

Against the Tide

Venice's long war with rising water

By RICHARD MONASTERSKY

As one of the most improbable cities on Earth, Venice has never failed to astound those who consider its precarious position, right at the water's edge.

"There lie your houses built like sea-birds' nests, half on sea and half on land," wrote a regional official in 523 A.D. "The solidity of the earth is secured only by willows and wattle [poles and thatch], yet you fear not to place so frail a barrier between yourselves and the sea."

The same sense of awe greets modern visitors, who ponder how a city came to grow at a site virtually devoid of dry land. "Who in their senses, one wonders, would leave the fertile plains of Lombardy to build a settlement—let alone a city—among these marshy, malarial wastes, on little islets of sand and couchgrass, the playthings of current and tide?" asks John Julius Norwich in *A History of Venice* (1982, Knopf).

Archaeologists are only now, however, coming to appreciate just how much Venice has struggled to stay dry over the centuries. In a study of sea level shifts going back 6,000 years, a team of researchers has determined that Venice has been battling rising waters since its birth, with the pace of change accelerating markedly in this century.

Their findings, they say, renew questions about a controversial multibillion-dollar project to save Venice from the *acqua alta*, or high water, that routinely floods the city and slowly gnaws at its foundations.

Although vulnerable today, Venice's water-logged location offered safety following the collapse of the Roman Empire 1,600 years ago, when so-called barbarian horsemen swept down from the North and overran the nearby plains. According to Venetian chronicles, local people retreated into the lagoons during the Goth invasion and founded a city in 421 A.D. on the islands of Rialto—the present location of Venice.

Scholars have questioned the accuracy of this legend, but they've had little hard evidence with which to reconstruct Venice's early years. "Until about 10 years ago, there really wasn't any archaeology. It's hard to believe that you have one of these great historical cities in Europe, but it had no urban archaeology," says archaeologist Albert J. Ammerman of Colgate University in Hamilton, N.Y.

The city itself is to blame. Built on soft, compactible sediments, Venice is slowly

sinking under its own weight. What's more, an industrial complex across the Venetian lagoon extracted groundwater from the 1930s to the 1970s, increasing the rate at which Venice subsided. Compounding these changes, Earth's seas have been gradually swelling over the past several millennia.

These various problems have pushed the earliest evidence of Venetian occupation 2 meters below the present surface of the lagoon. Excavations down to that level quickly fill up with water, making operations costly and difficult.

Ammerman and his colleagues have spent the past decade trying to uncover

Photo by Sam Abell © National Geographic Society



Venice's Grand Canal loops through the city.

the early archaeological levels in the lagoon. At three sites in Venice, and on two nearby islands, they used carbon-14 techniques to date buried structures. By measuring the position of these objects relative to current water levels, the researchers could estimate how quickly the city has sunk since its founding.

In a related effort, Charles E. McClenen, a marine geologist at Colgate, has traced the history of the lagoon itself by using sonar to penetrate its sedimentary layers. The lagoon started to form 6,000 years ago, and the water has risen 5 m since then, he determined.

In the June *ANTIQUITY*, the researchers combine their evidence to estimate how rates of sea level rise have changed over time. For the first 4,000 years after the birth of the lagoon, the water surface at the site of Venice rose relatively slowly, at a rate of 7 centimeters per century.

Around 400 A.D., people moved into the lagoon and settled on marginal marsh-grass islands, which flooded during the highest tides. To stay above water, these pioneers built up the islands with boatloads of sand. Later, Venetians started

driving innumerable wooden piles down into the sediment, forming level foundations on which to build the growing city. One existing church, according to records, rests on 1.1 million of these timbers.

Such efforts sparked a never-ending war with the water. As a result of the added weight on the islands, they began to sink and local water levels started increasing faster than before. From 400 A.D. until the end of the 1800s, the sea rose at about 13 cm per century, report the scientists.

This century, the rate jumped even further. Tide-gauge records indicate that sea level at Venice has risen 25 cm, driven in part by the water extraction and the global sea level rise spurred by increasing worldwide temperatures.

As the archaeological data show, early residents fought back by continually building up the ground surface, covering over earlier levels of the city, says Ammerman.

Daniel J. Stanley, a coastal geologist with the Smithsonian Institution in Washington, D.C., compares Venice to a man standing in a swimming pool. "His feet are embedded in lead and the water level in the pool is rising and it's already to his nose. He better not make any waves," says Stanley.

Conservative estimates of greenhouse warming suggest that global sea levels will climb between 38 and 55 cm by the end of the next century. "That doesn't augur well for the city of Venice," says Stanley.

To combat the *acqua alta*, Venice is considering a plan to install movable floodgates at the entrances of the lagoon. Before periods of flooding, the city could seal off the lagoon from the Adriatic Sea. The new archaeological data, however, suggest that the floodgates would need to close for many of the autumn months in the future, causing pollution and shipping problems in the lagoon, says Ammerman. He proposes instead that Venice take lessons from its past, when people built up the ground level. Such practices, though, would mean covering low-lying surfaces, such as the renowned Piazza San Marco.

"That is impossible," says Rafael L. Bras of the Massachusetts Institute of Technology, who chairs a panel reviewing the environmental impact of the floodgate project. "It's not physically feasible to raise the city and protect it against the high floods." Such efforts would cost billions of dollars and still not stop the building foundations from eroding. Only mobile or permanent floodgates will solve the problem, he says.

Whatever the solution, Venetians do not have long to wait. Each year, the seas continue to creep upward, lapping ever higher against the treasured city. □