HANS ERTEL AND INTERNATIONAL SCIENCE: THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

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When I was invited to prepare a paper for this volume honoring Hans Ertel, my immediate reply was that I had retired, my laboratory was closed down, and I had no new data or unpublished ideas to report. The Editor, Wilfried Schröder, generously suggested that in a volume honoring the work of a scientist dealing with problems of global scale, it would be appropriate for me to present a statement about the activities of the seven Associations comprising the International Union of Geodesy and Geophysics. Hans Ertel's research spanned several fields, as indicated by his titles of Professor of Geophysics, Theoretical Mechanics and Meteorology, and Director of the Institute of Physical Hydrography. The research ranged from interactions between the ocean and atmosphere to those between the stratosphere and troposphere. His theoretical work on fluid dynamics has wide applications, and he published in addition on geodesy, inhomogeneous magnetic fields, theory of earth currents, weather forecasting, coastal problems, geomorphology and seiches. His responsibilities as Vice-President or Director of Academies and Institutes during the 1950s involved international cooperation and exchange of ideas with scientists all over the world. He was an editor of several geophysical and meteorological journals (german language), and has stimulated many international conferences in physics and geophysics. He played a significant role in development of IUGG's International Geophysical Year (1957-58), and later worked on the program of the International Hydrological Decade. The 50th Anniversary of the International Geophysical Year will be celebrated very soon. The present interdisciplinary character of geophysical sciences was emphasized in my Presidential Address at the Opening Ceremony of the XXII General Assembly of IUGG in Birmingham, July 1999, the text of which is reproduced below. From what I have learned of Hans Ertel and his research I feel confident that, if still living, this "seminal figure in the development of modern meteorology and geophysics" (quotation from W. Schröder) would have fitted comfortably into the 1999 General Assembly Program, with honor.

Comptes-Rendus, **XXII General Assembly, International Union of Geodesy and Geophysics, 1999.** Birmingham, England, p. 6-8. **Opening Ceremony, July 18, 1999. Presidential Address**, by Peter J. Wyllie.

Distinguished guests, ladies and gentlemen:

Many times during the past four years since the Boulder IUGG General Assembly I have said at meetings of the Associations and Union: "I invite you to attend the next General Assembly of the IUGG in Birmingham, July 1999", and now I say instead: "Welcome to this General Assembly". A glance at the program should confirm that we have a good time ahead of us, and you may have noticed that many of your symposia are jointly sponsored by other Associations. You may even wonder what some of the sharing acronyms mean. Because many scientists come to these quadrennial General Assemblies with their Association in view, without being familiar with the other six international Associations that comprise IUGG, I decided to take this opportunity to outline the

overall structure, and to point out that by your attendance, you are now all IUGG members. IUGG is your Union, and it can be successful only as long as you and the other Associations work together on the many significant problems that face us.

The International Union of Geodesy and Geophysics is one of the oldest scientific unions (constituted in 1919), and it is your connection to ICSU, the International Council for Science (formerly the International Council of Scientific Unions).

IUGG is a Union of seven autonomous International Associations. These Associations are:

IAGA:	Geomagnetism and Aeronomy
IASPEI:	Seismology and Physics of the Earth's Interior
IAVCEI:	Volcanology and Chemistry of the Earth's Interior
IAHS:	Hydrological Sciences
IAPSO:	Physical Sciences of the Oceans
IAMAS:	Meteorology and Atmospheric Sciences
IAG:	Geodesy

The scope of the science covered by IUGG can be illustrated by this cross-section through the Earth. We deal with the magnetic properties of the Earth's core (IAGA), with the physical (IASPEI) and chemical (IAVCEI) structure of the Earth's interior and crust, with the near-surface consequences of dynamic processes within the mantle, earthquakes and volcanoes (IASPEI and IAVCEI), with the fluid envelopes of water (IAHS and IAPSO) and atmosphere (IAMAS), and with the magnetosphere (IAGA) and so into space where the physics and chemistry of planetary bodies increasingly attract our attention. Earth properties and dimensions are measured from the surface and from satellites (IAG).

Whenever I think of the Union and Seven Associations, I am reminded of Snow White and the Seven Dwarfs. The seven dwarfs correspond to the seven Association Secretaries-General, working diligently under the enlightened leadership of the Executive Committee, represented by Snow White. The Secretaries-General are probably the most influential group of IUGG members, and we owe them a great debt for their work in connection with this General Assembly. Those of you who know them can probably correlate each dwarf in the slide with a particular Secretary-General.

Each Association has its own domain, but the boundaries between them are artificial, as demonstrated by the work of many inter-disciplinary Committees and Commissions. The Associations are concerned with both local and global processes, and these are all interconnected. The Earth is undisciplined, and it does not recognize our academic subjects.

The General Assembly program this year developed from discussions with all Associations represented, and with consideration of scientific priorities as we enter the next century. It was agreed that although our scientific priorities must be based on beautiful science, and we have plenty of intriguing scientific problems to arouse our curiosity, we must give considerable weight to societal problems. These include the challenges of sustaining sufficient resources, of coping with geological hazards as humanity progressively covers the surface of the Earth, and of adjusting to

inevitable environmental and global climatic changes. These considerations explain the program, which emphasizes two features compared with previous Assemblies. First, more effort went into organizing co-sponsored multi-disciplinary symposia, and secondly there is more attention to the applications of our science to societal problems.

We can consider the Earth as being driven by two engines, the Earth's internal engine which powers slow convection within the solid interior, and the external solar engine, which drives faster motions in the fluid envelopes. The force of gravity makes sure that everything moves to its proper place. IAVCEI is the direct link between these two engines. I tell my students of petrology that all good things come from the Earth's mantle, and the eruption of Mt. Pinatubo in 1991 provides a graphic illustration of material transfer from the interior directly to the fluid envelopes. This small eruption not only covered the surrounding area in thick layers of volcanic ash, but it set the scene for subsequent landslides, floods and mud flows, as shown in these slides. Geological hazards such as this illustrate the interdependency of events, and water plays a significant role in these problems. The eruption also sent a plume of ash and sulfur into the stratosphere, with global consequences for climatic change that were documented in detail. The heavy rainfall in Los Angeles for February 1998 was attributed to the effect of El Niño. This diagram from the Los Angeles Times shows that the record February rainfall was in 1884, one year after the great eruption of Krakatoa. There is more than one way to make rain.

Let us now start with the Earth's interior, and follow through to the surface. There have been extraordinary developments during the last few years in our understanding of mantle composition, structure, and dynamics. Independent and combined approaches using seismology, geochemistry, volcanology, high-pressure experiments, geodesy, and geophysical fluid dynamics have brought us much closer to understanding the workings of the Earth's internal engine. The slide is an example of the first complete three-dimensional calculations of mantle convection, produced by Paul Tackley in his doctoral thesis at the California Institute of Technology. By including a phase transition known to occur at a depth of about 670 km, he and his colleagues have since generated even more complex models, elucidating some of the complex processes that may occur in the mantle. One picture shows the mushroom-shaped thermal plumes rising from the core-mantle boundary, and the other picture shows the cooler outer layers converging and sinking along linear features considered analogous to subduction zones.

Major interaction occurs between the solid earth and its fluid envelopes at subduction zones. There is no doubt that huge quantities of H_2O and CO_2 are carried down to depths of at least 100 km in subducted oceanic plates. As the rocks are metamorphosed with increasing pressure and temperature, dissociation reactions release the volatile components that become involved with mantle melting and volcanic processes, and reach the surface again through volcanic eruptions (IAVCEI). The slide shows the remarkable tomographic results obtained in recent years for the subducted ocean crust and mantle wedge beneath the volcanic arc of Japan (IASPEI). Correlation of the rock properties so revealed with the laboratory-calibrated dehydration and melting reactions will eventually elucidate the processes occurring in this environment. The intriguing uncertainty is how much of the

subducted volatile components escape these processes and are trapped and transported down to 670 km, or even to 2900km, the core-mantle boundary. Some seismologists and geochemists (IASPEI, IACVEI), from independent lines of evidence or argument, write in terms of perhaps 10-100 ocean masses of H_2O stored within the Earth's deep mantle. Has some of the water of IASPEI and IAHS sniffed the molten metallic iron of the Earth's core (IAGA)?

Another dramatic exchange between the fluid envelopes and the solid earth occurs along the mid-oceanic ridges where oceanic plates are diverging. Ocean water is forced down into the tension cracks toward the region where hot magma is rising from the mantle. The water is heated, experiencing enormous chemical exchanges with the basalt of the ocean floor, and then ejected in the submarine hot springs where the chilling causes immediate precipitation of dissolved material. The deposits include metallic sulfide minerals that will become ore deposits as they are later incorporated into continental margins. In these dark, warm, submarine oases, colonies of bacteria that derive energy from hydrogen sulfide, without photosynthesis, are accompanied by larger exotic fauna including giant tube-worms and crabs. The fate of the biosphere is intimately involved with the solid-fluid interaction; life in the oases alternately flourishes and dies out as lava is erupted, or as the positions of the venting solutions migrate. With the discovery of these vents in 1977, all previous attempts to explain the composition of ocean water had to be abandoned.

Interaction between atmosphere (IAMAS) and ocean (IAPSO) is responsible for the great global thermohaline circulation system in the oceans. The climate in the Arctic regions affects the salinity of surface waters, which is a driving feature of the global currents extending from the Arctic to the Antarctic ice sheet, where interaction with the Ross Ice Shelf in turn affects the stability of the West Antarctic Ice Sheet. The satellite picture of Byrd Glacier flowing into the Ross Ice shelf is a reminder that if the quite recently discovered fast ice streams should become invigorated by a change in the balance of salt and fresh water beneath the Ross Ice Shelf associated with global ocean currents, or by volcanic eruptions beneath the ice sheet (IAVCEI), the consequences could be dramatic. A partial collapse of the Antarctic Ice Sheet would release more fresh water than the total presently in rivers and lakes, but of course it would enter the ocean with disastrous consequences for the millions of people living in cities near sea level. This aerial view of a Moldaves Island shows how vulnerable the 250,000 inhabitants of the islands are to small increases in sea level.

IUGG has much to offer in basic research that can help us obtain a better understanding of climate change. Several Associations are strongly involved. There were many inter-Association sessions between IAHS, IAMAS, IAPSO, and IAVCEI at the Joint Assembly of IAMAS/IAPSO in July, 1997, and more will be found in the program for this IUGG General Assembly. The volcanoes of IAVCEI may exert a powerful influence on climate change, even to the extent of causing mass extinctions of dinosaurs, according to some experts. This cover of "Science News" warns us that "... the World Warms". The book by Imbrie and Imbrie reminds us that we are currently within an ice age. If global warming is an established fact, this warming is occurring within an Ice Age that has already experienced many major climatic cycles without any intervention by or influence of humankind. It is because of uncertainties in prediction that a close watch is maintained for signals

from the fast ice streams in Antarctica. We really ought to be sure which way we are going before we take corrective action, and we should be confident about the consequences of any actions.

As cities grow larger, "Time" magazine headlines megacities. Many of the world's megacities are situated in locations threatened by earthquakes, volcanic eruptions, landslides, floods, and rising sea-level. Volodya Keilis-Borok, past-president of IUGG, emphasized the idea that the basic science knowledge carried within the IUGG Associations should be brought to bear on megacity problems. Can some way be found to channel the IUGG scientific expertise to benefit society? I am pleased that IUGG vice-president Uri Shamir (past president, IAHS) is chairman of an IUGG Committee that will coordinate Association efforts in this direction. There is obvious overlap with the objectives of IDNDR (International Decade for Natural Disaster Reduction), which is drawing to a close. The concentration of population in megacities requires better management of resources, and also enhanced awareness of and mitigation of geological hazards. It is important to consider risk assessment and levels of acceptable risk. So far, it appears that many governments prefer to wait for a disaster and pay mop-up money rather than to provide significant research support for study of and prevention of hazards.

Mount Rainier is a beautiful mountain looming over Seattle. It is also a rotten volcano. My magma (IAVCEI) has been corroding the inside of the mountain through about 2,000 years since the last eruption. The atmosphere and water (IAMAS and IAHS), in the form of ice and running streams, have been attacking the outside of the mountain. Eventually the walls must break, and an eruption powered by subducted Pacific Ocean water (IAPSO) will produce a variety of explosive phenomena. During the volcanic eruption, there will undoubtedly be landslides, mudflows and floods, which could devastate much of the area around the volcano. A local volcanic disaster like this could have global consequences, not only through climatic change, but also in terms of the economy. Many of us wrote our abstracts using Microsoftware, and many of us flew here in Boeing aircraft. The headquarters of both companies are within striking distance of Mount Rainier, but I must add that the odds are very low for an eruption large enough to cause a global economic disruption.

Our human society is a small but influential part of the biosphere, perched between the solid earth and its fluid envelopes. Society extracts resources from the rocks and fluids of the environment, processes them, and returns them to the environment - to the earth cycles - as wastes, commonly in more toxic form that the original resource materials. This cover of "Time" magazine, which shows the globe of "endangered Earth" wrapped in cellophane and tied with string, reminds us that it is essential that we obtain a better understanding of how we as a society are affecting the Earth cycles, and contributing to environmental change. If we do irreparable damage and rupture the delicate films of air, water, and soil on which we depend, we will not be able to enjoy the luxury of conducting pure science to satisfy our curiosities.

I declare this 22nd General Assembly of IUGG to be open. There is opportunity for all seven Associations to evaluate their priorities in terms of research curiosity and society's needs. Enjoy your Symposia.

Meteorological and geophysical fluid dynamics

(A book to commemorate the centenary

of the birth of Hans Ertel)

Collected and edited

by

Wilfried Schröder