Plant Stones

Microscopic 'stones' that develop naturally in growing plants provide new clues about ancient human activities

By IVARS PETERSON

Almost any handful of dirt holds the microscopic, glassy remains of plants that have otherwise long since decayed away. These leftover fragments, called "phytoliths" or plant stones, display a profusion of intricate shapes — delicate crosses, rounded cones, etched plates, scalloped sheets and shells that faithfully preserve the forms of once-living cells.

The distinctive shapes of phytoliths, characteristic of particular plants and deposited in the soil when the plants die and decay, allow soil scientists to tell when a grassland was transformed into a forest or whether climatic periods were wet or dry. A few pioneering archeologists are beginning to use phytolith analysis as a tool to unscramble the origins of agriculture. In some cases, they can even identify the species of corn and other grains cultivated as much as 4,500 years ago.

Although the applications of phytolith analysis are steadily expanding, much about the nature and distribution of phytoliths remains unknown, and phytolith research, itself fragmentary, is scattered across many scientific fields. Irwin Rovner, an anthropologist at North Carolina State University in Raleigh, N.C., laments, "In the family of legitimized research, it is an orphan." That means research funding is often difficult to obtain, and even scholarly indexes fail to classify such research properly.

To discuss this "identity crisis" and to share their latest findings, Rovner brought a diverse group of phytolith researchers, including botanists, chemists, geologists, agronomists and archeologists, to a symposium at the recent American Association for the Advancement of Science annual meeting in Detroit. At the symposium, Rovner said, "It is practically impossible to pursue any form of plant silica research without either drawing critical information from relevant work in other disciplines or producing results that will be viewed as critically important by other disciplines."

"We need greater coordination, greater communication," Rovner told SCIENCE NEWS. "I think this will be achieved when we begin to get labels that identify the commonality of our research regardless of what our specific interests are."

Rovner likes to trace the history of phytolith research back to the early nineteenth century and "a young British naturalist on a five-year, round-the-world voyage." This naturalist, Charles Darwin, provided dust samples collected from the sails of his research vessel, the *Beagle*, to C. G. Ehrenburg, a German microbiologist. Ehrenburg was the first to study phytoliths (including those found in Darwin's dust samples) systematically.

P. Dayanandan

Rice leaf phytoliths

Biologist Lawrence Kaplan of the University of Massachusetts in Boston says botanists have been interested in plant silica since the nineteenth century because phytoliths are characteristic of certain plant families like grasses and palms. In fact, phytoliths form in most plants, and some species individually produce as many as a dozen different types.

Kaplan says silica phytoliths consist mainly of an amorphous form of silicon dioxide (known as opal) that is softer and less dense than quartz, the crystalline mineral form of silicon dioxide. When plant roots absorb groundwater, they also take in dissolved silica. The silica precipitates in the plant wherever significant amounts of water are used or lost. During a plant's lifetime, silica particles build up quickly in the spaces between cells, within cells or on the surface of leaves. Usually transparent and colorless, they range anywhere from a thousandth of a millimeter to 1 millimeter in size.

Silica bodies within plants are known to have several functions, says Kaplan. They form a kind of skeleton to stiffen plants and make structures like hair cells more rigid. Phytoliths may also discourage insect predation because silica-laden leaves wear down an insect's chewing mouthparts.

"Certainly some of the prairie grasses, especially in the tropics, with enormous amounts of this stuff can inflict terrible slashes on humans and animals going through these areas," says Kaplan. "Even corn can do that." As a child in Illinois, Kaplan remembers the cuts he received on his arms when he didn't wear a long-sleeved shirt while detasseling corn.

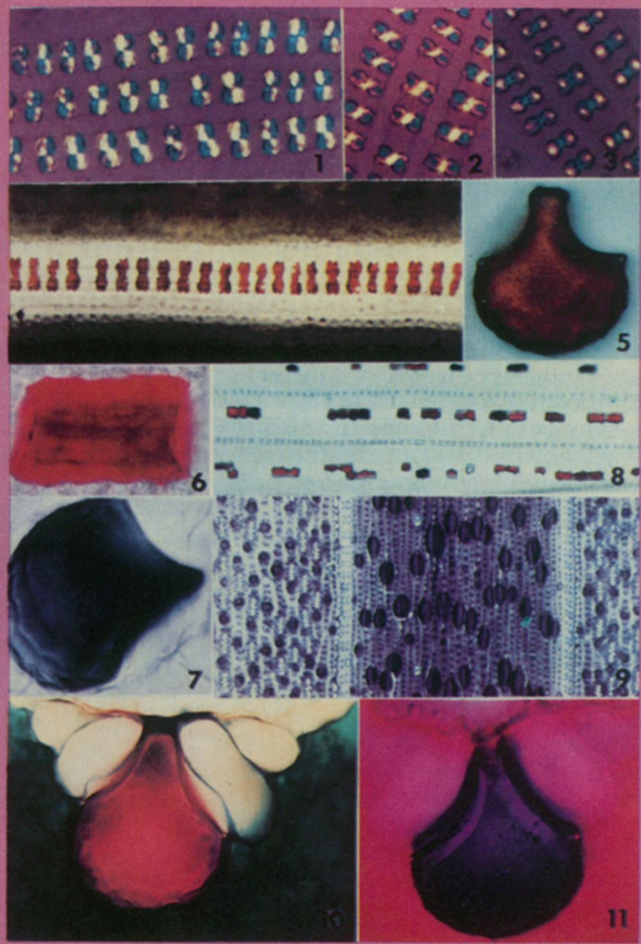
At the symposium, plant physiologist Peter B. Kaufman of the University of Michigan in Ann Arbor suggested that silica bodies may also be the natural equivalent of optical fibers. Silica-containing surface cells, acting like light pipes, may aid in transmitting and scattering light to cells deeper inside leaves, he says.

On the historic front, archeologists became interested in looking for phytoliths in the dirt at archeological sites when they realized that these silica fragments provide clues about early human uses of plant materials for food, shelter and other purposes. Wherever these plant materials decayed, recognizable phytoliths were likely to remain behind in the soil layers. About a decade ago, Rovner and others, including Deborah M. Pearsall of the University of Missouri at Columbia, began looking seriously at phytoliths as a way of providing more complete and precise information about archeological sites and artifacts.

Several years ago, Pearsall was able, for example, to show that cross-shaped silica bodies found in soils at two archeological

Ken Moran, Univ. of Minn., Duluth

Susan Mulholland and George Rapp Jr. prepare plant samples for phytolith extraction.



P. Dayanandan

A set of new staining techniques, developed by P. Dayanandan of the University of Michigan in Ann Arbor, unveils the normally colorless silica fragments that build up in or near plant cells. The staining reactions make phytoliths easy to recognize, while the extent to which silica bodies adsorb the dyes reveals something about the nature of silica surfaces (and perhaps the function of plant silica).

sites in Ecuador were maize phytoliths. The results supported arguments that maize was cultivated in coastal Ecuador as early as 2450 B.C. In more recent work, Pearsall examined soil samples from 12 archeological sites on the island of Hawaii. By determining when grasses and other weeds, which invade open fields but not forests, became predominant, Pearsall could distinguish periods when an area was disturbed and when the forest was cleared to allow cultivation.

"Studying phytoliths is still a relatively new science," says Pearsall, "but I feel it can supplement and strengthen other ethnobiological approaches to archeology."

Phytolith analysis, which requires soil samples of only tens of grams, lends itself to detailed, precise reconstructions of activities at an archeological site. Rovner foresees a time when the technique can be applied to a house that has collapsed into a series of thin soil layers. The analysis would distinguish the materials that made up, say, the thatched roof, kitchen stores and straw flooring.

"So far, we haven't even begun to test these kinds of sampling strategies," Rovner says. "But this technique has potential." Already, it is possible to say that different activities involving plants took place in different areas of a house, although identifying the specific plants is difficult, he says. In the context of what is already known or suspected about a site, phytolith analyses provide important independent confirmation.

Phytoliths also contribute to wear patterns on teeth and sometimes adhere to teeth and jaws. Researchers have, for instance, eliminated grass as a source of food for at least one human-like animal, *Ramapithecus,* because characteristic dental wear patterns were missing. Phytolith particles in plaque deposits on human dental remains could provide a useful source of dietary information.

Similar wear patterns, such as "corn gloss" or "sickle sheen" on stone tools, reveal their association with grain harvesting. Rovner notes, "This association of wear patterns with siliceous particles in plants was recognized long before attention was focused on the study of the particles themselves."

Researchers at the Los Alamos National Laboratory in New Mexico and at the University of South Carolina in Columbia are using the durability of phytoliths to study coal and peat deposits. The analysis of phytolith shapes could help the coal industry reduce exploration costs by predicting where silica fractions are likely to be high enough to ruin drill bits and cause other mining problems. Identification (from phytolith shapes) of plants that formed a deposit also could provide information on the quality of the coal and peat, the nature of toxic impurities that may exist in the deposit and the deposit's potential energy yield, their research shows.

Phytolith studies can also shed light on contemporary problems. A. G. Sangster of York University in Toronto has been studying the physiology of how silica gets into plants. His symposium paper highlighted silica production in the flowering parts of a few grass species. He noted that in two areas of Asia, one being Hunan province in China, one particular plant, in the form of a porridge, is a major food source. These people ingest high levels of small, sharp, claw-like silica particles along with their food, and they also have an extraordinarily high incidence of cancer of the esophagus.

Rovner comments, "Obviously, it'll take a great deal more research to prove that the silica particles cause throat irritation, which causes cancer, but the correlation is there." He adds, "Medical anthropologists are very excited about that kind of information. It's also another very interesting application of the broad nature of this area of research."

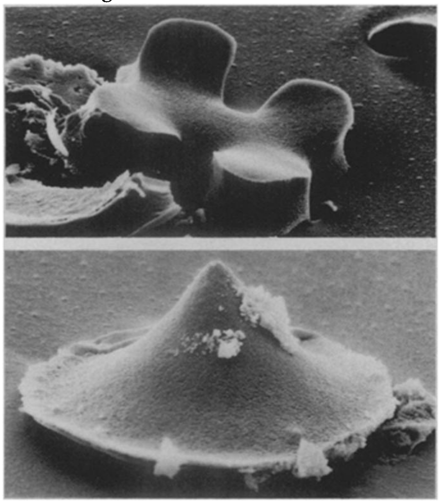
Despite these and other successes, phytolith analysis is still in the exploratory stage, says Rovner. The most obvious and pressing problem is the need for developing "phytolith systematics." That means being able to identify specific plants given a collection of phytoliths extracted from a soil sample.

Several researchers are systematically building reference sets of phytoliths from living plant species such as cereal grains. Kaplan has spent several years growing plants, extracting phytoliths and preparing microscope slides and electron micrographs for all the cereal grains that are known to occur in Middle Eastern archeo-

Continued on p. 94

Continued from p. 88

logical sites. One useful discovery has been that phytoliths show subtle changes in shape as the result of plant breeding. "Now we're accepting samples of soil from the Middle East and north Africa," says Kaplan. The aim is to trace the development of agriculture in the Old World.



Michael Andrejko, Los Alamos National Laboratory

The shapes of phytoliths from fossilized swamp grasses identify the peat source and aid in predicting the location, composition and energy yield of coal and peat deposits.

At the archeometry laboratory of the University of Minnesota in Duluth, George Rapp Jr. and several students are looking at how phytoliths vary among plants grown in different parts of the country. The analytical problem is further complicated because some plants have up to a dozen distinctive phytoliths. Rapp says, "By the time you get about a dozen plants with all their phytoliths, you get so many damn shapes to deal with that it becomes a horrendous statistical problem." Nevertheless, Rapp's group is slowly working on the problem of sorting out the numerous phytoliths found in a typical soil sample. "Some of these things get very complicated," says Rapp. "We've tried all sorts of computer techniques."

Rovner dreams of a time — perhaps 10 years in the future — when he can ask a computer to come up with a listing of plants that contributed to a given phytolith assemblage or, conversely, with the type of soil phytoliths to expect from a particular plant distribution. "That's still pie-in-the-sky," he admits. But already, he adds, "Phytolith analysis is an extraordinarily robust analytical system. It takes relatively little input to achieve substantial return in a wide variety of archeological situations."

James W. Geis of the State University of New York at Syracuse, who has studied grass and tree phytoliths, says, "We share the feeling that there's something important being developed.... Only recently has enough been known about it so that people are really taking a shot at trying to find applications for the technique." □