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The Implications of the "Final Storage" Concept for the Management of Hazardous Wastes

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Introduction

The term "hazardous waste" is normally used to characterize waste materials which contain a certain potential for detrimental impacts on the environment and which are not collected by public collection systems. A recent survey of the amounts and properties of wastes in the Kanton of Zürich [1] shows that 460 000 tons (400 kg/c, c=capita) of municipal solid wastes (MSW) and 35'000 to (30 kg/c) of hazardous wastes are produced per year.

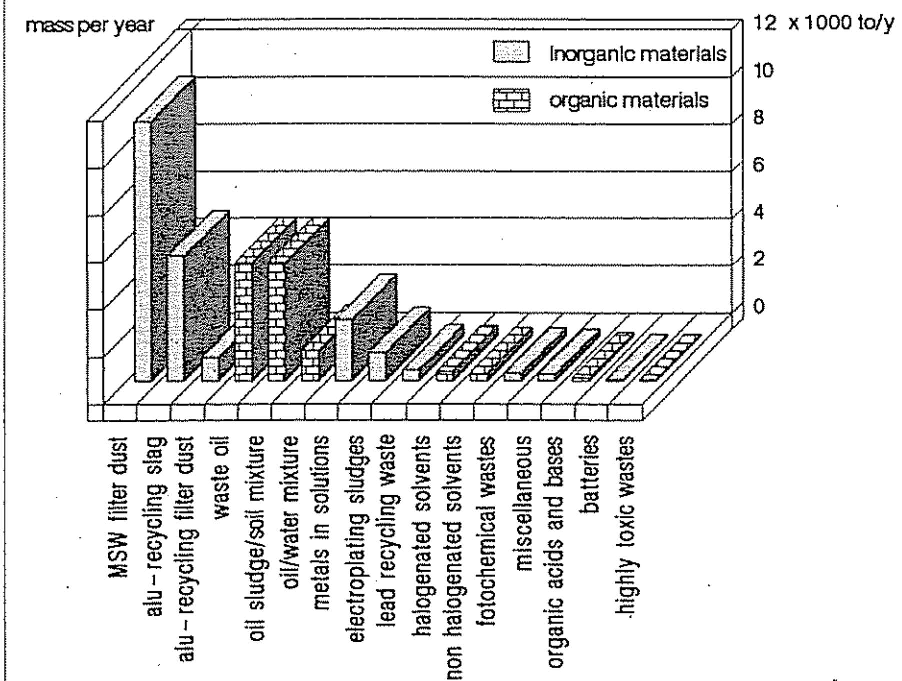

Fig. 1
Hazardous Wastes in the Kt. Zürich in tons per year (1985)

The most important hazardous waste material is filter dust from MSW incineration (10 kg/c/y, Fig. 1). Similar wastes comprise other inorganic ashes (e.g. 5.5 kg/c/y from aluminum recycling), and sludges from electroplating industries (1.0 kg/c/y). The second largest waste group is represented by oil containing materials such as waste oil (4.4 kg/c/y), oil sludges and mixtures of oil/soil (4.4 kg/c/y), and oil/water (1.1 kg/c/y). A third category contains various materials of diverse origins. Highly toxic wastes are only of minor importance (0.05 kg/c/y). The *amount* of wastes produced corresponds well with man's activities: the high consumption of goods by private households leads to large amounts of wastes, which are ultimately concentrated in MSW incineration products such as bottom ash, filter dusts or scrubber sludges. The demand for mobility and heating as well as the use of mechanical machinery implies a large flux of fossil fuels and lubricants, giving rise to large quantities of oily wastes.

From a *qualitative* point of view, the most important waste material is municipal solid waste (Fig. 2): the mass flux of most elements in MSW is larger than in any other waste product [2]. Since during incineration many elements are enriched in the filter dust [3], this material becomes the largest carrier of potentially hazardous elements in waste management.

The objective of hazardous waste treatment

The question arises how to treat and dispose of hazardous wastes. The objectives of waste treatment in Switzerland have been set by the Swiss Federal Commission on Waste Management [4]. According to these guidelines, wastes shall be treated in Switzerland (i.e. no export is allowed), and the treatment shall produce materials which can either be *reused* or *landfilled without "long-term implications"*.

In a recent EAWAG workshop (Swiss Workshop on Land Disposal of Solid Waste, Gerzensee, March 14-17, 1988), this landfilling without creating long-term implications, known as"final storage", was characterized as follows: the flux of materials from a final storage site shall remain of the same order of magnitude as the background fluxes in the environment around the site over long periods of time. In order to define more precisely the time period to be observed, it is important to note that processes like sedimentation, weathering and erosion constantly change the earth´s surface. For Swiss conditions, it can be estimated that after 10^4 to 10^5 years landfills will either be removed from the original site by erosion, or covered with new material from the continuing natural sedimentation.

There are three possible routes to a "final storage "quality landfill:

1. Construction of an envelope around the landfill body (top cover and bottom liner);
2. the attenuation capacity of the subsoil can be utilized to sorb or degrade substances;
3. the waste material itself can be changed such as to yield an inert material with very low leaching potential even over long periods of time.

Based on existing experience with sophisticated envelopes, it seems improbable, that such envelopes can reliably exclude the landfill body from the hydrological cycles for long periods of time. Geological formations which are not in contact with water, such as salt caverns, are either not present in Switzerland or only available at very high cost. The information currently available is inadequate for reliable predictions of the attenuation capacity of soils with respect to the hazardous waste mixtures which must be disposed. Therefore, the main approach to producing "final storage" quality landfills is to transform hazardous wastes into materials which will remain inert in the long-term of a landfill environment. This implies the mineralization of organic wastes before landfilling: the organic carbon may be leached, or microbially transformed to leachable species and organic and inorganic acids, thus changing the landfill conditions and favoring the mobilization of metals from the landfill.

For future waste management, this concept means that wastes have to be transformed to non-leachable, inorganic materials which are well suited to disposal in mono-landfills. In many cases, this transformation will involve a mineralization step such as incineration, followed by an additional immobilization of the incineration products.

A Standard Leach Test for "Final Storage" Suitability?

The main question is how to determine the suitability for "final storage" of a material. Numerous tests are available for the characterization of the leaching behavior of waste materials in landfills. A critical review of many of these tests is given by Löwenbach [8]. For legislative purposes a standard leaching procedure for all waste materials is often required. Based on our investigation [1] into the leaching behavior of seven common hazardous waste materials it appears *to be impossible to develop a single leach test to characterize the many wastes in various landfill sites.*

We applied the "Uniform Leach Procedure (ULP)" [5], the "Standard Leach Test (SLT)" [7] and the "Land Disposal Leach Test (LDLT)" [9] to waste materials from lead recycling, aluminum recycling, electroplating sludges, paint sludges, solidified paint sludges, sludge mixtures and oil sludges. Concrete leached by the same methods was used as a reference material.

When the leachate data obtained from these experiments were compared with surface water standards, the following conclusions were drawn:

1. the various tests may yield different results for a single material;
2. most materials are not suitable for disposal in landfills;
3. none of these tests can be used to assess the problems associated with the leaching of organic materials;
4. none of these tests can answer the question whether a material has" final storage" quality.

The main drawback of all standard leaching tests became evident when one of the materials (slag from aluminum recycling), which "passed" all three tests, was further analyzed by additional methods: Upon acidification at pH 4, large amounts of hydrogen sulfide were produced. When samples of fresh slag and of 20 years old landfilled slag were compared, the pH of the leachates appeared to have decreased by 3 to 4 units (from 9.5 - 10.8 to 6 - 7). Upon acidification, no more hydrogen sulfide evolved from the exposed sample, suggesting that the soluble sodium sulfide had been oxidized to sulfates or that in deeper layers anaerobic transformation to sulfides of lower solubility had occurred. When the fresh slag was mixed with water, hydrogen was produced by the reaction of elementary aluminum in the presence of metal ions with a higher redox potential such as copper, lead or zinc. The three reactions (production of H_2S and H_2, and the neutralization of the aluminum slag after 20 years of exposure in a landfill) are important observations for the practice of landfilling as well as for the judgement of the "final storage" suitability of the slag. According to the results, this slag does not comply with "final storage" criteria and needs further treatment.

Standard leaching tests are not designed to characterize all the potential reactions of the many waste materials, nor do they take the kinetics of these possible reactions into account. Specific, tailor-made methods are required to evaluate the behavior of a waste material. In the case of the aluminum slag, the study of the reactions with water, the buffering capacity when titrated with acids, and the possible redox reactions is a much more powerful tool for the characterization of this material than the application of even several leaching tests. In order to assess the suitability of a material for final storage, the following information is necessary:

1. The precise composition of the waste material must be known. This means that the matrix elements, the key variables determining the behavior of the material, have either to be determined by chemical analysis or by a material flux

analysis of the process which generated the waste material. In addition to the matrix (comprising about 95 % w/w of the mass of the waste) the important trace elements and (organic) compounds have to be known.

2. The behavior of the waste material in the proposed landfill environment must be evaluated according to chemodynamic principles and the information on the composition of the waste. In laboratory experiments, the reactions of the waste material with water, the resulting electrolyte, the mobile fractions, the acidity (or alkalinity) and the redox reactions should be assessed. Special attention should be paid to the kinetics of these reactions, since even very slow processes can become important in a final storage landfill.

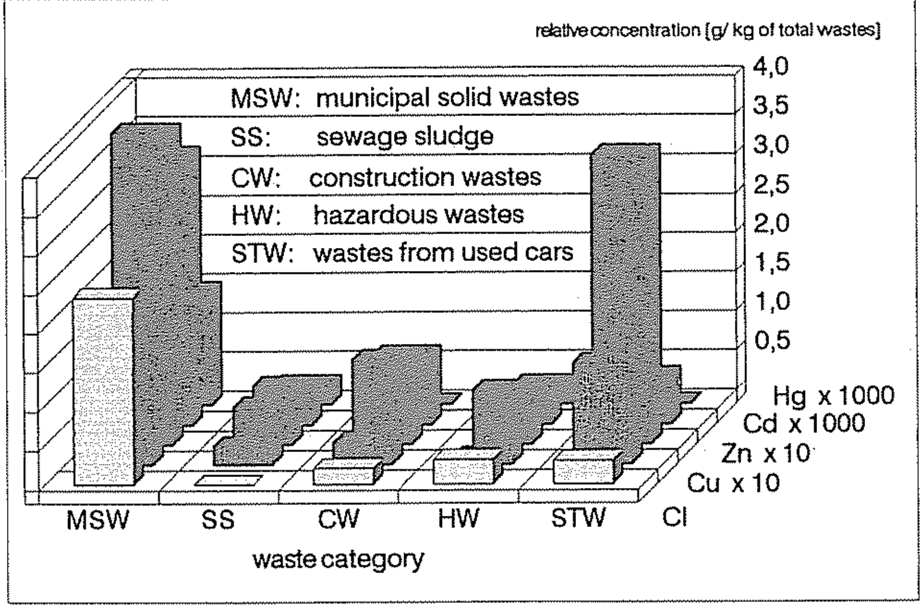

Fig. 2

Waste matrix: Wastes as carriers of hazardous elements

3. The content of organic carbon has to be carefully assessed. The potential for microbial transformation and degradation of the TOC should be assessed in parallel with the possible impact of the resulting transformation products on the waste material itself and the landfill environment. For many materials a TOC content as low as 1% may become an important proton producer when mineralized to carbon dioxide [6].

Conclusions

The largest single source of hazardous waste is the process of the concentration of the potentially hazardous elements contained in municipal solid wastes that is the consequence of their collection and incineration.

The new concept for the treatment and disposal of waste materials requires that only materials fulfilling "final storage" criteria are landfilled. In order to reach this goal, organic materials have to be mineralized and inorganic materials have to be immobilized prior to landfilling.

A test of the "final storage" suitability of the products from such waste treatment has to be based on comprehensive knowledge of the composition and the behavior of the material in the landfill environment. Instead of global standard tests, individual tailor-made chemodynamic studies of the various waste materials are needed. An initial attempt at such an investigation into one of the quantitatively important waste materials (bottom ash from municipal solid waste incineration) is given in [6].

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How does Lake-Plankton react to a Reduced Phosphorus Burden ?

Hans-Rudolf Bürgi, Heinz Ambühl, Heinrich Bührer and Ernö Szabò

The development of Lake Lucerne since 1960

A thorough investigation of Lake Lucerne at Kreuztrichter began after the takeover of the hydrobiological laboratory at Kastanienbaum by ETH/EAWAG in autumn 1960. Until then, little had been known about the lake, the few scientific studies having been performed many years previously. The start of the now 27-year study programme by the Hydrobiology/Limnology department of EAWAG coincided with the first significant increase in the phosphorus content of the lake [1].
Strict legislation from 1972 on led to reduction of the phosphorus input (P-precipitation in sewage treatment plants, banning of phosphates in washing powder, 1986). Maximum concentrations were recorded in 1980; from this point on the lake returned to its previous oligotrophic state.
Since from the beginning of the study great importance had been attached to the application of advanced and exact analytical techniques, the chemical and biological data still fulfill, even today, the rigorous requirements of scientific analysis. At first sight, agreement between changes in nutrient concentration and algal biomass appears to be poor: the highest algal abundances were observed in the years 1963-1971, when, although the nutrient concentration was increasing rapidly, it lay far below its peak. Indeed, during the final, still increasing, phase of eutrophication, algal biomass was already decreasing. This reduction resulted from, amongst other factors, the exact time of year of the nutrient input: the nutrients made available by winter turnover are only sufficient for growth during the spring; the summer peak requires a corresponding fresh input. This input may well have been greater in the late sixties than ten years later, when the annual average values reached their peak. However, the significance of the primary product's subsequent fate in the food-chain continued to increase until 1979; losses through interactions with zooplankton (grazing) increased internal cycling within the lake even as the algal biomass was declining.
The plankton analyses from 1960/1961 demonstrated clearly that changes in the range of species had occurred since the previous extensive biological studies decades before. Initially, however, the relative abundances of the various algal species did not change significantly; only with the appearance of *Oscillatoria rubescens* (Syn. *Planktothrix rubescens)* did a new accent emerge within the lake's plankton population. This blue-green alga, already well known from its salmon pink algal blooms in various lakes, caused the first long-term interruption of the diatoms' dominance.
During the initial phase of eutrophication, which began in the fifties, *Oscillatoria rubescens* was able to profit from the increased nutrient input. Subsequently, however, competition from the cryptoflagellates and green algae became significant. The large siliceous algae were increasingly replaced by small centric forms. This restructuring led to a long-term alteration in the light-absorption characteristics, and consequently thermal properties, of the surface layers. Blocking of light by the high algal densities in the uppermost layers reduced depth of the trophogenic layer.
The algae, whose nutrient requirements had increased as a result of their higher activity, were able to remain longer in the epilimnion thanks to their improved flotation characteristics. Here, the comparatively low nutrient supply of the narrower layer compensated, partly, for the effects of the continuing eutrophication. Together with losses through grazing, this reduction in living space led to a partial decoupling of algal production from the total available nutrient concentration, and also explains the apparent paradox of a reduction in algal biomass coinciding with an increase in the average nutrient supply to the whole lake.
Oscillatoria rubescens, an oligotrophic species, prefers a light density of 0.12 E/m^2 d, with a density gradient of about $5x10^{-5}$ g/cm^3 m^{-1} and high temperatures. Since, like almost all algae, *Oscillatoria rubescens* can convert high nutrient levels to correspondingly high quantities of biomass, it can be used as an indicator of eutrophication. For a long period of time, the necessary conditions for growth pertained at a depth of 7.5-15m. From 1965 onwards, the region of suitable light intensity moved upwards, where *Oscillatoria rubescens* was not able to compete successfully with the rapidly proliferating nanoplankton, and was gradually displaced.
An analogous ousting of *Oscillatoria rubescens* by dense surface algal populations had, years before, been observed in lake Zürich, where it returned after the surface layers became transparent again.

The rapid recovery of lake Lucerne was set in motion by two simultaneously applied anti-pollution measures in the drainage area: banning of phosphate in detergents and improvements in sewage treatment. The changes in the plankton biocoenosis (more zooplankton, dominance of silaceous algae, and disappearance of *Oscillatoria rubescens*) altered in their turn the balance between production and sedimentation, and shortened the residence time of phosphate in the trophogenic layer. The action of these factors is dealt with in more detail below.

Organic particles transport varying amounts of nutrients. Since still-intact algae continue to absorb available phosphate as they sediment, phosphate does not accumulate at depths between 20 and 30m, even though the oxygen concentration profilepoints to considerable mineralization. As sedimenting particles enter a layer in which algae have accumulated, the nutrients released by bacterial degradation and autolysis are in part immediately incorporated by the algae and used for biomass synthesis. This interruption of sedimentation can lead to unexpectedly elevated biomass synthesis at a particular overall nutrient concentration. The influence of the zooplankton in lake Lucerne was extensively investigated using limnocorrals (project MODEC). The preferentially filtered nanoplankton are converted to a more rapidly sedimenting form by the production of faecal pellets. A consequence of the selective predation of the small phytoplankton is the gradual domination of the larger forms. This process, which can be observed annually after the period of excess zooplankton populations, also increases sedimentation. Clear water phases, the result of almost complete elimination of the surface water algae by grazing, require a large algivorous biomass, which has only been observed in lake Lucerne since 1970 in May/June. As long as the spring production of the algal food source finished before the beginning of the exponential proliferation phase of the zooplankton (exact onset delayed by low water temperature), no correspondingly high zooplankton populations, the only populations able to fundamentally influence the phytoplankton, could develop. All the phenomena mentioned (replacement of the small algae and Oscillatoria by large, rapidly sedimenting siliceous forms, and the packing of the small plankton into faecal pellets by zooplankton) together result in increased nutrient sedimentation. This effect may also be followed by observing the silicate content of the epilimnion: although the silicate input from leaching of siliceous rocks has not changed, its concentration has decreased markedly in the last few years.

The question remains, whether this improvement is merely temporary since the grazing effect of the zooplankton will also decrease with decreasing eutrophication. The possibility remains that the Oscillatoria, still present at a low level, will make a come-back**.

** Indeed, actual plankton analysis (in July 1988) showed a new invasion of *Oscillatoria rubescens* in lake Lucerne in a depth of 10 to 30 m.

The Development of the Walensee since 1968

At the beginning of the sixties, it became apparent from the increasing changes in the appearance of the lake, (in particular the development of algal films on the lakeshore) that even the Walensee, hitherto famed for its purity, would suffer a fate similar to the majority of the other pre-Alpine lakes, which were already eutrophic to some degree. At the end of 1967, the Hydrobiology/ Limnology department of EAWAG and Canton St. Gallen Biological Laboratory Waterways Protection Board began a cooperative programme of study with the aim of clarifying the details of the eutrophication process. In 1974, due to concern for

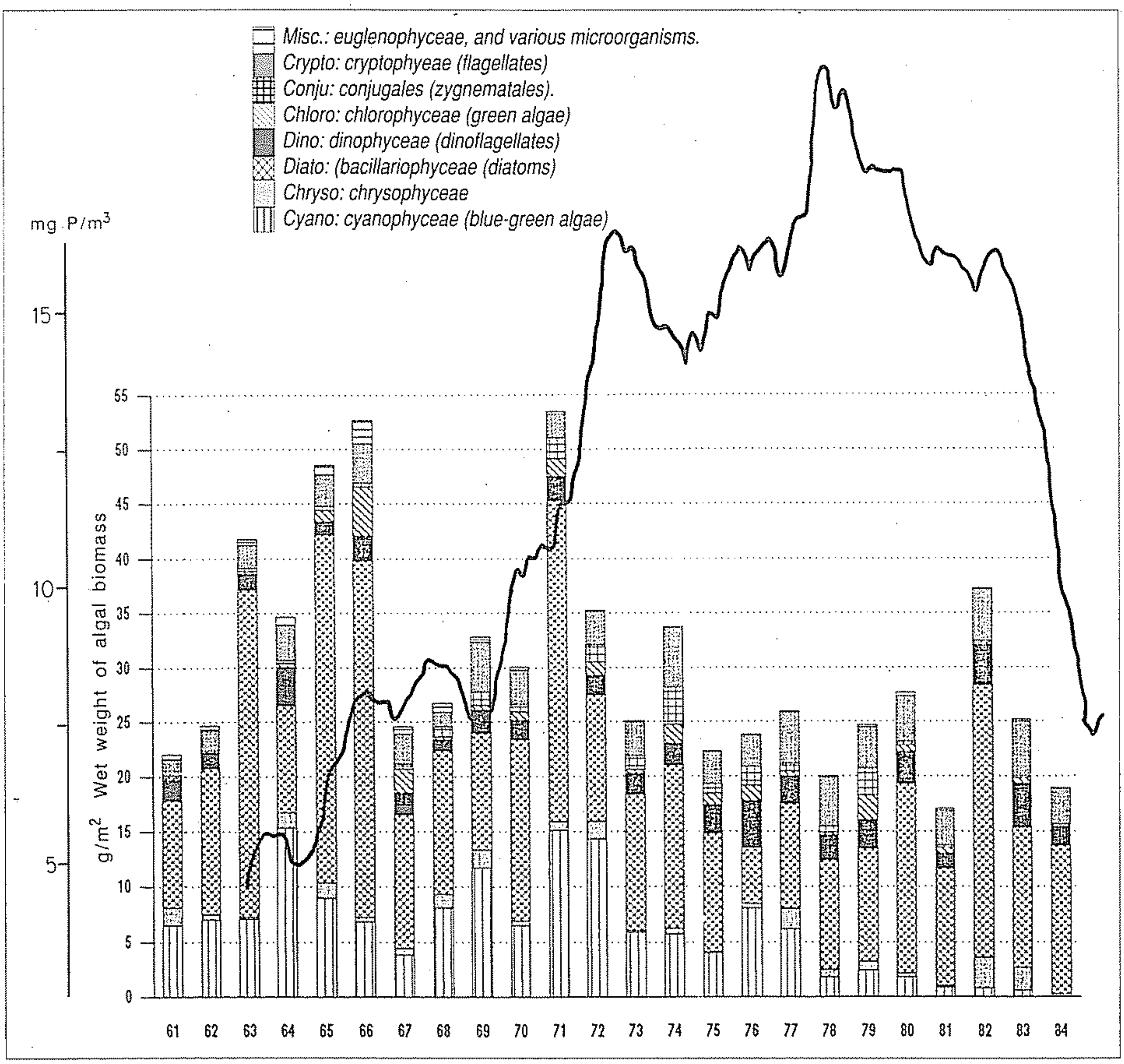

Fig. 1
The development of algal biomass and phosphorus in Lake Lucerne.
Phosphorus content (sliding mean) and annual average biomass, broken down according to algal class.

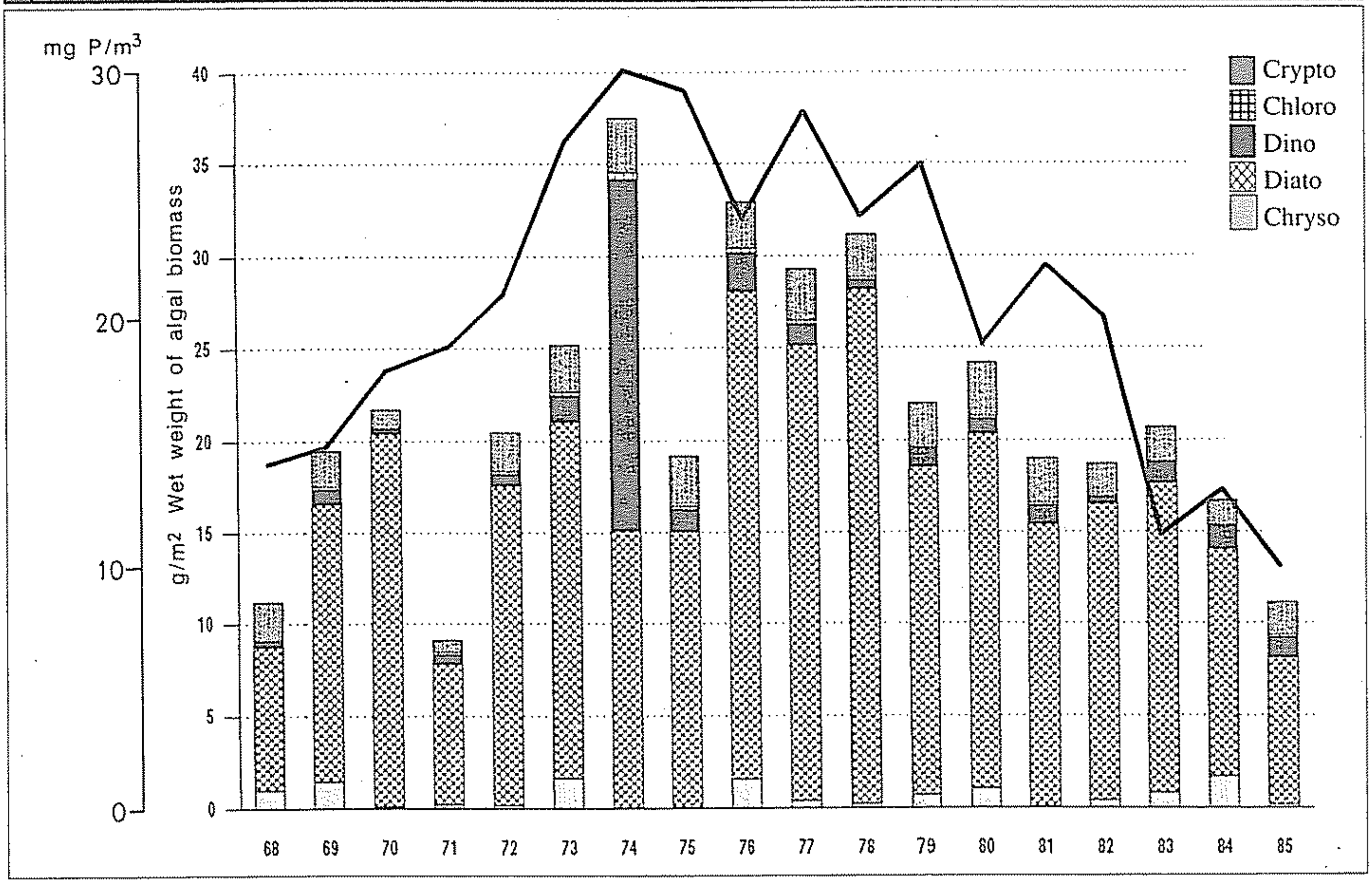

Fig. 2
<u>The development of algal biomass and phosphorus in the Walensee.</u>
Walensee: phosphorus content and annual average biomass, broken down according to algal class. Apart from green algae in the strict sense of the term, the chlorophytes here include the conjugales. The phosphorus curve links the maximum values of the phosphorus-content during the winter-turnover period.

its future use as a fresh-water reservoir, the Zürich City Water Board joined the surveillance programme with an extensive series of analyses, before finally taking over the whole programme. It proved possible to halt the eutrophication process at an early stage; blessed with regular and complete winter turnover, and a relatively low sewage input, the Walensee never passed beyond the mesotrophic stage. With a few exceptions, algal growth remained nutrient-limited [2,3].

Whilst exceptional climatic circumstances made their mark, their influence was not as great as in the case of eutrophic lakes. The most important restoration measure, apart from the legal requirement for a phosphate-precipitation stage in the water-treatment plants in the drainage area, was the re-routing of the treated effluent outflow from Glarus so that it discharged into the lake exit, rather than the lake itself.

None of the lakes in this study demonstrated the link between phosphate, biomass and oxygen as clearly as the Walensee (which may serve, for example, as a criterion for definition of oligo- and mesotrophic lakes). The algal species list has hardly changed during roughly 20 years of observation. Plankton analyses from the turn of the century and the thirties already showed the clear dominance of pennate diatoms. The contribution from flagellates, and blue-green and green algae was never large, only the chrysophytes and dinophytes ever, temporarily, forming a higher proportion of the total biomass. As a consequence of the moderate eutrophication of the lake, centric diatoms, and green algae increasingly extended the range of algal species. In 1974, at the height of the nutrient pollution burden, the dinophyte *Ceratium hirundinella* caused the first major disturbance of the plankton structure. After the nutrient burden fell, the species list did not return to its previous form, although the biomass did decrease to the 1968 level. Possibly, there was not enough time for the plancton ecosystem to react to the relatively sudden fall in the nutrient burden by altering the biocoenosis.

The Walensee provides a textbook example of the reaction of the system to nutrient input.

Here, this led to the substitution of large summer and autumn maxima for the slight maxima characteristic of the previous, fairly minimal seasonal biomass fluctations. These maxima were the first features to disappear after the reduction of the nutrient burden. The spring maximum, which relies on nutrient supplies made available during the winter turnover period, persisted until 1982. Overall, an increase in the nutrient supply caused both a prolongation and an earlier start to the main growth period.

Clear-water stages as a result of overgrazing of the algae, analagous to those observed in lake Lucerne, were only evident after large zooplankton populations had developed. At first, this stage appeared later than in other lakes, (June/July) because of the lower water temperature; towards the end of the observation period it appeared slightly earlier.

Because of the long-term stability of the algal levels in the lake, it is possible to observe cycles of individual algal species (which were described as algal calendars [4]) which are swamped by the vagaries

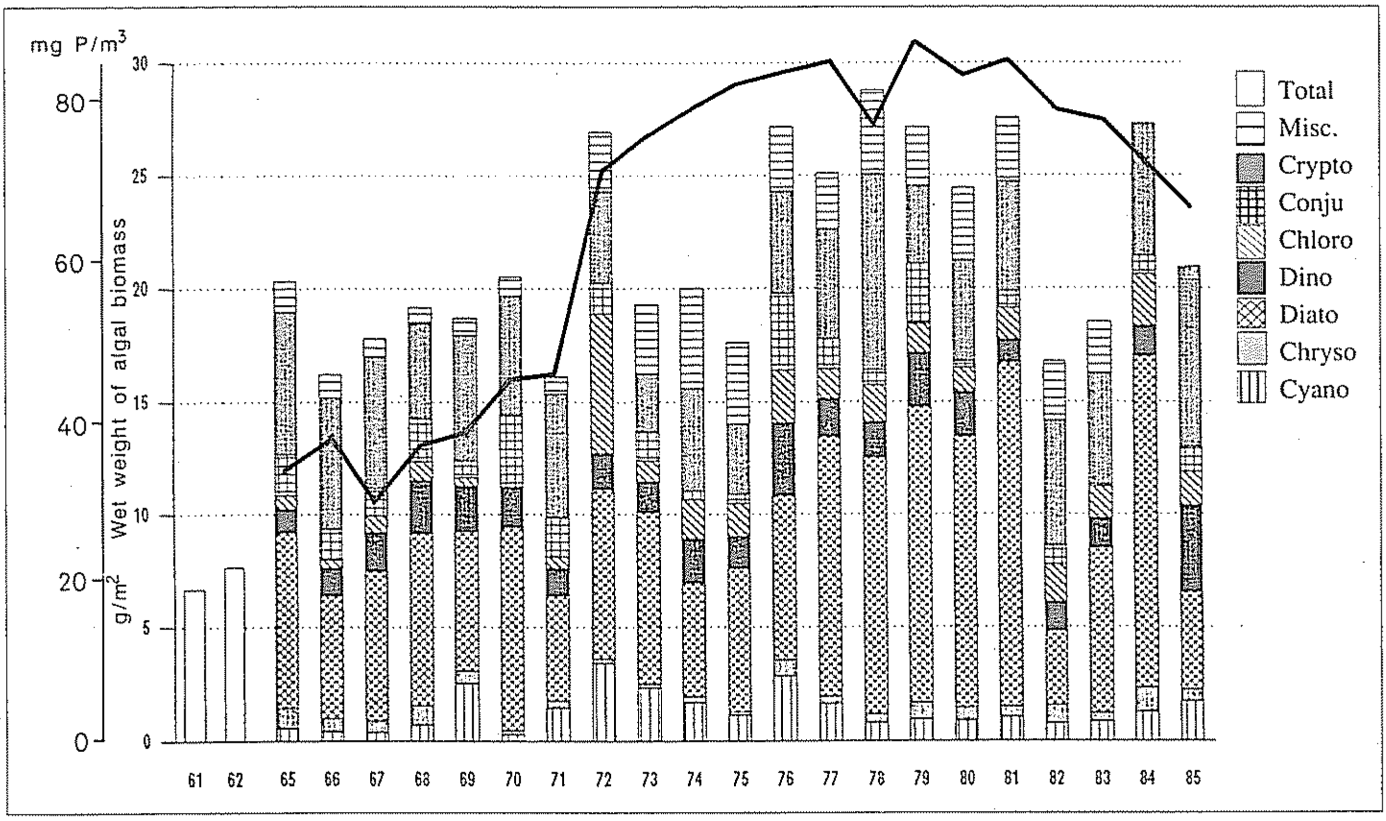

Fig. 3
The development of algal biomass and phosphorus in Lake Constance.
Lake Constance: annual average biomass, broken down according to algal class (after IKGB). Biomass data for the months of January to March were not available for the calculation of the annual average values for 1965, thus the value given is probably too high. The annual average values for 61/62 are not broken downinto algal classes in the IKGB report of 1961/62. The phosphorus curve is based on the average phosphorus content at the time of complete turnover.

of the weather in other lakes, thus the chrysophytes' three- to four-year cycle, for instance, is now a rare example.

The Development of Lake Constance since 1961

In the fifties, the nutrient situation in lake Constance deteriorated drastically. Because of the significance of the lake as a fresh-water reservoir, in 1960 the International Commision for the Protection of Lake Constance (*Internationale Gewässerschutz-Kommision zum Schutze des Bodensees, IGKB*) was founded, and within a year a broadly-conceived programme of study was set in motion. The results of the investigations were published both in scientific journals [5,6] and annual reports. EAWAG contributed to a number of study groups.

With a theoretical residence time for the total water volume (50km^3) of ca. 4.4 years, lake Constance constitutes a relatively inert system. Thus, it is surprising that the plankton system, in particular the zooplankton [7], reacted very rapidly to the reduction of the phosphate burden in 1980. Although the average phosphate concentration is still ca. 65mg/m^3, and thus 3/4 of its maximum value, considerable changes in the species list have occurred. *Mesocyclops leuckarti*, which was nearly completely excluded ten years ago, has reattained its 1963 levels. The algal biomass trend, particularly in the summer, is also downward. The annual average plankton biomass, and the pattern of the fluctuations of plankton biomass over any given year, both still show considerable variability. Exceptional years such as 1963 (lake froze over), 1970/71 (low rainfall and mild winter), 1976 (very dry for first half of the year), and 1983 (summer and autumn sunny with low rainfall) have left their traces: incomplete turnover, and thus inadequate oxygen transfer to the deeper waters, or increased incident sunlight, improved the conditions for growth, leading to increased production (partly in the following year). Thus, the lake is still far from the goal of a phosphate-limited system.

The Development of the Greifensee since 1973

The Greifensee, which as early as 1960 hit the headlines with unflattering pictures of blue-green algae, (so-called "algal bloom"), has shown a continuously decreasing phosphate concentraion since 1972. The average phosphate content decreased from its peak value of 500 mg/m^3, to values below 100 mg/m^3; however, this is still approximately four times the critical limit. Redissolution of phosphate from older sediments has reached a minimum, only the reserves from recent sediments being available for mobilization during the still regular anaerobicity of the deeper layers. Since all sewage treatment plants in the drainage area are equipped with a fourth purification stage, further improvements in water treatment technology are hardly possible: further progress will only come through the most careful agricultural methods, and rehabilitation measures within the lake.

In spite of enormous improvements, the biology of the lake has scarcely reacted; only the duration of the biomass maximum has decreased somewhat. Several massive growth surges still occur annually, accompanied by corresponding periods of water-colouration. Although the algae bringing about algal blooms increased recently, the tendency for algal blooms is declining in comparison to the condition 20 years ago.

In general, the absence of algal bloom in the above-mentioned lakes is probably a corollary of the N/P-ratio, which has increased as a result of the concentration of water treatment measures on the reduction of phosphate: Thus, nitrogen-limited situations, which are possible in highly-eutrophic lakes in summer/autumn, no longer occur, and nitrogen-fixing blue-green algae have lost their selective advantage. In the Greifensee, they have been replaced as the dominant species by green algae; cryptomonades are also present at above-average levels. In spring, diatoms are important, but summer growth can be silicate-limited in the Greifensee, since silicate input is not as high as in the case of the Alpine lakes whose drainage areas contain siliceous rocks.

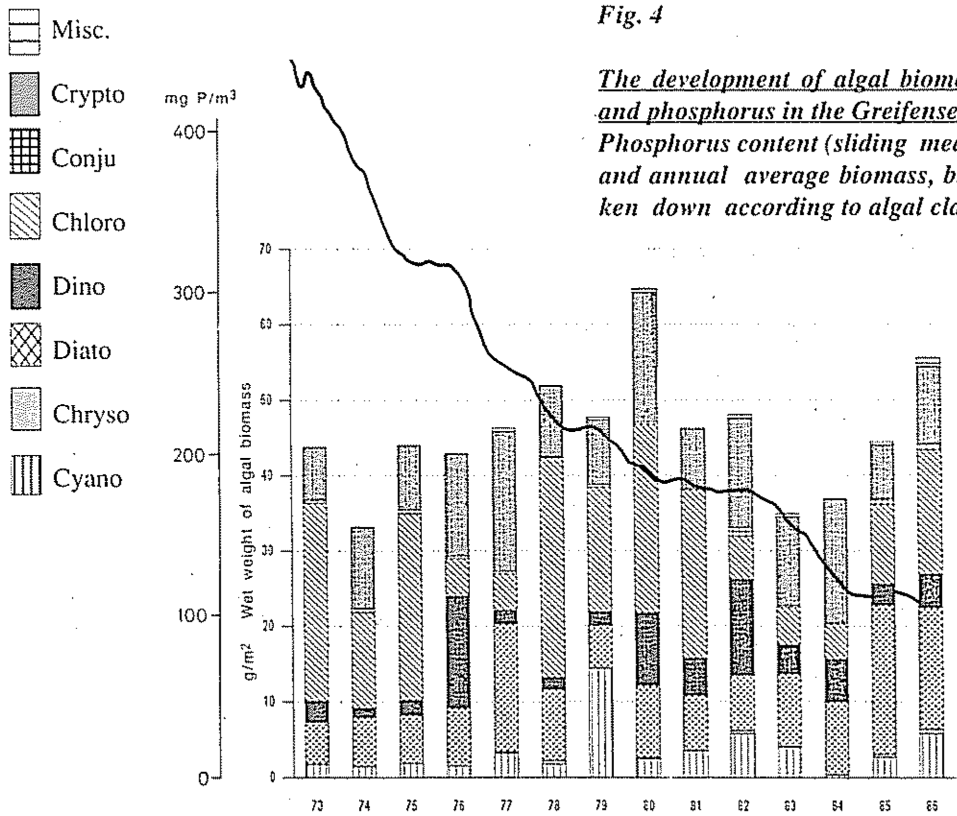

Fig. 4

The development of algal biomass and phosphorus in the Greifensee. *Phosphorus content (sliding mean) and annual average biomass, broken down according to algal class.*

Conclusion

Even in their reaction to nutrients, each of the lakes behaves differently. In particular, the structure of the biocoenosis (disappearance of key species, excess zooplankton, etc.) plays a rôle in determining the course and speed of any improvements. Even in an oligotrophic lake, true P-limiting is only possible once the P-reserves from the winter turnover have been exhausted. As the P-input is reduced, the period of P-limited growth extends backwards from late summer ever further towards spring.

The condition of the restored lakes has changed, fundamentally, even where the total phosphate-input is unchanged: in many sewage treatment plants, heavy rainfall, such as appeared repeatedly in 1987, leads to the activation of storm water overflow, whereas the plants are most efficient during dry weather. Therefore, nutrients now flow into the lakes intermittently, where previously the input was continuous, though at a low level. This allows different species to benefit, such as small algae capable of rapid reproduction. The range of species and the algal biomass may react very differently to changes in the nutrient supply. The whole trophic structure is influenced by supply at this fundamental level; partly indirectly via the dependent parameter oxygen.

Insensitivity of algal production to the effects of exceptional weather conditions during the period of maximum growth could serve as an indicator of complete recovery of the lake.

The intensity and frequency of clear-water periods resulting from biological interactions, point to a high availability of the algal food source during the zooplankton proliferation stage, since the bridging of the period between light- and nutrient-limited algal growth and zooplankton proliferation, which only begins at higher water temperatures, requires an elevated nutrient input in April/May. The reserves from winter turnover are exhausted relatively rapidly; spring algae are not famed for a thrifty attitude towards nutrients.

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GEOLOGICAL FINGERPRINTS OF CLIMATE HISTORY:
A COOPERATIVE STUDY OF QINGHAI LAKE (CHINA)

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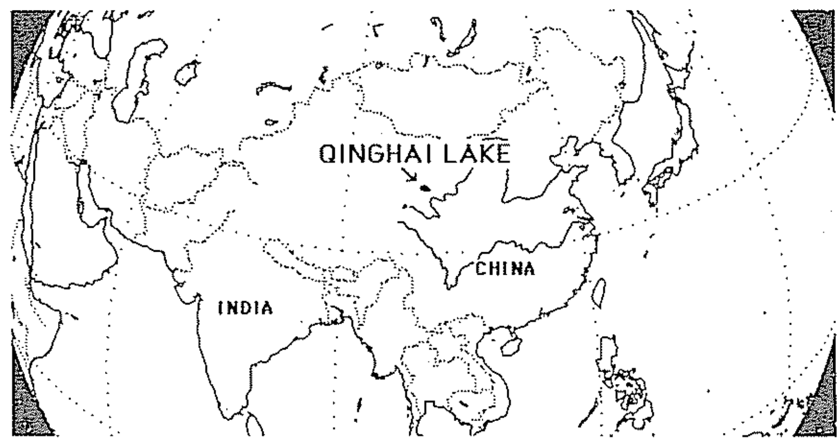

Fig. 1

<u>Location of Qinghai Lake within the Asian context.</u> Qinghai Lake is a closed-drainage lake located at 3194 m above sea-level in an active tectonic basin on the north-west corner of the Tibet-Qinghai Plateau of Central China. It covers 4635 km², up to 27 m deep with a brackish bitter magnesium-sulfate-rich, saline (14 g/l total dissolved solids), alkaline brine.

ABSTRACT

In 1985 an EAWAG/ETH limnogeological expedition to China's largest inland lake recovered seismic profiles and piston cores to help calibrate paleoclimate models of monsoon and insolation fluctuations over the northern Tibetan Plateau since the last Glacial maximum. The study is part of an international effort to understand how slow global warming may cause abrupt change of climate through a series of environmental feedbacks.

This was the first expedition to provide a set of continuous Late Quaternary-Holocene lake cores from the vast Qinghai Plateau.

Seismic profiles revealed a complex topography with channels, irregular bedding, tectonic-tilting and desiccation stages all buried uniformly under 5 m of flat-lying Holocene sediment.

Piston cores recovered a record of over 13'000 years with sedimentation rates from 0.25 to 0.7 mm/yr. Calcium carbonate content proved a sensitive monitor of lake environments and ranges from 20-85%. Radiocarbon dates by accelerator mass spectrometry provided a chronological framework. Sedimentation responds with higher resolution to climate change than vegetation.

Preliminary results suggest low levels in Qinghai, during the same early Holocene interval with intensified monsoon activity in Africa.

1. PAST AND FUTURE ENVIRONMENTAL CHANGE

The aim of this report is to aquaint readers of EAWAG News with an unusual lake which supports a unique ecosystem and holds an important record of environmental change. Often, new impulses from the study of unusual systems provide inspiration for understanding the limits of our more familiar ecosystems.

We are entering into a new era of environmental geology research where it is increasingly important to evaluate geological archives in terms of their relevance for understanding global changes on scales of decades to centuries.

Lake sediments are one of the high resolution archives on a regional scale that can be used to test various scenarios of climate change currently under development. Lake deposits also help us understand feedback processes on a regional scale. Nature has already carried out many short term experiments. In lake sequences, we can look closer at the resulting transitional zones in order to determine the magnitudes and rates of change that are possible in the natural environment. Precision dating and correlations are necessary to determine the synchroneity of events.

Lithology and sedimentation rates also change in response to environmental shifts.

How do we reconstruct past climate? Pollen has been one traditional tool. We now also have a plethora of sedimentologic and geochemical tools which can add higher resolution information. In order to properly interpret the indirect climatic signals held in lake sequences, it is imperative to understand how environmental signals are stored in lake sediments. Which signals carry what information? How can integration of numerous signals provide a clearer environmental picture or better models?

Modellers generally prefer to simulate stable periods whereas geologists prefer to focus on contacts that represent rare events and transitions in the record. Bringing the two together is time consuming. Modelers may run a global simulation on one weekend. In contrast, the field program and subsequent detailed lab work on cores necessary to test only one grid point will consume several dozen man-years.

2. EXPEDITION OF 1985

In late summer 1985, a 3-year cooperative limnogeology project between the EAWAG section Geology, the Geol. Inst. of the ETH and the Salt Lake Research Institute of the Academia Sinica in Xining, China, commenced with a 6-week expedition to Qinghai Lake. Approxi-

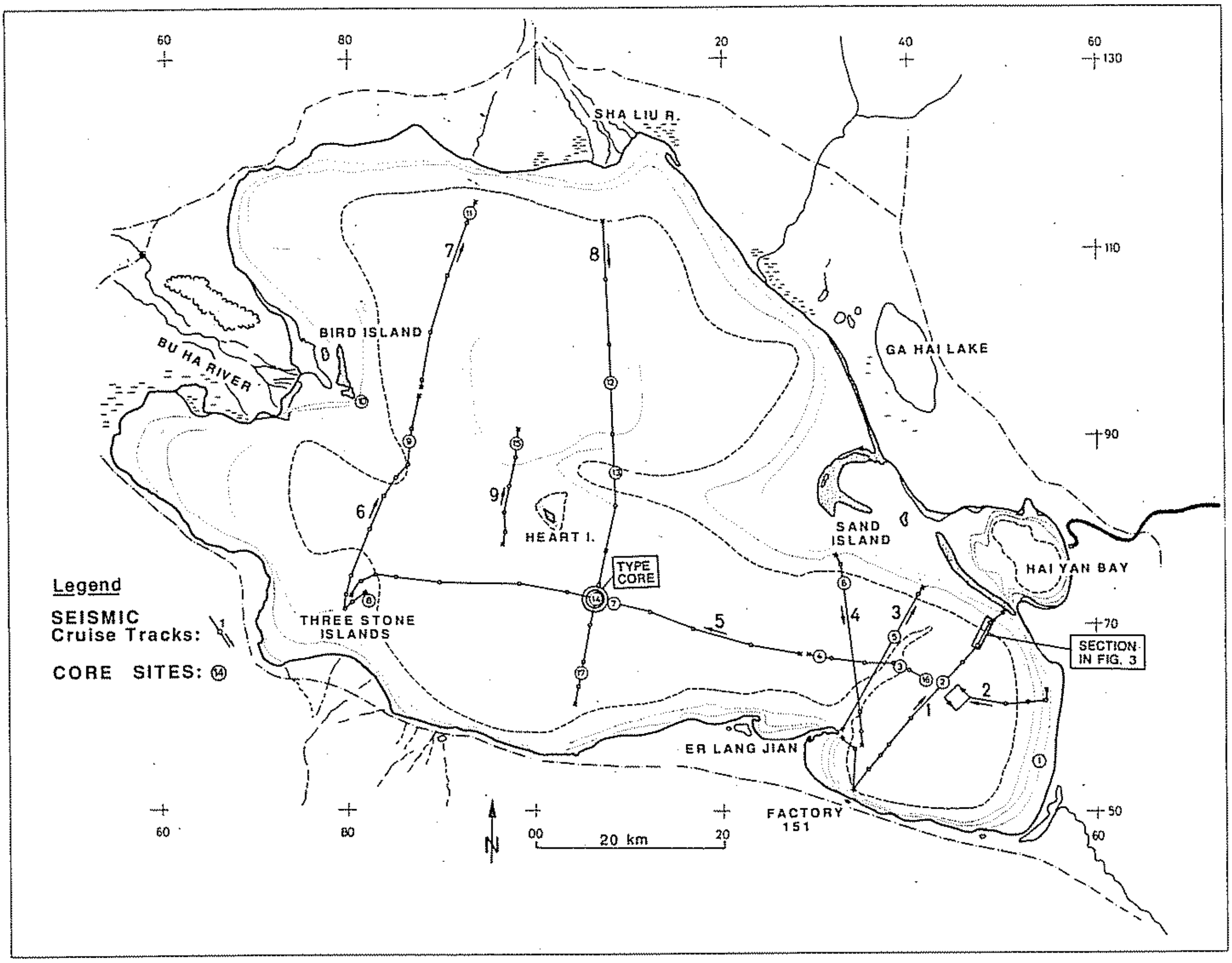

Fig. 2

Qinghai Lake bathymetry with cruise tracks for seismic lines and coring sites of the 1985 Sino-Swiss limnogeological expedition
Contour intervals 5 meters. Note location of typecore 14 and the short section of seismic profile 1 in Fig. 3.

mately 500 kg of ETH limnogeology equipment accompanied the expedition participants on the 66 hour train journey from Beijing to Qinghai.

Considerably more than the initial reconnaissance goals were completed. The Salt Lake Research Institute provided a 90-ton research ship for 22 persons on a 10-day coring cruise as well as a faster boat for seismic surveying. Approximately 500 km of high-resolution 3.5 kHz seismic profiles showed three separate basinal areas with evidence for several high and low lake level stands in the uppermost 30 meters of sediment (Fig. 2). We used the seismic results to select 17 coring sites for our gravity core system (1 meter samples) and another triplicate site for sets of 6-8 meter piston cores [1].

3. Importance of Qinghai Lake

The Plateau of Tibet-Qinghai (Fig. 1) is considered to be one of the most important continental regions controlling global climate. A stable low pressure center (caused by summer heating) influences the vital motions of monsoonal winds. Until our team cored Qinghai Lake we had no continuous records for the entire Qinghai region which show how the present climatic patterns fluctuated on decadal to century scales during the Late Quaternary. Global circulation models predicted decreased monsoon activity during the glacial maximum due to lowered sea levels and increased albedo in Tibet.

Qinghai-Tibet data are also important to European researchers trying to predict climate changes, especially the future feedback mechanisms of a rise in atmospheric trace gases.

The Chinese cooperation thus provided a unique opportunity for another EAWAG/ETH partnership in addition to regular exchange visits of researchers with our Chinese colleagues. Qinghai is an underdeveloped region with immense natural beauty. Our cooperative results provide a scientific basis that will help to protect the delicate ecological balance of this region and lake.

Chinese authorities are gravely concerned about the rapidly decreasing water levels (2 m in 15 years) and increasing salinity. Major fisheries and economic development are at stake. It is not unusual for EAWAG/ETH to participate in such international endeavors. Long years of pioneering research on the Swiss lakes have led to an unmatched expertise for sampling technology, a profound understanding of lake systems and of how environmental signals are transferred into the sediment record.

There are several reasons why Qinghai Lake provides ideal conditions for a paleo-environmental analysis:

- A major study of the lake was made by the Chinese in 1960-62. This comprehensive geological, limnological, and zoo-

Table 1.
Physiographic summary of Qinghai Lake and basin. (Mainly based on the years 1960-61 after the report of the Academia Sinica, 1979 [2], with modifications from our own 1985 observations marked with *)

Location	99° 36' to 110°47' E
	36° 32' to 37° 15' N
Elevation *	3196 m
Max. Length	106 km
Max. Width	63 km
Perimeter	306 km
Lake Area	4635 km^2
Catchment Area	34950 km^2
Ratio Catchment/ Lake	7.5
Max. Depth *	27 m
Average Depth *	ca 17.5 m
Volume of Lake	85.45 x 109 m^3
Total dissolved solids *	14.15 g/l
Hypolimnion summer around	6°C
	surface frozen Dec.-May
Annual runoff-input:	
surface	1.6 x 10^9 m^3 (frozen Dec.-May)
groundwater	0.6 x 10^9 m^3 (estimated)
Annual Precipitation	
north shore	377 mm
south shore	395 mm
Average annual temperature	0.9 to 2.7°
Ann. Evaporation	
north shore	1433 mm
south shore	1487 mm
Atm. pressure (annual average)	690 mm Hg
Modal wind directions	dominant from W and NW
Average annual sunshine	3640 hrs (70-80%)

Table 2
Water Chemistry of Qinghai Lake. (After Academia Sinica, 1979 [2], for 1961, and Chen KeZao and Tang, pers. comm. 1986)

	1986 (July)	1961
pH	9.21	9.1-9.4
Total dissolved solids	14,150 mg/l	12,489 mg/l
Na^+	3750 mg/l	3258 mg/l
K^+	157 mg/l	146 mg/l
Ca^{++}	13 mg/l	9.9 mg/l
Mg^{++}	798 mg/l	821 mg/l
Mg^{++}/Ca^{++} ratio	61	83
CO_3^{2-}	518 mg/l	419 mg/l
HCO_3^-	689 mg/l	525 mg/l
SO_4^{2-}	2380 mg/l	2034 mg/l
Cl^-	5847 mg/l	5274 mg/l
Br	2.7 mg/l	
Li^+	4.65 mg/l	3.7 mg/l
SiO_2		0.35 mg/l
HBO_3^-		12.8 mg/l
Sr^+		0.37 mg/l
PO_4^{3-}		0.02 mg/l
NO_3-N		0.036 mg/l

logical monograph provides a comparative framework [2].
- The presence of an endemic fauna suggests that the lake has been isolated over thousands of years.
- Carbonates occur as a variety of precipitates and benthic ostracods are abundant. The samples thus can be analysed isotopically for palaeo-hydrology,-temperature, and -productivity.
- In spite of the remoteness, the lake has excellent harbor, ship and barge facilities.
- The lake is located within the convergence zone of two climatic belts, and should sensitively register subtle interactions which are not continuously recorded in neighboring, more arid regions.

4. Qinghai Basin and Lake

Qinghai is one of China's largest provinces with 720'000 km^2, but sparsely populated. It comprises broad, sediment filled basins between narrow mountain ranges. It is tectonically active with abundant evidence of major strike-slip faulting, block-tilting, recent folding and rapid uplift [3]. Qinghai Lake lies in one intermontane basin at the northeastern corner of the Tibet-Qinghai plateau, about 1800 km inland from Beijing (Fig. 1). Most of the region has an alpine, continental climate with intense sunshine and a short frost-free season. Temperatures can vary 40°C between day and night. The drainage basins are treeless and arid with 100 to 550 mm annual precipitation [4]. The Qaidem Basin (2899 m above sea level.) to the south, is a large, (200 000 km^2), extreme playa desert with a vast, wind-swept salt crust [5] and includes rich potassium chloride brines in Dabuxin Lake. The capital, Xining City (2244 m a.S.L..= above sea level) has about 400 mm precipitation per year, 2600 mm evaporation and extended hours of sunshine with a low-humidity continental climate.

The "Bright Pearl" Qinghai Lake (Blue Sea) also called Koko Nor, lies at 3194 m elevation, surrounded by stately snow-capped mountains up to 4500 m a.S.L. The current lake covers about 4635 km^2. We measured a maximum water depth of 27 meters. Most of the lake is more than 16 m deep, with only a thin littoral rim.

The water is brackish salty (14.1 g/l), alkaline (pH= 9.3) and undrinkably rich in magnesium and sulfate (see Table 2). Sodium and chloride are dominant ions (Na-Mg-Cl-SO_4-type brine). Summer epilimnion temperatures reach 12-15°C (rarely to 19°) with a hypolimnion of less than 6° C. The lake has meter-thick ice cover for up to 5 months and is thus dimictic with brief stratification in high summer and in winter (under the ice). Strong winds from NW are common. The total dissolved solids have increased irregularly from 11 g/l measured in the 1920's [6] to the current 14.1 g/l.

Limnological framework

The following briefly summarizes the limnological findings of the Academia Sinica study of 1960-1962 [2] and [7]:
Transparency ranges from 1 to 10+ m.

The lake contained 35 phytoplankton genera (15 Bacillariophyta, 4 Chlorophyta, 4 Pyrrophyta, 6 Cyanophyta, 2 Chrysophyta, and 1 Euglenophyta).

Pelagic diatoms (*Cyclotella* dominant) accounted for 32-

89%, mainly in summer, followed by dinoflagellates 3.5-50%, dominant in winter.

Protozoans form 80% of the zooplankton in fall with *Strombidium, Strobilidium, Arcella, Difflugia, Didinium* and *Vorticella* in concentrations of 420 per liter. Rotifers include *Pedalia, Brachionus, Colurella (dom.), Mytilina* and *Notholca*. *Cladocera* include *Moina, Daphnia*, and *Chydorus*.

Macrophytes include abundant sessile *Cladophora fracta* colonies with *Rhizoclonium* which together form long green patches 0.5 m thick, 1 m wide and 100 m long.

Biomass reaches more than 50 g/m^2 wet weight .

Algae have profound effects on the bottom morphology and sediment trapping.

Chara are rare whereas *Potamogeton pectinatus* forms minor fringing swamps.

Gelatinous, mucilaginous and filamentous microbial mats are common along the rocky shores of Qinghai Lake. These are probably responsible for the thin aragonite crusts on most beach pebbles.

Nematodes are reported from Qinghai as are the *Oligochaetes Nais sp, Paranais sp*, and *Limnodrilus helveticus* estimated as 1.68 % of the biomass. Shells of gastropods, bivalves or other bioclastics are notably lacking from the modern shorelines although reports include some gastropoda: *Radix ovata, R. lagotis, Glabe pervia, Gryaulus groleri*, and *Choanophalus sp.* [2].

Ostracods are the most important component of the benthic community and include several endemic varieties. Qinghai Lake has dense populations in the bottom waters with up to 15 individuals per liter. Cm-thick sediment layers comprising mainly ostracod shells are common in cores and probably result from gentle winnowing of bottom sediments.

Chironomid insecta are very cosmopolitan. Seven species of Tendipes (Chironomus) occur in Qinghai. *C.gr. reductus* is most common (70%) with *Psectrocladius, Procladius, Psilotanypus, Cryptochironomus, Heptagia*, and *Cricotopus gr. silvetris*. In terms of biomass, chironomids also form a significant part of the benthos.

Fish are abundant but dominated by a single, bone-rich, naked-carp (Gymnocypris grzewalski) which is endemic in the system and forms the basis of commercial fisheries. In addition there are minor quantities of three types of loaches (*Nemachilus sclaropterus, N. alticeps* and *N. dorsonatalus*).

The islands provide welcome roosts and protected breeding grounds for Cormoran and a wide variety of fowl migrating long distances in Asia. Overall, total productivity of the Qinghai Lake waters seems low, in concert with low nutrient concentrations and a short growth season [7].

5. Results of the 1985 expedition

5.1 Seismic Investigation

We used the ETH-Geology 3.5 kHz ORE seismic profiler with an EPC 1600 digital recorder. Sound pulses were transmitted at one second intervals with ship speeds of about 10 km/hr. The profiles display high resolution (ca.15 cm) and penetration up to about 30 m. The lake bottom has a morphology with a narrow, abrupt littoral zone and a broad flat basinal area (Fig. 2 and Table 3). In some basinal areas, rills and mounds about 50 cm high, and on the order of 20-50 m by 100 m, occur aligned E-W with the dominant wind directions. Wave cut terraces were found at about 4 m depth.

Profiles show the lake divided into three main basins (N-, S-, & E-basins) by ridges uniformly at about 16 m water depth, which are capped with calcareous tufa (Fig. 2). The Er Lang Jiang Penninsula extends NE underwater as one typical, strongly asymmetric ridge with a sharp cliff to the west. Cliffs also occur along the E-W ridge that extends from the Buhar river mouth along the northern edge of the East Basin. These cliffs are thought to represent fault scarps because they can be linked to geomorphological expressions of active tectonics along the foothills.

Profile 1 (Fig. 3) provides a N-S cross-section of the East Basin that displays seismic stratigraphic features typical of the lake. The uppermost 6-10 milliseconds (4-6 meters) comprises generally parallel, closely-spaced reflectors. On close inspection some of these pinch and swell, but in general, the series (H-Series) seems to represent dominantly pelagic deposition in a perennial lake. A strong, planar reflector (we call the Q-reflector) defines the base of the H-Series. This widespread boundary appears to correlate with an unconformable layer of hard mud which stopped piston cores, and which represents a period of very low lake levels. It possibly is evidence of a playa or desiccation horizon that was swept planar by high winds. These winds may also have driven the large sand dunes along the northeast edge, cutting off Hai Yan Bay.

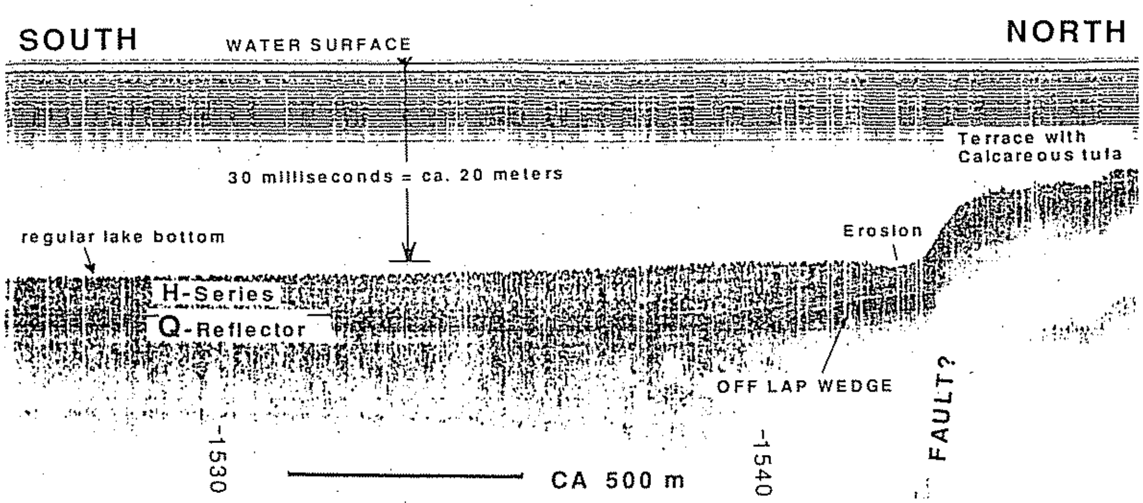

Fig. 3

Seismic profile Nr. 1 showing the Q reflector at about 5m depth, in the sediments. ***Other layered sediments visible down to about 20 m subbottom. Location given in Fig. 2. Tilted, offlapping beds below.***

Beneath the Q-reflector, echos are more diffuse. Irregular steps in two horizons suggest the presence of some channeling, possibly in an ancient soil or tundra cover. Although echos are weak, there are also some intervening layers with parallel reflectors that may derive from older lacustrine deposits.

Our seismic profiles provided important documentation of neotectonic tilting of the basin, and provide a tool for eventual dating of the most recent movements. Beds dip progressively towards the fault scarp along the northern basin boundary. The scarp ridge displays evidence of current erosion along its base. Progradation of the lake depo-center towards the north clearly shows that the main movements predates the formation of the Q-reflector.

Table 3
Depositional subenvironments of chemical and biochemical deposits in Qinghai Lake Basin: a hydrologically-closed, perennial lake.

SUPRALITTORAL:
Relict beach ridges with aragonite coated cobbles and pebbles. Some traces of calcareous shell debris.

INTRALITTORAL:
Beach-rock: aragonite cemented sands to gravels. Beds dip gently from shorelines beneath the lake. Recent origins as shown by cemented anthropogenic relicts.

Calcareous silts and muds with crust fragments. In some restricted lagoons evidence for recent dolomite, hydromagnesite and magnesite.

EULITTORAL:
Laminated or bioturbated muds. Rare tufa.

PELAGIC PLAIN:
Laminated aragonite muds with abundant calcitic ostracode shells. Massive aragonite tufa crusts along ridges.

5.2 Piston cores

We chose the Site 14 (Fig. 2) as an initial type locality because this site displays characteristic seismic features. Duplicate sets of piston cores up to 5.5 m long were taken in plastic core liners, cut into 1 m sections and sealed for transport. After whole core measurements of magnetic properties, the core sections were cut, photographed and described. Coulometer analyses of calcium carbonate is one of the most rapid and sensitive records of the environmental state of a lake. Therefore, an undisturbed strip was subdivided into 1 cm samples for a high resolution carbonate profile (Fig. 4). Other samples were selected for stable isotope, mineralogical and dating analyses.

A precise dating framework is the key to a reliable paleoclimate reconstruction. Samples of 2 to 20 g were selected from critical beds and sieved at 63 microns after gentle disaggragation of sediments. Fresh-looking seeds (mostly of the aquatic plant Ruppia) or algal threads were hand-picked under a binocular microscope and cleaned. Graphitization in HTP capsules followed the procedures of [8]. The paucity of well-defined organics provided only 5 samples to date. Samples were mounted on copper targets and measured at the Accelerator Mass Spectrometry facility at the ETH Inst. for Middle Energy Physics. Results are given in Fig. 4 and Table 4.

Lead-210 was analysed at EAWAG from short cores representative of each basin in order to determine sedimentation rates for the last 200 years [9]. The results varied from 0.4 mm/y (0.022 g/cm^2/y) in the North Basin to about 0.6 mm/y (0.033 g/cm^2/y) at the type locality in the South Basin and a somewhat higher 1.19 mm/y (0.062 g/cm^2/y) in the East Basin where high winds pile up waters and cause return flow.

Three main sedimentary units (A,B, & C) are distinguished in core 14 (see Fig. 4):

Unit C (ca. 13 500 to 10'000 years BP) includes a basal subunit (C3) of hard, gray, homogenous mudstone with 30% carbonate, sulfide pigment and bioturbation. This is interpreted as an arid, cold period, loess-derived deposit in a shallow swampy saline environment. There is a thin, burrowed sand at the top of this layer that suggests erosion. This is overlain by 40 cm of a subunit C2, comprising clastic laminations resulting from seasonal input during a wetter episode from about 11 000 to 10 000 years BP . The subunit C1 is a mottled, white, 20 cm transition zone that changes from less than 30% carbonate to 85% carbonate, and from mainly calcite-aragonite to almost pure dolomite mud [10]. This must represent the drawdown and concentration of a large water body.

Unit B (ca. 10 000 to ca. 6 000 yrs BP) comprises calcareous sediments, rich in diverse carbonates (60-95% $CaCO_3$) including dolomite and aragonite mud and aragonitic crusts, winnowed ostracod laminae, and algal varves, as well as characteristic reddish laminae. The interval is interpreted as deposits of a warmer, humid period with shallow, fresh to brackish to saline lake fluctuations.

Unit A (ca. 6 000 BP to present) comprises greenish-gray, banded aragonite muds (40% $CaCO_3$). The subunit A3 interval displays multiple upward-shallowing cycles. Subunit A2 is more uniform, with ocasional thin laminae, and subunit A1 represents the recent history, with bands of sulfide pigmented aragonitic mud and episodes that show low angle uncon-

Table 4.
Results from AMS radiocarbon dating from core QH85-14b.(ETH-AMS Facility)

Section/cm	Total depth interval (cm)	average depth (cm)	Material	Age years BP
1. 1/47.5-4.9	47.5-49	48.3	Algal	1780±23.2
2. 4/81.5-83	339.5-341	340.3	Seeds	8400±130
3. 5/21-22.5	382-383.5	382.7	Seeds	9730±130
4. 5/26-34	387-395	395	Seeds	9870±170
5. 5/77-79	438-440	439	Seeds	10900±250

formities due to bottom currents. In general Unit A is interpreted as representing brackish-to-saline lake conditions similar or deeper than the lake of today.

6. Discussion

Our preliminary publication [11] provides a more complete treatment of the evidence that Qinghai Lake sediments appear to hold the intact record of this large region. On a millenial scale, the chronological and sedimentary framework allows some general conclusions partly based on comparisons with other, more punctuated records of paleoclimate on the Qinghai Plateau. The resolution of century-scale variation must await detailed analyses.

The cold, dry climate is mainly a result of Quaternary tectonic uplift of the plateau and Himalaya mountains. During the glacial maximum, worldwide drops in sea level put the shorelines along the outer shelf edge, for example, in the South China Sea. This limited the possible sources of moisture transfer to the already arid Qinghai Plateau [12]. The deepest sediments penetrated by our cores are estimated around 13 500 years BP, but these do not show evidence of meltwater from major ice masses. Instead, they possibly document cold saline swamps receiving wind blown dust. During equivalent times, sedimentation in Swiss lakes was still dominated by proglacial varves. We suggest that the flat Q-reflector in Qinghai Lake may stem from planation by high winds during a cold arid Late Glacial that also contributed to loess deposition.

From 10 900 to about 10 000 years BP, the conditions of the lake freshened, and we believe the lake levels rose. Coarser grained, rhythmic clastic laminations are explained by a seasonal meltwater signal This period is the only time slice recovered by our cores that may represent a short overflow stage with lake levels over 150 m above the present. Europe at that time was experiencing a sudden climatic set-back known as the Younger Dryas.

Around 10 000 years BP conditions changed radically with a sudden increase in carbonate content and presumedly salinity. Sand and silt was replaced by fine carbonate mud with a bioturbating bottom fauna. The abundance of dolomite is a problem. As a larger water body concentrated, the already high magnesium to calcium ratio would have increased and presumedly promoted the precipitation of dolomite in concert with a highly alkaline environment. From 10 000 years BP onward the lake remained a closed hydrological basin.

For the period 10 000 to about 6 000 years BP, sediment structures, reworked sediment, and the presence of several carbonate crusts indicate that the lake went through near-desiccation cycles several times. While lake levels were very low, the effect of seasonal precipitation was concomitantly higher, and thus the lake was not continuously hypersaline. Indeed a tolerant ostracod population suggests that frequently, conditions during the early Holocene were brackish. Reddish, ferric mineral coloration of algal and clastic laminae may derive from weathering conditions in the basin that were different than today; for example, higher summer humidty. The interpretation remains speculative because this color could also derive from reworking of older red beds that outcrop in some local areas. Warmer mid-Holocene climates are however documented in southern Tibet by increases in Quercus (oak) pollen [12], and tree pollen in our Core 14. Many lakes in northern Tibet became closed basins, with salt lakes around 9'000 years BP followed by higher levels in mid-Holocene.

From 6'000 years BP to the present, the sediment character shows relatively steady conditions that do not differ greatly from today. The carbonate content curves however show the presence of a high frequency variability and some events that must be deconvolved with high resolution dating. For example, there are 7 cyclic drawdown-units of 20 cm each between 6 000 and 4 000 BP that could represent periodicity on a multiple century scale. A positive around 4 000 yrs BP and a negative carbonate excursion around 2 000 yrs BP may be linked to superregional events.

The steady lowering of lake levels is reflected in the uppermost few centimeters of core as a strong signal of more oxic conditions at the sediment water interface. The seismic records also suggest some scouring by bottom currents. Weather patterns suggest decreasing temperatures over the last decades with little increase in precipitation [12]. This instrumental record is however very short. Banding patterns on a 10 cm scale in short cores suggest that present trends may be part of a natural cycle which must be noted in ancient historical records.

7. Conclusions

Long lake sediment cores can be used to attack problems of both local and global importance. We have identified 5 major longterm paleoclimatic goals to guide further research on the Qinghai set:

1. Define trends and estimate rates of fluctuations in the lake level and salinity on a scale of hundreds of years. These are important for the industrial development of the region. Presently the lake level is dropping and salinity rising at rates causing great concern.
2. Obtain a record of recent loess deposition which may provide keys for time-correlation with salt deposition in Qaidem Basin to the west of Qinghai basin.
3. Test predictions of Milankovitch*-based computer models on the transfer of moisture to Tibet-Qinghai as a result of monsoon variations in intervals over the last 25 000 years. These may contribute to an understanding of the apparent lack of an ice cap in the Late Wurm (Isotope Stage 3/2) for Tibet-Qinghai, and/or a test whether Tibetan glaciation was in fact a trigger for world wide glaciation [13].
4. Clarify models of organic carbon production, sedimentation, facies, and preservation in stressed, shallow, brackish-saline, and unusually high-magnesiumrich system. Qinghai lake is widely quoted in China as a modern analogue of their ancient oil-rich continental deposits.
5. Provide another link in ETH-lake archive network of the Late-to-Post Glacial transition which now encompasses diverse lakes (Swiss Lakes; L. Urmia, Iran; Great Salt Lake , USA; L.Van, Turkey and L. Bosumtwi, Ghana).

Global lake level fluctuations

Numerous studies have shown that African basins have experienced large fluctuations in area, level and hydrology during the Late Quaternary-Holocene. The most striking feature is generally parallel development in many basins, with aridity between 17 000-12 500 years, and extensive lakes between 12'500 and 5 000 years. A south to north shift from 12.5 to 9 ky, is thought to follow Milankovitch cycles (i.e. [14]).

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* Milankovich theory relates to the effects of changes in the earth's orbitaal parameters as a control on glacial cycles

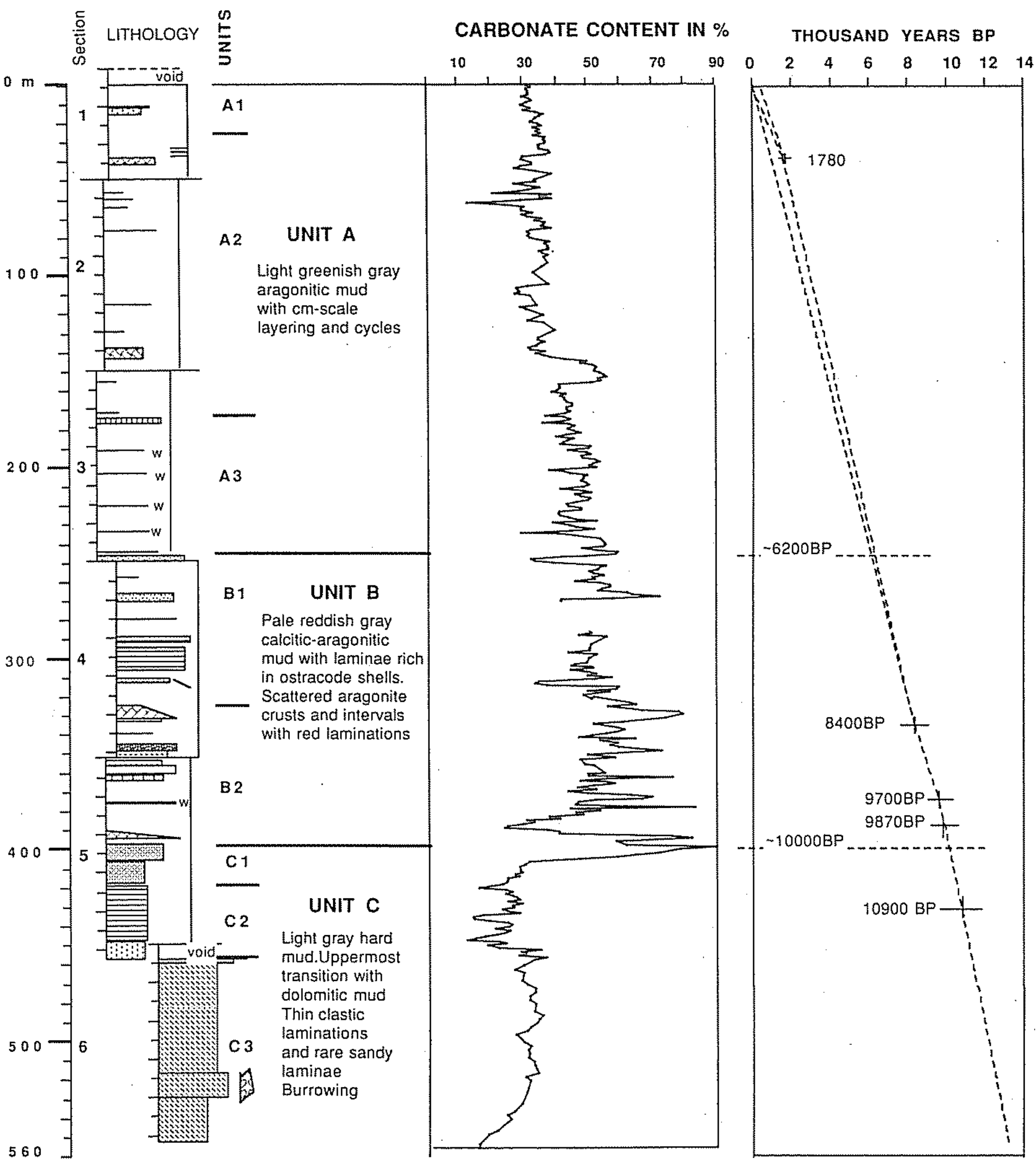

Fig. 4

Type-core Nr. QH-16b with combined logs for lithostratigraphy, calcium carbonate contents and radiocarbon chronology from accelerator mass spectrometry.

The reliability of many C-14 dates remains however insufficient to link synchronous developments into a global network. Qinghai lake hydrology is thought to reflect some monsoon influence. On a millenial scale, the record at Qinghai lake would appear out of phase with Africa with low level during early Holocene. However, this would seem consistent with Kutzbach and Otto-Bleisner [15] who predicted that a strengthening of monsoon over Asia would narrow the zone and leave Qinghai with a moisture deficit.

Further work in progress will focus on the record of episodic climate/hydrological anomalies.

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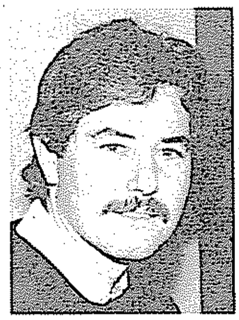


Dr Kerry Kelts, sedimentologist, head of the section Geology at the department of Multidisciplinary Limnological Research and Earth Sciences.

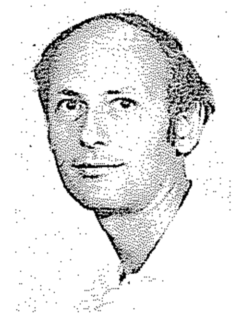
Announcement:

Climate, our future

(Main author: U. Schotterer). This book exists already in german (ISBN 3-259-08394-4, Fr. 38.-, 160 pages, Kümmerly +Frey, CH-3001 Berne), italian and french (ISBN 3-259-08395-2). The english edition (for which Dr Kerry Kelts is responsible) is due by end of 1988.

News about EAWAG Collaborators

Doctoral degrees *honoris causa* for Prof. *Werner Stumm*



Prof. *Werner Stumm* was awarded the degree of Doctor techn. (honorary) by the Royal Institute of Technology, Stockholm, for his research achievements in aquatic chemistry and surface chemistry in November 1987, and the degree of Doctor of sciences (honorary) by the University of Crete in June 1988.

Dr *Jürg Beer* (Dr. Peter Santschi's successor) has studied physics at the Univesity of Berne with special emphasis on the application of radio-isotopes in geosciences. He now became *head of the group Radioactive and Chemical Tracers* (*RCT*, formerly section of radiology) in the new department of Environmental Physics.

Chemviron Carbon Award 1988

Dr Christoph Munz, EAWAG

Out of 30 submitted papers, the prestigious 1988 Chemviron Carbon Award (created in 1976 by Europe's leading manufacturer out of a concern for environmental issues in the whole area of water treatment and purification) was presented to *Christoph Munz, Jean-Louis Walther, Markus Boller and Ralph Bland* on July 18, 1988, in Brighton, UK, for their excellent work on the *Layered Upflow Carbon Adsorption (LUCA) for the Removal of Trace Organic Contaminants*. This new mode of operating activated carbon adsorbers for the removal of chlorinated hydrocarbons was investigated in a pilot plant in Porrentruy, Switzerland, and will be implemented in the future drinking water treatment plant for the town of Porrentruy.

Dr Markus Boller, EAWAG

Conventional fixed-bed adsorbers are completely filled with activated carbon from the beginning of operation. The activated carbon is therefore exposed for prolonged periods of time to the natural background organic matter or DOC. Accordingly, the carbon can become preloaded with DOC, or fouled, which in turn reduces the efficiency for removal of trace organics such as pesticides, phenolic compounds and chlorinated hydrocarbons.

In contrast, in the LUCA mode of operation the carbon is added sequentially layer by layer, at a time determined by the effluent concentration of a given trace organic compound. The average time of exposure of the carbon to the natural DOC is thus significantly reduced. Consequently, higher loadings of the trace organics on the relatively fresh carbon are achieved throughout the entire filter depth.

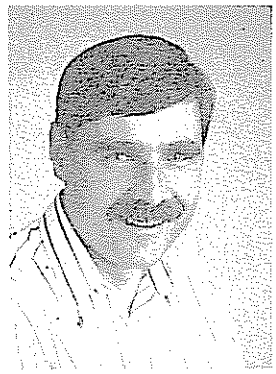
Jean-Louis Walther, engineer, Hofmann, Robadey et Walther S.A., CH-2900 Porrentruy)

At the end of the period of operation the LUCA filter will have retained a larger total mass of trace organics, and will have processed significantly more water while using the same amount of activated carbon as a conventional fixed-bed adsorber. While in the pilot plant investigation 50% more water could be treated, the full scale LUCA filters are expected to approximately double the throughput compared to a fixed-bed adsorber operated under similar conditions.

Ralph Bland, engineer, Hofmann, Robadey et Walther S.A., Porrentruy)

Dieter Imboden appointed as Professor for Environmental Physics at ETH.

With Dieter Imboden, a very colourful personality has been appointed as professor for ENVIRONMENTAL PHYSICS at the Federal Institute of Technology (ETH) in Zürich. For his colleagues at EAWAG and his students at ETH, his appointment seemed only a logical consequence of his distinguished scientific career and of his large devotion to teaching. However, it took a tempting offer from the University of Heidelberg in Germany to make ETH realize that it could not afford to lose such a valuable person.



Who is Dieter Imboden? After studies in physics in Berlin and Basel, he obtained a PhD in theoretical physics with Prof. Walter Baltensperger at ETH in 1971. In the same year, he joined EAWAG. Obeying an unwritten law given by our director, Prof. Werner Stumm, he soon left EAWAG again to spend the "compulsory year" in the USA. Working with the well known chemical oceanographer and geochemist, Prof. Harmon Craig at the Scripps Institution of Oceanography, he acquainted himself with the use of tracers for studying physical processes in the aquatic environment. Back at EAWAG in 1974, he was promoted to one of the three leaders of a new department for multidisciplinary limnological research (MLF), a position that he has held until very recently. Now, as a consequence of his appointment as a professor at ETH and because of other developments at EAWAG, he will be the head of a new department: the DEPARTMENT FOR ENVIRONMENTAL PHYSICS. A presentation of his new department will be given in the next issue of the EAWAG NEWS.

In his work, one of the major concerns of Dieter Imboden has always been to relate physical to biological and chemical processes in the environment. This has led to close collaborations with biologists and chemists. Together with his colleague René Gächter, he has made important scientific contributions to the area of lake eutrophication, and he has become one of the top experts for lake restoration in Switzerland. With his work on mixing processes in lakes and on the mathematical modelling of aquatic systems, he has also gained an excellent international reputation as an environmental physicist and modeler. As a teacher, he has developed courses in aquatic physics, and in mathematical modelling, and he is responsible for a program in which engineering students at ETH are taught about various environmental problems. He has also played a pivotal role in the development of the new program in environmental sciences that has started last fall at ETH (see page 19).

Dieter Imboden, the perfect professor for the field of environmental sciences? Considering his past activities and his personality, one is obviously tempted to answer this question with yes. In any case, because of his great versatility and his ability and willingness to interact with people from various disciplines, he will be an important "motor" for the future development of environmental sciences in Switzerland.

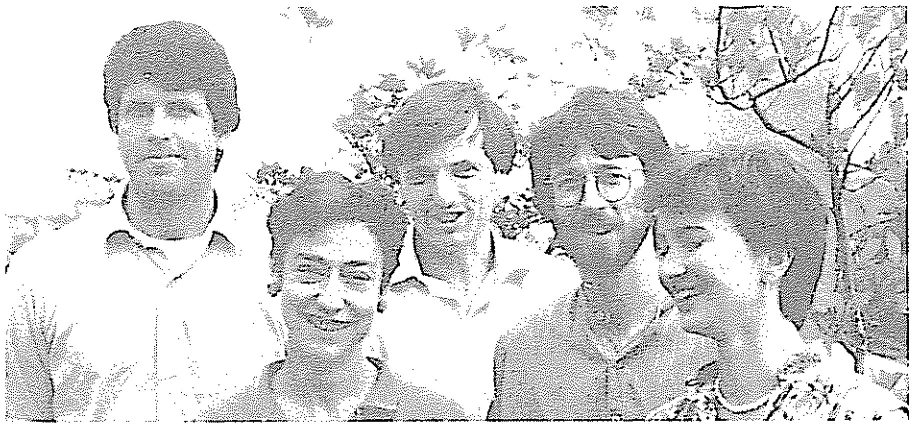
On behalf of all my colleagues at EAWAG, I wish him a successful future as a professor at ETH, and I wish EAWAG that Dieter Imboden will continue to keep his great interest in this institution.

René Schwarzenbach

Ecotoxicological Research at EAWAG

'Ecotoxicology is concerned with the toxic effects of chemical and physical agents on living organisms, especially on populations and communities within defined ecosystems; it includes the transfer pathways of those agents and their interactions with the environment.'

(Definition given in 'Principles of Ecotoxicology', G.C. Butler (ed.) 1978)



From left to right:
Giulio Genoni, Renata Behra, Herbert Güttinger, Karl Fent and Maja Lukač

More than ten years ago, the importance of research in ecotoxicology had already been recognized not only by some excentric individuals, but by a considerable part of the scientific community. It was widely appreciated that human toxicology was no longer appropriate to solve all the anthropogenic pollution problems, and that studies dealing with acute toxic effects did not provide full answers to questions about long-term disturbance of whole ecosystems.

The past years of ecotoxicological research revealed the complexity of the problems, the necessity of a multidisciplinary approach and the lack of overall concepts which are urgently needed to provide guidelines for scientists dealing with applied as well as basic problems of pollution.

To enhance the ongoing effort in ecotoxicological research at EAWAG, Prof. W. Stumm has engaged a new group of collaborators. They are all experienced scientists and had not been working in the field of ecotoxicology before their appointment at EAWAG. From the confrontation of their disciplinary scientific background with the problems of ecotoxicology as encountered at the EAWAG, new ideas toward a more conceptual approach should emerge. The group has not been integrated into an existing EAWAG-team in order to allow its members more freedom to develop their own projects within the scope of EAWAG research objectives.

Hereafter the group members are introduced and their scientific background as well as their specific interests in ecotoxicology are indicated:

Renata Behra: Biochemist, Ph. D. thesis at the University of Zürich on the biosynthesis of mitochondrial proteins, and postdoctoral research on the role of introns in tRNA genes. Her main ecotoxicological interest is the study of the effects of long-term exposure to low doses of metals on cell damage at the molecular level and their mechanisms, with the aim of linking early biochemical responses to late pathological effects, and thereby predicting the impact of metals on the health of populations.

Karl Fent: Ph. D. in biology at the Institute of Zoology, University of Zürich, involving a field study in the Sahara on the mechanism of polarization orientation, the functioning of the visual system and the behavioural ecology of desert ants. Postdoctoral work on nephrotoxicity in rats and the toxicity of interferon and interleukin at the Institute of Toxicology (ETH and University of Zürich). At EAWAG dealing with ecotoxicity of organotin. Interested in the extremely toxic trialkyltin compounds in a broader sense, and thus studying not only their toxicity to various organisms and their effects on the embryonal and larval development of fishes, but also their environmental concentrations and their chemodynamics in lake harbours and sewage treatment plants. General mechanisms of aquatic toxicity using these compounds as model substances will also be deduced.

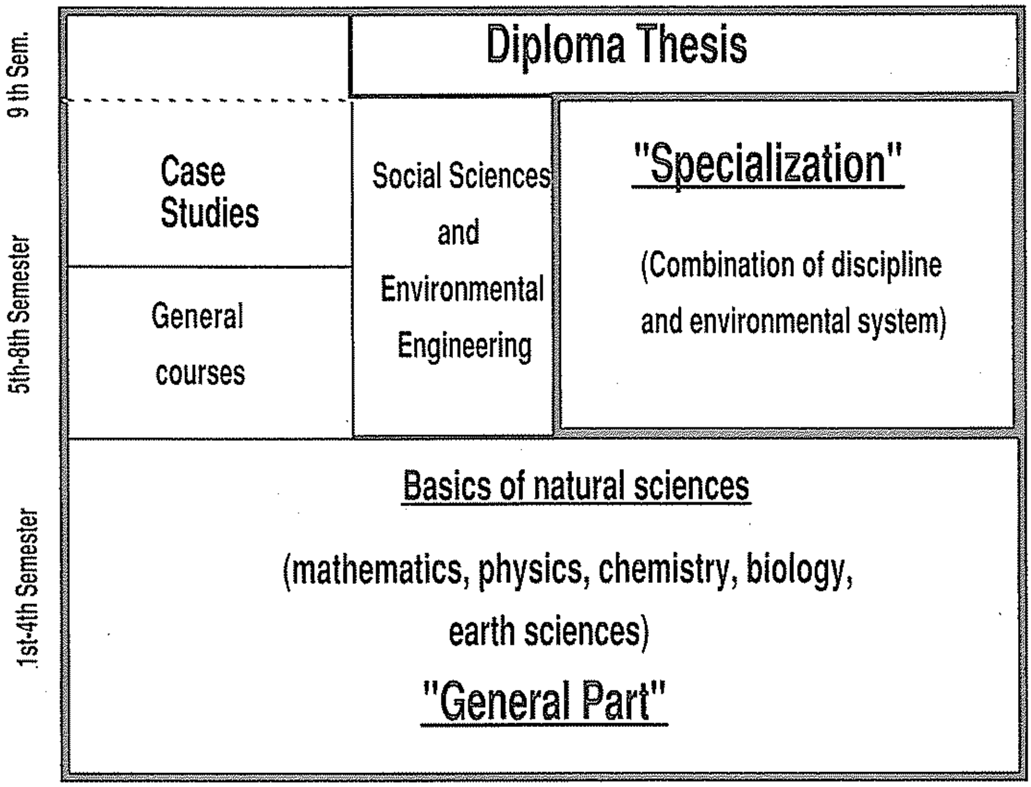
Giulio Genoni: Ph. D. from the Department of Zoology of the University of Florida, USA. Research on ecology of estuarine benthos, and particularly on how organisms may regulate other trophic levels by establishing feedback relationships, exemplified by the 'farming' of marsh grass by fiddler crabs. Participated in a study correlating a river's physico-chemical characteristics with biomass production and diversity, and fishery research integrating resource distribution, mating system and production of commercial crabs. He plans to study lake ecotoxicology, in particular the effects of toxicants at the population or community level, by developing a quantitative method for measuring disturbances in the dynamics of nutrient and energy fluxes. This model may allow to compare effects of different toxicants on a community or the effects of a toxicant on different communities.

Herbert Güttinger: Biologist, Ph. D. thesis and research projects in stream hydrobiology and the modelling of lake eutrophication. Coordination of energy research at the Swiss Federal Institutes of Technology. Presently administrative leader of the group and member of the staff of the directorate. Particular research interests lie in the fields of the application of ecological concepts to ecotoxicological problems, and the assessment of pollution and its effects at the ecosystem level.

Maja Lukač: Microbiologist, Ph. D. thesis at the Department of Microbiology, ETH Zürich, on the protein chemistry of the insecticidal delta-endotoxin of *Bacillus thuringiensis*. Postdoctoral research on the enzymology of exotoxin A of *Pseudomonas aeruginosa* by site-directed mutagenesis of its active site, at Harvard Medical School, Boston. She would like to apply her experience with bacterial toxins to algal toxins and study their biochemical and genetic regulation, especially under the influence of xenobiotica. Furthermore, she is interested in investigating the effects of xenobiotica on the cellular mechanisms of algae in general, which are an essential component of the ecosystem.

Environmental Sciences - a new diploma program at the Swiss Federal Institute of Technology (ETH)

Based on a decision taken in May 1987 by the Swiss School Board (which is responsible for teaching programs at ETH), a new curriculum carrying the ambitious name "Environmental Sciences" was started last fall at the ETH in Zurich. Instead of the expected 20-30 students, a total of about 130 registered for the new program, without any measurable decrease in the number of students in the other programs of the school. A momentary trend only? The result of a demand that had been held back for too long? It is clearly too early to predict how this "experiment" will proceed. Anyhow, most of the students who began this demanding program are continuing their studies into the second year, and it will be interesting to see how many new students will be attracted this fall.



Aim and structure of the program in Environmental Sciences

The new curriculum is designed to provide the knowledge necessary for the understanding of processes occurring in the environment. Aim and structure of the curriculum are circumscribed in the following manner:
The study is based on an integrated view of the environment and its sytems. It centers on the interdependence of the different subsystems and goes beyond the classical scientific disciplines. Specialization proceeds from this common basis. The program deals, on one hand, with the mathematical and scientific knowledge necessary to understand how man's environment functions. On the other hand, it yields insight into the various subsystems (atmosphere, hydrosphere, pedosphere, geosphere, biosphere). Correspondingly, the following goals can be formulated for the different phases of the program (see diagram).
The general part (1st to 4th semester) mainly consists of basic courses in mathematics, physics, chemistry, biology, and earth sciences. In addition, several interdisciplinary courses, an extensive lab course designed to deal with the experimental techniques of all the mentioned disciplines, and courses in social sciences are aimed to strengthen the understanding of the relationship between man and his environment.
In the special part of the program (5th to 8th semester) every student selects a combination of a particular discipline (e.g., chemistry, chemistry/microbiology, biology, physics) and an "environmental system" (e.g., hydrosphere, atmosphere, terrestrial systems, geosphere, anthroposphere). The courses in a given discipline/system combination take about 50 percent of the available time during the 5th to 8thsemester, whereby about three quarters of this time is allocated to the discipline. About 25 percent of the remaining time in the special part is dedicated to courses in social sciences and environmental engineering, and the last 25 percent are used for multisdisciplinary courses and for case studies.
Finally, the diploma thesis that is carried out in the field of the chosen discipline/system combination gives the student the opportunity to get acquainted with experimental research in environmental sciences.

The involvement of EAWAG in the new program

Quite a few collaborators of EAWAG will be involved in this program through practica, courses and the tutoring of diploma and doctoral theses. Combining this engagement with the teaching programs in which EAWAG scollaborators are already involved and with the other programs which are additionally planned (such as the program in environmental engineering), the capacity of some of the EAWAG staff will be demanded to its limits. In spite of this possible stress on the personnel and structural capacity, EAWAG must meet this enormous challenge. The program will help intensify the relationship between EAWAG and the ETH. The "settling" of new groups at EAWAG, like the new chair for environmental physics, and the growing importance of Dübendorf as a third location for ETH's activities will help us meet the growing demands in the field of environmental research in Switzerland.

Dieter Imboden and
René Schwarzenbach

A Workshop on Ecotoxicology of Freshwater Systems has been organized by Dr *Mario Snozzi* and Dr *Thomas Egli* of the EAWAG on March, 27-29th, 1988 at the University of Zürich.

1

Routes of entrance of compounds into ecosystems, Introduction by Chairman *Dr. W. Giger*, EAWAG/ ETH, Switzerland

Chemodynamics of volatile halogenated hydrocarbons, *Dr. M. Ahel*, Rudjer Boskovic Institute, Yugoslavia

Chemodynamics of nonvolatile halogenated aliphatic hydrocarbons: chlorinated paraffins, *Dr. A. Bergman*, Wallenberg Laboratory, University of Stockholm, Sweden

2

Biochemical aspects, Introduction by Chairman *Dr. A. H. Neilson*, Swedish Environmental Research Institute, Sweden

Aerobic and anaerobic transformations and degradation of halogenated hydrocarbons by microorganisms, *Prof. Dr. T. Leisinger*, ETH Zürich, Switzerland

Transformations and accumulation of halogenated hydrocarbons in higher organisms, *Prof. Dr. V. Ullrich*, University of Konstanz, Germany

3

Toxicity, Introduction by Chairman *Prof. Dr. P. Peterson*, King´s College London, United Kingdom

Primary effects: acute and chronic changes at the level of single organisms, Prof. *Dr. H. M. Bolt*, University of Dortmund, Germany

Secondary effects: population dynamics, long term stress, adaptation, development of resistence, *Dr. J. Solbé*, Water Research Centre, Marlow , UK

Quantitative structure activity relationship (QSAR) for chemicals and mixtures of chemicals, *Prof. Dr. M. Vighi*, Institute of Agricultural Entomology, University of Milan, Italy

4

Experiments in the laboratory, in the field and in model systems, Introduction by Chairman *Dr. J. Solbé*, Water Research Centre, Marlow, UK

From organism to ecosystem, key processes and key species, *Prof. Dr. Peter Calow*, University of Sheffield, UK

Perspectives of experimental model ecosystems in ecotoxicology, *Dr. Arno Rosemarin*, The Royal Swedish Academy of Sciences, Sweden

Summaries of the main lectures will be publisched by the Scientific Advisory Committee on Environmental Toxicology (SACET) of the ESF (European Scientific Foundation).

PARTICIPANTS OF THE EIGHTH POSTGRADUATE COURSE IN SANITARY ENGINEERING AND WATER POLLUTION CONTROL

(offered by the Institute for Water Pollution Control, IGW, and the Institute for Hydraulics and Water Resources Management,

First row: Emil Greber, Claudia Pahl-Wostl, Matthias Krödel, Pia Kugler, Sabine Brugger, Vincent Rebstein, Josef Tremp; second row: Joachim Guthruf, Andreas Schöll, Katrin Seiler, Peter Schwer, Markus Ammann, Stefan Haderlein, Martin Hess, Antonio Adrover-Leuenberger; third row: Albert Pazeller, Louis Egger, Homir Peric, Heiner Sturzenegger.

GUESTS TO THE EAWAG IN 1987/88

Ahel, Marijan, PhD, Chemist, Rudjer Boskovic Inst., Zagreb, Yugoslavia (June 88)

Beckett, Francis, Chemist, UK (Oct. 87-July 88)

Bruno, Jorge, Chemist, Royal Institute of Technology, Stockholm, Sweden (May-July 87)

Capri , Silvio, Chemist, Ist. di Ricerca sulle Acque, Rome, Italy (June 87).

Drever, James, Prof., Univ. of Wyoming, USA (Sept. 87-Sept. 88).

Emerson, Steve, Prof., Univ. of Washington, Seattle, USA (Feb.- Sept. 87).

Goncalves, Maria de Lurdes, Prof., Centro de Quimica Estrutural, Inst. Superior technico, Lisboa, Portugal (July- Aug. 87)

Hirschwehr, Herbert, PhD, Austria (Oct. 87-88)

Marcomini, Antonio, PhD, Chemist, Dip. di Scienze Ambientali, Università di Venezia, Italy (May-June 87)

McFeters, Gordon, Prof., Microbiologist, Montana State University, Bozeman, USA (Sept.87-Aug.88)

Nowell, Lisa, PhD., Department of Environmental Toxicology, University of California, Davis, CA 95 616, USA (Jan. 86-Dec. 87)

O'Connor, John, Prof., Univ. of Missouri, USA (July- Aug. 87)

Pavlova, Violeta, Chemist, Univ. Göteborg, Sweden (Sept. 86-87).

Pollinger, Utsa, Biologist, Prof., Israel Oceaonographic and Limnol. Res. Inst., Haifa, Israel (Aug. 87- July 88)

Ponton, Dominique, Biologist, Inst. de Limnologie, Thonon, France (Feb.- Dec. 87)

Rebhun, Menahem, Prof., Technion, Haifa, Israel (July- Dec. 87).

Schnoor, Jerald, Prof., Environmental Chemistry, University of Iowa, USA (Jan.- Feb. 87 and July-Dec. 88)
Sridhar, Mynepalli, Prof., Ing., Dept. of Preventive and Social Medicine, Univ. of Ibadan, Nigeria (Oct. 86- Sept. 87).
Stephanou, Euripides, Prof., Univ. of Crete, Heraklion, Crete (July- Aug. 87)
Wang, Ao Sheng, Geologist, Inst. Geography, Academia Sinica, Nanjing, PR China (Feb.-Sept. 87)
Xue, Hanbin, Chemist, Academia Sinica, Beijing, PR China (March 86- 87).
Yu, Jun Qing, Geologist, Qing Hai Salt Lake Res. Inst., Academia Sinica, Xinhing, PR China (Sept. 85- June 87).
Zepp, Richard, Prof., Univ. of Miami and EPA, Athens, USA (June- Aug. 87).

EAWAG-Publications

Reprints may be obtained by writing to: EAWAG, Library, CH-8600 Dübendorf

Corrigendum:

1239
Hoehn, E., Santschi, P.: Interpretation of Tracer Displacement During Infiltration of River Water to Groundwater. Water Resources Res. *23*, 4, 633-640 (1987).

New publications:

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Bundi, U.: Einführung in den Gewässerschutz: - Zum Themenbereich Wasser/Abwasser (Kap. 3/2);-Arten und Konsequenzen von Gewässerbelastungen (Kap. 3/3). In: "Abluft! Abfall! Abwasser! Neue Vorschriften und Lösungen für die betriebliche Praxis" (Hrsg.: P. Leumann, H. Eicher) WEKA Verlag, Zürich 1987

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Boller, M.: Nutrient Removal From Wastewater. 7th Eur. Sewage and Refuse Symp. EWPCA-IFAT, Munich, 19-22 May 1987, pp. 253-278.

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Sigg, Laura, Stumm, W., Zobrist, J., Zürcher, F.: The Chemistry of Fog: Factors Regulating its Composition. Chimia *41*, 5, 159-165 (1987)

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Wegelin, M., Boller, M., Schertenleib, R.: Particle Removal by Horizontal-Flow Roughing Filtration. Aqua No. 2, 80-90 (1987).

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