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ANDREW ELLICOTT DOUGLASS AND THE GIANT SEQUOIAS IN THE FOUNDING OF DENDROCHRONOLOGY

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ABSTRACT

The Giant Sequoia played several crucial roles in the founding of the modern science of tree-ring dating. These included at least two central theoretical constructs and at least two minor ones; however, historical studies of dendrochronology are actively continuing and this list is expected to expand. Second only to the importance of the ponderosa pine (*Pinus ponderosa*) in the earliest days of the infant science, the Giant Sequoia (*Sequoiadendron giganteum*) was at the very center of the establishment of the discipline of dendrochronology. How the sequoia came to be used by A.E. Douglass, and what vital information and how it provided such information is the topic here.

Keywords: A.E. Douglass, dendochronology, Giant Sequoia, historical studies.

INTRODUCTION

Dendrochronology, or tree-ring dating, is a science—or in the view of some, an amalgam of sciences—that has become a vibrant and richly productive discipline engaged in by a global network of scientists of wide-ranging backgrounds and interests, but which of many avenues of pursuit they follow depend upon the unifying features of the polyglot dendrochronology. Not unlike oceanography, scientists trained in numerous fields find that their data are best understood and their epistemology and theory generation are most logically interpreted by the application of dendrochronology and its own central theories. Dendrologists, ecologists, climatologists, astronomers, archaeologists, chemists, forest resource managers and many others have been well served by the possibilities provided by dendrochronology.

The discipline's own history, however, has been barely touched until recently. Works by Webb (1983), Nash (1999), and McGraw (2001) have, in very recent years, begun to alter that *status quo,* however. And, in all cases, these authors have found that to appreciate the creation and rise of dendrochronology, it is requisite that one comes to know its creator and long-time prime theorist and practitioner, Andrew Ellicott Douglass. Moreover, in the present case, the roles played by one species of tree, the Giant Sequoia, have also proven to illuminate much of the early developmental history of tree-ring dating (McGraw 2001).

Andrew Ellicott Douglass was born in Vermont in 1867 and died in Arizona in 1962 after a remarkably long and productive career, the last half-century-plus of which was at the University of Arizona where he practiced his primary discipline of astronomy, founded the Laboratory of Tree-Ring Research, the first facility of its kind, and sought proof that trees held evidence of the role of the 11-year solar cycle on Earth's weather—something neither he nor anyone else has yet conclusively proved. Douglass' primary drive was to demonstrate that this well-known solar cycle did, in fact, affect the long-term climate of this planet and so he spent much of his professional life trying to demonstrate that. In the process of so doing, he created what he came to christen dendrochronology as a tool to parse out his sought-after 11-year solar cycle records from the 'calendar' in the rings of trees. He truly became "the lord of the rings" (Nash 1999).

Douglass graduated from Trinity College with emphases in geology, physics and astronomy, but with no formal training in botany nor any graduate education or degrees. Later in life an honorary doctorate was bestowed upon him by his alma mater. His first professional position with Harvard University took him to Arequipa, Peru where he helped establish an observatory, which is still operating today. He was next sent by his superior, the well-known amateur astronomer Percival Lowell, to Flagstaff, Arizona to set up another observatory, again still in existence, this time for the purpose of viewing Mars in 1894 when its position was especially good for this purpose. Several years later Douglass and Lowell had a falling out over Lowell's obsession with the notion of civilizations on Mars. Lowell, it seems, had been deeply impressed with the Italian astronomer Giovanni Schiaparelli's 1877 observations of the markings on Mars (Webb 1983). Having used the term *canali* for these markings, Schiaparelli's word should have been translated as 'channels,' but this had been infamously mistranslated as 'canals,' the implication being, of course, that some intelligent force created them. Douglass could not support his mentor's views on this issue, so he wrote a letter to a colleague condemning Lowell's ideas and the letter unexpectedly fell into the senior astronomer's hands, thus leading to Douglass' dismissal from Lowell's service.

Having then to work at a number of odd jobs for a period of time, Douglass found these to be difficult years. Thus it was that in the first decade of the 20th Century Douglass' 'spare time' allowed him to create the early and very tentative science of tree-ring dating. In 1906, Douglass accepted a job with the University of Arizona, in Tucson, and departed from Flagstaff after some 12 years there and some 17 as a professional astronomer. But, to go back just a few years to 1901, while he was still working in the Flagstaff area after the split with Lowell, Douglass took a trip with a colleague and observed the changing scenery as they descended a steep incline. Many years later, Douglass explained his thoughts by saying that:

> I was making a three weeks wagon trip from Flagstaff to the towns of Fredonia and Kanab [in 1901] .... We crossed the old Lee's Ferry on the Colorado River. One day on the return we came down that immense grade on the east side of the Kaibab Plateau. We tied the back wheels of the wagon so that they could not turn, cut down a tree and chained it to drag behind .... In those horse-and-buggy days we had time to think .... In the descent our surroundings changed from pine forest to desert on account of decreasing altitude, because altitude controls the amount of rainfall, and rain controls the tree growth. If this happens in terms of location, why shouldn't something happen to the tree in terms of time . . . and therefore wouldn't it be reasonable to search for the sunspot or other solar cycles in tree-ring growth? (Douglass 1944)

This was the inspiration that led to his searching for evidence in tree rings of the 11-year solar cycle. It was not an original idea: it had been suggested for centuries that the effects of weather, though not solar cycles, might be recorded by tree rings. The great 18th century French biologist Comte de Buffon (sometimes thought of as a 'forerunner' of Darwin) and later the so-called 'father of the computer,' Charles Babbage, looked into tree rings and weather patterns (Heizer 1956). Any arguments to the contrary, the fact remains that Douglass was the only person to take the idea to the fullest and finally develop a viable science of tree-ring dating. The efforts of all his predecessors were short of that crucial viability issue no matter which, if any, of dendrochronology's central theories they may have discovered. From 1901 to 1904, Douglass did no field or lab work with trees, but gave considerable thought to what must be done.

Finally, on January 1, 1904, he examined cross-cut sections of ponderosa pines in a commercial wood yard in Flagstaff and was able to discern what he would later term *sensitive rings* in the sections. Sensitive rings were ones that were variously thick or thin because of the available moisture in the years that those rings were laid down: thin rings indicated a drought year and thick ones a year with sufficient moisture for plentiful growth. Such demanding weather conditions are typical in northern Arizona. From about 1906 and his move to Tucson to his first formal publication in 1909 on the idea that was to become dendrochronology, Douglass examined many cut sections and standing stumps and even extended his studies later (in 1912) to Prescott, Arizona, some miles distant from Flagstaff, where he was at first astonished to find similar tree-ring patterns.

His first publication on this subject was in the journal *Monthly Weather Review* (Douglass 1909) where he met with considerable resistance by a father and son editorial team (Cleveland Abbe, Sr., then 'dean' of American weathermen, and his son, Cleveland, Jr.) who saw his ideas as fundamentally heretical. Nevertheless, the astronomer had laid claim to a fascinating idea that clearly needed to be pursued. The fact that the editors of the *Monthly Weather Review* assailed him, though they approved his manuscript for publication, was enough for Douglass to fret about one aspect of the editors' resistance: Douglass did not have a very long record of weather history in his specimens of ponderosa pine. At that point, he had only several centuries' worth of data. The argument that the 11-year solar cycle could be seen easily in such material was contested by the Abbes and several reviewers of the 1909 paper. Furthermore, Douglass himself felt the need for very long chronologies. It is in that sense, among others, that the Giant Sequoia would eventually come into the picture and has been the object of interest of my recent and continuing research efforts.

Ellsworth Huntington (1876–1947), a Yale professor whose name is infamously familiar to those with an interest in the history of eugenics and those who are practitioners in the field of geography—Huntington's primary discipline—came into Douglass' life in 1910 when Huntington was on a trip to visit with a local Tucson botanist, Daniel MacDougal, who the geographer had met several years before. MacDougal and Douglass knew each other only slightly as fellow Tucson scientists, it seems, and so the astronomer was invited to a dinner at which the nationally well-known Huntington was being feted. It is possible that Huntington came to know of Douglass's aborning science at this dinner, but it was not until another year had passed and Huntington again was in Tucson on the way to California in 1911 that the geographer had become enamored of the possibilities of Douglass' infant science, he having by then read Douglass' 1909 paper in the *Monthly Weather Review*. Huntington's ideas about the role of climate as the primary formative agent for the nature of human civilizations led him to seek out the Giant Sequoia in order to see what weather histories he could discern in the rings. He knew, as did others at that time, that the sequoia grew to immense ages, though they are seldom as ancient as was then thought. Huntington had no interest in any solar connection to Earth's climate, nor to any regular cycles other than periodic ones he supposed must exist and must be correlatable with the waxing and waning of the various great civilizations. Perforce of this, when he did finally count rings in some 450 cut sequoia stumps in the logging shows north of Sequoia National Park, his methods were, at best, a bit sloppy. Later, Douglass would demonstrate that Huntington's ring counts could be off, as compared to a calendar, by as much as 300 years. Such imprecision would hardly do for Douglass when he was looking for near decadal-length cycles.

As it eventuated, Huntington asked Douglass to create a chapter for the geographer's next book (Huntington 1914). That contribution was basically an early primer on the youthful dendrochronology, but one that made use of only a single species of tree in its foundations, the ponderosa pine of Northern Arizona. The problems that inhered in that limited situation were not yet apparent to Douglass. One specific problem was that Douglass had *not* studied the pines in areas where they were likely to have sufficient moisture year round and year after year. The impact of the importance of this was soon to be seen, however, and that was via the Giant Sequoia.

On Huntington's first trip to the Sierra Nevada mountains of California, the only endemic area in the world for the Giant Sequoias, he found that the rings of the Big Trees were very hard to read: there is very little variation from year to year in this species—an evolutionary quirk quite independent of any weather history superimposed upon the rings. Much later this type of ring would be termed *semi-complacent. Complacent* trees are those, so Douglass would finally define it (in a letter to Huntington where he also coined and defined 'sensitive', see Douglass 1916a), that have enough moisture at all times that they do not show fluctuations in weather patterns, or are otherwise sensitive species but are individuals that stand in places where such fluctuations don't even exist—the Amazonian Rain Forest, for example. While the sequoia sees annual variations of snowy winters with spring runoff and then dry summers, the species is remarkable for still not showing much ring width variation. This genetic reality continues to make sequoia a challenge for dendrochronologists.

These ring characteristics led Huntington to conclude that the massive, but shallow, root system of the sequoia must hold water in the soil like a sponge parceling it out over several years, dry or wet. This, Huntington thought, explained the semi-complacency seen, and so he asked Douglass to create a mathematical formula for his chapter in his book, *The Climatic Factor,* that accounted for this. Douglass had yet to see the Big Trees in their native Sierra Nevada and so believed Huntington's assessment (this 'sponge phenomenon' was never proven, by the way). However, much worse would be Huntington's suggestion to Douglass, after the geographer's second trip west, that in order to avoid this semi-complacency problem when Douglass finally ventured to California, he should, to quote Huntington, do the following:

> In getting specimens I think you will find the best results are obtained with *trees growing in fairly moist places.* (Huntington 1915; emphasis added)

Such a suggestion would have been disastrous for Douglass' work had he been as uncritical as Huntington, but fortunately for the early development of the new science, Douglass realized for the first time that for the best sensitivity in rings he needed trees growing in areas that are NOT *'fairly moist places,'* but quite the *opposite.* He needed specimens from areas that are *water-stressed.* As it happens, Douglass could have made this crucial finding with ponderosas in Northern Arizona, but he just never happened to choose complacent pines, ones growing by continuously running streams, for instance.

So it was, then, that the first major contribution to one of the most central theoretical constructs of dendrochronology—that is, choose water-stressed specimens—came to Douglass in the form of the Giant Sequoia. Douglass realized this only after examining his cut sections, which had been shipped back to his office in Tucson, and told Huntington of it in one of the many letters the two exchanged over some three decades of friendship. The astronomer, now becoming the first dendrochronologist, stated it clearly some years later, in his first major book on dendrochronology when speaking of one of his specimen trees:

> Tree No. 6 grew at the edge of the little brook running [into the basin I was studying] . . . and its rings proved later very uncertain in identity, *because its habitat was complacent* . . . (Douglass 1919a; pg. 46; emphasis added).

Douglass had finally seen this when he first went to visit the sequoias in 1915, having literally followed a trail blazed by Huntington. Indeed, the astronomer even took cut sections from many of the same stumps that Huntington had looked at several years before. Huntington merely did counts on site by lying nose to wood on the tops of cut stumps and had procured no specimens to return to a laboratory setting where careful study could be undertaken—hence his often wildly inaccurate counts and calendar year assignments to given rings. The reason Douglass sought the sequoias in the first place, however, had nothing to do with sensitivity and complacency studies—that investigation was still to come at that point—but, rather, to work with trees which had lived for immense periods of time and could offer Douglass *long chronologies* for his solar cycle studies. Above all, Douglass was an astronomer committed to the discovery of an 11-year cycle of solar forcing of Earth's weather and a means to find evidence on this planet for what he was sure was true. Though the semi-complacency of the sequoia was a challenge for Douglass, he did obtain his much-desired long chronologies.

From the time of his 1909 *Monthly Weather Review* announcement to the world of science of his new discipline, he had continued to smart from the editors' and reviewers' skepticism. They had suggested that his pine chronologies were too short and so he knew he had to extend that record. Only with sequoia could he ever expect to find, handily in a single specimen, a tree that might have two or even three thousand years of data stored within. By late 1915, after his first trip to the Sierra Nevada, then, Douglass had discovered that the Giant Sequoia had 1) shored up his lack of long chronologies, and 2) as he said in a letter to Huntington (Douglass 1916a), Douglass had made the discovery of the need for water-stressed specimens. But by that time, the new science was only a decade old and for the next half century, Douglass would continue to return to the Giant Sequoia in order to gain ever more data in hopes of extending his chronologies yet further back in time.

Although the sequoia never truly played a role in the effort to date the ancient Anasazi Indian dwellings of America's "Four Corners" region, it was not because Douglass was not fully intent on trying to make it do so. For this reason, the matter needs some mention, vis-à-vis the role of sequoias in the founding of dendrochronology.

In the period around 1915–1916, Douglass was the Dean of Arts and Sciences at the University of Arizona, was teaching physics and astronomy, and was also deeply involved in attempts to identify a donor to help underwrite an observatory for the University. Those efforts and others kept Douglass very busy, yet he found time for pushing ahead on making dendrochronology a highly viable science, his trip to the sequoias being only part of that involvement. The first real application for tree-ring science came in those years (and continued well into the next decade) in the form of archaeological dating efforts. This matter has been covered in considerable detail only recently by Stephen Edward Nash (Nash 1999). Though I will say little here about this stunningly successful application of dendrochronology, I do want to mention it as there is a sequoia connection in the sense that Douglass attempted to employ sequoia data in his archaeological dating work. One reason that Douglass may have turned to the distant sequoias, they being in California while the ancient Anasazi Indians had built villages in Arizona, New Mexico, Utah and Colorado, was because only the sequoias could (at that time) provide long chronologies and dates 4,000 to 2,000 years of age. That time period had already been put forth as the likely cliff dwelling construction era by such famous archaeologists as Alfred Vincent Kidder and Frank H. H. Roberts (Nash 1999; see also especially Kidder 1924).

It was in this connection that Huntington once again appeared in the communications of Douglass; Huntington was involved in so much of American science. Having seen a newspaper clipping regarding Douglass' effort to apply tree rings to the dating of the Anasazi ruins in the Four Corners area, Huntington averred that: "My chief fear is that there may not be any trees of sufficient age near the ruins to make the correlations dependable" (Huntington 1916). There is an interesting problem presented by Huntington's 'fear.' It is evident that he still did not grasp the most fundamental theoretical construct of dendrochronology: cross-dating. By the use of cross-dating, the astronomer was able to date living and dead tree material and by *overlapping specimens backward in time,* discover similar ring patterns and filling gaps that any one specimen might not be able to fill as it was not long-lived enough. One can use living trees, by coring or cutting them, or use anciently-cut trees, such as Anasazi roof beams. The notion of cross-dating occurred to Douglass in the first years of his tree-ring studies. With the exception of Babbage (above) and possibly a few others who clearly grasped cross-dating, this concept was never incorporated into any viable early version of what could be called a science of tree-ring dating. (There remains some historical dispute on this and related matters pertinent to the science of dendrochronology: see, for instance, Heizer 1956; Stallings 1937; and Wimmer 2001, among others.) Cross-dating is what makes dendrochronology work. Huntington did not realize that Douglass would of necessity seek progressively older wood samples from a more restricted geographic location, here the Four Corners, to build a *local* long chronology, thus making it possible to date the ancient dwellings. In fact, it took Douglass, archaeologist Neil Judd and others until 1929 before the problem was solved, but building the *local* long chronology was exactly the method that was finally used.

In that same letter to the astronomer (1916, above), Huntington asked about Douglass' findings with regard to his recently collected sequoia samples and Douglass answered in such a fashion that it was clear, at that point, that he hoped to employ sequoias in his archaeological dating work. This remains something of an enigma as it implied that Douglass felt that data generated from tree rings from sequoias gathered many hundreds of miles away in California might present useful climatic data by which to build a long chronology suitable to dating the ruins of the Four Corners area. Douglass' response suggested that he felt, or at least hoped, that sequoia weather pattern data would be similar to that found in Arizona pines. Indeed, to some degree it did, and does, show gross similarities, but of insufficient correlative power to prove a surrogate for a long chronology applicable to Four Corners archaeological dating demands. But in those first years of doing archaeology, Douglass was optimistic for his sequoia data as he told Huntington that:

> I hope, however, that with the measurements which I am now making on the sequoias from California I can get a comparison that will have a good deal of reliability. I believe I shall be able to tie up the modern trees to the sequoias by some relation of growth and then perhaps find a similar connection between the old pueblo trees (*i.e.* roof beams) and the sequoias (Douglass 1916b).

Douglass 'hope(d),' he 'believe(d),' and he felt that 'perhaps' he might find a usable correlation. Clearly, he did not feel particularly sanguine about the prospects for success. Over a number of years he continued to 'hope' for such usefulness, but it became clear that the only truly reasonable way to gain an insight into the actual dates when the Anasazi were building in the Southwest (up until about the year 1300 A.D., as it was finally discovered) was to do so via a *locally-generated* chronology.

That hoping was not particularly characteristic of Douglass, a man to whom carefully worked data were the only really acceptable data. He was, to use Nash's term, an "analytical conservati[ve]." To leap ahead in time for a moment, it should be pointed out that Douglass made a total of five trips to the sequoias to build long chronologies for his astronomical interests, but he also held out hope of using sequoia for Anasazi dating until as late as 1926, for as Nash (1999) has shown one could argue that Douglass' 1924 and 1925 trips to collect specimens in the Giant Sequoia groves of California were because at that time his primary strategy for dating southwestern archaeological sites consisted of comparing their ring sequences with his by then 3,200-year-long sequoia chronology.

Implied in Nash's words is the notion that there was an alternative way to finally solve the dilemma of when the Anasazi were occupying the mesa country of the Four Corners. Indeed, there was and it has been known for decades in the discipline as the "bridging the gap" method. In short, it was to continue to build *local* long chronologies for the Southwest until at some point the various "floating chronologies," those that represented real roof beam data from ruins but which had unknown beginning and ending dates as compared against the established calendar, could be fixed in calendrical time; the 'gap' of time between 'floaters' could be 'bridged.' That occurred with the discovery of the famous beam HH-39 on June 22, 1929, in Showlow, Arizona and changed forever American archaeology (though Douglass understood the gap dates by as early as 1927, as Nash has shown). The point here for sequoia's role is that up until 1926, Douglass still hoped the Big Tree would be his salvation. He must have realized around then that would not be possible. Indeed, there would be three more years of uncertainty until "bridging the gap" with local southwestern wood finally did solve the problem. Douglass had hoped that a strong correlation in ring histories across a vast expanse of the American landscape would be the answer: it was not.

In regard to the other benefits that sequoia bestowed on the young science of tree-ring dating, one emerged from a way to ameliorate the semi-complacency problem. Douglass wrote to his contacts at the Carnegie Institution in Washington, who had provided grant monies to him and who published his series of books on dendrochronology, *Climatic Cycles and Tree Growth* of 1919 being the first, explaining his discovery thus:

> I am just ready to work out the very best sequoia ring-record for 3200 years, using only the best parts of the best trees. I have developed a criterion . . . that I call the mean sensitivity . . . . Expressed for a decade it is the average variation from year to year divided by the average yearly growth for the decade (Douglass 1919b).

While that was the version employed for decades, later dendrochronologists at the laboratory that Douglass founded in Tucson have since refined it, but have not discarded it.

Finally, a fourth contribution made to the basic tenets of tree-ring science was to find a tree species that does not produce what are known as false rings that can be seen in many species; sequoia does not produce false rings. Such rings can originate in several ways and can mislead a researcher who might interpret them as annual rings when they are something less, for instance evidence of a mid-summer wet period and a burst of growth mimicking an additional annual ring (the complex area of false rings is covered in greater detail in Stokes and Smiley 1968).

There has been much more of a role for sequoia over time and in the developmental history of the science of dendrochronology than has been covered in this short history (*e.g.* sequoia's role in the development of the skeleton plot; the history of which still remains unplumbed). Certainly, in Douglass' own lifetime, the Big Tree became the darling of the field for him as he sought ever-longer chronologies. Douglass became obsessed with not only the 11-year solar cycle search, but tended to find many, many other cycles, as well; a situation I term in my book as the 'too many cycles problem' (McGraw 2001). He invented several complex instruments, two of which, the periodograph and its later incarnation, the cyclograph, could project tree-ring cycles onto a screen or photographic negative and which were used by him to interpret cyclic data. The actual meaning of the visualizations so produced, however, is far from clear and the history of these several instruments and their applications is just now under study (by Mr. Shaw Kinsley of Tubac, Arizona).

In more recent times, the Giant Sequoia has been used to understand better the fire history of forest environments in which they occur (see, for instance, Swetnam 1993, among many). Few trees are as fire- and pathogen-resistant as the sequoia and as able to heal over damaged areas, thus preserving a record of historic events that affected a given tree specimen. Much basic science, including a better understanding of the El Niño events, and a much better grasp of resource management techniques has also come from use of sequoia.

In Douglass' later years, his obsession with 'too many cycles' overshadowed some of his achievements, some would argue, but the basic discoveries that came from the Giant Sequoia and that were made exclusively by the creator of dendrochronology, is a success story that, like the Big Trees themselves, will make forever Andrew Ellicott Douglass an 'enduring giant.'

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