In re patent of
Herman J. Heikkenen
Patent No. 4,373,393
Issued: Feb. 15 1983
For: A method of dendrochronology

Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

The undersigned herewith submits in the above identified patent the following prior art (including copies thereof) which is pertinent and applicable to the patent (originally submitted on 19 July 1978) and is believed to have a bearing on the patentability of claim 1 thereof:

REFERENCES:

Babbage, C. 1838. The Ninth Bridgewater Treatise, 2nd Ed. John Murray, London.

Baillie, M.G.L., and J.R. Pilcher. 1973. A simple crossdating program for tree-ring research. Tree-Ring Bulletin 33:7-14.

Bannister, B. 1963. Dendrochronology. Pages 191-205 in D. Brothwell and E. Higgs, eds. Science in Archaeology: A Survey of Progress and Research. Praeger Publishers, New York and Washington.

Douglass, A.E. 1914. A method of estimating rainfall by the growth of trees. Pages 101-121 in E. Huntington. The Climatic Factor as Illustrated in Arid America. Carnegie Institute of Washington, Washington, D.C. Publication No. 192.

-----. 1919. Climatic Cycles and Tree Growth. The Carnegie Institute of Washington, Washington, D.C. Publication No. 289.

-----. 1928. Climatic Cycles and Tree Growth, Vol. II. The Carnegie Institute of Washington, Washington, D.C. Publication No. 289.

-----. 1936. Climatic Cycles and Tree Growth, Vol. III. The Carnegie Institute of Washington, Washington, D.C. Publication No. 289.

Eckstein, D. 1972. Tree-ring research in Europe. Tree-Ring Bulletin 32: 1-18.

Fritts, H.C. 1976. Tree Rings and Climate. Academic Press, New York.

Ghent, A.W. 1952. A technique for determining the year of the outside ring of dead trees. Forestry Chronicle 28(4):85-93.

Gladwin, H.S. 1940. Tree Ring Analysis: Methods of Correlation. Gila Pueblo, Globe Arizona. Medallion Papers No. XXVIII.

Glock, W.S. 1937. Principles and Methods of Tree-Ring Analysis. Carnegie Institute of Washington, Washington, D.C. Publication No. 486.

Huber, B., and V. Giertz. 1970. Central European dendrochronology for the Middle Ages. Pages 201-212 in R. Berger, ed. Scientific Methods in Medieval Archaeology, University of California Press, Berkeley.

Lyon, C.J. 1936. Tree ring width as an index of physiological dryness in New England. Ecology 17:457-478.

-----. 1939. Objectives and methods in New England Tree-Ring Studies. Tree-Ring Bulletin 5(4):27-30.

Stokes, M.A., and T.L. Smiley. 1968. An Introduction to Tree-Ring Dating. The University of Chicago Press, Chicago and London.

In the following pages, the undersigned will demonstrate the pertinence and applicability of these references to the patent. In the first section of this document, the specific claims of the patent will be addressed, with quoted material from the aforementioned references. Second, the statistical theory underlying the claims will be discussed, and it will be shown that other workers had anticipated the invention by as much as 40 years. Finally, erroneous statements by the Inventor (or his legal representative) which exaggerate the originality of the invention will be pointed out.

SECTION ONE. CLAIMS

Claims 1(a-b) outline a sampling method to obtain tree-ring samples from timber structures and from mature living trees growing in the region. In both cases, suggested sampling methods are well in keeping with standard dendrochronological techniques in use for decades.

> **Claim 1(a)**: "taking a plurality of radial core samples from several portions of a timber structure,"
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> *Douglass (1928, p. 59)*: "The search for old pine records has taken a new turn in the use of early historic and prehistoric pine logs in the Hopi villages and the ancient ruins of the Southwest. This really began in 1916, when Mr. Earl H. Morris, for the American Museum in New York, sent me several early historic logs form Gobernador Canyon, near Aztec, New Mexico. This led to a series of specimens from the ancient ruin at Aztec."
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> *Douglass (1928, p. 59)*: "An examination of the logs in this ruin led to the construction of the tubular borer, which produces cores 1 inch in diameter, giving the series of rings from the outside to the center of the log without impairing its strength and without disturbing the original house construction."
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> *Bannister (1963, p. 193)*: "The first requirement is an ample supply of wood or charcoal tree-ring specimens in association with the archaeological environment to be dated."
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> *Stokes and Smiley (1968, p. 21)*: "Material for tree-ring dating comes from many types of habitation sites. . . The wood used in construction, and sometimes even in the charcoal remains of a fireplace, offer a potential source of information on the occupation period of a site."
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> *Stokes and Smiley (1968, p. 27)*: "Solid logs are selected, where possible, so that a complete ring pattern can be obtained; but any possibly datable specimen should be saved."
>
> *Fritts (1976, p. 23)*: "A number of specimens must be examined and crossdated from any given site to avoid the possibility that all collected specimens could be missing a ring for any one year or could have an intra-annual growth band appearing like a true annual ring. Further verification is obtained when several independently dated samples are compared and no inconsistency appears."
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> **Claim 1(b)**: "taking at least one radial core sample from each of several mature living trees of one or more species or trees of one or more species whose death date is known, from at least one well drained, site in the general vicinity of the timber structure,"
>
> In the "DESCRIPTION OF THE PREFERRED EMBODIMENT" section, the inventor states "Next, similar core samples are similarly obtained from a plurality of mature living trees or trees whose death date is known, at one or more sites in the general vicinity of the timber structure. The site may be many miles away from the timber structure."

Douglass (1914, p. 103): "At the beginning of the investigation [begun in 1901 -- DML] it was foreseen that enough trees would have to be measured to give a real average. The trees would have to be. . . sufficiently numerous to eliminate accidents of grouping and other minutely local conditions. . ."

Douglass (1928, p. 12): "One needs, in the first place, to collect from a homogenous area, that is, an area in which the various trees have somewhat similar conditions, enough to give similarity in rings, for on this recognition of the same rings in each depends assurance of climatic effects in the trees and reliability in dating of rings."

Douglass (1928, p. 12): "The tree bored, or the stump cut, is better if not near other trees. Trees under 10 feet apart are apt to have an effect one upon the other by undue shading or appropriation of moisture. This causes eccentric growth of the rings. . ."

Douglass (1928, p. 13): "This is a question of soil moisture and underground drainage, most important factors in the life of the tree, for while other influences may alter groups of rings and completely spoil parts of the record, the moisture supply in the soil may change the character of the entire record or even make it totally useless."

Douglass (1928, p. 17): "The main point in sampling living trees is to get a short radial sequence of rings without injury to the tree. The best instrument for this is the Swedish increment borer. . ."

Douglass (1936, p. 13-14): "It is evident at once that cross-identity depends on similarity in the records of different trees; it may extend over considerable areas. . ."

Glock (1937, p. 2): "He [the investigator -- DML] should take pains to secure only normal, healthy trees unless his interests run to those trees suffering from injury or some pathologic condition. . . Trees should be chosen, rather, from a midslope or ridge-top, because the rings from such trees can be read, whereas those which grow with a permanent water supply at their command can only be counted [i.e., tree-ring series from well-drained sites are more likely to contain distinct signatures of narrow and wide rings than trees from poorly-drained sites -- DML]."

Glock (1937, p. 2): "Mature trees are to be preferred either to saplings or to senile trees unless extremely long records are desired."

Ghent (1952, p. 86): "For the preparation of average graphs, discs should be cut from vigorous living trees of the same species, and where possible, from the same stands as the dead trees which are the object of study."

Bannister (1963, p. 194): ". . .it is still necessary to build a known tree-ring chronology back far enough to overlap and cross-date with the unknown segment in order to achieve absolute dating."

Stokes and Smiley (1968, p. 11): "If sampling sites are selected so that no permanent underground water is available for growth and the soil drainage is good, radial growth is nearly enough proportional to total precipitation to produce datable ring patterns."

> *Stokes and Smiley (1968, pp. 29-30)*: "Live trees used for compiling these regional chronologies were selected, when possible, from near the various archaeological sites to be dated. . . Trees from these sites were selected with several criteria in mind: Only datable [in which annual the ring patterns can be determined -- DML] species from sensitive sites were sampled. Trees in dense stands were avoided. . . Healthy individuals with no obvious injury or disease, which could affect growth, were selected. Older trees in good condition are always desirable. . ."
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> *Fritts (1976, p. 23)*: see quoted segment for Claim 1(a).

Claim 1(c) calls for measuring the width of the rings, again standard practice in tree-ring analysis since the 1910s. In fact, the practice was begun in 1904.

> **Claim 1(c)**: "measuring the absolute radial width of each annual ring for each of the samples taken in steps (a) and (b),"
>
> In the "DESCRIPTION OF THE PREFERRED EMBODIMENT" section, the inventor states "The core samples from the timber structure and the trees are then placed in a dendrochronometer or similar device and the absolute radial width of each annular growth ring is measured for each core sample."
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> *Douglass (1914, p. 103)*: "Work [actual measuring or tree-ring widths -- DML] was begun in January 1904, when I visited the log yards of the Arizona Lumber and Timber Company, Flagstaff, and spent several hours in the snow, measuring the rings of section No. 1. For subsequent measurements Mr. T.A. Riordan, president of the company, most kindly came to my assistance by having thin sections cut from the ends of logs or stumps and sent to me in town, there to be measured more conveniently."
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> *Douglass (1928, p. 37-40)*: in this section Douglass describes several early instruments used to measure tree rings.
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> *Douglass (1936, p. 7)*: "Measurements are made of the thickness of the ring, taken in the radial direction."
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> *Lyon (1936, p. 462)*: "The sections were taken to the laboratory and the exact widths of annual rings were measured. . . by means of a 10-power dissecting binocular with a graduated measure in one ocular."
>
> *Ghent (1952, p. 86)*: "Ring widths are measured by means of an ocular micrometer attached to a binocular microscope."
>
> *Stokes and Smiley (1968, p. 53)*: "While the skeleton-plot technique is an excellent tool for tentative dating, it is an unsatisfactory form for permanent storage or transmission of

> data. The construction of skeleton plots involves judgment, and the application of these plots is limited to the actual specimens plotted.
>
> "These limitations can be eliminated, if exact measurements are made of each ring width. . ."

Claims 1(d-h) outline a procedure by which the patterns of wide and narrow growth rings are compared in order to detect a correspondence (i.e., a match) and therefore establish the date of the structure. Such matching of ring-width patterns has been the primary method of ensuring that the dates obtained in dendrochronological studies are accurate. Again, this practice emerged during the early portion of this century.

> **Claim 1(d)**: "comparing the width of each annual growth ring to the width of the previous annular growth ring to determine if it is greater, less or equal in width to the previous annular growth ring, for each of the samples taken in steps (a) and (b),"
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> In the "DESCRIPTION OF THE PREFERRED EMBODIMENT" section, the inventor describes his method of denoting whether a ring is greater, less or equal in width to the preceding ring. "For example, the absolute width of the 1975 ring relative to the absolute width of the 1974 ring of the core sample will be either greater (+), less (-), or equal (0). The absolute width of the 1974 ring is in turn compared. . . until all the rings along the radial core sample have been measured, compared and tabulated as relative ring widths by a plus, minus or zero symbol, or other means of identification."
>
> *Douglas (1928, p. 42)*: "In consequence, a special 'skeleton' curve has sometimes been successfully used in cross-dating. Such a curve is a long, narrow strip. . . showing only the dates of very small microscopic or absent rings, which are indicated by vertical lines whose conspicuousness is proportional to the deficiency of the rings."
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> *Douglass (1936, p. 9)*: "First, one. . .finds the exact [within a tree-ring sequence -- DML] dates for various thin or otherwise well-characterized rings."
>
> *Lyon (1936, p. 465)*: "Briefly, the method (suggested by Huntington) consisted in tallying for each change from year to year, the nature of the fluctuations by means of the symbols +, -, and 0."
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> *Glock (1937, p. 11)*: "Variability of tree types: first, the algebraic decrease in width of rings with increasing age of a tree; second, the difference, either thicker or thinner, between two adjacent rings; and third, the difference, either thicker or thinner on the average, between adjacent groups of rings. . . Tree-ring work that depends upon the accurate dating of rings employs exclusively sequences of the second type."
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> *Glock (1937, p. 12)*: "A ring is thin or thick in relation to its near neighbors only, not in relation to the absolute standard."
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> *Ghent (1952, p. 88)* describes a similar method: "Viewing the graph lengthwise as if looking from the outside ring in towards the core, each point, with the exception of the

first and last, can be rated as a *right*, *left* or *zero* as the graph turns to the right, to the left, or continues straight ahead."

Bannister (1963, p. 195-196): "All of the different systems of tree-ring dating, and there are several currently being used throughout the world, are nothing more than alternate ways of representing growth patterns and establishing cross-dating."

Bannister (1963, p. 196): "Then Douglas method. . . emphasizes, first, those rings which deviate from the normal -- noticeably narrow or broad rings -- and, second, the internal relationship of those rings within the overall series."

Stokes and Smiley (1968, p. 47-48): "In a skeleton plot the narrow rings are the ones primarily being compared; so a line in marked at each interval where a narrow ring occurs. . . wide rings are marked with a 'B,' and average rings are not marked."

Claim 1(e): "comparing the samples taken in step (a) to determine index years in which the annual growth ring relative to the preceding ring coincides in at least 80 percent of the samples,"

Lyon (1936, p. 474): refers to years in which a majority of the samples coincide in year-to-year pattern as "critical" years.

Glock (1937, p. 17-19): "Attempts to compare skeleton plots give rise to questions immediately. What constitutes *acceptable* cross-dating? How many lines must match before cross-dating is valid and justified? Two tests may be cited: (1) The percentage of agreement must be very high, say 80 per cent or more, and. . . (2) All other possibilities of correspondence must be eliminated."

Lyon (1939, p. 30): "Preliminary estimates can probably be based with some certainty upon the relations between climatic factors and growth for the 'critical years' -- those with relatively narrow or wide rings."

Stokes and Smiley (1968, p. 49): "After each specimen in a group has been skeleton-plotted, several of these plots can be compared at one time. When this is done, similarities in their ring patterns can be noted and matched. . ."

Claim 1(f): "comparing the samples taken in step (b) to determine index years in which the annual growth ring relative to the preceding ring coincides in at least 80 percent of the samples,"

Lyon (1936, p. 474): see comment on Claim 1(e).

Glock (1937, p. 17-19): see quoted segment on Claim 1(e).

Bannister (1963, p. 196): see quoted segment on Claim 1(e).

Stokes and Smiley (1968, p. 49): see quoted segment on Claim 1(e).

Claim 1(g): "correlating on a first chronological scale the frequency pattern of the index years determined in step (e) with the frequency pattern of the index years determined in step (f) on a second chronological scale to establish a common period in the life of trees sampled in step (b) and trees used to make the timbers sampled in step (a),"

Babbage (1838, pp. 261-263): "The annual rings might however furnish other intimations of the successive existence of these trees.

"On examining some rings remarkable for their size and position, let us suppose that we find, in one section, two remarkably large rings, separated from another large ring, by one very stinted ring, and this followed, after three ordinary rings, by two very small and two very large ones. Such a group might be indicated by the letters--

oLLsooosLLoo

where *o* denotes an ordinary year or ring, *L* is a large one, and *s* is a small one or stinted ring. If such a group occurred in the sections of several different trees, it might fairly be attributed to general causes.

"Let us now suppose such a group to be found near the centre of one tree, and towards the external edge or bark of another; we should certainly conclude, that the tree whose bark it occurred was the more ancient tree; that it had been advanced in age when *that* group of seasons occurred which had left their mark near the pith of the more recent tree, which was young at the time those seasons happened. If, on counting the rings of this younger tree, we found that there were, counting inward from the bark to this remarkable group, three hundred and fifty rings, we should justly conclude that, three hundred and fifty years before the death of this tree, which we will call A, the other, which we will call B, and whose section we possess, had then been an old tree. If we now search towards the centre of the second tree B, for another remarkable group of rings; and if we also find a similar group near the bark of a third tree. . .

"The application of these principles to ascertaining the age of submerged forests, or to that of peat mosses, may possibly connect them ultimately with the chronology of man. Already we have an instance of a wooden hut with a stone hearth before it, and burnt wood on it, and a gate leading to a pile of wood, discovered at a depth of fifteen feet below the surface of a bog in Ireland: and it was found that this hut had probably been built when the bog had only reached half its present thickness, since there were still fifteen feet of turf below it."

Douglass (1914, p. 104): "Other interesting facts came to light. It was especially noticeable that a given year of marked peculiarities could be identified in different trees with surprising ease. This is illustrated in Plate 4. . . The other lines of crosses indicate the noticeable broad rings of 1868 and 1878. An examination of the photographs shows that the most characteristic feature is a group of narrow rings about the years 1879 to 1884. These can be identified in practically every tree, and an examination of stumps, which were not measured, showed that it was easy to pick them out whenever one chose. Striking verification of this was found in the case of a stump near town which had been cut about 20 years previously. By finding this group of rings the writer was able to name the year when the tree was felled and the date was verified by the owner of the land."

Douglass (1914, p. 106): "The chief feature of the Prescott series which places its results on a firmer basis than any previous work is the cross-identification of rings between trees. The extent and accuracy of this identification came as a surprise to the writer. After measuring the first 18 sections it became apparent that much the same succession of rings occurs in each, and thereupon the other sections were examined and the appearance of some 60 or 70 rings [characteristic tree rings-- DML] memorized. . . Certain characteristics were noted as common to all, for example, the red ring of 1896 is nearly always double, while the rings of 1884 and 1885 are wider than their neighbors. The most conspicuous feather was a series of compressed rings from 1878 to 1883, preceded by a very faint 1877 and then a long series of very wide rings."

Douglass (1914, p. 106-107): "The cross-identification of trees from the Prescott region was limited to an area only 10 miles long. It came as a surprise, then to find that shavings form the Flagstaff sections, such as are shown in Plate 4, could be identified at once in terms of the rings at Prescott. The narrow ring of 1851 was at once seen to correspond to one in the Prescott series. The dense series from 1879 to 1883 likewise had its counterpart at Prescott. . . The process of cross-identification appears to be applicable to areas far removed from one another. Two trees out of three which were tested from the Santa Rita Mountains in southeastern Arizona, 200 miles from Prescott, were found to have rings which could readily be identified in terms of the Prescott series."

Douglass (1928, p. 42): "Two of these skeleton curves. . . can be moved slowly past each other until similarity of spacing [of distinctive ring characteristics -- DML] discloses identity in dates."

Douglass (1936, p. 9): "Cross-identity which is established by a process called 'cross-dating or cross-identification,' depends on the sensitive type of ring sequence. It is the foundation stone on which long ring records have been based. It modern trees it involves the determination of the exact year in which each ring grew. There are three practical steps in this process. First, one counts in from the bark of trees whose outermost ring has an obvious date -- for example, the outermost ring in a tree just cut down -- and thus finds the exact dates for various thin or otherwise well-characterized rings. Second, a careful note is made of the time spacing of the specialized rings, which may now be regarded as a recognizable group, and search is made for an identical group in another tree of unknown cutting date; when found the group rings in the latter tree become known as to exact date. Third, in the second tree, an count is made either to the outside to find when it was cut, or toward the center to ascertain the exact dates of earlier groups of specialized rings."

Lyon (1936, p. 463-464): "The first point to be demonstrated is the degree to which individual trees in a group were alike in their responses to their environment, year by year. This will be referred to as cross-identification, since an established series of dated maxima and especially of dated minima enable one to identify the year of growth of any ring in a sequence of measured but undated rings."

Glock (1937, p. 12): "The two diagnostic features which make it possible not only to read tree rings but especially to date them are treated separately for the sake of emphasis. (1) In the method here described, chief stress is laid upon rings which are conspicuously narrow or conspicuously wide *in comparison with their immediate neighbors*. . . (2) The interval, or number or rings, between notably thin or thick rings constitutes a diagnostic feature second only to the one mentioned above. . ."

Glock (1937, p. 16): "Cross-dating as generally practiced is the establishment of the time identity in ring groups in two different trees by means of very high and convincing structural correlation between them."

Glock (1937, p. 19): "Cross-dating is thus seen to be the establishment of a direct and synchronous relation between the diagnostic features of ring sequences. . ."

Ghent (1952, p. 89): "The basis of this test is the strong agreement which can be found at one point of alignment of two time series having much the same internal organization of these ring size relationships."

Bannister (1963, p. 192): "Under certain conditions, contemporaneous ring records formed by sensitive trees will show remarkable similarity when compared with each other. The patterns of narrow and broad rings in one tree will closely match the patterns found in other trees. . ."

Bannister (1963, p. 196): see quoted segment on Claim 1(e).

Stokes and Smiley (1968, p. 49): "The purpose of aligning the individual plots and constructing a composite plot is to find a time period common to. . . the specimens."

Stokes and Smiley (1986, p. 51-52): "The plots are compared on a ring-by-ring basis along the entire length of their overlapping portion. When this has been done, the composite has been tentatively placed in time. Each individual specimen must then be compared ring-by-ring with the master chronology before dates are considered to be verified."

Huber and Giertz (1970, p. 202): "This is found by comparing two ring curves. . . then counting how often curves rise or fall together, or how often one curve rises while the other falls or vice versa."

Baillie and Pilcher (1973, p. 7): "The computer program described in this paper was devised to compare the ring patterns of individual timber samples with those of established chronologies whether floating or standard. It is also a powerful tool for establishing the position of highest correlation between the ring patterns of individual trees."

Baillie and Pilcher (1973, p. 11): "[The program] is designed for routing use in the crossdating of large numbers of timbers of unknown age. It is used by us for crossdating individuals and for crossdating against standard and floating chronologies."

Claim 1(h): "determining the last year of growth of the samples obtained in step (a) by comparing chronologically on the first chronological scale the date of the outermost growth ring of the samples taken in step (a) to the date of the outermost growth ring of the samples taken in step (b), on the second chronological scale."

Babbage (1838, pp. 261-263): see quoted segment on Claim 1(g), especially the section beginning with "The application of these principles. . ."

Douglass (1914, p. 104): see quoted segment on Claim 1(g), especially the section beginning with "Striking verification of this was found. . ."

Douglass (1936, p. 9): see quoted segment on Claim 1(g), especially the section beginning with "Third, in the second tree, a count is now made. . ."

Douglass (1936, p.10): "Cross-identity was observed in 1904 and recognized as a fundamental part of tree-ring work in 1911. From the start it was realized that chronological identification can be carried from tree to tree by grouping of the rings themselves as described above."

Douglass (1936, p. 105): ". . . the Arizona chronology is built of a large number of overlapping records matched together by cross-dating of ring groups."

Douglass (1936, p. 105): "The archaeological phase started in 1914 and in 1929 passed a milestone in the closing of a 'gap' between dated records extending back to or a little before 1300 and a 'floating' chronology extending back to what later proved to be A.D. 700."

Bannister (1963, p. 192): "First, in regions that contain modern cross-datable trees which can serve as controls, proper application will permit the assignment of calendar years to each of the individual rings within a specimen. It is this feature, of course, which has been responsible for archaeological tree-ring dating in the absolute sense."

Bannister (1963, p. 194): "Once a precisely dated master chronology is produced, however, the ring patterns contained in samples of unknown age may be cross-dated with the master chronology and assigned absolute dates."

SECTION TWO. STATISTICAL PROCEDURES

In a letter to the patent office dated 25 October 1978, the inventor's attorney, John I. Iverson, submitted three references which he felt may be helpful to the Patent and Trademark Office. One reference was a patent describing a method for the dating of obsidian artefacts, the other two were dendrochronological studies.

In the letter, Iverson made the statement, "The other two articles, copies attached, are summaries of dendrochronological studies prior to Applicant's invention. They do not disclose Applicant's claimed method."

Omitted from this list were two articles, which, it may be argued, do disclose the Inventor's claimed method. They are:

Ghent, A.W. 1952. A technique for determining the year of the outside ring of dead trees. Forestry Chronicle 28(4):85-93.

Lyon, C.J. 1936. Tree ring width as an index of physiological dryness in New England. Ecology 17:457-478.

Subsequent to the awarding of the patent, the Inventor wrote, "The key-year crossdating technique (U.S. Patent No. 4,373,393) is a combination of the studies of Lyon (1936) in New England and Ghent (1952) in Ontario."

This above quote appeared in the following article:

Heikkenen, H.J. 1984. Tree-ring patterns: a key-year technique for crossdating. Journal of Forestry 82:302-305.

In the following year, the Inventor wrote, "Regarding the originality of the key-year crossdating technique, I readily acknowledge the contributions of Lyon and Ghent: (1) Lyon's recognition of 'critical years' -- when hemlocks within and between stands had perfect agreement in ring-width increases or decreases relative to the previous year's growth, and (2) Ghent's ingenuity in applying the Chi-square statistic to the 2 x 2 contingency test when aligning the relative ring patterns of individual dead trees with the mean pattern of living trees within a given stand."

The above quote appeared in:

Heikkenen, H.J. 1985. Aged crossdating: Herman John Heikkenen replies. Journal of Forestry 83:54-55.

Later in the same article, the author stated, "What is new is the combination of Lyon's critical years, and Ghent's contingency test using the Chi-square and the binomial distribution -- thus permitting the derivation of the years when a significant number of trees for a desired level of probability are in agreement regarding relative growth, and the use of only such significant years when using the Chi-square and Kappa statistic with the continency test to crossdate tree-ring patterns."

Iverson makes the following statements in another letter to the Patent and Trademark Office, this one dated 7 February 1979, ". . . Applicant has in his system, developed a method of determining 'index years' which indicate significant changes common to all of the samples taken. This idea when applied requires only that the 'index years' of the artifact correspond to the 'index years' of the samples in order to key the date of the artifact."

It can also be strongly argued that Lyon's 1936 paper already anticipates the invention, not only in the concept of 'critical' years, which the Inventor later acknowledged, but also in the use of the binomial distribution to determine the statistical significance of the characteristic pattern.

Lyon, in the article cited above, on page 465 writes,

> "Briefly, the method (suggested by Huntington) consisted in tallying for each change from year to year, the nature of the fluctuations by means of the symbols +, -, and 0. If all 5 curves went up together, as they did in 1801 for example, the tally sheet showed a row of 5 +'s. A similar row of - signs indicated perfect agreement in a smaller growth increment in all 5 trees for a given year, such as 1806 and 1836. Instances of no change in ring width were infrequent.
>
> "The result of this analysis for the years 1801-1850 was 5 cases of 5 +'s and 7 cases of 5-'s, making a total of 12 perfect correlations out of a possible 50. The law of probability allows for such correlation in only year out of 16, disregarding the effects of the 0 symbol."

Disregarding the effects of the 0 symbol, there are only two possible outcomes, agreement (or +) and disagreement (or -). This is analogous to flipping a coin, and the appropriate statistical test for determining the probability of getting five heads or five tails in five flips is the Chi-square and binomial distribution. Apparently, this is also the test Lyon used, although Lyon failed to name it, to determine that the probability of obtaining 5+'s or 5-'s is 1 in 16.

The probability (P) of a single outcome recurring in a number of independent trials (n) times is equal to the following formula:

$$P(y) = \sum_{k}^{n} \binom{n}{k} p^{k} q^{n-k}$$

Where:
p = the probability of the outcome occurring once;
q = (1 - p);
n = the number of trials (in this case, the number of tree-ring samples for a given year); and
k = the number of successes (i.e., the number of times the trend in the samples (+ or -), agree.

In this case the probability of obtaining a + or - is equally likely (i.e., p = q). Thus the formula for calculating the probability of getting all + or all - reduces to p^n.

In the example of flipping a coin, the probability of obtaining a head is 0.5 (or ½). The probability of obtaining a tail is the same. Therefore the probability of getting all heads (or all tails) in n trials is $(0.5)^n$ or $(½)^n$, which is the formula the Inventor gives in the patent.

In Lyon's example, there are only two possible outcomes to be considered, + or -, so that p = 0.5 or 50%. Therefore the cumulative probability (P) of getting 5 +'s is given by $(½)^5$, which is equal to P = 0.0313. The cumulative probability of getting 5 -'s is likewise = 0.0313. The cumulative probability of getting **either** 5+'s **or** 5-'s is thus = 0.0616, which is equivalent to odds of 1 in 16.

Lyon further evaluated six sites in his paper. On page 467 he writes,

> "To express the degree of correlation between the six curves, as was done for the five graphs of figure 2, the same method was used for the same period -- 1800-1850. Since there is one more graph [series -- DML] in figure 3, the probability for chance agreement is less and will account for only 1 perfect correlation in 32 years. The total cases of perfect correlation actually numbered 21 for the 50 years. Of these, 10 showed 6+'s and 11 showed 6-'s while 10 other cases had 5 alike. There were at least 4 alike in 80 per cent of the years. . ."

Again, according to the binomial distribution, the cumulative probability of obtaining 6+'s is equal to $(½)^6$, or 0.0156. The cumulative probability of obtaining 6-'s is likewise equal to 0.0156. Therefore, the probability of obtaining **either** 6+'s **or** 6-'s is 0.0312, which is equivalent to odds of 1 in 32. As Lyon stated, and has been shown before, the odds of obtaining **either** 5+'s **or** 5-'s is equivalent to odds of 1 in 16. The cumulative probability of obtaining **either** 4+'s **or** 4-'s is 0.1250, giving odds of 1 in 8.

The Inventor offers the following example in the "DESCRIPTION OF THE PROPOSED EMBODIMENT" section of the patent. After having defined an "index" year (equivalent to Lyon's "critical" year) as one in which you get agreement (+, -, 0) in 80 per cent of the samples from a given site, he writes, "The chance occurrence of an index year is $(½)^n$, and thus with a sample size of ten $(½)^{10}$, the odds of an index year being a chance occurrence are at least 3.9×10^{-3}."

In fact, the Inventor erroneously applied the formula in the patent document. The formula he gives solves for the probability of getting eight matches out of eight samples. What the Inventor wants is the probability of getting eight matches out of 10 samples. The proper formula would be:

$$P(y) = \sum_{8}^{10} \binom{10}{8} 05^{8} 05^{10-8}$$

which gives a probability of 0.0547 for either eight + or eight -.

It should be noted that the Inventor, like Lyon and Ghent, disregards the effect of the 0. In his

1984 Journal of Forestry paper he writes, “Thus there is justification in assuming that for these study sites the + and - RRWs [raw ring widths -- DML] are equally likely; the 0 RRW may be subjectively omitted, as it comprises a low percentage of the total.” It is also implicit in his choice of the formula $(½)^n$ to determine the probability of a chance occurrence of an index year. If the inventor chose to give equal weight to all three possible outcomes (+, -, 0), then the formula for a chance occurrence of an index year would be p^n, or $(1/3)^n$.

It should be obvious that Lyon’s paper, which the Inventor subsequently acknowledged as a model in preparing his invention, anticipates the Inventor’s method in all but the 2 x 2 contingency test.

Ghent’s paper, again which the inventor subsequently acknowledged as a model, which uses an analogous method of comparing with width of adjacent rings (right, left, or zero instead of +, -, 0), provides the continency test. As in Lyon’s paper, Ghent advocates disregarding the effect of 0, therefore the only two possible outcomes are right or left (instead of + or -). When comparing two series at a given point, and disregarding 0, the potential result of Ghent’s method is right-right, right-left, left-right, or left-left. Ghent, on p. 88, writes, “. . . the agreement between these ratings assigned to the graphs of living and dead trees is assessed in a 2 x 2 continency test.”

The primary difference between the Inventor’s method and Ghent’s method is therefore the use of the (+, -, 0) system as opposed to the (right, left, zero) system. Both methods are identical in the use of the binomial distribution and Chi-square test to assess the overall pattern match between ring width series. And both methods allow the investigator to compare a series of unknown date to one whose date is known. Lyon’s method would allow that as well.

SECTION THREE: OTHER ISSUES

The Inventor, or his representative made claims that existing tree-ring dating methods had primarily been used on a single species of tree, bristlecone pine, in the southwestern United States.

Iverson makes the following statements in another letter to the Patent and Trademark Office, this one dated 7 February 1979.

> "The Michael article is a summary of the state-of-the-art of dendrochronology prior to Applicant's invention. As stated in the Michael article, the use of tree-ring dating is not new but that its application up to now has been primarily restricted to the use of a single species of tree (bristlecone pine) indigenous to the Southwestern USA. . .
>
> "Applicant, on the other hand, has invented a system which first determines the relative tree growth period for any kind of tree at one or more sites in any region of the USA or the world and is then able to correlate the relative tree growth patterns [sic] between the sites to determine the climatic history of the area."
>
> In a letter to the Patent and Trademark Office, dated 7 February 1979, the Inventor's attorney, John I. Iverson, writes, "Douglas [sic] and his successor, Schulman, were able to construct a master tree log based on the bristlecone pine that was able to date only those wooden artifacts that occurred in the Southwestern USA and they did it by attempting to match identically the tree ring patterns of the artifact with the master bristlecone pine master tree log. The Douglas [sic] technique requires an exact, or almost exact, identity between the tree ring pattern of the artifact and that of the master log and further it requires that the artifact be from the southwestern USA."

In fact, existing methods, including the ones the Inventor referred to while developing his technique, have been applied to numerous species all over the world by the time the Inventor's application for a patent had been filed. Lyon (1936) applied his method to eastern hemlock in New England. Ghent's method (Ghent 1952) was applied to quaking aspen in Ontario, Canada. Douglass (1914, 1919, 1928, 1936) reports on dating efforts on a wide range of species, from, yes, bristlecone pine in the White Mountains of California; giant sequoia in the Sierra Nevada Mountains of California; coast redwoods from northern California; Douglas fir, ponderosa pine, limber pine, foxtail pine, Engelmann spruce and corkbark fir from a number of sites in the western U.S.; eastern hemlock and American beech in New England; Scots pine from England, Norway and Austria; *Picea excelsa* in Sweden and Germany; and King William's pine in Australia. Eckstein (1972) lists about 40 oak, beech, pine, stone pine, spruce and larch chronologies from a sites in Europe ranging from southern England to Northern Russia.

As to the argument that the other methods require exact matches, I refer the reader back to the initial section dealing with the claims by the inventor.