How hot is the heart of the earth?

If the earth were all one temperature, the surface of the planet would be an uninteresting place indeed. The temperature differences and heat flow in the earth's interior power volcanoes and earthquakes as well as the formation of mountains and oceans. Measuring the temperature profile of the earth has, therefore, been an important goal in the geosciences, but until recently scientists' ability to determine the temperature of the planet, especially its deepest regions, has been lukewarm at best.

Now things are heating up. Technological advances are enabling scientists to study materials under the extreme pressures and temperatures found in the inner earth. With these advances, says Quentin Williams, a graduate student at the University of California at Berkeley, "we've been able, for the first time, to [find] the melting temperature of iron — the dominant material in the earth's core and probably in planetary cores in general — to pressures that actually exist within planetary interiors."

In the April 10 Science, Williams and mineral physicist Raymond Jeanloz at Berkeley, together with their colleagues at the California Institute of Technology in Pasadena, Calif., and the University of Illinois at Urbana-Champaign, report the results of the highest-pressure melting experiments ever performed on iron. From the observed melting temperatures of iron, the researchers say they have obtained the first experimentally determined upper limit on the temperature at the center of the earth.

Williams's group conducted two kinds of experiments. The Berkeley researchers studied the melting of iron in a laser-heated diamond cell to pressures of up to 100 billion pascals (GPa). In previous work using this technique, the maximum pressure was only 20 GPa, corresponding to a depth of 600 kilometers in the mantle. Williams says one of his group's main contributions has been to develop a system that can accurately measure the temperature at high pressures from the radiation spectrum emitted by the iron sample.

At Caltech, Bob Svendsen and Thomas J. Ahrens subjected iron samples to short bursts of even higher pressures by firing plastic and tantalum bullets at them. They achieved pressures of 250 GPa, which is slightly greater than previous studies. This time, however, the researchers measured the temperature of the iron directly, without having to make assumptions about the iron's heat capacity and other thermodynamic parameters.

After 500 experiments, they determined that the melting point of iron at 136 GPa (comparable to the pressure at the core-mantle boundary) is 4,800 ± 200 kelvins. They also determined that at 330 GPa (similar to the pressure at the boundary between the solid inner core and the liquid outer core), iron melts at 7,600 ± 500 K. "These [values] are somewhat higher than previous estimates of the melting temperature of iron," which were based in part on extrapolations from low-pressure data, says Williams.

The researchers estimate that the presence of other elements, such as sulfur, would lower the melting points in the core by about 1,000 K. This means that the temperature at the top of the molten core must be greater than about 3,800 K. This value is 1,000 K higher than what scientists have calculated to be the temperature at the base of the mantle, says Williams. He adds that the temperature contrast between the outer core and lower mantle suggests that there is at least one nonconvecting layer in the mantle that is keeping heat from escaping too rapidly from the core.

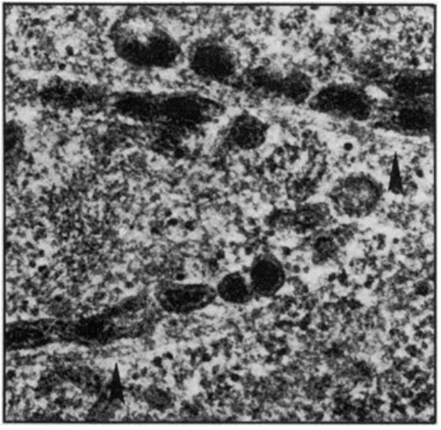
As for the temperature at the center of the planet, the researchers' best estimate is that the solid inner core can be no warmer than 6,900 ± 1,000 K.

— S. Weisburd

Aluminum: A high price for a surrogate?

Aluminum, prized for its conductivity of heat and electricity, is the most abundant metal in the earth's crust. But data suggesting that too much of the metal in the body could have some role in neurological and skeletal disease have dulled aluminum's sharp image. A new study now suggests that aluminum can play the heavy in intracellular structures called microtubules, in a mechanism that may help explain aluminum's adverse effects.

Like the ubiquitous metal, microtubules appear to be everywhere. They lend structural support to plant and animal cells, where, for example, they form the filaments called spindles that are essential for cell division. Bundles of the thread-like tubes lie inside the tails of sperm cells and along the elongated extensions of nerve cells. Microtubules apparently influence other structures inside cells as well (see photo).



Swanson et al./PNAS

Arrows point to microtubules in scavenger cells called macrophages. Recent studies at New York's Columbia University — reported in the April PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES (Vol. 84, No. 7) — suggest that microtubules affect the movement and shape of enzyme-containing structures called lysosomes, seen here as large, darkly stained bodies.

Excess aluminum in the body has been implicated as a possible cause of the characteristic tangle of nerve fibers seen in certain disorders such as Alzheimer's disease. To examine this relationship, researchers at the University of Virginia in Charlottesville decided to follow the effect of aluminum ions on microtubules, which are repeatedly assembled and disassembled within the cell using amino-acid chains called tubulin. Normal assembly of tubulin requires magnesium ions and is affected by calcium ions; the rate of disassembly is regulated by a compound called guanosine triphosphate (GTP).

Using data from experiments on purified tubulin, Timothy L. MacDonald, W. Griffith Humphreys and R. Bruce Martin report in the April 10 Science that aluminum ions are taken into this system of tubulin assembly at a rate that is 10^7 times that measured for magnesium uptake. MacDonald, who calls the 10^7 figure "stunning," says the results of the Virginia study support a theory, first proposed 10 years ago, that competition between aluminum and magnesium occurs in cells when aluminum concentrations reach abnormal levels.

Although the aluminum-induced microtubules have the same microscopic appearance as those formed in the presence of magnesium, aluminum as a surrogate causes problems. MacDonald told Science News that "the important point of the study is that aluminum is acting as a magnesium surrogate, but, because of [structural differences in the ions], aluminum gives completely different results." For example, microtubules from an aluminum-initiated system are less sensitive to calcium ions and have a lower rate of GTP-mediated breakdown of microtubules no longer needed.

Exactly how this disorganized microtubule process is related to aluminum's neurotoxicity needs to be determined, says MacDonald, who admits he is skeptical that tubulin will prove to be aluminum's final target. The identity of that target is a mystery that MacDonald says "is going to be tough to crack, because there are so many magnesium-dependent cell components."

— D.D. Edwards