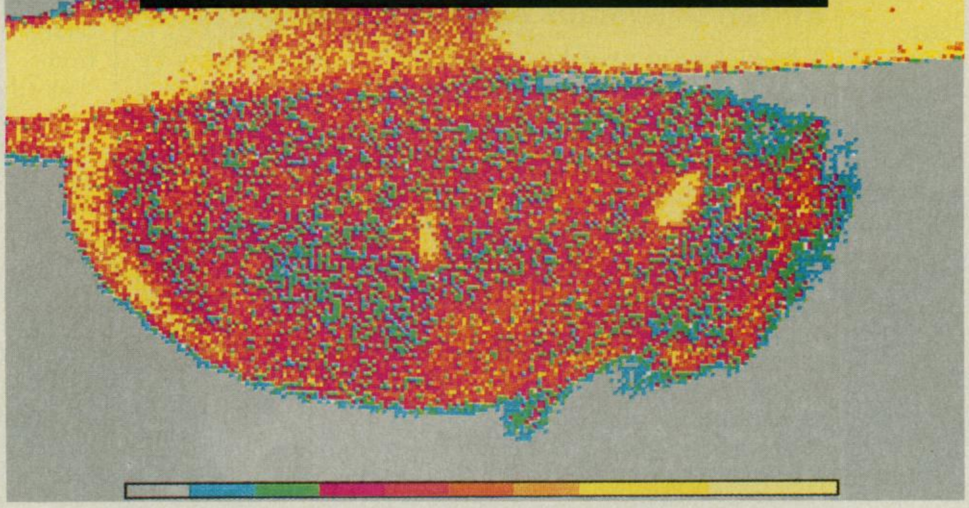


SPM Oxford

Nitty gritty. *A nit and a hair—both from an Egyptian mummy—as mapped by the proton microprobe for the presence of sulfur, which is especially high in the keratin of the hair.*

Proton Microbeam Probes the Elements

A remarkable new instrument devised at Oxford University can magnify a specimen and analyze its elemental composition at the same time

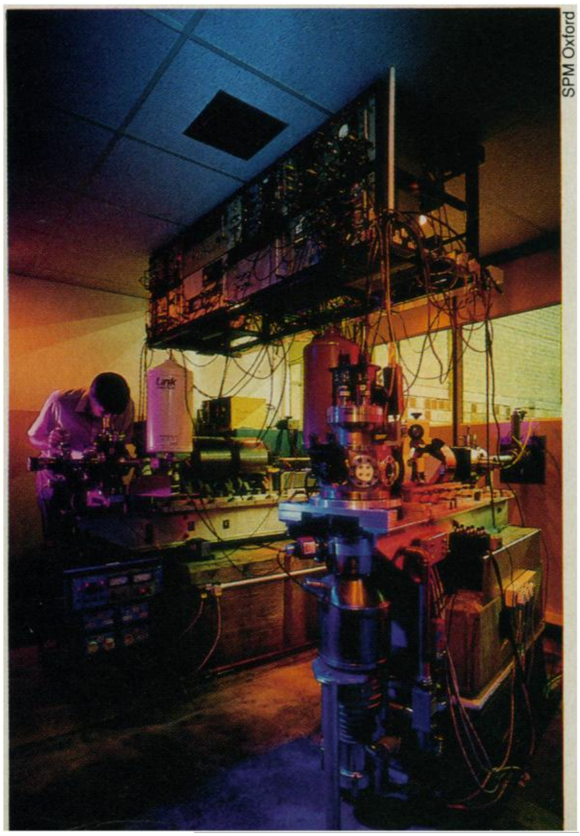
IMAGINE AN INSTRUMENT WITH THE analytical power of a mass spectrometer and the imaging capacity of an electron microscope. It would not only show you what things look like, in microscopic detail, but would also measure and map what they were made of. How might you use such a device? How about unraveling the composition of the nerve cell tangles that characterize Alzheimer's disease? Or measuring how much heavy metal microbes can absorb? Or finding out how an artist—Rembrandt, say—used pigments?

This instrument is not some chemist's dream. It exists—in the basement of the Department of Physics at the University of Oxford. Called a proton microbeam, it has been used to try to answer all these questions and more.

The basis of the microprobe is a beam of fast-moving protons that can be scanned across a sample. Occasionally a proton will smash into one of the atoms in the sample and dislodge an electron. As the remaining electrons reshuffle to fill the hole, they emit an x-ray characteristic of that particular atom. Measure the energy of the x-ray and you know the identity of the atom. Link that to the beam's position, and you can build up a map of the sample. That technique, known as PIXE (proton-induced x-ray emission), is the microprobe's most commonly used method, but by no means the only one.

Sometimes the proton will bounce directly off an atomic nucleus. This happens infrequently, perhaps a thousand times less often than it hits an electron, but the energy of the rebounding particle can also reveal the identity of the atom it bounced off. The phenomenon—Rutherford backscattering—was discovered by the British physicist Lord Rutherford, who used it to formulate with his picture of a heavy atomic nucleus surrounded by light electrons. For the microprobe, its beauty lies in the fact that it complements PIXE exquisitely: PIXE works best with heavy elements, those above about aluminum in the periodic table, whereas Rutherford backscattering is most informative about light elements.

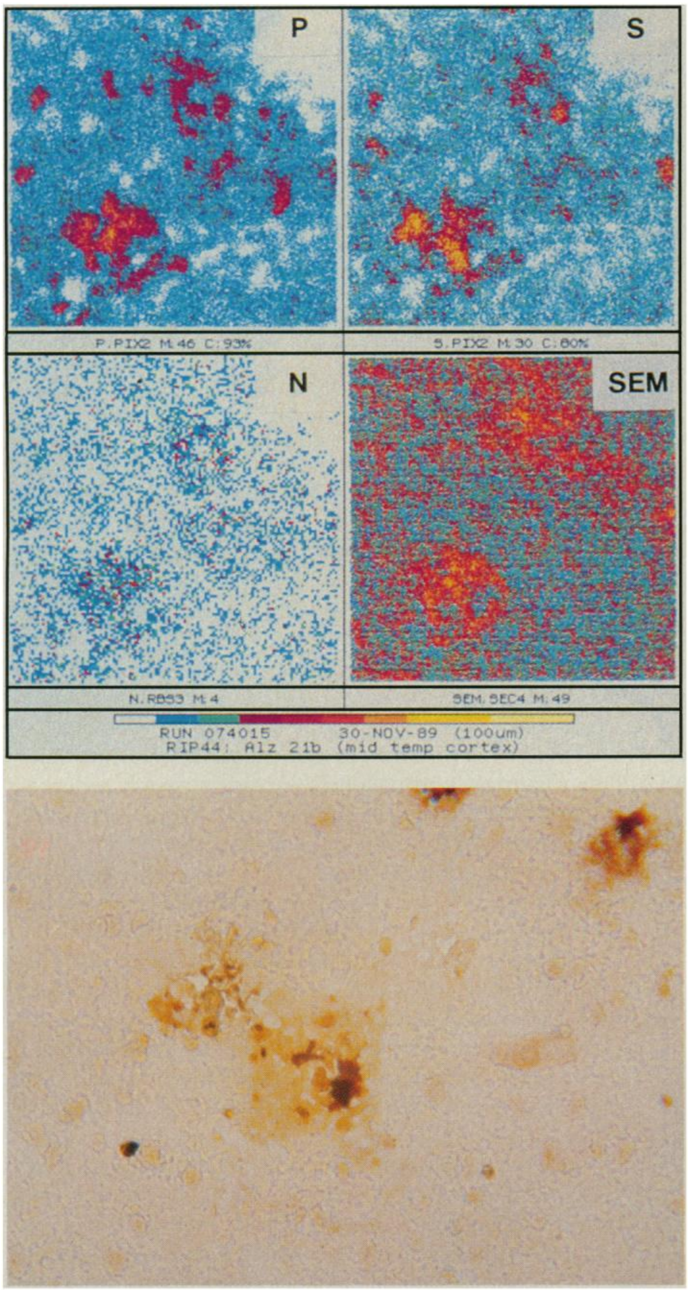
The men largely responsible for putting these functions together in a single, usable machine are Frank Watt and Geoff Grime of Oxford's physics department. Beginning 20 years ago, Watt and Grime tackled the difficult problem of focusing a beam of protons—difficult because the particles are heavy and hence need very strong magnetic fields to focus them. By 1980 they had solved the problem, routinely getting a beam 1 micrometer across. After that, they encountered a different problem: funding. Although everyone thought the probe was a nice idea, it cut across disciplines and it wasn't easy to get



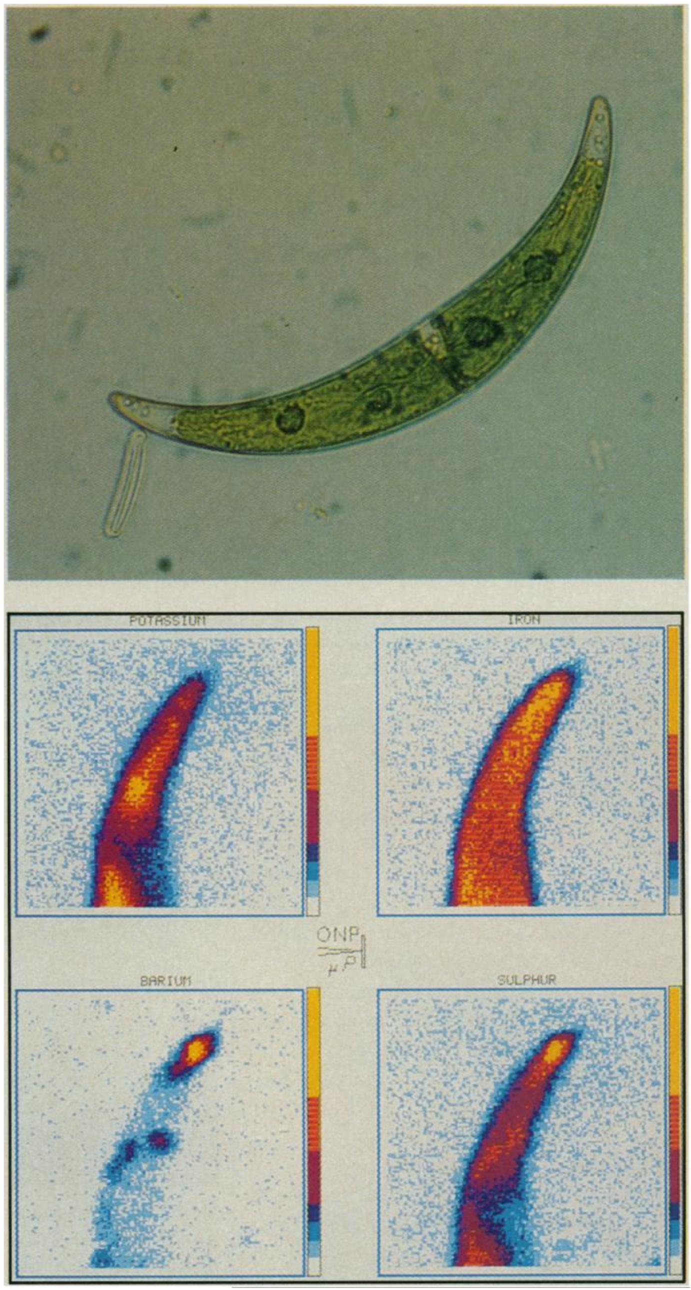
SPM Oxford

Beam me in, Scotty. *Oxford University's scanning proton microprobe, which both magnifies objects and maps their elemental composition. Geoff Grime, a member of the team that developed the Oxford system, adjusts one of the powerful quadrupole magnets that focus the proton beam.*

SPM Oxford



Elements of amnesia. *Brain tissue from an Alzheimer's patient, stained to reveal plaques characteristic of the syndrome (below), is paired with microprobe analyses of phosophorus (upper left), sulfur (upper right), and nitrogen (bottom left), along with a topographical map of the plaques. High concentrations of these elements correspond to amyloid, a plaque-associated protein. But the microprobe has failed to find aluminum—a suspected culprit—in most Alzheimer's plaques.*



A barium meal. Closterium tumidulus *(above) is a freshwater alga from the English Lake District. Microprobe scans reveal that the crystals in the vacuoles at the tips of the alga contain high concentrations of barium (lower left) and sulfur (lower right). These are almost certainly crystals of barium sulfate. Now researchers would like to know how these organisms accumulate barium, which occurs at very low concentrations in the water around them, and what the function of the crystals is.*

conventional funding.

In 1986, however, the Wellcome Trust, one of Britain's largest medical funders, decided to give some money to big equipment projects. The Trust decided to support the Oxford team—in the hope that the microprobe could be used to examine plaques in the brains of Alzheimer's patients and find out what role one suspected agent, aluminum, was playing there. With that funding, the proton microbeam became a reality. Since then, it's produced lots of interesting—and colorful—results, some of which are displayed on these pages.

Ironically, the question the machine was built to answer—whether there is aluminum in the brains of all Alzheimer's patients—hasn't yet been resolved. After scanning scores of samples of brains from patients, the one firm conclusion is that aluminum is not always present. It does turn up in about one-fifth of the specimens, but is by no means always associated with Alzheimer's disease.

It is, however, just about everywhere else. "All the reagents used to prepare specimens are contaminated with aluminum silicate," says Watt. "We can't get rid of the aluminum or silicon in our chemicals, it doesn't matter how hard we try." So, while aluminum might be a feature of the plaques, it might equally well be an impurity in the reagents, attracted to the amyloid protein that makes up the bulk of the plaques.

The machine is also being focused on other, less weighty matters, such as, can you tell a real Rembrandt from an impostor? "It's not in the cards at the moment," answers Julian Henderson, who, with a degree in archeology and a D.Phil. in nuclear physics, calls himself a science-based archeologist. "But in the very long term, there is a very slight chance we will be able to tell a Rembrandt from a non-Rembrandt."

Henderson, based in Oxford's Research Laboratory for Archaeology, is collaborating with scientists at the National Gallery in London to create a complete chemical characterization of Rembrandt's lead white pigment. What matters is not the pigment itself—usually lead carbonate and lead carbonate hydroxide—but the impurities, small amounts of nickel, copper, iron, and the like. It is those impurities that might distinguish one artist from another.

Henderson is reaping more immediate rewards by using the microprobe to look at trace impurities in glass from the second millennium B.C. Current archeological wisdom holds that at that time glass was made in only one place—Mesopotamia—and exported from there. Henderson has examined glass from Mesopotamia, Tel al Armana in Egypt, northern Greece, Crete, and Frattesina in northern Italy, and says guardedly that "it looks rather as though glasses used in northern Greece are radically different from glasses in Mesopotamia and Egypt, and therefore were not made in either of those places."

Henderson's program is just one of many vying for time on the microprobe. Plant scientists are using it to ask if they can predict when ripe oil palm fruits will fall, which would save growers wasted fruits. Environmental physicists are monitoring pollution and scanning and analyzing fly-ash particles. Materials scientists are peering into the crystal structure of high-temperature superconductors. Getting that much collaboration, even once the machine was in place, was not easy. "We're hitting science with a novel idea at a time when scientists are having to work damn hard just to survive," complains Watt. "There's no freedom to say, 'let's just give that a try.'"

The freedom to consider new possibilities, however, is the essence of using the proton microbeam now. "We consider the whole field of nuclear microscopy as being at about the same stage as electron microscopy was in the fifties," says Watt. "It had great potential, but no one knew what they were going to use it for." ■ Jeremy Cherfas

Signs of the Parkfield Quake?

Things had been pretty quiet around the central California town of Parkfield (population 34). A little too quiet for some seismologists. For more than 5 years they've been waiting for the moderate earthquake they had predicted for Parkfield. The wait was getting tedious. Not only did the expected earthquake fail to strike, but there was even less seismic activity than usual in the area.

But now the Parkfield area seems to be perking up again. From one end of this 30-kilometer segment of the San Andreas fault to the other, small quakes have been popping off in recent weeks in ways that suggest the long-awaited event might be going to happen in months rather than years. "Maybe we're entering a buildup phase of the earthquake," says Cathleen Aviles of the Menlo Park office of the U.S. Geological Survey.

It may seem callous, but geophysicists are keen on seeing some action at Parkfield. The fault's habit of generating a moderate quake of magnitude 5.5 to 6 every 22 years or so had led to a 1985 prediction, endorsed by the USGS, that the next Parkfield quake would strike in January 1988, give or take 5 years. Because previous Parkfield earthquakes had caused no injuries and limited damage, the scientists felt free to eagerly anticipate their closest look ever at a quake.

Last year Parkfield watchers were getting a bit antsy when they noticed their first clue that a Parkfield earthquake might be imminent—it was too quiet. During the summer, Aviles noted that the area around Middle Mountain (actually a 275-meter hill) just north of Parkfield had been devoid of earthquakes of magnitude 2.5 and larger since early 1985. That seemed too long to be a random, meaningless fluctuation. Max Wyss of the University of Colorado and his colleagues also noted the seismic silence around Middle Mountain, and they believed that a sharply reduced level of activity, a quiescence rather than a silence, extended the length of the Parkfield segment of the fault.


John K. Nakata/USGS

Be there. *Parkfield residents aren't worrying about their next quake.*

The absence of sizable quakes near Middle Mountain was intriguing because there had been plenty of activity registered there continuously from 1969, when good seismic records begin, until 1985, and seismologists expect the predicted quake will begin right beneath the mountain. Indeed, a few earthquakes elsewhere have been immediately preceded by periods of quiescence, and so Wyss and colleagues suggested early this year that the Parkfield quiescence heralds a quake that will strike in March 1991, give or take 1 year.

Wyss's bet has been looking better and better since four unfelt earthquakes of magnitude 3.0 to 3.3 struck the Parkfield fault segment during the past 6 weeks. Two were near the southern end of the expected rupture, one was beneath Middle Mountain, and one struck just north of the mountain. "It's a little early to tell" whether this will keep up, says Evelyn Roeloffs, the USGS's chief scientist for the Parkfield Prediction Experiment, "but this is the kind of activity we need to see to indicate the end of the quiescence."

Assuming that the quiescence was indeed an earthquake precursor and that the recent upsurge of activity means that it's over, then the next Parkfield quake might be only several months away, says Roeloffs. But she, like many others, is leery of reading too much into a simple jump in activity, even if a quiescence preceded it.

Although the renewal of activity may not be convincing by itself, some of the details of that seismic flurry are reinforcing the idea that something is afoot, says Roeloffs. For example, the concentration of activity at the two ends of the expected fault rupture is the same configuration that has been seen on other faults before they let go. The two quakes at the southern end were the first there of that size since 1975. And the recent activity near Middle Mountain is reminiscent of the 11 quakes that struck there in the 6 months before the 1966 Parkfield earthquake.

Parkfield has everyone's attention, but no one is bracing for the predicted earthquake just yet. What researchers are waiting for now is even more extensive action along the fault, action that paints a picture of rock pushed near the breaking point. It can't come too soon for Parkfield geophysicists. ■ Richard A. Kerr