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Oceanography in China

A Trip Report of the American Oceanography Delegation

Submitted to the Committee on Scholarly Communication with the People's Republic of China

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The Committee represents American scholars in the natural, medical, and social sciences, as well as in engineering and the humanities. It advises individuals and institutions on means of communicating with their Chinese colleagues, on China's international and scientific activities, and on the state of China's scientific and scholarly pursuits. Members of the Committee are scholars from a broad range of fields, including China studies.

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INTRODUCTION

An oceanographic delegation sponsored by the Committee on Scholarly Communication with the People's Republic of China (CSCPRC) visited China from September 25 to October 22, 1978. The delegation's main hosts were the State Oceanography Bureau and the Chinese Academy of Sciences (CAS). The delegation's itinerary was coordinated by the Chinese Society of Oceanography.

This trip followed the visit of two Chinese delegations to the United States:

- An Oceanographic Research Vessel Delegation led by Ceng Chengkuei (Dr. Tseng Cheng-kuei), Deputy Director of the CAS Institute of Oceanography, Qingdao, in April 1978.
- A Marine Science Delegation led by Luȯ Yuru, Deputy Director of the State Oceanography Bureau, Beijing, in May 1978.

Ours was a multidisiplinary group that covered the interests of both Chinese delegations. The strongest representation was in biology (Cohen, Frankenberg, Ryther, and Wallace), followed by geochemistry (Edmond and Peng), physical oceanography (Munk and Wunsch), geophysics (Talwani), shore processes (Inman), and history and politics (Tu, Borich, and Beemer). Professor Tu is a Professor of Chinese history, Mr. Borich is a political officer at the Department of State, and Mr. Beemer is a staff member of the CSCPRC.

Our itinerary* was planned with the benefit of discussions with the two Chinese delegations to the United States. We decided to leave Beijing to the last, so that we could

*See Appendix A for detailed itinerary.

ask informed questions when meeting with government officials. We placed strong emphasis on visits to field sites, where we wanted to collect water and geologic samples, beach sand, etc., as well as the customary visits to research institute laboratories, colleges, and universities. The final itinerary, which was worked out with the staff of the Chinese State Oceanography Bureau, involved visits to areas such as the Qiantang estuary, which had been previously inaccessible to non-Chinese scientists. We were not able to visit research organizations and production units involved in marine aquaculture anywhere along the South China or East China seas, study the beaches and nearshore waters along those coasts, nor visit the important research centers at Xiamen (Amoy).

We met at Hong Kong and traveled by train to Guangzhou, where we inspected two geophysical research vessels, *Haiyang No. 2* and *Shiyan*. Inman visited the ancient harbor and shipyard and a lighthouse built during the Tang Dynasty (Figure 1). Talwani, Tu, and Peng collected some volcanic rocks in Nanhai Xian for subsequent dating. We flew to Wuhan to visit the Institute of Hydrobiology. We then traveled by riverboat, *Tung Fang Hung No. 7*, on an overnight trip down the Yangtze, to Nanjing and by train to Hangzhou, where the entire delegation witnessed the tidal bore in the Qiantang River estuary at Haining during spring tide, not once but twice (overtaking the bore by automobile) (Figure 2). From Hangzhou we went by train to Shanghai. We took a somewhat stormy 36-hour passage from Shanghai to Qingdao aboard the ocean research vessel, *Xiang Yang Hong No. 1 (Facing the Red Sun No. 1)* (Figure 3), but without taking a hydrocast. After a 4-day stay at Qingdao, we split into two groups: One group drove to Yantai and then proceeded by ship northward to Dalian before flying into Beijing; the other group journeyed by train to Tianjin and then on to Beijing, with a side trip from Tianjin to the pre-Cambrian formation near Ji Xian in the Yan Mountains.

The main institutions we visited were the CAS Institute of Hydrobiology in Wuhan, the CAS South China Sea Institute of Oceanography in Guangzhou, the State Oceanography Bureau's Second Institute of Oceanography in Hangzhou, and the CAS Institute of Oceanography and Shandong College of Oceanography, both in Qingdao. We were told that the State Oceanography Bureau's First Institute of Oceanography in Qingdao and Third Institute of Oceanography in Xiamen (Amoy) were comparable institutions in scale. But we were unable to visit either of these places, the former

FIGURE 1 Old lighthouse now located in the center of the city of Guangzhou. The coast was here when it was built during the Tang Dynasty (618-906 A.D.)

because it was being moved from the campus of the Shandong College, the latter because Xiamen (Amoy) is closed to foreigners. (Personnel from the Third Institute and from Xiamen [Amoy] University did come to Hangzhou to brief us on their work, however.) We also saw the regional laboratories of the State Aquatic Products Bureau--the South China Sea Fisheries Institute in Guangzhou, the East China Sea Institute of Aquatic Products in Shanghai, and the Yellow Sea Fisheries Institute in Qingdao. In line with the general practice with CSCPRC delegations, the scientists in the group volunteered to give a few selected lectures to acquaint their Chinese hosts with some of the current U.S. research. We found ourselves scheduled at all the places we visited for a total of 30 lectures and ended up giving more than 50! Our audiences were large and enthusiastic, and the lectures were generally followed

FIGURE 2 Tidal bore on Jiantang River, near spring tide, October 4, 1978. One hundred years ago the *eagre* ("tide swelling above another tide") was 30 feet high at Hangzhou and discernible for 80 miles upriver. Dykes and sea walls have now drained most of its energy near the river mouth.

by lengthy discussions. We estimate that in this way our delegation had some personal contact with more than 3,000 marine scientists.

Inman's interest in marine archaeology and Tu's knowledge of Chinese history were constant reminders of China's marine traditions. China's long navigable rivers and cross-country canals early made shipping a major means of transportation. The 1,665-km Grand Canal from Hangzhou in the south to Beijing in the north, for example, was begun around 500 B.C. and completed in 1293. There are records of Chinese sea vessels trading in the Philippines by 111 B.C., and Chinese ships may have visited the west coast of the Americas around 500. From 1405 to 1433, the eunuch Zheng He (Cheng Ho) led seven or eight major expeditions involving 37,000 men and several hundred ships each. By 1433 Zheng He's fleet anchored off Mecca. This appears to have been the last of the great Chinese oceanic

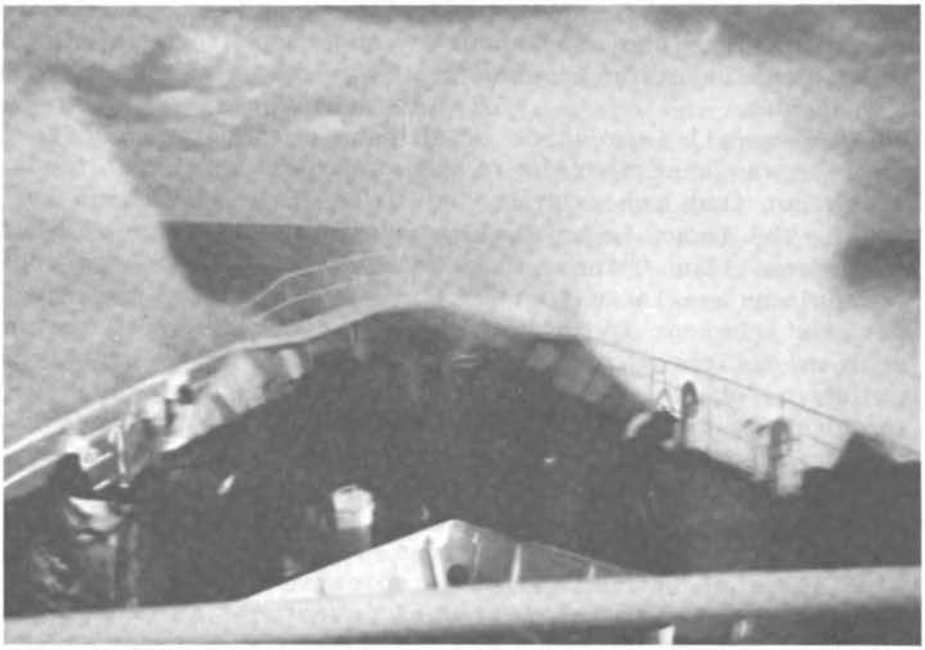

FIGURE 3 Waves breaking over bow of the oceanographic research vessel *Xiang Yang Hong No. 1* in the Yellow Sea.

expeditions. The reason for the abrupt termination remains a mystery.*

During most of our 1-month tour of China's oceanographic centers, we noticed the impact of recent Chinese policy changes favoring educational and scientific progress.† In contrast to some previous U.S. delegations that visited China during the aftermath of the Cultural Revolution (1972-1976), ours was received by professionally qualified researchers who were pursuing their work enthusiastically. Similarly, some of the college and university students we met had been admitted to their institutions because of their academic merit rather than their politics or social origins. Furthermore, at each of the places we visited, a substantial increase in staff was projected for 1985 and ambitious building programs were already under way. At Qingdao, for example, we learned that a National Research Center for Oceanography was being planned to include a

*Further information is found in Chapter 6.
†These are described in Chapter 7.

marine data base, computer facilities, and special platforms for submarines and airplanes. A second center was also under consideration for the south, perhaps at Xiamen (Amoy) or Hangzhou.

Our overall impression of Chinese oceanographic effort in 1978 was that there were adequate personnel and facilities but that research lagged 10 to 15 years behind the West. The focus is on shallow water and resource-related phenomena. The Chinese made good use of the oceanographic technology available to them, but suffered from the limitations inherent in their lack of basic scientific resources such as silicon chips, exotic alloys, and other high technology. Yet they were very interested in sophisticated measurement techniques, but sometimes failed to appreciate the practical problems that would arise in their use at sea. There was a tendency among theorists to develop elaborate analytical and numerical models that bore no obvious relation to observations. However, the uniformly high level of enthusiasm among scientists and administrators, coupled with the policy of investment in modern instrumentation, convinced us that the lag between Chinese and Western oceanography would rapidly diminish.

Before offering a few observations about the different subfields in oceanography, the type of vessels engaged in oceanographic activities, and the use of computers, we should emphasize that they are based on limited information. We did not visit every relevant institution, and in many instances we experienced difficulty in seeing data from current work.

In biology, we found that China's marine fish landings exceeded the amount estimated by the Food and Agriculture Organization. The freshwater production was also found to be very high, although somewhat lower than the total marine production. Predictably, the most impressive research we observed was directly oriented toward living resources. Most other biological research was descriptive and dealt with organism distributions and taxonomy of the national biota. Biological oceanographic theory lagged somewhat behind its Western counterpart and represented a potentially fruitful area of joint research projects between Chinese and non-Chinese scientists.

In chemistry, the Chinese focused on pollution research and instrument development. Data from work at sea were sparse and seldom available for discussion, and our general impression was that organized research had only just resumed after a long hiatus.

In geophysics, most research was applied and carried out in shallow water areas. The level of instrumentation varied. Magnetic measurements were made in nearly the same way as those at American institutions; but marine gravity measurements were somewhat behind that level, and marine seismologic measurements very much behind. Data from these measurements were not generally available for discussion, as was the case with most Chinese data pertaining to mineral resources. There was great interest in modern instrumentation, with respect both to its operating principles and its availability for purchase.

Shelf geology has obvious importance to oil exploration and to coastal engineering. However, there was not evidence of a coordinated scientific approach to the problem. Sediment studies were classically oriented towards grain size, mineralogical and heavy mineral analyses, and paleontology. There appeared to be no interaction with physical oceanography or with geophysics (which has an active profiling program). However, we did see distribution charts of the sediment properties of the shelf regions that were based on analyses of many thousand surface samples and hundreds of shallow cores. Large-scale integrated studies of this huge shelf area, involving all currently available resources and imported modern equipment and techniques, were clearly the next step.

In physical oceanography, the current Chinese focuses tend to be those with obvious applicability, i.e, tides, storm surges, waves and wave forcing, circulation and water masses of adjacent seas, and the influence of the ocean on typhoon paths. The separation between theoretical work, laboratory work, and work at sea is much sharper than it is in the United States and Europe. Some of the equipment is developed, built, and calibrated at a special institute of instrumentation at Tianjin. Many scientists are obviously eager to enter the mainstream of physical oceanography, to work in deep water, and to apply modern techniques to their observations and theories.

Shore processes are by necessity an interdisciplinary subject, requiring the collaboration of physical, geological, chemical, and biological oceanographers with the more traditional coastal engineers. China with its long (about 8,000 km) and diverse coastline, with major rivers depositing large quantities of sediments, and a growing demand for harbors and coastal structures, is in need of active research in this field. Although we saw engineering test facilities of considerable scope, the interdisciplinary research collaboration seemed to be absent. We had only limited access to the beaches and nearshore waters.

There were about 30 vessels of more than 800 tons engaged in oceanographic activities and many smaller vessels engaged in local marine studies.

The Chinese were engaged in a vigorous program of modernizing their research ships. In early 1979 they acquired two ships from the United States with up-to-date seismic and navigational equipment for geophysical research and for hydrocarbon exploration on the South China Sea shelf and slope. A large modern research ship equipped for carrying out research in various oceanographic disciplines was being built in Japan for delivery in 1981. The ship will not be confined to Chinese waters and will probably represent the Chinese contribution to collaborative international oceanography. In addition, about one-half-dozen 800-ton vessels were to be built in China by 1985.

Computers are a special problem for the development of Chinese oceanography. We saw various special-purpose Chinese-made computers at laboratories, but they were slow by current standards and lacked peripheral equipment, particularly plotters. Some computing was done away from the laboratories in regional computing centers, such as that in Shanghai. Laboratories were improving their facilities by purchase from abroad; we found a large modern Japanese computer in its final debugging stage at the Central Meteorological Bureau in Beijing, for example.

Our delegation aimed to explore the possibilities for scientific exchanges and collaborative work with Chinese oceanographers. The important policy changes that were evident during our trip and the establishment of normal diplomatic relations between our two countries soon after our return made us feel very optimistic. The prospects and opportunities for joint efforts between individual scientists, oceanographic institutions, and laboratories, made by direct as well as by government-to-government arrangements, seemed excellent.

Some of these opportunities are spelled out in this report. They include geophysical studies of the shelves of the China Sea, studies of the dynamics of shallow water circulation on the shelves, and research on inshore coastal processes. Chinese physical oceanographers are interested in the Kuroshio and look forward to conducting collaborative programs on the circulation of the western Pacific, including the mean flow and the eddy field. There are also significant opportunities for collaborative research on marine algae and for geochemical work on the large rivers of China and their estuaries. This work could be combined with studies of beach and nearshore processes. Collaborative studies of fish productivity of reservoirs and their interpretation in terms of energy flow and food chain efficiency theory could prove very rewarding to U.S. scientists, just as quantitative resource evaluation and marine ecology provide opportunities for U.S. scientists to contribute to the development of Chinese oceanography.

In any such joint efforts, it is essential to have free access to data, samples, and field sites. It is, therefore, crucial that guidelines for data and sample exchange be clearly and comprehensively spelled out in advance and that a mechanism be established for working out any problems on a case-by-case basis.

We cannot end this introduction without expressing our deep thanks to our Chinese hosts for their thoughtfulness and courtesy through our long and complex journey. One of the highlights of our trip was when we were all invited to the homes of Chinese oceanographers in Qingdao to share dinner with their families.

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BIOLOGY

MARINE FISHERIES

Although aquatic species are an important part of China's food supply, there are no precise catch statistics. The Food and Agriculture Organization (FAO) of the United Nations, for example, gave the same estimated production figure of 6 million metric tons in its annual reports between 1973 and 1978. (The FAO does not differentiate between fresh and salt water production.) Although we visited laboratories that collected regional statistics on marine fisheries (as well as on freshwater and marine aquaculture) and discussed marine statistics with personnel of the State Aquatic Products Bureau in Guangzhou, Shanghai, and Qingdao, we were not able to obtain precise, comprehensive statistics on total catches nor catches by species. Statistics were being collected on the large fishing operations, but they were incomplete.

However, marine fish production was clearly high. It was estimated that the catch for 1977 in the South China Sea and the East China Sea was 1 million metric tons each, followed by 800,000 metric tons in the Yellow Sea and 300,000 metric tons in the Bo Hai, making a total of 3.1 million metric tons. These estimated landings did not include catches by other countries. Catches in the Yellow Sea and Bo Hai by all countries, including China, were estimated at 2 million metric tons. (Japan and Korea conduct substantial fishing in the Yellow Sea, but no foreign fishing takes place in the Bo Hai.)

There were nine major fishing corporations operating along the coast, the largest based in Shanghai and the second largest in Dalian. The Oceanic Fishery Company of Dalian was a self-contained unit having its own shipyard, freezer-cold storage, 400 metric tons per day ice plant, net manufacturing plant, processing, packing, sales, and shipping. In 1978 it employed 7,000 persons, of whom 1,000 were women. They operated about 130 ships and 20 supplementary ships. (Some of the latter were 2,000 tons and capable of processing and freezing at sea.) Their annual production varied between 70,000 and 80,000 metric tons and consisted of several species of fish and shrimp. Most of the products were sold on the coast, but substantial quantities were also shipped inland. Some shrimp were exported to the United States and various other aquatic products to Japan.

The Oceanic Fishery Company divided its fishing operations among five brigades, which fished mostly in the Yellow Sea, the East China Sea, and south to Taiwan. Fishing was primarily pair trawling with each of the boats about 100 tons with 600-horsepower motors. Larger vessels up to 200 tons went further south to purse seine for mackerel, using seines about 1,500-m long and 20-m deep.

The boats generally stayed at sea 10 days or less, although supply and processing vessels supported those operating in the south. The crews were not mixed. However, there was one pair trawling team composed entirely of women. It had the reputation for working hard and making the highest catches.

Along with the trawling and seining, night light fishing was carried out in the East China Sea and Yellow Sea for mackerel and pompano-like species. The Oceanic Fishing Company also took about 300 metric tons of minke whales, which weigh from 3 to 10 tons apiece. This was described as China's only whaling operation.

Assuming that the average annual catch of each of the nine fishing companies is 80,000 metric tons, their total annual catch must come to almost 750,000 metric tons. Assuming that the remainder is caught by communes, hundreds of thousands of fisherman (using small boats of less than 25 m) must be taking about 2 million metric tons per year--an enormous catch. Unfortunately, we were unable to see this kind of small-scale fishing, because we were not given access to most parts of the coast.

In each of the three State Aquatic Bureau institutes we visited, in Guangzhou, Shanghai, and Qingdao, statistics for key species were compiled daily to aid fishermen by producing short-term predictions of fish concentrations. While some species were present in the South China Sea, the East China Sea, and the Yellow Sea, they varied in abundance. The catch composition varied from south to north in the three different seas, as did the trend in populations from species to species.

We were told several times that the trend for key species was down in the northern waters. However, we only obtained substantial information about the East China Sea. Personnel from the East China Sea Fisheries Institute in Shanghai said that most of the major species were declining. Without specifying the years involved, they said that annual catches of the big yellow croaker had dropped from 200,000 to 80,000 metric tons. Annual catches of the little yellow croaker had declined even more sharply, from 150,000 to 20,000 metric tons. Annual cutlass fish catches fluctuated between 540,000 and 400,000 metric tons, and catches of squid between 50,000 and 80,000 metric tons. Filefish catches, on the other hand, had risen rapidly since the establishment of a new fishery in 1974. In that year filefish catches in the East China Sea and southern Yellow Sea amounted to 45,000 metric tons. In 1975 the catch was 100,000 metric tons, in 1976 it was 210,000, and in 1977 200,000, with an estimated catch for 1978 of 240,000 metric tons.

Trends for key individual species were followed along some sections of the coast, but the Chinese were not able to make long-term predictions of stock sizes for individual species. The Yellow Sea Fisheries Institute of the Ministry of Aquatic Products of Qingdao was an exception. Its research director reported that the institute had been predicting annual shrimp production since about 1968 with considerable success in the Yellow Sea. Catches had varied between 4,000 and 30,000 metric tons in different years. He did not, however, explain the techniques used for making the predictions.

ESTUARINE FISHERIES

We obtained almost no information on China's estuarine fisheries, probably because they were substantially less productive than fisheries in fresh or saltwater. However, the results of one study of the Yangtze estuary were presented to us at the East China Sea Fisheries Institute at Shanghai. The study covered the river mouth to the limit of the tide 200 km upriver. The estuary had a typical mixed population of freshwater, saltwater, and anadromous species, with brackish water species predominating. Out of an average annual total catch of 9,000 metric tons, only about 400 metric tons of crustaceans were caught. The study concluded that navigation improvements, oil, and industrial pollution were having an adverse affect on the fisheries.

FRESHWATER AQUACULTURE

China has long relied on the productivity of freshwater lakes as a source of protein for human consumption. This reliance has led to the development of aquacultural practices and fish species that result in large harvests per unit area from intensively managed farm ponds. A radio broadcast from Xinhua (New China News Agency) on March 17, 1979, described the total harvest from freshwater aquaculture as having declined over the last 20 years as freshwater lakes have been drained and their bottoms converted to grain production. This broadcast was couched in pessimistic terms, but our visit provided us with data that can be used to calculate the potential harvest from China's freshwater areas, and these calculations suggest that pessimism may be an unwarranted reaction to recent declines in local harvests.

Several independent estimates have placed the total area of fresh water in China at about 20 million ha* (50 million acres). About half of that area is suitable for some form of fish culture, and in keeping with the Chinese principle of multiple, intensive use of all natural resources, virtually all suitable water areas are stocked with fish and managed to some degree.

About half of the 10 million ha of managed fresh water consists of large natural lakes or man-made reservoirs that, because of their size, receive less intensive management than small bodies of water (i.e., no feeding, fertilization, disease, or predator control). Annual yields from these larger bodies of water range widely, from 50 to 5,000 kg/ha. It seems that the smaller the lake or reservoir is, the greater the impact of management. Thus, in 1977 the annual yield of the 1,500-ha Dong (East) Lake near Wuhan was 450 kg/ha and that of the 560-ha West Lake in Hangzhou was 1,300 kg/ha.

The remaining 5 million ha of managed fresh water consist of small, intensively farmed ponds. These are mostly managed by agricultural and fish farming communes.

The smaller, intensively managed fish ponds are more productive than larger lakes and have annual yields ranging from about 1,000 to 10,000 kg/ha, averaging perhaps 3,000 kg/ha. The Qing Pu Fish Farm outside Shanghai produced 4,600 kg/ha in 1977, expected a yield of 5,600 kg/ha in 1978, and hoped to equal a nearby farm in Jiangsu Province that was reporting annual yields of 7,500 kg/ha.

Estimating yields of the less intensively managed larger lakes and reservoirs at a conservative 500 kg/ha and that

*ha = hectare

of the smaller fish farms at 3,000 kg/ha, the annual production of the entire 10 million of freshwater fish farms should amount to about 17 million metric tons. This astounding figure (nearly 25 percent of the total annual landings from all of the world's oceans) is only an estimate and needs verification, but whatever the correct number, potential freshwater harvest appears significantly greater than earlier estimates and projections made by J. J. Solecki and the FAO. Recent reports from the Chinese State Bureau of Aquatic Products state that current freshwater harvest is actually below that from marine waters.

The importance of freshwater aquaculture in China (perhaps 17 million metric tons per annum) and the apparent lack of emphasis on marine fisheries (perhaps 3 million metric tons per annum) can be readily explained when one realizes that much of the marine catch consists of less desirable sizes and species of fish than those grown in culture. Furthermore, China has logistical problems in distributing marine landings given its relatively small number of fishing ports, its poorly developed transportation system, and minimal refrigeration and processing facilities.

Aquaculture in China owes its success to several factors. First is the policy of making multiple use of aquatic resources. Reservoirs and smaller farm ponds may be constructed primarily for irrigation or domestic water supply, but they are simultaneously used for fish production. Second, fish pond culture in China has always been considered an integral part of agriculture. The agricultural and aquatic farms supplement each other in several important ways that increase yields of each component part. Finally, mixed species cultivation or "polyculture" is universally applied, with particular emphasis upon species low on the food chain.

Virtually all the fish species used in Chinese pond culture are members of the *Cyprinidae* (the carp and minnow family). The four most important are the so-called major Chinese carps or "family fishes": the grass carp (*Ctenopharyngodon idella*), the silver carp (*Hypophthalmichthys molitrix*), the bighead carp (*Aristichthys nobilis*), and the black or snail carp (*Mylopharyngodon piceus*). Smaller numbers of mud carp *(Cirrhinus molitorella)*, common and mirror carp *(Cyprinus carpio)*, crucian carp *(Carassius auratus)*, and the cichlid *Tilapia* spp. are also used.

The grass carp is a herbivore that normally eats aquatic macrophytes (both rooted and unattached and both submerged and floating aquatic weed species), but it will also feed voraciously on terrestrial plant wastes such as grass clippings and vegetable tops. Although fast-growing (5-10 kg a year or more), the grass carp is highly inefficient in its food utilization and produces large quantities of organic wastes. This material settles to the bottom and supports a community of benthic invertebrates that, in turn, serve as food for the black, common, mud, and crucian carps. The organic wastes also decompose, liberating nutrients that support communities of phytoplankton and zooplankton that serve as the principal foods for silver and bighead carps, respectively. The planktonic populations are further increased by periodic fertilization of the ponds with fermented pig manure or other organic wastes, such as those of ducks, that are often raised in the same ponds with the fish. It is the combination of polyculture, which takes advantage of every feeding niche in the pond ecosystem, and utilization of agricultural wastes that result in the low-cost, high-yield achievement of Chinese pond culture.

The major carps normally live in large river systems and are unable to spawn naturally in the stagnant farm ponds. Formerly, Chinese aquaculture depended upon the annual collection of fingerlings from their natural environment, but in 1958 the major carps were successfully induced to spawn artificially by injecting them with pituitary extract or human chorionic gonadotrophin.

By 1978, most counties in China's fish farming regions had a commune specializing in hatchery production and rearing of fry for distribution to the growout ponds located on other communes of the county. The personnel of these fishing communes were surprisingly accomplished in such fields as controlled induced spawning, selective breeding, larval rearing, disease prevention and treatment, and nutrition--areas normally thought to require highly specialized training and experience in the West. Workers at Qing Pu Fish Farm outside Shanghai, for example, told us that they could usually diagnose, treat, and cure a disease in three days and that 90-95 percent of fingerlings normally survived to become marketable adults. Staff at aquacultural communes took pride in solving problems and conducting their own independent research. The kinds of research that they could accomplish, however, were necessarily empirical and focused on immediate problems.

More basic research on freshwater fish culture problems was conducted at provincial and national-level institutes. The Institute of Hydrobiology at Wuhan, for example, conducted basic and applied research on fish breeding and genetics, disease control, and the basic productivity of lakes and reservoirs. It had successfully cultured a cyprinid herbivore, the Chinese bream *Megalobrama amblycephala*, to replace the grass carp as the essential first-stage herbivore in the Chinese polyculture system. (While the grass carp is difficult to rear in the early stages of its life cycle and is subject to severe disease problems, the Chinese bream is hardier and as good a table fish.) By 1978 the Chinese bream had been successfully introduced into fishing communes in 20 of China's provinces.

Scientists at the Institute of Hydrobiology also discovered that the nace, *Plagiognathops microlepis*, another cyprinid, is a detritus feeder. (One of the primary needs in pond polyculture is to have a detritus or humus feeder; for a long time, no species was available.) They developed techniques to propagate the species artificially in ponds so as to ensure adequate stocking fry. They found that it has several other advantages: It does not compete with other fish for food; it is adaptable to wide ranges of climate from north to south; it can be bred artificially; and it grows rapidly. By 1978 the species was widely used in many parts of China.

The same institute has also successfully crossbred several closely related cyprinids. The idea of this kind of breeding is to utilize the hybrid vigor of the first generation. The male mirror carp (*Cyprinus carpio*)--an inbred strain of the common carp--was mated with the female red carp (*Cyprinus carpio haematopterus*). The growth rate exceeded that of the parents by 60 percent. The cross has many advantages: It grows rapidly (in Guangdong 10 fingerlings will produce 7.5 kg in 18 months, 2.5 kg per year in rich ponds, and 1.5 kg per year in less favorable conditions); and it is omnivorous and has a very acceptable taste. By 1978 the cross was being used in 23 provinces.

Another successful cross mates male red carp (*Cyprinus carpio haematopterus*) with the female crucian carp (*Carassius auratus gibelio*). The cross grows to 250 g in 5 months and is flavorful and nutritious. It was successfully bred in 1977, but had not spread beyond the local province, Hubei.

The success of these genetic experiments led scientists at the institute to attempt to hybridize species that are not closely related. For example, they tried to cross grass carp and bream (*Megalobrama amblycephala*), but found that the hybrid was sterile. They tried to overcome this problem by artificial stimulation. They also tried a cold shock 5 minutes after fertilization by reducing the water temperature to 0°-2°C for 20 minutes, with limited success. However, by waiting 44 minutes after fertilization and having the cold shock last 25-30 minutes, they obtained somewhat better results. Another technique was to use cortisone treatment in a solution of 50 parts per million. By 1978 only preliminary results had been obtained and no viable progeny had been developed. Research was continuing, however, in an effort to produce a rapid-growing, disease-resistant, highly nutritious and tasty species.

The institute's ecological unit studied the productivity of China's larger lakes and reservoirs, including a 1,500-ha basin of East Lake on the outskirts of Wuhan, which they selected as a model study area. The unit aimed to determine the maximum carrying capacity of the lakes and reservoirs so that they might be stocked to that level, as well as the proper stocking ratios of different species so as to utilize all feeding niches fully. Because the lakes were recreational, they also wanted to stock the proper number of grazing and filter-feeding herbivores so as to preserve a desirable level of aquatic macrophytes and phytoplankton for esthetic purposes.

To achieve these objectives, the staff were carrying out basic studies of chemical nutrient cycling, primary productivity, and the abundance and distribution of phytoplankton, zooplankton, and benthos with the ultimate hope of developing a numerical model to predict potential fish yields. This was the only laboratory where we saw evidence of such work in progress, appreciation of the ecological concepts involved, and a working knowledge of the appropriate background literature. However, equipment, instrumentation, and methodology were, for the most part, outdated if not absent; a modest investment in that area and appropriate training to acquaint the staff with modern techniques would undoubtedly pay high dividends.

We also visited the CAS Institute of Biochemistry in Shanghai and the CAS Institute of Zoology in Beijing. They had conducted a cooperative project, involving other institutes, in which they had successfully synthesized, tested, and evaluated an ovulating agent for inducing spawning by farm fishes during the early 1970's. By 1978, this substance (an analog of the nonapeptide LH-RH) was commercially available to fishfarming communes, although the extent to which it had replaced the use of carp pituitary was not known. The synthesis of this ovulating agent was accomplished by the same laboratory at the Shanghai Institute of Biochemistry that synthesized insulin in 1965. The institute was housed in a large new laboratory building and was well-staffed and equipped with the best modern instrumentation, mainly from Europe and Japan. It was intellectually and technologically more on a par with the better research organizations in the West than any other research institute we visited.

MARINE AQUACULTURE

Unfortunately, we were unable to visit research organizations or production units involved in marine aquaculture anywhere along the South China or East China seas. We were told, however, about research under way at the coastal field stations of the South China Sea Fisheries Institute and the South China Sea Institute of Oceanography involving cultivation of the seaweeds *Porphyra quangdongensis, P. haetanensis, Gracilaria verrucosa, Eucheuma gelatinae,* and *Ligera* spp., the mussels *Mytilus edulis, M. viridis,* and *M. smarajdinus*; the oysters *Ostrea rivularis, O. plicatula,* and *Crassostrea gigas*; the clam *Arca granosa*; the penaeid shrimps *Penaeus merguiensis* and *P. monodon*; the pearl oyster *Pinctada martensci*; the crab *Erochier sinensis*; and certain finfishes, including mullet (*Mugil so-iuy*) and milkfish (*Chanos chanos*). Some of these species were apparently in commercial production. However, we did not obtain documentation of these activities.

Farther north, we observed mariculture research and production in the coastal waters of the Yellow Sea, near Qingdao, and the Bo Hai Gulf, near Dalian. In both areas the most important cultivated marine organism was the brown seaweed *Laminaria japonica*, a cold-water species of kelp introduced to China from Hokkaido, Japan. It was grown in more than 300 ha of China's northern coastal waters. Some 10,000 dry metric tons were produced each year, roughly half of which was consumed as food and the other half used to extract alginates. More than 1,000 dry metric tons per year were exported to Japan.

We also saw one of northern China's 15 kelp hatcheries near Qingdao. It consisted of two large (5,200 m^2) greenhouses fitted with shallow tanks through which fertilized, refrigerated (7°-9°C) seawater was circulated. In the spring, kelp spores attach themselves to strings mounted on frames in the hatchery tanks and develop into sporelings from 2 to 4 cm long during the summer and early fall. When the coastal seawater temperature drops below 20°C, the strings with sporelings attached are moved outdoors and attached to buoyed ropes. During the following 6 to 8 months, the plants are manually thinned, transferred to larger ropes, individually brushed to remove sediments and epiphytes, and fertilized daily. They grow to mature sporophytes ranging in length from 3 m in the Qingdao area to more than 5 m in Dalian, where the water cools more quickly in the fall and the growing season is longer. Annual production of kelp in the two areas was roughly 30 and 50 dry metric tons/ha, respectively.

A small species of red seaweed, *Porphyra yezoensis*, imported from Japan, is also grown in northern China. It, too, is reared in hatcheries during the summer months for part of its life cycle. In the Qingdao region, stock cultures of the spore-producing phase of *Porphyra* were maintained by the Yellow Sea Fisheries Institute, which provides direct services to fishing and mariculture organizations. The spores are attached to string nets in spring (as in Japan), are put out on buoyed ropes in October, and the mature plants are harvested in March-April. Annual yields of *Porphyra* are only about 0.5 metric tons/ha, much less than *Laminaria*, but the former is highly prized as a food and commands nearly 10 times the price of *Laminaria* (more than U.S. $5/lb). Yields of other, warm-water species of *Porphyra* in southern China, where the plant grows to a length of 9 m or more in one season, were presumably much greater, but data were not available to us.

The field of marine botany in general, and phycology in particular, was exceptionally well represented in Qingdao, due to the preeminance of Ceng Chengkuei and Wu Chaoyuan, respectively Director and Chairman of the Botany Department of the Institute of Oceanography and Fang Zongxi, Chairman of the Department of Marine Biology at Shandong College of Oceanography.

Varieties of *Laminaria* have been produced at the Institute of Oceanography through selective breeding and X-ray-induced mutation that improved growth characteristics and led to higher iodine content and higher temperature tolerance, the latter permitting culture to be extended south. These variations have been successfully bred through 5 to 15 generations and were available to culturists. Other scientists at the institute were studying environmental control of the physiology and growth of *Porphyra* and the biochemistry and natural products chemistry of *Laminaria*.

Fundamental research on the genetics of *Laminaria* at Shandong College of Oceanography has resulted in the production of parthenogenetic clones of female gametophytes, an accomplishment unique in the field of phycology and an important step in the ultimate genetic control and establishment of pure breeding lines of that important seaweed.

Marine fish and invertebrate culture in China is less well developed than that of marine plants or freshwater fishes. Most activity in the area was reportedly in the South China Sea region, and we did not see it.

In the East China Sea and the Yellow Sea, the large penaeid shrimp *Penaeus orientalis* was apparently grown with considerable success, although again we did not see it. According to Liu Ruiyu, crustacean specialist and Head of the Zoology Department of the Qingdao Institute of Oceanography, *Penaeus orientalis* matures sexually in captivity in holding ponds, in contrast to other penaeid shrimp species cultured elsewhere where gravid females are usually taken from the commercial fishery to obtain the young. Larval stages are hatchery reared and postlarvae grow more than 15 cm (25 g) in less than 5 months, making it possible to grow the animals to marketable size in one brief growing season. Yields of *P. orientalis* in China were not impressive, primarily because their culture depended largely upon natural food in the ponds, in contrast to shrimp culture in other parts of the world where heavy artificial feeding is practiced. However, the species has potential interest to culturists outside China.

In both the Qingdao and Dalian regions, the same fishing communes that culture seaweeds also engage in several kinds of invertebrate culture. Mussels (*Mytilus edulis*) are grown on buoyed ropes, using the same techniques developed in Spain and adopted in many other countries around the world, including the United States. About 18 months are required for the mussels to reach marketable size, and two crops a year, spring and fall, totaling about 480 metric tons/ha (shells included) are produced. This compares to some 600 metric tons/ha per year in Spain for the same species.

Smaller numbers of scallops (*Chlamys farreri*) are also grown, the juveniles suspended from ropes in layered lantern baskets. Sea cucumbers (*Stichopus japonicus*) are released on the bottom, where they live on detrital material falling from the plants and animals above. Mussels, scallops, sea cucumbers, and several other invertebrate species such as abalone, clams, and oysters are relatively recent introductions to Chinese mariculture, and, as of 1978, most were still at the experimental stage. For example, production of seed scallops at Jin Xian Aquaculture Station near Dalian increased from 1.7 million in 1977 to 7.9 million in 1978.

Production units did most of the empirical experimentation, including spawning and larval rearing in hatcheries. They were assisted, however, by research organizations. The Yellow Sea Fisheries Institute in Qingdao maintained several species of phytoplankton and provided the hatcheries with seed cultures as needed for their larval rearing. The Qingdao Institute of Oceanography carried out studies aimed at increasing production and survival of mussel spat. Cooperation between the aquaculture farms and the research institutes appeared to be close. Little, if any, distinction was made between applied and basic research with respect to either institutions or individuals, and both took pride in the direct application of their research.

DESCRIPTIVE BIOLOGICAL OCEANOGRAPHY

As of 1978 biological oceanographic research in China was almost exclusively descriptive and concerned with the distribution of organisms in a given oceanic region. Some research was being conducted on biofouling and pollutant assessment, but we observed none on primary production, trophic efficiency of marine food chains, nutrient uptake kinetics, remineralization rates, or other topics designed to elucidate functional features of marine ecosystems.

Descriptions of the distribution of organisms in various areas of the ocean near China have appeared for many years in *Oceanologia et Limnologia Sinica* and *Studia Marina Sinica*, the two major journals of Chinese oceanography. A review of biological publications in the 1977 and 1978 volumes of these journals showed a preponderance of systematics studies on samples collected during expeditions to the Xisha coral islands and the South China Sea. Other reports in these journals, and in *Oceanic Selections*, a new publication started in 1978, also reflected efforts to describe the marine biota of China. Their interest to U.S. systematists is discussed later.

However, scattered among these systematics papers were reports on the quantitative distribution of biota in Chinese seas. The 1978 volume of *Oceanologia et Limnologia Sinica*, for example, contained articles on the quantitative distribution of *Sticholonche zanclea* in the western part of the East China Sea, the geographical distribution of cephalopods in Chinese waters, and the geographical distribution and evolution of pelagic polychaetes from the South China Sea Islands. The 1978 volume of *Studia Marina Sinica* also contained a preponderance of systematics papers, but there was one article on the intertidal ecology of benthic marine algae on Hainan Island.

Descriptive studies of living resource distribution and the structure of ecological communities were beginning at many Chinese laboratories in 1978. (These followed a path blazed in 1963 by Liu Ruiyu and Shu Fengshan's ecological paper in *Oceanologia et Limnologia Sinica* entitled "Preliminary Studies of the Benthic Fauna of the Yellow Sea and the East China Sea," and the work of Professor Zheng Chong of Xiamen [Amoy] University on species abundance of planktonic copepods of the East China Sea.) For example, studies of coral reefs were under way at the South China Sea Institute of Oceanography in Guangzhou and the Qingdao Institute of Oceanography. We were told that studies of East China Sea plankton and benthic communities were being conducted by Xiamen (Amoy) University, the State Oceanography Bureau's Third Institute of Oceanography at Xiamen (Amoy), and the newly formed biological unit of the Second Institute of Oceanography in Hangzhou, which had the only marine microbiology laboratory that we visited. The Yangtze River estuary was being studied by the staff of the East China Sea Institute of Aquatic Products in Shanghai. Although the emphasis was on commercially important species, we were impressed with the ecological information collected by the staff and hoped that it would be published. The communities of the East China Sea and Yellow Sea were being studied by Liu Ruiyu and his colleagues at the Qingdao Institutute of Oceanography. At the Northeast Oceanographic Station in Dalian, Ma Shuliu was studying the plankton of the Gulf of Zhili of the Bo Hai and other staff were beginning to study benthos as part of the Dalian laboratory's major pollution program.

The beginning of quantitative resource evaluation opens a major area in which U.S. scientists could aid the development of Chinese oceanography, i.e., by advising on statistical sampling design, sampling techniques, data management, and data analysis. Modern methods used in large-scale surveys were unfamiliar to the Chinese, who could benefit greatly from knowledge of methods used in recent U.S. surveys.

BIOFOULING STUDIES

Research on biological fouling of hard substrates was included in lists of projects conducted at the South China

Sea Institute of Oceanography in Guangzhou, the Institute of Oceanography at Qingdao, and at the State Oceanography Bureau's Third Institute of Oceanography at Xiamen (Amoy). But apart from a 1978 article on the chemical and physical characteristic of the primary cement of the barnacle *Balanus reticulatus*, in *Oceanologia et Limnologica Sinica*, we learned little about this research and concluded that it was in its early stages. The area may be one in which U.S.-Chinese cooperation would be appropriate.

POLLUTION ASSESSMENT STUDIES

Most of the research organizations we visited had new programs, research units, or departments devoted to pollution studies. The individuals concerned were mostly preoccupied with developing analytical techniques. The state of the art in measuring pollutants in China is discussed later. The related activity of measuring the effects of pollutants on the environment, including both individual organisms and ecosystems, has received much less attention.

We saw no evidence of bioassay-type laboratory studies that might be used in setting water quality standards or in providing guidelines for environmental protection. The only exception was a small preliminary effort to select appropriate bio-assay organisms for measuring effects of oil pollution at the Northeast Oceanographic Station, Dalian; work was apparently under way in 1978, but no facilities or equipment were evident.

Several scientists expressed concern that the potential accumulation of heavy metals and pesticides in fish could make them unsafe for human consumption. Fish flesh was monitored in some areas for that reason. At the Institute of Hydrobiology, at Wuhan, for example, we learned that fish from certain local ponds had been designated unsafe by public health officials. Two sources mentioned that a standard would be set in the near future for mercury in fish muscle tissue of 0.3 ppm. The rationale for this standard was not given. (The acceptable limits of mercury in fish in the United States have recently been increased from 0.5 to 1.0 ppm.)

A few organizations have undertaken ecological surveys to establish baseline conditions in areas unaffected by pollution and to compare present conditions in polluted areas with those observed earlier when pollution was absent or less severe. The Shandong College of Oceanography, Qingdao, for example, conducted a series of "oil pollution surveys" in the Yellow Sea's coastal waters. The Biology Department of the Northeast Oceanographic Station at Dalian compared the abundance and distribution of plankton in the Bo Hai Gulf in May and August 1976 with that observed in May and August 1959. But both these studies suffered from a serious lack of modern equipment and methodology that probably precluded the possibility of drawing valid conclusions from the results.

SYSTEMATICS

Our experience of systematics in China was limited almost entirely to scientists working with fishes, crustaceans, and marine algae. Hence, it may not have been representative of the field overall. Most of the work consisted of isolated species descriptions, reviews of small groups restricted to China, and catalogs. There were two exceptions. One was the two-volume monograph on Chinese cyprinoid fishes produced by Professor Wu Xianwen and his colleagues at the Institute of Hydrobiology in Wuhan. It was comprehensive and paid some attention to modern theory. We hope it will be translated and become available to scientists outside China. The second major work was a monograph on the sciaenoid fishes of China written by Dr. Zhu Yuanding (Chu Yuan-ting) (who was trained at the University of Michigan) and his colleagues. Published in 1963, it was subsequently reprinted in Holland with an extensive English summary. The monograph treats a large and diverse group of ecologically and commercially important fishes living in marine and brackish shallow waters. Dr. Zhu's system of classification is based on a geographically limited area of the world and, as sciaenoid fishes are widely distributed, it may have limited use. Indeed, a more comprehensive paper on sciaenoid fishes published in 1977 by an English scientist challenges some of Dr. Zhu's conclusions. This does not devalue the commendable work of Dr. Zhu and his colleagues, but it does reveal a grave limitation of Chinese systematics: lack of sufficient attention to non-Chinese species. There are of course historical and political reasons for this preoccupation with Chinese biota. However, if the Chinese intend to do first-rate research in systematics in the future, they must look beyond their own borders.

Work in systematics at the CAS South China Sea Institute of Oceanography in Guangzhou paid particular attention to collections made during expeditions to the Xisha coral islands in the South China Sea. Surprisingly, considerable effort was expended on the taxonomy of gorgonians and non-commercial mollusks, echinoderms, and reef fishes. However, most of the activity in systematics was designed to support studies on reef ecology. The shallow-water Indo-Pacific reef fauna is the most diverse and complex of any in the world: To master it requires a high degree of expertise. Most of the institute scientists we met in Guangzhou were aware of relevant Western literature. Some were in contact with U.S. and other foreign specialists working abroad; some asked for assistance in contacting them.

The institute maintained a collection of about 400 species of South China Sea fishes and smaller numbers of invertebrates. Most of the species were represented by a single specimen. However, larger holdings of groups were being studied, such as gorgonians and parrotfishes. The South China Sea Fisheries Institute in Guangzhou had collections from the South China Sea that were about twice the size of those in the South China Sea Institute of Oceanography. These were serving as the basis for a book on the reef fishes of the South China Sea.

The Second Institute of Oceanography in Hangzhou maintained a specimen collection of about 600 species of fishes and 50 crustaceans, as well as representatives of other groups, chiefly from the East China Sea. We were unable to discover precisely what kinds of systematic research were being carried on at the institute.

During our meetings and discussions with scientists from Xiamen (Amoy) it became apparent that considerable research in marine biology was carried on there, both at the oceanography institute and the university. A paper on the phylogeny of diatoms presented by Dr. Jin Dexiang was one of the few examples of work in phylogeny that we encountered during our trip.

As of 1978, most Chinese systematists were engaged in producing a 60-volume *Fauna Sinica*. (A companion *Flora Sinica* was being prepared as well.) The fish section of the *Fauna Sinica* was to comprise 17 volumes and had been assigned to four institutes for preparation. The East China Sea Fisheries Institute of Aquatic Products in Shanghai, which has a collection of about 1,100 species, was responsible for the sections on sharks and rays, tetraodontoids, gobioids, and scorpaeniforms. The Qingdao Institute of Oceanography, which has a collection of 40,000 specimens of 1,200 species, was covering perciforms. The Institute of Zoology in Beijing, which has the largest collection in China (60,000 fishes), was dealing with clupeiforms, eels myctophoids, mugillids, flatfish, catfish, and other miscellaneous groups. The Institute of Hydrobiology in Wuhan was preparing the section on cyprinoid fishes. It maintains an important collection containing 750 of the approximately 800 known species of Chinese freshwater fishes and many specimens from Asia, parts of Africa, and North America.

We talked with many contributors (or at least potential ones) to the *Fauna Sinica* and *Flora Sinica*. Some were quite enthusiastic and bent on original interpretive research; others frankly admitted that their contributions would be little more than rote compilation.

The centers of research on crustacean systematics were Xiamen (Amoy) University, where Professor Zheng Chong was working on the distribution and taxonomy of copepods, and Qingdao Institute of Oceanography, where the Head of the Department of Zoology, Dr. Liu Ruiyu, specialized in stomatopod and penaeid taxonomy.

Qingdao must be a world center for the study of marine algae. As of 1978 research was under way in many fields, including taxonomy, life history studies, genetics, experimental manipulation of the life cycle, breeding, and mariculture. Information on phyletic relationships was obviously very important to research on the genetics and breeding of *Laminaria*, *Porphyra*, and agar-producing species. Systematics of China's marine biota was an active field during the decade 1968-1978, and many important monographs were produced that were for the most part descriptive rather than synthetic.

However, further work in systematics was needed. Researchers on benthos were handicapped by having to use outdated, extraterritorial Soviet manuals for identifying samples. In some cases our own communication with fishery biologists was limited because of their lack of information about the taxonomic identity and numbers of species on which they kept data. Studies on ichthyoplankton were in a preliminary state, partly because of the absence of good information about adult fish fauna. The expanding field of pollution biology also required input from systematics.

It was clear that if Chinese systematists wished to join the rest of the world they would have to expand their explorations into deep-sea and distant water areas, study material from non-Chinese regions, and relax restrictions on sending specimens out of China on loan or exchange.

MARINE ECOLOGY

Our delegation observed very little basic research in marine ecology in China. Almost all the biological oceanographic research we did see was oriented toward clear and obvious socioeconomic objectives, i.e., increasing production of marine organisms and assessing the impact of pollution. The only exception to this generalization were the studies of biotic distributions mentioned earlier, but even this research aimed at finding new, exploitable living marine resources. As of 1978, the Chinese lacked a modern theoretical framework within which to design and interpret their research. They also lacked understanding of biotic patchiness that seemed likely to lead them to waste their efforts in surveying living resources and pollution effects. Knowledge of energy flow and predator-controlled competition theory may inhibit Chinese research directed toward assessment and management of living natural resources.

U.S. scientists might assist the development of marine ecology in China by two kinds of cooperative studies. In one, processes would be described and quantified. There is too little of such information from China, and it is required to characterize the ecology of Chinese seas more completely. In the second, U.S. scientists would collaborate in interpreting Chinese data within a modern theoretical framework. We saw several examples where such collaboration could be mutually profitable. For example, at the Institute of Hydrobiology, in Wuhan, research on fish productivity of reservoirs, led by Deputy Director Chen Hongqi, had produced data that seems ideally suited to interpretation within energy flow and food-chain-efficiency theory. In addition, the institute's experimental ponds would make it possible to field-test hypotheses generated by collaborative efforts.

Other potential areas of collaborative effort include work with Ma Shuliu at the Northeast Oceanographic Station, in Dalian, in interpreting phytoplankton distribution data in terms of patchiness and ecotones, and with Huang Yuyao at the CAS Institute of Zoology in Beijing in interpreting food conversion efficiency and metabolic patterns in freshwater fish.

Needless to say, U.S. scientists who visit China to carry on research should be prepared to present lectures on their own and related research. Furthermore, the emphasis on U.S. aid to the development of Chinese oceanography should not obscure the fact that U.S. scientists can learn from the Chinese in many areas. The CAS Institute of of Biochemistry in Shanghai had much to offer and the laboratories of Dr. Ceng and Fang, and their phycological colleagues at the institute and college at Qingdao clearly offered opportunities for advanced study of marine algae that were equal to any in the world.

3

CHEMISTRY

Marine geochemistry, in common with the other areas of oceanography, embraces many diverse areas of study, some of which are not directly connected to work in the deep sea. In the United States, there is increasing interest in chemical processes in estuaries, continental freshwater systems, the atmosphere, and sediments. Classical descriptive chemical oceanography, originally an adjunct to marine biology and physical oceanography, is rapidly losing the centrality it once occupied in the field.

This chapter is necessarily restricted to what we actually saw of classical chemical oceanography, sedimentary geochemistry, pollution studies, and other geochemical work in China, as we were not able to visit every relevant institute.

Groups doing systematic water column sampling for oxygen, nutrients, and the carbon system were active at the Second Institute of Oceanography, at Hangzhou; the CAS Institute of Oceanography and Shandong College of Oceanography, at Qingdao; and The Third Institute of Oceanography and Xiamen (Amoy) University, at Xiamen (Amoy).

We met and talked to Professor Li Faxi and several of his colleagues at the Second Institute of Oceanography in Hangzhou. Their main activity was developing and standardizing various analytical techniques. We were informed that cruises had been made, but the data were not available. Methods development was centered around instruments built in China, principally at Xiamen (Amoy) and Shandong. These included conventional pH meters and colorimeters, a potentiometric titration setup for oxygen analyses and a portable thermostated conductive salinometer of rather elegant design. All instruments were designed for use at sea, and demonstrations showed that they were adequate for oceanographic work. However, it is difficult to combine laboratory technique with shipboard sampling and analysis successfully, and an active field program was the logical next step for the group at Hangzhou.

Two of the oceanographic ships we visited were equipped for coastal oceanography, with adequate laboratory facilities, winches, Nansens, etc. At the Institute of Marine Instrumentation at Tianjin, development work was well advanced on a self-recording salinity-temperature-depth instrument, with sensor design and configuration rather similar to the Bisset-Berman model widely used in the United States until about 1973. A salinometer very similar to the Hytech model currently used in the United States was also being produced. It was inferior in design to the portable thermostated conductive salinometers we saw at Qingdao. The Institute of Marine Instrumentation intended to purchase "Neil Brown" instruments from the United States in the near future. Although there were no plans for centralizing production of oceanographic instrumentation in 1978, the institute was to become China's center for intercalibration and standardization of instruments. We were shown a facility for calibrating reversing thermometers which was well up to U.S. standards.

SEDIMENTARY GEOCHEMISTRY

Studies of the mineralogy and geochemistry of shelf sediments were being pursued at the South China Sea Institute of Oceanography (Guangzhou), the Second Institute of Oceanography (Hangzhou), the Institute of Oceanography at Qingdao, and at Shandong College of Oceanography (Qingdao). Geochemists at the latter institution were also working on oil reservoir studies using drill core samples. Their techniques included: x-ray diffraction, x-ray emission spectrography, and differential thermal analysis. Induced thermoluminescence studies were under way at the Qingdao Institute using a clinical x-ray source. The instruments at all these different institutions were of widely varying vintage. The x-ray diffraction systems were mostly of Chinese manufacture, although an old Soviet machine was in use at Shandong College. (The geochemists there hoped to buy a Phillips computer-controlled system in the near future.) The emission spectrometers ranged from a very old German system (at Guangzhou) to Soviet machines and a new Zeiss (Jena) PQ22 purchased in 1977. The differential thermal analyses were either Hartman-Braun (Frankfurt) or Shimedzu (Japan).

At the South China Sea Institute of Oceanography, at Guangzhou, analyses were being made of local shelf sediments and organisms (principally seaweeds). At the Second Institute a systematic survey was under way of the East China shelf and Okinawa trough, in conjunction with studies of Recent foraminifera, ostracoda, diatoms, and pollen. Samples were taken with surface grabs, gravity cores (up to 4 m), and surface-powdered vibrating cores (restricted to 100-150 m in water depth).

At the CAS Institute of Oceanography at Qingdao, similar work was being done on the East China shelf (which duplicated that of the Second Institute) and the Bo Hai shelf, but there were no studies of the organic content and composition of sediments. Sedimentological studies were conducted independently of the geophysical work, including profiling, under way in the same regions.

To judge from the number and scale of the laboratories we visited, there was serious concern in China over pollution of water and foodstuffs by heavy metals, pesticides, and hydrocarbons. However, in the absence of data, it was impossible to estimate the extent of the problem or the laboratories' analytical capabilities.

We saw (or in some cases "came across" without prior information) pollution chemistry laboratories at the South China Sea Institute (Guangzhou), the Institute of Hydrobiology (Wuhan), and Second Institute of Oceanography (Hangzhou), the Xiamen (Amoy) groups, the East China Sea Institute of Aquatic Products (Shanghai), the Institute of Oceanography (Qingdao), Shandong College of Oceanography (Qingdao), and the Northeast Oceanographic Station (Dalian).

The level of instrumentation varied widely. Most uniform were Chinese-made gas chromatographs for pesticide and hydrocarbon analyses. Three or four models were found in most laboratories. Only at Wuhan did we see an imported instrument (Perkin Elmer 900). Heavy metal analyses were being performed by direct polarography, anodic stripping, or atomic absorption (flame or flameless) on preconcentrated samples. A Chinese-made cold-vapor atomic-absorption analyser for mercury was perhaps the most common instrument we saw on the trip. The polargraphs were generally primitive by U.S. standards. The atomic-absorption units included older Hungarian-made machines, either flame or with a Chinese-made graphite furnace; a well-designed, compact Chinese flame instrument; and an up-to-date U.S. machine, the Perkin Elmer 503.

As we saw no data and in general caught only glimpses of working laboratories, it was difficult to assess the analytical caliber of the pollution groups. However, given the very uneven experience of U.S. laboratories, particularly in the area of water analysis, one can only be pessimistic. One immediate problem was the general lack of laboratory supplies of the type necessary for sample containment and preparation. Another was the often dilapidated state of the various laboratory fixtures, a sure source of contamination. According to U.S. experience, it is easy, given the requisite financial resources, to acquire instruments of high performance and reasonable reliability. The difficulties lie in handling procedures. From discussions with scientists and administrators in several laboratories the Chinese clearly appreciated this problem. Although pollution chemistry figured large in anticipated overseas exchange programs, we gained no impression of the extent or organization of existing field or monitoring programs.

We visited one laboratory, at Shandong College of Oceanography, at Qingdao, doing work on experimental physical chemistry of seawater. Studies were under way on the speciation of zinc by anodic stripping voltammetry, on mercury by cold vapor atomic absorption, and on chromium by anion exchange.

We saw three radiochemistry laboratories, two for C-14 dating and one for uranium disequilibrium studies. The laboratories at Shanghai Normal University and the CAS Institute of Geology (Beijing) were working on shell dating in coastal studies. Another laboratory at the Institute of Geology was beginning work on U and U/Th dating techniques, using modern French counting equipment.

Several laboratories in oceanographic institutions were working on desalination, especially the physical chemistry of membrane processes.

Our overall impression, confirmed in discussion with our Chinese colleagues, was that organized research had just resumed after a long hiatus. Most of the scientists we met were laboratory chemists by profession who focused, understandably, on methodology and instrumentation. They had the capability of mounting a competent survey-type program analogous to CALCOFI or EASTROPAC in the United States. However, implementing such a project would be a different matter. Learning by doing is a persistent and expensive feature of chemical oceanography, even in the developed countries. We pointed out to our Chinese colleagues that the required transition from laboratory to field would be greatly facilitated in the context of an international collaborative program. This received enthusiastic appreciation.

A similar situation existed with pollution studies. We saw respectable standard curves, but little data. We felt that, until the Chinese appreciated both the difficulties and usefulness of designing field research programs for monitoring conditions, their work approached the point of diminishing returns. A considerable capability had been built up. It needed to be used. An exchange program would greatly accelerate this development.

4

GEOPHYSICS

ORGANIZATIONS, SCIENTIFIC PERSONNEL, AND WORK

Marine Geology Division of the State Geology Bureau

In 1978 this appeared to be the most active group in offshore geophysical work in China. Its main activity was to prospect for hydrocarbons. Mr. Lin Cengping, Deputy Director and scientific head, was an active sea-going type. We met various other people from his division, including the chief engineer and the personnel on the ship, *Haiyang No. 2*. They were all very enthusiastic about their work. We did not discover the total extent of the division's activities, but its personnel have been active on the continental shelf and slope of the South China Sea and have discovered a large sedimentary basin lying slightly below the shelf edge. They have also conducted drilling operations and had some oil shows in the basin and East China Sea. The division had ordered new equipment in the United States but had not been given export licenses for some of the components. Except for one or two pieces of processed seismic records, which were displayed on board *Haiyang No. 2*, we did not see any actual data.

INSTITUTES OF THE CHINESE ACADEMY OF SCIENCES (CAS)

Geophysical work was also carried out at two CAS institutes: the South China Sea Institute of Oceanography, in Guangzhou, and the Institute of Oceanography, at Qingdao. The South China Sea Institute had carried out mainly gravity and magnetics work in the South China Sea. But the scientists there were also interested in deep-water areas. We did not see any records or data, but we were told that their results on magnetic anomalies in the South China Sea Basin were similar to ours. We were given a reprint of a paper that interpreted gravity measurements on the shelf and its islands. The method of interpretation used isostatic anomalies calculated by conventional methods and seemed considerably out of date. The group at the South China Sea Institute was enthusiastic, especially Xia Kanyuan, a research scientist who was a member of the Scientific and Technical Association of the People's Republic of China Delegation that visited the United States in 1975.

Gravity and magnetic work was carried out at the Institute of Oceanography, at Qingdao, and we saw a very nice map of magnetic anomalies in the East China Sea that traced the continuation of anomalies from China to Taiwan and Japan. We also saw some proton precision magnetometer records. In addition, shallow seismic reflection work with sparkers as a sound source was done at this institute, partly to look for bedrock and thickness of sediments in harbors. The scientists used some of the shelf data quite imaginatively, especially in the area where the Yangtze River carries its sediments into the ocean. It was possible to trace features such as old terraces and to use them to determine the area's geological history.

The two institutes showed active interest in basic marine geophysical research in both deep and shallow-water areas, even though they were mainly motivated by practical problems.

INSTITUTES OF THE STATE BUREAU OF OCEANOGRAPHY

Our experience of the work done by these institutes was limited, as we only saw the Second Institute of Oceanography at Hangzhou. Its geophysical work was apparently an ancillary activity, the main geologic activity being sediment sampling and sediment study. The geophysical data was not examined at this institute, but sent elsewhere--presumably to the Marine Division of the State Geology Bureau. The large ocean-going ships that were being built in 1978 to carry marine geophysical equipment will be under the State Oceanography Bureau, and this may lead to increased geophysical activity. The ships *Xiang Yang Hong No. 5* and *Xiang Yang Hong No. 11* have carried out geophysical work in the Pacific Ocean.

COLLEGES AND UNIVERSITIES

The conduct of marine geophysics by colleges and universities was limited, as they had no ships and their equipment was poor. However, we were given the impression that there was going to be great emphasis on the study of marine geology and geophysics in the future. It was not quite clear where most of the teaching, research, or practical training would take place. Students of Jiaotung University, Shanghai, whom we interviewed, mentioned geophysical work at sea as part of their fieldwork. Similarly, at Shandong College of Oceanography, at Qingdao, geophysical work was part of student training. Thus, at these two places, and presumably others, there was interest in training in marine geology and geophysics.

Even though Chinese universities had carried out very limited marine geophysical work as of 1978, the scientists there seemed familiar with the work carried out by others in areas such as the South China Sea. They were also familiar with the concepts of plate tectonics and the geological implications of geophysical work done at sea.

GEOLOGICAL INSTRUMENTS FACTORY, BEIJING

Though not an institute of oceanography, the Geological Instruments Factory plays an important role in marine geophysical work, as it manufactures several of the necessary instruments. Given the resources available, it has done excellent work in developing gravity and magnetic instruments. With further help it could be a key factor in providing up-to-date equipment for marine geophysical work at Chinese institutions.

FACILITIES--INSTRUMENTS AND SHIPS

In 1978 the equipment for gathering marine geophysical data was limited in quantity and not up to the standard of the best equipment available in the United States--as judged from visits to various oceanographic institutions; two research ships, *Haiyang No. 2* of the State Geology Bureau and *Shiyan* of the South China Sea Institute of Oceanography; and to the Geological Instruments Factory, at Beijing. The Chinese were able to make marine magnetic measurements in very nearly the same way as American institutions, but lagged somewhat behind in marine gravity and very much behind in marine seismology.

The proton-precession magnetometer (manufactured by the Geological Instruments Factory, in Beijing) was widely used, and we saw it at several institutions. It was a direct reading instrument in gammas and used kerosene oil as the source of protons. An accuracy 0.25 gammas was claimed for the instrument. We saw some analog records with higher noise levels but were told that these were earlier versions of the equipment. Connections were provided to digital output devices such as a tape punch; but, somewhat puzzlingly, there appeared to be interfacing problems, and we did not see any digital data output on punched paper or magnetic tape. At Hangzhou, we were asked for help with this problem. (It was obvious that digital output on paper tape was widely used in China and that many other instruments automatically punched tape.) Total intensity fluxgate magnetometers were also built by the Geological Instruments Factory; they were probably used only for aeromagnetic work.

The Geological Instruments Factory had apparently also manufactured 10 surface ship gravimeters by 1978. We saw two on *Haiyang No. 2*, two on *Shiyan*, and one being tested at the factory. A single vibrating string was utilized in the latter. This flat string was 30 mm long, and beryllium-bronze, platinum-iridium, and phosphor-bronze had been used in its manufacture. The frequency of the vibrating string was about 2,000 Hz, and the meter has to be kept at a temperature constant of +0.1°C. A drift figure of 2 mgal/month was indicated.

Because the gravimeter's response was nonlinear to vertical acceleration, the filtering out of these accelerations was no trivial matter. An on-line digital computer (DJ57--of Chinese manufacture) was used for this purpose. The computer printed out a value every 3.5 minutes, presumably the interval over which the filtering was carried out. No on-line digital to analog conversion took place, although such conversion and automatic continuous plotting of the analog values have proved of great use in monitoring gravimeter performance at installations in other countries. We could not find out who did the analytical work for filtering and processing the gravimeter data. We were told that the analytical work and the development of computer programs was carried out by university researchers, but we could not find out who they were. We sensed that gravimeter development was divided between different units that communicated poorly, although we had rather meager factual information to substantiate our impression.

A geophysicist on one of the ships told us that the gravimeter's accuracy was 3 mgal even when the ship's vertical acceleration was as large as 75 gal. As we did not see any records, we are unable to assess the accuracy of these figures, but we had the impression that the Chinese were not fully satisfied with their accuracy, especially as we had repeated inquiries about the accuracy of Western gravity meters. (We got no such inquiries about magnetometers.) As of 1978, the Chinese were in the process of ordering German Graf-Askaina gravimeters.

Each of the ship installations consisted of two gravimeters mounted on gyrostabilized platforms. The gyros in the stable platforms, which were apparently surplus military equipment obtained from aircraft, became overheated after 12 hours' use and had to be switched off--hence the alternate use of two platforms. The expected useful life of the gyros was about 5,000 hours.

At Shandong College of Oceanography, a gravimeter in a watertight housing for use on the seabed, with remote controls on board ship through a conducting cable, was used mainly for instruction and possibly for some research. This instrument, which appeared to be very similar to Worden gravimeters, was manufactured by the Geological Instruments Factory, in Beijing. (We saw various stages of manufacture and testing and were told that 60 or 70 land meters were manufactured every year. These Worden-type instruments had a sensitivity of 10 μgal, a range of 100 mgal and drift of the order of 0.1 mgal/hour.) For comparison, land-type gravimeters in watertight housings were used by prospecting companies in the United States in the 1940's and 1950's. By the late 1970's, surface gravimeters were exclusively used by U.S. scientists for marine work.

The only seismic reflection equipment that we saw was on the State Geology Bureau's ship *Haiyang No. 2*. A conversation with an engineer of the Marine Geology Division of this bureau revealed that the Chinese did not have equipment more advanced than what we saw. The equipment was all manufactured at a factory in Chongqing, in Sichuan Province. A 225,000-J Sparker provided the sound source. Four air guns provided a total capacity of 16 liters and used air at a pressure of 150 kg/cm. However, it appeared that the Sparker was preferred as a sound source and was the only equipment used on *Haiyang No. 2*. The streamer used on this ship had 24 sections, and the total length of its active portion was 1,200 m. It was towed behind an inactive section 500 m long. The seismic signals were recorded on magnetic tape as analog records. By means of an analog to digital converter, also manufactured by the Geological Instruments Factory, the analog records were digitized and later processed at a computer installation in Beijing. Using this equipment, the Chinese were able to penetrate 3,000-4,000 m of sediments under the South China Sea continental shelf.

The Chinese appeared to be most anxious to improve their seismic equipment and to import the most up-to-date equipment from the United States, but as of 1978 they had been unable to do so.

At the Institute of Oceanography and Shandong College of Oceanography, both in Qingdao, the seismic equipment was employed for very shallow work. But we were told that explosives were utilized as the sound source and were shown some wiggly line seismograms.

We did not learn much about seismic data-processing techniques, as we were only shown one sample processed record on *Haiyang No. 2*. But processing was clearly slow and laborious because of the extra step of off-line analog to digital data conversion. Scientists at the CAS Institute of Geophysics, in Beijing, were familiar with sophisticated techniques such as migration, which they routinely applied to deep seismic sounding data on land.

We saw echo-sounding equipment only very cursorily. Chinese-made equipment was used in very shallow water. Some old Russian equipment (on *Shiyan*) was usable in intermediate water depths. Japanese equipment was favored for use in deep water. We did not see any echograms, although we did see good bathymetric charts.

As of 1978, marine geophysical work was carried out in ships belonging to three main categories of institution:

- *The Marine Division of the State Geology Bureau.* We saw one of its ships for oil and mineral prospecting, *Haiyang No. 2*. Built in 1972 at a shipyard in Shanghai, its displacement was 3,000 tons, and its length, beam, and draft were 106 m, 15 m, and 5.5 m, respectively. Although it could cruise at a speed of 18 knots, it usually employed a speed of 6 knots for its main work, seismic reflection profiling. It carried 25 scientists and a crew of 40. Its geophysical equipment has already been described.
- *The CAS South China Sea Institute of Oceanography, at Guangzhou and the CAS Institute of Oceanography, at Qingdao.* We saw the *Shiyan* of the South China Sea Institute, which carried gravity and magnetic equipment but no seismic equipment.
- *The State Oceanography Bureau's Institutes.* These institutes share a number of ships. We did not actually

see any of them, but marine scientists at Hangzhou mentioned that they had acquired gravity and magnetic data during their geological sampling cruises on the bureau's ships, which were also referred to in the literature. The ships *Xiang Yang Hong No. 5* and *Xiang Yang Hong No. 11* exceeded 10,000 tons displacement and have been used for long-range cruises in the Pacific.

Colleges and universities have access to some of these ships for training purposes.

PROSPECTS FOR COOPERATIVE WORK WITH THE UNITED STATES

There was great interest in cooperative research projects, and we believed the prospects of such projects were good. Some geological problems of interest to U.S. scientists can only be solved in areas adjacent to China. To gain access to these areas and to study the relevant land geology would necessarily involve Chinese scientists. Such projects would be especially valuable to Chinese scientists because of the training involved.

In 1978 the Chinese were trying to import equipment from the United States and Western Europe. There was a hitch in acquiring some of the seismic equipment from the United States because of export controls on array processors and depth control "birds" for seismic streamers, but equipment buying could make a fruitful area of cooperation in the future.

The Chinese were also interested in sending postgraduates for a period of 6 months to 2 years to learn marine seismic data acquisition and processing techniques. We should expect much activity and interest on their part in this area. However, although we can see Chinese students coming to America to study marine geophysics, we do not expect U.S. students to go to China for that reason.

5

PHYSICS

In common with other subdisciplines of oceanography in China in 1978, physical oceanography showed serious effects from 12 years of disruption of academic and scientific institutions. In addition, there had been an even longer period of isolation from scientific developments in Western countries dating back to 1949. These factors, combined with the inevitable communication difficulties that exist in a large, diverse, developing country, meant that institutions sharing common interests often worked in complete isolation from each other.

The oceanographic institutes we visited were in a sense starting all over again. Much work, particularly on the experimental side, was in the earliest exploratory stages, usually still in the laboratory. The Chinese suffered from two major general handicaps: lack of sufficient computing facilities and the absence of microelectronic chips. The computers we did see--usually of Chinese manufacture--tended to be of the sort available in the United States around 1960. There is little doubt that the Chinese have considered expertise in the construction and use of modern computers (we saw a modern Hitachi computer undergoing final checks at the Central Meteorological Bureau, in Beijing, for example), but it will take time for them to assimilate the hardware revolution of the 1970's. Similar comments apply to their ability to construct oceanic instrumentation--much of what we saw was state of the art in the United States in 1960.

Another serious problem is the Chinese' lack of experience in the use of instruments at sea. For example, fairly sophisticated up-to-date instrument development was under way in China in 1978, but the engineers were often insensitive to the practical problems that arise in using the instruments at sea and interpreting the data. This problem is not, of course, confined to China--engineers and scientists designing instruments are often not the ones using them, and they may in fact be separated from the ultimate user by long distances.

The main areas of interest in physical oceanography in the late 1970's tended to have fairly obvious, immediate applicability: tides, storm surges, waves and wave forcing, the circulation and water masses of the adjacent seas, and the oceans' influence on typhoons. These, and related topics, were nearly universally emphasized at all institutes. However, there was a tendency amongst theorists to develop elaborate analytical and numerical models, bearing little relationship to observation, reality, or the work at neighboring institutions. The scientists were generally anxious and eager to enter the mainstream of physical oceanography: to work in deep water, to apply modern techniques to their observations and theories, and to find out what the rest of the world had been doing during the past decade.

The physical oceanography at the major institutions we visited was usually a small fraction of the total activity. At the South China Sea Institute of Oceanography, in Guangzhou, we saw little of the work in progress but were told that it consisted of the usual studies of the structure of seawater masses and currents, wave spectra, and the development of marine instrumentation, including oceanographic and meteorological buoys. We did see a laser system for what was explained as short-range target-finding close to the water surface. The reluctance of the staff to show us their laboratories and work led us to think that they had little to show.

At the Second Institute of Oceanography of the State Oceanography Bureau, in Hangzhou, we were more successful in seeing the work under way, but it required a determined effort to do so. We had to overcome a reluctance to show us laboratories that had not been tidied up and work that the Chinese themselves regarded as subpar. When this initial reluctance was overcome, we had a spirited informal discussion in the laboratories themselves.

Here the work on storm surges was based on regression methods involving weather maps provided by the Central Meteorological Bureau and tide records obtained from tide gauges around the coast. The group working on surges consisted of six people. They had not yet tried to make a prediction. They had many questions directed at modern methods of tidal prediction in the United States.

A group studying the Kuroshio (the counterpart to the Gulf Stream in the Pacific Ocean) had about five people in it. They obtained their stations from Japan (data from the Cooperative Studies of the Kuroshio [CSK]). The group was essentially shorebound and was making no deep-water observations itself.

A remote-sensing laboratory was working on basic studies of light attenuation in the sea in the hope that at some future time their work would become applicable to remote-sensing techniques. The experiments were still only at the laboratory stage and had not been used at sea.

The Second Institute of Oceanography did its computing at the Shanghai Institute of Computer Technology, to which data and programs had to be transported. Among other things, the Shanghai computer was used to apply finite-element techniques to a study of the Kuroshio's flow, using what we would call diagnostic methods. We heard a talk on this subject by Yuan Yaochu, who had not been able to test his results against direct observations.

At the CAS Institute of Oceanography, at Qingdao, there were departments of marine hydrography and physics (physical oceanography) and marine instrumentation. Scientists at the institute studied the marine resources of the China Sea and adjacent areas and conducted basic research in marine science and technology. In the laboratory designing current meters, we were told that their printing Alexeev-type current meter was no good, and for that reason they were developing an acoustic Doppler current meter. We saw a prototype that consisted of a large vane and an acoustic Doppler system for measuring the speed of the current aligned with the vane. The optical laboratory was working on a laser Doppler velocimeter and a holographic system to study sand particles. This reflected a general Chinese interest in modern and sophisticated measurement techniques, which was often pursued for its own sake.

The hydrography of the East China Sea and nearby waters was also being studied. The topics covered were the summer circulation of cold water in the Yellow Sea, the circulation near the mouth of the Yangtze River, and the Kuroshio system. Again, CSK hydrographic data obtained by others was the basis of the studies. A wave group focused on the engineering of offshore structures and was developing instruments for measuring waves at sea. A wave recorder of the equal resistance type and a digital wave staff had been completed. There was fundamental work going on on the theory of surface and internal waves. A tide group was working on tidal predictions and shallow-water ports using a quasi-harmonic method. It was working on numerical solutions to the equations of motion to study the effects of friction on the tidal bore and on tidal dissipation in the Yellow Sea.

At Shandong College of Oceanography, in Qingdao, there were six departments, of which two were physically related, one called Physical Oceanography and Marine Meteorology, and the other Marine Physics (this involved acoustics and optics and we did not see it). In the Physical Oceanography and Marine Meteorology Department there were 120 faculty members, including 62 teachers, of whom 4 were professors and 4 associate professors. There were about 320 undergraduates. The graduate program had been reinstituted, but no physical oceanography graduate students had been admitted.

Research work was going on in storm surges using dynamical and regression models. Work on topographic shelfwaves was apparently just beginning. Other groups were studying ocean currents and circulation using modifications of the dynamic method, the prediction of sea-surface temperatures by statistical methods for fisheries purposes, and the dynamics of tides in shallow water and their prediction, including numerical models based upon Hansen's method.

At our delegation's talks at the institute and college at Qingdao, there were numerous questions, as elsewhere, about eddies and rings. Our Chinese colleagues made presentations on the prediction of storm surges and ultra shallow seas, the generation of internal waves caused by atmospheric pressure, and the circulation associated with the cold water mass in the Yellow Sea.

At Tianjin, we visited the Institute of Marine Instrumentation of the State Oceanography Bureau. This developed and constructed instruments for physical oceanography and was responsible for standardizing and calibrating instruments, including imports. Among the instruments being developed were an airborne infrared thermometer (which had been used at sea and compared to shipboard data), an *in situ* salinity temperature profiler device (STD) with a self-contained magnetic tape-recording system, an acoustic velocity-profiling system, a laboratory induction salinometer, and instrumentation for intercalibration.

Although these instruments were comparable to those available in the United States around 1963, the staff obviously knew what they were about and seemed to have a good idea of the discrepancy between what they were able to do and what they would prefer to do if they could obtain proper components.

The institute had developed its own tape recorder, for use with both the STD and a Savonius rotor-type instrument much like that produced by Geodyne, Inc., in the late 1960's. The large and impressive machine shop was used for small production runs of instruments. Work was farmed out elsewhere for very large production runs. Much of what the staff knew about American instruments came from studying catalogs rather than first-hand experience.

Our delegation visited a number of organizations with tangential interests and activities in physical oceanography. These included the Institute of Meteorology, in Guangzhou; the East China Water Conservancy College and the Institute of Hydrotechnology, both in Nanjing; the Institute of Computer Technology, Jiaotong University, and Normal University, in Shanghai; and the Central Meteorological Bureau and the CAS Institutes of Atmospheric Physics and Acoustics, in Beijing.

We had the impression that institutions with specific missions were in better shape than those oriented to basic research. Presumably, the former had been better able to defend themselves during the Cultural Revolution. Weather forecasting, for example, never ceased during that period, and the East China Water Conservancy College had several research projects under way aimed at understanding the effects of water projects either proposed or under construction. (These were largely engineering studies, but they also entailed a certain amount of basic research into wave effects.) While not really oceanographic, this work was of some interest to us.

The Shanghai Institute of Computer Technology combined the functions of what we would call a "service bureau" for computing services for scientific users with the design and construction of its own computers. Cheng Ansheng, a researcher at this organization, displayed a notable understanding of tide prediction and tidal bores, knowledge that he had acquired while working as a programmer for the Second Institute of Oceanography, in Hangzhou.

The Institute of Acoustics, in Beijing, seemed not to have been visited by any foreigner since the late 1950's. Its work included underwater acoustics. The institute had a field station in Qingdao (which we did not see) and four 600-ton ships for underwater acoustics. Although the work was clearly military in nature, and therefore secret, we were shown an impressive test facility for underwater acoustics.

We went aboard three Chinese research vessels and traveled on one from Shanghai to Qingdao. If these were typical, Chinese oceanographic vessels are on the large end of the scale and adequate as both shallow-water and deep-sea platforms. The equipment for doing physical oceanography tended to be of the Nansen bottle era. We did not see any shipboard computers. The vessels were generally adequately equipped with winches, although usually the cable could only go to about 2,500 m, even if the drums could take a longer one. We did not see any lifting capacity in the form of cranes or A-frames of the type normally found on Western ships, but we judged that deployment of conventional deep-water buoys, etc., would not be difficult from these ships.

The ships were evidently used to carry out classical physical oceanography: lowering current meters to make velocity profiles in shallow seas, doing Nansen cast work, and measuring wavefields with crude but qualitatively correct Tucker wave gauges, as well as measuring water-surface temperatures.

There were potentially several kinds of collaborative opportunities in physical oceanography, including visits of Chinese oceanographers to institutions in the United States for 1 to 2 years, invitations to American scientists to lecture and teach in China, and joint fieldwork, especially on the circulation of the Yellow and East China Seas and the mean flows and eddy field of the western Pacific Ocean. The Chinese vessels were capable of working in deep seas. Although equipped for shallow-water work, they would make more than adequate platforms for U.S. equipment.

6

SHORE PROCESSES AND MARINE ARCHAEOLOGY

Study and understanding of the complex interactions among waves, tides, currents, and sediments on beaches and in adjacent waters require an interdisciplinary approach involving physical oceanographers, geologists, chemists, biologists, coastal engineers, and marine archaeologists. Since the early 1960's, Western scientists from two or more of these disciplines have combined forces to make concentrated studies of nearshore phenomena. Combined research teams of physical oceanographers, geologists, and coastal engineers have made notable contributions to our understanding of the mechanics of nearshore processes.[1] This interdisciplinary approach, referred to as coastal oceanography, beach and nearshore processes, or simply shore processes, is now common in most large oceanographic institutions in the United States.

As of 1978, there appeared to be no interdisciplinary groups in China comparable to the "shore processes" research teams of the West. The Chinese were active in all of these disciplines, but had not advanced to the point where they were making concentrated interdisciplinary efforts to understand and solve coastal problems. They worked within the constraints of traditional disciplines, and, as a consequence, their understanding of shoreline problems had fallen behind that of the West. Given China's long and diverse coastline (Figure 4), major rivers supplying large quantities of sediment, and growing demand for harbors and coastal structures to handle shipping, oil drilling, etc., there was clearly a need for active research on shore processes. The most obvious way to expedite this need would be to have Chinese "postdoctoral fellows," particularly in the fields of physical oceanography and marine geology, spend a year or more studying and participating in research with shore processes research teams in the United States.

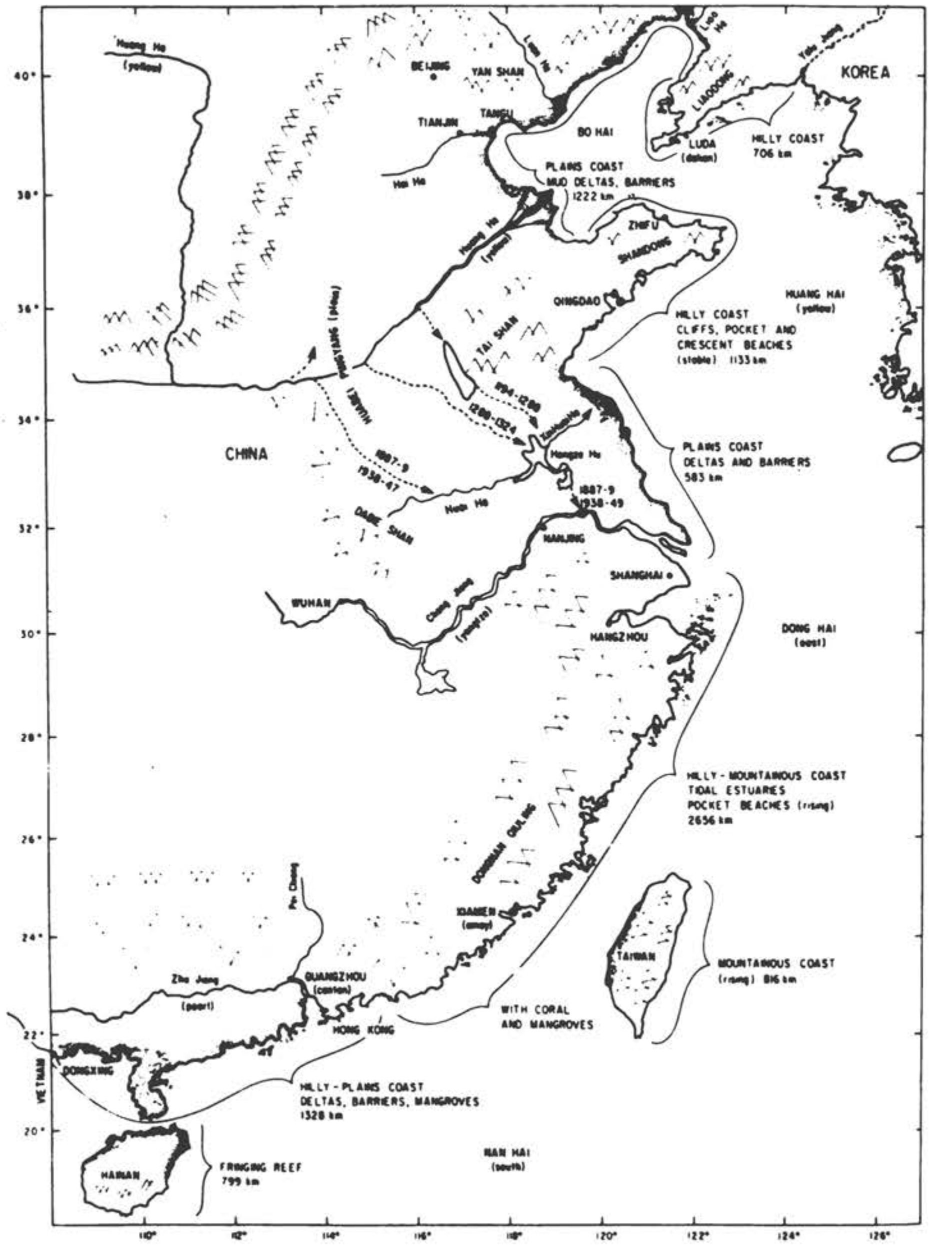

FIGURE 4 Coastline and coastal types of China based on Chinese navigational charts.[35]

The absence of interdisciplinary research in China has resulted, in part, from the confusion of bureaucratic agencies that support teaching and research. The Chinese Academy of Sciences, State Oceanography Bureau, Ministry of Education, Ministry of Agriculture and Forestry, Ministry of Water Conservancy, State Aquatic Products Bureau, Ministry of Electrical Power, and Ministry of Communications, with its Harbor Supervision and Water Transport bureaus, all supported oceanography in one way or another. The latter three, for example, were the principal sponsors for coastal engineering. Of course, there is an equally bewildering array of agencies in the United States, but the universities play a far more important research role, and it is through them that interdisciplinary fields such as shore processes and ecology have flourished.

The activities and status of Chinese research in several of the basic fields supportive of shore processes are described below. However, it should be noted that the Chinese provided our delegation with very limited access to the beaches and nearshore waters of the Chinese coast, as these areas are mostly under military restriction. Accordingly, our observations are based primarily on discussions with Chinese scientists and on a brief review of the recent literature.

COASTAL OCEANOGRAPHY

Since China has wide continental shelves and their waters tend to be marginal seas, Chinese oceanography has tended to be restricted to shallow waters and to applied studies designed to support fisheries and marine biology.[2,3] Studies of the dynamics of ocean and coastal current systems have been in the minority.[4-7]

There appears to have been very little application of physical principles of waves, tides, and currents to the understanding of nearshore processes. However, some studies of the driving forces, such as waves and tides, that are important to shore processes have been made, although there was relatively little emphasis on them.[8-10]

The most essential element lacking in the Chinese approach to physical coastal oceanography was the availability of good instruments for measuring waves and currents in shallow water. There were few wave sensors and no wave arrays or buoys for measuring wave energy-directional spectra.

Application of physical principles to the study of nearshore phenomena was the greatest shortcoming in the Chinese approach to coastal problems. Coastal studies were left to geologists and engineers, even though the mechanics of shore processes requires strong input from physics.

The combined academic and research capabilities of Qingdao's Shandong College of Oceanography and Institute of Oceanography made them potentially one of the strongest centers for the application of physical oceanography and geology to the study of shore processes.

COASTAL GEOLOGY

Coastal geology was flourishing in China, particularly descriptive geomorphology, structural geology, seismology, and geochemical dating. Coastal geology lacked essential interaction with physical oceanography and adequate means of measuring waves and currents, but, because it was an older discipline and necessary to the exploitation of oil and other minerals, it had made a rapid recovery from the setback of the Cultural Revolution. By 1978 there was a strong, active group of coastal geomorphologists working in China who could form the nucleus for the geological portion of teams working on nearshore processes.

China's 8,000-km-long varied coastline makes it particularly attractive for the study of shore processes. Coastal types include: the deltaic and plains coast dominated by rapid influx of sediment from the world's siltiest rivers, such as those surrounding the inland Bo Hai (Figure 5); extensive lines of ancient barrier beaches along the shores of Bo Hai and Jiangsu Province; hilly mountainous coasts with thousands of crescent and pocket beaches that occur along Shandong Peninsula (Figure 6) and the Dongnan Qiuling coast opposite Taiwan; the mangrove coasts southwest of Guangzhou (Canton); and the coral coasts of Hainan Island and the South China Sea. The Haining tidal bore near Hangzhou has been a tourist attraction for many centuries[2] (Figure 2).

Tectonics

China's coastline clearly reflects the tectonic structure and the erosional-depositional sequences of the past. Tectonic structures in China result from two principal forces: one from the southwest associated with the India-Asia plate collision and another from the southeast associated with the Philippine Sea and Pacific plates, whose collision with

FIGURE 5 Intertidal mud flats at entrance to the Huai He. Tangu New Harbor on left, Bo Hai in background.

FIGURE 6 Pocket beach on Shandong Peninsula east of Qingdao.

the Asian plate resulted in the formation of the Philippine and Japanese island arcs, with their complex series of intersecting NW-SE and NE-SW folds and faults.[11,12] Forces from the southeast, with their NE-SW striking structures, have been most influential in forming China's marginal seas and determining the location of mountainous and deltaic-barrier beach coastlines.[13] The mountainous and hilly portions of the coast are associated with NE-SW trending faults and folds, which produced the hard rock Liaodong and Shandong peninsulas and the rugged coast bordering the Dongnan Qiuling between Hangzhou and Guangzhou.

Pleistocene and Holocene Geomorphology

During Pleistocene sea-lowering, much of the mainland area west of Shandong Peninsula was eroded below the present sea level, and the major rivers flowed across the exposed continental shelf-cutting channels. The courses of these ancient channels, now 150 m below sea level and covered by recent sediments, have been found by coring and sub-bottom profiling. They are thought to date from the last interglacial 20,000 years before present (B.P.). They have been found between Hainan and Guangzhou and from north of Taiwan to opposite the Chang River estuary.

Present areas of coastal and interior low lands, such as Huabei Pingyuan, have resulted from the prograding deltas of the large rivers. The Huang He (Yellow River), which has the highest silt content of any river in the world, has alternately flowed into the Bo Hai north of Shandong Peninsula and into the Yellow Sea to the south, leaving deposits that form the shores and seafloor of the Bo Hai and connect the Shandong Peninsula to the mainland.

China's geomorphologists (for example, Chen Jiyu at Shanghai Normal University and Zhao Xitao at the CAS Institute of Geology, in Beijing), as well as geochemists at the latter institute's C-14 laboratory, have had an active program dating previous stands of the sea, both on and offshore.[15,16] Chinese geomorphologists believe that the coastline from northeast Hainan Island, north along the Dongnan Qiuling coast, to near Hangzhou is an area of relatively rapid holocene uplift, as is Taiwan Island.[14,15] The coast north from Hangzhou, along the Jiangsu coastal plain to Shandong Peninsula, is slightly subsiding. This also applies to the western coast of the Bo Hai from Shandong to the Yan mountains. The two most stable areas along the China coast are the Shandong and Liaodong peninsulas. (The former is mostly granite and has been the source for most of the granite statues in China.)

A number of high wave-cut terraces occur along the northeast coast of Hainan Island, along the Dongnan Qiuling coast, and on the Shandong Peninsula east of Qingdao. The highest terraces are on Hainan Island. One at 200 m above present sea level is thought to be early Pleistocene; there is another at 60 m elevation, and one at 30-40 m has been dated by teckites to be 700,000 years B.P.[16]

Ancient beach ridges are a common phenomena along China's coastal plains, particularly north of the Yangtze River estuary and the west coast of the Bo Hai. However, they are also found south and southwest of Guangzhou[17] and a few in the embayments along the Dongnan Qiuling coast. There are as many as four barrier ridges along the west Bo Hai coast. The oldest, about 3,000 years B.P., is nearly 50 km inland, almost reaching the city of Tianjin. The most recent, about 140 years B.P., are nearer the coast, off the deltas of the Huang He and the Luan He.

Chinese geomorphologists tend to favor Fairbridge's hypothesis of a climatic optimum high stand of sea about 3,000 to 6,000 years B.P.[18] (They think the deltaic-plains areas are subsiding, even though the ancient beach ridges are at present sea level.)

In general, rivers have caused a rapid progradation of their deltas and adjacent barrier-plains coasts. Rivers that enter narrow gulfs, such as the Liao in the northern Bo Hai and the Zhu River system at Guangzhou, have extended their deltas about 100 km during the past 20 to 30 centuries. The combined effect of the Huang He, Hai He, and Luan He has been to prograde the entire west coast of the Bo Hai about 20 to 30 km during the past 20 to 30 centuries. Most of the west coast of the Bo Hai consists of intertidal mud flats with little sand (Figure 5).[19]

Historical Estuarine and Coastal Morphology

Research groups at Tongji University and Shanghai Normal University (both in Shanghai) have undertaken extensive studies of the morphologic changes in the Chang and Hangzhou estuaries.[20,21] These have benefited significantly from archaeological and historical records. For example, during the fourth and fifth centuries A.D., a significant tidal bore extended up the Yangtze River for 290 km to within 100 km of Nanjing. It was of sufficient magnitude to attract emperors and other dignitaries, but it degenerated in the seventh century A.D. and now only occurs on the north side of Chongming Island.

There is a striking difference between the estuarine and delta-type river mouths. The former are typified by the Yangtze, Qiantang (Hangzhou Bay), and the Zhu (Pearl) rivers, the latter by the Huang, Luan, and Liao rivers that empty into the Bo Hai. It is apparent that there are differences in the geology, tidal range, and silt load of the rivers, as well as their protection from large waves. All three of the estuarine-type rivers appear to have cut deep channels during lower stages of sea level that have not yet filled. Also, the Yangtze and the Qiantang have large tidal ranges and tidal bores. However, the most important differences are in their silt load and their protection from intense wave attack. These latter are the hallmarks of the delta-type river mouth.

The Huang He has the highest silt load of any river in the world, 2×10^9 tons per year.[22-24] During historic times the Huang He has alternately drained into the Bo Hai north of Shandong Peninsula, through the Huang Hai via the Huai River valley, or via the Hongze Lakes into the Yangtze River. Between 1194 and 1288 the Huang He split and entered both the Bo Hai and the Huang Hai. From antiquity to 1194, it generally flowed into the Bo Hai, with its entrance ranging over the 220 km of coast north of Tianjin to its present location. From 1288 to 1855, the Huang He flowed to the south of Shandong Peninsula; for the first 36 years it entered the sea via the Hongze Lakes and the Yangtze River, and for the following 531 years it entered the Huang Hai via the Huai and Xinhuai rivers, building a vast delta that has now mostly eroded away. Since 1855, the Huang He has entered the Bo Hai by its present course except for two brief periods: 1887-1889, when it broke south and flowed into the Chang River again; and 1938-1947, when it was intentionally deflected south into the Yangtze River to prevent the Japanese advance from Nanjing.[23,25]

COASTAL ENGINEERING

The Ministry of Communications through its Seaways Control Division is the principal government agency responsible for coastal engineering in China. Its basic research facility is the Nanjing Institute of Hydraulic Engineering, which is analogous to the U.S. Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, in its range of activities and emphasis on model experiments of both fixed and movable bed type.[26-28] The Nanjing Institute also conducts harbor studies for several foreign countries such as Mauritania in Africa. Nanjing is also the site of the East China Water Conservancy College under the Ministries of Water Conservancy and Electric Power. There appears to be a good interchange of information between the institute and the college: together they make Nanjing the center for coastal engineering in China.

The Ministry of Communications also controls regional harbor supervision bureaus that study local harbor problems and administer dredging and other maintenance. There are such bureaus for Guangzhou (Canton), Shanghai, Tianjin-Tangu, and the Yangtze River. Here again there is an analogy with the U.S. Army Corps of Engineers district offices. The New Tangu Harbor, with its locks for lifting ships into the inner harbor on the Hai River, was designed by the Tianjin-Tangu Harbor Supervision Bureau and was under construction in 1978.

Basically China has two types of harbors: those situated in the mouths of big rivers such as Tianjin-Tangu, Shanghai, and the Huangpu Harbor at Guangzhou, and natural harbors sited in protected bays with ready access to deep water, such as Luda (Dalian) on the Liaodong Peninsula; Zhifu (Yantai), Weihai, and Qingdao on the Shandong Peninsula; and Zhanjiang (Chankiang) on the Leizhou Peninsula north of Hainan Island. The river mouth harbors are the most important because they serve China's industrial and agricultural centers and are connected to the interior by extensive transport systems including rivers, canals, railroads, highways, and airlines. Unfortunately, the river mouth harbors all require extensive dredging. Tangu New Harbor, which was still under construction in 1978, required maintenance dredging of 3.5 $\times 10^6$ m^3 of mud per year, for example.

In 1978 the Chinese were considering the construction of five new harbors: (1) in the Zhu (Pearl) River near Guangzhou; (2) Shanghai New Harbor on the southwest bank of the Yangtze River, 16 km upstream from where the Huangpu enters the Yangtze; (3) completion of Tianjin-Tangu New Harbor; (4) one near Luda (Dalian); and (5) one in Liaodong Bay. With the exception of Luda, all the proposed harbors will be in areas of high sedimentation.

The principal weaknesses in Chinese coastal engineering in the late 1970's were the absence of input on sedimentation and transport that could come from physical oceanographers and marine geologists, the lack of nearshore survey teams and instruments for field measurement of environmental factors, and an overdependence on models for harbor design. In view of the lack of interdisciplinary approach to environmental problems, it appears that the Chinese will face major problems in collating the necessary data for their massive harbor projects.

MARINE ARCHAEOLOGY

There has been a burst of archaeological activity in China since 1949. This is based on the Chinese deep-rooted interest in their past and a conscious effort to include archaeology as an important part of the people's political education.[29] Chinese archaeological activity is broad in scope, ranging from ancient man to maritime affairs. They have carried out extensive investigations of ancient man extending from sites like that of Peking Man at Choukoutian near Beijing to new sites in the southern province of Yunnan, where they date Homo erectus Yuanmoensis 1.63-1.64 million years B.P.[36,37] There has been substantial work on marine archaeology because of China's early dominance in maritime affairs. The long navigable rivers made shipping a major means of transportation from the start. This led to the development of sails for traveling upriver against the current. The Chinese lugsail (Figure 7), developed in the third century A.D., spread through the Middle East to the Mediterranean and to Europe.[25,30]

The Huabei Pingyuan, that vast river-deposited interior plain of China, was ideal for canals forming cross-country transportation links between rivers. (The first link in the Grand Canal was constructed about 500 B.C., and its total length of 1,665 km was completed in 1293.)[25] Chinese sea-going vessels also developed early, and there are records of Chinese trading in the Philippines by 111 B.C., in the Malaccas by A.D. 350, Kamchatka by 499, the Arabian and Red Seas by about 500, and along the east African coast by 1225.[25] Alternating monsoons and a choice of currents running in opposite directions simplified the Chinese voyages to Africa. It seems likely that Chinese ships visited the west coast of the Americas around 500[31] and that they followed the circular trade winds route that served Spain's Manila galleons 1,000 years later.

China's sea-going exploits culminated in a series of seven or eight major expeditions between 1405 and 1433 led by the "Eunuch of the Three Jewels," Zheng He, a Muslim courtier of the third Ming emperor. These expeditions visited 30 countries bordering the Indian Ocean and Red Sea. The fleet consisted of several hundred ships and more than 37,000 men. The 62 largest ships were nine-masted

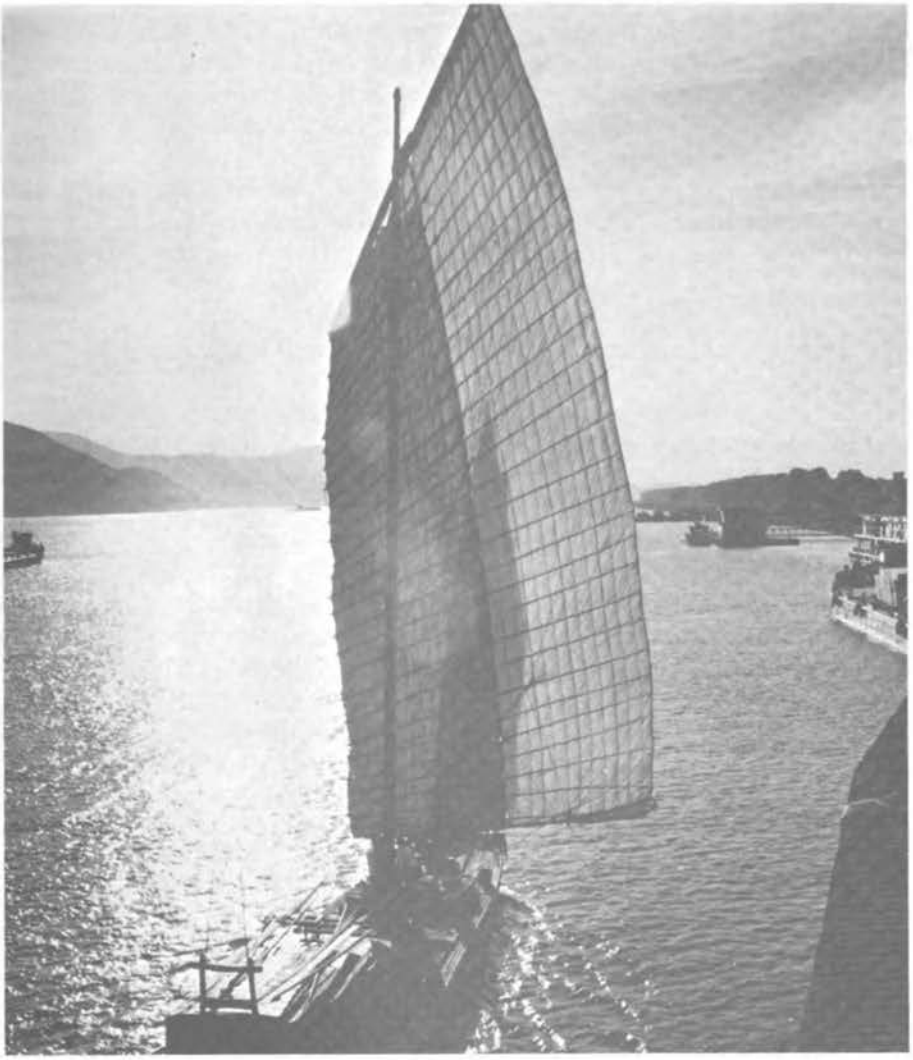

FIGURE 7 Chinese lugsail shown here on a junk in the Yangtze River has changed little since it was developed in the third century A.D.

junks, more than 135 m long, with a beam of 55 m. They contained water-tight compartments and axial rudders, the hallmarks of Chinese ship design since the third century A.D.[25,32] By 1433 Zheng He's fleet anchored off Mecca, where as the Muslim son of a hajji, he made his pilgrimage.

This appears to have been the last great Chinese oceanic expedition, and the reason for their abrupt termination after so many centuries remains a mystery. It may have been associated with the move of the capital from Nanjing, a great center of maritime activity, to Beijing in 1421.

Most of Zheng He's ships were built in the Long (Dragon) River Shipyard near Nanjing, which was 1,180 m long and 460 m wide. The Nanjing Museum has good exhibits of the Long River Shipyard and Zheng He's expeditions, which include a capstan (halyard winch) from one of Zheng He's ships (Figure 8) and navigation charts of the Yangtze River.

Qin Dynasty Shipyard and Harbor, Guangzhou

In 1974 a Qin Dynasty (221-206 B.C.) shipyard was found while excavating for a water main in downtown Guangzhou, 1.3 km north of the present bank of the Zhu (Pearl) River.[33] The lateral supporting foundation for the shipways consisted of squared hardwood beams spaced 1.8 m and 2.8 m apart. The vertical supporting posts, placed 1.6 to 3.2 m apart, were still in place (Figure 9). Ships were probably launched by piling sand bags between vertical supports, then knocking out the supports and cutting the sand bags. This is a procedure described in ancient texts and continued into the 1800's. From the spacing of supports, it is thought that nine vessels in three different sizes could be constructed at a time and that their lengths and beams were, respectively, 20 m by 5-7 m, 30 m by 6-8 m, and 40-45 m by a beam of

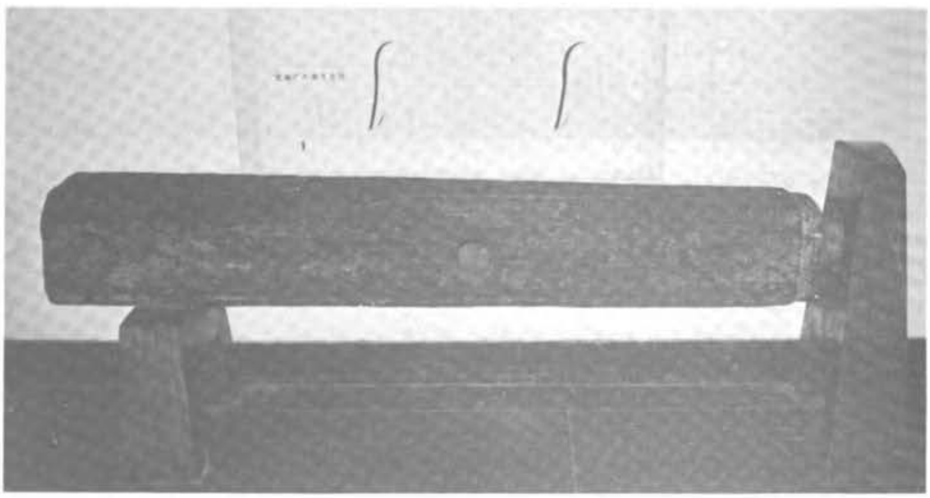

FIGURE 8 Portion of capstan (halyard winch) from one of Zheng He's ships, on display in Nanjing Museum.

FIGURE 9 Excavation site of the Qin Dynasty (206 B.C.) shipyard in Guangzhou. Parallel, horizontal foundation runners are 1.8 m apart, and remnants of the vertical posts for supporting ships are still in place.

unknown length. The shipyard, which was actually excavated in 1975, has been quite accurately dated by the presence of brass bolt heads with a triangular cross-section (Figure 10), which were only made in 206 B.C., at the end of the Qin Dynasty.[33] It is also known now that ships of the Qin State during the Warring States Period (circa 330 B.C.) carried crews of 50 men and provisions for 3 months.[34]

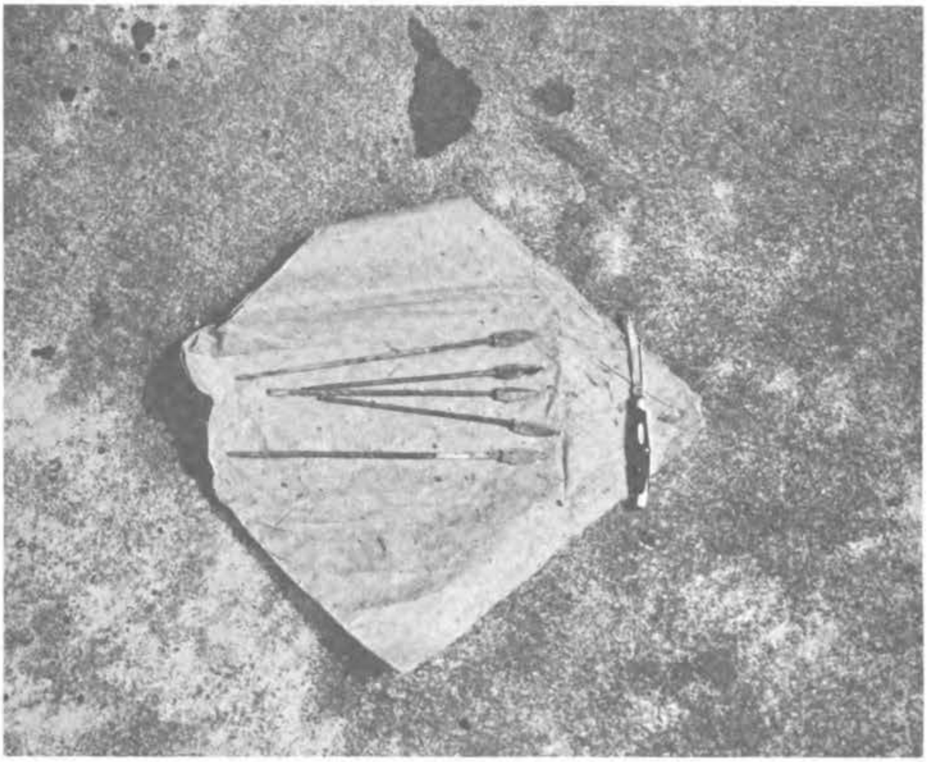

FIGURE 10 Bolts with brass heads and triangular cross-sections were used to date Qin Dynasty shipyard as 206 B.C. The open knife is 12 cm long. Photographed with permission of Guangzhou Museum.

The harbor of contemporary age with the shipyard has been found about 2 km east of the shipyard, and a Tang Dynasty (618-907 A.D.) lighthouse still exists near the shipyard (Figure 3). These three features, extending for 3.5 km in a near east-west line, indicate that Guangzhou was situated on a bay open to the ocean about 20 centuries B.P. and that the deltas of rivers such as the Zhu later filled in the western portion of the bay out to Macao, a distance of over 115 km. This makes nearly 6 km of delta accretion per century.[17,33] As corraborative evidence, it is known that the Zhu (Pearl) River got its name from a "pearl-shaped" rock that was once at the center of the Zhu River's large mouth, which is now situated some distance inland at Guangzhou. In addition, the remnants of the original bay are still apparent to the east, where Zhujiang Bay extends 60 km inland from Macao and Hong Kong.

The Qin Dynasty shipyard also tells us something about the sea level 2,180 years ago. The lateral portions of the foundation are now 4.9 m below sea level, and the ships are thought to have been built at a water level 1.9 m above the foundation supports. Therefore, the sea level has increased by a total of 3 m or about 14 cm per century, which is remarkably close to the suggested eustatic change of 15 cm per century!

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7

RESEARCH AND EDUCATION

As several intellectual historians of modern China have pointed out, the Chinese attitude toward science and technology has been greatly influenced by the pragmatism associated with John Dewey, which was prevalent in American universities in the first quarter of the twentieth century. The Science Society of China (1914-1937), for example, was dominated by graduates from American universities who believed that science was a method for bringing about visible social and economic benefits. The Germanic ideal of research as an end in itself never made headway. Instead, the American idea of the university as a "workshop" for farming, engineering, and social services (as well as an institution for scientific and scholarly research) inspired the Chinese. As Ren Hongjun put it in the late 1920's, science could "discover the secrets of nature, give guidance to life's activities, and regulate human relations." This highly pragmatic attitude to science (including oceanography) continued to dominate Chinese education and research after the founding of the PRC in 1949.

Indeed, when our delegation visited China in 1978, we found that the country's educational and research systems were returning to normal after 12 years of this pragmatism carried to extremes. (During the Cultural Revolution and its aftermath, 1966-1978, oceanographic activity was almost exclusively practical; laboratory work, seminars, and lectures had been seriously cut back or even suspended.) We also found that the Chinese were engaged in a major attempt to accelerate their country's modernization.

The general rubric under which these changes were occurring emerged in 1977 and 1978. In the fall of 1977, for example, the Ministry of Education arranged a major conference in Beijing that established 14 priority disciplines in applied science and new technology in institutions of higher learning. Immediately after the conference, 4-year undergraduate courses were reinstated, postgraduate training and research were reestablished, and nationwide, academically oriented college and university entrance examinations were introduced for 5.7 million potential students.

The following March a national policy of "four modernizations" was announced at the National Science Conference in Beijing that was attended by 6,000 people representing all disciplines and regions of the country. Fang Yi, Minister of the State Commission of Science and Technology, acknowledged that China was lagging 15 to 20 years behind advanced world levels in science and technology. He outlined an 8-year plan (1978-1985) for China that included four major goals: (1) to approach or reach advanced world levels of the 1970's in several important branches of science and technology; (2) to increase the number of professional research workers to 800,000; (3) to build a number of up-to-date centers for scientific experiments; and (4) to complete a nationwide system of scientific and technical research. Oceanography was specifically singled out as an important branch of science deserving priority attention, as were energy resources, materials, and electronic computers, all areas which will contribute to the future development of Chinese oceanography. The Chinese press characterized the conference as an historic event.

During our 1-month tour of China's major oceanographic centers, we witnessed the welcome impact of these policy changes on the scientific and technological personnel we met. In contrast to previous U.S. delegations, we met professionally qualified scholars who were able to conduct research, be it basic or applied, without hindrance. There was no sign of the "revolutionary committees" that had ruled over research and education during the Cultural Revolution. The serious attempts being made to upgrade the quality of scientific education among college and university students were also evident. The nationwide admissions examinations were helping to ensure that once again students would be admitted to college and university for their scholastic performance rather than their political attitude or class background. Candidates for science and engineering courses were being examined in politics, Chinese language and literature, mathematics, physics, chemistry, and foreign languages, such as English, Japanese, Russian, French, Spanish, German, or Arabic.

Shandong College of Oceanography at Qingdao was among 88 colleges and universities classified as key educational institutions. It had six departments: physical oceanography and meteorology, marine physics, marine chemistry, marine biology, marine geology and geophysical exploration, and marine fisheries and aquaculture. The curriculum in the Department of Physical Oceanography and Meteorology consisted of mathematics, physics, statistics, hydrodynamics, general oceanography, and general meteorology. The department also ran advanced classes for teachers from other universities and future graduate students.

Dr. Fang Zongxi, a phycologist who headed the college's Department of Marine Biology said that it had more than 100 majors involved in a 4-year course of study. He outlined the curriculum as follows:

Year 1 botany (morphology and taxonomy, marine emphasis), zoology, mathematics (calculus), chemistry, politics, and physical training.

Year 2 zoology, plant physiology (metabolism, biochemistry, and photosynthesis), organic chemistry, phycology (life cycles), politics, and physical training.

Year 3 embryology and histology, biochemistry, general oceanography, oceanography surveying (including two 2-week training cruises), plankton (plant and animal morphology and taxonomy), microbiology (bacteria), ecology, (natural history, biogeography, physical factors of the ocean), and politics.

Year 4 genetics (Mendelian, molecular, population and statistics), pollution, evolution, politics, and thesis and research.

Five postgraduate students began work in Dr. Fang's laboratory in 1978--the first since 1966. The faculty was not awarding advanced degrees, but hoped to do so soon.

Xiamen (Amoy) University--another major center of oceanographic training--was also among the 88 "key point" institutions. Although it did not award B.S. degrees in oceanography, it did train a large number of technicians who majored in the discipline. Professors Zheng and Jin of Xiamen (Amoy) University indicated that their oceanography department had 200 majors, with the biologists among them taking basic courses in general biology, vertebrate and invertebrate zoology, and specialized courses in ichthyology, marine physiology and marine ecology. Ocean-oriented biology majors took similar general courses, but went on to take specialized courses in genetics, embryology, etc.

Both these institutions planned to increase their student populations at an astonishing rate--as were several others that we visited. In 1978, Shandong College of Oceanography at Qingdao had a student enrollment of 1,000 and a staff of more than 900, including 400 teachers and 100 trainee teachers. Student enrollment was due to increase to 4,000 by 1985, with 500 postgraduate researchers. Xiamen (Amoy) University was expected to increase its student intake from 1,000 students in 1978 to 3,500 undergraduates and 500 graduate students in 1985.

Even a superficial glance at university education in China in the late 1970's indicated at least three serious challenges:

1. *The need to bridge a generation gap.* Most of the professors were in their late sixties and only a few leadership positions had been filled by people in their early forties. The 12 years lost to the Cultural Revolution and its aftermath had created major problems for reeducating and retooling thousands of displaced college students, as well as for educating those ready to enter college.
2. *The need for updated textbooks for virtually all scientific and technological disciplines.* By 1978 there had already been several national conferences on standardizing college-level teaching materials. There was an urgent demand for making the most advanced conceptual schemes, methods of analysis, and research results available to those involved in developing the materials.
3. *The need for laboratory equipment, library facilities, and information channels.* As of 1978 there was little access to newly published journals, monographs, and book-length studies in the basic sciences in Japanese or English at China's leading universities.

There were similar questions concerning the future of research in China. How will new leaders of oceanographic research be selected? How can interdisciplinary work be encouraged in ocean sciences given the rather rigid disciplinary boundaries of the 1970's? What policies on data exchange and collaborative experiments would be most help international exchanges?

Although we did not learn the answers to these questions, we felt confident that many of them were being faced by the Chinese oceanographers that we met.

APPENDICES

APPENDIX A
ITINERARY: September 25-October 21, 1978

<u>Monday, September 25</u>	GUANGZHOU, GUANGDONG
Noon	Met at Shenzhen by officials of the Chinese Society of Oceanography
2:15 p.m.	Arrive Guangzhou, Dongfang Hotel
3:00 p.m.	Visit to *Haiyang No. 2* Research Vessel, Huangpu New Harbor
<u>Tuesday, September 26</u>	
7:30 a.m.	South China Sea Institute of Oceanography. Visit to research vessel *Shiyan*, and laboratories
2:30 p.m.	Scientific lectures Group one: Talwani, Inman, Peng Group two: Ryther, Cohen Group three: Munk, Wunsch Geological field visit to Nanhai Xian Talwani, Tu, Peng Sightseeing
7:30 p.m.	Welcome banquet Host: Yang Ganhua, Vice Chairman, Guangdong Revolutionary Committee
<u>Wednesday, September 27</u>	
8:00 a.m.	Guangdong Aquatic Products Bureau Frankenberg, Wallace, Ryther, Cohen

	Guangdong Meteorological Station Munk, Wunsch, Borich, Beemer Geological field visit to Nanhai Xian Talwani, Tu, Peng Field visit to ancient harbor Inman
	WUHAN, HUBEI
1:20 p.m.	Fly to Wuhan
4:35 p.m.	Arrive Wuhan, Jianghan Hotel
7:30 p.m.	Welcome banquet Host: Shan Youji, Secretary General of the Hubei Revolutionary Committee

Thursday, September 28

8:00 a.m.	Institute of Hydrobiology, CAS Visit to laboratories
2:00 p.m.	Visit to East Lake (Dong He) Freshwater fish production
7:00 p.m.	Beijing Opera

Friday, September 29

8:00 a.m.	Scientific Lectures Cohen and Ryther
	Sightseeing - Yangtze River Bridge, Gui Yuan Shi Temple
2:00 p.m.	Institute of Hydrobiology Scientific discussions
	Water sampling on Yangtze River Edmond, Talwani, and Peng
	Wuhan University Tu

Saturday, September 30

8:00 a.m.	Depart Wuhan by river steamer *Dong Fang Hong No. 7*

Sunday, October 1 — NANJING, JIANGSU

4:30 p.m.	Arrive Nanjing
7:00 p.m.	Welcome banquet Host: Zhang Zhongliang, Vice Chairman, Jiangsu Provincial Revolutionary Committee

Monday, October 2

8:00 a.m.	Sightseeing - Yangtze River Bridge, Sun Yat Sen Memorial
2:00 p.m.	Scientific lectures Munk, Inman, and Peng
	Sightseeing - Xuanwu Hu Gardens
8:00 p.m.	Acrobatic show

Tuesday, October 3

8:00 a.m.	East China Water Conservancy College (Institute of Hydraulic Engineering)
1:00 p.m.	Purple Mountain Astronomical Observatory
2:00 p.m.	Nanjing Hydraulic Research Institute Munk, Inman, Wunsch, Edmond, Peng, Borich
	Institute of Geography, CAS, Jiangsu Frankenberg, Talwani, Wallace, Cohen, Ryther, Beemer

	Taiping Museum Tu
	Jiangsu Provincial Museum Inman
<u>Wednedsay, October 4</u>	HANGZHOU, ZHEJIANG
2:45 a.m.	Train to Hangzhou
10:45 a.m.	Arrive Hangzhou, Hangzhou Guest House
1:00 p.m.	Observe tidal bore on Qiantang River
4:00 p.m.	Sightseeing
7:30 p.m.	Visit Lantern Show
<u>Thursday, October 5</u>	
8:00 a.m.	State Oceanography Bureau, The Second Institute of Oceanography
2:00 p.m.	Sightseeing - Xi Hu (West Lake) Ling Ying Temple
7:30 p.m.	Welcome banquet Host: Ze Xiewu, Vice Chairman of the Zhejiang Revolutionary Committee
<u>Friday, October 6</u>	
8:00 a.m.	The Second Institute of Oceanography, State Oceanography Bureau
	Scientific lectures Talwani, Inman, Munk, Edmond, Cohen, Peng
2:00 p.m.	The Second Institute of Oceanography, State Oceanography Bureau Scientific discussions

	Water sampling on Qiantang River Edmond
	Freshwater aquaculture - West Lake Ryther, Cohen, Wallace, Frankenberg
6:30 p.m.	Train to Shanghai
10:30 p.m.	Arrive Shanghai, Qing An Guest House
<u>Saturday, October 7</u>	SHANGHAI
9:00 a.m.	Sightseeing and shopping
2:00 p.m.	East China Sea Institute of Aquatic Products Cohen, Wallace, Frankenberg, Ryther, Borich
	Shanghai Institute of Computer Research Munk, Wunsch, Beemer, Peng
	Shanghai Municipal Library Tu
	Shanghai Scientific and Technical Association Scientific lectures Talwani
7:30 p.m.	Shanghai Dance School and Shanghai Municipal Orchestra performance
<u>Sunday, October 8</u>	
9:00 a.m.	Shanghai Industrial Exhibition
2:00 p.m.	Nanxiang People's Commune, Chia Ting County Frankenberg, Talwani, Peng, Borich
	Qing Pu Brigade, freshwater fish cultivation

7:30 p.m. — Welcome banquet
Host: Li Zongzhun, Vice Chairman of the Shanghai Revolutionary Committee

Monday, October 9

5:30 a.m. — Shanghai Municipal Vegetable Market

8:00 a.m. — Jiaotong University
Munk, Wunsch, Tu, Talwani, Borich

Shanghai Scientific and Technical Association
Scientific lectures
Ryther, Frankenberg, Cohen, Peng

2:00 p.m. — Institute of Biochemistry, CAS
Frankenberg, Wallace, Ryther, Beemer

Shanghai Normal University
Munk, Wunsch, Talwani, Peng, Inman, Tu

Shanghai Scientific and Technical Association
Scientific lecture
Inman

6:00 p.m. — Depart for Qingdao on *Xiang Yang Hong No. 1*

Tuesday, October 10 — En route to Qingdao

Wednesday, October 11 — QINGDAO, SHANDONG

6:00 a.m. — Arrive Qingdao, Tunghai Hotel

8:00 a.m. — Sightseeing

2:00 p.m. — Institite of Oceanography, CAS

Evening: — Welcome banquet

Thursday, October 12

8:00 a.m.	Shandong College of Oceanography
2:00 p.m.	Scientific lecture Inman
2:00 p.m.	Visit to Laminaria culture and production areas Jiaozhou Bay
Evening	Movies

Friday, October 13

8:00 a.m.	Institute of Oceanography, CAS Scientific lectures Members of Oceanography Delegation and Institute of Oceanography
Evening	Dinner at scientists' homes

Saturday, October 14

8:00 a.m.	Institute of Oceanography, CAS Continuation of scientific discussions

Group A: Frankenberg, Wallace, Cohen, Ryther, Talwani, Borich

11:30 a.m.	Depart Qingdao
5:00 p.m.	Arrive Yentai
6:00 p.m.	Depart by ship for Dalian

Group B: Munk, Inman, Edmond, Wunsch, Tu, Peng

1:30 p.m.	Depart Qingdao for Tianjin

Sunday, October 15

Group A	DALIAN, LIAONING
Morning	Arrive Dalian
	Northeast Oceanographic Station

Group B	TIANJIN
3:24 a.m.	Arrive Tianjin, Tianjin Guest House
9:00 a.m.	Tianjin Institute of Marine Instrumentation, State Oceanograpny Bureau
4:00 p.m.	Drive to Ji Xian

Monday, October 16

Group A	Oceanic Fisheries Company of Dalian
Group B	
7:30 a.m.	Ji Xian, to visit pre-Cambrian Sinian strata
2:00 p.m.	Return to Tianjin

Tuesday, October 17

Group A	Dalian Navigation College
6:20 p.m.	Fly to Beijing
Group B	
8:00 a.m.	Tianjin-Tangu New Harbor Munk, Inman, Wunsch, Edmond, Peng
	Nankai University Tu
2:50 p.m.	Train to Beijing
Both Groups	
Evening	Arrive Beijing, Beijing Hotel

Wednesday, October 18	BEIJING
8:30 a.m.	Institute of Geology, CAS Talwani, Inman, Edmond, Peng
	Institute of Zoology, CAS

	Beijing Library Tu
2:00 p.m.	Beijing Univeristy Frankenberg, Wunsch, Edmond, Peng
6:30 p.m.	Welcome banquet Host: Shen Zhengdong, Director of the State Bureau of Oceanography

Thursday, October 19

8:30 a.m.	Meteorological Center of Central Meteorological Bureau
	Geological Instruments Factory
2:00 p.m.	Institute of Geophysics, CAS
	Bai Jia Dan Station of Geophysics
	Institute of Atmospheric Physics
6:00 p.m.	Reception at the United States Liaison Office

Friday, October 20

8:30 a.m.	Institute of Acoustics, CAS Munk
	Scientific lectures Wallace, Talwani, Tu, Edmond

Saturday, October 21

8:00 a.m.	Sightseeing - Great Wall and Ming Tombs
7:00 p.m.	Banquet hosted by Delegation

Sunday, October 22

10:30 a.m.	Departure from Beijing

APPENDIX B
INSTITUTES VISITED AND INDIVIDUALS MET

CHINESE ACADEMY OF SCIENCES

Institute of Oceanography, Qingdao

The institute had a strong marine biology division, and its director was a marine biologist. Work on marine geophysics in the nearshore area was also quite extensive. The chemistry division was mainly concerned with seawater pollution and environmental protection in the coastal area, especially with organic contaminants such as petroleum products and radioactive pollutants. The chemistry division conducted measurements of gross β-radioactivity in seawater using barium chloride-ferric ammonium alum. Analysis of mineral composition of nearshore sediments and a clay mineral study of the East China Sea were conducted by the thermoluminescent x-ray diffraction or differential thermal analysis. There was no work on chemical oceanography.

The people whom we met were:

曾呈奎 Ceng Chengkuei
Director

毛汉礼 Mao Hanli
Deputy Director; Professor of Ocean Physics

梅金生 Mei Jinsheng
Interpreter

吴超元 Wu Chaoyuan
Office of Botany; Professor of Marine Biology

刘瑞玉 Liu Ruiyu
Professor of Marine Biology (Shellfish and Invertebrate)

赵士金 Zhao Shijin
Director, Science and Research Department

纪明侯 Ji Minghou
Office of Chemistry; Professor of Ocean Chemistry and Inorganic Chemistry

秦蕴珊 Chin Yunshan
Director, Office of Ocean Geology

项锡洲 Xiang Xizhou
Deputy Director, Office of Foreign Affairs, Qingdao

张予庶 Zhang Yushu
Office Director

South China Sea Institute of Oceanography, Guangzhou, and Its Research Vessel *Shiyan* (Experiment)

This multidisciplinary institute was founded in 1959. In 1978 it was conducting research on marine geophysics, physical oceanography, and marine biology in the nearshore area, as well as on marine pollution and the distribution of major elements in seawater. There were few instruments for geochemical work. The emission spectrometer was more than 20 years old. The atomic-absorption spectrophotometer was from Hungary with a Chinese-made control panel and homemade replacement photocells. A graphite furnace for trace metal analysis attached to the instrument was also Chinese-made.

The institute had one research vessel *Shiyan* (Experiment), which was converted from a cargo ship in 1970. The main instruments on board were for measuring gravity, magnetics, waves, and satellite cloud pictures. The geochemical work was negligible. The instruments were all made in China, including a computer that was used for computing gravity measurements. A good number of instruments were manufactured by the Beijing Geological Instruments Factory of the State Geology Bureau. The area of work was confined to the continental shelf within the South China Sea.

The people whom we met were:

邱秉经	Qiu Binjing	Director
黄云耀	Huang Hunyao	Deputy Director
温扬朵	Wen Yangduo	Deputy Director
翁　寄?	Weng Ji ?	Planning and Management
谢　荣	Xie Rong	Captain
王国辉	Wang Guohui	Deputy Captain
吴世钦	Wu Shiqin	Chief Officer

OFFICE OF OCEAN GEOLOGY

刘昭蜀	Liu Zhaoshu	Deputy Director, Geology Office
赵焕庭	Zhao Huanting	Seashore Landscape
陈森强	Chen Senaiang	Structure
刘祖惠	Liu Zuhui	Structure
陈绍谋	Chen Shaomou	Geological Chemistry
黄金森	Huang Jinsen	Landscape
宋朝景	Sung Chaojing	Seashore Landscape

万良海	Wan Lianghai
叶龙飞	Ye Longfei Physical Instruments
蒋祥兴	Jiang Xiangxing Physical Exploration
夏勘源	Xia Kanyuan Physical Exploration

MARINE BIOLOGY RESEARCH OFFICE

陈清朝	Chen Qingchao Deputy Director
陈真然	Chen Zhenran Fish eggs and young fish
邹仁林	Zhou Renlin Benthic coral
陈兴乾	Chen Xingqian Ecology
严文侠	Yan Wenxie Ecology
沈寿彭	Shen Shoupeng Benthos
石小嫒	Shi Xiaoai Interpreter
潘国英	Pan Guoying Algae
谢玉坎	Xie Yukan Shellfish
杨家驹	Yang Jiaju Fish
叶加松	Ye Jiasung Plankton

OCEAN HYDROLOGY AND METEOROLOGY RESEARCH OFFICE

郭忠信 Guo Zhongxin
Deputy Director

随世峰 Sui Shifeng
Wave

?昌华 ? Changhua
Wave

仇德忠 Chou Dezhong
Ocean current

曾流明 Ceng Liuming
Ocean current

黄企洲 Huang Qizhou
Ocean current

柯佩辉 Ke Peihui
Ocean current

何大章 He Dazhang
Meteorology

鲁争寿 Lu Zhengshou
Meteorology

张庆荣 Zhang Qingrong
Meteorology

蔡清贵 Cai Qingquei
Wave

李少英 Li Shaoying
Wave

OCEAN PHYSICS RESEARCH OFFICE

陈世经 Chen Shijing
Instrument research and manufacturing

谭向明 Tan Xiangming
Laser

OCEAN CHEMISTRY RESEARCH OFFICE

何悦强 He Yueqiang
Deputy Director

韩舞鹰 Han Wuyan
Ocean chemistry

Institute of Hydrobiology, Wuhan

This institute was established in Shanghai in 1950 and moved to Wuhan in 1954. In 1978 it was mainly concerned with freshwater biology. It had a staff of 391, of whom 221 were scientific and technical personnel, 5 full professors and 16 associate professors. There were six laboratories:

- ichthyology: taxonomy and ecology of freshwater fish. There was a collection of over 750 species.
- genetics and breeding: freshwater fish genetics and farm fish breeding.
- fish diseases: parasitic, viral, and bacteriological diseases.
- lake and reservoir fisheries: methods of increasing fish yields in these bodies.
- phycology: taxonomy of freshwater algae, experimental physiology, use of blue-green algae as fertilizer.
- environmental protection: pollutants in surface water and their effect on aquatic organisms, biological monitoring, and microorganisms used in water treatment.

The Phycology Laboratory was mainly concerned with the study of algae and was very impressive. The scientists cultivated a species of green algae that can fix the nitrogen from the air. The successful application of green algae in agriculture permits considerable savings in nitrogen fertilizer.

Also impressive was the complete line of modern American-made instrumentation (e.g., Perkin-Elmer) for measuring trace elements in solution at the Environmental Protection Laboratory. According to Dr. Edmond, this laboratory's instrumentation was comparable to that of Massachusetts Institute of Technology.

The people whom we met were:

伍献文 Wu Xianwen
Director of the Institute; Professor of Ichthyology

胡鸿钧	Hu Hongjun Deputy Director of the Institute; Associate Professor of the Classification of Freshwater Algae
倪达书	Ni Dashu Director, Office of Fish Pathology; Professor of Fish Pathology
黎尚豪	Li Shanghao Director, Office of Algology; Professor of Freshwater Algology
刘建康	Liu Jiankang Director, Office of Lakes and Reservoirs; Professor of Fish Biology
曹文宣	Cao Wenxuan Deputy Director, Office of Ichthyology; Associate Professor of Ichthyology
陈宏溪	Chen Hongqi Deputy Director, Office of Genetics and Breeding of Fish; Professor of Genetics and Breeding of Fish
余敏娟	Yu Minzhu Deputy Director, Office of Algology; Associate Professor of Algology
章宗涉	Zhang Zongshe Associate Professor of Environmental Biology
陈宜瑜	Chen Yiyu Fish classification expert
陈湘粦	Chen Xianglin Fish classification expert

Institute of Geology, Beijing

In 1978 the institute had 340 staff members and nine research departments: structural geology, mineralogy, petrology, stratigraphy, engineering geology, geothermal geology, mathematical geology, isotope geology, and sedimentology. The institute was well equipped to do geological research. It had a Chinese-made electron microscope capable of enlarging 200,000 times for clay mineral study. The K-Ar dating technique was available for volcanic rocks of the Mesozoic and Cenozoic eras. A Cameca mass spectrometer was used for Sr-Rb dating.

The people whom we met were:

Zhang Wenyou

Sun Qu

Zhou Zuoxia

Xia Ming

Zhao Xitao

STATE OCEANOGRAPHY BUREAU

Second Institute of Oceanography, State Oceanography Bureau, Hangzhou, Zhejiang Province

This institute was responsible for research on the marine environment of the East China Sea and adjacent waters. Its work focused on the development of marine resources, environmental protection, remote sensing, and desalinization. Established in 1966, it had 300 scientific and technical employees working in six laboratories by 1978:

- desalinization: used methods of reverse osmosis and electrolysis
- marine geology: worked on the contemporary sediments and geomorphology of the East China Sea
- marine hydrology and meteorology: worked on sea fog, storm surge, and the hydrographic characteristics of the Kuroshio current
- marine chemistry: analyzed toxic elements in seawater
- marine physics: focused on remote sensing
- marine biology: concentrated on microbenthic organisms of the South China Sea.

The people whom we met were:

张振国	Zhang Zhenguo Director
肖易寒	Xiao Yihan Deputy Director
王荣君	Wang Rungjun Responsible Person, Science and Technology Department
金庆明	Jin Qingming Director, Office of Ocean Geology
王传昆	Wang Chuankun Deputy Director, Ocean Hydrology and Meteorology Office
朱锡成	Zhu Xicheng Director, Office of Marine Biology
刘金灿	Liu Jinshan Deputy Director, Office of Ocean Chemistry
向正才	Xiang Zhengcai Deputy Head, Science and Research Division
袁耀初	Yuan Yaochu Researcher, Ocean Hydrology and Meteorology Office
余国辉	Yu Guohui Assistant Researcher, Office of Ocean Chemistry
沈毅楚	Shen Yichu Staff Member, Science and Research Division

Third Institute of Oceanography, State Oceanography Bureau, Xiamen (Amoy), Fujian Province (not visited)

Established in 1959 as the East China Coast Research Institute, this institute became the State Oceanography Bureau's

Third Institute of Oceanography in 1965. We met Chen Cheng-hui, a geologist, at the Second Institute of Oceanography, Hangzhou. Its scientific staff of approximately 200 concentrated most of their activities on the South China Sea and the surrounding seas. The institute had four divisions. Their major activities were:

- physics: shallow water currents, waves, tides, storm surges, sea fogs, and marine hydrology instrumentation
- chemistry and geology: analysis of estuary chemistry, silicate composition, heavy metal monitoring and development of chemical instrumentation. The work in geology was not advanced, focusing mainly on the coast.
- biology: phytoplankton, benthic organisms, fouling organisms, taxonomy, ecology and radioactive analysis of organisms
- marine data: the collection and analysis of marine information

Institute of Marine Instrumentation, State Oceanography Bureau, Tianjin

This institute, founded in 1965, studies, designs, and manufactures instruments for measuring and monitoring the important elements in physical oceanography and marine geology. It is also responsible for the standardization and quality control of all marine instruments in China.

In 1978, it had 240 technicians, 140 supporting staff, and 100 workers. There were departments of optics, electromagnetics, acoustics, standardization, and research. There was also a library and a machine shop for making prototype instruments and producing small quantities of developed instruments.

In addition to developing instruments for measuring currents and waves, the institute made automatic recording units for STD measurements and an old-fashioned inductive-type salinometer. The signals of STD were recorded on magnetic tape within the electronic housing--which could only sustain a water pressure of 1,000 m. After recovering the tape, the signals were transferred to computer for STD computation. The STD trace could be plotted by hand on graph paper. There was no immediate plan for designing an automatic tracing recorder for instant plotting of STD as the sensors were lowered in the water column.

The people whom we met were:

松 文	Sung Wen	Director
杨耀中	Yang Yaozhong	Head of the Science and Technology Division
刘从信	Liu Congxin	Engineer
廖之和	Liao Chihe	Engineer
杨兆富	Yang Zhaofu	Head, First Research Division
冼福令	Xian Fuling	Head, Second Research Division
许玉崑	Xu Yukun	Head, Third Research Division
邸振仁	Di Zhenren	Head, Fourth Research Division
宋协进	Song Xiejin	Head, Fifth Research Division
田小平	Tien Xiaoping	Acting Head, Sixth Research Division
盛福丛	Sheng Fucong	Subsidiary laboratory plant

Research Vessel *Xiang Yang Hong No. 1* (Facing Sun the Red No. 1), State Oceanography Bureau

This 1,200-ton vessel belonged to the East China Sea research vessel fleet of the State Oceanography Bureau. When we sailed on it, it had just been released from dry dock and for that reason had few scientific instruments on board. It was equipped with five winches, all of them designed for shallow water (less than 1,000 m) work. It also had a balloon-releasing device for taking meteorological data. The room for chemical analysis was very large. It employed a crew of 75.

STATE GEOLOGY BUREAU

Geological Instruments Factory, State Geology Bureau, Beijing

This factory, which was founded in 1959, was a major supplier of scientific instruments for geological study, including marine geology, in China.

In 1978 it employed 1,600 workers. The main products were for measuring magnetics and gravity. The factory made some instruments for chemical analysis, such as atomic-absorption spectrophotometers and devices for measuring mercury concentration and thermal radiation dosage. It also produced various high-voltage supply units and electronic equipment for digitizing signals and numerical processing.

There was no research and development division for improving current designs or creating new ones.

The people whom we met were:

Gao Mingfa

Hua Fengshan

Ma Muzhou

Zhou Jikuang

Wang Anbang

Research Vessel *Haiyang Erhao* (Ocean No. 2), State Geology Bureau

This geophysical research vessel, part of the South China Sea Geological Survey Fleet of the Marine Geology Division of the State Geology Bureau, was mainly responsible for mineral and petroleum surveys in the South China Sea. Built in 1972 in Shanghai, and equipped with Chinese instrumentation, it worked mainly along the continental shelf. A

3,300-ton vessel, 106 m long, 15 m wide, with a 5.5 m draft, it had a cruising time of 30 days. Its maximum speed was 20.5 knots, with a regular cruising speed of 18 knots and a seismic reflection profiling speed of 6 knots. It had a crew of 40, with 20 scientists. The vessel had seismic, magnetic, gravity, and geological laboratories.

A 225,000-J Sparker provided the sound source. Four airguns provided a total capacity of 16 liters and used air at a pressure of 150 kg/cm. However, it appeared that the Sparker was preferred as a sound source and it was only used on *Haiyang No. 2*. The streamer used on this ship had 24 sections, and the total length of its active portion was 1,200 m. It was towed behind an inactive section 500 m long. The seismic signals were recorded on magnetic tape as analog records. By means of an analog to digital converter the analog records were digitized and later processed at a computer installation in Beijing. By means of this equipment the Chinese were able to penetrate 3,000-4,000 m of sediments under the South China Sea continental shelf.

The people whom we met were:

张东山	Zhang Dongshan Responsible Person, South China Sea Geological Survey Command, Department of Ocean Geology, National Bureau of Geology
王庭元	Wang Tingyuan Director, Production Department, South China Sea Geological Survey Command
郭 彬	Guo Bin Petroleum Geological Engineer, South China Sea Geological Survey Command
张国员	Zhang Guoyuan Physical Exploration Engineer, South China Sea Geological Survey Command
刘德定	Liu Deding Captain of the Oceanographic Vessel *Ocean No. 2*
汪德昆	Wang Dekun Petroleum Geological Engineer, Ocean Department, National Bureau of Geology

COLLEGES AND UNIVERSITIES

Shandong College of Oceanography, Qingdao

A Department of Oceanography was first established at Shandong University at Qingdao in 1952. The need to develop oceanography in China became so urgent that the whole university was converted into Shandong College of Oceanography in 1959. In 1978 the college had a staff of 900 and student enrollment of 1,000.

There were six departments: physical oceanography and meteorology, marine physics, marine chemistry, marine biology, marine geology and geophysical exploration, and marine fisheries and aquaculture. The college had two large research vessels of 2,500 tons. Little research work was under way at the Department of Marine Geology and Geophysical Exploration, where the facilities were mostly devoted to teaching purposes. In the Department of Marine Chemistry, however, research on the design and modification of instrumentation for precision measurement of trace metals in seawater was very active.

The people whom we met were:

张国忠	Zhang Guozhong Chairman, Revolutionary Committee
吴 非	Wu Fei Vice Chairman, Revolutionary Committee
赫崇本	He Chongben Academic Dean of the College and Professor of Oceanic Hydrophysics
方宗熙	Fang Zongxi Chairman and Professor, Department of Marine Biology
施正鉴	Shi Zhengjian Deputy Division Head, Science and Research Division
林乐夫	Lin Luofu Staff member, Office of the Dean
文圣常	Wen Shengchang Professor of Oceanic Hydrophysics

Xiamen (Amoy) University, Xiamen (Amoy), Fujian Province
(not visited)

The oceanography group at Xiamen (Amoy) University was formed in 1930, but only really began to develop in 1960. In 1978 the Department of Oceanography had a physical division working on typhoon and tide relationships; a biological division conducting research on zooplankton, benthic animals, fish, and sensory physiology of fish and squid; and a chemistry division concentrating on instrumentation, electrolysis, and pollution problems. There were 90 faculty members in the department and 200 undergraduates. The university planned to enroll 10 research students in 1978 and to buy one or two small ships for shallow-water work.

The people whom we met were:

郑 重 Zheng Chong
Professor of Marine Biology

金德祥 Jin Dexiang
Professor of Marine Biology

李法西 Li Faxi
Associate Professor of Ocean Chemistry

East China Water Conservancy College (Institute of Hydraulic Engineering), Nanjing, Jiangsu Province

Established in 1952, this college had a staff of 700 in 1978, of whom 60 were at the professor or associate professor rank, and about 1,700 students. There were plans to enroll 6,000 students by 1985. The college specialized in hydraulic structure, mechanical and electrical installation of hydroelectric power, navigable waterways and harbors, irrigation and drainage in agriculture, hydrology, ocean engineering, mechanics of hydraulic structures, automation of hydroelectric plants, and computer applications. It also offered courses in administration and maintenance of hydraulic structures and improvement of estuaries. The college had a sizable foreign student body and had hosted international programs organized by WHO and UNESCO. It ran two research institutes of hydraulogy and hydraulic engineering. A third institute of coastal engineering was planned in the near future. These research institutes were jointly run with the Ministries of Water Conservancy and Electric Power.

The people whom we met were:

严 恺 Yan Kai
Dean of College

薛鸿超 Xie Hongchao
Chairman, Department of Waterway and Harbor

张书农 Zhang Shunung
Professor of River Dynamics

谢金赞 Xie Jinzan
Director, Teaching and Research Office for Ocean Engineering and Hydraulogy

洪广文 Hong Guangwen
Instructor

常骏野 Chang Junye
Sophomore, Waterway and Harbor Engineering major

徐 兵 Xu Bing
Sophomore, Hydrology on the Land

周永红 Zhou Yonghong
Sophomore, Engineering Mechanics

王明军 Wang Mingjun
Freshman, Agricultural Hydraulic Engineering

王世夏 Wang Shixia
Instructor, Hydraulic Engineering and Structure Laboratory

夏维洪 Xia Weihong
Instructor, Hydraulic Engineering and Structure Laboratory

徐关泉 Xu Guanquan
Instructor, Hydro-power Utilization Laboratory

过 达 Guo Da
Director, Waterway, Harbor and Hydrodynamics Laboratory

Jiaotung University, Shanghai

In 1978 the university had departments in shipbuilding, marine engineering, electrical engineering and computer science, electronic engineering, materials science and engineering, mechanical engineering, precision instruments, applied mathematics, applied physics, and engineering mechanics.

There were five research centers in 1978 covering ocean engineering, materials science, engineering physics, marine engineering, and electronics and computer sciences.

The university had 3,800 first- and second-year students, about 150 graduate students; 1,625 faculty members, of whom 25 were professors and associate professors; and about 1,000 lecturers and 500 assistant lecturers. By 1985 the university planned to have 12,000 students.

The people whom we met were:

林栋梁	Lin Dongliang Vice President
吴善勤	Wu Shanjin Chairman, Department of Shipbuilding
黄祥鹿	Huang Xianglu Department of Shipbuilding
吴连元	Wu Lianyuan Department of Shipbuilding
姬 ?森	Ji ? sen Department of Applied Physics
步起跃	Bu Chiyue Department of Applied Mathematics (student)
夏 翚	Xia Hui Teaching and Research Group of Philosophy

Tongji University

An old Chinese university established along traditional lines of education with departments of physics, chemistry, geology, etc.

The people whom we met included:

Yen Chen-shang
Professor, Department of Geology

ADDITIONAL INSTITUTIONS AND INDIVIDUALS

Guangdong Provincial Meteorological Station

This meteorological station was primarily responsible for marine and land weather forecasting for Guangdong Province, which experiences an average of 7-8 typhoons each year. It identified and tracked storms that posed threats to marine traffic and agriculture. In making forecasts, the 90 staff members used radar detection, information received from American and Japanese satellites, and a network of 13 smaller stations in the South China Sea. The station was responsible for the territory from 25° north latitude to the equator and 131° east longitude west into China proper. The meteorologists used synoptic forecasting, hand-drawn mapping, and some satellite cloud pictures in predicting weather. The station claimed 75 percent accuracy on 24-hour predictions.

Individuals met included:

姚 元 Yao Yuan
Director

贺 忠 He Zhong
Engineer

韦有还 Wei Youhuan
Engineer

王荫桐 Wang Yintong
Engineer

杨 震 Yang Zhen
Engineer

周定番 Zhou Dingfan
Weatherman

何夏江 He Xiajiang
Weatherman

Guangzhou South China Sea Aquatic Resources Institute,
National Bureau of Aquatic Resources

佟广生	Dong Guangsheng	Deputy Director, Science and Research Management
张光育	Zhang Guangyu	Head, Science and Research Management Division
曾炳光	Ceng Bingquang	Deputy Director, Ocean Fisheries Resources Research Office
王步云	Wang Buyun	Deputy Director, Fishing Research Office
梁 拾	Liang Shi	Deputy Director, Processing Research Office
何国民	He Guomin	Fishery forecast research
陈冠贤	Chen Guanxian	Ocean hydraulogy
卢贤瑶	Lu Xianyao	Ichthyology
施流章	Shi Liuzhang	Freshwater cultivation

Institute of Computer Research, Shanghai

Established in 1969 as the Shanghai Computer Center to work on scientific problems associated with China's economic development, the center became involved in research in 1972. It has developed some small and medium-sized computers. In 1978 it employed some 560 persons, of whom over 200 were university graduates. The computation laboratory had 70 people working in it and used a 709 computer capable of 110,000 calculations/operations a second, with a 32K bit memory capacity, and a 731 computer capable of 320,000 calculations/operations a second with a 64K memory capacity. The computers were built by the laboratory in 1970 and 1973, respectively, and both used integrated circuits and transistors. There were two other small computers used for information retrieval and data processing. Algol 60 was the programming language, although a machine using Cobol for information processing was planned. The 731 computer could read magnetic tape but could not punch cards. Eight-hole tape was the preferred method of programming the computers.

There were similar computer research centers in Beijing, Shanghai, Tianjin, Xiamen, Hangzhou, Shenyang, Chengdu, Changsha, Wuhan, Nanjing, and Xi'an. The Science and Technology Commission was considering, in 1978, the establishment of a national coordinating body for these centers.

The individuals we met included:

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祁延年 Qi Yannian
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施成熙 Shi Chengxi
Professor

罗开富 Luo Kaifu
Professor

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邹国良 Zhou Guoliang
Deputy Office Director

刘思华 Liu Sihua
Deputy Head, Planning Division

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董漪平 Dong Yiping
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沈焕庭 Shen Huanting
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Geomorphologist

王宝灿 Wang Baocan
Geomorphologist

胡方西 Hu Fangxi
Hydrologist

陈吉余 Chen Jiyu

APPENDIX C
LECTURE TOPICS

Walter Munk
1. Ocean Weather
2. Internal Waves in the Sea

Daniel M. Cohen
1. Observation from a Submersible on Larger Animals at the Bottom of the Deepsea
2. Comments on the Classification of Gadiform Fishes

John H. Ryther
1. A Combined Waste Recycling Marine Aquaculture System
2. Aquaculture in the United States

Manik Talwani
1. Recent Advances in Geophysical Techniques at Sea and Some Results from these Techniques
2. Geophysical Studies in the South China Sea

Carl Wunsch
1. Mode and Polymode Experiments
2. Application of Inverse Methods to Determining the General Circulation of the Oceans

Dirk Frankenberg
1. Seasonal Changes in Subtropical Benthic Communities off the Coast of Georgia, U.S.A.
2. Prediction of Shrimp (*Peneus axtecus)* Harvest in the State of North Carolina, U.S.A.

Douglas Inman
1. Beach and Nearshore Processes and their Application to Coastal Erosion and Pollution
2. Longshore Transport of Sand by Waves and Currents
3. Ancient and Modern Harbors

John Edmond

1. The Chemical Processes of the Amazon Estuary
2. The Chemistry of Hot Springs on the Galapagos Spreading Ridge

David H. Wallace

1. Fisheries Research in the USA in Relation to Management of our Coastal Fishery Stocks
2. Impact of Pollution on Marine Fisheries

Tu Wei-ming

1. Historical Significance of Zheng He (Cheng Ho)'s Maritime Expeditions (1405-1433)