Charles D. Walcott: A Few Comments on Stratigraphy and Sedimentation

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ABSTRACT

Throughout his career, Charles D. Walcott was a prodigious scientist. Although perhaps best known for his contributions to our understanding of the Cambrian System, including discovery of the Burgess Shale Biota, Walcott made other important contributions to stratigraphy and sedimentology that have had a lasting impact. Some contributions seem to have been quite deliberate, whereas others may have been less conscious. Examples of his deliberate scientific efforts are: measuring and describing more than 8250 m (25,000 ft) of strata in Utah and Arizona; interpreting the origin of limestone breccia and conglomerate within a limestone matrix; calculation of geologic time from rates of sedimentary deposition; and consideration of the Ozarkian and Canadian as time periods. An interesting contribution that may have been less obvious is the observation that limestones could form quickly in shallow marine water.

INTRODUCTION

The name Charles Doolittle Walcott (1850-1927) is immortalized in the geologic community as the discoverer of the Burgess Shale in 1910 (Walcott, 1911), a Cambrian deposit of exceptional preservation (Cover Photo, Figures 1, 2) whose study has altered forever the way that paleontologists interpret the fossil record (e.g., Whittington, 1985; Conway Morris, 1989, 1998; Gould, 1989; Briggs et al., 1994; Yochelson, 2001). Paleontologists are aware of the importance of Walcott's description of the Burgess Shale fossils, beginning in 1911 (Walcott, 1911), and also of his numerous and important contributions to the study of early Paleozoic trilobites and brachiopods (see for citations Briggs et al., 1994; Yochelson, 2001). Walcott not only described many of the early Paleozoic trilobite genera and species known from North America up through the 1920s, but also was the first to clearly describe the appendages of trilobites (Walcott, 1876, 1918).

The science of paleontology includes two important components, biostratigraphy and paleobiology. Walcott practiced both, but the emphasis throughout his career was on biostratigraphy. Apart from the Burgess Shale, he collected primarily to interpret the relative ages of rocks in stratigraphic sections that he measured. Furthermore, he identified collections submitted by many others to aid their mapping and structural-geologic interpretations. Taphonomy as a subdiscipline of paleontology had not developed until the latter half of the twentieth century, but Walcott nevertheless developed arguments and conclusions that we could, in retrospect, regard as early taphonomic work (e.g., Walcott, 1898).

Other contributions of Walcott's that had longstanding effects on the science of geology were removal of "the Taconic period" from the geologic column; clarification and correction of what constituted Lower Cambrian and Middle Cambrian rocks in North America; definition of the base of the Cambrian System in North America at the lowest occurrence of the trilobite *Olenellus*; and strengthening of a three-fold division of the Cambrian System (see Yochelson, 2001). The practice of using Lower, Middle, and Upper Cambrian was accepted worldwide for more than a century. Ultimately, the tripartite division of the Cambrian System was abandoned (Geyer and Shergold, 2000; Peng et al., 2004; Babcock et al., 2005), in large part because of the addition to the Cambrian of a thick succession of strata below the first appearance of trilobites (Landing, 1994; Palmer, 1998; Geyer and Shergold, 2000; Peng et al., 2004; Babcock et al., 2005).

In 1902, colleagues thought of Walcott as the third most important geologist in America (behind G. K. Gilbert and T. C. Chamberlin; see Yochelson, 2001). Unfortunately, much of the rationale for that view has disappeared from geologic consciousness. The purpose of this paper is to review some of Walcott's less well remembered contributions to the science of geology in an effort to characterize the man whose work has touched the careers of all sedimentary geologists that have followed him. Walcott's work as a field geologist was impressive, and his field studies are an appropriate place to begin documentation of his importance.

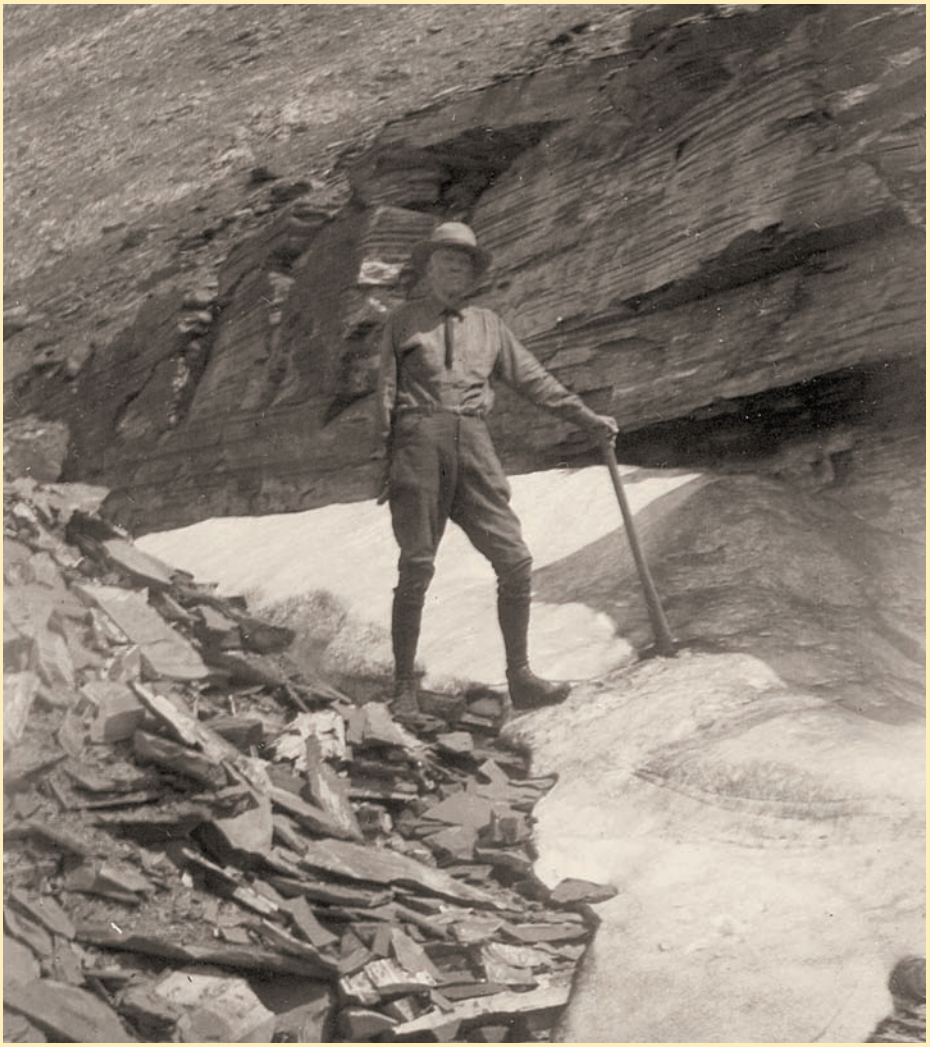

Figure 1: Charles D. Walcott digging snow out of the Burgess Shale quarry. Fossil Ridge, between Mount Wapta and Mount Field, Canadian Rocky Mountains, British Columbia, 1917. Photograph from Smithsonian Institution Archives, Record Group 95, Box 24.

PHANEROZOIC AND OLDER ROCKS

In 1879, during his first season with the U. S. Geological Survey, C. D. Walcott started with Locke Level and barometer in the Paleogene lake beds of the Bryce Canyon region of southwest Utah and measured downward to the Cambrian, which was exposed near the level of the Colorado Canyon at the mouth of Kanab Canyon. This was 4290 m (13,000 ft) of section!

During 1881 and 1882, Walcott measured sections and collected fossils throughout the Paleozoic section in the Eureka, Nevada, mining district. He published descriptions of the fossils in order to date the various units. All the fossils are reasonably well located stratigraphically, but only the descriptions of the fossils were published (Walcott, 1884). Old though it may be, this monograph is one of the principal sources of information on Paleozoic megafossils from the Great Basin.

In 1882-1883, Walcott "offset" his Kanab, Utah, section, about 70 km to the east and went into the Grand Canyon for 79 days. He began measuring downward at the Cambrian and added another 3960 m (12,000 ft) of sedimentary rocks, plus 330 m (1,000 ft) of volcanics, to his section (Yochelson, 1998). So far as I know, Walcott measured more of a continuous stratigraphic section than anyone, and I am unaware of anyone who measured 8 km (5 miles) of section.

Walcott's work in the Grand Canyon (Figure 3) serves as an exemplar of intellectual contributions that slip into sedimentary geology literature almost unnoticed. Based on a few scraps of fossils, primarily stromatolites, Walcott originally dated most of the Grand Canyon section as Cambrian (Walcott, 1883). Within a few years, he reconsidered and termed them "pre-Cambrian" (Walcott, 1886a, 1886b). Previous to this time, Archean was the name used for rocks below the Cambrian. Archean strata were metamorphics and intrusive igneous rocks that looked as though they were ancient and highly altered. That a thick sequence of non-metamorphosed sedimentary rocks, preserving stromatolites, mudcracks, and other features typical of Phanerozoic strata could actually exist below the Cambrian was a novel concept for the developing geologic time scale. Within a few years, the time term "Algonkian" was proposed for a large succession of these pre-Cambrian rocks (see for history Van Hise, 1892). A major philosophical advance marks the difference between references to the pre-Cambrian of the late1880s and the current use of the word Precambrian, but nevertheless Walcott's recognition of a fossiliferous "pre-Cambrian" represented a sea change for the time.

Three less far-reaching examples of Walcott's contribution to sedimentary geology are discussed below. Unfortunately, just as the significance of his use of pre-Cambrian has been overlooked, these examples also have largely faded from the collective memory of geologists.

CONGLOMERATES, BRECCIA, AND LIMESTONE

During 1882 and 1883, Walcott made two, short, intensive trips to examine the Cambrian around York, Pennsylvania (Walcott, 1892). One result was his observation of limestone conglomerates and breccias within the early-middle Cambrian limestone sequence (Walcott, 1894). A prevailing view in stratigraphy at the time was the importance of an unconformity. If an angular unconformity could not be observed, a conglomerate was commonly interpreted as evidence of a significant time break in the geologic history of an area.

By documenting the presence of conglomerates and breccias within a sequence of apparently continuous sedimentation, Walcott was directing caution to interpretation of one of the basic tenets of field geology. Following his publication (Walcott, 1894), there was no obvious discussion either for or against the concept that a conglomerate or breccia necessarily indicates a major unconformity. In part, this may have been because the only mechanism that he could propose for the transport of large blocks was rafting by sea ice, and that long-held concept was falling into decline. Walcott's understanding of limestone conglomerates was more than half a century before the idea of turbidity currents sweeping down continental slopes became an accepted concept.

In regard to the far smaller chips of limestone, Walcott had a simpler mechanism. He observed on a Rhode Island beach that modern sediments could form a hard crust rapidly which would then be broken into pieces and transported by the incoming tide (Walcott, 1895). The implication that limestone could form in exceedingly shallow water, harden rapidly, and be broken and transported was not pursued by him, nor did it register with other geologists of the time. In terms of understanding the formation of limestones, however Walcott's casual observation was decades ahead of its time.

GEOLOGIC TIME

Thanks to the efforts of Lord Kelvin, the age of the Earth was a major concern from the 1860s onward. Kelvin's ever decreasing time scale caused serious problems for the geologic community. Geologists had notions of rates of deposition and erosion, but as an eminent physicist, Kelvin had real numbers and formulas to bolster his arguments. Walcott (1893) approached the problem by considering in detail how much limestone, shale, and sandstone, was deposited in the western United States during the Paleozoic and proceeding from there. The method was not unique, but his analysis was the most sophisticated in this particular line of inquiry. He gave no details on where he obtained data for the Cenozoic and Mesozoic, although it can be assumed that his measurements came from his 1879 work on the Colorado Plateau.

Walcott's (1893) suggested age was a minimum of 25 to 30 million years, and a maximum of 60 to 70 million years for the post-Archean interval. "In conclusion, geologic time is of great but not of indefinite duration. I believe that it can be measured by tens of millions, but not by single millions or hundreds of millions, of years." This seemed to generate no discussion in literature from geologists, and one may assume from this that geologists were generally satisfied with his conclusion. Shortly thereafter, radioactive decay was discovered and, about a decade after Walcott published, the first radiometric dates were being discussed. Apparently his effort was never cited in a textbook and it rapidly faded from view, now being only an historical curiosity.

One aspect of Walcott's exercise, however, should not be ignored. His figures for the duration of the three eras of the Phanerozoic may be treated as a ratio of Paleozoic to Mesozoic to Cenozoic. This ratio (12:5:2) was strikingly different from what was then current in the literature, but is almost identical to that derived from the latest radiometric dates (Yochelson, 1989).

OZARKIAN AND CANADIAN

In 1907, Walcott left the directorship of the U.S. Geological Survey and became Secretary of the Smithsonian Institution. From his position with the Smithsonian, he then proceeded to do field work in western Canada for almost two decades. If one ignores the Burgess Shale and a few other geologic distractions, he basically began study at the base of the Lower Cambrian, systematically measuring sections and documenting fossils. Then he studied Middle Cambrian strata in a similar manner, proceeding on to the Upper Cambrian and then the Ordovician. He just also touched on the Silurian when he died in 1927. Many years later, a team of geologists from the Geological Survey of Canada, with strong logistical support, including helicopters, restudied these rocks. Walcott had gotten to all the best sections and had correctly interpreted the basic stratigraphic framework (J. D. Aitken, personal communication, 1993). About the time that Walcott began work in Canada, E. O. Ulrich began to forcefully push his concept of two new geologic systems, the Ozarkian and Canadian, to fit between more restricted concepts of the Cambrian and Ordovician (Weiss and Yochelson, 1995). Several eminent geologists of the past generation have indicated to me in informal conversations that the Canadian might have been accepted as a system by North American geologists, but Ulrich's insistence on a still older "system" and his attacks on other worker effectively doomed his efforts.

Walcott's was essentially the only prominent geologist who used both of the proposed systems in his publications. One may guess that throughout his career he was attuned to ever finer divisions of geologic time and thus was of an open mind in further dividing the Paleozoic.

One aspect of Ulrichian geology was that it was based on "layer cake" stratigraphy. Strata were presumed to remain essentially unchanged in sedimentary character throughout the length of their outcrop. The notion of a facies change in sedimentation of a stratigraphic unit was not acceptable. In Ulrichs's view, seas from one direction deposited sediment and then withdrew, to be followed by seas from another direction depositing a different type of sediment. It was in this manner that a change along strike from limestone to shale could be explained away. Ulrich's prose was not easy to comprehend. What may be the best exposition of Ulrichian notions is presented in a summary paper by Walcott (1927). Like many of the other examples of Walcott's work given above, one cannot judge what effect, if any, it had at the time, but Ozarkian and Canadian have disappeared as geologic periods.

LEGACY AND CONCLUSIONS

Charles Doolittle Walcott was a workaholic who never paused between manuscripts. In terms of volume of paleontological publication, he probably ranks among the three most productive paleontologists of the nineteenth or twentieth centuries (together with Joachim Barrande and James Hall). His laboratory investigations were closely linked to his field work. In the years since Walcott's work was published, stratigraphic investigations have been refined, with new terms added, but the subdivisions he identified and the thicknesses he measured remain virtually unchanged. Likewise his paleontological work has been closely reexamined, yet the basic structure of his conclusions remain little changed. Despite my investigations, I am still unable to fully explain how he was able to publish so much research of such a high quality.

ACKNOWLEDGMENTS

For about half a century, I have been, off and on, pursuing the life and scientific efforts of C.D. Walcott. I thank Chip Clark for providing the photograph of *Olenoides*, and the Smithsonian Institution Archives for permitting the use of archival photographs of Walcott. Use of the photos was arranged by Ellen Atlers. I also thank the anonymous reviewers and editors for helping to improve the manuscript and prepare it for publication.

REFERENCES

BABCOCK, L.E., PENG, S.C., GEYER, G., and SHERGOLD, J.H., 2005. Changing perspectives on Cambrian chronostratigraphy and progress toward subdivision of the Cambrian System: Geosciences Journal, v. 9, p. 101-106.

BARNES, L.G., 1979, Fossil enaliarctine pinnipeds (Mammalia: Otariidae) from Pyramid Hill, Kern County, California. Contributions in Science, Natural History Museum of Los Angeles County, v. 318, p. 1-41. BRIGGS, D.E.G., ERWIN, D.H., and COLLIER, F.J., 1994. The fossils of the Burgess Shale: Smithsonian Institution Press, Washington, D.C.

CONWAY MORRIS, S., 1989. Burgess Shale faunas and the Cambrian explosion: Science, v. 246, p. 339-346.

CONWAY MORRIS, S., 1998. The crucible of creation: The Burgess Shale and the rise of animals: Oxford University Press, Oxford.

GEYER G., and SHERGOLD, J., 2000. The quest for internationally recognized divisions of Cambrian time: Episodes, v. 23, p. 188-195.

GOULD, S.J., 1989. Wonderful life: The Burgess Shale and the nature of history: Norton, New York.

Figure 2: Slab of Burgess Shale (Cambrian) showing two trilobites, Olenoides serratus *Walcott, both retaining their calcified exoskeleton and their nonbiomineralized (originally chitinous) appendages. Exoskeleton of the specimen at lower right = 8 cm. Photograph by Chip Clark.*

Figure 3. Charles D. Walcott standing on Cambrian strata looking into the Inner Gorge of the Grand Canyon, Arizona, 1915. Photograph from Smithsonian Institution Archives, Record Group 95, Box 24.

LANDING, E., 1994. Precambrian-Cambrian boundary global Stratotype ratified and a new perspective of Cambrian time: Geology, v. 22, p. 179-182.

PALMER, A. R., 1998. A proposed nomenclature for stages and series for the Cambrian of Laurentia: Canadian Journal of Earth Sciences, v. 35, p. 323-328.

PENG, S.C., BABCOCK, L.E., ROBISON, R.A., LIN, H.L., REES, M.N., and SALTZMAN, M.R., 2004. Global Standard Stratotype-section and Point (GSSP) of the Furongian Series and Paibian Stage (Cambrian): Lethaia, v. 37, p. 365-379.

VAN HISE, C.R., 1892, Correlation papers - Archean and Algonkian: U. S. Geological Survey Bulletin 86, 549 p.

WALCOTT, C.D., 1876. Preliminary notice of the discovery of the remains of the natatory and branchial appendages of trilobites (advance printing [New York State Museum Annual Report, 1879]).

WALCOTT, C.D., 1883. Pre-Carboniferous strata in the Grand Canyon of the Colorado, Ariz.: American Journal of Science, ser. 3, v. 26, p. 437-442, 484.

WALCOTT, C.D., 1884. Paleontology of the Eureka district: U. S. Geological Survey Monograph 7, 298 p.

WALCOTT, C.D., 1886a. Classification of the Cambrian system of North America: American Journal of Science, ser. 3, v. 32, p. 138-157.

WALCOTT, C.D., 1886b. Second contribution to the studies on the Cambrian faunas of North America. Cambrian faunas of North America: U. S. Geological Survey Bulletin 30, 369 p.

WALCOTT, C.D., 1892. Notes on the Cambrian rocks of Pennsylvania and Maryland, from the Susquehanna to the Potomac: American Journal of Science (third series), v. 44, p. 52-57.

WALCOTT, C.D., 1893. Geologic time, as indicated by the sedimentary rocks of North America: Journal of Geology, v.1, p. 639-676). [See Yochelson, 2001 for location and dates of subsequent reprintings].

WALCOTT, C.D., 1894. Paleozoic intraformational conglomerates: Geological Society of America Bulletin, v. 5, p. 191-198.

WALCOTT, C.D., 1895, The Cambrian rocks of Pennsylvania: U. S. Geological Survey Bulletin 134, 43 p.

WALCOTT, C.D., 1898, Fossil medusae: United States Geological Survey Monographs, no. 30, p. 1-201.

WALCOTT, C.D., 1911. Middle Cambrian Merostomata. Cambrian geology and paleontology II: Smithsonian Miscellaneous Contributions, v. 57, p. 17-40.

WALCOTT, C.D., 1918. Appendages of trilobites. Cambrian geology and paleontology IV: Smithsonian Miscellaneous Contributions, v. 67, p. 115-216.

WALCOTT, C.D., 1927, No. 4- Pre-Devonian sedimentation in southern Canadian Rocky Mountains: Smithsonian Miscellaneous Collections, v. 74 (40, p. 147-143.

WEISS, M. AND YOCHELSON, E.L., 1995. Ozarkian and Canadian systems: Gone and nearly forgotten, in Cooper, J.D., Droser, M.L., and Finney, S.C. (eds.) Ordovician Odyssey: Short papers for the Seventh International Symposium on the Ordovician System: Pacific Section of the Society of Sedimentary Geology (SEPM), p. 41-44.

WHITTINGTON, H.B., 1985. The Burgess Shale: Yale University Press, New Haven, Connecticut.

YOCHELSON, E.L.., 1989, “Geologic time” as calculated by C. D. Walcott: Earth Sciences History, v.8, p. 150-158.

YOCHELSON, E.L. 1998, Charles Doolittle Walcott, Paleontologist: Kent State University Press, Kent, Ohio, 44242, 510 p.

YOCHELSON, E. L. 2001, Smithsonian Institution Secretary, Charles Doolittle, Walcott: Kent State University Press, Kent, Ohio, 44242, 589 p.

Accepted 28 February 2006