A January view of the canyon in a remote corner of Yosemite National Park that serves as a laboratory for lead-pollution research.

Lead Pollution in the High Sierra

A pioneering study of the pollution of a pristine environment

"Lead Pollution in the High Sierra" is a transcript of a radio interview with Clair C. Patterson, senior research associate in geochemistry. This is one of a series of interviews with Caltech faculty members, broadcast regularly (Mondays, 7:15 p.m.) over KPCS (89.3 FM), Pasadena. The program, "Frontiers of Science," is conducted by Irving Bengelsdorf, Caltech director of science communication.

BENGELSDORF: Everything in the world is made up of submicroscopically tiny building blocks called atoms. We now know of 104 different kinds of atoms—possibly 105—one of which is called lead. Lead atoms are poisonous. They can interfere with many of the normal processes of life. One of the world's authorities who is keeping track of how much lead we have accumulated in our bodies is Clair Patterson, senior research associate in geochemistry at Caltech. Dr. Patterson, could you tell us some of the history of man's relationship with lead? When and how did lead first become useful?

PATTERSON: Lead first became important in man's history when he discovered that lead ores contain tiny amounts of silver. This was back about 2000 B.C.

B: Therefore, he went after the silver?

P: He went after the silver, and huge piles of lead were left over. He finally worked out methods for utilizing these piles of residue lead, and then there is a gap in our knowledge for about 1,500 years. About 500 or 600 B.C. there is written evidence and archeological artifacts of the multitudinous uses of lead: paints, gutters, cisterns, cosmetics—they put it in old ships to keep the worms out.

B: There are some people, I understand, who feel that lead actually had something to do with the decline of the Roman Empire.

P: Yes, Dr. Collum Gilfillan, who is a friend of mine—a sociologist and an elderly man now—has proposed that the Roman Empire fell largely because of lead in the wine they drank. The aristocracy drank a better type of wine than the rest of the population—a more expensive kind that wasn't sour. It contained an ingredient called—from the Greek word—sapa. Sapa was simply sweet grape juice boiled down in lead pots. It took several days to boil it down very slowly and gently, and they didn't know it but the process incorporated a whole lot of lead.

B: They were dissolving lead atoms into the sapa.

P: And then they put that into the wine as a preservative, and the lead killed the bacteria and kept the wine from souring. They couldn't taste the lead, of course, and it

Wearing plastic gloves and a plastic parka, graduate student Todd Hinkley takes samples from various depths in the winter snow pack for metals analysis.

A researcher on snowshoes uses a corer to measure the depth and density of snow in the canyon.

Todd Hinkley uses a stream gauge to measure the rate of water flow to determine the amount of metals that leave the valley each year.

poisoned them over a period of weeks or months or years. This is what Dr. Gilfillan thinks. He got the formula, and we made some in the laboratory according to Roman recipes and analyzed it, and our sapa had huge, poisonous amounts of lead in it.

B: It sounds like a reasonable idea. You have also been keeping a lead calendar, so to speak, by looking at the snow that has, for example, fallen on Greenland during past centuries. Can you tell us how that works?

P: When we smelt ores, part of the lead in fine particles goes out of the chimney into the atmosphere in various places, and it's brought back here in various kinds of precipitation. Sometimes it's incorporated in snowflakes and snowfalls which bring it to the earth. Again, when we burn gasoline, the lead in the gasoline goes out the tailpipe in small particles and wafts around, and is finally returned to the earth—some of it incorporated in snowflakes. Now, up near northern Greenland these annual layers of snow never melt; they just simply accumulate like pages in a book. So you have a record of the concentration of lead in the air when the snow falls, because it is automatically recorded. If there's a high amount of lead in the air, you see a high amount of lead in the snow of each annual layer.

So we dug a very deep shaft going back down through these layers—through the centuries—and took samples out and analyzed them for lead. We found that the concentration of lead has increased by a factor of about 500 over the natural levels in the snow during about the last 300 to 400 years. Most of the increase has occurred recently. We could see the effects of industrial civilization. For example, in 1750, when they began smelting lead, we could see an abrupt rise—and it sort of held there for quite a long while, a century or so. Then about 1940 there's another abrupt rise, which is due to the sudden effect of leaded gasoline, which man started to manufacture in 1920. The reason the level didn't change much in the period before about 1940 was that two factors were opposing each other: The amount of lead being smelted was increasing, and they were also recovering ever increasing amounts of it from the fumes coming out. That was valuable, so they kept on recovering larger and larger fractions of it. So, with both increasing production and increasing recovery, it pretty well held its own for about a century.

B: But, of course, from automobile exhausts you don't have this recovery operating.

P: No, it's emitted directly. About two-thirds of the lead in your gasoline is emitted out the tailpipe.

B: What does this amount to each year—the total tonnage?

P: On a world basis, about 500,000 tons of lead per year are burned as lead alkyls in gasoline. It's not a lead metal in gasoline, it's a compound—tetraethyl.

B: Now you undoubtedly have one of the more sophisticated laboratories in the world for looking at the problem of lead contamination. And I understand that recently you have taken your analytical techniques and concepts up to a canyon in the High Sierra. Can you tell us about that, and what the study was supposed to show?

P: We chose an area in the United States that was one of the most pristine areas we could find—located at an altitude of 10,000 feet in a remote corner of the mountains of Yosemite National Park. It was as free as possible

Clair Patterson checks a stand of plastic grass, used in measuring the accumulation of lead from the air.

from any form of lead pollution. There aren't very many places like this because almost every place you go has been farmed, has been grazed, and trees have been cut down, or there's a road nearby. So you have to go to the National Parks—or to the tops of mountains.

It happens that we chose the top of a mountain because that's the last place man has gone to pollute. This one is about two miles high, 300 miles from Los Angeles and 150 miles from San Francisco. We studied the following thing. You see, lead is a toxic metal, but it belongs to a family of metals in which one member—calcium—is nutritious. We need it for good health. We are in a food chain. We get our nutritious metal and our toxic metal from rocks—ultimately we have to go back to the earth. The sun shines on the earth and there's interaction, and these nutrient metals end up in our bodies through a food chain—from soil, to plants, to herbivores, and then into us. So, standing between us and rocks are these other things, and we don't get either the calcium or the lead directly from rocks. What happens is that in the travel of these metals to our bodies the calcium is kept but the lead is rejected at each step along this progression—this chain. Each one tends to keep the calcium and throw out the lead by a biological mechanism.

B: This would be unlike DDT, where there's an accumulation all the way up along the chain.

P: That's correct. It has been commonly assumed that lead does accumulate at the ends of food chains like DDT, but this has never been studied before. We have tested the assumption and find that it is apparently incorrect. We studied the components of the food chain—the rocks, the soil, the plants, and the animals. We had to choose a valley that had only one kind of rock in it, where hikers don't camp, and so forth. We measured the amount of lead coming in with the snow. But these little particles that zoom around in the air are not brought down to earth just by snow or rain; they also bounce around and finally hit the surface of a tree leaf or a blade of grass, where they stick and don't come off. That's called aerosol impact.

B: So you have two kinds of industrial-lead input, and also a natural source of lead coming from the rocks that are forming the soil.

P: And lead would leave the canyon by stream runoff. So we measured the amount leaving and the amount entering, and we found that the amount coming in was about 25 pounds per year in this 14-kilometer-square canyon. But the amount leaving was less than 1 percent of that which came in. Industrial lead is therefore accumulating in the canyon. We knew that the lead coming in was industrial because industrial lead is different from natural lead, and we can measure them separately.

B: So you can tell the difference between lead coming from rocks and lead coming from automobile exhausts, and so on?

P: Yes. And most of this lead entering the canyon came from auto exhausts by air and snow. We found that it collected on the grass, and that the meadow mice we were studying ate that grass, and as a consequence the mice and grass contained substantial concentrations of industrial lead. We believe that at least 95 percent of the lead in the mice and grass came from industrial sources. So this entire canyon in this remote area is heavily polluted by industrial lead—and this lead comes from gasoline exhausts originating in Los Angeles and San Francisco.

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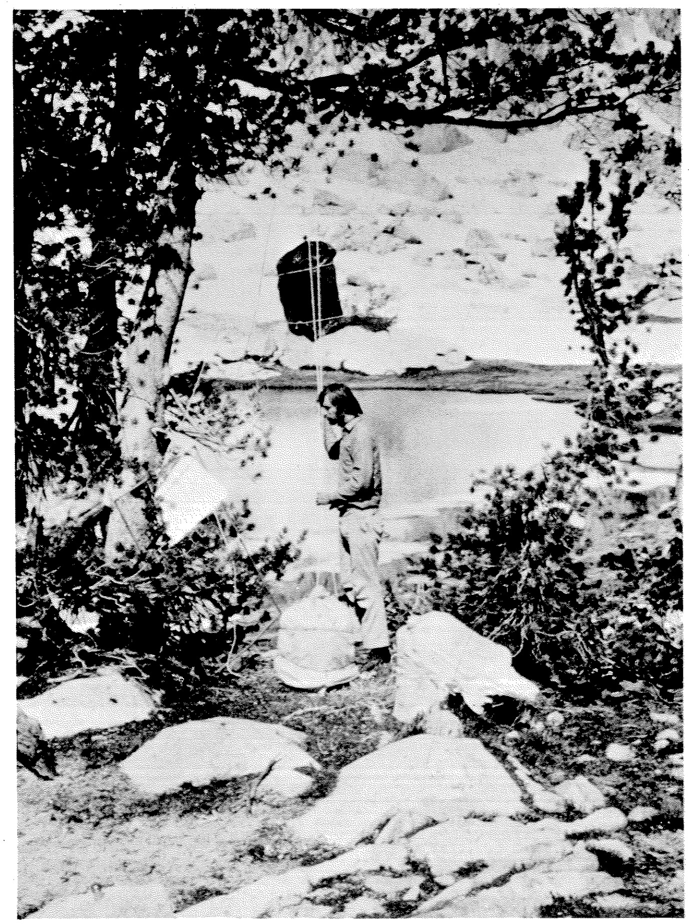
B: So this is really a pioneering study to show that even in what would be considered a pristine environment there already is considerable lead pollution.

P: Yes. Most people today are aware that lead pollution exists, but they seem to think it's only near freeways and in the centers of cities. That's not true. Lead pollution is pervasive throughout the whole United States. It has increased. You and I have about 100 times as much lead in our bodies as we should have—as would be expected from natural sources.

Results from the Sierra Nevada experiment are helping researchers in other universities and public agencies recognize that modern industrial metal pollution is extensive in remote, wild, and so-called natural regions of the earth, instead of just near freeways and downwind from smelters. Sampling and analytical techniques developed in the Sierra project are helping other investigators of environmental problems to improve the quality of their work by increasing the accuracy of their measurements and the significance of their samples. The Sierra project has also fostered similar investigations in foreign countries. □



Autumn chore (above): hanging supplies and equipment in the trees to protect them from bears and snow-burial.
Winter chore (below): digging out the tent. As a pollution-control measure, the camp is located outside the valley.