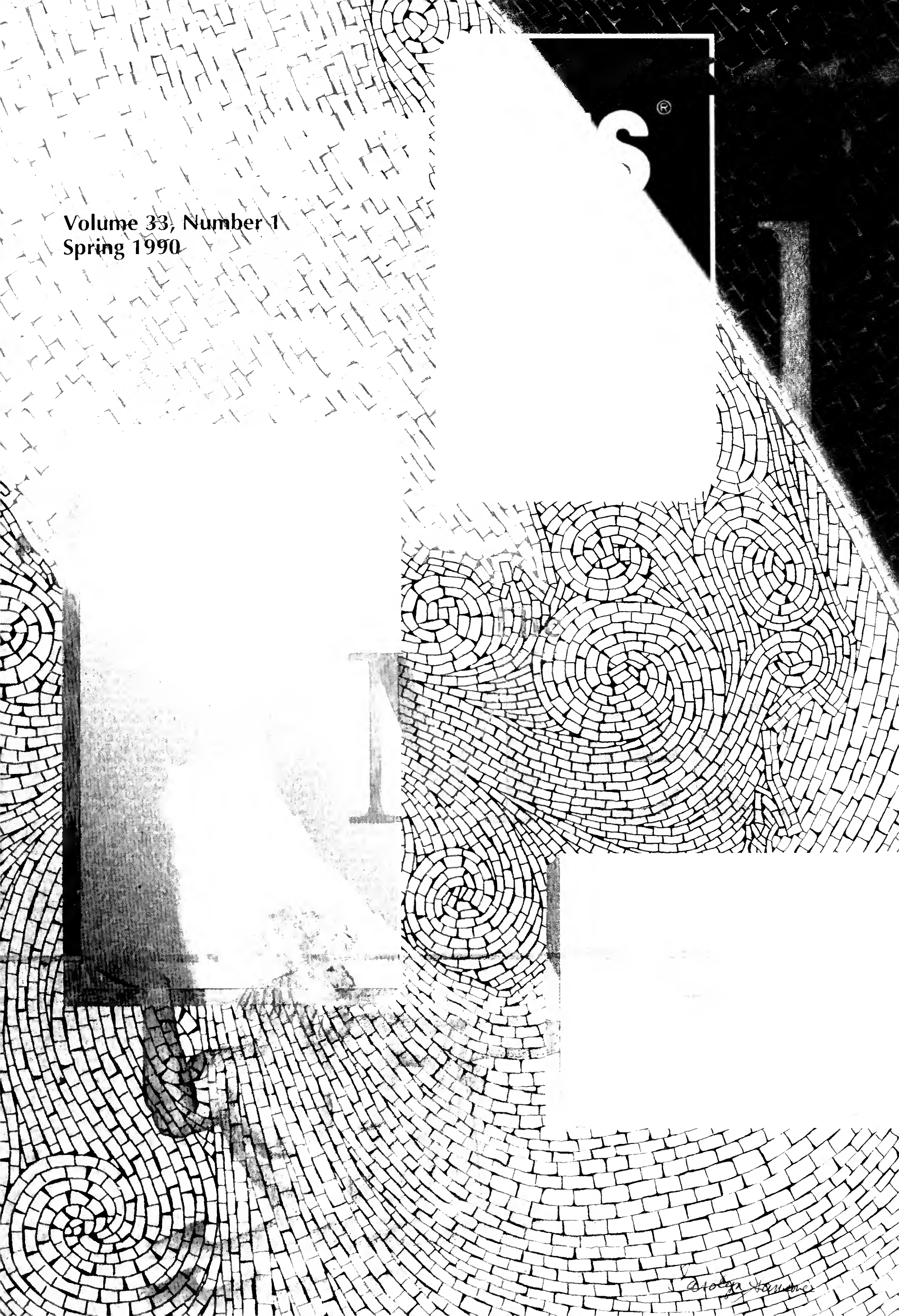

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Finally, we hope you enjoy the changes to our format introduced in this issue. We're striving for improved readability while retaining our thematic concentration.

—Craig E. Dorman
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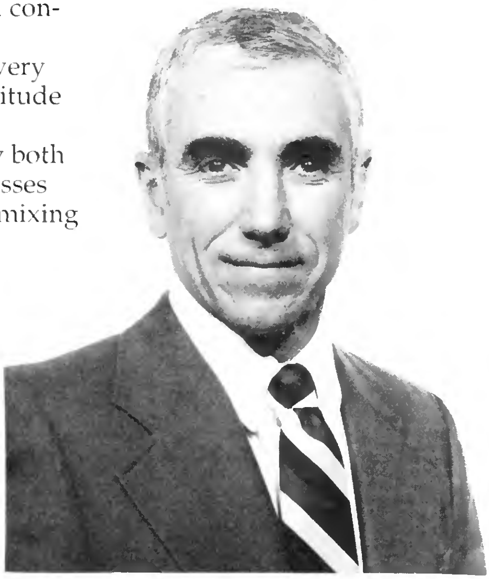
From the Bridge

The Mediterranean, theme of this issue of *Oceanus*, has throughout history held a pivotal position in the development of Western Civilization. The Med and its adjoining seas have served variously as barriers to and conduits for international conquest while dominating the surrounding climate and providing for both resources and trade. Indeed, the very terms we use to position ourselves on the globe, longitude and latitude, derive from and reflect its orientation.



The Mediterranean is important to oceanography both in its own right and as a model for many of the processes that drive the global oceans. Deep-water formation, mixing and flow across sills, biochemical processes in anoxic bottom water, and sea-level rise are just a few topics for which the Med is an ideal laboratory. And its waters that spill out across the Strait of Gibraltar serve as an important tracer throughout much of the North and Central Atlantic.

The Med also opens exceptional opportunities for collaborative science; for example, I had the honor last year of hosting a meeting of the POEM (Physical Oceanography of the Eastern Mediterranean) group—headed in the United States by Allan Robinson of Harvard and Paula Malanotte-Rizzoli of MIT—where oceanographers from nations as diverse as Israel, Egypt, Greece, Turkey, Italy, and Yugoslavia are working together to improve their knowledge of common waters. Similarly, some of WHOI's closest contacts in the Soviet Union derive from our collaborative work in the Black Sea.

In this issue, *Oceanus*, in its deliberately eclectic fashion, brings you a sampler of the sea flavors of the Med—from its present and past physical characteristics, through its biology and the dual (and often dueling) issues of use and protection of its resources, to its fascinating archaeology (some of which, you may recall, we explored with "Jason" last summer). The very diversity of our topics reflects the endless fascination of the area and its limitless challenges to our field. As our science becomes more centrally relevant to social issues like global change, and economic and environmental security, an ability to integrate such diversity becomes ever more important.

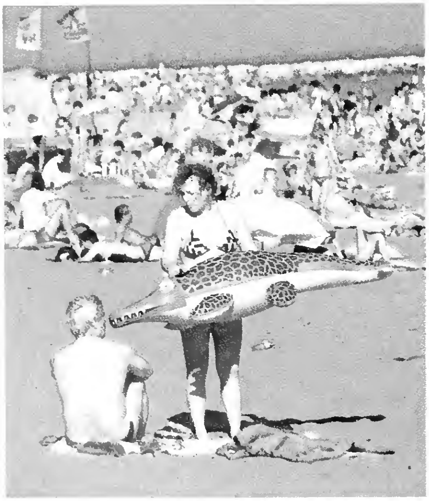
Finally, we hope you enjoy the changes to our format introduced in this issue. We're striving for improved readability while retaining our thematic concentration.

—Craig E. Dorman
Director, Woods Hole Oceanographic Institution

THE MEDITERRANEAN


Cousteau aboard *RV Atlantis II*


RV Atlantis at Monaco


Cleaner beaches at Cannes

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Headings and Readings

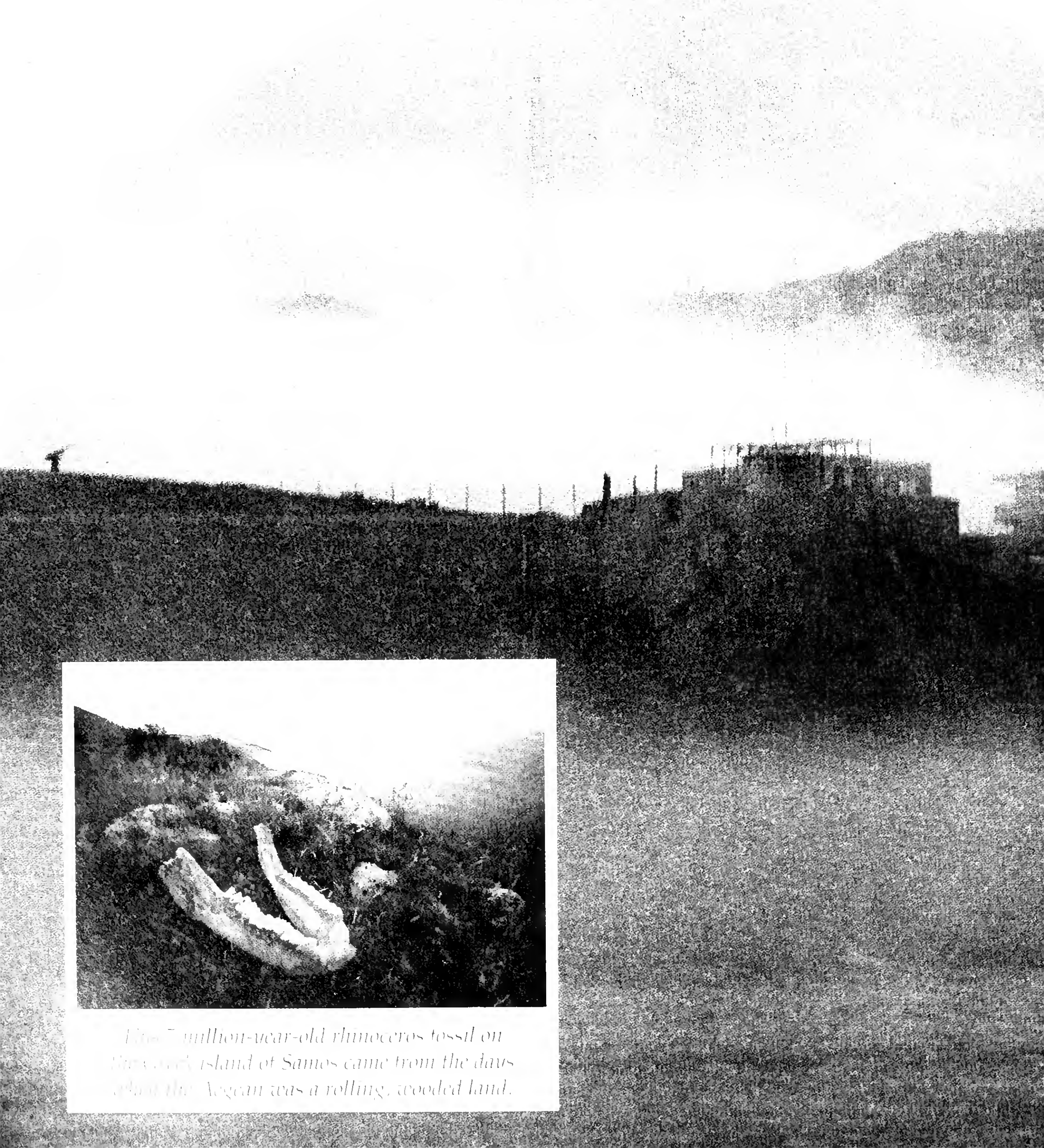

Fishing on the Nile


Jason recovers artifact


Ancient anchors at Haifa

COVER: Our cover is the work of Carolyn Sansone, a freelance illustrator and designer living in Mashpee, Massachusetts. The photograph in this mixed-media work was taken from the space shuttle (see pp. 8–9). Other credits appear on page 12.

Introduction:



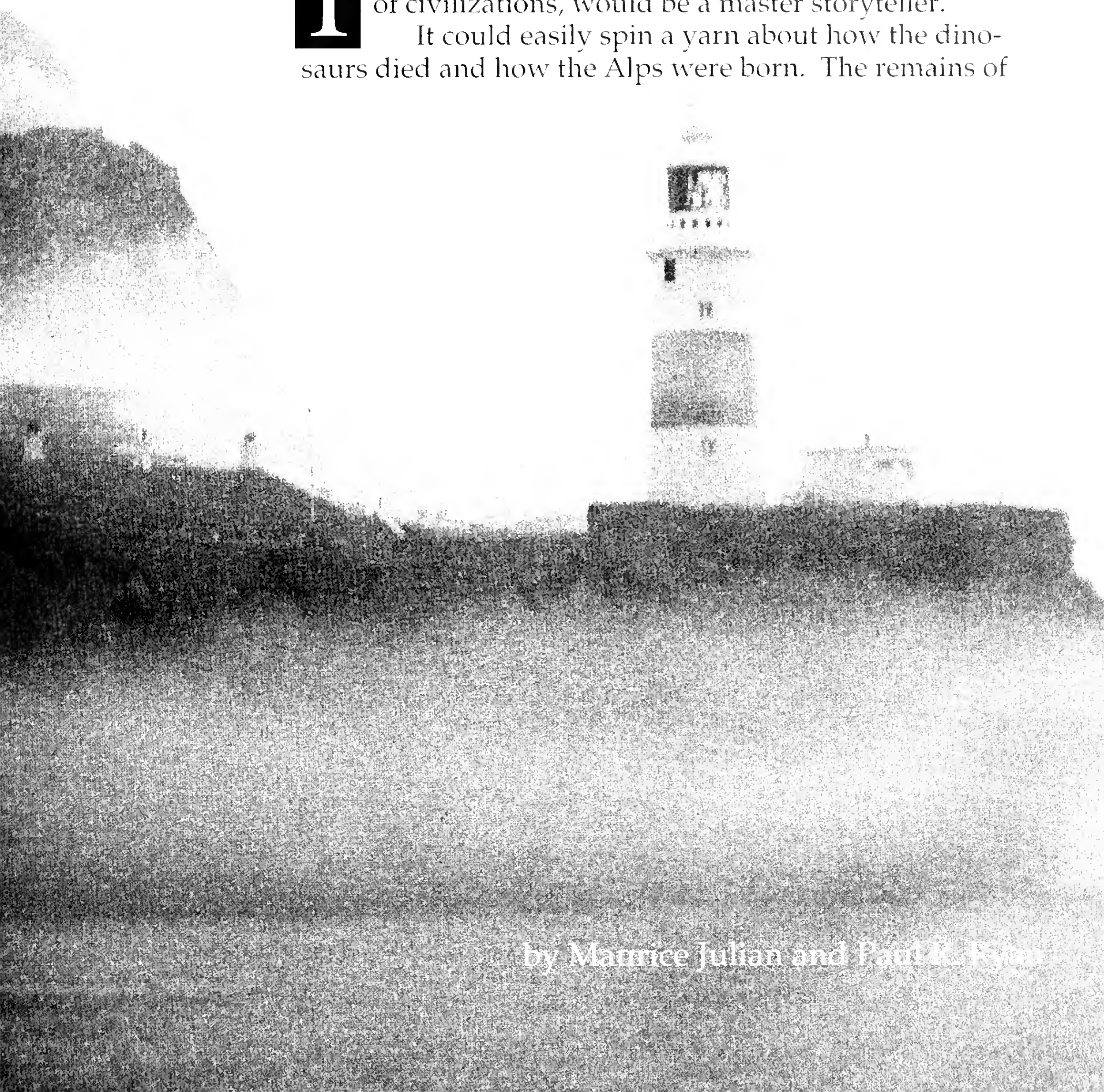
This 7-million-year-old rhinoceros fossil on the Greek island of Samos came from the days when the Aegean was a rolling, wooded land.

The Med—

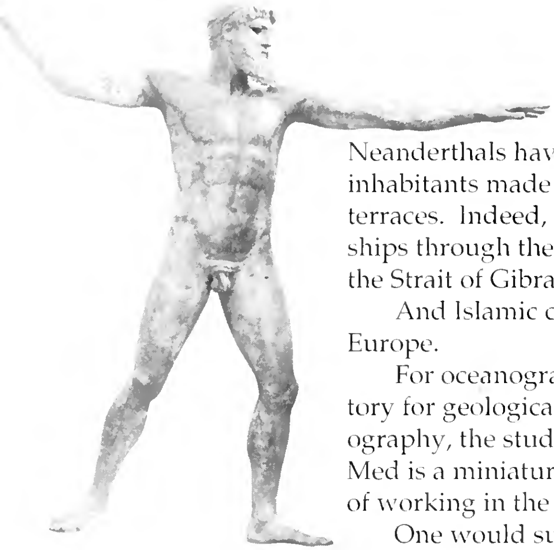
For oceanographers, a small, hospitable world ocean

If rocks could tell tales, the Rock of Gibraltar, western gateway to the Mediterranean, the cradle of civilizations, would be a master storyteller.

It could easily spin a yarn about how the dinosaurs died and how the Alps were born. The remains of



by Maurice Julian and Paul R. Ryan



Poseidon, the Greek god of the sea, was the protector of all waters.

Neanderthals have been discovered in its recesses. Neolithic inhabitants made fire and pottery and farmed and hunted on its terraces. Indeed, much of western history has passed this rock on ships through the narrow, 13-kilometer tongue of water known as the Strait of Gibraltar.

And Islamic conquerors have used the strait as a bridge to Europe.

For oceanographers, the Mediterranean is an excellent laboratory for geological and geophysical studies and for physical oceanography, the study of currents and eddies and so forth. Indeed, the Med is a miniature world ocean in many respects. Another benefit of working in the region is that the weather is usually pretty good.

One would suppose that by this time pretty much all that there is to know about the Mediterranean would be known. Not so, as the articles in this issue attest. Earth scientists, as Smithsonian scientist Daniel Stanley points out (see page 14), are still trying to unravel the geological history of the two complex deep-sea basins that comprise the Mediterranean proper.

Just 20 years before, geologists depicted the Mediterranean of 6 million years ago as a vast desert lying some 3,000 meters below sea level. The floor of this desert was covered by evaporite salts. And high ridges in the Gibraltar region served as a barrier to the Atlantic Ocean. The region was a vast Death Valley, we were told. Eventually, about 5 to 5.5 million years ago waters from the Atlantic surged into the basin in the form of a huge waterfall at Gibraltar.

Today, the concept of such a deep and dry Mediterranean is not universally accepted. As a noted marine geologist, Robert Dietz, stated: "Remarkable hypotheses require extraordinary proof! That proof is lacking."

The latest thinking is that the Mediterranean was different some 5.5 million years ago, but that it almost assuredly was covered by water with a high salt content, or a briny consistency. Just how deep this basin was—it is now thought that water from the Atlantic was restricted, but not cut off entirely—is still unclear. Theories range from 100 to more than 1,000 meters. The floor of the basin thus was considerably higher than it is today.

Huge salt deposits lie out of reach beneath the Med. Salt is mined on islands where deposits are near the surface.

The circulation of Mediterranean waters provides oceanographers with a model of how the world ocean works (see page 26). Basically, cool surface waters with low salt content enter from the

Atlantic through the Strait of Gibraltar, while saltier deep water exits from the Med.

Demystifying the processes of heat and water exchanges that occur as the water comes, circulates, and goes is crucial to an understanding of the mechanisms that drive global climate and the "Greenhouse Effect," or gradual warming of the Earth. Thus, the Mediterranean is a major focus of modern oceanography.

The Med is a particularly good model for the study of how deep-water currents form. Outside the Med, nearly all deep water forms in polar regions. Because ice conditions are unpredictable from year to year, it is difficult for oceanographers to follow the process of how deep waters form and move in polar regions. The Mediterranean deep water exchange rates are as interesting to marine scientists as the currency exchange rates are to tourists and businessmen.

A typical quiet day at the beach. Yearly, 80 million tourists slather on lotion and soak up the Med's glorious rays.

The length of the Mediterranean is about 4,000 kilometers. It has an elongated shape, its width being very narrow in places—in one instance only 140 kilometers across. The Med covers an area of 3,000,000 square kilometers. It is composed of a series of juxtaposed basins associated with geologically young mountains. The tectonic activity in some areas of the region is intense, engendering earthquakes and nurturing volcanic activity.

Traveling from the Strait of Gibraltar eastward, there are several complex basins of which the most important are the Western, Tyrrhenian, Ionian, and Eastern. Depths in these basins range from 2,000 to 3,000 meters with troughs nearly 5,000 meters deep. The Mediterranean also includes several more-or-less enclosed seas with corresponding straits, such as the Pelagic, Adriatic, Aegean (known for its multitude of islets), and Black seas (see map, pp. 54–55).

Probably many Americans do not think of the Black Sea as being part of the Mediterranean. But scientists, particularly European ones, generally do. The Black Sea is the largest of the enclosed seas, covering an area of 452,000 square kilometers. It is separated from the rest of the Mediterranean by the narrow Bosporus Straits with a depth of only 92 meters. The presence of these straits results in anoxia, or a lack of oxygen, in the Black Sea at depths greater than 200 meters. It is thus a scientific El Dorado.

Two other major features are the lengthy stretches of rocky coast and the numerous islands, which cover 4.1 percent of the area of

the sea and support a total population of more than 9 million people.

The Mediterranean is bordered by large continental drainage basins whose area amounts to 67 percent of that of the sea itself (the basins drained by the Black Sea and the tropical part of the Nile are excluded). Rainfall and river discharge account for 36 and 16 percent, respectively, of the water balance in the Mediterranean. The deficit is made up by inputs from the Atlantic and the Black Sea. The largest rivers flowing into the Med are the Po, Rhône, Ebro, and Nile.

The amount of pollutants entering the Mediterranean has decreased somewhat in recent years (see page 39). However, the Mediterranean environment still needs special attention as regards both sediment and pollution control. It still is an endangered sea, although perhaps not a dying one.

The true Mediterranean climate is restricted to the coastal margins and corresponds to areas of olive cultivation. The mountains and the desert roughly constitute the boundaries of this climatic zone. However, above 1,000 meters in the North and at greater altitude in the Maghreb and Levantine mountains, marginal climates occur, resulting in a wide variety of climates with adapted vegetation and land-use belts.

A long and dry summer is a regular feature of the Mediterranean climate; this season is one of high evaporation rates, resulting in water deficit and stress for both plants and crops. Despite the lack of real subtropical winter temperatures, the variety of plants, many of which are exotic, is great.

Rain occurs in autumn or winter. Heavy snowfalls are essentially limited to mountains, enhancing the aesthetic value and

beauty of these landscapes. The most eloquent examples are the French Riviera, the Amalfi peninsula south of Naples, and Mount Etna.

Rainfalls allow for the accumulation of precious water stocks for summer irrigation. The very sunny weather (from 2,000 to 3,000 sunshine hours a year) makes the shores of the Mediterranean a real Sun Belt, with coastal regions similar to California.

Unlike the Caribbean, the Mediterranean, which is squeezed between the 30th to the 47th parallels, is not affected by tropical hurricanes. The influence of continental winds, however, is strong. These include cold northern winds like the mistral and the bora, burning hot winds like the Saharan sirocco, and refreshing summer winds. The worst climatic excesses are cloud bursts over mountains in the cold season, resulting in floods and landslides.

Cradle of Western Civilization and source of many myths, religions, and philosophies, the Mediterranean countries today remain a major seat of culture. The Med is a link between the Western World and the Orient, a natural route to and from the Indian Ocean through the Suez Canal for trade and oil. It also is a meeting point between the Third World countries of the South and the developed world of the North.

It is as well a political "hot-spot." Despite the recent thaw in relations between the Soviet Union and the United States, one need only think of the Israeli-Arab conflict, Cyprus, Lebanon, the Islamic Revolution, and the recent Iran-Iraq war. Recent events in Eastern Europe will likely have a bearing on the Med in terms of trade, tourism, and pollution monitoring.

The total population of the 18 nations bordering the Mediterranean is about 376 million of which 260 million live along the coast.

Perhaps the ancient gods looked down upon the Med as we can from spacecraft today.

Marked contrasts exist between the countries in terms of social welfare, health, education, employment, and per capita income.

Studies by the World Bank forecast a high urban growth rate in the region—435 million by the year 2000 and more than 500 million by 2025, a large percentage of which will be in Algeria, Morocco, Turkey, and Egypt.

Because of its rich history, the Med is a storehouse of artifacts from ancient days. Marine archaeology continues to contribute to our understanding of ancient cultures and mores. It also supplies us with visual art beyond compare, not to mention a thrilling form of recreation when supervised properly.

The Mediterranean is poor in marine resources. Fishing and aquaculture have a production of less than two million tonnes. Salt production for the chemical industry, however, is important. The bordering countries produce various raw materials for industry, such as phosphates, mercury, chromium, bauxite, and cotton.

Only 15 years ago, there were no rules against dumping industrial waste into the Med. International cooperation is now curbing pollution.

Oil and gas are the most important products, however, with an annual production of about 160 million tonnes (see page 56). This represents less than 5 percent of world production. Italy, Algeria, Libya, and Egypt are the most important producers in almost equal amounts. Offshore oil exploration and development today is encouraged on the continental shelves.

The oil refining industry is twice as important as total local oil production and accounts for about 10 percent of the world total. Although oil production and reserves are high, the refining industry is dependent on trade-shipping and transshipment of the oil from the Near East (40 percent of world production).

Much oil comes through pipelines in war-torn countries: the Suez Canal has become the major transit route since it was re-opened in 1975 (83 million tonnes a year are carried on this seaway, which links Near East oilfields to the developed countries north of the Mediterranean). Oil shipping is an important component of port activities and industries.

The 13 major Mediterranean ports (handling a combined total of more than 15 million tonnes) have refineries and petrochemical plants. Only a few ore-handling ports, such as Fos-sur-mer, near Marseille in France, and Tarente in Italy were expressly built to supply the major ironworking plants.

There also are new agricultural landscapes. The change from a traditional agriculture to a modern farming system with greater productivity is gaining impetus.

In the old economy, much of the produce was destined for subsistence, with little surplus sold on the local market. In contrast, the new agricultural system is founded on crop specialization for the northern European markets: orchards of olive, orange, and lemon trees, large vineyards, rice fields, and *huertas* that produce various rare vegetables. Greenhouse cultivation is also gaining greater favor.

Mechanization, attended by a drastic exodus of agricultural workers, use of fertilizers, and development of high-tech irrigation in the plains following the eradication of malaria, are the common hallmarks of the modern agriculture.

The seafloor is scattered with ancient remnants like these 11th- and 14th-century B.C. shipwrecks off Turkey.

Seventy percent of the world's tourists flock to the Mediterranean, some 80 million a year. Fifty-eight percent of world tourism income is generated in the Med. They come because of the sun, the fun, the food, and the history. After all, there are the remains of the Greek and Roman empires to feast on, not to mention devouring the first-hand images of a whole legion of authors that range from de Maupassant to Durrell, Fitzgerald, Camus, Churchill, and beyond.

The tourists also come for the color—that special Aegean light that sparkles off a limpid sea covered by a Mediterranean blue. Artists have long celebrated the special sun-blessed colors of the region.

The earliest tourist centers are more than a hundred years old. More recent centers have sprouted up in the last decades: for example, the Costa Brava and Costa del Sol in Spain, the Costa Smeralda in Sardinia, Languedoc-Rousillon in France, as well as resorts on the Balearic Islands, Tunisia, Greece, and Turkey. Malta is now a fully fledged tourist island.

Fresh fish is extremely valuable. Most fishermen make many short trips in small boats.

The construction of long urban sea fronts, buildings, villas, and many marinas have transformed radically the ancient landscapes of the Mediterranean.

These changes, such as urban growth—several cities of more than a million inhabitants now dot the Mediterranean coast—and the oil trade with its associated oil spills have increased the danger of pollution in marine ecosystems and damage to the coastline.

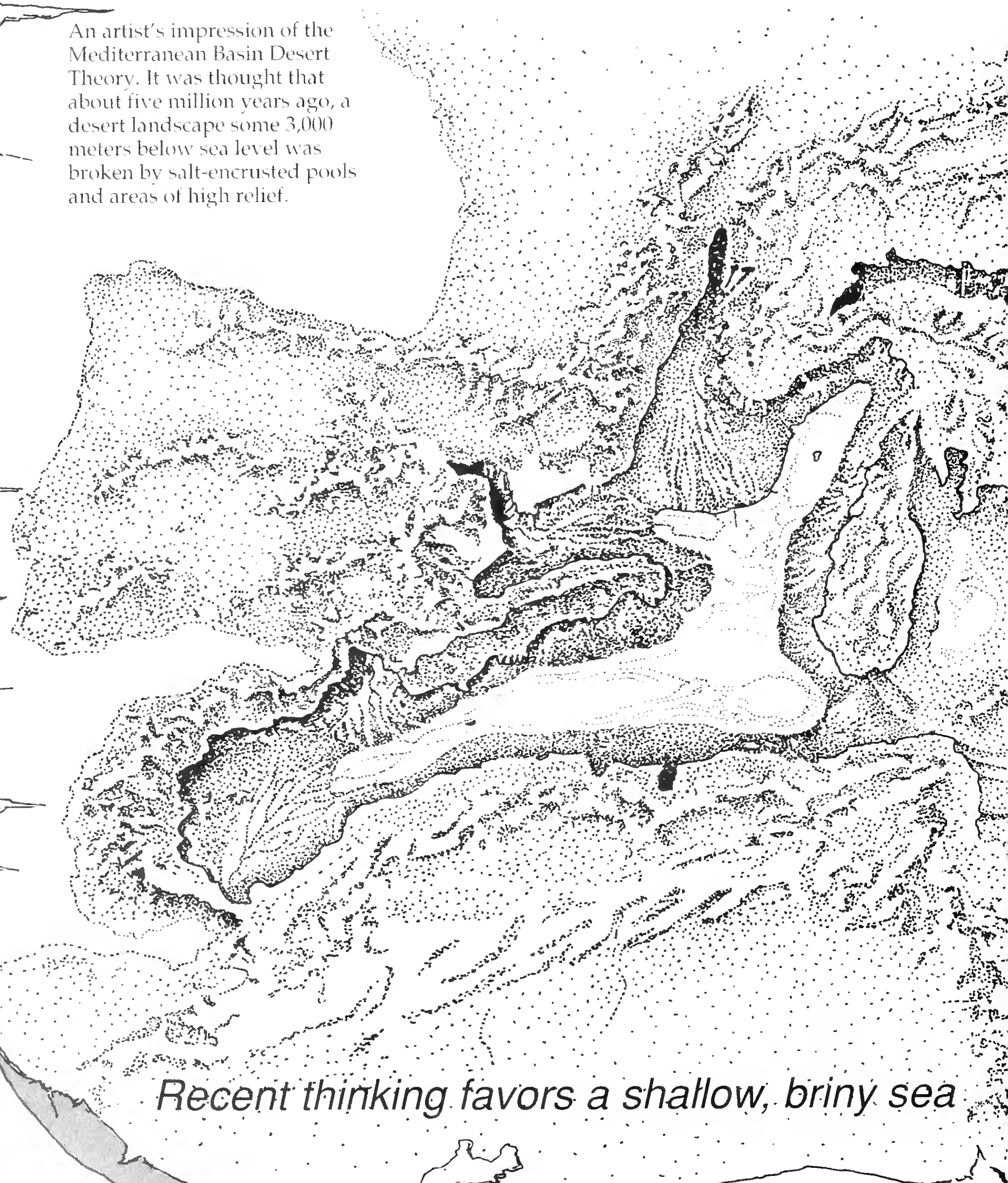
Water discharge from the rich Italian plains of the Po River threaten an ecosystem, a city (Venice), and a coastline. The catastrophic growth of algae in the Adriatic last summer (see page 52) may be one result of the high concentration of pollutants (nitrates and phosphates). The prevention of further pollution along with cleansing measures against existing pollution is a priority concern in the Mediterranean.

Maurice Julian is a Professor and scientist with the Laboratoire de Géoécologie Alpine et Méditerranéenne, Université de Nice. Paul R. Ryan is Editor of Oceanus.

If rocks could tell tales,
the Rock of Gibraltar
would be a master
storyteller.

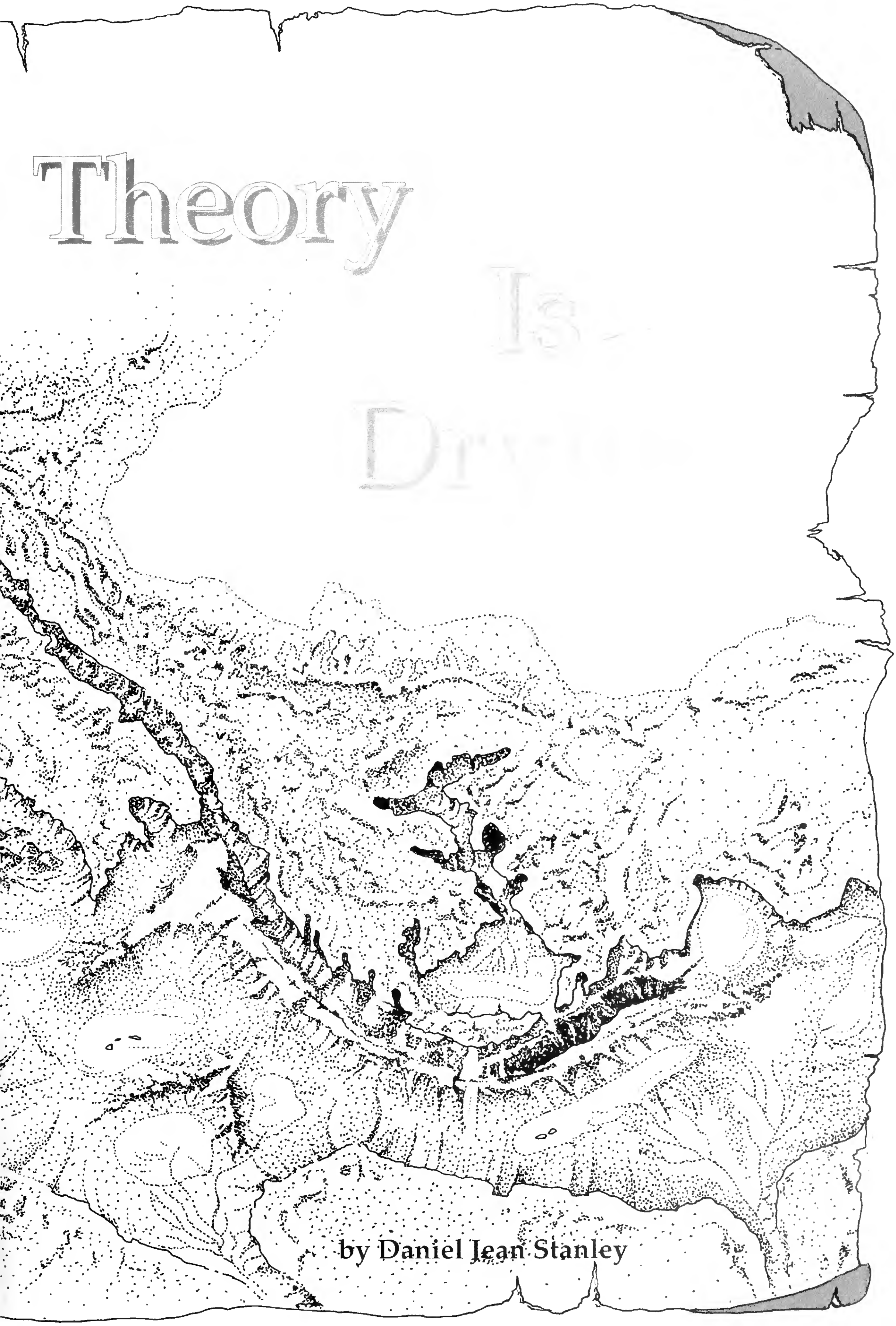
Med Desert

An artist's impression of the Mediterranean Basin Desert Theory. It was thought that about five million years ago, a desert landscape some 3,000 meters below sea level was broken by salt-encrusted pools and areas of high relief.



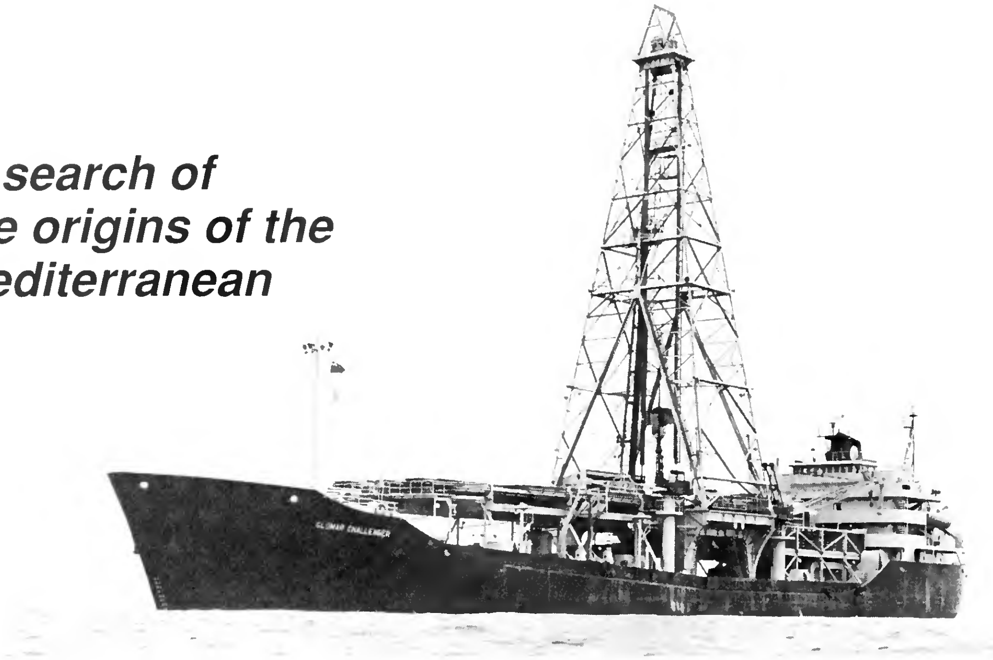
Recent thinking favors a shallow, briny sea

Theory Is Dry



by Daniel Jean Stanley

In search of the origins of the Mediterranean



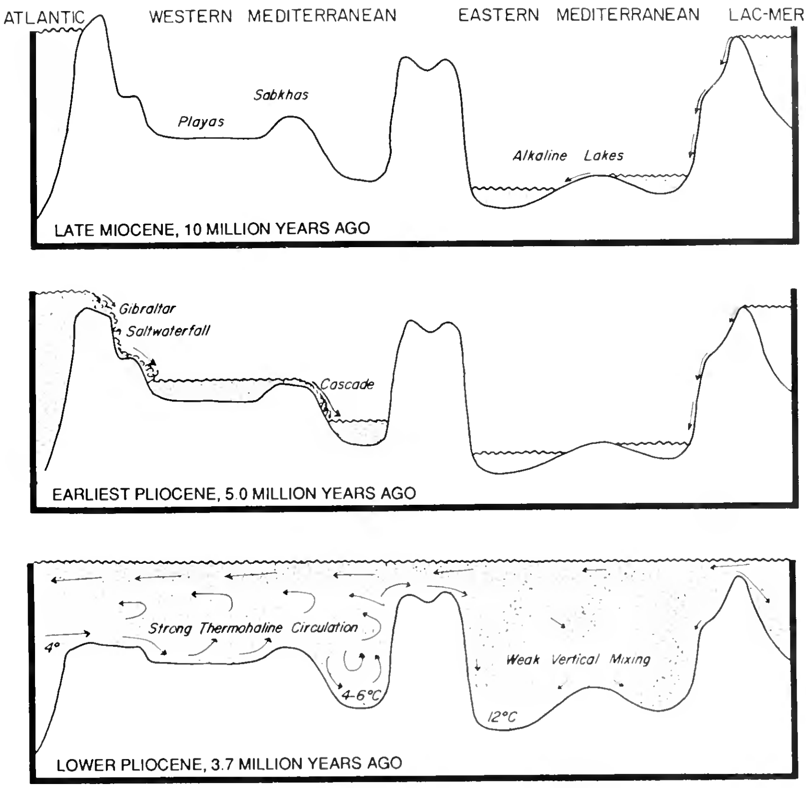
For the last two decades many earth scientists have supported the notion that the Mediterranean was once a huge dry desert, lying 3,000 meters below sea level. This "death valley" was thought to have existed at the end of Miocene time, about 6 to 5.5 million years ago. Geological theories usually fall at a glacial pace into a sea of controversy, and this one is no exception. Today—charging that proof for the theory is lacking—many scientists believe that the Med always contained saltwater, with only the depth of the seafloor and the water being in question.

The desert theory surfaced in 1970 at the end of the first deep-sea drilling cruise organized by the Joint Oceanographic Institutions' Deep-Earth Sampling program aboard the *Glomar Challenger*. Upon arrival, the chief scientists, William Ryan and K. J. Hsü, presented their findings to the press, declaring that about 6 million years ago the Mediterranean basin had dried and was partially covered by thick evaporite salts.

High relief near what is now the Strait of Gibraltar served as a barrier to the exchange of waters with the Atlantic. Exposed to a hot and dry climate, water evaporated and the then-dry basin elicited comparison with a gigantic Death Valley. At the beginning of the Pliocene, about 5.5 million years ago, waters from the Atlantic Ocean surged into the basin as a giant waterfall at Gibraltar. This dramatic depiction lent itself to publicity and media attention.

This theory was reasserted during a second deep-sea drilling cruise in the Mediterranean in 1975. It has generated considerable discussion among earth scientists trying to unravel the geological history of the complex ocean basin known as the Mediterranean. Some of the tenets on which the theory was formulated are, if not defective, very seriously in question. To interpret their findings, a

Daniel Jean Stanley is Smithsonian Senior Oceanographer and Director of the Mediterranean Basin Program at the National Museum of Natural History in Washington, DC.



According to the Desert Theory, the Mediterranean dried up almost completely after being cut off from the Atlantic Ocean. Waters later cascaded in at the Strait of Gibraltar, filling the sea back up and allowing for deep waters to exchange between the two basins.

respectable number of geologists studying the surrounding emerged borderland as well as subsea sections indicate that alternative, more comprehensive, concepts must be envisioned.

What are we to make of this? The American oceanographer Robert Dietz of Arizona State University may have hit the nail on the head when he presided at a session devoted to the origin of the huge Mediterranean salt deposits at the most recent annual meeting of the Geological Society of America. He spoke for a growing body of respected scientists when, referring to a deep, dry Mediterranean, he asserted that "Remarkable hypotheses require extraordinary proof! That proof is lacking."

These are strong words. It thus seems appropriate, in this issue of *Oceanus*, to highlight some areas of contention in interpreting the origins of the Mediterranean.

From a geological point of view, the Mediterranean is a tectonically mobile land-enclosed depression—small (about 3,000,000 square kilometers) in comparison to the major world oceans. Nearly isolated from the Atlantic Ocean and Black Sea, it extends almost 4,000 kilometers from the Strait of Gibraltar to the foot of the Lebanon mountains. One is never more than 370 kilometers from shore, and usually much less.

Immediately obvious on all charts is the highly variable topography and relief of both the seafloor and adjacent borderland. The coastline is highly irregular; and continental shelves, though generally narrow, are well developed off the major river deltas (Nile, Rhône, Po, and Ebro). Moreover, the deep-sea basins and trenches have distinctive relief, with basin plains ranging in depth from less than 1,000 meters to more than 4,000. It is convenient to distinguish western, central, and eastern Mediterranean provinces, each of which is further subdivided into distinct basins by submarine ridges; tectonic blocks; and the Iberian, Apennine, and Hellenic peninsulas.

In the late 1800s, European geologists put forth a series of intriguing theories on the tectonic origin of the Med. Testing these theories had to wait until deep-sea drilling technology became available in this century.

Coastal and near-shore processes retained the attention of philosophers, navigators, and naturalists from the time of Herodotus to the Renaissance. Publication in 1725 of *Histoire Physique de la Mer*, by Count Luigi Ferdinand Marsigli—or Marsili—signals the beginning of modern oceanography, especially with regard to the Mediterranean. Marsili's observation that rocks dredged offshore are similar to those on land raised a fundamental concept—the key to understanding Mediterranean history lies in the adjacent emerged land masses, and vice-versa.

More than two centuries would pass before geologists, in a concerted effort, would make breakthroughs at sea in unraveling the history of the Mediterranean. The prolific publications in the 1940s and 1950s by French oceanographers were instrumental in calling attention to the complexities of seafloor structures and associated sediment transport processes in the Med. Also during this period, French, Italian, American, and Russian surveys compiled evermore precise charts of seafloor contours and depths.

How did the different parts of the Mediterranean evolve? A series of intriguing theories on the tectonic origin of this ocean basin had been proposed by land-based European geologists late in the 1800s and early in this century. Testing these theories would have to wait nearly half a century until better at-sea technologies were developed. Verification began in earnest when geophysical and deep-sea drilling methods made it possible to map subbottom horizons and then actually recover specific sections.

Antisubmarine warfare and energy needs drove modern scientific inquiry into the geological history of the region and its complex tectonic motion.

A first view of what lay below was provided by gravity studies in the 1930s. The major impetus to study the nature of what is beneath the Mediterranean seafloor and its geological movement was provided in the years following World War II as a result of intensified military considerations, especially antisubmarine warfare. Increased energy needs, which led to oil and gas exploration, also contributed to greater interest. Data disclosed that the crust underlying Mediterranean basins is nearly as thin as that beneath the major world oceans.

Notable milestones include discoveries made on seismic cruises from 1958 to 1964 by the Lamont-Doherty Geological Observatory at Columbia University and the Woods Hole Oceanographic Institution—in particular, the pioneering work of Brackett Hersey and David Fahlquist. These geophysicists mapped the boundaries between abyssal plains and those forming continental margins. They recognized, as work on land had previously suggested, that the modern Mediterranean records the effects of widespread, geologically recent tectonic motion.

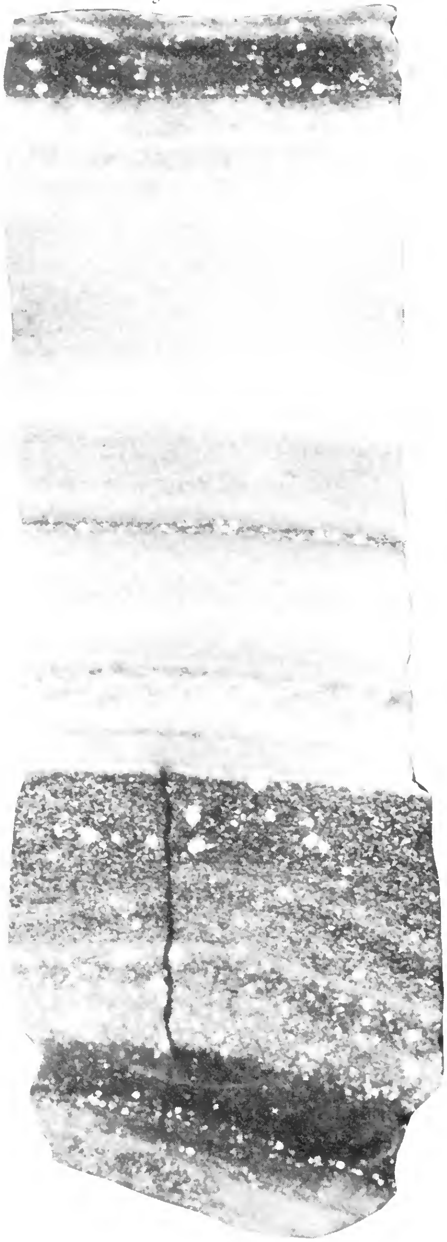
Study of piston cores indicated that the upper sedimentary and volcanic layers covering basins and lower slopes had accumulated very rapidly, in some places a a meter or more every 1,000 years. In 1969, Ryan, Hersey, and I identified a group of distinct subbottom deposits, particularly in the western Mediterranean, that were estimated to be about 4.3 million years old. These early Pliocene deposits were deformed and pierced by irregularly distributed salt domes. Seismic profiles indicated that the salt was of variable thickness, up to a kilometer or more.

Piston cores indicate sediment and volcanic layers accumulated at a very rapid rate—up to a meter or more every 1,000 years.

At the time seismic studies were opening a window on the subbottom configuration of the Mediterranean, the earth sciences were experiencing a major revolution—that is, the concept of seafloor spreading, or the idea that the seafloor moves away from mid-ocean ridges, where new seafloor is formed from deep volcanic material. Previously, the Mediterranean had been considered to be a simple remnant of a much larger and very long seaway, the Tethys, which once existed between the northern and southern continents. In just a few years, a growing number of geologists began to reconstruct the Mediterranean in light of new global geological concepts.

A series of carefully computed maps by Alan Smith of the University of Cambridge, for example, showed just how the Mediterranean region evolved through time in a long-lived continental collision zone. While this sea is largely related to the oceanic crust between Europe and Africa, it would appear that the present Mediterranean does not really incorporate any of the older (Early Jurassic, or more than 200-million-year-old) Tethys seafloor.

The sediment core below was collected during the Deep-Sea Drilling Project. The upper light part is salt, and the lower, dark section is layered silt.



The western Mediterranean is probably floored by a crust only 20 million years old or less. The eastern Mediterranean is floored by older crust (but younger than Early Jurassic). As Europe and Africa came together, this sector was probably the last remnant of the Tethys.

The complexity of the region on land and at sea, shown on the time-lapse maps (see opposite) generated by Smith and other workers, could be viewed as the result of the creation of continental margins and then their subsequent destruction.

Let us return to the question of whether the Med basin at the end of the Miocene was once deep and then became a desert. This concept did not arise with the shipboard scientists aboard the *Glomar Challenger* in 1970. Published interpretations on this topic had been made more than 50 years earlier by geologists. These studies called attention to the importance of two arms of the western Mediterranean that had assured an exchange of water with the Atlantic—that is, the northern Betic Strait and the southern Rif Strait.

These early paleogeographic reconstructions showed that the once-open communication with the Atlantic deteriorated during the upper Miocene. Water-mass exchange continued for a while in the Rif Strait, but then ceased completely just prior to the beginning of the Pliocene.

The story unfolds as we recall the publications of G. Ruggieri in Italy in the mid-1950s and 1960s, again well before deep-sea drilling cruises. His contributions, in my view, have not received the attention they truly deserve. Focusing on the data from the Italian peninsula and Sicily, Ruggieri set forth his Mediterranean desiccation theory and what has since been called the Messinian "salinity crisis."

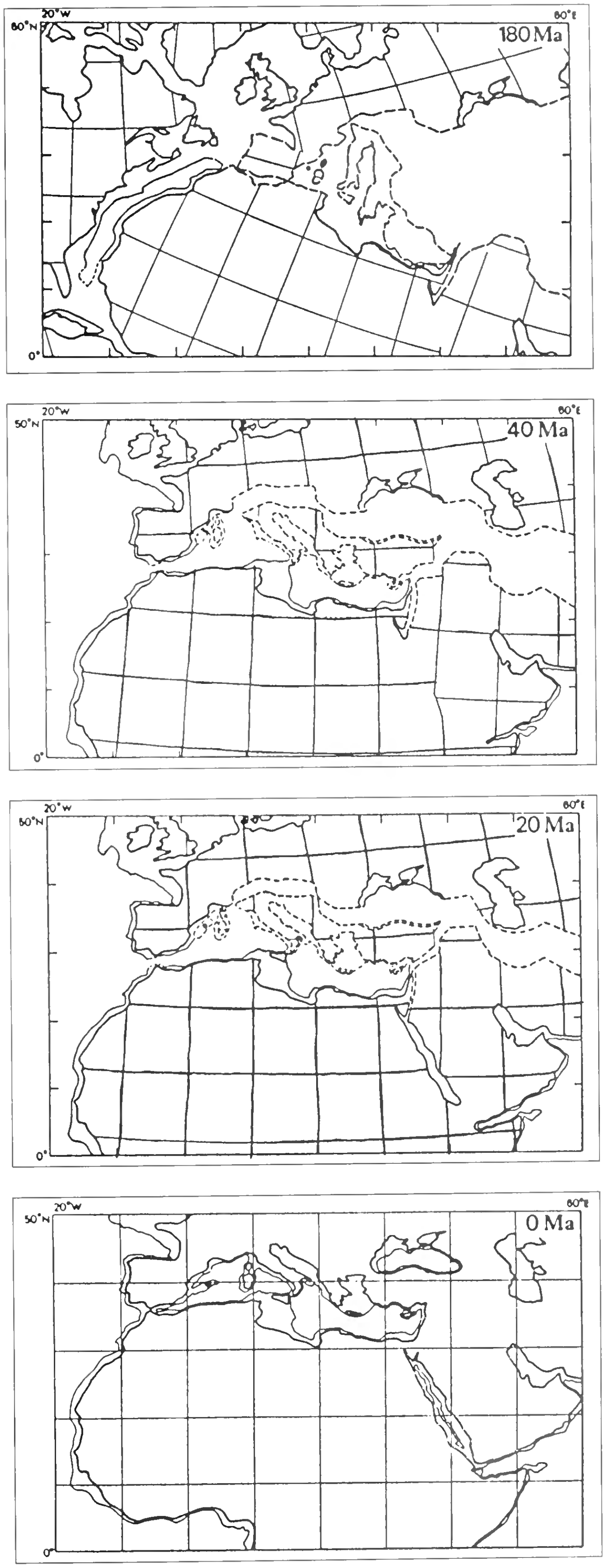
In his "catastrophe" model, Ruggieri showed that after the Atlantic became closed to the Med—a period when conditions favoring evaporation prevailed—evaporite salts and sulfur minerals began to accumulate in the western Mediterranean. Some of the deeper parts of the central and eastern Mediterranean basin became lakes. These lakes received waters from a large inland sea, the Paratethys, in eastern Europe and the Middle East.

An unusual fauna, suggesting a shallow restricted environment, markedly distinct from underlying Middle to Upper Miocene open marine faunas, began to accumulate. Lake levels were several hundreds of meters below the general oceanic level. As these basins became increasingly isolated, gypsum and salt accumulated, probably squeezing most of the remaining Miocene faunas out of existence.

Large areas of seafloor subsided, but some sectors may have been uplifted in response to weight reduction accompanying removal of water. Within a short while, the waters of the Atlantic Ocean poured across a tectonic dam in the region at or near Gibraltar, re-establishing truly marine conditions.

This opening was wider and deeper than the present passageway at Gibraltar. This flooding event is recorded by the Miocene/Pliocene boundary, a time when open marine faunal assemblages were suddenly reintroduced from the Atlantic.

This catastrophic scenario thus was available for consideration by the shipboard party of the 1970 *Glomar Challenger* cruise. Also available to these scientists were seismic reflection profiles showing the wide distribution of salts underlying many parts of the seafloor. During the cruise, they obtained more profiles of subbottom erosional features and actually recovered salts from a number of bore holes. Corre-



The Med has changed shape drastically in the last 180 million years. The major influences have been Africa's movement relative to Europe, and seafloor spreading in the Atlantic.

lations with some sections on land, particularly those in Italy, were made by comparing microfossils and the chemical composition of rocks. The stage was now set for the rediscovery of a deep, dry Mediterranean.

Microfossil studies suggested that the depth of the Mediterranean basin at these times had been "deep." Estimates suggested a dry seafloor as far as 2,000 meters below ocean level. This was 5.5 million years ago, in a drier and cooler (not warmer) climate. As a response to suddenly lowered sea level, rivers feeding the Mediterranean and canyons on the now-dry seafloor began a geologically dramatic phase of erosion. Deep, Grand Canyon-like gorges of the Nile and Rhône rivers, presently buried on land, were apparently cut during a great drawdown of water—when the Mediterranean floor lay exposed 1,000 meters or more below its present level.

The sudden flooding through a gigantic waterfall at Gibraltar drowned the exposed basin floor. These falls would have been 1,000 times bigger than Niagara Falls. One strong proponent of the deep, dry Mediterranean theory, Hsü, has commented: "What a spectacle it must have been for the African ape-men, if any were lured by the thunderous roar."

Present research is not rigidly locked into the salinity crisis framework. New observations and ideas are helping us to revise concepts to more accurately understand the recent history of the Mediterranean.

A minority view is the one held by W. D. Nesteroff of the University of Paris, for example, who favors a desert playa and thin-water-layer origin for the salts, but with deposition in a fairly shallow setting isolated from the world ocean. As with the deep, dry Mediterranean school, he postulates an intermittent communication with the Atlantic and more than a single epoch of evaporation of the basin to explain the great thickness of Messinian salts. Nesteroff, however, envisions this deposition of salt on a seafloor surface lying at moderate depths—200 to 500 meters below world ocean level.

It has long been the consensus of Mediterranean geologists that the shape of the seafloor and surrounding emerged land masses continued to change markedly between 65 and 1.7 million years ago in response to structural events. The idea that the configuration of the region has recently changed is strongly supported by the recent movement of young (less than 1.7 million-year-old) Quaternary deposits on land. Such motion is even now modifying the seafloor, which is attested to by extensive earthquake belts and zones of volcanic activity.

It should not be thought that the seafloor configuration at the end of the Miocene, only 5.5 to 5 million years ago, resembled closely that of the present sea. Surely it did not. An ever-growing number of geological studies show a considerable offset and deformation of seafloor in both eastern and western basins during the Pliocene and Quaternary. A most spectacular example is that of the Tyrrhenian.

The study of this basin has demonstrated that the Tyrrhenian basin floor, presently about 3,500 meters in depth, was much shallower in the Pliocene. This basin experienced a very large amount of subsidence during post-Messinian time. In fact, this may be one of the world's youngest deep ocean basins.

> ***It is not realistic to envision the Mediterranean seafloor of about 5 million years ago as a desert, some 3,000 meters below ocean level.***

Our Mediterranean Basin Program team at the Smithsonian Institution, however, does not—in the case of the large western basin during the salinity crisis—confirm depths in excess of 2,500 meters as proposed by Hsü and others, nor does it support a much shallower (200 to 500 meters) basin floor as indicated by Nesteroff. Rather, our measurements of the western basin indicate moderate bathyal depths, from at least 200 to as deep as 1,500 meters.

In many cases depth cannot be precisely determined by the associated faunas, which tend to be reworked along the seafloor after dying. Thus applying general terms like "deep" and "shallow" to these can be very misleading.

My assessment is that the configuration of the Mediterranean Sea at the end of the Miocene was considerably different than at present. This seafloor was subdivided in a series of distinct basins of variable topography, including some of intermediate depth, to 1,500 meters. These and other relief features have continued to evolve as the Eurasian and African plates continue their bump and grind.

The passageway or "portals" through which oceanic waters from the Atlantic entered the western Mediterranean shifted with time and did restrict flow. The seafloor nevertheless remained almost continuously covered by very saline waters, perhaps one hundred to several hundred meters deep from which salt precipitated to the bottom.

> ***I believe the seafloor remained almost continually covered by very saline waters, perhaps one hundred to several hundred meters deep.***

It is not realistic to envision the Mediterranean seafloor of about 5 million years ago as a desert at 3,000 meters below present ocean level. Several years ago I compared the Mediterranean to a complex picture-puzzle that comprises numerous intricate pieces, many of which are already in place. A general image is emerging, although gaps in some areas of the picture remain fuzzy and indistinct.

A model of the world ocean

Water, Salt, Heat, and Wind in the Med

by Henri Lacombe

From the shores of the Mediterranean have sprung great civilizations and models for political, religious, and artistic developments that have endured for thousands of years. But only recently have oceanographers recognized that the waters of the Mediterranean provide them with a model of the world ocean itself.

In the relatively benign confines of the Mediterranean, we can study in detail such processes as deep-water formation, air-sea interactions, and sediment deposition—studies that would otherwise require expensive cruises to remote and inhospitable regions. The ancient idea of Oceanus—the great river encircling the Earth that is linked to the center of the world, the Mediterranean, at Gibraltar—thus takes on a new significance.

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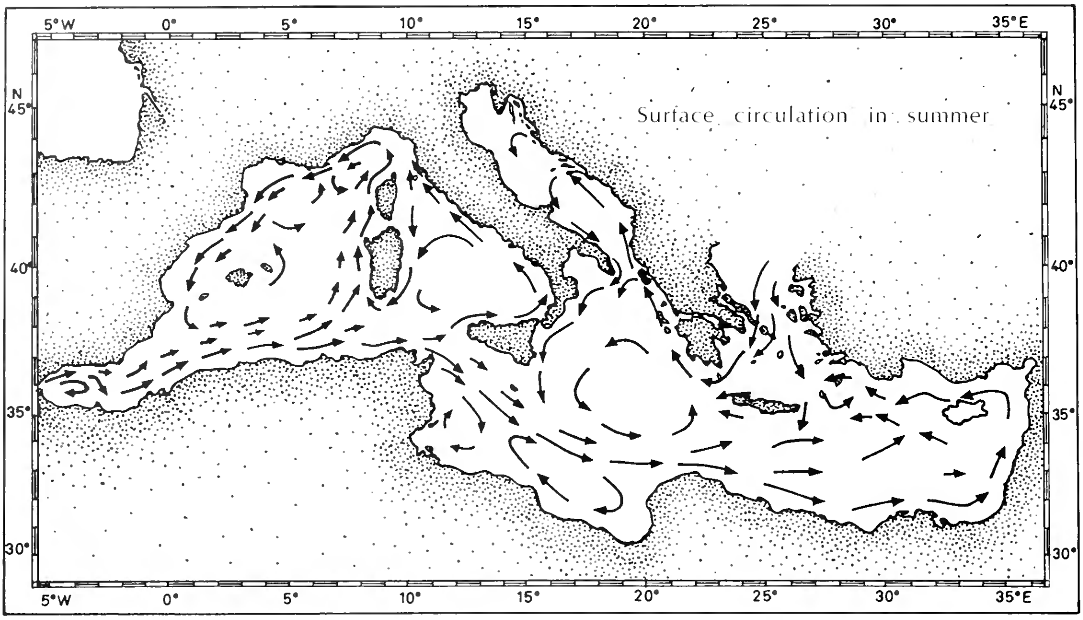
WHOI scientists first studied the Med in 1947 aboard the research vessel Atlantis.



Surface circulation is influenced by winds and incoming water flow.

The Phoenician navigators of 3,500 years ago are said to have had a fantastic store of empirical knowledge of Mediterranean hydrodynamics. If the legends are true, they lowered their sails several tens of meters into the sea and—taking advantage of the dense, subsurface outflow of the Mediterranean—easily entered the Atlantic despite the strong surface current flowing into the Mediterranean at the Strait of Gibraltar.

It was some 1,100 years after the days of the Phoenicians, however, that the dynamics of the sea were first studied "scientifically." Aristotle (384–322 B.C.) puzzled over the strange currents in the strait between the island of Euboea, or Évvoia, and the Greek mainland north of Athens. A regular, twice-daily tide streams back and forth for about four days before and after the new and full moon, and highly irregular currents sweep the strait for two or three days before and after the quarters. A (false) legend says that, despairing of explaining this unusual pattern, Aristotle finally threw himself into the strait. But 23 centuries were needed to discover that "seiches,"or sloshing oscillations in lakes or gulfs, cause the irregular currents near Khalkis, the harbor on this strait where Aristotle died, in fact, of natural causes.

Much of the Phoenicians' knowledge was lost, and it wasn't until the end of the 17th century that the possibility of opposite, over-and-under currents was again raised. Count Luigi Ferdinando Marsili, in the course of his extraordinary careers as politician, diplomat, geographer, physicist, hydraulicist, geologist, and oceanographer of the Mediterranean, discovered the two opposite flows in the Bosporus while on a "discreet mission" for Venice. During the mission, he became acquainted with Turkish fishermen and proved the existence of the countercurrents—a brackish surface flow into the Sea of Marmara and a deep, saltier flow into the Black Sea. He did this by means of drifting, neutrally buoyant floats that were color-coded for different depths.

Marsili went on to build a tank divided by a partition with holes near the surface and bottom, one side containing fresh water and the other salted water, to simulate the opposite flows of superposed fluids of different density. Even so, a hundred years passed before the possibility of such flows was acknowledged by all scientists, this only after the British *Porcupine* and *Shearwater* cruises in the Strait of Gibraltar in 1870.

Count Marsili proved in the 17th century that layered waters of different densities flow in opposite directions, but the countercurrents at the Strait of Gibraltar were only discovered some 150 years later.

After World War II, the Mediterranean became the focus of an oceanographic effort the pace of which is still accelerating. Oceanographers from the Woods Hole Oceanographic Institution (WHOI) first came to the Mediterranean aboard the *RV Atlantis* in 1947 and '48, returned in 1961 and '62, and have had a more-or-less constant presence ever since. Postwar French research was led by Paul Tchernia, who directed studies aboard navy vessels such as the *Elie Monnier*. During the International Geophysical Year (1957 to '58) we started working in the Strait of Gibraltar, where we returned in 1960 and '61 with Captain Jacques-Yves Cousteau's *Calypso*.

In 1961, the North Atlantic Treaty Organization's (NATO) Sub-Committee for Oceanographic Research (SubCOR) sponsored hydrography and current-measurement work in the Strait of Gibraltar with seven vessels of NATO nations. I vividly remember that cruise, with so many unexpected situations resulting from most of the vessels being anchored to the bottom for weeks. We were to focus our attention not only on currents—the purpose of the cruise—but also on strong winds, fog, and even the drifting swordfish-lines of Spanish fishermen that got entangled in our anchor chain.

The fact that cool, relatively low-salt Atlantic near-surface water enters the Mediterranean at the Strait of Gibraltar over an opposite flow of colder, much saltier, Mediterranean water implies that 1) both heat and water are lost to the atmosphere from the

Mediterranean, and 2) Atlantic surface water is thereby "transformed" into Mediterranean deep water during its sojourn in this nearly enclosed sea. The processes of heat and water exchange between the world ocean and the atmosphere, and the process of deep-water formation are two great problems in modern oceanography; they are crucial to understanding how the ocean influences global climate. And since it is possible to study them in greater detail in the Mediterranean, they have been the focus of a large research effort during the last 20 years.

An understanding of heat and water exchange and deep-water formation is essential to fathoming how the ocean influences global climate.

The strait and sill of Gibraltar is the last of a sequence of straits and sills that act as many steps imposed against the flow and exchange of different water masses in the Mediterranean (see map, pp. 54–55). From the Bosporus, the sequence in the eastern basin proceeds from the Dardanelles to the many straits and sills of the Aegean Sea, the arc of sills between Anatolia and the Peloponnesus, the Strait of Otranto between Italy and Albania, and through the straits of Sicily and Messina into the western basin. In the western basin, the sequence proceeds from the Strait of Sardinia and the Corsica channel out of the Tyrrhenian to the sills and straits around the Balearic Islands, including the Ibiza channel, and finally through Gibraltar.

These internal sills play varying roles in the hydrography, or the variations in temperature and salinity, of the sea. For instance, the Strait of Sicily, about 430 meters deep in a narrow valley, is sufficiently deep to allow the passage only of eastern water of intermediate depths into the western basin; the deep waters of the two basins have no connection, and there are small, but clear, differences between the deep waters. Since the eastern intermediate water becomes a component of western deep water, a "print" of the eastern Mediterranean is present on the whole sea.

Squeezed between dry southern Europe and the north African desert, the Mediterranean is strongly influenced by the climate of these lands. Rains come mainly in winter, principally near the coastlines with high topography. Summer and winter each have characteristic winds, but even these are subject to very sudden and localized variations. The effect of Mediterranean weather is to transform Atlantic water into typical Mediterranean water. The transformation is most obvious in the salinity of the waters, and takes more than a century to complete.

The transformation of Atlantic water into Mediterranean water takes more than a century to complete and is strongly influenced by the regional climate.

In summer, low pressures over sunny western Asia and north Africa bring hot and dry air to the Mediterranean, carried by the etesian winds that blow from the north over the Aegean and Adriatic, and from the northeast over the Mediterranean's southwest shores. In the northern half of the western basin, however, the Azores anticyclone generates north or northwest winds off the coasts of Spain and France. The sea surface gives up quite a bit of moisture to the air under such conditions.

While intense Mediterranean sun is generating suntans, it also is changing the temperature of the water column, affecting rates of evaporation.

The same intense sunlight that generates all-over tans on the Côte d'Azur each summer also generates a strong thermocline, or water layer of rapidly declining temperatures, at a depth of about 30 meters. This thermocline acts as a screen between the water masses above and below it, and evaporation at the surface has no effect below the screen.

In winter, fiercely cold, high-pressure air masses over Europe and Asia generate strong, cold, and dry winds from the northeast that sweep over the Aegean, Adriatic, and the northeastern Levantine basin. Meanwhile, similarly cold-and-dry winds, such as the mistral, sweep down the Rhône and Ebro river valleys and over the western basin. Throughout January, February, and March, these winds soak up moisture and heat across the sea, resulting in the build-up of dense surface-water layers.

In the western Mediterranean, water deeper than about 2,000 meters has remarkably constant values for temperature and salinity (12.70 degrees Celsius and 38.40 parts per thousand). So constant, in fact, that in 1970 a working group of United Nations Educational, Scientific, and Cultural Organization's (UNESCO) International Oceanographic Commission (IOC) raised the possibility of using it as a standard salinity reference. But research cruises in 1972 and '73 revealed a new phenomenon: an occasional bottom layer below 2,000 meters that was somewhat warmer (12.73 degrees Celsius) and saltier (38.42 parts per thousand) than the "reference."

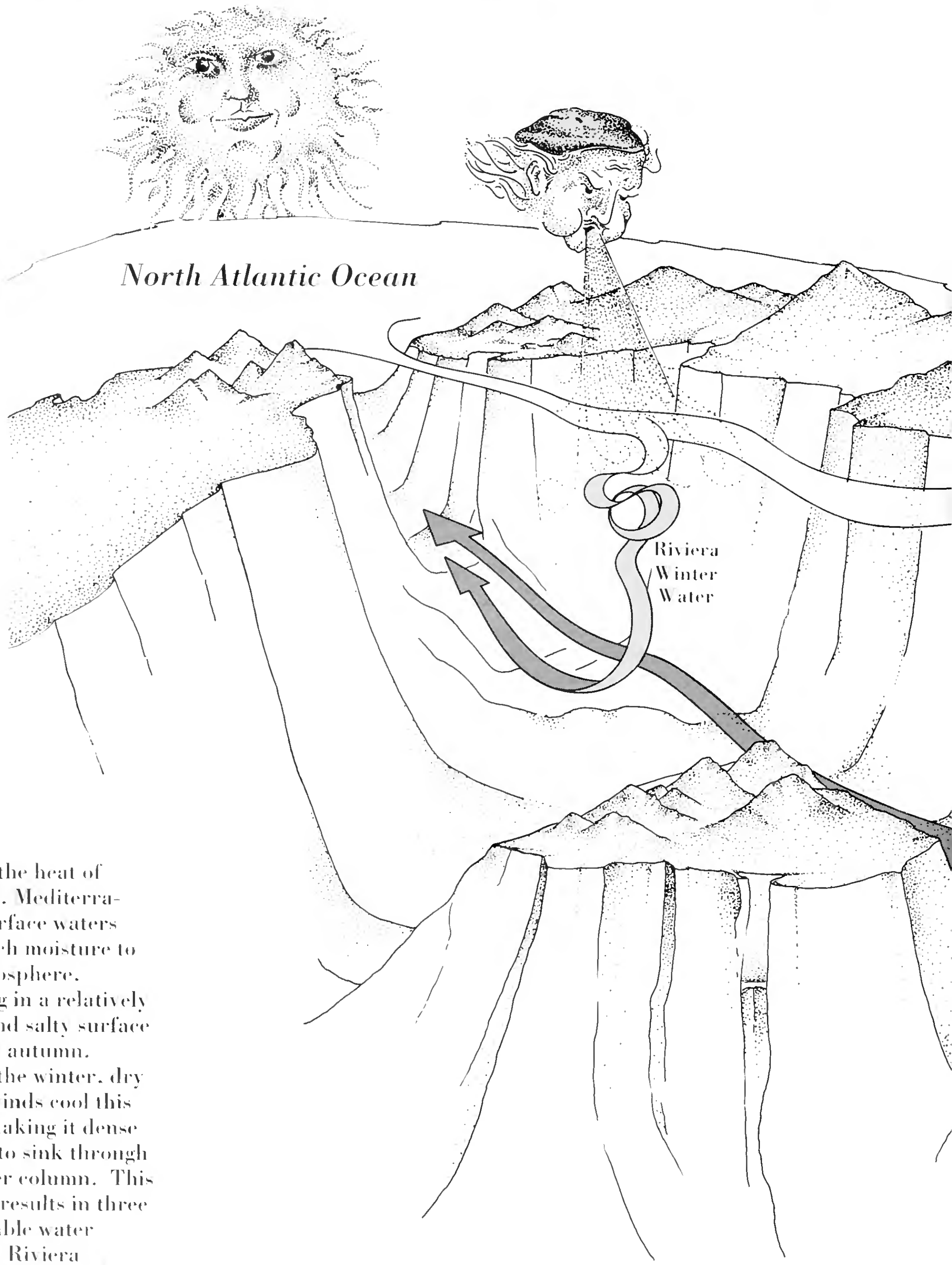
Satellite imagery gives important information on eddy formation and duration, coastal upwelling, and wind-induced currents.

The mysterious layer disappeared in 1974 and 1975, but recent cruises in the Gulf of Genoa and off the west coast of Sardinia showed still warmer and saltier anomalies in very localized areas. Scientists are now faced with the possibility that these anomalies are linked to a trend toward warmer climate.

The various water masses interacting with each other and the

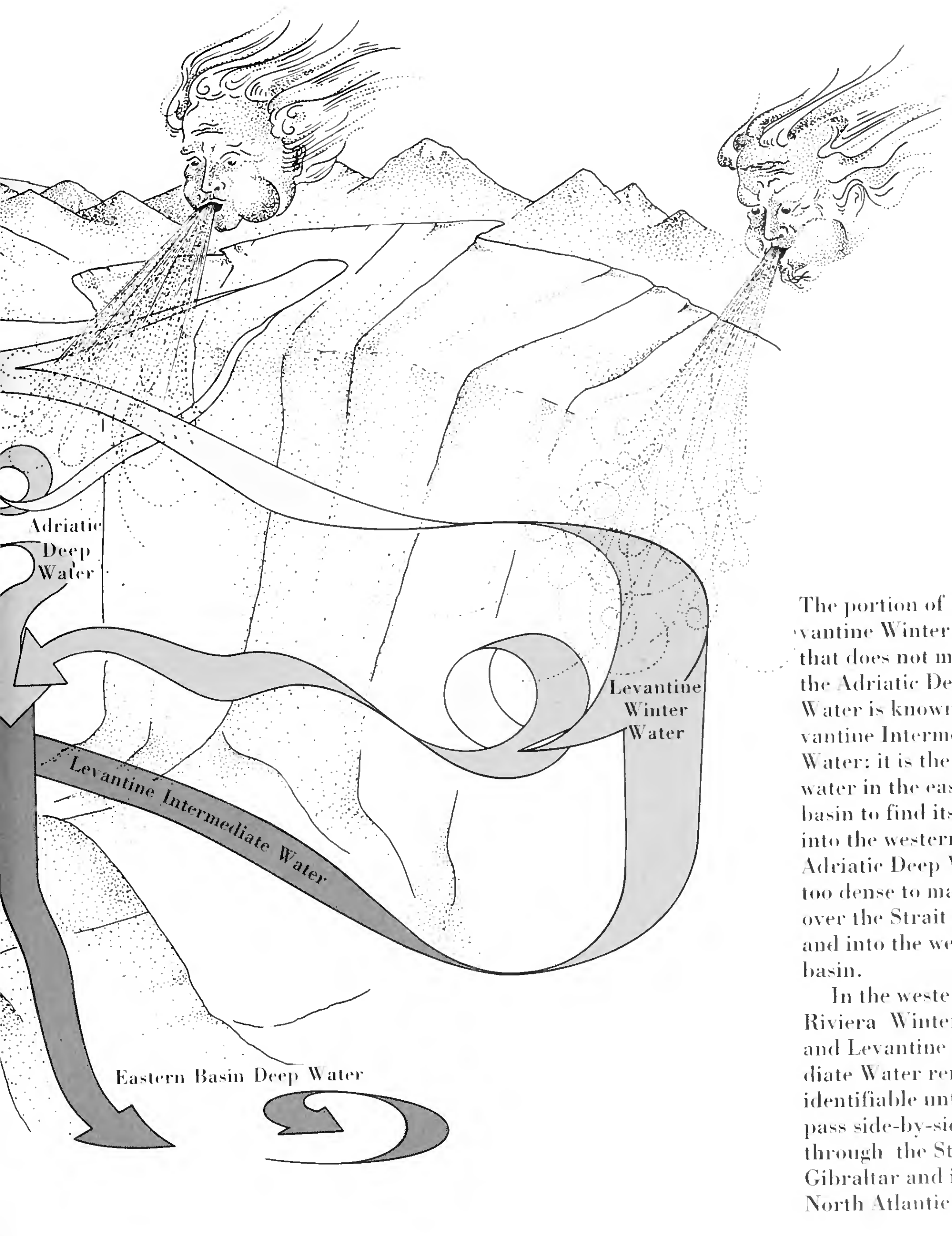
(continued on page 34)

Deep-Water Formation



During the heat of summer, Mediterranean surface waters lose much moisture to the atmosphere, resulting in a relatively dense and salty surface layer by autumn. During the winter, dry Arctic winds cool this layer, making it dense enough to sink through the water column. This process results in three identifiable water masses: Riviera Winter Water, Adriatic Deep Water, and Levantine Winter Water.

in the Mediterranean



The portion of Levantine Winter Water that does not mix with the Adriatic Deep Water is known as Levantine Intermediate Water: it is the densest water in the eastern basin to find its way into the western basin. Adriatic Deep Water is too dense to make it over the Strait of Sicily and into the western basin.

In the western basin, Riviera Winter Water and Levantine Intermediate Water remain identifiable until they pass side-by-side through the Strait of Gibraltar and into the North Atlantic Ocean.

Mediterranean climate give rise to general circulation patterns recognized by Marsili back in the early 18th century. The patterns are of course far more complex than Marsili's description; and because the Mediterranean is such a focus of modern oceanography, currents can be related to bottom topography and day-to-day weather changes with a precision undreamed of in Marsili's time. Other oceanographers can then use this information to explain the behavior of currents elsewhere.

Satellite images are especially appropriate for the Mediterranean, where the skies are often clear, and depict such surface phenomena as eddies and thermal fronts, which exist on a scale of 10 to 100 kilometers. For instance, satellite images of the anticyclonic eddy in the western Alboran Sea give indications about its movement in time, which is probably linked to weather conditions.

On one side of a cape in France, the tourist may find the water too cold to enter, while on the other it invites a dip.

Satellites also have given us information about the Algerian Current, which is very far from being a regular flow; eddies form eastward of about 1 degree East, and grow to 250 kilometers across and 1,000 meters deep. In the eastern basin, the surface circulation flowing to the east-southeast in the Strait of Sicily is generally cyclonic except for a large anticyclonic gyre in the Gulf of Sidra and an anticyclonic eddy that a satellite detected in the "lee" of the Cyrenaïca peninsula. In summer, during the etesian winds, Aegean surface water flows out over the sills between eastern Crete and the islands of Kárpathos and Kásos; this current sometimes generates eddies in the lee of the islands, particularly south of Crete.

Satellite imagery also has pointed out an interesting coastal phenomenon: extremely localized upwelling and downwelling. When mistral or tramontane winds are blowing nearly perpendicular to the coast of the Golfe du Lion, patterns of upwelling and downwelling develop that are related to coastal promontories. Theoretical studies explain the phenomenon, which occurs about a day after the winds begin. Thus, some tourists who wouldn't brave the 18-degree Celsius water on one side of a small cape may not believe their friends, who, staying at a resort on the other side, might have enjoyed long swims in 24-degree water on the very same day!

The intermediate and deep waters of both basins appear to follow cyclonic paths, although small eddies of intermediate water occasionally break off the main circulation in the northern Ionian. A 1989 report from the Physical Oceanography in the Eastern Mediterranean (POEM) project details deep-water circulation in the eastern basin, where Adriatic Deep Water flows along the Italian continental slope in the northwest Ionian.

The existence of the opposite, over-and-under currents of different salinity at Gibraltar reveals the Mediterranean to be a concentration basin—that is, the Mediterranean loses more water

From space it is easy to see Atlantic water flowing in through the Strait of Gibraltar (upward from lower left). The numbers refer to changes in the complex inflow and outflow currents as determined from sunglint patterns.

to the atmosphere than can be compensated for by rainfall and river input.

The total amount of salt and water in the sea has remained constant since at least 1910. This is because the salt carried in by a given volume of less-saline Atlantic Water (salinity about 36 parts per thousand) is compensated by a smaller volume of more-saline and dense Mediterranean water flowing out (salinity about 38 parts per thousand, or 5 percent higher than Atlantic water). The relative increase in salinity implies that outflow volume is 5 percent less than the inflow of Atlantic water.

The problem then becomes doing the most adequate and accurate flow measurements that are possible in a very difficult section of the strait, and calculating the absolute volumes exchanged per unit time—obtained only after subtracting out the effects of tidal currents, weather, and so on. From these measurements and calculations come estimates of the "residence time" of a particle of water in the Mediterranean, or how long it takes to transform Atlantic water into Mediterranean water.

The first such evaluation was done by Gerhard Schott in 1915: he proposed values of about 1.8 million cubic meters of water entering the Mediterranean each second and about 1.7 million cubic meters a second flowing out. This translates into a residence time of about 70 years. Our measurements of 1960 and '61 gave us an inflow estimate of 1.2 million cubic meters of water a second—in addition to the roughly 50 meters of swordfishing net snagged during September 1960. This comes out to a 100-year residence time. Now, as a result of measurements taken during the 1985–1986 Gibraltar Experiment (GIBEX) project, we have an inflow value of 760 thousand cubic meters of water a second, or a residence time of about 150 years.

Since about 1975, many Mediterranean nations, such as Italy, Israel, Yugoslavia, Turkey, and France, have carried out ambitious research programs in both basins. Action of bodies such as NATO's SubCOR, UNESCO's International Oceanographic Commission (IOC), and the International Commission for the Scientific Exploration of the Mediterranean (ICSEM) have promoted collaborative international efforts and encouraged the involvement of nonbordering countries including the United States, West Germany, and Belgium.

In the last six or seven years, however, U.S. oceanographers in particular have really "turned to the Mediterranean," recalling their "turn to the sea" of the 1960s. DON DE VA? (Spanish for "Where is it going?") is a U.S.-Spanish program that studies circulation in the Alboran Sea; it began in 1982. The Western Mediterranean Circulation Experiment is an effort by American, Italian, French, and Algerian oceanographers to study the currents off the Algerian coast. The United States and Italy developed the POEM project with the participation of Yugoslavian, Greek, Turkish, Israeli, and Egyptian scientists aboard their own vessels and West Germany's *RV Meteor*; the project looks at eastern basin hydrography throughout the year and develops circulation models. Most of the sea-work is now completed and several papers are being published.

The GIBEX program, however, is probably the most exemplary of these projects. During 1985 and '86, it described in detail the processes of water and energy flow occurring in the Strait of Gibraltar—making this strait a reference for all other straits in the world ocean. The measurements taken will improve our values of the exchange coefficients for salt, water, and heat flow through the strait. They also will help to determine more precisely the oceans' role in absorbing and reflecting energy from the sun, and so improve models of the Greenhouse Effect.

Acknowledgment
This article is dedicated to our late friend, Professeur Paul Tchernia, in memory of 40 years of common interest and work in the Mediterranean.

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Landsat image of Cape Cod

Launching a sediment trap off the *R/V Knorr*

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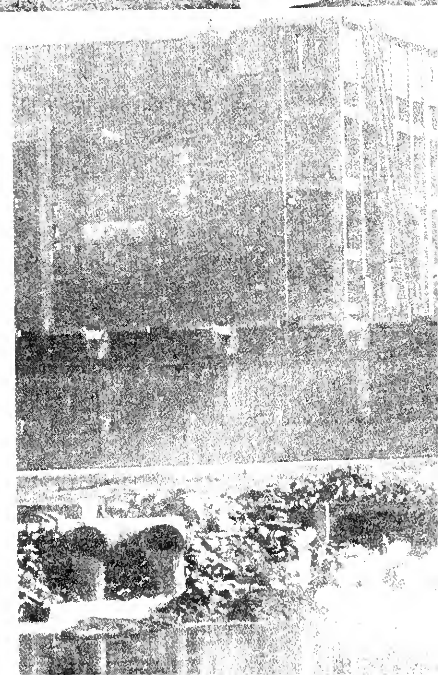
1930

The Med is Cleaner

It's still diseased, but not terminally ill

by Peter M. Haas and Julie Zuckman



The quality of Mediterranean seawater has in some respects improved during the last few years. Sewage treatment plants have been built or are under construction in 12 port cities throughout the region. Some beaches once considered unsafe for swimming are now open, and toxic emissions from rivers running into the sea have been reduced.

In general, pollution levels have stabilized and are now about the same as those recorded in the early 1970s. This is a significant accomplishment when one considers the rapid growth in coastal population and industrialization during the last 20 years. Thus, a sea once headed for extinction is still diseased, but not terminally ill.

Despite more than 10 years of research, there is no overall understanding of Mediterranean water quality. But the percentage of beaches considered unsafe for swimming has dropped to 20 percent from 33 percent in 1976. And during the late 1970s, toxic emissions into the Rhône river were reduced 44 percent.

The credit for this qualified success story is in large measure due to the Mediterranean Action Plan, or Med Plan as it is more popularly known, developed by the United Nations Environment Programme (UNEP). In 1974 and '75, UNEP was invited by Mediterranean countries to develop a plan that would build on efforts of the United Nations' Food and Agriculture Organization (FAO) to combat fishery problems caused by widespread pollution.

The Med Plan is a four-part program, consisting of legal, assessment, management, and administrative components. In 1976, the then-12 participating nations, meeting in Barcelona, Spain, adopted the Convention for the Protection of the Mediterranean Sea Against Pollution, better known as the Barcelona Convention.

Later, four protocols were negotiated: 1) governing dumping from ships and aircraft (1976); 2) enhancing cooperation in cases of oil-spill emergencies (1976); 3) controlling pollution from land-based sources (1980); and 4) establishing specially protected areas (1982).

The Barcelona Convention and the four protocols were ratified or acceded to by all Mediterranean coastal states, except Albania. They are all presently in force.

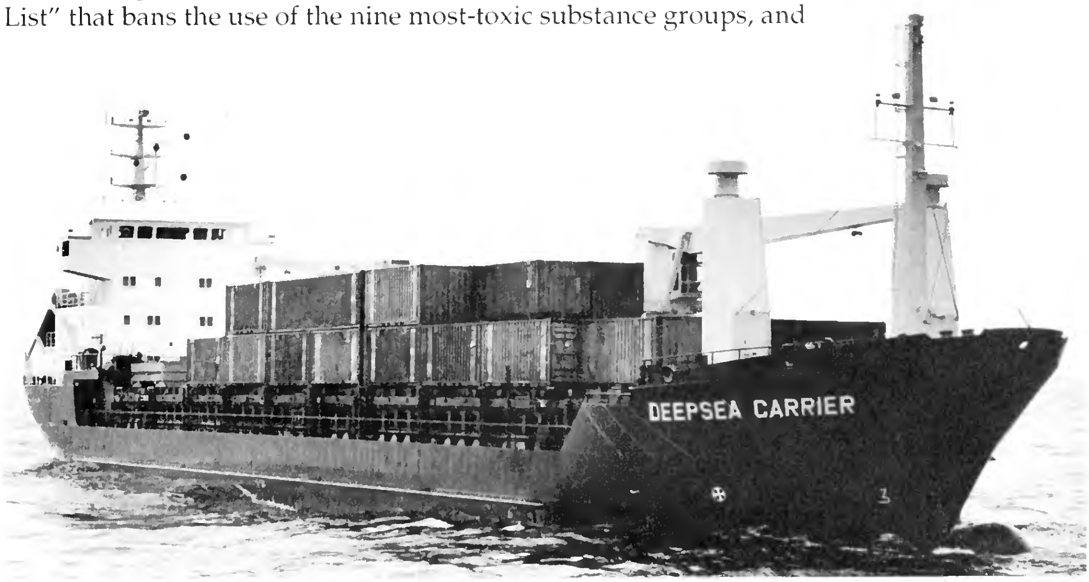
Several monitoring and research studies have been carried out since the first Barcelona conference. A study of land-based sources of pollution, called Med X, compellingly demonstrated the need for dealing with land-based pollutants and pollution transmitted by rivers.

The Med X study determined that 85 percent of all pollutants in the Mediterranean Sea originated on land—and that of these, 80 to 85 percent were transmitted to the sea by rivers. Med X also found that 80 percent of the sewage reaching the Mediterranean was untreated.

Peter M. Haas is Assistant Professor of Political Science at the University of Massachusetts, Amherst. Julie Zuckman is a freelance writer.

This was not news for the many tourists who came down with typhoid, infectious hepatitis, and other diseases after swimming in the Med. In some areas, swimmers had a one-in-seven chance of getting a skin infection. The study also found that much of the oil in the Mediterranean comes not from tankers, but from automobile owners draining their used motor oil into municipal sewers.

The Med X findings led to the adoption, after contentious and difficult negotiations, of the Land-Based Source Protocol's "Black List" that bans the use of the nine most-toxic substance groups, and



its "Grey List" that designates 13 groups of less-toxic substances to be controlled by discharge permit. These protocols required nations to change their domestic practices according to common pollution standards, because country A's pollution washes up on country B's beaches.

The Med Plan was developed to control industrial wastes like these toxic chemicals off the Italian coast, as well as sewage and oil pollution.

In addition to the Med X study, there have been two other assessments of Mediterranean pollution, collectively known as Med Pol, which comprises phases I and II. Med Pol I was carried out between 1976 and 1981, and Med Pol II between 1981 and the present. At a cost of about $10 million annually, the agenda for Med Pol II is to determine the overall effects of the Med Plan, and to generate findings relevant to setting controls on land-based sources of pollution.

While the Med Plan now bans or limits the emissions of many hazardous substances, and requires states to develop specific guidelines for controlling these substances, pollutants are still entering the sea because few nations have yet introduced adequate national guidelines. Also, nonlittoral states with rivers or connecting seas, such as Bulgaria, Romania, Switzerland, Portugal, and the Sudan—all of which contribute large amounts of pollution to the Mediterranean—do not participate in the plan.

One of the early advocates of pollution control in the Med was Jacques-Yves Cousteau. In 1972, he noted that life abundant some 30 years before had practically disappeared. In those early crisis years, scientific data were scant. What did exist was often too specialized to be generally applicable.

Early on in the political process, leaders of less-developed countries, fearing that strict environmental controls would hinder their critical development plans, were often hostile. Algerian President Houari Boumedienne, for example, commented: "If improving the environment means less bread for Algerians, then I am against it."

In addition to initial opposition to joint negotiations on pollution problems between neighboring countries, there were disagreements about just how clean a Mediterranean was desirable, how fast it should be cleaned, and how the sea should be used in the future, not to mention the question of who should pay for cleaner waters.*

Data showed that while different countries polluted differently, all polluted. Under the auspices of the Med Plan, developing countries gained scientific expertise and were able to generate and share new, more-accurate marine research data.

Many of the early problems were solved through dogged negotiation. The Med Plan thus represents the foremost example of how to collectively manage pollution in semi-enclosed seas.

As coastal population continues to increase, so too does the need to maintain and upgrade pollution controls. In 1988, the Med Plan began to put greater emphasis on sound coastal-zone planning in the region. The World Bank and other lending institutions are now starting to fund environmental projects.

Ballast reception facilities for oil tankers are planned or under construction in ports of five Mediterranean countries. At present, ballast tanks are cleaned at sea in specified areas of the Med.

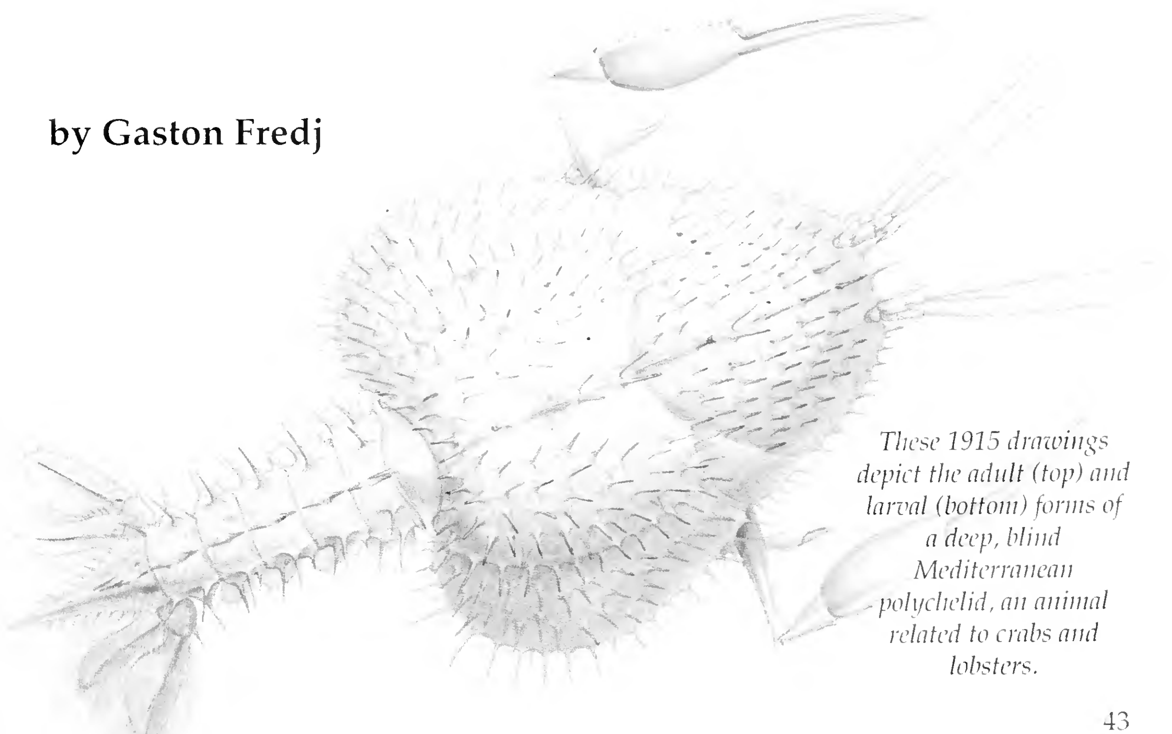
The Mediterranean is not, and probably never will be, pristine. The Med Plan can mitigate, but not eliminate, the toll of urbanization and industrialization; without the plan, the sea was headed for extinction.

* For a detailed description of the subtle and adroit politics by which these international agreements were resolved, see Haas' book: *Saving the Mediterranean: The Politics of International Environmental Cooperation* (1990. New York: Columbia University Press).

Med Biology

From beyond the pillars of Hercules

by Gaston Fredj



These 1915 drawings depict the adult (top) and larval (bottom) forms of a deep, blind Mediterranean polychelid, an animal related to crabs and lobsters.

Brachiopods like these lamp shells grow abundantly on the muddy gravels of the upper continental slope.

There are few places on Earth that have not been touched by Mediterranean culture, but all the creatures of that sea are themselves immigrants of a sort. At the end of the Messinian Salinity Crisis (see page 14), the Mediterranean was a nearly lifeless basin. As the waters of the Atlantic filled the basin during the Pliocene period about five million years ago, so, too, did plants and animals fill the new sea's ecological niches.

While the Mediterranean is poor in terms of the total amount of sea-life it sustains, it is rich in species diversity. Until 120 years ago, virtually all of this life came by way of the North Atlantic; but since the opening of the Suez Canal in 1869, Indo-Pacific fauna have started colonizing some niches in the eastern part of the sea.

The relative scarcity of life in the Mediterranean, combined with the long tradition of scientific study there, makes the fauna of the region one of the best described on Earth. The Med's recently discovered hydrothermal vents, however, may provide new mysteries for biologists.

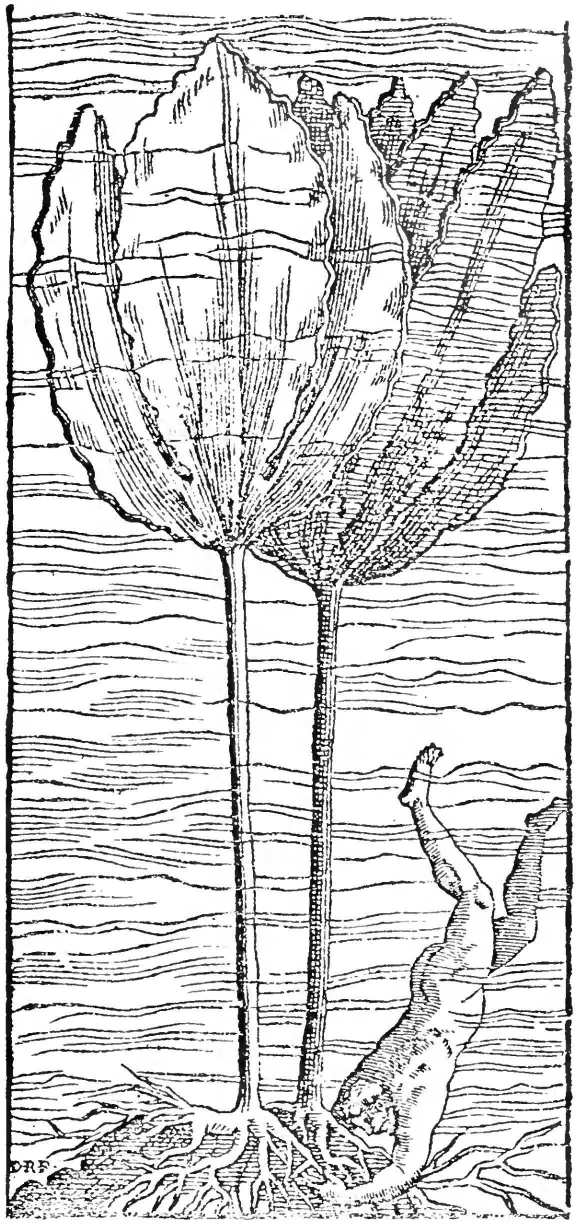
Deep-sea fauna were first discovered in the Mediterranean by the Niçoise apothecary and lecturer Antoine Risso. He obtained his specimens from fishermen, and published a series of papers between 1810 and 1827 on fish and crustaceans living in the Gulf of Genoa at depths of 600 to 1,000 meters. Risso's papers were ignored for several decades, during the heyday of Edward Forbes' theory of an "azoic [lifeless] zone" in the deep ocean below 550 meters. Alphonse Milne-Edwards, however, confirmed Risso's

Gaston Fredj is Professor of Biological Oceanography at the Université de Nice, in Nice, France.

results in 1861 when he identified molluscs and corals attached to a broken piece of telegraph cable brought up from 1,800 meters depth between Cagliari in Sardinia and 'Annaba in Algeria.

There are about 12,000 species in the Mediterranean, and about 30 percent of these species, and 1 or 2 percent of their genera, are endemic. The ratio of endemic genera to species indicates that the sea has been colonized only quite recently. The Université de Nice maintains a database known as MEDIFAUNE that makes taxonomic information available on, among other things, the east-west and depth distribution of endemic, North Atlantic, and Indo-Pacific species in the Mediterranean.

Species diversity generally declines in a west-to-east trend, a trend that is even more sharply drawn for endemic species. From the surface to the depths, species diversity also generally declines, and virtually all the endemic genera live near the surface. There are almost no deep-sea genera endemic to the sea; and the deeper a species is found in the Med, the wider its extra-Mediterranean distribution is likely to be. While 5 percent of the species found in the sea today have entered by way of Suez, this migration has yet to contribute to the deep-sea fauna.



One of the oldest records of kelp in the Straits of Messina is Ferrante Imperato's book, Historia naturalis, *where this drawing appeared in 1599.*

Rocky littoral areas in the western Mediterranean provide a substrate for encrustations of *Lithophyllum tortuosum*, known as "corniche." Meadows of endemic seagrass, found between 60 and 200 meters, are sensitive to pollution and have been seriously damaged during the last 30 years. The deep gorgonian *Isidella elongata*, which today occurs primarily in dense meadows in the western basin between 400 and 650 meters, has been found as fossils in the oldest Pliocene layers, which represent the end of the Messinian Salinity Crisis. The fossils argue against the theory of Messinian salt deposition in a very deep basin. The deepest-living animals in the Mediterranean are sedentary polychaete worms that have been collected from as deep as 4,690 meters in the Matapan trench.

The Richness of Scarcity

The various Mediterranean fisheries are among the most valuable in the world. This comes, oddly enough, not from a great abundance of fish, but rather a scarcity. Fish populations have always been low because the Med is poor in nutrients. Since fresh fish are considered a real luxury, low numbers make for high prices, which in turn encourage overfishing.

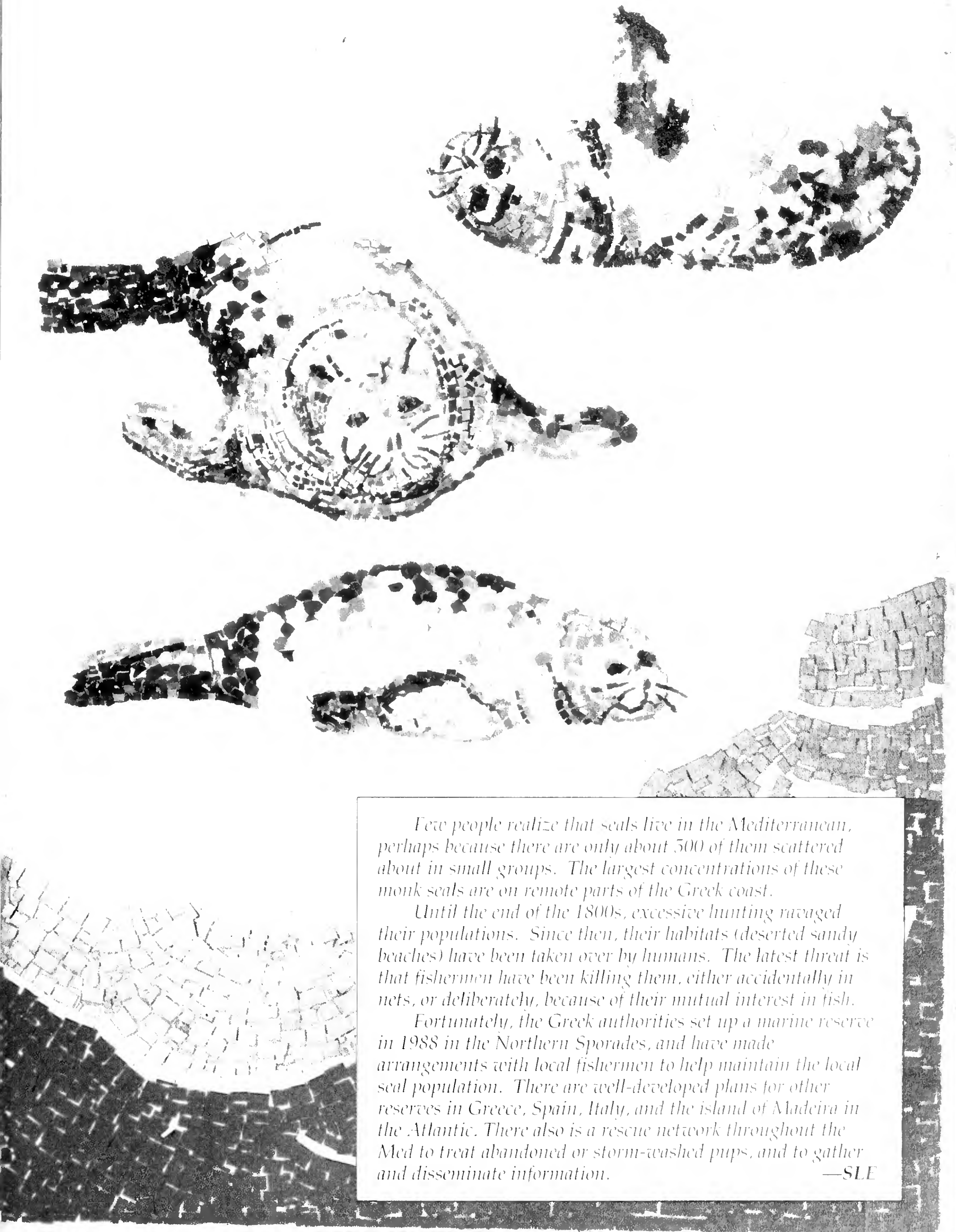
The fisheries are generally small-scale and local. The largest populations of fish tend to live near shore, where nutrients are most abundant thanks to upwelling and coastal runoff. Fishermen usually make many short trips for small catches. Since independent fishermen are never the best record keepers (especially when taxes are based on landings in many of these countries), catch statistics for the region are unreliable.

Nonetheless, it is clear that certain stocks are in bad shape. Coastal demersal fisheries of hake, sole, and red mullet have been depleted seriously along the southern coast of Europe. Bluefin tuna migrate from the Atlantic to the Black Sea, but in the last few decades increased fishing in the Atlantic has drastically reduced their migration numbers. The Aswan Dam has reduced nutrients flowing in from the Nile, causing a collapse in the local sardine fishery and reducing shrimp catches.

The General Fisheries Council for the Mediterranean, part of the United Nations' Food and Agriculture Organization, has been encouraging careful international management to bring back depleted species. One step to improve demersal fisheries in the eastern Mediterranean is to increase the mesh size of nets, but a wide variety of gear is used, making regulation difficult. Many vessels deploy trawls, traps, or long-lines, depending on the season or market. In the last few years, Italy and Spain have started using driftnets—giant walls of nylon mesh, up to 24 kilometers long and 12 meters deep—despite cries from environmentalists that the nets accidentally kill whales, dolphins, and turtles.

In the face of unproductive and endangered fisheries, aquaculture is becoming popular in the eastern Mediterranean, according to Adam Ben-Tuvia of the Hebrew University of Jerusalem. Freshwater pond culture—particularly polyculture, in which several species are raised together—is well established in Israel. Aquaculturists there, as well as in Greece and Cyprus are raising rainbow trout. In Egypt, fishermen turn parts of coastal lagoons into earth-ponds called hosha, *where they keep an eye on the fish but don't add any food. These are very productive and the fishermen can harvest them several times a year.* ***—SLE***

A Prayer for the Monk Seals?



Few people realize that seals live in the Mediterranean, perhaps because there are only about 500 of them scattered about in small groups. The largest concentrations of these monk seals are on remote parts of the Greek coast.

Until the end of the 1800s, excessive hunting ravaged their populations. Since then, their habitats (deserted sandy beaches) have been taken over by humans. The latest threat is that fishermen have been killing them, either accidentally in nets, or deliberately, because of their mutual interest in fish.

Fortunately, the Greek authorities set up a marine reserve in 1988 in the Northern Sporades, and have made arrangements with local fishermen to help maintain the local seal population. There are well-developed plans for other reserves in Greece, Spain, Italy, and the island of Madeira in the Atlantic. There also is a rescue network throughout the Med to treat abandoned or storm-washed pups, and to gather and disseminate information. —*SLF*

Marine
Around

Oceanography is a relatively young discipline. It synthesizes global results from the various sciences to understand the major laws governing the pulse of water masses and the complex canvas of links in the food chain. It is not a single science, but rather a combination of all the sciences as applied to the sea: biology, geology, physics, chemistry, and meteorology.

The nature of oceanography makes it extremely expensive, and even in developed countries data are gathered by a central structure that—in principle—places vessels at the disposal of different laboratories. Working together, these labs undertake large projects that they simply could not do with their own finances or manpower.

Today there are more than 40 marine stations around the Med that

Country	Institution
Spain	Instituto Español de Oceanografia, Fuengirola
	Instituto Español de Oceanografia, Palma de Mallorca
	Instituto de Investigaciones Pesqueras, Barcelona
France	Institut Français de Recherche pour l'Exploitation de la Mer
	Laboratoire Arago, Banyuls-sur-Mer
	Centre d'Océanologie, Marseille
	Station Zoologique, Villefranche-sur-Mer
	Laboratoire de Physique et Chimie Marines, Villefranche-sur-Mer
	Centre d'Etudes et de Recherch de Biologie et d'Océanographie Medicale, Nice
	Laboratoire d'Océanographie Physique, Paris
Monaco	Centre Scientifique de Monaco
	Musée Océanographique
	International Atomic Energy Agency
Italy	Stazione Zoologica, Naples
	Gruppo Richercha Oceanologica, Genoa
	Istituto per la Geologia marina, Bologna
	Istituto di Biologia del Mare, Venice
	Dipartimento di Biologia animale ed Ecologia marina, Messina
	Istituto de Scienze della Terra, Catania
	Istituto di Geologia e Paleontologia, Trieste
	Dipartimento di Biologia, Trieste
Yugoslavia	Institute of Oceanography and Fisheries, Split
Greece	Institute of Oceanographic and Fisheries Research, Athens
	Laboratory of Hydraulics, Thessaloniki
	Zoological Laboratory and Museum, Athens
Turkey	Institute of Marine Science, Erdemli
	Institute of Marine Science and Technology, Izmir
Cyprus	Department of Fisheries, Nicosia
Syria	Marine Research Center, Latakia
Lebanon	Marine Research Center, Jôunié
Israel	Institute of Oceanographic and Limnological Research, Haifa
Egypt	Department of Oceanography, University of Alexandria
Libya	Marine Research Center, Tripoli
Tunisia	Institut National Scientifiques et Techniques d'Océanographie et de Pêches, Salambo
Malta	Department of Mathematics and Science, Msida
Algeria	Institut des Sciences de la Mer et de l'Aménagement du littoral

For locations, see map, pages 54–55.

* Two manned submersibles and two remotely operated vehicles

Stations the Med

cooperate nationally and internationally (the major stations are listed below). The oldest is the Stazione Zoologica in Naples, founded in 1872 by Anton Dohrn (1840–1909). In France, zoologist Antoine Marion (1846–1900) created the Station Marine d'Endoume in 1879, and zoologist Henri de Lacaze-Duthiers (1821–1901) founded the Laboratoire Arago in Banyuls-sur-Mer in 1881. Prince Albert I of Monaco (1848–1922) was one of the pioneers of far-reaching scientific expeditions. He founded Monaco's Musée Océanographique in 1910 and equipped it with his own research vessels.

—Guy Leger
Associate Professor
Université de Nice

Major Research	Scientific Staff	Research Vessels (length in meters)		
		12–25	25–50	>50
hydrology, fisheries, and plankton in Alboran Sea	13	1		1
pelagic fisheries	11	1		
plankton on continental shelf	29		1	
living resources, technology, and aquaculture	N.A.	4*	1	2
benthic and pelagic ecosystems	35	2		
ecology, pollution, and aquaculture	62	2		
plankton, cell biology	30	1		
biochemistry, physics, remote sensing	12	1		
toxicology, microbiology	11	1		
physical oceanography, modeling, remote sensing	23			
chemistry, biology, microbiology	12	1		
host to foreign investigators, public education	5	1		
radioactivity, pollution	21			
plankton, cell biology, biochemistry	25	1		
biology, chemistry, geology, physics	48			
geology, mineral resources, palaeomagnetism	20	1		1
biological oceanography in Adriatic Sea	18	1		
biology, aquaculture, fisheries, chemistry	35		1	
geology, volcanism, hydrology, biology	39	1		
geology, sedimentation	18			1
zoology, comparative anatomy, biological oceanography	N.A.			
pollution and chemistry in Adriatic Sea	36		1	
oceanic surveys, pollution, aquaculture, fisheries	33		1	
environmental engineering, coastal pollution	18	1		
pollution, aquaculture	15			
marine resources, coastal protection	9	2	1	
open sea oceanography, thermal and metal pollution	22		1	
fisheries, pollution, local physical and chemical oceanography	12	1		
local coastal studies	26			
pollution, aquaculture	10	1		
physical, chemical, and biological oceanography, pollution	47		1	
plankton, fisheries, hydrography, chemistry	34			
coastal resources, aquaculture	15		2	
fisheries, aquaculture, pollution	20	2		
pollution	15			
fisheries, plankton, coastal monitoring	13	1		

N.A.= not available

Plankton Patterns in the Med

The warm colors in this satellite image show the distribution of phytoplankton, the ocean's microscopic plants that form the base of the food chain. They are eaten mainly by tiny animals called zooplankton, which are in turn eaten by fish, so all three groups congregate in the same general areas. Offshore, the Mediterranean contains much less plankton

than the Atlantic waters off northwest Spain (upper left). The gyre in the Alboran Sea, near the Strait of Gibraltar (mid left), comes from the complex circulation caused by water exchange between the Mediterranean and the Atlantic. Some of the other localized high production is due to pollution by human activities.

Red Tides and Slime

Recently, the media have described the Adriatic Sea as dead or dying. Thousands of tourists who normally summer on the Adriatic's sweeping beaches are now staying away. Two phenomena have scared them off—red tides and "slimy waters." These are highly sporadic, last only a few weeks, and neither is at all new, so the media hype really seems to be an exaggeration.

Red tides are population explosions of several species of microscopic organisms called dinoflagellates, normally in the phytoplankton in low concentrations. When their populations burst, the water takes on their red or yellow hue.

Red tides have been occurring in the Mediterranean for millennia. The Bible's book of Exodus, in which Moses was instructed by God to set a plague on the Egyptians, may be the first record: "He raised his staff. . . and all of the water in the river changed to blood. The fish in the river died and the river smelled so foul. . ."

These "plagues" have become quite frequent in the Adriatic, especially along north and central Italy. They deplete oxygen from the bottom waters, suffocate benthic organisms and fish, and cause a build up of hydrogen sulphide. The awful color and stench are enough to drive away even the most dedicated sun worshiper.

The exact causes of red tides are difficult to pinpoint. The blooms are usually blamed on excessive nutrients, especially phosphorus, in rivers and streams draining into the northern Adriatic. Several factors probably work together to trigger and maintain these tides.

"Slimy waters" have occurred in the Adriatic for the last two summers. They are unsightly masses of yellowish-grey mucus on the sea surface, made up of billions upon billions of planktonic diatoms. In 1989, slime covered the entire northern Adriatic Sea. At dawn, before tourists arrived on Italian beaches, workers tried to scoop up the gooey mess.

Usually, slimy waters do not kill animals. But the mucus is disastrous to fishermen since it jams up motors and nets, and its sheer weight can tear the nets.

Slimy waters were first recorded in 1726, and have since been reported at least 16 times, but their cause remains a mystery. Two opposing views are emerging. Some scientists blame increased pollution, while others suggest unknown biological or environmental factors. As with red tides, the causes are probably multiple. We hope that all scientific and political efforts will be made to understand these complex biological events.

—Elvezio Ghirardelli and Adrianna Ianora

Zooplankton—Indicators of Change

Zooplankton, the ocean's tiniest animals, give oceanographers a way to monitor the environment, not only from place to place, but also through time. One of the things that they are indicating is that the Black Sea is becoming more like the Med.

Oceanographers have a good understanding of Mediterranean zooplankton community structures in different parts of the sea. The western Mediterranean is richer in zooplankton than the eastern, stocks are higher near the coast than offshore, and areas of coastal upwelling—like the northern Alboran Sea, not far from the Strait of Gibraltar—are richest.

Certain species live offshore, while others live near the coast. There is, of course, some overlap, since the sea is so narrow in many places. Communities usually have low populations of many species. Below 100 meters, waters are notably plankton-poor compared with other oceans.

Changes in these general patterns indicate outside influences, such as major construction projects. For example, the Aswan Dam built on the Nile in 1966 reduced the river's flow of nutrients into the sea. Near the Nile delta and beyond, zooplankton populations suffered and the local sardine fishery collapsed. Another big project in this area was the Suez Canal; new species of zooplankton have been immigrating through it from the Red Sea.

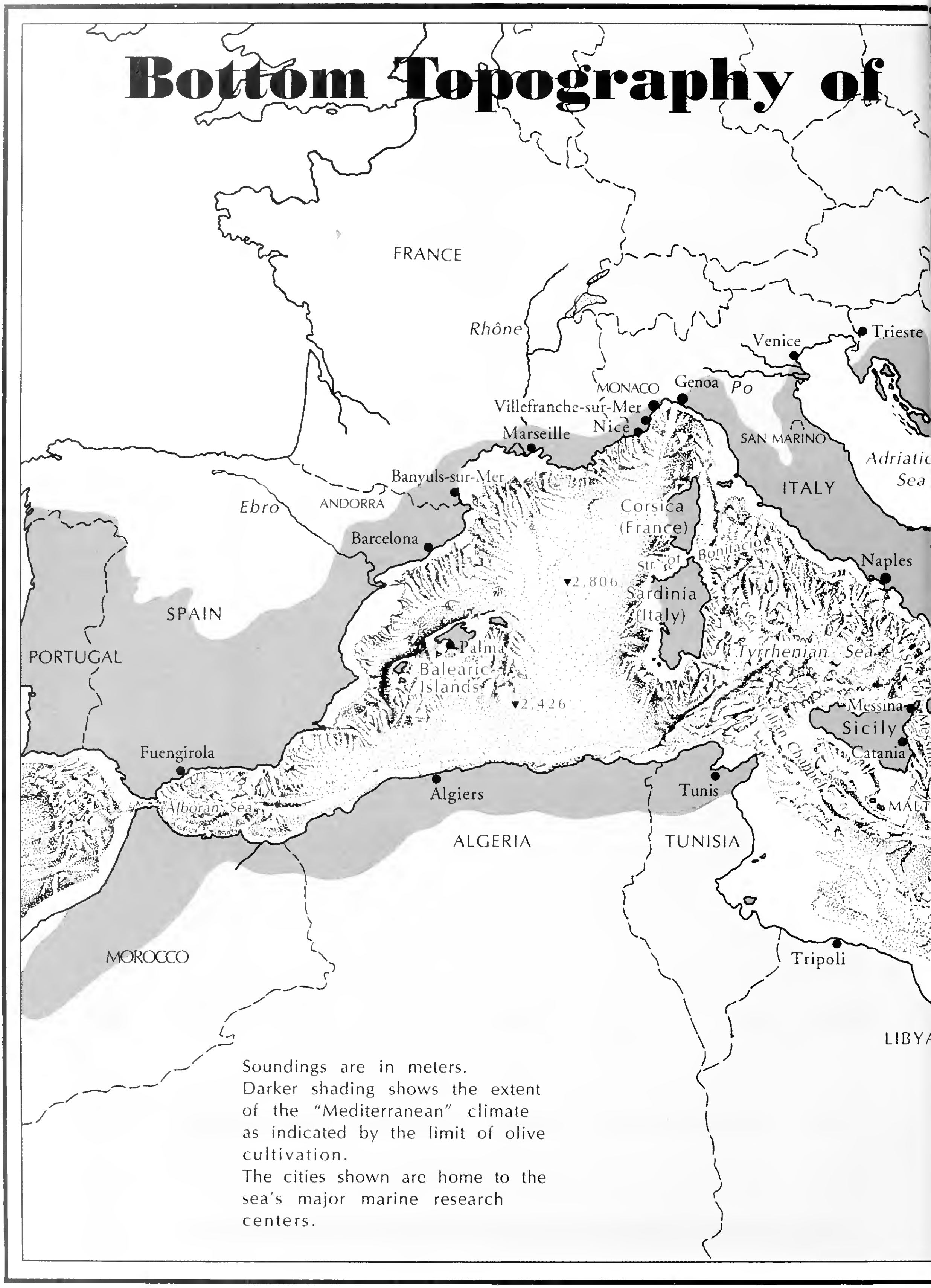
With its anoxic lower layer, the Black Sea has always been an oceanographic anomaly. Entire marine groups are missing from this sea. But recently a series of dams across major rivers emptying into the Black Sea has decreased its outflow to the Med. The subsurface current from the Aegean has increased, bringing along Mediterranean water and planktonic hitchhikers. So while people are beginning to stream out of eastern bloc countries, an unseen undercurrent of tiny immigrants is making its way from the Med toward the waters of Bulgaria and Romania!

— Elvezio Ghirardelli
Professor of Zoology, University of Trieste
— Adrianna Ianora
Research Scientist, Zoological Station of Naples

Copepods are the most common zooplankton in the Mediterranean.

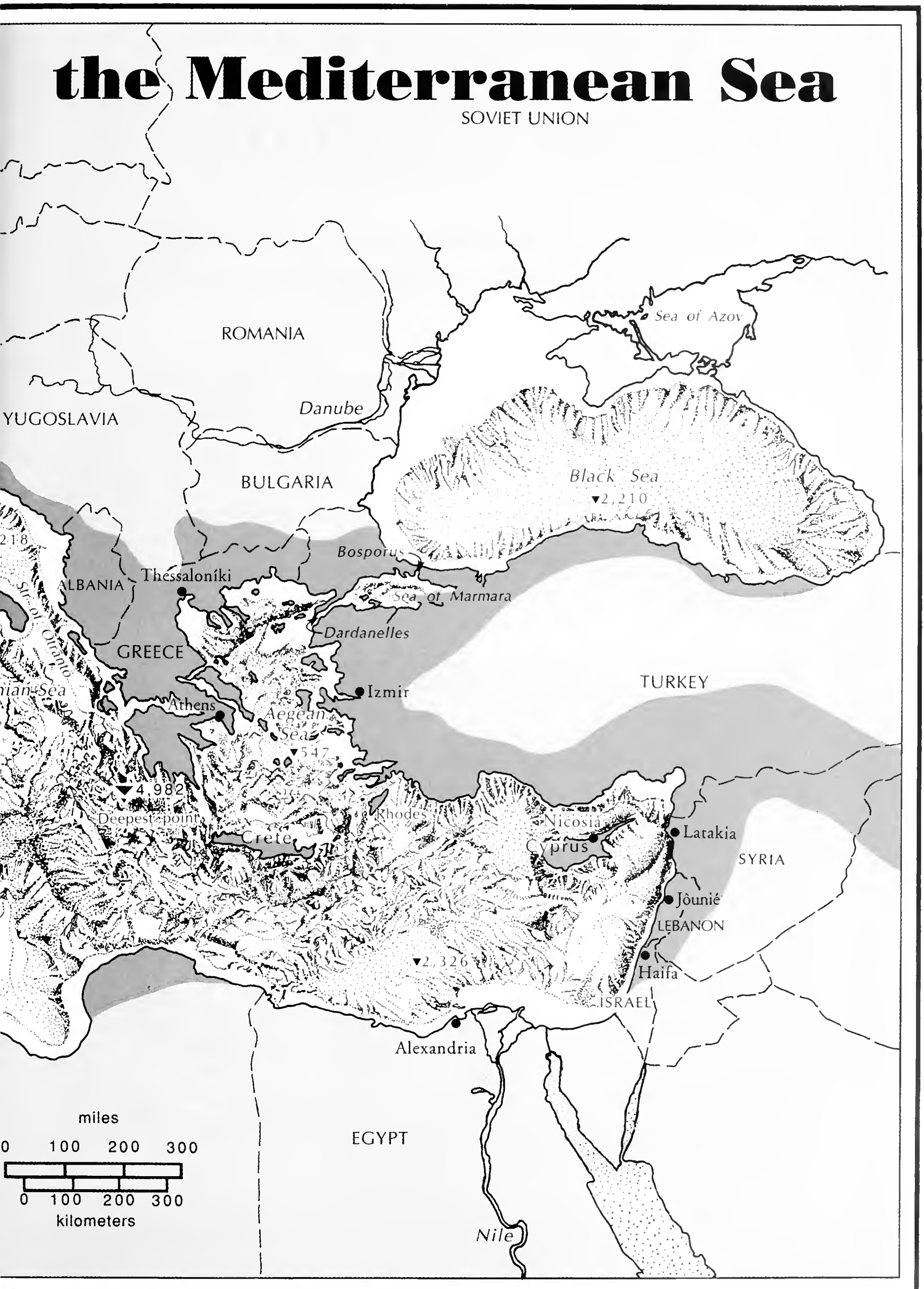
Most zooplankton are microscopic their whole lives, but others, like this decapod larva, grow into large adults that settle onto the bottom.

Bottom Topography of



Soundings are in meters.
Darker shading shows the extent of the "Mediterranean" climate as indicated by the limit of olive cultivation.
The cities shown are home to the sea's major marine research centers.

the Mediterranean Sea



Deep Water Over Complex Tectonics

Gas & oil exploration and production are hindered by subsurface factors

by Kathy Sharp Frisbee

In the last 10 years, oil and gas exploration and production have increased with cautious enthusiasm in the Mediterranean Sea, becoming more intensive in the last two. On a global scale, however, these efforts continue to represent no more than a drop in the proverbial barrel.

The Glomar High Island VIII drilling rig at work in the Mediterranean.

The latest worldwide statistics for offshore oil and gas production indicate that gas from the Mediterranean Sea totaled more than 5.51 million cubic meters a day in 1988, while world per-day production amounted to more than 849 million cubic meters. Oil production in the Mediterranean was more than 165 thousand barrels a day, compared to a world per-day production of nearly 15 million barrels. In each instance, Mediterranean production represented less than 1 percent of world offshore output.

Only 20 percent of the Mediterranean's nearly 3,000,000 square kilometers is shallower than 200 meters. The remaining 80 percent is mostly covered by very deep water, as deep as 4,900 meters, and thus is still considered a distant target for petroleum and gas exploration.

"I think it's a spotty resource area, part of which is known, part of which is unknown," says Donald C. Rusk—a private consultant who was a senior geological associate with AMOCO overseas for 31 years and with Exxon in South America for 4 years. "I think a large part of the Mediterranean isn't prospective mainly because it's floored by oceanic crusts and has a very thin layer of young sediment, which offers reduced potential—that combined with very deep water," added Rusk.

Oceanic crusts, a thin sediment layer, and deep water combine to reduce the potential of offshore oil and gas finds.

It's really difficult to compare the Mediterranean with such major-league sites as the North Sea and Gulf of Mexico, according to Rusk. "In terms of tectonics, the Mediterranean has been subjected to some pretty extreme plate tectonic episodes which have destroyed some areas that may have been potential [producers]. As a result, mountains and oceanic crusts have developed that do not have potential; and then there's the deep water factor," said Rusk.

"Take the Gulf of Mexico, for example. Although they're exploring in 1,800 to 2,100 meters of water now, you've got an enormous thickness of sediment on the bottom. In much of the Mediterranean where you have the deep water, there is a thin veneer of sediment over oceanic crust, and, in other places, nonprospective sediments that have suffered too much alteration through tectonic collision."

Therein lies one of the biggest differences between the Mediterranean and other major offshore oil and gas resource sites. Neither the Gulf of Mexico nor the North Sea, for example, have undergone the kind of tectonic history the Mediterranean has experienced. And so, along with other scientists in the industry, Rusk confirms that the prospective resource zones of the Mediterranean lie in "the periphery of the stable or more-or-less stable European and African continents."

Kathy Sharp Frisbee is a freelance writer living in Falmouth, Massachusetts.

The Mediterranean has been described by scientists as "geologically complex." Claudio Villa, of AGIP, Milan, Italy—one of the largest and most active resource exploration and production companies operating in the Mediterranean today, and the first company to initiate deep-water exploration strategy there in 1972—explained during a presentation at the Mediterranean Basins Conference in Nice, France, in September 1988, that "Most prospects are subtle traps, and many will be found only with the application of up-to-date technology. These plays will be located in the overthrusts, in the deep floundered platforms, and in the deep-sea basins."

Fewer than 10 rigs are producing, while about 75 are exploring. The main players are Libya, Italy, Spain, Tunisia, and Greece.

The Mediterranean's 18-year history of offshore oil and gas exploration and production has pretty much paralleled the almost tideless characteristic of the sea itself, rising and falling nearly imperceptibly in most places. Its importance, today as in the past, is not so much the amount of oil produced, but rather its proximity to western Europe, a large (350 million people) and growing consumer of tremendous supplies of oil and gas.

Well activity in the Mediterranean is presently in an ebb of its usual ebb-and-flow pattern. Fewer than 10 mobile and floating well-rigs are producing, with as many as 75 others under exploration or appraisal. The main players are Libya, Italy, Spain, Tunisia, and Greece. Important companies other than AGIP include Elf, Eniepsa, Shell, Chevron, Texaco, Total, and Getty. Italy's once-lucrative VEGA field off the shores of Sicily has slackened to three operating wells due to water production problems, though there are about seven other developing fields around VEGA, which predominantly produces gas, but also produces some crude. There's some development off Yugoslavia, but not much. Spain's best prospects are in deep water and, though state-of-the-art equipment has arrived to tackle these zones, today's economics aren't helping matters, according to spokesmen from *Offshore Magazine*.

A return of $25 a barrel is necessary to make deep-water exploration economically viable. Today's prices are about $20.

Chevron, for example, recently drilled to 670 meters offshore Greece, but recovered very little, and so tapped the well. The present industry viewpoint on moving ahead with deep-water explorations is that a return of about $25 a barrel would be necessary to make the efforts viable. Per-barrel prices presently stand at about $20.

As of May 1988, proven reserves in the Mediterranean have been calculated at 2.4 billion barrels of oil and 350 billion cubic meters of gas. As-yet-undiscovered reserves are estimated at 3 billion barrels of oil and 360 billion cubic meters of gas.

The biggest story in the Mediterranean in the last two years has been Bouri, Libya's first offshore oil field. At 5 kilometers wide by 32 kilometers long, it's also the Mediterranean's biggest, and one of the largest offshore fields in the world. Bouri started production in August 1988, 11 years after it was first discovered by AGIP through a lease granted to the Italian firm in 1974. Bouri and related areas have an estimated reserve of 5 billion barrels of oil and 70 billion cubic meters of gas. Initial production called for 30,000 to 50,000 barrels a day, rising to about 150,000 barrels a day in the 1990s. Bouri cost more than $2 billion to develop.

Libya's Bouri offshore field is the Med's largest. It is the first of its size developed without an American contractor playing a major role.

One of Bouri's many distinctions is that it is the first large field developed without an American contractor in a major role, though limited U.S. equipment and supplies were used, according to *Offshore Magazine*. The project used Italian companies almost exclusively for product design and engineering, with some assistance from French and British engineers, and Koreans for exterior construction.

Located 120 kilometers north of Tripoli, Bouri's DP-4 mother platform was constructed of 61,000 tonnes of steel and is anchored in 53 meters of water. A satellite platform, DP-3, anchored a short distance away, weighs 32,000 tonnes. The structures are operated by Libya's National Oil Company and AGIP, though it is reported that Italy remains cautious in its role due to world political sensitivity to Libya.

Reports indicate that the Bouri hydrocarbons are within the Metlaoui formation, which is believed to be part of the Upper Paleocene and Lower Eocene zones. The Metlaoui formation has been determined to be a carbonate sequence of sediments with a thickness of 274 meters. The net pay at Bouri is approximated at 107 meters, noted by *Offshore Magazine* as sizeable by any standard except the best of Middle East fields.

The industry rates Mediterranean oil and gas explorations as high- to medium-risk endeavors. The outlook is for calm activity.

While Bouri's DP-4 platform has 66 well slots, with 30 operating initially, the DP-3 platform has 20, and three additional satellite platforms are planned for the future. In addition to complete drilling capabilities, DP-4 can process and treat the crude before shipment. A 225,000-tonne storage tanker will be permanently moored alongside DP-4's tower, and other tankers will take crude from there to market.

Refinery production in the Med accounts for about 12 percent of the world's total of 72.9 million barrels a day.

Bouri's electronics are state-of-the-art, with duplicate control room capability onshore at Tripoli, as well as the potential for unmanned operations throughout the processing chain. DP-4 is also equipped with telemetry and satellite communications. Complex process control and alarm systems are likewise built-in in case of an accident.

Environmental concerns relative to oil and gas exploration and development in the Mediterranean Sea are minimal at this time for two reasons.

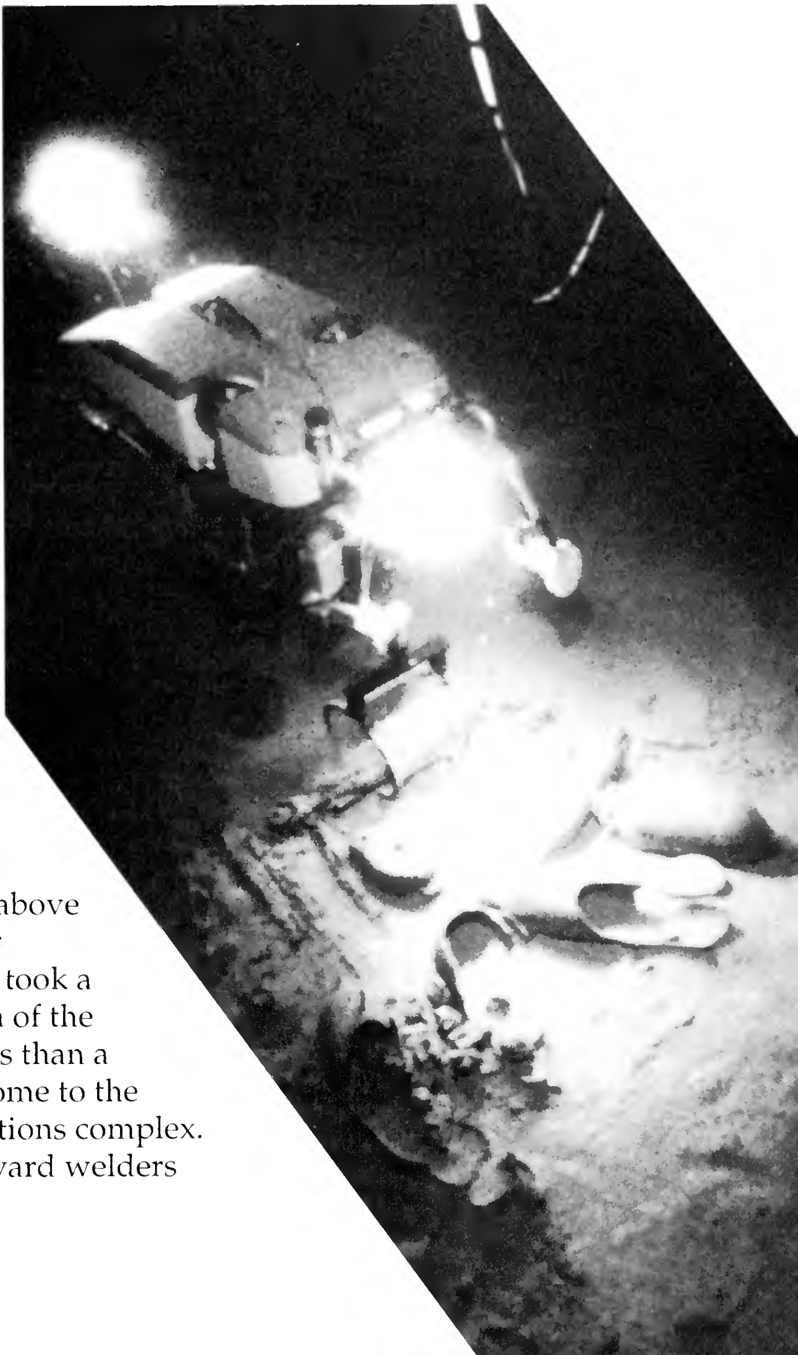
One, refinery production in the overall Mediterranean region accounts for about 12 percent of the world's total production of 72.9 million barrels a day. Refineries operating at varying points nearer the perimeter of the sea itself number less than 30.

Two, the marginal subsea work being done is strictly regulated for air and biological pollution by the individual host countries which contract with drilling companies, and by the big European oil companies themselves, such as AGIP of Italy, and Total and Elf of France. Countries and companies both are cautious because they recognize the Mediterranean Sea is essentially a closed body of water with little ebb-and-flow filtration capability.

On the whole, the Mediterranean is still viewed by industry professionals as a high-risk find, with the exception of such areas as offshore Sicily, Malta, Libya, and Tunisia, which have proved to be medium-risk finds. Until state-of-the-art technology meets the industry's determined economic need, it appears that oil and gas exploration and development in the Mediterranean will remain relatively calm.

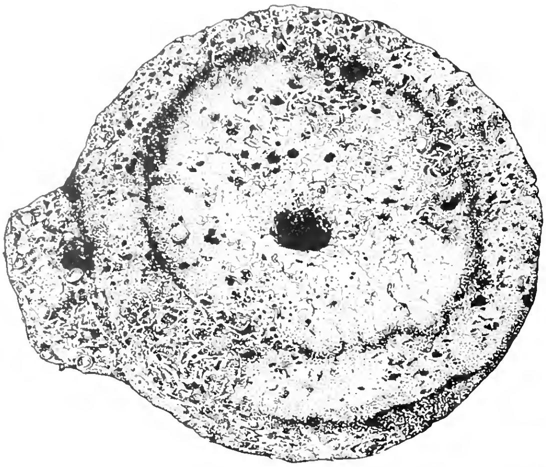
Jason's Med Adventure

Unexpected events at sea challenge WHOI's deep-sea explorers

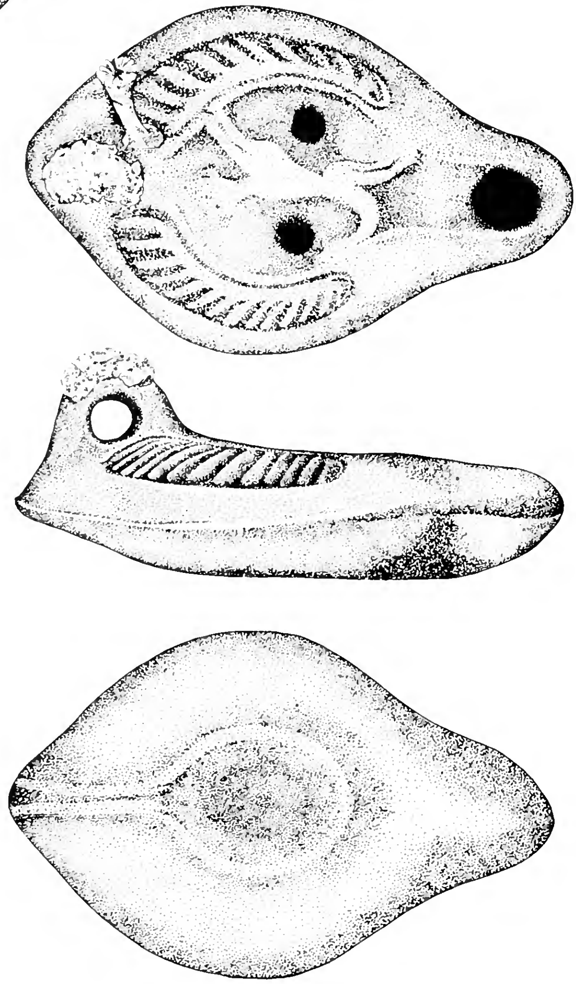


by Martin F. Bowen

Standing three decks above the fantail of the *Star Hercules*, facing aft, I took a "before" photograph of the vacant 50-meter deck. In less than a week, that deck would be home to the Jason Project's mobile operations complex. Here in Hull, England, shipyard welders



The Jason team collected several objects from Isis, *a 4th-century* A.D. *Roman shipwreck, including this small grain-worn grinding stone (36 centimeters wide).*



On the last day at the archaeological site, the author experimented with a small collection device on Jason and retrieved this fragile, 12-centimeter-long ceramic oil-lamp (viewed from top, side, and bottom).

were gearing up for five days and nights of man-made smoke and lightning to create a miniature city of shipping containers weighing more than 80 tonnes.

Our shipboard "Jason-town" was founded on April 9th, 1989, after eight years of development by Robert D. Ballard and the Woods Hole Oceanographic Institution's Deep Submergence Laboratory (DSL). Joining us were the Turner Broadcasting Corporation, the Electronic Data Systems Corporation (EDS), the

The deep-water archaeological site was strewn with Roman amphoras and jugs made in North Africa that once carried wine, grains, spices, and olive oil. Here are several that Jason collected, as well as a grinding stone and a ceramic oil-lamp (middle; detailed sketches on opposite page).

National Geographic Society, the U.S. Navy's Submarine Development Group One, the Marquest Group, marine archaeologists, and six U.S. high school students.

DSL's operations team was aboard the *Hercules* on an educational mission: to use "telepresence" as a means of rekindling interest in the sciences among U.S. students (*Oceanus*, Vol. 32, No. 2, pp. 84–87). Our tasks and discoveries were broadcast live via satellite to thousands of students throughout North America.

In place of a standard expedition schedule, adaptable to weather, accidents, or equipment problems, we had to stick to a strict broadcast agenda: 84 programs, six a day for two weeks. In place of our usual shipboard isolation, we would have thousands of students watching us work.

We met the schedule—despite two devastating incidents at sea—but not without a new educational experience of our own. This is the back-stage story of how we did it.

The main technological event in Jason-town was the debut of our fiber-optic cable (f/o) Argo-Jason system: two deep-ocean, search-survey-and-sampling robots controlled from the surface. The

1,270-kilogram Jason rode inside f/o Argo, which is a bit larger and longer than a minivan. Argo-Jason was chained to the deck beside the original coaxial-cable Argo, the discoverer of the *Titanic* and the soon to be discovered *Bismarck* (*Oceanus*, Vol. 32, No. 3, pp. 27–35). Fiber-optic Argo could out-perform "co-ax" Argo by transmitting four color-video images rather than a single black-and-white view. Mini-Angus and two Jason Jr. vehicles were stowed inside a van.

The ship carried its full company and a partial science crew on the 13th as it left Hull for Gibraltar, where the rest of the personnel would be picked up. Rising seas and gale-force winds were predicted for the next day. With millions of dollars in hand-crafted, one-of-a-kind electronics on welded risers only half a meter above the decking (itself only two meters over the waterline), the *Hercules* was facing heavy weather with a cargo considerably more valuable than its usual 1,800 tonnes of drilling pipe.

During 60-knot winds and Force-11 seas, the oilers heard a "metallic snap" on deck. The 2,200-kilogram co-ax Argo had broken loose from four heavy chains and washed aft.

By the 15th, the *Hercules* plodded southwest through a storm of sustained 60-knot winds and Force-11 seas in the Bay of Biscay. Neither the recent gales nor the storm gave us trouble, but a distress call from a 10-meter sailboat did. When the *Hercules'* captain ordered search-pattern maneuvers requiring 180-degree turns, one of the turns—coupled with impressive wave heights and unlucky timing—brought a monstrous wave across her starboard side.

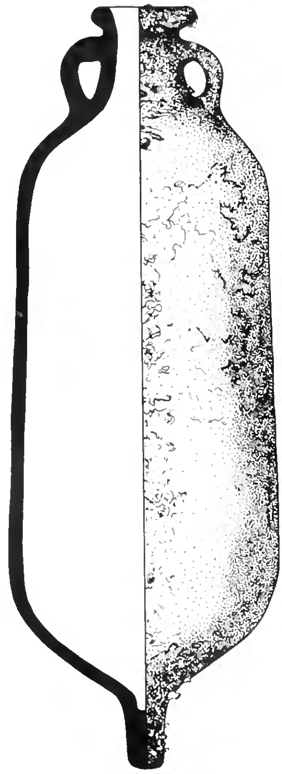
A frightened call came from the engine room to the bridge where we were watching for the sailboat: the oilers had heard a "metallic snap" on deck. The 2,200-kilogram co-ax Argo had broken loose from four heavy chains and washed aft toward f/o Argo. Obstacles in co-ax Argo's path slowed and finally stopped the unbridled slide. When we got to the deck, we looked up at 12-meter wave crests.

During our emergency, news came that the sailboat crew had abandoned ship for their inflatable life raft, where one was to die of exposure. A few hours later, a German freighter rescued the survivors from the raft. Their sailboat hadn't sunk. As seasoned mariners, we knew that the man who perished from exposure may have lived had the crew stayed with the vessel. We felt their loss: the severe consequence of lonely decisions born of panic.

The now-infamous "rogue wave" crushed two vehicle-retrieval winches, or "tuggers," misaligning their steel pedestals; damaged the frame of co-ax Argo; tore the ventilation assemblies on the EDS satellite van; drove the remains of an air-conditioner through the wall of the DSL tool van; made mincemeat of expensive fiber-optics testing equipment; flooded an electro-optical slip-ring; soaked toolboxes; and filled a winch-electronics junction-box that now would have made a dandy aquarium.

During the rest of the transit to Gibraltar, all able-bodies rebuilt salvageable equipment. Ocean Engineer Bob Elder bandaged together our portable fiber-optic laser from a few components not consumed by frothing, saltwater-soaked nickel-cadmium batteries. Project manager Andy Bowen assessed the saltwater damage to the electro-optical slip-ring, another space-age machine sold without "user-serviceable parts." Electrical wizards Bill Hersey of DSL and Bob Buhro of EDS, with no prior knowledge of its design, revived the winch junction-box. Diesel specialist Frank Smith rebuilt the tugger pedestals. Curt Murphy and navy volunteers did body work on co-ax Argo. Skip Gleason tried to save the traumatized tuggers, but finally had to give them their last rites, and called ship-to-shore for two new units from France. I gutted, dried, and reopened the fractured tool van—our sea-going hardware store.

All repairs were completed in time to deploy f/o Argo-Jason in about 700 meters of Mediterranean water on a "full-up," high-voltage test. Once at depth, the free-swimming Jason remotely operated vehicle (ROV) left the towed Argo garage and "flew" via joystick commands sent to its seven thrusters.



The largest amphora collected from Isis *was this 36-centimeter-wide specimen.*

The *Hercules* feathered her thrusters to hover in a computer-generated, or dynamically positioned, stance over Skerki Bank, near the Sicilian Channel. Dana Yoerger, graduate student Franz Hover, and veteran DSL deep-water guide Tom Crook navigated with data from global-positioning satellites, Loran-C stations, and long-baseline transponders. Although they had worked with the ship's system for only a week, they kept her in a tight holding pattern, never more than three meters off target.

A high, rolling sea pestered the *Hercules*—approximate sea-state 4, long swells with a six-second period, light chop on top. On the third test-lowering, one week before live TV transmissions were to start, we lost Argo and Jason.

Just below the surface, with Jason still inside f/o Argo's garage, the vehicles' armored tow-cable snapped with a toneless "thump." The ship's deck shook for an instant. TV displays from subsea cameras went black. The cable pulley at the A-frame peak wagged briefly, no longer supporting the 3,300-kilogram vehicle cluster that was now free-falling at 24 kilometers an hour to the muddy bottom 725 meters below. Gone, just like that. The silence was deafening.

Was Jason still inside Argo? If not, would Jason's reinforced tether remain attached to Argo, preventing the neutrally buoyant ROV from wandering for decades in deep currents? Were the vehicles upright or toppled? A survival instinct—calm though troubled—lessened our sense of tragedy. Over the satellite link, we heard disturbing news that younger students thought Jason had "died." "Let's get them back," Ballard said.

The missing Argo was nicknamed "Hugo," short for huge Argo. That brought a few smiles. For the DSL operations team, there would be strength in humor, but little rest until both vehicles were recovered.

This two-handled jug was intact, which made it a rare and exciting find for archaeologists.

Almost immediately after the accident, we rolled a third vehicle out of a storage van and onto the aft deck. Originally called Mini-Angus, this was to be our replacement camera sled and, potentially, Jason's rescuer. Since the Medea of Greek myths was Jason's wife and life-saver, Ballard renamed the sled accordingly.

Our one-ton robotic Medea would have to search for the fallen vehicles in the depths below. Bill Hersey scribbled a hook-up schematic on the back of an envelope to update Medea's wiring. In only a few hours she was water-proofed, tested, and attached to a repaired cable. Navigators Yoerger and Crook continuously monitored position information from emergency acoustic beacons on the lost vehicles. The signals suggested that they were still mated—a good sign.

Medea is dispatched to find the missing Argo and its companion Jason.

Medea was lowered. As she approached the bottom, a small silver rectangle appeared in the gloom of the video monitors. We could see Hugo with Jason still inside. The pair were upright on the clay bottom with no obvious damage, their metallic surfaces reflecting the light from Medea's lamps. Yoerger and Crook placed the Hercules directly above the stricken robots on their first attempt.

On the second lowering, Medea would have to guide a grappling hook onto Hugo. In preparation, we modified the hook by welding curved steel barbs to each of its four stabbing tines. Once set, it should not release until Hugo was on deck and secured. Medea's camera would act as a video viewfinder for the winch operator who, in cooperation with the navigators, would try to maneuver the hook into Hugo's frame.

Back to the bottom went Medea. As the *Hercules* acted on dynamic-positioning commands, I watched the subsea view from Medea's camera and maneuvered the winch's joystick for swipes at the sunken Hugo. The time delay between ship maneuvers and sled reaction caused long, tense pauses after each attempt. Hugo's silver frame and the dangling grapple filled the television screens. On what was to be the last approach, I managed to bounce the 100-kilogram lure over Hugo's frame. In a violent lurch from a swell, it grabbed the frame near the worst possible place, the main electrical junction-box.

I hauled the vehicle cluster off the bottom as fast as the winch's screaming diesel engine would allow. Luckily, it didn't stall. I had to be careful and relax the haul-in speed just prior to the passing of every new swell; otherwise, the cable might snap again. While I played the hooked fish for half an hour, Bill Lange read off cable-tension numbers—now 1,500 kilograms, then up to 12,000, back down to 4,000, then up again to 12,000. When Medea rose out of the water, I stopped hauling and joined ranks at the A-frame. Every available line was made fast around the two stray vehicles as they bumped against the *Hercules'* transom.

Then, what we had been fearing all along happened at the surface. Welds holding Hugo's garage door split apart. Jason broke free of Hugo and floated away on its tether; but Ballard and two crewmen were standing by in a small boat, and hastily attached more lines to the robot and saved it.

After 23 anxious hours, both vehicles were rescued. Hugo was replaced by Medea as Jason's support vehicle, and after a baroque process of hardware shuffling and software sleight-of-hand, the robots were ready to perform. Deck operations were going to be more complex for Medea-Jason than for Argo-Jason. Since Medea was not designed to hold Jason, the pair had to be launched and recovered as a two-body system rather than a single, mated unit.

The first live broadcasts of the Jason Project began on cue from above the Marsili Seamount, an underwater volcano south of Naples, suspected by Ballard to be active. From 9,000 miles away students witnessed, along with us, Jason's close-up discovery of undocumented hydrothermal vents. Flying Jason around the eruption-tortured slopes of Marsili, I had the fortune to reveal panoramas of newly formed subsea regions only a few hundred years old to this audience.

Jason breaks away from Hugo and floats away on its tether, but Ballard and two crewmen rescue it.

It was a bizarre place. At the top of the volcano 500 meters beneath the surface, blue-green groupers swam among mineral chimneys as tall as a person and twisted like trees such as Dr. Seuss might draw. Everything was dusted with yellow sulfide. Hot, shimmering water waved like a mirage and dissipated in seconds.

Jason's motors, cameras, sensors and manipulating arm seemed to improve in performance as they acclimated to the dark, pressure, and cold. Occasionally, the 25 meters of yellow tether between Jason and Medea drifted into view. Power, data, and optics immediately combined in that tether to produce sharp images of Marsili. If the students felt they were "touching" the volcano through our nonintrusive technology, then we had achieved a step toward telepresence in exploration.

Jason took random samples of Marsili's fauna and geology with its mechanical arm and claw, and deposited them into baskets mounted on either robot. Though an organized sampling program was not part of the Jason Project, deep-sea coral polyps, platelet-cloaked starfish, a *Pholoe* scaleworm, unidentified fish larvae, and various small arthropods were all collected and then preserved on board, later identified at WHOI, and archived at DSL. None of the animals were found to be specific to hydrothermal vents and none of the weathered sulfide samples of Marsili were new to scientific records, but together they represented Jason's ability to collect benthic denizens and a slice of their substrate.

The *Hercules* returned to Skerki Bank for the second week of live broadcasting. Here lay more than 50 square kilometers of level topography, the resting place for hundreds of ancient amphoras and a shipwreck discovered and mapped in 1988 by co-ax Argo. Marine archaeologist Anna M. McCann named the 4th-century site "Isis" after the goddess that ancient sailors prayed to for a life after death. McCann directed Jason's mapping of artifacts and their retrieval from this site, 750 meters beneath a trade route used between 300 B.C. and A.D. 400.

Never before had a deep-water antiquarian site been approached and probed by a robot's mechanical arm, and the DSL team felt the responsibility. Previously, submerged sites as deep as 40 meters had been excavated by SCUBA divers. Jason had to display a diver's coordination in safely recovering the artifacts while disrupting the site as little as possible.

Hydraulically driven "Knuckles" cradled artifacts from the **Isis** *site in its soft, synthetic fish-netting.*

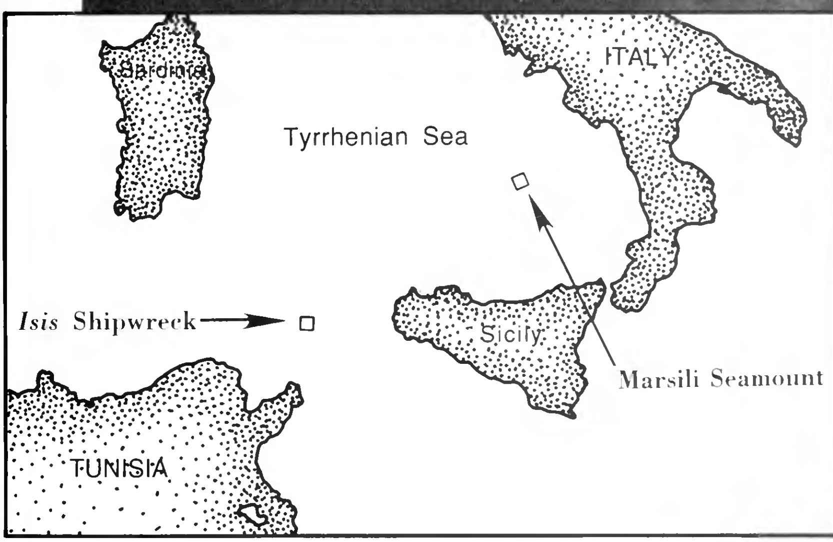
Before the expedition, John Salzig, Hagen Schempf, and Betsy Robinson studied illustrations of amphoras from the *Isis* era and fabricated a retrieval device. It could accommodate the largest—40 centimeters wide—North African jars photographed a year earlier. The invention was named "Knuckles," and Jason's wrist assembly was easily modified to support it. Opening and closing like a large bivalve, hydraulically driven Knuckles cradled artifacts in soft, synthetic fish-netting.

Knuckles worked in concert with an elevator that we named "Otis." An aluminum and glass-float device, Otis would descend to the bottom near the shipwreck. After Jason loaded artifacts into the elevator's four netted compartments, Otis was acoustically instructed to rise to the surface by releasing an anchor. A small boat waited at the surface to tow Otis to the *Hercules*. In this way, we gently transported more than two dozen ancient jars that once contained wine, grains, fish-sauce, spices, and olive oil.

Household utensils, jewelry, and coins were too small for Knuckles, so Gleason and Smith devised a dwarf version that consisted of a frame-and-netting assembly bolted onto the wrist's standard pair of gripping jaws. I tried it on Jason's final dive of the expedition.

A few terra cotta bits had been charted in a muddy depression north of the main wreck-site. The elevator was full and on its last transit back to the surface. The only remaining receptacle for artifacts was an empty basket strapped to the side of Medea's frame. I dipped Jason's tiny new hand into the depression and raised a billowing cloud of mud. Jason rose, pivoted, and faced Medea. The drop had to be timed with Medea's up-and-down movements or we would lose the sample. I opened the webbed jaws, watched the silty cloud tumble into the basket, and drove Jason away toward the surface for recovery.

Inside the basket was a delicate ceramic oil-lamp that Aladdin might have recognized. Studies of it would fix the age of the



Jason was outfitted with a specially designed contraption called "Knuckles" to lift artifacts delicately off the seafloor.

wreck. The enthusiasm of the archaeologists confirmed the worth of all our efforts. My reward was the *Isis* lamp. At the very last, after weeks of technical acrobatics, our Jason-town team was adept enough to extract that one fragile prize from history.

Martin F. Bowen is a Research Associate and senior Remotely Operated Vehicle pilot at the Deep Submergence Laboratory of the Woods Hole Oceanographic Institution. He has documented six shipwrecks, including the RMS Titanic *and the battleship* Bismarck.

Ships of Tarshish to the Land of Ophir

Seafaring in Biblical times

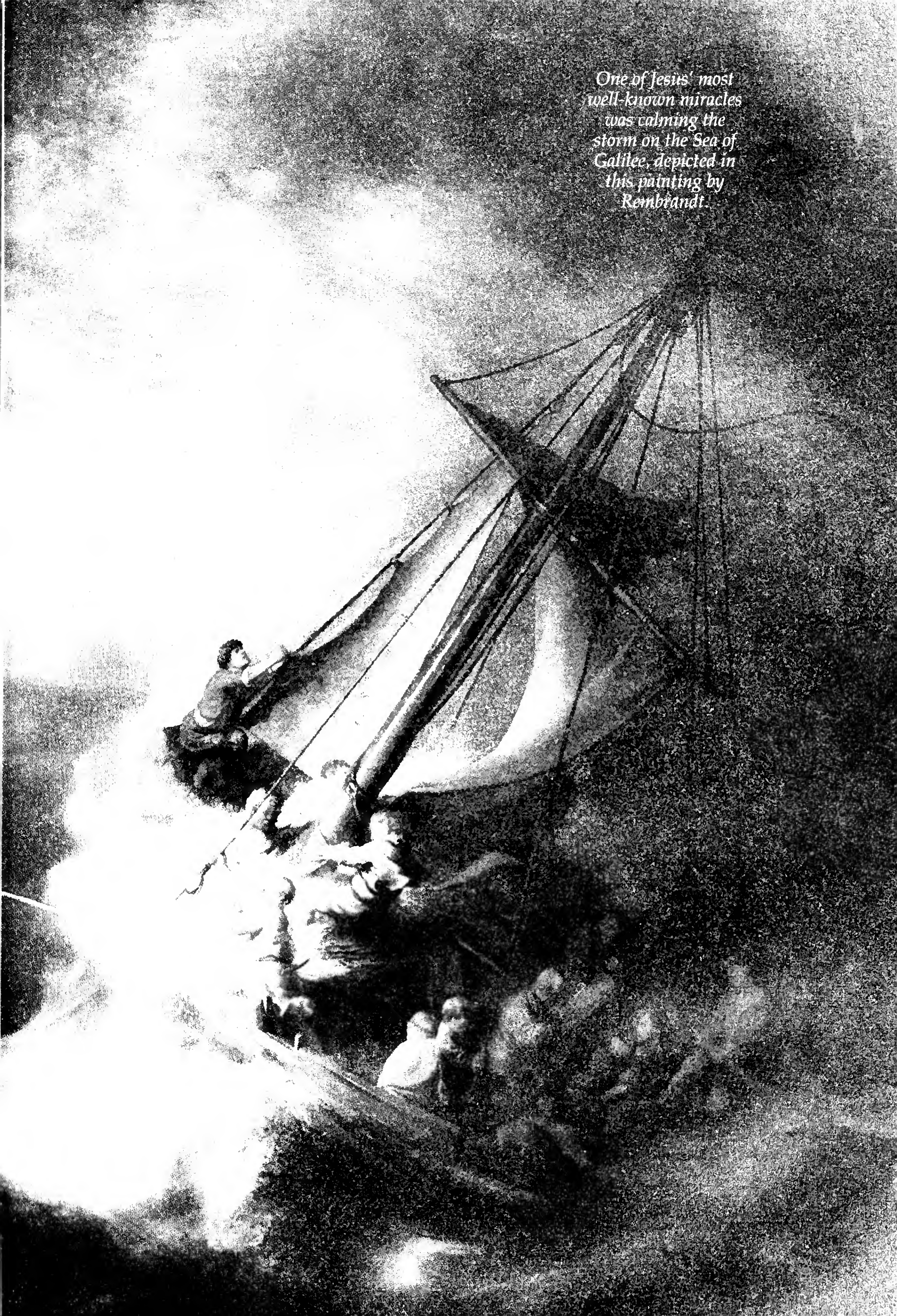
by Shelley Wachsmann

Others, taking ship and going to sea,
were plying their business across the ocean;
they too saw what the Lord could do,
what marvels on the deep!
He spoke and raised a gale,
lashing up towering waves.
Flung to the sky, then plunged to the depths,
they lost their nerve in the ordeal,
staggering and reeling like drunkards
with all their seamanship adrift.
They called to the Lord in their trouble
and he rescued them from their sufferings,
reducing the storm to a whisper
until the waves grew quiet,
bringing them, glad at the calm,
safe to the port they were bound for.

Psalm 107:23–30

Shelley Wachsmann is Inspector of Underwater Antiquities for the Israel Antiquities Authority.

From the story of Noah's Ark to the various shipwrecks of Saint Paul, the Bible is full of references to seafaring. The sea—deep, wide, and unpredictable—is a powerful symbol for



One of Jesus' most well-known miracles was calming the storm on the Sea of Galilee, depicted in this painting by Rembrandt.

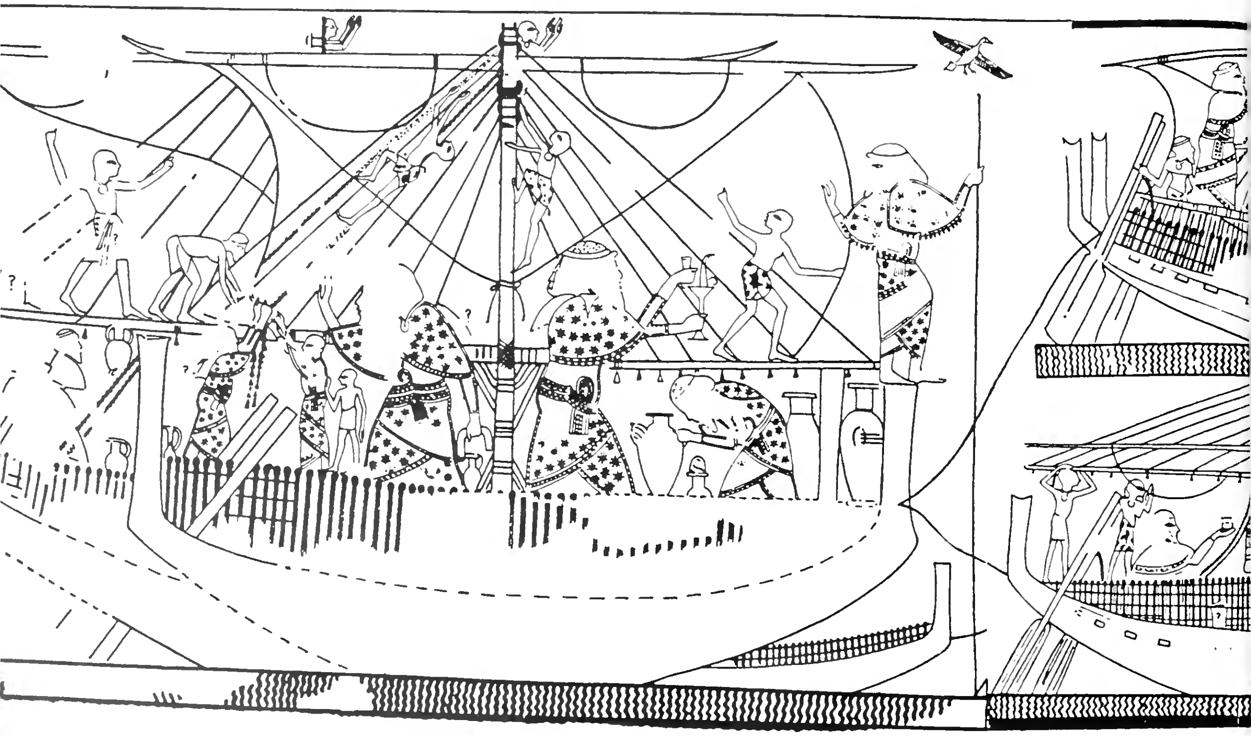
divinity or the subconscious. The Mediterranean was also, on a more physical level, the ancient Israelites' front door through which came both treasure and terror, and on which sailed perhaps the most intrepid mariners the world has ever seen.

Marine archaeologists of the Israel Antiquities Authority are working with historians to piece together a coherent picture of seafaring on the ancient Mediterranean. Israel's coast abounds with the remains of ancient ships and their cargoes. On the average, there is probably a shipwreck, or the remains of a wrecked ship's cargo every 100 meters along the Israeli Mediterranean coast. The study of these remains—whether they are a Bronze Age ship's cargo, an inscribed anchor, or the hull of a ship that sailed during Biblical times—considerably enrich our understanding of ancient seafaring and Biblical descriptions.

Even the word "Bible" has seafaring connections. In the third millennium B.C., the town of Byblos, about 35 kilometers north of Beirut, was the heart of the trading empire of the Canaanites, whom the Greeks later called "Phoenicians." During its centuries of power, Byblos called itself the oldest city on Earth.

Records of the seaborne trade in copper from Cyprus, gold from Nubia, and cedar from the mountains of Lebanon were kept on papyrus scrolls by the scribes of Byblos. So much papyrus was used and traded at Byblos that the name of the city eventually became synonymous with the records of these transactions, and was translated into Greek and medieval Latin as "biblos" and

In this wall painting from a 14th-century B.C. tomb in Thebes, Late Bronze Age merchant ships are arriving at an Egyptian port.



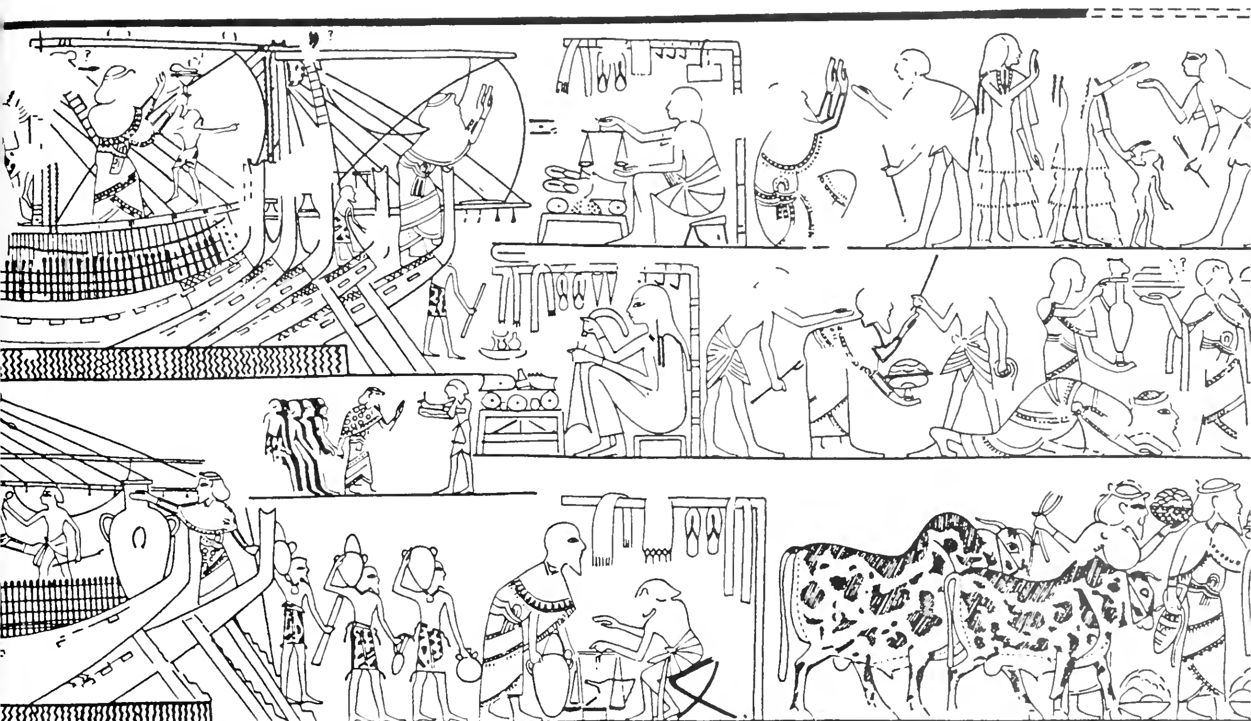
"biblia" both of which meant "(the) book."

In the Late Bronze Age (1550–1200 B.C.) the city-kingdom of Ugarit, on the coast of what is now northern Syria, was a major maritime power. The people of Ugarit, although they did not consider themselves Canaanite, belonged to the same cultural and religious entity. Clay tablets unearthed at Ugarit indicate that the city-kingdom then had a fleet of more than 150 ships. The tablets were unearthed between 1929 and 1966 by the archaeologist Claude F. A. Schaeffer, and date from the reign of King Hammurapi, the last king of Ugarit. Tablets such as these are invaluable sources on Late Bronze Age maritime practices, as we know of only two coherent shipwrecks from this era—the oldest shipwrecks ever found.

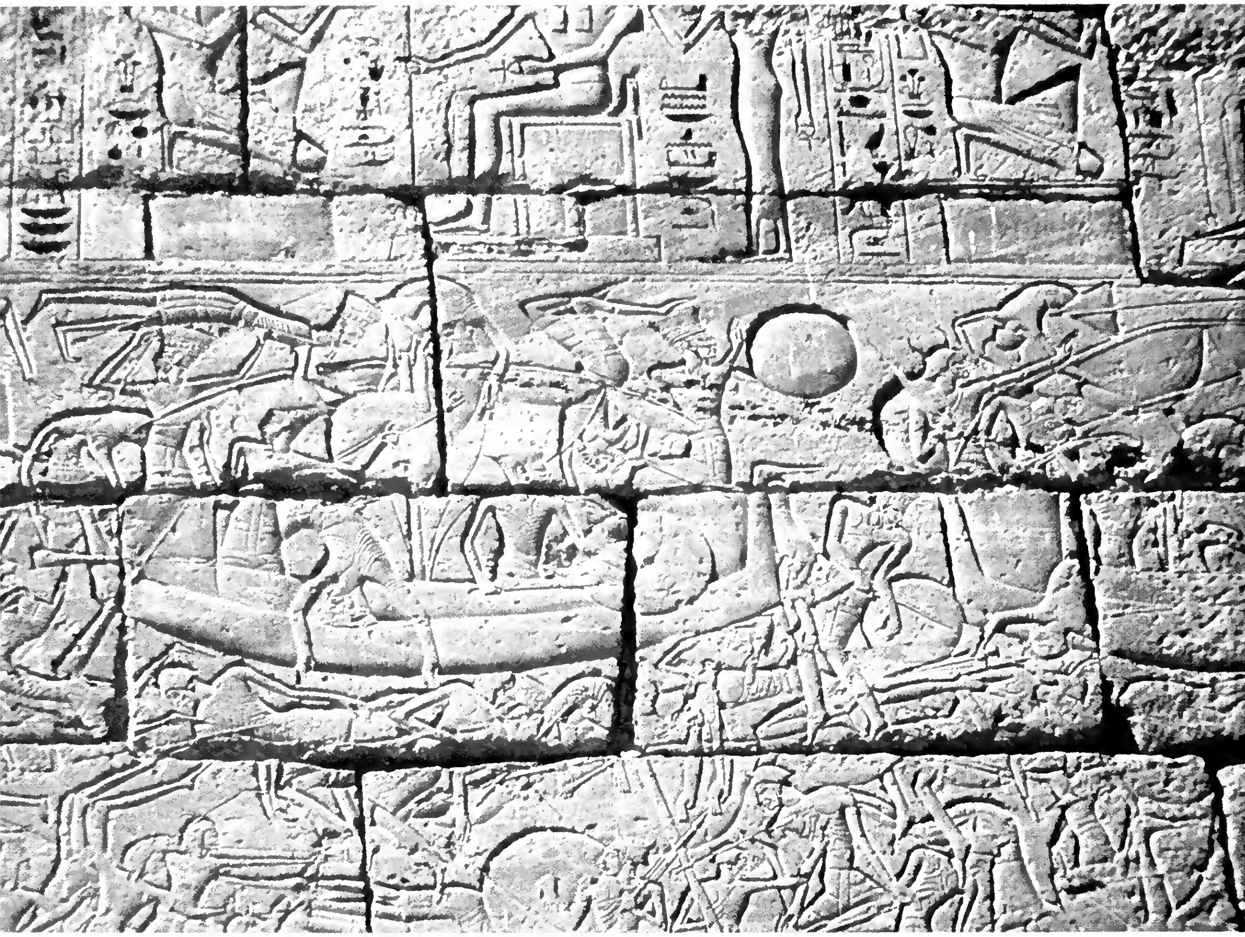
A tiny, but detailed Hebrew seal shows a seagoing merchant ship from the eighth or seventh century B.C.

According to the tablets, Ugarit's ships were large enough to carry up to 450 tonnes of grain, overthrowing the notion that the Late Bronze Age people of the northeastern Mediterranean had only small boats of the type that could be pulled up on shore each night. An Egyptian tomb painting, dating to the 14th century B.C. shows these craft arriving at an Egyptian port. In the center are ships that have docked, and to the right is a fascinating depiction of the hustle and bustle of a port—the merchants hawking their wares in stalls as the ships are off-loaded by porters.

Eastern Mediterranean civilizations, including Ugarit, the ancient Israelite, and the Canaanite, were besieged and terrorized



during the 13th and 12th centuries B.C. by a loose coalition of audacious sea raiders known to the Egyptians as the "Sea Peoples." Their ships had bird-head devices at stem and stern, an Aegean motif that supports the idea that their ships were derived from Aegean prototypes. One of the tablets is a copy of a letter sent by King Hammurapi to the king of Alashia—which is usually identified as part or all of Cyprus. It describes the fury of the Sea Peoples:



Egyptian pharaoh Rameses III crushed the fierce Sea Peoples in two battles that he commemorated on his mortuary temple.

My father, behold the ships of the enemy came; my cities by fire he burned and an evil thing in the country, they did . . . and the country is abandoned to itself. My father, this matter may you know. Now the seven ships of the enemy that came here and damage they did to us.

(continued on page 76)

Rediscovering Royal Purple and Biblical Blue

The textile dyeing industry was one of the economic mainstays of eastern Mediterranean civilizations between the seventh centuries B.C. and A.D. Centuries after the loss of the recipe for two of these dyes—the Royal (or Tyrian) Purple (Argaman in Hebrew) and the Biblical Blue (Tekhelet in Hebrew), we now know that they were produced from marine snails.

In ancient Rome, togas dyed purple were imperial symbols; and in ancient Jewry, these colors had religious and social significance. The purple dye was worth 10 to 20 times its weight in gold.

The first step toward the rediscovery of the purple dye was taken by the French zoologist Henri Lacaze-Duthiers in 1858 during an expedition to the island of Minorca. He noticed a poor fisherman dyeing his shirt with crushed rock-shell, Thais haemastoma. The dye gave a yellowish hue at first, that changed in the sunlight to light purple while emitting an unpleasant odor.

The ancients knew that they must use fresh snails for their dye industry. In addition, since the amount of dye stuff that could be obtained from one snail is minute, they needed thousands of live snails in order to dye a small area of yarn. In order to collect such a multitude, they probably first lured the snails with wicker baskets baited with smashed limpets and winkles. After the snails adhered to the basket by inserting their snouts through the tiny spaces between the wickers they would stay attached even when the baskets were taken out of the water.

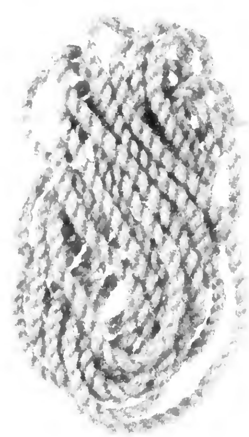
Despite some earlier controversy surrounding the secret of the Biblical Blue, we have recently discovered that the blue dye, in addition to the Royal Purple, can be produced from T. trunculus.

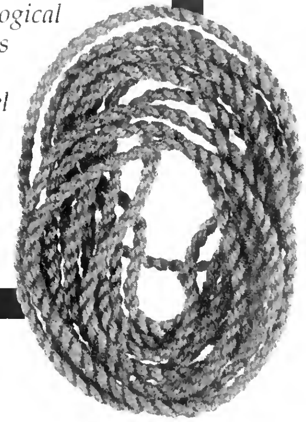
Careful, indirect heating, removal of the protein residues, addition of fresh glands (with active enzymes), and proper exposure to air and light can yield the genuine dyes. Glands of female rock murex give mainly dibromoindigo, or Royal Purple, whereas male glands largely produce Biblical Blue. The latter compound is identical to animal-derived indigo.

Dyed purple textile from a 1,700-year-old archaeological site in the Syrian Desert near Palmyra was identified as containing the molecule 6,6′ dibromoindigo. Traces of purple dye also were found on shards of a ceramic vessel from Tel Shiqmona, near Haifa and were identified as this genuine Royal Purple.

—Ehud Spanier
The Recanti Center for Maritime Studies
University of Haifa, Israel

To collect dye-producing snails, ancient people baited baskets with smashed limpets and winkles.





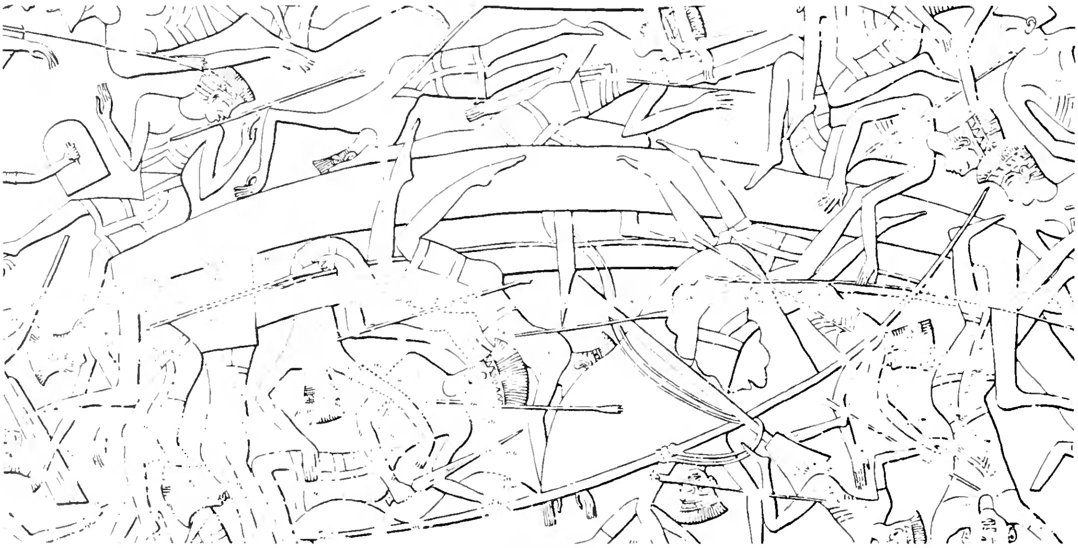
The Mycenaeans (Bronze Age Greeks), the Hittites, and many of the Canaanite city-kingdoms all fell before the onslaught of the Sea Peoples, who were the Biblical equivalent of the Huns and the Vikings all rolled up in one. In fact, the tactics of the Sea Peoples were not unlike the later Vikings. They would arrive at a seaside settlement, ravage it, and disappear before the local military could come to grips with them. However, again like the later Vikings, when they met an organized army they were likely to lose.

Rameses III, the last great pharaoh of Egypt, managed to stop the Sea Peoples in two battles that took place in the Nile delta about 1174 B.C., one on land the other on water. Rameses commemorated these battles graphically on his mortuary temple at Medinet Habu, near modern-day Luxor. The depiction of the ships with sails furled, and the accompanying text, suggest that the Egyptians mounted a surprise attack:

> The countries which came from their isles in the midst of the sea, they advanced to Egypt, their hearts relying upon their arms. The net was made ready for them to ensnare them.

A detail from Rameses III's tomb shows one of the Sea Peoples' ships capsized in the melée of battle. The manner in which warriors are intertwined in the ship informs scholars about the ship's structure.

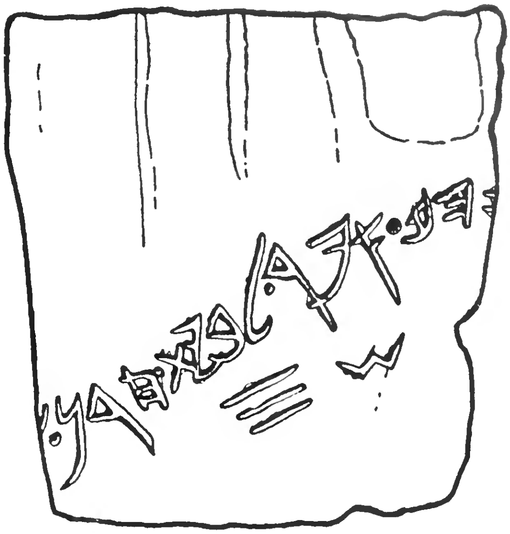
The nautical battle scene shows that the ships of the Sea Peoples were undecked, and traveled under both sail and oar. One of the Sea Peoples' ships is shown below, capsized in the melée of battle. By studying the manner in which the bodies of the warriors are intertwined in the ship, it is possible to understand the structure of the ships themselves. In particular, there is a figure sitting on the center of the upturned ship. His left leg disappears behind the hull but reappears in an open space between the hull and a raised screen. To his left, two other bodies are placed in



positions that support the conclusion that an open area, which can only be a rowers' gallery, existed on these ships.

Another fascinating text found at Ugarit—a letter from the Hittite king to the chief ministers of the Ugaritic king—relates to how a group of Sikila, one of the Sea Peoples who later settled in the area of Dor (near modern-day Zichron Yaakov in Israel), were captured by a Ugarit man named Lunadushu. In the text, the Hittite king orders the man responsible for the capture of "the Sikila who on ships live," to be brought to him.

During the height of ancient Israel's power, under King Solomon in the 10th century B.C., the king entered into a joint venture with Hiram, the Phoenician king of Tyre, for shipborne trade to the mysterious land of Ophir.



> King Solomon equipped a fleet at Ezion-Geber, which is near Elath on the shores of the Red Sea, in the land of Edom. For this fleet Hiram sent men of his, sailors who knew the sea, to serve with Solomon's men. They went to Ophir and from there brought back four hundred and twenty talents of gold, which they delivered to King Solomon.
>
> I Kings 9:26-28

No one yet can say where Ophir was located: some suggest along the Arabian or African shores of the Red Sea; others think it was further south, along the Somalian or Kenyan coast of the Indian Ocean; still others hazard a guess that it may have been a city on the west coast of India. But while the site of Ophir remains unknown, its reality is indicated by an ostracon, or inscribed pottery sherd, from Tel Qasile, near Tel Aviv. The ostracon carries the words: "gold of Ophir to Beth Horon 30 shekels."

While the location of Ophir is still a mystery, the inscription on this potsherd proves it did exist: "gold of Ophir to Beth Horon 30 shekels."

While Hiram's daring Phoenician seafarers carried out impressive feats of navigation, their descendants did them proud. In addition to the legends claiming they entered the Atlantic by means of the cold, salty, undercurrent at Gibraltar (see page 28), later Phoenician sailors are credited with the first recorded circumnavigation of Africa. The fifth-century B.C. Greek historian Herodotus tells us that about 200 years before his time, Phoenician mariners under the orders of the Egyptian Pharaoh Necho II, sailed down the Red Sea and into the Indian Ocean, only to return through the "Pillars of Hercules" after three years. During their voyage, they stopped each autumn to plant and reap crops, and so keep themselves supplied.

Interestingly, even as Herodotus tells this story, he refuses to accept one statement made by the sea rovers: they claimed that while they were traveling around the southern half of Africa, or "Libya" as they called it, the sun had been on their right, or to the north. However, it is precisely this statement that proves the authenticity of the story. For while voyaging in a generally westward course in the southern hemisphere, the Phoenicians would have indeed had the sun on their right; and after rounding the Cape of Good Hope, they would have been heading north and the sun would be rising on their right.

The Bible refers twice to a regular trade carried out by Solomon in partnership with Hiram of Tyre. A fleet of "ships of Tarshish" would bring gold, silver, ivory, apes, and peacocks once every three years. Now a trip to Tarshish, located in the Mediterranean, would not normally have taken three years to complete if the ships were sailing to and from a Mediterranean Levantine port. However, these Biblical passages, combined with Herodotus' comments, raises a fascinating possibility. Is it possible that the Tarshish ships of Solomon and Hiram were regularly circumnavigating Africa 3,000 years ago?

Is it possible that the Tarshish ships were regularly circum-navigating Africa 3,000 years ago?

This hypothesis may be supported by considering one description of the attempt made by the Hebrew kings Jehoshaphat and Ahaziah to later renew this trade. They built:

> . . . ships to go to Tarshish, and they built the ships in Ezion Geber [near the site of modern-day Eilat on the Red Sea]. And the ships were wrecked and were not able to go to Tarshish.
>
> 2 Chronicles 20:35–37.

Tarshish was apparently the name for Tartessos in Spain, near modern-day Cádiz; so the only way to reach Tarshish from Ezion Geber would be to circumnavigate Africa. However, the parallel description of this event in 1 Kings 22:47 has Jehoshaphat building "ships of Tarshish to go to Ophir for gold," which significantly changes the purpose of the trip. But why are the vessels called "Tarshish ships?"

The Bible often speaks of seagoing Tarshish ships or of ships that are going to Tarshish. While several interpretations have been advanced by scholars, the most likely one is this: normally, a specific class of craft receives a geographical name because it was used on a specific route. This concept is paralleled by the "East Indiamen" or "Boston packets" of the recent past. It seems likely, therefore, that Tarshish ships were the type of craft normally used on the run to Tarshish.

In general, then, Tarshish ships were seagoing ships, and when the prophet Jonah fled to Tarshish—the voyage on which he was thrown into the sea—he was figuratively running away to the ends of the Earth.

When the Phoenicians organized trips to Ophir it was only natural to use Tarshish ships, the class of merchant ship capable of

Off Ulu Burun, Turkey, the oldest complete shipwreck ever found (14th century B.C.) has taught archaeologists about ancient trade and seafaring.

long sea voyages. So this may have been the case with the Tarshish ships of Solomon and Hiram, but there is as yet no archaeological evidence for it. Until such evidence is forthcoming, this idea must remain no more than a hypothesis attractive to the author.

The most detailed description of seafaring in the Bible is given us by the sixth-century B.C. prophet Ezekiel. In lamenting the fall of Tyre, he compares that great Phoenician city to the sinking of a great seagoing merchant ship. In raising his dirge, Ezekiel gives wonderful details of the ships' construction and rigging, and the merchandise bartered by the Phoenician mariners.

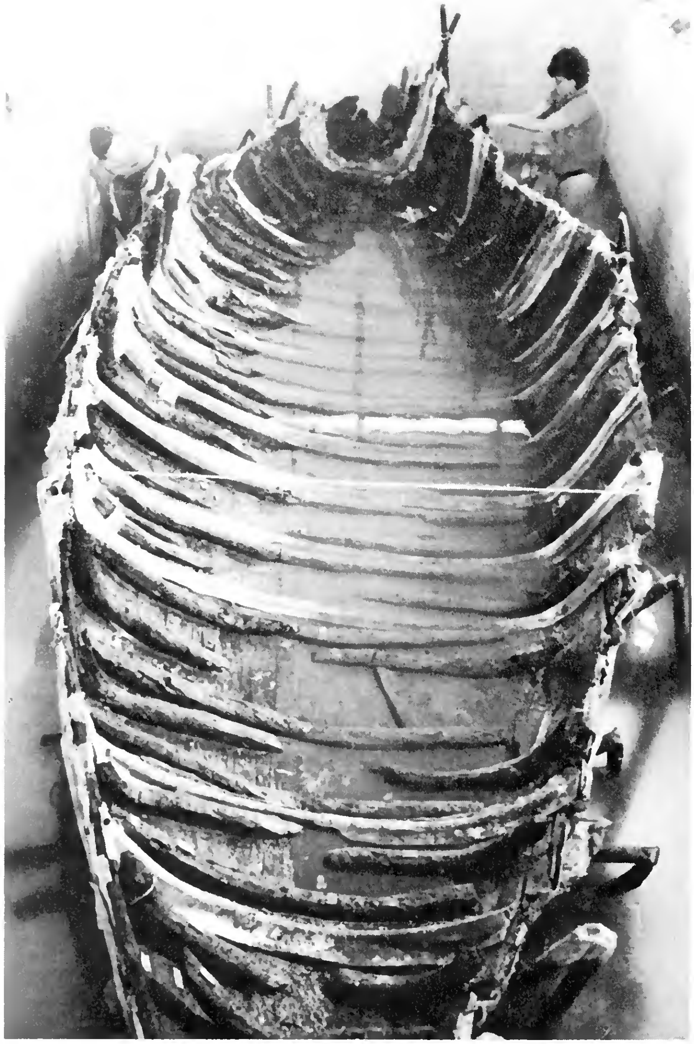
When Jonah fled to Tarshish, he was figuratively running away to the ends of the Earth.

> Tyre, you used to say: I am a ship
> perfect in beauty.
> Your frontiers stretched far out to sea;
> those who built you made you
> perfect in your beauty.
> Cyprus from Senir they used
> for all your planking.
> They took a cedar from Lebanon
> to make you a mast.
> From the tallest oaks of Bashan
> they made your oars.
> They built you a deck of cedar inlaid with ivory
> from the Kittim isles.
> Embroidered linen of Egypt was used for your sail
> and your flag.
> Purple and scarlet from the Elishah islands
> formed your deck tent.
> Men from Sidon and from Arvad
> were your oarsmen.
> Your sages, Tyre, were aboard
> serving as sailors.
> The elders and craftsmen of Gebal were there
> to calk your seams.
>
> Ezekiel 27:3–9.

A Hebrew seal bearing the depiction of a ship dating to the eighth or seventh centuries B.C. may indicate what these ships looked like (see seal, page 73). The seal belonged to a certain "Oniyahu Ben Merab." Despite the seals' minute size—the image of the ship is only eight millimeters long—the ship is excellently detailed. This type of ship is also depicted in numerous other seals, graffiti, and pottery of antiquity.

During his ministry, Jesus lived and worked primarily in the area around the Sea of Galilee. As some of his Apostles were fishermen, it is not surprising that many of the Gospel stories are connected with boats and seafaring on this small (21 by 12 kilometers) freshwater lake. The stories often refer to Jesus crossing by boat from one side of the lake to the other and his practice of sometimes retreating from large crowds by taking a boat to a "lonely place." Two of his most well-known miracles are the calming of the storm on the Sea of Galilee and his walking on its waters.

Because of this, the discovery in 1986 of an ancient workboat buried in the seabed of the lake is of particular interest. The boat was found by two brothers, Yuval and Moshe Lufan, from Kibbutz Ginosar, during a period of drought when the lake had receded revealing vast expanses of dry seabed. Almost immediately, the discovery of "a boat from the time of Jesus" was transformed in the popular imagination into the discovery of "the boat of Jesus."



The Kinneret boat, imagined by some as "the boat of Jesus," is being conserved in a special pool.

Rumors of a "treasure wreck" had scavengers scurrying to salvage what they could of it. To prevent damage to the boat, a rescue excavation was begun at once that continued 'round the clock for 11 days.

At the conclusion of the excavation the boat was successfully moved in one piece to a specially built conservation pool where it is currently undergoing conservation treatment.

Following several years of research by a variety of experts and scholars, the "Kinneret" boat (Kinneret is the Hebrew name for the Sea of Galilee) has allowed us an intimate look at a time and place that literally changed world history. The boat dates to between 100 B.C. and A.D. 70. It represents the largest class of boat commonly used on the lake during antiquity and the class of boat used by Jesus and his apostles in the Gospel stories.

Virtually all the historical and iconographical sources concerning seafaring on the Kinneret in the first century A.D. refer to a large class of boat that normally had a crew of 5—the same number of crew postulated for the Kinneret Boat—and could accommodate as many as 15 men, inclusive of crew. Relatively expensive, boats of this size were normally owned and operated by a family. When family members were insufficient to crew the boat, additional workers were hired. The first four Apostles comprised two such family crews; Peter and Andrew were brothers, as were James and John.

Boats of this class were primarily used for fishing, adapted specifically for use with the seine net—the type described by Jesus in his "Parable of the Net" (Matthew 13:47–50). It was apparently this factor that defined the size of the class; the boats had to be large enough to employ this net and to transport the large crew required to work the net. The boats had large stern decks on which the net was carried and from which it was spread. To judge from recent ethnological parallels on the Kinneret, they probably had a smaller deck at the bow, but were open amidship.

The boats also were used to transport men and supplies. In times of war, they could be pressed into service for battle, mainly as rapid transports; with their shallow draft they were ideally suited for swift commando attacks on the shelving coasts that predominate in the Kinneret. They were apparently not unlike boats used for coastal piracy in the Mediterranean at that time. The Kinneret boat suggests that boats of this size moved under both square sail and oars.

Continued research on ancient Mediterranean shipwrecks, together with textual and iconographic study, will continue to enrich our knowledge of ancient seafaring techniques. Most recently, the Texas-based Institute of Nautical Archaeology's excavation of the Late Bronze Age wreck at Ulu Burun in Turkey has already contributed immeasurably to our understanding of seafaring and trade. The University of Haifa's new excavation of a fifth-century B.C. shipwreck off the Israeli coast near Maagan Michael also will deliver a cargo of knowledge.

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Child's Play: Bouillabaisse

by Sara L. Ellis

"There's always such a lovely aroma of garlic and olive oil. You can just smell them everywhere down there," says Julia Child, reminiscing about culinary delights of the French Mediterranean. "And of course, lots of fish."

Sara L. Ellis is Editorial Assistant at Oceanus.

Child has brought French cooking into the homes of millions of North Americans since the 1960s. After four PBS television series, beginning with *The French Chef*, as well as numerous cookbooks and how-to videos, she just finished her beautifully illustrated magnum opus, *The Way to Cook,* last fall at the age of 77.

Julia is fond of the distinctive food and informal atmosphere in the south of France. I had the pleasure of hearing her thoughts on this regional cuisine, over lunch at her home in Cambridge, Massachusetts.

A great fan of seafood, Child worries about the effects of ocean pollution on Mediterranean fish: "I don't know how polluted the Mediterranean has gotten. That's one of the big problems there—as well as here. I know there used to be lots of wonderful, colorful, little fishes around that you made your fish soup out of, but how much of that is left?"

Child, worrying about Mediterranean pollution, fights for clean and fresh seafood in the United States.

These are legitimate concerns. Compared with other seas and oceans, the Mediterranean is infertile. The scarcity of fish and the related high prices encourage overfishing. The southern coast of Europe has been hit the hardest, with stocks of coastal fish like hake, sole, and red mullet seriously depleted.

Pollution has lengthened the odds on recovery. Raw sewage, oil tanker waste, and industrial sludge were all dumped freely into the Mediterranean. In the 1970s, their effects began to be noticed in a big way—swimmers were coming down with nasty diseases, and tar balls were everywhere.

Fortunately, environmental degradation has slowed down, and in some cases even reversed. Thanks go mainly to the Med Plan (see article, page 38), an international agreement to monitor and cut back sources of pollution. Whether this will give fish stocks a second chance remains to be seen.

Child has been a champion for clean seafood in the United States. Last fall she criticized the shellfish industry for its inattention to the increasing bacterial contamination in oysters, clams, and mussels. She stopped eating shellfish for a while, even though oysters are one of her favorite foods.

As she pleads in *The Way to Cook*, "Serious and continual bacteriological inspection seems. . . to be our only safeguard. It is up to us as the consumers and voters to insist that all regulations and inspections be enforced—and we have to be willing to pay for them." She has started to eat shellfish again, but only when it comes from a thoroughly reliable source.

Julia also stresses that the key to any good seafood dish is freshness. I asked her how she thought freshness compared between fish markets in southern France and Boston. "The fish market in Cannes was wonderful—one of those big covered sheds, with people screaming and yelling, and selling. But you have to watch out because toward the end of the day they try to sell their old stuff if you're not wary. . . . Still, I think that generally fish is fresher over there. Here in Boston, a lot of boats go way out to the Grand Banks and you just don't know how long the fish has been sitting in the bottom of the hold."

In her book *From Julia Child's Kitchen*, she gives a few pointers: "Fresh whole fish have bright bulging eyes, bright red gills, and moist glossy skin. Fresh fillets and steaks have a glossy look too: the meat holds closely together and is springy to the touch." Ultimately though, she contends that your nose is your best judge. "You can certainly tell a fresh fish by smelling it can't you?"

Julia has had plenty of experience sampling Mediterranean cuisine. Her husband Paul (whom she met in Ceylon while doing "lowly" file work for the Office of Strategic Services during World War II) entered the diplomatic service after the war. They were sent to Paris in 1948, and from there to Marseille. Subsequently they built a house slightly inland of Cannes and Nice, on the property of Julia's colleague Simone Beck (a coauthor of *Mastering the Art of French Cooking*). They lived there on and off over the years.

"In Marseille, we were right on the Old Port, next to the wholesale fish market called the *Criée aux Poissons*, or fish auction. It was a very jolly place—you know, lots of noise and shouting and so forth. There were these wonderful fishwives who sounded terribly fierce, all screaming and yelling and having fake fights with each other." On a more recent television assignment in France, Julia was pleasantly surprised to see that the fish markets have remained relatively unchanged. "You might think these unique wonderful old gals would all die off, but there always seems to be somebody who comes in to replace them. I think they just enjoy it very much."

Those wonderful old French fishwives, terribly fierce while screaming and yelling in their fake fights, are not a dying breed.

Undoubtedly, the most famous seafood dish from the French Med is *bouillabaisse*, a hearty stew flavored with tomatoes, garlic, olive oil, onions, saffron, herbs, and fish. Although bouillabaisse is popular on restaurant menus, it is quite an elaborate production, with the whole fish served on a platter, and the soup in a tureen. A less complicated version, *soupe de poisson*, has the same flavorful base but the fish is puréed and the soup is served with grated cheese, toasted croutons, and a red garlic sauce called *rouille*.

There are many variations on the bouillabaisse theme, particularly in countries where you can't get the typical fish such as rockfish, sea eels, gurnards, red mullets, and wrasses. Dogmatic French experts don't believe in substitutions. Julia's attitude is that anything goes, as long as you use the traditional flavoring and have a good strong base made from fresh, non-oily fish.

Last October she was one of the judges of an unusual bouillabaisse contest in Santa Barbara, California. "About 20 restaurants entered, and each chef made his or her own version. They were all very interesting—one was flavored with fennel, another had Mexican seasonings. It was rather difficult for me as a judge, since I was used to regular bouillabaisse and these were *so* different, but it was certainly a lot of fun. With such nontraditional flavors perhaps 'Santa Barbara fish stew' or some such name might have been more appropriate."

The mainstay of most Mediterranean cuisines is olives, which thrive in the hot, dry climate. They set French Mediterranean cooking apart from the classic French style. "In the South of France, they use olive oil instead of butter. Some people think it's healthier since there's no cholesterol in olive oil. And they don't use all that cream" (see box, opposite). Other typical ingredients are capers, anchovies, saffron, and many herbs and spices.

The Italian connection in French food extends to pizza with anchovies and black olives.

Markets abound with different preparations of both black and green olives. One kind that Julia remembers well is *olives cassées* which are whole, green olives, cracked and floating in an onion-garlic-herb marinade. But she has a special fondness for the small black olives—a craving she can satisfy on both coasts of the United States. They grow near her third home in Santa Barbara, and a local company is processing them and making olive oil. Back in Cambridge, it's only a quick trip to the North End of Boston, a predominantly Italian part of town. There the markets carry plenty of Mediterranean olives and capers.

It's no coincidence that Italian markets carry some of the ingredients used in the French Med. As Julia pointed out to me, there are many similarities between the two cuisines, especially near the border:

"In that part of the Mediterranean, the French use lots of pasta. But the French cuisine is always a little more elaborate. When we went over to Italy to teach a one-week cooking course in Venice in the 1960s, they didn't have much of the equipment that they had in France. They don't make many of the classic dishes, so we couldn't find a lot of utensils that we wanted. The Italian cuisine is more simple. Quite frankly I think the French cuisine more fun—but you'd anger the Italians if you said that!"

In the south of France they also make a great deal of pizza. They have a wonderful one called *pissaladière*, which is an onion tart with anchovies and black olives. As I was secretly salivating over the lunch that Julia was preparing for me before my very eyes—smoked salmon from the Pacific Northwest, cheese, homemade bread, and salad with a garlicky olive oil vinaigrette—she lovingly described this French tart:

"You cook the sliced onions in olive oil with herbs and garlic until very tender. You have your dough all rolled out, and then you spread it with a little anchovy paste and olive oil. Then you put the onions on top and decorate it with black olives and anchovy filets. That's a really great combination!"

Another famous Mediterranean dish that uses olives is *Salade*

(continued on page 88)

. . . and it's good for you, too!

There is an inverse relationship between fish consumption and mortality from cardiovascular disease. Diets rich in fish, unlike those rich in meat, appear to be related to better cardiovascular health. This is presumably due to the type of oil found in some fish.

The "Mediterranean diet" meets many of the criteria of a prudent and healthy diet. For reasons of climate, soil, geography, and culture, the diet has a relatively low percentage of calories from saturated and polyunsaturated fats, and a high content mono-unsaturated fats—mostly from olive oil—and fiber. Mono-unsaturated fats have been considered to have a neutral effect on blood lipids, which are linked to cardiovascular disease. Mediterranean populations experience lower incidence of heart disease, strokes, obesity, diabetes, and cancer than do people from other developed parts of the world.

The type and amount of fat in the Mediterranean diet have the effect of lowering blood cholesterol. This is a particular concern given the relationship between elevated blood cholesterol and the incidence of death from cardio-vascular disease. The use of margarine is unheard of, and only small amounts of butter enter the diet.

The Mediterranean diet contains about two-thirds the fat of the typical U.S. diet. Epidemilogic data suggest an inverse relationship between total fat intake and death from cancer. Their foods are often flavored with garlic, which lowers blood cholesterol.

The Mediterranean diet is high in fruits, vegetables, and cereals. Eating foods high in fiber decreases the symptoms of chronic constipation and colon diseases. It also has been suggested that diets low in fiber may increase the risk of colon cancer. Eating plenty of fruits and vegetables ensures not only sufficient amounts of fiber but also of vitamins A, C, and E. These nutrients are thought to inhibit and protect against cancer, which may help to explain the health-promoting qualities associated with the Mediterranean way of eating.

No diet can guarantee good health. Health also depends on exercise, lifestyle, heredity, and environment. But good eating practices, such as those of the Mediterranean diet, based on moderation and variety, can definitely improve the odds against certain diseases. Besides, the Mediterranean diet lends to an attractive, palatable, and inexpensive way of eating!

—Elizabeth J. Johnson
Human Nutrition Research Center
Tufts University, Boston, Massachusetts

Niçoise, which is made with green beans, sliced potatoes, tomatoes, black olives, hard-boiled eggs, tuna, and anchovies, surrounded by leaves of green lettuce. As with bouillabaisse, epicureans debate the proper ingredients of this dish. Believe it or not, in this case the controversial point is potatoes. "Some say it should never have potatoes," explains Child, "but I happen to like potatoes, so I belong to the 'potato school.' And besides, Escoffier [one of the most famous French chefs] has potatoes in his and he came from Nice. That's good enough for me!"

I asked Julia whether she had noticed any changing trends in French Mediterranean food over the last few decades. She thought that the cuisine itself has stayed pretty much the same, but in some cases the quality of the produce has deteriorated. "When I first went over there, life was simpler at that point. They didn't have electric beaters or food processors or anything like that—not even refrigerators. So everyone had to shop for food each day. Then, of course, you only had things that were in season, which makes all the difference in freshness and flavor.

Shopping for food every day in the French tradition makes all the difference in flavor and freshness.

"Now the area is much more modernized. There's more traffic and loads of tourists, but it still remains very French in atmosphere, thank heaven. These days there are lots of supermarkets. Of course this makes for more variety; however, very often I can be there in one of those markets and find myself saying I'd just as soon be back in Cambridge at the Star Market where things are a little fresher.

"In the French supermarkets often the produce isn't as fresh because they don't tend to have our facilities. They do pretty well on their displays of fish, though it depends on where you are. I think we're always inclined to romanticize France, whereas we do pretty well here."

But wait! Romantic it seems and, surely, romantic it should remain. Or else, where would we armchair travelers head for next? On the facing page is one of Julia Child's recipes for Mediterranean fish stew, specially adapted for *Oceanus*.

As you go out and buy the ingredients, imagine yourself at the *Criée aux Poissons*, haggling with a fishwife. Once you've finally made your way back to your little villa, through the crowds and the swerving *bicyclistes*, once you've prepared this wonderful concoction, be sure to take it out onto your tiled patio with a lovely bottle of *Côtes de Provence*. And with each whiff of the aroma of your stew, be certain not to miss the subtle smell of the sea air as it wafts gently past you. . . .

MEDITERRANEAN FISH STEW

(makes about 2 1/2 quarts, enough for 6 to 8 people)

Ingredients

SOUP BASE

1/2 cup fruity olive oil.

1 cup sliced onions and 1 cup sliced white of leek (or 2 cups onions).

6 to 8 tomatoes, cored but unpeeled, roughly chopped.

8 large cloves unpeeled garlic, chopped.

1/2 tsp. thyme, 1/4 tsp. fennel seeds, 3 big pinches saffron threads, and a 3- by 1-inch piece of dried orange peel.

Either: 2 quarts of trimmings from fresh, non-oily fish or shellfish, 2 1/2 quarts water and 1 Tbsp. salt—or: 1 quart clam juice or chicken broth, 1 1/2 quarts water, and salt to taste.

FISH

2 pounds lean fish fillets (cod, hake, monkfish, sea bass, catfish, snapper, or halibut). It can all be of one kind, but a variety is preferable.

Equipment

A heavy 8-quart kettle or casserole and a large sieve or colander.

Instructions

Stir into the kettle or casserole the onions, leeks, and olive oil; simmer 5 minutes until tender but not brown. Stir in the tomatoes and garlic, and cook 5 minutes more. Then add the rest of the ingredients for the soup base and bring to the boil. Skim, and boil slowly, uncovered, for about 40 minutes. Strain, pressing the juices out of the ingredients, correct the seasoning, and set it aside uncovered.

Bring the soup base to the simmer. Meanwhile, cut the fish fillets into medium-size serving chunks. Add to the broth, and simmer about 5 minutes until the fish is cooked through.

Serving suggestion: Serve the soup just as it is, accompanied by rounds of hard-toasted French bread (*croûtes*), and a bowl of freshly grated Parmesan cheese, perhaps with the Mediterranean red garlic sauce called *rouille* (see page 25, *The Way to Cook*).

Then, as Julia Child would say in her unmistakable staccato voice, "Bon appétit!"

The Bismarck - 1989

LETTERS

To the Editor:

I have been intending to write to you for some time to express my admiration for your splendid work, *Oceanus*. The recent issue with the theme, "Pacific Century, Dead Ahead!" (Vol. 32, No. 4) forced my hand. It's hard to imagine, but each edition is better than the preceding one. I read it cover-to-cover and always come away better educated.

One small point: to my knowledge, there are no Typhoon-class SSBNs operating out of the Soviet Far East, as was suggested in the caption on page 18.

I was particularly fascinated by the issue because I also had the opportunity to travel to Vladivostok last November and was on hand to watch the traditional naval parade on November 7th. I was told this was the first year that no naval hardware was displayed, except for the usual ceremonial ships at anchor in Vladivostok harbor. My hosts said it was Gorby's way of de-emphasizing military power.

As a fellow editor, I know the hard work and long time that is necessary to put out a quality publication and that is quite evident with *Oceanus*. I applaud you for your fine efforts and salute your contribution to educating your readers about the importance of the seas.

Deam Given
Editor/Publisher *Subnotes*

To the Editor:

While it's true that the International Whaling Commission (IWC) moratorium on whaling is unlikely to end in 1991 ("Oops!," Vol. 32, No. 4, page 85), this doesn't necessarily mean that whaling won't start up again. On the contrary, as nations opposed to the ban have made clear, unless some exceptions are made that would allow hunting of certain "recovered" stocks of whales, these countries may well quit the IWC and resume whaling under a new regulatory body of their own creation. Indeed, the Icelandic scientist Jóhann Sigurjónsson expressly warned of such a possibility in his article in your whale issue (Vol. 32, No. 1, pp. 29–36).

Frederic Golden
San Francisco, CA

To the Editor:

The issue of *Oceanus* on the Pacific Century (Vol. 32, No. 4) is an extremely interesting one that will be very useful in my teaching.

Associate Professor Theodore C. Bestor
Anthropology and East Asian Studies
Columbia University, New York, NY

To the Editor:

My compliments on your fine job of researching the *Bismarck* (Vol. 32, No. 3)—a job well done. There were several pictures, apart from the recent underwater shots, that I had not yet seen.

The story was captivating. The *Bismarck* was an extraordinary ship, literally unsinkable in the sense that dinosaurs were forever. The last ship of her class, the epitome of a technique—and to fight a battle—which was obsolete. Brought down by a miserly Swordfish and a torpedo, and then, at the end, had to sink herself because the enemy's weapon could only ravage but not sink her.

I found your article more interesting and informative than the one in *National Geographic*, and was under the impression that their article had been scaled down significantly.

Klaus Lindemann
Jakarta, Indonesia

EDITOR'S NOTE: Klaus Lindemann is a relative of the *Bismarck*'s Captain Ernst Lindemann, whose picture appeared on page 10 of that issue.

To the Editor:

I recently saw the special issue of *Oceanus* dedicated to the matter of ports and harbors (Vol. 32, No. 3). Since I have been working on a United Nations Environmental Programme (UNEP) report concerned with the state of the world's oceans, I found the various articles most informative. Your recent *Oceanus* has added significantly to my understanding of world harbors.

However, I was struck by the fact that despite the several articles dedicated to the many aspects of ports and harbors, none added substantively to the argument that in the future, water transport must be greatly enhanced in this country. This would include transportation between coastal maritime ports and ports along the various inland waterways leading to our principal midwestern and southwestern cities. There are many compelling arguments today about increasing the tonnage of materials moved by waterborne vessels. The fact is that very few people seem familiar with the possibilities inherent in maritime transportation.

Moving materials by water, today, can be done very rapidly (well over 30 miles an hour), with far less expenditure of energy than conventional surface or air transportation, and can be implemented and conducted without any pollution whatsoever.

I therefore question, why wasn't a significant article put in the issue that dealt with: 1) the various forms of economical, nonpolluting, and energy-saving marine transportation, and 2) what has to be done to upgrade the port/harbor infrastructure to service expanded maritime commerce—especially where the lines of commerce might extend into the "heartlands?"

John R. Pearce
Deputy Center Director
DOC/NOAA/NMFS/NEFC
Washington, DC

EDITOR'S REPLY: Because of space constraints, we limited our coverage to marine coastal areas. We did cover inland waterways briefly on pages 42 and 43.

To the Editor:

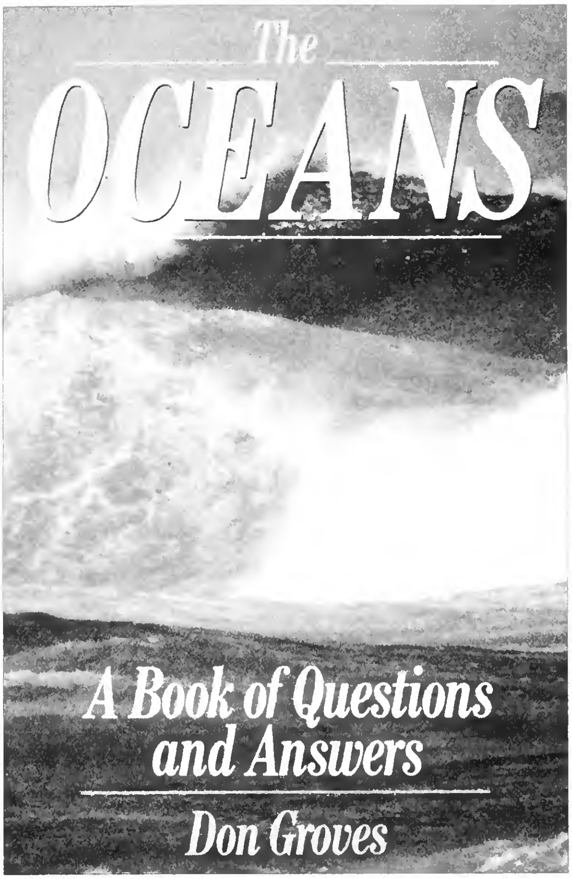
In order to relieve Captain John Bean's puzzlement over the pronunciation of the word "quay" (Letters, Vol. 32, No. 4), I offer the following limerick, one of my originals:

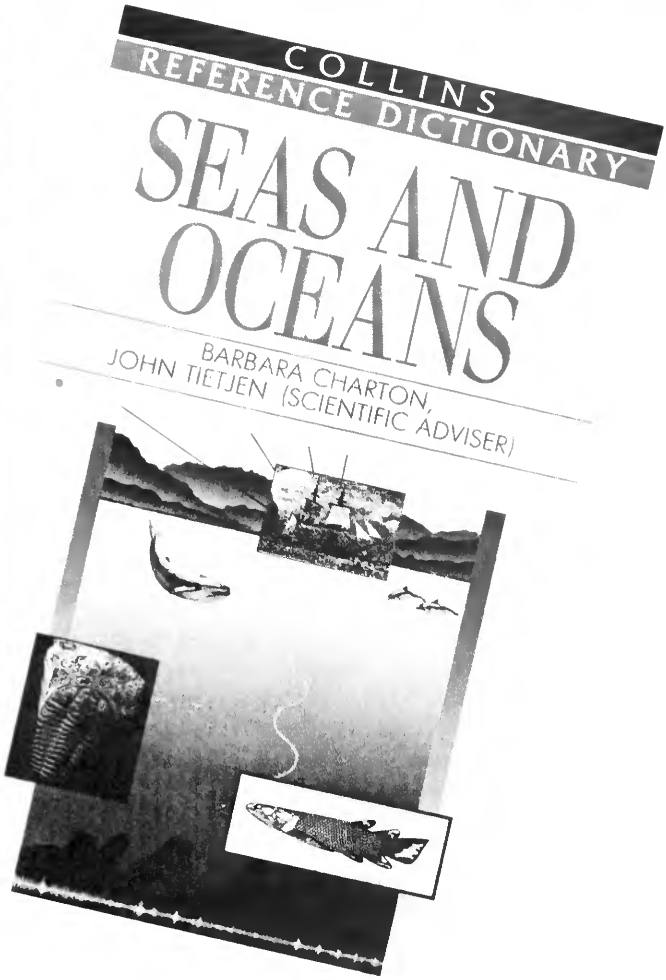
There was a young man on a quay
Who was sipping a glass of iced tuay.
On a peel his heel slipped,
His whole body flipped,
Over the edge and into the suay.

My first visit to Woods Hole was as a nine-year old in 1910. I consider your well-edited magazine the most deeply interesting of all that I read.

Richard Edes Harrison
New York, NY

BOOK REVIEWS





The Oceans: A Book of Questions and Answers **by Don Groves. 1989. John Wiley & Sons, New York, New York. 205 pp. + xviii. $12.95.**

*Seas and Oceans: A Reference Dictionary** **by Barbara Charton and John Tietjen (Science Advisor). 1989. Collins, Glasgow, Scotland. 458 pp. £5.95.**

Here are two books that will be of interest to some *Oceanus* readers. Not only are they informative, but they are small pocketbooks, and relatively inexpensive.

The question-and-answer book by Groves is actually more appealing than it might appear from its title. I first thought it was going to be a collection of short questions and quick answers, but it's better than that. The questions are presented in a coherent series of seven categories: the physical ocean, the chemical ocean, the biological ocean, the geological ocean, the meteorological ocean, the engineer's ocean, and the global ocean—past, present, and future. There are also five tables detailing various characteristics and dimensions of the ocean, an 18-page glossary, a bibliography, and a good index.

The questions range from the general, such as "What is a physical oceanographer and what do they do?," to some more specific ones such as "What kinds of currents are there and what causes them?" Others delve into the

* Available in hardcover in the United States as *The Facts on File Dictionary of Marine Science.* 1988. Facts on File, 460 Park Ave. S., New York, New York 10016. 326 pp. $24.95.

unimportant, such as "What are the seven seas?" or "How many kinds of tides are there?" The answer to the last question is three types: semidiurnal, diurnal, and mixed. This is probably not the answer most physical oceanographers might have given, but the one most understandable by a general reader (the types are described).

In a way, the questions are a general introduction to the various fields of marine science. The answers sometimes go on for a few paragraphs or even pages. Some questions are very insightful, but a few are meant to titillate and would have been better left out. For example, there are two questions concerning Atlantis (the lost civilization, not the ship). Mr. Groves leaves us with the opinion that perhaps Atlantis is really not a myth, reminding us that for thousands of years the cities of Troy, Pompeii, and Herculaneum were also considered to be mythical places. He further pursues the subject of evidence of Atlantis and implies that the odd 5,000- to 7,000-mile breeding migration of eels may have something to do with avoiding an ancient land mass.

These little things aside, the book does make for interesting reading and could be a nice present for somebody who has a passing interest in the ocean. The author makes it very clear in his preface that the book is not intended for professional practitioners of oceanography and ocean engineering. Indeed, we already have enough books.

Seas and Oceans is clearly a reference dictionary of various and numerous terms related to all aspects of oceanography. It is apparently one of a series of reference dictionaries ranging from biology to music. Unfortunately, the book does not explain its rationale. It just starts with "Abalone" and continues 436 pages later to "Zostera" (eel grass).

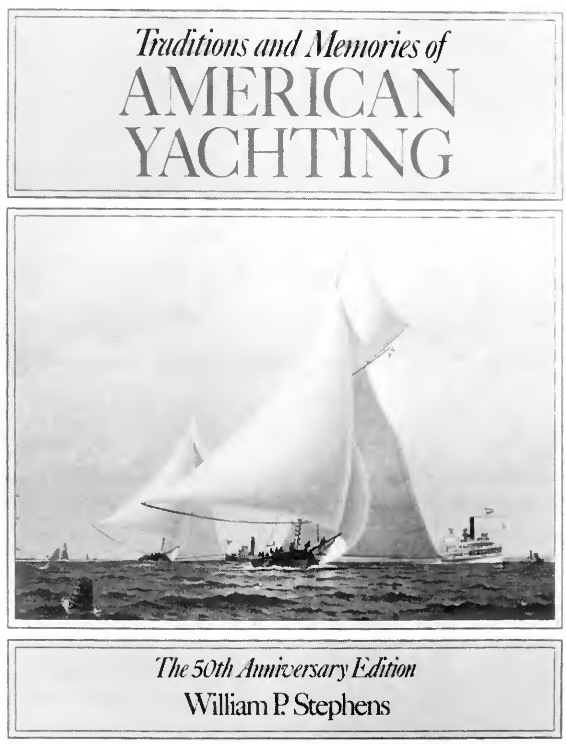
Along the way it defines many oceanographic and geographic terms. It also gives brief biographies of some early explorers and individuals who were directly, or indirectly (for example, German meteorologist Gabriel Daniel Fahrenheit, who devised the well-known temperature scale), related to oceanography.

This book seems more appropriate for oceanographers than the general public. It also has a series of appendices, one on the geologic time scale, another listing important events in marine history, including many I never knew about before. There is also an appendix on the taxonomic classification of plants and animals and a small one on the Law of the Sea Treaty.

My one peeve is that entries in the book are considerably skewed toward biological subjects. The sea anemone gets almost a page, as does the sea cucumber. The entry for the complicated geological process of seafloor spreading says "see ocean," and there it gets only a paragraph. Oh well, many of my biology friends have told me that seafloor spreading was not that important anyway. Their entry for "eel" is about twice the size as that for seafloor spreading, but at least there's no reference to Atlantis.

There is considerable cross-referencing between individual entries, which is helpful in gathering information. This book will also be useful to science writers—in fact they might be the ones who would benefit most from this type of volume.

David A. Ross
Chairman, Geology and Geophysics
Woods Hole Oceanographic Institution



Traditions and Memories of American Yachting, the 50th Anniversary Edition **by William P. Stephens. 1989. WoodenBoat Publications, Brooklin, Maine. 467 pp. + xii. $49.95.**

William P. Stephens is rightfully known as the dean of American yachting. His memories and commentary on American yachting are the most important source of information on the develop-

ment of the sport in this country. Jonathan Wilson, the creator and editor of *WoodenBoat* magazine, has done the yachting world a huge favor by repackaging and printing Stephens' writing in what is its first truly accessible form.

Wilson's book, beautifully designed and printed, is the fifth edition of a collection of articles by Stephens that originally appeared in *Motor Boating Magazine* between 1939 and 1946. In the new WoodenBoat edition, the articles have been retypeset, the original art located whenever possible and carefully reproduced, and some 45 additional pieces of art have been added. The most important part of this lovely book, however, is its index. Since the book is a series of articles, there is no particular order to the information. Mary Jo Davies' index will prove a veritable Rosetta stone to anyone using this work for research.

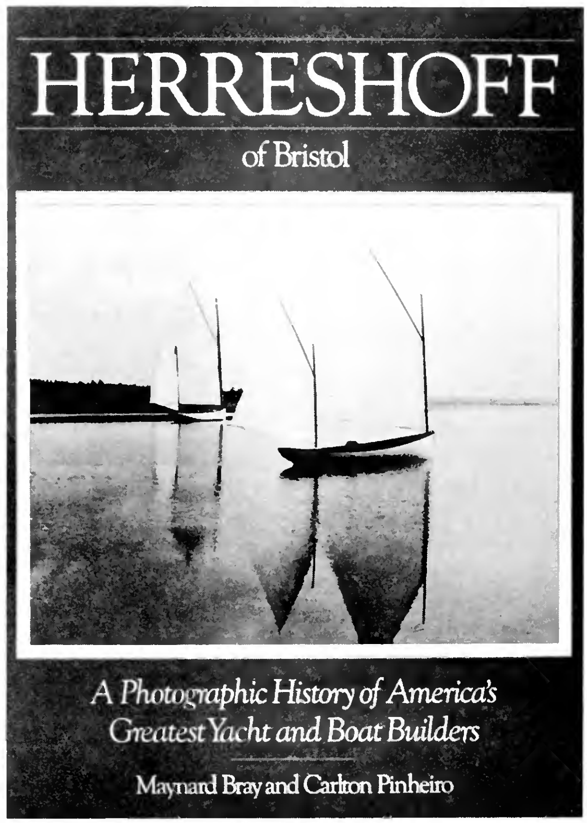
All yachtsmen should be familiar with at least some of the writings of Stephens. His life spanned a significant and, I think, the best era of American yachting—1854 to 1946. Stephens was a talented and salty writer with an engineer's ability to see to the heart of things. His yachting career included (incredibly): organizing the Society of Naval Architects and Marine Engineers in 1893; editing Lloyd's register of American yachts for 29 years; originating the Seawanhaka Cup; designing a number of good and great race-boats; designing, building, sailing, and winning races in many sailing canoes; acting as historian of the Cruising Club of America; rewriting all the yachting definitions for *Johnson's Encyclopedia;* and—most lucky for us—researching, sailing, and commenting upon every yacht and workboat-cum-yacht of the era.

Stephens' book is a must-read for anyone even remotely interested in yachting. From the first chapter, "The Genesis of American Yachting," in which we read about a racing catamaran built in 1820, through the chapter on Sandbaggers, which were equipped with hiking racks for movable ballast and had hand-rubbed graphite bottoms, Stephens' book is riveting. Here is a carefully written commentary on the history of the America's Cup by a man who was on the committee boat for most of the matches he describes.

Nor will the reader languish through dry writing. He describes a test match between two dissimilar boats as "a pig and eagle race. . . sailed at the end of the season. . . in a fruitless attempt to obtain reliable data in the very heated controversy over a proposed change in the classification." He also comments: "Though the centerboard or 'shifting keel' is believed to be an English invention, it was long regarded by Englishmen with the same aversion with which Americans looked upon the lead keel." I particularly enjoyed Stephen's assessment of Lord Dunraven: "Having broken into yachting with the enthusiasm and finesse of a bull in a china shop, Lord Dunraven, undeterred by the failure of *Petronilla*, aimed at no less a mark than the America's Cup."

In short, this fantastic collection of important history, juicy writing, and lovely evocation of times past is now available in a wonderfully readable format for yachtsman and landlubber alike.

Elizabeth Meyer
Yachting Historian and Yacht Restorer
The Museum of Yachting
Newport, Rhode Island



Herreshoff of Bristol: A Photographic History of America's Greatest Yacht and Boat Builders
by Maynard Bray and Carlton Pinheiro. 1989. WoodenBoat Publications, Brooklin, Maine. 241 pp. + vi. $45.00.

I was one of those sailboat lovers who assumed they could spot a Herreshoff design anywhere—distinctively feminine, lean, alive with motion, clean, simple—a look that is both durable and fragile at the same time. Perhaps I wasn't able to identify each Herreshoff by its name, as can a friend of mine, and sometimes I confused the work of the master, Captain Nat, with that of his son, L. Francis. But I could recognize that Herreshoff look in any harbor. Or so I thought until I read this book and learned how limited was my Herreshoff knowledge.

John Brown Herreshoff, blind from boyhood, was the businessman, builder, and manager of The Herreshoff Manufacturing Company. Nathanael Greene Herreshoff was his perfect partner, the consummate engineer and designer. In this age of mass-produced images, engineering specialists, and team design, the scope and capacity of these two brothers is simply incredible.

Together, over a 35-year span in their Bristol, Rhode Island, shops they created an awesome array of marine innovation and beauty. They designed and built the world's fastest steam yachts and torpedo boats, including the engines. From their shops came the largest and most powerful racing sloops that ever sailed—five of which successfully defended the America's Cup—and a score of yachting's most successful designs, from the famous "twelve-and-a-half" to the New York 50. They custom-made hundreds of boats, many for the rich and outrageously demanding robber barons of the 19th century. In 1875, they patented a catamaran design. They conceived the first fin keeler, the first duralumin mast, both cross-cut and full-battened sails, and the longitudinal construction method for hulls—enough engineering and boat-building ingenuity to fill the lives of at least a dozen normal men.

This book is billed as a "photographic history," and with more than 250 photos it certainly qualifies as such. But the authors have given us much, much more. The photos are very crisply reproduced and many are published here for the first time. More importantly, they illuminate and direct us through the entire compelling story.

It is a story of what may arguably be the finest engineering art America has ever produced in sailing craft and steamboats. It is also a story of the professional lives and values of two men who, in so many ways, exemplify this country during its golden age of industry. This significant book is carefully researched, well written, and skillfully printed.

Dodge Morgan
Portland, Maine

BOOKS RECEIVED

BIOLOGY

Birds Asleep by Alexander F. Skutch. 1989. University of Texas Press, Austin, TX. 219 pp. $24.95.

The Herring Gull's World by Niko Tinbergen. 1989. Lyons & Burford, New York, NY. 255 pp. $14.95.

The Legacy of the Tethys: An Aquatic Biogeography of the Levant by Francis P. Dor. 1989. Kluwer Academic Publishers, Dordrecht, The Netherlands. 214 pp. + xii. $82.00.

Orcas of the Gulf: A Natural History by Gerald Gormley. 1990. Sierra Club Books, San Francisco, CA. 166 pp. $24.95.

Return of the Whooping Crane by Robin W. Doughty. 1989. University of Texas Press, Austin, TX. 182 pp. $24.95.

ENVIRONMENT

Earthmind by Paul Devereux, John Steele, and David Kubrin. 1989. Harper & Row, New York, NY. 235 pp. $17.95.

Global Climate Change: Human and Natural Influences edited by S. Fred Singer. 1989. Paragon House, New York, NY. 424 pp. $34.95.

Our Seabed Frontier: Challenges and Choices by the Marine Board of the National Research Council. 1989. National Academy Press, Washington, DC. 138 pp. $30.00.

Report to the Congress on Ocean Pollution, Monitoring, and Research by the U.S. Department of Commerce NOAA. 1989. United States Department of Commerce, NOAA, Rockville, MD. 68 pp. Free.

SECOND WORLD CLIMATE CONFERENCE

GENEVA, 29 OCTOBER–7 NOVEMBER 1990

The Second World Climate Conference, sponsored by WMO, UNEP, UNESCO and ICSU, will be held in Geneva 29 October–7 November 1990. Topics of discussion shall include the World Climate Programme and the issue of climate change, including consideration of the Report of IPCC. Attendence will be by invitation only, but will include senior authors of Poster Session papers accepted. For further information on Poster Session papers, which are to be submitted by 15 May 1990, write to:

Co-ordinator SWCC
c/o World Meteorological Organization
P.O. Box 2300
1211 Geneva 2, Switzerland

Turning up The Heat by Fred Pearce. 1989. Grafton Books, London, England. 230 pp. £4.99.

FIELD GUIDES

Chesapeake Bay: Nature of the Estuary, A Field Guide by Christopher P. White. 1989. Tidewater Publishers, Centreville, MD. 212 pp. $12.95.

Reptiles and Amphibians of The World by Massimo Capula. 1989. Simon & Schuster, New York, NY. 256 pp. $10.95.

GENERAL READING

The Compleat Surfcaster by C. Boyd Pfeiffer. 1989. Lyons & Burford, New York, NY. 200 pp. $14.95.

The Day That Lightning Chased the Housewife and Other Mysteries of Science edited by Julia Leigh & David Savold. 1989. Harper & Row, New York, NY. 229 pp. $7.95.

Latin American Politics: A Theoretical Framework by Torcuato S. Di Tella. 1990. University of Texas Press, Austin, TX. 236 pp. $27.50.

Lucy's Child: The Discovery of a Human Ancestor by Donald Johanson and James Shreeve. 1989. William Morrow & Company, New York, NY. 318 pp. $22.95.

Six Days In Havana by James A. Michener and John Kings. 1989. University of Texas Press, Austin, TX. 144 pp. $24.95.

OCEANOGRAPHY

Biomass Yields and Geography of Large Marine Ecosystems by Kenneth Sherman and Lewis M. Alexander. 1989. Westview Press, Boulder, CO 493 pp. $45.00.

Chemical Oceanography SEAREX: The Sea/Air Exchange Program, Volume 10 edited by J. P. Riley and R. Chester. 1989. Harcourt Brace Jovanovich, New York, NY. 404 pp. $48.00.

Productivity of The Ocean: Present and Past by W. H. Berger, V. S. Smetacek, and G. Wefer. 1989. John Wiley & Sons, Somerset, NJ. 473 pp. $146.00.

UNESCO Reports in Marine Science: Year 2000 Challenges for Marine Science Training and Education Worldwide by Unesco. 1989. Unesco, Paris, France. 129 pp. Free.

REFERENCE

Adventuring in the Caribbean by Carrol B. Fleming. 1989. Sierra Club Books, San Francisco, CA. 388 pp. $12.95.

Azimov's Chronology of Science & Discovery by Isaac Asimov. 1989. Harper & Row, New York, NY. 737 pp. $29.95.

Marine Parks and Aquaria of the United States by Anthony L. Paheco and Susan E. Smith. Lyons & Burford, New York, NY. 160 pp. $9.95.

This Is Diving by Duilio Marcante. 1989. Sheridan House, Dobbs Ferry, NY. 160 pp. $24.95.

SHIPS AND SAILING

The Cockpit Quiz Book by C. Dale Nouse. 1989. Seven Seas Press, Camden, ME. 83 pp. $7.95.

Historic Ship Models by Wolfram zu Mondfeld. 1989. Sterling Publishing, New York, NY. 352 pp. $19.95.

Tropical Shipwrecks by Daniel and Denise Berg. 1989. Aqua Explorers, East Rockaway, NY. 150 pp. + x. $18.95.

Warships of the Civil War Navies by Paul H. Silverstone. 1989. Naval Institute Press, Annapolis, MD. 272 pp. $36.95.

Alvin.

- **Sea Grant Issue,**
Vol. 31:3, Fall 1988—Covers activities from biotechnology to estuary rehabilitation.
- **U.S. Marine Sanctuaries,**
Vol. 31:1, Spring 1988—Features all the operating, and various proposed, sites.
- **Caribbean Marine Science,**
Vol. 30:4, Winter 1987/88—Biology, geology, resources, and human impacts.
- **Galápagos Marine Resources Reserve,**
Vol. 30:2, Summer 1987—Legal, management, scientific, and historical asp
- **The Titanic Revisited,**
Vol. 29:3, Fall 1986—Radioactivity in the Irish Sea, ocean architecture, more.

Vol. 28:2, Summer 1985—The oceans from the viewpoint of the modern navy, strategy, technology, weapons systems, and science.

- **The Exclusive Economic Zone,**
Vol. 27:4, Winter 1984/85—Options for the U.S. EEZ.
- **Deep-Sea Hot Springs and Cold Seeps,**
Vol. 27:3, Fall 1984—A full report on vent science.
- **Industry and the Oceans,**
Vol. 27:1, Spring 1984—The interaction of the oceans and industry.
- **Sharks,**
Vol. 24:4, Winter 1981/82—Behavior, physiology, repellants & swimmer's advice

Issues not listed here, including those published prior to 1977, are out of print. They are available on microfilm through University Microfilm International, 300 North Zeeb Road, Ann Arbor, MI 48106.

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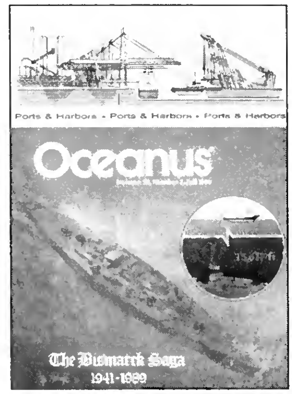
Additional Reading . . . Back Issues of **Oceanus**

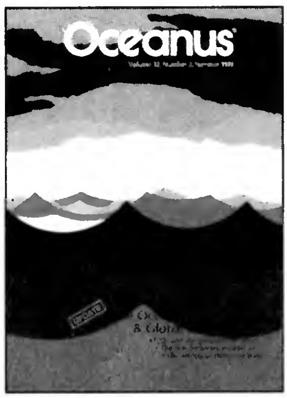
Pacific Century, Dead Ahead!

Vol. 32:4, Winter 1989/90—A study of the political and economic structure of the Pacific region with an eye toward the future and the important role that this region will play in the global economy. Piracy, Greenpeace in the Pacific and dolphins. 1st International Submarine Races and a futuristic look at the Slocum Mission.



The Bismarck Saga and Ports & Harbors

Vol. 32:3, Fall 1989—Highlights the little-known U.S. involvement in the heroic battle of 1941, and addresses the question of whether the *Bismarck* was sunk or scuttled. Japanese port innovations, Dutch successes, Third-World problems, and American plans are examined, as are the longshoremen's history and waterfront renovation.



The Oceans and Global Warming

Vol. 32:2, Summer 1989—Update of efforts to understand and predict ocean/atmosphere interactions. The limits of computer modeling, El Niño, rising sea levels and water supplies, a worst-case scenario, and Venus' "runaway" greenhouse effect are explored. Also articles on life aboard a Soviet research vessel, and the Jason project.

other available issues . . .

- **Whither the Whales?,**
Vol. 32:1, Spring 1989—Cetacean research, intelligence, research and tracking; whaling and dolphins.
- ***DSV Alvin:* 25 Years of Discovery,**
Vol. 31:4, Winter 1988/89—A review of the history and contributions of *DSV Alvin.*
- **Sea Grant Issue,**
Vol. 31:3, Fall 1988—Covers activities from biotechnology to estuary rehabilitation.
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- **The Titanic Revisited,**
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- **The Great Barrier Reef: Science & Management,**
Vol. 29:2, Summer 1986—Describes the world's largest coral reef system.
- **Beaches, Bioluminescence, and Pollution,**
Vol. 28:3, Fall 1985—Science in Cuba, and Jacques Cousteau's turbosail vessel.
- **The Oceans and National Security,**
Vol. 28:2, Summer 1985—The oceans from the viewpoint of the modern navy, strategy, technology, weapons systems, and science.
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