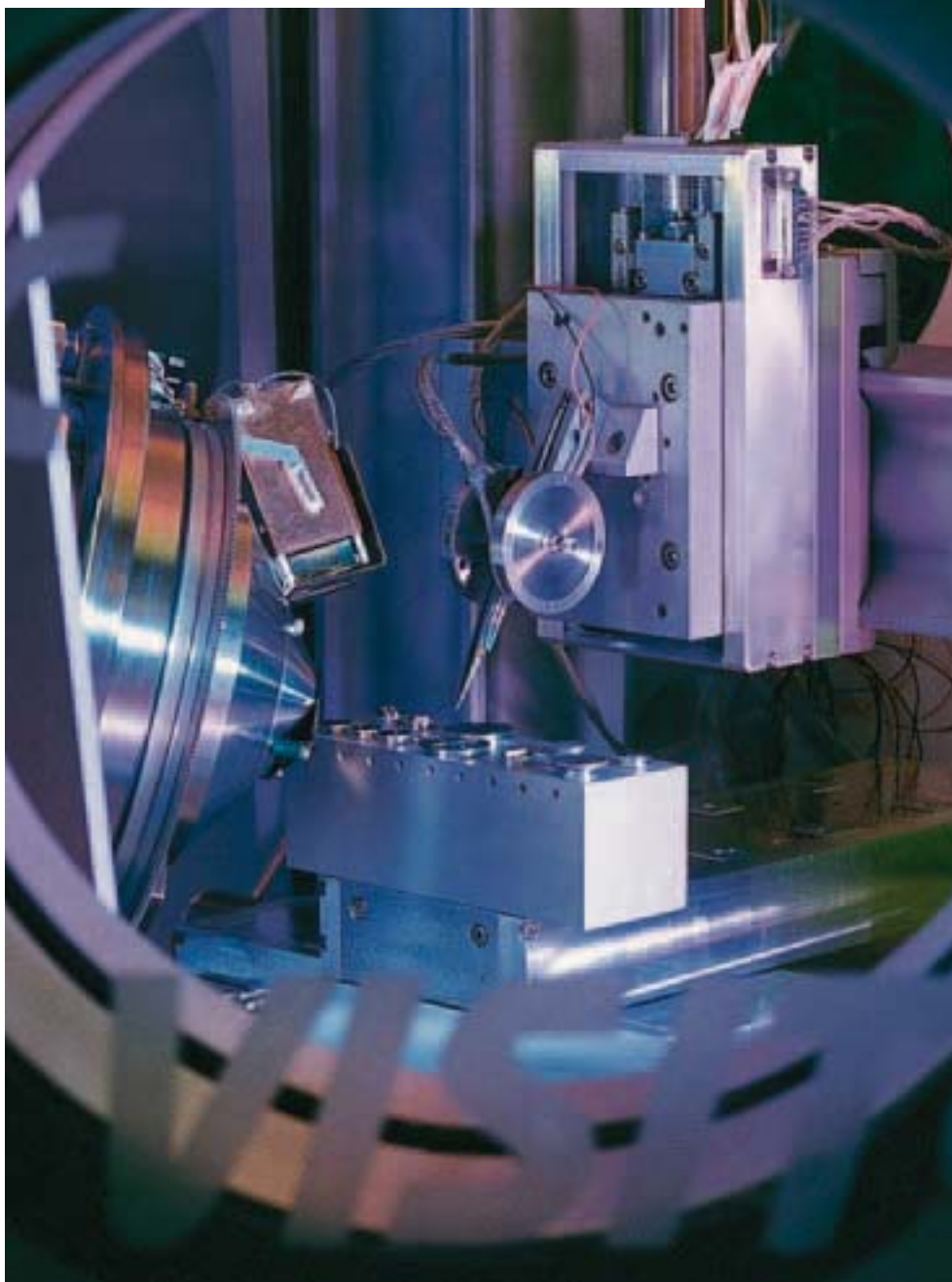


forschung

Das Magazin der Deutschen Forschungsgemeinschaft

german research

Magazine of the Deutsche Forschungsgemeinschaft



SPECIAL 2004 ▶ Peep into a Different World ▶ How a Town
Can be Created in a Test Tube ▶ Afghanistan: The Culture
of the Kafirs ▶ In the Service of the Crown
▶ When Plants Tell of Their Environment

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In this issue

When Merapi Spits Fire

Of the 129 active volcanoes to be found in Indonesia, Merapi, 2,691 metres in elevation, is the most restless. Over the past 450 years it has erupted every seven years on average. The local population is relying on scientists to improve their chances of survival after an eruption. **Page 8**

Life and Death in Ancient Egypt

Modern Egyptologists can read the mortal remains of mummified corpses of ancient Egyptians buried three and a half millenia ago like medical case histories, enabling far-reaching conclusions to be drawn regarding their contemporary society and its "health system". **Page 14**

The Fly as a Model

Thanks to its large, faceted eyes, the fly enjoys almost completely all-round vision. This makes it possible for it to perform its breath-taking flight manoeuvres. Using a panorama cinema, "FliMax", scientists investigated how the sequential images received in the fly's headlong flight are processed in its brain. This method enables biologists to gain important insights into the neuronal processes and mechanisms of image processing. **Page 28**

Content

...an Investment in the Future	p. 2	Expedition to the Volcanoes of the Arctic Seafloor . . .	p. 44
A Rose is a Rose?	p. 4	When Plants Tell of Their Environment . . .	p. 50
On the Trail of Glowing Lava Flows . . .	p. 8	Peep into a Different World	p. 55
Life and Death in Ancient Egypt	p. 14	On the Battlefield of Chiapas	p. 59
Travel Educates – Clichés Persist	p. 20	The Refuge under the Bark	p. 62
Ornamental Gothic Vaults from Computer . . .	p. 24	A Treasury in Sibiria	p. 66
In the Cockpit of the Fly	p. 28	The Loneliness of Island Life	p. 73
Afghanistan: The Culture of the Kafirs	p. 32	In the Service of the Crown	p. 76
A Climatic Archive with Hide and Hair	p. 37	How a Town Can be Created in a Test Tube . . .	p. 80
		The Deutsche Forschungsgemeinschaft	p. 84



Innovations for the Microscopic World

Microsystem technology can open up the way to new products in medicine, analysis and electronics. The aim is to combine microcomponents to form novel types of microsystem. Researchers are investigating the fundamental concepts for this. (Cover photo: IPT-Aachen)

Impressum

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In today's world, science is increasingly dependent on the collaboration of researchers, on the joining of minds and resources across disciplinary, national and cultural boundaries. Since its inception, the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) has been committed to fostering and facilitating the international cooperation of researchers. A large and growing number of research projects in Germany is conducted in collaboration with partners from other countries. Many of these projects – for instance in the fields of earth and environmental sciences – are integrated into international programmes coordinated at European and global levels. International cooperation is thus a necessary and increasingly important component of research funding and is, in fact, one of the DFG's strategic priorities.

Cooperation with international partners is encouraged in all of the DFG's funding programmes, beginning with the support of young researchers. Of the nearly one thousand fellowships awarded every year by the DFG to young postdoctoral scientists more than two-thirds are used to fund research stays abroad. The United States of America hosts the majority of these fellows. The personal experience gained and contacts made as a result of these visits form a basis for future cooperation. Another example illustrating the international dimensions of the DFG's programme portfolio are the Research Training Groups. In these university training programmes doctoral students pursue their degree within the framework of a coordinated research and study programme run by a team of university teachers. So far, 28 International Research Training Groups – a variant of the traditional programme – have been established between German universities and universities in other countries. The research and study programmes are developed and supervised jointly and provide the participating students with the opportunity for research stays at their respective partner universities. The framework of such "centre-to-centre"

collaboration offers particularly favourable conditions for the international training and mobility of researchers.

The highly dynamic developments in Europe bring about new challenges and opportunities for research and research funding. The DFG is firmly committed to contributing to the realisation of a European Research Area and to collaborating with European partner organisations on initiatives designed to enhance the funding of cross-border activities, support the mobility of researchers, and create joint funding schemes. A recent example for these efforts is the establishment of the European Young Investigator Award (EURYI) programme which is funded jointly by 18 national research organisations from 14 European countries. This programme offers outstanding

young investigators from all over the world the opportunity to work in one of the participating European countries for a five-year period as leaders of independent junior research groups.

In order to intensify international cooperation and networking, the DFG has established representations in selected regions of the world which are of particular significance for present and future collaboration. The Sino-German Center for Science Promotion, which is operated jointly by the DFG and the National Natural Science Foundation of China, was opened in Beijing in 2000. The DFG has recently established liaison offices in Washington, D.C., and in Moscow.

The United States continues to be a particularly attractive country for

Prof. Ernst-Ludwig Winnacker

International cooperation is becoming an increasingly important part of science and research. Therefore, the DFG is committed to fostering collaboration and exchange between German researchers and partners across the globe. Enabling scientists to work together across disciplinary and national boundaries helps tackle the world's major scientific questions and is thus...

...an Investm in



ent the Future

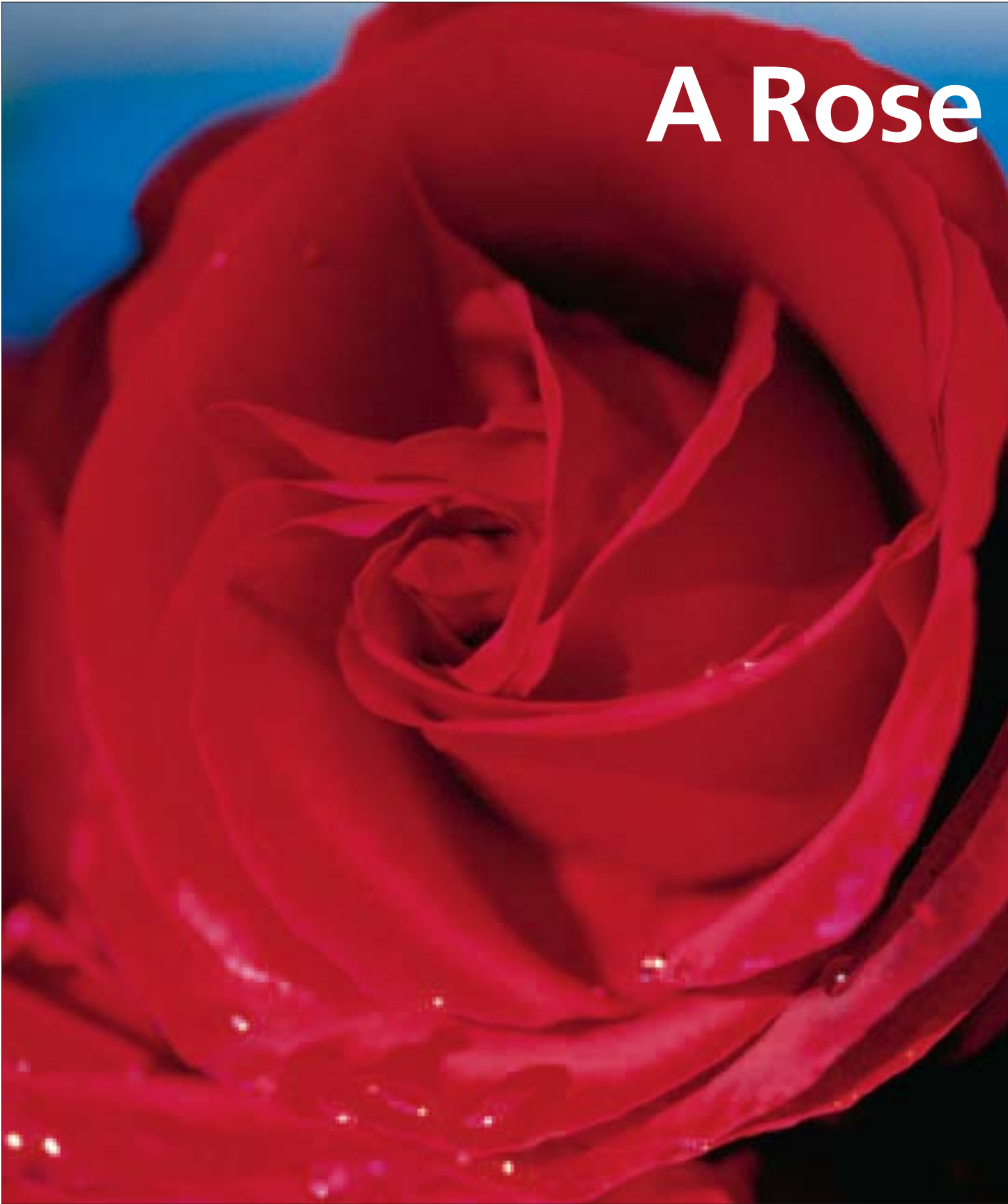
German researchers. One of the main tasks of the DFG Washington Office therefore is to support the numerous DFG fellows in the US, both with regard to their return to Germany and to opportunities for transatlantic cooperation. In addition, the office is dedicated to expanding cooperation with our partner organisations in the US, and providing information for American scientists and research institutions about opportunities for collaboration with partners in Germany. Several joint activities have been initiated in recent years. Among them are the Arabidopsis Functional Genomics Network initiative, which was implemented in close cooperation between the DFG and the National Science Foundation. Other examples include joint funding activities in the areas of digital libraries and materials science, programme networking in education research, as well as the establishment of a Transregional Collaborative Research Centre on process chains for the replication of optical elements, a cooperative effort of researchers from the universities of Bremen and Aachen and Oklahoma State University at Stillwater.

In April 2004, the first DFG Research Conference will be held in Washington, D.C., in the field of geosciences. It will be co-sponsored by several partner organisations in the United States and is designed to bring together young researchers from both sides of the Atlantic and serve as a forum for developing joint research activities.

Enabling international cooperation in research is an investment in the future, and the DFG will continue to foster collaboration and exchange between the German research community and partners across the globe.

*Ernst-Ludwig Winnacker
President of the
Deutsche Forschungsgemeinschaft*

A Rose



is a Rose is a Rose?



What everyone has always wanted to know about the sexuality of roses: study of their reproduction is primarily of benefit to plant breeders

There is scarcely any plant that has so inspired the imagination and cultural history of mankind as the rose. As the symbol of love and innocence it has acquired the role of "queen of the flowers".

For the plant taxonomist, however, it presents a totally different picture. Of the nearly 200 species of rose in the world, the group of the Dog Roses, the section *Caninae*, comprising some 30 species, are regarded by botanical taxonomists as critical plants. Although the majority of the problems involved are attributable to the specific biological, and primarily genetic, characteristics of Dog Roses, there nevertheless remains a significant portion of problems in this group which arise from their history.

The theologian and naturalist Albertus Magnus (ca. 1200 to 1280) was already able to distinguish between the thorns of a rose, which grow on the bark, and the thorns of other plants, which spring from

inside the body of the plant. He had also noticed the different form of the sepals on many roses, a feature which is still used today to distinguish the group of the Dog Roses from all the other roses. However, the scientific study of roses, rhodology, dates from the beginning of the 16th century. It was at this period that, in the wake of the botanical Renaissance, the first scientific herbals made their appearance. These books distinguish in essence between only two groups: the "tame", meaning the double, cultivated blooming roses, and the "wild" ones, the single, wild roses; both groups in their individual white and red colour variations. Up to the end of the 16th century, the "inventory of species" in these herbals continued to expand, partly through the introduction of new roses from other areas. One of the last herbals of this epoch was compiled by John Gerard in 1597. His "Herball" already contained 16 different roses, and marks

the beginning of the parting of the ways between scientific and horticulturally orientated rhodology.

The following centuries saw near stagnation in the progress of rhodology. However, as the 19th century dawned, interest in roses exploded and led to an incredible abundance of literature, which today encompasses around 6,000 titles. The growing knowledge of new species and forms in the family demanded a more comprehensive principle of classification. The start was marked in 1818 by a publication by the botanist Pyramus Auguste de Candolle. Using morphological characteristics as a basis, he divided the family into a total of eleven sections. The 19th and early 20th centuries saw the Golden Age of rhodology.

Controversy long reigned over the mode of reproduction in Dog Roses. Today, we know that they normally have a sexual relationship in which the barriers to hybridisation between the various species are only weakly marked. Roses are largely pollinated by insects, although the open flower is also amenable to wind pollination. Right: Molecular research clearly identified the "Soft-Downy rose" as the mother of a natural hybrid. The other parent originated from the Asiatic Japanese rose.

Around 1930, some 2,000 names of different taxonomic ranks for roses were in existence. In 1931, the Swiss botanist Robert Keller co-ordinated and evaluated this abundance of published names, using morphological criteria to extract those species for Central Europe, approximately 30 in number, which are still accepted today. Finally, in 1940, the most popular comprehensive system was developed as a synthesis of the numerous precursor systems. In this, nearly 200 species are listed world-wide, and the genus is subdivided on the basis of specific morphological characteristics into four sub-genera and ten sections.

Early in the 20th century, the Swedish botanist Gunnar Täckholm discovered that the group of the Dog Roses – the dominant section of the roses in Central Europe – is characterised by a unique mode of sex cell formation. All Dog Roses are polyploid, which means that they contain more than two sets of chromo-

somes; in the case of the Dog Roses, there are normally five sets of chromosomes. However, the formation of the sex cells, the gametes, does not generate cells with an identical number of chromosomes, as the egg cell retains four sets of chromosomes, while the fertile pollen grains only contain one chromosome set. This mode of unequal distribution is called "heterogamy". On fertilisation, the original five-fold

(pentaploid) state is restored, with the result that progeny from hybrids bear a greater similarity to the mother plant, as she provides 4/5 of the genotype (namely, four out of five sets of chromosomes).

The discovery of this so-called "Canina meiosis" raised two immediate questions: what had caused the appearance of such a form of reproduction and this internal genetic structure of the Dog Roses, and were organisms with such a remarkable genetic system in any way capable of sexual reproduction, or did this happen simply through apomixis, i.e. seed formation without fertilisation? Despite the fact that scientists had been able to describe the sexual reproduction of the roses as long ago as in the years 1908 to 1915, Täckholm believed in apomictic reproduction within the group. Logically, then, each individual rose bush and its progeny, having its own fate in evolution, and not participating in any genetic exchange with other individuals in the group, ought to be regarded as a "species" in itself. This led to the view that each morphological change, no matter how small, characterised a new species and had thus earned a new name, which added considerably to the flood of names mentioned above. Even today, we are not completely able to explain the biology of dog-rose reproduction, even though as preparation for this research project nearly 500 hybridisation experiments were conducted amongst wild populations, and the results published in 1997.

Mistaken understanding of the reproductive processes of roses led to the discovery of a flood of new "species"



As far as is known today, Dog Roses reproduce almost exclusively sexually, with scarcely any barriers to hybridisation between the individual species. Self-pollination is also successful, and also seed formation without fertilisation, in other words, the apomictic reproduction mentioned above.

With a view to answering the questions regarding the causes of the appearance and origins



of this type of meiosis reproduction and genetic constitution, a genetic analysis, so-called sequencing, was conducted on a section in the genome entity of the plants.

For the first time, working at the molecular level, we succeeded in detecting hybridisation both in artificial and natural hybrid roses. A hybrid is an individual produced as a cross between two genetically different parents. This process is known as hybridisation.

Our experiments revealed that all the roses of the *Caninae* section which we examined were so-called permanent hybrids. Thus the *Rosa canina*, the Dog Rose, contains four different sets of chromosomes. At the same time we were able to demonstrate that set A is not confined to the Dog Rose, but is also present in the Red (French) Rose, *Rosa gallica*, which is a member of another section, that of the *Gallicanae*. *Rosa gallica* contains, in addition, a B set, which we were finally able to identify again in *Rosa jundzillii* (Rough-leafed Rose), a member of

the Dog Roses. This confirms the thesis postulated by Robert Keller back in 1904, that *Rosa jundzillii* is a hybrid between *Rosa gallica* and a representative of the Dog Roses.

This project furnished the first-ever identification of the permanent hybridogenous constitution of the Dog Roses, and facilitated the initial characterisation of the sets of chromosomes. This will, in principle, make it possible to explain the complete phylogensis of the group, enabling statements to be made on the occurrence of, and justification for, described "species". Furthermore, the selective characterisation of individual genome elements will permit the integration of the Dog Roses and their valuable characteristics, such

as resistance to frost and disease, into special breeding programmes. Apart from their relevance for basic research, and especially for taxonomic botany, the results of this study are of great interest to plant breeders. They can in the long term lead to new breeds of enormous economic significance, and thus reforge the link between the two "horticultural" and "scientific" lines in rhodology, which were instituted by the "fathers of botany" in the 16th century when they created the division into tame and wild roses.

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*For the local population
Merapi is the "fiery mountain".
To improve their chances
of survival after an eruption,
they are trusting in a
reliable early warning system*



Natural Sciences

On the Trail of Glowing Lava Flows

Merapi, 2,961 metres high, rises out of the clouds like the battlements of some enchanted fairy-tale castle. It is the most restless of the 129 active volcanoes in Indonesia. In the past 450 years it has erupted every seven years on average.

On 22 November 1994 a large part of the viscous blocks of lava which had accumulated on the summit of the volcano Merapi started to slip. Two million cubic metres of rock cascaded into the valley. The flow of detritus was accompanied by explosions and clouds of ashes with temperatures ranging up to 700° C. A village at the foot of the volcano was destroyed, 66 people died, many hundreds suffered third-degree burns. In the days before, the seismometer stations of the Volcanological Survey in Indonesia had registered slight, but not abnormal, activity in the volcano. Scientists and the local populace were equally surprised by the eruption and by the fact that the glowing avalanches of lava flowed to the south, and not, as in previous years, to the south-west.

Merapi (lit. "fiery mountain"), 2,961 metres high, lies in central Java and is the most restless of Indonesia's 129 active volcanoes. In the past 450 years it has erupted every seven years on average. The fact that it is located in the zone where the Eurasian and Indo-Australian plates collide means that Merapi is classed as an explosive volcano. This type is found everywhere where the rigid plates forming the outer skin of the earth are forced on top of each other. On so-called "subduction" into the hot mantle, the dipping plate and its wedge of mantle become partially molten. The melts then begin to rise. On their way up their chemical composition alters until the magmas reach the earth's surface in an eruption. Should the gush of viscous lava and the unimpeded escape of gases be prevented, then the pressure inside the volcano will rise until, finally, parts of the edifice of the volcano are blown off in an explosion. Three of the world's five greatest explosive eruptions of the last two hundred years have taken place in south-east Asia: the disastrous eruptions of Tambora (1815), Krakatau (1883), and Pinatubo (1991). Apart from any local destruction, volcanic eruptions of this magnitude affect the global climate, giving rise in former times to disastrous famines.





Merapi was also largely destroyed at some time in the past by a major explosion which took a south-westerly direction. The greatest eruption in recorded history occurred in 1872. This was a highly explosive eruption accompanied by the formation of a high eruption col-

Measuring the temperature at Merapi's summit. The composition and temperature of the rising gases furnish information on the state of activity of the volcano. Below left: A seismometer in process of installation. Every article of equipment has to be laboriously transported up the slopes to the metering stations by porters.

on average once a year. Due to the dense settlement at the foot of the volcano and the farming of its flanks, even minor volcanic events can present a threat.

Systematic monitoring of Merapi began back in the thirties of the 20th century. The Dutch colonial government of that time built five observation stations on the flanks of the volcano. These were equipped with a seismograph, meteorological sensors and, in more recent times, sensors for determining the sulphur dioxide content of the volcanic gas cloud. The crucial element of this monitoring system, however, were observers maintaining round-the-



umn. Subsequent to this, the prevailing eruptive mechanism underwent a change. Today, Merapi very gradually forms a dome, a tumefaction of loosely stacked, partially consolidated, boulders of lava, which then suddenly begins to slip. Incandescent lava starts to flow at speeds of over 100 km/h into the valley. 32 of the 67 documented historical eruptions of Merapi have been accompanied by pyroclastic flows – a frequency unique amongst the world's volcanoes. At the present time, this phenomenon occurs

clock observation of the volcano's activities and reporting each change – as they are still doing today. Since the early eighties, the observation network has been extended in co-operation with research groups from Germany, France, the USA and Japan.

Since mid-1994, the GeoForschungsZentrum Potsdam (GFZ) has been building a ground observatory, which has enjoyed DFG support since 1997. A total of 18 universities and geoscientific institutes in Indonesia and Germany are partici-



On 17th January a mighty cloud rose high into the air as Merapi erupted. Despite its threatening aspect it did not cause any damage. At the present phase of activity of the volcano such explosive eruptions are the exception. Right: Scientists have erected a tented camp on the slopes of the volcano Merapi.

pating in the MERAPI (Mechanism Evaluation, Risk Assessment, Prediction Improvement) project, which aims to improve our understanding of volcanological processes, and our ability to evaluate threats and predict volcanic eruptions in the short and medium terms.

A dense network of metering stations is continually recording the parameters relevant to volcanic activities. The data are transmitted by radio to the central office in Jogjakarta. The vital parameters of a volcano's activity are volcanic earthquakes, deformations of the volcano's edifice, and changes in the gases it expels. Improved understanding of the processes inside the volcano will enable future eruptions to be predicted more exactly and reliably than hitherto, but only if we have precise knowledge of the sources of the metered signals, and if distortions, and especially those due to the weather, can be eliminated from the data.

One of the best known seismic phenomena associated with volcanoes are prolonged regular vibrations, also known as "tremors". Controversy still reigns over their origin; the most likely cause are oscillations of the magma column in the passages and vents of the volcano, similar to the noises in the pipes of heating systems. Another type are tremors with very complex seismograms, which are briefly identifiable as very flat earthquakes directly under Merapi's summit. They must almost certainly be linked to the growth of the lava dome, and are possibly generated by tearing of the brittle outer skin of the dome. Last year, for the first time, scientists succeeded in monitoring the composition and temperature of the fumarolic gases at the



summit. This world "first" was achieved through a gas chromatograph especially adapted to rough conditions.

One elementary part of the project are geological studies of the magma development and the eruptive history of Merapi. At some point in the past, Merapi suffered vast damage from a disastrous eruption. Until recently, and relying on historical sources, this eruption had been dated to 1006, and had been associated with the demise of the once flourishing Hindu culture in central Java. Dating by the carbon isotope C¹⁴, however, indicates that it took place much earlier. According to this, the greatest known eruption occurred 6,000 years ago or more. The results obtained so far are a step towards improved understanding of Merapi. The local populace, however, are less interested in its mechanism, than in predicting

The people are less interested in the mechanism of Merapi than in predicting eruptions

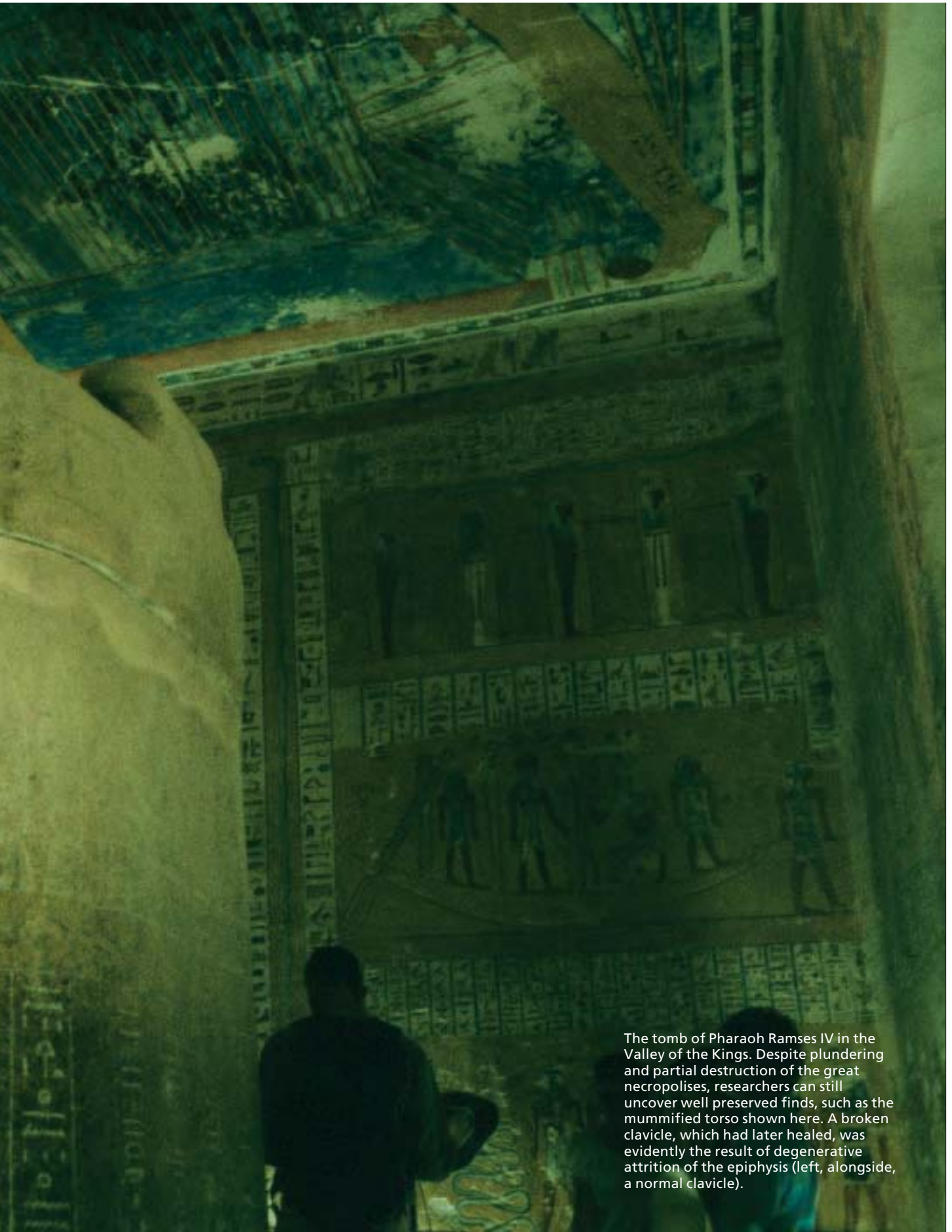
eruptions. Hence, the experiments are now to be increasingly integrated into the local early warning system. Early warning has so far been based essentially on the time lag between the beginning of an eruption and its arrival in the inhabited areas. The people have up to eight minutes to reach their shelters or to move to safe areas. Each extension of this time, maybe for erecting barriers or for early evacuation, can save lives. As the flanks of the volcano, however, are not only a lethal threat, but also, and primarily, the life-blood of the peasants, such instructions will only be complied with if the predictions are held to be soundly based.

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Life and Death in Ancient Egypt

Modern Egyptologists can read the mortal remains of mummified corpses of Egyptians buried three and a half millennia ago like medical case histories, enabling far-reaching conclusions to be drawn regarding their society and its "health system"





The tomb of Pharaoh Ramses IV in the Valley of the Kings. Despite plundering and partial destruction of the great necropolises, researchers can still uncover well preserved finds, such as the mummified torso shown here. A broken clavicle, which had later healed, was evidently the result of degenerative attrition of the epiphysis (left, alongside, a normal clavicle).



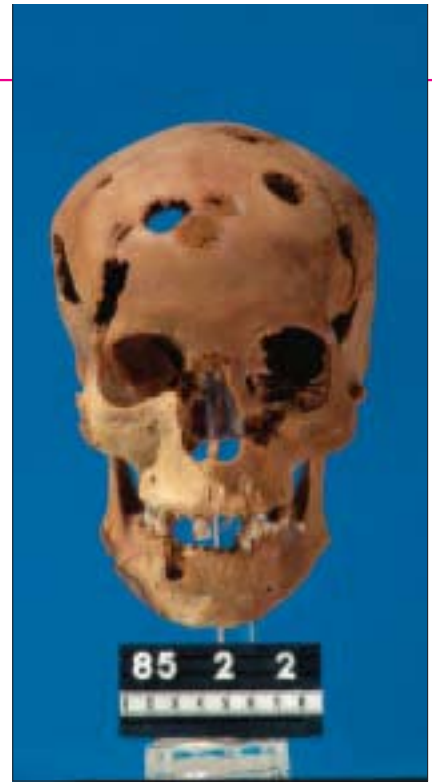


Current knowledge of the life led by ancient populations stems largely from archaeological studies, and especially from the analysis of scripts, graphic representations and the remains of buildings and other constructions. These activities furnish indirect information on the living conditions and customs native to ancient cultures which – depending on the spirit of the age and interpretation – can give rise to considerable conjecture. The precise extent to which they do in fact reflect the conditions of life must remain an open question. A much more direct insight can be obtained from examining human remains, as these reveal the physical disorders and other suffering with which these witnesses to the past were confronted. In the majority of cases, these remains consist of bones and teeth, which are comparatively immune to deterioration over prolonged periods of time.

Researchers into ancient peoples whose dead have become mummified through natural causes (hot-arid climate) or by artificial methods (embalming) have an especially easy task. In these cases, many of the remains will contain internal organs and soft-part tissue which can in individual cases furnish far-reaching information, for example, through analysis of still detectable biomolecules. Thus we can thank the religious beliefs of the ancient

Egyptians that we now have well preserved human remains dating back to around 5,000 years ago. Since 1966, an interdisciplinary team from Munich University has been examining the human remains in the great necropolis of Thebes West, in Upper Egypt, in order to discover

the composition and way of life of its inhabitants during that period, and the prevalence of specific diseases. During the “New Kingdom” (from ca. 1500 B.C.), Thebes was



The “Necropolis of the Scribes and Scholars” is cut into a rocky ridge in Thebes West in Upper Egypt. This mummy of a man aged around 35 exhibits osseous changes of the lower lumbar vertebral column with partial destruction of the anterior face. The computer tomographic examination reveals the bone destruction caused by an inflammation. Above: The disintegration of the skull of this 35- to 40-year-old woman indicates a malignant tumour. The body of a man aged 20 to 25 (small illustration, left) also exhibited bone probably destroyed by a metastasising tumour.

the capital of the Egyptian empire. The location of the burial grounds examined revealed that they were predominantly occupied by members of the upper social strata, who were presumably well provided for. Hence it has been widely assumed that the incidence of cancer would have been relatively low, although very few concrete studies have been conducted on this topic to date. The interdisciplinary approach is vital, as interpretation of the data can often only be made in the context of the Egyptological observations at the site of the find, the dating of the finds, and associated data on the social environment of the individuals interred there. In individual cases this analysis can go so far as to identify historical per-

sonages and important aspects of their lives.

The biomedical studies embrace detailed, on-the-spot, recording of every conspicuous find; this is supplemented by endoscopic examination, especially of internal skull cavities, and by x-rays and computer tomographs of selected artefacts. Furthermore, molecular biological examinations furnish supplementary information regarding specific diseases. Despite the fact that the desert climate contributes greatly to the preservation of the dead, time, and interventions by grave plunderers and predatory animals have also

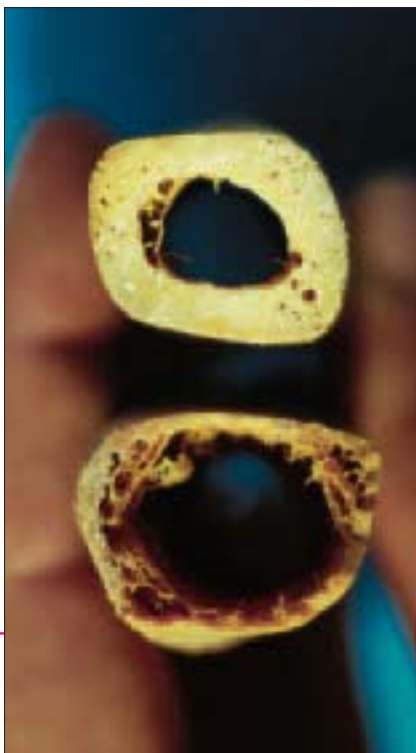
left their marks. The remains often consist of mere fragments of bone tissue. As a result, most medical finds relate solely to diseases which manifest themselves in the bones and joints.

The mean age at death of the population under study showed a maximum at between 20 and 30 years of age

The remains of over 400 individuals have so far been examined in three major burial grounds in Thebes West, of which children and adolescents, with 90 individuals, made up

around 22 per cent of the total. The mortality rate for children was found to be very low when measured against that in modern Egypt at the turn of the present century, which lay at around 60 per cent! One must, however, remember that there could have been special children's cemeteries and children's burials within the settlements. The mean age at death of the population under study showed a maximum at between 20 and 30 years of age, with a peak at around 40; in other words, a comparatively low life expectancy for the inhabitants of a capital city sporting a populace whose needs were adequately provided for. It is presumed that the distribution of the age of death for the highest social stratum in ancient Egypt, the Pharaohs, was also similar, as has been suggested by earlier examinations of the mummies of kings now housed in the Cairo Museum. Studies suggest that this could be attributable to a broad range of infectious diseases. The number of finds involving physical disorders of the most diverse kinds was exceptionally high. Thus many old bone fractures have been found where the victim had at least survived the injury. Furthermore, the effects of caries have been identified, whose diffusion had been promoted by marked abrasion of the teeth – a feature which was presumably attributable to sand in the food. Surprisingly often finds reveal osseous changes indicative of chronic anaemia, dysshaematopoiesis (disorders affecting the formation of the blood), and vitamin C and D defi-

100 years ago, examining mummies was a "social event" and lacked any great scientific value. The externally intact head of this mummified man (small illustration, above, right), raises no suspicions of a severe trauma due to a blow to the head. Only the computer tomograph revealed a gaping wound above the parietal bone – a trauma he did not survive for long. Below: Lack of bone substance (osteopaenia) is often found in Theban mummies (above, a normal, below, an affected, bone). One cause could have been chronic vitamin D deficiency.





ciency – numerous indications that the general state of health was poor. Attrition of the joints (arthrosis) and degenerative changes of the spinal column are evidence of chronic stressing and straining of the joints from considerable physical loads. The discovery of malignant tumours, especially bone tumours, furnishes evidence not only of the fact that malignant tumours occurred in the contemporary populace, but it also reveals that the frequency of such carcinomas was only a little less than it is today amongst people of the same age and sex spectrum.

Our studies also revealed individual cases of social care, nursing and medical treatment of the sick. For example, the skull of an elderly man exhibited the results of a severe fracture of the middle part of his face. This man he had survived this injury for a long time afterwards. The fact that this individual could survive this massive trauma for any length of time at all is indicative of special nursing care, for example, through the medium of a special diet. A further example of surgery is the skull of a mummy with a defect of the left parietal bone. The form and alignment of the trauma are typical of a heavy blow. The fact that the skin and bandages are intact indicates that the bone fragments resulting from the injury had been removed "therapeutically". In other words, this had been a surgical operation.

In the course of this study of pathological changes, special techniques of molecular biology were employed to diagnose diseases which would have otherwise remained undiscovered. Thus we were able to detect the genotypes of certain bacteria which cause typical syndromes, and to employ molecular evidence to detect the oldest known cases of tuberculosis. Tuberculosis was evidently much more prevalent in ancient Egypt than has hitherto been supposed, and could be (co-)responsible for the low life expectancy of the ancient Egyptians.

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Travel Educates – Clichés Persist

Do educational tours really broaden the mind? A study has revealed that they serve to entrench old clichés and prejudices

Tourism in developing countries embraces one form which is lauded for its extreme social compatibility, gentle impact on the environment and even its importance for intercultural communication – educational travel.

It is a fact that educational travel is planned by reputable travel agencies; it is very expensive and tours are conducted by German (or, at least, German-speaking) guides who have specialised in the country concerned; the participants are mostly middle class (teachers, self-employed, pensioners); most of them engage in intense preparation for their journeys, primarily by reading the guide-books.

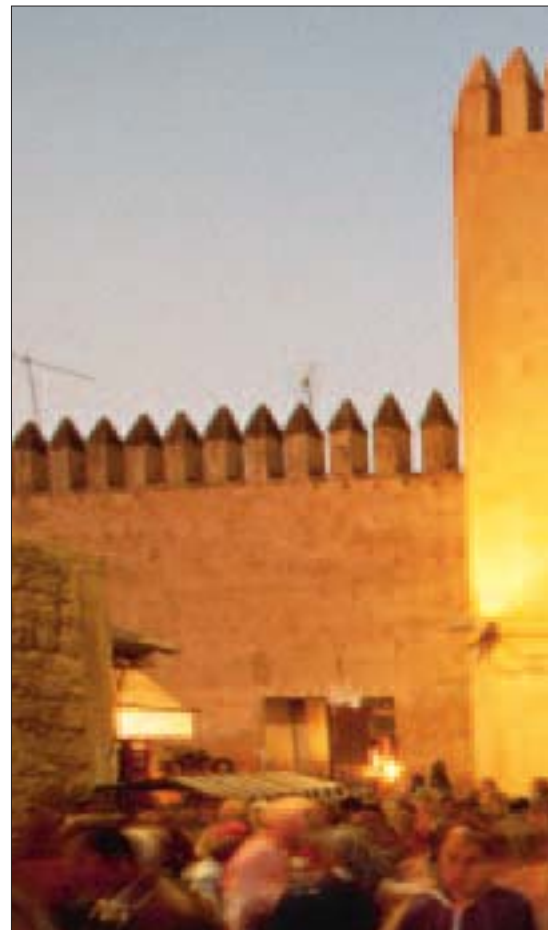
Morocco was selected as the country for an empirical study of the function of educational travel. This country in North Africa is considered to be an attractive, many-faceted tourist destination. It forms part of the Islamic-oriental cultural sphere, and so instruction in various aspects of this different cultural background in the sense of achieving closer contact, pleading for sympathetic understanding of an alien people, and even making an approach to comprehending their culture, becomes, in the ideal case, "enlightenment". A survey of just under 500 educational tourists from Germany's largest travel agency in this field was conducted in this sense prior to and on their return from their tours.

The routes followed by the travel agencies are similar and have remained almost unchanged for decades. In Morocco, they are concentrated on the four royal cities

(Rabat, Meknès, Fez and Marrakesh) and the South (Anti-Atlas, Road of the Casbahs, and the oases of Drâa and Tafilalet). Further regions of the country, on the other hand, which would be either scenically or culturally extremely rewarding, including the Rif, the Mediterranean coast, Beni Snassen, or places of economic importance such as Casablanca, Gharb, Phosphate Plateau, Oujda, and Nador, are not on offer. The dominating themes are history and the presentation of the special characteristics of natural regions of the country.



The fact that the visits made on educational tours to Morocco are almost exclusively confined to old cities and rural areas (our large photo shows the casbah in Fez) creates the impression of a living museum.



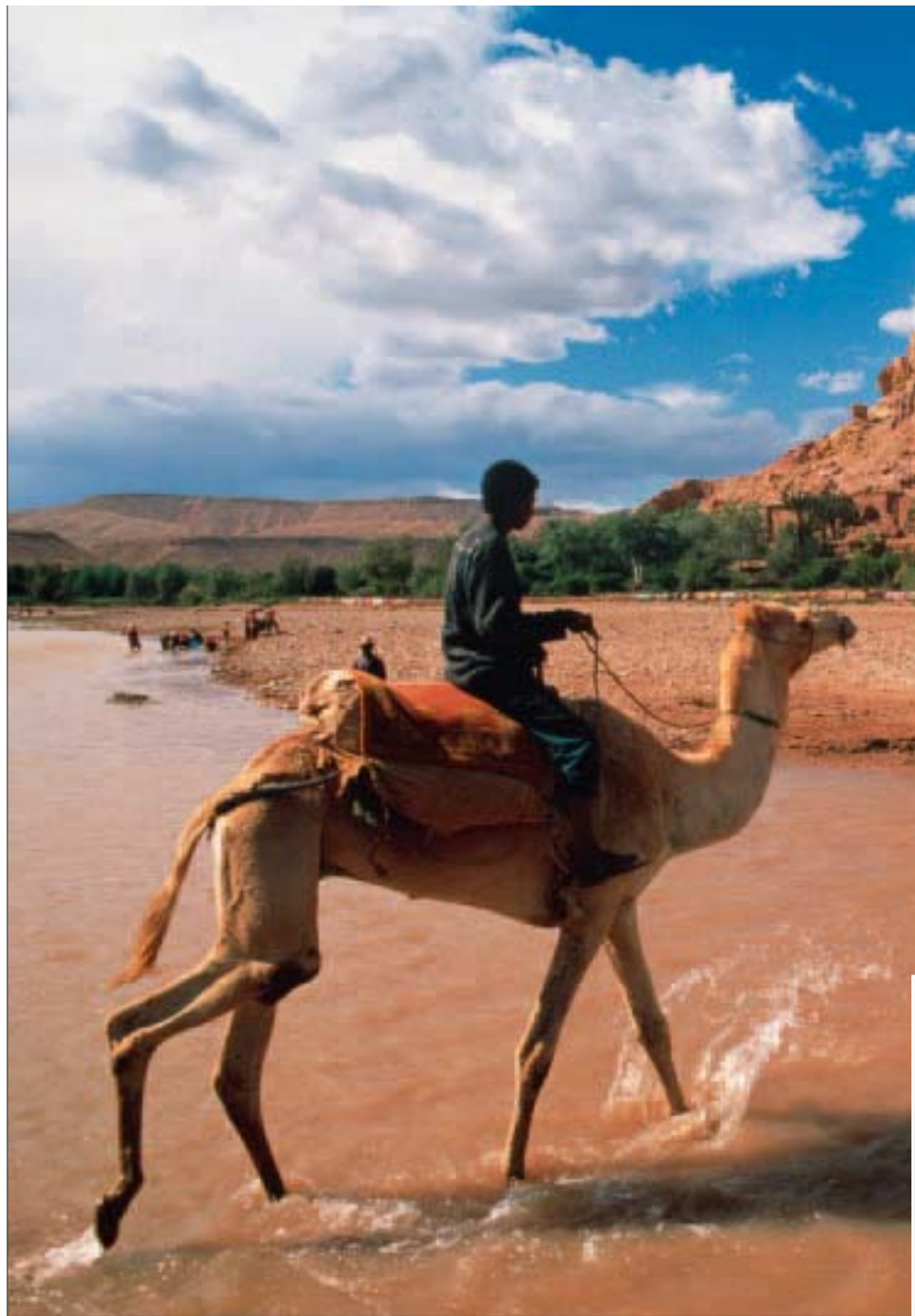


Current social, economic and political aspects are neither offered in the travel catalogues, nor do they play any important role during the tour. Educational tours provide a very selective picture of the country concerned, and do not furnish any realistic reflection of the current society. Guides tend to concentrate on traditional, even archaic, but at the same time visually perceptible, elements with picturesque, exotic and aesthetic features.

People embarking on an educational tour to Morocco harbour certain expectations: they go because they expect a qualified guide, a high level of information and strict organisation. Especially in Morocco, they expect to see bizarre landscapes (79 per cent), visit historic sites (72 per cent), acquaint themselves with art and the trades (63 per cent) and feel the flair of the Orient (60 per cent). Nevertheless, a third of them also hope to meet the people; half of them wish to experience the desert; and a quarter of them wish to learn about Morocco as a developing country.

In the course of their preparations for the tour – and over 90 per cent do prepare themselves – 90 per cent of participants rely on guide-books; compared with these, all the other media and sources of information (TV programmes, conversations with people who know Morocco, and regional literature) pale into insignificance. Thus these guide-books largely determine the extent of their prior knowledge of the country and the picture they form of it in their minds. The guide-books, the travel catalogues and the information imparted by their guide are three stars which form a framework of perception and reference for the tourist.

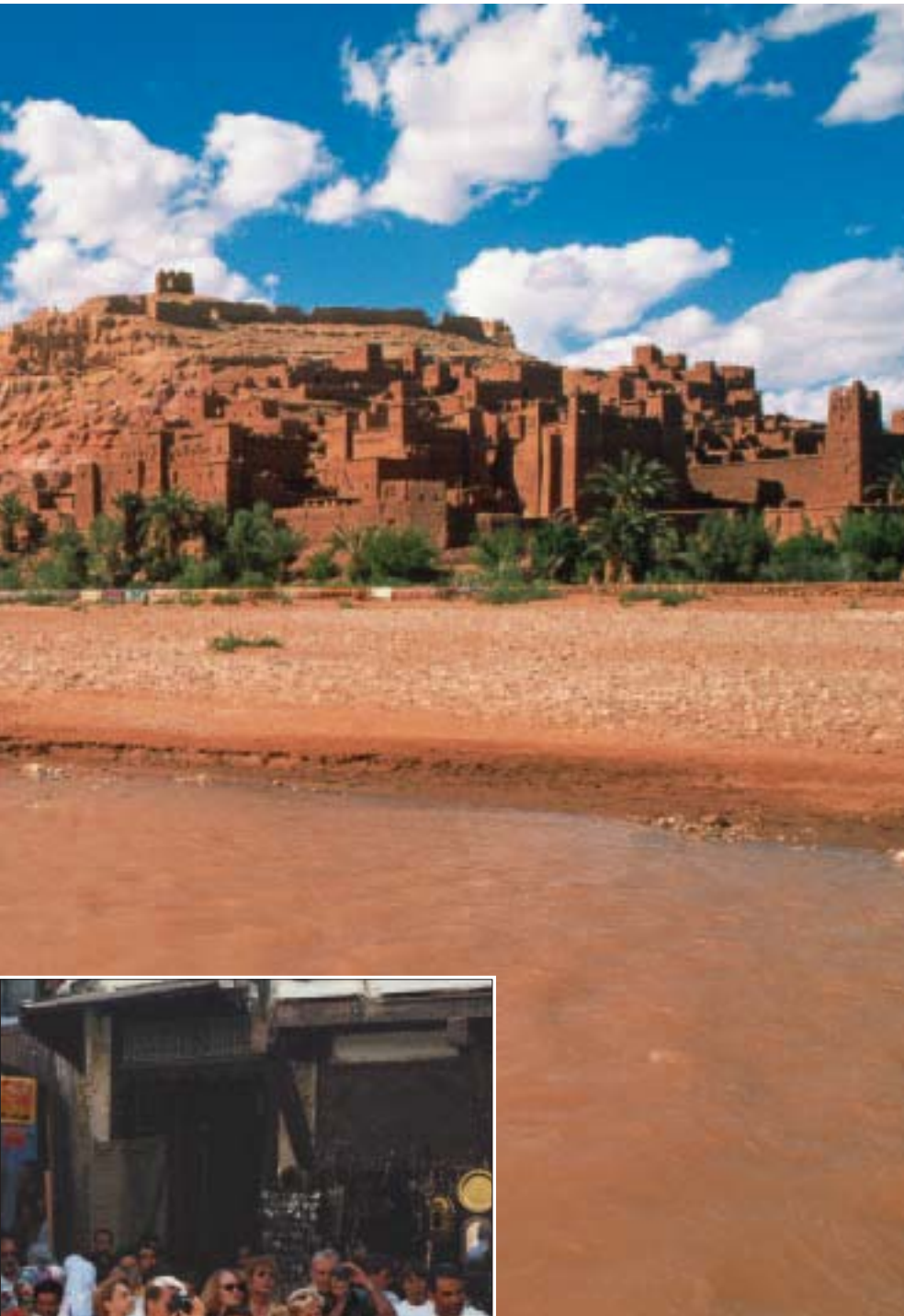
Nevertheless, before the journey starts, their image of Morocco is based not so much on any specific knowledge as on prejudices dominated by such stereotypes as Islam, desert, exoticism and ideas about alien landscapes and people. Under these circumstances impartial acquaintanceship, discovery or gaining of experience is only possible to a limited degree during the tour.



The special knowledge students have acquired will be clearly enhanced as a result of their travels. The clichés also become modified in the course of the journey, but only to a minor degree. Prejudices persist. After their tour, the travellers no longer consider Morocco a suitable place for a seaside holiday, they find it more industrialised than they had thought, and also a democratic, surprisingly clean, country, with very importunate inhabitants, where women have more rights than they had expected, and fundamentalism

is less significant than they had supposed.

Certain preconceived associations and ideas closely bound up with Morocco will be reinforced: "landscape", "traditional rural society", "poverty", "oases", "desert", "traditional and modern agriculture", "traditional forms of housing" and "elements of everyday life". The fact that visits are largely confined to old towns and rural areas creates the impression of a living museum. Associations with respect to "Orient", "Islam" and "colonial



Bizarre landscapes, historic sites (our illustration shows the casbah in Aït Ben Haddou), art, trade and the flair of the Orient – these are what the (educational) traveller to Morocco expects.

heritage", on the other hand, become weaker. These changes can also be related to the places visited. In the areas of southern Morocco inhabited by Berbers, none of the orthodox forms of Islam are to be found, and with the absence of Arab

elements, the classical associations with the Orient tend to fade. A number of pictures become confirmed in the minds of the tourists: "desert", "developing country" and "bizarre landscapes".

Hence, in the course of an educational tour clichés and prejudices already held will be strengthened. Of course, these are augmented by fresh knowledge, but this is of only secondary significance compared with the emotional contents. As a result of the journey it is primarily those aspects which will be perceived and integrated into the existent image of Morocco which do not demand any cultural rethinking, or even the making of any concessions to the alien culture. Consequently, the overall image is scarcely changed. The participants evidently only seek a dosed and controlled encounter with what is alien to them – an expectation which will be met in full by the travel agencies offering these journeys.

Should anyone be expecting to find any high claim to emancipation in connection with these educational journeys (as inferred by the travel agencies), then they will be disappointed. Are the travellers aware of how one-sided their introduction to the land and its people has been? Guidebooks, catalogues and guides each back up the information provided the others, thus inevitably creating the impression that it is correct. Just how superficial the information supplied by guidebooks on Morocco is has already been revealed in detail. Although travellers are not plied with a negative picture of Morocco, it is still nevertheless a very one-sided and frequently incorrect one.

It would be no problem at all for travel agencies to change or supplement their programmes. But demand and satisfaction are so high that there is little incentive for them to alter their strategy.

And, despite all the criticism, educational travel can compare very favourably with other forms of tourism.

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The mediaeval workshops were scenes of constant innovation, and the technological processes employed in them can certainly be included amongst the top technologies of that period. With the introduction of the late Gothic ornamental vaults a state of the art was reached which is applicable virtually unchanged even today for the performance of comparable tasks. Thus the figured ribbed vaulting found in late Gothic German architecture is undoubtedly one of the master products of the stone-mason's art. Was this sophisticated technology based on some comparable theory?

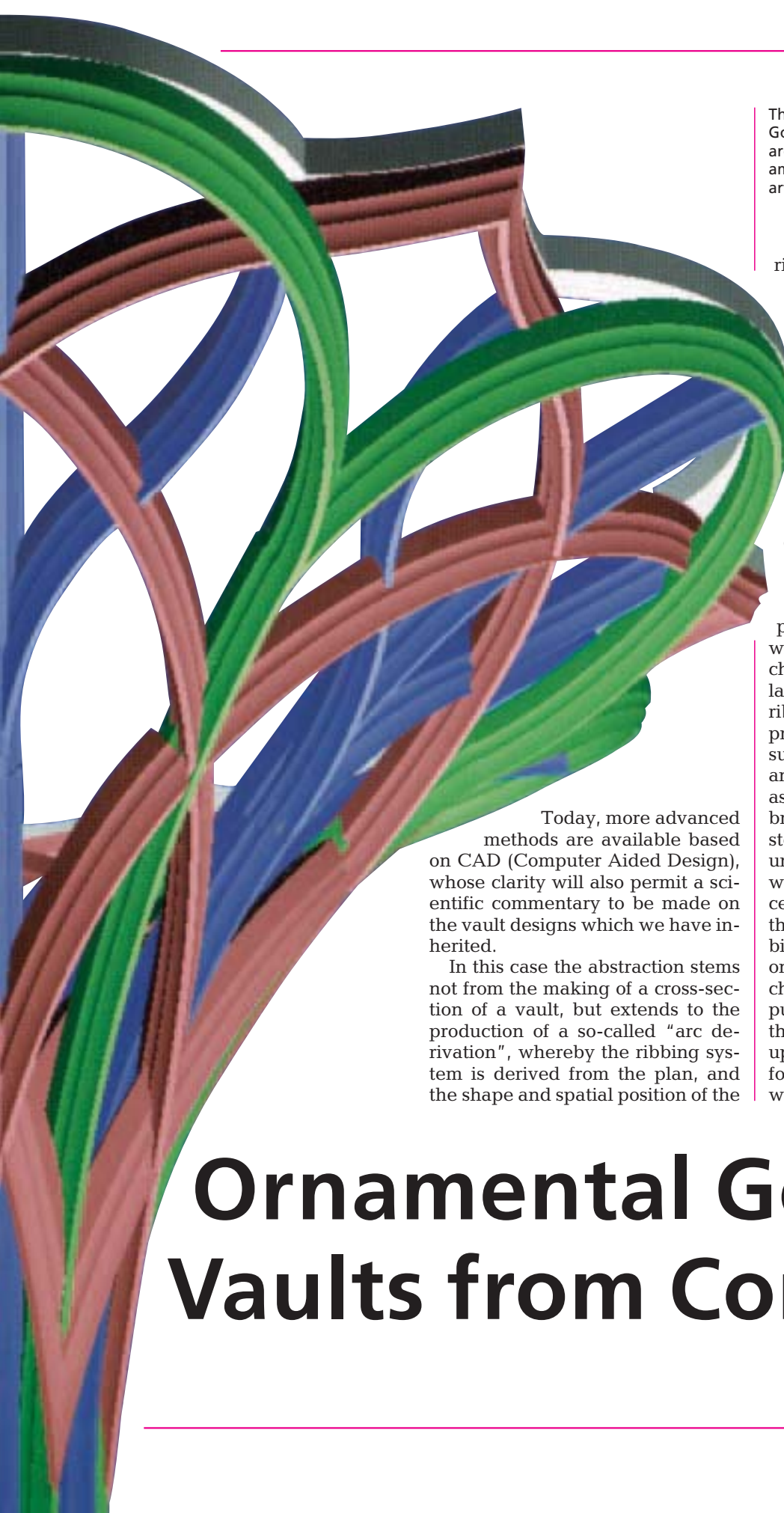
The meaning of the term "theory" has changed with the passage of time, and can acquire different meanings even within the space of a single historical epoch. Measured against the understanding of theory which arose with the Italian Renaissance, the German architects of the late Gothic had no theory. But they did possess the criteria for judging whether an architectural form had been created and shaped "in accordance with the rules". On the other hand, the production of elevations according to the rules of perspective did not form part of the teaching syllabus of late Gothic architects.

Thus it was essentially models which were employed to visualise the design of a vault. The centring models which had to be made for the master's examination in the stone-mason's guilds in southern Germany – the so-called "centring model" supported the ribbing during the construction of the building – furnished only a vague idea of the

vault from the plan view, a viewpoint of little consequence for its aesthetic impact. The architectural drawings in the contemporary sample collections exhibit such a high degree of abstraction that the result of the shaping processes they were supposed to represent could only be elucidated by actually drawing the required views or by preparing a model of the ribbing system. The obscurity of the designs can be compared to that of a shorthand text or a musical notation.

The rich and variegated ornamentation of late Gothic vaulting is based on rules now under investigation by scientists using computer simulations; in this way they are succeeding in reading the minds of the contemporary architects





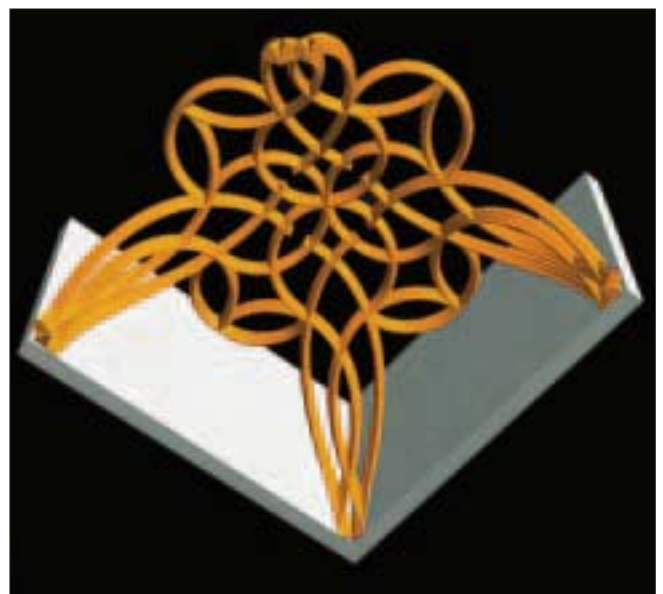
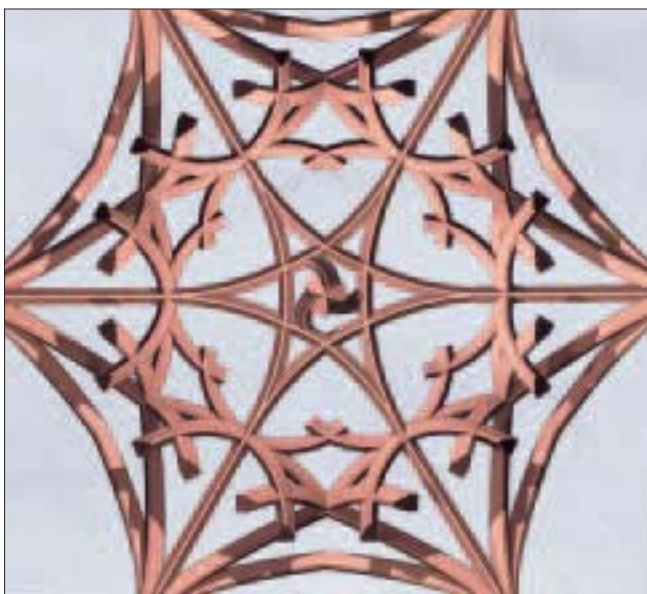
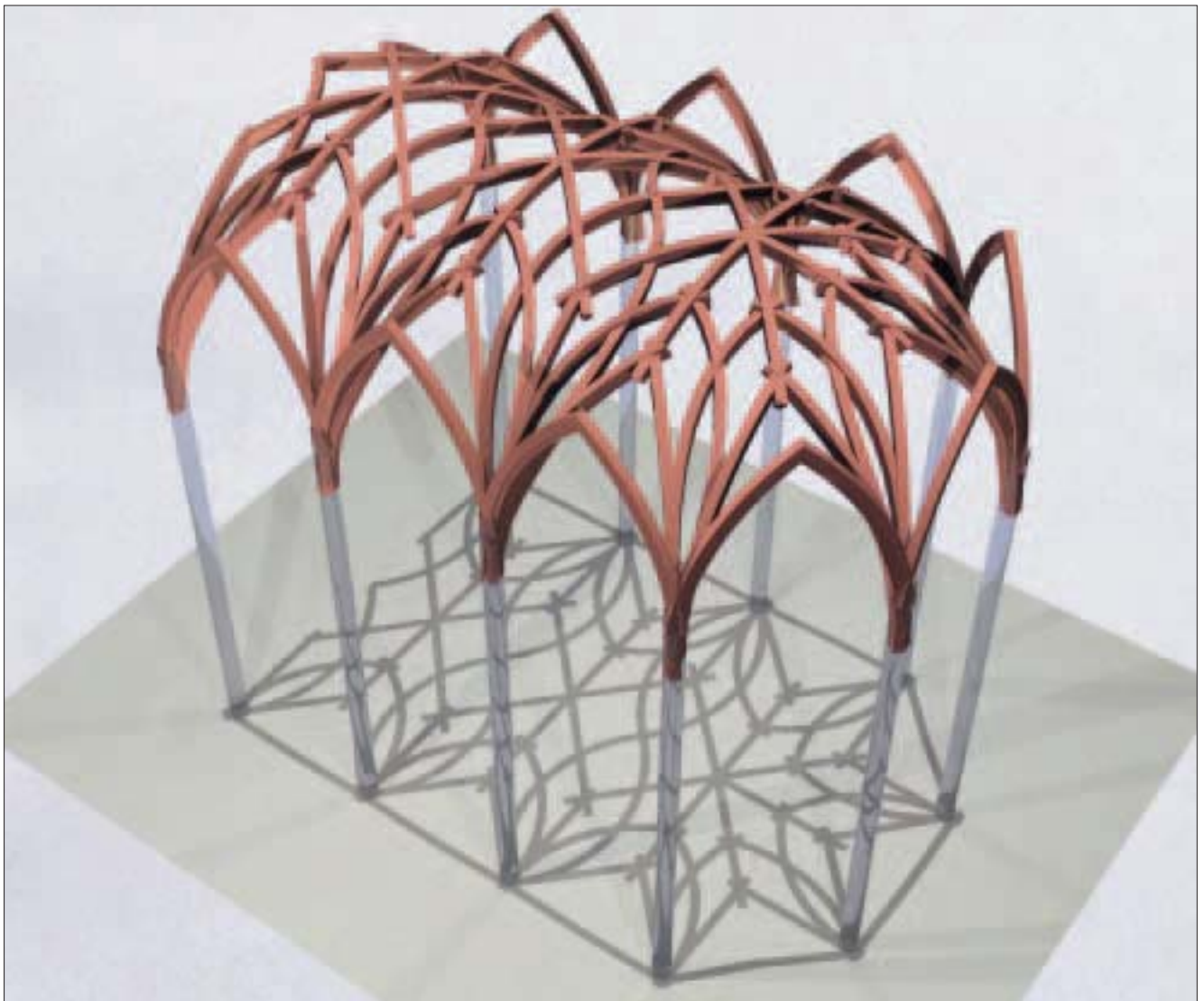
The virtual ribbing system of a late Gothic ornamental console. The vault architecture of the Middle Ages ranks amongst the masterpieces of the mason's art.

ribbed arches and their stones of connection are then determined – something reminiscent of a geometrical algorithm. The plan of the vault and the arc derivation in the complicated ribbed vaults of the late Gothic are of no help here in realising a concept of what has to be built, but they do determine the form of the ribbing system. Seen from the point of view of a theory, they have the character of a dictum accepted without question: "This is how it should be!" This is not to say that this set of rules would not have had any practical relevance. When working with preprepared material, as was characteristic of architecture in the late Gothic, the representation of a ribbing system was not based on the projections familiar to us today, such as front and side elevations and cross-sections, but comprised assembly plans in which all the rib branches, including those on the stones of connection, were shown unshortened. These assembly plans were based on the application of certain rules for deriving an arc from the plan. Just how closely the ribbing systems reflected these rules once they had been built has to be checked in each case. The indisputable fact remains, however, that these rules were the foundations upon which the fantastic forms found in late Gothic architecture were based. What was to appear

Today, more advanced methods are available based on CAD (Computer Aided Design), whose clarity will also permit a scientific commentary to be made on the vault designs which we have inherited.

In this case the abstraction stems not from the making of a cross-section of a vault, but extends to the production of a so-called "arc derivation", whereby the ribbing system is derived from the plan, and the shape and spatial position of the

Ornamental Gothic Vaults from Computer



The virtual ribbing system of a late Gothic choir (left), a vault plan (below, left) and an ornamental arch (below, right). Right: Computer representation of the choir of a church.

rich and complicated could be created very economically because the concepts behind the standardised individual elements and the shaping of the total entity were closely related. Hence we are now able to make computer models of vaults from a plan. Being created according to the rules of the contemporary stone mason's art they may justly claim to be historically authentic. We are hoping that this will now enable us to produce an experimental history of architecture. Prior to modelling a vault for which only the plan exists this plan must first be converted into a "true-to-rule" arc derivation. Scarcely any arc derivations are available for existing vaults, but they are available in the plans of later buildings. No-one is going to take all the trouble to boost up an arc derivation in order to model the vault. But it is a different matter when the problem lies in reading the thoughts of the designing architect in order to read his mind regarding a case in point, and to confirm this by the experiment. This was achieved, for example, with the ribbing system on the underside of the pulpit steps in St. Stephen's cathedral in Vienna. The surviving sketch plan was held to be a page from the exercise book of a "not ungifted beginner", but of no great consequence for the performance of the actual work. In contradiction to this, however, an experiment confirmed that the original design exhibited only minor differences in appearance from the apprentice's sketch. This plan contains in essence all the information required by a trained stone mason for the practical implementation of this work. The simulation of the ribbing system was achieved using the data we had succeeded in extracting from the drawing.

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Dr. Werner Müller, Ludwigshafen
PD Dr. Norbert Quien, St. Ingbert*



In many fields of performance small brains, such as that of the fly, can completely outclass large ones, to say nothing of technical systems. One aspect is the rapidity of visual image processing. Thanks to a broad spectrum of research effort we are now beginning to understand the neuronal mechanisms underlying this process.

Anyone who has observed two flies chasing each other will be conversant with the breath-taking aerial acrobatics these tiny pilots can produce. Whilst the human eye is scarcely capable of even following their flightpaths, the pursuer fly is quite capable of catching its speeding prize. To do this it relies to a great extent on its large, faceted eyes, which give it almost all-round vision. The continuous images these eyes deliver to its brain are evaluated in fractions of a second and transformed into navigating signals.

In order to learn what the fly sees during these breath-taking manoeuvres let us imagine we are sitting in the fly's cockpit. Immediately after take-off our environment starts to move past both our eyes from front to rear. Suddenly, the fly makes a sharp turn to the left, whereupon the environment in our field of vision moves temporarily to the right. Then, without any warning, we find ourselves approaching an obstacle. This appears to keep on growing in size, and its contours shift from the middle of our field of vision to the edges. By another sudden turn to the right, accompanied by broad image shifts to the left, the fly succeeds in avoiding the obstacle. Now the target, another fly, comes into view. It, too, is moving, but at a speed different from that of its environment. The resulting relative movement makes the prize visible against its background. The chase can begin.

A succession of images such as this is not confined to flies' eyes, but also occurs with our own eyes, for instance, when driving a car. However, the changes in the in-flight image-flow of flies is many times faster than that experienced by human beings. This is true even of Formula-1 racing drivers or the pilots of jet aircraft. Thus flies can

In the Cockpit



of the Fly

Small brains can completely outclass large ones in their performance. Thus the fly has proved to be an outstanding model system for image processing in the brain



make up to ten sudden turns per second, during which they reach angular velocities of up to 5,000 degrees per second – velocities which no human body could even begin to withstand.

The fly has proved to be an outstanding model system for tracing the activities in the brain which serve to process image-flows proceeding from the eyes. On the one hand, the visual system of the fly is optimised for the performance of this task and, on the other, experimental analyses can be conducted here employing a broad spectrum of methods. Every method of investigating neuronal circuits can be applied to a largely intact creature, thus making it possible to study the processes occurring in the brain during the actual reception of its natural sensory inputs.

We are now at least able to study basic aspects of the neuronal circuits which evaluate the moving images on the retina of a fly. These moving images are not perceived directly by the eye. The fly's eye, rathermore, sees just a continuously changing array of brightness. From this, the brain has to go through a series of steps to evaluate information on the image movements. In this manner, the flood of information contained in the retinal images is reduced to its essentials.

The light-perceptive cells on the retina of a fly only register the brightness of its environment. The next higher group of nerve cells, the local movement detectors, compare the brightness data of adjacent light-sensitive cells and react only to a spatial or temporal change in brightness. Movement is signalled when two adjacent light-sensitive cells report the same brightness value in immediate succession, for example, bright-bright. During this process, each motion detector reacts

Thanks to its spherical, faceted eyes, the fly has almost complete all-round vision. This enables it to pursue other flies in flight and at high speed.

with maximum strength to movement in a given direction. The information from numerous local motion detectors is summated by integrating neurons. These are able to recognise characteristic relationship situations, such as occur, for instance, when a flying body changes direction.

We gained our knowledge about this from studies based on relatively simple stimuli, such as black bars moved in front of the fly's eyes, whereby the neural networks for visual image processing were subjected to electrophysiological analysis. For this analysis, fine measuring probes are introduced into individual nerve cells to register their electrical activity. However, these experiments cannot tell us how information relating to the environment

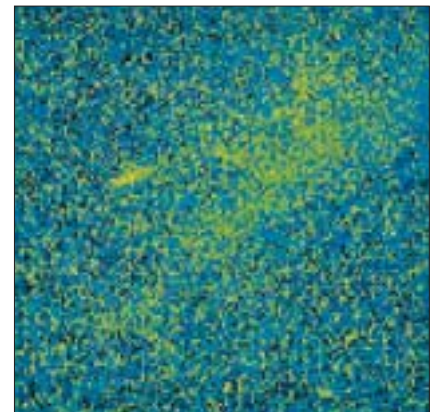
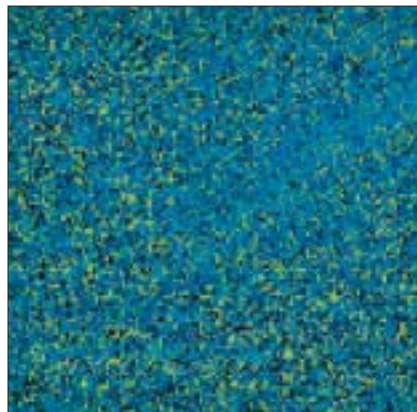
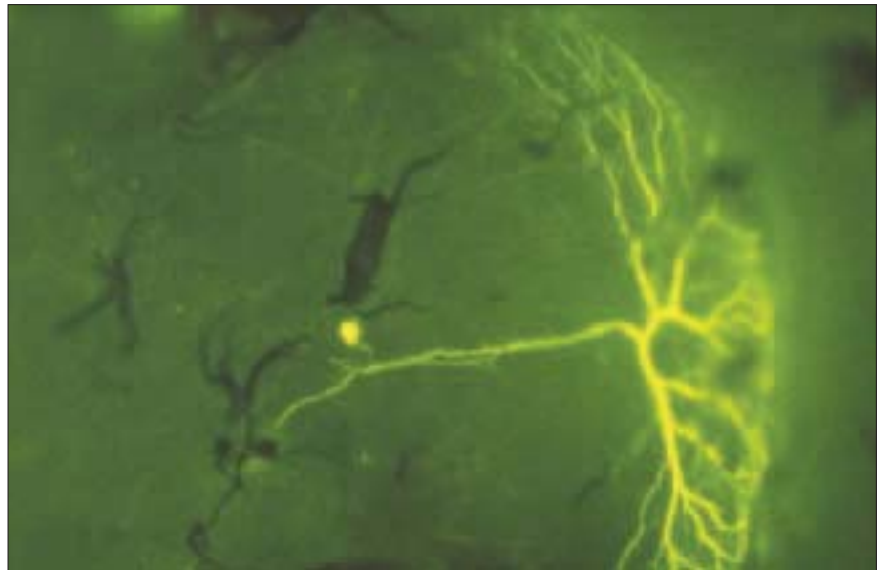
The nerve cell of a fly has been filled with a fluorescent dye. The stained cell is most sensitive to small moving objects. Below: An image-creating process elucidates neuronal information processing. Left, the ramified exit region of a nerve cell can be seen. If something should move in the fly's field of vision, calcium will flow into the nerve cell. In the image-sequence this is revealed by the increasing intensification of the yellow tone.

reliable, in other words, they react very differently to the repeated presentation of a stimulus. Secondly, visual stimuli in real behavioural situations are not, as in an experiment, predetermined by an external source, but are determined by the manner in which the creature moves.

In order to study the neuronal processing of natural visual stimuli we developed a sort of panorama cinema for flies ("FliMaX"), which now, for the first time, permits the image-flow seen by flies in free

images is much greater than that of a human being. Hence the film in our "FliMaX" is played at a speed of 370 images per second. At this speed the image sequences fuse in the fly's eye to a natural impression as would be seen by the eyes during a rapid flight manoeuvre.

Current studies in the "FliMaX" suggest that the mechanisms for visual image evaluation in flies are only able to present the brain with the necessary information on the environment so rapidly and efficiently because they require rela-

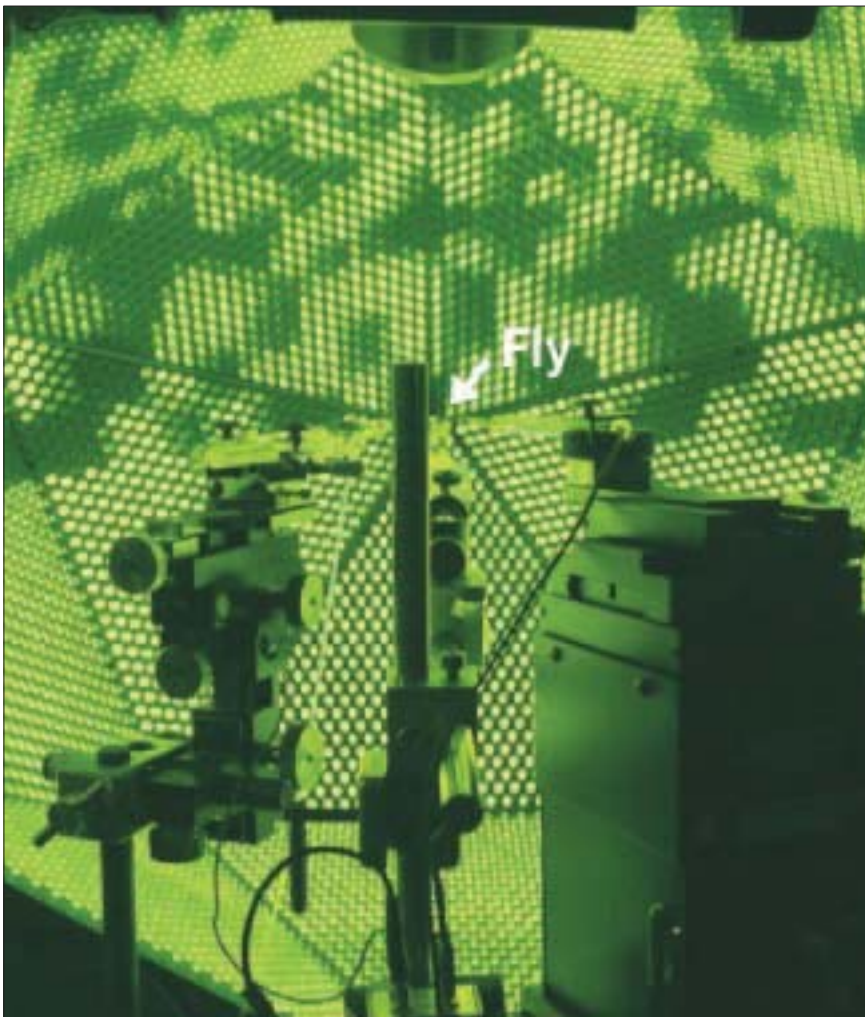


in its normal context, for instance, when simply flying around, is processed.

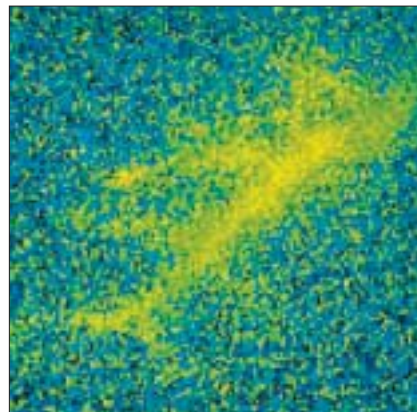
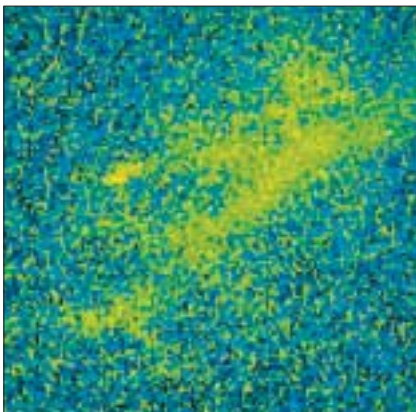
The scientist wishing to study how these natural visual impressions are processed must bear two aspects in mind. First, neurons, at least compared to technical computational elements, are extremely un-

flight to be relayed to a fly under physical restraint, and simultaneously to register the activity of its nerve cells. With human beings, sequential images of a cinema film begin to fuse into a natural impression already at 25 images per second. However, the temporal ability of the fly's visual system to resolve

tively few computational elements. Although these simple mechanisms do not function under every possible condition, they are nevertheless especially effective when the fly is within its normal behavioural context. The processing of the visual impressions is thus optimally adapted to the specific conditions of the



The "FliMaX" panorama cinema was developed specifically for studying the brain performance of flies. The fly is located at its centre and looks onto the screen. Fine measuring probes are introduced into its brain from behind.



fly's way of life. Whether these considerations are correct or not will have to be tested using detailed modelling. For this purpose our research group has developed a computer programme which simulates the neuronal processing of the retinal images of flies in free flight. In doing this, we took into account

what we had already learnt about neuronal processing of images, and the fact that nerve cells will not always react identically to the same stimulus. With the very first version of a "virtual fly" we were able to explain essential aspects of visual image processing, including those found under the conditions obtain-

ing in normal behavioural situations. At the moment, we are continuing this development to transform our "virtual fly" into an autonomously acting agent capable of navigating in complex environments with degrees of efficiency and virtuosity similar to those of a real fly.

Even if the development of this "virtual fly" is being pursued primarily for reasons of scientific interest, the mechanism of biological information processing could provide valuable leads for the development of technical systems. This has, in fact, already happened in diverse study groups in Europe and the USA, where scientists are using models developed for parts of the motion vision system of flies to develop computer chips for use in robot control. Despite this, there is still no technical system at the moment which can meet the demands of flight control so quickly as a fly.

Mechanisms for autonomous navigation, the avoidance of obstacles and the pursuit of moving targets are of crucial significance in the technical sphere, especially when they are relatively simple and efficient.

This is the case with the fly, for it produces its performance with a brain weighing no more than 1 milligram(!). This is most assuredly only possible because the neuronal circuits have had a very much longer test-phase than is possible with any technical system. Or should 200 million years of evolution not have sufficed in the interplay of mutation and selection to lead to optimally economical and adequately sophisticated solutions for equipping the cockpit of the fly?

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Afghanistan: The Culture of the Kafirs

Amongst their Muslim neighbours they had the reputation of being savage idolaters who thirsted after the lives of adherents of Islam – the “Kafirs of the Hindu Kush”

Until a little more than a hundred years ago, isolated in their narrow, wooded, mountain valleys south of the Hindu Kush in north-eastern Afghanistan, the so-called Kafirs had succeeded in remaining true to their ancient beliefs and “primitive” traditions. The mostly steep and narrow valleys where they dwelt lay remote from the impor-



tant routes linking Central Asia and India. Known to their Islamic neighbours as “heathens” – in Arabic, “kafir” – they had the reputation of being savage idolaters who thirsted after the lives of Moslems. In the winter of 1895/96, the forces of the Emir of Afghanistan finally put an end to their ancient culture. They were forcibly converted to Islam, and given the new name “Nuristanis”, the inhabitants of the Land of Nuristan (“Land of Enlightenment”). In this way, a cruel, but many-faceted, “primitive” culture, richly endowed with deities and ancestor figures, was extinguished. Thirty-one such figures were brought to the court in Kabul in 1896 or shortly thereafter as “trophies”. Many of them landed in the Museum of Kabul, four in the Musée Guimet and the Musée de l’Homme

Left: As though they had grown into the mountain slope, the houses of the village of Nisheigram nestle terrace-like into their surroundings. Above: Two elderly Nuristanis from Wama in the Pech Valley, descendants of prestigious Kafirs, supplied important information for our research project.

in Paris. At least a great part of the figures in Kabul has reportedly survived the chaos of the recent war years and the iconoclastic frenzy of the Taliban.

It was in the fateful year of 1896 that the famous work, “The Kafirs of the Hindu-Kush”, by the British doctor Sir George Scott Robertson, appeared. From September 1890 to October 1891, acting under orders from the British Raj in India, he had

resided with the Kati Kafirs in eastern Afghanistan and compiled a detailed report on them. This book, being the first-ever and only eyewitness report of the Kafirs, enjoyed great success. Thereafter, the rulers in Afghanistan stopped all further research activities in Nuristan. Not until 1935 did a German Hindu Kush expedition sponsored by the

Deutsche Forschungsgemeinschaft succeed in visiting this region again. After World War Two specific field research projects were undertaken once again. Most prominent among them are the DFG-supported undertakings of the Indologist Georg Buddrus and the author.

The cultural characteristics of the Kafirs, from their languages and religious beliefs to their individual forms of architecture and settlement, were narrowly regional. In general, polytheism, strict concepts of purity and impurity, and a highly developed system of feasts-of-merit, were often found in association with a heroic warrior tradition embracing aspects of head-hunting.

In line with the five different languages spoken, of which four are classed as ancient Indo-Iranian idioms, the Kafir culture numbered 33



five distinctive regional brands. These are the cultures of Waigali and Ashkun-speakers in the south of the region, and those of the Katispeakers in the north-west and north-east. Between these, the minor culture of the Parun Kafirs had spread its roots. One further minor Kafir culture is that of the Kalasha, who speak a north-west Indian language. Native to Chitral in north-western Pakistan, this people escaped enforced Islamisation and have been able to preserve their Kafir culture until today.

Robertson's detailed description only covered the eastern Kati culture in the Bashgal Valley, near the border between Afghanistan and Pakistan. The western Kati culture remained unexplored to the last. Robertson paid only a brief visit to the Parun Kafirs. In addition to his observations, important aspects of their culture have been documented in recent decades. Until the publication of the DFG-supported study by the author in 1999 (see below) the cultures of the Waigal and Ashkun Kafirs were almost a closed



A house in the village of Gurcheilam in the Ashkun region. Left: The anthropoid crown of a triumphal post "immortalises" the glory of a "big man". Above, right: The village of Dewa in the Parun Valley. Pilgrims from every region of Kafiristan were drawn to this valley. Right: A respected elderly couple in Nisheigram are seated on a plank just as their forebears once sat on their Kafir "benches of honour".

book. Outstanding amongst these regional Kafir cultures is that of the Parun as this was influenced by religion to an unusually great degree. There had once been a time when their massive central temple dedicated to the god Mara, located in the narrow Parun Valley in northern Kafiristan (Nuristan), attracted pilgrims from all over Kafiristan. In addition there were numerous smaller village and clan temples and assembly halls, whose supporting posts bore carvings of deities. The original decoration of some of these buildings survived, surprisingly, into the seventies of the 20th century, as the author was able to discover.



er. A great many free-standing carvings of deities served as cult figures. These deities are always seated on goats or stools – only the supreme deity, Mara, was shown on horseback. These figures often share gigantic, shield-like, heads, which lend them an extremely bizarre appearance.

The Waigal and Ashkun Kafirs, in contrast, were less preoccupied with religious rites and cults which generally involved, in all of Kafirstan, the offerings of goats, sheep and cattle. Their prime interest lay in social status, and they outbid each other with great feasts and warlike deeds. In the case of the Waigals, social betterment was subject to important conditions, whereas in the Ashkun region this was not taken so seriously. Successful "big men" announced their own services in the form of tree-high triumphal posts. These were crowned by stereotype human figures. Pegs were hammered into their sides for disclosing the number of people killed. They also had triumphal gates, benches and tomb housings 35



The open hearth is the focus of family life in a Nuristani, formerly Kafir, house. Carved motifs on the posts proclaimed the elevated status of the owner of the house.

sought to impress by their size and the richness of their carvings rather than by any motifs specific to the owner's rank. Ancestor figures held particular significance for proclaiming affluence, family traditions and a firmly established social status. The peripheries of the cemeteries were once "populated" by vast assemblies of life-sized ancestor figures carved in standing and sitting positions. These included male equestrian figures, occasionally riding on two horses. In the Waigal and Ashkun cultures, on the other hand, ancestor figures were unknown (as was also the case in the Parun culture). Social status was in their case

built, and had the façades and the interiors of their houses richly carved. In particular, the four supporting posts round the hearth and the rear wall of the house served to display motifs illustrating the principal's rank achieved by meritorious deeds. Other prestige-promoting

possessions were chairs of honour with twin backs, wrought-iron table- and torch-stands, and silver wine goblets.

In the case of the Kati culture in the eastern part of the region, power and worldly estate were manifested in a different manner. Here houses

Left: A cedar wood post bearing carved status symbols. Cedar was the preferred wood for local architectural and sculptural art. Centre: These "lovers" once crowned the post of a bench of honour in the Ashkun area. Right: Carving of the supreme god, Mara, in equestrian pose on a post in a clan temple in Dewa in the Parun Valley.



so easy to lose that no ancestor cult like that of the Kati Kafirs had been able to develop.

One feature unique to the Ashkun culture were the carvings of intertwined "lovers", over 60 centimetres in size, which crowned the smaller posts. Presumably, these were elements from benches of honour, whose purpose was to enable the worthy wife, too, to occupy a place at the side of her "big man' husband".

These lovers vivify the once omnipresent sexual symbolism of the Kafirs. They originated from philosophies which held the world to be an animated system subdivided into antitheses of "male" versus "female", and "pure" versus "impure". The Kafirs ascribed every social or material success to the interplay of these partial worlds, or to the observance of the laws of purity. Even today, cattle raising is a uniquely male occupation, and only the men may accompany the animals, primarily goats, to the mountain pastures, into the world of the indigenous markhor, which by reputation is a particularly pure and sexually potent animal. Women, in contrast, remain responsible for farming. They were regularly exposed to the stigma of impureness, and had to withdraw into their remote menstruation and maternity houses.

The manual workers, moreover, were also considered to be fundamentally "impure". These "bari" lived in a form of bondage and were kept largely isolated from village life. Only the Parun Kafirs engaged in any craftsmanship themselves. Thus the magnificent cultural artefacts of the Kafirs were all, with the exception of the many deity figures and the other wood carvings created by the Paruni, the products of "impure" craftsmen. After the destruction which accompanied Islamisation and many decades of sale to antique dealers and deliberate clearances only very few of these witnesses now survive in Nuristan.

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How Engineering learnt to walk

When biologists and engineers examine how humans walk, astonishing developments become possible: for example, four-legged walking machines

Biological systems, and especially animals and human beings, walk, swim and fly; technical transport machines roll, sail and fly. At least, this is the state of affairs today. One typical component of biological locomotion is the

predator and the victim, and also, as is the case with birds and fishes, and even insects, to covering vast distances. The speeds of technical systems are several orders of magnitude higher. Hence they also demand forms of energy not available



leg, which, in a manner similar to that of the wing, evolved in the course of time from the fins of marine animals. An equally typical component of technical locomotion is the wheel, in a certain sense the first human artefact which did not exist in nature. Legs, wings and fins provide a simple solution to logistical problems, such as the transportation of loads. Their instrumental implementation is adapted to mastering a disordered environment frequently subject to unpredictable change; technical locomotion requires, at least on land, organised tracks and areas of ground, ships require harbours, and aeroplanes runways.

The speeds of biological locomotion are very modest, and are often orientated towards the demands of hunters and the hunted, of the

Walking processes have always exerted a fascination of their own. One of the first representations of walking people was published back at the beginning of the last century. It stems from the work of the photographer Eadweard Muybridge (1830–1904).

to biological systems. Nevertheless, the exploitation of biological resources is incomparably more efficient than in engineering. Which also applies to walking. So, despite the completely different problems confronting biology and engineering, it is worth taking a look at how biology solves these problems. In terms of quality, efficiency and intelligence, technical walking is far removed from biological walking. The biological design of propulsion systems, for instance, acting 37

through the medium of joints and muscles, is more effective, usually also lighter, and certainly more adaptable and economical in terms of energy than anything available in engineering. Moreover, groups of muscles often offer a certain redundancy of motor effort which can be of advantage, for example, should some muscles tire. Biological control

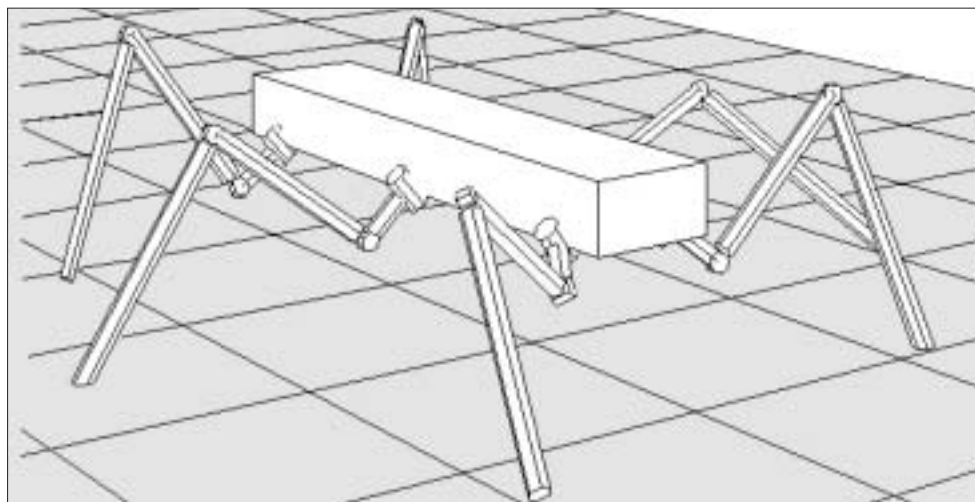
with redundancy, so that information on the momentary state of motion is available to the control structures both inside and outside the brain to a degree unmatched by engineers. The astonishing thing here is that novel and unknown physical principles are involved only in rare cases, but the familiar ones already available are applied

machines are the most commonly built, followed by four-legged ones, as these provide good locomotive stability. Two-legged machines are not so common, as walking on two legs always involves dynamic elements, too, and is thus more difficult to put into practice.

For years now, the stick insect, which has been the subject of intense biological research, has been serving as the model for six-legged motion. Germany leads the world in this respect. Some of the six-legged walking machines made in Germany, and in the USA and Japan, too, have used this leg design, and have achieved great practical success after a decentralised control structure analogous to that found in stick insects has been adopted. This has now become the commonest control structure in the world for six-legged robots.

One problem affecting the practical realisation of such technical legs lies in the ratio between the installable performance of their joints and their weight. In biological terms, this performance:weight ratio declines by the power of 1.5 of the geometrical dimensions. The volume of a living organism, and thus its weight, grows as the cube of its size, but its muscle power only grows as the square of its dimensions, as it is approximately proportional to the cross-sectional area of the muscle. This produces a steadily declining performance:weight ratio as animals become larger, whereas smaller animals, such as ants, mostly exhibit high ratios. So, if a six-legged machine is built according to the model provided by insects, it is impossible to achieve their performance:weight ratio by technical means.

There are probably only 20 to 30 such six-legged machines in the whole world, and about half as many four-legged ones. If we take



concepts react quickly and intelligently to changes in the environment. This is technically almost impossible to imitate at the present time. Biological systems contain autodidactic properties which greatly enhance their adaptability and facilitate a certain degree of self-repair. The first steps towards self-repairing systems have been taken in the sphere of space travel, but we are still far removed from biological perfection.

The arrays of sensors available to biological systems are breathtaking. Biological sensors monitor every detail of the course of a movement, and

The stick insect has been serving engineers as a model for six-legged walking for a long time now. This leg design has been adopted for applications involving robots, with electric motors substituting for the muscle drives.

and implemented to much better purpose. In the course of millions of years of evolution, the leg, as the central instrument of walking, has adapted itself to the most diverse demands of this motion. Anyone wishing to build walking machines should first take a look at what nature has to offer in the way of design concepts. In engineering, six-legged

biological four-legged animals, the technical problem on the evidence becomes quite clear: from mice to elephants, and from piping hares to horses, four-legged animals walk, trot and canter, whereby they use motor areas, in some cases dominantly, which can only be stabilised dynamically and no longer exhibit any properties of static stability. As a consequence, not only are the patterns of motion more complicated, because they include jumps, stabilisation in the air, and shock avoidance during the brief contacts with the ground, but the demands made on the control structures with their lavish adaptive and intelligent properties, such as those controlling the eye movements, become incomparably greater than is the case with six-legged animals. Two four-legged machines are being developed and built within the framework of the DFG-sponsored priority programme "Autonomous Walking". Four-legged machines offer a series of advantages: they are quick, mobile, better able to surmount obstacles, and the fact that they have only four legs and not six means that they demand less technical effort.

Two-legged walking machines are orientated,

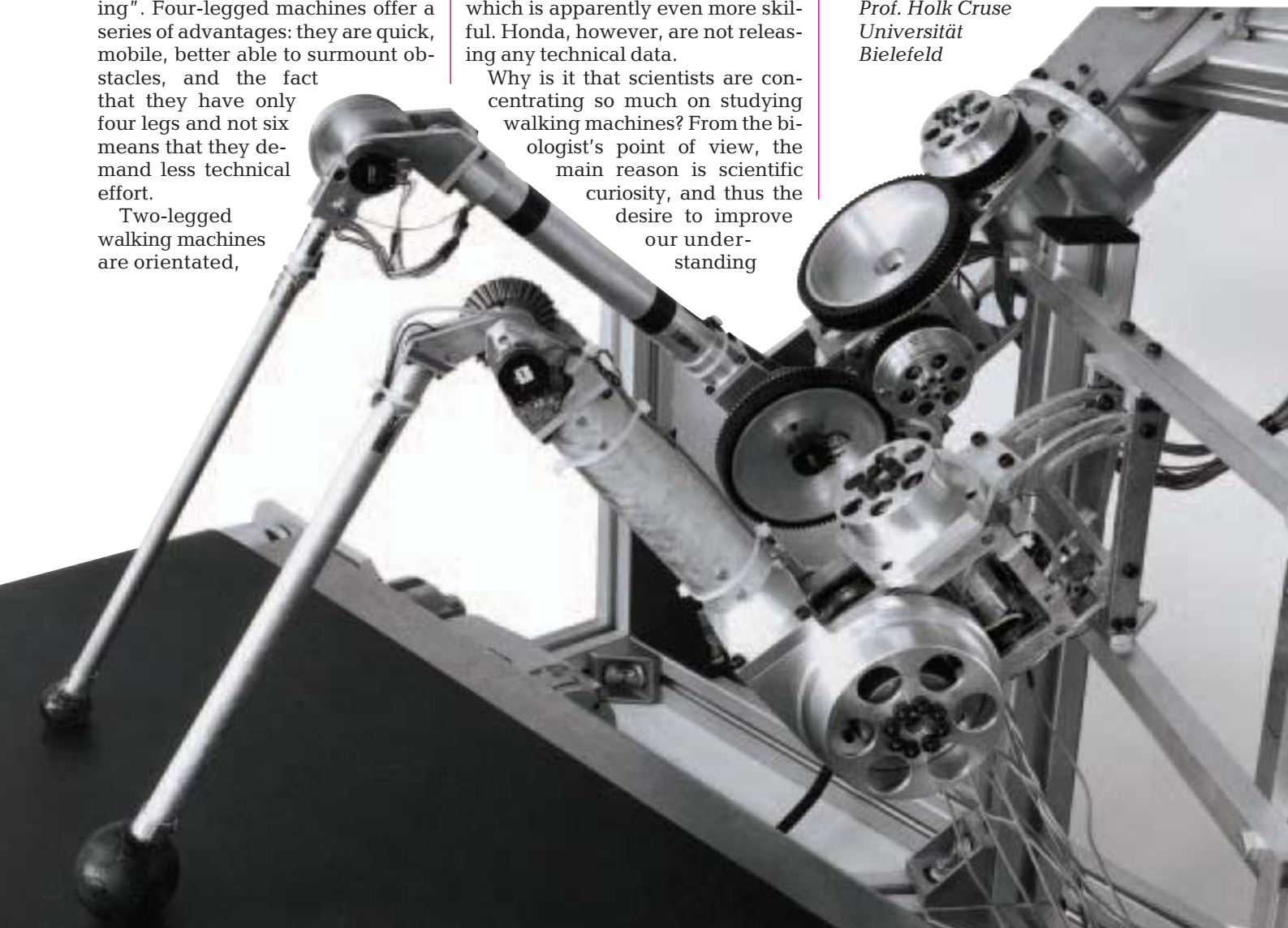
naturally enough, on the human model, whose walking characteristics have already been under investigation for many decades. Hence the kinematic sequences are perfectly familiar, but, although much is also known of the supporting sensor mechanisms, much has yet to be learnt. Consequently, in the priority programme "Autonomous Walking", doctors and biologists are also studying the motor sequences and learning processes associated with walking. They are also now constructing a two-legged machine which, in contrast to former developments, will be able to walk dynamically. In this respect it is a departure from the developments achieved by the Japanese, the world leaders in the field of two-legged walking machines. One machine which is already at a very advanced stage is WABIAN, whose astonishing performance is only exceeded by that of Honda-man, which is apparently even more skilful. Honda, however, are not releasing any technical data.

Why is it that scientists are concentrating so much on studying walking machines? From the biologist's point of view, the main reason is scientific curiosity, and thus the desire to improve our understanding

of complicated biological structures. Engineers give a different answer: they see themselves as "implementation scientists". The engineer hopes that biology will furnish ideas and inspiration for his formative tasks.

A further aim, which has already been partially realised today, is to use walking machines in areas inaccessible to human beings, for example where chemical or nuclear contamination is present, or for fire-fighting, for working under water and in pipes, and for waste-water drainage. Walking machines may also be used for performing routine tasks in offices, hospitals or households. The technological know-how gained through building such machines could be directly transferred to artificial limbs, as Japanese projects have impressively demonstrated.

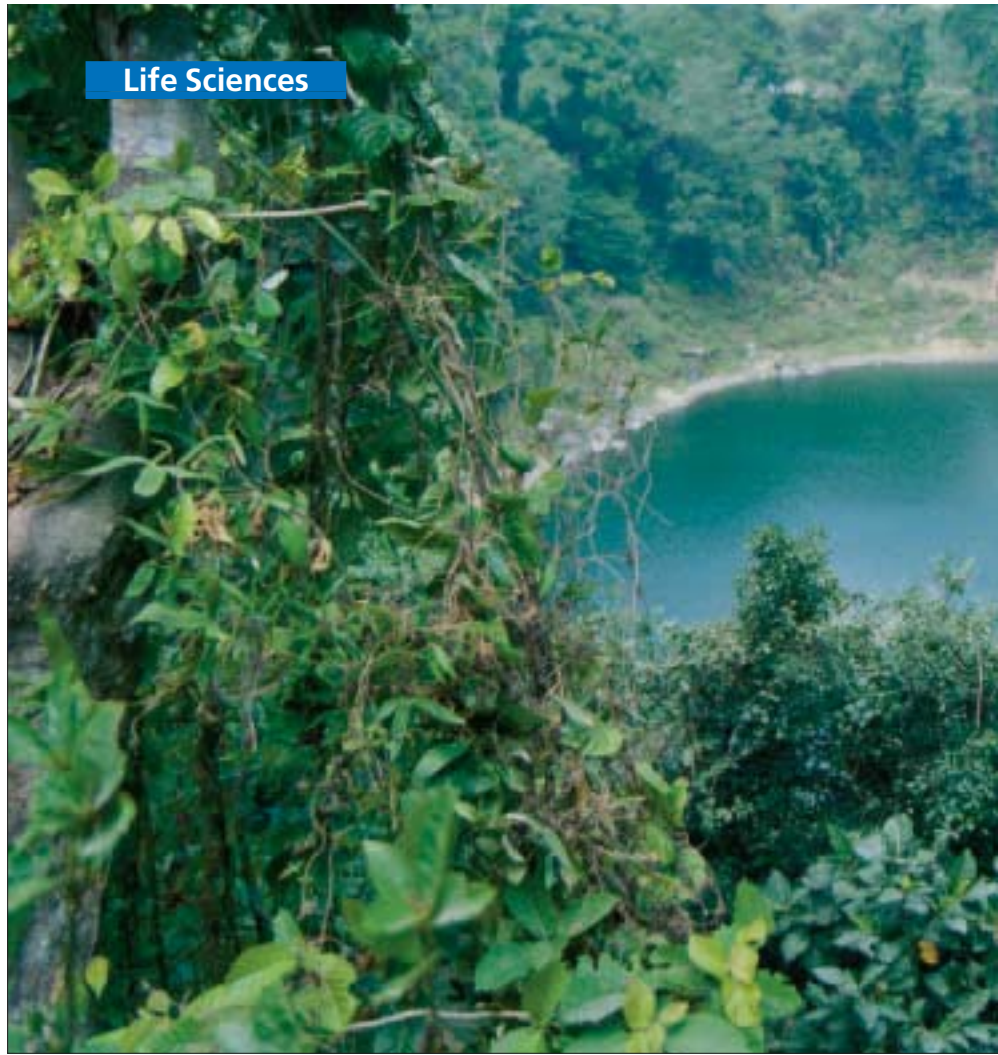
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The impact of man on the future development of the climate and the dynamics of ecosystems can only be realistically evaluated if their geological history is known. The time-window of the Eocene – the period from 54 to 33 million years ago – is of exceptional interest in this connection for this was the last time that the world was to have a largely uniformly distributed warm climate exhibiting certain characteristics of the popularly awaited “greenhouse climate”. Moreover, it was at that period that the explosive development of the mammals and flowering plants began. Thus for the first and only time in the history of the earth the preconditions now obtain for a direct comparison of today’s – and possibly future – current processes with those in a “greenhouse climate” still uninfluenced by man.

The Middle Eocene Eckfeld Maar near Manderscheid in the Volcanic Eifel has proved to be an ideal subject for research into such questions. Its sediments have preserved not only a plethora of plant and animal chemo-, micro- and microfossils, but they also hold a broad spectrum of palaeoclimatic information. The Eckfeld Maar is a unique geological archive in which the natural fluctuations of the climate and their impacts on flora and fauna are documented over a period of tens of thousands of years in the Middle Eocene.

The Eckfeld Maar lies together with two further volcanic edifices of the Middle Eocene epoch on the southern periphery of the High Eifel volcanic field. Its four hundred or so volcanoes bear witness to the fact that this region of the High Eifel was the scene of violent and continuous volcanic activity from the Middle Eocene to the Lower Miocene. Both the pollen spectrum and the mammalian fauna indicate that the Eckfeld Maar erupted in the Middle Eocene, giving it an estimated age of 44 to 45 million years. Weathered volcanic rocks from the Eckfeld Maar are nothing new and may be assumed to have been ejected during the eruption of the Maar. Hence one aim of the core drilling programme in 1996 was to obtain



A Climatic Archive with Hide and Hair

Over 35 million years ago, the global climate exhibited characteristics of the popularly awaited “greenhouse climate”. The sediments of the Eckfeld Maar in the Eifel are yielding numerous witnesses to that period



At the onset of oil shale formation the lake was chemically stratified: its body of water comprised an upper, oxygen-rich part, and a lower, low-oxygen part with a high content of dissolved minerals and a correspondingly high density. In the long term, this special feature prevented any regular mixing of both

When these beetles, fishes and "dawn horses" were still living near the little town of Manderscheid in the Eifel, the local maar, surrounded by lush tropical vegetation, looked like the Ranu Lading in Java.



unweathered volcanic rocks for radiometric age determination. One volcanic scoria was shown to be 44.3 ± 0.4 million years old – an age which coincides with the biostratigraphic estimates, and marks both the emergence of the crater itself and also the age of the fossils. This has thus presented Europe with its first numerical dating of a continental biocenosis from the Eocene.

Once the eruptions had run their course, the crater of the Eckfeld Maar, up to 1,000 metres in size and

down to 210 metres in depth, rapidly filled with groundwater. The resulting lake was originally at least 110 metres deep, possibly going down to 150 metres. The gross masses of volcanic detritus forming its bottom were initially covered by a sequence of light coloured, finely stratified clays only a few metres thick. These were then covered almost as a matter of course by dark coloured oil shales, which probably formed over a period of less than 250,000 years, and gradually filled the lake.

bodies of water, or any colonisation of the lake bottom by, for example, burrowing organisms. This explains the perfect preservation of both the finest sedimentary structures and the organisms which had sunk down to the lake bottom. The reduced degree of recycling of organic material in the depths of the lake ensured the survival of even complex organic molecules. Although, of course, the steepness and instability of the early banks would certainly have inhibited any major colonisation of the bank region by aquatic plants and terrestrial organisms, it is obvious that the special chemical conditions at the deeper

even the "contents of their stomachs" have been preserved for posterity.

In addition to algae, fungi, mosses and ferns, the flora embraces a multitude of seed-bearing plants. Some two hundred genera found in a single profile section only some three metres thick bear witness to woodlands rich in species, whose bank communities were quite evidently characterised by lianas. Thousands of leaves, fruits and seeds have been found. Almost eight hundred flowers and inflorescences from different families have now been recovered. Their significance lies, firstly, in the fact that most of their

amphibians, reptiles, birds or mammals also document the extraordinary potential for preservation in these sediments of the Eckfeld Maar. The commonest and richest in species are, as might be expected, the insects, twelve orders of which have already been discovered. Evidence of amphibians, in contrast, is only presented by a single partial skeleton of a frog. This is surprising, but understandable considering the steep banks of the lake and its special hydrochemism. Amongst the numerous finds, already embracing over twenty different species of mammal, the first remains of two primate species and five skeletons of the "dawn horse" genus *Propalaeotherium* are especially worthy of mention. Also of importance are the first-ever finds of undeformed skulls of this genus.

In the Middle Eocene a uniformly warm climate prevailed world-wide far into the northern latitudes. This is also confirmed by bioindicators found in the Eckfeld fossil beds, such as palms and crocodiles. Eckfeld, however, is able to furnish much more detailed information on the climate of the Middle Eocene, for maar lakes, as recent studies have shown, are high-resolution climatic archives. This is because we are concerned here with so-called "varvites", whose fine laminations occur due to annual and even seasonal periodicities, enabling them to store sedimentary and biological events with the maximum conceivable temporal differentiation. Recently conducted spectral analyses of finely laminated oil shale samples from Eckfeld have revealed high frequency solar periodicities. This, together with the fact that, due to the former latitude of Eckfeld (approx. 42°–44°N) we can assume a well defined seasonality, permits the conclusion that the accumulation of the Eckfeld oil shale followed an annual rhythm. Hence here, too, we are concerned with varvite, and the current spectral analytical evaluation of the oil shale drillings from 1996 and 1999 might well reveal the existence of even longer-term extraterrestrial periodicities (Milankovitch cycles).



levels would also have strongly influenced the colonisation conditions of the surface water when, for instance, occasional collapses of the banks or violent storms had led to partial intermingling of the two bodies of water. This aspect led to an episodic, and fairly significant, intoxication of the surface water, which would explain the comparatively narrow spectrum of biodiversity amongst the lake-dwelling organisms, and the observation that these were in part, at least, species impervious to fluctuating salinity.

The species and individuals of terrestrial organisms, on the other hand, have been richly documented, and are for the most part excellently preserved. Thus, for example, species of beetles, with their original structural colouring, and mammals with "hide and hair", and

The Eckfeld Maar, on the southern edge of the Volcanic Eifel, presents scientists with a time-window on the Eocene (54–33 million years ago), the last epoch in which a global "greenhouse climate" prevailed.

anthers still contain pollen, and can thus help to elucidate the systematic position of forms of pollen hitherto only found in isolated cases. And, secondly, in the information they provide on the co-evolution of flowering plants and insects. The high degree with which interactions between both groups can be deduced directly from the fossils is shown by a "honey bee" which, even today, is still carrying pollen on its body and hind legs.

Finds of such diverse groups as freshwater sponges, mussels, snails, ostracods, arachnids, insects, fishes,

The magnetisability of the rock over the entire oil shale profile was also determined in steps of one millimetre with a spatial resolution of 4 millimetres. Based on an assumed mean annual oil-shale sedimentation rate of 0.4 mm, this would correspond to a temporal resolution of approximately ten years. The resulting curve yields the medium- to long-term climatic fluctuations. The first indications of climatic fluctuations soon came to light from analyses of the oxygen and carbon isotopes formed from the iron (ferrous) carbonate in the Eckfeld Lake. Copious series of samples from the new cores are now available for further studies.

The current interdisciplinary evaluations of palaeo-climatic data are producing a detailed reconstruction of these climatic fluctuations and an analysis of their possible causes. The crosslinking of these palaeoclimatic data with the finds and findings solely retrievable from excavations is creating an opportunity to analyse the effects of climatic fluctuations on the ecosystem of Eckfeld and the dynamics of these changes for the approx. 11,000 years so far covered by the excavations. The over 30,000 fossils already recovered form an indispensable data base for this.

Favourable circumstances have led to deposition of other sediments from this epoch in the western Eifel, in addition to those in the Eckfeld Maar. These have enabled scientists to make rough reconstructions of the Middle Eocene relief and the regional drainage system, so that the finds made in the Eckfeld Maar can now be placed into a palaeographic framework. We now know that the centre of the Tertiary High Eifel volcanic field, which lies some 20 kilometres north of Eckfeld, towered several hundred metres above the surrounding landscape and contained the source of the Manderscheid river. This flowed west of Eckfeld as a boundary river of the Buntsandstein escarpment. At that period, this escarpment, which rises up to 200 metres, was probably less than 4 kilometres away from the Eckfeld Maar. The current excavations have already produced the first



This "dawn horse" mare and foal were found in the Eckfeld Maar. The dark mass in the body cavity is a dense package of leaf fragments.

indications of a temporary connection between the Eckfeld Maar and the Manderscheid river. This system debouched into the original course of the River Saar in the Arenrath basin, a few kilometres to the southwest of Eckfeld, whose sediments – sand and gravel with occasional inclusions of plant-bearing clay lenses – are still widely distributed over the western Eifel. The plant fossils – no animal remains have as yet been identified – permit reconstruction of the vegetation along the riverside.

In its sediments and fossils, and their state of preservation, Eckfeld

bears a close similarity to Messel. Bearing in mind the fact that the latest finds show that Messel might also once have been a maar, then these shared features are easy to explain, although Messel was formed in the Lower Middle Eocene, making it four to five million years older, and opens a window onto an earlier phase of the Eocene climatic optimum. Hence, studying the finds in both sources together offers a unique opportunity for multidisciplinary research within the time-window of the Middle Eocene – the last epoch in which a global "greenhouse climate" prevailed.

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Expedition to the Volcanoes of the Arctic Seafloor

The AMORE Expedition headed for the so-called "Gakkel Ridge" where, on the floor of the Arctic Ocean, there is hot work afoot – for this ocean ridge is composed of active volcanoes



Three research vessels meet in the Arctic Ocean: The RSV "Polarstern" and "USCGC Healy" have yet to ply their way to the Pole through the icy water, the Swedish "Oden" (foreground) has already completed its mission.

When Jules Verne made his imaginary journey of exploration to the centre of the earth through the vents in an Icelandic volcano over a hundred years ago, he assumed that all volcanoes are interlinked in a subterranean system. But even his imagination failed to visualise the worldwide system of submarine volcanoes that extends over a distance of over 60,000 kilometres and only breaks the surface of the ocean at Iceland. This mid-oceanic ridge, which spans the entire world ocean, has evolved along the boundaries between the tectonic plates of the Earth's crust. Gakkel Ridge, in the central eastern Arctic Ocean is the northern most spur of the plate boundary between Eurasia and North America, and at the same time the most slowly opening ridge segment in the world, opening only a few millimetres each year.

In October 2001, the research vessel RSV "Polarstern" and the ice-breaker USCGC "Healy" from the U.S. Coastguard returned to port bringing dramatic data from an expedition to the Gakkel Ridge which lasted over four months. The AMORE 2001 (Arctic Mid-Ocean Ridge Expedition) marks a milestone in Arctic Ocean exploration in that scientists have for the first time accurately charted, surveyed and sampled the western part of the Gakkel Ridge.

Geophysical surveys were conducted to determine the thickness of the crust along the Gakkel Ridge and its adjacent ocean basins. Initial evaluation of the data shows that the crust thickness along the Gakkel Ridge, which varies between six kilometres and a few hundred metres, does not accord with existing model concepts. In contrast to previous assumptions, it now appears that there are magmatic centres spaced at regular intervals along the ridge, where clearly greater accumulations of basalt have formed than in the other parts.

Magnetic measurements made from helicopters indicate that these submarine volcanoes were active over very lengthy geological periods. The geophysical measurements undertaken along the Gakkel Ridge, and especially studies of the adjacent basins, revealed that not only does the thickness of the sediments under the ocean floor, otherwise so level, vary greatly, but also that a part of this sedimentary cover has been transported into the ocean basins from the neighbouring continental shelf edges by dramatic slides.

Under the two-metre layer of ice and the 4,000-metre-deep Arctic Ocean lay the volcanoes from which the samples were to be taken using TV-controlled grabs and dredges. These basic tools returned with loads of up to three tonnes of rock from the ocean floor to the surface in one lift. Initially, we had expected that this submarine ridge would most probably have been the result of extrusion caused by tectonic movements rather than by any volcanic processes, and so we had ex-

pected to find a majority of peridotites and gabros in the samples. Peridotites deep-seated rocks from the earth's upper mantle, and gabros form in the lower oceanic

crust, so that both types of rock can only be brought to the surface of the ocean floor by tectonic movements. And these rocks were indeed found in many locations.

The majority of the rock samples, however, were found to contain basalts, the solidified products of volcanic eruptions from submarine volcanoes. The shapes of the samples reflected the violence of the clash of red-hot lava with ice-cold sea water during these submarine eruptions. The freshly expelled lava solidifies to a thick, black, tubular glass periphery into which the lava flows, rather like blowing up a balloon. In the course of this process, so-called basalt pillows are created to form the upper 2,000 metres or so

Probes measure ice and melt-water. The data recount the climatic changes in the Arctic



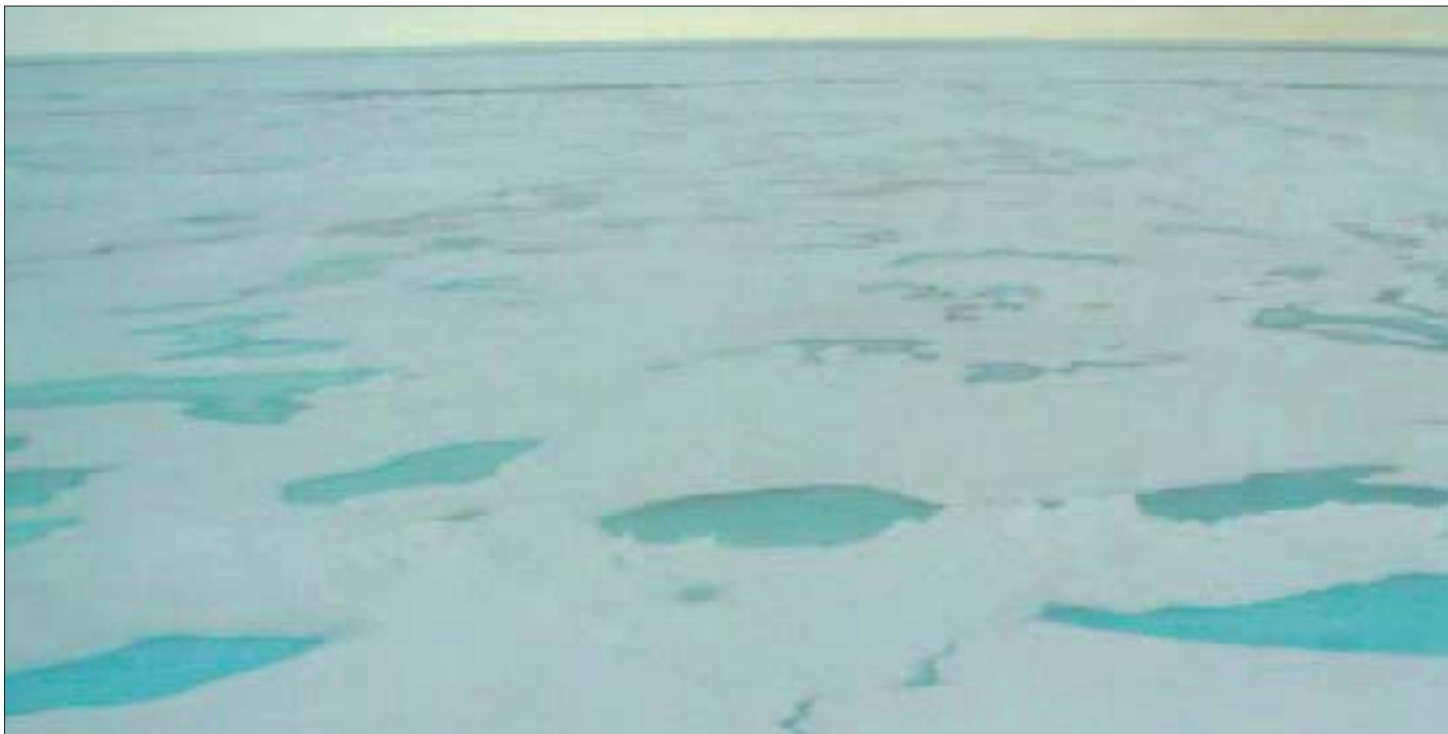


A helicopter flying at an altitude of 20 metres measures the thickness of the ice cover beneath it using a helicopter electromagnetic probe ("HEM-Bird"). Left: Magnetic fields are also probed. Above: A basalt sample from the ocean floor. The "giant pillow" weighs several tonnes.

of the oceanic crust. These basalts contained a variety of types, which we had not expected to meet on the Gakkel Ridge. In particular, the high proportion of interspersed crystals in the rock can only be explained by the presence of large magma chambers, and stands in clear contrast to the conventional wisdom that the extremely slowly spreading Gakkel Ridge simply doesn't produce enough magma to keep such chambers in operation. After the initial assessment of the rock samples, thin sections were prepared on board ship. Microscopic measurement of the optical properties of these sections enabled us to make precise statements regarding the composition and origin of a sam-

ple only a few hours after the rocks were recovered. The composition of the rocks measured on board coincided roughly with what had been expected. However, as these studies point to the existence of a thin crust along the entire Gakkel Ridge, and thus stand in contrast to the violent volcanic activity observed, more detailed studies must now be undertaken to elucidate the ratio between the rate of spreading and the thickness of the ridge crust.

Examination of the "hot springs" under the Arctic Ocean was also on the expedition's agenda – springs, whose chemical composition is rather more reminiscent of a witch's cauldron. Mid-oceanic ridges are the scenes of broadly spread and quantitatively very significant hydrothermal exchange processes between the rocks of the oceanic crust and the water columns. Where these springs discharge, at their so-called "vents", highly specialised communities of invertebrates are often found which, to judge by their external appearance, should not actually dwell in the ocean depths. They include, for example, large 47



Smaller-sized air guns towed through the ice behind the ship generate acoustic signals to obtain geophysical reflections. Above: Gigantic ice flows with blue pools of melt water. The weathered surface is typical of the summer. Right: A TV-controlled "grab" brings samples up to the surface from the ocean floor.

tube worms and mussels which have adapted to a very specific form of metabolism. Back in 1998, the "Polarstern" had collected vent fauna of this sort along the continental shelf of the Laptev Sea off Siberia, from the immediate prolongation of the Gakkel Ridge. They testify to the possible presence even more of them further to the west, and are the best proof of the broad distribution of hydrothermal springs further along the Gakkel Ridge.

Every exploration of the ocean floor demands accurate charting. Although such charts are a matter of course for seas in temperate latitudes, knowledge of ocean floor morphology of the Arctic Ocean up to this point had been very broad brush, having been passed on to a very restricted circle of people by the U.S. Navy, which had from time to time made nuclear submarines

48



able to ravel submerged under the ice and make a continuous depth profile, and thus to compile a chart. However, due to the relative inaccuracy of the navigation facilities in the submarines, this proved to be somewhat problematic, as much of the planning for the AMORE Expedition was based on this chart. However, the "Polarstern" and the "Healy", working independently and over long distances under

favourable ice conditions, were able to survey the northern and southern flanks of the Gakkel Ridge respectively while satellite navigation facilities allowed them to make highly accurate fixes of their positions. One very valuable result of this expedition was the resulting detailed and extremely precise cartographic record made of the morphology of a stretch of the Gakkel Ridge extending over a distance of almost 900



diameter. Interspersed between these were narrow channels already bearing a covering of new ice. Comparisons with 1991 revealed marked changes in the observed thickness of the ice. Whereas the typical thickness in 1991 was 2.5 metres, this year it lay between 1.9 and 2.1 metres. These measurements were for the most part made using an electromagnetic probe carried on a sledge that was dragged over the frequently rough terrain presented by the ice. In this manner a total of 52 ice flows were surveyed over a distance of 100 kilometres. However, new types of probe were also employed which enabled the thickness of the ice to be measured from a moving ship or a helicopter. In particular, the new "HEM-Bird", a geophysical probe drawn along under a helicopter on a 20-metre cable, enabled the acquisition of data of surprisingly high quality. These measurements of the ice

diverse types of surface. Observing the feeding habits of minor invertebrates which had adapted to the extreme living conditions in brine channels in the ice flows, and whose body fluid did not freeze, proved very exciting.

The northern Arctic Ocean is permanently covered by pack ice today, even though the exchange processes with the adjacent seas and the seasonal melting processes ensure that this sea ice never lasts for more than a few years. The task of the marine geologists was to take sediment cores from the region off the great Siberian shelf. As terrestrial sediment sequences are often subject to major errors in dating we are hoping that these submarine cores will help to throw further light on chronological processes. Major ice shields on the adjacent land areas can be identified in the Arctic Ocean sediments through coarse and fine rock residues carried by the icebergs. The sediment cores from the Gakkel Ridge at 70 degrees East, which had never previously been subject sampled, were indeed found to contain a number of layers of coarse sand and stones, typical sediments from the melting phases of great glaciers. From the variously coloured layers in the sedimentary cores we were able to estimate that these were around 200,000 years old. Laboratory studies are now expected to provide more precise dating and to reveal the extent of the glaciation in Northern Siberia in its individual phases, the role played by the transport of moisture from ephemeral stretches of open water in the build-up of the ice, and the points in time when the melt water of the warm phases of melting glaciers reached the ocean.

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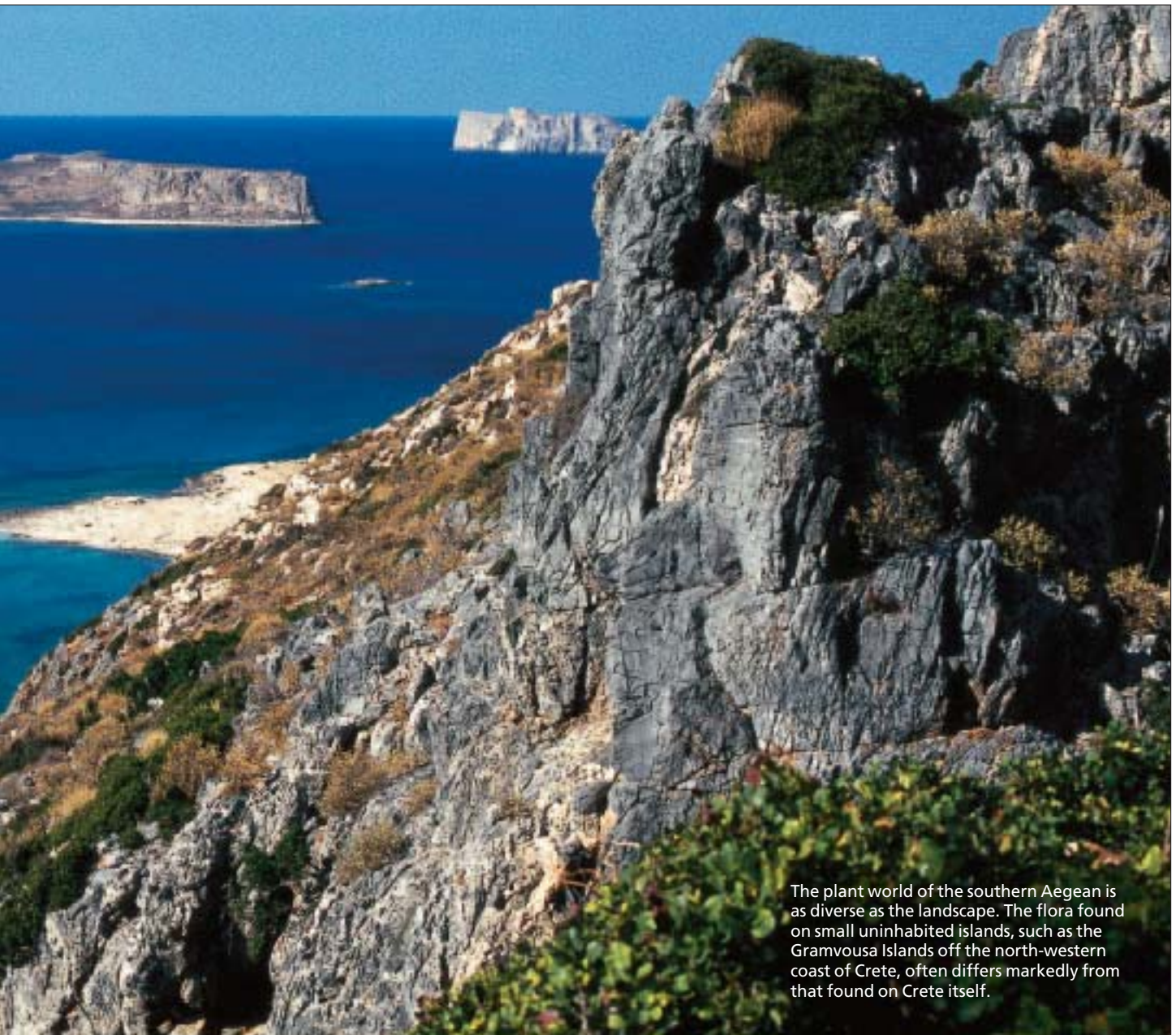
km. One of the purposes of the expedition was to observe changes in the thickness and distribution of the ice and to compare the results with previous measurements made by "Polarstern" in the central Arctic Ocean in 1991 and 1998. In summer 2001, no extensive areas of water were encountered at the North Pole. Over 90 per cent of the surface was covered by large flows of multi-year ice measuring several kilometres in

thickness also served as preparation for the European Space Agency's (ESA) "Cryo-Sat" satellite mission, due to map the Arctic and Antarctic ice cover beginning in 2004. Measurement of the sea ice also included determination of the physical and biological properties of the ice and melt pools. In addition to this, we drilled ice cores, evaluated satellite and aerial photographs, and determined the reflective capacity of

When Plants Tell of Their Environment

*The flora of the southern Aegean area
provides valuable pointers for agriculture and forestry
to the climate and the constitution of soils*





The plant world of the southern Aegean is as diverse as the landscape. The flora found on small uninhabited islands, such as the Gramvousa Islands off the north-western coast of Crete, often differs markedly from that found on Crete itself.



Plants can act as indicators by furnishing information on their environment. Such bioindication, however, presupposes the ability to recognise the indicative qualities of the plants with respect to essential soil and climate parameters. Appropriate numerical values have now been provided for the first time for a large floristic domain in southern Europe, with the Aegean area of Greece being used as an example. A by-product of this study was the discovery of hitherto unknown plant species.

The species composition, vitality and structure of the plant cover of a given area reflect the main features of an ecosystem's habitat characteristics. Many plants grow on soils with special properties such as high moisture, very low nitrogen content, or high acidity, or they may only grow under a given temperature regime. As a result, they acquire indicator value and can be used for habitat classification, environmental (passive) monitoring or for ecological interpretation of specific vegetation sectors. Indicator plants are pointers to the energy-matter budget of nature, and especially of its bioeffective system components and, naturally, also of anthropogenic and biotic influences.

Forest botany and the study of forest habitats has resulted in the accumulation of a wealth of knowledge on the habitat conditions under which plants thrive in central Europe. "Pflanzensoziologische Exkursionsflora", the standard work written by the forest botanist Erich Oberdorfer, and already in its seventh edition, contains copious data of this kind. Heinz Ellenberg's system of "indicator values" is a breakthrough towards a "numerical" treatment of phytoindication, and thus to its quantification and further operationalisation. Starting from five-value scales for segetal weeds, he developed nine-to-twelve-point indicator value scales for the ferns and flowering plants of central Europe.

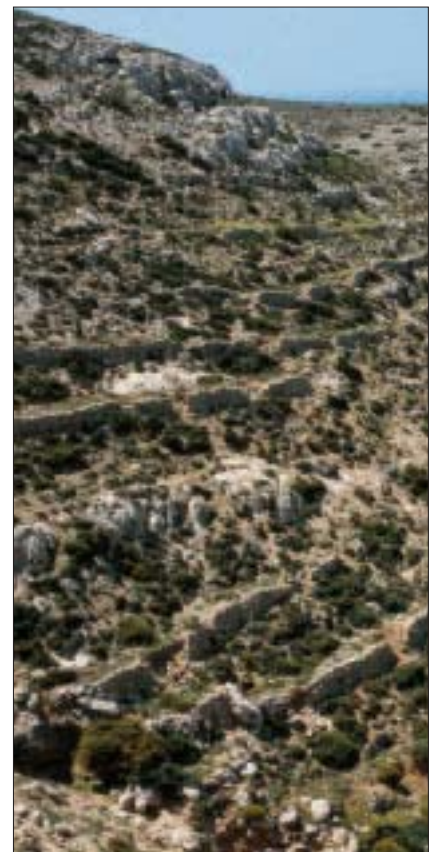
The potential practical applications of this system are legion. It can aid farmers introducing novel crop plants, or assist forest planners selecting tree species, or it can furnish

crucial hints for range management. It can also supply information for regional tourist development. These indicator values are also of significance for the cultivation of Southern Aegean plants, many of which are potentially or actually endangered, where precise knowledge of their demands on habitats is a vital element that biodiversity research can contribute to species conservation. Ecological preferences can also provide criteria for the systematist when he delimits, classifies and



When the snow melts, crocuses (*Crocus sieberi*) (left) bloom in the moist mountains of Crete. Thorny chicory (above, right) is a popular wild vegetable. The remains of terracing walls bear witness to the former much more intensive use of the landscape and higher settlement density. Many a plant's distribution pattern can only be explained against a historical background.

names plant taxa. Ellenberg's temperature scale covers values from one to nine. In each case, the lowest value reflects the minimum intensi-



ty of a habitat factor, and the top value the highest intensity, whilst the intermediate values indicate the transition between the extremes. Plants with a temperature value of one are indicators of cold, and only occur at high elevations in the mountains. Temperature value three is allocated to the indicators of cool conditions, which are found mainly in sub-alpine habitats. The indicators of moderate warmth (temperature value five) are plants of the lowlands and hills, with their greatest concentration in the sub-montane temperate belt. Temperature value seven is allocated to indicators of heat, and nine to "extreme heat", centred on the Mediterranean in this distribution. Logically, plant species with a broad ecological amplitude with respect to a given habitat factor, in other words, which occur over a broad range of habitats, have no indicator function. Such plants are described as "indifferent" with regard to their preferences. Using mean or dominant indicator values, phytoindication will enable an area to be classified by means of detailed ecological maps (climate maps, soil-conditions) drawn to a variety of scales. It is hardly sufficient to base generalised statements on locally made measurements alone, but the almost omnipresent vegetation – combined, for greater security, with the geomorphological features – ensures the effective production of such maps. Today, just on fifty years after its introduction, Ellenberg's indicator value system is in general use for resolving questions of plant ecology and regional planning. It has been extended, in a slightly modified form, beyond its original range to be used in neighbouring areas such as Scandinavia, Poland, Hungary, Romania, the Benelux countries and Great Britain. Until recently, no corresponding studies were available for any regional flora of southern Europe. Only in 1994 was an indicator value table produced to evaluate the indicator properties of the flora of the Greek island of Naxos, with its diverse landscape.

Since 1997, scientists at the Botanic Garden and Botanical Mu-

seum of the Free University in Berlin have been engaged in a research project entitled "Indicator Values for the Vascular Plant Flora of the Southern Aegean Area (Greece)". The South Aegean phytogeographical province extends from the island of Kythera in the west, via Crete and Karpathos, to Rhodes in the east. It hosts approximately 2,500 species and sub-species of higher plants (excluding Mosses, Lichens, Fungi, and Algae). The aim of the project is to determine ecological indicator



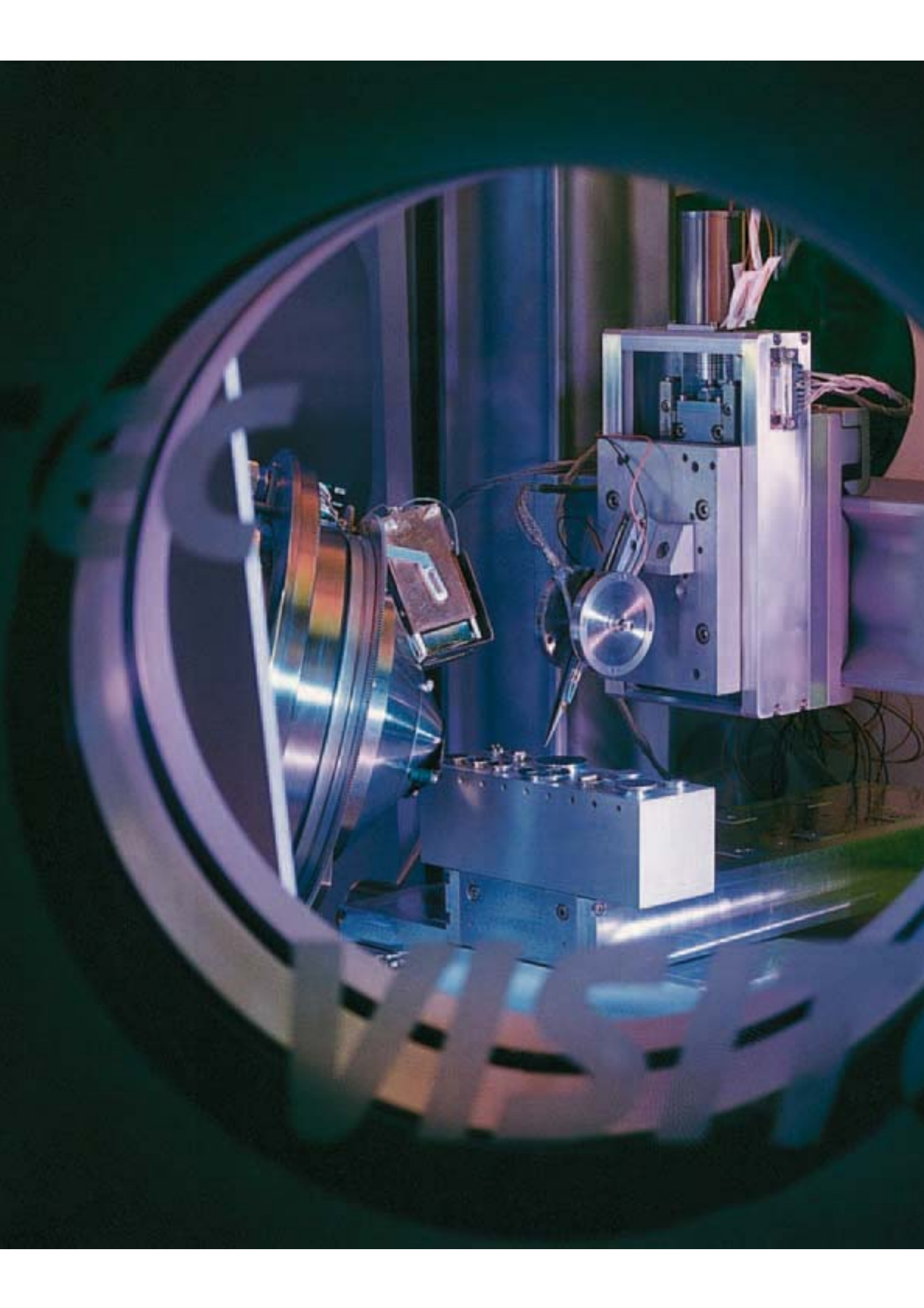
values with respect to temperature, moisture, nitrogen and light supply, plus soil acidity and salinity, augmented by further specific indicator functions for all flowering plants and ferns. To achieve this, Ellenberg's indicator value system had to be modified by adapting the scale of temperatures to the much warmer conditions prevailing in the southern Mediterranean. The aridity of the Mediterranean habitats also exceeds that for central Europe, which entailed a different spectrum of moisture values.

Extensive studies are needed in order to assess the ecological behaviour of plants. The work centres on vegetation analyses, repeated in different seasons for complementarity, combined with complex habitat characterisation. Soil samples were analysed at the Landwirtschaftliche Untersuchungs- und Forschungsanstalt Augustenberg (LUFA) and the results were combined with the floristic and ecological data in a databank, which also holds literature and herbarium data. The identification of plants that cannot be named with confidence in the field is a time-consuming process that requires comparison with the voluminous reference collections (herbaria) and consultation of the specialised library of the Botanical Museum Berlin-Dahlem. Correct determination of the plant taxa is essential for high quality results, being an indispensable basis for any studies of vegetation ecology.

Despite the fact that Crete, floristically speaking, is one of the best known regions in the Mediterranean area, it has still been good for surprises, too. Thus, for instance, *Trifolium phitosianum*, a species of clover, had to be described as a species new to science. This is a small annual herb whose distribution appears to be confined to the eastern end of Crete, underscoring the importance of Crete as a centre of diversity of the genus *Trifolium* (38 species and sub-species). Further new species are awaiting their description, many have been recorded for the first time in the project area.

In the medium term, the opportunity now exists to develop a pan-European system of indicator values by working north from the Southern Aegean area in southernmost Europe to close the gap between this and central Europe.

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A Peep into a Different World

Microsystems technology holds great potential for novel products in medicine, analysis and electronics – a collaborative research centre in Aachen is elaborating the necessary principles

To elaborate the principles for the production of microsystems in hybrid (mixed) modes of construction – this is the aim of the basic research currently being conducted by the collaborative research centre established in 1997 at the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen entitled “Assembly of Hybrid Microsystems”. Five institutes of the RWTH Aachen and two Fraunhofer institutes from Aachen are collaborating closely on the processes required for handling and joining the microcomponents. The details of

these microcomponents are only perceptible using optical instruments. Having once seen the diversity of minute individual components comprising a microsystem the problem is immediately obvious: how can these tiny components be handled, joined together, and then assembled to form a complete component?

In the simplest case, handling is effected using a magnifying glass and a pair of tweezers. Having said this, the two main tasks in this process have already been described: the moving and positioning of the tiny components, and the observation and monitoring of this process. A variety of instruments are required for this, of which one of the most important are the pincers. In view of the small size of these microsystems, the pincers must not be much larger than the components. Their points should therefore only be a few micrometres in thickness and width. This is the only way in which even difficult assembly positions can be reached.



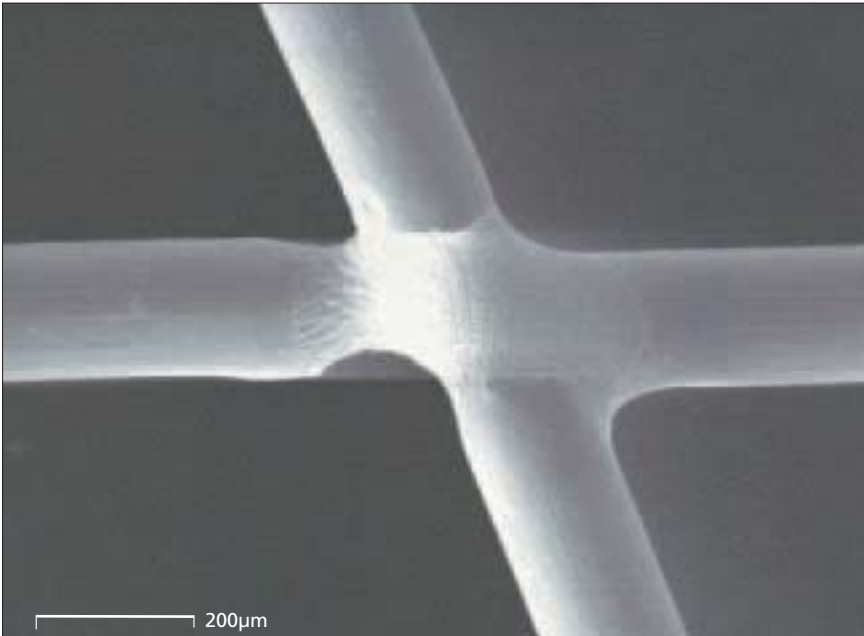
A look into the large-chamber scanning electron microscope at the Fraunhofer Institute for Production Engineering in Aachen. Here, tiny components – for example, gears – are combined into microsystems (small photo).

Physical properties often act differently at the micro-level or may lead to different effects from those familiar in the "macroworld". For example, the behaviour of handling devices is normally largely determined by their weight. Whereas the

stress. If damage is to be avoided the selection of the pincers' drive system is of crucial importance. Piezo elements, which change their length proportionally to the applied stress, and thus enable infinitely fine adjustments to be made, have

both the micro- and the millimetre ranges. The demands placed upon the assembly unit's ability to adapt to variations in size are therefore much higher than has hitherto been the case. The gripping width and the form of the points of the pincers, for example, have to be adjusted accordingly. It is safe to say that there will never be a pair of universal pincers capable of gripping every component employed in microsystems engineering.

One attractive possibility for monitoring the assembly process is offered by the scanning electron microscope (SEM). These instruments

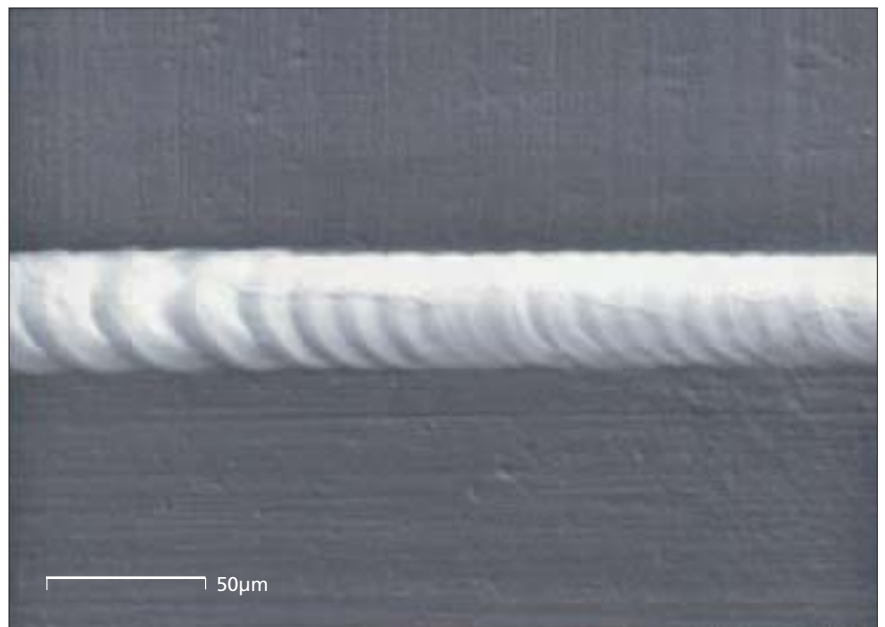


The steel wires welded together in the SEM are only 175 micrometres thick (above). Small photo: Mechanical pincers help when handling tiny components. Right: A microwelded seam.



force exerted by their weight decreases by the power of 3 of the dimensions, the surface forces only decrease by the power of 2. As a consequence, the micro-objects which have been gripped may adhere to the pincers when these are opened. In terms of micro-assembly, this means that special countermeasures have to be found. One approach is to join the already positioned components to other components whilst they are still in the grasp of the pincers.

The small size of microcomponents produces further challenges. Thus the areas available for gripping by the pincers are also very small. Gripping with the pincers can lead to extremely high pressures per unit area which clearly exceed the maximum permissible



proved to be particularly effective. Components in microsystems engineering differ in form from those found in microelectronics. Their size-range, especially, embraces several orders of magnitude covering, for example, components in

achieve much greater magnifications (up to 300,000 times) than light microscopes, although the crucial advantage for microassembly lies, in fact, more in the greatly enhanced depth of field they offer. A component is sharply depicted not



only in a certain plane, but is recognisable over the entire extent of the field. Hence the images have an almost three-dimensional plasticity.

Due to the heavy investment involved, this monitoring system plays a negligible role in industrial production processes, but for research purposes SEM offers unbeatable opportunities for observing processes during micro-assembly operations. A further approach to acquiring a cost-effective means of observation lies in integrating an endoscope into the pincers. This makes it possible to look directly between the arms of the pincers. The first prototype with this modification has already been made. Furthermore, the integration of a laser lens will enable the components, once positioned, to be soldered on the spot. The tiny components have not only to be moved and positioned

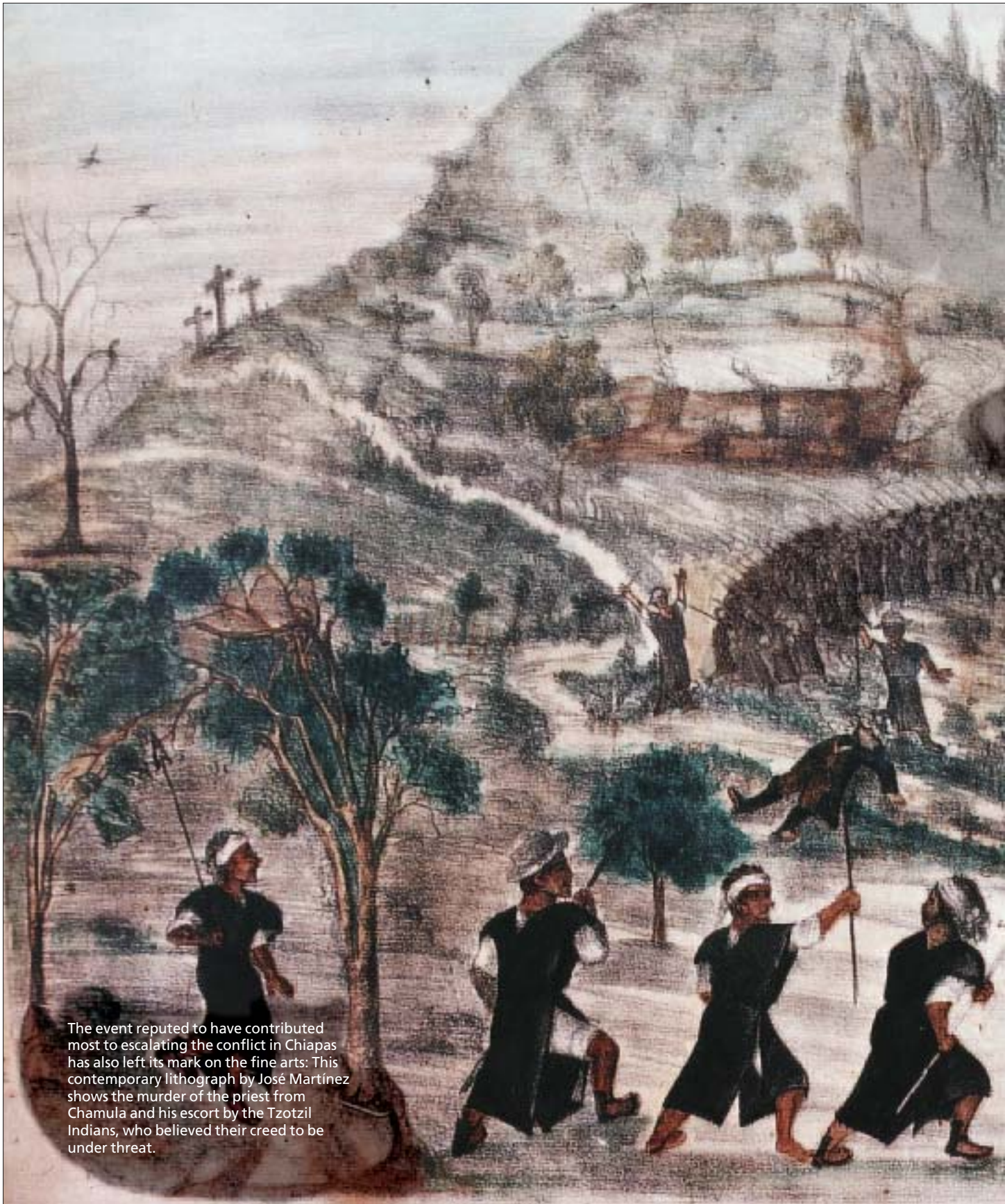
Electrical, optical and mechanical components are combined into an overall system

with the help of the pincer device, but in most cases, they also have to be joined together. Very often, electrical, optical and mechanical components made of a diversity of materials have to be combined into an overall system. This presents a great challenge. Amongst the processes under study are the welding of plastics, plastic assembly injection moulding, microsoldering, microelectron-beam welding, and laser-beam welding and soldering. A further joining technique embraces the use of adhesives. Apart purely mechanical fixing, glues often perform additional functions, such as sealing against liquids or gases. Microelectron-beam welding is a recently developed joining method. Within the framework of our research mandate we have modified a normal scanning electron microscope in such a way that it

Microscopic drops of adhesive were placed on a glass surface in a regular pattern of dots. They are only 1.5 billionths of a litre in volume.

can be employed for electron-beam welding with a small beam diameter and high output density. In addition to being used for microwelding, the SEM also offers the advantage of affording an observation facility. Despite the fact that simultaneous observation and welding are not possible, it nevertheless enables the positioning of the joined components to be checked and the joints to be displayed and measured once the welding process has been completed.

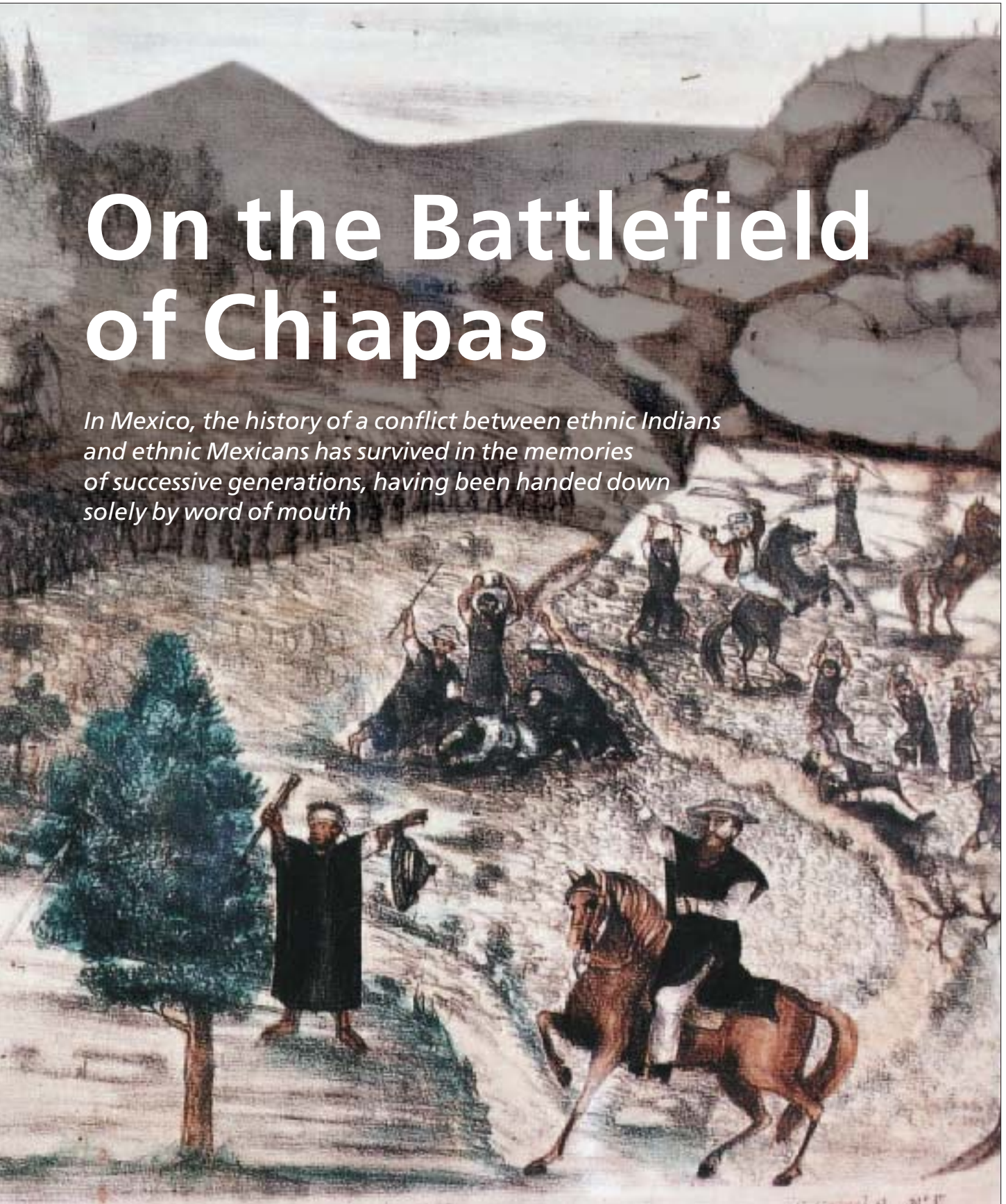
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The event reputed to have contributed most to escalating the conflict in Chiapas has also left its mark on the fine arts: This contemporary lithograph by José Martínez shows the murder of the priest from Chamula and his escort by the Tzotzil Indians, who believed their creed to be under threat.

On the Battlefield of Chiapas

In Mexico, the history of a conflict between ethnic Indians and ethnic Mexicans has survived in the memories of successive generations, having been handed down solely by word of mouth



It began with the worship of effigies of new gods, and ended in a violent uprising and a host of dead. This was the situation at the beginning of the 18th and around the middle of the 19th centuries, when the Indians in Chiapas rose against repression by the Church and state. When the interest of ethnologists becomes focussed on such distant events the inevitable problem arises that documents relating to these events are either incomplete or no longer existent. So how can evidence of the true motives underlying the conflicts in those days be collected? The point of view of the Indians can only be discovered from what has been handed down by word of mouth. What in Europe would have been a hopeless undertaking – just think, for example, of trying to discover new aspects of the Franco-Prussian war of 1870–71 from purely oral records after a time-lapse of over 100 years – was, under the special conditions prevailing in the highlands of the Chiapas, rewarded with surprising success.

Not even the political upheavals of the Mexican Revolution (1910 to 1917) had any impact on the local mountain villages and their broadly scattered farmsteads. No political events of any note have taken place in this region since 1870. And since neither the few schools nor the media have exerted any manipulating effect, the events of those distant days have remained in vivid local memory. Between 1970 and 1998, visiting diverse Indian communities, we succeeded in recording 22 reports, narrated in “tzotzil”, the Maya-language spoken by the Indians, and a further two from Spanish-speaking Mexicans (Ladinos). Some of the more elderly narrators had still acquired their knowledge from eye-witnesses, and the younger ones had relied mostly on their grandfathers or grandmothers. Most of these reports were compiled between 1970 and 1982, i.e. after a lapse of 100 to 112 years since the events.

Our investigation was not only concerned with discovering the Indian viewpoints and comparing them with contemporary Ladino documentary sources. We also aimed to discover the precise course of this religious revitalisation movement and to test basic premises of



Narrator from San Andrés, head of a school for Indian women weavers, in a self-made blouse. Right: Narrator from the parish of San Pablo Chalchihuitán. This specialist in oral history retails reports on local history, myths, prayers and hunting episodes.

current narrative research. Has this picture of the past just been constructed on the basis of the narrator's current situation? Are the narrators relating their tales truly in accordance with their social and ethnic identities? This question, especially, can be investigated through the medium of an inter-ethnic conflict such as experienced by the Tzotzil Indians of Chamula.

It began at the end of 1867 in Tzajhemel, a remote hamlet in the parish of Chamula. The local populace held regular festivals in honour

of their new “Santo”, effigies of gods similar to the holy statues found in churches. Where the highlands merged into the lowlands, in other words, in an ideal geographical location, a flourishing Indian market grew up, as a result of which trading in the highland town of San

Cristóbal was brought almost to a complete standstill. In the course of this development, mounted terror commandos sallied out of the town to destroy the market, and priests destroyed the holy shrine, which was always subsequently rebuilt. When the priest from Chamula destroyed it for the third time he was killed by the enraged Indians. This was followed by three days of counter-terror. The Indians now engaged in the indiscriminate slaughter of innocent Ladinos. More than a hundred victims were counted, mostly women and children.

A few days later, near San Cristóbal, the Indians and the Ladinos clashed once again – this time there were over 80 dead on each side, but no clear victor. A week after this, the government troops, now reinforced, inflicted a crushing defeat on the Indians. The rebels fled, and although they tried to regroup in various places in the mountains, and to resume the

practice of their religious cult, the government forces, having pursued them for over a year, nevertheless finally triumphed in the autumn of 1870.

Very different interpretations of the nature of these events have been expressed. Some people talked about an inter-ethnic conflict fired by the centuries-old hate felt by the Indians against the Ladinos, others called the dispute simply a barbarian attack on a superior culture. Some historians later interpreted the conflict as a class struggle, a struggle for a paradisaic early form of communism – however, no evidence from original sources was ever produced in support of this postulation.

Contemporary documentary sources had already made it clear

that at the beginning of the revolt a religious movement was involved. From the numerous oral traditions, however, we now know that the religious motivation regained the upper hand after the military defeats in June and July 1869, and was clearly dominant in the final phase. At the start, effigies of gods were worshipped whose names had been derived from Catholic saints, then Indians had paraded as these gods, and later on, only the new gods were mentioned. In their last stronghold in the remote mountain region of San Pablo, the number of these gods had doubled to eight. At their head was the god Sanmateo, personified by the founder of the new religion, the Chamula Indian Pedro Díaz Cuscat.

Whereas the contemporary literature is almost exclusively concerned with battles and the numbers of killed and wounded, the narratives of the Indians furnish a vivid picture of the religious cult itself. In no way did the self-appointed gods appear in full pomp and splendour in an attempt to bridge the gap to the ancient Indian forms. They were much more orientated towards the festive costumes of rich Ladinos. As reports from various districts relate, Sanmateo was obsessed by the idea of using ritual dances to prevent the approach of the soldiers. But as they still appeared and pressed home their attacks, serious doubts arose as to the legitimacy of these new gods.

After their expulsion from the territory of the Chamula, the fleeing rebels found themselves on the territories of diverse other Tzotzil communities, and had to find some mode of cohabitation with the indigenous Indians. It is clear from the narratives handed down by the affected communities that they were unable to do this. The new arrivals acted as lords in the territories of their hosts and became a burden on the local economies. As a result, the native populace appealed to the government to send troops to drive

out the devotees of the cult – a fact which effectively confutes the long-held vision of a widespread Indian revolt.

One motive has excited special interest in the Chamula revolt, and has even been explored in detail in fictional literature: the macabre cru-



cifixion of a young Indian on Good Friday of the year 1868. The aim of this action was purported to have been the acquisition of a Christ "of their own". However, the veracity of this has also now been placed in great doubt by the traditional narratives. It is noticeable that not a single narrative – either from the Indians or the Ladinos – mentions the crucifixion, whereas several do indeed report on the murder of the priest, which occurred within the same chronological and geographical framework. Inspection of the documentary sources revealed that only one single author had reported on the crucifixion, and that was twenty years after the event, moreover, there is not the slightest evidence of a crucifixion to be found in any of the numerous anti-Indian

newspaper articles of those days. Worthy of note is the way in which today's Ladinos assess the person of Galindo. This Ladino had gone over to the devotees of the cult in the Chamula area three weeks prior to the outbreak of hostilities. In contemporary reports he is described as being the leader of the rebels, a blood-thirsty killer, who had been branded as a traitor to his race. After the massacres in the hinterland he did indeed appear at the head of the Indian masses before San Cristóbal. However, he refrained from attacking, and instead requested negotiations to secure the release of the Indian leader Pedro Díaz Cuscat, who was imprisoned at that time. After lengthy deliberations, Galindo himself entered the town under a personal safe conduct granted by the authorities of San Cristóbal. By doing this, Galindo prevented an attack by the Indians, but a few days later the governor of Chiapas rescinded this safe conduct and Galindo was summarily shot. No mention at all is made of Galindo in Indian narratives, raising doubts as to his role as a leader. In contrast to this, in Ladino records, he is the leading character. Quite unlike the negative picture of him painted in contemporary sources, he is portrayed here as

a tragic figure, and as the victim of squalid political intrigues. In this case, the Ladino version is obviously a true reflection of the actual events.

From the way all this has been narrated, which is also typical of the Indians, it may be deduced that the current political situation and the ethnic origins of the narrators have little influence on the content of their narratives. Only in exceptional cases was any form of tendentiousness detectable.

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All these narratives and detailed analyses have been published in Ulrich Köhler, *Der Chamula-Aufstand in Chiapas, Mexiko, aus der Sicht heutiger Indianer und Ladinos*. Münster 1999. The book contains lengthy summaries in Tzotzil, Spanish and English. 61



The Refuge under the Bark

Nearly one quarter of Australia's insect species live under the bark of eucalyptus trees. These fissured trees afford carabids in particular protection from the sun, fire and rapacious enemies. Carabids have adapted extremely well to life under the bark

Australia has always stimulated the interest of biologists, for the flora and fauna of this island differ considerably from those otherwise familiar to us. For 40 million years, over almost the entire geological era which began around 67 million years ago and lasted some 60 million years, Australia lay isolated. This continent is like a raft which tore free and only touched land again after a very lengthy passage of time. Many of the creatures involved in this journey perished during the voyage, others were able to make their way and multiply. Hence, although contemporary Australian flora and fauna are lacking in major divisions, in many of the groups large numbers of for the most part closely related species have developed.

At the beginning of the Tertiary, Australia lay far to the south of the lower half of the southern hemisphere, at the eastern edge of today's Antarctic continent. Conse-



quently, most of its inhabitants were adapted to cool climatic conditions. In the course of the continental drift, however, it moved northwards, where it became increasingly arid. The overall climate became warmer, forcing the animal world to adapt to these drier conditions. At all events, the carabids adapted well. This is a group of insects numbering just under 35,000 species world-wide, whose members are mostly carnivorous, and good, fast, runners. In temperate latitudes the majority of these animals are ground-dwellers, in the tropics, in contrast, many live on leaves or the trunks of trees.

Interestingly enough, although known in Germany as "running beetles", just in Australia this name is inappropriate as the proportion of these species which actually runs around the surface of the earth there is small compared with other continents. Almost three quarters of the surface of Australia lies under threat of water shortage, and the carabid's chances of surviving this growing aridity are small. Either they have withdrawn to the banks of rivers and lakes, where they can still find a certain amount of humidity, or they dwell – better protected from heat and aridity – in the soil, from whence they make their way to the surface at night or after rain

has fallen. Some of the beetles have switched to the trees for shelter from the blazing sun. As a rule, these trees are eucalypti, the prevailing group of trees in the deciduous forests, savannahs and tree steppes of Australia, where they colonise every mildly humid habitat in large numbers, stamping their own unique mark on it. Even in arid areas, these adaptable plants are to be found growing along watercourses.

Eucalypti are a very richly endowed group of trees, encompassing not only gigantic, but also small, shrub-like representatives. They exhibit a multitude of different growth, leaf and bark forms. A considerable portion of the eucalypti possesses a bark which is regularly shed in long strips from the trunk, leaving crevices in the wood into which a unique animal world has moved. Under the bark of a single tree tens, or even hundreds, of thousands of animals are to be found, extending in

range from tiny springtails to representatives of nearly every group of insect, isopods, millipedes, spiders, and even small vertebrates. These form food chains with numerous links. How has this rich fund of fauna developed under the eucalyptus bark? There has quite evidently been an interplay between supply and demand for, despite the fact that Australia's arid areas offer better conditions for survival than those in other continents, survival nevertheless presents problems. In particular, the eucalyptus forests appear to be more accommodating

Left-hand page: Eucalypti like this gnarled river eucalyptus can host over 100,000 insects. Beetles of the most diverse species dwell under the bark. There (left) long-legged, sap-sucking tree bugs are also moving in. Above: A carabid, *Philophloeus eucalypti*, displaying its characteristic colour pattern.

than they actually are, for which three main factors are probably responsible: the growth form of the crowns, the shape and position of the leaves, and the high frequency of bush fires.

Most eucalypti have windswept, open crowns highly permeable to light. As, moreover, their leaves are mostly elongated in shape and vertically suspended, reflecting the light from their glossy, leathery surfaces, the soil under the eucalypti is open to abundant radiation. So it is not without good reason that people talk about the "shadeless forests" of Australia. Even in the densest woodland, soil animals have to contend with very high temperatures on the ground. The third factor are the frequent bush fires. These regularly destroy the dead leaves and undergrowth, thus endangering any ground-dwellers unable to escape in time.

Animals on the ground and in the detritus strewn around the floors of eucalyptus forests thus have a difficult time. They can only counter the high temperatures and frequent bush fires in two ways: either by digging in, or by colonising the innumerable crevices offered by the eucalypti.

The bark of the eucalyptus tree affords its inhabitants not only protection from their enemies, but also astonishingly good thermal insulation. Measurements have revealed that the temperature gradient between the outer and inner sides of larger pieces of bark can be 25 degrees Celsius or more. Hence bush fires, which normally pass through the forests at a fair speed, can scarcely affect the crevice dwellers. Only a more prolonged and intensive conflagration can drive the temperature under the bark to a dangerous height. Even where the external temperature is extremely high, small water droplets under the bark create a relatively high degree of atmospheric humidity, which

lowers the internal temperature. Under these harsh conditions, numerous animals have resorted to this unique refuge. Many only emerge at night to hunt on the surface of the bark. Others leave the trees under the protection of darkness and move to the ground, and many pass their whole lives under the bark. It is postulated that almost one quarter of all the known species of insects in Australia use the bark of the eucalyptus tree either as a refuge or a habitat, as do the carabids, too. Amongst the latter, the proportion living under the bark is especially high – probably over 700 "subcorticolous" species exist.

These are distributed amongst surprisingly few species-rich genera. It would appear that in the case of the carabids only a few survived the long passage through the Tertiary, but that they then colonised their new habitats without delay, and have since developed an amazing abundance of species. This is not surprising, bearing in mind the rich diversity of fauna inhabiting the crevices, which offer carnivorous insects a host of possibilities.

However, the immigration of these carabids into this habitat cannot have taken place so very recently, as some astounding forms of adaptation have occurred in the process. That the bodies of the majority of these beetles are elongated and very flattened is not difficult to understand, nor that the soles of their feet are equipped with thick brushes to improve their hold on the



Right: The bark of many eucalypti is regularly shed in long strips. To protect themselves from the sun and predatory enemies, carabids, a group of insects embracing an estimated 35,000 species, find refuge in a habitat beneath the bark. The carabid *Amblytelus curtus*, here in its warning coloration, also forms part of this community.





Regular bush fires on the Australian continent and “shadeless forests” in the tropical tree savannah (left) make life difficult for beetles on the ground. Examination of the bark fauna (below left) using a simple umbrella to catch the beetles falling out when the bark is stripped off.

smooth surface of the trunk. But what is the significance of the conspicuously dark colour pattern on a yellow or bright red background? In view of their way of life, these beetles are classified as nocturnal, in which case conspicuous warning colours are not actually necessary.

The entire complex of camouflage, warning and mimicry has yet to be studied. However, one theory – not yet confirmed by observation or experiment – holds that these colour schemes serve as protection against birds specialised in preying on bark animals. The so-called tree creepers, in particular, regularly use their beaks to lever off pieces of bark and so gain access to the insects underneath. It is still not

clear whether these bright colour schemes might not exist to feign an unpleasant taste or toxicity.

One sub-family of the carabids has taken adaptation to the subcorticle way of life so far that its members can scarcely be recognised, even by carabid specialists. The group of the Pseudomorphinae, especially, have developed extremely original forms in the course of their evolution: the head has become increasingly recessed under the pronotum (dorsal plate), and the wing-covers so broadened that they cover the legs. The feelers and legs can be folded into grooves, and the legs have become so foreshortened and broadened that they really bear no similarity at all any more to those of normal carabids. With this powerful physique, these beetles have adapted themselves marvellously to their subcorticle way of life. At the same time, it protects them from the ravages of redoubtable ants and termites.

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Natural Sciences

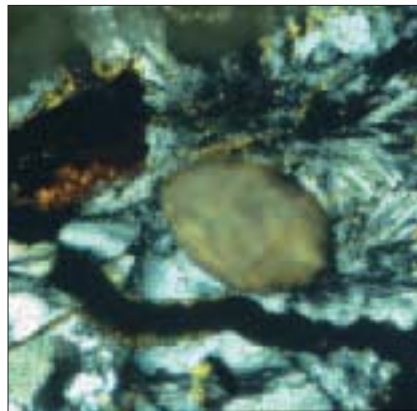
A Treasury in Siberia

35 million years ago a cosmic projectile struck the earth in North-western Siberia and left a crater over three times the size of Luxembourg – Popigai. UNESCO had good grounds for designating this crater as part of the world's geological heritage



From the results of ground-based remote sensing and space missions we know that the surfaces of nearly every solid planetary body exhibit a multitude of craters due to the impact of asteroids and comets. The impact of these projectiles at a velocity of many kilometres per second causes immediate release of massive amounts of energy. This creates a crater, causes the ejection of large amounts of rock, and induces unique, irreversible changes in rocks and minerals (shock-metamorphism). An impressive example of such an impact was that of comet Shoemaker-Levi 9 on Jupiter in July 1994.

Approximately 160 impact craters and just under 20 sediment horizons with ejecta material are known to date on Earth. Most craters are located on continental shields. Vredefort, in South Africa, with a diameter of about 250 kilometres and an age of 2,023 million years, is the largest and oldest known terrestrial impact structure. About 60 per cent of the terrestrial craters, however, are considerably younger, less than 200



Above: The remnants of the main camp contain still valuable old drill cores.

Left: Micrograph of a rock containing a diamond grain about 0.15 mm in size, which was generated from graphite at 350,000 times atmospheric pressure.

Right: Fresh tracks – wolves follow the geologists as an invisible escort during the fieldwork.



million years old. This distribution in space and time reflects the dynamic nature of the Earth: erosion and plate-tectonic processes erase

the traces of these impacts, removing mostly old and small craters. Other structures, such as the Chicxulub crater on the Yucatan Peninsula in Mexico, which is approximately 180 km in size, are buried under thick sequences of younger sediments and can only be detected by geophysical methods. Today, the search for geological evidence of impact events is primarily linked to the question of whether impacts and their short- and long-term effects have influenced the formation and evolution of the atmosphere and biosphere. For example, sediments deposited worldwide 65 million years ago bear traces of the Chicxulub impact; these findings demonstrate the causal link between this impact event and the sudden mass extinction at the transition from the Cretaceous to the Tertiary period (K-T boundary).

**The Popigai crater –
at 35 million years old,
fairly young – has
scarcely been altered
by erosion**

The analysis of terrestrial craters also has a “planetary” dimension. While the morphology of impact structures on other bodies in our solar system is known in detail from spacecrafts and Earth-based observations, the sub-surface structure and the spatial distribution of rock formations – the third dimension – can only be understood if results of ground-based research on terrestrial craters are taken into account. Where such a structure is well exposed it stands as a three-dimensional model that is accessible on foot. Fieldwork, geophysical investigations, drilling into the basement and multi-disciplinary laboratory studies of rock samples furnish data necessary for setting up a generally valid model for the formation of craters. Amongst the terrestrial impact structures, Popigai, in North-western Siberia, is outstanding:

aged only 35 million years, it is the only complex impact structure on Earth that shows scarcely any traces of erosion, and is thus completely preserved. Complex impact structures differ from the much smaller, simple or bowl-shaped craters through the presence of ring-walls and annular troughs, and in certain cases, a central peak of uplifted rocks. Popigai, approximately three times the size of Luxembourg, contains fantastic outcrops of typical impact rocks. Some of these – the “impact melt rocks” – originated within a few seconds from material that was heated to well above 2,000 degrees Celsius after release from the high pressure of the shock-wave. Other rocks are multi-

Reaching the outcrops along the banks of the Rassokha River was only possible by means of rubber boats. The scientists collected over 200 kilograms of rock samples in Popigai – an immense reservoir for future investigations, too.





coloured breccias consisting of a variety of crushed rock fragments from different sources in the crater. The size of these clasts ranges from small mineral grains to several tens of metres – the mixing and crushing of the material give an idea of the giant forces which are released during an impact process. The components of these breccias are mixed together during ejection. In Popigai, the impact rocks form steep cliffs along the banks of the rivers, displaying a palette of colours from browns and ochre-coloured pastel shades to deep blue, depending on the incident light.

But Popigai's outstanding rank amongst terrestrial craters results not only from these excellent outcrops and their pristine state of preservation, but also from the presence of an extraordinary variety of diamonds. That diamond forms in impacts has been known since the sixties, when diamond was synthesised from graphite for the first time using shock-wave experiments. Based on this discovery, it was soon

Members of the expedition studying veins and pockets of black rock debris in a large limestone block.

Right: During ejection, this "gneiss bomb" was coated with impact melt in the vapour plume above the growing impact crater.

realised that at least part of the diamonds known since the last century to occur in specific meteorites had evidently been generated in violent collisions within our solar system. In the early seventies, a team of Soviet geologists then discovered the first terrestrial impact diamonds, initially in a placer, and later in the Popigai area, which was later identified as an impact crater. Russian scientists subsequently succeeded in identifying impact diamonds in numerous craters in the former USSR, and also in the Nördlinger Ries in Germany. The diamonds, whose colours range from transparent, to white, yellow, grey and black, originated by transformation from graphite flakes and grains. The graphite was a mineral component of the crystalline rocks in the crater target, which were over



2,000 million years old. These diamonds are not suited for cutting, yet their hardness slightly exceeds that of normal diamonds – a property of great interest to industry (drilling, grinding and polishing). Between 1970 and 1986, intense geological research was conducted in Popigai, involving mapping, drilling some 500 exploration wells, and transporting many tons of rock to research facilities in the European part of the USSR. The extreme climatic and geographical conditions in North-western Siberia, where



Over 140 metres high, spectacularly steep cliffs string along the banks of the Rassokha River. Individual rock fragments can reach the size of a house. Above, left: Two eagle chicks in their nest high above the Rassokha River. Left: The rock "bombs" ejected from deep target levels during the impact, are now a component of the breccias, which also contain finer-grained material.

temperatures down to minus 50 degrees Celsius occur, presented an exceptional challenge. The investigations revealed that Popigai, with a diamond content of 5 carats/ton of rock, represents a giant, yet economically inexhaustible diamond deposit. Nevertheless, it was a strategic resource for the Soviet Union as the crater contains many more diamonds than all the world's other diamond deposits put together. Hence all the results of these geological investigations remained under lock and key. Popigai was only accessible to Soviet scientists, and is still a prohibited area. It was only in 1997 that a small German-Canadian-Russian scientific expe-

dition got permission to visit Popigai. A few helicopter hours away from Khatanga, the nearest base manned continually all the year round, the scientists constructed their primitive camp on a gravel terrace on the banks of the Rassokha River. Within days, floodwater turned the river into a raging torrent which, although posing a threat to the tents, nevertheless uncovered the skull of a mammoth in a sandbank.

In view of its extreme location, the Popigai structure, which UNESCO has declared to be part of the world's geological heritage, will remain a hidden treasure, despite its wealth of diamonds. – Our sample material, however, forms a sheer inexhaustible stock for current and future scientific studies.

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The Loneliness of Island Life

In his classical novel from the early 18th century, Daniel Defoe describes the life of Robinson Crusoe, who was shipwrecked on an uninhabited island, where he subsequently spent the next 28 years. One day, cannibals appeared from the mainland, and it was at this juncture that he realised that inter-human contacts are not necessarily a good thing, and that isolation can also have its advantages.

This inherent conflict of island life also becomes apparent on inspection of the impoverished communities of the flora and fauna in island

habitats. Analogous to the advantages and disadvantages of the isolation which Robinson Crusoe experienced, the absence of partners for organisms on an island can have both beneficial and prejudicial consequences. In the absence of natural antagonists no prejudicial interactions will occur. For example, a rare species of butterfly which has lost a predator through the drastic reduction in its habitat will enjoy a lower mortality rate, and a greatly diminished threat to its existence. In a similar manner, plants can profit from the absence of exposure to dis-

ease or seed predators. The loss of a beneficial interaction might occur, on the other hand, when pollinators or seed distributors have disappeared from the scene.

It has long been known that small and isolated habitats support few plant and animal species. As habitats increase in size and become less isolated their biodiversity expands because the immigration rate has become greater and the extinction rate has fallen. Moreover, larger habitats offer greater diversity and can provide more niches than smaller ones. In recent years, this concept



The continuing reduction and fragmentation of habitats is not only affecting biodiversity, but has also led to the loss of important ecosystem functions

has not only been applied to oceanic islands, but also to island habitats in cultivated country. For through human intervention, and especially through the dramatic intensification of farming which has taken place in recent decades, many natural habitats, such as oligotrophic grassland or stone-fruit meadows, have tended to disappear. In many places, these habitats are now only present in the form of tiny, isolated residues, so that their communities exhibit an isolation similar to that found on "real" islands. There is now growing evidence of a link between the

loss of species on islands and the drop in interactions. From the point of view of nature protection there is a specific interest in documenting the impacts on ecological functions, in other words on the interplay between the organisms themselves or between the organisms and their inanimate environment. The question arises as to whether there is any connection between loss of species due to habitat fragmentation and the impairment of the functionality of ecosystems. In two DFG-supported projects we have been addressing this topical and little researched

field by studying the links between the loss of natural antagonists and the mortality rate of herbivorous insects on the one hand, and those between the loss of flower-pollinators

Even a plot of land of the size of this stone fruit meadow functions amongst tilled fields as an island habitat. Left: Bumble Bees, Skippers, Long-horn Beetles and Shield Bugs visit the blooms of a thistle. Solitary bees and bumble bees play an outstanding role in the pollination and seed set of most plants.

and the reproductive success of plants on the other.

The consequences of habitat fragmentation with respect to biodiversity and interactions were analysed experimentally. Island habitats for clover insects were created by placing pots of red clover on the edges of cornfields. These islands, lying in cleared agricultural landscapes, were much more successfully colonised by herbivorous insects from the group of weevils (beetles), than by their natural antagonists, the parasitic wasps. However, not only was the number of parasitic wasp species on these islands smaller than that of the herbivores, but infestation with these parasitoids was also reduced: on isolated islands 500 metres away from the nearest field with red clover, it was only one third of what had been expected. This reduced mortality to such a low level that it was no longer possible to assume any successful control of these herbivores by their antagonists. This experiment revealed that the isolation of a habitat has a greater impact on the antagonists than on their hosts or prey.

The high extinction rate of the parasitic wasps on the habitat islands, however, was not solely attributable to their "higher" position in the food chain. Other aspects characteristic of species under threat of extinction were also involved. The parasitic wasps exhibited a lower frequency and much greater variation in population density. Species of greater rarity or more marked population fluctuation are regarded as being particularly endangered. The results obtained from these landscape islands were supplemented by a comparison between large and small stone-fruit meadows. A similar picture emerged. The red clover populations on small stone-fruit islands exhibited almost as many species of herbivorous insects, but far less parasitoid species. Here, too, the mortality rate induced by the parasitoids was extremely reduced. The results showed that isolation (of the "artificial" red clover islands) and contraction (of the stone-fruit meadows) led to similar effects. In both



cases, not only was there a reduction in biodiversity, but also a much reduced mortality rate amongst the herbivores.

Farmland has been exhibiting ever-decreasing numbers of bees, and the pollination of wild and cultivated plants can no longer be taken for granted. This supposition was checked using habitat islands comprising potted oil radish and wild mustard. Both plants are annuals, which means that their reproduction is dependent on seed production, and both are dependent on cross-fertilisation by insects. The habitat islands were so positioned in the cleared agricultural landscape around Göttingen that they were up to a thousand metres from the nearest calcicolous oligotrophic grassland (with its numerous species of bees). As expected, the number of visits paid by bees to the flowers dropped significantly (but not those by flies or other insects). The loss of bee species was linked to the reduction in the seed potential, in other words, with the reproductive loss or

loss of fitness of the oil radish and mustard. Thus, even at a distance of 250 metres from the nearest oligotrophic grassland, the number of seeds produced by the oil radish was halved, and those of the mustard at a distance of 1,000 metres. Working with potted plants eliminated alternative hypotheses regarding the causes of this island effect (genetic erosion, lack of nutrients, population size): every island had genetically identical plants, the same supplies of nutrients and the identical number of plants. Similarly to the insect communities on red clover, this experiment in flower ecology showed that there can be a connection between the loss of species and the loss of an important ecosystem function. Since over 80 per cent of all cultivated plants, and over 90 per cent of all wild plants, are dependent upon cross pollination, this increasing loss of wild bees and other pollinators presents a great potential threat.

Arable fields can also be regarded as islands. Each year they are cleared after the harvest and

colonised anew. Correspondingly, great biodiversity and pronounced interactions can only be expected if there is a close connection of annual crops combined with long-term habitats (fringe biotopes or fallow land). This project at the Göttinger Forschungs- und Studienzentrum für Landwirtschaft und Umwelt (Research and Study Centre for Agriculture and Environment in Göttingen) was designed to investigate whether field margin strips and fallow placed alongside rape fields would serve to promote the natural antagonists of the blossom rape beetle. By eating the buds, the blossom rape beetle prevents pod forming and thus occasions considerable

An experimental island of red clover at the edge of a cornfield. Below: Old strips of arable land bordering a field of winter rape (left) offer a habitat to the natural antagonists of the blossom rape beetle. Insects such as parasitic wasps reduce the numbers of pests.

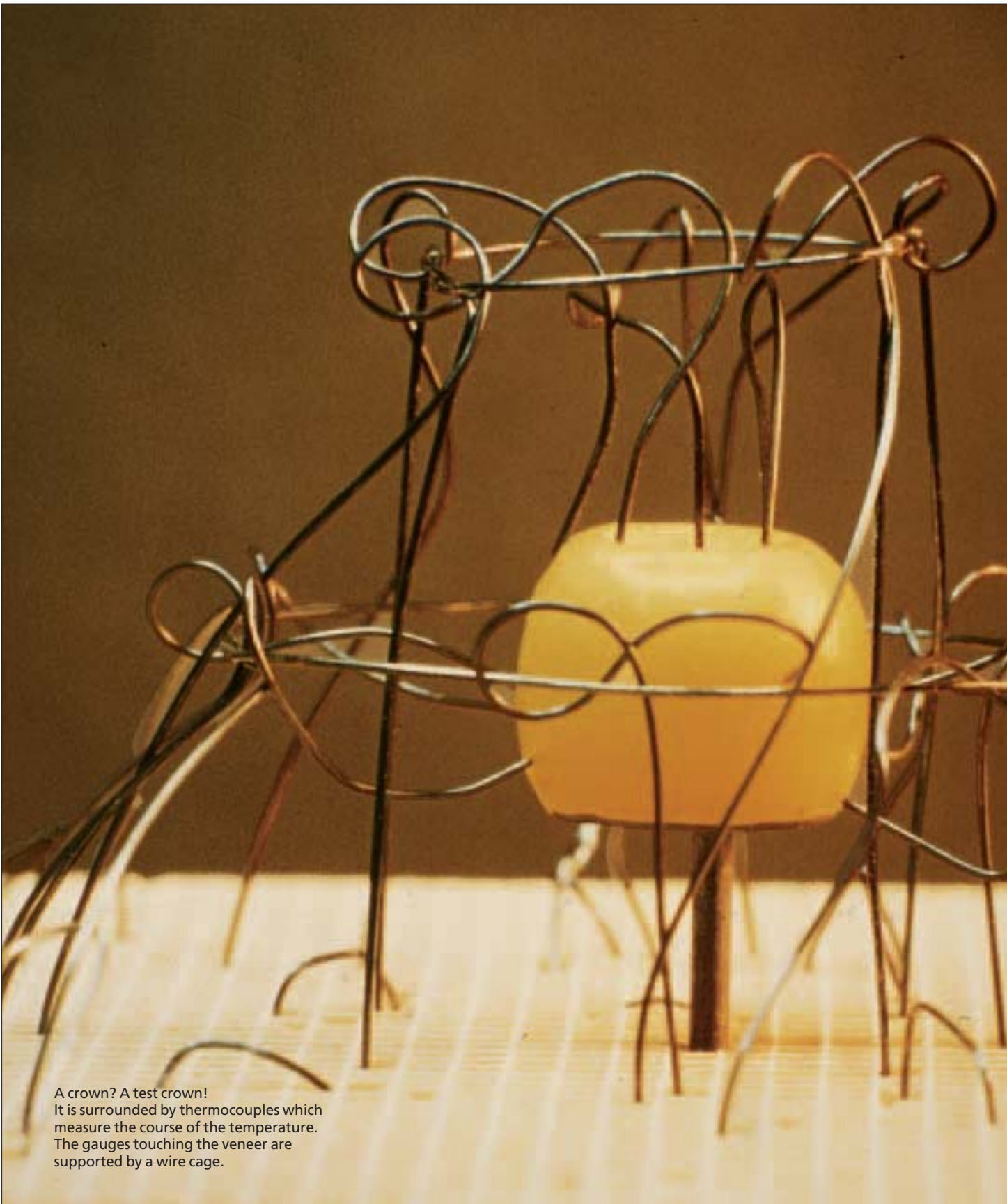
damage. Its predator is a specialised parasitic wasp. A comparative study of field-margin strips revealed that infestation by parasitic wasps was promoted by old, but not by young strips. The mortality rate due to parasitic wasps directly along the edge of a field was in both cases high, but only in the case of the old strips, did these parasitic wasps move out into the field and so produce similar mortality rates within the field itself. It was discovered that this dissemination of the large antagonist communities into the peripheral biotopes trebled the mortality rate. Yet old field margin strips are not the non plus ultra for the promotion of useful insects. If, instead of old strips, old fallow borders the winter rape field, then the infestation with parasitoids is even higher. The results show that the significance of natural antagonists increases with the age and size of the adjacent natural habitats. Moreover, it became clear that the mortality rate of this pest can be increased radically by altering its

habitat. In a DFG-supported project we followed up the idea that these parasitic wasps, which can attack the flower rape beetle so successfully, play a much greater role in diverse, complex landscapes than in monotonous, simple ones which have been cleared of almost all perennial vegetation. Our data confirm the hypothesis that the mortality rate caused by parasitic wasps is higher, and the damage to rape considerably lower, when the rape field lies in complex farmland.

These examples show that the increasing diminution and isolation of habitats is causing the extinction of many species. It is an important argument for nature protection that the loss of diversity is frequently linked to the loss of important functions of the ecosystem, such as pest control or plant pollination.

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A crown? A test crown!
It is surrounded by thermocouples which
measure the course of the temperature.
The gauges touching the veneer are
supported by a wire cage.

Each year ceramometallic dental restorations worth several hundred million euros are fabricated in Germany. However, during fabrication such restorations can be damaged by thermal stresses. Basic research is supporting the safe production of such porcelain-fused-to-metal systems

In the Service of the Crown

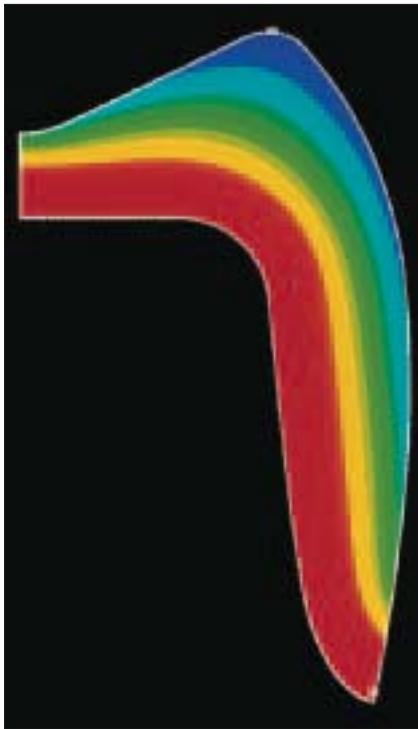
Ceramometallic dental restorations (crowns, bridges, prostheses) have been in routine use in dental prosthetics now for about 35 years. But still, and especially when dental technicians resort to a new alloy and/or ceramic, cases always occur where spallations or cracks appear in the ceramic veneer, or where the metal-ceramic bond between the veneer and the metallic substrate is damaged by shearing. This damage can take place either already during fabrication of the restoration in the laboratory, or when fitting it into the patient's mouth, or after a short wearing time. Since ceramometallic restorations worth several hundred million euros are produced each year in the Federal Republic alone, it is of national economic importance to investigate the origin and distribution of the thermal stresses responsible for this damage.

Ceramometallic dental restorations comprise an alloy frame onto which a ceramic ("porcelain") is sintered. They thus combine the high rigidity of the alloy with the beneficial properties of ceramics: excellent biocompatibility, unsurpassed and highly durable aesthetic ap-

pearance, and outstanding resistance to wear. In recent years, in order to reduce costs, in addition to high gold-content alloys, palladium-based and non-precious alloys have also been employed. The CoCr-alloys, especially, provide markedly better rigidity than the classical precious alloys while offering comparable resistance to oral corrosion.

When fabricating ceramometallic restorations, an alloy frame ("substrate"), cast according to dental impressions submitted by the dentist, is coated with ceramic material. Being a mixture of powder and liquid, this is initially of a pasty consistency. The object is mounted onto a special firing tray and heated to a high temperature in a furnace. Depending on the ceramic, the firing temperature will vary between 850 and 900 °C. The restoration is subsequently cooled to room temperature according to a pre-programmed schedule, initially in the furnace, and subsequently outside in the ambient air. Due to the fact that the ceramic contracts during sintering, the firing process normally has to be repeated several times. At the glass (transition) temperature, which usually lies between 550 and 600 °C, 77

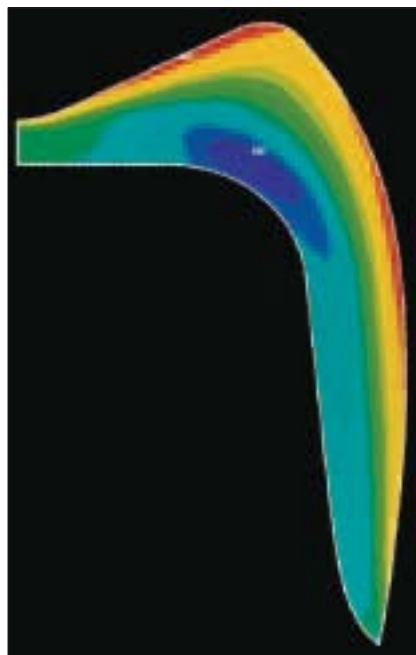
during cooling the ceramic changes from the plastic-viscous into the elastic-brittle state. Above the glass temperature, the ceramic is sufficiently fluid to follow its own contraction without generating any stress. Below the glass temperature, in contrast, thermal stresses develop in the ceramometallic system due to the differences in thermal expansion behaviour between the ceramic, now "hard", and the alloy. Left to themselves, the veneer and its substrate would no longer follow the same geometry, but now they are bonded together at the material interface. Consequently constraint stresses develop. In the case of "thermally incompatible" combinations critical thermal stresses can produce damage, either during fab-



rication or, later, due to additional load stresses arising in the course of cementing or mastication.

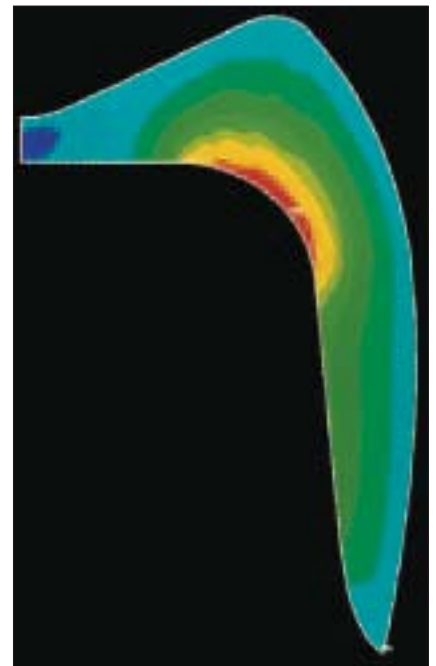
In a DFG-sponsored research project scientists investigated the genesis of thermal stresses in ceramometallic crowns. Apart from the differences in thermal expansion behaviour between the two materials, the locally distinct cooling rates in the crown are also of great importance. Due to the complexities of the crown geometry it is not yet possible

to determine analytically or numerically the precise rate of heat loss to the ambient air. Consequently the surface temperature was measured experimentally during the cooling process using thermocouples. With the given initial temperature distribution in the complete crown, this information permits unique computation of both the temperature and the thermal stress distribution inside the crown.



During cooling, a test crown is exposed to high stresses. 26 seconds after opening the furnace the temperature gradients (left, showing full crown), and thus also the transient thermal stresses, are at a maximum (red: high values, blue: low values). They are first concentrated at the surface of the ceramic veneer (centre, displaying only the ceramic veneer), but in the crown at room temperature at the interface between frame and veneer (right, ceramic veneer only).

Measurements of the time-temperature relationships at particular surface points were interpolated to a steady temperature distribution over the surface of the crown. This served as an input for a so-called Finite-Element (FE) model for calculating the stress distribution inside the crown with respect to time and space. Linear thermoelastic material behaviour was assumed for both the alloy and the ceramic.



In a first simulation, long-term cooling in the furnace was simulated. At a homogeneous crown temperature of 600°C, and thus just slightly above the glass temperature of the ceramic (581.7°C), the lid of the furnace was opened and the crown extracted. Considerable temperature gradients (differences) immediately built up in the crown: the highest temperatures were all measured on the substrate, the lowest at the surface of the veneer. This was because the ceramic is able to radiate its heat freely into the environment, whereas the surface elements in the hollow space of the frame are subject to mutual radiation. Moreover, the surface of the veneer loses more heat to the passing air by convection than can a cavity such as the interior of the substrate.

The maximum temperature gradient between substrate and ceramic surface occurs approximately half a minute after cooling has started. It can exceed 120 °C. Tensile thermal stress, too, is at its maximum at this time. Tensile stresses are detrimental to a brittle material like ceramic. In the critical case they can lead to cracks or spallations. On the other hand, the interior of the veneer is under compression, or at the most, mild tensile stress. As cooling proceeds, the temperature in the crown equalises out, i.e. the temperature

gradients decrease, and the maximum tensile stresses migrate from the surface of the ceramic into the bond interface with the alloy. The stress distribution "frozen" into the crown after fabrication, is called its residual stress state.

However, of interest – and hitherto, most likely, unknown – is the fact that the magnitude of the so-called transient thermal stresses, i.e. those occurring during the cooling phase, can clearly exceed that of the final residual stresses.

This can produce cracking or spalling, even during the cooling process.

Tests on model crowns which were geometrically identical but made of different substrate alloys, revealed that thermal stresses decrease with decreasing rigidity of the alloy. Alloys of high gold-content will reduce the indicated stresses by around 35 per cent. Hence, when using non-precious metals great care must be taken to ensure that no excessive deviation in the coefficient of thermal expansion of the ceramic and its substrate exists. With the majority of ceramics this difference from the alloy can be compensated

Model crowns show that the thermal expansion properties of the partner materials must be compatible

for by long-term (slow) cooling. The residual stresses in the veneer are uniquely determined by the glass temperature of the ceramic, the expansion behaviour, and the stiffness of the two partner materials. The transient thermal stresses, in contrast, can be manipulated by the cooling process: for example, if the furnace is opened only at the temperature of 450 °C – and thus well below the glass temperature of the ceramic – they will be reduced by

around one third. In a dental laboratory, however, where speedy fabrication of ceramometallic products is the sine qua non, the temperature at the opening of the furnace, due

to the correspondingly longer duration of use, cannot be reduced at will.

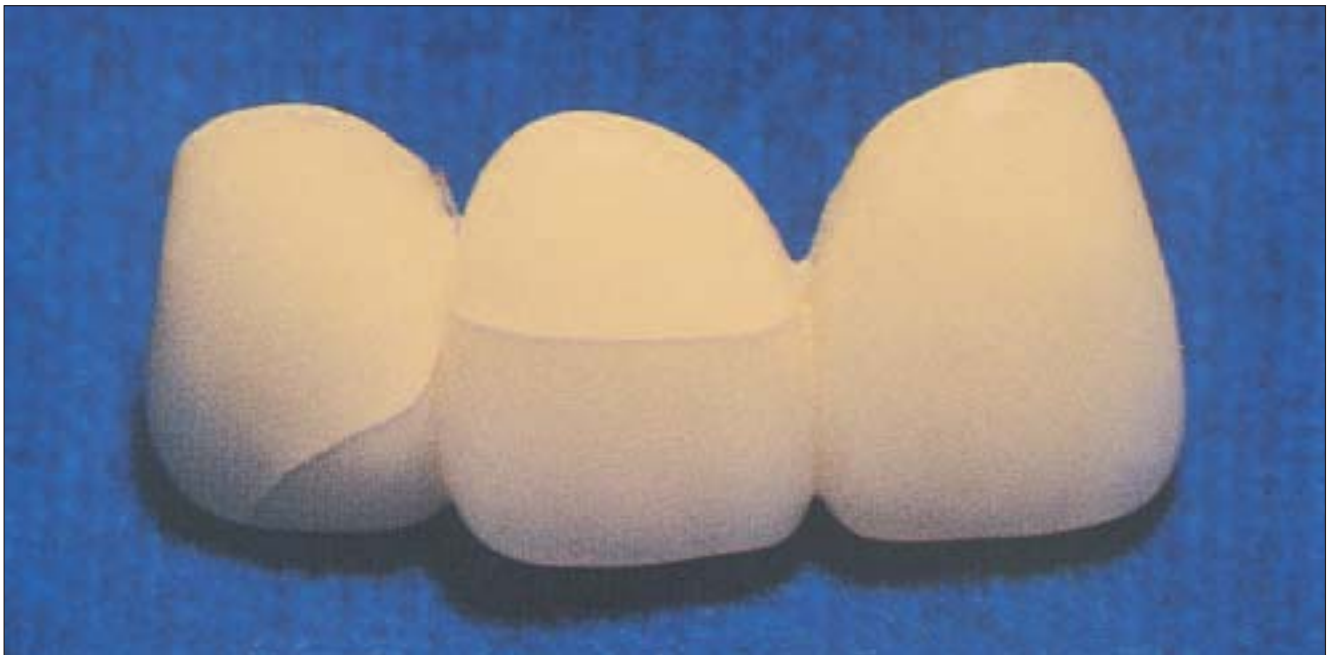
It is a well-known fact that the maximum stresses present in the bond interface of the cooled crown are critically dependent on the local radius of curvature. Hence the dental technician is well advised to round off the surface of the substrate. The dentist can also make a useful contribution to this by an appropriate preparation of the tooth to

be reconstructed. Surprisingly, the experiments showed that the maximum transient thermal stresses were also critically dependent on the interstice between the crown and its firing tray.

Hitherto, the simplified case had been simulated whereby the veneer is sintered onto the alloy frame in a single firing process. The scientists at Karlsruhe University are currently studying the more realistic firing process in several steps. This is enabling them to take due account of the change in the ceramic's coefficient of thermal expansion in relation to the number of firing processes. After all, these simulations are designed to furnish both dental technicians and dentists with rules for the safe fabrication of ceramometallic restorations.

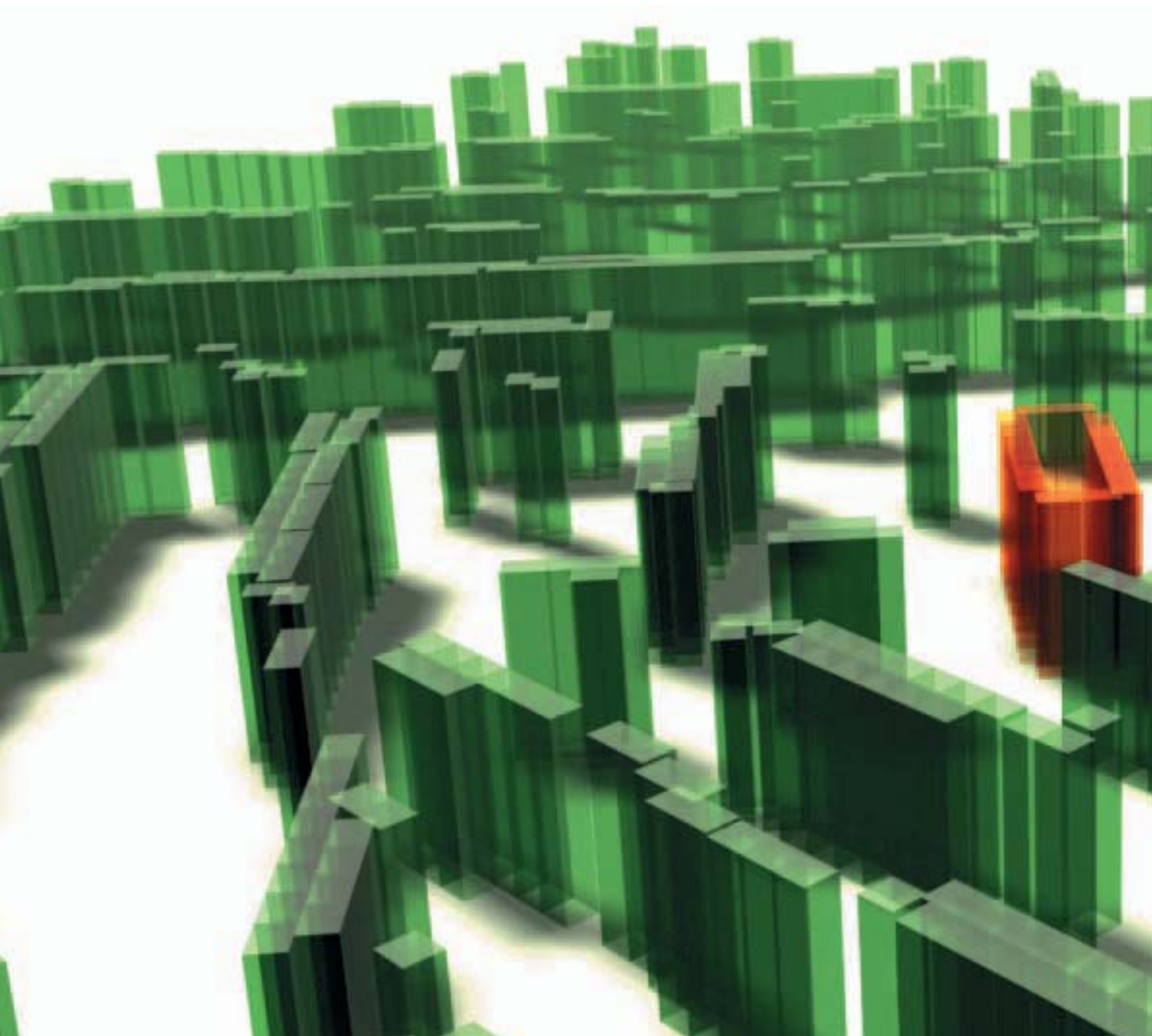
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After firing, fine cracks have appeared in the veneer of a bridge. Studies showed that fabrication purposes, not only must the "thermal compatibility" of the materials which have been used and the firing and cooling processes be taken into account, but also the curvature of the surface of the alloy frame.



How a Town Can be Created in a Test Tube

In the computer scientists breed houses, villages and whole urban districts to check the interactions between buildings and their environs – a vital aid to planners and architects



The creation of architecture is a process subject to numerous influences. Plans drawn up by architects and urban planners are extracts related to given scales whereby, depending on the selected or prescribed degree of accuracy, abstractions of the desired and planned reality are drawn, thus creating blurs. For a given degree of detail, external influences such as topography, existing buildings, green areas and geographical orientation may be included in the overall design in exactly the same way as architectural data, the desired density of building, or spatial distributions. Sometimes the designs simply

contain a hierarchical road network, and other times they show a complete estate depicting the individual houses down to the last detail. Degrees of detail not embraced by the given scales are not included in the architects overall plans.

This is particularly evident with historical urban structures which have evolved over the centuries. The interrelationship between these conglomerates are so complex that it is difficult to discern any laws of growth. The growth of the urban population is similar in form and shape to that found in animate and inanimate nature, so that aerial photographs of these settlements bring to mind colonisation by plant populations or cell formations.

The DFG-sponsored research project "Media-experimental Design in Architecture and Urban Design" is addressing the creative use of computers in architecture, and is examining the processes of growth of urban structures. The aim is to identify the apparently unplannable processes of urban growth, and to express them in terms of algorithms (recurring processes of computation). These laws of growth can be applied in a virtual-reality environment, thus enabling this phenomenon to be simulated on the computer. Using this technique it is possible to proceed beyond three-dimensional visualisation and, by programming the laws, standards and legal acts of a virtual world, to model the development of urban structures and to observe their be-



haviour. In this way, it is possible to "breed" towns as in a test tube. One element of current research is, in fact, to achieve the, so to speak, evolutionary and genetic "cross-breeding" of urban development modules and their algorithms; in view of the similarity between organic structures and growth in urban development this idea would appear to be an obvious step.

A limited number of selected parameters, including the growth of the buildings, geographical orientation and the topography, are introduced into the virtual environment known as the "village generator". The virtual buildings are created by



Above: Urban development modules can be crossed and „bred“ in a computer. Right: Generators sort the virtual buildings according to previously programmed laws, and at the same time they seek the most attractive sites for them.

generators which pass through the virtual world checking the attractiveness of the location in line with prescribed environmental factors. A sort of communal "social" behaviour is programmed amongst the virtual house-builders to enable them to change their direction depending on their proximity to their neighbours. This so-called "swarm

behaviour" is a natural phenomenon copied from the behaviour of flocks of birds and swarms of insects. Once the prescribed conditions have been met, the generator produces a building. Because these generators are all interactive this comparatively simple programming results in very harmonious and natural paths of movement which would otherwise have been impossible to pre-calculate with this clarity. The resulting forms are organic in the architectural theoretical sense of the term, meaning that they have developed from the inside to the outside.

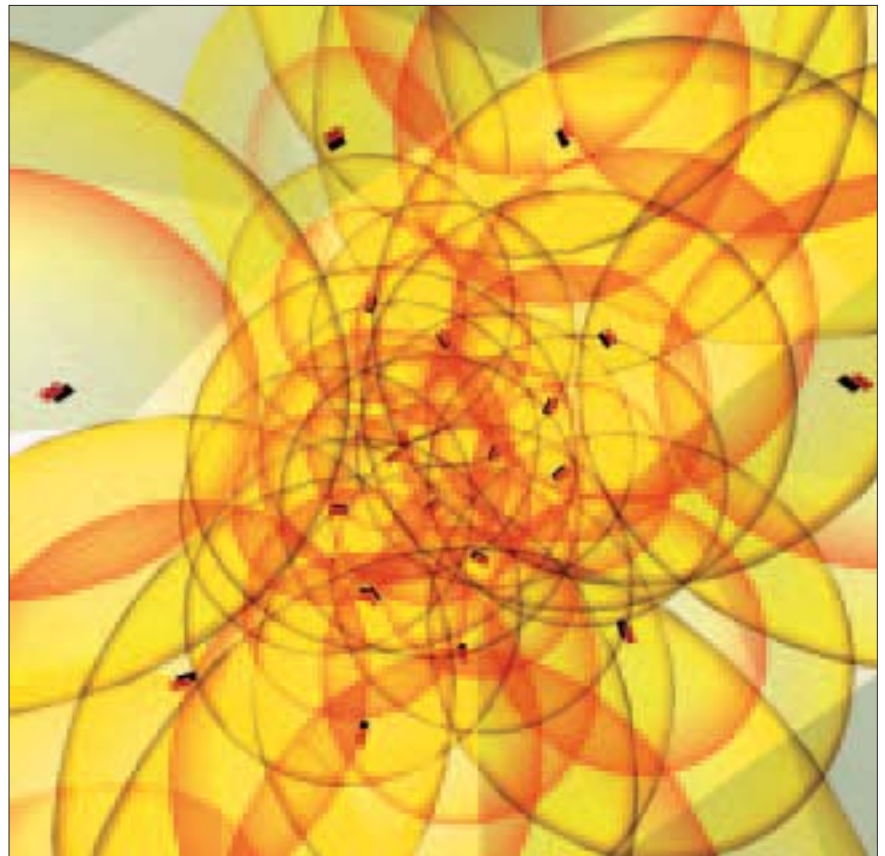
Despite the fact that the programmed modes of behaviour are not directly derived from urban developmental experience, the results display close similarity to the existing structures found in mountain villages. This forming of analogies for the development of complex

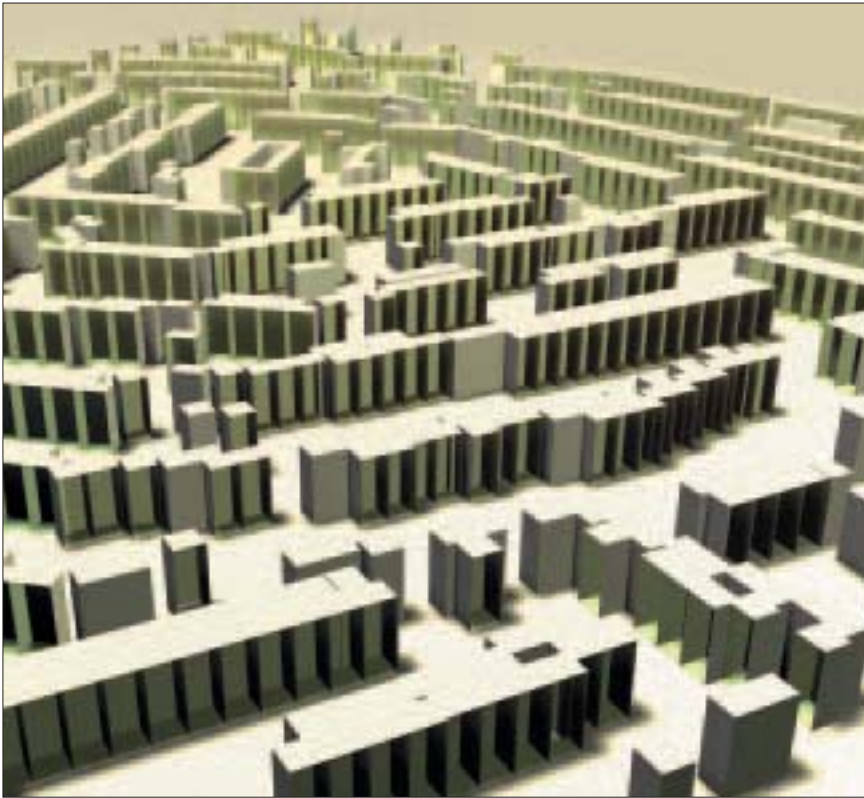
types of architecture has already been studied by Prof. Frei Otto, the designer of the roof of the Olympic stadium in Munich, who based his architectural forms on examples from nature.

The structures of villages create an organic, unintelligible and complex effect and are less subject to formal laws than towns or cities which have developed along normal lines. A townscape is characterised by axes, squares and spatial density.

Hence other laws had to be defined for the simulation of urban areas. Although simple, clearly defined laws cover the necessary "exposure" and "development" of the virtual houses, a complicated programme of laws for behavioural patterns is required for controlling the position and alignment of the neighbouring modules. This is effected discretely throughout the entire vir-

A communal "social" behaviour pattern was programmed into the virtual "house-builders"





tual town, which means that each individual house stands in formal relationship to its neighbourhood. Each building informs its neighbourhood where subsequent buildings can still be positioned. Structures or buildings can be imported into the urban generator so that it is required to react to the current situation. It is precisely during these experiments that astonishing similarities occur to actual urban planning situations.

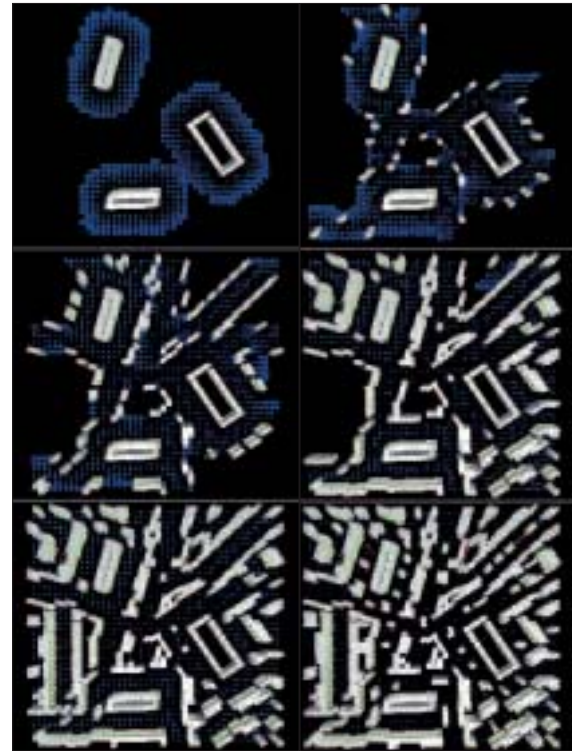
Two of the most important and complex tasks for architects and urban planners are that of building amidst standing structures and that of addressing the problem of urban concentration. For these it is essential that the numerous parameters influencing the attractiveness of each plot should be placed in their correct order of priority. Using a concrete example as a basis, a controlled progressive increase in urban density was created in a computer simulation. The drawings for a block of buildings were generated on the computer and given certain characteristics in a virtual world. These were quantitative parameters, such as density of building, plot

As in reality, the townscape is characterised in the simulator by axes, squares and spatial density, and is clearly distinguished from the structure of villages, which often create a complex and random effect reminiscent of organic growth. Right: Each building exerts control over any further building in its proximity by influencing the attractiveness of its surroundings (in blue).

price and residential density. Formal characteristics were also applied, such as size and mode of use. These data were then entered in the drawings in an order of priority reflecting their weighting. The resulting attractiveness was displayed as a three-dimensional structure in its virtual surroundings. The result is an abstract building. The designer decided which conditions the new building had to meet, for example it desired residential density or the rough distribution of the individual types of building in the area. He also defined the limiting values for these different types of building (maximum height, optimum alignment or building depth).

The computer now proposed ways of increasing the density, and

calculated their effects. By means of programmed loops and recursive functions an approximation of an optimum result under the given conditions was created, whereby it was open to the designer to intervene at any time to control the course of computation. A programme is currently in course of development which will enable the



different urban planning modules to acquire their own form by learning. Using "neuronal networks", a form of programming based on the brain, and "genetic algorithms", the elements of the virtual world can be trained to acquire intuitive behaviour. These intelligent structural elements are to be furnished with selective perception of their surroundings, and their knowledge improved in training units.

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The Deutsche Forschungsgemeinschaft

The Deutsche Forschungsgemeinschaft (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 area of basic research through to applied research. Particular attention is paid to promoting young researchers. Every German scientist and academic is eligible to apply for DFG funding. Proposals are submitted to peer reviewers, who 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.

Illustrations

IPT-Aachen (cover, pp. 54/55, 55, 56 a. r.), ZEFA – A. Inden (pp. 4/5, 5), Wissemann (p. 6), Staats- und Universitätsbibliothek Göttingen (p. 7), Mauritius-Peebles (p. 8 a.), Lühr (pp. 8/9, 10, 10/11, 11 b., 13), Zimmer (p. 11 r.), Subronto (p. 12), Hüsken (pp. 14/15, back cover), Nerlich (pp. 14 b., 16, 17, 18, 19 a.), Leicester Gallery, London (pp. 18/19), Popp (pp. 20 l., 23 b.), Mauritius-Age (pp. 20/21, 22/23), IWR Müller/Quien (pp. 24/25, 26, 27), ZEFA-Rauschenbach (pp. 28/29), Universität Bielefeld (pp. 30, 31), Klimburg (pp. 32, 33, 34, 35, 36), Dover Publications, N. Y., 1955 (p. 37), Pfeiffer/Cruise (pp. 38, 39), Kastenholz (pp. 40/41), Landesamt für Naturkunde Rheinland-Pfalz (pp. 41, 42, 43), AMORE-Expedition (pp. 44/45, 46/47, 47, 48, 49), Böbling (pp. 50, 51, 52, 53), ISF Aachen / Jäger (p. 56 a. l., b.), ISF Aachen / Möller (p. 57), Kramsky (pp. 58/59), Taccone (p. 60), Köhler (p. 61), Baehr (pp. 62, 63, 64, 65), Deutsch, Langenhorst, Masaitis (pp. 66/67, 68, 69, 70, 71), Kruess (pp. 72/73, 74, 75), Tscharrntke (p. 72), Haßler (pp. 76/77), Lenz (p. 78), Archiv (p. 79), Universität Kaiserslautern/Technion Haifa (pp. 80/81, 82, 83)

Layout of pictures: l. = left, r. = right, a. = above, b. = below

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.

Around 25,000 research projects from all scientific disciplines are currently funded each year by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation). More than 700 employees work at its head office in Bonn in the service of research funding.



Liaison offices in Washington, Moscow and Beijing serve to intensify international scientific cooperation. The DFG also has a branch office in Berlin, the main task of which is to maintain links to Parliament and the German Federal Government as well as to foreign embassies.

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