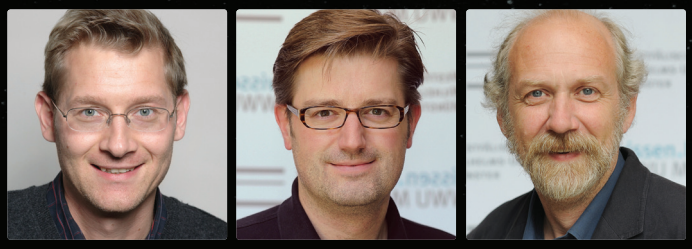
Growth of the geosciences

Fascinated by the evolution of the Earth, **Professors Andreas Stracke**, **Thorsten Kleine** and **Harald Strauss** have established a centre that provides access to innovative isotopic techniques to inform its study. Here, they discuss recent advances and the diverse research facilitated by the centre



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Over recent decades, geochemistry has evolved into a modern, interdisciplinary science. How does research in this area close the gaps between geoscience disciplines?

Research in geochemistry has always been driven by technical innovations. Novel analytical tools enabled researchers to make discoveries previously deemed impossible. This sparked cross-disciplinary collaborations between geochemists and geoscientists and has opened entirely new fields of research.

Geochemical techniques have become standard repertoire in almost all areas of the geosciences. Hence, geochemical research has been one of the main driving forces behind many recent breakthroughs in the Earth and planetary sciences, ranging from climate and environmental research, to exploration of natural resources and fundamental topics such as the evolution of the Solar System.

What demand does the Münster Isotope Research Center (MIRC) address? What is the overall aim of the facility?

Advances in analytical techniques have not only introduced a wealth of new geochemical information, but also led to a high degree of researcher specialisation. This is in contrast to the increasing demand for diverse geochemical data. The acquisition of comprehensive isotopic data is highly challenging, because geochemical techniques are far from routine and require extensive technical facilities and expertise. On a collaborative basis, the MIRC offers access to state-of-the-art analytical facilities and the possibility to acquire a wide range of isotope data.

Can you outline your respective professional backgrounds? In what capacity do you work together at MIRC?

AS: We all have a broad background in the geological sciences, but have specialised in different areas of isotope geochemistry. My major research focus is on investigating the compositional evolution of Earth's mantle and crust and the underlying geochemical cycles that govern this evolution.

TK: I am a geologist-mineralogist by training. My research focuses on early Solar System evolution, planetary accretion and core formation.

HS: I am a geologist and geochemist, specialised in stable isotopes. I study sulphur and carbon isotopes to understand Earth System evolution, with a strong focus on the early part of Earth's history.

How many laboratories are hosted at MIRC? Could you encapsulate the research taking place at the Center?

The MIRC hosts three different laboratories for isotope geochemistry, located in three different institutes of the Geoscience Department: the Institut für Mineralogie (geochemistry group, led by Professor Stracke), the Institut für Planetologie (cosmochemistry group, led by Professor Kleine), and the Institut für Geologie und Paläontologie (stable isotope group, led by Professor Strauss).

Our research covers many areas in the Earth, planetary and life sciences. We use radiogenic and stable isotopes to trace the origin of a substance and investigate geological or biological processes from a nano to global scale. Active areas of research include the early history of the Solar System, the geochemistry of Earth's mantle and crust, and reconstructing changes in the chemical composition of the atmosphere-ocean system. Hence, we are interested in the (bio)geochemical cycles that govern present and past interactions between crust-mantle-core and the lithosphere-atmosphere biosphere-hydrosphere.

Can you explain how the MIRC facilitates interdisciplinary research?

Many of the existing ties between our institutes have been strengthened, and new collaborations initiated, through the establishment of the MIRC. Our research groups collaborate with researchers across the globe and the newly established laboratories have created fantastic possibilities, which allow us to expand and diversify our research and links to international researchers.

MIRC funds a selection of postdoctoral researchers. What is the focus of their research?

The initial phase of the MIRC was dedicated to establishing new facilities and methods in the Institut für Mineralogie, the Institut für Planetologie, and the Insitut für Geologie und Paläontologie. In these groups, one postdoc has set up techniques to investigate the variation in isotope ratios of alkaline earth and transition metals in meteorites and magmatic rocks, which are sensitive tracers of crust-mantle-core evolution. Another postdoc has developed a technique for investigating compound-specific isotope analyses of carbon. The carbon isotopic composition of individual organic molecules offers new insights into metabolic pathways, which has become increasingly important in many areas of organic (geo)chemistry and environmental research.

MIRC will host an opening event later this year. They are also planning to offer a 10 day, hands-on training course in isotope geochemistry for advanced Master's or early PhD students, to be held on a regular basis.

Investigational isotopes

The **Münster Isotope Research Center** in Germany is a unique isotope analysis facility for the Earth Science community. Through the provision of new techniques and state-of-the-art facilities, it aims at advancing our understanding of the workings of our planet

THE PLANET'S EVOLUTION has fascinated humankind for centuries, leading to the inception of its own scientific field: Earth Science. In recent years, the discipline has transformed into a highly technological and quantitative science, spurred, among others, by advances in geochemistry. Geochemical isotope research has enabled rapid scientific progress in many diverse fields of the earth, planetary and environmental sciences. Alongside this evolution has grown the demand for extensive isotope data, requiring cutting-edge analytical facilities and expert knowledge.

Such high-level facilities and expertise are labour intensive and thus often untenable in a university environment. Facilities that can offer a wide range of isotope tools under the same roof are therefore scarce, preventing scientists from obtaining the comprehensive datasets needed for modern geoscience.

Professors Andreas Stracke, Thorsten Kleine and Harald Strauss are improving the prospects for others in his field, by establishing the Münster Isotope Research Center (MIRC), a German Research Foundation (DFG)-funded joint facility of three different isotope laboratories at the University of Münster. As such, the MIRC represents a new development in geochemistry. It provides timely access to facilities for diverse isotope analyses to researchers from different disciplines in the Earth, planetary and environmental sciences.

ADVANCED FACILITIES

MIRC is funded by the DFG's 'Core Facilities' initiative, established to improve research infrastructures in the country. Despite competition from over 50 proposals, MIRC was selected as one of 11 projects in 2012 to receive €450,000 over a three-year period.

This DFG funding enabled MIRC to unite its existing laboratories under a common structure, providing users with the possibility to pursue complex isotope research within a single research unit, comprising leading-edge analytical facilities and internationally renowned expertise.

Access to MIRC takes place through collaboration with members of host research groups and is regulated by an MIRC panel that directs research priorities. The Center provides cutting-edge instruments to all of its collaborators, enabling a broad range of both stable and radiogenic isotope measurements. "Our facilities are state-of-the-art, including several isotope ratio mass spectrometers, among these multi-collector inductively-coupled plasma (ICP), thermal ionisation and gas mass spectrometers," the co-PIs explain. Users are able to characterise their own materials on site, or measure the isotope ratios of previously characterised materials.

Beyond the technical amenities, extensive advice and logistical support is also provided. "Guidance from scientists and technical staff is provided throughout the entire analytical work phase," the professors expand. "This includes initial training, support with data acquisition and interpretation, and publication of the results." It is hoped this will attract both national and international users, specialists, interested in isotope measurements not available in their own institution, and less experienced doctoral students, thereby fostering geochemical education and interdisciplinary research for a mixed audience.

PROBING EARTH'S PAST

MIRC allows scientists from all areas of geoscience to perform sophisticated isotope measurements on very different materials,

Converging institutes

The MIRC hosts three different laboratories for isotope geochemistry, with research potential ranging from the geological and planetary, to life and marine sciences

GEOCHEMISTRY GROUP – PROFESSOR ANDREAS STRACKE

Research areas: the geochemistry of the Earth's mantle and crust, geochronology, palaeo-oceanography and experimental geochemistry

Isotope systems: U-series decay chain, stable Ca and Mg isotopes, and Rb-Sr, Sm-Nd, Lu-Hf and U-Pb isotope systems

COSMOCHEMISTRY GROUP - PROFESSOR THORSTEN KLEINE

Research areas: the early history of the Solar System, and the accretion and differentiation of asteroids and planets

Isotope systems: Hf-W, Lu-Hf isotope systems, and stable Mo, Cr, Ag and Ru isotopes

STABLE ISOTOPE GROUP - PROFESSOR HARALD STRAUSS

Research areas: reconstructing changes in the chemical composition of the atmosphere-ocean-system. Past and present interactions between the atmosphere, biosphere, hydrosphere and lithosphere

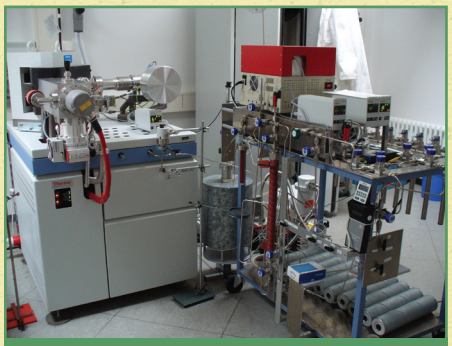
Isotope systems: stable H, C, N, O and multiple S isotopes, and compound-specific C isotopes

Together, these laboratories apply a diverse range of isotope techniques, use different analytical methods and cover a broad research spectrum. They provide an environment for comprehensive analysis of isotopes for Earth and planetary scientists, such that they no longer have to use labs scattered around the globe.

from volcanic rocks and meteorites to fossils and water samples. The isotopic composition of a sample can be used to derive fundamental information about it, such as its age, but can also provide broader information about the chemical composition and evolution of the Earth for instance, or the climate in Earth's past.

At present, research at the Center is focused on Solar System evolution and chronology; planet formation, differentiation and evolution; biogeochemistry; atmosphere-ocean interaction; and palaeoclimate. But by expanding the techniques offered, the researchers hope to form new links among participating institutes, as well as widening the scientific questions that can be addressed, in turn increasing the potential user pool.

The main targets for future development involve stable isotope measurements of so-called heavy elements, a rapidly growing field in geoscience. Focus will be on meeting the associated demand for methods, concentrating on isotopes of the alkaline earth and transition metal elements at first. These elements complement the traditional stable isotope measurements already in use at MIRC, and will enable investigations of a diverse range of processes from planet formation and differentiation, to processes relevant for evolution of the atmosphere and life.



ISOTOPE APPLICATIONS

Sr, Nd, Hf, Pb, Ca and Mg isotopes, studied using Thermo Scientific Triton (TIMS) and Thermo Scientific Neptune (MC-ICPMS), can be used to study palaeo-oceanography, the palaeo-climate and crust-mantle evolution.

Studies of organic carbon isotopes, based on the Thermo Scientific Delta Plus instrument, can help reconstruct metabolic pathways. Multiple sulphur isotopes, measured on a Thermo Scientific MAT 253, reveal important changes in Earth's early atmosphere and ocean compositions.

Using MC-ICPMS, W, Hf, and transition metal isotopes can model the evolution of the Solar System, interactions between the Earth's crust and mantle, and atmosphere-ocean evolution.

TACKLING THE BIG QUESTIONS

MIRC's research is helping to answer the big questions about the evolution of the Solar System and our planet, including the emergence and evolution of life on Earth. "We are addressing questions such as: what processes formed and governed the evolution of our early Solar System; how do planets form and evolve; how did earth become a habitable planet; and what are the underlying (bio) geochemical cycles that govern interactions between Earth's different subsystems? All of these are fundamental questions that will lead to a better understanding of how our planet works," the project's leaders elaborate. Isotope geochemistry can also help to develop strategies to manage future global environmental challenges, by helping to explain the causes of climate change.

Over the last three years, work has been dedicated to developing a portfolio of techniques and setting up the laboratories. These new labs are now fully operational and are used by local researchers and students, and collaborators from around the world. Excitingly, the first results from this embryonic research are soon to be published.

Already an incomparable isotope research centre in a university environment, in the coming years MIRC aims to establish itself as a centre for isotope geochemistry in Germany and the world. But future development depends on funding, both for individual research projects and for facilities. If this is obtained, the three professors hope to further expand the scope.

INTELLIGENCE

MÜNSTER ISOTOPE RESEARCH CENTER (MIRC)

OBJECTIVES

On a collaborative basis, the MIRC provides access to facilities that allow a broad range of stable and radiogenic isotope measurements for Earth and planetary scientists. This allows researches to make a diverse range of isotope analyses using state-of-the-art facilities that are not available in their own institution. In the three different participating institutes, these include: thermal ionization (TIMS), multi-collector inductively coupled plasma (MC-ICPMS) and gas source mass spectrometers.

KEY COLLABORATORS

Co-Principal Investigators:

Professor Thorsten Kleine, Institute for Planetology, University of Münster, Germany

Professor Harald Strauss, Institute for Geology and Palaeontology, University of Münster, Germany

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ANDREAS STRACKE received his PhD from Florida State University, USA, in 2001. He was appointed Professor for Geochemistry at the University of Münster in 2010.

THORSTEN KLEINE received his PhD from the University of Münster in 2004. He was appointed Professor for experimental and analytic planetology at the University of Münster in 2009.

HARALD STRAUSS received his PhD from the University of Göttingen, Germany, in 1985. He was appointed Professor for Historical and Regional Geology at the University of Münster in 1999.

MI RC Münster Isotope Research Center