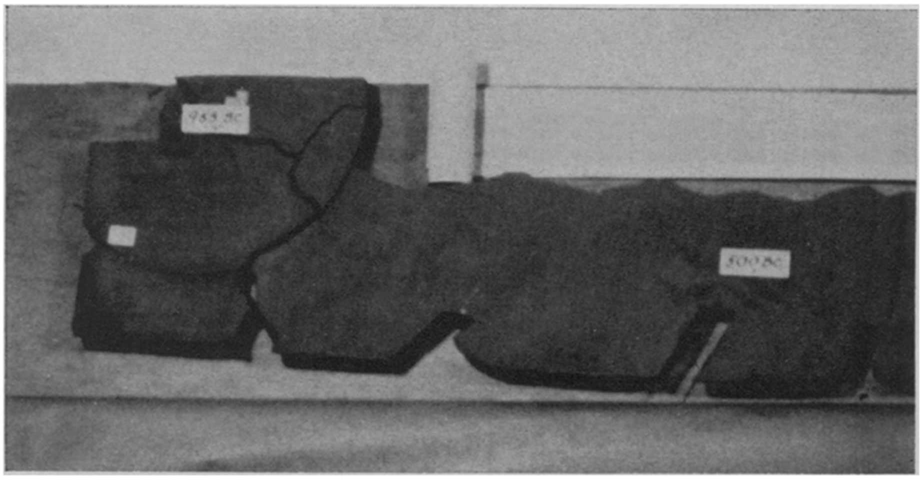
Upgrading radiocarbon dating

Scientists are trying to refine a 20-year-old archaeological research tool



Univ. of Pennsylvania

Ages of sequoia tree sections determined by tree-ring dating method.

When it first burst upon the scientific scene 20 years ago, an assortment of scientists, including archaeologists, anthropologists, biologists, geochemists and even historians, snatched up radiocarbon dating.

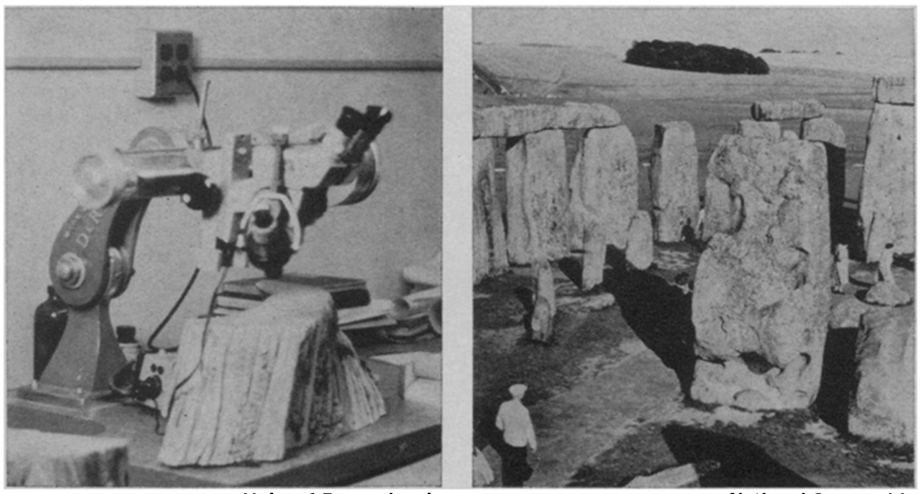
They have since used it to determine the age of the Dead Sea Scrolls, the duration of the ice age, the movement of ancient peoples, evolutionary rates of development, the dates of sediments and even the authenticity of works of art. Discovery of the method helped win for Dr. Willard F. Libby of the University of California at Los Angeles the 1960 Nobel Prize in Chemistry.

It is still an invaluable tool, but not an infallible one. Since the mid-50's, investigators have observed that some of the dates obtained by the method have been short, sometimes by as much as 750 years for a 6,000-year-old artifact (SN: 7/29/67, p. 119).

Now enough background information has accumulated and dating techniques have improved to the point that scientists are confident they can reduce the inaccuracies. But they still cannot get near pinpoint accuracy.

"The best accuracy we can foresee at present—all errors corrected—would be within five percent," says Dr. George Bien of the Scripps Institution of Oceanography, La Jolla, Calif. The method is good for dates back to about 40,000 years.

The first discrepancies were observed in the mid-50's, when dates fixed by radioactive carbon dating for Greek and Roman pottery conflicted with the pottery's style. Other disputes arose over dates of early Egyptian artifacts, whose age had been established with the aid of king lists. Still other discrepancies turned up when the known ring-based dates of trees were compared with the dates obtained by radiocarbon dating.



Univ. of Pennsylvania — National Geographic

Tree-ring dating (left) corrects the carbon-determined date of Stonehenge.

The latest discrepancy, reported last week from London, shows that the age of the ancient stone structures at Stonehenge as determined by the method is between 500 and 700 years off; Stonehenge is even older than the 3,670 years derived from dating charcoal found near the structure. Tree rings again provided the proof.

Scientists at several places are working on the problem and the National Science Foundation has just thrown $56,000 into the pot to assist the University of Pennsylvania—a major center of archaeology—in straightening out the method.

Radioactive carbon dating uses the decay rate of radioactive carbon 14 atoms as a nuclear clock to determine the age of organic material. All living things incorporate minute amounts of radiocarbon into their tissues along with the predominant carbon 12 atoms. While alive, a plant or animal replenishes both, so that the same ratio of C-14 to C-12 atoms is maintained. When the organism dies, no new C-14 is taken in. From that point on radioactive decay continually reduces the number of radiocarbon atoms by one-half every 5,730 years, give or take 40 years. Since the decay rate, the starting number of carbon 14 atoms and the present number of carbon 14 atoms can all be measured, it is simple to calculate how long it took to arrive at the present number.

However, the calculation is based on the assumption that the amount of radioactive carbon in the atmosphere has always been constant. This assumption is not held to be true any longer.

One thing believed to throw it off is the cyclic change in the earth's magnetic field. Since the fluctuations of carbon 14 may also be cyclic, the variations in the magnetic field are suspect.

Cosmic rays were also suspected of being a source, but there has been no apparent change in cosmic ray intensity for the last five million years. However, changes in the earth's magnetic field could influence the volume and intensity of cosmic rays coming into the atmosphere. A strong field would keep more out while a weak one would let more in.

A minor factor is the burning of fossil fuels which puts more carbon 12 into the air, thus altering the ratios during the past 100 years. Another factor is the climatological changes that have occurred. An ice age, for example, would change the carbon content of the atmosphere by altering ocean temperature.

The nature of the radiocarbon dating aberrations is mostly upward, which makes dates more recent than they would actually be. A time profile of the discrepancies obtained so far shows deviations in radiocarbon levels from 1500 to 1700 A.D., followed by a leveling off until 500 B.C., when there is another period of discrepancy, followed by an apparent trend toward leveling off until 5150 B.C. At that point the skein of information runs out, and scientists are just not sure what happened before. There are also gaps in the profile from 4100 to 3600 and 4850 to 4400 B.C.

One of the purposes of the research at the University of Pennsylvania is to determine if indeed the fluctuations are as cyclic as they seem to be. Also the investigators would like to know the size and duration of the fluctuations.

In their experiments, the researchers, led by Elizabeth K. Ralph, will be making measurements of known-age samples of bristlecone pines. Longer lived than the sequoia tree samples, the pine samples will be dated by the carbon 14 method and the resulting ages compared.

Another tool the investigators will be calling on is thermoluminescent dating (SN: 11/30, p. 552). This method is based on the fact that electrons in a material subjected to radioactive bombardment become excited and emit light upon heating. The intensity of light emitted depends on the accumulated amount of radiation damage, which in turn depends on exposure time. Thus, by measuring the intensity of emitted light, an indication of the time that has elapsed can be obtained.

The Pennsylvania scientists will corroborate the half-life of carbon 14 with this technique. They will take phosphors susceptible to radiation damage and expose them to carbon 14. The phosphors will be heated and the light emitted measured.

The problem still facing the researchers is to figure some way to calibrate the emitted light to get a disintegration rate for carbon 14. Once the specific disintegration rate for a calibrated amount of light is known, it is the same as knowing the half-life of the substance. Since the technique is not a highly accurate one, the team hopes to come up with a "ballpark figure" for the true half-life of carbon 14.

The people most affected by the discrepancies are those who try to relate radiocarbon ages to calendar time. "It would affect the archaeologist the most," says geochemist James E. Mielke of the Smithsonian Institution in Washington, D.C. "He has to interpret the number the laboratory turns out."

But there is no thought of discarding the method. "It's serious but we're learning more about it," says Pennsylvania's Elizabeth Ralph. "As we obtain more information, we will obtain correction factors." ◇

UNDIFFERENTIATED ROCK

Ancient moon samples exhilarate selenologists

Scientists studying the earth to learn about its ancient past face much the same problems as sleuths trying to unravel a crime in which the criminal has carefully destroyed much of the evidence, shuffled the rest and smudged his fingerprints.

To a geologist, this tampering with the evidence is largely known as differentiation: the separation of rocks, minerals and elements into light and heavy components, due to heating, gravitational attraction and other forces. Differentiation has the effect of obliterating forever the original distribution of materials with which a planet was formed, and added to it are the planet's internal stresses which keep mixing and remixing the materials many times over.

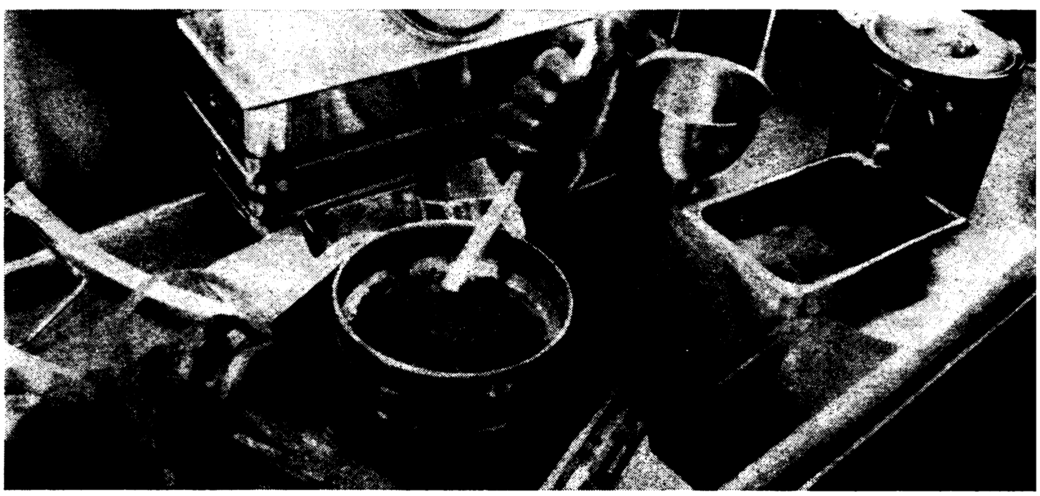
On earth, all this rock-shuffling has meant that reconstruction of the planet's early days involves a lot of guesswork, intuition and going out on limbs. There has also been evidence that the moon has undergone the same stirrings and churnings—the apparently volcanic nature of the Apollo 11 samples, for example—which could mean that the same difficulties are in store for lunar researchers.

Now, however, there is reason to believe that the moon may be in a much better preserved state than was previously thought, with remnants of its early composition readily accessible to researchers. At the Lunar Receiving Laboratory in Houston, scientists have discovered that the Apollo 11 samples, simply picked up on the surface by the astronauts, contain rocks more than three billion years old.

The rocks were dated by measuring the degree to which radioactive potassium 40 had decayed into stable argon 40, a process which takes place with a fixed half-life of 1.3 billion years. The more argon present in the rock, the older it is. The abundances of the two elements were measured twice, in a pair of samples each weighing only a few milligrams. The second sample contained about four times as much potassium as the first, and about four times as much argon, says Dr. Oliver Schaeffer of the State University of New York at Stony Brook, meaning that the ratio in the second sample verified the conclusion from the first.

The conclusion: It has been at least 3.1 billion years since the two rock chips were subjected to any significant heating, such as the volcanic activity, which might have given them their initial charge of potassium 40.

One of the samples, says Dr. Schaeffer, was probably deposited on the surface about 50 million years ago, when a meteor impact may have jarred it into an exposed position, while the other



NASA

Ancient moonchips may mean that the moon's old face can still be seen.