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2/2006 ► Top Priority: Innovation ► No Snow on Kilimanjaro? ► Diving Underwater With Sea Turtles ► On Board the Maria S. Merian ► How Our Climate Is Influenced by Soils ► Behind the Façade of Saint Mark's

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In this issue

Research on Kilimanjaro

Africa's highest mountain provides a habitat for fascinating plant communities. The montane forest belt, with over 1,200 plant species, including more than 100 ferns, has the greatest biodiversity on the mountain. However, more and more of the forest is disappearing due to forest clearing and fires, and the entire ecosystem is under thread from climate change.
Page 4

The Maiden Voyage of the Maria S. Merian

The new research vessel, the Maria S. Merian, which is capable of navigating the edges of the polar ice cap, headed for the northernmost reaches of the Baltic on its maiden voyage, allowing the oceanographers on board to take samples in a wide variety of locations. The various samples of ice, water and sediment were analysed by an international team of researchers while still on board – yielding fascinating new insights.
Page 13

Tracing the Origins of St Mark's Basilica

St Mark's Basilica in Venice is one of the most famous buildings in the Christian world. Architectural historians have used various methods to peer behind its façade, enabling the complex history of this ornate building to be put together like the pieces of a puzzle and understood. **Page 16**

Commentary

Arend Oetker
Top Priority: Innovation . . . . p. 2

Life Sciences

Andreas Hemp
No Snow on Kilimanjaro? . . . . p. 4

Sandra Storch
Diving Underwater With Sea Turtles . . . . p. 10

Report

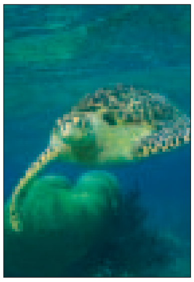
Anja Neutzling
Ob Board the Maria S. Merian . . . . p. 13

Engineering Sciences

Manfred Schuller, Karin Uetz
Behind the Façade of Saint Mark's . . . . p. 16

Natural Sciences

Ingrid Kögel-Knabner, Margit v. Lützow
How Our Climate Is Influenced by Soils . . . . p. 21



Understanding the Behaviour of Sea Turtles

Hawksbill turtles lay their eggs on beaches and spend the remainder of the time underwater. New studies shed light on their diving habits and their marine way of life. (Page 10)
Cover: Solvin Zankl

Impressum

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Dr. Arend Oetker

Top Priority: Innovation

Germany needs interaction between science and business as well as an advocate for basic research – an independent view

The dependence of the performance, productivity and competitiveness of companies, regions and even national economies on research and development is more or less a platitude nowadays. This has in fact always been the case, but the rate of technological progress has accelerated significantly in recent decades. The cycles of innovation have become drastically shorter. The relationship between basic and applied research has changed. The route from an initial idea to a finished product has become shorter, but at the same time more complicated. In the past, people believed that the development from a new discovery to a marketable product followed a straight path. A publicly funded researcher discovered something, a research and development employee working for a company would then turn it into a product, which was then marketed by the marketing department and sold by retailers, generating profits for the company.

Nowadays we know that the process of innovation is a two-way street, that the creation of value can only take place in a productive and appropriate manner from a repetitive process involving a multitude of interrelationships and knowledge transfer between every member of the chain. In this spirit, industrial companies want to play their part to make Germany a more innovative country. The "Stifterverband für die Deutsche Wissenschaft" has, as a joint initiative of German industry to promote science, set itself this objective as a priority under the slogan "Processes of exchange between academia and industry" ("Austauschprozesse zwischen Wissenschaft und Wirtschaft"). The Villa Hügel Discussion in November 2006 will be on the topic of cluster strategies and management of networks between academia and industry. Traditionally the Stifterverband holds a meeting for leaders from science, industry and experts on science policy at Villa Hügel in Essen every two years in the late autumn, where they debate fundamental issues of science, innovation or education policy.

Through these debates, the Stifterverband hopes to break down barriers between industry and academia, which still make it very difficult to transform outstanding ideas into marketable innovations in Germany. Following the example of the British *Lambert Review* of Business-University Collaboration, the Stifterverband and the DFG intend to appoint a group of renowned experts to conduct a review of the entire system of cooperation between publicly funded research institutions and industry in Germany. This, it is hoped, will identify deficiencies and put forward recommendations for creating more innovation-friendly conditions.

Richard Lambert, former editor of the "Financial Times" for many years and a renowned expert on innovation, wrote a widely acclaimed independent review of business-university collaboration in the UK commissioned by the British Government. In his review he concluded that, in order to increase innovation, the biggest challenge lies in stimulating the demand by business, rather than in a need to increase the number of innovative ideas generated by universities. If the same were to apply in Germany, then there can essentially only be one response: Innovation has to be given top priority by business and industry. Only if the direction is set from the very top will everyone within a company realise that less spending on research in the present means less innovation in the medium term and potentially the demise of the company itself in the longer term.

And the same applies in politics as it does in business. Here, again, innovation has to take top priority. The most logical step would be to bundle all research and innovation policy-making in a single, powerful Federal Ministry for Innovation, which would unite the various responsibilities that have so far been distributed between the Federal Ministry of Education and Research (BMBF), the Federal Ministry of Economics and Technology (BMWi) and the Federal Environment Ministry (BMU) and even such entities as the German Foreign Office (Auswärtiges Amt) and the German culture minister. Naturally, changing the responsibilities of ministries is a tricky business. For this very reason the Stifterverband recently recommended that the main guidelines for research and innovation policy should be drawn up, coordinated and consolidated at cabinet level. This recommendation is now to be put into practice, with the foundation of a council for innovation, which will advise the Federal Chancellor.

However, publicly funded research is also facing new challenges. The issue of the future course of the DFG, as an organisation dedicated to funding research according to purely scientific criteria, is particularly urgent at the moment, because, as the trustee for the 1.9 billion euro Excellence Initiative, its importance within the scientific landscape has grown significantly. This is not only due to the larger sums of money involved, but first and foremost due to the greater implications of its funding approvals on the new research infrastructure and on research policy. The DFG will find answers.

The DFG ought to accept this strategic challenge and expand its funding programmes in this field, whilst maintaining its role as an independent and incorruptible advocate for basic research. Because, important though it is to increase Germany's innovative output, it is equally important to take up the cudgels for basic research. The DFG's independence from politics is its main trump card. It will never come under suspicion of following short-lived fads in research policy. It would, nevertheless, be desirable for the DFG to reinforce the aspect of knowledge transfer in a more systematic manner within its programmes, in order to raise the performance of German innovation. The DFG could, for example, increase the importance of the involvement of business in its Research Centres and in the projects, which are part of the Excellence Initiative, or it could even initiate a cluster programme which requires the involvement of corporate research. This would allow the DFG to make a significant contribution to networking between business and academic research. Economic and research policy both have a valid interest in the tax money spent on publicly funded research bearing fruit, economically. The emphasis is no longer on simply investing more money in knowledge. We need to pay greater attention to addressing the issue of how knowledge can be turned back into money.

This process requires great patience, however. The development of the laser is a prime example of this. The laser was one of the most important discoveries of the 20th century, but was also one that took a long time to bear fruit, with 43 years passing between the theoretical foundations being laid and the first laser actually being built. This period is far beyond the time span of any conceivable form of coordinated innovation planning. Hence, my conclusion is that really great innovations simply can't be planned. The state can, at best, create an innovation-friendly environment. It is therefore important for the state and business to resist the temptation to prescribe the specific topics basic research should focus on. Science can best serve society if it is allowed to aim for maximum achievement. This has to take place according to its own rules, for example through peer review by experts in the field. Because if it is impossible to predict which scientific discovery will lead to an actual innovation, and it is therefore also impossible to determine the likely innovation potential of a discovery, then it is also impossible to use this factor as a criterion for allocating funding. The DFG is thus able to assume the role of primary advocate for basic research.

Nevertheless, researchers involved in basic research should be encouraged to consider potential applications of their work – not only by means of distinctions, public recognition and other immaterial rewards, but also through financial incentives. There is also a need for more systematic and long-term opportunities for researchers and business to meet and collaborate, because innovative processes can only come about if the researcher's creative ideas and the needs of their "customers", in other words business, are combined. The American elite universities, where the campus is the hotbed of interaction, provide us with a great example of effective collaboration between science and business.

Dr. Arend Oetker

Arend Oetker is the president of the Stifterverband, an entrepreneur and a member of the DFG's Executive Committee.

Life Sciences

No Snow on Kilimanjaro?

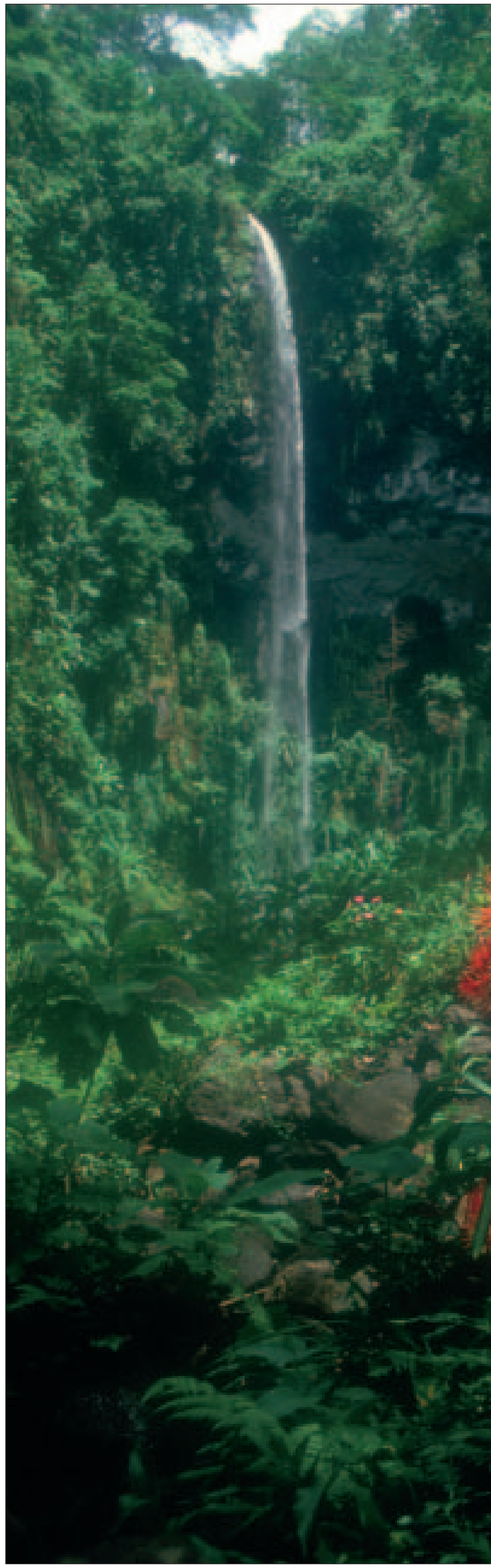
Africa's highest mountain rises majestically above the savannah. Its slopes offer a variety of habitats to fascinating flora. But the entire ecosystem is threatened

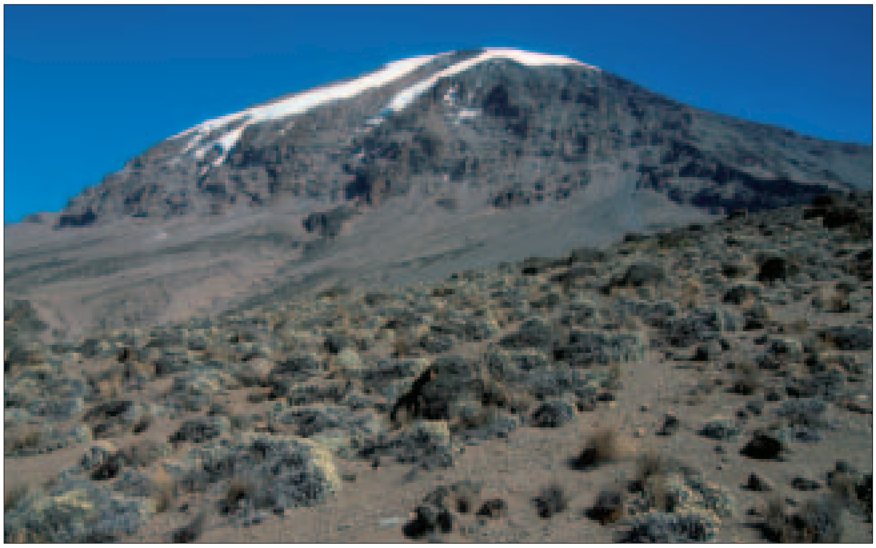
Kilimanjaro researchers can climb to great heights. The peak of this majestic volcano rises over the African savannah, protruding far above the clouds that veil its slopes every day. Since its discovery in 1848 Kilimanjaro, which is a world heritage site, has attracted countless scientists. But it was not until Ernest Hemingway's novel "The Snows of Kilimanjaro" that the "African Olympus" entered the consciousness of the world's public.

What makes Kilimanjaro so special? It is not only Africa's highest mountain, with a continuously ascending slope of more than 5,000 metres, but also one of the world's highest free-standing mountains. This is the reason why it has highly contrasting climatic and vegetation zones – from the dry-hot tropical savannah to the damp cloud forest belt to the snow covered glacier zone – that offer ideal conditions for studies of the vegetation ecology. Another characteristic of the volcano is its comparatively young age and isolated location. These raise interesting questions concerning plant geography and vegetation history. Processes of species' evolution can also be examined here. The research work carried out on Kilimanjaro by several DFG projects has been the topic of both an episode of the German television series, *"Humboldts Erben"* ("Humboldt's Heirs", broadcast by ZDF) as well as featuring in the American CNN series "Global Challenges".

The variety of habitats on this mountain contribute to its great biodiversity. In the 1,300 to 1,400 metre zone alone, in the middle of the main settlement zone of the Chagga, a Bantu people, over 800 vascular plant species have been discovered. This is all the more astonishing given the population density of more than 500 people per square kilometre. One reason for this lies in the particular form of tree gardening (agroforestry) favoured by the Chagga in their homegardens; i.e. the tree-, shrub- and herb layers are equally utilised. Wide areas of this agricultural belt resemble open woodlands with dense banana groves. This explains why so many types of forest have managed to survive. The deep river gorges represent crucial retreats for flora and fauna and thus contribute to the great number of species living in these densely populated regions. Fascinating forest remnants have been preserved at some of the especially inaccessible locations. When walking (or rather slipping) through these wet escarpment forests you can just imagine yourself in the land

Below: Fire takes hold of the vegetation on Kilimanjaro. Each year fires destroy large areas of bush and forest. The peak of Mazweni reaches 5,300 metres and is thus the second-highest mountain of the Kilimanjaro massif. The smoke shows that the forces of nature do not stop even at these heights.





With or without waterfall: The "ravine forests", with their lush vegetation, represent the repositories of East Africa's forest evolution. Today, they are amongst the threatened habitats (left). Flora becomes sparse above 4,000 metres. Almost nothing but heather grows here (above).

of the giants: Some of these tree titans achieve heights of over 60 metres. The structure and range of species in these submontane forests differ completely from the montane forests only a few hundred metres higher. They resemble more those of the Eastern Arc Mountains, a geologically ancient mountain chain in Tanzania and Kenya, which also includes the Usambara Mountains.

Beside plant species that have not been previously described, numerous other species, formerly only known to botanists from the Eastern Arc Mountains, thrive here. The remnants of forest remaining in the Kilimanjaro's deep gorges therefore represent an irreplaceable archive of East Africa's forest evolution. Looking at these lush tropical forests one can only imagine how wide expanses of the lower slopes of Kilimanjaro must have looked before intensive settlement by humans began about 2000 years ago. The future of these remnants of forest appears all the more dismal in light of the continued deforestation.

Forest relics in Kilimanjaro's deep gorges provide new insights into the evolution of Africa's forests

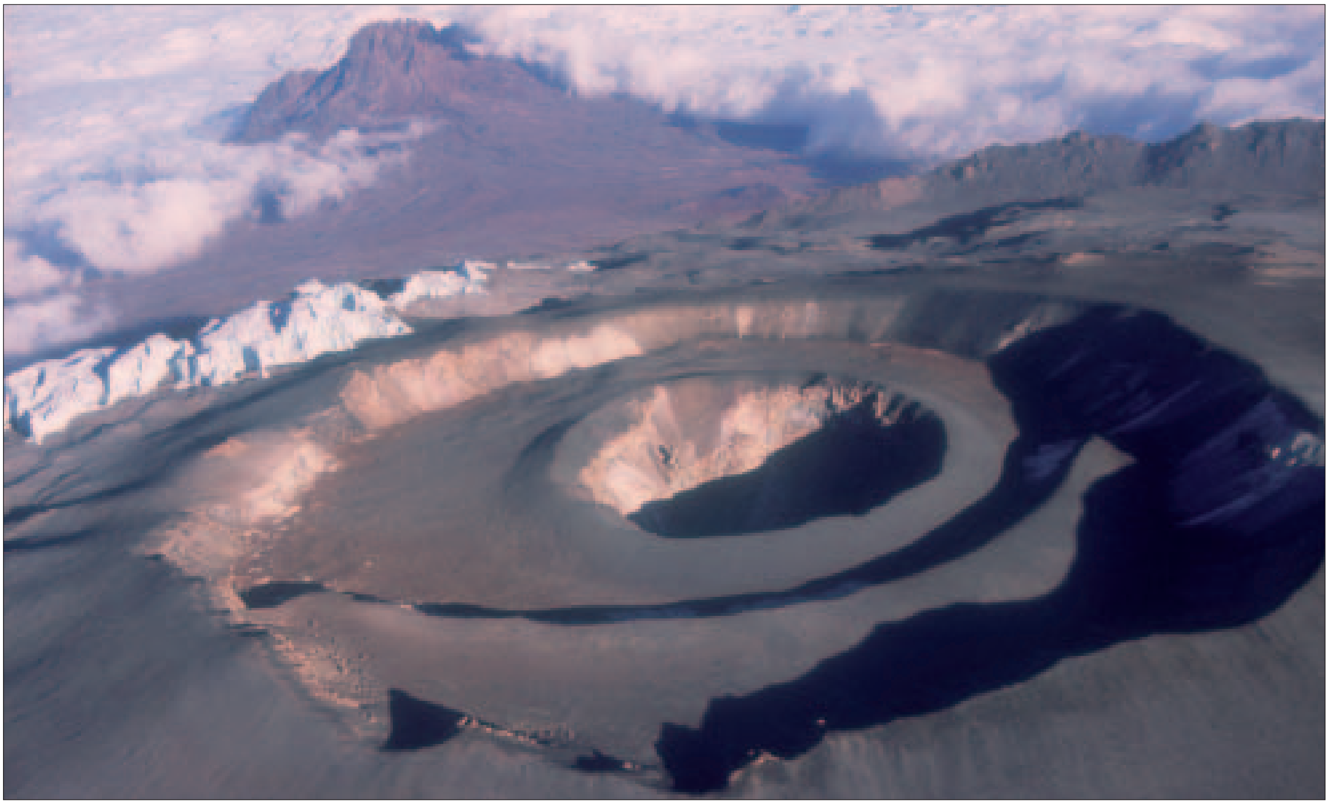
From an ecological perspective, the most important habitat on Kilimanjaro is the montane forest belt. In terms of species this is the most diverse habitat on this and on the neighbouring East African mountains, with more than 1,200 plant species, including over 100 ferns alone. For the first time in a tropical montane forest, it was possible to include all vascular plant layers in a vegetation survey. This allows conclusions to be drawn on the ecological relevance of various groups of species and vegetation layers in this complex habitat. Ferns, for example, dominate in the forests of the wet southern slope and in some places more plants thrive in the epiphytic layer than on the ground. Every branch and every trunk here is thickly covered with the swollen cushions of filmy ferns and other epiphytes, an expression of the enormous humidity in Kilimanjaro's middle forest belt. 3,000 to 4,000 millimetres of rain fall here in some places, far more than on the other high volcanoes of East Africa. This explains why the impressive camphor tree, a *Lauraceae* and reminiscent of a gnarled oak, enjoys optimal development to heights of over 40 metres and trunk diameters of up to five meters. Also widespread are humidity-loving 10 to 15 metre high tree ferns. The lack of a generally very monotone bamboo belt, typical for so many other East African mountains, has a positive influence on Kilimanjaro's species diversity. Species-rich cloud forests containing *Podocarpaceae* and tree-like *Rosaceae* are found in the upper montane belt. The forests change dramatically at around 3,000 metres above sea level: The *Podocarpus* forests transform abruptly to pure *Erica excelsa* forests – a result of fires. Forest fires play an important ecological role in Kilimanjaro's sub-alpine belt, as they do on other African mountains. During dry periods lasting several years with repeated forest fires these *Erica* forests extend down the slopes, because the giant heather *Erica excelsa* benefits from forest fires. Wetter periods, on the other hand, lead to regeneration of the *Podocarpus* forests. However, the fire risk increases with an increasing proportion of *Erica* forests because *Erica* burns easily even when fresh. This in turn reduces the chances of regeneration of the *Podocarpus* forests. The consequence is recurrent fires, which first turn the *Erica excelsa* forests to low bushland with other *Erica* species and then, assuming uniform fire intensity, degrades them to open heath – the characteristic vegetation at heights above 4,000 metres.

Current research on the Kilimanjaro presents scientific and environmental policy challenges

Research on Kilimanjaro is not only a scientific challenge; it is absolutely necessary as a matter of environmental policy in order to develop guidelines and basic principles for the sustainable use and effective protection of this susceptible mountain ecosystem. Around 100 years ago approximately 50,000 people lived on the slopes of Kilimanjaro; today they number more than one million. These figures emphasise the pressure exerted on the montane forest in particular. For this reason an aerial survey of forest damage was carried out in cooperation with the United Nations Environmental Programme (UNEP). Almost 8,000 freshly felled trees were counted, even though tree felling is prohibited in the natural montane forest. Despite this, illegal use of wood or the collection of cattle feed represents the greatest hazard to the lower regions of the montane forest. An additional hazard primarily affects the upper forest regions: the increasingly intense fires. Evaluation of satellite images shows that 150 square kilometres of sub-alpine forests have fallen victim to the flames since 1976. The total may amount to more than 300 square kilometres in the past century. Together with losses caused by tree clearing, Kilimanjaro has lost half its forest area during this time. Beside the stabilising effects that the montane forests have on both water runoff and on the soil, a further factor influences the higher regions: the ability to do what is known as fog water interception; moisture from fog is extracted from the air and thus an additional source of water. The annual loss in the hydrological balance due to the loss of this natural fog trap in the sub-alpine zone amounts to around 20 million tonnes of water. This constitutes the approximate annual water demand of the population of one million living in the vicinity of Kilimanjaro who, with their intensive irrigation system, are entirely dependent on the water from the forests.

Most of the fires are caused by human negligence. But their im-

Dramatic environmental changes: At Lake Chala (above), a crater lake, the savannah vegetation can still hold its ground, despite agricultural use. Above right: Global warming is causing the glaciers at the crater of the main peak on Kibo to melt to an ever greater extent. Below right: The tall Aloe ballyi is typical of the savannah vegetation.



pact would not be nearly as devastating without the additional climatic changes, which also cause the melting of the glaciers. In the last 100 years the annual precipitation on Kilimanjaro has fallen by over 30 percent and temperatures have increased considerably since 1976. Correspondingly, the glaciers have lost more than 80 percent of their area since the first detailed survey in 1912. Researchers expect them to disappear completely in the next few decades. Nevertheless, the effects of the melting glaciers on the hydrologic balance of the mountain ecosystem fade to insignificance considering these numbers: Less than one million tonnes of meltwater annually pour forth into the mountain's rivers. Compared to the more than 1000 square kilometres of montane forest where more than 90 percent of precipitation falls, the loss of the 2.6 square kilometre glacier is negligible.

The glacier melting cannot be halted, but something can be done about the destruction of the forests. In addition to the proper use of one approximately 90 square kilometre strip of forest at the lower boundary of the montane forest, its inclusion into the national park would appear to be beneficial. This step was decided upon after the alarming results of the forest damage survey became clear. Thanks to the improved situation of this national park in terms of personnel and financial provision, more effective opportunities now exist for monitoring the forests and for fire-fighting.

These studies show that even in tropical habitats highly disparate questions of ecology and nature conservation can be efficiently addressed using phytosociological approaches. In particular, the vegetation map produced for Kilimanjaro has proven to be an important basis for monitoring landscape changes and for supporting management of the national park. In order to understand in detail the complex ecological interrelationships climatic, pedological and silvicultural investigations can provide further contributions to the phytosociological foundation.

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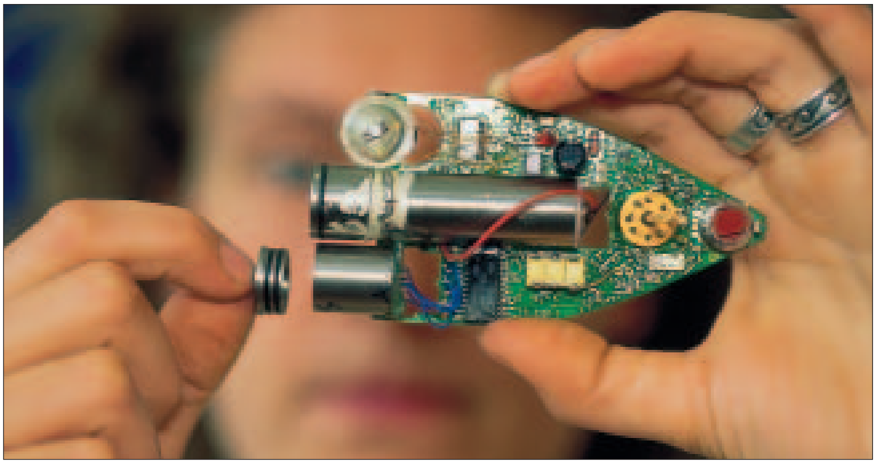
Diving Underwater With Sea Turtles

Hawksbill turtles live on inaccessible islands in tropical oceans. In order to gain insight on their diving behaviour and their marine way of life some have been equipped with modern "trip recorders"

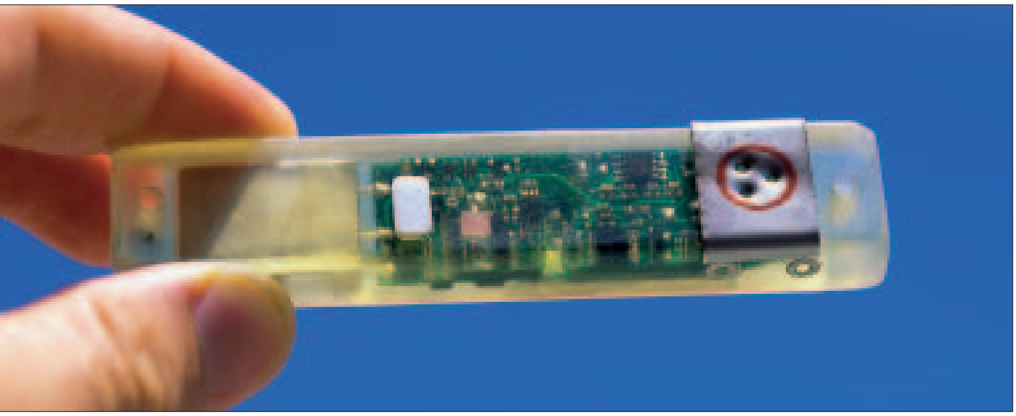
A massive reptile crawls slowly out of the water and pushes itself across the sand. The creature, which resembles a living fossil, digs a hole and lays more than a hundred ping-pong ball sized eggs, before disappearing again into the waves. This is the image that springs into most people's minds when they think of sea turtles, and was also the impression scientists had for many decades, because for years the focus was on the nesting beaches, where Archie Carr, founder of the Center for Sea Turtle Research, began his work in the 1950s for instance. Since then researchers studied the egg laying process as well as the hatching and the entire development process of the embryos in minute detail, focussing in particular on the green sea turtle and the loggerhead sea turtle, two of the most common species. By marking egg-laying females on the beach using flipper tags, scientists gradually began to obtain an overall picture of repeating cycles in the creatures' lives. Long-term studies revealed evidence of the so-called nest site fidelity which causes turtles to return to the nesting beaches where they were born. However, this land-based approach neglected the sea turtles' actual way of live. It was not until about 25 years ago that it finally became possible to indirectly observe the behaviour of the animals in the water as complex electronic instrumentation became ever smaller. In contrast to transmitter technology, which has been available for some time, but is only able to provide the isolated locations of animals which dive for prolonged periods of time, new data storage devices record chronological data sequences of factors such as the diving depth and duration, water temperature, swimming direction and speed. From a scientific and especially from a physiological point of view the sea turtles have assumed a very interesting position among the air-breathing aquatic vertebrates, since as cold-blooded reptiles they are subject to different metabolic requirements than warm-blooded seals, whales and seabirds while underwater. Up to now research on the Hawksbill turtle *(Eretmochelys imbricata)* has been sparse, because their nesting grounds are located on inaccessible, small islands in tropical oceans and because the females do not congregate in spectacular large groups in the way other turtle species do during the nesting period. This endangered turtle species, which can grow to be more than a meter long and weighs between 50 and 70 kilogrammes on average, only used to receive attention from poachers due to its colourful carapace that consists of overlapping scutes, which is highly valued as a raw material for the production of jewellery and luxury items in Japan.

Since 1998 the DFG has funded research into the diving behaviour of immature Hawksbill turtles and adult females in the Caribbean. Researchers fitted nesting females on a beach on Buck Island (an islet off St. Croix, one of the American Virgin Islands) with "trip recorders", which allowed them to record the animal's behaviour while at sea. The devices were then removed from the animals after approximately two weeks. The recordings revealed that during the two-week intervals between nesting the female Hawksbill turtles spend 95 percent of the time underwater. Most of the time the turtles lay motionless on the seabed at a depth of 10 to 12 metres. The observation that the depth of consecutive resting dives made by the turtles was often identical led the researchers to the conclusion that they must have favourite resting spots on the reef, to which they return after coming up for air. During the breeding season, during which a female lays three to five nests, the recordings usually provide no evidence of foraging. In other words, the turtles fast during these months. For the first time it was possible to demonstrate that from the 13th day after the previous egg deposition on the females become noticeably agitated at night, performing short dives between which they remained close to the surface and thus showing a clear deviation from the "normal" rest pattern. This was observed in all of the data sets obtained. The beginning of this restlessness during the nesting period can be viewed as a physiologically predetermined point in time, which appears to be associated with the maturing of the new clutch of eggs in the oviducts. However, the moment at which the eggs are actually laid can be delayed for several days by external factors, such as disturbance on the nesting beach or problems reaching the shore.

Despite the success of this study, the nesting phase only represents a small portion of the life cycle, since female adult Hawksbill turtles only breed every two to four years. To address this problem, smaller sturdy long-term measuring instruments, capable of recording data on the diving depth, light intensity and water temperature over a period of two years, were attached to selected females in 1999. This allowed more information to be gathered about the migration and diving activities between breeding periods. The evaluation of the recordings from the devices provided the first chronological diving data over a pe-



Left: The mighty Hawksbill turtle spends more than 95 percent of its life under water. Above: In order to study the diving behaviour, a "trip recorder" is attached to the turtle's carapace to collect data. It is equipped with complex electronic sensors.



Above: In good hands holding an immature Hawksbill turtle. Below: High-performance and handy: For a period of at least two years, data about the diving depth and swimming speed is recorded on miniature "trip recorders".

riod of 22 months. Rough determination of the turtles' positions was possible by analysing the light data obtained using Global Location System (GLS). This showed that all three females that were under observation had left the nest site at Buck Island in different directions after laying their last clutch of eggs in 1999. Their journeys, which lasted only a couple of days, led them to feeding grounds up to 360 kilometres away from the nesting area. The diving behaviour that is probably the normal diving pattern of Hawksbill turtles, since it occurs in a by far larger part of their life cycle, was soon observable in these feeding grounds. It consisted of a clear daily cycle, with nocturnal resting dives and active foraging during the day. Nocturnal activity is only "switched on" during the egg laying season. Active daytime dives in the feeding grounds were more diverse in terms of their depth and briefer, as the turtles foraged for sponges and polyps in the rigidly structured habitat of the coral reef. While foraging, oxygen consumption is much faster than during resting dives at night, meaning that the animal needs to come up for air more frequently. During the travelling phase more complex dive patterns than during the nesting and feeding periods were observed. The Hawksbill turtles' foraging and resting dives typically took them to the coral reef on the seabed and thus consisted of a direct descent, a constant base depth and a direct ascent back to the surface. During the journey from the reef off the shore of the nesting island to the foraging grounds the Hawksbill turtles crossed deep expanses of ocean, allowing them to dive in open water. All three turtles under observation typically dived rapidly to a depth of about 30 metres. They did not remain there, however, but gradually ascended back to the surface. A series of such dives probably serves as an energy-saving method of locomotion for covering long distances. Occasional particularly deep dives of up to 108 metres were also recorded for all three of the females during their journey. The purpose of these dives could not be conclusively determined, however. Conspicuously long periods at the surface, lasting up to 6 ½ hours, were also recorded during the migrations. These could possibly be linked to basking behaviour, which is a typical characteristic of reptiles, or may provide evidence of offshore mating with males in view of the sudden darkening registered by the light sensors.

During the field studies in 1999 the area in which the research was being conducted was hit by hurricane "Georges". This was the first time data on the dive behaviour of a sea turtle could be recorded continually during a hurricane. The turtles affected did not retain their normal pattern of resting dives, but were almost constantly in motion throughout the hurricane. In addition to this direct effect, which lasted only a couple of hours, the water temperature dropped by approximately 1°C for a period lasting several days.

The fact that this had a greater impact on the sea turtles than the acute storm phase can be seen from the analysis of the water temperature in the long-term study. During the nearly two-year period spent in the feeding grounds, the recorders on the animals measured seasonal fluctuations in water temperature of between 24 and 30 °C. The nocturnal resting dives provided an ideal opportunity to study the correlation between temperature and dive duration. By proving that the turtles physical rested at night, with the exception of the constant necessity to surface for air between dives, it was possible to rule out an activity-related influence on the selected dives and a direct association between water temperature and dive duration could therefore be recorded. During the winter, when the water temperature was low, extremely long dives were observed. When the water temperature began to rise, the animals began to surface more frequently. This behaviour is due to the increased metabolic rate resulting from the passive increase in body temperature in cold-blooded marine reptiles. By means of this indirect method it was possible to prove that a temperature increase of approximately 10 °C caused the metabolic rate to more than quadruple. Subsequently, five juvenile Hawksbill turtles were fitted with trip recorders off the coast of Mona Island, Puerto Rico. The young animals, weighing between five and 34 kilogrammes, spent an average of 97 percent of their time underwater. They displayed a very clear day-night rhythm, with strong swimming activity during the day and nocturnal resting. Due to the increase in oxygen consumption when foraging, dives during the day were significantly shorter than average night dives. Overall, the research provided important insights into the life of Hawksbill turtles at different stages of life. Their migration in different directions and across national boundaries also emphasises the vulnerability of these living fossils to modern, human influences.

Dr. Sandra Storch
Leibniz Institute of Marine Sciences at the Universität Kiel

▶ www.seaturtle.org

On Board the Maria S. Merian

The maiden voyage of the Maria S. Merian: On its first expedition the new ice-margin research vessel set course for the northernmost reaches of the Baltic

"Very nice." That was all that Professor Klaus Jürgens had to say as he closed the door of the refrigerated hold of the Maria S. Merian at about 2 a.m. on 2 March. The molecular biologist from the Leibniz Institute for Baltic Sea Research in Warnemünde (IOW) was thrilled and his eyes lit up. He had just stowed away the samples for his experiment, which had only just become accessible to him. Ice cores from the Gulf of Bothnia, which is covered by a layer of sea ice up to 50 centimetres thick for several months each winter.

The samples were taken during the Merian's scientific maiden voyage, which lasted from the 16 February until the 20 March. Researchers from the IOW and oceanographers from the Leibniz Institute of Marine Sciences in Kiel accompanied by Swedish and Finnish researchers had traversed the Gotland Sea, the Bothnian Sea and the northernmost reaches of the Baltic. The members of the expedition all agreed that the part of the expedition in the ice was the most exciting.

"Studies in the Arctic and Antarctic have revealed that the sea-ice is teeming with life," emphasises Jürgens. The ice in the Baltic has been neglected a bit in the past though – now all that is set to change, since the Merian has come on the scene. With this new research vessel, Ger-

Expedition into the ice: At -15 °C the Maria S. Merian parks in the ice-bound Baltic. Oceanographers have left the ship to take samples, while work on studying the water and sediment samples is already underway on board.

man oceanographers now have a ship that permits interdisciplinary collaboration at the highest level and with which they are capable of navigating the margins of the ice cap. This gives them the opportunity to forge into virgin territory, for instance they are now able to navigate the Bothnian Sea and the Bothnian Bay in winter, which up until now was a void from a microbiological point of view.

"We know that microorganisms breed in the channels between the ice and that they play a vital role in initiating the spring bloom, which makes them an important part of the food chain in the Baltic," he explains. Jürgens intends to segment the DNA and compare his findings with the results of a molecularbiological analysis of the Arctic ice. He already laid the foundation for this work on the Merian's maiden voyage, during which he took a large number of ice samples at a wide variety of different stations – the largest measuring 59 centimetres in diameter – with the assistance of Finnish researchers from the Finnish Marine Research Institute in Helsinki.

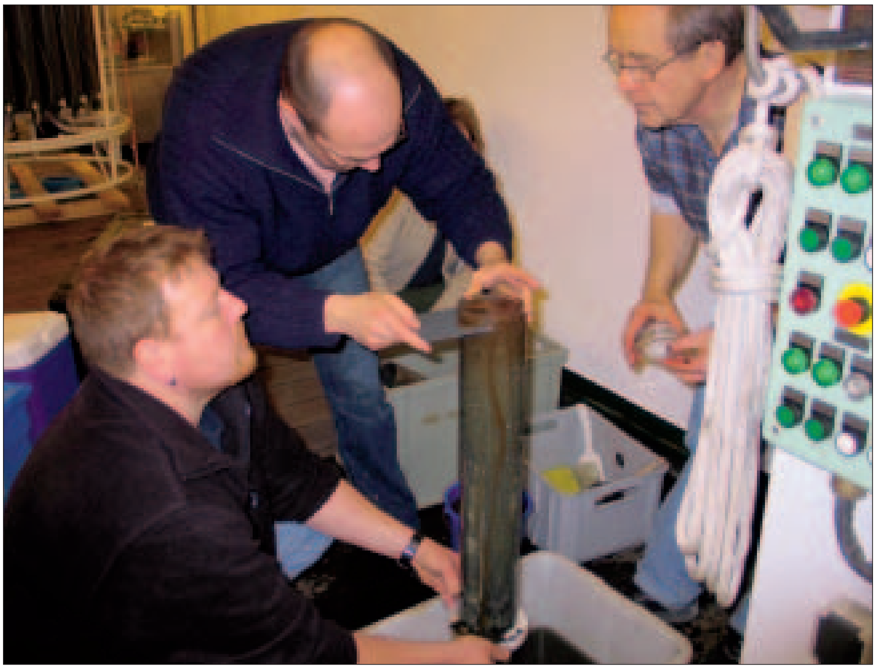
"I'm really pleased with the ship," says its captain, Friedhelm von Staa. Its innovative propulsion drives give the vessel a 360° rotation angle – allowing it to turn almost as if it were on a turntable – and to "park" accurately, with a deviation of just 50 centimetres even at wind force 6 to 7. In storm conditions the ship moves by one and a half metres at most. The Merian has a system called DP – dynamic positioning. The navigation is controlled by a computerised satellite tracking system, with commands being sent to the computer, which in turn controls the drives. The navigators on the bridge constantly monitor the navigation system to check that it is working properly.

They also maintain permanent contact with the hangar, which is the focal point of all scientific activity on the Merian. Generously proportioned, it offers ample space for all the scientific equipment and instrumentation, which needs to be stowed on the open deck on other research vessels and would freeze up in the icy temperatures of between -10 and -20 °C. They can then be slid out of the hangar and let down into the water through the side gate of the ship using one of the side booms. The cable – the connection between the ship and the equipment underwater – is wound on large winch drums. The Merian can carry up to 6,000 metres of cable, allowing work to be conducted even in the deep ocean.

"We were involved in the planning right from the earliest stages, and that was really worthwhile," explains Siegfried Krüger, head of the instrumentation group at the IOW. The Merian also has a data centre, from which you can look down at the equipment in the hangar. The highly sensitive computer controls and data transmission systems are well protected, nevertheless. Krüger also highly praises the cooperation of the ship's crew. In his opinion the fact that the sailors, the crew in the machine room and on deck and the electricians have a wealth of experience thanks to their previous work on other research vessels is really valuable. "The crew made us feel really welcome on board. Not only do they refer to themselves as being in the service of science, they act that way too," Krüger emphasises. The measurement technician was in great demand on the maiden voyage. The researchers congregate in the data centre, his main area of activity, when the CTD probe (Conductivity and Temperature with Depth), the standard measuring device in oceanography, which is used to measure changes in temperature, salinity and clouding at depth, is let down through the water column and the graphs it generates appear on the monitor. Together with Professor Detlef Schulz-Bull, who was in charge of the second leg of the voyage through the Baltic ice, the depths at which the water would be sampled at were decided upon. These water samples, taken from all manner of locations in the sea using the CTD, are in great demand. Various aspects relating to its carbon and CO_2 content, bacteria colonies and heavy metal distribution can be analysed. So the water samples taken with the CTD are taken to research labs. Thanks to a newly developed piece of equipment, the pump CTD, it is also possible to pump water directly from the sea to the on-board lab. This is very useful for Dr. Bernd Schneider's research work, for example, since his CO_2 measurements need a continuous flow of water. To date this was only possible for surface water, which is permanently sucked in and provided for experiments on most research vessels. Using the pump CTD he is now able to conduct his experiments on water from any depth.

Its propulsion drives give the Maria S. Merian a 360° rotation angle – allowing it to turn almost as if it were on a turntable

The marine chemist has been working on the CO_2 cycle in the Baltic and the exchange of carbon dioxide between the sea and the atmosphere for the past 15 years. "Carbon dioxide measurements from the Gulf of Bothnia are very scarce, and not very reliable. We need precise data though, in order to be able to calculate the total CO_2 balance for the Baltic," Schneider explains. In the laboratories – up to 21 container labs can be accommodated on the Merian in addition to the permanent lab – it is possible to work undisturbed thanks to two stabilisers which ensure that the ship's vibrations can barely be felt. "These conditions are ideal for microscopy as well as for using other analytical equipment," Jürgens explains, reporting his experience on board the Merian. This allowed him, for the first time ever, to find out before getting home to shore that the samples taken on the first leg of the voyage in the Gotland Sea contained a newly discovered bacteria population, now accompanying him on his return journey for detailed analysis on the mainland. The sediment cores, taken from the sea bed regularly throughout the voyage by



A team of researchers takes ice samples from the Bothnian Bay. The fresh holes in the ice can then be used to measure the water temperature or salinity of the water below the ice, for example. Below: A slice is taken from each layer of a sediment core for subsequent analysis in the lab.

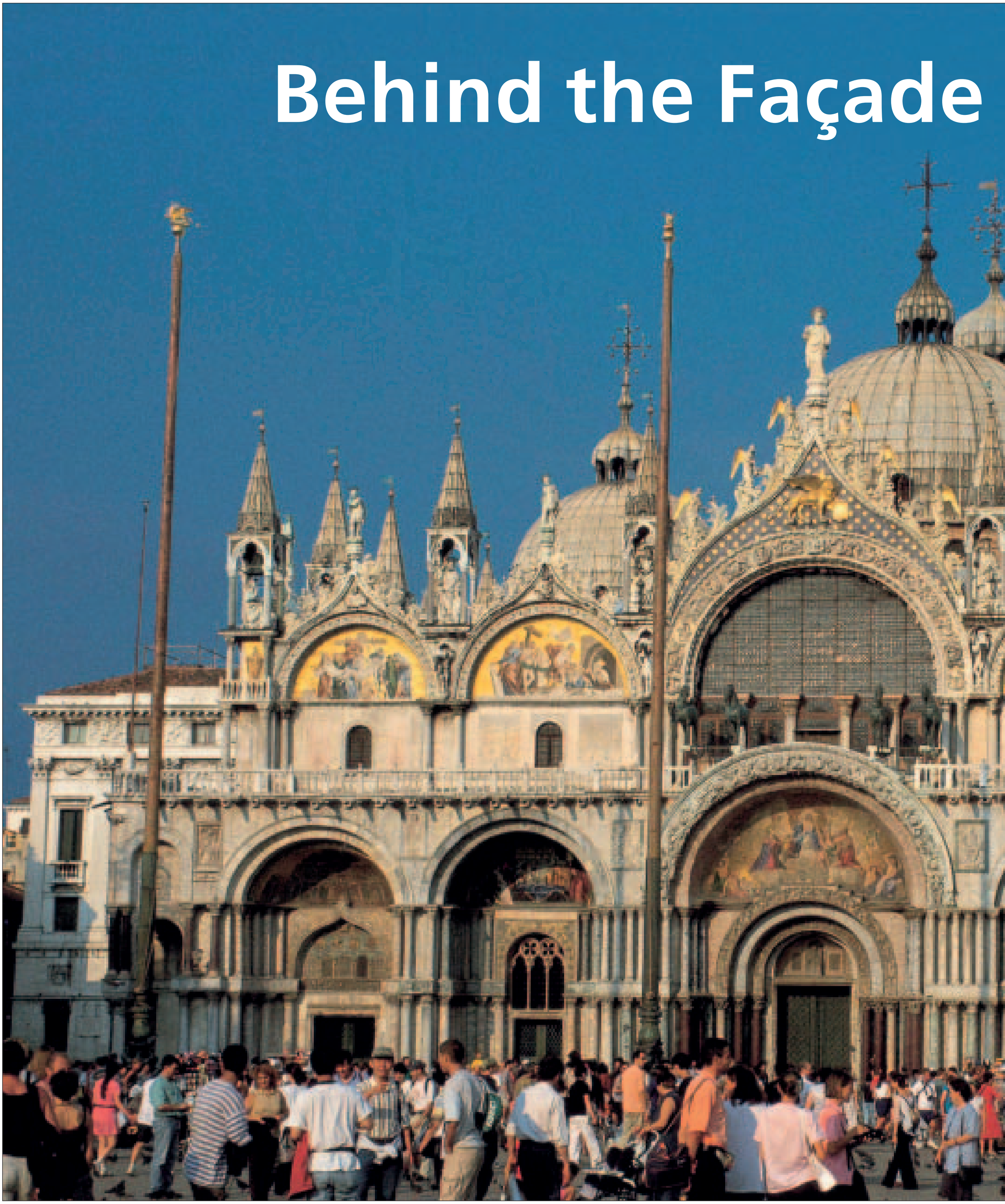
Dr. Falk Pollehne, an expert in marine biogeochemistry from the IOW, and IOW technician Uwe Hehl, using the multicorer, referred to as the Muc, are more or less just as sought after as the water samples. They usually got down to work after midnight, because before they could set to work churning up the sea bed with their high-tech machine all the water that was needed had to be on board. Otherwise the water samples would have been useless.

They were just as undaunted by the need to work late into as they were by the wind and ice. And once the Muc was hauled back on board and the various layers of sediment were immediately clearly visible then the strenuousness was soon forgotten. In any case, the Muc team was never abandoned while they worked. Members of the other research groups, such as the team from the Institute of Applied Environmental Research in Stockholm, including Dr. Christoph Humborg, were also busy until after midnight. The Swedish researchers are working on predictions of the carbon cycle between the sea and the atmosphere in view of the climate changes brought about by global warming. "We are very grateful that we were able to participate in this expedition, as it gave us the opportunity to take samples in a region which is crucial to our research in the winter," explains Humborg, who is fascinated by all the high-tech equipment on board and the opportunities presented by this co-operation. "The data gathered by just about every group on board is valuable to us, and we have encountered no problems at-all sharing it."

Anja Neutzling
Rostock

▶ www.io-warnemuende./de/miscell/merian/

Behind the Façade



# of Saint Mark's

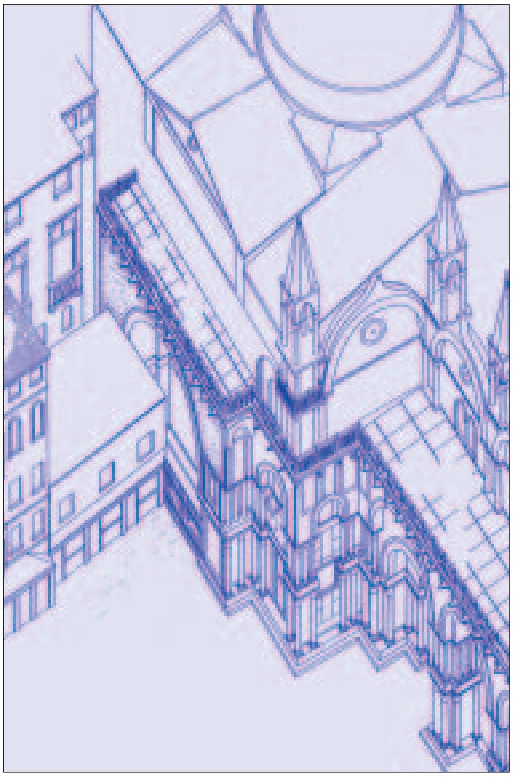
Tracing the history of Saint Mark's Basilica in Venice: Historians have carried out painstaking research into the changes made to this elaborate building through the centuries.

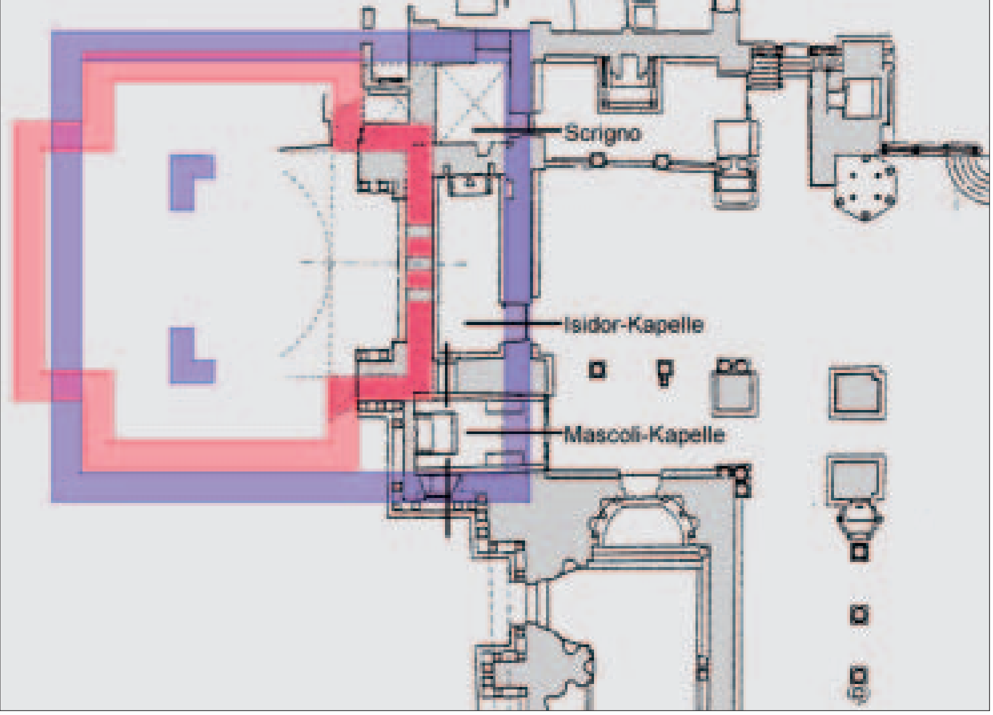
For most tourists who visit Venice, Saint Mark's Basilica appears to be a uniform work of art, a masterpiece of magnificent masonry and mosaics. But there is more to it than meets the eye. Saint Mark's Basilica has been influenced by more eras in history than any other piece of architecture in the Christian world. A large domed church was erected in place of the original church, dating from 830 AD, near the end of the 11th century, which was further worked on, expanded and restored throughout the following 900 years. The consequences of the Fourth Crusade to Constantinople in 1204 were especially dramatic. The most significant items of loot sacked from Constantinople and brought back by the Venetians were used to decorate Saint Mark's. The appearance of the church changed completely during this period: The façade was hidden behind marble columns and finely hewn slabs of stone. The original structure from the 11th century is visible through this cladding in places, but it has been difficult to say accurately how the church appeared before that time. This enigma left architectural researchers and historians with plenty of room for speculation until now.

The recent restoration of the northern façade of the basilica, including the north transept, in 2003/04, provided a great opportunity to examine the building thoroughly employing architectural research methods. Although the north façade of Saint Mark's is by far overshadowed by the renowned west façade, discrepancies in the room sequence in the area of the transept indicate that this is precisely the spot which holds the key to the entire architectural history of the basilica. The initial phase of the research work involved a precise survey and graphic documentation. This procedure, which was literally stone-by-stone, was used in order to become intimately familiar with every aspect of the architecture at hand, including details which may have appeared to be secondary at first glance. These details came together over the years, a bit like a puzzle gradually forming a recognisable picture, even if some of the pieces were missing. Initially it was necessary to differentiate between the original structure and subsequent restoration work. The researchers discovered that until 1840 the north-east wall of the church visible today had been covered by buildings dating as far back as the 12th century. Only after they were demolished was the marble cladding in the classical style completed. In other areas the façade was so thoroughly reworked in 1860 that it provides almost no information on the condition in the Middle Ages.

To the west of the transept there was evidence of the existence of a portal that was included in the 13th century marble-clad façade. The existence of this portal had previously been unknown, since it had been enclosed in 1430 during the construction of a new chapel in the transept and covered by the masonry cladding. This evidence is important, since it shows that a separate area (the function of which still remains unclear) that was accessible from outside the basilica already

Right: Until 1840 the façade of Saint Mark's Basilica to the north-east was obscured by buildings from the Middle Ages. Below: For example, the back side of a marble tablet with a relief of the monogram of Christ was found. Bottom: The reconstructed drawing of the archway shows bricks which date back to the 13th century, shaded yellow, and modern building material, shaded red.





existed in the transept prior to the erection of two chapels – the St. Isidor Chapel built in 1355 and the "Mascoli Chapel" built in 1430.

Some of the marble cladding had to be removed during the restoration process, which provided a great opportunity for the researchers, since it allowed them to study the tiles, how they were attached to the wall, and – last but not least – the supporting wall structure beneath them. The cladding consists primarily of reused material brought from Constantinople. The methods used to attach the tiles varied startlingly: At times the tiles were fixed using metal hooks, elsewhere they were simply "stuck on" with mortar. Most of the tiles are attached directly to the façade surface dating from the 11th century, however, recent masonry work was required behind the cladding in some places. The bricks used for this can be dated to the late 13th century, providing evidence that the north façade was in fact clad later than the more elaborately decorated west façade, which was already completed in 1265.

But what did the north flank of Saint Mark's look like previously? The research team once again took advantage of the "archaeological windows of opportunity" which were opened when the cladding tiles were temporarily removed. On the west façade of the transept a very hard and smooth, dark red brick dust plaster was found under the tiles. At least the north façade, but most probably the entire outer structure of Saint Mark's was not clad in "brick-look" before the 13th century, as was generally assumed in literary works, but rather was covered in a uniform coloured plaster. This has an overall effect that is distinctly different from the previously accepted perception of the 11th century appearance of the

Above: The floor plan of the lost St. Theodore Church from the 9th century: The foundation was not square, as was previously assumed, but was probably the shape of a cross. Left: The removal of the armour plates also led to remarkable discoveries: The Byzantine material used for construction was skilfully decorated on both the front and back.

The ideas for decoration were almost limitless, ranging from spiral patterns made of mosaic stones to three-dimensional busts. Right: The architectural guidelines of the past were followed rigorously when extending the north façade. Columns which had been planned (shown as broken lines) were therefore not realised.

basilica. The original parts of structure of the north façade have not yet been clearly identified. The method by which the walls are joined reveals that the current inner room sequence at the end of the transept – both chapels mentioned previously and an adjacent room to the east that is unused, the so-called "Scrigno" – is a result of the complicated architectural history. Two mighty buttresses rose from the corners of the basilica to support the vaults. According to the construction material used, the space in between had already been transformed into a succession of vaulted rooms in the first half of the 12th century. The new information gained on the area of the Scrigno, which is approximately four by four meters square and eight meter high, is especially plentiful. Its ceiling is a cross-shaped vault. Originally there was at least one more bay, in addition to the remaining intact bay to the north. The spacious, chapel-like room was most probably divided soon thereafter – probably in the second half of the 12th century – into two storeys by means of a wood beam ceiling. Its function had evidently changed. This once elaborately designed room had been turned into a storage room for the basilica. The Scrigno also leaves room for a new interpretation of the lost sister church of Saint Mark's, Saint Theodore's, dating from the 9th century, which was believed to have stood in the area now occupied by the north transept.

So far now it had been assumed that this church had an isosceles cross-shaped floor plan. It is believed to be surrounded by a closed square, so that the outer walls enclose four so-called "angle rooms". The southern arm of the cross supposedly corresponded to today's Isidor Chapel, the south-east angle room of the Scrigno. The information obtained on the development of the Scrigno contradicts this assumption, as do the newly discovered remains of a group of three windows in the northern end wall above the Isidor Chapel, which probably belonged to the façade of the southern wing of St. Theodore's. Consequently, the position, shape and size of the former church can be reconstructed with an open cross floor plan without angle rooms. Both of the impressive buttresses of the basilica connected both of the adjacent buildings, forming a "church family". However, St. Theodore's Church was soon demolished following the devastating earthquake of 1117. The research performed in the space of a year has opened a tiny window into the complicated architectural history of Saint Mark's Basilica, which provided incredible insight into the period from the 11th to the 19th century. A significant portion of the previous approaches taken by historical architectural research will need to be revised and updated on the basis of this new information. In addition to further studies throughout the construction phase, all of the archived documents, including the particularly important files about the restoration, will need to be checked in order to ensure that statements about the architectural history of Saint Mark's Basilica are indeed reliable.

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How Our Climate Is Influenced by Soils

The latest news on old matter: Four-fifths of the globe's carbon reserves are stored in its soil. Humus not only has a large impact on soil functions; it is also important in the global carbon cycle, which influences climate

Strange though it sounds, our climate is not influenced exclusively by above-ground factors; those under the earth's surface also play a role. Approximately four-fifths of the carbon resources actively involved in the global carbon cycle are bound up in soils, while only about 19 percent are bound up in vegetation. Soils are thus the largest carbon reservoir. Not only, therefore, does humus (organic matter in the soil) have a decisive influence on all soil functions; it also plays a key role in the global carbon (C) cycle and thus in the generation and regulation of carbon dioxide (CO_2), the most important climatic gas. During the biomass formation/decomposition cycle carbon dioxide is either released from our soils or is stabilised as humus. If soil is used carefully, the amount of carbon stabilised will be greater than that liberated, and the carbon will be stored in the humus for several thousands of years. Research into humus is not only of interest to science, therefore, but also, as it relates to our climate and the greenhouse effect, to politics and the economy.

The binding and liberation of carbon dioxide in soils is influenced by both the molecular degradation properties of the organic matter in the humus and by the binding of carbon dioxide to soil minerals. An additional important factor is the question of whether the humus is freely accessible to microorganisms or whether it is occluded by the soil structure (in so-called aggregates). The interplay between these mechanisms is extremely complex and there has been little research in this field so far. To be able to answer urgent questions regarding the regulation of the carbon balance in soils,

Soil samples can be examined using an HVEE Tandetron accelerator mass spectrometry system. The analyses provide precise information on the transformation processes and properties of organic soil.

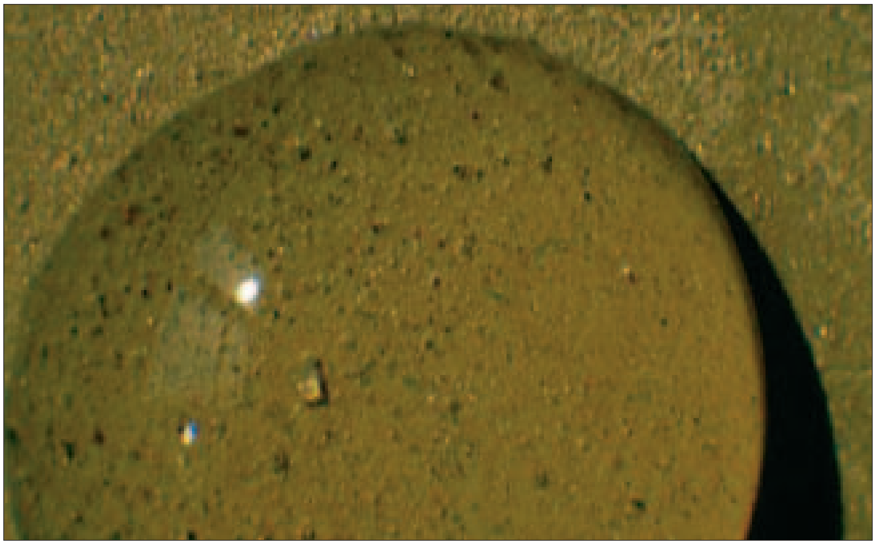
therefore, it is necessary to fully understand and quantify the diverse processes involved in the formation and decomposition of organic matter.

The Priority Programme "Soils as a source and sink for CO_2 – Mechanisms and regulation of organic matter stabilisation in soils" thus focuses on the interplay of these processes in the soil – with some surprising results.

Because most degradation processes in the ground are very slow (some take decades), well-documented, long-term field experiments and the associated sample archives proved valuable sources of information for these investigations. Researchers focused specifically on the farmed soils of the "Statischer Düngungsversuch", a long-term fertilisation experiment in Bad Lauchstädt, an area in Rotthalmünster, and the "Ewiger Roggenbau" (Eternal Rye Cultivation) experiment in Halle, which was started in 1878, while forested areas were closely monitored by the Bayreuth Centre for Ecology and Environmental Research. The scientists also benefited from the considerable progress made in the development of new humus research methods in recent years. In contrast to classical methods, soils can, for example, now be investigated in their near-natural state, without, for example, being modified through extraction with solvents. This has given rise to a completely new picture of carbon stabilisation in the soil.

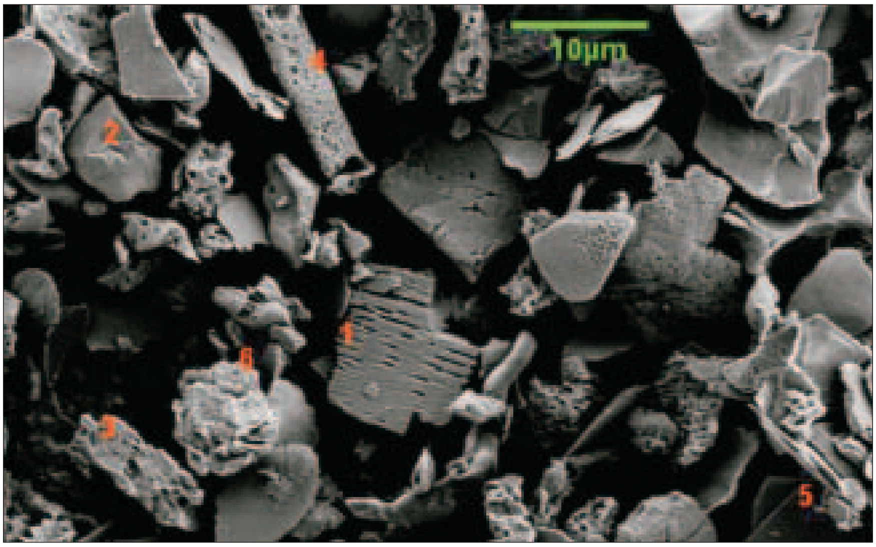
Which chemical substance classes produce stable humus? Researchers used magnetic resonance spectroscopy in conjunction with chemical and thermal decomposition methods to identify the molecular structures involved in the stabilisation processes in situ, i.e. at their site of formation. Contrary to popular opinion, they were able to show that aromatic structures, which are considered extremely difficult to decompose under laboratory conditions, are not stabilised in nature. This also applies to lignin, an aromatic substance contained in wood. Even highly-aromatic carbon particles in the soil can be utilised by microorganisms.

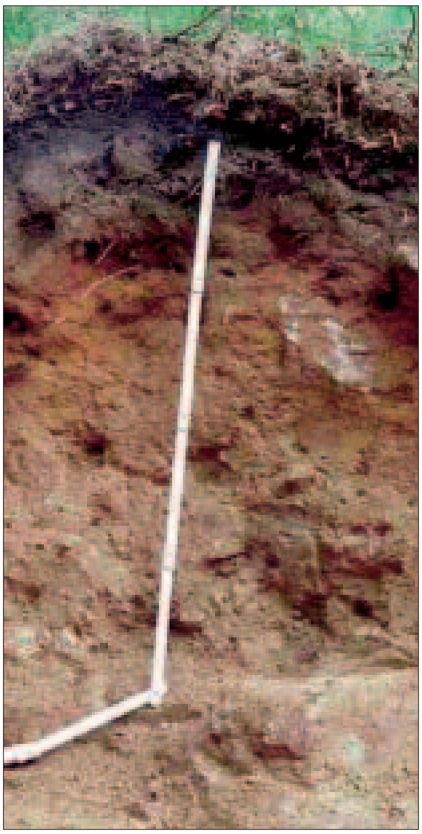
Further contrasts with hitherto existing ideas were discovered by the researchers: In addition to fats and waxes, which are difficult to decompose, compounds which were regarded as being readily decomposed, such as polysaccharides and proteins, are in fact enriched in the clay component that is, the component with the smallest particles. The unexpectedly long residence time of



A droplet of water resting on a finegrained layer of soil material, taken from above. Even small amounts of hydrophobic organic matter cause the characteristic "pearling" effect on soil particles. It would also be impossible for the water to penetrate coarser soil materials. Right: Humus can also be studied using equipment which analyses the effect of soil fauna on the turnover of organic matter in the soil.

these compounds indicates that factors, such as the degradability of organic matter, play a secondary role in long-term carbon stabilisation in soils. Active stabilisation mechanisms, including the intensive recycling of these substances by microorganisms and the restricted access of degrading organisms to organic matter in aggregates, are, in fact, more important.





A soil sample under a scanning electron microscope shows minerals with different degrees of corrosion. Left: Humus research in the field – a soil profile in the Fichtel Mountains.

Evidently, the soil matrix prevents microbial degradation by providing opportunities for organic matter to "retreat" into pores or aggregates or by creating differing degrees of binding strength between the mineral surface and the organic matter which microorganisms find difficult – or even impossible – to "crack". Separating the soil into fractions of differing grain size and density enables the plant residues and organ-mineral compounds to be studied separately. Organic matter, particularly in particle fractions smaller than 6.3 microns, has a comparatively high age of 2500 to 5500 years. Both the percentage of mineral-bound organic matter and its age increase as the soil depth increases.

While carbon concentrations in subsoils are lower than those in topsoils, subsoils still contain considerable quantities of carbon. The binding (sorption) of dissolved organic matter to iron oxides and iron hydroxides, to poorly crystalline aluminium silicates and to clay minerals is a decisive factor here. Investigations have shown that the reactivity of the mineral surfaces and their wetting properties are important parameters with respect to stabilisation. Hydrophobic surfaces, which can form due to adsorption of fats and waxes, therefore reduce access for decomposing organisms and their enzymes and favour aggregation. The decomposition rate is considerably reduced in humus-rich aggregates with a density greater than 1.6 grammes per cubic centimetre and by encapsulation in hydrophobic organic macromolecules. Other factors include the compartmentalisation of biological activity into different pore spaces, the incomplete colonisation of the soil by microorganisms and soil fauna and factors such as temperature and water content. The functions of the decomposing organisms are analysed using different methods, such as by measuring enzyme activity or by identifying and analysing the specific genes which play a decisive role in the process.

A key innovation in the applied investigation methods is the coupling of qualitative statements (process mechanisms) with quantitative statements (reaction rates). It is, therefore, also necessary to quantify the humus turnover in on-site analyses. Because plants such as wheat and maize (so-called C3 and C4 plants) have different carbon isotope contents, a measurement of the isotope ratios in soils on which the vegetation is changed from C3 to C4 plants enables the carbon residence time to be determined and the carbon turnover to be modelled.

Future interdisciplinary cooperation will allow a better understanding (and, more importantly, quantification) of the complex processes which govern carbon stabilisation in the soil. At the same time, the key processes must be identified and both the relationships between the soil properties and soil fractions and their turnover elucidated. The results will form the basis for the Priority Programme's primary objective: the creation of a conceptual model which includes the key processes involved in stabilisation and their effectiveness in various soils.

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The Deutsche Forschungsgemeinschaft

The DFG (German Research Foundation) is the central self-governing organisation responsible for promoting research in Germany. According to its statutes, the DFG serves all branches of science and the humanities. The DFG supports and coordinates research projects in all scientific disciplines, in particular in the areas of basic and applied research. Particular attention is paid to promoting young researchers. Researchers who work at a university or research institution in Germany are eligible to apply for DFG funding. Proposals will be peer reviewed. The final assessment will be carried out by review boards, the members of which are elected by researchers in Germany in their individual subject areas every four years.

The DFG distinguishes between the following programmes for research funding: In the *Individual Grants Programme,* any researcher can apply for financial assistance for an individual research project. *Priority Programmes* allow researchers from various research institutions and laboratories to cooperate within the framework of a set topic or project for a defined period of time, each working at his/her respective research institution. A *Research Unit* is a longer-term collaboration between several researchers who generally work together on a research topic at a single location. In *Central Research Facilities* there is a particular concentration of personnel and equipment that is required to provide scientific and technical services.

Collaborative Research Centres are long-term university research centres in which scientists and academics pursue ambitious joint interdisciplinary research undertakings. They are generally established for a period of 12 years. In addition to the classic Collaborative Research Centres, which are concentrated at one location and open to all subject areas, the DFG also offers several programme variations. Transregional Collaborative Research Centres allow various locations to cooperate on one topical focus. Cultural Studies Research Centres are designed to support the transition in the humanities to an integrated cultural studies paradigm. Transfer Units serve to transfer the findings of basic research produced by Collaborative Research Centres into the realm of practical application by promoting cooperation between research institutes and users.

DFG Research Centres are an important strategic funding instrument. They concentrate scientific research competence in particularly innovative fields and create temporary, internationally visible research priorities at research universities.

Research Training Groups are university training programmes established for a specific time period to support young researchers by actively involving them in research work. This focuses on a coherent, topically defined, research and study programme. Research Training Groups are designed to promote the early independence of doctoral students and intensify international exchange. They are open to international participants. In International Research Training Groups, a jointly structured doctoral programme is offered by German and foreign universities.

Other funding opportunities for qualified young researchers are offered by the *Heisenberg Programme* and the *Emmy Noether Programme*.

Humanities Research Centres were created in the new federal states to improve the existing research infrastructure. These centres have been established for a specific time period and serve to promote interdisciplinary research.

The DFG also funds and initiates measures to promote scientific libraries, equips computer centres with computing hardware, provides instrumentation for research purposes and conducts peer reviews on proposals submitted within the framework of the *Hochschulbauförderungsgesetz*, a legal act which provides for major equipment and the construction of institutions of higher education in Germany. On an international level, the DFG has assumed the role of Scientific Representative to international organisations, coordinates and funds the German contribution towards large-scale international research programmes, and supports international scientific relations.

Another important role of the DFG is to provide policy advice to parliaments and public authorities on scientific issues. A large number of expert commissions and committees provide the scientific background for the passing of new legislation, primarily in the areas of environmental protection and health care.

The legal status of the DFG is that of a private association. Its member organisations include research universities, the Academies of Sciences and Humanities, the Max Planck Society, the Fraunhofer Society, the Leibniz Association, the Helmholtz Association of National Research Centres, research organisations of general importance, and a number of scientific associations. In order to meet its responsibilities, the DFG receives funding from the German federal government and the federal states, as well as an annual contribution from the Donors' Association for the Promotion of Sciences and Humanities in Germany.

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Illustrations

Zankl (pp. cover, 10-12); J. H. Darchinger (p. 2); Hemp (pp. 4-9); Neutzling (pp. 13, 15): Superbild (pp. 16/17); Schuller (pp. 18-20); Nadeau (p. 21); Bachmann/Universität Hannover (p. 22 a.); Fox/Universität Gießen (p. 22 b.); Eusterhues/TU München (p. 23 c.); Kalbitz/ Universität Bayreuth (p. 23 b.); Unterstell (back).

Layout of pictures: l.: left; r.: right; a.: above; c.: centre; b.: below

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The "DFG" bus stop. The bus doesn't only stop in the Kennedy Allee in Bonn for the DFG's employees and visitors. Major scientific organisations are located all around the science centre, which is right next door.