ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

MONTAG, 19. NOVEMBER 2018
BEGINN: 13.30 UHR
ÖAW, THEATERSAAL
HERBERT HUNGER-HAUS
SONNENFELSGASSE 19, 1010 WIEN

SYMPOSIUM
50YEARS OF OCEAN DRILLING – A SUCESS STORY

KOMMISSION FÜR GEOWISSENSCHAFTEN DER ÖAW

PROGRAMM und ABSTRACTS

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SYMPOSIUM

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ECORD: A Key for the Future of Scientific Ocean Drilling?

Dr. Gilbert Camoin

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ECORD is a unique European distributed research infrastructure that connects research facilities at multiple sites across Europe. These facilities are engaged in the multidisciplinary aspects of the subsurface scientific research and have a longstanding culture of cooperation in science, technology and education.

ECORD combines research, education and innovation and offers a unique portfolio of science and educational activities, world-class capabilities, state-of-the-art technology and remarkable knowledge-based resources.

Since 2013, the new framework and funding scheme of the International Ocean Discovery Program (IODP) has offered new challenges and opportunities to ECORD, as an independent platform provider in charge of the funding and the implementation of mission-specific platform (MSP) operations that are an ECORD's landmark since 2004. The mutations regarding the ECORD governance, business plan, programmatic innovations and funding scheme have been designed to maximise its efficiency in delivering information and services to the ECORD science community. These changes have also allowed ECORD to simultaneously exercise its functions with greater versatility and to create or improve its partnership opportunities with other science programmes and initiatives.

The ECORD member countries are in strong position to lead the international scientific exploration of the subseafloor through its invaluable scientific contribution to the international ocean drilling programmes since five decades, including 15 years as an independent entity, and its more recent roles in the development of many innovative endeavours and cutting-edge technologies for subsurface investigations.

> ***Gilbert Camoin*** *is Senior Research Scientist at the CNRS-CEREGE, Aix-en-Provence, France. His major scientific interests concern the records of sea level and environmental/climatic changes by reefs and carbonate platforms and the impact of such changes on carbonate systems.*
>
> *He has been and is still deeply involved in ocean drilling programmes as scientist, co-Chief scientist and as member and/or Chair of various committees (SSEP, SPC, ESSAC, IWG+, SPWC, IODP Facility Boards...). Since 2012, he is managing ECORD (European Consortium for Ocean Research Drilling), the European and Canadian participations to the International Ocean Discovery Program.*

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The Odyssey of Ocean Research Drilling: Past and Future Directions

Prof. Dr. Judith A. McKenzie

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In his article titled "*The Past and Future of Ocean Drilling*", which was published as an introduction to a special volume celebrating the tenth anniversary of scientific ocean drilling, Roger Revelle (1981) summarized the principal results achieved by the Deep Sea Drilling Project (DSDP) from 1968 – 1978. Specifically, the original goal of the DSDP was to test the newly evolving plate tectonic/seafloor spreading hypothesis. Through ocean drilling campaigns using the facilities of the *Glomar Challenger*, sediment and rock samples were recovered from beneath the seafloor to provide the direct proof of the hypothesis, and, in fact, the primary goal was amazingly achieved within the first 10 years of ocean drilling. During the same 10-year period, this major accomplishment was enhanced by additional discoveries, many of which have continued to impact Earth science research during the following 40 years with scientific ocean drilling programs (DSDP, ODP and both IODP's).

Revelle (1981) listed 10 principal results stemming from the first 10 years of ocean drilling. The importance of these initial findings illustrates how scientific drilling of the deep sub-seafloor has evolved and continues to impact our knowledge of the Earth System. For example, the early recognition of past climatic and ecological changes in the ocean has since evolved into the major overlapping research fields of paleoceanography and paleoclimatology. Additionally, the discovery of the presence, via methane sampling in 1971, and ultimately the recovery of intact gas hydrates from deep-sea sediments have led to systematic probing of the nature and extent of the "deep biosphere" and associated *in situ* diagenesis, such as the precipitation of the enigmatic carbonate mineral dolomite. The mapping and evaluation of the extent of the environmental hazard versus exploitation potential of the methane locked up in gas hydrates, an energy resource frozen solidly into deep-sea sediments, continues to drive scientific research in new directions.

Undoubtedly one of the more extraordinary surprises of early DSDP drilling was the discovery, during DSDP Leg 13 in 1970 and the follow-up cruise DSDP Leg 42A in 1975, of the most recent and largely undeformed salt giant deposited in the deep Mediterranean basins between 5.96 to 5.33 Ma. This astounding revelation of deep desiccated basins, resulting from the apparent drying up and later refilling of the Mediterranean Sea during a geologically very short period, remains a controversial topic until today calling for further fundamental exploration of the Mediterranean massive salt deposits. Recently, a European-driven network has been inspired to submit a new IODP proposal to drill and fundamentally explore these Mediterranean massive salt deposits based on extensive seismic surveys and using the more advanced drilling technology that was not available during the first 10 years of ocean drilling.

Although major advances in our knowledge of what lies deeply buried below the seafloor have been made during the first 50 years of ocean research drilling, many of the already recognized phenomena need to be explored further and studied in greater detail. Indeed, it is even highly likely that there are more phenomena just waiting to be discovered with future international ocean drilling campaigns.

Revelle, R., 1981, *The Past and Future of Ocean Drilling*, SEPM Spec. Publ. No. 32, p. 1-4.

Judith A. McKenzie *is Professor emeritus in the Geological Institute, Department of Earth Sciences at the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland. Her current research interests include the following topics:*
1) geomicrobiology with emphasis on microbial dolomite precipitation,
2) modern and ancient carbonate/evaporite sedimentation in hypersaline environments and
3) microbial diagenesis associated with deep subsurface biosphere.
She has been active in the international ocean research drilling program during many years, sailing as a shipboard scientist on 5 drilling campaigns, once as Co-Chief Scientist. She is currently involved in drilling-proposal development for the Mediterranean Sea, as a member of the MEDSALT COST Action CA15103 network: "Uncovering the Mediterranean Salt Giant".

Windows of Climate and Carbon Cycle Variability on Orbital Time Scales from the Late Cretaceous to Quaternary

Prof. Dr. Dick Kroon

Leg 208 Scientific party and many others | Regius Professor of Geology
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One of the grand challenges of Paleoceanography is the development of an orbital-scale, astronomically-tuned deep-sea benthic C and O isotope stack spanning the length of the Cenozoic (i.e., last 66 myr) and into the Late Cretaceous. As a major step toward this goal, Leg 208 drilled several boreholes along a depth transect to recover complete sequences covering this time interval. I will present an overview of key segments of the geological record informing our understanding of past oceans and climate. These segments, generated with samples (~ 3ky) from pelagic cores recovered during ODP Leg 208 from sites on Walvis Ridge, is the result of more than a decade long coordinated effort of several groups. In addition to over thousands of stable isotope analyses of benthic foraminifera, a parallel effort was undertaken to resolve (by core log and XRF) and tune bedding cycles to orbital curves, an iterative process involving correlation and calibrations to sections with radiometric age constraints. There are several critical climate/extinction events imbedded within these segments including the Late Maastrichtian warming event, K/Pg boundary, Paleocene Carbon Isotope Maximum (PCIM), Paleocene-Eocene Thermal Maximum (PETM), and Mid Pleistocene Transition (MPT), the nature of which are now better understood within this high-fidelity long term stable isotope framework. I will conclude that these tuned hi-fidelity isotope records resolve key features of the evolution of climate and the carbon cycle across major intervals, but also that new records along depth transects from different oceans are required to make further progress.

***Dirk (Dick) Kroon** is a marine geologist and paleoceanographer with over 160 publications. His current research includes Paleogene hyperthermal events, the evolution of hominids, the history of Neogene carbonate platforms, and the geology of Cyprus. No stranger to scientific ocean drilling, Dick has sailed on six IODP cruises, twice as co-chief scientist. He is also experienced in the IODP leadership structure, chairing the Dutch IODP Committee from 2002 – 2006 and leading IODP's Science Evaluation Panel as co-chair from 2012 – 2016. Dick will begin a three-year term 1 October 2018 as IODP Forum chair.*

What Controls Abundance and Activity of Microbial Life in Subsurface Sediments? New Insights from Scientific Drilling

Dr. Jens Kallmeyer

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It is commonly accepted that the deep sedimentary biosphere harbours a vast and diverse microbial ecosystem that forms an active interface between biological and geological element cycles. While the total number of cells and their contribution to the global living biomass are still the subject of debate, the discussion becomes futile if we just focus on the numbers, instead of identifying the factors that control microbial abundance in subsurface sediments.

However, even the most accurate predictions of the abundance and biomass of subsurface life provide no information about the metabolic capabilities of this massively underexplored ecosystem. Although much progress has been made with regard to detection and quantification of microbial activity in subsurface sediments, many processes remain elusive.

From a practical standpoint the biggest challenge for deep biosphere exploration is still the lack of sensitivity of many turnover quantification methods, which is mainly caused by two factors: The first one is the very low turnover rates, formation of appreciable amounts of product or consumption of a substrate taking up to millions of years and therefore extend way beyond human timescales; the other factor are very short residence times of detectable compounds. For example, organic substrates produced by abiotic cracking reactions or hydrogen from radioactivity-induced radiolysis are immediately consumed by the microbes, keeping concentration levels below the minimum detection limit. In such cases, modelling can provide reliable estimates, although there are also inherent problems associated with this approach, e.g. the availability of high quality geochemical and petrophysical data.

The lecture will review recent advances in detection and quantification of subsurface biomass and activity and present the conclusions that could be drawn from these new data. Additionally, the lecture will also highlight the technical challenges that still lie ahead of us.

After studying Geology in Hannover, Bremen and Southampton, ***Jens Kallmeyer*** *spend one year at UNC Chapel Hill before joining the Max Planck Institute for Marine Microbiology in Bremen for his PhD. After Postdoc positions at GFZ Potsdam and the NASA Astrobiology Institute at the University of Rhode Island he became head of the Geomicrobiology Junior Group at the University of Potsdam. Since 2012 he works as a currently senior scientist at the Geomicrobiology section of GFZ Potsdam, Germany.*

Dr. Kallmeyer's research focus lies on detection and quantification of microbial activity in the deep subsurface both on land and at sea. Consequently he is involved in both IODP and ICDP and has participated in several drilling expeditions, leading him to Mud Volcanoes off the coast of Japan, and the South Pacific Gyre as well as Lake Towuti on Sulawesi Island, Indonesia, Lake Van in eastern Turkey and other places. ECORD recognized his contributions to the program selecting him as Distinguished Lecturer. Currently he serves on the IODP Scientific Evaluation Panel (SEP).

Austria´s role in Ocean Drilling

Univ.-Prof. Dr. Werner E. Piller

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In 1970, during the first phase of ocean drilling - the Deep Sea Drilling Project (DSDP: 1968 – 1983) - Herbert Stradner (Geological Survey of Austria) was the first Austrian Scientist sailing on board of the D/V *Glomar Challenger* on Leg 13 in the Mediterranean Sea. In addition, Stradner sailed on Leg 66 (Mexico – Guatemala) in 1979 and on Leg 75 (South Atlantic) in 1980. Two other Austrians sailed during the DSDP phase, Fred Rögl (Leg 35) and Michael Sarnthein (Leg 47), however, both were affiliated to non-Austrian institutions while they attended these cruises. During the Ocean Drilling Program (ODP) phase (1983 – 2003) no Austrian scientist participated in any cruise. It was only during the phase of the Integrated Ocean Drilling Program (IODP: 2003 – 2013) when Austria became a member of the European Consortium for Ocean Drilling (ECORD) in 2004. The first participation of an Austrian scientist was in 2011/2012 at Expedition 339 followed by two more participations (Exp. 337: 2012, Exp. 344: 2012/2013). Austria continued its participation also in the International Ocean Discovery Program (IODP: 2013 – 2023) and was involved in five expeditions (Exp. 352, 356, 364, 366, 369) so far. Two more participants are already invited to sail at Exp. 358 in early 2019.

Overall, the number of scientists who sailed within both IODP-phases is high compared to the amount of the membership fee paid by Austria. Furthermore, the benefit for these scientists is even higher when considering their scientific standing, their prospects for personal growth and their career moves.

> ***Werner E. Piller*** *is full professor for Palaeontology and Historical Geology at the University of Graz since 1997. His main scientific fields cover micropalaeontology and carbonate sedimentology in the Mesozoic and Cenozoic focusing on palaeoclimate, palaeoceanography, palaeolimnology as well as biogeography and stratigraphy. He is full member of the Austrian Academy of Sciences (OeAW) and was long-term chair of the Commission for palaeontological and stratigraphical research of Austria of the OeAW. He is chair of the Austrian National Committee of Geosciences to IUGS, chair of the International Subcommission on Stratigraphic Classification (ISSC) of the International Commission on Stratigraphy and chair of the Austrian National Committee of Geo/Hydro-Sciences including the International Geoscience Program (IGCP) of UNESCO. Within IODP he is the Austrian delegate of ESSAC, which is the ECORD Science Support and Advisory Committee, member of the Steering Committee of Magellan Plus, the Workshop-Program of ECORD, and member of the Science Evaluation Panel (SEP). He is author of more than 300 scientific publications and books. In 2016, he was awarded the Eduard-Suess-Medal of the Austrian Geological Society.*

Slipping and Sliding: Capturing the Earth in Motion by Scientific Ocean Drilling

Univ.-Prof. Dr. Michael Strasser

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Since the beginning of ocean drilling, sampling and dating reflection-seismically imaged tectono-stratigraphic sections and recovering sediments and rocks from marine convergent plate-boundary systems has advanced our understanding of subduction zone structures and evolution. It further evidenced the dynamic nature of deformation, fluid flow and mass fluxes within such systems. With the advancement in developing borehole observatories, monitoring data is increasingly becoming available to analyze and quantify the dynamic processes, such as those leading to and resulting from earthquakes, slides and tsunamis. Short instrumental records, however, limit our perspective of maximum magnitude and recurrence of such submarine geohazard processes. Examining past events expressed as sedimentary or geochemical perturbations preserved in the marine record provides IODP the key to address this challenge on relevant time scales.

This talk summarizes efforts by Ocean Drilling and related method-developments to unravel the marine-geological record for advancing our understanding on past earthquake occurrences and resulting dynamic responses of deep-water seafloor and sub-seafloor environments. In particular, I highlight the past present and future involvements of Austrian scientists in studying the Earth in Motion by Scientific Ocean Drilling.

***Michael Strasser** is a full professor in Sedimentary Geology at the University of Innsbruck since October 2015. He conducts research on the quantitative characterization of dynamic sedimentary and tectonic processes and related geohazards. Important pillars of Strasser's research is the study of lakes as models for oceans, and his involvement in the International Ocean Discovery Program (IODP). He sailed on 4 (I)ODP cruises, was co-chief scientist of IODP Expedition 338 and is currently involved in the ongoing NanTroSEIZE – Plate Boundary Deep Riser IODP Expedition 358 and leading the IODP-Proposal 866 Submarine Paleoseismology initiative. He has published nearly 100 papers since 2005 and received prestigious awards, including the AGU/JPGU Asahiko Taira Prize 2017 and IAS young scientist award 2014.*

Convergent Margins and Fore Arc Processes in the Western Pacific Ocean

Univ.-Prof. Mag. Dr. Walter Kurz

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Geologic processes at convergent plate margins control seismicity, geochemical cycling, and deep biosphere activity in subduction zones. Two approaches are typically taken to study such zones. One approach is to characterize inputs into a convergent plate margin by sampling the downgoing plate. These inputs provide the geochemical reference necessary to elucidate what geochemical factors may influence the production of supra-subduction zone crust and mantle. A second approach is to study outputs in terms of magma and volatiles in volcanic arcs and backarc basin settings. Such outputs constrain processes that exist deep within the subduction zone and the lithosphere in the hanging-wall.

IODP Expeditions 352 and 366 revealed data from two different fore arc systems along the Izu-Bonin-Mariana system. Whereas the Izu-Bonin arc shows fore arc magmatism, the Mariana arc is characterized by serpentinite mud seamounts with unconsolidated flows of serpentine muds containing clasts of serpentinized mantle peridotite and several other lithologies, such as blueschist materials derived from the subducting slab via deep-seated faults.

From a plate tectonic perspective, forearcs with serpentinite mud volcanism seem to represent an intermediate setting of convergent plate margins, in comparison with either low-angle subduction, accretionary, erosive, amagmatic or high-angle subduction magmatic convergent margins. Such a setting therefore provides fore arc extension permitting the development of fluid conduits along extensional faults at a lithospheric scale without triggering magmatism. The Mariana convergent margin therefore provides the environment where a natural process brings materials from great depths directly to the surface.

***Walter Kurz** is a full professor for Geology at the University of Graz since October 2018. He conducts research on Alpine tectonics with emphasis on the tectonic evolution of convergent settings, especially within the Alps-Carpathians-Dinaride system, and on the tectonic evolution of Penninic and Subpenninic nappes. Recent projects and field studies within this orogen focused on the evolution of pre-Alpine basement units within the Austroalpine nappe edifice and subduction and obduction processes during Late Jurassic to Paleogene times. Previous projects tackled the deformation of deeply subducted continental crust at eclogite facies conditions and the exhumation of high-pressure and ultra high-pressure units, and the structural evolution of cataclastic fault zones, including the geochronological dating of cataclastic fault rocks and paleoseismic events by low temperature geochronology.*

Walter Kurz sailed on IODP cruises 344, 352, and 366. Post-cruise research related to these expeditions focused on the structural evolution of the Cocos Plate, on supra-subduction zone tectonics within forearc settings.

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Current affairs: A look at IODP Expedition 339 and beyond

Prof. Dr. Patrick Grunert

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Many ocean drilling campaigns over the past 50 years have been dedicated to the exploration of past shifts in ocean-climate dynamics. Among the key aspects are forcings and feedbacks in the climate system related to the variability of heat transport through ocean currents. Drill cores form the North Atlantic provide a unique archive in this respect as they chronicle the sinking and overturning of dense waters at high latitudes, the driver of the Great Conveyor Belt. Mediterranean Outflow Water (MOW), entering the North Atlantic through the Gibraltar Strait, potentially provides a crucial source of heat and salt for the promotion of this overturning circulation. IODP Expedition 339 (2011 – 2012) recovered 4.5 km of sediment cores along the SW Iberian Margin with the aim to reconstruct the variability of MOW over the past 5.3 Ma and to evaluate its driving forces and feedbacks with thermohaline circulation in the North Atlantic. The present paper reviews what we have learned about MOW and how research helps to improve our tools for the reconstruction of ocean currents and their role in the climate system.

The research presented in this paper has been funded through project P25831-N29 of the Austrian Science Fund (FWF), a grant by the Max Kade Foundation, and the ongoing project GR 5285/1-1 of the German Research Foundation (DFG).

***Patrick Grunert** is professor of micropaleontology and paleoecology at the University of Cologne. He holds a master's degree in paleobiology from the University of Vienna (2007) and a doctoral degree in geobiology and paleoecology from the University of Graz (2011). He participated as shipboard micropaleontologist on the research vessel JOIDES Resolution in IODP Expedition 339. His subsequent postdoctoral research in Graz, Cambridge and at Rutgers focused on the reconstruction of Mediterranean Outflow Water and its past variability. In 2015, he was awarded the Outstanding Young Scientist Award of the European Geosciences Union in recognition of his scientific work.*

Timing and Pacing of Indonesian Throughflow Restriction and its Connection to Late Pliocene Climatic Shifts

Dr. Gerald Auer

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The Pliocene 5.3 to 2.6 million years ago was characterized by a fundamental reorganization of Earth's climate to a cooler, dryer and more seasonal mean state, similar to the modern. The progressive tectonic constriction of the Indonesian Throughflow (ITF) 5.0 – 3.0 million years ago is often put forward as a possible trigger that enhanced these Pliocene climatic shifts towards stronger meridional thermal gradients. A reduced ITF, caused by the northward movement of Australia and uplift of Indonesia, impedes global thermohaline circulation and therefore may also have contributed to late Pliocene cooling in the Northern Hemisphere via complex atmospheric and oceanographic teleconnections. Untangling the exact timing of ITF constriction is thus critical for resolving the mechanisms driving Earth's climatic evolution during the Pliocene, a time in the Earth's past that is considered one of our best analogues for current and future climate change.

To resolve these questions we reconstructed surface water conditions and ITF connectivity between 3.66 to 2.97 Ma by using paleoecological and paleoclimatic records from International Ocean Discovery Program (IODP) Expedition 356 Site U1463. Located on the northwest shelf of Australia within the Leeuwin Current, at the edge of the Indo-Pacific Warm Pool, the site provides a record of local surface water conditions and Australian climate in relation to changing ITF connectivity. Our research illustrates how this ongoing tectonic ITF reorganization significantly altered the water masses flowing through the Indonesian Archipelago into eastern Indian Ocean around 3.54 Million years ago. This tectonically driven switch in ITF source waters changed how the Indian Ocean responded to cooling in the southern high-latitudes, during a severe glaciation 3.3 million years ago. The interplay between global climate and this new ITF configuration in the Indian Ocean consequently also enhanced seasonality and aridification on the Australian Continent. Research following IODP Expedition 356 thus contributes to our understanding of how changes in ITF connectivity and Indian Ocean dynamics affect both Australian and global climate.

Gerald Auer *is a Postdoctoral Research Fellow at JAMSTEC, Dept. of Biogeochemistry, Yokosuka, Japan. He earned his master's degree in geobiology and paleoecology (2013) and doctoral degree in geobiology (2016) at the University of Graz. In 2015 he joined IODP Expedition 356 Indonesian Throughflow as a shipboard sedimentologist along the western coast of Australia on the research vessel JOIDES Resolution. Currently he holds a grant by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT; Grant 17H07412) for his research into the dynamics of the Indonesian Throughflow during intense climatic shifts in the Pliocene and Pleistocene.*

What Have We Learned from the IODP-ICDP Expedition 364 Drilling into the Dinosaur-Killing Chicxulub Asteroid Impact Crater?

Mag. Dr. Ludovic Ferrière

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In 2016, the joint International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) Expedition 364 drilled into the peak ring of the Chicxulub impact crater. The ~200 km diameter and ~66 Ma, K-Pg boundary, Chicxulub crater (Mexico) is the only known terrestrial impact structure with a well-preserved peak-ring. A total of 830 m of core were recovered (505.7 – 1334.7 mbsf), and three main lithological units were identified in the core, namely, from top to bottom, a "post-impact" section of Paleogene sediments, an "upper peak ring" section of suevites and impact melt rocks, and a "lower peak ring" section of shocked granitoid rocks intruded by different types of sub-volcanic dikes, and intercalations of suevite and impact melt rock units. Analyses done on the core samples, downhole logs, and geophysical site survey data have led to a series of significant advancements to our understanding of impact cratering processes in general and to how the Chicxulub impact affected the Earth’s environment leading to the Cretaceous-Paleogene mass extinction. In terms of impact cratering processes, we were able to validate the dynamic collapse model for the formation of large impact craters and to better understand the weakening mechanism allowing the target rocks to behave temporarily as a fluid in response to hypervelocity impact, also corroborating the acoustic fluidization hypothesis. The recovered samples have also allowed us to explain the large reductions in density and enhancements in porosity generated by impacts. We were also able to better understand how impact cratering can affect life, positively and negatively, with the colonization of impactites by thermophiles and with the rapid recovery of marine life within the flooded Chicxulub crater basin. A number of studies are currently in progress on the (modeling of the) hydrothermal system, the impact thermochronology, the identification of a possible impactor signature, shock effects in minerals, and on a great variety of other topics. Expedition 364 can be declared a success based on all what was achieved within the last two years and knowing that much more is to be expected for the next years from the extraordinary rocks that were recovered…

> ***Ludovic Ferrière*** *is chief curator of the rock collections and co-curator of the meteorite collection at the Natural History Museum Vienna (Austria) since 2011.*
> *After his studies of geology in France and in Canada, he started his Master in Planetology (/Earth and Planetary Sciences) at the University of Nantes (France) and completed it at the University Pierre and Marie Curie in Paris (France). He obtained his PhD thesis in Vienna (Austria) in 2009, on the geological and geochemical aspects of impactites from the Bosumtwi crater (Ghana). He then conducted postdoctoral researches on shatter cones and associated shock-induced microdeformations in minerals at the University of Western Ontario (in London, Ontario, Canada). Ludovic has confirmed (together with colleagues) three (soon four!) of the currently 190 recognized meteorite impact craters on Earth (i.e., Keurusselkä in Finland, Luizi in the Democratic Republic of Congo, and Hummeln in Sweden).*
> *He is author and co-author of more than 45 peer-reviewed scientific papers published in international journals, over 150 abstracts presented at international conferences, and a book on meteorites.*

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