peatlands, innumerable lakes, and a rich archaeological heritage, the island has long fascinated Quaternary scientists. Indeed, Ireland has a history of Quaternary research dating back to the nineteenth century, including famous visits by Agassiz in 1840 and Carl H. Lewis in 1846, and its diverse Quaternary archives continue to provide fruitful avenues for research.

The Royal Irish Academy (RIA) Committee for Quaternary Research in Ireland was established in 1954, providing a key stimulus for the study of Ireland's Quaternary history. In the 1970s, the Irish Quaternary Association (IQUA) was founded with a view to co-ordinating and energising all aspects of Quaternary research in Ireland and passing on established expertise through conferences and especially field excursions. Notable contributors over the lifetime of the Association include Frank Mitchell, Francis Synge, Alan Smith, Bill Watts, Marshall McCabe and Willie Warren. The INQUA Congress held in Birmingham in 1977, which included excursions to Ireland led by Watts and Synge, gave a further impetus to Quaternary studies in Ireland. Frank Mitchell, as President of INQUA for the intervening period 1969–1973, and later through his classic book 'Reading the Irish Landscape', also greatly helped in highlighting the multi-dimensional character of the Quaternary record in Ireland.

Currently, IQUA is a thriving organisation with well over 100 members, and disseminates information about its activities through its webpage (www.iqua.ie) and email list. The link between the RIA and IQUA continues to be positively fostered by active Quaternary scientists representing the RIA Committee (formerly the National Committee for Geology) and by leading IQUA's national delegates to attend INQUA congresses. Furthermore, the recipient of IQUA's inaugural Frank Mitchell Award for Distinguished Service to Quaternary Research and Teaching, Pete Coxon, has served as both IQUA President (2009–2012) and as Secretary-General of INQUA (2003–2011), thus strengthening the link between IQUA and INQUA.

The following links will give you a sample of the Congress facilities and Ireland's Quaternary science community and landscape:

The Irish Quaternary Association (IQUA): http://www.iqua.ie

IQUA Field Excursions: http://www.iqua.ie/publications.html

The Convention Centre Dublin (the Congress Venue): http://www.theccd.ie

Wild Atlantic Way (Ireland's scenery): http://www.wildatlanticway.com/home/

Sign up for Congress Newsletters: www.inqua2019.org

Details of pre-, mid- and post-congress field trips are now available on the web: http://www.inqua2019.org/field-trips/.

A list of proposed sessions can be found at http://www.inqua2019.org/programme/proposed-sessions/.