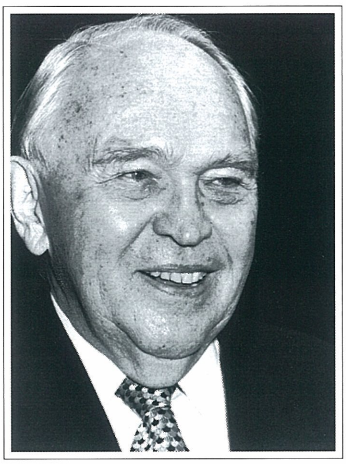
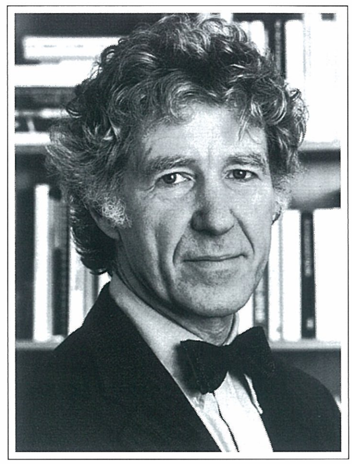
The Winners of the Blue Planet Prize
1994

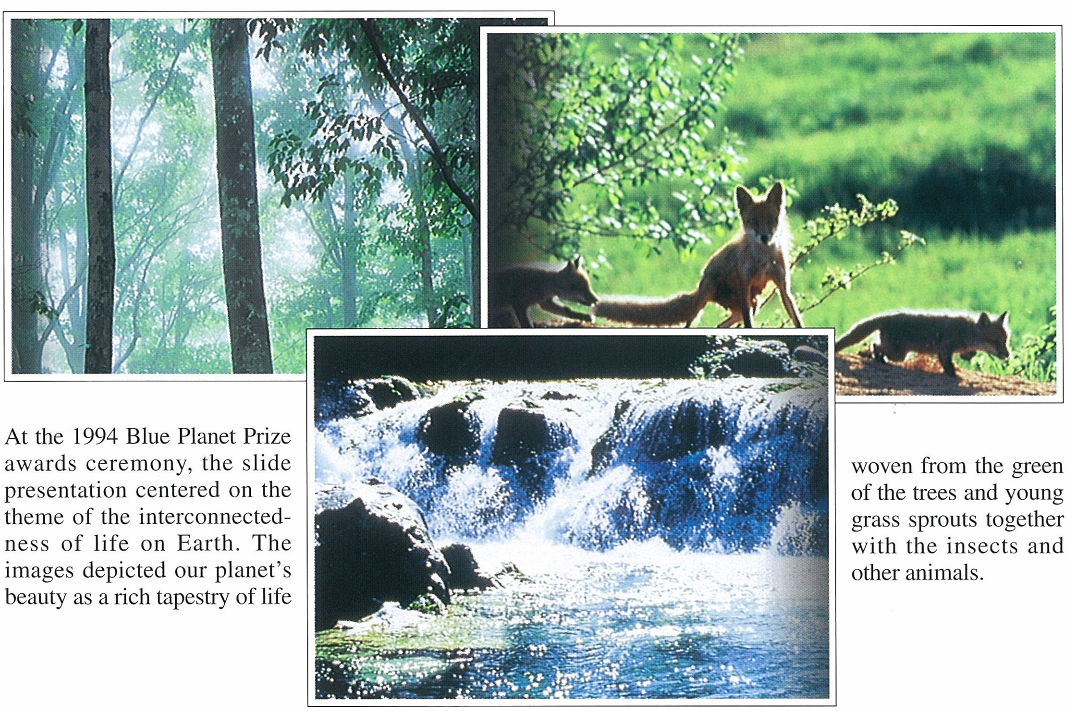
1994
Blue Planet Prize

Professor Dr. Eugen Seibold (Germany)
Professor Emeritus at the University of Kiel

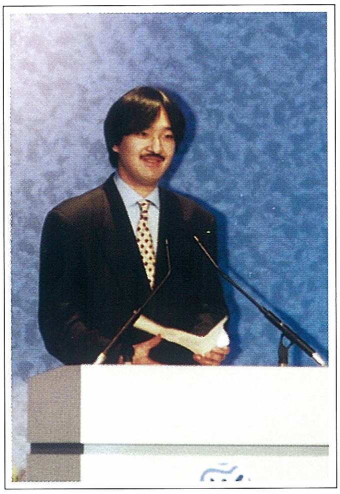
Lester R. Brown (U.S.A.)
Founder and President of the Worldwatch Institute





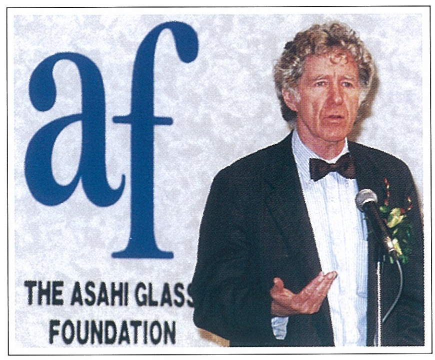


At the 1994 Blue Planet Prize awards ceremony, the slide presentation centered on the theme of the interconnectedness of life on Earth. The images depicted our planet's beauty as a rich tapestry of life woven from the green of the trees and young grass sprouts together with the insects and other animals.



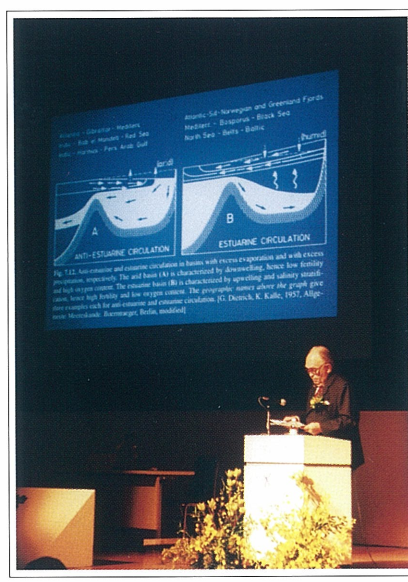
His Highness Prince Akishino delivering a congratulatory speech.

His Highness Prince Akishino and Her Highness Princess Kiko.

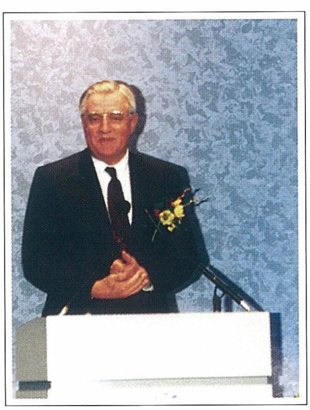


Lester Brown gives his speech on the Environmental Revolution—a restructuring of the global economy in line with environmentally sound practices.

Professor Jiro Kondo, chairman of the Selection Committee, explains the rationale for the determination of this year's winners.



Dr. Seibold delivering his lecture about the influence of the sea floor on the environment.



Walter F. Mondale (left), ambassador of the United States of America to Japan, and Dr. Heinrich Dieckmann (right), ambassador of the Federal Republic of Germany to Japan, congratulating the laureates.

Profile

Professor Dr. Eugen Seibold

Professor Emeritus at the University of Kiel

Education and Academic and Professional Activities

1948– Ph. D., University of Tübingen
1949–51 Assistant Professor, University of Tübingen
1951–54 Assistant Professor, Technical University of Karlsruhe
1954–58 Associate Professor, University of Tübingen
1958–79 Professor and Director, Geological-Paleontological Institute, University of Kiel
1964–70 Chairman, Geological Association (Geologische Vereinigung)
1967 Chairman, Scientific Committee on Oceanic Research (SCOR) 19th meeting on Micropaleontology, in Cambridge, U.K.
1970 Chairman, SCOR 31st meeting on Geology of the East Atlantic Continental Margin, in Cambridge, U.K.
1971 Member, Deutsche Akademie der Naturforscher, Leopoldina/Halle
1972 Member, Akademie der Wissenschaften und der Literatur, Mainz
1974 Member, Jungius Gesselleschaft der Wissenschaften, Hamburg
1974 Chairman, SCOR 37th meeting on Marine Plankton and Sediments, in Kiel
1974 Chevalier Ordre Palmes Académiques
1976 Honorary Member, Geological Society, London
1980–84 President, International Union of Geological Sciences (IUGS)
1980–85 President, Deutsche Forschungsgemeinschaft (DFG), Bonn
1982 Member, Société Géologique, France
1982 Honorary Fellow, Geological Society, U.S.A.
1982 Honorary Fellow, Geological Society, Africa
1982 Corresponding Member, Bayerische Akademie Wissenschaften, Munich
1983 Grosses Bundesverdienskreutz
1983 Honorary doctorate, Université Parisien
1984 Honorary doctorate, University of Norwich, U.K.
1985 Member, Heidelberger Akademie Wissenschaften
1985 Honorary Professor, University of Tengji, Shanghai
1986 Honorary Senator, University of Kiel
1986 Honorary Senator, University of Giessen
1987 Honorary Member, Deutsche Akademie der Naturforscher Leopoldina/Halle
1988 Member, Akademie Europaea
1989 Member, Akademie Wissenschaften, Göttingen
1989 Membre Associé Étranger, Académie des Sciences, Paris
1984–90 President, European Science Foundation (ESF), Strasbourg, France

1986–	Honorary Professor, University of Freiburg
1994	Member, Kroatian Akademie Wissenschaften
1994	Asahi Glass Foundation Blue Planet Prize, Tokyo

Dr. Eugen Seibold, professor emeritus at the University of Kiel, is a marine geologist whose career has been devoted to exploring seafloors and the processes that shape them. Through his important seminal research ranging from coastal waters to deep-sea zones, Dr. Seibold has informed and inspired a generation of marine geology researchers.

Conducting his research from a geological perspective, Dr. Seibold has promoted an integrated, interdisciplinary approach to marine geology by combining geophysics, geochemistry, oceanography, marine biology, soil engineering, and environmental science, and his research has covered a broad range of activities. Lauded as a researcher of extreme foresight, Dr. Seibold has accumulated experience and knowledge that bear directly on solutions to global environmental problems.

Dr. Seibold received his Ph.D. from the University of Tübingen in 1948. In 1954, he was appointed associate professor at the University of Tübingen and in 1958 joined the University of Kiel as a full professor and director of the Geological-Paleontological Institute. From 1980 to 1985, Dr. Seibold served as president of the Deutsche Forschungsgemeinschaft and from 1984 to 1990 as president of the European Science Foundation. Since 1986, he has been an honorary professor at the University of Freiburg.

Essay

Earthquakes and Volcanic Eruptions: Protection versus Prediction

Professor Dr. Eugen Seibold

February 1997

We usually regard our Earth as a symbol of solidity. To us, it is the soil on which we stand firmly with our two legs, the bedrock for our buildings and their reliable foundations. But this solid bedrock is only a thin crust about 100 km thick. The material underneath, in the earth's mantle, reacts plastically, like paste. In places where it reaches the surface, as in volcanoes, it may even become fluid and flow out as lava. However, the mantle material as a whole is moving, too, if only by a matter of centimeters a year, dragging the brittle crust above it along with it. Because of its movements in different directions the brittle part, called the lithosphere, breaks into pieces of various dimensions.

The biggest of these, the so-called plates, may move apart, as often happens underneath the central parts of our oceans. At what is known as their divergent plate boundaries, this results in provinces of active volcanism and minor earthquakes, for example in Iceland. If the plates pass each other in a strike-slip fashion, earthquakes may occur, as around the San Andreas Fault in California. In the convergent plate boundary regions, one plate normally plunges underneath its neighboring plate and finally reaches the earth's mantle, where it is incorporated again. Many active volcanoes and some major earthquakes occur around these "subduction zones." The Pacific, for example, is surrounded by convergent plate boundaries which form a volcanic "ring of fire."

For three decades, the theory of plate tectonics has enabled us to explain the origin and distribution of many volcanic eruptions and earthquakes. It has also provided initial data which can provide regional warnings of such natural disasters.

Projections suggest a global population of more than 10 billion for the beginning of the next century. From a regional point of view, this number is even more dramatic than when seen in the global context because humans tend to concentrate in urban agglomerations. Growing cities need more and more underground pipelines for energy, water, and traffic. Therefore they become increasingly vulnerable to earthquakes. In Greek antiquity the City, or Polis, was a symbol of protection against life-threatening situations. Today, things are becoming different. Many of these agglomerations are situated near convergent or strike-slip plate boundaries (Fig. 1) and nearly all major losses of life from earthquakes are concentrated there (Fig. 2).

Risk Maps

Figure 2 presents a kind of risk map. Its large scale is, of course, unsuitable for detailed plan-

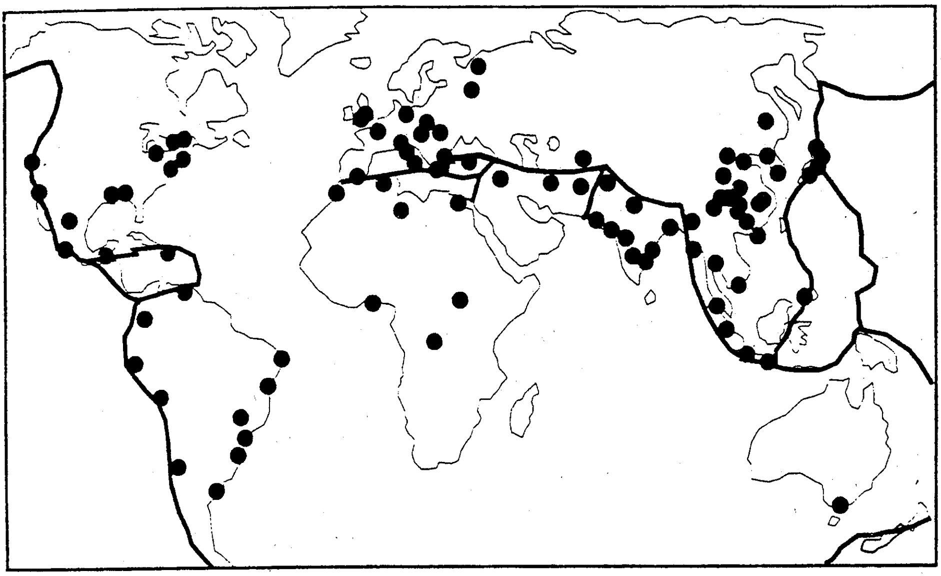


Figure 1 Distribution of cities with a projected population of two million or more in the year 2000. Bold lines represent converging or strike-slip boundaries, explained in the text.

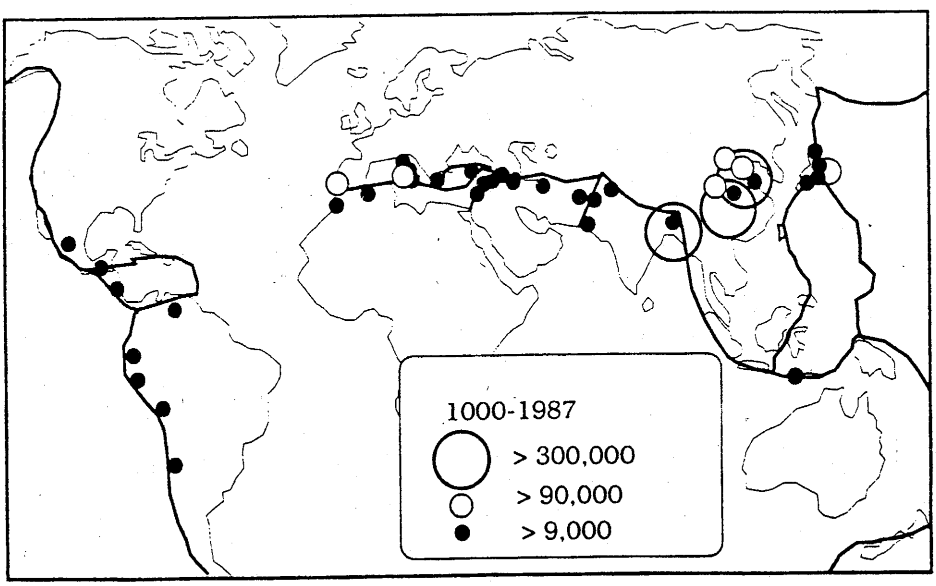


Figure 2 Distribution of earthquakes in the past 1,000 years in which more than 9,000 people died. Most occurrences are located near plate boundaries.
(Figures 1 and 2 after R. Bilham-Cires, *Nature*, Vol. 236, 1988, pp. 625-6.)

ning and practical purposes. To be useful, risk maps must be constructed on a much smaller scale. Factors that are morphological (e.g. slope stability), geological (fault patterns, occurrence of hard rocks or unconsolidated sediments from rivers, the sea or artificial infillings etc.) or oceanographic (exposure of near-shore areas to tsunamis etc.) have to be combined with historical investigations into the locations and magnitude of former earthquakes. The situation in

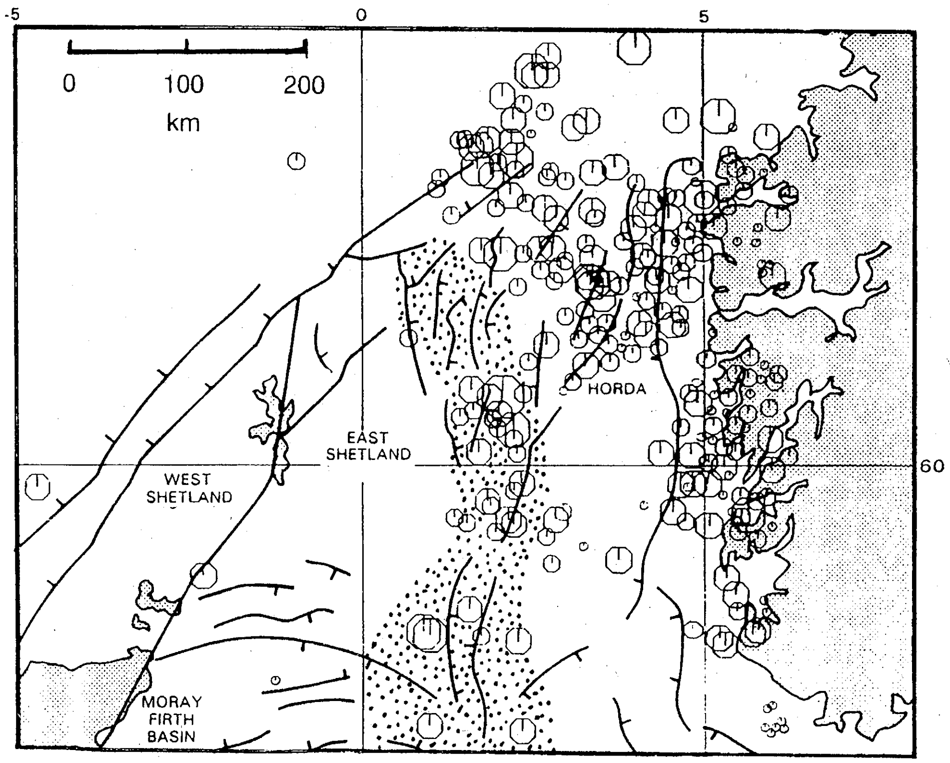


Figure 3 Earthquake risks for offshore structures. Earthquakes between 1980 and 1985 with different magnitudes (circles) are concentrated near the west coast of Norway, especially near faults. The most important offshore platforms for the production of oil are situated in the shaded area.
(After E. Seibold, *Entfesselte Erde*, DVA, Stuttgart, 1995, p. 141.)

parts of the North Sea is illustrated in Fig. 3. Only after such preliminary studies can microzoning risk maps be constructed as a base for land-use planning and detailed advice for sites concerning earthquake-resistant structures.

Similar risk maps should be made for the environment of active volcanoes. Valleys with possible lava or pyroclastic flows are especially dangerous, as was demonstrated during the 1990 Unzen eruption in Kyushu, Japan. Ashfalls are concentrated in leeside areas of prevailing winds. An example is given in Fig. 4.

Prediction of Natural Hazards

There is a curious antagonism in Earth sciences. Thanks to the relatively new theory of plate tectonics we are able to define, on a global scale, the most dangerous regions where major earthquakes and volcanic eruptions may occur, namely near plate boundaries. (Nevertheless, there are exceptions: both the catastrophic earthquake near New Madrid in the U.S. heartland and the Cameroon volcano in Africa both happened within plates. These and similar occurrences cannot be explained simply by plate tectonics.)

In spite of the knowledge of plate tectonics, long-term predictions of earthquakes or volcanic eruptions are very difficult. Unfortunately, it still remains one of our biggest challenges to

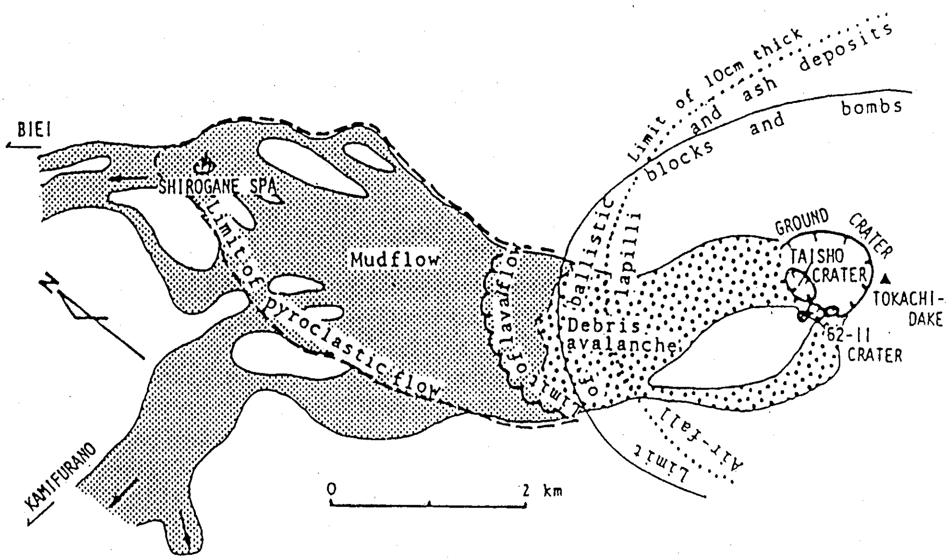


Figure 4 Risk map of Tokachi Dake volcano (Hokkaido, Japan). Mud flows (shaded areas) are threatening wide areas. Limits of possible pyroclastic and lava flows are indicated. Prevailing westerly winds transport blocks, bombs, and ashes mostly to the east.
(Made available by Yoshio Katsuo, Sapporo, 1992.)

forecast such events precisely—where, when, and with what magnitude an earthquake or eruption will take place. Some pessimists even believe that such forecasts will be possible only in exceptional cases. It is easier to forecast volcanic activity because in this case we can concentrate our efforts on one spot, the volcano itself. Continuous monitoring in the field from observatories or even from satellites with thermosensors helps, and such volcanoes as Vesuvius, Etna, Kilauea, or Mount St. Helen are excellent examples of successful predictions and even short-term forecasts.

Forecasting, if it is carried out well, is part of human self-protection. This was excellently demonstrated during the sudden 1991 eruption of Mount Pinatubo in Luzon, the Philippines. The volcano had been dormant for six centuries. However, careful observations, together with a well-organized alert system, mitigated loss of life dramatically.

Wrong forecasting results in public disappointment and fuels the criticism of science in general, as was illustrated by the forecast of an eruption of the Souffrière volcano in Gaudeloupe in 1976. Fortunately, the eruption did not occur—although 72,000 people were evacuated in vain for several months. On the other hand, Colombian authorities failed totally on the occasion of the catastrophe caused by the eruption of Nevada del Ruz, the most northerly volcano of the Andes. They did not react properly to the justified warnings issued before the eruption in 1985—and 25,000 people were killed. Even so, scientists cannot always decide which volcanoes-active or dormant—are more dangerous, or whether active faults are more conducive to earthquakes than dormant ones.

Predictions or even forecasts of earthquakes are much more difficult than for volcanic eruptions. Earthquakes may occur anywhere in fault zones hundreds or even thousands of kilometers in length. Up to now, all our efforts have had no convincing results except in some lucky instances. The usefulness as warnings of small precursor quakes or the often observed pseudocyclicity of earthquakes at a given location have not proven to be reliable. The same is true of the use of geodetic as well as several geophysical and geochemical methods and of the observation of unusual behavior in animals.

Why have the results of very intensive research all over the world to improve earthquake predictions been so disappointing up to now? The material and structural conditions including the influence of fluids underground are different regionally. In addition, these extremely complex systems are chaotic and imply all sorts of nonlinear difficulties. What is worse, there are still many fundamental gaps in our understanding of basic principles and processes. In what way and how strongly do stresses accumulate in the earth's crust? How do fractures form and expand? Which messages from the earth's mantle underneath a volcano are reliable? How do they come to the surface? Why are there fewer dangerous explosions with ash falls, but, on the other hand, more with catastrophic pyroclastic flows?

Prevention

Even if science becomes much more successful in predicting natural disasters, people, organizations, and public authorities must be better prepared to face them. Nature produces earthquakes and volcanic eruptions and we can do nothing but react. We have to obey nature's laws when planning suitable manmade structures and we must try to avoid settling in high-risk areas in spite of growing populations. As in medicine, prevention is better than cure. Therefore, the siting of nuclear power plants, chemical factories, roads, schools and all other forms of concentrations have to be planned carefully on the basis of risk maps. Geotechnical engineers have to improve hazard-resistant designs, following official building codes that must undergo continuous improvement.

Of course, there are many other factors that surpass the competence of scientists or engineers, as in the improvement of public education and plans to prepare for medical and technical emergencies, in the adaptation of legislation to such hazards or in the contrivance of suitable financial measures such as insurance schemes.

Increasing population density increases not only risks in general, but also those specific risks for scientists involved in studying this problem. In medieval times in Europe, natural hazards were treated as God's punishment. Since the Enlightenment, God has been replaced by Fate. With growing scientific success in some of the fields discussed, things look less inescapable. Therefore scientists will increasingly be blamed if they are unable to give at least an earlier or a more exact warning before a disaster. Thus, we have to continue basic research in order to arrive at a better understanding of the mechanism of earthquakes and volcanic eruptions. With this better knowledge we can hope to improve ideas and methods for better predictions. However, at present, it seems to me that multidisciplinary approaches to the improvement of all sorts of prevention are even more important.

Lecture

The Seafloor as Part of Our Environment

Professor Dr. Eugen Seibold

To the audience of a Blue Planet Prize lecture, it is well known that our Earth is the only planet with fluid water and that this is the precondition for both our oceans and for life. Of course, it is also known that the oceans cover more than two-thirds of our globe, of our blue planet.

This means that there are many interactions between sea and land environments. Through evaporation, the oceans supply the remaining third of our globe, the land masses, with rain and snow. With their currents, they transport heat from the equator to polar regions and influence the wind system. The oceans are therefore a weather machine controlling continental droughts or river floods, together with agriculture or traffic. In this way, they even influence our daily life. Long-term variations in this dynamic system determine climatic fluctuations with drastic consequences for our environment.

Oceans are as deep as our highest mountains are high. Ocean dimensions, including their water masses, are huge. They correspond to 160 times the water and ice on land and to 100,000 times the water in the atmosphere. Therefore, the oceans are buffers for all sorts of variations. They may store or release heat or carbon dioxide (CO_2).

Most of these factors that characterize oceanic research require much comprehension on the part of the general public up to the level of governments, and because humankind has begun to influence some of these factors a number of relevant issues concerning the oceans were defined in 1992 in Rio in a 540-page document, Agenda 21. This came as a result of the United Nations Conference on Environment and Development (UNCED).

The Third Blue Planet Prize Academic Award is given to a marine geologist, and I can only accept this honor if I see myself as a representative of my many colleagues around the world. What is a marine geologist? A marine geologist investigates the present situation of the seafloor and the processes which shape it. Furthermore, he tries to learn from the layers beneath the seafloor, i.e., he tries to learn from the past. With this knowledge from the present and the past, he has a responsibility to comment also on future developments if he is able to do so with scientific reasoning, and I would like to stress this aspect.

With the following remarks, I shall try to illustrate some of these points with a few examples from my own work during the last decades. I would like to invite you to come with me to the coasts, where I shall stress coastal management, then to the shallow seas with some remarks about pollution, then to the continental margins with their potential petroleum resources, and finally to the deep sea with its sediments as archives for historical climatic changes. Let us go to the coasts.

Coasts

For two decades after the end of World War II, we had no oceangoing research vessel in

Germany. Therefore, we concentrated our efforts on the North Sea and Baltic Sea and their coastal regions. In any case, the marine environment begins at the coasts and with its many interactions with the neighboring inland. It is said that 80% of the world's population is settled in the 50-kilometer zone along the shores.

The coasts are very peculiar landscapes because they are shaped by processes belonging equally to the hydrosphere, the atmosphere, and the lithosphere. Water, air, and rocks must therefore be studied.

Waves and currents may be destructive and cause coastal erosion. They can also be constructive in transporting sand and forming offshore bars, as in the Baltic. Of course, harbor authorities have to fight against this type of sand transport. For them, sand and mud coming from offshore or from rivers is a kind of pollution.

To obtain qualitative or even quantitative data, one uses tracer sands and one has to observe the sea bottom carefully for bed forms indicating currents, especially with the help of enthusiastic divers, ideally students. Furthermore, one has to combine all these measurements and observations with hydrodynamic calculations and models. These and other coastal problems are an immense task even for a country like Germany, which has only a few centimeters of coastline per inhabitant. Japan, with its 3,600 islands and a coastline of about 27,000 kilometers, has about 23 centimeters of coastline per inhabitant and therefore has much more to do with coastal management than we do in Germany.

Everyone who is concerned with such questions will know that coastal management is even more important for developing countries. In fact, in such regions, it is probably the most important oceanic aspect. How should the coast be developed? Should one dig out channels for bigger ships and harbors? Establish water-dependent industries, like nuclear reactors? Protect lagoons for breeding marine animals? Or protect sandy beaches for tourism? Use beach and dune sands as mineral resources? In many cases, one special use excludes others. Therefore, the marine geologist has to give advice in examining the consequences of different potential uses. But before that he must try to understand the processes behind the screen.

I would like to give only one example, from the coast of India. Tropical weathering conditions destroy quartz and other minerals more than some so-called heavy minerals and ore particles containing iron, titanium, gold, platinum, thorium, zirconium, and so on. Near-shore processes can concentrate them to so-called placer deposits. India is famous for such beach placers around the semicontinent.

How do placers originate? I cannot go into detail, but the processes involved have much in common with panning for gold, as we could demonstrate in beach studies. Of course, this is a problem for fundamental research, but its investigation helps toward exploring placers if you apply this principle to beaches where monsoon waves attack dune sands, like in India. The combination of both is the optimum for placer exploration.

A geologist always has in mind that the sea level has risen by some 100 meters since the melting of the huge continental ice masses some 15,000 years ago. Therefore, former beach sand placers can be expected offshore. Of course, all other mineral resources, including oil and gas, are also products of concentration by nature to be studied by geologists.

We know as well that at present the sea level is rising in most regions by some millimeters per year—here in Japan, too—and that this rise can be accelerated by further global warming, a dramatic threat for lowlands and many islands. But it would lead us too far to treat these aspects today. Now let us go to the second chapter, the shelf seas.

Shelf seas

Offshore we enter the so-called shelf sea with water depths up to about 200 meters. Here we need well-equipped ships and special instruments to study morphological features of the seafloor or to recover sediments and organic remains from the surface or from cores in the sediments. For example, underwater side-scan echo sounders reveal details down to the centimeter, such as ripple marks and other current indicators, where you have an indication that the bottom current is flowing this way or that way, or not at all. In order to obtain large-volume sediment cores for the distribution of samples to all interested specialists, at the University of Kiel we developed the box corer. It was emphasized yesterday that one of my specialties was to always stress interdisciplinary approaches for solutions to problems. Interdisciplinary means that one needs a lot of material, and therefore we developed this special sampler, the box corer.

Trying to approach environmental problems, I concentrated for years on the comparison between the Baltic Sea and the Persian (Arabian) Gulf. Both are adjacent seas to the great oceans and are enclosed by land masses. Therefore, land climate dictates many processes in these marine environments.

The seas in the arid climatic belt, characterized by excess evaporation, have a common and typical exchange pattern with the open ocean: shallow water flows in and deep water flows out. Typical examples are not only the Gulf, but also the Mediterranean Sea and the Red Sea.

Here the loss of water by evaporation greatly exceeds the influx from rain and rivers. Thus, the sea level drops and water enters from the open ocean at the surface to replace the losses in the basin. Evaporation in the basin increases the salinity, and therefore the density of the water, which makes it sink. This sinking is a motor for outgoing currents of heavier deep water, flushing out many kinds of pollution.

The reverse situation can be studied in the Baltic, Black Sea, and in northern fjords: shallow water flows out and deep water flows in, because here rain and river influx exceed evaporation.

One of the consequences of the influx of heavier, saltier bottom water to the Baltic is a relatively stable stratification of the adjacent sea water column, preventing oxygen from the air reaching the deeper parts where hydrogen sulfide (H_2S), a poisonous gas, can develop and kill everything. Pollution by sewage discharge from about 20 million people and industrial wastes, together with fertilizers from agriculture, increase organic productivity and therefore deep-water oxygen deficiency—a continuous threat to surface waters and the organisms in them, because H_2S can reach the surface when there are storms.

I would like to bring just one example from our fieldwork to your attention. These are investigations in the channels of the North Sea going to the western part of the Baltic. Here, we were able to investigate the sea bottom to discover current indicators. These current indicators show both the bottom-water influx and the outflow of surface water in shallow areas. Now let us go to the continental margins.

Continental margins

The continental margin begins with the shelf. We continue on, crossing the continental slope and descend to water depths of about 4,000 meters, where the deep sea, strictly speaking, begins. I would like to stress only one aspect, the opportunities for finding offshore oil and gas underneath our continental margins.

Continental margins are the dumping sites for the debris coming from the continents. Therefore, they may collect sediments of thicknesses surpassing 10 kilometers. Furthermore, these sediments contain a high proportion of organic matter because of the high productivity of the oceanic regions around the continents. Both facts favor the formation of oil and natural gas. This formation and the migration to reservoir rocks require higher temperatures underground and some time in geological dimensions. A sediment cover of one to two kilometers is generally necessary for these processes to happen. As the sediment cover of vast parts of the deep sea is too thin and also too young, more than 80%—and that is a very important figure—of the oceanic seafloor offers no chance for exploration of oil. This very disappointing figure of 80% is deducible from the concept of plate tectonics, a rather new concept of how the ocean and the ocean crust are formed which I cannot treat here today. This is one of the exciting consequences of the application of an academic hypothesis, and it clarifies important aspects of global energy resources.

Plate tectonics also sheds light on the character of Japan's continental margin, the nature of which causes many problems. It is a so-called active margin shaping your environment in many respects. A lithospheric plate sinks beneath another one, accompanied by earthquakes, volcanic eruptions, and extreme disturbances of the sediments there. This plate is sinking down underneath Japan, and in this region earthquakes occur, and when going deeper everything is melting, and you get the Fujis here on your islands. The Japan Sea is a very complicated area upon which I will not touch too much now.

Now why is it so disappointing for oil companies? First of all, all these movements below are very complicated and create complicated structures, as we could see in the Nankai Trough of Japan between Shikoku and Honshu in a 1990 drilling expedition on the vessel *Joides Resolution*. In addition to that, unfortunately, potential sandy reservoir rocks here are mostly cemented and offer insufficient permeability for oil. This is because these sands are of volcanic origin and therefore chemically very reactive. There are a lot of negative points for oil exploration around Japan.

In 1975, I worked as co-chief scientist aboard the drill ship *Glomar Challenger* off West Africa, a typically passive continental margin. In all types of passive continental margin, thick sediments, a succession of possible source and reservoir rocks like porous sandstones or cavernous limestones, and many other positive features come together. However, I would prefer not to go into more detail, but rather to add some general remarks.

At present, world production of oil is about 3.15 billion tons annually. Around 30% comes from offshore. A total for potential global resources, as well as reserves, is hard to estimate. World resources may reach 200 to 300 billion tons of oil. As opposed to this, world reserves of producible petroleum under the prevailing economic and technological conditions are estimated to reach only about 135 billion tons.

As a geologist, I am not stressing the so-called static life expectancy of the oil reserves; at present, they are good for only some 43 years, given the proven reserves divided by annual production. But of course, geologists and geophysicists are talented and will find new reserves, and therefore it will last longer. As a geologist interested in much longer time spans, I can calculate that nature needed millions of years to accumulate these resources.

By an order of magnitude, nature over a period of time collected only some 2,000 tons of oil annually: if you divide 300 billion tons, for example, by 150 million years, you get the incredibly low figure of an annual natural production of 2,000 tons. And we use three billion tons a year. Therefore, this ratio is very bad—about 1:1,500,000 or 1:2,000,000. We are thus guilty of incredible exploitation, even robbery, without an eye to future generations.

Even more generally speaking, for me the energy supply for both the industrialized and developing countries should be top priorities on our problem-solving global agenda. Because with energy you can even convert sea water into fresh water for irrigation. It is nonsense, of course, because it is too costly and not energy-efficient, but in principle you can do it. Now let us go to the deep sea.

Deep sea

I would like to demonstrate that deep-sea sediments are excellent archives for environmental changes, and with modern methods we can even make up for some losses or disturbances of the archive pages. Here, I concentrate on only one aspect, on rhythmicity in many sequences of deep-sea sediments, as in deep-sea drilling cores off West Africa. This alternation is a sequence between whitish layers, i.e., layers rich in calcareous particles, and darker ones called marls with higher quartz and clay mineral contents.

How can we explain these sequences? There are many possibilities. In a detailed analysis, we were able to prove that here the most important factor was different dissolution of calcareous particles and, additionally, that the periodicity of the fluctuations was around 40,000 years. This was the situation in the Atlantic some 15 million years ago. Fluctuation at that time was mainly controlled by processes in high latitudes, around Antarctica and in the northernmost Atlantic and in the Arctic Ocean.

Climatically, the Atlantic is the most sensitive ocean because it is connected with both polar seas. The Pacific, on the other hand, is separated from the north by the Bering Strait, which is too shallow for deep-water exchanges.

However, much more sophisticated methods used during the last few decades disclosed truly revolutionary relations between deep-sea sediments and climatic oscillations. One uses tiny organisms like foraminifera whose tests consist of calcium carbonate, $CaCO_3$. They contain oxygen which is taken from sea-water. The ratio of oxygen-16 to oxygen-18 indicates mainly the volume of ice masses stored at any given time, i.e., in colder or warmer phases, on the continents during the last two to three million years, the so-called ice age.

From a deep-sea sediment core, which is over 10 meters long, one can give a summarized survey of the last 400,000 years. I included an example in a textbook translated into Japanese eight years ago because it looks to me like a musical score with its rhythmic and melodic variations. One can easily see prominent 100,000-year cycles for this period. In the curves, downs are colder phases called glacials, and ups are warmer phases called interglacials. Additionally, downs mean lower sea level because of the ice masses stored on the continents. Fortunately, at present we live in an interglacial. Seen geologically, it looks reasonable to say that in some millennia we shall approach a new glacial phase.

The summary curves also reveal smaller ups and downs. But let us stress only one of the many aspects being discussed at present for possible future climatic fluctuations: How quickly can these fluctuations occur?

In a sediment core from the Atlantic off West Africa, in about a 5.5-meter core depth we found a boundary between greenish and greyish colors. It marks the beginning of the last interglacial, some 140,000 years ago. The boundary is very sharp. Therefore, the transition probably took only some centuries to happen. The core was taken on *Meteor Cruise 25* in 1971. Since then I have emphasized how rapid such transitions of our climatic system can be because the system is nonlinear. We should bear in mind that such rapid changes could occur in the future, too, if we approach a threshold for one or several factors. An increase of global temperatures or growing CO_2 contents may be examples of such factors causing climatic change.

Indeed, many more and partly extremely rapid variations were recently discovered in two Greenland ice cores. According to these results, our colleagues believe that temperature changes of several degrees centigrade may occur even within a few decades. But as yet most of these minor variations have not been discovered in the Russian Antarctic ice core Vostok. Hopefully, the planned Japanese Antarctic ice-core drilling can add much new information.

But we have to keep in mind that these changes I have been pointing out in these ice cores are atmospheric changes. We have to deal with changes of the oceanic system, with huge water masses which store such huge amounts of heat and which buffer all sorts of variations. Thousands of years may elapse before relevant climatic changes are to be felt in the oceans globally. This is reassuring for us on one hand, but alarming on the other. Devastation on land with landslides, soil erosion, or river pollution is directly visible. In our oceans, long-term variations prevail and countermeasures may therefore come too late.

Conclusions

But now back to marine geology, back to going aboard, and back to the many different feelings evoked by the vast oceans. Of course, cool, sober, objective oceanography and marine geology are only one part of the approach to the seven seas and to our blue planet. We cannot leave out emotion. Thomas Mann once observed that "the sea is not landscape; it is expression of eternity, of nothingness and death, a metaphysical dream." According to Paul Valery, "a look at the sea is a look at the possible."

I identify more closely with Valery's vision. Also, I appreciate the atmosphere aboard a research vessel, as did Henry Stommel of Woods Hole in the United States, the pioneer of Gulf Stream research, who wrote that "work at sea rubs off the sharp edges and makes us better people. The ship becomes a home away from home." This statement implies many facets even of the ocean itself. The ocean is a good teacher which deals with many different people, with many disciplines, and with problems in space and time of very different dimensions. We have to measure ocean currents in meters per second, but the growth of deep-sea manganese nodules in millimeters per million years.

As a university professor I am a teacher, too. Therefore, I am grateful for a generally friendly "teacher ocean" and for the fact that it can be mastered by many excellent ship crews. I am grateful to all my exemplary teachers in science and to all friends and colleagues around the globe, including those in Japan, who are giving me advice. But a good professor should only be happy if he has students and collaborators who will surpass him in research. Looking around in Germany and abroad I feel really happy that many of my former students are surpassing me in research. I am especially grateful to them as well.

Finally, I would like to give thanks to the people at home, away from my home at sea, and first of all to my family.

In summary, I have tried to demonstrate some relationships between the seafloor and the environment from the coast to the deep sea and from the present to the past and possibly to the future. But I had to select only very few mosaic stones from my own work and the work of the Kiel team. These stones must represent reliable results. Only then can you use these stones to put together at least the design of the whole mosaic. I suppose that the Blue Planet Prize was given to me because I have always stressed the importance of careful and reliable investigations as a base for more general statements.

Of course, we all have to think globally, but just like in daily life we have to begin with regional or even with local actions and investigations. The ocean, however, where everything reacts with everything and where there are no real boundaries, offers better opportunities to think globally than do the continents. What a challenge to unveil the secrets of the sea and what a chance to use some of the results and apply them to urgent problems of present and even future global, regional, and local environments. Thank you very much.

Major Publications
Professor Dr. Eugen Seibold

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