RADIOCARBON: AGES IN ERROR†

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"It may come as a shock to some, but fewer than 50 percent of the radiocarbon dates from geological and archaeological samples in northeastern North America have been adopted as 'acceptable' by investigators". J. Ogden III.

Discusses problems that have made radiocarbon unreliable, from ancient carbon-14 levels and contamination to abuse of reported ages. Illustrates effect of faulty chronology on genuine knowledge, with Ernst Antevs as example. Drastic change in attitude essential, if radiocarbon is to become a valid means of dating the past.

The troubles of the radiocarbon dating method are undeniably deep and serious. Despite 35 years of technological refinement and better understanding, the underlying *assumptions* have been strongly challenged, and warnings are out that radiocarbon may soon find itself in a crisis situation. Continuing use of the method depends on a *"fix-it-as-we-go"* approach, allowing for contamination here, fractionation there, and calibration wherever possible. It should be no surprise, then that fully *half* of the dates are rejected. The wonder is, surely, that the remaining half came to be *accepted.*

It was in the early fifties that archaeologists and geologists alike adopted the method itself as acceptable,[1] placing it above all other means of dating sites and materials. The previously-determined age estimates and cultural sequences did show radiocarbon to be in error, but were themselves tossed aside—even though this meant turning the physical evidence of stratigraphy upside down.[2] The cautionary words of Dr. Willard Frank Libby, who with J.R. Arnold developed the method, were thrown to the winds; readily apparent warning signs were ignored; skeptics were scornfully called "non-believers". Indeed, radiocarbon swept the scientific world with all the fervor of religious fanaticism, as the new and *"absolute"* chronology was established.

The Radiocarbon Method

Radiocarbon dating can be applied to virtually anything that is carbon-bearing, such as charcoal or bone, provided that it is not much more than 40,000 years old. The basic theory, worked out in the late 1940's, is attractively and deceptively straightforward.

In any suitable material, the amount of one particular type of carbon gradually decreases with the passage of time, at a *fixed rate*. By measuring what remains, the age of the sample can be calculated. This carbon-14, as it is called, can be detected through the radioactive disintegration of its individual atoms.

Carbon-14 exists in fixed proportion to ordinary carbon. Green plants draw both of them out of the air at the same time, in the process of photosynthesis, while aquatic organisms use bicarbonate ions that are dissolved in the water. Thus, carbon-14 enters the food chain and is distributed to every living thing.

At death, this fixed proportion begins to change, because the slow radioactive decay of carbon-14 is no longer balanced by food intake. Like the sand in an hourglass, carbon-14 trickles away, until too little is left to be measurable.

An accurate determination for some long-buried object is not quite so simple as might at first appear, though. Indeed, a great part of the original assumptions and methods have been called into question. Some of them can be modified, perhaps, for continuing use. But for others, no one ever yet has found a sure solution.

Synchronizing Radiocarbon with Reality—Maybe

It was necessary to assume, in the early days of radiocarbon dating, that the supply of carbon-14 to living things had always been constant. Had it been otherwise, the radiocarbon clock would have started its run from different initial settings, and all of the dates from a given period would be out of kilter. Over the years, as we are now aware, evidence continually mounted against that assumption of constancy. The production of carbon-14, in fact, has been known to vary over long periods, causing dates from much of the past seven millennia to be too recent by nearly a thousand years. Beyond that range, the difference between the radiocarbon age, as it is called, and the true age, can only be *guessed* at.

Libby began with the most estimable caution in this matter of constancy. As his method grew in importance, however, he became increasingly inflexible and, after several years of rising challenges, sought to defend what had become his *position*.

Examining the information then available, he did find that the age discrepancies were real, but argued that they were too inconsistent to have meaning. The fledgling tree-ring studies he dismissed, because "some trees add more than one ring per year". Egyptian historical dates that also failed to match radiocarbon, he said, "may be somewhat too old".[3]

Having managed to shift attention away from the shortcomings of his own methods, Libby then felt able to apply rigid restraints to the potential causes of carbon-14 variation—on the mistaken grounds that carbon-14 *production* seemed to have been constant.

In the face of this desperate attempt to stem the tide of doubters, research into tree-ring comparisons accelerated tremendously. Well over a thousand radiocarbon dates were checked by dendrochronology. It thus became clear that many of the samples previously dated

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by radiocarbon were, in fact, much older than the determinations arrived at. A *new* radiocarbon revolution was touched off immediately. Ages past began to stretch, and the "facts" of prehistory were drastically altered in the process.

1) Checking Against Tree Rings

The gnarled form of the bristle-cone pine has become symbolic of radiocarbon calibration. This tree, a native of certain upper mountain slopes along the California-Nevada border, provided a 7000-year record, against which checks have been made on radiocarbon dates. The accuracy of that record, however, has been challenged by Gladwin,[4] who characterizes the bristlecone as a tree "even more undependable than the junipers", which may not grow annual rings at all in dry years. They respond so closely to local weather, he argues, that ring patterns from within a few hundred miles of each other "show no similarity whatever". Understandably, therefore, he was leery of the practice of forcing patterns to match by arbitrarily inserting "missing rings" to bring them into line.

Whether accurate, or merely approximate, comparison with tree rings did prove that radiocarbon dates **were wrong—usually being much too young. At the same time, it seemed that the precise *extent* of the errors was** indicated. When plotted against counted rings, radiocarbon dates fall into a wandering line that runs some hundreds of years from where it ought to be. By means of this *calibration curve*, any appropriate radiocarbon date can be corrected. As seen in Figures 1 and 2, such curves have several important characteristics—and these have been tied to variation in atmospheric carbon-14 levels.

2) Magnetic Field Effects

The general trend of dates away from what they should be is thought to reflect major shifts in the shielding effect of the earth's magnetic field. Carbon-14 is produced high in the atmosphere by the action of cosmic rays. A weaker magnetic field, some 4000 years ago, would have allowed *more* cosmic rays to reach the atmosphere, resulting in excessive concentrations of the radioactive isotope. Samples from that period would consequently have a C-14 activity equivalent to only 3000 *true years*.

It is believed that only in times of magnetic-pole reversal does the shielding effect diminish noticeably. Theoretically, however, a reversal could throw radiocarbon dates off by enough to make 18,000 years come out as 13,000—quite enough discrepancy to upset a lot of firmly held beliefs.[5] The actual timing of such events is not known, but there is evidence of at least two of them, in the past 35,000 years. Measurement of ancient field strengths, as preserved in artifacts of fired clay, support the inference that the magnetic field has indeed been weaker in earlier times.

3) The Presumed Influence of the Solar Cycle

Most calibration curves are not really so smooth and simple as that shown in Figurel, but record numerous small fluctuations in radiocarbon activity. These irregularities are commonly attributed to the effects of the 11-year sun-spot cycle, for sudden bursts of cosmic rays are known to produce greater quantities of carbon-14. It is quite reasonable to assume, of course, that these episodes of high carbon-14 concentration would show up in tree rings. The resulting wriggles would make calibration curves much less useful, because many radiocarbon dates now match more than one position in time, as indicated by the curve (Figure 2).

These minor fluctuations are obvious, explainable, and expected. Yet there is good reason to believe that they do *not* represent cycles in solar activity. It seems that different calibration curves may wriggle in *opposite* directions, so that a date corrected on one curve may come out 400 years different from the same date "corrected" on another curve.

Applying statistical principles to what is really a statistical problem,[6] Clark found that there is simply too much error inherent in the radiocarbon technique to permit measurement of such fine fluctuations. Those wriggles that were so easily tied to solar activity are actually nothing more than random variations in radiocarbon measurement. By gathering the dates from

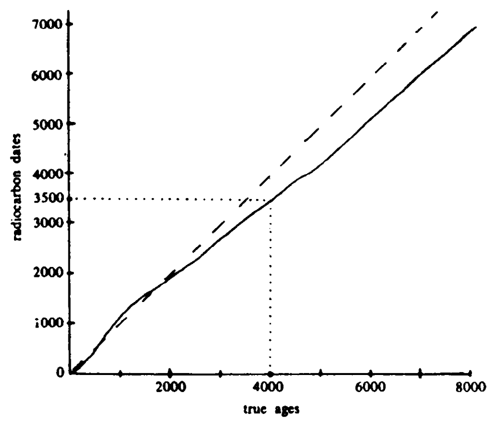

Figure 1. A smooth calibration curve allows correction of some Carbon-14 dates. Thus, 3500 years comes out as 4000 true years.

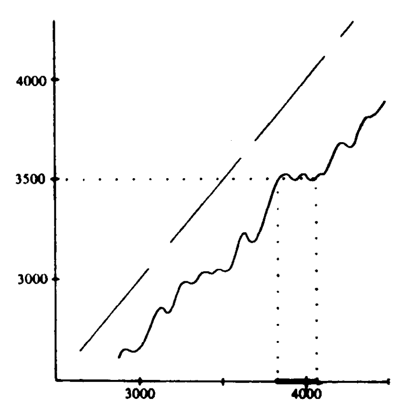

Figure 2. Most calibration curves wriggle up and down, giving multiple—hence unreliable—values for a single radiocarbon sample. (Vertical scale, radiocarbon dates; horizontal scale, true ages.)

many radiocarbon labs, Clark assembled and published his own very smooth, *statistically-sound* calibration curve, much like that sketched in Figure 1.

There has been no agreement, however, on which calibration curve to use. It is plainly not possible for *all of them* to be right, and the final version may be a long time coming. Meanwhile, no informed person is eager to use obviously uncalibrated dates in his work. "Eventually", noted Stuckenrath,[7] "those 'corrected' dates will have to be uncorrected in order to be recorrected in order to be correct". It *could* become confusing, with different dates for the same sample appearing at different times in different journals—especially if conclusions have to be changed as a result.

4) Extension of the Calibration Curve

At best, the bristlecone calibration curve reaches back only 7000 years. Beyond that point, at which the difference between radiocarbon and real ages is about 1000 years, the discrepancy is more or less unknown. True, there have been attempts to extend our knowledge, but with uncertain results. Radiocarbon dating of a single long core of varved clay, for instance, appeared to show general agreement with the tree-ring curves where they overlapped, and suggested a continuation of the 1000-year difference back to at least 10,000 years ago.[8]

On the basis of comparison with the more recent dating method, *uranium-series*[9], Stuiver was also led to claim[10] that the difference should not exceed 2000 years over the period of 22,000 to 32,000 B.P. (years before present, as of 1950). In discussing magnetic pole reversals, though, Barbetti and Flude[11] see support in uranium-series for a theoretical *5000-year* discrepancy. Whatever the truth may be—and it does seem a little hard to come by—it should be remembered that this uranium-series method was originally *validated* by the very technique now under question, a clear case of applied circular reasoning!

Atmospheric and Oceanic Mixing

Once produced, radiocarbon seems to spread around the world fairly rapidly and evenly, through movement of the air. There are, however, some tricky situations of local scope. In the vicinity of a volcano, for instance, living plants can absorb enough inactive carbon-14 to date to more than 4000 years ago. Ancient materials, too, can seem to be that much older than they really are.[12]

The amount of carbon-14 actually available is kept fairly stable by the action of the great ocean reservoirs. The seas have an enormous capacity for soaking up carbon dioxide from the air, thereby moderating changes in atmospheric levels of radiocarbon. The rather slow circulation of ocean waters also allows time for radioactive decay—and this balances the continuous production of carbon-14 in the upper atmosphere.

Organisms such as shellfish, seals, and whales obtain their carbon from seawater, rather than from atmospheric sources, and are getting radiocarbon already in circulation for some hundreds of years. Although this "reservoir effect" is usually estimated at 350 years, it is not everywhere equal. In Scottish coastal waters, modern shells do indeed date 350 years too old.[13] But off Norway the apparent age is 440 years, at Spitsbergen 510, and all of 750 years off Ellesmere Island[14]. Further, *some* shallow-water species appear to use a certain amount of atmospheric carbon, after all, and *their* dates are not nearly so far off. Much as a correction factor is needed in dealing with marine remains, no single figure is properly applicable. Yet it is common practice to use a standard estimate of the reservoir effect to cancel out the opposite fractionation effect—without direct measurement of either!

Vastly older carbon can affect dates on shellfish and aquatic plants when, for instance, limestone underlies the water. The "hard-water effect", as it is called, varies considerably from place to place, but is claimed not to exceed 3000 years.[15]

Carbon in Living Things

Carbon-14 generally appears, in plants and animals, in the same proportion as prevails in the air or water about them, since the isotopes of carbon are chemically indistinguishable. This should mean that, at death, all radiocarbon clocks start running from the same initial setting.

Carbon-14 is a little *heavier* than ordinary carbon-12, however, and some plants actually *prefer* these heavier atoms when they are building food molecules. This separation of different carbon isotopes is called fractionation. Plants of arid lands, and also of salt marshes, thus *enrich* the carbon-14 in their tissues, so that they date a couple of hundred years too young. Certain other plants handle the isotopes indiscriminately, except when facing adverse growing conditions. Alteration of *their* radiocarbon age depends on *what life was like* for the plant in question.

Among animals, fish-flesh dates 50 years too young; bone, horn, antler, and shellfish-meat 175 years too young; and mammoth-ivory 250 years too young. Shellfish carbonate is even more strongly affected, giving readings of 400 years too young. Stubbornly, blubber leans the other way, dating 200 years too old.[16]

By good fortune, another isotope, carbon-13, can be measured in an affected sample, and the results used to correct the radiocarbon date for fractionation. These extra determinations, now made individually, will someday be available for each species in turn.

Contamination in the Ground

At the death of every organism, the absolutely unalterable process of radioactive decay begins to change the isotope *ratio* in its tissues. All exchange of carbon is presumed to cease. A piece of bone or a lump of charcoal is supposed to lie inert and isolated in an earthen tomb.

However, modern carbon, which is high in carbon-14, continually penetrates the soil and is absorbed by materials buried there. Some, the product of recent decomposition, washes downward, while growing plants push their *living* roots far more deeply into the ground than is commonly realized. Modern carbon appears to be the usual contaminant,[17] causing most radiocarbon dates to be younger than their true ages. Sometimes, modern carbon *itself* is so contaminated by radioactive fallout that such materials as ancient American Indian pottery actually date into the future![18]

Even the most minute amounts of contamination are significant in extremely old samples. In the case of a sample that is really 75,000 years old, for instance, introduction of just *100 parts per million* of modern carbon lowers the apparent age by 5000 years.[19] Five percent contamination would simply overwhelm the depleted original radiocarbon, yielding a date of 25,000 years. Is it not possible that some of the samples we now accept as 25,000 years old are actually *vastly* older?

Indeed, 5% contamination may not be all that uncommon. Stuckenrath[20] was even more pessimistic: "The majority of organic samples from the northeast are contaminated in this direction and the likelihood of 10 percent is probably a conservative estimate". Under *these* conditions, any date published as 7500 BP could really be read as 10,000 BP.

Materials

A wide range of carbon-containing substances have been subjected to dating, with inconsistent results. Charcoal, being the nearest thing to elemental carbon, is favored as the most reliable, while shell and bone are usually viewed with well founded mistrust.

1) Charcoal and its Problems

Although so porous as to readily absorb organic compounds from the soil, charcoal can be thoroughly cleansed of contaminants—if the sample is large enough, and *if* cleansing is done. If it is *not* done, an erroneous date, influenced by contaminants, will result.

Without these special techniques, not even the most meticulous collecting and handling can ensure accurate dates. In an early test case, designed to demonstrate the absolute consistency and reliability of radiocarbon, five samples of good charcoal were carefully collected from a single Paleo-Indian hearth some 12 feet below the surface, at the Lehner Kill site in southern Arizona. But alas! when tested,[21] the radiocarbon dates were spread from 7022 ± 450 to 12,000 ± 450. In great glee, Ernst Antevs wrote, "This proves beyond all doubt that the Indians kept a fire burning for 5,000 years!"[22]

Another experiment, intended to show that charcoal-bearing soil could be concentrated for dating, also took an unexpected turn. In the field, the larger chunks and bits of charcoal were separated by hand, and the visible plant rootlets removed. Smaller particles of carbon were caught when the soil was subsequently washed through fine-mesh screens, and again when dust-like carbon floated to the top of the water. With a fair degree of consistency, the finer the material, the younger the radiocarbon dates. The maximum difference was about 10%. No satisfactory explanation has been given.[23,24]

2) Peat and Other Soils

The widespread belief that peat is another highly reliable material no doubt stems from the superb preservation of organic material within it, such as seeds, leaves, and insect eggs in undisturbed clusters. So great is the degree of confidence in it that few people trouble themselves to ask for special pre-treatment. Not even the chilling warning of "less than 200" years for sample W-130 has shaken their faith—even though *that* sample of peat was obtained from 30 feet down, *under* glacial till!

Actually, peat is subject to a high degree of contamination and consequent error. The various chemical parts of a single block of peat can be separated by treatment with a series of organic solvents and acids, yielding different dates on each compound. Reasoning that the most resistant compounds are the least likely to be affected, the last remaining part is thought to represent the original carbon content. Dates on this residue are older than dates on the other fractions, and older than on the whole sample, indicating that the contaminant is modern carbon. The more ancient the sample, the greater the difference—sometimes adding more than 15,000 years to the age that would normally be determined![25]

Using such chemical treatments, other soils too can be broken into fractions, and dated. Again the most resistant part, the humic fraction, is found to give the oldest dates. But even this most-nearly-original carbon appears to be contaminated, since the humic acid dates still fall well short of the true ages, as determined by other means. Apparently, no chemical or physical process can isolate the original carbon of the sample. Concluded Gilet-Blein *et al.* "Most fossil soils cannot be dated by [C-14] measurements."[26]

3) Bone

Similarly, radiocarbon dates on bone have never been satisfactory. Not only do they disagree with associated charcoal dates, but among themselves too. From the famous Cooperton Mammoth site in Oklahoma, for instance, a single animal produced leg bones dated at 17,575 ± 550, and ribs 20,400 ± 450 years old. Still another figure came from testing its tusks!

Bone dates can be determined either upon the solid carbonate, which is the easier method, or on the organic (collagen) fraction. Because the carbonate is subject to exchange with modern atmospheric carbon, it gives falsely *young* dates, and is not well regarded. The collagen fraction is not without problems, either. Fungus hyphae, plant rootlets, and bits of charcoal or wood—too small to be removed by hand—can contaminate the sample, and standard methods of decalcification fail to remove them.[27]

In all cases studied by Tamers and Pearson[28] the bone-dates were too young. The discrepancies between associated bone and charcoal dates were more pronounced in older samples, ranging to so much as 3000 years at determined ages of 10,000 BP. Through experiment they found that bone carbonate exchanges only with atmospheric carbon, and not with old carbon in ground water. They also took issue with the normal chemical treatments given bone samples, and made improvements. Even so, two-thirds of their dates came out too young. They, too, concluded that "the majority of radiocarbon dates on bone are in error."

4) Shell

Even more than bone, shell is deserving of suspicion. Not only must reservoir and hard-water effects, as well as fractionation, be taken into account, but contamination can throw dates off unexpectedly. To illustrate: a fossiliferous shell horizon of apparent Pleistocene age gave a series of dates, stretching from 2000 to 3500 BP.[29] In Egypt, another Pleistocene deposit (determined on charcoal as 19,000 BP) also yielded erroneous shell dates: 12,850, 4040, and 3170 BP; these were rejected as "much too recent" by Wendorf *et al.*[30] Apparently, the fault lies with modern carbon replacing the original material. This kind of exchange should be expected in well drained sites, especially on raised beaches.

Naturally, contamination is worse on the surface of a piece of shell than in its core. Separation by acid treatment shows that the surface tends to date younger then the innermost fraction of the same shell—occasionally, by so much as 500 to 1000 years. It is an unfortunate, though quite common practice to wholly dissolve shells for dating[31].

Contamination in the Hands of the Collector

After untold ages in the ground, material destined for the radiocarbon lab will be unearthed by some dedicated geologist or archaeologist—often by an inexperienced student. To get a good sample, this individual must exercise the greatest care—requiring a degree of knowledge that he may not have. The material must not be handled as it comes out of the soil, nor be dusted off with organic tools, such as bristle brushes. Even cigarette smoke is a contaminant, to say nothing of the ashes that tumble into the sample.

A proper container ought to be on hand—exposure to the air allows fresh dust and pollen to settle. The sample should be gathered as quickly as possible, and wrapped in *new* aluminum *foil*—not dropped into a lunch bag or one's pocket. Samples submitted in cloth, plastic, paper, or any kind of tissue "are almost useless"[32]. Naturally, it is folly to put different samples together, even temporarily. Finally, it is important to ship the sample off to the lab *promptly*—especially if it is moist. Otherwise, fungi may begin to grow, using modern carbon from the air for their metabolism.

Badly deteriorated materials should *not* be coated with preservative, if the intention is to submit them as radiocarbon samples. While some chemicals can be removed, failure to do so can halve the date. In the case of some Colorado mammoth bones, contaminated samples dated to only 5240 BP. Chemical cleaning of the material permitted a new date of 9240 years to be obtained.[33]

All of these problems have been discovered through unfortunate experiences. Porous samples of charcoal were indeed collected in used coffee cups, giving erroneous dates that—if not immediately rejected—entered the literature to be listed again and again. Today, most people in the profession know better, but through carelessness or unwillingness to discard a risky sample, unnecessarily erroneous dates are still being obtained.

The Laboratories

Since the beginning of radiocarbon dating at the University of Chicago, dozens of labs have sprung up across the United States and around the world. For a number of years, the solid-carbon method was the only one available. Sample materials of all kinds were burned to charcoal, washed with acids, and placed in a shielded Geiger counter. Unfortunately, charcoal in the lab, as in the ground, is prone to contamination. Some labs in particular lay in the path of radioactive fallout from atomic bomb tests, or suffered from leaks of radioactive sewer gas. For such labs, there were serious problems.

Solid-carbon is also capable of absorbing some of its own beta-rays, by which the radiocarbon is to be detected.[34] For still other, *unknown* reasons, solid-carbon dates from arctic and sub-arctic samples "were erratic in distribution, and unsatisfactory, even though occasional dates appeared to be useful."[35]

In the mid-fifties the gas-counter rapidly replaced the old method. In this procedure, samples were converted to carbon dioxide. The dates thus obtained were thought to be more accurate, but Johnson observed that on northern samples, the new method still "failed to produce a chronology that was unequivocal . . ."

Further advances in technology brought liquid-scintillation counting, which seems to be neither more nor less reliable than gas counting.[36] Both are limited to a practical range of 30,000 to 40,000 years, even though theory suggests greater extremes.

And now, we stand on the threshold of a new, totally different kind of technology—one that is expected to routinely date materials 100,000 years old. Minute samples will be specially prepared, then sped past magnetic lenses in a tandem electrostatic accelerator. Different atoms and ions will be deflected according to their atomic properties, and their numbers will be directly determined, rather than inferred from radioactive decay.

Introduction of this high-energy mass spectrometry is delayed by unsolved problems. Apparently, ions having the same magnetic rigidity as carbon-14 can heavily contaminate the prepared samples. Additionally, there is an altogether *unknown* source of carbon-14 somewhere within the equipment.[37]

Although samples so small as half-a-gram can be dated in conventional counters, much larger samples are preferred by the labs. With 50 or 100 grams (two to four ounces) of charcoal adequate chemical decontamination is feasible. On less concentrated materials such as bone or shell, a much greater quantity is required. It is common practice, nonetheless, for archaeologists and geologists alike to collect insufficient material, and most labs will run the samples through the counter anyway. If the dates are disagreeable, sample size is faulted.

In general, radiocarbon labs seem to do a fair job of determining sample activity. It is said that they make a second run on each sample, a week later, to detect possible radon gas contamination (radon decays swiftly). However, many GSC dates, at least, are based on only one run[38]. Recounts *usually* coincide, but in a notable exception, "the determined age of sample M-411 was increased more than 2000 years by extending the time of measurement from the conventional 48 hours to a fortnight".[39] It raises a question about what would result if *all* tests were thus extended.

The Statistics of the Thing

All labs estimate the *statistical* uncertainty of their age determinations, and express it as a plus-or-minus figure, which is appended to each date. They do *not* take into account the age of a tree when it died, or from what part of a large-diameter trunk the sample came. Neither do they concern themselves with the *extent* of contamination. Their sole concern in this matter is the amount of error involved in laboratory measurement. This *standard error*, as it is called, is *not* intended to bracket the possible range of the date, but is instead a measure of *probability*. It indicates, to the informed, that there are two chances in three of the date falling within the indicated spread, and one out of three that it actually lies *outside*.

When two dates are compared, the statistics of the thing dictate that there is a fifty-fifty chance of at least one of them lying outside its own standard error. If *four* dates are being compared, you may reasonably expect one or more to exceed its own plus-or-minus figures—the probability is four out of five.

In applied statistics, however, use of what amounts to a 68% confidence-interval is virtually unknown. By *doubling* the standard-error figure, a more acceptable 95% interval is obtained. *Now*, when two dates are compared, the chances of one of them lying outside the interval are only *one in ten*. If, however, *ten* dates are to be compared, the odds once more approach fifty-fifty.[40]

Although cross-checking of specially prepared standards in eight different labs did yield "impressively close" results[41], the practical side of radiocarbon dating tells *another* story. When one lab dates tree rings of a given period, the results ought to coincide with the dates obtained in another lab, or in *all* labs—within the limits of standard error.[42] Instead, Clark[43] found that the actual variability was "far in excess" of what should be expected.

Pardi and Marcus[44] calculated that the actual error was more than *four times as great* as that shown in the standard error. Both for individual dates and for the tree-ring calibration curves, Pilcher and Baillie[45] felt compelled to assign a *minimum* of 100 years as the proper standard error for any date. To achieve an acceptable level of 95% confidence, this figure had to be doubled to 200 years. *Any* calibrated date, they pointed out, must combine both its own confidence interval and that of the calibration curve. This gives a plus-or-minus spread of 800 years for the *best* of radiocarbon determinations, after calibration.

Proper use of radiocarbon dates really does require an education in statistics. In a hypothetical situation, suppose that one has to work with two old dates from published sources, 3000± 150 and 3500± 150 (Fig. 3). They appear to suggest a good separation for the two samples, but there is some degree of risk that one might lie outside its standard-error limits. Better to double

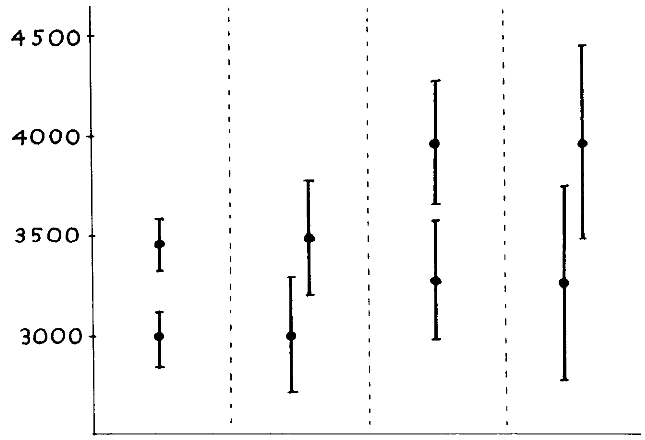

Figure 3. Step by step, the same pair of radiocarbon dates is transformed by better statistical treatment. From left to right: Uncalibrated, 68% confidence interval; uncalibrated, 95% confidence interval; calibrated, 95% confidence interval; and calibrated, combined confidence intervals. Do these two dates really represent different ages?

those limits and obtain a 95% level of confidence. Now, however, the dates *overlap*. But wait—there is more. Neither one of the dates was ever corrected on a bristlecone calibration curve! Try the famous curve of Dr. H. Suess—and delight in the fact that the gap between the dates widens to 700 years, making them 3310± 300 and 4000± 300! *Now* they can be claimed as proof of different levels—or *can they?* Whispering in the back of one's mind are the words of the statisticians, who say that the standard error has to be *added* to that of the calibration curve, for each date. Once more, study the results, and try to figure out your chances of being wrong—in the final analysis, the dates are 3310± 500 and 4000± 500. The standard errors overlap even *more* than before! Shakes you a bit, *doesn't* it?

Actually, the fact that the standard errors overlap a little is not sufficient reason to rule out separation of the dates. It all comes back to *probability*, for the greater the overlap, the more *likely* it is that the dates really apply to the same event. The lesson in this is that "there will be situations where conclusions drawn by the archaeologist from a given radiocarbon date will depend critically on which formula is used to estimate the accuracy of the date after calibration"[46]. Working out the probability associated with the varying degrees of overlap is no easy matter, but Carl Hubbs and Alfred Perlmutter[47] did set forth general guidelines.

The Part Played by the User

The collector of a sample—and he *alone* is familiar with the circumstances on the site—must exercise a comprehensive knowledge of the problems involved in radiocarbon dating. Proper handling of the material in the field is essential, together with competent evaluation of possible contamination. Later, when a date has been determined, he should act responsibly in using it.

A sample that is not associated with the culture of particular interest is quite useless, as some have learned after spending their money.[48] It took two tries on sample M-1530 to persuade one archaeologist to check his *own* records, and lo!—the carbon was thus belatedly discovered to have been separated from the major cultural component by *six inches of sterile soil!*[49] A discrepancy of 1000 years had resulted.

Although there *are* means for clearing samples of their contamination, the collector has to *ask* for special pre-treatment. Otherwise, it will not be done. The resulting poor dates have to be explained away—perhaps by noting somewhat tardily that the sample material had been "saturated by solution from [an] overlying bed of manure"[50] Much more commonly cited as contaminants are plant roots. These were blamed by Martijn as an infestation giving rise to the troubling rejuvenation of one of his dates to nearly modern levels[51]. Such poor samples as these should never have been submitted at all, for dating.

Remembering Ogden's stunning observation that collectors come to reject *more than half* of all dates obtained for them[52], one surely must wonder how they can presume to know age *better* than the sophisticated technology picked to measure it. They *do*, though, as attested by the astonishing frequency of their comments in radiocarbon date lists: "apparently too old", or "100 years too late", or "5000 years too late", or "impossible," and "also impossible"—to give just a few examples from an enormous body of them.

As Sanger innocently expressed it[53], "Chronology constitutes a problem if all the radiocarbon dates are used". Some dates, evidently, just have to be *eliminated*, if others are to become "plausible". Internal consistency in a series of dates is popularly taken as a sure sign of accuracy—but the date must also fall into line with *accepted beliefs*. One author managed to meet both criteria by rejecting *one-third* of his dates, making it possible to "erect a chronology which is compatible with the known late Pleistocene and Recent history."[54]

Sometimes it seems imperative that even lone dates must be tossed aside, as when "acceptance of [McGhee's] date would place Canadian Thule culture earlier in time than [its own ancestors]"[55] Yet, so entranced were professional people, the authorities, with their new toy that such bizarre results, somehow, were taken in stride, and such a careful scientist as Antevs was could be scornfully rejected, ignored, forgotten.

Occasionally, imperfect dates are *adjusted*, rather than rejected. In this way, they can be pushed toward what the user *thinks* they ought to be. In one instance, "the date is acceptable, but [Taylor] prefers to add 120 years of range to obtain [a] date of about A.D. 1125."[56]

Another date, 14,200± 1150 BP, which Bryan thought[57] was *too daring* for the age of Early Man in Brazil, was "used with great caution, tripling the range of error and conservatively assigning a 'date' of 10,750 BP to level 10." That bit of arithmetic brought it safely into the time of Clovis man, making it acceptable to the Establishment. *Surely* the standard-error figure was never intended for this kind of abuse? It is, after all, an indication of *probability*.

Full acceptance of a date, on the other hand, can be based on nothing more substantial than finding "no compelling reasons for rejecting it". That does *not* mean that it is right. At other times a date like Wright's GaK-1267 is accepted largely because it "reinforces [the] apparent association" of artifacts.[58]

Armed with one or more of these *selected* dates, the collector will naturally attempt to draw some conclusions from them. Believing, as Johnson did,[59] that "without exception, they are directly comparable", many authors make unjustifiable and even ludicrous use of the dates. Two geographically separated dates, for instance, fell so nearly alike in age that Ritchie[60] was led to speculate on the course of a single canoe voyage some 3000 years ago! Hough[61] went farther, if such were possible, in reversing the known *sequence* of some post-glacial lakes on the basis of just two dates, even though there was considerable overlap between them!

When using published dates, one must rely somewhat blindly on the care and knowledgeability of other investigators. As de Laguna observed,[62] "both authors [Borden and Byers] seem ready to accept dates published . . . for my Pacific Eskimo materials . . . even though [they] were from samples suspected of contamination". She went on to point out that the deposits had been saturated by seawater, and that the samples were washed in seawater; that the wooden objects were treated with paraffin, while the bone and antler material was soaked in a solution of shellac and wood alcohol; and that everything sat gathering dust for a quarter-century, prior to dating. Unbelievably, these were the samples held by Borden[63] to be "sufficient to demonstrate that the ground slate industry . . . could not possibly have been derived from Eskimo culture"!!

The First Radiocarbon Revolution

In the light of what is known about the radiocarbon method and the way it is used, it is truly astonishing that many authors will cite agreeable determinations as "*proof*" for their beliefs. Such blind faith in radiocarbon was more characteristic of the beginning years for the method, when the first dates encouraged wholesale abandonment of the existing age estimates, and open ridicule of dedicated men who had spent their lives in building up meaningful relationships.[64] There was an enormous gap between the new magic numbers and the old chronologies—*a gap much wider than we now have*, following corrections and improvements in C-14 methods.

One of those now-forgotten chronologies was based on the counting of clay varves in the ancient beds of glacial lakes. Using the annually-deposited layers as one would tree rings, Ernst Antevs[65] painstakingly arrived at conservative estimates for the deglaciation of eastern North America. He had placed the last major ice advance—other than Cochrane—at 19,000 years, and the end of *main* Lake Algonquin at 16,300 years ago.[66] Then came radiocarbon, Krieger announcing[67] that the whole of the Wisconsin period *began* "not more than 25,000 to 30,000 years ago". Today, one may well gasp in disbelief at such naivete!

An embattled Antevs argued in vain, while exhibiting a rare understanding of the problems involved in radiocarbon dating.[68] He discussed modern-carbon contamination and chemical exchange, isotope fractionation, and variation in carbon-14 concentrations, *before* *these things were even measured!* The great thrust of his argument concerned the implications of those radiocarbon dates then being accepted by "authorities", right and left. Some of the dates, he observed, were impossible on *stratigraphic* grounds. No one was listening—he was just a doddering old fool.

The correlation of Two Creeks with the Champlain Sea,[69] for instance, was in Antevs' opinion untenable because "1) the Two Creeks forest is older than 2) Valders till which is older than 3) Lake Algonquin which is older than 4) post-Algonquin lakes (Wyebridge through Korah), some of which drained into the arm of 5) the Champlain Sea".[70]

Other radiocarbon dates implied wildly improbable behavior on the part of the retreating ice sheet, he argued. Johnson,[71] however, ridiculed Antevs' meticulous and serious approach as "unprovable opinion" and "absurdity". Rapidly, radiocarbon dates that cut Antevs' estimates in half replaced his chronology, and it became unpopular even to mention him. The new order, which somehow had gotten hold of God's Truth in a laboratory, remains entrenched to this day—for it is not the way of "science" either to acknowledge or dwell upon its embarrassing mistakes.[72]

Although our present understanding of glacial chronology is indeed dependent on radiocarbon dating, the ages *we* know and are using are *not* the ages that were first announced. Were Antevs alive now, he would be amused at the performance of his detractors, upon seeing some of those extremely young dates being pushed back to what he said they should be in the first place. It is true that certain dates are still only halfway there, or are in some cases static. But increasingly, there has been a tendency for the first determinations to be superseded by much older dates (Table 1). Additionally, re-study by Terasmae and Hughes [77] *"confirms Antevs' counting of the varves and his calculations of the rate of retreat of the ice sheet"*. (italics mine).[78]

The varve chronology established by Antevs was not alone in being discredited, nor is it the only one now partly verified. Far distant from our glacial lakes, new radiocarbon dates *also* have come to approximate the old and rejected archaeological synchronisms for the Aegean Bronze Age.[79] For the most part, though, the systems of dating used formerly are still scorned—if indeed anyone remembers them at all.

What we believe we know is very much based on radiocarbon dating; that is, on radiocarbon dates that were *selected* to fit other, earlier determinations. Traced back through the literature, it would appear that those early and often erroneous radiocarbon determinations were *accepted without question*, at a time when the many problems were scarcely even recognized.

Table 1. Changes in Age Estimates

	Antevs	Early C-14	Current C-14
Duration of Great Lakes Nipissing	4500-3500	2619-3400	5500-3700
End of main Lake Algonquin	16,300	3656	10,500
References	73	74	75 & 76

Implications

When radiocarbon dating was introduced on a *wide* scale, back in the early fifties, it quickly replaced the older methods of estimating ages. Thus it was freed from any embarrassing checks on its accuracy. Instead, adjustments were made to achieve *internal* order in the radiocarbon chronology! Once that comforting operation was completed, a feeling of security enveloped the exponents and their faithful followers. As Flint and Rubin[80] viewed it, "the consistency of the group of dates under consideration is such as to justify the assumption that all are accurate."

Even so, there were problems. Lee,[81] who had heard it parroted over and over on the Sheguiandah site that *"radiocarbon dates are consistent"*, observed that "an immediate result of the acceptance of the C-14 datings is the squeezing of tremendous cultural developments into an unreasonably short time span". To relieve this extreme compression of events and time, there was constant tinkering, whereby, for instance, the date of 3656 BP for Lake Algonquin was transferred to Great Lakes Nipissing, and the Nipissing date of 2619 BP was reassigned to a still more recent lake level, called Algoma! We should take note, too, that the Wisconsin is no longer just 25,000 years old, but is now permitted to occupy a niche at more than 60,000 years, as we may see in Minshall.[82] The ages past, we might say, are being *stretched* a little! "Improvements" are piling up, and we still have some little distance to go. But as Antevs might have said with his wry humor, "We're getting there!"

Many authors, Flint and Rubin included, took special pains to report their dates in terms of radiocarbon years, determined ages, and apparent ages. Curiously, while *individual* dates were recognized as being inaccurate, radiocarbon chronologies as a whole were *not*. Yet it is really a *relative* chronology, in which dates tend to be too young, but are *assumed* to be in correct sequence.

In similar fashion, the necessity for calibration over the last 7000 years is well recognized and attended to, while the probable error in older dates receives no practical consideration at all. At a range of 20,000 to 30,000 years, it is true, one can only guess at the full extent of the problem. But one can be reasonably sure about its trend: *too young*.

First of all, we know that dates immediately beyond the range of the bristlecone curves must *also* be about a thousand years too recent, as a result of changing carbon-14 concentrations. Similar work on varved clay suggests a continuation of that trend to at least 10,000 B.P. For more ancient dates, the gap between radiocarbon and *real* ages may be still wider, as indicated by comparisons with uranium-series dating.

Those bristlecone dates, however, were special determinations, obtained from *uniform* wood samples. Excavated materials such as bone, shell and charcoal, on the other hand, all suffer from contamination—both in the ground and in the hands of careless or ignorant collectors. With peat, other types of soil, and bone, there is apparently no way to completely remove contaminants. Even *fully* treated samples give dates that are too young. Lamented Goh *et al.* "That contamination increases in significance with age is well established . . . and yet [C-14] dates 20,000-40,000 years BP derived from peats and organic silts and wood remains . . . are still cited in the literature without any consideration given".[83] They also observed that an orderly succession of dates in a deposit is often—and *wrongly*—argued as evidence of insignificant contamination.

Ultimately, we must question the reliability of radiocarbon dating—even for use as a *relative* chronology. For one thing, we are trying to compare dates obtained on *different* materials, some of which are more prone to contamination than others. Even where the material is of only one kind, as in the case of peat, dates from just *above* an impermeable zone will date younger than the more recent deposits nearer the surface, because modern-carbon contaminants *accumulate* in just such places.[84]

Difference in environment, too, would influence the degree of contamination—and hence, the error—from one region to another. Hunt[85] commented on the fact that samples from eastern North America yielded dates only half as great as those from drier climates in the West: "It is possible to select a long or short timetable depending on one's choice". He suggested that the eastern dates were strongly affected by the more abundant decomposition products of a moist environment.

If we are trying to make comparisons with dates already reported in the literature, then we must surely wonder how those dates and samples were handled. Were the samples *large* enough? Were they collected *meticulously*? Was special *pre-treatment* used to attempt decontamination—and was it successful? Did the lab correct for *fractionation*, or in the case of shell, was that simply *assumed* to cancel the estimated reservoir effect? Were those dates calibrated *at all*, and if so, was the curve *smooth* or *irregular*? Did the collector accept the standard error assigned by the lab, or did he follow the advice of the statisticians? Were the dates *manipulated* in any way? In short—*what assurance do we have that the dates are correct?* After all, acceptance by the collector merely tells us of his belief that *he* was right!

Additionally, we will have to acknowledge the fact that the radiocarbon time scale is not *evenly* foreshortened. Fairly young dates can be calibrated to compensate for variation in past carbon-14 levels, but not the older dates. And yet it is the older dates that may have been affected by *extreme* changes in the carbon-14 supply, depending on the severity of ancient magnetic-pole reversals. Then, too, the more ancient samples are all the more sensitive to modern-carbon contamination, such as atomic fallout, and are likely to be disproportionately young.

Conclusion

Radiocarbon dating has somehow avoided collapse onto its own battered foundation, and now lurches onward with feigned consistency. The implications of pervasive contamination and ancient variations in carbon-14 levels are steadfastly ignored by those who base their argument upon the dates.

The early authorities began the charade by stressing that they were "not aware of a single significant disagreement" on any sample that had been dated at different labs.[86,87] Such enthusiasts continue to claim, incredible though it may seem, that "no gross discrepancies are apparent",[88,89] Surely 15,000 years of difference on a single block of soil is indeed a *gross* discrepancy! And how could the excessive disagreement between the labs be called insignificant, when it has been the basis for the reappraisal of the standard error associated with each and every date in existence?

Why do geologists and archaeologists still spend their scarce money on costly radiocarbon determinations? They do so because occasional dates *appear* to be useful. While the method cannot be counted on to give good, unequivocal results, the numbers do impress people, and save them the trouble of thinking excessively. Expressed in what *look* like precise calendar years, figures *seem* somehow better—both to layman and professional not versed in statistics—than complex stratigraphic or cultural correlations, and are more easily retained in one's memory, "Absolute" dates determined by a laboratory carry a lot of weight, and are extremely helpful in bolstering weak arguments. If they are sufficiently numerous to "cluster at A.D. 1000", as is erroneously claimed for L'Anse aux Meadows in Newfoundland, they can be presented as "overwhelming evidence" to sweep aside any dissenting voices.[90]

No matter how "useful" it is, though, the radiocarbon method is still not capable of yielding accurate and reliable results. There *are* gross discrepancies, the chronology is *uneven* and *relative*, and the accepted dates are actually *selected* dates. "This whole blessed thing is nothing but 13th-century alchemy, and it all depends upon which funny paper you read."[91] Is it, then, time for the *final* radiocarbon revolution?

It may be possible to save radiocarbon from the fate that unjustly befell its old rivals, such as time scales of Antevs. Sometimes, it seems to be the *only* clue an investigator has. But it must be understood that a radiocarbon date is nothing more than just exactly *that*—a clue. It has to be used accordingly, and as just *one* piece of evidence leading to an informed age estimate.

As a mere piece of evidence, of course, each date will have to be reported in full, answering all of the questions that might arise. In this way, its background will be out in the open, where it can be scrutinized and evaluated. The figure finally presented to the reader, as an informed age estimate, should make pretense of no greater degree of precision than befits *any* estimate.

Radiocarbon, I suggest, *can* have a future. But if no radical changes in *attitude* are forthcoming, that future can hardly be an illustrious one. Let it be "a useful tool"—but not a death warrant for all powers of observation and reasoning. As the great teacher L'Abbe Breuil advised, let us observe and *think*!

References

[1]In 1947, at a University of Chicago "round table", I first learned of

the new "wonder-tool", described as a by-product of the atomic bomb research, which had been carried out in the football stadium of their Stagg Field. The results had been tested against Egyptian materials of known age, and found to tally very closely. It was declared capable of precise dating on charcoal, wood, bone, and shell. Other materials were being tested. TEL. (Notes marked "TEL" were added by Thomas E. Lee, Editor of the *Anthropological Journal of Canada.)*

[2]Vividly I recall the shock and excitement among archaeologists at the University of Michigan, as they hurried from door to door with the news that C-14 had proven Hopewell older than Adena! TEL.

[3]Libby, Willard F., 1963. Accuracy of radiocarbon dates. *Science* 140(3564):278-280.

[4]Gladwin, Harold S., 1976. Dendrochronology, radiocarbon, and bristlecones. *Anthropological Journal of Canada.* 14(4):2-7.

[5]Barbetti, M., and K. Flude, 1979. Geomagnetic variation during the late Pleistocene period and changes in the radiocarbon time scale. *Nature* 279(5710):202-205.

[6]Clark, R.M., 1975. A calibration curve for radiocarbon dates. *Antiquity* 49(196):196-266. See especially p. 251

[7]Stuckenrath, Robert, 1977. Radiocarbon: some notes from Merlin's diary. *Annals of the New York Academy of Science* 288, 181-188.

[8]Stuiver, M., 1970. Tree ring, varve, and carbon-14 chronologies. *Nature* 228 (5270):454-456.

[9]Davis, Emma Lou, George Jefferson, and Curtis McKinney, 1981. Man-made flakes with a dated mammoth tooth at China Lake, California. *Anthropological Journal of Canada* 19(2):2-7. See especially p. 6.

[10]Stuiver, M., 1978. Radiocarbon timescale tested against magnetic and other dating methods. *Nature* 273(5660):271-274.

[11]Reference 5, p. 205.

[12]Saupé, F., O. Strappa, R. Coppins, B. Guillet, and R. Jaegy, 1980. A possible source of error in ^{14}C dates: volcanic emanations. *Radiocarbon* 22(2):525-531. See especially p. 528.

[13]Jardine, W.G., 1978. Radiocarbon ages of raised-beach shells from Oronsay, Inner Hebrides, Scotland: a lesson in interpretation and deduction. *Boreas* 7(4):183-196. See especially p. 189.

[14]Mangerud, J., and S. Gulliksen, 1975. Apparent radiocarbon ages of recent marine shells from Norway, Spitsbergen, and Arctic Canada. *Quaternary Researches* 5(2):263-273.

[15]In classrooms prior to 1950, both at U. of Chicago and U. of Michigan, I heard it stated that modern shells picked up on the beach would date to as much as 3000 years. It seems very odd to me that, in all the years since, I have seen no mention of this in archaeological site reports dealing with the dating of shells, and no allowance for it in connection with the dates obtained on ancient shells.TEL.

[16]Reference 7, p. 186.

[17]It has long been my opinion—perhaps under the influence of Ernst Antevs, who told me in 1955 that such was his belief—that older carbon can be moved upward by circulating groundwater, to impregnate a youger sample, thereby diluting the carbon-14 in the sample. The actual process may be a replacement of the younger carbon by the older carbon—thus providing a date that is too old, a date that is false. TEL.

[18]de Atley, S.P., 1980. Radiocarbon dating of ceramic materials. *Radiocarbon* 22(3): 987-993. See especially p. 988.

[19]Taylor. R.E., 1980. Radiocarbon dating of Pleistocene bone: toward criteria for the selection of samples. *Radiocarbon* 22(3):969-979. See especially p. 971.

[20]Reference 7, p. 183.

[21]Wise, E.N., and D. Shutler, Jr., 1958. University of Arizona radiocarbon dates. *Science* 127(3289):72-74.

[22]Lee, Thomas E., 1971. How old is "definite"? *Anthropological Journal of Canada* 9(2):14.

[23]The consistency of these results was indeed only fair. In the early fifties, J. Normal Emerson, University of Toronto, reported to me that a stunning discrepancy of 3000 years (34%) had been obtained on one of these samples. Because this result made the fine particles older, instead of younger, Libby had to try again before achieving the consistency he sought. TEL.

[24]Matson, F.R., 1955. Charcoal concentration from early sites for radiocarbon dating. *American Antiquity* 21(2):162-169.

[25]Goh, K.M., P.J. Tonkin, and T.A. Rafter, 1978. Implications of improved radiocarbon dates of Timaru peats on Quaternary loess stratigraphy. *New Zealand Journal of Geology and Geophysics* 21(4):463-466. See especially p. 464.

[26]Gilet-Blein, N., M. Gerard, and J. Evin, 1980. Unreliability of ^{14}C dates from organic matter of soils. *Radiocarbon* 22(3):919-929.

[27]Hassan, A.A., and D.J. Ortner, 1977. Inclusions in bone material as a source of error in radiocarbon dating. *Archaeometry* 19(2):131-135.

[28]Tamers, M.A., and F.J. Pearson, 1965. Validity of radiocarbon dates on bone. *Nature* 208(5015):1053-1055.

[29]Silar, Jan, 1980. Radiocarbon activity measurements of oolitic sediments from the Persian Gulf. *Radiocarbon* 22(3):655-661. See especially p. 659.

[30]Wendorf, F., R. Schild, and R. Said, 1970. Problems of dating the late Paleolithic age in Egypt. (In) Radiocarbon variations and absolute chronology, 12th Nobel Symposium, Uppsala, ed. I.U. Olsson. Pp. 57-77. See especially p. 60.

[31]Reference 13, pp. 188-190.

[32]Ogden, J., III, 1977. The use and abuse of radiocarbon. *Annals of the New York Academy of Science* 288, 167-173.

[33]Agogino, G.A., 1968. The experimental removal of preservatives from radiocarbon samples. *Plains Anthropologist* 13(40):146-147.

[34]Ralph, E.K., and N.H. Michael, 1974. Twenty-five years of radiocarbon dating. *American Scientist* 62(5):553-560.

[35]Johnson, F., 1967. Radiocarbon dating and archaeology in North America. *Science* 155(3759):165-169.

[36]Re-runs on solid-carbon samples W-76, W-77, and W-174 (14,000 BP) by the gas-counting method yielded new dates of greater than 36,000 years. See Karlstrom, Thor N.V., 1957. Tentative correlation of Alaskan glacial sequences. *Science* 125(3237):73-74.

Again samples of wood from a single source have been dated at 11,050 ± 400BP (L-190A), older than 30,840 (Y-242), and older than 40,000 (W-189)—all by solid carbon. Later, scintillation-counting gave a date of 20,000 ± 800. See Pringle, R.W., W. Turchintcz, B.L. Funt, and S.S. Danyluk, 1957. Radiocarbon age estimates obtained by an improved liquid scintillation technique. *Science* 125(3237):69-70.

[37]Grootes, P.M., 1980. Discussion of paper by Gove *et al. Radiocarbon* 22(3):793.

[38]Lowden, J.A., R. Wilmeth, and W. Blake, Jr., 1970. Geological Survey of Canada Radiocarbon Dates X. Dept. of Energy, Mines, and Resources. Ottawa, Ontario, Canada.

[39]Stearns, C.E., 1956. Review: The Midland Discovery. *American Antiquity* 22(2):198.

[40]Reference 6, p. 265.

[41]Otlet, R.L., A.J. Walker, A.D. Hewson, and R. Burleigh, 1980. ^{14}C interlaboratory comparison in the UK: experimental design, preparation, and preliminary results. *Radiocarbon* 22(3):936-946.

[42]Almost in a state of limbo now is the fact that in the early years, one was required to declare, when submitting a sample for radiocarbon testing, that it had not been sent to any other lab. So late as the mid-fifties, Fredrick J. Pohl (1955) was strongly protesting this requirement, and pointing out that it made a mockery of the scientific method. Quite justifiably, he further protested being asked by the lab to state what date he would accept. In his opinion (and in mine) the testing, if a valid method in the first place, should provide that information, not the collector. TEL.

[43]Reference 6, p. 252.

[44]Pardi, R., and L. Marcus, 1977. Non-counting errors in ^{14}C dating. *Annals of the New York Academy of Science* 288, 174-180.

[45]Pilcher, R.J., and M.G.L. Baillie, 1978. Implications of a European radiocarbon calibration. *Antiquity* 52(206):217-222.

[46]Reference 6, p. 258.

[47]Hubbs, Carl L., and A. Perlmutter, 1942. Biometric comparison of several samples, with particular reference to racial investigations. *American Naturalist* LXXVI(767):582-592.

[48]At U. of Chicago in 1947 I was told that a test would cost \$1500, but that the cost would come down as increasing use was made of the method. Such has been the case. In the late sixties I had tests done at \$110 each. Today, allowing for variations from lab to lab, the cost is around \$140 to \$160 per test. TEL.

[49]Wilmeth, R., 1969. Canadian archaeological radiocarbon dates. National Museum of Canada Bulletin 232, pp. 68-127. See especially p. 73.

[50]*Ibid.*, p. 98.

[51]*Ibid.*, p. 112.

[52]Reference 32, p. 173.

[53]Sanger, David, 1973. Cow Point: an archaic cemetery in New Brunswick. National Museum of Man, Mercury Series 12. Ottawa, Ontario, Canada.

[54]Colinvaux, P.A., 1964. The environment of the Bering land bridge. *Ecological Monographs* 34, 297-329. See especially p. 314.

[55]Reference 49, p. 83.

[56]*Ibid.*, p. 78.

[57]Bryan, A.L., 1978. An early stratified sequence near Rio Claro, East Central Sao Paulo State, Brazil. (In) Early Man in America ed. A.L. Bryan, Arch. Res. Int'l. Edmonton, Alberta, Canada. Pp. 303-305.

[58]Reference 49, p. 101.

[59]Johnson, F., 1958. Reflections upon the significance of radiocarbon dates (In) Radiocarbon Dating, by W.F. Libby, University of Chicago Press, 1967, pp. 141-161.

[60]Ritchie, W.A., 1965. The archaeology of New York State. The Natural History Press, Garden City, New York. P. 171.

[61]Hough, J.L., 1953. Revision of the Nipissing stage of the Great Lakes. *Illinois Academy of Sciences Transactions* 46, 133-141. 1958. The geology of the Great Lakes. University of Illinois Press.

[62]deLaguna, Frederica, 1962. Intemperate reflections on Arctic and Subarctic archaeology (In) *Arctic Institute of North America Technical Paper No. 11*, ed. J.M. Campbell, pp. 164-169. See especially p. 166.

[63]Borden, C.E., 1962. West coast crossties with Alaska. (In) *Arctic Institute of North American Technical Paper No. 11*, ed. J.M. Campbell. Pp. 9-19. See especially p. 14.

[64]At the Early Man site, Sheguiandah, a visitor responded again and again to my criticisms of radiocarbon dating: "Radiocarbon dates are consistent!" On that ground it was argued that Lake Algonquin had fallen from its maximum to the low point, the waters rising again to 71 feet above present Lake Huron to form Great Lakes Nipissing—all in the space of 200 years. Such was the madness that swept Antevs under the rug, such was the blind faith in radiocarbon. TEL.

[65]This almost forgotten man (see obituary, 1974, *Anthropological Journal of Canada* 12(3): 18-20) did his tremendous field studies in Northern Ontario on foot, by horseback, and with railroad handcars—the "hard way". Almost no money was available in the twenties for scientific work. In the early fifties, there were still "Old-Timers" in the Geological Survey of Canada who remembered seeing this wiry and tough little man clinging to the nearly vertical railway cuts, patiently counting and measuring the layers of clay put down in ancient lake bottoms. TEL.

[66]Antevs, Ernst, 1957. Geological tests on the varve and radiocarbon chronologies. *The Journal of Geology* 65(2):129-148. See also Antevs, Ernst, 1955. Varve and radiocarbon chronologies appraised by pollen data. *The Journal of Geology* 63(5):495-499.

[67]Krieger, Alex D., 1957. News and notes, early man. Ed. Clement Meighan. *American Antiquity* 22(3):321-323. See especially p. 322.

[68]It is only fair, in view of the painful castigation and rejection to which this great and kindly man was subjected in his declining years, and the scorn and contempt with which he is dismissed even now, that I mention a letter which Ernst showed me. It read, in part: "It is a well known fact that you never attend conferences, yet you continue to criticize radiocarbon, about which you know nothing."

In his reply Antevs said: "In the first place, I was not invited to the Conference. In the second, I didn't know there was a Conference. And in the third place, now that I know there was a Conference, I see that you had only people there who were favorable to radiocarbon, and none of its critics.

As for your charge that I know nothing about radiocarbon, I would like you to consider the following eight points." He then proceeded to list his objections.—to my great delight, including some that I too had arrived at when excavating the Sheguiandah site. TEL.

[69]Reference 61. (Geology of the Great Lakes.)

[70]Broecker, W.S., and W.R. Farrand, 1963. Radiocarbon age of the Two Creeks forest bed, Wisconsin. *Bulletin of the Geological Society of America* 74(6):795-802.

[71]Reference 59.

[72]In my experience, very few professional men take kindly to being reminded of their early enthusiasm for radiocarbon dates that were only a small fraction of the currently acknowledged ages. "Oh, but those dates were from the block carbon method—we've improved the methods now, and there is little if any error." The improvements I recognize—they are getting close to the dates set by Antevs 50 years ago. But let me remind them that their scorn for Antevs was based on those now-rejected and never-mentioned dates. TEL.

[73]Reference 66, p. 141.

[74]Flint, R.F., 1953. Probable Wisconsin substages and late-Wisconsin events in northeastern United States and southeastern Canada. *Bulletin of the Geological Society of America* 64(2):897-920.

[75]Cowan, W.R., 1978. Radiocarbon dating of Nipissing Great Lakes events near Sault Ste. Marie, Ontario. *Canadian Journal of Earth Science* 15(12):2026-2030.

[76]Dreimanis, A., 1977. Late Wisconsin glacial retreat in the Great Lakes region. *Annals of the New York Academy of Science* 288, 70-89.

[77]Terasmae, J., and O.L. Hughes, 1960. Glacial retreat in the North Bay area, Ontario. *Science* 131(3411):1444-1446.

[78]When an extremely important book was published . . . Antevs wrote a Commentary for publication. Back it came, with a letter . . . "— is very highly regarded here . . . and we would not wish to publish anything that might seem to detract from his reputation and the quality of his work." TEL.

[79]Cadogan, G., 1978. Dating the Aegean Bronze Age without radiocarbon. *Archaeometry* 20(2):209-214. See especially p. 212.

[80]Flint, R.F., and M. Rubin, 1955. Radiocarbon dates of pre-Mankato events in eastern and central North America. *Science* 121(3149):649-658.

[81]Lee, Thomas E., 1968. (Review) Archaeology of New York State, by Wm. A. Ritchie. *Anthropological Journal of Canada* 6(1):21-31.

[82]Minshall, Herbert L., 1981. A stratified early man site at San Diego: tentatively early Wisconsin. *Anthropological Journal of Canada* 19(1):13-17. See especially p. 16.

[83]Reference 25, p. 464.

[84]Kigoshi, K., N. Suzuki, and M. Shiraki, 1980, Soil dating by fractional extraction of humic acid. *Radiocarbon* 22(3):853-857 See especially p. 855.

[85]Hunt, Charles, B., 1955. Radiocarbon dating in the light of stratigraphy and weathering processes. *Scientific Monthly* 81(5):240-247. See especially p. 244.

[86]Reference 59, p. 142.

[87]A rather astonishing statement. The 5000-year discrepancy in five samples from one small Paleo-Indian hearth at depth on the Lehner Kill site, collected in 1955, should have been known . . . even if not yet in print. TEL.

[88]Reference 32, p. 172.

[89]No gross discrepancies? . . . I submitted . . . a large block of peat from the bottom of a five-foot profile on the Sheguiandah site. See Lee, T.E., 1956. The position and meaning of the radiocarbon sample from the Sheguiandah Site, Ontario. *American Antiquity* 22(2):79 . . . Later, another letter enthused over the importance of the date, 9130 ± 250 years—at that time by far the oldest C-14 date for man in Canada.

The enthusiasm stemmed from the fact that the profile registered the Cochrane glacial advance, at a higher level, and my date "proved" Antevs wrong. But then someone . . . noticed that the peat was necessarily post-Algonquin. Since Algonquin's maximum was at that time carbon-14-dated at 3,600 years, my date was in direct conflict—and silence descended . . . TEL.

[90]The 16 radiocarbon dates (or is it 21, as stated by Anne Ingstad?) range all the way form A.D. 630 to A.D. 1080, and the weighted mean is A.D. 920-not A.D. 1000. The early dates are explained away as being from charcoal that was derived from centuries-old driftwood—totally ignoring the fact that one of them was made from turf from a "longhouse wall". Other dates on turf were thought by Henningsmoen to be too young—and this was blamed on recent rootlet contamination. See Ingstad, Anne, 1969. The discovery of a Norse settlement in North America, volume 1.

[91]Reference 7, p. 188.