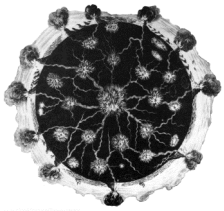
THE MESOZOIC/DEFINING DISCIPLINES: LATE NINETEENTH-CENTURY DEBATES OVER THE JURASSIC–CRETACEOUS BOUNDARY

DEBRA LINDSAY

Department of History and Politics
University of New Brunswick, Saint John, NB, Canada E2L 4L5
dlindsay@unb.ca



Earth Sciences History
2011, Vol. 30, No. 2
pp. 216–239

ABSTRACT

The last two decades of the nineteenth century were exciting times in American paleontology, with disputes over Jurassic dinosaurs between Edward Drinker Cope and Othniel Charles Marsh appearing in the press. Less well known is the dispute over defining the Mesozoic that began in 1888 when Marsh invited Lester Frank Ward, a colleague with whom he had been working on the Potomac Formation for the United States Geological Survey, to speak on the plant fossils found there. Initially agreeing with Marsh that the Potomac was a Jurassic formation, work on fossil cycads led Ward to conclude that the Potomac was Lower Cretaceous. As Ward and Marsh grappled with the question of how to determine the age and identity of Mesozoic systems, they joined other paleontologists and geologists such as William J. McGee, Albert Charles Seward, and Samuel W. Williston in a debate that often reflected scientific training and sub-specializations as much as stratigraphic principles, becoming caught up in a trans-Atlantic dispute in which their reputations were on the line as they claimed that 'their' fossils were key determinants of Mesozoic systems. In the end, Marsh's reputation as a paleontologist was far better established than that of Ward, who moved on to another career as a sociologist at Brown University, but cycad discoveries from Maryland, Colorado and Wyoming, and fieldwork, trumped laboratory studies—even when performed by a master systematist—as the Potomac Formation proved to be Lower Cretaceous.

1. INTRODUCTION: O. C. MARSH, L. F. WARD AND THE POTOMAC FORMATION

In 1888, after working together as part of a team pulled together by John Wesley Powell (1834–1902) to study the Potomac Formation in Maryland, Othniel Charles Marsh (1831–1899) (see Figure 1) asked Lester Frank Ward (1841–1913) (see Figure 2) to speak to the National Academy of Science about the fossil plants that had been discovered there.[1] Interest in the Potomac had begun over forty years earlier when William Barton Rogers (1804–1882), working for the State of Virginia, examined the formation; but systematic study was not undertaken until scientists with the United States Geological Survey went there in the 1880s. Thereafter there was a flurry of activity, with William John McGee (1853–1912), a geologist with the Survey, and Marsh, being the first in print.[2] In a 'Notice of a new genus of *Sauropoda* and other new dinosaurs from the Potomac Formation' Marsh stated that the vertebrate fossils "seem to prove conclusively that the Potomac formation in its typical localities in Maryland is of Jurassic age",

[1] Ward stated he was officially asked to work on the Potomac Formation for the USGS in 1885, and Marsh refers to a similar request made the previous year. See Ward, 'Annotation to 'The Potomac Formation' (April 1896) in *Glimpses of the Cosmos* 5: 260. See Annotation to 'Evidence of the fossil plants as to the age of the Potomac formation' in *Glimpses of the Cosmos* 4, pp. 114–115 for reference to Marsh's request.

[2] An overview of paleontological research on the Potomac, and other allegedly Cretaceous formations, was provided by Stanton (1897, pp. 579–624). See p. 585 and the accompanying bibliography, pp. 610–621. More specifically: Rogers (1841 and 1875, pp. 101–106), Tyson (1860), and Fontaine (1879, pp. 25–39, 151–157, 229–239). Publications from the 1880s included: McGee (1886, pp. 19–20 and 23–25; 1888a, pp. 120–143, 367–388, 448–466; 1888b, pp. 537–646), Marsh (1888, p. 94), Uhler (1888, pp. 42–53), Ward (1888, pp. 119–131), and Fontaine (1889). Publications from the 1890s included: White (1890, pp. 93–101), White (1892, p. 332), Darton (1891, pp. 431–450 and 1893, pp. 407–419), Uhler (1892, pp. 185–200), Bibbins (1895, pp. 17–20), Clark (1895, pp. 479–482), Ward (1895a, pp. 307–397; 1896, pp. 463–542; and 1897, pp. 411–419), Fontaine (1896), and Marsh (1896b, pp. 295–298; 1896c, pp. 433–447; and 1898, pp. 105–116).

and assuming they shared similar views, Marsh approached Ward, through Powell, requesting that he deliver a paper on Potomac plant fossils (Marsh 1888, p. 94).

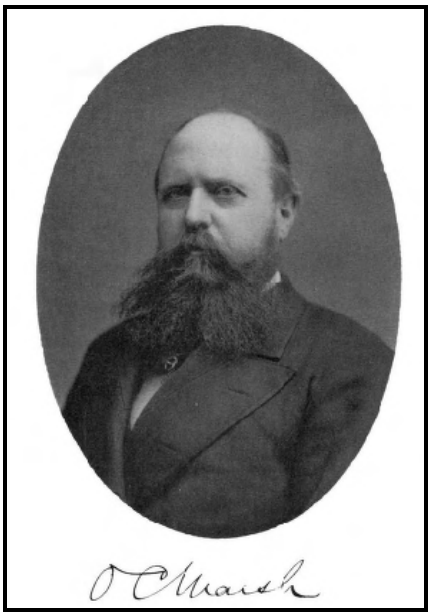


Figure 1.
Othniel C. Marsh (1831–1899). By courtesy of Yale University Archives.

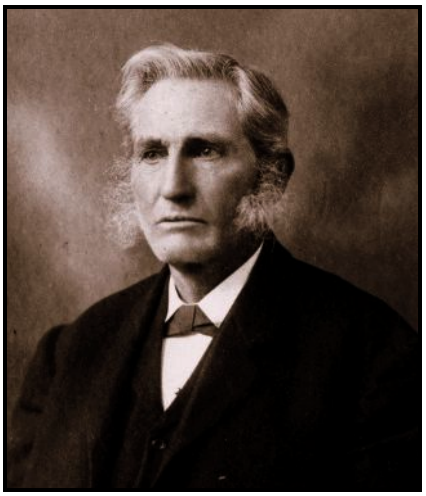


Figure 2.
Lester Frank Ward (1841–1913). By courtesy Yale University Archives.

Much the junior paleontologist, Ward initially demurred, suggesting that Marsh find a better-qualified speaker. When this suggestion was not accepted, Ward went to William Morris Fontaine (1835–1913), the author of two important works on the Potomac—'The Mesozoic strata of Virginia' (*American Journal of Science* 1879) and the soon to be published *The Potomac or Younger Mesozoic Flora* (United States Geological Survey, 1889)—as well as a monograph on the *Older Mesozoic of Virginia* (1883), and personally asked the professor of geology at the University of Virginia to deliver the paper. Fontaine declined, ominously stating that Ward was better suited to the task as he "would come with ideas unbiased by long delving over the minutiae of description, and would probably examine it from new points of view. . . . I

am besides heartily sick of it, while your interest would be fresh".[3] Ward subsequently accepted Marsh's invitation—a decision ultimately responsible for transforming an amiable relationship into one that was sometimes anything but collegial.

The controversy that followed suggests that Fontaine was wise to steer clear of the request, but any inkling of trouble brewing was missed by contemporaries and has been subsequently ignored by historians. Perhaps it was inevitable that the two men would eventually disagree as Ward was a paleobotanist and Marsh a vertebrate palaeontologist, but at the time their differences paled compared with those between Marsh and Edward Drinker Cope (1840–1897). So intense was the rivalry to out-do each other in finding, identifying, and classifying vertebrate fossils that by 1890 Marsh and Cope exchanged accusations in the popular press of destroying fossils and plagiarizing papers, contributing, according to Mark Jaffe, to Congressional decisions to cut funding to the United States Geological Survey so as to virtually eliminate funds for paleontology, whereas Marsh and Ward went about their work without dissent.[4] So far as anyone could see, they were in agreement on the Potomac, with British botanist Albert Charles Seward (1863–1941) going so far as to intimate that Ward was rather sycophantic, capitulating to a dinosaur man and providing "another example of an apparent discrepancy between plants and animals as indices of geological position" (Seward 1894, p. xxviii).

That Ward deferred to Marsh was hardly surprising. Although Ward had published on a variety of topics—history, religion, philosophy, psychology, anthropology, sociology, chemistry, embryology, botany, entomology, and evolution, in both popular and scholarly formats—and had managed to have his first essay on the 'geological history of plants' published in 1879 within months of doing the fieldwork, a systematist like Marsh would have seen Ward's record as esoteric (at best) and probably irrelevant to science (Ward 1879, pp. 3,089–3,090). Despite being the honorary curator of fossil botany at the United States National Museum (since 1880) and a geologist at the United States Geological Survey (since 1882), Ward's efforts had produced little that was original (Ward 1905, pp. 357–369). His major publications, for example: the 'Sketch of paleobotany' in the *Fifth Annual Report of the United States Geological Survey* (1885); the 'Evolution in the Vegetable Kingdom' in the *American Naturalist* (1885); or the 'Geographical distribution of fossil plants' in the *Eighth Annual Report of the United States Geological Survey* (1886–1887, 1889) were synthetic.[5] None were comparable to what Marsh had done—despite twentieth-century critics' descriptions of the vertebrate paleontologist's output as underwhelming in comparison to his rival Cope. Ward admitted as much.[6]

By 1888, Marsh was a well-known vertebrate palaeontologist. Following the advice of Carl Ferdinand von Roemer (1818–1891), one of his professors at the University of Berlin, who had advised him to look for Jurassic formations in North America where, Roemer was sure, they would be found "full of fossils", Marsh—or his collectors—had devoted almost thirty years to searching for Jurassic fossils, finding them in Colorado, Wyoming, Kansas, and Utah (Marsh 1896c, p. 433; Rainger 1990, pp. 14–18; West 1990, pp. 47–49; Jaffe 2000, pp. 185–199). Through detailed anatomical studies, Marsh identified the distinguishing features of *Sauropoda*

---

3 William Fontaine to Lester Ward, 22 February 1888, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1. Fontaine's work is rarely discussed; but see Gillespie and Latimer Jr (1961, pp. 161–163).

4 There are several accounts of the Cope–Marsh feud, the most recent by Jaffe (2000). See pp. 321–344 regarding the public feud and its consequences and p. 367 for a paragraph on Marsh's interest in the dispute over the Jurassic–Cretaceous boundary as it contributed to his collection of cycads. Only one recent reference to the Potomac dispute has been found—by Peter Kranz (see: http://terpconnect.umd.edu/~gdouglas/ironores/index.html).

5 Ward provided a history of the events of 1883–1888 in 'Status of the Mesozoic floras of the United States, Second Paper, Part I' (1905, pp. 357–369) but he always maintained a comprehensive record of his publications that was included, where appropriate, in *Glimpses of the Cosmos*. The original list is in the Lester Frank Ward Collection, John Hay Library, Brown University, Providence, RI, Ms. 90.23, Series I, Sub-series A–5 and Sub-series C.

6 On Marsh's career Jaffe cites biographers Schuchert and Le Vene (1940, reprinted 1978, p. 310). Marsh had 270 publications or one-fifth that of Cope (Jaffe 2000, pp. 281 and 370).

(1878) (an order he proposed) and he reconstructed whole dinosaurs (McIntosh *et al*. 1997, pp. 265–266). He also had other firsts to his credit, differentiating between carnivorous (theropods) and two-footed, bird-like dinosaurs (ornithopods) in 1881, and classifying his finds into a number of genera, nineteen of which are still considered valid by contemporary vertebrate paleontologists (Brett-Surman 1997, pp. 331; Jaffe 2000, pp. 380–382). That Marsh was an expert on the Jurassic was beyond doubt, and when one of his most knowledgeable and experienced western collectors, J. B. Hatcher, presented him with fossilized skulls, vertebrae, limbs, feet, and teeth from the Potomac, Marsh immediately recognized their similarity to dinosauria from western formations and thus named them *Pleurocoelus nanus, Pleurocoelus altus, Priconodon crassus, Allosaurus medius,* and *Coelurus gracilis* (Marsh 1888, pp. 89–94). Although four of the Potomac dinosaurs Marsh classified as Jurassic have since been re-classified as Cretaceous, the western species with which they were compared were, as Marsh had contended at the time, from Jurassic formations.[7] But in the absence of other data, it is unsurprising that Marsh believed that the Potomac Formation was Jurassic. Thus the less experienced palaeontologist Ward would have been ill advised to question the expert—especially as he had not yet done much in the way of original research.

Despite protesting many years later that he had been ambivalent about the age and composition of the Potomac in 1888, stating that the Potomac "flora contains a large proportion of Jurassic types, and that its dicotyledonous forms are very archaic in character, constituting in all probability, their earliest recorded appearance . . . [and it] is maintained that, owing to this peculiar character, they do not necessarily prove that the Potomac Formation is Cretaceous" (Ward 1915, pp. 302–303), at the time his comments were interpreted as supporting Marsh's claim. In a letter to his justifiably cautious friend Fontaine, Ward stated that he had been misunderstood, and the responses of Edward Drinker Cope and John Strong Newberry (1822–1892) in particular caused him to state:

> I do not think that a proper understanding of my remarks commits me at all to the Jurassic theory. It is true I say more about that than the other, but it is because it had been assumed that a flora with so many dicotyledons must of necessity be Cretaceous. All I aimed to prove was that this was not a *necessary* conclusion, and I intended to leave it so that if the stratigraphy and the animal remains required its [*sic*] reference to the Jurassic the plants would not present any serious obstacles to such a reference.[8]

How this qualification improved on his original statement is unclear, and furthermore, others such as McGee and Seward interpreted his talk in the same way.[9] Ward was, as Marsh assumed, an ally.

By 1891, however, Ward had reassessed his position. If he had been, as Seward implied, subservient to more senior scientists like Marsh in 1888, Ward's transformation from supplicant to specialist was relatively rapid and without humility. Experience in the field and in the scientific community, where he was founder, Vice-President, President, and executive member of the Biological Society of Washington every year until 1896, and where his papers on botany and paleobotany were staples of the Society's bi-monthly meetings,[10] convinced him he had earned the right to speak his mind and dispense advice as someone who had himself grappled with the question of the age and identity of geological formations. Contrary to what most twentieth-century critics have said about his work, namely that it was amateurish and unimportant, Ward behaved in a manner befitting an expert in the earth sciences as he waded

---

7 Information on the age, location, paleoenvironment, class, and synonymy of vertebrate fossils may be found in the Paleobiology Database, associated with the National Center for Ecological Analysis and Synthesis. Available at: http://paleob.org. Accessed 10 October 2010.

8 Ward to Fontaine, 21 May 1888. In: Ward (1905, pp. 368–369).

9 Ward to Fontaine, 21 May 1888 and Fontaine to Ward, 14 June 1888, in Ward (1905, pp. 368–369).

10 Smithsonian Institution *Annual Report* (1881), p. 109 and *Proceedings of the Biological Society of Washington* 5 (1890), p. v and *passim*.

into debates that were far from settled.[11] In particular, he weighed in on the principles of geologic correlation when fossils were still considered far from essential by some of his colleagues at the Geological Society of America.

2. STRIFE AMONG STRATIGRAPHERS: EARLY DEBATES

Ward joined the Geological Society of America soon after it was formed in 1889, and the following year an exchange occurred that encapsulated differences between the geological and paleontological membership that were only resolved in 1933 when the Society formalized rules for stratigraphic classification and nomenclature, including the appropriate use of fossils (Section II, Article 6; Section V, Article 23).[12] At a meeting in 1890, Charles Doolittle Walcott (1850–1927), paleontologist and future head of the USGS, noted that geologist William John McGee ignored fossils evidence in his paper on the Appomattox Formation, stating:

> I have listened with a great deal of interest to Mr. McGee's paper, because it describes the determination of a geologic horizon over a great area without the aid of paleontologic data. It is true that the underlying unconformable series is determined by the contained fauna and gives the approximate horizon, but it is very rarely that we have an illustration of a satisfactory attempt to identify by the stratigraphy alone a formation so widely distributed as the Appomattox (McGee 1890, p. 549).

Paleontologist–geologist James Hall (1811–1898) replied: "[t]he communication shows very clearly that physical geology can be successfully carried on without the use of fossils"; and returning to the topic a year later there was still reluctance to accord fossils greater significance. While scientists tended to agree that Old World classifications could be applied in the Americas and elsewhere, there was less agreement about which systems were identical (in a time before continental drift theory came on the scene), even less consensus as to whether those systems were contemporaneous, and a complete breakdown when it came to deciding the criteria to use in the determinations (Fontaine 1889, pp. 331–332; Woodford 1963, pp. 75, 80, 93–94, 97–98, 108). The recognition that fossils were once living organisms and that fossil distributions differed from one stratum to the next (vertically) did not resolve the tensions over the relative merits of paleontological and lithological evidence that emerged during the nineteenth century and persisted well into the twentieth century as geologists worked through the implications of the 'new stratigraphy'. So when in 1891 McGee declared that a number of plant fossils had been found by collectors and studied by Leo Lesquereux (1806–1889) Ward averred that "the age indicated by the few fossils thus far identified is hardly consistent with the voluminous evidence of stratigraphic position" (McGee 1891, p. 4; Morello 2003, pp. 259–261).

If paleontologists admitted to the Geological Society thought they would be leading the debate over the identity and age of geological strata/systems, they were to be disabused of such ideas, but as Ward considered himself both geologist and palaeontologist, in a Society whose Constitution stipulated that all Fellows were to be working geologists and teachers of geology, he was confident that he had something innovative to say and seized the opportunity to share his views at the Washington meetings of the American Association for the Advancement of Science

[11] The most laudatory analysis of Ward's scholarly contributions is by James J. Chriss (2006), followed by somewhat less positive accounts by Gerver (1963), Nelson (1968, 1972), Romans (1973) and Lubick, (1988). An edited volume of Ward's writings by Samuel Chugerman (1939) bridges positive and negative assessments. More commonly held views are negative, for example: Burnham (1954), Becker (1968, pp. 68–96), Russett (1976, pp. 102–111), Bowler (1993, pp. 62, 67), Cravens (1977, pp. 817–818 and 1985, p. 199), and Zimmerman (2007).

[12] See introductory comments in G. H. Ashley (1933, pp. 424–427). The successor to this early effort is the North American Stratigraphic Code, North American Committee of Stratigraphic Nomenclature, *American Association Petroleum Geologists, Bulletin* 89, No. 11 (2005, pp. 1,547–1,591).

(Friday, 21 August) and the International Geological Congress (29 August).[13] He did not seem to suspect that his efforts to educate geologists who believed "that the determinations of vegetable paleontologists are in large measure mere guess-work" (Ward 1884b, p. 532)—an assumption he found prevalent among critics who believed paleobotanists had "unsound principles or improper methods [that] have been employed in reasoning from paleobotanical data" (Ward 1891, p. 282)—might offend his colleagues.

As Ward laid out the requirements of his discipline, a specialization he described as more exacting and demanding than either botany or geology, he pointed out that it had suffered from the ignorance of outsiders, who had an incomplete understanding of its constraints, and insiders, who had been working in a nascent science that was "in an unsettled and unorganized state", and who were in need of principles to guide their work. Speaking to four points he argued that different deposits may be "homotactically correlated without being contemporaneous, while, on the other hand, those having very different floras may have really been contemporaneous"; that the "great types of vegetation are characteristic of the great epochs in geology" and may thus be used as guide or index fossils; that when considering fossil evidence it is important to consider the sufficiency or abundance of evidence rather than its uniqueness so that "where the material is ample, fossil plants are as reliable as any other class of paleontological data"; and that

> The correct systematic determination of fossil plants concerns biology and does not concern geology. . . . [A]ll that is required from his point of view is that the fossil be definite, constant, and easily recognizable. . . . Such as possess these qualities and are also characteristic of a given deposit have their full diagnostic value independently of the question whether their true systematic position has been determined or not (Ward 1891, p. 282).

Those present might have expected Ward to challenge the views of paleozoologists (like Marsh) who disputed the 'diagnostic value' of fossil plants in determining the age and identity of geological formations—especially as Ward had changed his stance on plants as guide fossils and as Marsh had delivered a paper to the Congress the previous day on 'Geological horizons as determined by vertebrate fossils'—but Ward adopted a new strategy. He focused on the failings of geologists and botanists.

While chastising the "[p]urely stratigraphical geologists" for criticizing work done in a discipline when they did not understand the most basic assumptions underlying such work", he added that paleobotanists had to deal with uninformed stratigraphic geologists who misunderstood the value of "limited material or fragmentary specimens" when determining the age of a geological formation as if they were "unscientific persons" (Ward 1892a, p. 37). He then levelled a similar charge against botanists whose concerns were, he alleged, misplaced. Botanists assumed they could easily identify fossil plants by comparing them with living species, and they had "little patience with such fragmentary material as constitutes the bulk of most collections of fossil plants". As a result they left "the impression that there is great uncertainty with regard to the true nature of vegetable remains", suggesting "that nothing can be

[13] For information on founding the Geological Society of America see: 'Provisional Constitution and By-laws', *Bulletin of the Geological Society of America* 1 (1890): p. 7, and 'List of Fellows, 20 May 1889', *Bulletin of the Geological Society of America* 1 (1890): p. 132. Ward's presentation was published, in part, in three places: [Abstract of] 'Principles and methods of geologic correlation by means of fossil plants', *Science* 18, No. 459 (1891): p. 282; 'Principles and methods of geologic correlation by means of fossil plants', *American Geologist* 9 (January 1892), pp. 34–47; and 'Principes et methodes d'étude de corrélation géologique au moins des plantes fossils' (*Extrait du compte-rendu de la cinquième session du Congrès Géologique International*, Washington, 1891), *Proces-verbaux des séances*, Washington, 1892, pp. 97–109. The last publication was examined in the Lester Frank Ward Papers, 1883–1919, Special Collections and University Archives, Gelman Library, George Washington University, Washington, D.C., MS 0247, Series 2: Articles, 1888–1913. There is an interesting synopsis of the Congress in Clifford M. Nelson (2006), pp. 279–286. Participants and topics discussed between 27–31 August are listed, and Nelson notes that Ward "made his case for the chronologic utility of fossil plants", whereas Marsh advanced an argument preferring vertebrates over all other fossils for the same purpose. See pp. 282–283; quotation from p. 283. Marsh's views appeared in 1879, pp. 335–359.

known of a plant without having all its organs and parts before them"; and consequently they drew "leaves so carelessly that the paleobotanist is unable to tell the genera to which they belong" (Ward 1892a, pp. 38–39).

Ward's comments were not well received and he was greatly insulted when his paper on the 'Relations of the plant-bearing deposits of the American Trias,' which included his conference presentation, was not published in full in the *Bulletin of the Geological Society of America*. And in January 1892 he resigned from the Society, never to rejoin.[14] That his manuscript was not published should hardly have been surprising though. In addition to slighting the geological profession on an international stage, American geologists did not support at least two of Ward's claims, specifically: (1) that biological evidence was crucial to determining the identity and age of geological strata; and (2) that it was possible to compare and classify lithographically similar strata separated by vast distances using fossil flora and fauna. Feeling spurned by the Geological Society and clearly smarting from what he saw as unwarranted criticism, Ward refocused his attention where it might be more profitable—on the botanists—attacking them for what he saw as attitudinal and methodological deficiencies.

The botanists were upbraided no less publicly than were the geologists at the Washington conferences. Allegedly concerned about the "absurdities of botanical nomenclature" since his first forays in botany more than two decades earlier, Ward participated in the discussions to reform botanical nomenclature in May 1892 that culminated in a fractious debate between the 'conservatives' who did not want change and signed the so-called Harvard Circular, and the radicals, a minority group that wanted to apply precepts adopted by the American Ornithologists' Union in 1886 to plants (Ward 1895b, p. 313; Ward 1917, pp. 197, 199–200). As a member of the 'radical' faction Ward castigated botanists for using what he regarded as an irrational and outdated method of naming specimens, and provoked them further by accusing them of doing half a job when it came to fossil plants. At a meeting of the Biological Society of Washington in January 1893 he pointed out that "hitherto the study of fossil plants has been conducted wholly from the geological standpoint", thus overlooking the complexity of plants, both present and past (Ward 1893, p. 44; Ward 1915, p. 367). He continued:

> Do they prefer to drudge upon the tissues of living plants to learn what may be known by actually confronting the witnesses themselves of the real character of the ancient vegetation of the earth and the true lines along which it has developed? It cannot be. And yet such would be the logic of their action" (Ward 1893, p. 44).

After thus antagonizing the botanists, he tried to goad them to action, saying:

> A new method is therefore loudly called for, by which far greater certainty than heretofore can be reached in establishing the real nature and affinities of extinct floras. In other words, they must be studied from the botanical standpoint and all the light brought to bear upon them that the known flora of the whole globe is able to shed. This is no simple task, it is one that demands the highest ability and the widest facilities (Ward 1893, p. 44).

As usual, Ward was tactless. He did, however, raise some valid points. Almost seventy years later Tom M. Harris, a paleobotanist who had studied under Seward, agreed with him. Equally forthright, Harris expressed his concerns with paleobotanical principles and methods in the fourth annual address to the Palaeontological Association (United Kingdom), making three recommendations. He urged scientists to move out of the laboratory into the field so as to see for themselves if there was "evidence of association" among specimens. Relying on donations from paid collectors or dilettantes had encouraged species multiplication, as paleobotanists who did

[14] Ward (1915, p. 308). Ward also mentions his resignation in his diary, or 'Record of work and principal events, 10 January 1892', Lester Frank Ward Papers, Special Collections and University Archives, Gelman Library, George Washington University, MS0247, Box 1. The article was published as 'The plant-bearing deposits of the American Trias', *Bulletin of the Geological Society of America* 3 (1892): pp. 23–31.

not do fieldwork often classified fragments as separate species on the basis of bits and pieces that seldom included the reproductive organs of fossil plants—the best clues, he claimed, to their true identity (Harris 1961, pp. 322–323). He appealed to his colleagues to resist the temptation to classify every stem and leaf as a separate species. But while Ward may have anticipated Harris's admonitions, he was as guilty as any when it came to the problem of species multiplication. Ward 'found' some three-dozen new species of cycads, most of which he placed in a genus that he created (*Cycadella*)—subsequently considered to be no more than two or three species of the genus *Cycadeoidea*—as well as more than two-dozen new species of non-cycad Mesozoic plants.[15] (See Figure 3.)

Both discoveries were key to Ward's work on the Mesozoic: they could fill in a gap of which Ward was only too well aware. Two years earlier when he had surveyed the literature on paleobotany for *Johnson's Universal Cyclopaedia* he had to refer to cycads as a "rare group". Even though Europeans had been studying them for decades and had determined they were "the leading type of vegetation over the greater part of the earth" in the Jurassic, few had been found in America and those that had were accompanied by dicotyledonous plants—that is, with plants associated with Cretaceous rather than Jurassic strata.[16] Ward therefore believed he had at his command, together with a small number of fossil cycads discovered in Maryland in 1859 by Phillip Tyson, the specimens needed to trace the origins and development of an important Mesozoic plant (see Figure 5).

Figure 3.
Cycadella jejuna, *from the Jurassic of Wyoming, in the collection of the Museum, University of Wyoming, Plate CLIX; from Ward,* Status of the Mesozoic Flora, Part I: The Older Mesozoic Twentieth Annual Report of the United States Geological Survey, Part II *(Washington, 1900), p. 412.*

3. FIELDWORK AND THE MESOZOIC: BOTANICAL *VERSUS* ZOOLOGICAL EVIDENCE

Despite Ward's rousing appeal for reform, two events encouraged his propensity to 'find' new Mesozoic plants. First, in 1893, within a month of informing the botanists of their shortcomings, Ward received photographs of six plant fossils collected by a 'resident' living near the Black Hills of South Dakota, which he 'perceived' to be similar to fossil cycads collected over thirty years earlier in Maryland (Ward 1894b, pp. 251–252). He therefore arranged to inspect the site where the fossils had been found and purchased specimens on behalf of the National Museum. These arrived in Washington in May, and Ward travelled to South Dakota in September.

15 Ward's *Cycadella* species were eventually transferred to the *Cycadeoidea*. See Chester Arnold (1947, pp. 250–251) and Theodore Delevoryas (1960, p. 778).

16 Ward (1895c, pp. 643–644). For an extensive list of publications on fossil cycads to 1917, see Seward (1917, pp. 592–639), though a fuller list of publications by William Carruthers, probably one of the most important English experts, is available in Lindsay (2005, pp. 60–61). It should be noted that the majority of relevant entries in Seward are post-1893, after Ward began working on cycads.

Second, Ward learned of an impressive discovery of thirty-five fossil cycads from the Potomac Formation that had been donated to the Baltimore Woman's College. These donations occurred while he was inspecting the Dakota beds, otherwise known as the Cretaceous rim of the Black Hills that ultimately produced over seven hundred cycad specimens and were described in 1947 by Chester Arnold as "the most important American locality for American cycadeoids" (Ward 1915, p. 382; Arnold 1947, p. 250). Although Ward rapidly published descriptions of the Dakota cycads in the *Proceedings of the Biological Society of Washington* (1894) he was much more impressed by the Potomac specimens as he believed they would enable scientists to "give something like a complete history" of the cycads, making their discovery "one of the most important events in the history of palaeobotany in America"[17] (see Figure 4).

Both discoveries were key to Ward's work on the Mesozoic: they could fill in a gap of which he was only too well aware. Two years earlier when he had surveyed the literature on paleobotany for *Johnson's Universal Cyclopaedia* he had to refer to cycads as a "rare group". Even though Europeans had been studying them for decades and had determined that they were "the leading type of vegetation over the greater part of the earth" in the Jurassic, few had been found in America and those that had were accompanied by dicotyledonous plants—that is, with plants associated with Cretaceous rather than Jurassic strata.[18] Ward therefore believed he had at his command, together with a small number of fossil cycads discovered in Maryland in 1859 by Phillip Tyson, the specimens needed to trace the origins and development of an important Mesozoic plant (see Figure 5).

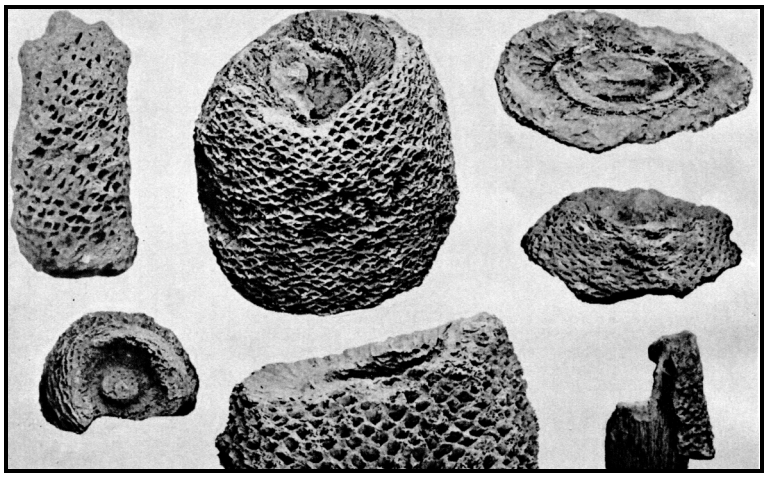


Figure 4. Cycadean trunks from the Black Hills of South Dakota, from: 'Some analogies in the Lower Cretaceous of Europe and America', Part I, Plate C. Sixteenth Annual Report, United States Geological Survey, *1896.*

While his paleobotanical efforts were largely empirical, by 1897 Ward was also attempting to re-conceptualize evolution and extinction. He believed that the branching metaphor used to depict evolution was inadequate, even misleading, as its advocates suggested evolution was a uniformly progressive process. He found another plant metaphor more illustrative. Aided by both lantern slides and actual samples of the many cycad specimens he had collected, Ward lectured on 'sympodial evolution'—the idea that evolutionary change followed a 'rhizomous' growth pattern in which plants sprouted new buds that matured while the original branch withered away (Ward 1903, pp. 71–78; Ward 1917, pp. 167–171). Beginning with a

[17] On the Dakota cycads see Ward (1894a, pp. 75–88). For details of the discovery and subsequent fieldwork on the Potomac cycads see Ward (1894c, pp. 291–298); the quotation is from p. 293. Also see Ward (1905, pp. 404–416). On the history of research on American fossil cycads, and especially on Marsh's collection at Yale, see Wieland (1906, pp. 7–8).

[18] Ward (1895c, pp. 643–644). For an extensive list of publications on fossil cycads to 1917, see Seward (1917, pp. 592–639), though a fuller list of publications by William Carruthers, probably one of the most important English experts, is available in Lindsay (2005, pp. 60–61). It should be noted that the majority of relevant entries in Seward are post-1893, after Ward began working on cycads.

lecture on 'Some of the remarkable extinct floras of ancient North America' in 1895, through the 'Vegetation of the ancient world', 'The evolution of the plant world as shown by paleobotany' and culminating in the 'Evolution of plant life' delivered in 1911, Ward used fossil cycads to illustrate his theory that sympodial evolution explained why some plant fossils were found in several strata while others disappeared entirely.

One of the first steps in realizing Ward's research agenda was to obtain access to the specimens from the Potomac Formation, and he therefore contacted John F. Goucher (1845–1922), President of the Women's College, suggesting a specimen exchange with the United States National Museum (Ward 1894c, pp. 291–298; Ward 1905, pp. 404–416). An agreement was reached in which the type specimens were deposited with the National Museum. His next step was to ascertain exactly where these specimens had been found; and so he contacted Arthur Barneveld Bibbins, the museum curator at the Women's College. Bibbins had convinced the farmers and miners who had collected these specimens to donate them to Goucher College, and so he was the logical person to arrange meetings with local collectors who knew where the fossils had been found. Although the location of only one specimen was pinpointed when the men visited the Maryland beds near those communities in March 1894, Ward was nonetheless pleased as more than one hundred 'trunks' were discovered *in situ* nearby, providing (he believed) convincing proof that they had found the 'cycad horizon'.

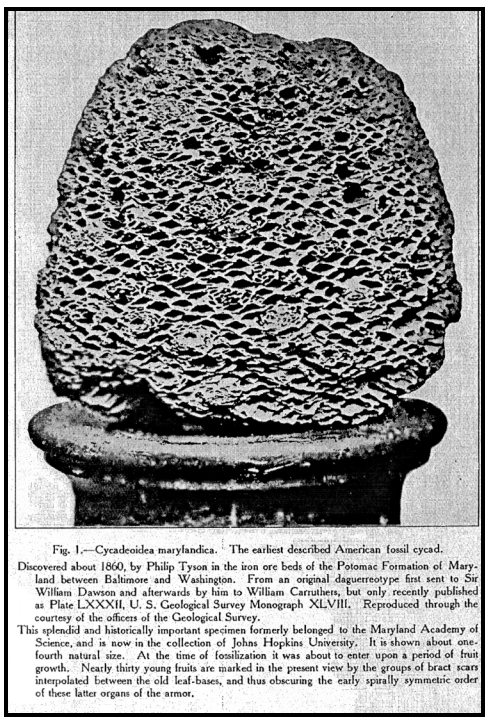


Fig. 1.—Cycadeoidea marylandica. The earliest described American fossil cycad. Discovered about 1860, by Philip Tyson in the iron ore beds of the Potomac Formation of Maryland between Baltimore and Washington. From an original daguerreotype first sent to Sir William Dawson and afterwards by him to William Carruthers, but only recently published as Plate LXXXII, U. S. Geological Survey Monograph XLVIII. Reproduced through the courtesy of the officers of the Geological Survey.
This splendid and historically important specimen formerly belonged to the Maryland Academy of Science, and is now in the collection of Johns Hopkins University. It is shown about one-fourth natural size. At the time of fossilization it was about to enter upon a period of fruit growth. Nearly thirty young fruits are marked in the present view by the groups of bract scars interpolated between the old leaf-bases, and thus obscuring the early spirally symmetric order of these latter organs of the armor.

Figure 5.
Tyson's Cycadeoidea marylandica. *From: G. R. Wieland,* American Fossil Cycads. *Carnegie Institution of Washington, No. 134. 1906.*

The cycad discoveries could not have been better timed, as Ward was drafting 'The Potomac Formation' for the United States Geological Survey. Eager to publish what he considered to be compelling evidence that the Potomac was a 'series of beds' from Martha's Vineyard through Virginia to the Carolina border, rather than a 'geological unit' as some believed, Ward announced his findings immediately in the *Bulletin of the Torrey Botanical Club* (1894). He reiterated his point a year later in the *Fifteenth Annual Report of the United States Geologica Survey*, emphasizing that if other scientists considered the paleobotanical evidence seriously—specifically the distribution of ferns and cycads, conifers and mono-cotylelons, as well as dicotyledons, in the geological strata making up the formation—rather than relying on

'useless' animal remains, or focusing on the marine deposits along the coast, they too would come to the same conclusion (Ward 1895, pp. 341–343).

Ward's classification of the Potomac as Lower Cretaceous was equally clear, and a year later he also took a hard line on a related dispute: the age and identity of the Wealden beds of southeast England. Agreeing with most European experts and US Geological Survey scientists who disputed the long-held view that the Wealden was Jurassic, Ward did not equivocate. In 'Some analogies in the Lower Cretaceous of Europe and America'—which he referred to as a "sort of sequel" to the Potomac Formation—he argued that the English formation was Lower Cretaceous (Ward 1896b, pp. 469–543). In this he was hardly daring, as his colleague Robert T. Hill pointed out: that is where Horace Woodward (1848–1914) placed the Wealden when he 'excluded' it from the Jurassic in *The Jurassic Rocks of Britain* for the Geological Survey of the United Kingdom (Woodward 1893, 1894, 1895) (Hill 1896, p. 918).

There was, however, still at least one important sceptic: O. C. Marsh. Not only was Marsh convinced the Wealden was Jurassic but also he believed that these 'Jurassic' beds were analogous to both the Potomac and the Atlantosaurus beds of Colorado and Wyoming, arguing, for example, that *Hypsilophodon* (Huxley) was the Wealden counterpart of *Dryosaurus* (his *Laosaurus altus*, 1878).[19] Regardless of whether Ward's conclusions were based on examinations of museum specimens or inspections of fossils sites in two continents, Marsh was unconvinced (Ward 1917, p. 322). The dinosaur man was unimpressed with Ward's evidence—whether from repositories close to home or prestigious institutions such as the British Museum, Kew Gardens, the University of Bologna, or the Geological Museum of Bologna. And he said so. That Ward had visited sites where European specimens were obtained was admirable, but not unusual. Marsh had also been overseas—thirty years earlier—and reports of Ward's travels to see the earliest known dicotyledons on the west coast of Portugal, or the cycadean trunks from Ozzano (Italy) and the Isle of Portland (England) did not sway the man who had visited the Tilgate Forest to examine where the first Iguanodon had been found in the 1820s (Marsh 1896a; Ward 1896b, pp. 484–485, 502–510). Moreover, between the time Ward travelled to Europe in 1894 and his article appearing in 1896, Marsh went to England. As Ward's 'Analogies in the Lower Cretaceous' was readied for printing in the autumn of 1895, Marsh was appealing to the members of the British Association for the Advancement of Science's meeting in Ipswich to 're-examine' the age of the Wealden, confident that further study would confirm that the Wealden was Jurassic 'in type' and 'age' (Marsh 1896a). And it was not long before British scientists supplied evidence such as Marsh requested. Despite Woodward's impressive work, a letter appeared in *Nature* in March 1896 announcing that Smith Woodward, an expert on fossil fishes, supported Marsh's view. A week later, Albert Charles Seward wrote to *Nature* to express his support for Marsh's claim that the Wealden was Jurassic (Seward 1896).

This was an about-face for Seward who had earlier criticized Ward for what amounted to scholarly cowardice, and Ward struck back in June. In a review of Seward's *Catalogue of Mesozoic Plants* (1894) he commended the botanist for his overview of the Wealden flora and was generally flattering in his review of the section on cycads but found Seward guilty of refusing to take a stand on the classification of *Bennettiteae* (Ward 1896a, p. 870). Were they or weren't they distinct from *Cycadaceae,* as many paleobotanists believed? An expert such as Seward owed his readers an honest assessment. Ward also chided Seward for not using all of the specimens at his disposal—"a pity" he wrote, since he knew from personal experience that "nearly all" the Wealden material was "actually in the British Museum" (Ward 1896a, p. 871). More serious, however, was a criticism that appeared to suggest selectivity within a series of similar fossils: Ward believed Seward provided an incomplete view of the Wealden as he omitted to discuss some of the beds within the formation.

[19] See Marsh (1894, p. 86 and 1896c, pp. 435–439) for a more detailed explanation of his views on the synonymy of these beds. For critiques of Marsh's view on the *Atlantosaurus*–Potomac analogy see Williston (1905, pp. 342–344) and Robert T. Hill (1896, pp. 918–922). Hill incorrectly stated that only Marsh and Jules Marcou remained convinced that the Wealden was a Jurassic formation into the 1890s. Also see Ward (1884a, pp. 172–173).

As Ward worked his way through Seward's *Catalogue*, the depth of his antipathy emerged slowly but surely and by the time he concluded his remarks the hollowness of his earlier praise was revealed. Almost half of the review was devoted to demonstrating how Seward eschewed one of the most fundamental of precepts—the principle of priority—to the detriment of both truth and truth-seekers. By the end, Ward abandoned any effort to be tactful (tact was never his strong suit) stating:

> These three cases will suffice to furnish the standard by which the whole is to be judged, and it is obvious that the system of citation adopted in this work . . . involved both the *suppressio veri* and the *suggestio falsi*. That this should be tolerated in any department of science, the essence of which is truth, is surely beyond ordinary comprehension (Ward 1896a, p. 876).

That Ward was implicated in one of Seward's transgressions by the latter's idiosyncratic nomenclature no doubt exacerbated his uncharitable outlook and contributed to the vehemence with which he denounced the British botanist. Ward made a special effort to show he had had no part in 'deliberately' altering the name of a cycad or in claiming credit for a discovery he had not made.

Far from this being his last stab at Seward—Ward offered a tepid review of his *Fossil Plants for Students of Botany and Geology* two years later—Ward devoted himself to his work in paleobotany and sociology. In addition to his reports for the United States Geological Survey and the United States National Museum, he prepared a second edition of *Dynamic Sociology* (1883, 1897), wrote the *Outlines of Sociology* (1898), published a number of essays and reviews, and travelled both at home and abroad, conducting fieldwork in Rhode Island, Kansas, Oklahoma, Montana, Dakota and California, as well as speaking on the lecture circuit and describing specimens deposited with the National Museum.[20] He also focused on acquiring his own collection of cycads, adding to the twenty that he had purchased from a quarry-master when visiting the Isle of Portland. He obtained specimens from Professor Walter P. Jenney, a 'mining expert' who had served as director of a surveying expedition to the Black Hills just prior to the Sioux War of 1876 and who had shared his knowledge with Ward when he visited the Black Hills in 1893 and 1895, from Philip Reese Uhler (1835–1913) of the Maryland Academy of Sciences and Peabody Institute, and John C. Merriam (1869–1945), an able young paleontologist who later did fieldwork for the University of California and became Director of the Carnegie Institute of Washington in 1920.[21]

As Ward contemplated Seward's newest publication in the early summer of 1898—ultimately accusing him of writing an unnecessary book having no purpose other than to demonstrate "how much better he can treat the more advanced and recondite aspects of the subject than his predecessors", making the book fit only for advanced students rather than a general readership—he also described fossil cycads in the museum at Yale University (Ward 1898a, p. 336). After receiving specimens from H. F. Wells, a collector who forwarded fossil cycads from South Dakota, Colorado, and Wyoming, Marsh pursued cycads with the same enthusiasm exhibited more than twenty years earlier when trying to out-collect dinosaur expert Edward Cope, acquiring more than seven hundred cycad specimens before he died. A few years later, these specimens were described as "the most important in the world" by George Reber Wieland (1865–1953) (see Figure 6), and although it was Marsh's laboratory assistant Wieland who later became known as the cycad expert, in 1898 Marsh turned to Ward as "the authority on the subject" (Wieland 1906, p. 8).

---

[20] For information on Ward's activities see Ward (1918, pp. 48–49, 49–50, 64–70) and Ward, 'Record of work and principal events', 1 July 1890 to 30 June 1897, in Lester Frank Ward Papers, Archives and Special Collections, Gelman Library, George Washington University, Washington, D.C., Box 1.

[21] Information on Jenney is from Kime (1996, pp. 3–26). Information on Uhler is from his obituary in the *New York Times*, 22 October 1913. Information on Merriam is from Stephen R. Mark, 'John C. Merriam (1869–1945)' in the *Oregon Encyclopedia: Oregon History and Culture* (Portland State University, 2008–2010). Information on specimens and Ward's activities is from: Ward (1894b and 1895). A letter dated 21 January 1896 from Merriam detailing specimens forwarded to Ward from California is reprinted in Ward (1899, p. 338).

Figure 6.
George Reber Wieland, Yale University Archives.

When Marsh wrote to Ward informing him of his acquisitions, inviting him to examine the hundred specimens then in his possession, Ward was not exactly surprised as Marsh had been to Washington to look at the collections in the National Museum, asking questions that suggested he intended to "try to get specimens for Yale to rival the Museum".[22] Ward conceded this "would be a good thing, as the Museum had no funds to devote to that purpose, and I had gone as far in my Survey work in that line as I thought consistent with the purposes of a Geological Survey".[23] Soon thereafter Ward went to New Haven. Once there, he saw that the information about where the specimens had been found was "wholly inadequate, being exceedingly vague and generally uncertain" making iden-tifications difficult.[24] Ward wrote to Marsh: "[t]he Yale collection, so far as I know it, is virtually a large series of specimens without labels, and by common consent, in all branches of natural history, a specimen without a label is worthless".[25] When Marsh refused to divulge the requested information, Ward went to the men who had collected the specimens, hoping to ascertain the source of the fossils, but they were equally uncooperative. Ward tried to impress upon Marsh the seriousness of his intransigence, threatening to send his manuscript he was drafting on the fossil plants of the Black Hills for the United States Geological Survey *Annual Report* without his specimens. He wrote:

> I sincerely hope that you will furnish me with his information at the earliest possible moment so that the report may not be delayed. It must go in as early as the first of June, and if I cannot have the data mentioned at an early day the Yale collection will have to be treated as if it did not exist.

22 Marsh to Ward, 17 March 1898, Lester Frank Ward Collection, John Hay Library, Brown University, Providence, RI, MS 90.23 Series 1, Sub-series 2, Box 51, Folder 2. Subsequent offers were made in letters of 4 November 1898, Lester Frank Ward Collection, John Hay Library, Brown University, Providence, RI, MS 90.23 Series 1 Sub-series 2, Box 51, Folder 2; 5 May 1898, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1; and, 7 and 23 February 1899, Lester Frank Ward Collection, John Hay Library, Brown University, Providence, RI, MS 90.23 Series 1, Sub-series 2, Box 51, Folder 3. Quotation is from: Ward 1918, pp. 65–66.

23 Ward 1918, pp. 65–66.

24 Ward to Marsh, 4 May 1898, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

25 Ward to Marsh, 4 May 1898, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

> The Director is decided upon this point, and so far as I am personally concerned, I am not willing to take any part of the responsibility for the concealment of the facts.[26]

With such pressure from the top, Marsh instructed his collectors to provide the missing data.

As Marsh complied with the request, he flattered Ward and attempted to smooth over the disagreement. He offered, for example, what he believed to be cycad fragments that predated any others at his disposal, but Ward doubted whether the specimens were, as Marsh claimed, collected from the 'Ceratops beds of Colorado' in 1887.[27] Other overtures, such as a proposal to move the Yale cycad collection to Washington, were also rejected. Since Marsh suggested that the removal costs be borne by the Survey or the National Museum, this was a costly 'gift' that Ward could not afford.[28] While he had sometimes purchased specimens in the past, in 1898 he had no funds to pay for the transportation and acquisition of several tons of plant fossils. He also refused to consider a suggestion that he publish his descriptions in the *American Journal of Science*. Even if, as Marsh believed, there was some urgency as other collectors were harvesting specimens from the same sites, Ward stated he was too busy to work up the specimens immediately and, when he did get to them, he would submit his manuscript to a journal of his choosing.[29]

A month before he died in February 1899, Marsh made one last attempt to convince Ward to purchase the cycad specimens, threatening to sell them to European scientists who had already approached him about the plant material. Ward was, however, only slightly concerned that Marsh's specimens might find their way "into the hands of such experts as Carruthers, Seward, Solms-Laubach, or Lignier" as he had already published a "preliminary paper" in the *Proceedings of the United States National Museum* (Volume 21, October 1898), describing Marsh's cycads as well as those in the United States National Museum, the Baltimore Women's College, and the South Dakota School of Mines.[30] He was also editing a manuscript in excess of four hundred pages on fossil plants for the *Nineteenth Annual Report of the United States Geological Survey* (November 1899), and was not worried in the least that he might be scooped by "species-mongers". In any event, as he told Marsh, the Europeans had different ambitions: they were mainly interested in figuring cycad 'fruits'.[31] A little too insouciant, Ward ignored these at his peril as the reproductive organs the Europeans were so interested in 'figuring' were soon to become the basis for classifying fossil cycads, and in the early twentieth century paleobotanists who re-examined Ward's 'new' species found he had made errors in his identifications.[32]

---

26 Ward to Marsh, 4 May 1898, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

27 Marsh to Ward, 6 May 1898, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

28 Marsh's request for remuneration is mentioned in a letter from Ward to Marsh, 19 May 1898, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

29 Marsh to Ward, 5 May 1898 and 30 January 1899, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1. Marsh disagreed with Ward's choice of the *Proceedings* of the Biological Society of Washington in the letter of 5 May 1898.

30 Marsh to Ward, 30 January 1899, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1.

31 Ward to Marsh, 1 February 1899, Lester Frank Ward Papers, Smithsonian Institution Archives, Washington, Record Unit 7321, Box 1. Also see Ward (1898b and 1918, pp. 49–50).

32 Ward's protégé, George Wieland, was well aware of the importance of cycad cones to identification and classification, as he devoted more than a third of *American Fossil Cycads* (pp. 107–186) to this material. See assessments of Ward in Arnold, (1947, pp. 250–251) and Delevoryas (1960, p. 778).

4. FROM *SAUROPODA* TO CYCADS: MARSH'S MESOZOIC HORIZONS AND WARD'S FOSSIL PLANTS

By this time, however, Ward was acting as if he had the upper hand. No longer the junior scientist trying to impress his peers and make as few enemies as possible, he was as self-assured as Marsh, dispensing honors as he named species for friends and colleagues—including *Cycadeoidea marshiana* (1898) for Marsh. No longer as insecure as had been the case formerly, he did not respond to Marsh's hectoring. When Marsh insinuated that the paleobotanists, especially Ward and Arthur Hollick, were hostile to criticism from outside their 'bailiwick' and then accused Ward and his paleobotany co-conspirators at the Survey—R. T. Hill, G. K. Gilbert, and C. A. White—of confusing fact with fantasy so as to totally misinterpret the American Jurassic and call into doubt his work, Ward remained silent (Marsh 1898). Rather than squabbling with Marsh on settled matters, specifically that the Potomac Formation was Cretaceous, Ward ignored his provocations.[33] Perhaps even a little dismissively, he refused to respond to allegations that the paleobotanists were "responsible for much of the confusion that had so long delayed the solution of similar questions, East and West" (Marsh 1898, p. 108).

But Marsh was correct. There was confusion. The fact that Ward, Marsh, and others jockeyed for position—sometimes modifying, sometimes retrenching—as they attempted to grapple with defining the Mesozoic illustrated his point perfectly. Early on, Ward's position shifted dramatically as his work on fossil cycads changed his views on the age and identity of the Potomac entirely. However, even Marsh modified his views—even if so slightly as to be almost imperceptible. In 1896, for example, he still believed that most of the Potomac Formation was Jurassic—and most especially the Maryland beds—but he conceded to those present at the National Academy of Sciences meeting in November that "some of the upper strata may possibly prove to belong to the Dakota" (Marsh 1896c, p. 436). At the same time, he argued that the Rhode Island section of the Potomac Formation was Jurassic, stating that the *Sauropoda* that had been found there demonstrated their Jurassic age beyond reasonable doubt (Marsh 1896c, p. 435). He castigated American geologists for not finding Jurassic formations on the Atlantic coast asking: "[m]ay not the missing strata be represented in the characteristic series of Block [Rhode] Island clays? The evidence as it now stands points to this conclusion" (Marsh 1896b, p. 298). This conclusion was, he reminded those present, arrived at in 1888 but was now "fully confirmed by more recent discoveries". Those who considered the beds to be Cretaceous were simply wrong. That the scientists who disagreed with him based their conclusions on fossil plants provided additional support for his views. He stated that "were the fossil plants of the Potomac that have been pronounced Cretaceous unknown, the Jurassic age of this extensive series would have been accepted as a matter of course long ago" (Marsh 1896c, p. 440). In other words, if fossil plants had never been found, there would be no dispute over its age. Whether marine or terrestrial, invertebrate or vertebrate, the fossil fauna was conclusive. The Potomac was Jurassic—even if the identity of the upper stratum was not fully resolved.

Marsh also believed the geological evidence suggested a Jurassic formation. While it was perhaps unfair to criticize Marsh for glossing over lithological distinctions in a public presentation, especially since his October publication on the physical characteristics of the beds on Rhode Island was quite fulsome, his speech before the Academy tended towards common usage rather than geological analysis, and those present had to accept his claims uncritically. In any event, lithology was not his main concern. Rather, he wanted to impress his American colleagues that vertebrate rather than plant fossils provided the best evidence of the age and identity of geological strata. Despite a small concession to the possibility that there might be some Cretaceous beds overlying the Jurassic, Marsh's views in 1896 were no different from what they had been when he first laid eyes on the Potomac beds. At that time he had been "reasonably sure, even before I had examined them, that this series would turn out to be

[33] As Ward later pointed out: a comprehensive and, Ward stated, self-explanatory bibliography of the literature on the Potomac appeared in 'Status of the Mesozoic floras of the United States' (1900), p. 334.

essentially the same age as the Atlantosaurus beds of the West" (Marsh 1896c, p. 435). Indeed, he saw no reason to accept the views of scientists who could not even agree amongst themselves as to how to interpret the fragmentary evidence with which they worked, and Marsh stated that to "attempt to make out the age of formations by the use of such material is too often labor lost and must necessarily be so" (Marsh 1896c, p. 440). While triumphantly proclaiming he had been right all along, he accused the paleobotanists who stuck to their analyses of continuing to use "the same methods, the same material, with the same confidence, that formerly misled their predecessors" (Marsh 1896c, p. 440). Unfazed by the irony of his accusation, he continued: "is it too much to ask them to reconsider their verdict as to the age of the Potomac formation?"

If the plant men present were insufficiently impressed by his pleas, Marsh believed they could be swayed by one of their own and he quoted Sir Joseph Hooker, who in 1877 had stated that fossil plants were "most unsatisfactory witnesses" in determining the age of geological formations. Failing acceptance of Hooker's comments, Marsh suggested an adjustment of the paleobotanical time scale by "one notch" to bring it into line with that of the paleozoologists (Marsh 1896c, p. 438). Doing so, he pointed out, would foster a resolution of the Potomac problem just as the Wealden problem had been resolved when the botanist Seward accepted the findings of research on fossil fish and reptiles. Again, missing the irony, Marsh proposed that this 'adjustment' was a made-in-America solution to the dispute as "[t]he north American botanical timepiece was originally set by the European clock, which was one period too slow, as many facts now indicate. Sooner or later, an adjustment must be made" (Marsh 1896c, p. 438).

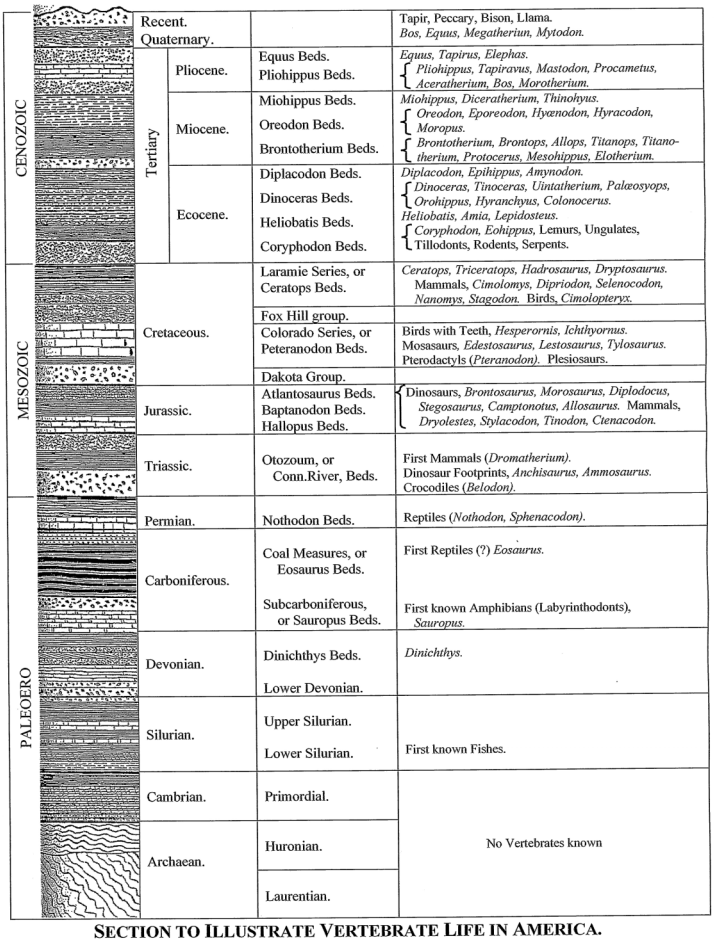
Marsh concluded his presentation by promising to return to the Potomac, as "the Mesozoic interests me most of all, especially its middle section, the Jurassic, as I believe great injustice has been done, since this has been denied its rightful place, and a name not its own stamped upon it". But he added he had "no time to devote to the surface geology of this belt or to the earlier deposits of Tertiary time" (Marsh 1896c, p. 447). A year later, however, he was at it again. Speaking before the National Academy of Sciences in Boston in November 1897, he reminded those present that fourteen years earlier in 1877 at the American Association for the Advancement of Science meetings in Nashville he had made a case for the priority of vertebrate fossils in defining the Jurassic—reiterating the point made the previous year as he rebuked the paleobotanists for their intransigence on the issue (Marsh 1896c, p. 439 and 1898 p. 111). He added that, in America, vertebrate fossils had been used to classify geological formations (as guide/index fossils) just as profitably as ammonites had been used in Europe and his experience suggested: "vertebrates afford the most reliable evidence of climate and other geological changes".[34] Neither plants nor invertebrates were as useful to North American research, although he had to confess that "no vertebrates are yet known in the Archaean or Cambrian" in either Europe or America (Marsh 1891, p. 337) (see Figure 7). Hopeful that future finds would fill in the gaps, Marsh moved quickly (very quickly!) from the unknown to the known—to Connecticut foot-prints and fossil finds in Colorado, Dakota, Wyoming and Utah—discarding terms with which the well-informed would be familiar: *Atlantosaurus*, *Baptanodon*, and *Pliohippus*; *Hallopus victor*, *Nanosaurus*, and *Parasaurus striatus*.

Here too Marsh ran afoul of colleagues, specifically Samuel W. Williston (1851–1918), one of his field assistants from 1876 to 1879 who, during the 1890s, emerged as an important vertebrate palaeontologist, becoming a professor at the University of Chicago. Although Williston benefited from experience gained in the field and in the laboratory, he moved on after eleven years, as Marsh would not recognize his contributions (Shor 1971, pp. 110–111). Privately, Williston described Marsh as narrow-minded with "a sort of contempt for all knowledge that did not bear directly upon his own special work", but more substantively and publicly he challenged his views on the fossil beds near Morrison, Colorado.[35] In 1905, when Williston's critique was published, the erstwhile employee deftly summarized why his former

[34] Marsh (1891, p. 336) on guide fossils, especially the use of ammonites in the Mesozoic, see Woodford (1963, pp. 75–104).

[35] His private thoughts are contained in 'Recollections', an unpublished manuscript found among the possessions of Williston's descendants and used by Shor in writing his biography. See Shor (1971, p. 72).

employer's work had been both contentious and problematic: Marsh had not provided precise geographical information as to where the specimens used to determine the geological age of these beds/strata/outcroppings had been obtained; and because he was reluctant to share such information it was difficult to assess the validity of his work (Williston 1905, p. 347). Indeed, Marsh's secretiveness was an impediment to future research, and Williston virtually ignored Marsh's findings as he worked on the Morrison beds. Williston concluded that no matter how commonly was Marsh's claim that the beds he had named "Atlantosaurus" represented "some brief epoch" in the Jurassic period was accepted, he was simply wrong. The Morrison beds were Cretaceous. Moreover, the Hallopus and Baptanodon beds of Colorado and Wyoming that Marsh had classified as Jurassic were also Cretaceous.[36] Williston then took the next logical step, deducing that Marsh's claim that the western beds were analogous to the Wealden was also incorrect. Uncharacteristically diplomatic, or possibly just cautious, Williston stated: "[u]ntil more is known of the different faunas contained in it, the only proper designation for the composite faunas included in them is Jura–Cretaceous; this assumes that the Wealden is really Jurassic" (Williston 1905, p. 348). Of this he was highly doubtful—as was Ward.



SECTION TO ILLUSTRATE VERTEBRATE LIFE IN AMERICA.

Figure 7. Chart from O. C. Marsh, 'Geological horizons as determined by vertebrate fossils', American Journal of Science *42, No. 336 (1891): 359.*

[36] Williston (1905, pp. 338–350 and especially 347). Williston's early fieldwork is mentioned in M. K. Brett-Surman, 'Appendix: a chronological history of dinosaur paleontology', 1997, pp. 710 and 712; and for a brief account of the circumstances of Williston's appointment at the University of Chicago see Rainger (1993, pp. 486–488).

Williston and Ward agreed that Marsh had it wrong, but they were miles apart in two ways. Ward's critique was directed eastward as he disputed Marsh's claim that the Potomac was an eastern extension of the Atlantosaurus beds, and he sought answers in evidence that neither Marsh nor Williston could accept (Hill 1896, pp. 918–922). Despite misgivings about Marsh's findings, Williston did agree with him on one important point: "the final solution of the problem must be left chiefly to the vertebrate palaeontologist, since the evidence presented by the invertebrates and plants is not only scanty, but also, in the nature of things, insufficient" (Williston 1905, p. 343). Nothing, according to Ward, could have been further from the truth. And if Ward was initially hampered by the fact that the American Jurassic had not yet yielded fossil plants—the only known specimens coming from "the next higher horizon" (Lower Cretaceous)—after the cycad discoveries he was in a better position to demonstrate just how wrong were the dinosaur men (Ward 1892c, p. 24 and 1893, pp. 43–44). He was in an even stronger position to dispute the paleozoologists' dismissal of plants as guide fossils after the summer of 1899, when he found cycads embedded in the Jurassic strata of Wyoming. The discovery was, Ward stated, highly significant, as the Jurassic "had not hitherto been supposed to yield any fossil plants in America" (Ward 1900a, pp. 382–392 and 1918, p. 104).

A year later Ward published the first of two important works on the 'Status of the Mesozoic floras of the United States'. In his paper 'The Older Mesozoic' the Wyoming cycads that he named *Cycadella* were cited in reference to 'Plant-bearing deposits of undoubted Jurassic age', while the Potomac was discussed in terms of 'Plant-bearing deposits *supposed* to be Jurassic' (Ward 1900a, pp. 334–339, 339–421, italics added). The five hundred pages of text and more than fifty plates in which he detailed the misclassification of fossil plants was supplemented with a more comprehensive 'Second paper' in 1905, a monograph in excess of six hundred pages and a hundred plates devoted largely to Cretaceous plants. These were Ward's last major contributions to paleobotany, and while Marsh did not live to see how they would call into question his interpretation of the Jurassic, before he died in 1899 he was clearly confident that his view would stand. He not only encouraged his laboratory assistant, George Wieland, to pursue his interest in cycads but also he shared specimens with Ward—a courtesy he would never have extended to his rival Cope. By 1899, Marsh seems to have overcome concerns voiced only two years earlier about what Ward, Fontaine, Knowlton and others—men he saw as co-conspirators working against him—were up to. By this time, Marsh was clearly confident he had interpreted the evidence correctly.

As Ward worked on specimens in early 1899, Marsh was working on what turned out to be his last publication, pushing one more manuscript past the editorial board of the *American Journal of Science* (Ward 1918, p. 104). 'Footprints of Jurassic dinosaurs' appeared in March, the same month that Marsh succumbed to pneumonia. One last attempt to elevate the Jurassic age to its rightful place in American paleontology, Marsh's paper on dinosaur tracks found in the Black Hills, rejected conventional interpretations of footprints as "naturally supposed to be of Triassic age, as all footprints of similar character known in this country had been found in deposits of that formation" (Marsh 1899, p. 227). It also departed from the views of paleobotanists. Eager to pronounce on the cycads that his museum was collecting, Marsh commented on them in an article otherwise devoted to paleozoology, stating:

> The Cycad beds, as they may be termed, from the great number and variety of remains of this group of fossil plants, are abundantly represented around the rim of the Black Hills, apparently at a higher level, but, as the Cycad remains, although distinctive in themselves, have not yet been found absolutely in place in undisturbed strata, their exact position in the series cannot at present be definitely fixed. Part of this series was formerly referred to the Dakota by various geologists, but this reference is fairly open to question, as the writer has shown elsewhere (Marsh 1899, p. 229).

Ironically, Marsh then inserted a chart detailing the flora and fauna associated with formations in the Mesozoic and Cenozoic. Temporally, he grouped the cycads with the dinosaurs, many of which he had identified, in the Jurassic, and referred to a new formation—the 'Cycad Beds'—

alongside the Atlantosaurus and Baptanodon Beds of the Jurassic (see Figure 8). Marsh would doubtless have been pleased by Ward's discovery of Jurassic cycads in Wyoming (even if he would have been less than thrilled by the fact that the Wyoming specimens were deposited in the museum at the University of Wyoming), but even before the specimens were found in August he claimed that *all* Black Hills cycads were Jurassic.[37]

A year later, Ward took up Marsh's suggestion that he publish his cycad findings in the *American Journal of Science*. Although he had initially resisted the suggestion, he prepared a brief article listing the accession numbers of the 715 specimens in the Yale Museum, reserving the more important descriptive entries for his Survey publications (Ward 1918, pp. 107–108). In 'Elaboration of the fossil cycads in the Yale Museum' he described only six species, prefacing all with ostensibly laudatory references to Marsh's contributions to paleontology. Some of his comments would, however, probably have been more unsettling than appreciated, had Marsh been alive to see them. It is unlikely that the man who never altered his opinion on the value of vertebrate fossils for determinations of the age and identity of geological formations would have accepted Ward's claim that "cycads are to the vegetable kingdom what dinosaurs are to the animal, each representing the culmination in Mesozoic time of the ruling dynasties in the life of that age" (Ward 1900b, p. 327). Moreover, while acknowledging his adversary's vision as a collector, who "as the last act of his life, had the sagacity to make the Yale Museum for all time the Mecca for all who shall wish to gain a realizing sense of the fauna and flora of America in a period now forever closed", Ward glossed over the fact that fundamentally Marsh's views on the role of plant fossils were no different at the end of his life from what they had been when he first began work on the Mesozoic (Ward 1900b, p. 327). Both men were adamant that paleontology was the key to determining the age and sequence of geological formations, but they held very different opinions when it came to the merits of their respective areas of expertise.

CENOZOIC	Recent. Quaternary.			Tapir, Peccary, Bison. *Bos, Equus, Tapirus, Dicotyles, Megatherium, Mylodon.*
	Tertiary.	Pliocene.	Equus Beds. Pliohippus Beds.	*Equus, Tapirus, Elephas.* { *Pliohippus, Tapiravus, Mastodon, Procamelus, Aceratherium, Bos, Morotherium, Platygonus.*
		Miocene.	Protoceras Beds.	*Protoceras, Miohippus, Diceratherium, Thinohyus.*
			Oreodon Beds.	{ *Oreodon, Eporeodon, Hycenodon, Ictops, Hyracodon, Agriochœrus, Colodon, Leptochœrus.*
			Brontotherium Beds.	{ *Brontotherium, Brontops, Allops, Titanops, Titanotherium, Mesohippus, Ancodus, Entelodon.*
MESOZOIC	Cretaceous.		Ceratops Beds of Laramie Series.	*Ceratops, Triceratops, Claosaurus, Ornithomimus.* Mammals, *Cimolomys, Dipriodon, Selenacodon, Nanomyops, Stagodon.* Birds, *Cimolopteryx.*
			Atlantochelys Beds of Montana Group.	*Atlantochelys, Coniornis.*
			Pteranodon Beds of Colorado Series.	Mosasaurs, *Edestosaurus, Lestosaurus, Tylosaurus.* Pterodactyls, Plesiosaurs, Turtles.
	Jurassic.		Cycad Beds.	Cycads, *Cycadeoidea.*
			Atlantosaurus Beds.	Dinosaurs, *Barosaurus, Brontosaurus, Morosaurus, Diplodocus, Stegosaurus, Camptosaurus, Allosaurus.* Mammals, *Dryolestes, Stylacodon, Tinodon, Ctenacodon.*
			Baptanodon Beds.	*Baptanodon, Pantosaurus, Belemnites, Trigonia, Pentacrinus.*
	Triassic.		Red Beds.	A few plants.

GEOLOGICAL HORIZONS ABOVE PALEOZOIC OF BLACK HILLS REGION.

Figure 8. Chart from O. C. Marsh, 'Footprints of Jurassic dinosaurs', American Journal of Science*, Series 4, 7 (March 1899): pp. 227–233.*

[37] See credits attached to plates depicting the Jurassic cycads in Ward (1900a, pp. 532–744).

5. CONCLUSIONS: LESTER FRANK WARD'S LEGACY

If, in 1888, either Marsh or Ward thought a presentation on fossil plants from the Potomac would simply initiate discussion, their expectations were exceeded. Although both made their share of mistakes when identifying and classifying fossils, they also contributed significantly to the earth sciences. But while Marsh is today considered one of the most important paleontologists of the nineteenth century Ward has not fared so well. Until recently, the view that his "specific contributions to paleobotany and sociology were so meagre that perhaps he ought to be ignored" was common and one of his sharpest critics, Hamilton Cravens, described his "ponderous writings" as bearing "little relationship intellectually or professionally" to the sociologists who followed him and stated that "academics had little use for Ward" (Cravens 1977, p. 817; 1985, p. 199).

Ward, no doubt, bears some responsibility for uncomplimentary assessments of his career. After all, his rather immodestly titled six-volume retrospective, *Glimpses of the Cosmos*, invited derision. No matter how useful the explanatory notes inserted among the reprinted correspondence, reports to government officials, formal lecture notes, published and unpublished manuscripts, abstracts and reviews of his publications, as well as annual cumulative (and annotated) bibliographies, his *magnum opus* reeked of egocentrism. In this, however, he met his match with Othniel Marsh, the scientist who encouraged his work on the fossil plants of the Mesozoic. If he did not quite reach the heights scaled by Marsh—or others such as Walcott or Seward—he nevertheless made a lasting contribution to paleobotany.

ACKNOWLEDGEMENT

I thank our Departmental Secretary, Christine Robson, for preparing Figures 7 and 8 for publication.

ARCHIVES

Much of the information for this paper came from contemporary imprints, many of which are readily available online. Those not available in digital format were examined at the New Brunswick Museum Library (Saint John, New Brunswick). Other holdings consulted include the Smithsonian Institution, the Special Collections and University Archives, Gelman Library, George Washington University, and the John Hay Library, Brown University.

REFERENCES

Arnold, Chester A. 1947. *An Introduction to Paleobotany.*New York and London: McGraw–Hill Book Co. Inc.

Ashley, G. H. 1933. Classification and nomenclature of rock units. *Bulletin of the Geological Society of America* 44: 423–459.

Becker, Ernest. 1968. *The Structure of Evil: An Essay on the Unification of the Science of Man.* New York: George Braziller.

Bibbins, Arthur B. 1895. Notes on the paleontology of the Potomac Formation. *Johns Hopkins University Circular* 15: 17–20.

Bowler, Peter J. 1993. *Biology and Social Thought, 1850–1914*. Berkeley Papers in History of Science 15. Berkeley: Office for History of Science and Technology.

Brett-Surman, M. K. 1997. Ornithopods. In: *The Complete Dinosaur*, edited by James O. Farlow and M. K. Brett-Surman, 330–346. Bloomington and Indianapolis: Indiana University Press.

Brett-Surman, M. K. 1997. Appendix: A chronological history of dinosaur paleontology. In: *The Complete Dinosaur*, edited by James O. Farlow and M. K. Brett-Surman, 707–720. Bloomington and Indianapois: University of Indiana Press.

Burnham, John C. 1954. Lester Frank War as natural scientist. *American Quarterly* 6: 259–265.

Chugerman, Samuel. 1965. *The American Aristotle: A Summary and Interpretation of his Sociology.* Chapel Hill: Duke University Press, 1939; reprint, New York: Octagon Books Inc.

Clark, F. W. 1895. Cretaceous deposits of the northern half of the Atlantic coastal plain. *Bulletin of the Geological Society of America* 6: 479–482.
Cravens, Hamilton. 1985. History of the social sciences. *Osiris*, 2nd Series 1: 183–207.
Cravens, Hamilton. 1977. Review of Clifford H. Scott, *Lester Frank Ward*. Boston: Twayne, 1976. *Journal of American History* 64: 817–818.
Chriss, James J. 2006. The place of Lester Ward among the sociological classics. *Journal of Classical Sociology* 6: 5–21.
Darton, N .H. 1891. Mesozoic and Cenozoic formations of eastern Virginia and Maryland. *Bulletin of the Geological Society of America* 2: 431–450.
Darton, N. H. 1893. The Magothy Formation of northeastern Maryland. *American Journal of Science* 45: 407–419.
Delevoryas, Theodore. 1960. Investigations of North American Cycadeoids: trunks from Wyoming. *American Journal of Botany* 47: 778–786.
Fontaine, William Morris. 1879. Notes on the Mesozoic strata of Virginia. *American Journal of Science*, 3rd ser., 17: 25–39, 151–157, 229–239.
Fontaine, William Morris. 1883. *Contributions to the Knowledge of Older Mesozoic Flora of Virginia* 6. Monographs of the United States Geological Survey. Washington.
Fontaine, William Morris. 1889. The Potomac or Younger Mesozoic flora. *Monographs of the United States Geological Survey* 15. Washington.
Fontaine, William Morris 1896. The Potomac Formation in Virginia. *Bulletin of the United States Geological Survey* 145. Washington.
Gerver, Israel. 1963. *Lester Frank Ward*. New York: Thomas Y. Crowell & Co.
Gillespie W. A. and I. S. Latimer Jr. 1961. History and bibliography of western Virginia paleobotany. *Castanea* 26: 157–171.
Harris, Tom M. 1961. The fossil cycads. *Palaeontology* 4: 313–323.
Hill, Robert T. USGS. 1896. Letter to the editor: a question of classification. *Science*, New Series 4: 918–922.
Jaffe, Mark. 2000. *The Gilded Dinosaur: The Fossil Wars Between E. D. Cope and O. C. Marsh and the Rise of American Science*. New York: Crown Publications.
Kime, Wayne R. ed. 1996. Introduction to *The Black Hills Journal of Colonel Richard Irving Dodge* (Norman: University of Oklahoma Press), 3–26.
Kranz, Peter M. 2010. Notes on the sedimentary iron ores of Maryland and their dinosaurian fauna. Available at: http://terpconnect.umd.edu/~gdouglas/ironores/index.html.
Lindsay, Debra. 2005. *Prototaxites* Dawson, 1859 or *Nematophycus* Carruthers, 1872: geologists v. botanists in the formative period of the science of paleobotany. *Earth Sciences History* 23: 35–61.
Lubick, George M. 1988. Soldiers and scientists in the petrified forest. *Journal of Arizona History* 29: 391–412.
Mark, Stephen R. 2008–2011. John C. Merriam (1869–1945). *Oregon Encyclopedia: Oregon History and Culture* (© Portland State University).
See: http://www.oregonencyclopedia.org/entry/view/john_c_merriam/.
Marsh, O. C. 1879. History and methods of paleontological discovery. *American Journal of Science and the Arts*, Series 3 18: 323–359.
Marsh, O. C. 1888. Notice of a new Genus of *Sauropoda* and other new dinosaurs from the Potomac formation. *American Journal of Science* 35: 89–94.
Marsh, O. C. 1891. Geological horizons as determined by vertebrate fossils. *American Journal of Science* 42: 336–338 and 359.
Marsh, O. C. 1894. The typical Ornithopoda of the American Jurassic. *American Journal of Science* 48: 85–90.
Marsh, O. C. 1896a. The age of the Wealden. *Nature* 12 March: 436.
Marsh, O. C. 1896b. The geology of Block Island. *American Journal of Science*, Series 4 2: 295–298.
Marsh, O. C. 1896c. The Jurassic formation on the Atlantic coast. *American Journal of Science*, Series 4 2: 433–447.
Marsh, O. C. 1898. The Jurassic formation on the Atlantic coast–Supplement. *American Journal of Science*, Series 4 6: 105–115.
Marsh, O. C. 1899. Footprints of Jurassic dinosaurs. *American Journal of Science*, Series 4 7: 227–233.
McGee, W. J. 1886. *Geology of Washington and Vicinity*. Report of the Health Officer of the District of Columbia for the year ending June 30 1885.
McGee, W. J. 1888a. Three formations of the middle Atlantic slope. *American Journal of Science*, Series 3 35: 120–143, 367–388, 448–466.

McGee, W. J. 1888b. The geology of the head of Chesapeake Bay. *Seventh Annual Report, United States Geological Survey*. Washington, 537–646.
McGee, W. J. 1890. Abstract of the southern extension of the Appomattox formation. *Bulletin of the Geological Society of America* 1: 546 –548.
McGee, W.J. 1891. The Appomattox formation in the Mississippi embayment. *Bulletin of the Geological Society of America* 2: 2–6.
McIntosh, John S., M. K. Brett-Surman and James O. Farlow. 1997. Sauropods. In: *The Complete Dinosaur*, edited by James O. Farlow and M. K. Brett-Surman, 264–290. Bloomington and Indianapolis: Indiana University Press.
Morello, Nicoletta. 2003. Birth of stratigraphy in Italy and Europe. In: *Four Centuries of the Word Geology*, Ulisse Aldrovandi, 1603, edited by Gian Battista Vai and William Cavazza, 251–263 Bologna: Minerva Edizioni.
Nelson, Alvin F. 1968. *The Development of Lester Ward's World View*. Fort Worth: Branch-Smith Inc.
Nelson, Alvin F. 1972. Lester Ward's conception of the nature of science. *Journal of the History of Ideas* 33: 633–638.
Nelson, Clifford M. 2006. The Fifth International Geological Congress, Washington, 1891. *Episodes* 29: 279–286.
Notes and News: Paleobotany. 1895. *Science*, New Series 1: 137–138.
Paleobiology Database, associated with the National Center for Ecological Analysis and Synthesis. Avail: http://paleob.org.
Rainger, Ronald. 1990. Collectors and entrepreneurs: Hatcher, Wortman, and the structure of American vertebrate paleontology circa 1900. *Earth Sciences History* 9: 14–21.
Rainger, Ronald. 1993. Biology, geology, or neither, or both: Vertebrate paleontology at the University of Chicago, 1892–1950. *Perspectives on Science* 1: 478–519.
Rogers, W. B. 1841. *Report of Progress of Geological Survey of Virginia for 1840*. Richmond.
Rogers, W. B. 1875. On the gravel and cobblestone deposits of Virginia and the middle states. *Proceedings Boston Society for Natural History* 18: 101–106.
Romans, Robert C. 1973. A history of paleobotany in Arizona. *Plateau* 45: 93–101.
Russett, Cynthia Eagle. 1976. *Darwin in America: The Intellectual Response, 1865–1912*. San Francisco: W. H. Freeman & Co.
Schuchert, C. 1938. Biographical memoir of Othniel Charles Marsh, 1831–1899. *Biographical Memoirs of the National Academy of Sciences* 20. Washington, D.C.: National Academy of Sciences.
Seward, A. C. 1894. *Catalogue of the Mesozoic Flora in the Department of Geology, British Museum (Natural History) The Wealden Flora, Part I, Thallophyta—Pteridophyta*. London.
Seward, A. C. 1896. The age of the Wealden. *Nature* 19 March: 462.
Seward, A. C. 1917. *Fossil Plants: A Textbook for Students of Botany and Geology 3: Pteridospermeae, Cycadofilices, Cordaitales, Cycadophyta*. Cambridge: Cambridge University Press.
Shor, Elizabeth Noble. 1971. *Fossils and Flies: The Life of a Compleat Scientist, Samuel Wendell Williston, 1851–1918*. Norman: University of Oklahoma Press.
Stanton, Timothy William. 1897. A Comparative Study of the Lower Cretaceous Formations and Faunas of the United States. PhD dissertation, Columbia University [George Washington University], 1897. Published in *Journal of Geology* 5: 579–624.
Tyson, Philip T. 1860. *First Report: State Agricultural Chemist to the House of Delegates of Maryland*. Annapolis.
Uhler, P. R 1888. The Albirupean formation and its nearest relatives in Maryland. *Proceedings of the American Philosophical Society* 25: 42–53.
Uhler, P. R. 1892. Notice of Albirupean studies. *Transactions of the Maryland Academy of Science*. 185–200.
Ward, Lester Frank. 1879. Homologies in the Lauraceae [laurel]. *Scientific American Supplement* 7: 3,089–3,090.
Ward, Lester Frank. 1884a. Abstract of the fossil flora of the globe. Read before the AAAS, Philadelphia, 1884. *Botanical Gazette* 9: 172–173.
Ward, Lester Frank. 1884b. *Caulinites* and *Zamiostrobus*. *Science* 3: 532–533.
Ward, Lester Frank. 1885a. Sketch of paleobotany. *Fifth Annual Report of the United States Geological Survey*, 1883–1884, edited by John W. Powell, 357–452. Washington.
Ward, Lester Frank. 1885b. Evolution of the vegetable kingdom. *American Naturalist* 19: 637–644 and 745–753.
Ward, Lester Frank. 1888. Evidence of the fossil plants as to the age of the Potomac Formation. *American Journal of Science*, Series 3 36: 119–131.

Ward, Lester Frank. 1889. The geographical distribution of fossil plants. *Eighth Annual Report of the United States Geological Survey*, 1886–1887, Part II, edited by John W. Powell, 663–960. Washington.
Ward, Lester Frank 1891. [Abstract of] Principles and methods of geologic correlation by means of fossil plants. *Science* 18: 282.
Ward, Lester Frank. 1892a. Principles and methods of geologic correlation by means of fossil plants, *American Geologist* 9: 34–47.
Ward, Lester Frank. 1892b. Principes et methodes d'étude de corrélation géologique au moins des plantes fossils. [Extrait du compte-rendu de la cinquième session du Congrès Géologique International, Washington, 1891]. In: *Proces-verbaux des Séances*, 97–109. Washington.
Ward, Lester Frank. 1892c. The plant-bearing deposits of the American Trias. *Bulletin of the Geological Society of America* 3: 23–31.
Ward, Lester Frank. 1893. The new botany. *Science* 21: 43–44. Reprinted in *Glimpses of the Cosmos*, Vol. 4, 367–372.
Ward, Lester Frank. 1894a. Fossil cycadean trunks of North America, with a revision of the Genus *Cycadeoidea Buckland*. *Proceedings of the Biological Society of Washington* 9: 75–88.
Ward, Lester Frank. 1894b. The Cretaceous rim of the Black Hills. *Journal of Geology* 2: 250–266.
Ward, Lester Frank. 1894c. Recent discoveries of cycadean trunks in the Potomac formation of Maryland. *Bulletin of the Torrey Botanical Club* 21: 291–298.
Ward, Lester Frank. 1895a. The Potomac formation. In: *Fifteenth Annual Report of the United States Geological Survey*, 1893–1894, edited by John W. Powell, 307–397. Washington.
Ward, Lester Frank. 1895b. The nomenclature question. *Bulletin of the Torrey Botanical Club* 22: 308–329.
Ward, Lester Frank. 1895c. Fossil plants. *John's Universal Cyclopaedia* 6, 639–645. New York: A.J. Johnson Co.
Ward, Lester Frank. 1896a. Review of A. C. Seward, *Catalogue of the Mesozoic Plants in the Department of Geology, British Museum (Natural History): The Wealden Flora*, Part I—*Thallophyta–Pteridophyta, London, 1894*; Part II—*Gymnospermae*, London, 1895. *Science* 3: 869–876.
Ward, Lester Frank. 1896b. Some analogies in the Lower Cretaceous of Europe and America. *Sixteenth Annual Report, United States Geological Survey*, Part I, 463–542. Washington.
Ward, Lester Frank. 1897. Professor Fontaine and Dr. Newberry on the age of the Potomac Formation. *Science*, New Series 5: 411–419.
Ward, Lester Frank. 1897b. *Dynamic Sociology, or Applied Social Science as Based upon Statistical Sociology and the Less Complex Sciences*. 2 vols. 2nd edn. New York: Appleton and Co. (1st edn, 1883).
Ward, Lester Frank. 1898a. Review of A. C. Seward, *Fossil Plants for Students of Botany and Geology* 1, Cambridge Natural Science Manuals, Biological Series, Cambridge, 1898. *Science* 8: 335–340.
Ward, Lester Frank. 1898b. Description of the species of *Cycadeoidea*, or fossil cycadean trunks, thus far determined from the Lower Cretaceous rim of the Black Hills. *Proceedings of the U. S. National Museum* 21, No. 1,141: 195–229.
Ward, Lester Frank. 1898c. *Outlines of Sociology*. New York and London: Macmillan and Co., Ltd.
Ward, Lester Frank. 1899. The Cretaceous formation of the Black Hills as indicated by the fossil plants. With the collaboration of Walter P. Jenney, William M. Fontaine, and F. H. Knowlton. In: *Nineteenth Annual Report of the United States Geological Survey*, Part II, edited by Charles D. Walcott, 521–946. Washington.
Ward, Lester Frank. 1900a. Status of the Mesozoic floras of the United States. First paper: the older Mesozoic. With the collaboration of W. M. Fontaine, Arteus Wanner, and F. H. Knowlton. Extract from: *Twentieth Annual Report of the United States Geological Survey, Part II, General Geology and Paleontology, 1898–1899*, edited by Charles D. Walcott, 211–748. Washington.
Ward, Lester Frank. 1900b. Elaboration of the fossil cycads in the Yale Museum. *American Journal of Science*, Series 4 10: 327–345.
Ward, Lester Frank. 1903. *Pure Sociology: A Treatise on the Origin and Spontaneous Development of Society*. New York: Macmillan.
Ward, Lester Frank. 1905. *The Status of the Mesozoic Floras of the United States Second Paper, Part I: Text.* In collaboration with William Fontaine, Arthur Bibbins and G. R. Wieland. *Monographs of the United States Geological Survey* 48. Washington.
Ward, Lester Frank. 1913–1918. *Glimpses of the Cosmos*. 6 vols: Vol. 1, 1913; Vol. 2, 1913; Vol. 3, 1913; Vol. 4, 1915; Vol. 5, 1917; Vol. 6, 1918. New York and London: G. P. Putnam's Sons.

West, Robert M. 1990. Vertebrate paleontology of the Green River Basin, Wyoming, 1840–1910. *Earth Sciences History* 9: 45–56.

White, [Charles] David. 1890. Cretaceous plants from Martha's Vineyard, *American Journal of Science*, Series 3 39: 93–101.

White, [Charles] David. 1892. The Cretaceous at Gay Head, Martha's Vineyard. *Science* 20: 332.

Wieland, G. R. 1906. *American Fossil Cycads*. Washington D. C.: Carnegie Institution of Washington.

Williston, Samuel W. 1905. The Hallopus, Baptanodon, and Atlantosaurus beds of Marsh. *Journal of Geology* 13: 338–350.

Woodford, A. O. 1963. Correlation by fossils. In: *The Fabric of Geology*, edited by Claude C. Albritton Jr, 75–111. Stanford: Freeman, Cooper and Co.

Woodward, Horace B. 1893. *The Jurassic Rocks of Britain: The Lias of England and Wales (Yorkshire Excepted)*. Memoirs of the Geological Survey of the United Kingdom 3. London.

Woodward, Horace B. 1894. *The Jurassic Rocks of Britain: The Lower Oolitic Rocks of England (Yorkshire Excepted)*. Memoirs of the Geological Survey of the United Kingdom 4. London.

Woodward, Horace B. 1895. *The Jurassic Rocks of Britain: The Middle and Upper Oolite Rocks of England (Yorkshire Excepted)*. Memoirs of the Geological Survey of the United Kingdom 5. London.

Yochelson, Ellis L. 2005. A forgotten local geologist—Atreus Wanner of York, Pennsylvania. *Pennsylvania Geology* 35: 2–9.

Zimmerman, Katharine. 2007. Disciplining the Reception of Darwin: The Botanical and Sociological Work of Lester Frank Ward. MA thesis, Oregon State University.