REPORTS OF MEETINGS

INTERNATIONAL UNION FOR QUATERNARY RESEARCH (INQUA)

Shore-Level Change in Patagonia

Mar del Plata, Argentina, September 30 thru October 12, 1984

World shorelines represent very nearly the intersection of the geiod and the lithosphere. Global sea level is, therefore a function of crustal level, gravitational equilibrium and eustatic ocean volume. A lengthy record of Late Cenozoic paleoshores can thus outline the tectonic movement, subcrustal mass transfer, and climatic modulation of the hydrosphere. As changing climate and consequent shore-level fluctuation have been a characteristic feature of the Quaternary, the International Union for Quaternary Research (INQUA) established in 1953 its Commission on Shorelines to promote studies aimed at understanding paleo-sea levels in a global context.

The Commission regularly organizes major field conferences in areas where recent research adds new insight to global processes. Computer models can now transform the vast bulk of paleo-shore-level data into global solutions for glacier variation, regional tectonics, and deep rheological properties. The Commission is, therefore, increasingly focussing its attention on filling spatial and temporal gaps in the data sets so that the modelling can be improved to yield reliable extrapolations into unknown areas. Accordingly, two major field conferences have been held in recent months: one in north Germany and Denmark to trace and compare the course of post-glacial sea-level recovery in three successive interglacials, and another in southern Argentina to compare the regional levels of Holocene and last interglacial transgressive maxima.

With financial support from UNESCO, the Subcommission for the Americas hosted the 1984 annual meeting of the "Sea Level Project" (IGCP/200) in Mar del Plata, including an international symposium on Late Quaternary Sea-Level Changes and Coastal Evolution and a 7-day excursion. Fourteen countries were represented by more than 60 participants, about half being young scientists from Argentina. The program comprised 31 papers of which 16 were South American (12 from Argentina).

The symosium featured topics ranging from computer simulations to biostratigraphic zonation. It clearly illustrated the growing trend in paleo-shoreline research to link field data with mathematical models of sea-level response to mass redistribution on the globe. The debate centred on the course of sea-level change during the present interglacial period, as a consequence of glacier melting in the Northern Hemisphere. Discordances and discontinuities between ancient and present sea levels within a given region reveal local tectonics or gravitational change, as does comparison of previous interglacial maxima with the present one. Indeed several authors argued that crustal movement and subcrustal mass transfer explain at least as much of the relative sea-level change as does the return of glacial meltwater to the ocean.

Current work is, thus taking two main directions: the documentation of local sea-level histories reliable enough to derive the causes, and the manipulation of the global data set to reveal regional distortions of crust and geoid as well as to further substantiate and refine global rheological models. The Holocene sea-level record is of central importance because it reflects in a most elegant way Earth's total response to the glacial perturbation of mass. The prospects are good that more and better paleo-sea-level data, and their fuller exploitation in numerical models will play an important part in our understanding global geodynamics.

N.A. Mörner (Sweden) stressed the concept that geoidal variations may originate as phase changes in the mantle; for example, a one milligal gravity change translates to a vertical movement of 3.3 m in sea-level response and 1.7 m in crustal movements. In addition, climatic stress on sea surface topography could contribute a further 2 to 5 m change. Comparison of Holocene sea-level curves in five widely scattered regions of long term stability shows discordances of 5 to 7 m, which can only be regarded as geoidal in origin.

W.A. Newman (USA) manipulated a global data set of 4272 paleo-shoreline indicators to conclude that the general climatic signal expressed by post-

glacial sea-level recovery is strongly modulated by local and regional nonsystematic gravitational changes. D.B. Scott (Canada) reported that the varied sea-level record in eastern Canada substantiates a numerical model of crustal recovery based on disappearance of an ice sheet delimited by mapping. P.A. Pirazzoli (France) re-evaluated 1178 tide-gauge records and concluded that no part of the world's coast could be regarded as stable, even for a few decades.

On the subject of modern ocean level and its previous interglacial analogues, L. Ortlieb (Mexico) and C. Zazo (Spain) used "staircases" of terraces to define tectonic displacements that were as large in the horizontal as in the vertical directions, again demonstrating that well-developed paleoshores provide excellent ways to assess crustal stability. They and others cited evidence for a high sea level in the middle of the last glacial stage (ca 30,000 to 50,000 years), an event usually discounted on glaciological grounds. However, if recent interpretations that the Laurentide and Fennoscandian ice sheets disapeared at least once in this period, and perhaps calved as quickly as they did in the mid-Holocene, then the possibility exists that, on some coasts at least, relative sea level during the last glacial stage may have been higher than at present.

The field excursion, which followed a 3,000 km itinerary along the Patagonian coast south of Mar del Plata, served to illustrate many of the findings presented in the Argentinian papers. Although the coast here is generally subsiding and submerging at present, it features several raised strandlines. Apart from the Miocene transgression, the most prominent paleoshore dates from the Middle Holocene (5,000 to 7,500 BP) and rises southward from +2 m to +12.6 m over 800 km. Above it over part of the distance is a prominent rock platform and beach complex referred to the last interglacial. The difference in altitude between these two paleoshorelines could be ascribed to subsequent epeirogenic tilting and/or gravitational changes. In contrast, in Brazil, only submerged equivalents of these raised shorelines are known. Further research on the Late Quaternary transgressions in southern Argentina should thus provide much valuable information.

Throughout the meeting both in the lecture hall and out on the pampas, our Argentinian hosts promoted lively discussion on a wide range of topics. In the bright Patagonian sun, new friendships began, samples were collected for donation of analyses, ideas exchanged, and joint programs planned. The small group from the shorelevel community who were privileged to attend the meeting came away invigorated, inspired, and intent on organising further meetings of the same high calibre. The proceedings will appear in the serial publication, Quaternary of South America and the Antarctic Peninsula (Balkema).

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THE INTERNATIONAL GEOGRAPHICAL UNION

Commission on Coastal Environments

During the 25th International Geographical Congress held in Paris last August, the General Assembly approved the continuation of the Commision on Coastal Environment for a further four years (1984-88). Roland Paskoff (France) was appointed Chairman of the Commission; Vice-Chairman is Eric Bird (Australia), and the Secretary is Norbert Psuty (USA). Members include: Paolo Fabbri (Italy), Paul Kaplin (USSR), Kazuyuki Koike (Japan), and Dieter Muehe (Brazil). The main goal of the Commission is to investigate five areas: (1) dune-beach interactions; (2) coastal lagoons; (3) coastal hazards; (4) recreational use of coastal space, and (5) nature and impact of national policies for coastal open space, including coastal waters. In addition, there is an initiative to stimulate specialists to prepare and circulate working papers on methodologies of sediment budget calculation. Additional suggestions on topics of interest will be appreciated because the Commission wishes to encourage an exchange of ideas and research findings. It hoped that this effort will promote discussion and criticism of work in progress in the broad field of coastal studies.

The Newsletter will continue to be issued, now from the desk of Norbert Psuty, Director of the Center for Coastal and Environmental Studies at Rutgers, the State University of New Jersey.

The Commission will sponsor symposia during the period 1984-88. Proposals for regional or topi-

cal meetings are gratefully received. The Commission needs the collaboration of corresponding members for coastal areas throughout the world. Volunteers are welcome.

The objective of the Commission on the Coastal Environment of the International Geographical Union is to develop coastal research and its application in seaside management by an international team of geographers (physical geographers as well as human geographers) working in close connection with geologists, ecologists, engineers, and planners. It is hoped that this multinational and interdisciplinary organization will continue the useful work initiated in 1976.

Those interested in the work or programes of the Commission may write for information from the Chairman (Roland Paskoff) or to the Secretary (Norbert Psuty, Center for Coastal and Environmental Studies, Rutgers the State University of New Jersey, New Brunswick, New Jersey 08903, USA)

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CONTAMINANT FLUX THROUGH THE COASTAL ZONE

If pollutants are discharged into rivers, what proportion moves through the coastal zone and enters the deep ocean? Because of the enormous quantities of chemicals produced and discharged into rivers and estuaries, regulatory authorities need to know whether chemicals are retained and recycled within the coastal zone or dispersed into ocean basins. The partitioning of contaminants on a global scale amongst the sediments, biota, and water of rivers, estuaries, and the continental shelves requires scientific insight into processes of chemical transfer, physical movements, and mass balance of substances. The fate of a given chemical greatly depends on the form taken, either as a solute or as a suspended particle, and on the physico-chemical conditions of the environment that could induce a change in the form. Most global budgets deal with river-borne fluxes into the ocean and have not taken into account the removal or addition of contaminants in the coastal zone. Clearly, there are pressures on the coastal zone, and a need for different countries to regulate and monitor pollutant inputs to avoid contamination of seafood resources, risks to human health, and degradation of ecosystems.

Recognizing the complexity of the problem, the International Council for the Exploration of the Seas (ICES) in collaboration with the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Intergovernmental Oceanographic Commission and the Office of Marine Pollution Assessment (OMPA/National Oceanographic Atmospheric Administration, USA) sponsored a symposium and workshop in May, 1984 at the Institut Scientifique et Technique des Peches Maritimes facility in Nantes, France. G. Kullenberg of the Institute of Physical Oceanography, University, Copenhagen convened the symposium.

The 51 research papers representing a broad range of disciplines, presented information on various environments and contaminants including heavy metals, nutrients, and radionuclides. Although papers revealed contrasting viewpoints, there were common questions throughout the symposium: How are reliable flux measurements obtained? How reliable are pollutant budget calculations? Can all chemical inputs be identified? How can the mass balance for different coastal systems be intercompared? These questions brought forth some of the latest ideas on budgets and prompted suggestions for improving future flux research.

CONTAMINANT ESCAPE

A striking case for flux of contaminants through the coastal zone was provided by H. Dahlgaard and colleagues, who tracked low-level radiocesium (^{137}Cs) 6000 km from its source at the Windscale nuclear reprocessing plant (Sellafield, UK) on the Irish Sea, to the east coast of Greenland via the North Sea and Norwegian coastal current. The estimated time for transport was 4 to 5 years. Since most contaminants have more diffuse sources and higher background levels than radionuclides, Dahlgaard suggested using radionuclide "signals" as long-distance tracers or surrogates, of other contaminants. Pentreath *et al.* showed that only 3 to 17 percent of the $^{239/240}Pu$ and ^{241}Am annually discharged at Sellafield leaves the Irish Sea. The bulk of these nuclides are adsorbed on particulate matter. They are then incorporated into fine sediment deposits which accumulate either in an eastern "nearfield" zone or a western "farfield" zone of the Irish Sea. Pentreath revealed evidence from ^{14}C

techniques and plutonium isotopic ratios in sediment cores that Pu has been incorporated to depths of 0.5 to 1.0 m, a trend attributed to intense biological reworking. "The sediments therefore represent both a present-day sink and a future source of transuranium nuclides," Pentreath said. He recognized that Pu and Am can be remobilized by post-depositional chemical changes, but the overriding factor affecting the future distribution is the long-term stability of the sediments themselves.

In one of the most comprehensive budgets of trace metals in an estuary, the Gironde, France, Jouanneau *et al.* reported more than 80 percent of the mean annual river input of Cu, Pb, and Zn is exported from the estuary into the ocean mainly in dissolved form. In contrast, enormous loads of particulate metals are retained within the estuary in an oscillating "stock" of dense suspensions at the turbidity maximum (> 1 g/l) and in pools of fluid mud (> 400 g/l). The major fraction of exported metal comes mainly from the turbidity maximum, where it is remobilized from particulate matter. In a separate paper on the Gironde, Donard and Bourg explained the chemical exchange of Cd, Cu, and Zn as a two-step process: (1) particle deposition into anoxic fluid mud and transfer from particulate to dissolved form, and (2) particle resuspension into overlying oxic water and transfer to particulate form. Although the net effect of these processes favors dissolved metal flux into the ocean, Jouanneau explained: "The turbidity maximum is an important regulator of metal flux; when fluvial input is high, the 'stock' acts as a sink for metals, whereas when input is low, it acts as a source of metals for the ocean."

The geochemical and sedimentological flux-related processes found in the Gironde also materialize in France's Seine estuary. According to Avione *et al.*, seaward export is amplified by river floods that force the turbidity maximum into the estuary mouth and allow direct escape of metals and nutrients to the shelf. This is an outstanding case where man has changed the geologic role of an estuary by landfill and construction of jetties during the last 150 years, from a sink for fluvial and marine sedimentary materials to a source of fluvial materials for the shelf. The French studies show that exchange at the seaward coastal boundary is the greatest unknown in the mass balance. Whereas the limits of most box models have been defined geographically, temporal variability at the boundaries can be reduced by defining hydrographic boundaries and covering a broad range of salinity.

CONTAMINANT ENTRAPMENT

A case for entrapment in the coastal zone was provided by T. Church from trace metal mass balanced in the Delaware estuary. Church found that less than 3 percent of the total input of the geochemically reactive metals, *e.g.* Cu, Ni, and Zn are exported. The bulk of the metal input, of which about one-half come from bordering marshes, is retained in the estuary, presumably in the sediments. Nichols noted the high sediment-trapping efficiency, determined from sediment budgets of estuaries on the northern US East Coast. This efficiency results from high volumetric capacity, low flushing velocity, and the nearly closed circulation.

L. Brugmann presented preliminary mass balances for eight major trace metals covering inputs, exports, and major exchanges for the entire Baltic Sea. Budgets are now possible in this area from acquisition of new data from water, air, and sediments using improved analytical techniques, laboratory intercalibrations in different countires, and a greater frequency of analyses. Results show a significant metal-enriched influx of Cu, Ni, and Zn through the western sector. At least 70 percent of the total influx of Fe, Co, and Hg is reportedly removed within the Baltic, and 35 to 60 percent of the Cd, Cu, Ni, and Zn is removed.

J. Trefry *et al.* traced the contaminant flux in the Mississippi River delta from distribution coefficients (kd's), which provide a measure of equilibrium partitioning between dissolved and particulate phases independent of particle loading. This approach is a valuable adjunct to mass-balance models, which are limited by fluctuating inputs and the open system of deltas and shelves. By utilizing Kd values, it is possible to predict the partitioning behavior of different ions. Recognizing that Cd, Mn, and Pb have a great affinity for particles, the investigators found these metals are largely removed from seaward transport by sedimentation. In a separate paper, T. Nelson and J. Trefry pointed out the importance of biological aggregations in promoting settling and deposition. The investigators concluded that the delta is an efficient sink for many river-borne contaminants, thus restricting flux through the coastal zone.

Santschi *et al.* used Kd values to predict the removal rate (inverse of residence time) and the retention of various radioactive trace elements in coastal sediments from experimental measurements in the Marine Ecosystem Research Labor-

ecosystems. The high retention capacity (> 75 percent) predicted for Narragansett Bay in the U.S. was confirmed from mass-balance calculations of inputs and sediment storage for radioisotopes (Th, Pb, Pu); trace metals (Pb, Cu); and sediment. The tank experiments also revealed that high sediment resuspension, or anoxic bottom water, increases the retention and storage capacity of coastal sediments for many trace elements, except those linked to the Mn redox or organic-carbon cycle. The response of water-sediment partitioning in the tanks is believed to be indicative of element behavior in open coastal systems having residence times of several months. According to M. Bewers, Santschi's paper showed that complex geochemical processes can be characterized in a simplistic way (through distribution coefficients), so that we can obtain a more generic or universal picture of flux through the coastal zone.

FLUX MODELS

The predictive capabilities of dispersion and contaminant flux models were noted by several researchers. T. Hopkins and D. Dieterle presented a baroclinic circulation and particle-dispersion model to simulate waste dispersal patterns on the U.S. mid-Atlantic shelf. M. Devien, M. Norton, and M. Champ assessed the dispersion of sludge contaminants from flow and wave characteristics at different shelf sites. M. Reed *et al.* assessed the ecological effects of ocean disposal from pollutant trajectories, areas of influence, and biological impacts. P. Wyle developed a simplified tidal circulation model, for use in a personal computer, to assess potential pollutant disperal in New York. D. Thomas *et al.* used a mass balance to compare the natural and anthropogenic fluxes of proposed metal and hydrocarbon inputs from the Mackenzie River into the Beaufort Sea.

CONFLICTS AND CONSENSUS

Discussions uncovered conflict in defining how well mass balances are quantified and how well they serve their purpose. For management it was noted, "What difference does it make how much is coming or going; it's the 'exceeded' concentration in a given compartment or component that counts. It doesn't matter where the rest goes." Few papers included a rigorous analysis of uncertainties or documented the reliability of budgets. And few papers defined the practical implication of discharging wastes in the coastal zone; *e.g.* should wastes be diluted or contained? Bewers noted that most papers dealt with individual estuaries or confined areas and provided little description of shelf processes. Therefore, it was difficult to comprehend the net effect of contaminant fluxes on a regional or global scale. Bewers commented, "Are there systematic trends and agreement among the results of budget calculations for related chemicals or similar types of coastal systems?" A generic and universal basis is needed to compare studies and evaluate the total flux through the coastal zone.

A consensus confirmed that mass balances and phase partitioning indicate that coastal zone transformation of riverine inputs is of major importance. The rates of transformation, however, are poorly known. Most information comes from estuarine studies; much less is known from the continental shelf, particularly the exchange at the boundary between the coastal zone and the ocean basin. Measurements of flux in landward-flowing as well as seaward-flowing waters are necessary. It was generally agreed that the net flux of contaminants in and out of tidal areas is impossible to derive from direct measurements of velocity and concentration, because the difference in concentration between ebb and flood is usually small and the temporal and cross-sectional variability of flow and concentrations is large. The flow of water, a dominant term in flux calculation, is subject to forcing by major events of meteorological conditions. Therefore, the product of mean flow and concentration over a given time can yield misleading flux values. Additionally, mass balances address steady-state conditions which are probably not achieved over the time scales of most models. Many inputs are keyed to pulses, and the dispersion can fluctuate with human activities or with major natural events. It was generally agreed that mass balances serve scientists as a means of accounting for materials at a simplistic level. Budgets can reveal the gross effects of processes that cannot be addressed directly. They are not accurate enough, however, to regulate waste discharges and define detection limits. But a mass balance can predict where major problems may lie in a given compartment, and can therefore serve as a guide for planning. The consensus was that distribution coefficients are a key to predicting transport behavior, *i.e.* to quantify reactivity, removal rates, and redistribution of contaminants during transport through the coastal zone.

Many participants shared the impression that the coastal zone is much more complex and more difficult to observe and comprehend than pre-

viously realized. There seemed to be some concern about having another "Tragedy of the Commons" unless major steps are taken to establish the coastal zone's carrying capacity for contaminants. Since coastal zone contaminant flux involves freshwater inputs, atmospheric deposition and marine water and sediment exchange, questions are better answered if there is contact and cooperation between coastal scientists of many disciplines. In this respect, the symposium was a success because it brought together diverse research interests.

The symposium papers will be published in the ICES series, Rapports et Procesverbaus. Recommendations from the workshop will be used as input to the ICES Advisory Committee on Marine Pollution and will be included in the next ICES Annual Report. For further information concerning the symposium papers, contact the ICES General Secretary, Palaegade 2-4, 1261 Copenhagen K, Denmark.

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