

Synopsis:
First Impressions: Petroleum Geology at the Dawn of the North American Oil Industry*
By
Raymond P. Sorenson¹

Search and Discovery Article #70032 (2007)
Posted May 8, 2007

*Overview of AAPG publication, entitled “**First Impressions: Petroleum Geology at the Dawn of the North American Oil Industry,**” and prepared by the author. This article, which is essentially taken from the publication explains the importance of each article in AAPG Discovery Series No. 9, available from the AAPG Bookstore (<http://www.aapg.org/eSeries/source/orders/index.cfm?>).

¹1912 S. Cheyenne Ave., Tulsa, OK 74119 (sorensonrk@sbcglobal.net)

Abstract

In 1859, the petroleum industry exploded onto the world scene from the forests of northwestern Pennsylvania with the drilling of the Drake discovery well. Almost overnight, petroleum was transformed from a cottage occupation where oil was collected from seeps and as a byproduct of the brine wells used for salt manufacture, to a major commercial activity.

Boom-time business ventures were accompanied by a demand for an assessment of the resource distribution and size, and a scientific explanation for the origin of oil and gas. Numerous geologists, many of them veterans of governmental geological surveys from the 1840s and 1850s, published their ideas based on observations of seeps, bituminous shale, and other petroleum indications in areas they had worked. Over the course of a few years, literature was generated demonstrating impressive insight into the geological controls on petroleum occurrences.

Although a few historians have recognized the contributions of these early authors, most current petroleum geologists have never seen the original papers that created the scientific framework for their profession, nor would they find it an easy task to locate them. On the eve of the 150th anniversary of Drake’s well, many of these documents are being made available through the contents of this reprint volume.

Notes

Within the publication (AAPG Discovery Series No. 9) itself, underlined text citations indicate papers that have been reproduced in whole or in part and provide links to them. Similar links are provided in the References section in the publication. Papers that have not been digitally reproduced are cited in the normal manner.

For those who desire more background information than is provided by the abbreviated accounts presented in Discovery Series No. 9, the two major AAPG works that cover the history of petroleum geology (Dott and Reynolds, 1969; Owen, 1975) and the essays by Forbes (1936; 1958; 1959) are strongly recommended as points of departure.

Introduction

As petroleum geologists, we commonly find ourselves confronted with novel situations: new exploration plays, unexpected results from a recent well, or technology breakthroughs that open the door to fresh discoveries. In the early 1860s, North American geologists were faced with an entirely new field of endeavor, a major natural resource industry unfolding in the remote Allegheny River watershed of northwestern Pennsylvania.

Imagine yourself as a geologist at the close of the American Civil War in 1865, assigned to travel to northwestern Pennsylvania to apply your scientific knowledge in the search for new oil fields. In preparation, you research the available scientific literature for current thinking on the origin and distribution of oil, and the exploration methods in use. What would be included in a contemporary library collection on petroleum geology?

1860s-vintage geological literature related to petroleum generally falls into three categories: (1) anecdotal descriptions of petroleum seeps or bituminous rocks and their geographic distribution, (2) theoretical discussions of the origin of petroleum, with special emphasis on the relationship to coal, and (3) descriptions of petroleum producing areas, with discussion of trapping mechanisms and reservoirs.

The literature collection included in this volume portrays a broad cross section of thought on the origin and distribution of petroleum at the onset of the commercial petroleum industry. Some papers have long been recognized as cornerstones of the science, others of equal importance have been neglected by historians and generally forgotten, and some represent ideas that have not withstood the test of time. This volume places emphasis on the scientific literature available to geologists working in the North American oil industry, where the immediate post-Drake explosion in petroleum geological literature, like the drilling boom itself, was predominantly a North American phenomenon.

The Dawn of an Industry

Although the petroleum industry justifiably traces its origin as a major commercial enterprise to the drilling booms that followed the 1859 Drake well discovery in northwestern Pennsylvania, it did not emerge from a vacuum. Oil had been utilized from surface seeps and shallow wells for millennia, at numerous sites around the world that foretold the locations of many of today's petroleum provinces (Forbes, 1936; 1958; 1959). Some regions outside of North America, like the Carpathian Mountain region of eastern Europe (Sozanski et al, 2006) or Baku along the Caspian Sea, clearly had ongoing commercial petroleum activity at the time of the Drake discovery. Numerous occurrences were mentioned by some of the early authors (Taylor, 1855; Gesner, 1861; Humboldt, 1858; Newberry, 1860; Robb, 1861; Hunt, 1862), indicating that only the scale of the Pennsylvania activity, not the discovery itself, could be deemed a surprise.

In North America, hydrocarbons had been produced, in some places for decades, from seeps or wells in Ontario, New York, California, Ohio, Kentucky, (West) Virginia, Pennsylvania, and elsewhere. Brine produced for salt manufacture was accompanied by crude oil at several locations along the Ohio River and in the western Appalachians during the early and mid-19th century. The oil was looked upon as a contaminant in some locations, but in others was separated for medical, lubricant, and other uses, and sold commercially prior to 1820. In Canada, near the southern tip of Lake Huron at Enniskillen, and in Los Angeles, California, commercial production of oil began in 1857 from wells dug specifically for oil in the vicinity of tar seeps.

Natural gas from shallow wells was used in Fredonia, New York, as early as 1821 for lighting and heating, and within less than a decade brine producers in the Ohio River valley were using byproduct natural gas for fuel. Although large scale pipeline systems for natural gas transport were a product of the 1870s, a pipeline for manufactured coal gas, modeled after an 1812 London innovation, was in operation in Baltimore by 1817. Most of the major cities in the eastern United States had distribution systems for coal gas street lighting by the 1850s (Peebles, 1980; Stotz and Jamison, 1938; Waples, 2005).

Much of what was known about North American geology in general, and the distribution of petroleum in particular, can be traced to the antebellum state and federal geological surveys in both the United States and Canada. Petroleum was not then considered to be a significant economic resource, but its occurrence in seeps and as a byproduct of salt production was a routinely noted curiosity. In the immediate aftermath of the Drake discovery, former employees of these surveys authored a preponderance of the literature related to petroleum geology.

Before the Boom

As the Drake well appeared on the horizon, an essay on gas springs, mud volcanoes, and petroleum seeps conveniently appeared in the form of a chapter in the fifth volume of Alexander von Humboldt's monumental *Cosmos*, completed shortly before the author's death in 1858 (Humboldt, 1858). Humboldt focused on the physical process of fluid emanations from the earth, in comparison to true volcanoes. Humboldt probably had more hands-on familiarity with global petroleum occurrences than any author of his generation, including visits in 1799-1804 to the abundant seeps in Spanish colonies that became Venezuela, Trinidad-Tobago, and Cuba, as well as surface manifestations of petroleum in Europe and Russia. His wide-ranging interests also made him aware of the centuries-old practice of drilling for oil and gas in China, and the reports of petroleum from many regions throughout the globe. Much of the information that allowed immediate comparison of the Pennsylvania discovery to worldwide analogs resulted from the widespread availability and popularity in North America of Humboldt's numerous works.

S. P. Hildreth was the first North American author to cover petroleum geology in detail (Owen, 1975, p. 39-41). In a series of American Journal of Science and Arts reports on the settlements along the Ohio River valley (Hildreth, 1826; Hildreth, 1833; Hildreth, 1836) and a summary included in the first Ohio Geological Survey annual report (Mather et al., 1838), he described the salt manufacturing business, at the time a critical item of commerce. Southeastern Ohio and (West) Virginia brine wells commonly encountered carburetted hydrogen gas (methane) that was utilized for lifting salt water to the surface and to a limited degree as fuel, unless excessive gas flows caused the wells to be abandoned. Another occasional contaminant was liquid petroleum, which had value for medicinal, lighting, and lubricating purposes, but which interfered with the more lucrative practice of producing salt.

New York, beginning in 1833, was the standard bearer for antebellum state geological surveys, with 5 major summary volumes published in 1842-43 that covered the geology of the entire state (Aldrich, 1974; Owen, 1975, p. 42-46). Survey geologists paid special attention to bituminous shales and gas springs, in the unfulfilled hope that they would prove to be indicative of proximity to coal. Beck summarized observations regarding oil and gas seeps in New York, and mentioned sales of "Seneca oil" for medicinal purposes from oil seeps on Oil Creek in Venango County, Pennsylvania, the future site for the Drake well (Beck, 1842). Many of the petroleum examples originated with James Hall's

survey of western New York, which has anecdotal observations of gas and petroleum distributed throughout the volume (Hall, 1843). One of these seeps, at Cuba, New York, had been previously described in detail in one of the first American scientific reports on the subject (Silliman, 1833).

The most widely debated hydrocarbon controversy of the pre-Drake era concerned the coal-like product of the Albert mine in New Brunswick, Canada, which was commercially used for gas manufacture in Boston and other New England cities. Language used for conveyance of coal rights provided questionable title for solidified hydrocarbons deposited in veins, and numerous expert opinions regarding the geological origin were solicited on behalf of litigants. A jury in 1852 followed the majority of experts (Jackson et al, 1851) in declaring the mine's product to be a coal. With a few exceptions (Dawson, 1855), subsequent researchers (Taylor, 1855, p. 516-517; Gesner, 1861; Hitchcock, 1865) generally took a position consistent with modern interpretations (King, 1963; Chowdhury et al., 1991) that the albertite had solidified in large tectonic fractures along an anticlinal axis after migrating from nearby oil shales.

The United States government sent numerous military exploring parties to the west during the 1840s and 1850s, charged with evaluating potential railroad routes from the Mississippi River to the Pacific coast. Surveys along the southern California coastline encountered the prolific oil seeps between Los Angeles and Monterey. The novelty of these phenomena, plus the possibility of their use for locomotive fuel in a region lacking major coal resources, caused scientists assigned to the military expeditions to describe them in detail (Antisell, 1856; Blake, 1858).

One of the most commercially influential chemical analyses of all time was that conducted by Benjamin Silliman, Jr., professor at Yale and editor of the American Journal of Science and Arts, the preeminent scientific periodical of North America. His 1855 analysis of seep oil from Oil Creek in northwestern Pennsylvania, and his positive judgment as to its potential economic value, was distributed in pamphlet form as a prospectus to raise money to fund the drilling of the Drake well (Silliman, 1855). Silliman's subsequent attempt to duplicate this success in California (California Petroleum, 1865) had a significantly different outcome, as will be discussed elsewhere.

Lessons from Coal

Much of the theoretical framework that allowed rapid development of petroleum geology concepts was derived from decades of coal research. Mapping the distribution of coal deposits and their volatile contents, in support of industry and rapidly expanding railroad transportation, was a major goal of the antebellum geological surveys. The bituminous content of coal was important as an indication of coal quality, first for use directly as fuel, and later as a source material for the manufacture of coal gas and coal oil. Other bituminous materials, in the form of active seeps, veins of solid hydrocarbon, and organic-rich shale, were routinely described as well, both as geological curiosities and as potential indicators of coal proximity.

Henry D. Rogers, state geologist of Pennsylvania during its active field phase in 1836-42, wrote a keystone paper (Rogers, 1843) describing facies relationships and coal quality throughout the entirety of the Appalachian coalfield. A key focus was a west-to-east decrease in coal volatility and its correlation to the degree of structural deformation and gross stratigraphic thickness. Two decades later, Rogers (Anonymous, 1863; Rogers, 1863) correlated the volatile content of coal and bituminous shale to the distribution of oil fields, a concept that modern authors commonly credit to a twentieth century geologist.

In the early 1850s, James Young developed methods for distilling oil from cannel coals, and the technology quickly spread from Britain to the New World. By the late 1850s, coal was rapidly displacing the declining whale industry (Coleman, 1994) as a source of oil for lubrication and lighting. The antebellum Kentucky Geological Survey under David Dale Owen (Owen, 1856; 1857a; 1857b; 1861) systematically analyzed all known coals and bituminous shales in the state with the express goal of supporting a domestic coal oil industry, creating what was, in effect, the first regional source rock survey. Owen and his assistants continued their research for the adjacent state of Indiana in 1859 and 1860 (Lesquereux, 1862), with the program ending after a single volume due to the death of Owen and the onset of the Civil War.

Nascent industries set up in the 1850s to manufacture coal gas or coal oil fostered an increasing understanding of hydrocarbon chemistry. These ventures were generally unable to compete with the new flood of cheap petroleum (Newberry, 1860), but the technical knowledge they generated proved invaluable for the petroleum refining industry that loomed on the horizon. Thomas Antisell, following his stint in California with the Pacific railroad surveys, described the manufacture of illuminating oils from coal on the very eve of the first oil boom in 1859 (reprinted in 1865), with a detailed chapter comparing the products that were generated from coals with those from bitumen (Antisell, 1865). Antisell's book was soon followed by a similar effort from Abraham Gesner, an early practitioner of coal oil manufacturing and the inventor of kerosene (Gesner, 1861).

The standard reference volume on coal distribution and related commercial activity was assembled by R.C. Taylor (Taylor, 1855), who included numerous descriptions of petroleum and bitumen along with the more lengthy reports on coal. Taylor's summaries related to Canada, New York, Texas, and the West Indies were among the better sources of information for these areas available in the contemporary literature, and are excerpted for this volume.

Another work that focused on coal and iron mining (Daddow and Bannan, 1866) included a chapter proposing an abiogenic, volcanic theory for petroleum generation. This concept was not new (Humboldt, 1858; Dott and Reynolds, 1969; Owen, 1975, p. 29-31), but deserves recognition as an alternative viewpoint that was generally not represented in publications originating in North America.

The View from Canada

Under the direction of Sir William Logan, Canada had the only continuously active North American geological survey of the 1850s and 1860s, and devoted more effort than any other survey to the scientific study of petroleum, with T. Sterry Hunt as its most prolific commentator. Oil seeps on the Gaspé Peninsula and in western Ontario were sought out and described long before petroleum had been shown to represent a viable economic venture. Significant attention was paid to the expanding coal oil industry, with the goal of adapting the technology to production of oil from asphalt seeps or the widespread bituminous shales of the Lower Paleozoic. After petroleum production became a commercial industry, all developments regarding petroleum in both Canada and the United States were the subject of comparative study. Curiously, the controversial albertite deposit in New Brunswick was an isolated petroleum related topic that was almost completely ignored.

Asphalt from Enniskillen, near the southern tip of Lake Huron in western Canada (now Ontario), had been described in two Geological Survey of Canada reports from the early 1850s (Murray, 1852a; 1852b), mentioned in at least three other reports, and displayed by the survey at the Universal Exposition in Paris in 1855. Widespread knowledge of this deposit, coupled with rapid expansion of the coal oil industry, resulted in commercial production beginning in 1857, two years prior to the

Drake well in Pennsylvania. Robb (Robb, 1861) provided the first detailed information on Enniskillen field development and speculated on the origin of the oil, while making a clear claim of industrial priority, with the Pennsylvania activity portrayed as a response to the initial Canadian success. The year 1862 brought the first flowing wells at Enniskillen, and Fleming described the production characteristics and inferred reservoir properties by showing interference between adjacent wells and structural control of well performance (Fleming, 1863).

Geological conditions at Enniskillen formed the basis for the first anticlinal theory of oil accumulation in 1861 (Hunt, 1862; Harkness, 1931; Owen, 1975, p. 61-62), and became a routine reference point for all aspects of petroleum geology in T. Sterry Hunt's subsequent publications (Hunt, 1863a; Hunt, 1863b; Hunt, 1866). Hunt (Hunt, 1866, p. 254-256) argued against the Devonian Hamilton Shale and in favor of Lower Silurian (Ordovician) beds as the source for most of the oil in western Ontario, a disputed subject that modern geochemistry has resolved in Hunt's favor (Powell et al., 1984). He also produced the most thorough geochemical study to date, describing the composition and properties of numerous natural hydrocarbon types and comparing them with extracts obtained by distillation from coals and organic-rich shales (Hunt, 1863a).

The Midwest Perspective

The petroleum industry exploded into prominence in northwestern Pennsylvania, but much of the knowledge base that made it possible came from Kentucky and the areas of Ohio and western Virginia (now West Virginia) near the Ohio River valley. Petroleum was obtained from wells as a byproduct of salt manufacture as early as 1806, and commercially marketed long before the Drake well was drilled. Much of the drilling technology used by Drake and successors was developed in this area (McKain and Allen, 1994). More important for the purposes of this reprint volume, some of the best early geological literature on petroleum came from workers in this geographic region, starting with the previously mentioned work of S. P. Hildreth in southeastern Ohio (Hildreth, 1826; Hildreth, 1833; Hildreth, 1836; Mather et al., 1838).

John Newberry (Newberry, 1960), the state geologist of Ohio, provided one of the first reviews of the rapidly expanding petroleum industry, with frequent analogies drawn to historical oil production from numerous worldwide locations, and a discussion of the future business potential for oil production in Ohio. Newberry argued that the petroleum in both northwestern Pennsylvania and the Ohio valley was derived from Devonian bituminous shale, even though the latter area produced from Coal Measures (Mississippian-Pennsylvanian) reservoirs, and the oil was thought by other workers to be derived from coal.

E. B. Andrews (Andrews, 1861), a professor at Marietta College in southeastern Ohio, had a first hand view of the early production along the Ohio River valley. Although a close second to Hunt (Hunt, 1862) in publishing a theory of structural entrapment and fractured reservoirs, Andrews' paper was influential due to the accompanying geological figures and its *American Journal of Science and Arts* venue. Andrews described the nature of the production at several locations in West Virginia and Ohio in support of his theories. Andrews (Andrews, 1866) provided an update a few years later, demonstrating that his theories had held up with the rapid expansion of drilling activity. He also claimed the same structural trapping and production mechanisms for Pennsylvania fields that later turned out to be sandstone stratigraphic traps.

The antebellum petroleum legacy of Kentucky was as rich as in Ohio and West Virginia, with commercial oil sales beginning with a well drilled for salt in 1818 (Shepherd, 1988). Kentucky, with

the Breckinridge and other cannel coals, became a center for the rapidly expanding coal oil industry in the 1850s. This was the focus for the first Kentucky geological survey (Owen, 1856; 1857a; 1857b; 1861), which systematically described and analyzed a large number of coal beds for their economic potential, not only directly as a fuel, but for their oil or gas yield. Bituminous shales were routinely analyzed for their oil production potential as well, providing what is effectively the first regional assessment of source rock potential, and more than twenty examples of oil or gas encountered in seeps or salt-water wells were documented. By the time of the Drake discovery, this survey had created an unparalleled knowledge base for evaluating Kentucky's petroleum potential.

At the time of his death in 1860, David Dale Owen was directing simultaneous state surveys in Kentucky, Indiana, and Arkansas. Leo Lesquereux, who was a paleontologist with the Kentucky survey, also conducted coal studies in the adjacent state of Indiana. He provided a summary chapter on coal for the latter state, and argued strongly that the petroleum being found had its origin in the coal strata (Lesquereux, 1862).

J. P. Lesley (Lesley, 1865) provided a review of early oil activity in Kentucky, comparing the characteristics of the production with other oil developments throughout eastern North America. His detailed descriptions of oil field developments in Kentucky concentrated on the eastern portion of the state. He provides some of the first detailed well records, along with a plea for the retention of better subsurface geological information.

The Michigan Basin would have to wait a few years before becoming a significant producing area, but clues to petroleum potential were showing up along the basin margin. Henry Schoolcraft, returning from an early government expedition to find the headwaters of the Mississippi, found oil in outcropping carbonates along the western shores of Lake Michigan (Schoolcraft, 1821, p. 383). Alexander Winchell, the state geologist of Michigan, responded almost immediately to the Enniskillen developments by projecting the productive strata under southeastern Michigan, with the potential for production portrayed as dependent on the presence of porous sandstone (Winchell, 1861, p. 73). He expanded on this theme a few years later (Winchell, 1865), having studied the situation in more detail as an industry consultant. Along the basin's southwest margin, an 1865 well in Chicago encountered oil in multiple shallow horizons before drilling had to stop due to strong water flows (Shufeldt, 1865).

California Controversies

From the times of the first explorers, the prolific oil seeps along the Pacific coast of southern California, between San Diego and Monterey, were a novelty described in many historical accounts. The generally heavy oil of southern California was used locally in its native form for construction and similar purposes but was not considered of significant economic value. Early reports by the California state geologist (Trask, 1854; 1855) mentioned bitumen occurrences, particularly in the Los Angeles area, and speculated about their possible use for gas manufacture, but naturally focused attention on metal deposits following the gold rush of 1849.

Military parties of the 1850s, evaluating potential railroad routes from the Mississippi River to the Pacific coast and along the California coastline, inevitably encountered these seeps, and made efforts to document their characteristics as potential mineral resources. Thomas Antisell (Antisell, 1856), and William Blake (Blake, 1856a; 1856b; 1857), scientists attached to the railroad survey parties, devoted considerable space in their reports to the California bitumen deposits located at or in close proximity to the Pacific coastline, with Blake later combining his studies in a separate, privately published version (Blake, 1858). Antisell's work in particular was a systematic attempt to describe all of the seeps, and

includes a map portraying their locations. Extra attention was paid to the Santa Barbara and Los Angeles areas, where surface bitumen accumulations were so large as to merit volumetric assessments demonstrating the reliability of future supplies. Antisell mentioned activity on a hand dug well, later successfully completed by Captain Dryden in Los Angeles in 1857 (Crowder, 1961), two years prior to Drake's well and the same year as the Enniskillen development in Canada.

After the Pennsylvania oil boom attracted national attention in 1859, speculators quickly recognized the possibilities presented by tar that leaked from the ground in abundance in southern California. In a scenario reminiscent of his Pennsylvania report (Silliman, 1855), Benjamin Silliman, Jr. provided an optimistic analysis of the refining potential of a Santa Barbara area seep that was used as part of a prospectus for raising drilling funds (California Petroleum, 1865; Silliman, 1865). J. D. Whitney, the state geologist of California, concluded unequivocally in a discussion of bitumen occurrences along the Coast Ranges that the prospectus was not believable (Whitney, 1865, p. 115), and proceeded to spend the next decade trying to have Silliman removed from the National Academy of Sciences and his position on the Yale University faculty. Ultimately, additional analyses and an exchange in the *American Journal of Science and Arts* (Peckham, 1867; Silliman, 1867) ended with the conclusion that samples originally provided to Silliman for analysis had probably been doctored by mixing the heavy asphaltic California bitumen with refined oil from Pennsylvania. The melodrama of these disputes has been captured in an exceptional manner in a book-length historical study (White, 1968), and summarized by Owen (Owen, 1975, p. 71-75).

The Southwest

Indications of oil in eastern and coastal Texas had been known for centuries, inspiring a drilling effort in 1859 and a first producing well in 1866 (Rister, 1949), but scientific study and descriptions were sparse. The first state geological survey, conducted from 1858-1861, was terminated at the start of the Civil War with most of the results being lost. The only surviving official report of the survey, reprinted years later along with three unpublished manuscripts (Shumard, 1886), is an abstract of an 1861 presentation to the legislature, containing the comment that petroleum "has been observed at several points in the state" and a brief description of Sour Lake, where abundant seeps (Taylor, 1855, p. 498; Shumard, 1886) marked the position of what would become one of the first salt dome oil fields of the early 1900s.

The anecdotal comments available in the scientific literature gave no more clue to the future petroleum potential of the Midcontinent than was the case for Texas. Brief descriptions of seeps from Oklahoma (Johnston, 1845; Marcy, 1854, p. 79), Arkansas (Owen, 1860, p. 127), Kansas (Mudge, 1866; Swallow, 1866) and Missouri (Swallow, 1855) attracted little attention from the scientific community, although local knowledge of oil shows and publicity regarding the Drake well was enough to attract drilling ventures as early as 1860 in eastern Kansas (Schruben, 1972; Merriam, 2002). Oil as a byproduct of brine production, analogous to the situation along the Ohio River valley, occurred even earlier, in 1859, in eastern Oklahoma (Rister, 1949). Further west, oil production was established in 1862 at Canon City, Colorado, but without early scientific description.

What about Pennsylvania?

Henry D. Rogers had been state geologist for the Pennsylvania Geological Survey in its active period in 1836-1842, creating the first regional geologic analysis of the Appalachian coalfields (Rogers, 1843). The survey was terminated due to a governmental financial crisis, and Rogers persevered for

more than a decade before finally obtaining the necessary state funding to publish the final volumes in 1858 (Rogers, 1858a; 1858b), the year before the Drake well was drilled.

Unlike virtually every other antebellum government geologist, who routinely mentioned even minor signs of petroleum, Rogers appears to have intentionally avoided the subject. The surface geology of the Oil Creek area was described, without mention of the numerous seeps which inspired the Drake well to be drilled. The Kier salt water well at Tarentum (Owen, 1975, p. 10-11), which was well known as the source of the Kier's Rock Oil sold for medicinal purposes, was specifically mentioned during discussion of local geology, but without any reference to petroleum. Within more than 1600 pages of exceptional geological detail, there is only one, single sentence, mention of petroleum, added almost as an afterthought in coverage of Devonian sandstone quarries.

Although his major published work completely ignored liquid hydrocarbons, Rogers was justifiably respected as the acknowledged expert on Pennsylvania geology. After the oil boom exploded onto the scene, Rogers, who had retired to Scotland, responded with locally published essays on the subject. In a paper in a British religious publication (Rogers, 1863), Devonian and older bituminous shales were credited as the source rocks for the petroleum, even though Coal Measures occupied the surface and furnished some of the reservoirs in part of the Pennsylvania oil belt. Rogers adopted the structural trapping theories proposed for Ohio valley and Canada (Andrews, 1861; Hunt, 1862) oil accumulations, and stated unequivocally that the Pennsylvania fields were anticlinal in nature, although his previous reports had remarked on the gentle SE dip and general lack of structural deformation in the area where the oil fields were being developed. Unfortunately, northwestern Pennsylvania oil fields were predominantly sandstone stratigraphic traps, and nearly two decades would pass before John Franklin Carll, in arguably the best petroleum geology publication of the 19th century (Carll, 1880), would demonstrate their true nature.

A few months after the release of Rogers' essay (Rogers, 1863), the magazine Harper's Monthly published an unattributed article entitled "Coal and Petroleum" (Anonymous, 1863). Harper's popularity and circulation almost certainly made this paper the most widely read of any petroleum geology discussion during the Civil War era. Comparison of the Harper's text with the Rogers paper shows it to be a verbatim copy, minus only the section subheadings and the author credit. This paper was reviewed in detail by Howell (1930).

J. P. Lesley was one of the few contemporary authors on petroleum geology with experience in Pennsylvania, and an isolated dissenter against widespread application of the anticlinal trapping theories based on conditions in Ohio and Canada (Andrews, 1861; Hunt, 1862). While accepting the anticlinal controls for accumulations along the Ohio River, as described by Andrews, he pointed out that "... there are no anticlinal axes in the Pennsylvania oil region of the French and Oil Creek wells, nor in the Pennsylvania and Ohio oil region of the Beaver River, nor in the E. Kentucky oil region of the Sandy and Licking waters" (Lesley, 1865, p. 190). Although primarily known as a coal geologist, he would later play a significant role in the development of theories of stratigraphic entrapment (Carll, 1880) as director of the Second Pennsylvania Geological Survey.

19th Century Impact of Petroleum Geology

After a brief flurry of activity in the mid-1860s, petroleum geology as a profession had limited visibility for the next half century. It became prominent only in the early twentieth century, when successful geologically-directed exploration programs in California, the U. S. Midcontinent and

onshore Gulf Coast led to widespread employment of geologists in the oilfields, and eventual formation of the Southwestern Association of Petroleum Geologists, now AAPG, in 1917.

Several aspects of petroleum systems, such as the nature of source rocks and the importance of thermal maturity and migration pathways, were already a focus of discussion by the mid-1860s. The importance of buoyancy and structural highs in trapping oil was quickly recognized (Howell, 1934), and the role of fracturing and matrix porosity as containers for hydrocarbons was readily apparent. With most of the main components for a profession of petroleum geology already in place, what took so long for geologists to gain credibility among the “practical oilmen” of the late nineteenth century?

A significant factor was the lack of detailed geological study of Pennsylvania oil fields. With the exception of Carll’s work in the 1870s and 1880s, which yielded seven published reports, it was almost $\frac{3}{4}$ of a century before substantial geological publications were available for the first big oil patch. The popular literature on the petroleum industry concentrated on activities in Pennsylvania, but the geological community focused their studies elsewhere.

A second factor was the immediate recognition of structural trapping as a control for the oil fields in Canada and along the Ohio River valley (Andrews, 1861; Hunt, 1862). Henry Rogers, the foremost authority on Pennsylvania geology, gave his endorsement to the theory from his remote location in Scotland (Rogers, 1863; Anonymous, 1863), and the geological community, with one major exception (Lesley, 1865), jumped on the bandwagon.

Geologists who entered the oil region in the 1860s quickly proved to practical oil operators that geology was a waste of money. In northwestern Pennsylvania, which dominated the upstream petroleum industry for most of the nineteenth century, sandstone stratigraphic trapping controlled most of the fields (Carll, 1880; Sherrill et al., 1941). Sound exploration methods, inappropriately applied, were a distinct failure in the most prominent petroleum province of the time, for anticlinal theories of trapping did not work in the absence of anticlines. General acceptance of geology in the petroleum industry had to await the emergence of petroleum provinces that conformed to accepted theories.

References

- Aldrich, M.A.L., 1974, New York Natural History Survey, 1836-1845. PhD Dissertation, University of Texas at Austin, 481 p.
- Andrews, E.B., 1861, Rock oil, its geological relations and distribution: *The American Journal of Science and Arts*, 2nd series, v. 32, no. 94, p. 85-93. (Andrews, 1861)
- Andrews, E.B., 1866, Petroleum in its geological relations: *The American Journal of Science and Arts*, 2nd series, v. 42, p. 33-43. (Andrews, 1866)
- Anonymous, 1863, Coal and petroleum: *Harper's New Monthly Magazine*, v. 27, June-November 1863, p. 259-264. (Anonymous, 1863; *Henry D. Rogers was the uncredited author*)
- Antisell, T., 1856, Geological report: chapter XVI, Bituminous effusions, p. 107-114, + map and 3 plates, in *Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853-6, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Vol. VII, 1857: House of Representatives Executive Document 91, 33d Congress, 2d Session, A.O.P. Nicholson, Washington. (Antisell, 1856)*
- Antisell, T., 1865, Of the nature of coals, carbonaceous schists, native bitumens, and organic substances yielding mineral oils, chapter II, in T. Antisell, *The manufacture of photogenic or hydro-carbon oils, from coal and other bituminous substances, capable of supplying burning fluids*: D. Appleton, New York, p. 17-38. (Antisell, 1865) *Reprinted in 1865 from the 1859 edition*
- Beck, L.C., 1842, Gas or carburetted hydrogen springs (p. 128-132), and Bitumen (p. 182-184), in L.C. Beck, *Mineralogy of New-York; comprising detailed descriptions of the minerals hitherto found in the state of New-York, and notices of their uses in the arts and agriculture*: W. and A. White and J. Visscher, Albany, 536 p. (Beck, 1842)
- Blake, William P., 1856, Report on the geology of the route, near the thirty-second parallel: prepared from the collection and notes of Capt. Pope, 50 p., in *Reports of explorations and surveys, to ascertain the most practicable and economical route*

- for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853-6, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Vol. II, 1855: Senate Executive Document 78, 33d Congress, 2d Session, Beverley Tucker, Washington.
- Blake, W.P., 1856, Report on the geology of the route; route near the thirty-fifth parallel, explored by Lieut. A.W. Whipple, topographical engineers, in 1853 and 1854, 170 p., *in* Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853-4, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Vol. III, 1856: House of Representatives Executive Document 91, 33d Congress, 2d Session, A.O.P. Nicholson, Washington.
- Blake, W.P., 1857, Part II, Geological report; routes in California, to connect with the routes near the thirty-fifth and thirty-second parallels, explored by Lieut. R.S. Williamson, corps topographical engineers, in 1853, 370 p., *in* Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853-4, according to acts of Congress of March 3, 1853, May 31, 1854, and August 5, 1854: Vol. V, 1856: House of Representatives Executive Document 91, 33d Congress, 2d Session, A.O.P. Nicholson, Washington.
- Blake, W.P., 1858, Report of a geological reconnaissance in California: made in connection with the expedition to survey routes in California, to connect with the surveys of routes for a railroad from the Mississippi River to the Pacific Ocean, under the command of Lieut. R.S. Williamson, Corps Top. Engrs. in 1853: H. Bailliere, New York, 370 p. (Blake, 1858, excerpt p. 177-182 and 284-288)
- California Petroleum Co., 1865, A description of the recently discovered petroleum region in California, with a report on the same by Professor Silliman: Francis & Loutrel, New York, 24 p. + map. (California Petroleum, 1865)
- Carll, J.F., 1880, The geology of the oil regions of Warren, Venango, Clarion, and Butler Counties, including surveys of the Garland and Panama conglomerates in Warren and Crawford, and in Chautauqua Co., N.Y., descriptions of oil well rig and tools, and a discussion of the preglacial and postglacial drainage of the Lake Erie country: Report of progress I.I.I., Second Pennsylvania Geological Survey, Harrisburg, 482 p.
- Chowdhury, A.H., M.G. Fowler, and J.P.A. Noble, 1991, Petroleum geochemistry and geology of the Albert Formation, Moncton subbasin, New Brunswick, Canada: Bulletin of Canadian Petroleum Geology, v. 39, no. 4, p. 315-331.
- Coleman, J.L., Jr., 1994, The American whale oil industry: a look back to the future of the American petroleum industry: Houston Geological Society Bulletin, Part 1, v. 37, no. 2, p. 13-16; Part 2, v. 37, no. 3, p. 15-19; Part 3, v. 37, no. 4, p. 13-16.
- Crowder, R.E., 1961, Los Angeles City oil field, *in* Summary of operations, California Division of Oil and Gas, Forty-third annual report of the State Oil and Gas Supervisor, v. 43, no. 1, p. 67-77.
- Daddow, S.H., and B. Bannan, 1866, Petroleum – its geology, distribution, etc., chapter XXX, *in* S.H. Daddow and B. Bannan, Coal, iron, and oil; or, the practical American miner. A plain and popular work on our mines and mineral resources and a text-book or guide to their economical development: Benjamin Bannan, Pottsville, Pa., 808 p. (Daddow & Bannan, 1866, excerpt p. 651-673)
- Dawson, J.W., 1855, The Carboniferous—2. Coalfield of New Brunswick *in* Acadian geology: an account of the geological structure and mineral resources of Nova Scotia, and portions of the neighbouring provinces of British America: Oliver & Boyd, Edinburgh, 388 p. (Dawson, 1855, excerpt p. 195-211)
- Dott, R.H. Sr., and M.J. Reynolds, 1969, Sourcebook for petroleum geology: AAPG Memoir 5, Tulsa, 471 p.
- Fleming, S., 1863, Notes on the present condition of the oil wells of Enniskillen: The Canadian Journal of Industry, Science, and Art, v. 8, no. 45, p. 246-249. (Fleming, 1863)
- Forbes, R.J., 1936, Bitumen and Petroleum in Antiquity. E.J. Brill, Leiden, 109 p.
- Forbes, R.J., 1958, Studies in Early Petroleum History. E.J. Brill, Leiden, 199 p.
- Forbes, R.J., 1959, More Studies in Early Petroleum History 1860-1880. E.J. Brill, Leiden, 199 p.
- Gesner, A., 1861, Practical treatise on coal, petroleum and other distilled oils: Bailliere Brothers, New York, 134 p.
- Hall, James, 1843, Geology of New York. Part IV, Comprising the Survey of the Fourth Geological District. Carroll & Cook, Albany, 525 p.
- Harkness, R.B., 1931, Account of early endeavors on anticlinal theory in Canada: AAPG Bulletin, v. 15, no. 6, p. 597-610.
- Hildreth, S.P., 1826, Facts relating to certain parts of the state of Ohio: The American Journal of Science and Arts, v. 10, p. 1-8.
- Hildreth, S.P., 1833, Observations on the saliferous rock formation, in the valley of the Ohio: The American Journal of Science and Arts, v. 24, July 1833, p. 46-68. (Hildreth, 1833)
- Hildreth, S.P., 1836, Observations on the bituminous coal deposits of the valley of the Ohio, and the accompanying rock strata; with notices of the fossil organic remains and the relics of vegetable and animal bodies, illustrated by a geological map, by numerous drawings of plants and shells, and by views of interesting scenery: The American Journal of Science and Arts, v. 29, p. 1-154.
- Hitchcock, C.H., 1865, The Albert coal, or Albertite, of New Brunswick: The American Journal of Science and Arts, 2nd series, v. 39, p. 267-273. (Hitchcock, 1865)
- Howell, J.V., 1930, How old is petroleum geology?: AAPG Bulletin, v. 14, no. 5, p. 607-616.

- Howell, J.V., 1934, Historical development of the structural theory of accumulation of oil and gas, part I. History, *in* Wrather, W.E., and F.H. Lahee (eds.), Problems of petroleum geology: a sequel to Structure of typical American oil fields: AAPG, Tulsa, p. 1-23.
- Humboldt, A. von, 1858, Vapor and gas springs, salses, mud volcanoes, naptha fire, Section II c., p. 198-214, *in* A. von Humboldt, *Cosmos: a sketch of a physical description of the universe*, vol. V, translated from the German by E.C. Otte: Harper & Brothers, New York, 462 p. (Humboldt, 1858, excerpt p. 198-214)
- Hunt, T.S., 1862, Notes on the history of petroleum or rock oil, *in* Annual report of the board of regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the institution for the year 1861: House of Representatives Miscellaneous Document 77, 37th Congress, 2nd Session, Government Printing Office, Washington, p. 319-329. (Hunt, 1862)
- Hunt, T.S., 1863a, Contributions to the chemical and geological history of bitumens, and of pyroschists or bituminous shale: The American Journal of Science and Arts, 2nd series, v. 35, May 1863, p. 157-171. (Hunt, 1863a)
- Hunt, T.S., 1863b, Chapter XVII, Mineral species: bitumen; coal; plumbago or graphite, *in* W.E. Logan, Report of progress from its commencement to 1863; illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. Geological Survey of Canada, Dawson Brothers, Montreal, 983 p. (Hunt, 1863b; excerpt p. 521-529) *Logan, in his Preface, gives credit to Hunt for this otherwise anonymous chapter.*
- Hunt, T.S., 1866, Report of Dr. T. Sterry Hunt, L.L.D., F.R.S., chemist and mineralogist, addressed to Sir W.E. Logan, F.R.S., F.G.S., director of the geological survey Petroleum, p. 181-291, *in* W.E. Logan, Report of progress from 1863 to 1866: Geological Survey of Canada, Ottawa, 321 p. (Hunt, 1866, excerpt p. 233-262)
- Jackson, C.T., A. Gesner, R.C. Taylor, J. Bacon, Jr., J.G. Percival, A.A. Hayes, J.R. Chilton, G.C. Hudson, A. Ure, J. Torrey, J.C. Booth, F. Penney, R. Foulis, B. Silliman, Jr., and B. Silliman, Sr., 1851, Reports on the geological relations, chemical analyses, and microscopic examination of the coal of the Albert Coal Mining Co., situated in Hillsboro, Albert Co., New Brunswick: George F. Nesbitt & Co., New York, 48 p. (Jackson et al., 1851)
- Johnston, A.R., 1845, Remarks on the geology of the vicinity of Fort Washita: Proceedings of the sixth annual meeting of the Association of American Geologists and Naturalists, held in New Haven, Conn., April, 1845, p.75-77.
- King, L.H., 1963, Origin of the Albert mines oil shale (New Brunswick) and its associated albertite: Canada Department of Mines, Mines Branch Report 115, 26 p.
- Lesley, J.P., 1865, On petroleum in the eastern coal field of Kentucky and records of borings in Pennsylvania: American Philosophical Society Proceedings, v. 10, p. 33-68 and 187-191. (Lesley, 1865)
- Lesquereux, L., 1862, Report on the distribution of the geological strata in the coal measures of Indiana, *in* R. Owen, Report of a geological reconnoissance (sic) of Indiana, made during the years 1859 and 1860, under the direction of the late David Dale Owen, M.D., state geologist: H.H. Dodd & Co., Indianapolis (sic), 368 p. (Lesquereux, 1862, p.273-290)
- Marcy, Randolph B., 1854, Exploration of the Red River of Louisiana in the Year 1852. U. S. Senate, Washington, 310 p.
- Mather, W.W., et al., 1838, First Annual Report on the Geological Survey of the State of Ohio. Samuel Medary, Columbus, 134 p.
- McKain, D.L., and B.L. Allen, 1994, Where it all began, the story of the people and places where the oil and gas industry began, West Virginia and southeastern Ohio, part one: David L. McKain, Parkersburg, 400 p.
- Merriam, D.F., 2002, Exploring for petroleum in the flatlands: history of oil and gas exploration in Kansas: Oil-Industry History, v. 3, no. 1, p. 56-71.
- Mudge, B.F., 1866, First annual report on the geology of Kansas. John Speer, Lawrence, 56 p.
- Murray, A., 1852a, Report of Alex. Murray, Esq., assistant provincial geologist, addressed to W. E. Logan, Esq., provincial geologist, *in* W.E. Logan, Report of progress for the year, 1850-51: Geological Survey of Canada, Quebec, p. 13-33.
- Murray, A., 1852b, Report of Alex. Murray, Esq., assistant provincial geologist, addressed to W.E. Logan, Esq., provincial geologist, *in* W.E. Logan, Report of progress for the year, 1851-52: Geological Survey of Canada, Quebec, p. 57-91.
- Newberry, J.S., 1860, The rock oils of Ohio, p. 605-618, *in* Fourteenth annual report of the Ohio state board of agriculture, with an abstract of the proceedings of the county agricultural societies: to the general assembly of Ohio, for the year 1859. Richard Nevins, Columbus, 630 p. (Newberry, 1860)
- Owen, D.D., 1856, Report of the geological survey in Kentucky, made during the years 1854 and 1855. A.G. Hodges, Frankfort, 416 p.
- Owen, D.D., 1857a, Second report of the geological survey in Kentucky, made during the years 1856 and 1857. A.G. Hodges, Frankfort, 376 p.
- Owen, D.D., 1857b, Third report of the geological survey in Kentucky, made during the years 1856 and 1857. A.G. Hodges, Frankfort, 589 p.
- Owen, D.D., 1860, Second report of a geological reconnoissance of the middle and southern counties of Arkansas, made during the years 1859 and 1860. C. Sherman & Son, Philadelphia, 433 p.
- Owen, D.D., 1861, Fourth report of the geological survey in Kentucky, made during the years 1858 and 1859. J.B. Major, Frankfort, 617 p.
- Owen, E.W., 1975, Trek of the oil finders. A history of the exploration for petroleum: AAPG Memoir 6, Tulsa, 1647 p.

- Peckham, S.F., 1867, On the supposed falsification of samples of California petroleum: *American Journal of Science and Arts*, vol. 43, p. 345-351. (Peckham, 1867)
- Peebles, M.W.H., 1980, *Evolution of the gas industry*: New York University Press, New York, 235 p.
- Powell, T.G., R.W. MacQueen, J.F. Barker, and D.G. Bree, 1984, Geochemical character and origin of Ontario oils: *Bulletin of Canadian Petroleum Geology*, v. 32, no. 3, p. 289-312.
- Rister, Carl Coke, 1949, *Oil! Titan of the southwest*. Univ. Oklahoma Press, Norman, 467 p.
- Robb, C., 1861, On the petroleum springs of western Canada: *The Canadian Journal of Industry, Science, and Art*, vol. 6, no. 34, p. 313-323. (Robb, 1861)
- Rogers, H.D., 1843, An inquiry into the origin of the Appalachian coal strata, bituminous and anthracitic: Reports of the first, second, and third meetings of the Association of American Geologists and Naturalists, p. 434-474. (Rogers, 1843)
- Rogers, H.D., 1858a, The geology of Pennsylvania, a government survey, v. I: J.B. Lippincott & Co., Philadelphia, 586 p.
- Rogers, H.D., 1858b, The geology of Pennsylvania, a government survey, v. II: J.B. Lippincott & Co., Philadelphia, 1045 p.
- Rogers, H.D., 1863, Coal and petroleum, p. 374-379, in Norman MacLeod (ed.), *Good Words*, Alexander Strahan & Co., London, p. (Rogers, 1863)
- Schoolcraft, Henry R., 1821, *Narrative Journal of Travels Through the Northwestern Regions of the United States Extending from Detroit Through the Great Chain of American Lakes, to the Sources of the Mississippi River. Performed as a Member of the Expedition Under Governor Cass in the Year 1820*: E. & E. Hosford, Albany, 419 p.
- Schruben, Francis W., 1972, *Wea Creek to El Dorado: Oil in Kansas, 1860-1920*. University of Missouri Press, Columbia, 176 p.
- Shepherd, R.G., 1988, America's first commercial oil well: *Earth Sciences History*, v. 7, no. 2, p. 134-139.
- Sherrill, R.E., P.A. Dickey, and L.S. Matteson, 1941, Types of stratigraphic oil pools in Venango sands of northwestern Pennsylvania, in A.I. Levorsen (ed.), *Stratigraphic type oil fields*: AAPG, Tulsa, p. 507-538.
- Shufeldt, G.A., Jr., 1865, On an oil-well boring at Chicago: *American Journal of Science and Arts*, 2nd series, v. 40, p. 388-389.
- Shumard, B.F., 1886, Geological survey of Texas: abstract from the report submitted to the legislature at its eighth session, in Shumard, G.G., A partial report on the geology of western Texas, consisting of a general geological report and a journal of geological observations along the routes traveled by the expedition between Indianola, Texas, and the valley of the Mimbres, New Mexico, during the years 1855 and 1856; with an appendix giving a detailed report on the geology of Grayson County. Texas State Printing Office, Austin, 145 p.
- Silliman, Benjamin, 1833, Notice of a fountain of petroleum, called the Oil Spring: *American Journal of Science and Arts*, v. 23, p. 97-102. (Silliman, 1833)
- Silliman, B., Jr., 1855, p. 37-54, in Henry, J.T., 1873, *The early and later history of petroleum, with authentic facts in regard to the development in western Pennsylvania*: Jas. B. Rodgers, Philadelphia, 607 p. (Silliman, 1855)
- Silliman, B., Jr., 1865, Examination of petroleum from California: *American Journal of Science and Arts*, vol. 39, p. 341-343. (Silliman, 1865)
- Silliman, B., Jr., 1867, On naptha and illuminating oil from heavy California tar (maltha): *American Journal of Science and Arts*, vol. 43, p. 242-246. (Silliman, 1867)
- Sozanski, J., et al., 2006, How the modern oil and gas industry was born: historical remarks, in J. Golonka and F.J. Picha (eds.), *The Carpathians and their foreland: Geology and hydrocarbon resources*. AAPG Memoir 84, p. 811-834.
- Stotz, L., and A. Jamison, 1938, *History of the gas industry*: Stettiner Bros., NY, 534 p.
- Swallow, G.C., 1855, The first and second annual reports of the geological survey of Missouri. Missouri Geological Survey, Jefferson City. Part I, 207 p. Part II, 240 p.
- Swallow, G.C., 1866, Preliminary report of the geological survey of Kansas. State of Kansas, Lawrence, 198 p.
- Taylor, R.C., 1855, *Statistics of coal: including mineral bituminous substances employed in arts and manufactures; with their geographical, geological, and commercial distribution, and amount of production and consumption on the American continent*. Second edition, revised by S.S. Haldeman: J.W. Moore, Philadelphia, 640 p. (Taylor, 1855, excerpt p. 439-40, 498, 511-517, 561, 575-586)
- Trask, J.B., 1854, A report on the geology of the Coast Mountains, and part of the Sierra Nevada: embracing their industrial resources in agriculture and mining: Senate Document No. 9, State of California, 95 p.
- Trask, J.B., 1855, Report on the geology of the Coast Mountains, embracing their agricultural resources and mineral productions. Also, portions of the middle and northern mining districts: Document No. 14, State of California, 93 p.
- Waples, D.A., 2005, *The natural gas industry in Appalachia; a history from the first discovery to the maturity of the industry*: McFarland & Co., Jefferson, NC, 276 p.
- White, G.T., 1968, *Scientists in conflict: the beginnings of the oil industry in California*: Huntington Library, San Marino, 272 p.
- Whitney, J.D., 1865, Geology of the coast ranges, in J.D. Whitney, *Geology of California. Volume I. Report of progress and synopsis of the field-work, from 1860 to 1864*: Geological Survey of California, 498 p. (Whitney, 1865, excerpt p. 108-175)
- Winchell, A., 1861, First biennial report of the progress of the geological survey of Michigan, embracing observations on the geology, zoology, and botany of the lower peninsula, made to the governor, December 31, 1860: Hosmer & Kerr, Lansing, 339 p.

Winchell, A., 1865, On the oil formation in Michigan and elsewhere: The American Journal of Science and Arts, 2nd series, v. 39, p. 350-353. (Winchell, 1865)