Center for Applied Geoscience
Department of Geoscience
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WHO WE ARE

The Center for Applied Geoscience (Zentrum für Angewandte Geowissenschaften, ZAG) at the University of Tübingen is internationally renowned for its research and teaching in environmental sciences and applied geology. Special focus lies on studying and solving water-related environmental problems with particular emphasis on subsurface environments.

Reducing the burden of chemical pollution on our environment, including atmosphere, water and soils, and sufficient supply of clean water, are prerequisites for human health, ecosystem functioning, and economic prosperity. The researchers of the ZAG study fundamental processes in environmental systems to guide governmental institutions and society towards a sustainable use of our, often non-renewable, resources that are threatened by pollution, over-exploitation and consequences of climate change. Our teaching enables the next generation of professionals to make decisions of resources management on a solid scientific basis with in-depth system understanding.

ZAG researchers also work in the fields of geo-resources, geodynamics, boundary-layer meteorology, and wind energy.

We follow a quantitative, interdisciplinary approach, combining the fields of environmental chemistry, microbiology, geophysics, fluid mechanics, and geology to address urgent questions of environmental quality, anthropogenically altered natural cycling, and geo-resources management, as well as to gain a fundamental understanding of processes in the environment and in the earth system.

We merge cutting-edge analytical laboratory techniques, pioneering field assessment methods, and advanced modelling tools to gain a quantitative holistic view of individual processes and their interactions in environmental systems.

We provide high-quality teaching on the undergraduate and graduate level, preparing our students for a variety of career opportunities in academia, governmental institutions, consulting companies, engineering offices, and industry.
TEACHING

The Center for Applied Geoscience participates in the following study programs at the University of Tübingen:

- Geowissenschaften (BSc & MSc)
- Geökologie (BSc & MSc)
- Umweltwissenschaften (BSc)
- Applied & Environmental Geoscience (MSc)

The lecturers of ZAG provide the base education in microbiology, groundwater hydrology, systems analysis, geophysics, biogeochemistry, analytical and physical chemistry, environmental physics, and sedimentology, differently represented within the various study programs.

ZAG hosts the international MSc program Applied & Environmental Geoscience with three specializations. It contributes to the MSc Geökologie with courses in environmental chemistry and microbiology, and to the MSc Geowissenschaften specializing in exploration.

The emphasis in teaching lies on fundamental understanding of processes in earth and environmental systems, their interaction and quantitative description to solve complex environmental problems of practical relevance. Teaching involves laboratory courses, extended computer exercises, field courses, and excursions.

For more information visit the websites of the respective programs: http://www.geo.uni-tuebingen.de/en/study.html
SEDIMENTARY GEOLOGY

The group of Prof. Dr. Thomas Aigner works in the field of sedimentary geology, with a focus on sedimentary facies analysis and sequence stratigraphy, lately with an emphasis on carbonate systems. This research is applied to practical questions such as reservoir and aquifer characterization as well as 3D-modelling, in addition to raw materials geology. In short, our work is devoted to the study of geological bodies (“geobodies”) that form the containers of oil, gas, water and other natural resources.

We emphasize: a) integration of scales: from microscopic to seismic scale, b) integration of dimensions: from one-dimensional to three-dimensional analysis, c) integration of techniques: from sedimentological to geophysical methodology, and d) integration of work spheres: combining outcrop, subsurface, laboratory and modelling work.

Most of our projects take place in collaboration with partners from industry or governmental agencies. Recent research areas include the regional geology of Southern Germany, petroleum geology of various parts of Asia and Arabia, especially in the Sultanate of Oman.

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GEOPHYSICS

The group of Prof. Dr. Erwin Appel works on various research topics in environmental magnetism, palaeomagnetism and rock magnetism. The laboratory is equipped with state-of-the-art instrumentation for highest sensitivity measurements, and a variety of field equipment is available for in situ surveying.

Our palaeomagnetic research focuses on tectonic deformation in mountain belts, predominantly in the Himalaya and Tibetan Plateau region. Dating of sedimentary sequences by magnetic polarity stratigraphy is another regular activity. In general, we approach our research goals in an interdisciplinary framework of different geoscientific disciplines, and perform the projects within international cooperation.

In the field of environmental science, the group pursues two major research directions. In the first, we study magnetic properties to understand palaeoclimate evolution and palaeoenvironmental processes. Here we focus on monsoon dynamics in and around the Tibetan Plateau, and the development of aridification in central Asia. In the second, we investigate magnetic signatures of pollutants in the environment in order to support the assessment of contaminated sites and of air quality, i.e. environmental compartments affected by particulate matter such as fly ash emissions and other industrial tailings.

Besides the activities in magnetism-oriented fundamental and applied research, the group offers students the possibility to learn a wide range of geophysical methods for investigating shallow subsurface structures, comprising seismics, geoelectrics, and field magnetics.

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ENVIRONMENTAL PHYSICS

The Environmental Physics group, led by Prof. Dr. Jens Bange, studies mainly atmospheric flows using automatically operating unmanned aircraft (UAV), measurement-station networks (Ammer valley and urban terrain), and numerical simulations (CFD).

The group's expertise lies in investigating turbulent exchange and transport processes in the atmospheric boundary layer (ABL), including momentum, heat, water vapour, CO₂ and aerosol fluxes. Besides fundamental research, the group uses this expertise in various projects on wind-energy research, both off-shore and in complex terrain.

The atmospheric environment that affects life on earth the most is the lower troposphere (about the lowest 2000 m above ground level). It comprises the surface (Prandtl) layer, the ABL, the entrainment zone, and the adjacent lower free atmosphere. Most of the physical and chemical interactions of the earth's surface with the atmosphere happen here.

Although we feel this interaction every day, many processes in the ABL are unknown, especially in the late afternoon, at night, and in the early morning, when thermal stability of the ABL changes rapidly.

More insight into these processes (i.e. a proper physical and mathematical description) leads to a better understanding of the Earth's surface budgets, the propagation of matter and gas, and more reliable forecasts of weather and climate. This also has an applied and engineering focus, as it aids the understanding of wind turbines and their interactions with the ABL.

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HYDROGEOLOGY

The hydrogeology group, headed by Prof. Dr.-Ing. Olaf A. Cirpka, mainly studies physical flow and reactive transport processes in the subsurface by means of mathematical modeling and field investigations.

The spatial variability and uncertainty of hydraulic aquifer parameters pose a major challenge to site characterization, assessment of aquifers, and design of water-resources management schemes. The hydrogeology workgroup tackles this problem by stochastic analysis, uncertainty assessment, inverse modeling, and improved site investigation techniques, analyzing the effects of complex subsurface structures on flow and reactive transport.

The hydrogeology workgroup operates the Lauswiesen Hydrogeological Research Site close to Tübingen to test advanced field investigation techniques, combining direct-push probing, aquifer tests, hydraulic tomography, tracer tomography using heat and solutes as tracers, and geophysical monitoring of hydraulic tests.

Aquifers are interacting with other compartments of the water cycle (rivers, unsaturated zone, land surface), which we study by integrated modeling and field investigations. At larger scales, we evaluate the complete hydro-system response (water fluxes, residence times, biogeochemical status) to changes in climatic forcing and land use within a fully coupled modeling framework supported by high-performance computing environments.

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ENVIRONMENTAL AND ENGINEERING GEOPHYSICS

The Environmental and Engineering Geophysics group of Prof. Dr. Peter Dietrich is strongly linked with the Department of Monitoring and Exploration Technologies at the Helmholtz Centre for Environmental Research (UFZ) in Leipzig. The focus of the research is on the development and evaluation of methods and method combinations for a goal-oriented characterization of the shallow subsurface.

Monitoring and exploration technologies are essential for the understanding of the investigated system, the identification of processes as well as for the development and evaluation of models for the prognosis of the development of the system. In particular, the use of the shallow subsurface for hydrogeological and geotechnical purposes can require a detailed investigation of sites with complex geological settings or intricately constructed sedimentary deposits, e.g., fluvialite regimes where hydraulic conductivity can change over short horizontal and vertical distances in several orders of magnitude. For this purpose, the Environmental and Engineering Geophysics group further develops geophysical methods in combination with Direct Push technologies. The work comprises theoretical and numerical aspects as well as sensor development.

The UFZ MOSAIC research platform (Model-Driven Site Assessment, Information and Control) is used for the testing and evaluation of innovative mapping and monitoring technologies under field conditions. This platform is made up of vehicles equipped with geophysical measuring techniques in combination with Direct Push probing devices, borehole logging, hydrogeological and geotechnical equipment.
ENVIRONMENTAL TOXICOLOGY

The Environmental Toxicology group of **Prof. Dr. Beate Escher** is a collaboration between the University of Tübingen and the Helmholtz Centre for Environmental Research UFZ Leipzig, Department of Cell Toxicology. The laboratories are situated in Leipzig.

Our key objectives are to understand the causative processes leading to adverse effects by micropollutants, their mixtures and transformation products and to translate these findings into predictive models for risk assessment and to apply the developed tools for environmental monitoring.

We study the mechanisms governing the adverse effect of chemicals on humans, wildlife and ecosystems. We apply modern instrumental analyses coupled to bioanalytical tools with a focus on cell-based bioassays. We use reporter gene assays that respond to known modes of toxic action associated to evaluated mixtures of chemicals including unknowns and transformation products in pure form and in complex environmental samples (water, sediment, biota, tissue, blood etc.).

By combining chemical analysis with mixture toxicity assessment and modelling, we can identify which fraction of effect is caused by mixtures of known and which by unknown micropollutants. Innovative sampling methods such as polymer-based extraction of chemicals from complex samples such as sediment, biota, blood and tissue complement our work on water quality assessment in natural and engineered systems, where we investigate processes such as biodegradation, ozonation and disinfection with bioanalytical tools.

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HYDROGEOCHEMISTRY/
APPLIED GEOLOGY

The group of Prof. Dr. Peter Grathwohl has a wide research scope ranging from basic studies on the environmental fate of organic pollutants to practical investigations e.g. in the field of waste management and groundwater remediation.

Research topics comprise studies in atmosphere-soil exchange of organic pollutants (deposition and revolatilization), leaching behavior of inorganic and inorganic pollutants from soils and recycling materials, as well as specific process investigations such as sorption mechanisms involving carbonaceous materials, sorption/desorption kinetics in soils and sediments, particle facilitated transport of strongly sorbing pollutants in rivers and karst systems and diffusion limited mass transfer in porous media in general. Practical studies address groundwater protection issues e.g. with optimum design of earthworks (roads, dams, backfills) with recycling materials.

The laboratory provides up-to-date analytical methods for pollutant analysis in water, air and solids as well as a wide spectrum of methods for characterization of environmental solids and experimental facilities for contaminant transport investigations.

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This research team lead by Prof. Dr. Stefan Haderlein covers a wide range of areas in molecular environmental sciences, especially biogeochemical processes in soils and groundwater, transformation and phase transfer processes of pollutants and development and application of analytical methods to characterize and quantify processes in pristine and polluted subsurface environments.

Reactive solid surfaces, especially minerals including redox active elements such as iron and/or natural organic matter, play a key role both in direct transformations of pollutants or nutrients as well as in defining the geochemical redox milieu. Thus, we work towards a process-based understanding of the factors that control the formation of such reactive surfaces and how such surfaces interact with natural and anthropogenic compounds.

The overall objective of our research is to provide through an improved understanding of biogeochemical key processes the scientific basis for assessment, management and remediation options of soil and groundwater environments.

For our laboratory and field studies we apply a wide array of modern instrumentation and techniques, including compound specific stable isotope analysis (CSIA), Mössbauer and fluorescence spectroscopy as well as electrochemistry, reactive tracer techniques and geochemical modeling. Current research topics include investigations on the constraints of slow biotransformation processes of halogenated organic pollutants using isotope analysis, interactions and reactivity of natural organic matter (NOM) at minerals and redox buffering by iron minerals and NOM in soils and groundwater.
The group of Prof. Dr. Andreas Kappler works in the field of Geomicrobiology. The research includes topics ranging from Environmental Microbiology, Microbial Ecology, Mineralogy to Geochemistry.

The Tübingen geomicrobiologists study microbial formation and transformation of iron minerals and implications for the fate of toxic metals and nutrients in modern environments and for rock formation on ancient Earth, in particular for Precambrian Banded Iron Formations. Electron transfer strategies of microorganisms are identified, including the importance of extracellular electron shuttling by redox-active organic and inorganic compounds. The effect of biochar on greenhouse gas emission (N₂O) in soil and on compost fertilization is determined in laboratory and field experiments.

A combination of cultivation-based and molecular techniques is used to study the ecology of iron(II)-oxidizing bacteria in terrestrial and aquatic environments including soils and freshwater and marine sediments. Minerals are analyzed by X-ray diffraction, Mössbauer spectroscopy and electron microscopy.

The binding of metals and metalloids such as arsenic, cadmium and nickel is studied in laboratory cultures, in soils, sediments, rice root environments and drinking water filters using geochemical analyses, confocal laser scanning microscopy and synchrotron-based X-ray absorption techniques. In collaboration with industry and authorities, microbially-assisted extraction of precious metals from slag produced in waste incineration plants is investigated.
We are globally faced with so-called “Megatrends”, e.g. growing pressures on ecosystems or increasing environmental pollution (EEA 2015), that affect both, the environment and ourselves.

The group on Environmental Systems Analysis headed by Jun.-Prof. Dr. Christiane Zarfl integrates human impact and ecosystem functioning in mathematical models to provide the scientific basis for management decisions that help tackling those megatrends. The research activities are thus devoted to analyzing environmental pressures, especially with a focus on freshwaters, elucidating underlying processes and identifying potential development pathways. The members of the research group deal with ecological impacts of large infrastructure, like hydropower dams, on freshwater systems, including changes in toxic cyanobacterial blooms, aquatic biodiversity and biogeochemistry. They also analyze the fate of organic pollutants and metals as well as of microplastics as a pollutant itself and as a transport vector, and combine this with effects on freshwater organisms.

Experimental investigations, also in cooperation with other research groups from the ZAG and from other institutes, are complemented by different modelling approaches ranging from mathematical models to Geoinformation Systems (GIS). Field research is combined with controlled laboratory experiments as well as sample analytics e.g. toxin detection, molecular analysis, and microscopy.

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ENVIRONMENTAL ANALYTICAL CHEMISTRY

The research of the group of Prof. Dr. Christian Zwiener includes topics ranging from Analytical Chemistry, Environmental Chemistry to Water Treatment.

A focus of the group of Environmental Analytical Chemistry is on organic micropollutants and their occurrence and fate in the aqueous environment and in water treatment. Analytical screening and multi-residue methods are mainly based on gas (GC) and liquid chromatography (LC) coupled to high- and low-resolution mass spectrometry (MS). Electrochemical approaches are applied in analytical and water treatment applications. Compounds of interest are pharmaceuticals and personal care products, pesticides, industrial chemicals and disinfection by-products, as well as their transformation products and metabolites formed in environmental and water treatment processes.

Non-target screening approaches based on accurate mass measurement by LC-Quadrupol-Time-of-Flight-MS and data evaluation algorithms are developed to enlarge the analytical window for the detection of the anthropogenic impact on water quality. The major attenuation processes are considered in rivers, groundwater and water treatment (e.g. photolysis, biodegradation, oxidation, sorption). Unintended contaminant recycling due to the application of fertilizers produced from organic biowaste and sewage sludge are traced back. Micropollutants are also used as indicators for transport and transformation processes in surface and groundwater (e.g. impact of sewer leaks on groundwater). Electrode surfaces and electrochemical processes are optimized to support identification of metabolites and transformation products by LC-MS. The occurrence and minimization of halogenated and oxidized disinfection by-products are investigated in swimming pool water and drinking water (e.g. trichloramine exposure). New active membrane materials based on carbon nanotubes and metal nanoparticles are developed for analytical and water treatment approaches. Collaborations are with authorities, industry partners and various disciplines of environmental sciences, toxicology, engineering and epidemiology.
LABORATORIES

The modern and state-of-the-art laboratories of the Center for Applied Geoscience allow trace and routine analytics for organic and inorganic contaminants in water, soil and air. Besides quantitative analysis of nonpolar organic compounds and the sensitive compound-specific isotope analysis more and more polar and ionic organic compounds are in the focus of our research.

Our laboratories provide equipment for anaerobic and aerobic environmental microbiological research including the application of modern microscopy, molecular biology, genetic and omics techniques.

Another focus of our analytical equipment is the characterization of porous media (nano-) particles and the determination of soil and rock properties in our geophysical, hydraulic, and soil mechanical labs.
At the Center for Applied Geosciences a large variety of state-of-the-art field equipment is operated for advanced site characterization and environmental monitoring. Beside routine applications, the equipment allows for physical and chemical, high-resolution investigations of complex subsurface environments and their interaction with surface water. The modern equipment offers unique possibilities for the development of new approaches for environmental monitoring and investigation in the framework of our research, and the instruction of students with latest field devices.

The field equipment includes a Direct-Push probing unit, a large number and variety of hydrogeological test devices such as high- and low-capacity pumps, flowmeters, optical pressure transducers, and equipment for different types of tracer tests (salt, dye and heat). For environmental monitoring automated monitoring networks, sampling devices, and meteorological stations are available. Also, geoelectrical, seismic, and borehole logging methods are in use for geophysical subsurface characterization.
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