jacked up land on one side of a fault by 5 meters — an amount comparable to the uplift in Seattle.

Because such rapid shifts in land height often cause tsunami waves, Brian F. Atwater and Andrew L. Moore of the University of Washington searched the region for evidence of past surges. At two sites, they found signs that a tsunami flooded tidal marshes, blanketing them in centimeters of sand. Using especially precise carbon-14 dating techniques, they found that the tsunami hit between 1,000 and 1,100 years ago.

In previous work, Atwater had found tsunami deposits along the Washington coast. This and other evidence convinced many scientists that the Pacific Northwest coast has produced great quakes of magnitude 8 or larger, caused by a piece of ocean floor subducting beneath the North American continent (SN: 2/17/90, p.104). The discovery of these tsunami deposits led many researchers to look within the Puget Sound area for signs of shaking caused by great coastal quakes. While the search has turned up hints of coastal shocks, some of the emerging evidence fits the idea of a jolt on the much closer Seattle fault, Atwater says.

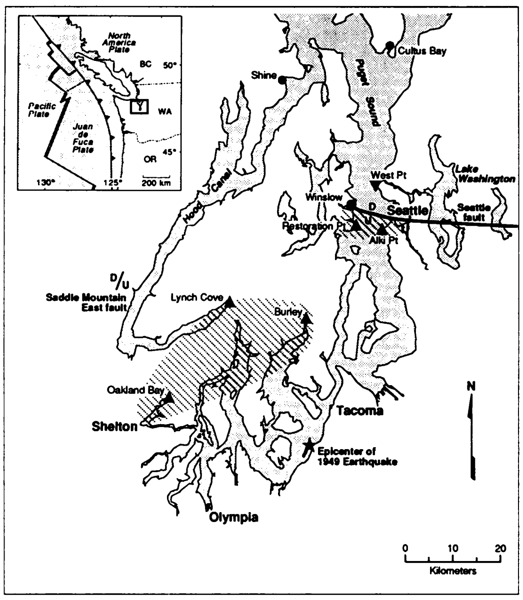
In particular, tree-ring specialists have studied deposits left from landslides that carried trees and rock into Lake Washington. The researchers, from Lamont-Doherty Geological Observatory in Palisades, N.Y., and from the University of California, Berkeley, recovered trees from the lake and used carbon-14 dating to determine that the landslides occurred between 1,000 and 1,300 years ago.

With a bit of luck, they established an even more precise connection by comparing rings in Douglas firs found in Lake Washington with rings in a Douglas fir found in the tsunami deposit discovered by Atwater. Though these sites lie 23 km apart, the ring analysis shows that the trees all died within the same year and season — sometime in the fall, winter, or early spring.

Other researchers studying sediments in Lake Washington found evidence of a major disturbance about 1,100 years ago. In the Olympic mountains, geologists dated six prehistoric rock avalanches to between 1,000 and 1,300 years ago.

In a commentary in SCIENCE, geophysicist John Adams of the Geological Survey of Canada in Ottawa says that a repeat of the Seattle quake would shake the city far more than would a larger subduction quake along the coast. Damage from a shallow Seattle quake would also exceed that from deep quakes that hit Puget Sound in 1949 and 1965, Adams says.

Bucknam's group has also found evidence of uplift between 1,000 and 1,500 years ago in an area southwest of Seattle. He suspects a different fault may have caused the prehistoric uplift there, raising the possibility that the Puget Sound area has several active faults. While these quakes could cause considerable damage, geologists have yet to find enough evidence to determine how often they occur. "It might be thousands of years [from now] or it might be tomorrow," Bucknam says. *— R. Monastersky*



Bucknam

Diagonal lines show two uplifted areas.

Fullerene-like molecules without carbon

To date, all known hollow, cage-like molecules have contained at least some carbon. The widely studied fullerenes consist of nothing but carbon atoms, while the metallo-carbohedrenes (SN: 4/18/92, p.250) mixed in a few titanium atoms to help bend the structure into a puckered ball.

Now materials scientists have discovered a molecular cage with no carbon whatsoever — tungsten disulfide. This inorganic semiconductor will also curl up to form cylindrical and closed polyhedral structures, says Reshef Tenne at the Weizmann Institute of Science in Rehovot, Israel. He and his colleagues have made microscopic tubules ranging from less than 10 nanometers to more than 100 nanometers long, as well as cages of various sizes, they report in the Dec. 3 NATURE.

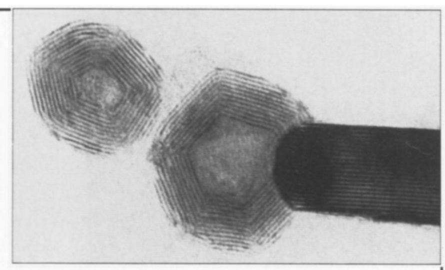
Because it is an inorganic cage, the tungsten disulfide crystal will likely have properties very different from those of fullerenes. "[The discovery] opens up a whole new area; it will stimulate research on nanotubes in new materials," says Thomas W. Ebbesen, materials scientist at NEC Corp. in Ibabaki, Japan.

For the past two years, Tenne and his colleagues have been designing better photovoltaic cells by making thin films of tungsten sulfide. In one experiment, they deposited tungsten in thin layers onto quartz, then exposed it to hydrogen sulfide in an oven heated to 1,000°C. They examined the resulting films with an electron microscope.

Only after seeing electron micrographs of the onion-like fullerenes that form when fullerene films are subjected to high-energy electron beams (SN: 10/24/92, p.277) did the Israeli scientists realize that the unusual shapes in their micrographs of the tungsten disulfide warranted a closer look, Tenne says.

When Tenne and his colleagues tilted their samples in the electron microscope, they could distinguish closed three-dimensional structures from open curved sheets. Also, the electron diffraction patterns and a technique called lattice imaging further verified the closed nature of these molecules, says Tenne. However, they have yet to develop a way to make large quantities of these new molecular cages.

Like fullerene tubules (SN: 7/18/92, p.36), the tungsten disulfide tubules consist of concentric layers. They seem to sprout from the tungsten film and are sealed at the top. The smallest, with four layers, has an internal diameter of 4 nanometers. The polyhedrons exist singly or in linked chains of three or more, Tenne's team reports.


Tenne et al./NATURE

Electron micrograph of tungsten disulfide tubule.

Like graphite atoms, tungsten disulfide atoms arrange in layers of parallel honeycomb sheets. Hexagons of tungsten are sandwiched between hexagons of sulfur. A seventh atom lies in the center of each hexagon. Weak forces link the sulfur sheets.

High temperature may cause the sheet to curl or convert the hexagons to pentagons or other formations that can stabilize the rounded shape, the researchers suggest. Or, oxygen or some other contaminant may escape from the quartz substrate during heating and help cause the sheets to curve, they add. *— E. Pennisi*