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From a Modest Start to a Flourishing Marine Research Environment: The Institutional Development of Marine Geosciences in Kiel after World War II

1. A Modest Start

Contrary to classical oceanography in Kiel (Zenk et al., 2018) the development of the marine geosciences at CAU (Christian-Albrechts-Universität zu Kiel)* was not linked to earlier and somewhat more modest beginnings of studies in marine geology in Kiel and other localities in Germany. Their development was therefore different from the new (after WW II) Institute of Marine Sciences (IfM) of CAU which was able to draw on the legacy of its predecessors in Berlin and in Kiel. The new IfM grew quickly beyond the means of a regular university institute and Günter Dietrich succeeded in having it transferred 1968 to the “Blaue Liste” Institutes (later called Leibniz Institutes) which were co-funded in equal shares by the local and the federal (West-) German governments. None of this did at first apply to the marine geology working group which developed at the CAU’s Institute for Geology and Paleontology (GPI). But as for the new postwar Kiel IfM the participation of the marine geologists from Kiel in the International Indian Ocean Expedition (IIOE, 1960–1965), made possible through the availability of the new research vessel *METEOR*, meant a quantum leap in possibilities, perspectives and internationality (McElheny, 1964). It allowed this marine geology group to become a major player, both on the national scene and in an international context, with important incentives for the later development of the marine sciences in Kiel.

The German participation in the IIOE, the second part being led by ma-

*A list of all acronyms used this article is given on pp. 138–140.

rine geologists (Dietrich et al., 1966), was conducted under severe political constraints (Seibold, 1998) due to tensions in the Persian Gulf area in 1965. The previous experience from working in the Baltic Sea and the comparison with sedimentation patterns in the Persian Gulf resulted in a new conceptual framework of the geological records of shelf seas in arid and humid climatic zones (Seibold, 1970). Overall, 92 scientists and technicians had participated. The largest part of projects and 40 of the participants came from the IfM and several other groups of CAU. This cruise marked the revival of blue-water oceanography in Kiel.

2. The Dawn of Marine Geosciences in Germany: Some General Matters

This review article describes the emergence of the marine geosciences in Kiel after WW II and is accompanied by an article about the development of oceanography *sensu lato* at the same place and for a similar time span (Zenk et al., 2018). We limit our account to the time span after WW II to the early years of this millennium when completely new organizational structures for the marine sciences in Kiel were founded (Hoffmann-Wieck, 2015; Visbeck & Schneider, 2015). It cannot pay justice to all persons involved, but an eclectic choice had to be made to mention mainly those who had made important strategic contributions to this development.

Early Marine Sciences in Germany

Early marine sciences in Kiel linked to the CAU were initiated by geographers, oceanographers and marine biologists. Very little attention was paid to the properties of the sea floor and its sediments. An exception were the geographical descriptions of the seafloor morphology (Krümmel, 1879). However, the first German Antarctic Expedition (1901–1903; Drygalski, 1904) started from Kiel, after its dedicated research vessel *GAUSS* had been built in Kiel. This expedition collected sediment cores along its course to Antarctica (Philippi, 1905; see also Murray & Philippi, 1908), and was the first to detect stratigraphic changes in their sediment composition.

The early development of marine sciences at the CAU was mostly initiated by biologists and later had its focus at the Institute and Museum of Zoology. Adolf Remane (Storch, 2009) started there as research assistant in 1923, becoming fascinated by the diversity of marine life and discovering a hitherto unknown and remarkable assemblage of microscopic invertebrates living within marine sediments (Higgins & Thiel, 1988). Adolf Remane as the founding director of the new (= prewar) IfM pointed out at the inauguration (June 15, 1937) in Kitzberg on the east shore of Kiel Fjord (Remane & Wat-

tenberg, 1938) that the key research focus of the new institute would be the Kiel Fjord and the Baltic Sea, the largest body of brackish water worldwide. It included a Department of Marine Geology (probably based on Remane's interest in seafloor sediments). It was led by Erich Wasmund and studied the stratigraphy and paleogeography of Holocene deposits in the western Baltic Sea. It involved scientific diving as an observational tool (Werner, 1998).

In the meantime and prior to the Kiel institute the "Institut und Museum für Meereskunde" (= Institute and Museum of Marine Sciences) of Berlin University had developed into the leading German marine research institution. Geosciences, however, were not part of its research portfolio, with the exception of studies of the seafloor morphology (Stocks & Wüst, 1935). After WW II Georg Wüst (formerly at the Berlin Institute) moved to Kiel and re-established the IfM of CAU covering all major marine disciplines with the exception of geosciences (Zenk et al., 2018).

The Separate Role of Marine Geoscientific Disciplines

Early German works of geoscientific relevance can be found in the textbook on "Meeresgeologie" (= Marine Geology) by Karl André (from Königsberg, 1920) and the geographic descriptions of the Atlantic and Pacific/Indian (1935, 1942) Oceans (by P. Gerhard Schott – 1866–1961 – working at the "Deutsche Seewarte" in Hamburg). Otto Pratje, also from Hamburg, published a remarkable paper on the morphology of the deep Atlantic Ocean (Pratje, 1939). Carl Wilhelm Correns (1883–1980) and Wolfgang Schott (1905–1989) were probably the first true marine geologists of international renown in Germany. Both joined the University of Rostock in young years and their scientific legacy is based on studies of samples collected during the famous METEOR expeditions ("Deutsche Atlantische Expedition", 1925–1927) to the central and South Atlantic Ocean. These expeditions had collected numerous sea floor samples, which were then studied for their mineralogy and microfossil contents (Correns & Schott, 1935–1937). Correns later moved to the University of Göttingen, and after WW II Schott joined the BGR ("Bundesanstalt für Geowissenschaften und Rohstoffe", the Geological Survey of the Federal Republic of Germany). Schott (1935) established the first biostratigraphies of deep-sea sediment cores and related the compositional changes of the planktonic foraminiferal assemblages to the Late Quaternary glacials and interglacials (Dullo & Pfaffl, 2016).

Within a completely different field Alexander Behm in Kiel tested a vertical echo-sounder (Behm, 1916), which then was further developed by companies in Kiel and Bremen. The system was used routinely during the "Deutsche Atlantische Expedition" 1925–1927, documenting the continuity of a ridge in the middle of the central and southern Atlantic Ocean, which had been suggested by earlier expeditions (Maurer & Stocks, 1933; Stocks &

Wüst, 1935). These observations supported the hypothesis of Alfred Wegener about the origin of continents and ocean basins (Wegener, 1929). A major result of these echosounder records was also the first genuine recognition of ocean spreading (Ampferer, 1941).

After WW II working groups of marine geology, geophysics and geography in Kiel developed essentially outside the IfM. Over the years an increasingly closer cooperation grew with the IfM scientists, driven by joint expeditions on research vessels and ultimately resulting in the development of large, mostly interdisciplinary projects (see paragraphs on SFBs). Graduates took this research-based attitude along to their later places of work, in particular to several governmental institutions in the country as well as to universities outside Schleswig-Holstein or abroad. As a result, the marine sciences in Kiel can be considered to be the cradle of marine sciences in Germany. Many Kiel graduates accepted positions at foreign universities or research institutions in the Americas, Asia, Australia and Africa.

Research Vessels

When Eugen Seibold (see below) joined CAU in 1958, he succeeded in convincing his colleagues in oceanography to give him and his group access to the first small research vessel of the IfM, the research cutter SÜDFALL, later renamed HERMANN WATTENBERG, which was a great chance and advance. Later plans for new and dedicated research ships were developed in Kiel, always with the active involvement of marine geologists. The IfM or the University variably owned these ships. Kiel scientists frequently also used the larger German research vessels with different homeports, often providing the chief scientists for cruises. All these vessels, except for the navy research vessel PLANET, are now considered members of a German research vessel fleet for joint use (much like the UNOLS system in the U.S.). In the construction of many of these ships, Kiel scientists, in particular Klaus von Bröckel for oceanography and Friedrich Kögler as well as Friedrich Werner for marine geology, played an important role. They provided the links between the scientific community and marine engineers, both in the planning and the testing phases of new research vessels.

On a European level a tri-partite barter arrangement with the United Kingdom and France for ship time exchange was developed; it is now controlled by JMFG (Joint Marine Facilities Group) under the auspices of the European Marine Board. It was later extended to the Netherlands, Spain and Norway. It became increasingly important for researchers to participate in expeditions on vessels of other nations. For the marine geoscientists, the German participation in the deep-sea drilling projects (DSDP, ODP, as mentioned further below) was critical for the development of this discipline in Germany, in particular in Kiel. Kiel Scientists participated in many legs of GLOMAR

Challenger and JOIDES Resolution, and in expeditions of the IMAGES (International Marine Global Change Study) program using the French vessel *MARION DUFRESNE* which specialized in retrieving very long sediment cores. They learned to value their participation not only as a challenging scientific exercise, but also as members of floating international “universities” (also called by some the “great floating seminars”) of marine geosciences.

Funding Opportunities for Marine Sciences in Germany

The marine scientists in Kiel benefitted from an increasing number of funding sources in Germany and later in the EC (= European Commission) after the war. The IfM had grown substantially under the leadership of Georg Wüst and Günter Dietrich and was transferred to the “Blaue Liste” (= jointly funded by the local and federal governments) institutes in 1968. It could then draw on a firm budget from the local and the Federal (West-) German government. This did not apply to the marine sciences outside the IfM of CAU until many years later. The marine geology working groups at the GPI as well as other marine disciplines sprinkled over various university institutes had to live with and start their activities based on the modest means of the university, supplemented with funding from other sources. The most important external source was the DFG, first through individual grants, later through SFBs (see below). As some of the instrumental developments of the marine geologists in Kiel were of interest to the West German navy, some funding was also obtained through the contacts to the “Forschungsanstalt für Wasserschall und Geophysik” (= FWG in Kiel, see below) and thus from the Federal Ministry of Defence (“Bundesministerium der Verteidigung” = BMVtg). Later, when federal programs on marine and climate related studies were defined, relatively large projects were funded through the BMBF, sometimes when marine non-living resources were concerned also from the Federal Ministry of Economy (“Bundesministerium für Wirtschaft und Energie” = BMWi). In recent years funding through the research programs of the EC has played an increasingly important role.

Since most of the marine research groups devoted their major efforts to basic sciences, the DFG had become an important sponsor ensuring high quality standards with its demanding review system. It provided funding for individual projects and for major research programs. It established important advisory bodies (“Senatskommission für Ozeanographie”, “Geokommision”, with some of the Kiel scientists becoming members or even chairpersons) where scientists from Kiel could develop their plans and research perspectives jointly with the relevant colleagues from other institutions in Germany.

The SFBs played a particularly strong role in bringing scientists together in major long-term programs (over a decade or more). Funding by the DFG of

a whole series of SFBs was acquired over the years providing stable funding. Three of them were of particular importance for the geoscientists. The SFB 95 (1971–1985) on interdisciplinary “studies of sea/sea bottom interaction” was the first program for the marine geologists. The SFB 313 (1985–1998) on “Sedimentation in the northern North Atlantic” emphasized the geosciences in this high-latitude region and SFB 574 (2001–2012) was oriented towards studying “volatiles and fluids in subduction zones”. The multidisciplinary DFG Research Unit 451 “Ocean Gateways” (2001–2006) pioneered the research of past changes in the interocean exchange of heat, salinity, and species and their implications for climate change and the evolution of species.

Later, the “Graduierten Kolleg” (Graduate Colleges) program provided new opportunities by the DFG for funding junior scientists (PhD candidates and Postdocs). A group of academic teachers from both the GPI and IG of the CAU and GEOMAR joined forces in 1991 to submit an application for the Graduate College under the theme “Dynamics of Global Cycles in the Earth System” (headed by Hans-Ulrich Schmincke). The Graduate College was highly successful and provided stable funding for 22 junior scientists (with an additional 17 associated junior scientists funded through other sources). It thus enlarged the pool of junior scientists produced by SFB 313.

Another source of encouragement in the development of the marine geosciences in Kiel was the Gottfried Wilhelm Leibniz Program of DFG (the most prestigious German science award, with substantial financial resources for “free” research over several years). The program was proposed in 1984 by Eugen Seibold, then president of the DFG, to recognize scientific excellence, based on external reviews and funded between the DFG and the BMBF. The program was inaugurated in 1985 and the first eleven prizes were made public in 1986. The following marine scientists from Kiel were awarded such prizes: 1989 Michael Sarnthein and Jörn Thiede, 1991 Hans-Ulrich Schmincke, 2000 Peter Herzig, 2002 Christian Dullo and 2012 Ulf Riebesell.

3. The Evolution of Marine Geosciences in Kiel

Roots of Marine Geology and other Marine Disciplines outside the IfM in Kiel

The early beginnings of marine geology did not happen in Kiel, but at other universities in Germany (Königsberg – today Kaliningrad, Rostock). However, the early Kiel IfM (1937–1945) originally also included a modest department of “Marine Geology” led by Erich Wasmund, but it disappeared towards the end of the war. After the war, Adolf Remane returned to Kiel, but did not rejoin the new IfM of CAU (Storch, 2009). When Georg Wüst refounded the IfM of the CAU after the war, “marine geology” was not in-

cluded into its research portfolio, but following the Berlin tradition Günter Dietrich and colleagues in Kiel pursued many aspects of the geography/geomorphology of the sea floors (Dietrich & Ulrich, 1968; Ulrich, 1960). The restart and early growth of oceanography and other marine disciplines at the IfM under Wüst and Dietrich was highly successful.

The geoscientific institutions of the CAU did not devote much of their research efforts to marine sciences during the early years after the war. The GPI, later home for a large team in marine geology, was mainly devoted to Quaternary Geology (mostly of Schleswig-Holstein). But it also included comparative studies of modern analogs on Svalbard and Greenland, and some coastal studies (Köster, 1955 and 1961). The IG (= Institute of Geophysics) added marine geophysics only after Rudolf Meissner became the successor of Karl Jung in the early 1970s. The latter was a geophysical modeler and specialist in gravimetry. His position in 1956 had been physically linked to the IfM where he had an office and conducted his teaching. This position was later transferred to the newly founded IG (1960). The Institute of Mineralogy and Petrography of the University never devoted any efforts to marine sciences.

The situation was different at the University's Institute of Geography where a tradition of studies of coastal regions existed (Kortum & Paffen, 1979; Paffen & Kortum, 1986; Klug, 1989) and within the biological disciplines where Berndt Heydemann, originally from the Biology Center, conducted studies of coastal research/applied ecology. There were other smaller groups at various university institutes devoting some efforts to marine and maritime studies. However, they did not contribute to the development of marine sciences in Kiel in an international context as much as the oceanographers and geoscientists. The Walther-Schücking-Institute for International Law has a tradition of pursuing legal aspects of maritime affairs.

3.1 Marine Geology at the Institute of Geology and Paleontology (GPI)

The Early Years

This situation changed dramatically when Eugen Seibold (figs. 1a–c) followed Karl Gripp as professor and director of the GPI in 1958. Almost at the same time Dietrich succeeded Wüst at the helm of the IfM. Coming from the University of Tübingen, Seibold was a classical geologist and paleontologist. He had only modest experience in marine geology, having studied varved sediments from the northern Adriatic (Seibold, 1958). After arriving in Kiel he recognized its future research potential for the state of Schleswig-Holstein lying between the Baltic and the North Seas. He brought new ideas, concepts and disciplines to the institute. He decided to reorient the main research direction of the Institute towards marine geology and succeeded in



Fig. 1b. Eugen Seibold (1918–2013) as president of the DFG. At that time he was an established international scientist and marine geologist.

Fig. 1a. Eugen Seibold in his best years, here opening the “Barbara party” at the GPI (St. Barbara is the Saint of miners and geologists in Germany and a party in her honor is celebrated at many geoscientific outfits in Germany during the early days of December). The picture illustrates vividly that E. Seibold was a great academic teacher and communicator.



Fig. 1c. Eugen Seibold during his last visit in Kiel on the premises of GEOMAR on the “Seefischmarkt”, with Mrs. Seibold (foreground, 3rd from left) and surrounded by former colleagues, collaborators and doctoral students (on August 29, 2009). (Photo courtesy of Dr. Heidemarie Kassens, GEOMAR)

doing so with surprising speed. He was assisted in many facets of his new professional challenge by his congenial wife Ilse Seibold, who was a micropaleontologist and whom he had met in Tübingen. She cooperated with him not only in scientific matters, but she also helped him in his social contacts by running a very guestfree household. He attended to other geoscientific

Fig. 2. The old “mansion” in Stift which housed working groups on marine micropaleontology for many years, until the new GPI was built on the university campus 1964–1966 (cf. Figs 3a–b).



disciplines through existing staff, thereby maintaining the scientific breadth of the institute. Seibold also became the first dean of the newly founded Faculty of Natural Sciences (1963) of CAU, no small achievement after he had arrived in Kiel only five years before.

In 1964 Seibold was joined by Karl Krömmelbein (1920–1979) in a new professorship for Paleontology and Historical Geology. He had worked in South America and was an ardent defender of Alfred Wegener’s hypothesis of the “Origin of Continents and Oceans” (Wegener, 1929).

It was a very difficult start, because there was no one with any real marine experience or expertise, virtually no relevant literature, nor any instrumentation to speak of. The building which housed the institute was an old factory within a large compound shared by many institutes of the university after the war. It was small and no sophisticated laboratories were available. In the early 1960s part of the marine geology working group (mainly the micropaleontologists) moved to an old villa close to the IfM which they shared with meteorologists (Hans Hinzpeter) from the IfM. Later, they moved to a small mansion in Stift, a suburb just to the north of Kiel (fig. 2).

It was not until the end of 1966 (Werner, 1998) that the institute was able to move into a new building providing space and modern laboratories for most of the members of the entire marine geology group (as part of the complex of “Angerbauten” in the western part of the CAU campus; figs. 3a–b). The new building allowed installation of modern instrumentation, such as a Scanning Electron Microscope (SEM) which came under the responsibility of Christian Samtleben and which was made available also to other CAU institutes (Seibold, pers. comm.). This new instrument enabled the development of new unconventional methods for studying sediment particles. This work culminated in the “Habilitation” thesis of Dieter Fütterer (1968), who analyzed compositional patterns of fine-grained surface sediments from the NW-African continental margin, and who became later leader of the marine geology group of the Alfred-Wegener-Institute (AWI), now the Helmholtz Centre for Polar and Marine Research in Bremerhaven.

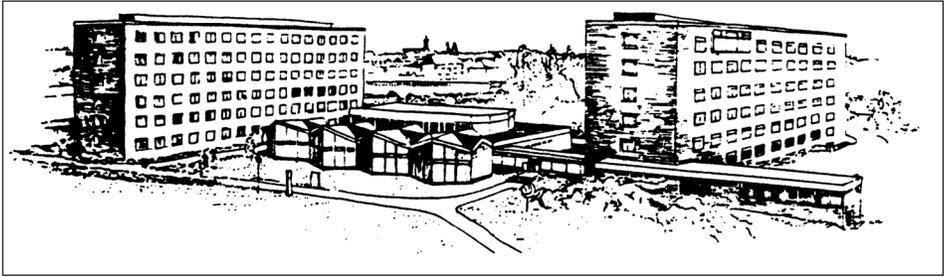


Fig. 3a. Sketch of the GPI by G.F. Lutze (Prof. in Micropaleontology at the GPI) showing the GPI building on the left side, the pavilions of the Geological-Mineralogical Museum with attached auditoriums in the middle and the building of the Department of Geography, which also housed part of the GPI, on the right side.

One of the other relatively early investments was the development of a sophisticated sediment balance by Eckart Walger to measure hydraulic grain sizes and of a flume channel (installed in the new building) soon used for experiments on the erodibility of sediment surfaces (cf. paragraphs on SFB 95 further below; Einsele et al., 1974). Another example of the introduction of new techniques was the preparation of radiographs of well-prepared sediment slices collected from the large volume box cores which allowed to study mechanical and biogenic sediment structures in great detail. This ac-

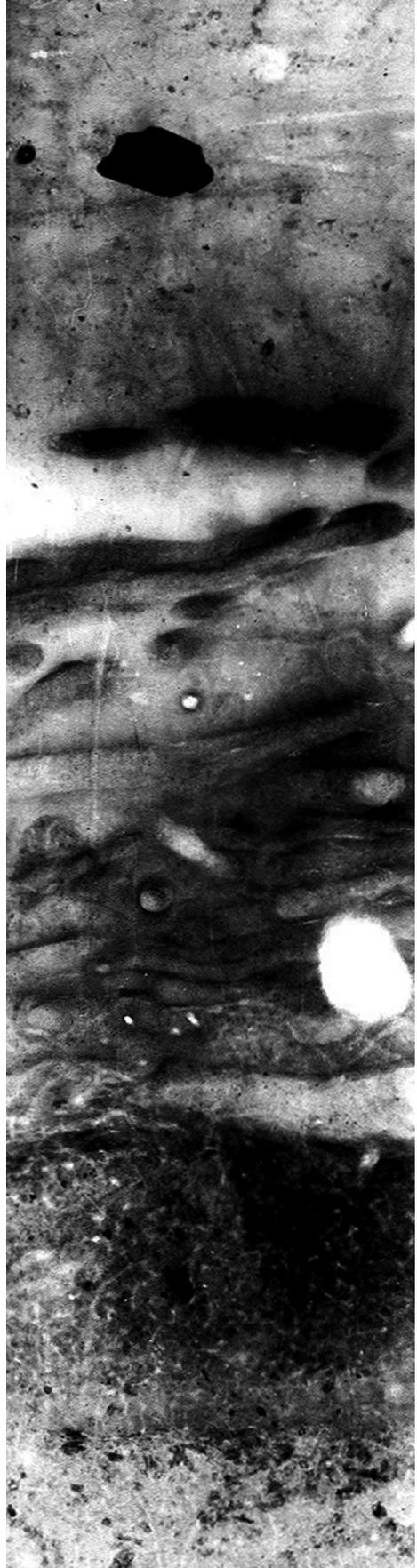


Fig. 3b. Picture of the “Angerbauten” in the Ludewig-Meyn-Strasse of the CAU campus which had been built in the mid-sixties, but which will be demolished in the near future because of constructional deficiencies. The new GPI (from 1967 onwards) as part of the “Angerbauten” is located on the far left corner of this group of buildings. The art of the building was modest at that time with the result that a decision has been reached in 2015 to demolish it and to plan for a new building, also as part of the CAU campus, but at some distance to this location. (Photo by permission of Volker Rebehn, Kiel)

tivity at the GPI had been developed under the supervision of Friedrich Werner, one of the earliest members of the GPI marine geology group. An example is given in fig. 4.

As one can see from listings of the lectures in geology he had given in the early 1960s (to be found in the official course directories = Vorlesungsverzeichnisse of CAU) it took Eugen Seibold some time to introduce marine topics into his teaching portfolio (for example: Geology of the North and Baltic Seas; Exercises in Marine Geology; Marine Geology; Scientific Diving). He absorbed modern ideas about marine geology from many foreign visitors (Börje Kullenberg, University of Gothenburg; Lambertus Marius Joannes Ursinus van Straaten and Philip Henry Kuenen, both from the University of Groningen) and from the current scientific literature. This work culminated in his writing a text book (Seibold 1964) which has become a classic work. Members of the marine geology group also started to contribute to and organize national and international meetings. These included the Annual Meeting of the "Geologische Vereinigung" under the theme "Das Meer" (= The Sea) 1970 in Kiel and the II. Planktonic Conference (1970 in Rome). To

Fig. 4. Radiography of a box core slice from the Vöring Plateau (one of the central working areas of the SFB 313) with clear indications of the occurrence of IRD (ice-rafted debris) and well developed biogenic sediment structures. Width of the box core slice approx.. 5 cm. (Courtesy of Dr. H. Kassens from GEOMAR)



transfer modern ideas into his group he invited many foreign guests from abroad (for example Alan Bé, a specialist in planktonic foraminifers from Lamont-Doherty Geological Observatory close to New York) and hired several young German scientists back from U.S. marine institutions, e.g. Wolfgang H. Berger from Scripps and Erwin Suess from Hawaii, both of whom later became internationally leading scientists in marine geosciences.

Seibold's original idea was to study modern sediments and sedimentation processes in order to better understand ancient deposits, following a philosophy which had been developed at "Senckenberg am Meer" in Wilhelmshaven (Schäfer, 1962). He kept the institute independent and did not try to integrate it into the IfM, which might have been a logical step considering the original discipline portfolio of its predecessor prior and during WW II. The beginnings of the new research direction were modest and difficult (Werner, 1998) because Seibold had virtually neither people nor instruments, but he was on friendly terms with the other marine colleagues in Kiel and could draw on some of their resources, for example using the small research cutter HERMANN WATTENBERG of the IfM.

During his first years he succeeded in acquiring soft money funding to appoint additional scientists and to develop new instrumentation. However, the earliest marine geological investigations were limited in scope and methodological sophistication. Most of the research efforts at that time were devoted to coastal or nearshore regions and shallow water sediments. He established a group in scientific diving (headed later by Theo Kollatschni) with himself being an active participant (Seibold, Dill & Walger, 1961). Early investigations aimed at understanding transport processes of near shore sand accumulations by means of luminophores (luminescent sand grains), direct diving observations and the determination of grain size distributions. In this context, another "import" from Tübingen has to be mentioned, Eckart Walger (Matthess & Werner, 2003). He was remarkably well versed in mathematical methods and developed a settling tube for investigating the relationship of shape and specific weight of fine and coarse fractions of marine sediments. Determination of these parameters was of special importance for evaluating the transport of sediment particles in marine environments.

The marine geology working group specialized in granulometry, micropaleontology, clay mineralogy, geochemistry and many subfields needed to develop a fundamental understanding of the depositional environment of marine sediments. At the same time conditions of sediment formation, investigations ("actuopaleontology", with Gerd F. Lutze, formerly University of Southern California, Los Angeles) of marine microfossils (foraminifers), evaluation of marine resources and investigations of paleoclimatology were carried out with regional emphases on the Baltic and North Seas including the Waddenzee. Fig. 5 shows the growth of the numbers of employees in the GPI marine geology group during and after Eugen Seibold's tenure in Kiel.

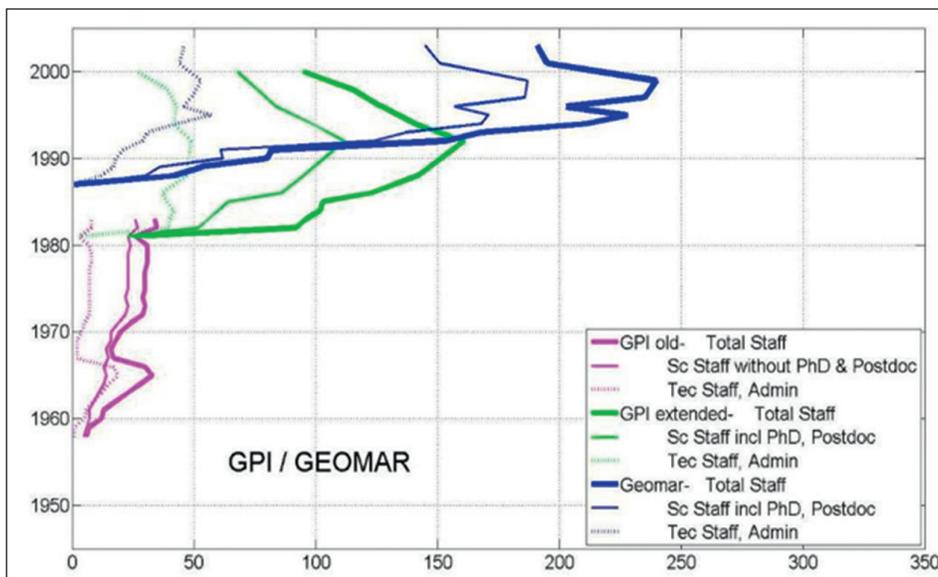


Fig. 5. Growth years of marine geology and geosciences at Kiel University Department of Geology and Paleontology (GPI) and at the GEOMAR Center for Marine Geosciences at CAU. The figures for the early years of the department are probably incomplete because no annual reports including the staff members supported through soft money were available.

The result was the establishment of a major research environment which provided a base for the later foundation of the GEOMAR Research Center for Marine Geosciences at the CAU.

Planning for the German participation in the IIOE and the use of the new research vessel *METEOR* absorbed much of Seibold's attention. Major changes in oceanographic research were linked to the *METEOR*. The ship was put into operation in 1964 and after a short test cruise she made her maiden voyage to the Red Sea and Indian Ocean (chief scientist Günter Dietrich) and then into the Persian Gulf (chief scientist Eugen Seibold). *METEOR*'s leg into the Persian Gulf occurred at a time when that area was a politically difficult terrain (Seibold, 1998). Groups from eleven disciplines (from meteorology and oceanography to biology and geology and even shipbuilding) from 17 West German marine institutions were involved. Most of the members of his young team in marine geology were invited to participate in the Persian Gulf leg. This expedition collected extensively sediment surface samples and cores, which were the basis for a number of PhD theses and "Habilitationen" (e.g. Sarnthein, 1971) aimed at characterizing Persian Gulf surface sediment properties. They led to an understanding of the relationship between climate and sedimentation in shallow seas and towards a comparison of shallow water sediment properties and sedimentation patterns under humid and arid climate conditions (Seibold, 1970). The collection of sediment cores from this

expedition later allowed the comparison of a “pristine” Persian Gulf sediment surface with its perturbations caused by the later war between Iran and Iraq (1980–1988) when the Persian Gulf was heavily polluted due to the destruction of nearby oil fields (Graf et al., 1993). These studies also involved J. Mienert who is now a senior marine geologist at the University of Tromsø (Norway).

The efforts of the early years of this marine geology group were also devoted to the improvement of technologies required to collect samples more efficiently than was possible before. Examples are the short and long, large volume box corers (fig. 6), multicorers and vibrocorers developed by Friedrich Kögler (vital for the collection of relatively coarse grained sandy sediment strata). In the 1980s these efforts led to new echosounders with a fan-shaped acoustic pattern (Multibeam Echosounder) and high resolution shallow “sediment echo sounders” (Parasound). For regional mapping of sediment types and the morphology of the sea floor the group also acquired side scan sonar systems. All of this resulted in close cooperation with pertinent industry and many other scientific institutions in Germany as well as abroad.

A Decade Later

The scientific thrust of the marine geology group at the GPI changed considerably during the late 1960s and early 1970s. Attention turned to the continental margins off Western Europe and Northwest Africa and various deep-sea basins, as well as to marine non-living resources (von Rad et al., 1982). A number of METEOR expeditions were organized to study sedimentation patterns and processes along profiles across the shelves and adjacent slope regions, primarily off the Iberian Peninsula and Northwest Africa. Again, geophysical data and sediment distributions were investigated relating them



Fig. 6. “Kastenlot” from the central Arctic Ocean and acquired by research vessel POLARSTERN (long and large volume box corer developed by the marine geology group of GPI).

to water depth, surface and bottom water currents. Sediment cores recovered during these expeditions soon revealed the presence of ice-rafted materials in the glacial intervals, even off the Canary Islands, documenting that icebergs reached "subtropical" zones in the Atlantic approximately 20,000 years ago. For the first time, underwater TV cameras were deployed for visual inspection of surface sediment structures and the distribution patterns of benthic floras and faunas. In close cooperation with oceanographers and marine biologists, submarine highs off these continental margins were investigated intensively ("Atlantische Kuppenfahrten" of research vessel METEOR; cf. Cloos et al., 1969). The data and their interpretations were presented at international conferences such as the ICSU/SCOR Working Party 31 Symposium in Cambridge (1970) "The Geology of the East Atlantic Continental Margin".

During those years, the micropaleontological working group belonging to the GPI marine geologists reached a substantial size. Gerhard F. Lutze's "Habilitation" covered the influence of brackish waters on the distribution of benthic foraminifers in the Baltic Sea. Rudolf Röttger studied the reproduction of a large foraminifer *Heterostegina depressa*, which was cultured under laboratory conditions. Friedrich Wilhelm Haake investigated the seasonal reproductive cycle of benthic foraminifers from the North Sea Wadden Sea. Pinxian Wang used a Humboldt professorship to study benthic foraminifers in the Elbe estuary and laid the foundation for a longstanding cooperation of the GPI with the Tongji University in Shanghai. Gerhard F. Lutze, Alexander Altenbach (later professor at Ludwig-Maximilians-University in Munich) and Andreas Mackensen established the NOSOFO transect and detected the vertical distribution patterns of benthic foraminiferal faunas along the East Atlantic continental slope between the equator and the highest northern latitudes. Finally, Uwe Pflaumann, an expert on flysch foraminifers, was introduced by Hans Bolli (Zürich) to planktonic foraminifers and studied their records in the DSDP Leg 41 drill cores. Later, he also developed new transfer functions for the reconstruction of sea surface temperatures from planktonic foraminiferal census counts.

When Germany became an active participant in the DSDP, Eugen Seibold and Yves Lancelot (from France) were selected to be co-chief scientists of DSDP Leg 41 off Northwest Africa. Its drill sites penetrated into some of the oldest Atlantic deep-sea sediments of Jurassic age. Seibold was able to draw on his earlier experience working on Mesozoic strata in southern Germany comparing the micropaleontology and biostratigraphy of the two regions (Lancelot, Seibold et al., 1977). He succeeded in involving many of his colleagues from the GPI as shore-based scientists in the analysis and interpretation of the samples and data, thus offering them international exposure. The interest of marine geologists from Kiel in the paleoclimatic history of the eastern tropical Atlantic Ocean continued for many years and resulted

in a reversal of the then widely accepted “Pluvian Theory” into an “Aridity Theory” for deserts in the subtropics during peak glacial times (Sarnthein et al., 1980). Naturally it was reinvigorated when ODP Leg 108 visited the area with William F. Ruddiman and Michael Sarnthein as co-chief scientists (Ruddiman, Sarnthein, Baldauf et al., 1988). Again, several scientists from Kiel (e.g. Rüdiger Stein, later professor at the AWI, Bremerhaven) were involved in the subsequent evaluation of the stratigraphic records of the cored sediment sequences. They allowed a detailed description of the Late Miocene to Pleistocene evolution of climate of Africa and low latitude Atlantic (Ruddiman, Sarnthein et al., 1989).

Again, international linkages were very important for the young team in marine geology at the GPI. Seibold cultivated these through invitations to famous marine geoscientists from the U.S. (Kenneth Emery), the UK (Anthony Laughton, Brian Funnell), France (Xavier Le Pichon) and other countries. He himself spent a sabbatical at the Scripps Institution of Oceanography in California in the mid-1970s. He made sure that the scientific staff of his group was exposed to new ideas during international conferences. He invited well-known scientists from Scandinavian countries and France to Kiel to talk about the new ideas arising from marine studies. He was the major professor of 45 PhD students, 30% of them being foreigners coming from seven countries on four continents other than Europe. Several of his former students assumed high positions in academia and in industry, both in Germany and abroad. As his international reputation grew, he became involved (sometimes as a member, but often in a leading capacity) in numerous science organizations such as the DFG, the Scientific Committee of Ocean Research (SCOR), International Union of Geological Sciences (IUGS), European Science Foundation (ESF), to name a few. Based on his experience with the American-led DSDP he was able to convince a group of European countries first to join DSDP, thus forming IPOD (International Phase of Ocean Drilling) and later to found ECORD (European Consortium of Ocean Research Drilling). These became the largest and most successful marine research initiatives of our time and have revolutionized our understanding of how planet Earth functions. Thus, beside its internationally well-known oceanographers CAU owes him much of its international reputation as a center of excellence for marine sciences.

After the 1970s Seibold became involved into high-level science administration positions. He was elected president of IUGS 1980–1984, of DFG 1980–1985, vice-president 1980–1983 and later president of ESF 1984–1990. As a consequence, he moved from Kiel first to Bonn, later to Freiburg. New people with other interests took over. He also bolstered the international reputation of CAU by seeing to that honorary doctoral degrees were awarded to famous foreign scientists (to Tom Barth from Oslo/Norway – not very easy shortly after the war – and to John Imbrie, the famous paleoclimatologist

from Brown University RI whom he had confronted directly during WW II as a member of the German infantry in the battle of Monte Cassino, as they were able to reconstruct during personal discussions; Seibold, pers. comm.).

The Marine Geology teams had matured during the late years of Eugen Seibold's tenure in Kiel. They had acquired much equipment ("Meeresgeologisches Gerätelager"), were intellectually strong and continued to grow into the new millennium (cf. fig. 5), with Michael Sarnthein as one of the central figures. The group devoted its efforts to analysis of samples and data from an increasing number of expeditions. The immediate successor of Seibold was Peter Stoffers from the University of Heidelberg. This was a time crucial for the marine sciences in Kiel, with several new ships being acquired by the IfM.

The Phase of the SFB 95 (Seawater-Sediment Interactions in Coastal Waters)

The efforts of the marine geologists to understand processes and modes of sediment formation soon resulted in the recognition that progress could only be achieved through an intensive collaboration with colleagues from other marine disciplines in Kiel. After a thorough evaluation by external referees under the oversight of the DFG, SFB 95 (one of the earliest SFBs in marine sciences in Germany) had been launched in 1971. It lasted through two six-year-funding cycles. It involved mainly scientists from the IfM and from the GPI of the CAU. The investigations concentrated first on the inner part of Kiel Bay, where (in the outer Eckernförde Bay) a special research area had been reserved, and where a fixed installation (plankton tower) had been established for a decade. A school for scientific diving (later under Theo Kollatschni's supervision) was founded. This required an administrative and technical cooperation with the German navy which was achieved through a close coordination of activities with the FWG. Chairs of the SFB 95 over the years were Eugen Seibold, Gotthilf Hempel, Bernt Zeitzschel, Gerd F. Lutz and Eckart Walger. The first phase concentrated largely on studying the inner part of Kiel Bay. In support of these activities the CAU acquired the research vessel LITTORINA. During the second phase distant and very different shallow water depositional regimes (Harrington Sound in Bermuda, Hilutangan Channel near Cebu City/Phillipines) were investigated. The main contributors to the final SFB 95 Report were Friedrich Werner and Gerold Wefer from the GPI, Brigitta Babenerd, Wolfgang Balzer, Lutz-A. Meyer-Reil and Viktor Smetacek from the IfM (Rumohr et al., 1987).

The first phase of this SFB covered an interesting mix of instrumental developments, experimental work both in the lab (flume channel) and at sea (plankton tower, bell jar experiments, SEMIRAMIS experiment: floating sediment substrates to record benthic growth at different water depths), but it lacked a modelling component. Sediment distributions, stratification and the basic physiographic patterns of Kiel Bay were mapped. First observations

of the drag on benthic boundary layers were performed (Gust, 1976; Schauer, 1987) and the relationship between coastal wave induced currents and sediment transport were studied (Siedler & Seibold, 1974). However, adequate studies of the physical processes at the sediment surface-sea water interface ("Benthic Boundary Layer") were sparse. Other problems also surfaced. The maintenance of *in situ* systems faced enormous difficulties because of leakage, fouling and corrosion. The concluding report of the SFB 95 (Rumohr et al., 1987) stated (on p. 10): *"that the major processes affecting change in the systems were driven on an event scale and that more frequent monitoring was desirable during the comparatively brief periods when significant changes occurred"*.

The second phase of SFB 95 then widened the scope of its investigations by including shallow water regions far distant from Kiel and under very different climatic conditions. Its main aims (Rumohr et al., 1987) were to study *"a) turnover of material in tropical and subtropical shallow waters, b) structural dynamics of benthic communities, c) function of benthic organisms in exchange processes at the benthic boundary layer, and d) biogeochemical exchange between water column and sediments"*. This phase of the SFB was also highly successful. It strengthened the expertise in organic geochemistry and bacteriology and it became increasingly clear that *"in-situ experiments in the marine environment were a formidable undertaking"*.

The great success of the SFB 95 was in forming "leaders" in marine sciences first in West, later in the reunited Germany: Ulrich Bathmann (director IOW), Bodo von Bodungen (director of IOW), Burkhard Flemming (director of "Senckenberg am Meer" in Wilhelmshaven), Gotthilf Hempel (director IfM, founding director of AWI, ZMT, IOW and IPOE), Karin Lochte (director AWI), Michael Sarnthein (acting director of the GPI 1982–1985 and founder of the Leibniz Laboratory), Erwin Suess (director GEOMAR), Gerold Wefer (founder of the marine geology group at the University of Bremen and MARUM). The SFB 95, with its goal of increasing interdisciplinary cooperation between various disciplines of marine sciences, was obviously an excellent training ground for the future.

Marine Geology at the GPI During the 1980s/1990s/Towards the End of the 20th Century and Beyond

The 1980s saw a quick evolution of the marine geology in Kiel. It was a wise decision of the CAU to let the marine geology group of the university continue to flourish through the 1980s and 1990s up to recent times, despite new developments at GEOMAR and the IfM. This is illustrated by the continued growth of the relevant personell of the institute (cf. fig. 5). In fact, the close partnership of university institutes and relevant research institutions outside the university proved to be of special advantage for acquiring funding.

Michael Sarnthein worked at the GPI since 1966. In 1985 he was appointed full professor when declining the position of a founding director of the new institute for marine geosciences offered by the University of Bremen (subsequently accepted by Gerold Wefer, assistant professor at the GPI). Sarnthein deepened his international cooperation while spending various sabbatical leaves in the U.S.A., France and the United Kingdom. Starting with guest lectures in 1985, Michael Sarnthein and Gerold Wefer established for the GPI a long-term close scientific cooperation in marine geology and monsoon research with the Tongji University in Shanghai. It culminated in a joint two months cruise with research vessel SONNE in the South China Sea. The results of that cruise formed the basis for planning ODP Leg 184 and the synthesis of Wang et al., 2005.

In 1982 Jörn Thiede, who had been professor at the University of Oslo, joined the GPI succeeding Karl Krömmelbein as professor in "Paleontology and Historical Geology". He had a major interest in the history of oceans in high northern latitudes including the Arctic Ocean and in the development of Cenozoic climates which led to the alternations of glacials and interglacials (addressed also in the "Habilitation" of Rüdiger Henrich, later professor at Bremen University). At that time it was already known for many decades that northern hemisphere glaciations were not limited to the Quaternary. Gerhard Bohrmann, who is now a professor in marine geology at Bremen University specializing in the study of the methane hydrates, at that time studied diagenesis in marine sediments (carbonates, baryt and silicates). Glaciations clearly reached back into the Miocene (Köppen & Wegener, 1924, but their insight had been based strictly on terrestrial evidence). Since DSDP Leg 38 (Talwani, Udintsev et al., 1976) it was also known that ice-rafted debris (IRD) was found in Miocene and Pliocene deep-sea sediments in the Norwegian-Greenland Sea. It had become evident that widespread glacial phases in the northern hemisphere much older than the Quaternary had occurred. However, spot coring available at the time prevented recovery of the entire story. Thiede had led several expeditions into high northern latitude waters (including the Arctic Ocean; Pfirman & Thiede, 1992) and he had initiated the ODP drilling program "North-Atlantic Gateways", resulting in ODP Legs 104 (Eldholm, Thiede et al., 1987; Eldholm, Thiede et al., 1989), 105 (Srivastava, Arthur, Clement et al., 1987, 1989), 151 (Myhre, Thiede, Firth et al., 1995), 152 (Larsen, Saunders, Clift et al., 1996) and 162 (Jansen, Raymo, Blum et al., 1996). This drilling program showed that the Cenozoic Northern Hemisphere history of cold climates reached back into the Oligocene (Thiede et al., 2011a and 2011b). The ECORD ACEX expedition to the Lomonosov Ridge close to the North Pole (Backman & Moran, 2009) as well as Site 913 (ODP Leg 151) later proved that this history actually could be followed back into the Eocene, thus rewriting the entire history of the development of an "ice-house" climate on the northern hemisphere.

In 1987 Jörn Thiede was offered a professorship in “Paleoceanography” at CAU and became the founding director of the newly established GEOMAR Research Center for Marine Geosciences at the CAU. After he left the GPI to join the new GEOMAR he was succeeded by Priska Schäfer in the professorship devoted to “Paleontology and Historical Geology”. She developed an interest in shallow water carbonates from low and high latitudes. Karl Stattegger studied littoral sediment facies, and together with Michael Schulz (now at MARUM in Bremen), pursued ocean modelling with Till J.J. Hanebuth (also now at MARUM) and achieved a breakthrough in understanding deglacial sea level curves (Hanebuth, Stattegger & Grootes, 2000).

The BMFT Program on Marine Paleoclimate Research, a Subprogram of the German National Program on Climate Research (1982–1998)

Based on existing studies of East Atlantic sediment records of continental climate change and paleoceanography (von Rad et al., 1982) and encouraged by his membership in the U.S. research group CLIMAP, Michael Sarnthein concluded that major innovations in the analysis and age control of proxy data and ongoing data-model intercomparisons were crucial for progress in paleoclimate research and paleoceanography. Accordingly, in 1982 he joined with Klaus Hasselmann of the Max-Planck-Institute of Meteorology (MPI) in Hamburg) in initiating a long-term German National Program of Climate Research. The program included close cooperation with the BMFT (now BMBF) Program on Terrestrial Paleoclimate Research coordinated by Burkhard Frenzel in Stuttgart-Hohenheim and a data-model comparison with Hasselmann and his colleagues at the MPI, and later on with Dan Seidov at the GPI.

In Kiel, this research program induced a major push for paleoceanography. A number of scientific cruises with various research vessels 1983, 1985 (GEOTROPEX), 1986 (ODP Leg 108), 1988 (METEOR 6-5), 1989 (METEOR 11-1) helped generate a broad array of sediment records covering the central, and eastern equatorial and northern Atlantic. In 1986 Sarnthein was co-founder of the new AGU journal “Paleoceanography”, with J.P. Kennett as chief editor. In 1992 Sarnthein, Thiede and Zahn organized the 4th International Conference on Paleoceanography (ICP IV) in Kiel.

Oxygen isotope stratigraphy became the backbone of paleoceanography in Kiel (with support from Nicholas John Shackleton in England and Jean-Claude Duplessy in France). New analytical techniques formed the basis for the “Habilitation” of Gerold Wefer (1983) on the stable-isotope composition of modern calcareous marine organisms. Major progress in mass spectrometry (MAT 251 and the new fully automated “Kiel Carbo Prep Line” developed by Helmut Erlenkeuser in cooperation with “Finnigan Mat GmbH” in Bremen) was ready for presentation at the international conference on

“Geology of the Oceans” in Kiel in February 1985. Major results included a continuous orbital-scale time series of the Brunhes chron (Sarnthein et al., 1984; Herterich & Sarnthein, 1984) and was evaluated by time series analysis in the “Habilitation” of Klaus Herterich 1984 (MPI Hamburg, later professor at University of Bremen, working in cooperation with the U.S. research group SPECMAP). A further pioneer time series including the last five million years at ODP Site 659 was published by Tiedemann et al. in 1994, who later became professor at AWI Bremerhaven. Pioneering results included the definition of stable isotope signals of coastal upwelling (Gerald Ganssen in 1983). He became later professor at Vrije Universiteit Amsterdam. A reconstruction of glacial-to-deglacial changes in the plume of Mediterranean Outflow Water (MOW; Zahn et al., 1987) represented an exciting discovery. The latter became later professor in Cardiff and Barcelona. An array of 95 epibenthic carbon isotope records finally led to the reconstruction of East Atlantic deep-water transects for eight glacial-to-interglacial time slices, the basis for definition of three basic modes of Atlantic Meridional Overturning Circulation (AMOC) (Sarnthein et al., 1994).

Accurate age control on carbon accumulation rates enabled the Kiel group to reconstruct global maps of glacial and deglacial paleoproductivity patterns, a measure for past changes in the carbon transfer from the sea surface to the deep ocean (Sarnthein & Winn, 1990). As counterpart to the Atlantic records, the Kiel group also reconstructed the records of glacial-to-deglacial wind regimes, paleotemperatures, paleoproductivity, and paleoclimate in the Arabian Sea (“Habitations” of Kai Emeis 1993, later professor in Hamburg, and of Frank Sirocko 1995, later professor in Mainz).

In 1994, an AMS ^{14}C facility was established at the University of Kiel (see Leibniz Laboratory). It enabled Kiel scientists to generate decadal-to-centennial-scale time series of marine climates of the last 60,000 years. These records were fine-tuned to the incremental time scale of paleoclimate records of Greenland ice cores and helped to constrain the origin of millennial-scale Dansgaard-Oeschger events. Also, they showed that there had been major shifts in atmospheric ^{14}C as the result of Laschamp and Mono Lake geomagnetic events (van Kreveld et al., 2000; Voelker et al., 1998).

GLAMAP 2000 (Glacial Atlantic Ocean Mapping 2000) produced maps of peak glacial sea surface temperatures (SST) for the whole Atlantic based on an array of 275 densely sampled deep-sea cores (Sarnthein et al., 2003). SSTs were mainly derived from census counts of planktonic foraminifers (using the SIMMAX transfer function technique by Pflaumann et al., 2003), but in high southern latitudes they were interpreted from species counts of diatoms. Nine papers by 26 colleagues of GPI and GEOMAR, AWI Bremerhaven and Bremen University on peak glacial SST and sea ice margins were published in a special volume of “Paleoceanography”. Long-term access to these extensive paleoclimatic data sets is through the databank PANGAEA, which was

founded by Dieter Fütterer (AWI) and Michael Sarnthein in 1994. It has now become a part of the World Data Center (WDC) complex.

The German national efforts were embedded into a series of EC projects which also involved Nicholas John Shackleton at Cambridge, Jean-Claude Duplessy at Gif-sur-Yvette, Eystein Jansen from Bergen, Geoffrey Eglinton from Bristol, Joan Grimalt from Barcelona, and others). From 1999–2004 Michael Sarnthein acted as executive director of the SCOR/PAGES program on “International Marine Global Change Study” (IMAGES) that hosted marine geoscientists from 26 countries.

In addition to the efforts of the German national climate program, Leg 145 of the ODP led a group of GPI scientists (Michael Sarnthein, Ralf Tiedemann, Mark Maslin, Gerald Haug, Thorsten Kiefer) to pioneering studies of orbital-scale changes in Plio-Pleistocene climate and oceanography of the subpolar Northwest Pacific (Haug et al., 1999). Later, Mark Maslin became professor at the University College London (UCL), Gerald Haug became professor at GFZ Potsdam and then at the ETH Zürich. He is now director of MPI Mainz; Thorsten Kiefer became director of the Paris hub of UNESCO’s “Future Earth” program.

A New Challenge for the GPI Marine Geologists: Sophisticated Geochemistry

In 1986 Eugen Seibold was succeeded by Peter Stoffers from the Institute of Sediment Research, University Heidelberg. This resulted in a new orientation of the Marine Geology/Geochemistry Working Group at the GPI. Now the focus was on dating of marine sediments, gas chemistry, marine minerals, and marine petrology.

New laboratories for alpha and gamma spectroscopy and silica fluorination were established under the leadership of Reiner Botz and Jan Scholten. Within the framework of SFB 313 (see further below), high resolution age dating using the ^{230}Th excess method was developed and applied to carbonate-poor sediments from high latitudes (Scholten et al., 1990). Investigations of the behaviour of natural radionuclides in the water column were conducted in the Arctic Ocean and in the Indian as well Atlantic Oceans as part of the “Joint Global Ocean Flux Study” (JGOFS) (Scholten et al., 2008). Diatoms in sediments of northern latitudes were evaluated as a paleo-seawater proxy (Schmidt et al., 2001).

In 1987 one of the first Inductively Coupled Plasma Mass Spectrometry (ICP-MS) laboratories in Germany was installed in Kiel. This laboratory focussed on the analyses of trace and ultra-trace elements in rocks, manganese crusts and sulfidic ores, seawater and hydrothermal fluids (Garbe-Schönberg, 1993). Of special interest were Rare Earth Elements, $^{230}\text{Thorium}$ and other radionuclides. Under the leadership of Dieter Garbe-Schönberg the lab was continuously improved and enlarged (e.g. quadropol ICP-MS, high-res-

olution Sector Field ICP-MS, laser ablation system). Development of new methods, especially in the field of laser ablation microanalysis, along with cooperation with other national and international research groups resulted in a large number of publications in international peer reviewed journals.

The equipment pool for seagoing operations was extended by a large TV-Grab and the Ocean Floor Observation System (OFOS) developed by "Preussag Meerestechnik". High-temperature water samplers and conductivity-temperature-depth recorders (CTDs) were developed in cooperation with "Sea and Sun Technology", allowing operations in extreme environments (i.e. Red Sea brines).

The Marine Geochemistry working group focussed on the research on geochemical cycles of the seafloor-water-atmosphere system, in particular the processes and timescales of mass transfer. Areas of particular interest were the hydrothermal systems occurring at spreading centres. Here mineral formation as well as trace gas-formation, -degradation and -transport processes were studied (Botz et al., 1999; Schmidt et al., 2003).

For almost 15 years, research was conducted on intraplate volcanoes, especially in the South Pacific. This was done in cooperation with IFREMER, Brest, and the Institut de Physique du Globe in Paris. More than ten joint cruises were carried out including the French submarines NAUTILE and CYANA. These studies aimed to clarify melting processes in the mantle, the development of the crust and the dynamics of the Earth's interior (Woodhead et al., 1993; Haase et al., 1996). A summary of the results was published in Springer's book "Oceanic Hotspots" (Hekinian, Stoffers & Cheminée, 2004).

In cooperation with the Vrije Universiteit, Amsterdam, Ar/Ar dating was performed on many of the rocks from the studied hotspot trails which led to a better understanding of plate motion and the hotspot melting history (O'Connor et al., 2007 and 2015).

In 1998 a joint program with various institutions in New Zealand was started in order to investigate the Tonga-Kermadec arc/back arc system, one of the longest continuous intraoceanic arcs in the world. A number of cruises were conducted using the research vessel SONNE and the submarines JAGO and PISCES. The study of the hydrothermal systems along this volcanic arc provided insight into the types of fluids generated in subduction zone-related hydrothermal systems (Botz et al., 2002). Trace element and isotopic data from the rocks studied indicate significant magma source heterogeneity both along and across the arc resulting from variable subduction of continent-derived sediments, pelagic sediments and oceanic crust, and/or interaction with continental crust (Haase et al., 2002).

Hydrothermal emissions were discovered above several of the volcanic sites. These ranged from low-temperature, diffuse venting, to high-temperature vents discharging clear hydrothermal fluids with temperatures at the seawater boiling curve to characteristic black smoker venting at Brothers

Volcano (Stoffers et al., 2006). A highlight was the discovery of active mercury-depositing in hot subsea springs in nearly 200 m water depth. These vents contain the first documented occurrence of elemental mercury on the seafloor and provide an important link between offshore hydrothermal activity and mercury-depositing geothermal systems on land (Stoffers et al., 1999).

From 1994 to 1998 Peter Stoffers also was in charge of the Coastal Geology group at the institute. Rolf Köster had retired in 1994, but together with Karl Statterger had given many impulses to the research in coastal geology. Klaus Schwarzer was hired and became one of the leading scientists of the large MAST III BASYS (Baltic Sea System Studies) project funded by the EC. This involved investigating detailed biogeochemical, sedimentological, geomorphological and coastal engineering aspects of the coastal zones of the Baltic Sea.

It was the first time after the collapse of the “Iron Curtain” that scientists from Eastern and Western European countries cooperated in common coastal field works and cruises. Major results involved the response of coastlines to natural and human interventions on time scales ranging from short-term events like a storm to millennia in response to the sinking of the southern part and rise of the northern areas since the last deglaciation (Schwarzer et al., 2003).

Recent activities of Peter Stoffers and his group led to two major scientific achievements for the Marine Science in Kiel. Together with colleagues from GEOMAR they established SFB 574 “Volatiles and Fluids in Subduction Zones: Climate Feedback and Trigger Mechanisms for Natural Disasters” in 2004, and the Cluster of Excellence “The Future Ocean” in 2006. A number of young scientists out of the geochemical workgroup were appointed professors at other universities such as Colin Devey (GEOMAR), Kai Emeis (Hamburg), Karsten Haase (Erlangen), Dieter Mertz (Mainz), and Doris Stüben (Karlsruhe). In 2007 Peter Stoffers was succeeded by Lorenz Schwark in the professorship which is now devoted to Organic Geochemistry.

The phase of SFB 313 (Sedimentation in the Northern North Atlantic)

After SFB 95 was successfully concluded another SFB 313 (“Sedimentation im europäischen Nordmeer” = Sedimentation in the Norwegian-Greenland Sea, 1985–1998) was awarded to Kiel (Schäfer et al., 2001). It had become clear that the extension of the Gulf Stream system into high northern latitudes had an enormous impact on the climate system over Northwest Europe. It was a logical step to include this area and its environmental changes into the perspectives of this new SFB. This new effort was dominated by marine geologists/paleontologists, but an intense cooperation developed between marine geology (from the GPI), marine biology (from the IfM) and

marine geophysics (from the IG). SFB 313 lasted from 1985 to 1998 and its reports have been published by Schäfer et al., 2001 and Grobe et al., 2005. Jörn Thiede acted as the head until 1993, Priska Schäfer from 1994–1998.

The northern North Atlantic region includes the Norwegian-Greenland and Labrador Seas. The North Atlantic Ocean is connected to the Norwegian-Greenland Sea across the Greenland-Scotland Ridge, with the Denmark Strait and the Faroe-Shetland Channel as the most important passages. In turn, the Norwegian-Greenland Sea is connected to the Arctic Ocean through the Fram Strait. The Labrador Sea is linked to the Arctic Ocean through Nares Strait. This is the key region for driving both the northern hemisphere glaciations and the global ocean's thermohaline circulation system, Wally Broecker's "global ocean conveyor belt" (Broecker, 2010).

This SFB focused on an ocean region extremely important for the global climate. Cold saline, dense waters sink to the depths of the Norwegian-Greenland Sea, filling it until it overflows the Greenland-Scotland Ridge into the deep North Atlantic basin. There it mixes with cold dense waters formed in the Labrador Sea and dense saline Mediterranean Outflow Water to form the mass of the North Atlantic Deep Water flowing southward toward the Antarctic and then into the other deep basins of the world ocean. The hydrographic contrasts between the temperate North Atlantic Drift/Norwegian Coastal Current and the cold, partly ice-covered waters flowing southward from the Arctic Ocean along the coast of East Greenland (East Greenland Current) to the temperate North Atlantic are enormous.

Sediment cores from this region not only document the glacial-interglacial transitions, but also the rapid changes in the ocean circulation during the Late Quaternary related to the extreme variations in temperature observed in the Greenland ice cores known as Dansgaard-Oeschger events. They also record the brief episodes when flotillas of icebergs (Heinrich events, and Heinrich was one E. Seibold's doctoral students) originating from phases of instability of the Laurentide Ice sheet entered the North Atlantic.

The SFB 313 scientific program addressed these changes through a wide variety of disciplines ranging from marine geophysics, modelling, marine biology (including plankton and benthos), and others as documented in Schäfer et al., 2001 and Grobe et al., 2005. One of the particularly interesting aspects of these studies covered the history of pelagic biota (SYNPAL), spearheaded by Christian Samtleben from the GPI (Schäfer et al., 2001). Sarnthein et al. (2001) presented a synthesis of the fundamental modes and abrupt changes in North Atlantic circulation and climate over the last 60,000 years.

Again, this SFB produced young scientists which later grew into leading positions in marine sciences at other universities; the best examples of such careers are those of Gerold Wefer and Rüdiger Henrich who completed their "Habilitationen" under the framework of the German National Climate Project (Wefer) and of this SFB at the CAU (Wefer in 1983; Henrich in 1993)

and who both went as young professors to the University of Bremen. Gerold Wefer later founded MARUM and acquired the IODP Core Repository for all Atlantic deep-sea drill cores, both located at the University of Bremen. This SFB also led to very close cooperation with Norwegian marine geologists from the Universities of Tromsø and Bergen.

DFG Research Unit 451 “Ocean Gateways”

After SFB 313 was successfully concluded an attempt to launch a further SFB failed. However, its projects (“Impact of Gateways on Ocean Circulation”, “Climate, and Evolution”) were immediately regrouped into a new proposal for a DFG Research Unit that was awarded to Kiel in 2001 and successfully concluded in 2007, with Michael Sarnthein and Wolfgang Kuhnt acting as heads. Over the years, the marine geology group in Kiel had widened its interests to processes governing the evolution of circulation patterns and climate in the global ocean.

In particular, the group of GPI and GEOMAR scientists enlarged by ocean modelers and marine biologists have focused on (1) the timing of the gradual closure of the Central American Seaways (CAS) and its impact on global oceanography and climate; (2) Neogene evolution of the Indonesian Throughflow (ITF); (3) the impact of changing gateway configuration on the onset of major Northern Hemisphere Glaciation; (4) the impact of the CAS closure on the evolution of marine nannoplankton and benthic ecosystems in the Caribbean and eastern tropical Pacific; and (5) the impact of Nordic Sea gateways on glacial-to-interglacial changes in thermohaline ocean circulation.

The project was particularly successful in promoting multidisciplinary interaction between the modeling and reconstruction approaches of paleo-oceanographers and paleobiologists. Most of the innovative results of the Research Unit originated from this cooperation such as a better understanding of the role of the final closure of the CAS (1) for the onset of major Northern Hemisphere Glaciation (Gretta Bartoli, Michael Sarnthein), (2) for productivity changes in the North Atlantic (Mara Weinelt), (3) for the development of stratification in the East Pacific surface ocean (Ralf Tiedemann, Dirk Nürnberg), and (4) for the development of the present-day carbonate ecosystem off the Pacific coast of Panama (Priska Schäfer, John Reijmer). On glacial-to-interglacial timescales, the main interdisciplinary results concern (1) the reduction of the ITF and the fundamental change of its vertical structure during glacial times (Wolfgang Kuhnt) and (2) evidence for peak glacial deep-water formation in the Nordic Seas and a southward flowing overflow that reversed during Heinrich episodes (Michael Sarnthein, Piet Grootes, Mara Weinelt, Rolf Käse, and Andreas Schmittner).

After (and already during its final phase) the research unit had ended, sev-

eral prominent principal investigators were successful in being appointed as professors to other universities and research institutions in Germany (Ralf Tiedemann at AWI), the Netherlands (John Reijmer), the U.S. (Andreas Schmittner) and the ETH in Switzerland (Gretta Bartoli).

3.2 GEOMAR, the New Research Center for Marine Geosciences (1987–2003) at CAU

The Origin of the Idea, Location and Development of GEOMAR

The foundation of the Alfred-Wegener-Institute for Polar and (later) Marine Research (AWI, now a Helmholtz Centre) and its location in Bremerhaven shook the marine scientists in Kiel to the bones. It became clear that the marine sciences had to be diversified if Kiel was not to lose out in the national competition as a center of competence within these fields.

During and due to the discussions about the potential German contribution to and participation in the U.S.-led DSDP (later IPOD) and other large projects (such as the operations of manned and unmanned underwater vehicles) the DFG appointed a dedicated Working Group to look at the marine geosciences in Germany in general (under the auspices of the “Geokommision” and led by Hans Füchtbauer from Bochum). At that time the scene was fragmented, consisting mostly of relatively small groups (except at CAU and BGR) at a number of universities and state research institutions. The Working Group concluded that a new institution should be established to further develop this discipline (Deutsche Forschungsgemeinschaft, 1984).

After much rivalry amongst the West German coastal states a new Research Center for Marine Geosciences (GEOMAR), linked to but not part of the CAU, was established in Kiel during 1987. It received substantial support from the local government and Jörn Thiede was its founding director. A new scientific approach was developed adopting many broad “oceanographic principles”. “Meeresgeologie” became the broader topic of Geological Oceanography and was to be pursued, with adopting many ideas from U.S. institutions. The research fields and departments, all new to Germany, would cover Marine Environmental Geology (Head: Erwin Suess), Paleooceanography (Head: Jörn Thiede), Marine Geodynamics (Head: Roland von Huene) and Volcanology/Petrology (Head: Hans-Ulrich Schmincke). The established marine geology team at the University would continue its successful work. Suess (formerly of Oregon State University) and von Huene (formerly from the U.S. Geological Survey) brought many new ideas to this young institution. When Jörn Thiede left GEOMAR to join the AWI in Bremerhaven, he was succeeded by Erwin Suess and later by Christian Dullo in the directorship. He was replaced by William Hay from the University of Colorado at Boulder who brought new ideas into the areas of paleoceanographic and



Fig. 7. First premises of the GEOMAR Research Center for Marine Geosciences at the CAU in the area of the old fish market (“Seefischmarkt”) on the eastern shore of “Kieler Förde”. The first GEOMAR offices were established in the pictured building no. 4.

paleoclimatic research (Hay, 2016). He had been involved in the ocean drilling programs since their inception and had served on a number of JOIDES Panels and its Planning and Executive Committee for the DSDP and IPOD.

While attempting to join the ranks of the so-called “Blaue Liste” (institutions funded in equal shares by the local and the federal governments) from the very beginning, the German “Wissenschaftsrat” (the Federal Republic’s



Fig. 8. Main location of the new GEOMAR in the “Seefischmarkt” area in eastern Kiel. The attraction of the location was a long pier where research vessels can dock (cf. fig. 9), old buildings which after renovation could be taken into use right away and sufficient space to plan for new buildings. The complex of brick-buildings in the center is the new lab facility which has been erected in the early 1990s.



Fig. 9. The youngest METEOR built in the early 1980s on the pier of GEOMAR. The new METEOR was used many times during the SFB 313 in the Norwegian-Greenland Sea.

highest scientific review committee with members appointed by its president) evaluated the plans and recommended for GEOMAR to start as an independent research institution, but linked to the university and funded entirely through the local government. Since many of the employees at GEOMAR were from foreign institutions where research work was mostly supported through soft money, GEOMAR was following that route, too. Soon its budget was augmented through the acquisition of substantial external funds, allowing it to hire many motivated young scientists (cf. fig. 5) and to buy sophisticated equipment for its labs. The early fast growth of GEOMAR was achieved using a combination of 25% local permanent funds and 75% soft money. This allowed for substantial flexibility.

The original idea at the time of founding GEOMAR was to outsource the technical services needed by the research center to a commercial company “GEOMAR Technologie GmbH” (GTG). This company would serve both GEOMAR and other marine institutions in Germany. However, the composition of the shareholders and their internal rivalry for these services, as well as lack of sufficient funding for the technical services resulted in its financial failure. In addition, it was thought that the “Seefischmarkt” on the eastern shore of Kiel Bay would provide for space and opportunities for a marine technology park (GEOTEC) where small and medium size specialized companies would flourish (Dullo, 2001). After some difficulties during the early years of GEOMAR, a “GEOTEC” (though not as a formal unit) now exists on these premises.

The 1990s saw rapid growth of GEOMAR (cf. fig. 5). The “Seefischmarkt” location (figs. 7–9) on the Eastern side of the Kieler Fjord had been chosen because of its long water front. GEOMAR’s activities began in suitable, but

aged buildings which had to be renovated step by step. The space available at the “Seefischmarkt” allowed to plan for new state-of-the-art laboratories (Dullo, 2001). It had much success in acquiring research grants and recruiting bright young people. After another successful evaluation by the “Wissenschaftsrat” in 1997, it indeed became an Institute of the Leibniz Association (formerly “Blaue Liste”) in 2004 and fused with the widely recognized IfM to form IfM-GEOMAR. SFB 313 was successfully concluded (Schäfer et al., 2001) and new scientific ideas emerged, culminating again in the new SFB 574.

The Phase of SFB 574 (Volatiles and Fluids in Subduction Zones)

Financial support of SFBs by the DFG is largely targeted at universities, but in the case of the SFB 574 this was different. Many of the leading scientists including the last chairman Kai Hoernle came from GEOMAR, while holding their academic positions at CAU. Much of the ground work leading to this SFB had been carried out by Erwin Suess and Roland von Huene who had been among the founders of GEOMAR. This complex project would not have been possible without the very close cooperation between the marine geophysicists and geologists of CAU and the new groups at GEOMAR. The title of the concluding report on the results of this SFB reflects this unique combination of scientific expertise: *“Volatiles and fluids in subduction zones: climate feedback and trigger mechanisms for natural disasters”* (Freundt et al., 2014). The authorship of many of the exciting papers in this volume does not only express the close internal and institutional cooperation, but also the international character of the marine geosciences in Kiel.

Two principal field areas of SFB 574 were the Central American and Central Chilean convergent margins. The Geodynamics group investigations of these margins laid the groundwork for further multidisciplinary studies of geochemistry and volcanism. Produced during the first scientific cruise of the renovated research vessel SONNE (1991–1992), a multibeam bathymetric map defined the dynamic tectonics of the Costa Rica margin. Multiple seamounts were known to collide with and then subduct beneath the continental slope. Contrary to prevailing ideas, the geophysical and geologic data showed that seamounts are not detached as they collide with the margin, but are subducted intact with the downgoing plate to as much as 20 km depth beneath the coast. Clear geophysical imaging of subducting seamount damage was developed with the advanced seismic processing systems at GEOMAR. Multiple middle slope vents releasing fluids from deeply underthrust subducting crust were later discovered in high resolution bathymetric imagery and confirmed by geochemistry. Tectonic erosion rather than accretion along this margin was convincingly demonstrated. The gross geology showed features producing ruptures related to two damaging earthquakes, one of them

a seamount, the other a subducted ridge linking marine geology to earthquake seismology.

In cooperation with the Chilean Geological Survey, the team produced multibeam bathymetric and magnetic anomaly maps along the Central Chilean subduction zone. They showed the subduction of the Juan Fernandez Ridge beneath the region around Valparaiso and its relation to the damaging 1958 San Antonio earthquake. This bathymetry was expanded on successive cruises giving coverage in the region of the great 1960 earthquake. Ocean bottom seismic instruments produced data indicating the erosional character of this convergent margin. In Northern Chile, the plate interface along which aftershocks of the 1995 Antofagasta earthquake occurred were recorded in a local network of GEOMAR ocean bottom seismometers. In cooperation with the BGR, the research vessel SONNE also acquired multibeam bathymetry in the area of investigation.

A GEOMAR cruise on the SONNE, in cooperation with the U.S. Geological Survey, advanced understanding of tectonics along the Cascadia margin off Oregon and Washington. This was followed by investigations of the near surface gas hydrates and fluid chemistry in the region. SFB 574 involved *“some 70 scientists with expertise in structural geology, geophysics, sedimentology, geochemistry, empirical and experimental petrology, volcanology and biology for eleven years”* (2001–2012; Freundt et al., 2014). The overarching theme addressed the role of volatiles in subduction zones of Central America and Southern Chile. The main areas of research were subduction zones of Central America and Southern Chile. Many other topics including tectonic, hydrological, metamorphic and magmatic processes and hazards were investigated. The concluding report contains a long series of exciting, original papers, but also a classical review article by Erwin Suess on marine cold seeps (Suess, 2014).

Scientific Cooperation with Russian Research Institutions in the Arctic

After Perestroika, Kiel’s marine geoscientists developed an intense cooperation with Russian institutions for research in the Arctic. Projects were initiated in and around Russia’s coastal waters. Important links were established to research institutions of the Russian Academy of Sciences, but also to several universities. One of the earliest contacts were established with POI and SIO of the Russian Academy of Sciences (RAS), when Dr. Anikiev and Academician Il’ichev contacted GEOMAR. These early contacts prepared a basis for large cooperative research projects in the Sea of Ochotsk and in the northernmost Pacific Ocean, with Boris Baranov from SIO being one of the leading colleagues on the Russian side. Heavy emphasis also was paid to the Laptev Sea area to the north of Yakutia.

The first decade of the 21st century saw the foundation of the Mainz Acad-

emy Project “Early Warning Systems for Climate Change” (= Frühwarnsysteme ..., funded according to the key applied to Leibniz Institutes). It concentrated on Northern Siberia and the adjacent Arctic Ocean and cooperated closely with the AWI and the IPOE of CAU. Together with scientists from GEOMAR and financial support of the BMBF under the research initiative “The Laptev Sea System” it led to an extensive bilateral Russian-German cooperation in the high northern latitudes, involving research institutions in Moscow, St. Petersburg, Tiksi and Murmansk (Kassens et al., 1999). One result of this cooperation was manifested in an internationally recognized Ms-course in Marine and Polar Sciences (POMOR) at Saint Petersburg State University. The project was formally run by a group of North German universities and Saint Petersburg State University. It also resulted in the foundation of the Otto-Schmidt-Laboratory (OSL) together with the Arctic-Antarctic Research Institute (AARI) of the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) in St. Petersburg. The cooperation between Russian and German marine research institutions allowed German research vessels to operate in Russian waters (POLARSTERN in the Laptev Sea, SONNE in the Sea of Okhotsk).

3.3 Structural Changes of the Marine Sciences in Kiel

There was close cooperation between the young GEOMAR institute and its relevant partners at the CAU (marine geosciences, marine geophysics and the IPOE), as well as with the IfM (Kiel), AWI and other German institutions outside Kiel. Ocean sciences have been changing fast with many new ideas emerging, in particular in the fields of plate tectonics, climate change and organic carbon budgets, modelling.

After a renewed evaluation by the “Wissenschaftsrat” of the marine sciences in Kiel in 1997 it was proposed that the IfM and GEOMAR should join to form the IfM-GEOMAR Leibniz Institute for Marine Sciences at CAU; the merger of the institutes occurred in 2004 (Hoffmann-Wieck, 2015). Another round of changes occurred after a political decision to move IfM-GEOMAR from the Leibniz to the Helmholtz Association. This was in 2012, with funding henceforth 90% from federal and 10% from local government sources, with additional soft money funded projects. The name GEOMAR (Helmholtz Centre for Ocean Research Kiel) was chosen for the new institute, an “old” name, but with new and widened scientific perspectives. The link to the university was retained through the establishment of the Kiel Cluster of Excellence “Future Ocean” and KAIMS (Kiel Academy of Interdisciplinary Marine Studies) (cf. Visbek & Schneider, 2015). It is clear that this development would have been very different if not Wüst, Dietrich and successors had taken care of the growth of IfM after WW II ensuring Kiel’s position in the arena of European marine sciences.

In 1998, the GPI and IG were amalgamated with other groups into the Institute of Geosciences (Institut für Geowissenschaften = IfG) of CAU.

4. The Leibniz Laboratory for Radiometric Dating and Isotope Research

For many years CAU had had a research and service laboratory devoted to ^{14}C dating (headed by Horst Willkomm and Helmut Erlenkeuser). It was the first basis for Michael Sarnthein's idea of establishing an "Accelerator Mass Spectrometry" dating facility at CAU. At the end of the 1980s Gottfried Wilhelm Leibniz Prizes were given to marine scientists in Kiel by the DFG; these included major funding for science. They enabled important developments in the marine geology of the university. Michael Sarnthein had a longstanding interest in paleoclimatology and needed laboratory facilities that could produce a large number of age determinations. After receiving the prize, in 1994 he took the initiative in founding the Leibniz Laboratory for Radiometric Dating and Stable Isotope Research of the CAU. It was located in a new building finished in 1998 and headed by Pieter M. Grootes. At that time, it was the most modern facility of this type in Germany. It added a new 3 MV Tandem Accelerator Mass Spectrometer (AMS) to the conventional Radiocarbon and Mass-Spectrometry Laboratories which had been established in 1962 and had been linked to one of the physics institutes of CAU. The Leibniz Laboratory provides radiocarbon dating and stable isotope measurements to scientists from CAU and others from all over the world.

Services are provided for a wide range of scientific problems. The paleoclimatic research of Michael Sarnthein is mainly linked to marine sediments from ocean basins with high accumulation rates, hence allowing for high temporal resolution time series. These permit, for example, determination of benthic ^{14}C ventilation ages in the abyssal ocean (cf. Sarnthein & Haug, 2015). This facility has given the marine geology group of the GPI, now part of the IfG of CAU, the opportunity to make worldwide visible contributions to the decipher young paleo-environmental history of the world ocean.

5. Marine Geophysics in the Institute of Geophysics (IG)

There was no marine geophysics at CAU before Rolf Meissner (fig. 10) joined the IG in 1971. He came from the University of Hawaii, was well versed in the concepts of sea floor spreading and plate tectonics (up to that time virtually unheard of in Kiel). Under his tutelage the institute grew from a relatively small group covering mainly terrestrial gravimetry and seismology to one with teams on "Crustal Research and Deep Seismics", "Engineering and



Fig. 10. Rudolf Meissner, the founder of marine geophysics at the IG of CAU. The picture reflects very nicely the lively personality of Rudolf Meissner which beside his science helped him to gain international stature, for example as president of the European Geophysical Society (1985–1987). (Photo courtesy of J. Zschau, formerly Kiel, now GFZ Potsdam)

Environmental Geophysics”, “Regional and Global Geodynamics”, “Planetology” and “Marine Geophysics”, the latter being of special interest in this context (Meissner & Tiedemann, 2008). It was particularly important for the ability of the marine scientists in Kiel to develop interdisciplinary and transdisciplinary approaches to marine scientific problems, such as the SFBs mentioned above. This latter team developed expertise in seismic reflection methods which were needed for the determination of sediment distributions, structural patterns of the ocean crust and for site surveys in preparation for deep-sea drilling activities. Studies were conducted in the North Atlantic Ocean (important for SFB 313; cf. Schäfer et al., 2001), Bransfield Strait, Antarctic shelf regions and in the North Sea. The team acquired a range of instruments suited to determine the *in-situ* geophysical properties of surface near sediments (such as magnetism, electric and other geophysical parameters). The marine geology teams of the GPI had constructed sampling gear to collect large volumes of undisturbed sediment samples (cf. figs. 4 and 6) which then allowed in the laboratory to measure properties and absorption coefficients of seismic P- and S-waves.

As mentioned above, GPI and IG were later amalgamated into the IfG of CAU. During his tenure in Kiel Meissner became also president of the European Geophysical Society (EGS).

6. Marine Acoustics and the FWG

After WW II there were initially no German armed forces, but they were re-established in Western Germany during the mid-1950s as a contribution to NATO. They included a small navy with newly developed conventional submarines and hence needs to understand the acoustic properties of com-

plicated coastal waters and seafloor. It was therefore a logical step to establish the FWG (Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik) for providing scientific and technical advice on acoustical properties of water masses, water mass boundaries and seafloors to the mariners (Sellschopp et al., 2006). The new institution was founded in 1964 as an Oceanographic Research Institute of the German armed forces, belonged to the German Ministry of Defence (BMVtg) and was later renamed FWG.

In technology and research, it had some historic roots in Kiel, where the echosounder had been invented independantly (Behm, 1916) and where the German physicist Hugo Lichte (1891–1963) became internationally acknowledged as founder of ocean acoustic physics through understanding and quantifying the refractive sound propagation by the sound speed stratification of the ocean, forming ocean wide channels with extremely low transmission losses (Wille, 1986 and 2015).

A building for the FWG was erected on the eastern shore of Kiel Fjord (in the neighbourhood of the future GEOMAR). It had five major research themes: Ocean Acoustics; Environmental Parameters; Measuring Concepts; Technology of Measurements at Sea; and Sound Propagation Modelling. Over the years it developed a highly productive research program. The scientific and technical cooperation involved NATO Institutions and the universities of Hamburg and Kiel, in particular GEOMAR.

The FWG soon gained national and international reputation because of its sophisticated scientific and technical structure. In 2004, its original research vessel PLANET which had been launched in 1967 was replaced by a highly advanced new PLANET. The new ship is a large twin hull vessel with very quiet seagoing properties up to high sea states. Both vessels (figs. 11a–b) operated in the Baltic and North Seas as well as in the North Atlantic and Mediterra-



Fig. 11a. The first RV PLANET of FWG, launched in 1967.



Fig. 11b. The second RV PLANET of FWG, launched in 2004.



Fig. 11c. The North Sea Platform (NSP) of FWG 1975–1993.

nean. The cooperation between the seagoing working groups of the universities and FWG was to the benefit of both sides. In particular, the new PLANET with its very low self-noise and seagoing up to high sea states is also useful in mitigating the damaging effects of underwater noise on the behaviour/fate of marine mammals while conducting experiments.

During 1974–1983, the FWG was also the operator and main scientific user of the first permanently manned offshore platform (FPN = Forschungsplattform Nordsee; fig. 11c). Its distance to the shore of some 30 nm northwest

of Germany's island of Helgoland allowed to conduct special projects related to the acoustics of the water masses of a shallow shelf sea. In particular, this platform comprised installations for long-term measurements such as environmental and technical noise as well as sound propagation. The platform's fields of hydrophone arrays and vertically steered transmitters enabled sound signal resolution in comparison to shipborne and towed arrays to improve modelling.

Today, the FWG has been moved administratively to the technical service unit of the navy located in Eckernförde (WTD71), but the research institution with its scientific working groups remained in Kiel. The nearly hundred FWG employees working in Kiel comprise scientists, engineers, and technicians; the international visibility of the FWG is documented by the fact that it cooperated closely with a related NATO Research Centre in La Spezia/Italy, which recruited several of its directors/scientific group leaders from the FWG.

7. The Research and Technology Centre, West Coast ("FTZ Westküste") of CAU

Kiel is located between two shelf seas, the North Sea and the Baltic Sea. While most of the groups in Kiel were concentrating on research in the deep ocean, a number of smaller research groups at various institutes in Kiel (GPI, Geography, Ecology, Archeology, Applied Physics, IfM) established a center where applied aspects of coastal research can be pursued.

The "FTZ Westküste" (West Coast) was founded in 1988 as a central facility of the CAU. A location for a building was found in the small town of Büsum, some 100 km to the west of Kiel and very close to the dike-protected shores of the North Sea mudflats that contrast the cliffs and fjords of the Baltic Sea coast. The scientific leaders (Rolf Köster, Peter Stoffers, Franciscus Colijn, Roberto Mayerle) developed a scientific profile building on the expertise of their close to 50 members of staff. Most of the senior scientists also hold positions at the CAU. Three research divisions were established: (1) CORELAB (Coastal Engineering and Remote Sensing Systems), (2) ECO-LAB (Marine Animal Ecology and Coastal Ecosystems) and (3) GEOLAB (Coastal Geosciences and Marine Measuring Techniques). A small research vessel, *SÜDFALL*, is used intensively for work in shallow waters.

The FTZ has issued annual reports since 1989 and the reader is referred to them for details of the FTZ research. The research groups have been highly successful in acquiring soft money, and have spread their activities to distant coasts in the Mediterranean, South America, China, and elsewhere. The study by Leussen et al. (1996) discusses the integrated analysis of shelf processes off Northwest Europe and may be considered as an example of the FTZ research efforts.

8. Summary: The Evolution of the Marine Geosciences in Kiel and their Impact on the National and International Scene

- The development of the marine geology/geosciences in Kiel was very different from that of oceanography (IfM), but had much to do with personalities. The close linkage to a relatively small, but scientifically broadly positioned university (CAU) guaranteed a continuous flow of students into these emerging fields. The outstanding personality of the early years was Eugen Seibold.
- The emerging young research teams in marine geology at the GPI concentrated on developing new instrumentation, methods to be employed in a growing number of expeditions. They stretched from the nearshore waters close to Kiel to distant continental margins and deep-sea basins of other oceans. Sophisticated and advanced laboratories have been established at the CAU as well as at GEOMAR. The expansion into deep-ocean basins also resulted in a close cooperation of the marine geoscientists with other marine disciplines at the IfM devoted most to “blue water oceanography”.
- Since 2004 there has been a substantial restructuring of the marine disciplines in Kiel through amalgamating the IfM and GEOMAR first into the Leibniz Institute IfM-GEOMAR, later into the GEOMAR Helmholtz Centre for Ocean Research, one of the most potent European marine research institutions.
- The scientific success of the marine SFBs in Kiel and other work of the scientific staffs led to changing scientific perspectives. The respect of the international scientific community for the marine science in Kiel grew. This is reflected in international scientific conferences conducted in Kiel, the Conference on “Geology of the Oceans” 1985 (75th Annual Meeting of the Geologische Vereinigung) and the International Conference on Paleoceanography (ICP IV) 1992. Kiel geoscientists held memberships (often chairs) in international organisations such as IUGS CMG, ILP WG 7-Paleoceanography, SCOR WG 82-Deep-sea paleoenvironments, ODP and IMAGES, to name a few. Thus, over the past years since WW II the German marine scientists have been successfully reintegrated into and now play a major role in the international marine science community.
- Fridtjof Nansen built the first dedicated polar marine research vessel (the FRAM) for his famous crossing of the Arctic Ocean (1893–1896), very similar to the German GAUSS, built in Kiel and used for the 1st German Antarctic Expedition (1901–1903). However, it took the international marine research community more than another 50 years to recognize that efficient and successful marine research in the extreme environments of the open and deep ocean (and of the polar seas) required dedicated, sophisticated research platforms. This trend continues and has been recognized in many

- countries, and Germany (with inputs from the Kiel scientists) has made important contributions to this development.
- From modest beginnings based on national efforts 15 years after the end of WW II the marine geoscientists in Kiel have evolved into a thriving international science community. This has also had its impacts locally by establishing young forward thinking scientists and technicians into communities in Kiel which had not been academically or internationally oriented, like that on the eastern shore of Kiel harbour.
 - And about the future: The world faces enormous challenges in terms of understanding (and then managing) future environmental change. The world ocean and its marginal seas are the largest contiguous compartment of the global environment and hence deserve the research efforts of many nations. The marine scientists from Kiel are contributing their share to meet these challenges. Kiel is located, where such environmental changes are felt early and hence there exists an urgent motivation and obligation to make contributions to meet these challenges. The large diversity of marine disciplines at and around Kiel and the vibrant, international research community in Kiel holds great promise for future ocean research.

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List of Abbreviations/Acronyms:

AARI	Arctic and Antarctic Research Institute of Roshydromet in St. Petersburg/RF
ACEX	Arctic Coring Expedition
AMOC	Atlantic Meridional Overturning Circulation
AWI	Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research
BGR	“Bundesanstalt für Geowissenschaften und Rohstoffe”
BMBF	Federal Ministry for Research and Education, “Bundesministerium für Bildung und Forschung”
BMFT	Federal Ministry for Research and Technology, “Bundesministerium für Forschung und Technologie”
BMVtg	Federal Ministry for Defence, “Bundesministerium für Verteidigung”
BMWi	Federal Ministry for Economy, “Bundesministerium für Wirtschaft und Energie”
CAS	Central American Seaway
CAU	Kiel University, “Christian-Albrechts-Universität”
CLIMAP	Climate Long-range Investigations: Mapping and Prediction
DFG	German Research Foundation, “Deutsche Forschungsgemeinschaft”
DSDP	Deep-Sea Drilling Project (1966–1983)
EC	European Commission

ECORD	European Consortium for Ocean Research Drilling
EGS	European Geophysical Society
ESF	European Science Foundation
FTZ	Research and Technology Center West Coast of CAU, "Forschungs- und Technologiezentrum Westküste der CAU"
FWG	Research Institute of the German Navy for Underwater Acoustics and Geophysics in Kiel, "Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik"
GEOMAR	1987–2004 Research Center for Marine Geosciences at CAU, "Forschungszentrum für Marine Geowissenschaften der CAU"; 2012– Helmholtz Centre for Ocean Resarch Kiel, "Helmholtz-Zentrum für Ozeanforschung Kiel"
GEOTEC	GEOMAR Marine Technology Park
GLAMAP	Glacial Atlantic Ocean Mapping
GPI	Institute and Museum of Geology and Paleontology of CAU, "Geologisch-Paläontologisches Institut und Museum der CAU"
GTG	GEOMAR Technologie GmbH
IFG	Institute of Earth Sciences of CAU, "Institut für Geowissenschaften der CAU"
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICSU	International Council of Science
IfM	1946–1968 Institute of Marine Research of CAU, "Institute für Meereskunde der CAU"; 1968–2004 Institute of Marine Research Kiel at CAU, "Institut für Meereskunde Kiel an der CAU"
IfM-GEOMAR	Leibniz Institute for Marine Sciences at Kiel University, "Leibniz-Institut für Meereswissenschaften an der Universität Kiel"
IG	Institute of Geophysics of CAU, "Institut für Geophysik"
IIOE	International Indian Ocean Expedition
IMAGES	International Marine Global Change Study
IODP	Integrated Ocean Drilling Program (2003–2013), since 2013 the International Ocean Discovery Program
IOW	Institute for Baltic Sea Research in Warnemünde, "Institut für Ostseeforschung"
IPOD	International Phase of Ocean Drilling
IPOE	Institute of Polar Ecology of CAU, "Institut für Polarökologie"
IUGS	International Union of Geological Sciences
JMFG	Joint Marine Facilities Group under the auspices of the European Marine Board
JGOFS	Joint Global Ocean Flux Study
KAIMS	Kiel Academy of Interdisciplinary Studies
MARUM	Centre for Marine Environmental Sciences, Univ. Bremen, "Zentrum für Marine Umweltwissenschaften"
MAST	Marine Science and Technology Program of the European Union
MOW	Mediterranean Outflow Water
ODP	Ocean Drilling Program (1983–2003)
OFOS	Ocean Floor Observation System
OSL	Otto-Schmidt Laboratory at the AARI
PAGES	Past Global Changes
POI	Pacific Oceanologic Institute, Far Eastern Branch of the RAS in Vladivostok
POMOR	Course in Polar and marine Sciences, St. Petersburg State University
RAS	Russian Academy of Sciences
REE	Rare Earth Elements

SCOR	Scientific Committee on Ocean Research
SFB	Special Research Project, "Sonderforschungsbereich"
SIO	P.P.Shirshov Institute of Oceanology of RAS, Moscow
SPECMAP	Spectral Mapping Project
SST	Sea Surface Temperature
UNOLS	University-National Oceanographic Laboratory System
WTD71	"Wehrtechnische Dienststelle" 71 of the German Navy in Eckernförde
WW II	Second World War
ZMT	Centre for Tropical Marine Research, a Leibniz Institute in Bremen, "Leibniz-Zentrum für Marine Tropenforschung"

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Von sehr bescheidenen Anfängen zu einem blühenden Bereich der Meeresforschung: Die Entwicklung der Institutionen in den marinen Geowissenschaften in Kiel nach dem Zweiten Weltkrieg

Zusammenfassung

Meeresgeologie/Marine Geowissenschaften in Kiel entwickelten sich als ein neuer Forschungszeitung etwa 15 Jahre nach dem Ende des Zweiten Weltkriegs. Sie entstanden in einer kritischen Zeit, nämlich vor der Entdeckung des »Sea floor Spreading« und der Plattentektonik, als die marine Geophysik noch in ihren Kinderschuhen steckte, sowie bevor Tiefseebohrungen möglich waren und diese neue Technologie die Entwicklung von Wissenschaftsfeldern wie die pelagische Biochronologie und Paläo-Ozeanographie ermöglichten. Aufbauend auf neuen Erkenntnissen konnten seither die mesozoische und känozoische Paläoklimatologie entziffert werden. Die Beprobungen der flachen und tiefen Teile der magmatischen Teile der ozeanischen Kruste bewiesen, dass die Ozeane im Gegensatz zu den Kontinenten nur sehr junge geologische Provinzen umfassten.

Die Meeresgeologen der Christian-Albrechts-Universität Kiel hatten anfänglich nur wenige und technisch bescheidene Forschungsmöglichkeiten, so dass sie sich dieser Disziplin widmeten, um aus Erkenntnissen der modernen Ablagerungsbedingungen die Eigenschaften fossiler Sedimente zu erklären. Ihre Untersuchungen konzentrierten sich daher auch auf die küstennahen Schelfmeere, zunächst in der Ostsee, bezogen aber bald tropische Flachmeerebereiche ein. Ein erster großer Erfolg stellte sich ein, als man lernte, die Sedimentationsmuster in Flachmeeren unter humiden und ariden Klimabedingungen zu unterscheiden. Gleichzeitig versuchte man, die methodischen und technischen Arbeitsbedingungen zu verbessern.

Die wissenschaftlichen Zielsetzungen erweiterten sich schnell und bezogen bald Kontinentalränder (vor allem im Ostatlantik) und die angrenzenden Tiefseebecken ein, die durch eine zunehmende Teilnahme an großen, oft internationalen Expeditionen ermöglicht wurden. Die Forschungen umfassten viele paläo-ozeanographische und -klimatische Einzelthemen, es wurden neue geochemische Methoden entwickelt; die Erforschung der Gashydrate in den Ozeanen wurde eines der großen und herausfordernden Probleme.

Geowissenschaftler aus Kiel nahmen an zahlreichen Expeditionen der Tiefseebohrprogramme (DSDP, IODP und ECORD) teil, mit einem Schwerpunkt im Atlantik. Das Einsetzen und die Geschichte der Vereisungen auf der nördlichen Hemisphäre und der Einfluss der großen Meeresstraßen auf die Geschichte der ozeanischen Wassermassen wurden untersucht. Dabei spielten die ozeanischen Verbindungen zwischen dem Nordpolarmeer und dem Nordatlantik sowie die mittelamerikanische Verbindung zum Pazifik

eine besondere Rolle. Die Untersuchungen konnten stark verfeinert werden, als hochauflösende Datierungsmethoden in Kiel entwickelt wurden.

Die erfolgreiche Einwerbung von Großprojekten (Sonderforschungsbereichen, einer Graduiertenschule) von der Deutschen Forschungsgemeinschaft und aus dem Bundesministerium für Bildung und Forschung bildeten dafür eine unverzichtbare Grundlage. Folgende Themen konnten so bearbeitet werden: Wechselwirkungen zwischen Meeresboden und Wasser in Küstennähe (SFB 95, 1971–1985), Marine Paläoklimaforschung (1982–1998), Sedimentation im europäischen Nordmeer (SFB 313, 1985–1998), Meeresstraßen (DFG Forschungseinheit 451, 2001–2008), Volatile und Fluide in Subduktionszonen (SFB 574, 2001–2012), Dynamik globaler Zyklen im System Erde (1990–1997, Graduiertenkolleg).

De très modestes débuts à la réalisation d'une branche de la recherche en sciences de la mer tout à fait florissante: le développement institutionnel de la géologie marine à Kiel après la seconde guerre mondiale

Résumé

Les sciences de la mer, dont la géologie marine, ont commencé de se développer à Kiel 15 ans après la seconde guerre mondiale. Elles s'y sont implantées à une période critique, à savoir avant la découverte de la « Dérive des continents » et de la « Tectonique des plaques », et ce à une époque où la géophysique marine en était encore à son tout début et durant laquelle, faute de forages océaniques profonds, la biochronologie pélagique et la paleo-océanographie n'avaient pas encore été promues au rang de composantes modernes des sciences de la mer. Ces technologies nouvelles apportèrent, en effet, une contribution essentielle à la paléo-climatologie globale relative au Mésozoïque et au Cénozoïque. Elles permirent aussi l'échantillonnage des couches superficielles et profondes de la croûte océanique, ce qui conduisit à la mise en évidence de provinces océaniques encore très jeunes, d'un point de vue géologique, par rapport à l'âge des continents.

Au sein de l'Université de Kiel, la « Christian-Albrechts-Universität » (CAU), les géologues marins ne disposaient, à l'origine, que de très peu de moyens de recherche, dont des équipements techniques très modestes. Cela explique qu'ils se soient plutôt orientés vers l'étude du modèle sédimentaire actuel pour comprendre les conditions environnementales des conditions de dépôt des couches sédimentaires fossiles.

Leurs premières études se sont concentrées sur les zones littorales, tout

d'abord le long des côtes de la mer Baltique, puis, assez vite, vers des mers de faible profondeur, situées sous climat tropical (les Bahamas et le golfe Arabo-persique). Les premiers résultats principaux obtenus à cette époque furent, d'une part, la distinction entre deux modèles de sédimentation existants en mer peu profonde, l'un sous climat humide et l'autre sous climat aride, et, d'autre part, l'amélioration des conditions de travail sur le plan technique.

Par la suite, les objectifs scientifiques se diversifièrent rapidement et concernèrent la marge continentale (en particulier la marge Est-Atlantique), ainsi que les bassins profonds adjacents. Cette évolution fût rendue possible grâce à une participation accrue des chercheurs à de grandes expéditions internationales. Une forte priorité fût accordée au développement rapide des recherches en matière de paléo-océanographie et de paléo-climatologie, ainsi qu'à celui de nouvelles méthodes analytiques en géochimie. L'exploration des hydrates de gaz dans l'océan constitua l'un des plus importants défis à relever.

Les géologues de Kiel prirent part à de nombreuses campagnes de forages océaniques profonds (DSDP, IPOD et ECORD), dont la majeure partie s'est déroulée en Atlantique. Leurs recherches portèrent sur l'histoire des glaciations dans l'hémisphère Nord, ainsi que, à la même époque, sur l'influence des seuils océaniques sur la circulation des grandes masses d'eau marines. Dans ce contexte, ils ont mis en évidence le fait que les liaisons entre l'océan Arctique et l'Atlantique Nord, ainsi que le détroit de l'Amérique centrale reliant l'Atlantique à l'Océan Pacifique, jouèrent un rôle particulièrement important. Ces recherches s'approfondirent au fur et à mesure du développement à Kiel des méthodes de datation de plus en plus sophistiquées et aux capacités de résolution de plus en plus fines.

Les succès obtenus dans le cadre d'appels à candidatures pour participer à d'importants projets, tels des projets thématiques de la Fondation Allemande pour la Recherche (la D.F.G.), ou ceux du Ministère Allemand pour l'Éducation et la Recherche (le B.M.B.F.) contribuèrent à la mise en place, à Kiel, d'un socle scientifique de grande qualité et pérenne. Les thèmes de recherche suivants purent ainsi être pris en compte: « Interactions mer-sédiments en zones côtières » (SFB 95, 1971–1985); « Recherche sur le paléo-climat » (1982–1998); « Processus sédimentaires dans les mers d'Europe du Nord, entre la Norvège et le Groënland » (SFB 313, 1985–1998); « Seuils océaniques » (DFG, section de recherche 451, 2001–2008); « Etude des gaz volatiles et des fluides dans les zones de subduction » (SFB 574, 2001–2012); « Dynamique des cycles globaux au sein du système terrestre » (1990–1997, travaux de collègues doctorants et post-doctorants).