

# Harry Eugene Wheeler (1907-1987): A Pioneer of Sequence Stratigraphy

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**ABSTRACT:** Harry Eugene Wheeler (1907-1987) of the University of Washington was a pioneer of genetic stratigraphic principles that form the basis of our modern concept of sequence stratigraphy. Wheeler's papers on what he liked to refer to as "stratology" included the classification of stratigraphic units into lithostratigraphic and biostratigraphic entities, as well as cyclothems, unconformity-bounded units, and the analysis of base-level and its role in forming stratigraphic discontinuities. His work on unconformity-bounded "sequences" ultimately led the International Subcommission on Stratigraphic Classification to define them formally in 1987. The plots used to clarify the time-relationships of rock units are now referred to as "Wheeler diagrams". It is not uncommon that, in any scientific paradigm shift, many of the key pioneers are not fully recognized for their contributions at the time, being significantly ahead of prevailing concepts. It is also not uncommon that, by the time their points of view come into vogue, their contributions may have been largely forgotten with greater recognition given to those who synthesized or "popularized" their concepts. This is certainly true in the fields of seismic and sequence stratigraphy, where, despite the theoretical framework for sequence analysis formulated by Wheeler (1958a), little reference was made to Wheeler's work in the early formulation of these concepts in the 1970s and 1980s. Wheeler, schooled by Blackwelder, Mueller, and Schenck at Stanford and armed with the base-level concept of Joseph Barrell, was one of the first to recognize the concept of time stratigraphy. Due to his unorthodox view of stratigraphy, Wheeler was involved in one controversy after another and his views were deemed to be provocative. While the valuable contributions of latter practitioners and synthesizers are justifiably lauded, the works of original pioneers such as Harry Eugene Wheeler are largely underappreciated.

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## INTRODUCTION

In his excellent history of stratigraphy, Miall (2004) indicated that Harry Eugene Wheeler (1907-1987) of the University of Washington was one of the early pioneers of genetic stratigraphy (text-fig. 1). Stratigraphy, considered by many to be a routine and mundane discipline consisting mainly of the dry cataloguing of lithostratigraphic units, has undergone a dramatic renaissance. With the ascendance of genetic stratigraphic paradigms and their refinement over the past three decades, stratigraphers have radically altered how we perceive and, therefore, interpret the rock record. Such frameworks rely heavily on clastic facies analysis, and as such, allow insights derived from process sedimentology to be applied to our characterization of stratigraphic bodies. One could argue that genetic stratigraphic paradigms, especially those that emphasize the processes that control and create stratigraphic patterns and bounding surfaces, serve as the unifying theory of sedimentary geology.

Genetic stratigraphy lies at the core of three main stratigraphic schemes: genetic stratigraphic sequences or T-R (transgressive-regressive) sequences, allostratigraphy, and sequence stratigraphy.

The recognition and assessment of the genesis and chronostratigraphic significance of stratigraphic breaks are crucial to genetic stratigraphic paradigms, but are challenging to resolve, particularly in subsurface analysis.

Stratigraphic discontinuities reflect processes that operate outside the influence of individual depositional environments (i.e., are allogenic). Such processes typically initiate or terminate deposition of sedimentologically related facies successions. Interpreting the causative mechanism(s) of stratigraphic discontinuities can be vital in resolving depositional environments of the associated deposits and in determining the allogenic controls on depositional systems. Linking these allogenic mechanisms to the chronostratigraphy of depositional successions is crucial and marks a major turning point in the evolution of stratigraphy as a science.

It is an unfortunate fact that in any paradigm shift in science, many of the key pioneers are not properly recognized for their contributions. At the time such visionaries undertook their work, they were ahead – and in many instances decades ahead – of the prevailing concepts. By the time their points of view come into vogue, their contributions were overshadowed by



TEXT-FIGURE 1  
Harry Eugene Wheeler 1907–1987 (photograph courtesy of Carolyn Wheeler Van Wyck).

those of workers who synthesized or popularized the concepts, rather than invented the paradigm. We suggest that this has been the unfortunate fate, to date, of Harry Eugene Wheeler. It is telling that Wheeler himself defined the term “sequence” to refer specifically to unconformity-bounded stratal units (Wheeler 1958a; 1959a), and utilized the term “sequence” in a profoundly modern sequence stratigraphic context (Wheeler 1958a).

Sloss et al. (1949) were the first to use the term “sequences” in a stratigraphic context. They stated that: “*Sequences should be considered as rock units, assemblages of formations and groups. They are simply the strata which are included between objective, recognizable horizons, and are without specific time significance since their limits do not coincide with time lines and may include rocks of different ages in various areas*” (Sloss et al. 1949, p. 110). On that basis, they erected four continent-wide sequences (the Sauk, Tippecanoe, Kaskaskia, and Absaroka). Wheeler took exception to this definition, and in his 1958a paper stated “*A sequence, as the term is employed in the present discussion, is thus defined as a preserved stratal assemblage which is unconformably separated from underlying and overlying rocks.*” (Wheeler 1958a, p. 1051). A year later, he specified that a sequence “*should not be envisaged as a unit belonging to the hierarchy or category as group, formation, or*

*member, for it is by definition and nature independent of them.*” (Wheeler 1959a, p. 1976).

Wheeler (1959a) then concluded that an unconformity-bounded unit is defined as a body of rock bounded above and below by specifically designated, significant, and demonstrable discontinuities in the stratigraphic succession (angular unconformities, disconformities, etc.), preferably of regional or interregional extent. This is shockingly similar to the definition of “sequence” articulated nearly 20 years later by Mitchum (1977) and Mitchum et al. (1977, p. 53), who defined a *sequence* as “*a stratigraphic unit composed of a relatively conformable succession of genetically related strata bounded at its top and base by unconformities or their correlative conformities*”, (without, by the way, any reference to Wheeler); a definition that prevailed for an additional 30 years. With the advent of additional genetic stratigraphic frameworks, a more generic definition has been proposed as “*a succession of strata deposited during a full cycle of change in accommodation or sediment supply*” (Catuneanu et al. 2009), a definition that nevertheless accommodates Wheeler’s visionary concept.

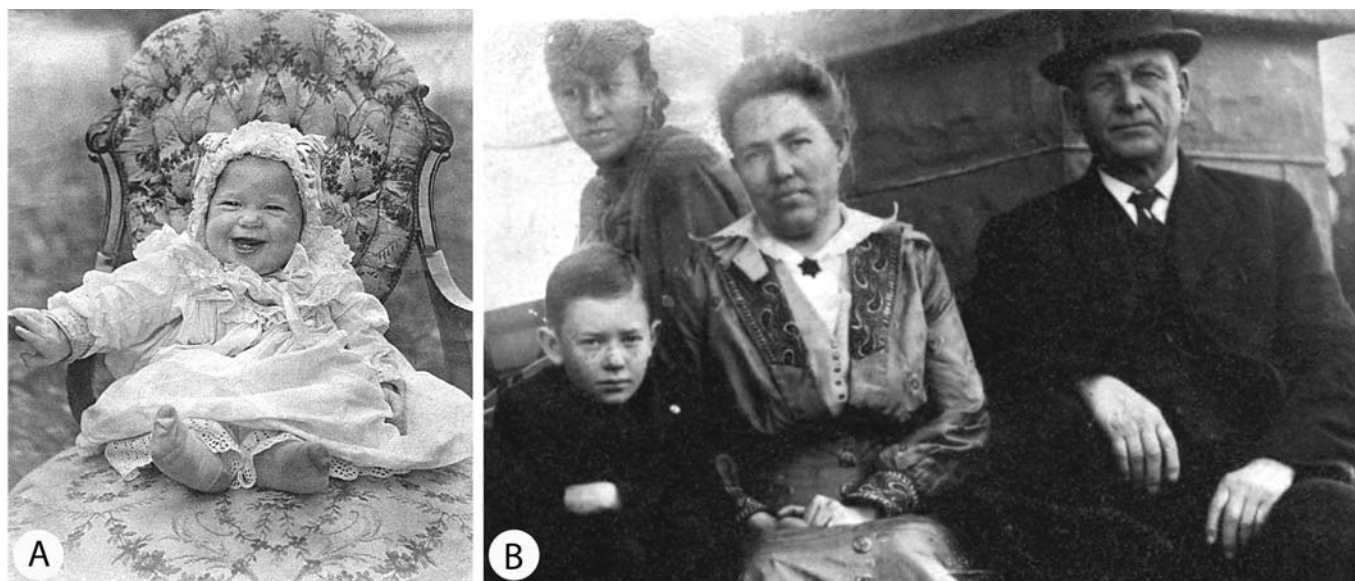
Harry Wheeler was schooled by Eliot Blackwelder, Siemon Mueller, and Hubert Schenck at Stanford University, who were armed with the earlier “base level” concepts of Joseph Barrell. He was a close colleague of Larry Sloss, who in turn was one of the first to formalize the time-stratigraphic analysis of unconformities. Due to his unorthodox view of stratigraphy, Wheeler was involved in one controversy after another, with his views deemed provocative or even heretical at the time. While we now value and recognize the later contributions of Bill Galloway, John Van Wagoner, Mac Jervey, Henry Posamentier, Peter Vail and others who resurrected sequence stratigraphy, the work of the original pioneers like Joseph Barrell, Amadeus Grabau, Eliot Blackwelder, John Rich, and Harry Wheeler often receive scant attention or mention. It is a sad commentary that, in the case of Harry Wheeler, there exists only a single, 3-page memorial published in a State Survey Bulletin to extol his contributions to the stratigraphic community.

#### HARRY EUGENE WHEELER (1907–1987)

Details on Harry Wheeler’s life were gathered from memorial papers written by Barksdale (1982), Cheney (1987), and Illman (1996); comments from past students (Gary Peterson, online comments; C.V. Aiken, personal communications); comments from colleagues (Julian Barksdale); and details given to the first author by his daughter, Carolyn Wheeler Van Wyck.

Harry Wheeler was born on February 1, 1907, in Pipestone, Minnesota (text-fig. 2A), the son of Mary Belle Denhart Wheeler and Benjamin Franklin Wheeler (named after a famous relative, apparently). The family left Minnesota soon after Harry’s birth and his boyhood was spent in Eugene, Oregon. He was the only son and was born late in his mother’s life; as a result, he was doted over by his parents and his two, much older sisters (text-fig. 2B). Wheeler’s education took place during the Great Depression and his family lost most of their accumulated wealth during this time. He told stories about attending “speakeasies” during prohibition, and said that his ability to continue his education during the depression was a wonderful opportunity, brought about with the help of his family and the fact that jobs that might have drawn his attention were non-existent.





TEXT-FIGURE 2

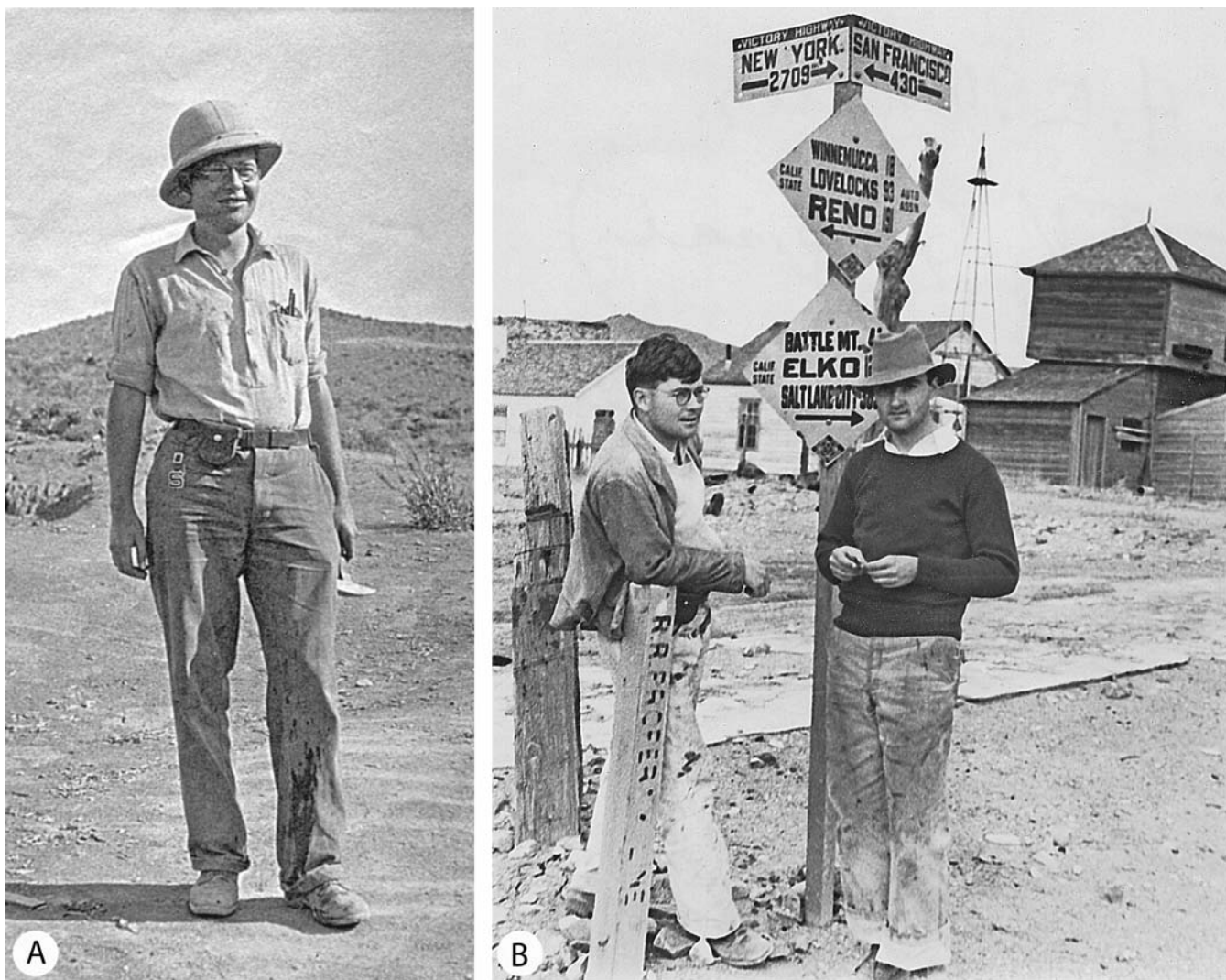
A. Harry Wheeler in 1908 at the age of one. B. Harry in 1913 at the age of 6 with his father Benjamin Franklin Wheeler, his sister Gretchen, and his mother Mary B. Wheeler (photographs courtesy of Carolyn Wheeler Van Wyck).

Harry attended the University of Oregon and graduated in 1930. During his studies at Oregon, he served as a field assistant for Earl Packard and Arthur F. Buddington, and there developed his life-long love affair with fieldwork (text-fig. 3A). Harry then went to Stanford University as a Jordan Fellow, completing his Masters in 1932 and his PhD in 1934 (text-fig. 4A) on the Lower Permian McCloud Limestone of northern California (Wheeler 1934). It was at Stanford that Harry became acquainted with the stratigraphic philosophy of a remarkable faculty that included Hubert G. Schenk, Siemon E. Mueller, and Eliot Blackwelder. Stanford was a virtual factory for the generation of insightful stratigraphers, including life-long friend Larry Sloss, Bob Weimer, George Ashley, and Charlie Stelck, to name just a few. In 1935, Wheeler accepted the position of Assistant Professor in the Mackay School of Mines at the University of Nevada in Reno. Wheeler stayed in Reno for 13 years and worked on paleontological and stratigraphic problems in the Paleozoic rocks of Nevada, eastern California, and northern Arizona (text-fig. 3B). In Reno, Wheeler met his wife, Loretta Rose Miller (text-fig. 4B) who taught in the botany department at the University, and they were married in 1938. Loretta quickly became a mother three times over (Eugene Anthony Wheeler 1939, Carolyn Wheeler Van Wyck 1940, and David Beebe Wheeler 1942), and due to the university's nepotism rules, was not able to go back to teaching botany. During World War II, Wheeler served (1943-1946) in the U.S. Naval Reserve and in 1944 moved his family to Nebraska briefly where he taught in the V-12 program. Soon after, he moved them to Washington, DC (text-fig. 5A and B), where he worked in the Hydrographic Office. After the war, George E. Goodspeed recruited Wheeler for the University of Washington following the retirement of Charles E. Weaver. In 1948, Harry took up his position at the University of Washington, where he remained until his retirement in 1976. After retirement, Wheeler remained at the University in the position of Emeritus Professor until his death in 1987.

Wheeler was a very genial person. That said, he was also very confident of his findings, and his geology was out of synch with the prevailing doctrines. His children remember him occasionally speaking laughingly of fellow geologists who thought he was completely nuts (in fact, his campus nick-name was "Crazy Harry"). He spoke often of the trap of conventional thinking (the habit of building knowledge on prevailing wisdom/assumptions) that prevented clear thinking. His ability to take a global view in separating data from his insight and being able to integrate it into a fresh interpretation was what made him tick. His daughter Carolyn remembers that his passion for integrating knowledge was his purpose in life. Wheeler's unconventional thinking personified the well-known axiom attributed to Abbie Hofmann who asserted, "*Sacred cows make the best hamburger*"!

Gary L. Peterson (online blog), one of his graduate students, remembers him as a brilliant geologist. "*All in all, Harry required patience, knowledge and perseverance in order to follow and understand him. It most certainly wasn't easy and a lot of the students suffered. But when you took the time and effort and tried, Harry was one of the most interesting and inspirational geologists I've ever met. He had his own unique explanations for practically everything. His knowledge of stratigraphy was overwhelming. If it was stratified, Harry knew about it and if an idea was expressed, Harry probably had his own better idea. The man was simply amazing. I've seen him back down several visiting speakers to the point that they had to admit that Harry's explanation fit their data better than their own explanation. I've also seen him use a speaker's data to refute the speaker's interpretation, all of which was extremely interesting but did not endear him with visiting speakers. Harry was an extremely controversial man and strong opinions were voiced on all sides.*"

Julian D. Barksdale, a colleague and close friend of Wheeler's at the University of Washington, also noted "*Harry is a mild-mannered, soft-spoken person with a very rough pen; so rough in fact, that a close friend and fellow stratigrapher has been known to*



TEXT-FIGURE 3

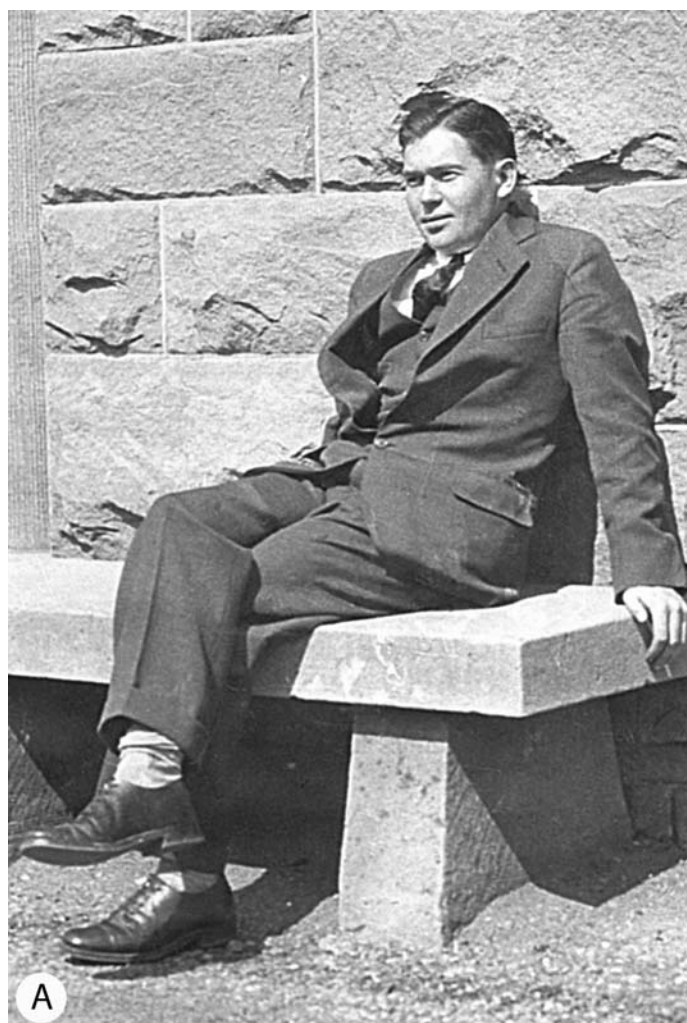
A. Harry doing fieldwork in Nevada, 1935. B. Harry and J. V. Galgiani in Golconda, Nevada, 1934 (photographs courtesy of Carolyn Wheeler Van Wyck).

publish what he said was a paraphrase of an old Magyar proverb: “With Wheeler as a friend, who needs enemies?” Rough but without malice.... Wheeler’s stratigraphy is not always orthodox, but it is provocative.” (in Cheney 1987, p. 394).

His sharp pen resulted in a number of interesting exchanges with his fellow scientists. In 1963, he published a paper entitled “Post-Sauk and Pre-Absaroka Paleozoic Stratigraphic Patterns in North America” The paper generated a total of six discussions (Sloss 1964; R. R. Wheeler 1966; Franks 1966; Muehlberger 1966; Hayes and Gerdemann 1966; and Moody 1966) followed by six replies from Wheeler (1964b; 1966a, b, c, d, and e). In one of these replies Wheeler (1966d) accuses the authors of Lysenkoism by concluding his reply with the statement “In this light perhaps there is no need to reply to the Lysenkoism expressed in the last paragraph of the Hayes-Gerdemann discussion” (Wheeler 1966d, p.1052). Such a bold statement would have been a telling rebuke in the mid-1960’s. In Forbes magazine, Ferrara (2013) summed up Lysenkoism

with “Scientists who promoted Lysenkoism with faked data and destroyed counterevidence were favored with government funding and official recognition and award. Lysenko and his followers and media acolytes responded to critics by impugning their motives, and denouncing them as bourgeois fascists resisting the advance of the new modern Marxism”. Likewise, in response to a discussion of one of his papers by Weller (1958), he concluded his reply with the statement “Regarding Weller’s concluding words of warning against “spurious evidence in the form of attractive generalizations,” we offer the reminder that we did not propose most of the essential generalizations on which this theory is based. They were presented by Weller (1956, p. 26-27) and the few remaining essential generalizations have not yet suffered disparagement merely by his assertion that they are “spurious.” (Wheeler and Murray 1958, p. 446). Other examples of his controversies with other geologists can be found in Cheney (1987, p. 394) and include: the defining of a number of Tertiary sequences in the Cordillera that workers in the Pacific Northwest only began to rediscover two decades





TEXT-FIGURE 4

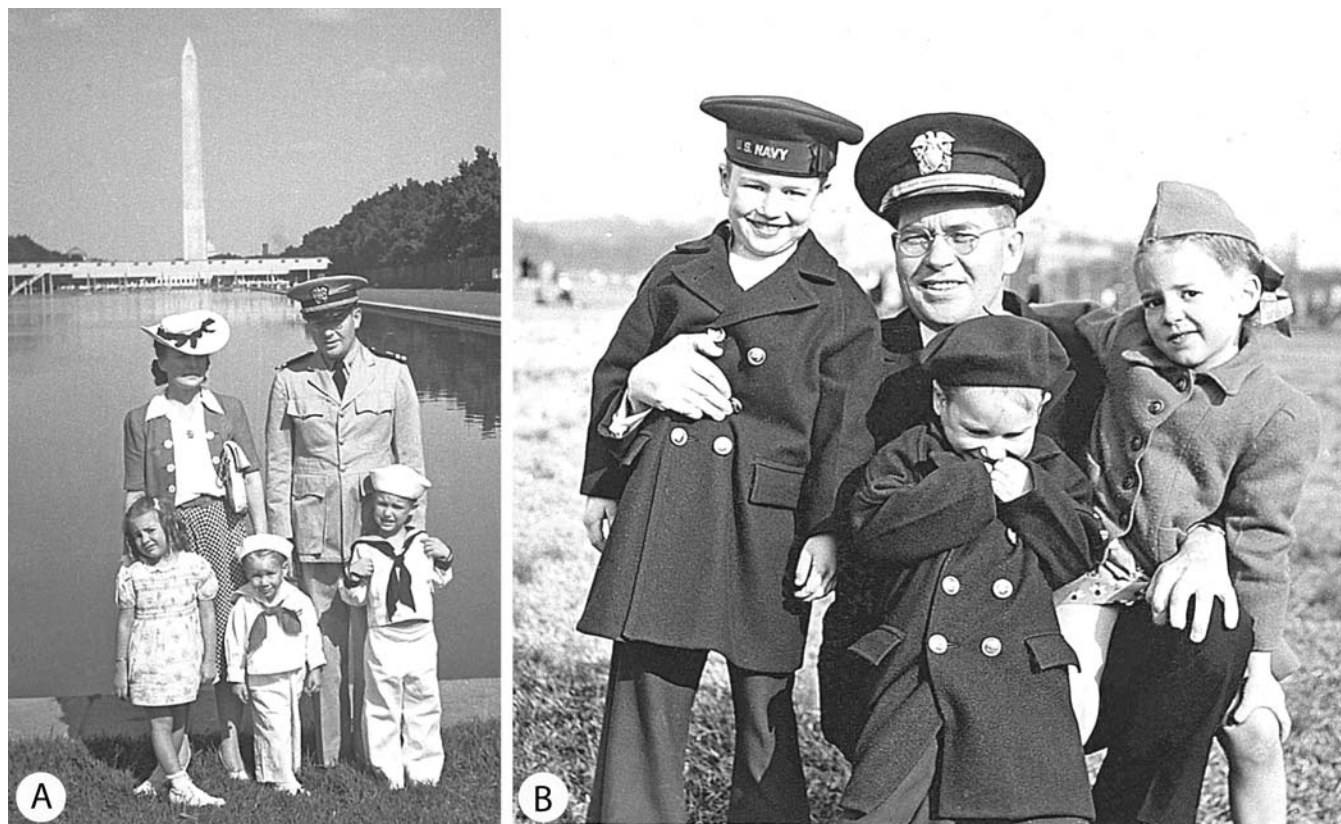
A. Harry Wheeler at Stanford, 1932. B. Harry and Loretta in Reno, 1940 (photographs courtesy of Carolyn Wheeler Van Wyck).

later; the assertion that the middle Devonian Catskill delta as well as the Illinois and other intracratonic basins and domes were erroneous constructs; his contention that deformation in the Pacific Northwest was younger than commonly supposed; and the argument that the Columbia River basalts once extended over (not below) the Cascade Range of Oregon. In each case, his views upset the *status quo* and generated considerable debate within the geological community.

As a graduate student advisor, Wheeler inspired his students and allowed them to think for themselves. Gary L. Peterson (online blog) noted that “*Harry became my graduate school mentor and I couldn’t have made a better choice. He was kind, gentle, understanding, patient, always available, always a good listener and he spent countless hours trying to unravel my tortured prose. Many people used to consider Harry something of an ogre and they wondered how I could possibly work under such a man. Nothing could be farther from the truth. I could freely express my ideas to Harry and we’d spend hours discussing all the ramifications. On several occasions, my explanations ran directly counter to the ideas he had expressed in our*

*courses. As long as my approach was logical, Harry offered nothing but encouragement.*”

Harry’s daughter Caroline remembers that Harry was an extremely interesting conversationalist, and was passionate foremost about geology. His second passion was world affairs. During the McCarthy years, his children recall Harry and Loretta arguing about his signing the loyalty oath, which was required in order for him to hold his job at the University of Washington. The oath was later removed, of course, but he was always angry about the need to sign it. He was a consummate liberal, and viewed his position in life as being a world citizen rather than only a citizen of the United States. In the 1950’s, he often stated that China would be the awakening giant that would eventually turn the world, as we know it, on its head. He dismissed the then prevalent problems with the Soviet Union as transitory. His children recall that Wheeler, as most geologists will do, often made derisive statements about the geologically risky places humankind selects to put its cities and developments - and explained why geologic events would cause them to fail. Subsequent events, of course, have proven the correctness of his perspective.



TEXT-FIGURE 5

A. The Wheelers in Washington, 1944. B. Harry and his children Eugene, David and Carolyn in Washington, 1944 (photographs courtesy of Carolyn Wheeler Van Wyck).

Carolyn indicated that Harry knew how things worked. He fixed everything and passed his knowledge (or his wiring) down to his children. He also loved bargain hunting, and second-hand shops were his means to buy his clothing as well as just about everything else. Once, he found an old antique roll-top desk while doing fieldwork in Nevada. He bought it for \$10.00 and brought it back to Seattle where he “antiqued” it with a greenish finish. It took quite a bit of work years later for one of his children to remove the “antiquing” and restore it to its original antique condition. Another project was his wallpapering of Loretta’s old upright piano. The result was a rather startling faux woven-mat appearance. The final outrage was his spray paint job of a 1953 Hillman Minx automobile. He masked out the windows and then used 13 cans of metallic green spray paint purchased from Sears to transform it. The re-born Hillman was suddenly transformed into a gigantic blue-bottle fly. Many years later, when the car was on its last legs, he drove it into a local used car lot. He sold it on the spot for \$300.00 and then took the bus home rather than risk having to drive back with it later after arranging return transportation. Carolyn indicated that the used car lot went out of business shortly thereafter.

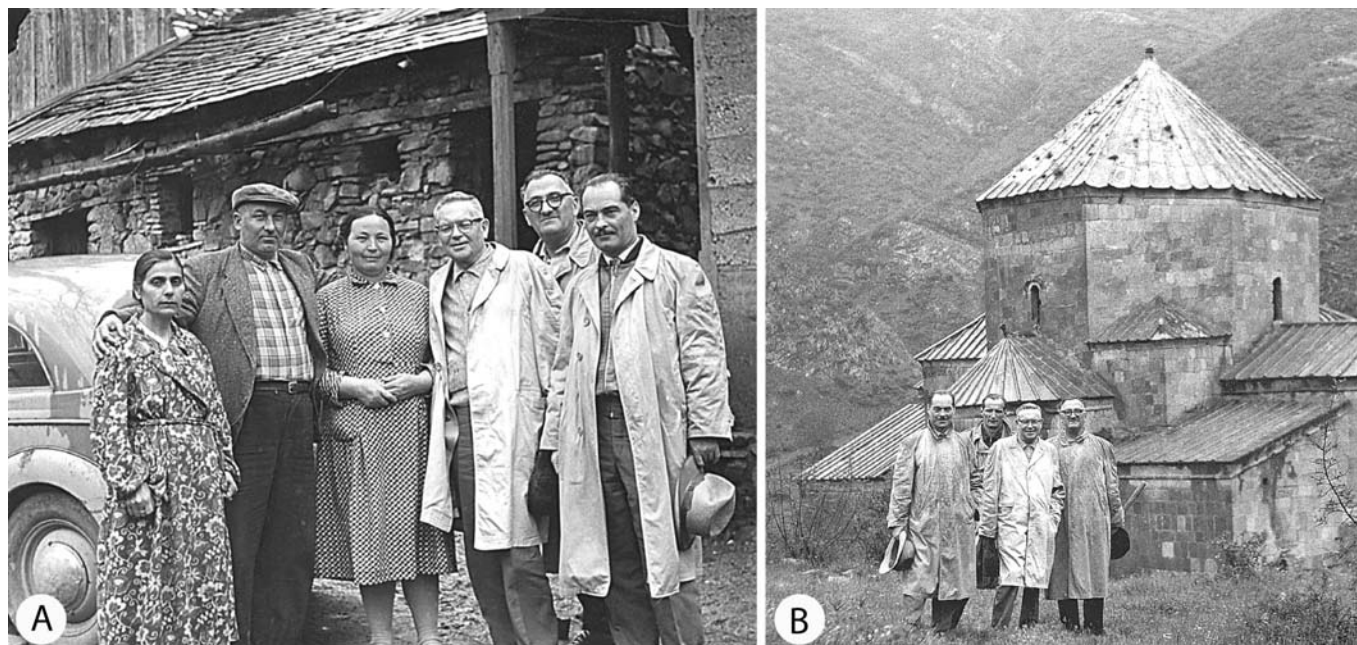
During his career at the University of Washington, Wheeler developed a peripatetic style and was a Visiting Professor at Indiana University (1956–1957), the University of Texas (1961), and Southern Methodist University (1966). In 1957, he was a guest of the French National Center for Scientific Research and,

in 1960, completed his Grand European geology tour of Europe. Perhaps his most intriguing tour, however, came in 1963 when he was a member of a National Academy of Science-Soviet Academy of Science Exchange Program. Traveling extensively in the USSR in 1963, then firmly behind the “iron curtain”, Wheeler toured not only Moscow, but also extensive parts of Georgia (text-fig. 6), Armenia, and the Crimea. When he returned, the CIA interviewed him to find out if he had anything to share. He didn’t. He was already angry that fellow geologists from the Soviet Union weren’t given the same courtesy he had been accorded when he was a visitor in their country. His Soviet counterparts were usually forbidden by the US State Department to come to the United States or, if allowed, their travel was extremely restricted and heavily monitored.

Harry also served as an industry consultant and worked for both Phillips Petroleum (1948–1949) and the Gulf Oil Corporation (1950–1958) doing various studies. He had intended to continue writing his final book on stratigraphy after he retired, but the advance of Binswanger’s disease (much like Alzheimer’s disease in its symptoms) robbed him of that opportunity. Harry Eugene Wheeler passed away in Seattle, Washington, on January 26, 1987.

Anecdotal information from former University of Washington student Carlos V. Aiken (now Professor at UT Dallas), who overlapped with Wheeler, suggests that during Wheeler’s last years at Washington he expressed that he was not enamored of





TEXT-FIGURE 6

A. Harry with his hosts in Atremi, Georgia, USSR, 1963. B. Harry at the Zion of Atemi, Atemi Valley, Georgia, in 1963 (photographs courtesy of Carolyn Wheeler Van Wyck).

the “new” global plate tectonic theory. We speculate that his reluctance to accept plate tectonic theory, unlike his colleague Larry Sloss, may have led to the dismissal of his scientific contributions by the wider academic community at that time, and may explain why his work was ignored for so long. We would argue that whether he accepted plate tectonics or not hardly invalidates his approach to analyzing stratigraphic patterns; approaches that are still practiced today.

The final word should go to Harry Wheeler’s daughter Carolyn, who summed up Harry best with “*Dad’s life was devoted to, and consumed by geology. He taught in the winter and spent his summers doing fieldwork; and on the occasions that he was with us as we drove across the country, he was always the teacher, explaining to us what we were seeing. We all miss him!*”

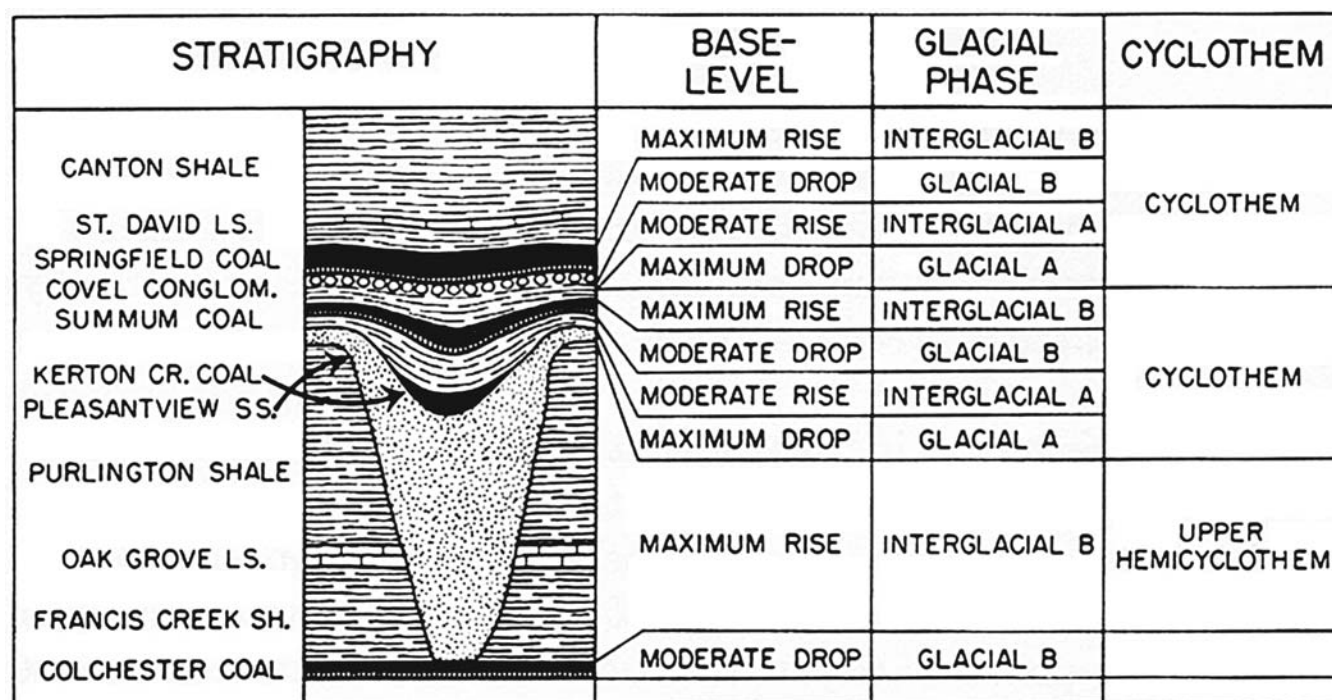
## WHEELER’S STRATOLOGY

Wheeler’s colleagues stated that instead of stratigraphy, Wheeler practiced what he referred to as “stratology”. Stratology stressed the idea that stratigraphic analysis must include integration of observations of stratal patterns, analysis of the time associated with unconformities, the interpretation of these surfaces in the context of base level change, and their implications with respect to regional and interregional analysis and historical interpretations. One of his students, Gary L. Peterson, recalled, “*Harry had his own precise definitions and even his own words for all sorts of stratigraphic principles and concepts. He was constantly berating all the sacred work in the literature and all the standard ways of doing things.*”

Wheeler’s papers on stratology included: the classification of stratigraphic units (Wheeler and Mallory 1953; Wheeler 1959a)

into lithostratigraphic (Wheeler and Mallory 1956) and biostratigraphic (Wheeler 1958b) frameworks, as well as cyclothems (Wheeler and Murray 1957); the analysis of unconformity-bounded units, to which he applied the term “sequence” (Wheeler 1959a); and the true nature of base-level (Wheeler 1964a). His work on unconformity-bounded units led the International Subcommittee on Stratigraphic Classification to formally define them in 1987. In the publication, they noted “*Wheeler (1958b; 1959a; 1959b; 1960; 1963) was probably the first to recognize unconformity-bounded units as clearly distinct from other kinds of stratigraphic units.*” (Salvador 1987, p. 233). Wheeler was instrumental in re-introducing the concepts of Joseph Barrell on base-level, and used them to interpret the significance of key stratigraphic surfaces (see Romans 2007 for an excellent discussion of Wheeler’s 1964a paper). Wheeler summed this up with “*Constantly varying undulations of the baselevel surface relative to the ever-changing lithosphere surface may be seen as a consistent function of the ebb and flow of depositional and erosional environments in the space-time continuum.*” (Wheeler 1964a, p. 607). Wheeler then took this concept and interpreted surfaces (text-fig. 7) that can be considered to delineate the first incised valley complex, described earlier by Wanless and Shepard (1936).

Not all of his concepts have been adopted, however (Bhattacharya and Abreu 2016). His sequences, for example, were defined by arbitrary vertical cutoffs. This followed earlier ideas about the designation of lithostratigraphic units, also defined on the basis of arbitrary cutoffs (Wheeler and Mallory 1953; Wheeler and Mallory 1956; text-figure 8), the use of which was criticized at the time (Fischer 1954). Wheeler and Mallory (1953, 1956) primarily were attempting to explain what they understood to be the common, but uncoded practice of using these cutoffs in actually defining and naming lithostratigraphic units (text-fig-



TEXT-FIGURE 7

Wheeler was instrumental in re-introducing the concepts of Joseph Barrell on base-level, and used it to interpret the significance of key stratigraphic surfaces. Wheeler took the concept and interpreted surfaces in what can be considered the first incised valley complex described earlier by Wanless and Shepard (1936) (after Wheeler and Murray 1957).

ure 8A). In other words, they regarded most lithostratigraphic units at that time to have been defined using arbitrary cutoffs, and they believed that it was their role to explain and codify what was being informally practiced. In this respect, they did not consider that they were introducing anything new or particularly radical. They indicated a need for the recognition of three fundamentally different kinds of lithostratigraphic units: (1) *Formal lithostratigraphic units*, such as groups, formations, and members, which are traditionally designated on the basis of their position in a vertical sequence and in places defined by arbitrary cutoffs, especially where interfingering occurs (text-fig. 8A); (2) laterally varying *lithofacies* (text-fig. 8B); and (3) mutually intertongued bodies or *lithosomes*, which are segregated on the basis of their vertical and lateral position and their component lithology (text-fig. 8C).

Bhattacharya (2011) pointed out that most formal lithostratigraphic units, especially those defined and named in the 1950s and 1960s and characterized by interfingering were also defined by arbitrary vertical cutoffs, such as in the Cretaceous clastic wedges of the Western Interior of North America (Wheeler and Mallory 1953; 1956; text-fig. 9). Bhattacharya (2011) went on to stress that the lithofacies concept was fundamentally different in Wheeler's day (Wheeler and Mallory 1953; 1956), in that lithofacies were defined by the ratio of general lithologies within gross stratigraphic units, which might include several formations (text-fig. 8B). This is in marked contrast to the modern, more depositionally/paleoenvironmentally based lithofacies concept practiced today. The net result of the Wheeler and Mallory (1953) lithostratigraphic approach was a proliferation of different names for the same

rocks that was ultimately confusing to all except those geologists deeply concerned with the rules of stratigraphic nomenclature (Bhattacharya and Abreu 2016).

#### Wheeler's Stratology Terminology

**Lacuna:** Geochronology: A chronostratigraphic unit representing the interpreted space-time value of both non-deposition (hiatus) and the erosionally removed part of the subsequent transgressive-regressive succession (Wheeler 1958a, p. 1058; Wheeler 1964a, p. 599).

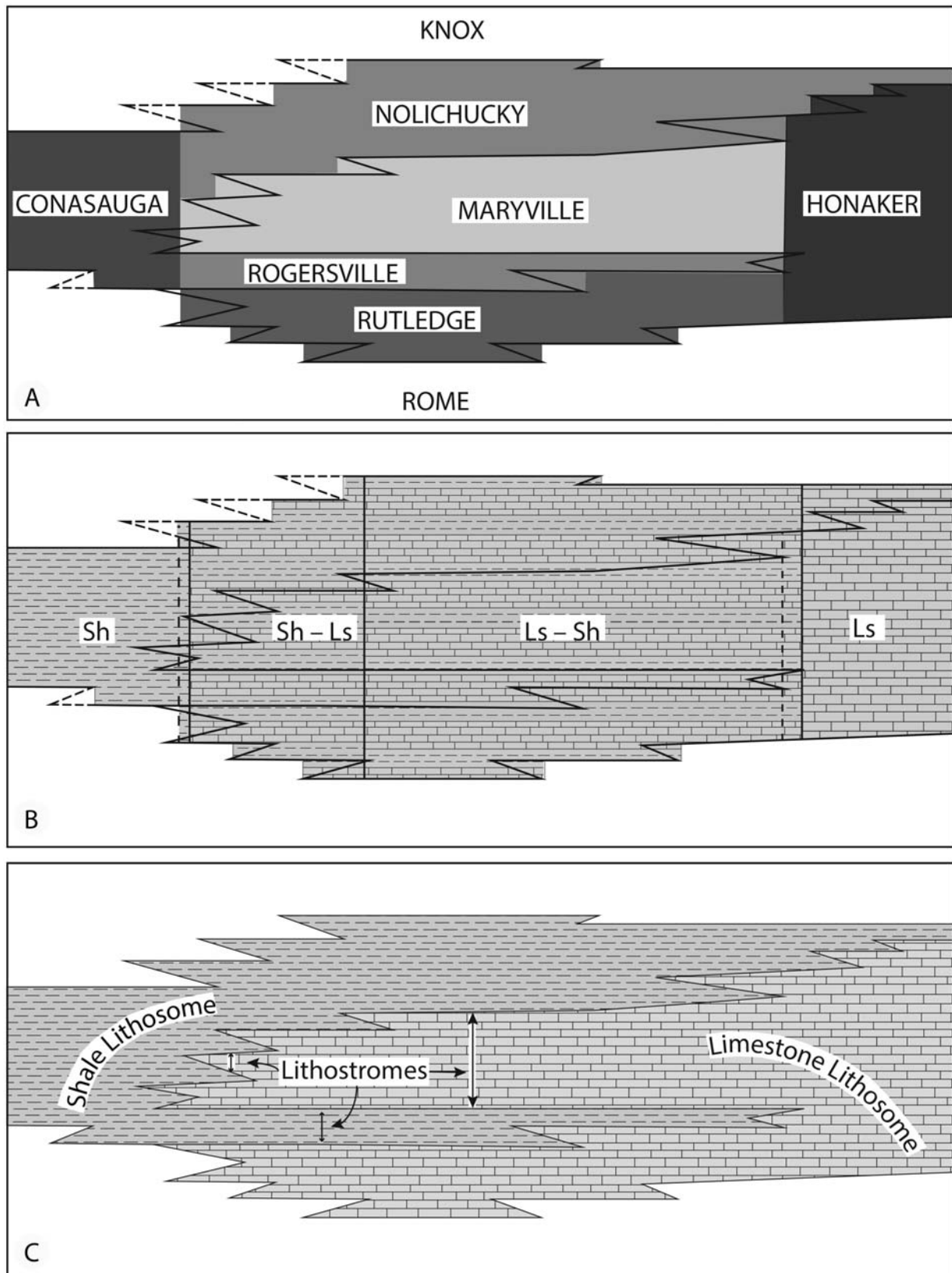
**Lacuna:** Stratigraphically: A period of time during which sedimentation was either nil or, more likely, was removed by erosion (Gignoux 1955, p. 15-16).

**Total Vacuity:** A missing interval or hiatus in a stratigraphic sequence caused by both erosion and non-deposition (Wheeler 1958a, p. 1058).

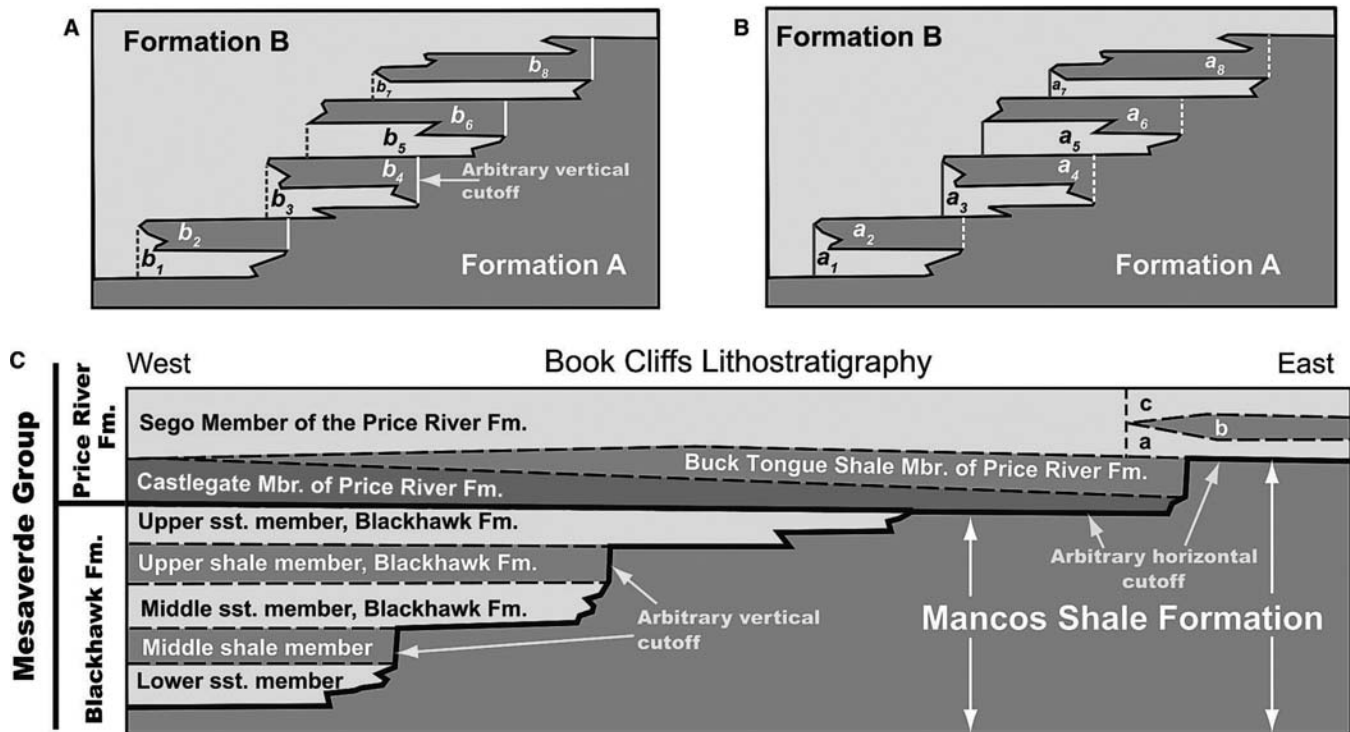
**Erosional Vacuity:** A term used by Wheeler (1958a p. 1057), later replaced by "degradation vacuity" (Wheeler 1964a, p. 602; see below).

**Degradation Vacuity:** The space-time value of the degradationally removed part of a transgressive-regressive depositional sequence (i.e., the part of a stratigraphic lacuna resulting from erosional removal of previously existing rocks at an unconformity). The term was used by Wheeler (1964a, p. 602) to replace erosional vacuity. Mitchum et al. (1977, their figure 1) later referred to this as the erosional hiatus, but neglected to acknowledge Wheeler.





TEXT-FIGURE 8  
Generalized stratigraphic cross-sections of rock units in the Cambrian of Tennessee, Kentucky, and Virginia, illustrating: A. Formations, which are traditionally designated on the basis of their position in vertical sequence; B. Lithofacies, which are lateral quantitative variants; and C. Mutually intertongued bodies or lithosomes, which are segregated on the basis of both their vertical and lateral position (after Wheeler and Mallory 1956).



TEXT-FIGURE 9

Lithostratigraphic subdivision within interfingering clastic wedges. (A) Intertonguing units are assigned to Formation B using arbitrary vertical cutoffs. (B) Intertonguing units are assigned to Formation A using arbitrary vertical cutoffs. (C) Application to the Campanian Mesaverde Group strata of the Book Cliffs, Utah. Shale tongues are assigned to the Blackhawk Formation, rather than to the Mancos Shale Formation. Modified after Wheeler and Mallory (1953). sst = sandstone (after Bhattacharya 2011).

**Hiatus:** A geochronologic unit representing the space-time value of non-deposition during a transgressive-regressive episode (Wheeler 1958a, p. 1057).

**Holostrome:** A term introduced by Wheeler (1958a, p. 1061) for an intertongued chronostratigraphic unit, which restores sediments removed by the degradational vacuity, and which may be either depositional (comprising one or more contiguous holostromes) or hiatal (consisting of combined, contiguous hiatuses).

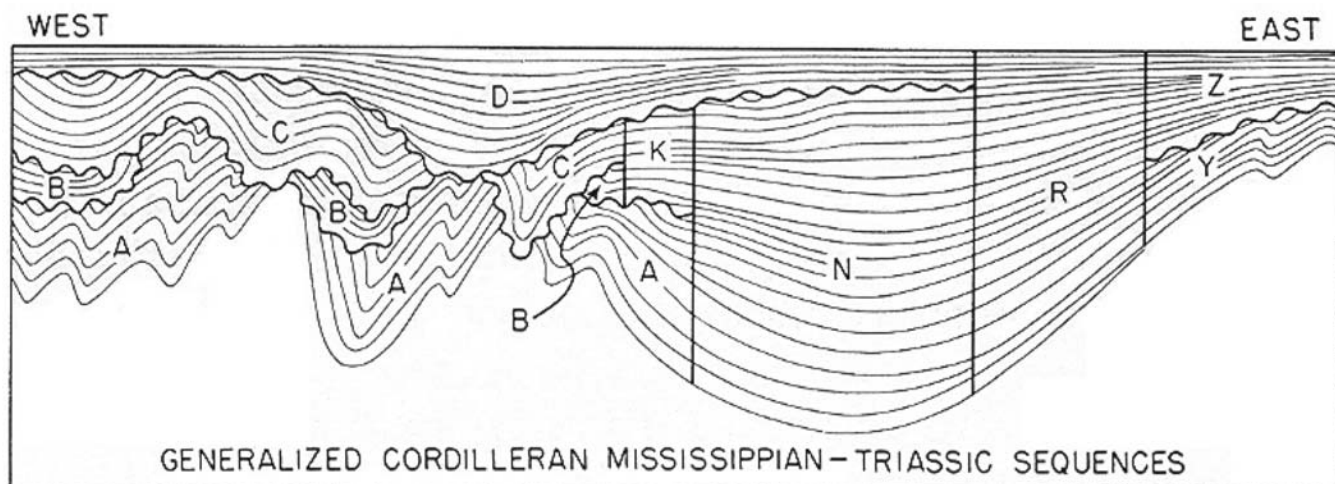
**Lithosome:** A rock mass of essentially uniform or uniformly heterogeneous lithologic character, having intertonguing relationships in all directions with adjacent masses of different lithologic character (see text-figure 8C). The term was introduced by Wheeler and Mallory (see Fischer 1954 and Wheeler and Mallory 1954, p. 929) and defined by Wheeler and Mallory (1956, p. 2722) as a lithostratigraphic body or vertico-laterally segregated unit that is "mutually intertongued with one or more bodies of differing lithic constitution" (Wheeler and Mallory 1956, p. 2722). This is somewhat closer to the modern usage of the facies concept, albeit at a rather larger scale.

**Lithostrome:** A term introduced by Wheeler and Mallory (1956, p. 2720-2722) for a sedimentary unit "consisting of one or more beds of essentially uniform or uniformly heterogeneous lithologic character" and representing the "three-dimensional counterpart of a lithotope", especially an individual tongue projecting from a lithosome.

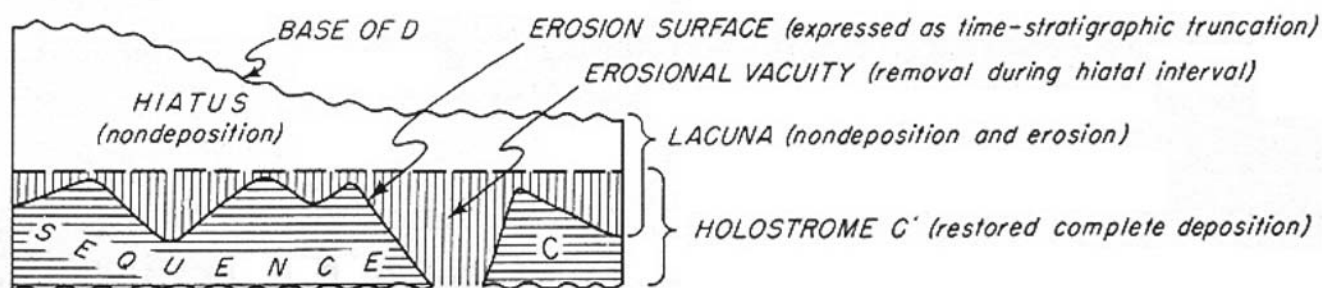
**Arbitrary Cut-Off:** A concept presented as: "If a rock unit terminates by combined lateral and vertical gradation (or otherwise pinches out), or if its lateral limit is one of erosion or faulting, there are no serious problems about termination. Moreover, no difficulties are encountered where one rock unit pinches out between two other distinct units, .... On the other hand, no such convenient point or line of termination is present in the case where one rock unit bifurcates with mappable parts passing laterally below and above an opposed terminating unit. In this case, if each of the bifurcations is recognized as a formal stratigraphic unit, their planes of separation from the parent unit are not marked by lithologic distinction, and must therefore be established arbitrarily. If this arbitrary cut-off is generally recognized and applied as standard procedure in the preparation of both stratigraphic cross sections and geologic maps, much of the present mistrust and disagreement among stratigraphers and physical geologists should be eliminated." (Wheeler and Mallory 1953, p. 2412).

**Base-level Transit:** Wheeler (1964a, c) indicated that, because deposition and degradation always alternate due to the upward and downward transit of base level across the lithosphere surface, base level may be seen as an undulating, abstract, world-wide surface. He termed this the Base-level Transit Cycle. Wheeler (1964a) defined Base-level transit as: "If in an erosional environment at a given locality, the supply-energy ratio increases sufficiently to induce deposition, baselevel is forced upward across the lithosphere surface at that point at the moment deposition begins, thus initiating the first or depositional

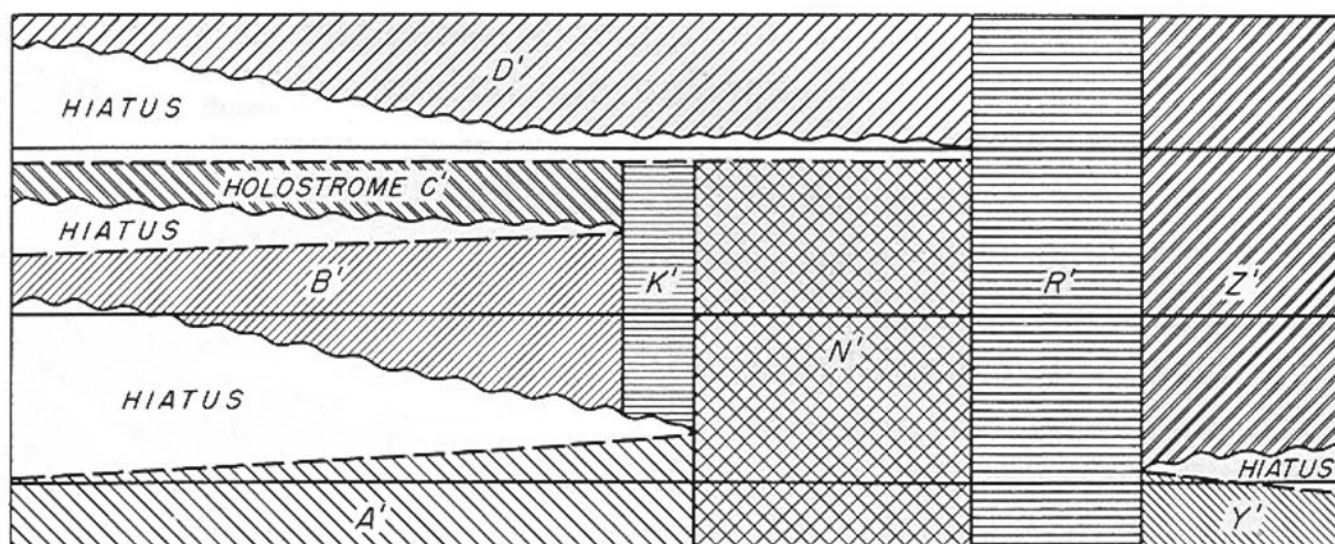




A



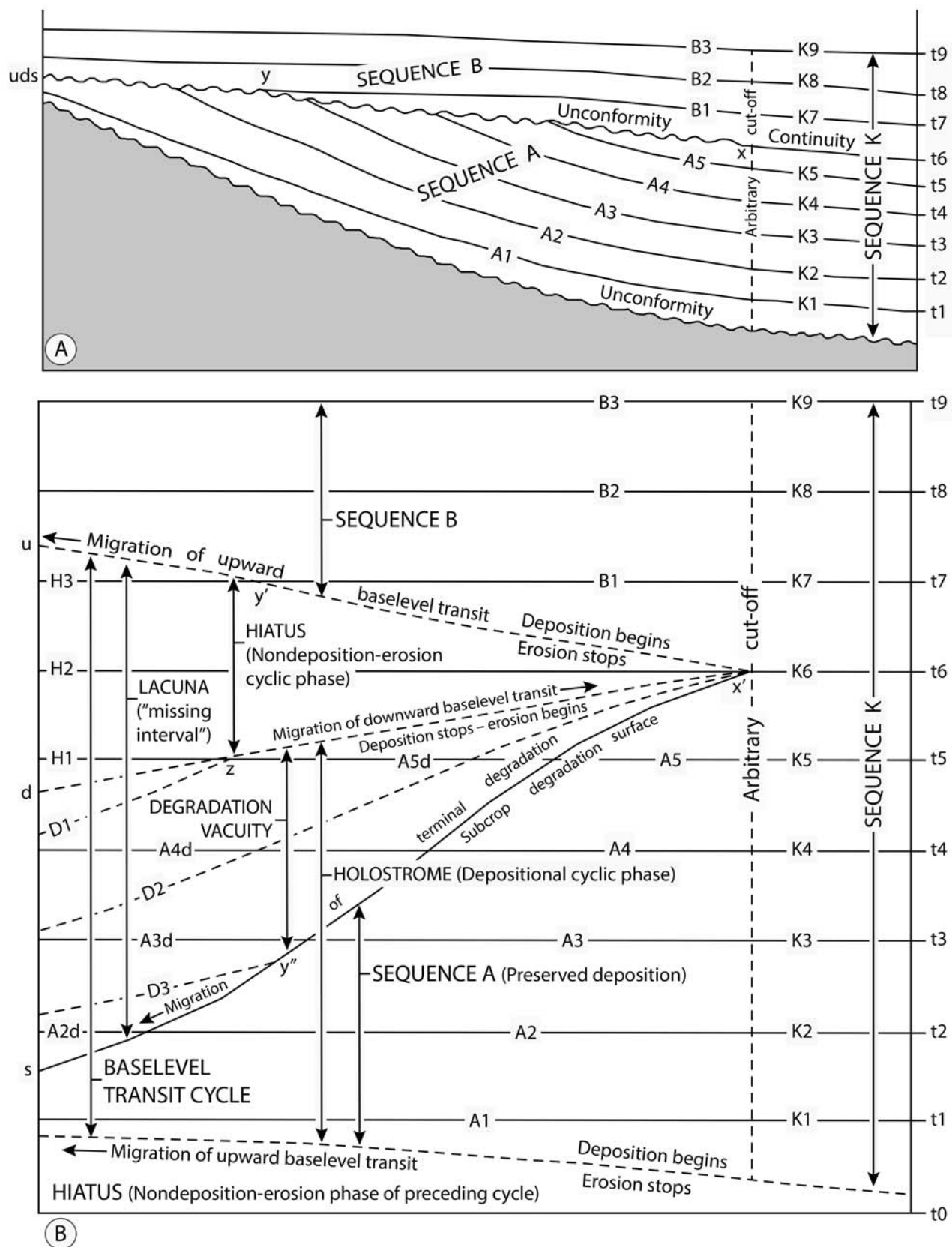
B



C

TEXT-FIGURE 10

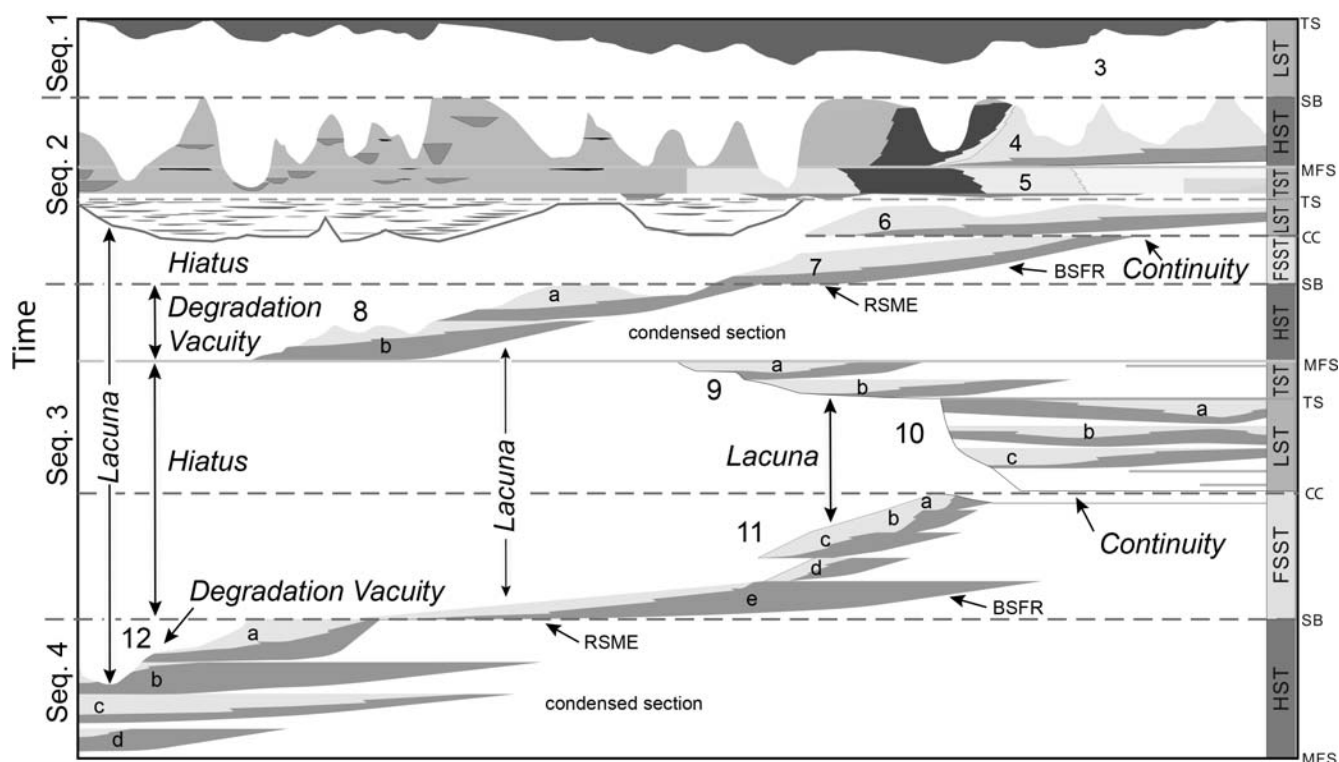
A. Generalized cross-section approximately along the Fortieth Parallel from the Pacific Coast to the Rocky Mountains showing principal sequences and intervening unconformities from base of the Upper Mississippian (Chesterian) to the Triassic-Jurassic boundary. B. Time-stratigraphic cross-section through the lateral extent of Sequence C in Figure A, illustrating derivation of holostrome and hiatus as primary components of regional stratigraphic cycle. C. Time-stratigraphic cross-section showing holostromes and hiatuses derived from sequences shown in A (after Wheeler 1958a).



TEXT-FIGURE 11

A. Section showing physical relationships of successive unconformity-bounded sequences. B. Area-time projection of A showing lithosphere surface-moment and base level transit migration patterns in time-stratigraphy (after Wheeler 1964a).





TEXT-FIGURE 12

Charts such as this have now become recognized as Wheeler diagrams and are considered a standard procedure in genetic stratigraphic characterizations of chronostratigraphic relationships. The diagram shows Wheeler's "stratology" terminology that corresponds to key stratigraphic surfaces and systems tract positions commonly employed today (modified after Bhattacharya 2011 and Zhu et al. 2012).

phase of a new cycle. This cyclic phase continues until the supply-energy ratio is decreased sufficiently to stop deposition and induce erosion, at which time baselevel makes its downward transit of the surface, thus beginning the second or hiatal cyclic phase" (Wheeler 1964a, p. 604). Wheeler (1964b) also noted that the major baselevel transit cycles generally differ from what he termed "insignificant" ones by several orders of magnitude. This foreshadows more recent work on the order of cycles that are recognized on modern sea-level charts.

**Law of Surface Relationships:** Wheeler (1964a) defined what he called the "Law of Surface Relationships" as "Insofar as this logic is sound, it implies the existence of the following stratigraphic principle, which may be called the law of surface relationships: time as a stratigraphic dimension has meaning only to the extent that any given moment in the Earth's history may be conceived as precisely coinciding with a corresponding worldwide lithosphere surface and all simultaneous events either occurring thereon or directly related thereto. At any given moment the Earth's lithic surface is divisible (sic) into innumerable areas, each of which is characterized by one or the other of two processes—deposition and erosion. The boundary between any two of these areas is at baselevel." (Wheeler 1964a, p. 603).

### Wheeler Diagrams

With the advent of genetic stratigraphy, interest in Wheelers' work on stratology has been revitalized. In 1958a, Harry Wheeler produced the most sophisticated chronostratigraphic

charts of the time (text-figs. 10 and 11), which were able to clarify the time-relationships of rock units. He recognized that an unconformity's total time gap (lacuna) consists of a portion reflecting the removal of pre-existing strata (degradational vacuity) and a period of sediment bypass and non-deposition (hiatus), and understood that unconformities pass distally into correlative conformities (continuity) (text-figs. 11 and 12). Although not all of Wheeler's terminology for the various components of a chronostratigraphic analysis has been retained (see text-fig. 11), his general approach is now used as a standard procedure in depicting genetic stratigraphic relationships in time (text-fig. 12). Sloss (1984) applied the name "Wheeler diagram" to such constructs, in homage to their originator. Brown and Loucks (2009) stressed that the advantage of such a "Wheeler chart" is that it displays strata deposited during the same time slice as equivalent strata and reduces problems of laterally confusing litho-stratigraphic correlations. Although it is common practice to take a measured section, well log, or geological cross section and place it next to a chronostratigraphic chart, such as the geological time-scale, the only correct approach is to convert the geological section to a Wheeler diagram, given that there is no obvious relationship between unit thickness and geological time. The conventional Wheeler diagram aids in the construction of a spatio-temporal framework of strata and is generally created manually using outcrops, wells, or seismic data. Wheeler diagrams may use a relative vertical time scale, where absolute chronometry is unknown, or they may use an absolute time scale, where ages of units are well constrained. Mitchum et al. (1977) and Vail et al. (1977) outlined the procedures for constructing and

using Wheeler diagrams (referred to by them simply as “chronostratigraphic charts”) to decipher magnitudes of eustatic sea-level change based on the analysis of lap-out patterns on seismic cross sections. Despite being landmark publications and the first major salvo in seismic stratigraphy, these papers make no reference to Wheeler.

Bhattacharya (2011) and Zhu et al. (2012) have recently used Wheeler diagrams to illustrate alternate hypotheses to test different time-stratigraphic relationships associated with sequence boundaries, especially in degradational deltaic systems that are overridden by fluvial systems. They also illustrate some of the uncertainties that may be associated in converting a stratigraphic cross section to a time-stratigraphic cross section. A key problem remains – the well-known Sadler effect (Sadler 1981; Miall 2016), in which thicker and temporally longer stratigraphic sequences appear to be deposited at ever-slower rates. Part of this dilemma reflects the fact that sediments are not always deposited as basin-wide layers. In many depositional settings (e.g., rivers, deltas, continental slopes), deposition is localized to dipping bodies (e.g. accretion beds, clinothems) or localized channels, lobes or bars, such that they actually record time by lateral deposition versus vertical accretion, and which in many areas may experience local erosion causing diastems. Wheeler-style analysis is a key method that captures the time-stratigraphic record, wherein sedimentation shifts laterally and provides a robust method for evaluating associated unconformities and more local diastems (note, the term diastem was coined by Barrell 1917).

Qayyum et al. (2012) documented the historical development of Wheeler diagrams. Recently, innovative work has been done on the next generation of Wheeler diagrams by Qayyum et al. (2012, 2014, and 2015). Automated methods using seismic data now exist, which support the construction of 2D, as well as 3D Wheeler diagrams. Such 3D diagrams resolve much of the “missing record” that plague 1D and 2D records (Sadler 1981; Miall 2016). Qayyum et al. (2012) emphasized that the diagrams are only complete if one utilizes the thicknesses of a sequence-stratigraphic unit (sequence, systems tracts) – a missing dimension that turns a 3D Wheeler diagram into 4D.

## SUMMARY

Conceptually, Harry Wheeler’s major contributions to stratigraphy include: 1) formalizing the concept of time stratigraphy; 2) recognizing that hiatuses and time gaps are as important in analysis of stratigraphy as the rocks themselves; 3) depicting stratigraphic cross-sections with time on the vertical axis, pioneering the concept of chronostratigraphy; 4) resurrecting the base-level concept of Powell (1875) and Barrell (1917); and 5) defining sequences as unconformity-bounded units, and re-establishing the concepts pioneered by Blackwelder (1909).

It is an unfortunate fact that in any scientific paradigm shift, many of the true pioneers are not fully recognized for their contributions. At the times they were active, they were probably decades ahead of the prevailing concepts and by the time that their points of view are fully appreciated, they have been forgotten and later synthesizers become recognized in their stead. This has been the unfortunate fate of Harry Eugene Wheeler. Wheeler schooled by Eliot Blackwelder, Siemon Mueller, and Hubert Schenck at Stanford University and armed with the base level concept of Joseph Barrell was one of the first to recognize the concepts of time stratigraphy and the significance of uncon-

formity-bounded units. Due to his unorthodox view of stratigraphy, Wheeler was involved in one controversy after another and his views were deemed to be provocative, controversial, and confrontational. Sequence stratigraphy was resurrected in the late 1970’s, largely through the availability of seismic cross sections that were amenable to the analytical techniques of sequence stratigraphic pioneers, such as Laurence Sloss, Harry Eugene Wheeler and their predecessors, Joseph Barrell, Eliot Blackwelder, and Amadeus Grabau. Despite the importance of these pioneers, we suggest that many have not received as much attention and recognition as they deserve, and especially Harry Eugene Wheeler, to which we devote this paper to highlight the importance of his contributions in our field.

## ACKNOWLEDGMENTS

We are indebted to Carolyn Wheeler Van Wyck, the daughter of Harry Wheeler for supplying SGP with family photographs and reminisces about her father. We are also grateful to Eric Cheney of the University of Washington for supplying a field photograph of Harry Wheeler. We extend our thanks to the two anonymous reviewers who helped strengthen the final manuscript. Funding for this project was from the Natural Science and Engineering Research Council of Canada NSERC Discovery Grant program for funding to SGP, JPB and JAM.

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