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Detroit Observatory: nineteenth-century training ground for astronomers

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Abstract
Detroit Observatory was founded in 1854 at the University of Michigan in Ann Arbor, Michigan, USA, by Henry Philip Tappan, the University's first President. In 2004, the University celebrates Detroit Observatory's sesquicentennial year. Tappan named his creation the "Detroit Observatory" to honour the city's major benefactors. Tappan, who was inaugurated in 1852, was a visionary leader in the history of higher education. The creation of an astronomical observatory was one of his first steps toward the integration of a new scientific course with the traditional classical course of study, following the Prussian model of higher education. Tappan's observatory was built in the frontier state of Michigan at a modest cost, yet it was equipped with the best European and American instruments available. The facility was impressive, but Tappan's success in launching the University of Michigan to the forefront of American astronomical science was achieved through the recruitment of the renowned Prussian astronomer, Franz Brünnow, of the Berlin Observatory. The instruction in precision astronomy Brünnow offered to American students produced some of the most notable astronomers of the era, which led to the recognition of an 'Ann Arbor School of Astronomy'. Subsequent Directors and Assistants, including James Watson, Mark Harrington, J Martin Schaeberle, and Asaph Hall Jr., produced students with exceptional talent in astronomy, geodesy, surveying and meteorology. Michigan's talent pool was then widely deployed across the nation. This paper documents and preserves this history, and serves as a focal point for celebrating in 2004 the 150-year milestone in Detroit Observatory's fascinating history.

Keywords: *Detroit Observatory, University of Michigan, Franz Brünnow, James Watson, nineteenth-century astronomy, U.S. Lake Survey*

1 INTRODUCTION

In 2004, the University of Michigan celebrates the 150th anniversary of the founding of Detroit Observatory (Figure 1) in Ann Arbor. There is much to recognize in Detroit Observatory's distinguished history: its creation in 1854 by the University of Michigan's inaugural president, Henry Philip Tappan; the vision and generosity of its major benefactors from the City of Detroit; the impressive telescopes, including a 15.2 cm (6-inch) meridian circle made by Pistor and Martins of Berlin, and a 32.1-cm (12.625-inch) refractor by Henry Fitz of New York City; the discovery at the Observatory of twenty-one minor planets by James Watson, and two comets by Martin Schaeberle; the timekeeping service provided by Detroit Observatory during the mid-nineteenth century for the Great Lakes region; the longitude determination made in 1861 in collaboration with the United States Lake Survey, which became the fundamental reference point for all subsequent land surveys from Detroit across the Western states; and the fact that the building, its original telescopes, and many pieces of original apparatus have persisted intact over the course of the Observatory's 150-year history, in spite of the predilection of Midwestern American universities to raze old buildings to make way for new facilities.

The distinguishing facts of Detroit Observatory's rich history are becoming more widely known. What is less known is the Observatory's impressive record as a training ground for some of America's most prominent nineteenth-century astronomers. This paper documents and chronicles the breadth and depth of the impact made in the United States by students trained at Detroit Observatory during the nineteenth century. The individuals selected for inclusion in this article represent only a small fraction of the students trained at Detroit Observatory, and no implication is intended by the exclusion of other meritorious alumni and alumnae.

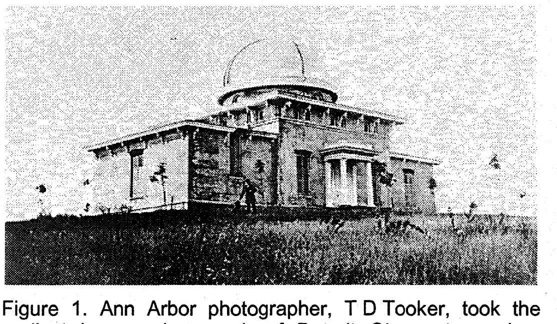

Figure 1. Ann Arbor photographer, T D Tooker, took the earliest known photograph of Detroit Observatory, circa 1858 (Courtesy: Bentley Historical Library, University of Michigan).

2 FOUNDING OF DETROIT OBSERVATORY

When the University of Michigan relocated to Ann Arbor in 1837 from its original location in Detroit, Ann Arbor was a town of about 2,000 citizens. In many ways, it was still a frontier town, surrounded by log cabins and newly-cleared farm fields. Cattle grazed on the pastoral forty acres the town donated to attract the University away from Detroit. There were no campus buildings until 1840 when four identical professors' houses were constructed. By 1850, the graduating class included only twelve students, and seven buildings were completed (Figure 2). An absentee Board of Regents governed the University, but it had become clear that the University required the presence of full-time leadership.

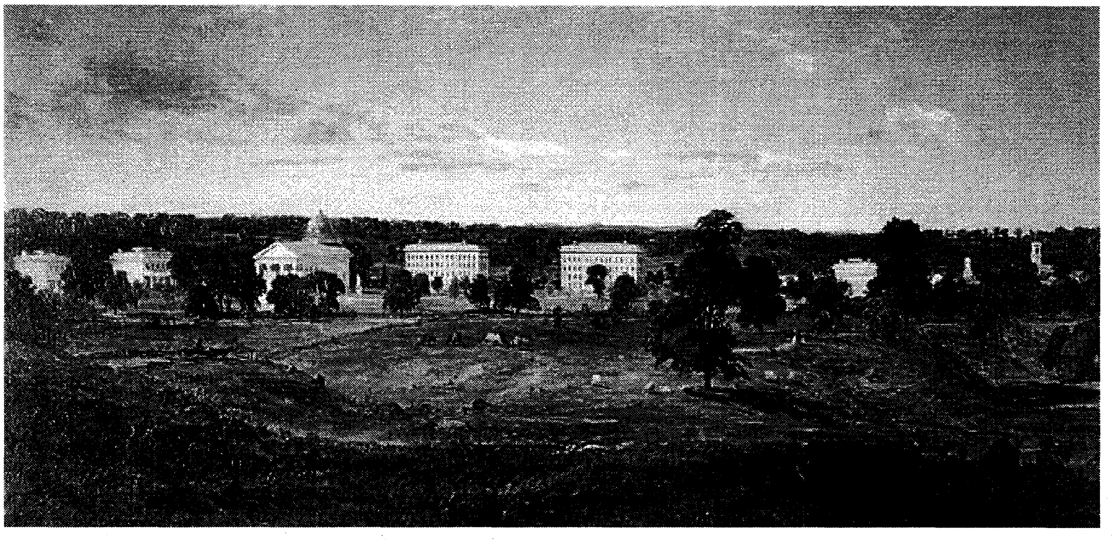

Figure 2. This 1855 landscape painting of the University of Michigan campus by Hudson River School artist, Jasper Cropsey, was done while he was visiting his friend, Henry Tappan. During the same visit, Cropsey also painted the Detroit Observatory, and it is the earliest known image of the Observatory. Both original paintings are in the Bentley Historical Library (Courtesy: Bentley Historical Library, University of Michigan).

Henry Tappan (1805-1881) was recruited from New York in 1852 to be the University's inaugural President. He was a prominent philosopher and educator who had served on the faculty at the University of the City of New York (now New York University). He brought to Michigan a progressive vision, based on the model of education espoused by French philosopher, Victor Cousin. Coincidentally, the educational plan for the State of Michigan, which was ratified in 1835, was influenced by Cousin's ideas. In his inaugural speech, Tappan shared the details of his vision, which was to supplement the standard classical course of study with a scientific course. As a top priority in implementing the plan, Tappan wanted to erect an astronomical observatory as the University's first dedicated scientific facility.

Henry Walker, a prominent citizen of Detroit, was in the audience the day Tappan articulated his vision. After the speech, Walker stepped forward to offer assistance in raising funds to erect an observatory. The collaboration Tappan and Walker established was the ideal reciprocal relationship: Tappan would have his observatory and telescopes for instructional use and basic research, and Walker and others across the Great Lakes region would benefit from a timekeeping service that an observatory with a fixed telescope and a trained astronomer could provide. Walker was heavily invested in the Michigan Central Railroad, which was rapidly laying down tracks across the State. He was also involved in banking, and was a leader among the intellectual elite of Detroit. A time-keeping service would keep Walker's trains on schedule and prevent collisions, which tragically happened with unfortunate regularity. It would also help ensure that financial markets closed simultaneously, to prevent competitive advantage.

Tappan and Walker's vision and collaborative effort helped to launch the Great Lakes region into the intellectual, technological, industrial, and commercial forefront. Today, historians of higher education recognize Tappan as the progenitor of the research university. In a recent speech, University of Michigan Provost, Paul Courant (2003:5) characterized Tappan and Walker's alliance of academy and commerce as being "...uniquely American, [having] persisted to produce a set of institutions of learning and research that are quite extraordinary."

3 INSTRUMENTS AMONG THE BEST IN THE WORLD

Detroit Observatory was one of the best-equipped observatories in the world when it was completed in 1854. The facility was quite exceptional, especially when consideration is given to its remote location in the frontier State of Michigan, the fledgling status of the University's scientific curriculum, and the Observatory's overall low cost.

Walker's desire for an Observatory was so great that he provided the entire sum required to purchase the best meridian circle telescope available in the world. He also used his influence among Detroit's intellectual and wealthy citizens to raise the remainder of the funds needed for the Observatory. The distinguished donors included Lewis Cass, Governor of Michigan; Zachariah Chandler, Mayor of Detroit; E C Litchfield, a lawyer and banker who later endowed the Observatory at Hamilton College in Upstate New York, and Bela Hubbard, Litchfield's brother-in-law, who was a distinguished scientist and explorer on Douglass Houghton's geological survey of Michigan. Tappan named his new Observatory in honour of these citizens of Detroit, whose generosity made the project possible.

3.1 The Fitz Equatorial Refracting Telescope

In 1853 February, Tappan travelled with Walker to New York City, where they met with Henry Fitz Jr. at his telescope shop. Fitz was the first American telescope maker of note, and until he gained a reputation in the 1840s, the best telescopes were exclusively made in Europe. Tappan and Walker placed an order with Fitz for a 30.5-cm (12-inch) achromatic refracting telescope with an equatorial mounting (Figure 3). Fitz was behind in filling his orders and did not have the telescope ready when Detroit Observatory's new Director, Franz Brünnow, arrived from Berlin in 1854 July, so Fitz provided a telescope on loan. Fitz finally delivered a new telescope in 1854 December, but Brünnow rejected it because the mounting was deficient. Fitz's innovative new mounting was made of cast iron to provide superior strength at a lower cost, but Brünnow was not impressed and insisted that the mounting be cast in traditional bell metal. In 1857 November, Fitz finally delivered a telescope that Brünnow would accept.

When it arrived in Ann Arbor, the Fitz telescope was among the largest refractors in the world, with an objective lens of 32.1 cm (12.625 inches) clear aperture. The instrument's wooden tube, which provided a 5.38 m (17 foot 8 inch) focal length, was constructed of pine covered with strips of mahogany veneer, and flanked on each side by wooden flexure rods for stability. Seven positive and six negative eyepieces were included, the highest magnifying power being 1200 times. Accessories included a ring-micrometer, 'sunshades', a filar micrometer, and a finder telescope of 5.72 cm (2.25 inch) clear aperture. A clock drive provided slow motion control.

By 1907, astronomers had lost confidence in wood as a stable material for telescope tubes, because it was too easily influenced by changes in temperature and relative humidity. The decision was then made to replace the wooden tube with one made of steel, and also to replace the flimsy clock drive with a better one by Warner & Swasey. In 1997, the refractor was restored to its 1907 condition, and a scale model of the telescope with its wooden tube and flexure rods was constructed to document its original details, and to interpret the 1907 modifications to visitors.

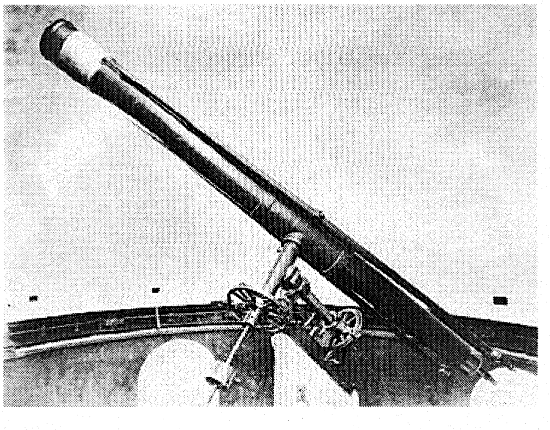

Figure 3. Detroit Observatory's 32.1-cm Fitz refracting telescope (Courtesy: Bentley Historical Library, University of Michigan).

Today, the original 32.1-cm objective lens is widely believed to be the largest surviving lens made by Fitz that has not been refigured by another telescope maker.

3.2 The Pistor & Martins Meridian Circle

In the 1850s, meridian circle telescopes, which were used for timekeeping, longitude determinations, and precision astronomy, were available only in Europe. After Tappan and Walker ordered the refractor from Fitz, Walker left New York for Detroit, and Tappan proceeded on to Europe as previously planned. He intended to personally examine the European system of higher education, and he also wanted to visit various observatories to obtain recommendations for the purchase of a meridian circle.

After visiting observatories at Greenwich, Rome, and Munich, Tappan went to the Berlin Observatory, where he met with the renowned astronomer Johann Encke and his assistant Franz Brünnow. They enthusiastically recommended the instruments of Pistor & Martins, and clockmaker C F Tiede, both of Berlin. Tappan was convinced, and he placed his order with the condition that Brünnow inspect the instruments for accuracy before they were shipped to America. Brünnow's admiration of the instruments later prompted Tappan to offer him the inaugural Directorship of Detroit Observatory.

The Pistor & Martins meridian circle (Figure 4) was a work of art, and exacting in its specifications. Its tube, mounted between two limestone piers, had a 2.44 m (eight foot) focal length and 15.2 cm (6 inch) diameter lens. Its two circles, each 96.5 cm (three feet two inches) in diameter, were finely divided on an inlaid band of silver to two-minute intervals, and equipped with four microscopes on each circle to read the finely-inscribed lines. Oil lamps provided indirect light to illuminate spider lines in the reticle, and an adjustable interior aperture controlled the amount of light that could enter. A spirit level covered in leather to equalize the temperature, and two collimating telescopes mounted on limestone piers at the north and south ends of the telescope room, facilitated the precise alignment of the telescope. Directly beneath the telescope was a metal basin into which mercury was poured to provide a perfectly level mirror. A star reflected in the mercury pool helped determine the nadir and the zenith. Another mercury basin that rolled on a narrow gauge track on the floor was used for reflex observations. A reversing carriage on a larger gauge track was used to flip the telescope 180 degrees in its mount. This made possible observations first to the north, and then to the south. The observational data were then compared to identify any error in the instrument. For the observer's comfort, a couch on wheels was provided, with an adjustable back to facilitate the proper level of incline. For daytime observations, a parasol mounted on a trolley was provided. This large black screen, with an adjustable aperture in the middle and controls to adjust for elevation and angle, prevented sunlight from interfering with the observations.

The Ann Arbor instrument is the only one of thirteen meridian circle telescopes made by Pistor & Martins to survive intact in its original mount anywhere in the world, and is the oldest surviving meridian circle in America.[1] Pistor & Martins made meridian instruments for the major German observatories at Leipzig, Bonn, and Berlin (two), the observatories at Leiden, Copenhagen and Palermo, the U.S. Naval Observatory, the U.S. Naval expedition to Chile in 1849, Amherst College in Massachusetts, Dudley Observatory at Albany (New York), Dunsink Observatory in Ireland, and Detroit Observatory. Brünnow personally installed three Pistor & Martins meridian circles, at the Dudley, Dunsink, and Detroit Observatories.

The meridian circle made by Pistor & Martins in 1856 for the Dudley Observatory is currently in storage at the New York State Museum, but only a few pieces survive, and the empty brass tube was badly damaged by a blowtorch. The 1865 meridian circle telescope of the U.S. Naval Observatory is no longer extant, nor is the instrument from the expedition to Chile. The Dunsink instrument is gone, as is the Amherst College meridian circle. The instrument made for Leiden Observatory is on display at the Boerhaave Museum in Leiden (The Netherlands), and the meridian circle from the Observatory at Bonn is on display at the Deutsches Museum in Munich. Copenhagen's instrument is on display at the Steno Museet in Ärhus, Denmark, and the instrument from the Berlin Observatory was destroyed, but its lens and Berlin's 1867 meridian circle are at the Astrophysikal Institut in Potsdam. Finally, the meridian circle at Palermo was modified nearly beyond recognition and placed on a different pier, prior to its recent restoration.[2]

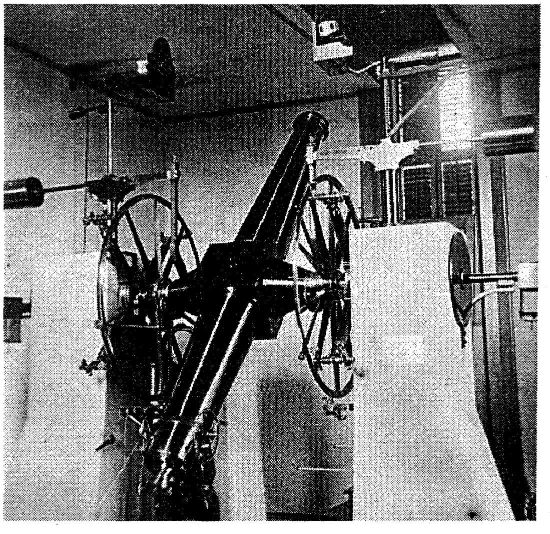

Figure 4. Detroit Observatory's Pistor & Martins meridian circle telescope. The astronomical clock by C F Tiede is mounted on the limestone clock pier (behind the left circle) (Courtesy: Bentley Historical Library, University of Michigan).

4 DETROIT OBSERVATORY ARCHITECTURE

For the design of the Detroit Observatory building, Tappan turned to a former colleague at New York University. Professor Richard Bull, who taught mathematics, surveying, astronomy, architecture and constructional methods, possessed the unique combination of astronomical and architectural knowledge needed to successfully design an observatory (Whitesell, 1998:87-88). Observatories that were designed by individuals unfamiliar with astronomy typically failed to meet specific scientific requirements. For example, a pair of famous architects, Andrew Jackson Downing and Calvert Vaux, designed the Dudley Observatory in Albany, New York. While the architecture was pleasing, the plans had to be radically modified during construction in order to provide the required distance between the collimating telescopes (Whitesell, 1998:90-94).

Professor Bull was the ideal person to design an observatory, given his academic training and practical understanding of astronomy. He was an experienced amateur astronomer, and for a number of years determined astronomical time for the City of New York at his private observatory (Whitesell, 1998:89).

University of Michigan Chemistry Professor, Silas Douglas, supervised construction of Detroit Observatory, a duty he similarly performed for several other campus construction projects. The University selected as the site a 1.62-hectare (4-acre) hilltop located 800 m (half a mile) from the Campus, and work commenced in 1853 and was completed the following year. The floor plan was typical of nineteenth-century observatories (see Loomis, 1874a and 1874b), consisting of a two-storey central mass topped by a revolving dome, and two one-storey wings, one for the meridian circle and the other for the Director's office and library (Figure 5). The main building was 9.75 m (32 feet) square and 7.3 m (24 feet) high, with a solid brick pier ascending through its centre into the dome above to provide a stable base for the refracting telescope. The building was designed to avoid touching the pier.

The walls of the building were solid brick covered with stucco that was scored to resemble individual blocks of stone. Pigments were added to the wet stucco, and the resulting effect was that every scored section was a different shade resembling granite. White and black paint was finely spattered on the stucco to resemble the sparkles in granite, and the mortar joints were painted white. From a distance, the building appeared to be made of stone. Inside, similar faux finishes were used to fool the eye, such as grain-painting of the pine woodwork to make it look like more expensive oak, and blue-grey stucco on the central telescope pier that was scored to look like blocks of limestone and striped with black paint to accentuate the mortar joints. (Whitesell, 1998:100-103) Solid limestone piers were obtained from a quarry at Sandusky, Ohio, to provide stability for the meridian circle, two collimating telescopes, the clock, and the refracting telescope.

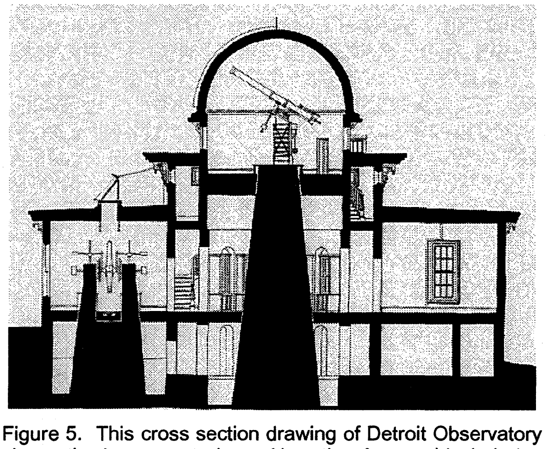

Figure 5. This cross section drawing of Detroit Observatory shows the instrument piers. Note that for graphical clarity, the refracting telescope is shown in an east/west (rather than the proper north/south) position (Courtesy: Detroit Observatory Collection).

To keep the dome lightweight and breathable, it was constructed of wood, lined with cotton canvas and paper, and protected on the exterior by tin plates. A continuous rope was pulled to rotate the dome. Originally, the dome revolved on five cannonballs, but there was no provision made to space these and when they inevitably clustered together the dome had to be lifted in order to reposition them a distance from one another. This proved to be cumbersome, as did the original shutter, which was rolled up and over the back of the dome to provide a slit for observing. Equally irksome was the observer's chair, which was attached to the dome and rotated along with it. In 1890, all of these features were altered: railroad-style wheels replaced the cannonballs, a new shutter opened to the side, and a free-rolling observer's chair was obtained. The hatches on the roof of the meridian circle telescope wing were opened by means of a crank attached to cables that passed through the roof to the exterior side of the hatch covers.

Over the years, several additions were constructed to expand the Observatory complex. In 1868, a Director's residence was added to the Observatory's west wing (Figure 6), into which James Watson (see Section 7, below) moved his entire extended family. By the turn of the nineteenth century, the Observatory's telescopes were outmoded, and more powerful telescopes were needed to keep pace with advancing technology. The Astronomy Department then successfully secured funding for a new wing, and equipped it with a 95.3-cm (37.5-inch) reflecting telescope. The residence was demolished in 1954 to make way for expansion of an adjacent dormitory, and the 1907 addition was razed in 1976 when it was condemned due to termite damage. The original 1854 building was placed in the National Register of Historic Places in 1973, and then saved from the wrecking ball in 1976 through the efforts of local preservationist John Hathaway, Astronomy Professor Hazel (Doc) Losh, and others dedicated to the cause.

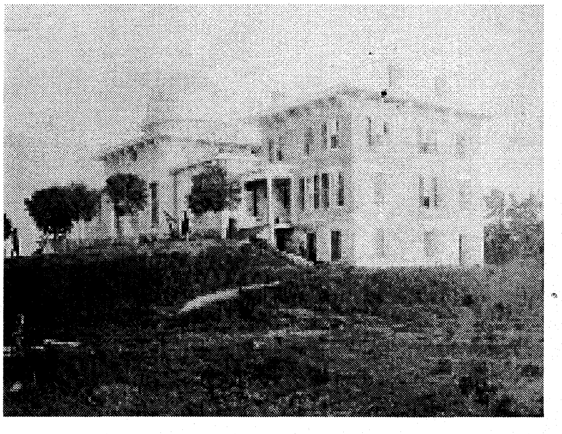

Figure 6. While serving as second Director of Detroit Observatory, James Watson added a Director's residence in 1868. Watson is standing in front with a small telescope, and his wife, Annette, is at the front porch (Courtesy: Author's Collection).

In 1997, the Detroit Observatory building and telescopes were restored, with exacting attention paid to historical detail. The award-winning result[3] is an Observatory that immediately transports the visitor back to the 1850s. Students and visitors can now examine the facility within which Michigan astronomers provided instruction, conducted research, made scientific discoveries, provided a time service, determined the longitude that established the fundamental reference point for the survey of the Great Lakes, and prepared students for a variety of careers.

5 PRUSSIAN PRECISION: THE RECRUITMENT OF FRANZ FRIEDRICH ERNST BRÜNNOW

Director, Detroit Observatory 1854–1863 [1821–1891]

Franz Brünnow (Figure 7), a German-born and trained astronomer, was the first foreigner to receive appointment as Director of an American observatory, and introduced his students to German astronomical methods, which stressed precision in both spherical and observational astronomy. When he was appointed in 1854 as the inaugural Director of Detroit Observatory, Brünnow was the first Faculty member to hold the Ph.D. degree, and his appointment immediately launched the University of Michigan to the forefront of American astronomical science.

The significance of Brünnow's contribution to American higher education and astronomy has been likened to the contributions of Alexander Agassiz in natural history (Bruce, 1987:87). Upon the seventy-fifth anniversary of the founding of the University, an alumnus trained at Detroit Observatory, Robert Woodward (see Section 9.5, below), commented on the significance of Brünnow's contributions:

> ... in the science of astronomy, including all its branches, Americans have been the leaders for more than fifty years. Two schools have been founded in America, the first by Professor Benjamin Pierce of Harvard University and the second by Professor Brünnow of this University. It was Brünnow who introduced in America before 1860 the methods of the illustrious Gauss and the incomparable Bessel, the German astronomers who laid the foundations of modern spherical and observational astronomy. From Brünnow are descended some of the most distinguished American astronomers. (University of Michigan, 1915:135).

Brünnow's expertise in astronomy was an excellent fit with the innovative scientific curriculum Tappan introduced in 1852–1853. Freshmen studied algebra, geometry, and history; sophomores concentrated on trigonometry and conic sections, descriptive and analytic geometry, mensuration and navigation, natural history, German, history, and rhetoric; juniors studied natural philosophy, German, drawing, perspective and architecture, calculus, rhetoric, civil engineering, and chemistry; and seniors took civil engineering, chemistry, animal and vegetable physiology, and geology. Interestingly, astronomy was offered through the classical rather than the scientific course to third term juniors.

What distinguished Michigan from other institutions was Tappan's newly-instituted graduate programme, that students could enter following receipt of a Bachelor's degree. This course included astronomy. Students who wanted to pursue a course in higher astronomy began in their senior year and continued for four semesters, taking them one year beyond graduation. Brünnow's course in higher astronomy included:

- Spherical Astronomy and Theory of the Instruments
- Calculation of the Orbits of Celestial Bodies
- Numerical Calculus; Theory of Interpolation; Method of the Least Squares
- Physical Astronomy; Calculation of the Special

and General Perturbations of the Heavenly Bodies.

This rigorous theoretical and highly-technical training, and practical experience through hands-on use of the meridian circle and refracting telescopes, was not available to students at other comparably-equipped observatories in America.

Figure 7. Franz Brünnow, 1821–1891 (Courtesy: Bentley Historical Library, University of Michigan).

Franz Brünnow was born on 1821 November 18 in Berlin, the son of Johann Brünnow, a German Privy Councillor of state, and Wilhelmine Weppler. He was educated at the Friedrich-Wilhelm Gymnasium in Trier, and at the University of Berlin (where he studied mathematics, astronomy, and physics). In 1843, upon completion of his thesis "De Attractione Moleculari", he received the Ph.D. degree. He was appointed Director of the private Bilk Observatory at Düsseldorf in 1847, where he authored an important paper on De Vico's comet (see Brünnow, 1849). He was honoured the following year with a Gold Medal from the Amsterdam Academy.

In 1851, Brünnow was appointed at Berlin Observatory as First Assistant to Johann Encke, replacing Johann Galle when Galle became Director of Bresslau Observatory. Brünnow was trained by Encke as part of a distinguished group of young astronomers that included Galle, Carl Bremiker and Heinrich d'Arrest. Brünnow was present when Galle discovered Neptune on 1846 September 23, based on predictions made earlier by French astronomer Urbain LeVerrier. Brünnow's most important work, *Lehrbuch der Sphärischen Astronomie*, or *Handbook of Spherical Astronomy*, was published in 1851, and he personally translated the text into English in 1865. Other translations were later published in Spanish, French, Russian, and Italian. This text established Brünnow as an astronomer of international renown. From 1851 to 1854, he served as Assistant Director of Berlin Observatory under Encke.

It was in Berlin in 1853 that Brünnow met University of Michigan President, Henry Tappan, and Tappan later recruited Brünnow as inaugural Director of Detroit Observatory. Brünnow arrived in Ann Arbor in 1854 to assume his new duties, and three years later, in 1857, he married Tappan's only daughter, Rebecca. Years later, Tappan reflected on the Observatory he created as being the achievement at Michigan that was his greatest source of pride, and said that his daughter's marriage to Brünnow made him feel thus "wedded" to the Observatory.

Brünnow's arrival at the University was newsworthy, and was quickly attached to boastful statements concerning the University's eminence. Undergraduate student, William Anderson, wrote to a friend on 1854 August 21:

> I sent you a catalogue of the University of Michigan, of which I am an unworthy member, and which I may tell you ranks very high among the educational institutions of America. There are very great improvements going on here. We have built an observatory here and have called one of the best astronomers in the world to take charge of it, namely Dr. Brünnow of Berlin Prussia. On his way here he stopped at some of the [?] colleges and caused many of them to envy the University of Michigan its good fortune on obtaining the services of such a man. His name will bring a large procession of students ... (Anderson, 1854).

Brünnow's academic career was characterized by high standards and ideals, extremely hard work, and amazing perseverance. The study of double stars was an obsession of his, with particular attention paid to 85 Pegasi, the measure of which he calculated in 1870. Brünnow started the University of Michigan's first scholarly journal, *Astronomical Notices*, to publish the discoveries and research findings made at Detroit Observatory, as well as contributions sent in by other astronomers. He studied the motions of minor planets, and published several studies, including "The General Perturbations and Elliptical Elements of Vesta" and "Tables of Victoria."

Few students were sufficiently prepared in higher mathematics to receive instruction from Brünnow, and in the early years following his arrival, he sometimes lectured to just one student. That student was James Watson, who later succeeded him as Director of Detroit Observatory. Students held Brünnow in high regard, but his thick German accent made him the unfortunate target of student pranks and taunting. History Professor, Andrew White, later reminisced about this, during his years as President of Cornell University: "There was in him a quiet simplicity which led those who knew him best to love him most, but it occasionally provoked much fun among the students." (White, 1905:274). Yet, Brünnow's writing was flawless in English and in German.

Between 1858 and 1869, numerous university observatories collaborated with the U.S. Lake Survey on longitude determinations in the Great Lakes region, and Detroit Observatory was an important participant. Brünnow (1861:17-18) first determined the longitude of Detroit Observatory in 1858 from occultations of the Pleiades, and two years later, in 1860 May, while he was at Dudley Observatory, Watson worked with the U.S. Lake Survey to determine the longitude by an exchange of arbitrary telegraph signals. The method was less accurate than use of an electric telegraph and chronograph, but it was the most advanced method available at the time. However, the results were not entirely satisfactory, and when Brünnow returned to Ann Arbor from Dudley Observatory he brought along a chronograph made by William and George Bond of Harvard College, and obtained approval from the University Regents to install a telegraph line from Detroit Observatory to the nearby Michigan Central Railroad depot. Observations were performed in 1860 April and May in co-operation with the Lake Survey, and personal equations were checked in June. This collaboration with the Lake Survey resulted in the establishment of Detroit as the fundamental reference point for all positional determinations made by the Lake Survey in the Great Lakes region (Loomis, 1874b:527-528). In addition, the Detroit longitude was eventually used to connect longitude determinations between observatories all the way to the West Coast. (see Whitesell, 2000).

Brünnow resigned from the University in 1863 in direct response to the controversial and much-contested dismissal by the Regents of President Tappan. Although he spent only nine years in America, Brünnow left his mark on the history of American astronomy, and is considered to have been one of the best of the small band of astronomers active in America during the mid-nineteenth century.

In 1865, he was appointed Astronomer Royal of Ireland, Andrews Professor of Astronomy at the University of Dublin, and Director of Dunsink Observatory. At Dunsink, he continued his research on stellar parallaxes, which he published in his *Astronomical Observations* (1870) and *Researches Made at Dunsink* (1873). In 1869 he was elected a Fellow of the Royal Astronomical Society, and in 1871, with John Stubbs of Trinity College, he expanded and updated the classic text, *Brinkley's Astronomy*. Failing eyesight forced his resignation in 1874. He retired to Switzerland, and in 1889 settled in Heidelberg (Germany) to be with his son, Rudolph. Poor eyesight precluded any scientific work, so he occupied himself through his considerable musical talents. He once remarked that had he not pursued astronomy, he ought to have devoted himself entirely to music.

Brünnow's death in Heidelberg on 1891 August 20 at age sixty-nine was unexpected, although he had been seriously ill in June of that year. He was making preparations for a trip to Switzerland when he developed a blood clot in his leg, which led to a fatal stroke.

6 BRÜNNOW'S STUDENTS, 1854–1863

Students were attracted to the University of Michigan from great distances for the opportunity to receive instruction from the renowned astronomer, and some of Brünnow's students went on to lead distinguished careers. Among them were Asaph Hall Sr., discoverer of the moons of Mars; DeVolson Wood, founder of the engineering courses at Michigan; Cleveland Abbe, the eminent meteorologist; Orlando Wheeler, engineer with the U.S. Lake Survey; Stillman Robinson, engineer, professor and inventor; and James Watson, second Director of Detroit Observatory and discoverer minor planets.

In addition, the astronomer Charles Young learned German astronomical methods from Brünnow (Russell, 1927:206), although he never attended the University of Michigan. In 1858, Young and Brünnow participated with the U.S. Lake Survey in the longitude determinations for Hudson, Ohio, Ann Arbor and Detroit (Whitesell, 2000:147). Later, Young accompanied Watson on astronomical expeditions to Iowa and China, built a distinguished reputation, and became Professor of Astronomy at Dartmouth and Princeton Universities.

6.1 Asaph Hall Sr., attended 1856 [1829–1907]

Asaph Hall Sr. distinguished himself in astronomy in diverse ways, but he is best known for his discovery in 1877 of the two moons of Mars. Another notable achievement was his discovery of the motion line of the apsides of the orbit of Hyperion, one of Saturn's satellites.

It was at the University of Michigan in 1856, while studying under Brünnow, that Hall first began a serious study of astronomy. For personal and financial reasons he did not remain at Michigan very long, but he later made a remarkable contribution to Michigan's astronomy programme when his son, Asaph Hall Jr., served from 1892 until 1905 as fourth Director of Detroit Observatory. The name 'Asaph Hall' is therefore associated with Detroit Observatory through both father and son.

Asaph Hall Sr. was born at Goshen, Connecticut, on 1829 October 15 to Asaph and Hanna Hall. His early education was at Norfolk Academy, and was supplemented and stimulated by his father's extensive library. Hall then attended Central College in McGrawville, New York, in 1855. He financed this education by making repairs to College buildings, capitalizing on his skill as a carpenter. While at Central College, he met Angeline Stickney, his instructor in geometry and German, and they were married at Elkhorn, Wisconsin, on 1856 March 31. They set out that same day for Ann Arbor, where they intended to stay for three or four years while Asaph attended school. The marriage produced four children; Asaph Jr., the youngest, was born on 1859 October 6.

Brünnow was so impressed by Hall Sr. that he arranged for the brilliant young student to continue his studies without paying tuition fees when he complained of financial difficulties. The Halls considered staying in Ann Arbor, but after only three months they moved to Shalersville, Ohio, to live with Angeline's aunt. There they earned their board, with Asaph working in the fields and Angeline in the house. Asaph then took a teaching position at the Shalersville Institute, and in about a year they saved sufficient funds to repay family debts, freeing Asaph to return to college. Brünnow attempted to entice Hall back to Ann Arbor, but he decided instead to relocate to Cambridge, Massachusetts, where George Bond, Director of Harvard College Observatory, needed an assistant.

Before commencing work at Harvard College

Observatory, Hall first went to Plymouth Hollow in Connecticut to work as a carpenter, in the hope of saving sufficient funds for them to settle in Cambridge, while Angeline lived with his mother at Goshen, Connecticut. The Halls moved to Cambridge in 1857 August, but continued to struggle financially. Asaph earned a dollar for each Moon culmination he observed for the Army engineers, and for computations he made for the Nautical Almanac. His persistence and ability impressed Bond, and Hall was permanently hired and placed on salary. Independently, he continued his studies, which included Brünnow's text, *Lehrbuch der Sphärischen Astronomie* (which he was able to read because Angeline taught her husband German). In 1858, Hall published his computations of the orbital elements of a comet in the *Astronomical Journal*. In 1862, he was appointed an Astronomer at the U.S. Naval Observatory, and the following year he became Professor of Mathematics with the U.S. Navy.

Hall's greatest contribution to astronomy took place on 1877 August 11. Night after night he had used the U.S. Naval Observatory's 66.6-cm (26-inch) refractor to methodically search for any sign of the satellites of Mars, which had long been thought to exist. It was during the early morning hours that he first noticed a faint star-like object near Mars. He spotted it again on August 16, and he and his assistant, George Anderson, detected a second, inner, moon the next day. He named the moons Deimos and Phobos. On August 18 the news was telegraphed, the observations were confirmed, and the discoveries were announced to the world (National Cyclopaedia of American Biography, 1893). In 1878 Hall was awarded the Gold Medal of the Royal Astronomical Society for this discovery, and other awards he received during his lifetime included the Lalande and Arago Prizes from the National Academy of Sciences and the Cross of the Legion of Honour of France.

During his eminent career, much of which was spent in service with the U.S. Navy, Hall travelled on many astronomical expeditions, including to Plover Bay near Bering Strait in 1869 to observe a solar eclipse, Sicily (1870) for a solar eclipse, Vladivostok (1874) for the transit of Venus, Colorado (1878) for a solar eclipse, and Texas (1882) for another transit of Venus. In recognition of his achievements, he received honorary degrees from Hamilton College (Ph.D.), Harvard (AM) and Yale (LL D) in 1879, and another from Harvard (LL D) in 1886. He resigned from the Navy in 1891 – as retirement regulations required – with the rank of Rear Admiral, but remained at the U.S. Naval Observatory completing various projects until he accepted an appointment as Professor of Mathematics at Harvard in 1896. He remained there until his final retirement in 1902, and died at Annapolis, Maryland, on 1907 November 22 at the age of seventy-eight.

6.2 DeVolson Wood, Class of 1859 [1832–1897]

DeVolson Wood is considered to be the founder of the courses in engineering at the University of Michigan (Cooley, 1947:87). He was born at Smyrna, New York, in 1832, and spent his early life on the family farm. Wood was a creative, clever, and expansive thinker. He graduated from Albany Normal School, enrolled at Rensselaer Polytechnic Institute in Troy, New York, and graduated in 1857 with a degree in civil engineering. It was at this time that he conducted a serious study of a solar eclipse, predicting well in advance the precise moments of ingress and egress. Wood then made his way to Ann Arbor, introduced himself to Tappan, and was fortunate in his timing: Professor Peck had not yet returned from a leave of absence, and Tappan needed a substitute. When Peck failed to return, Wood became permanent, and was appointed Assistant Professor of Physics and Civil Engineering.

While teaching at Michigan, Wood pursued graduate studies along with James Watson (see Section 7, below), studying under Brünnow and others. Both Wood and Watson received Master's degrees in 1859 – the first advanced degrees ever granted by the University. That same year, Wood also received a Master's degree from Hamilton College at Clinton, New York, most likely facilitated by Brünnow's close association with C H F Peters, Director of the Hamilton College Observatory. In 1859, Wood was promoted to full Professor of Physics and Engineering.

Students at the University could pursue the traditional classical course or the scientific course. The scientific course offered students scientific and practical training while they simultaneously pursued classical training in fields such as history and English. During their first two years, students in the scientific course studied mathematics through trigonometry and descriptive geometry, history, English language and literature, surveying, and drawing. In the third year, they studied practical engineering in the first semester, and then devoted the second semester to practical astronomy, analytic investigations of the resistance of materials, motors, machines, and construction. In this way, engineering students were taught some astronomy, and if they desired further training and practical experience they could pursue this at the master's level through Brünnow.

While at Michigan, Wood had visionary ideas about advancing the scope of engineering education, but he subsequently accepted the Chair of Engineering at Stevens Institute of Technology in Hoboken, New Jersey, and stayed there for the remainder of his working life. He died in New York City on 1897 June 27.

6.3 Cleveland Abbe, attended 1859–60 [1838–1916]

Cleveland Abbe is a legendary figure in the history of meteorology, and was the first American to provide regular weather forecasts based on daily telegraphic reports and synoptic maps. He was born in New York City on 1838 December 3 to George and Charlotte Abbe. He received his early education at the New York Free Academy, graduated in 1857, and went on to pursue a Master's degree, which he completed in 1860. To help meet his educational expenses, he worked as a Tutor in Mathematics at Trinity Grammar School in 1857–1858, at the State Agricultural College (Michigan State University) in Lansing in 1859, and at the University of Michigan in 1859–1860. When Abbe graduated from the Free Academy in 1857, every astronomer he consulted suggested that the best place to study astronomy in the United States was under Brünnow (*Michigan Alumnus*, 1903). Abbe followed this recommendation, and in 1859 he was successful in obtaining an appointment at the University of Michigan as Instructor in Physics and Civil Engineering under Professor Wood. While teaching, Abbe seized the opportunity to study astronomy under Brünnow.

Abbe was disappointed when Brünnow left Michigan in 1859 to assume leadership of Dudley Observatory, but was likely even more disappointed when he returned to Michigan in 1860. This prompted a reshuffle of the staff that left no slot for Abbe, and the Regents were forced to terminate his appointment at the end of the academic year. Abbe then accepted a position with the United States Coast and Geodetic Survey, and from 1860 to 1864 worked in Boston under Brünnow's professional adversary, Benjamin Gould (Whitesell, 1998:149-151). He then spent two years at Pulkova Observatory in Russia under Otto Struve, which established him as the only nineteenth-century American known to have studied science in Russia (see Bruce, 1987:290). Abbe returned to the US and spent the next year as an aide at the U.S. Naval Observatory.

After many years of training and practical experience, in 1868 Abbe settled into an established role as Director of Cincinnati Observatory. During his time in Michigan and Boston he had developed an interest in atmospheric refraction, and at Pulkova Observatory he had concluded that atmospheric conditions significantly influenced observations with the meridian circle to such an extent that atmospheric data must be factored into the calculations. Not enough was known about meteorological science at that time, and Abbe resolved to pursue it further. In his first report on the state of Cincinnati Observatory, he proposed a collaboration with the Cincinnati Chamber of Commerce and Western Union Telegraph Company in order to create a telegraphic system for the distribution across Ohio of daily weather maps and forecasts prepared at the Observatory. His vision was that this service would eventually extend across the country and widely serve both commercial and agricultural interests. In 1869 September he released the first official public weather forecast in the form of the Cincinnati Weather Bulletin, and this profound innovation became the model for the national weather service that is maintained to this day. Abbe's daily weather bulletins earned him the nickname 'Old Probabilities'.

The year 1869 certainly proved to be a busy one for Abbe. In addition to the aforementioned meteorological developments, he designed a new building for the Cincinnati Observatory and selected a new site for it. The new Cincinnati Observatory was constructed in 1873 at Mt. Lookout, to the northeast of the city. (see Cincinnati Historical Society, 1944). This building, and another constructed in 1904, have survived through to the present day, and now serve as the Cincinnati Observatory Center. The 1873 building shares several elements in common with Detroit Observatory, no doubt because of Abbe's familiarity with the Ann Arbor structure. The distinctive rotunda surrounding the central telescope pier replicates Detroit Observatory's unusual archways, while the brick walls are covered with grey stucco scored to look like blocks of stone and striped in black to simulate the mortar joints, a treatment identical to that used at Detroit Observatory. The author has not found such features in any other American observatories of the same period.

Abbe's meteorological innovations spurred others with an interest in meteorology to co-ordinate their efforts towards creating a national weather service. In 1870, Abbe's idea was put into effect, and in 1871, he was appointed as a civilian Assistant in the office of General Meyer, the Chief Signal Officer. Abbe took the lead in co-ordinating an international consortium for weather observations, which led to the establishment in 1873 of the Daily Bulletin of Simultaneous International Meteorological Observations.

In addition to weather forecasting, Abbe was interested in co-ordinating standard time across the country to ensure that weather data were consistently collected. He published his *Report on Standard Time* in 1879, which led to the creation in 1884 of four standard time zones for use by the railroads. Abbe was similarly innovative and persistent in advancing meteorological science through the study of oceans and rivers, standardization of thermometry and barometry, use of kites and balloons for data gathering, and studies of atmospheric electricity and earthquakes. In 1871 he instituted a system of visible signals to disseminate weather information: coloured flags were hoisted atop buildings and displayed on passing trains, while bells, whistles and other devices all communicated cautionary weather forecasts.

Abbe published nearly 300 research papers during his career, on topics related to meteorology, astronomy, geography, geology, physiography, and chemistry. One publication of particular note was titled "On the improvements of the elements of a comet's orbit: Brünnow's Method based on one of Brünnow's lectures."

When the National Geographic Society was founded in 1888, Abbe was among the thirty-three founding members. He received many honours and awards during his career, including the Symons Gold Medal from the Royal Meteorological Society in 1912 and the Hartley Gold Medal from the National Academy of Sciences in 1916. He received honorary LL D degrees from the University of Michigan (in 1888) and the University of Glasgow (1896), and Mount Abbe in the Fairweather Range, Alaska, is named in his honour.

In 1895 Abbe retired to a position as Lecturer at Johns Hopkins University, and remained there until his death at Chevy Chase, Maryland, on 1916 October 28 at the age of seventy-eight. One of his three sons, Cleveland Abbe Jr., became a noted meteorologist and scientific editor.

6.4 Orlando Belina Wheeler, Class of 1862 [1835–1896]

Orlando Wheeler (Figure 8) was born to Belina and Malinda Wheeler on 1835 November 29 in Lodi Township, Michigan, not far from Ann Arbor. He is next mentioned, in 1856, as a teacher at Brighton District School (*History of Livingston County Michigan*, 1880:212).

Wheeler soon enrolled at the University of Michigan, and graduated with the Class of 1862, receiving both AB and BS degrees. He studied astronomy under Brünnow, along with fellow classmate James Watson, and was an assistant to Brünnow in his final year of studies and also following graduation (*Michigan Alumnus*, 1896). In 1879 the University awarded him an honorary degree in civil engineering.

Figure 8. Orlando Wheeler, 1835–1896 (Courtesy: Bentley Historical Library, University of Michigan).

Wheeler devoted the first twenty years of his career to service with the United States Lake Survey, from 1862 August until the survey was completed in the summer of 1882. During this period, he seized many opportunities to undertake collaborations with his fellow-students and colleagues from the University of Michigan. For example, his name regularly appears in the literature relating to the determination of the longitude of observatories. For the 1864 longitude determination of Fort Edward, located at the head of Green Bay in Wisconsin, Wheeler served as the Lake Survey observer in Chicago, James Watson made intermediate observations at Ann Arbor, Colonel William Raynolds and Stillman Robinson (Wheeler's classmate at Michigan – see Section 6.5, below) were at the Lake Survey's observatory in Detroit, and Charles Young was at Fort Howard (Comstock, 1882:627). In 1880 October, Wheeler worked with William Payne (see Section 8.2, below), who attended the University of Michigan in 1863–1864, on the determination of the longitude of the Carleton College Observatory (Payne, 1881). Wheeler used a Pistor & Martins transit instrument in 1869 to determine the latitude of Toledo, Ohio (Comstock, 1882:635).

In 1865, while serving under Colonel Raynolds, Wheeler and Robinson developed a novel solution to the problem of communicating between triangulation stations. The distance between stations ranged from 81 to 145 kilometres (50 to 90 miles), and it was difficult to communicate with field parties over this distance. Wheeler and Robinson developed the heliograph, which sent Morse code messages using a heliotrope, or small reflecting mirror, by interrupting the reflection to correspond with the dots and dashes of the code (Comstock, 1882:318).

When an office position became available in 1871 in the Lake Survey's Meteorological Department, Wheeler assumed these duties, and was also placed in charge of water level computations. In 1874, perhaps to escape prolonged deskwork and in order to indulge his astronomical interests, he took leave of absence from the Lake Survey to serve under Asaph Hall Sr. as Assistant Astronomer on an expedition to Vladivostok to observe the transit of Venus. Four years later, in 1878, he took a second leave to observe the total eclipse of the Sun with a group stationed at Central City, Colorado, and was then deployed by the Lake Survey to assist with determination of the Mexico-Guatemala boundary. In 1882, he served under Lieutenant Samuel Very of the United States Navy on a transit of Venus expedition to Santa Cruz, Patagonia. He relocated to St. Louis, Missouri, in 1884 to serve as Assistant Engineer with the Missouri River Commission, and died in St. Louis, Missouri on 1896 June 3.

In 1928, Wheeler's wife and children established the Orlando B Wheeler Fellowship and Publication Fund in Astronomy at the University of Michigan.

6.5 Stillman Williams Robinson, Class of 1863 [1838–1910]

Stillman Robinson was born at South Reading, Vermont, on 1838 March 6 to Ebenezer and Adeline Robinson. His early education was in the South Reading schools. To help meet his living expenses and save for college, he served an apprenticeship as a machinist from 1849 until 1853. He received a degree in civil engineering from the University of Michigan in 1863, and like others in his field of study went to work for the U.S. Lake Survey. In 1864 he collaborated with Watson, Wheeler, and Young to determine the longitude of Fort Howard, Wisconsin. That same year, Robinson published an article in the *Journal of the Franklin Institute* on Brünnow's magnetic break circuit.

The University of Michigan recruited Robinson away from the Lake Survey in 1866 to serve as an Instructor in Engineering under Professor Wood, and he remained at Michigan until 1870 when the Illinois Industrial University (now the University of Illinois) lured him as Professor of Mechanical Engineering and Physics. In 1878, Robinson transferred again, this time to a similar role at Ohio State University, where he remained until his retirement in 1895. In 1887 he served as a consulting engineer for the mounting of the Lick Observatory 91.4-cm (36-inch) telescope, at the time the largest refractor in the world. This was to be his last astronomical project. He died suddenly at his home in Columbus, Ohio, on 1910 October 31. He was seventy-two years old.

7 JAMES CRAIG WATSON: ASTRONOMER AND ENTREPRENEUR[4]
Director, Detroit Observatory 1863–1879 [1838–1880]

James Watson (Figure 9) was Brünnow's most promising student at Detroit Observatory, and he eventually became the Observatory's second Director. Watson was born near the village of Fingal, in Ontario, Canada, on 1838 January 28. His father was a farmer and carpenter, and he also taught school, passing along to local children and his own three sons and daughter the knowledge he gained through books.

Figure 9. James Watson, 1838–1880 (Courtesy: Bentley Historical Library, University of Michigan).

In 1850, Watson's father fell on hard times and was forced to abandon his house. The family relocated to Ann Arbor for the educational opportunities it could offer the children. Watson's father found work at a small factory, and James took on various menial jobs, learning quickly by observing. Soon he became a skilled machinist, and displaced a less competent factory engineer. Meanwhile, he seized every spare moment to study Latin, Greek, and other subjects, and he excelled at mathematics. When the factory closed, he was reduced to selling apples and books at the railway station, which he found so humiliating that he soon ran away to Detroit, and was about to sail off on a Great Lakes trade ship when he was recognized and convinced to return home.

At the young age of fifteen Watson entered the University of Michigan, graduating with honours in 1857. He was Brünnow's first (and sometimes only) student in astronomy, and in 1859 was the first student to receive an advanced degree, when he obtained his Masters in astronomy. Both theoretical and practical astronomy interested Watson, but his mechanical talents led him to telescope-making and lens-grinding and polishing, guided by his translation from the German of Prechtl's *Praktische Dioptrik*, and by his correspondence with American telescope maker Henry Fitz.

Watson was regarded as brilliant. He was facile with numbers, and he used this skill to great advantage in the study of astronomy. Under the tutelage and mentoring of Brünnow, he was staged for an outstanding career. When Brünnow was questioned as to why he would teach a class of only one student he replied, "That class consists of Watson." (Obituary…., 1892). Yet, Watson's reputation was repeatedly tarnished by his obsession with the pursuit of financial gain.

Following Watson's graduation in 1858, Brünnow made him Assistant Astronomer, a position he held while completing his graduate studies. Watson went on to make a name for himself by discovering twenty-one minor planets at Detroit Observatory, and another, Juewa, on 1874 October 10, while in Peking (China) to observe the transit of Venus. His discovery during 1868 of six different minor planets was a remarkable achievement, and two years later won him the Lalande Gold Medal of the French Academy.

Watson's success at discovering minor planets was due to his remarkable memory and command of detail. He prepared detailed charts with the positions of stars located near the ecliptic, and these helped him recognize objects not previously identified. After his death, tables on Watson's minor planets were computed and published according to his wishes, and were generously funded in his will. Some minor planets proved so elusive that it took many years for them to be relocated.

During his lifetime, Watson published numerous research papers and reports on astronomy. Most notable was his 1868 textbook, *Theoretical Astronomy*, which contained little original material yet was considered exceptional in its thorough coverage of the subject, drawing as it did from a great many different sources.[5] The text challenged all but the most exceptional astronomy students.

Professor Pierce of Harvard, who was also Superintendent of the U.S. Coast Survey, funded his friend Watson in 1869 to perform research on the lunar tables. The existing tables in the *American Ephemeris and Nautical Almanac* needed improvement for use in practical navigation, and Watson supervised a team of Michigan alumni to perform the complicated computations, an enterprise that continued for five years. While the outcome was satisfactory, the tables were never published and were lost (University of Michigan, 1958a:450).

Practical topics not related to astronomy were also subjects Watson pursued. In 1870, he went into the book and stationary business in Ann Arbor, and three years later purchased Dr A W Chase's lucrative Ann Arbor Printing and Publishing Company (Watson, 1873c) in partnership with local businessmen.

While Brünnow was at Dudley Observatory in 1859–1860, Watson had charge of Detroit Observatory, and when the Regents called Brünnow back to Michigan – at the urging of the Detroit donors – Watson was enraged and made his feelings known through an article published in the newspaper. Watson wanted the post for himself. Instead, the Regents offered Watson the positions of Professor of Physics and Instructor in Mathematics (to assist DeVolson Wood), which Watson initially declined but eventually decided to accept. But, relations with Wood proved difficult, and Watson made several attempts to locate another position. He even volunteered to become a field officer in the U.S. Signal Service – with the stipulation that he be made a Major or Lieutenant Colonel (Watson, 1861). Watson's financial problems worsened to the point where the Regents were on the verge of dismissing him, but action was delayed because of his "...earnest pleas, protestations and promises." (Beakes, 1906:31).

When Brünnow resigned in 1863, in response to Tappan's dismissal from the University, Watson saw an opportunity to realize his ambition to become Director of Detroit Observatory. He proceeded to nominate himself for the post, and sought letters of recommendation from Benjamin Gould, Elias Loomis, William Chauvenet, Joseph Winlock, Benjamin Pierce, J M Gillis, and other prominent scientists. His strategy was successful, and in 1863 August he succeeded his mentor as Director.

Subsequently, Watson was repeatedly criticised because he would not admit visitors or students to the Observatory. For example, the following note appeared in the bi-weekly student paper *The Chronicle* in 1874 May:

> During the present week the juniors have been granted the privilege of making their long-wished for visit to the observatory. A passing glance at pale Luna and girdled Jupiter was allowed each man as his row slided along the seat, and then his only sight of the big telescope during his four year's course of study was over. Thinking we understand the connection of the Observatory with the University, a protest is just against such complete isolation of its advantages from those students who do not intend to spend life in formulating their way through space. (University of Michigan, 1874:199).

To negative opinions expressed about him, Watson was indifferent, holding himself aloof from others and devoting his energies to his work. In a biographical memoir penned after his death, Comstock of Washburn Observatory wrote of Watson:

> He had bitter enemies and they circulated reports, to the discredit of his personal character, which went uncontradicted and gained undeserved credence. It cannot be denied that a measure of truth attended many of these statements, but they were habitually distorted and magnified all out of proportion. (Comstock, 1888:284).

That Watson was vain is indisputable. The notebooks he kept while he was a student at Michigan are repeatedly signed by him every few pages in elegant handwriting. Sometimes the signature appears numerous times, as if he were practicing his autograph. Watson viewed his penmanship as an asset, and this paid off on at least one occasion, when he landed a job as a clerk to help earn money for expenses during college. In one place in his notebook, he signs "James Craig Watson, Astronomer Royal", which is a designation reserved for only the most renowned astronomers of Europe. In a draft description of a telescope he proposed to make, Watson wrote:

> The Hon. James C. Watson, one of the greatest astronomers that this country has ever produced to whom immeasured devotion to science owes some of its greatest blessings. Astronomy under his patronage has reached a summit rarely attained.
>
> The Telescope which the Hon. James C. Watson, LLD, F.R.S., F.A.S., &c &c &c proposes to make is of the Gregorian construction and will bear a magnifying power of 1200 Times! Great indeed!!! 1200! 1200! (Watson, n.d.:62).

Physically, Watson was described as being vigorous and healthy, but he reached 240 pounds toward the end of his life. He was, religiously, a fundamentalist, believing that it was impossible for a mathematician to be an atheist (*American Journal of Science*, 1881:65).

Watson was elected to the National Academy of Sciences in 1867, to the Royal Academy of Sciences in Catalina, Italy, in 1870, and to the American Philosophical Society in 1877. He received numerous honorary degrees, including Ph.D.s from Leipzig (in 1870) and Yale University (1871), and a Doctor of Law from Columbia College (in 1877).

During his lifetime, Watson participated in several important astronomical expeditions. In 1869, he accompanied a number of other prominent astronomers to Iowa to observe a total eclipse of the Sun (Figure 10). Watson's party included his former student George Merriman (see Section 8.1, below), by then Assistant Professor of Mathematics at the University; Donald McIntyre, Treasurer of the University, financier, former Regent, and amateur astronomer; Professor John Van Vleck of Wesleyan University, a civil engineer, son of a former University of Michigan Regent, and amateur astronomer;[6] Van Vleck's assistant, William Johnston; Professor E C Pickering[7] of Massachusetts Institute of Technology; Professor Henry Morton[8] of University of Pennsylvania; and Watson's wife Annette, who capably assisted her husband.

Figure 10. James Watson led a solar eclipse expedition to Burlington, Iowa, in 1869. Left to right: E C Pickering, Donald McIntyre, James Watson, William Johnston (Van Vleck's assistant), John Van Vleck, and George Merriman (Courtesy: Collection of Leonard Walle).

In 1870, Watson travelled to Sicily to observe a total eclipse. Then, in 1878 July, he participated in another solar eclipse expedition to Separation, Wyoming (Figure 11), for which he borrowed a 10.2 cm (4-inch) Clark refracting telescope from the Michigan State Normal School (now Eastern Michigan University). Many famous astronomers and scientists travelled to the western frontier for this eclipse, including Henry Draper of New York and the famous inventor Thomas Edison. Thirty-one year old Edison intended to test his new tasimeter by measuring the temperature of the solar corona during the eclipse (see Baum and Sheehan, 1997:196).

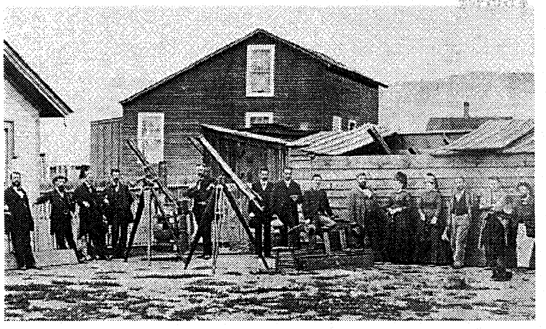

Figure 11. Watson and his wife Annette (fourth and fifth from the right) accompanied other prominent astronomers to Wyoming in 1878 to observe a total eclipse of the Sun. Thomas Edison (second from right) was along to test his new tasimeter (Courtesy: Collection of Leonard Walle).

It was in Wyoming, while searching for objects near the Sun during the eclipse, that Watson became convinced he had discovered two intra-mercurial planets. He hoped that one of these was Vulcan, the existence of which was first postulated by the French astronomer LeVerrier. In 1859 a French physician, Lescarbault, thought he observed this planet as it transited the Sun, and subsequently many astronomers sought to document the existence of Vulcan. Watson was one of these, and he corresponded with LeVerrier in order to obtain the predicted transit times. Conditions during a total solar eclipse presented astronomers with an ideal opportunity to look for Vulcan.

Watson announced his discovery by telegraph from Wyoming, and was inundated with mail by the time he returned to Ann Arbor. Lewis Swift, who was stationed at Denver during the eclipse, also claimed to have seen Vulcan, but the positions reported by the two astronomers conflicted. Most astronomers believed the two had mistaken stars for the elusive planet. Watson's claim was controversial, to say the least, and he was never able to confirm his sighting, even though he devoted significant energy to proving his claim, right up until his death in 1880. The controversy was finally put to rest in 1929, with the conclusion that Vulcan does not exist (see Baum and Sheehan, 1997).

In 1874, Watson and his wife went to Peking (now Beijing) to observe the transit of Venus, and they then continued around the world from east to west. While in Egypt, at the request of the Khedive, Watson surveyed the base line of that country, measured the pyramids, and taught mathematics to an officer of the Royal Guards. For these contributions, he was decorated as a Knight Commander of the Imperial Order of the Medjudieh of Turkey and Egypt, and was loaned a houseboat and crew for a trip up the Nile (Beakes, 1906:10; 13-14).

An opportunity arose in 1878 for Watson to become Director of the University of Wisconsin's new Washburn Observatory. Newspaper accounts suggest that Watson was wooed by both Wisconsin and Michigan "...with an ardor nowadays reserved for football coaches." (Bless, 1978:2). Wisconsin won the contest. At Washburn, Watson undertook new initiatives using his own funds, such as the construction of a students' observatory and a solar observatory of his own design (which he intended to use in a search for the elusive intra-Mercurial planets).

Watson died unexpectedly of peritonitis in Madison on 1880 November 22; he was only forty-two years of age. Letters received by the University from around the country mourned the tragic loss and praised the brilliant astronomer. Many gathered in Ann Arbor for the funeral, and Watson was buried at Forest Hill Cemetery, near Detroit Observatory. Andrew White (President of Cornell University and former History Professor at Michigan) wrote on Watson's death:

> I came to form a very high estimate of his genius and services. The breadth and depth of his knowledge and the hearty way in which he imparted it laid a great charm on me. (Watson, 1881).

Many were surprised to learn the extent of the savings that Watson had amassed from his extensive business activities. Although he had been criticized for devoting too much time to personal gain over scholarly pursuits, in his will he expressed his devotion to science by designating a bequest to perpetuate scientific excellence. He left a considerable sum to the National Academy of Sciences (to which he was elected a member in 1868) for orbital calculations associated with minor planets he had discovered, and he established a medal to recognize significant discoveries or other contributions to astronomical science. The Watson Medal is still awarded today. Inexplicably, Watson's will provided relatively little for his widow, elderly mother, and brothers.

8 WATSON'S FIRST STUDENTS

Watson's teaching methods were both praised and criticized, but he was popular with his students, though not necessarily for laudable reasons. Watson's full attention was paid only to those students who were eager to learn about astronomy, yet his charming discourse in lectures, his full voice, and his reputation for being an easy grader attracted flocks of students.

8.1 George Benjamin Merriman, 1864 (by examination) [1834–1918]

George Merriman (see Figure 10) held many important positions in astronomy, for which he was trained under James Watson at Michigan. He was born at Pontiac, Michigan, on 1834 April 15 to Isaiah and Caroline Merriman. Following preparatory school, he enrolled at Ohio Wesleyan University in 1855, but he returned home the following year when his father became ill and eventually died. He studied law, passed the Michigan bar exam in 1860, and was admitted to practice, and then resumed his studies at Ohio Wesleyan in 1861, graduating in 1863. He immediately pursued graduate studies at the University of Michigan, where he received a Master's degree upon examination in 1864. From 1864 to 1866, he served as Assistant Astronomer for the U.S. Naval Observatory expedition to Chile. No doubt, Watson recommended him for this post.

Merriman returned once again to Ohio Wesleyan and received a Master's degree in 1866. That same year, he was recruited back to Ann Arbor as Assistant Professor of Mathematics and Assistant to Watson at Detroit Observatory, and he remained at Michigan until 1875. During this time he accompanied Watson on the 1869 solar eclipse expedition to Mt. Pleasant, Iowa (see Figure 10). In 1871, he switched his instructional focus to physics, under the eminent Professor George Williams. When Williams retired in 1875, mathematics and physics were combined into one Department, and Merriman departed for a Professorship in Mathematics at nearby Albion College, where he taught for two years.

From Albion College, he moved in 1877 to Rutgers College in New Jersey, where he was Professor of Mathematics and Astronomy. He moved again in 1891 to Middlebury College in Vermont, to a comparable position, and relocated yet again in 1894, this time to Lawrence University in Wisconsin. His final move took place in 1899, when he became an Assistant at the Nautical Almanac Office in Washington. He died in Washington, DC, on 1918 April 3.

8.2 William Wallace Payne, non-graduate 1863–1864 [1837–1928]

William Payne graduated in 1863 from Albion College, located 81 kilometres (50 miles) west of Ann Arbor. After graduation, he travelled to Ann Arbor to study law, eventually receiving his law degree in 1866 from the Chicago Law School. Payne was not the first astronomer to pursue the study of law as a fallback career. Among the astronomers trained at Michigan, Merriman as well as Kintner and Comstock (see Sections 9.1 and 9.9, below) all studied law. But, Payne had a keen interest in astronomy, sparked when he was a boy by reading Smith's *Astronomy*. While studying law at Michigan, Payne spent time at Detroit Observatory with James Watson, where he learned about the astronomical instruments and the details of Watson's intensive minor planet programme (Fath, 1928:268).

Payne was born at Somerset, Michigan, on 1837 May 19 to Jesse and Rebecca Payne. As a boy, he worked on the family farm and attended country schools, where he developed a great interest in and facility with mathematics. He started teaching at age seventeen, but returned during the summers to work on his father's farm. His struggle to support himself through school no doubt raised his anxieties about his future ability to make a living through the science he loved.

In 1868 he moved to Mantorville, Minnesota, to practice law with a college friend, but he soon returned to teaching, which he preferred, working his way up to Superintendent of Schools for Dodge County, Minnesota. In 1871 he moved to Carleton College, in Minnesota, to accept a Chair of Mathematics and Natural Philosophy. Payne was determined to have an observatory at Carleton, and to prepare for this undertaking he spent a summer at Cincinnati Observatory with Ormond Stone in order to gain skill in the operation of astronomical instruments and to learn about the design of observatories. The design Payne submitted for Carleton's observatory was approved, and construction was completed in 1878.

Payne began a time-service even before the Observatory was completed, and time balls around the region were eventually controlled by a signal from the Carleton College Observatory. In 1880, Lieutenant Wheeler of the U.S. Lake Survey assisted Payne in determining the longitude of the Observatory, which was an essential prerequisite for an accurate time service. Over the years, the time service expanded, and it became indispensable to the district and to the regions west of Minnesota, including Iowa, Nebraska, the Dakotas and Montana – altogether encompassing 8,937 kilometres (5,541 miles) of railroad line (Payne, 1881).

In 1882, Payne started publication of the *Sidereal Messenger*, which later evolved into *Astronomy and Astrophysics*, and subsequently, under different editorship, into the *Astrophysical Journal*. In 1893, he created *Popular Astronomy*, which he described as being "plainly worded and untechnical in language." This astronomy magazine continues publication today.

The fact that Payne carried off the construction of two fully-equipped observatories, a time-service, academic instruction, and the creation and editing of important astronomical publications is an incredible achievement for an individual acting largely alone. He worked tirelessly, with great dedication, encouraged throughout by Carleton's President J W Strong. When Payne retired in 1908, he ceased teaching but immediately launched into the creation of a time service for the Elgin Watch Company in Illinois, for whom he designed yet another observatory. He died at Elgin on 1928 January 29, at age ninety-one.

9 WATSON TRAINS STUDENTS TO MEET THE SCIENTIFIC NEEDS OF THE 1870s

The United States faced enormous geographical change following the Civil War in the extent, shape, and prospects of its territorial holdings. It acquired Alaska in 1867, and in 1869 the 'golden spike' completed the transcontinental railroad, thereby facilitating access by exploration parties to previously impenetrable regions of the US and its new territories. International commerce was revolutionized when the Suez Canal opened, providing direct passage between the Mediterranean and Red Seas.

In response to national growth and related changes, higher education entered a period of significant redefinition to "...meet the now imperative needs of an expanding industrial nation and of a developing national power." (Rudolph, 1962:242). New scientific schools, such as the Massachusetts Institute of Technology and a school of engineering at Princeton, were created to accommodate programmes in applied and pure science, to expand upon the scientific training previously provided nearly exclusively by the U.S. Military Academy and the Rensselaer Polytechnic Institute. Between 1870 and 1873, more than fifty new scientific schools were started (Elliott, 1996:108).

In this new environment, enrolments in scientific and technical fields at the University of Michigan steadily grew. Unfortunately, despite an enthusiastic President, the University was unsuccessful in creating a new scientific school until funding eventually materialized in 1895. The outfall was the loss of key Faculty member DeVolson Wood to the new Stevens Institute of Technology, and Wood's protégé, Stillman Robinson, to the Illinois Industrial University. Nonetheless, Michigan produced many outstanding scientists, engineers and surveyors during the 1870s.

Astronomy was an essential element of surveying and navigation, which made James Watson an integral part of the team that trained students in engineering, mathematics, and physics (e.g. see Figure 12). Following graduation, students were in demand to serve with the national surveys, which acted as graduate and field schools for a whole generation of aspiring astronomers, surveyors, and naturalists. Some students undertook fieldwork during summer vacations to help pay college expenses. Others assisted Watson on projects funded by the U.S. Coast Survey and the Nautical Almanac Office.

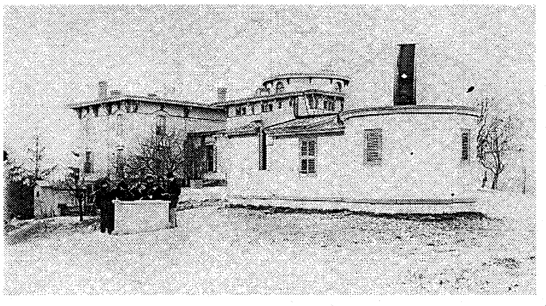

Figure 12. Michigan students gathered behind the Students' Observatory with sextants in hand and textbooks open, ready for instruction in use of the instrument. Detroit Observatory is in the background (Courtesy: Collection of Leonard Walle).

Many astronomers and surveyors trained by Watson at Michigan during the 1870s went on to lead distinguished careers.

9.1 Charles Jacob Kintner, Class of 1870 [1848–1921]

Charles Kintner (Figure 13) was born in the town of Boone, Harrison County (Indiana), on 1848 April 19 to Jacob and Elizabeth Kintner. His youth was spent in rural farm life, on a 243 hectare (six-hundred acre), unique – to Indiana – antebellum plantation-style complex of buildings his father built, called Cedar Farm. The family placed a high value on education, and at an early age Charles Kintner resolved to pursue that path.

The natural world particularly captured Kintner's attention. He saw in nature its beauty and its mysteries, and it helped him recognize the value of an education:

> ...I discovered at an early age that the glorious tints of the morning sun as seen upon the 'cloudlets' have no beauty to the boy who is forced to follow the drudgery of farm life. ...I learned in early life to look with envious eyes upon the short hours of labor which fall to the lot of city people and resolved to obtain an education and follow professional life. (University of Michigan, 1870a).

At age seventeen, following a preparatory course at New Albany, Indiana, Kintner headed north to the University of Michigan to join the Class of 1870. He pursued a course in chemical and civil engineering. In the archives of Michigan's Bentley Historical Library is a bound collection of "Specimen Drawings" sketched by Kintner and his classmates (University of Michigan, 1870b). Kintner's sketch is of the North and South College buildings on the Michigan campus, and it is perhaps the finest, most detailed sketch of the group, with the most exacting use of perspective. Following graduation, he was appointed by Watson as Assistant at the Observatory, a position he held until 1877. During that time, he was active in local affairs, serving as the City Recorder in 1876, and running unsuccessfully in a close race for County Superintendent of Schools. Watson had served as City Recorder as a younger man, so he doubtless guided his student into these activities.

In 1876, when Watson came under attack in the *Ann Arbor Currier*, Kintner wrote a letter to the Editor of the rival *Ann Arbor Register* in defence of his mentor. The "scurrilous" attack written under an assumed name complained that visitors were not permitted entry to the Observatory, and that the Professor spent all of his time pursuing "...miserable little asteroids." Kintner (1876) defended Watson as a dedicated man of science who worked tirelessly, contributed greatly to scientific knowledge, and served as a dedicated teacher.

Kintner's opportunity for scientific adventure came in 1877 when he was appointed Assistant Astronomer in the United States Corps of Engineers under Lieutenant George Wheeler. There is little doubt that Watson recommended Kintner for this position. The Wheeler Survey of the Western States was first organized in 1869 to map the geological features of the West for military purposes. The project was expanded in 1872 with a Congressional appropriation of $75,000, and the project was dubbed the 'Geographical Survey West of the One Hundredth Meridian', shortened by most to the 'Wheeler Survey'. By 1879, another $800,000 was invested. Kintner's two years with the Survey saw him to the end of the monumental project. His appointment as Assistant Astronomer began at the base camp in Ogden, Utah, in 1877 May and ended at Washington, DC, where he reduced the observations he made throughout the Rocky Mountains.

Figure 13. Charles Kintner, 1848–1921 (Courtesy: Bentley Historical Library, University of Michigan).

Following the tradition started at the University of Michigan by faculty explorer Joseph Steere, Kintner wrote a series of fascinating letters from the

West for publication in the *Ann Arbor Register*. It is no coincidence that Watson was one of the proprietors of the *Register*. The ten letters Kintner wrote were published in their entirety in a 1966 issue of the *Utah Historical Quarterly* (see Bidlack and Cooley, 1966), and were packed with adventure and the rich details of everyday life in the West that were craved by readers back in the Midwest. Kintner brought the rugged Western terrain to life with his vivid descriptions of such things as daily life in a surveyors' camp; the soil, crop yields and prices, irrigation methods; weather and climactic events; the Mormon enclave at Salt Lake City; both the awe and fear native Americans stirred up in him; geological features and historical landmarks; and wildlife spotted along the trail. He had a special talent for descriptive prose: his account of ripe strawberries found along the trail was mouth-watering. About Salt Lake City he wrote:

> The scenery is truly beautiful and the great lake lies shimmering and glistening in the sunlight like a great sea of mercury, while the deep blue background made up of the mountains over a hundred miles [161 kilometres] away adds very much to the effect, but best of all is the sight of the hundreds of comfortable homes that look like mere specks in the distance and the comforting thought that here is room for thousands of our fellow beings to earn a livelihood if they will but labor. (Bidlack and Cooley, 1966:69-70).

True to the personal pledge he made to himself as a boy, when the Wheeler Survey disbanded in 1879 Kintner pursued an office job in the city as a patent lawyer. He advanced through the ranks of the Patent Office in Washington, DC, from Assistant Examiner up through the civil service grades to Chief Clerk under the Commissioner of Patents. In 1893 he was promoted to Principal Examiner in Charge of Electrical Patents, and was later made Secretary of the Civil Service Board of the Patent Office. He resigned in 1897 to pursue the practice of patent law and electrical engineering, first in Philadelphia and then in New York. Kintner also produced and patented several electrical inventions.

Upon retirement, he returned to Ann Arbor, where his health deteriorated (Carter, 1921:262). He died at home on 1921 July 7.

9.2 William Francis McKnight Ritter, Class of 1871 [1846–1917]

William Ritter (Figure 14) was born in Milton, Pennsylvania, on 1846 June 23. The details of his early life remain elusive, but in 1870, he enrolled at the University of Michigan. He graduated in 1871, and received his Master's degree in 1874. Ritter was a favourite student of James Watson, and they shared in common a special facility with mathematics. Through Watson, Ritter became interested in computing the orbits of minor planets, work that was painstaking and exacting.

In the archives of Michigan's Bentley Historical Library are the detailed computations that Watson performed – perhaps assisted by Ritter and other students – for the orbits of minor planets that he discovered. Each computation consists of up to a ream of paper, each sheet completely covered with detailed calculations. In Watson's papers, evidence is found that he received much pressure from the scientific community to complete these time-consuming calculations. Watson was disgruntled by the lack of compensation for the laborious process, and the lack of understanding and appreciation by the University and others regarding the significance and importance of the endeavour. Later in life, Ritter devoted much attention to the study of perturbations of minor planets, and his book, *New Method of Determining the General Perturbations of the Minor Planets*, was published in 1896. In the acknowledgements, he credits assistance from his classmate and friend, Monroe Snyder (see Section 9.3, below).

Figure 14. William Ritter, 1846–1917 (Courtesy: Bentley Historical Library, University of Michigan).

Ritter served as Assistant Observer at Detroit Observatory under Watson from 1871 through 1876. In 1874 he was given management responsibility for the Observatory when Watson went to Peking to observe the transit of Venus and continued on a voyage round the world. During Watson's long leave of absence, the Ritters lived in the Director's residence at the Observatory, and the Watsons regularly corresponded with them. The Ritter and Watson families established a family tie when Annette Watson's sister, Della Waite, married Ritter's brother, Dr Thomas Ritter.

In 1876, Ritter left Ann Arbor for the U.S. Naval Observatory, where he remained until 1887. His work at the Nautical Almanac Office was in close association with George Hill. Ritter died at his home in Pottsgrove, Pennsylvania, on 1917 November 6 at the age of seventy-one.

9.3 Monroe Benjamin Snyder, Class of 1872 [1848–1932]

Monroe Snyder (Figure 15) was born on 1848 March 13 at Quakerstown, Pennsylvania. His early education was at the Bucks County Normal and Classical School in Quakerstown. Following two years at Pennsylvania College in Gettysburg, he spent two years teaching school while recovering from ill health. He then returned to college, but after one term transferred to the University of Michigan in order to study theoretical astronomy under James Watson. He graduated with the civil engineering Class of 1872, and formed a close friendship with William Ritter that persisted throughout their careers.

In 1873, when Watson was asked by the Central High School in Philadelphia to recommend an astronomer to direct their Observatory, he suggested Snyder, who was happy to accept the post (University of Michigan, 1872b). Snyder served as Instructor of Astronomy and Assistant Professor of the Higher Mathematics, and simultaneously as Professor of Physics at the Artisan's Night School of the Philadelphia Central High School. The Observatory was in a moribund state, but Snyder invigorated it, and with its instruments he was able to make important contributions to astronomical science. He received a Master's degree from the University of Michigan in 1875.

Figure 15. Monroe Snyder, 1848–1932 (Courtesy: Bentley Historical Library, University of Michigan).

Snyder observed the transit of Mercury in 1878, and developed a new method of observing the transit of planets across the Sun (University of Michigan, 1872a). In 1882, the Philadelphia Observatory served as a transit of Venus station, and Snyder's long-time friend William Ritter (by then at the Nautical Almanac Office) joined him for the observations (Seen through a hazy sky, 1882:2). By 1897, Snyder had worked his way up to the Head of the Department of Mathematics and Astronomy and Director of the Philadelphia Observatory. His published research included a study of "Radium in Spiral Nebulae and in Star Clusters".

Snyder's achievements captured the attention of the community, and he was successful in acquiring funding for a new observatory building and instruments. Unfortunately, the new Philadelphia Observatory was nearly totally destroyed by fire in 1905.

Snyder served as Secretary to the United States Electrical Commission in 1884, the year they held an Exhibition in Philadelphia. It was during this year that he first proposed the formation of a National Board to oversee Physical Standards. Although this plan was widely applauded by many leaders in science, it was not until 1901 that Snyder's vision was finally acted on through creation of the National Bureau of Standards (Obituary…., 1933). He was made a Fellow of the Royal Astronomical Society the following year.

Snyder's career was long and distinguished, and he did not forget the great teachers who influenced him. For the fortieth reunion of the Class of 1872, which he was unable to attend in 1912, he wrote:

> Particularly remember me to those of the old class of six who took Watson's course on "Have faith, gentlemen. Have faith." ...each of them has had a much wider horizon since the sunshine of Watson's smile beamed permanent encouragement through the mists of youth. (University of Michigan, 1912:18).

For the fiftieth reunion, in 1922, he continued to express sentiments about his old professors:

> May I, on this notable occasion, pledge you to the remembrance of three great teachers whose imagination and forward look kindled the highest in us-Cocker, Winchell, Watson. To know them was to imbibe the university spirit for a life-time. (University of Michigan, 1872b:9).

Snyder died on 1932 September 28, at age eighty-four.

9.4 Otto Julius Klotz, Class of 1872 [1852–1923]

Otto Klotz (Figure 16) distinguished himself in the history of Canadian science as Director of the Dominion Observatory. His formal scientific training was largely at Detroit Observatory under James Watson.

Klotz was born on 1852 March 31 in Preston, Ontario. Preston was located in what was then known as Upper Canada, a remote area where his father, Otto, served as a prominent notary public and an advocate for free public education. Klotz was educated at the local school, and then won scholarships to the Berlin High School and the celebrated Galt Grammar School. At the University of Toronto he pursued the study of astronomy, mathematics, and science, but he transferred to the University of Michigan in 1870 for more concentrated study in these subjects, graduating in 1872. In Ann Arbor, he met his future bride, Marie Widenmann, daughter of the German consul at Ann Arbor. They married in 1873 December.

After graduation, Klotz followed a course typical of many of Watson's graduates: he entered government service with the U.S. Lake Survey and the Coast and Geodetic Survey. But, he soon returned to his native Canada, passed the examination for Dominion topographical surveyor, and in 1879 was appointed by the Canadian Government as a surveyor in the unexplored regions of Western Canada. His early work also involved several boundary determinations, including the Alaska boundary (see Green, 1982:49-53). Since this work required astronomical techniques, Klotz was granted the title of Astronomer. His expertise led to contributions to the determination of the Greenwich-to-Montreal longitude in 1892. In 1902, following the establishment of an underwater cable that linked Vancouver, British Columbia, with Australia and New Zealand, Klotz was assigned the responsibility of determining the first trans-Pacific longitude. This completed the longitudes encircling the globe, with only one-fifteenth of a second of error in the entire circuit. This impressive undertaking earned Klotz several honorary degrees, including an LL D from the University of Toronto, Sc.D. from the University of Michigan (in 1913), and LL D from the University of Pittsburgh (1916).

Figure 16. Otto Klotz, 1852–1923 (Courtesy: Bentley Historical Library, University of Michigan).

Klotz was methodical in his work, and in his daily life. A daily journal began on 1866 August 16 and kept until a few days before his death is held in the Ottawa Public Archives; it reveals much about his life and career, and contains a fascinating account of the Alaskan boundary dispute.

Canada did not have a fixed observatory at this time, so longitude work and the rating of chronometers was done from a small transit house. Klotz and his colleague, William King, agitated to change this, and when they received support from the Minister of the Interior, this led – in 1905 – to the erection of the Dominion Observatory, in Ottawa, Ontario. King was appointed Director, and Klotz his First Assistant. Klotz then turned his attention to seismological work and the study of terrestrial magnetism, fields in which he made many important contributions, including the publication of his *Seismological Tables* (1916), which became a valuable reference work. He also devised a means of determining the epicentre through stereographic projection.

After King's death, action toward appointing a replacement was delayed, perhaps by wartime prejudice against Klotz's German ancestry (Jarrell, 1988:103-104), but Klotz was ultimately appointed Director and Chief Astronomer of the Dominion Observatory, a position he held for the remainder of his career. While in Europe in 1922, his health failed, and following a year of health challenges, he died on 1923 December 28.

9.5 Robert Simpson Woodward, Class of 1872 [1849–1924]

Robert Woodward (Figure 17) produced some of the most important research on geophysics ever published in America. He excelled at mathematical physics, but he applied this expertise broadly to encompass the Earth's mass, shape, size, rotation, tides, atmosphere, internal temperature, earthquakes and volcanoes, and density.

Woodward was born on a farm in Rochester, Michigan on 1849 July 21 to Lysander and Peninah Woodward. His father, who at one time was an unsuccessful candidate for Governor of the State of Michigan, took a scientific approach to farming, and passed on these interests to his son.

As a boy, Woodward attended Rochester Academy, and then worked as a clerk in a general store in Rochester in 1866. Determined to pursue a collegiate course, he studied independently for two years to prepare for enrolment at the University of Michigan, where he concentrated on mathematics, astronomy, and engineering. He and Klotz were in the same class, and they received their civil engineering degrees in 1872.

Woodward spent his summers doing fieldwork with the U.S. Lake Survey. Following graduation, he pursued this work full time as Assistant Engineer, and remained in this role for the next ten years until the survey of the Great Lakes was nearly completed. He worked under General Comstock performing primary triangulations for the determination of latitude and longitude.

From 1882 to 1884, Woodward joined Professors Asaph Hall Sr. and William Harkness as Assistant Astronomer with the United States Transit of Venus Commission. Eight field parties were deployed to observe the 1882 transit, four in the United States and four in foreign countries (Wright, 1926:117; see Dick *et al.*, 1998). Hall's team was stationed at San Antonio, Texas. Following the transit, Woodward was engaged in the laborious work of measuring photographic plates to determine a more precise value of parallax. In 1884, he relocated to the U.S. Geological Survey as Assistant Astronomer. In short order, he was appointed Geographer, and then Chief Geographer in charge of the Division of Mathematics. This was an invigorating environment for him, and during his six years at the Geological Survey he produced the most important scientific papers of his career. The topics included the conditioned cooling of a homogeneous sphere, and the possible laws of arrangement of density in the Earth's mass.

Figure 17. Robert Woodward, 1849–1924 (Courtesy: Bentley Historical Library, University of Michigan).

To the regret of his colleagues at the Geological Survey, Woodward departed in 1890 to join the U.S. Coast and Geodetic Survey. The lure was an opportunity to devise a means of testing the efficiency of various forms of apparatus used by the Survey for precise triangulation. In particular, he turned his attention to the calibration of steel tapes, and devised a method that was adopted and remained the standard method for decades to follow (Memorial of Robert Simpson Woodward, 1926). He also prepared geographical tables for the Smithsonian Institution.

In 1893 Woodward joined Columbia University as Professor of Mechanics and Mathematical Physics. Two years later he became Dean of the College of Pure Science. His congenial personality and facility with administrative matters made him well suited to academia. His success prepared him for his next distinguished position, as President of the Carnegie Institution in Washington, DC, in 1905, a position he held for the next sixteen years.

Woodward received numerous honorary degrees, including two from the University of Michigan (Ph.D. 1892, LLD 1912). He was also a member, and in many cases an officer, in the top American scientific and academic organizations. In addition, he served for forty years, from 1884 to 1924, as Associate Editor of the journal *Science*.

Woodward's career was distinguished, yet he expressed regret at not following his true passions. In 1917, he wrote to the captain of his graduating class at Michigan:

> Curiously enough, although I have sought since 1872 to practice engineering, the world has not permitted me to do so. On the contrary, it has taught me the severe but perhaps wholesome lesson that unless one is very inefficient or very selfish he may not do what he would wish but he must do what society demands of him. Hence I have been working chiefly during these years for other people, while the astronomy, physics, and engineering to which I am most attached have had to be pursued rather as avocations than as vocations. (Woodward, 1917).

Woodward died in Washington on 1924 June 29 at the age of seventy-five.

9.6 Horatio Nelson Chute, Class of 1872 [1847–1928]

James Watson's students pursued various scientific careers, but at least one student, Horatio Chute, distinguished himself as a teacher of physics.

Horatio Nelson Chute (Figure 18) was born on 1847 December 26 at Malahide, Ontario (Canada) to Walter and Catherine Chute. His early education was at the local district school, and he then enrolled at Woodstock College in Ontario. He taught briefly at a country school, then served as Principal of the Aylmer schools from 1866 to 1869, and was Assistant Professor of Latin at Woodstock from 1869 to 1870 before transferring to the University of Michigan in 1870 on the recommendation of a Michigan graduate with whom he taught at Woodstock. Chute received his bachelor's degree in 1872, and continued on for his Masters, which he received in 1875. His senior thesis was a detailed study titled simply "Coal." During his graduate studies, he served as Assistant in Astronomy at Detroit Observatory from 1872 to 1873 under James Watson.

To support his family, Chute found employment at Ann Arbor High School in 1873. He was appointed first as Instructor in Science and Mathematics and later in Physical Sciences. This marked the beginning of what was to be a long and distinguished teaching career that spanned forty-nine years, until his retirement in 1922. His lengthy service, enthusiasm for teaching, devotion to his students and distinctive long beard (which he sported even during his early college years), all made him a legend in Ann Arbor.

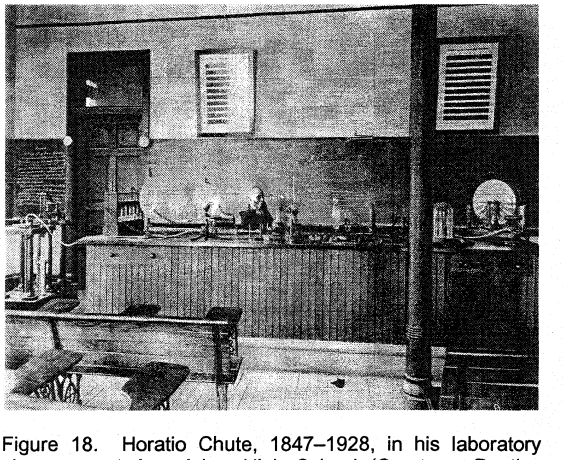

Figure 18. Horatio Chute, 1847–1928, in his laboratory classroom at Ann Arbor High School (Courtesy: Bentley Historical Library, University of Michigan).

When Chute began teaching at Ann Arbor High School he initiated a new emphasis on instruction in physics. Harvard College began accepting a unit in physics in 1873 as an entrance requirement, and other colleges quickly followed this example. Soon, a unit in high school physics was a widespread graduation requirement, and Chute's classroom was crowded with students.

In his first year at Ann Arbor High School, Chute's laboratory equipment consisted of "...one glass tube and a few pieces of worn out mechanism..." (Chute n.d.), but the ill-equipped laboratory placed under his charge was soon outfitted with the best available equipment, including ripple tanks, Wheatstone bridges, a spectroscope, a pendulum clock, and even a 10.2-cm (4-inch) refracting telescope and an observatory to house it (Buell, 1962).

Chute demanded the attention of his students, and was a stickler for precision, clarity, and neatness. Yet, he was a favourite with students. One of his associates wrote: "How can one re-create on paper the complex of brilliance, force, thoroughness, wit, logic, industry, clowning, sharpness, and kindness that was 'Chute,' all embodied in a little man, during much of his adult life hidden behind a cascade of black whiskers?" (Duff, 1958). Another wrote: "...he devoted himself so wholeheartedly to his task that he awakened a feeling of respect and emulation in his students which may frequently have been of far more value in their education than any facts of physics which they may have acquired." (Chute, n.d.).

Chute distinguished himself far beyond the city limits of Ann Arbor through the publication of several physics textbooks that became classics in the field: *Chute's Practical Physics* (1889); *Elements of Physics* (1892) – which was co-authored with University of Michigan Physics Professor, Henry Carhart – and *A Laboratory Guide to Accompany Carhart and Chute's First Principals of Physics* (1913).

His career at Ann Arbor High School was punctuated by a great calamity that took place on the morning of 1904 January 31, when a student walking across the school campus in the early morning hours noticed that the fire in a stove was out of control. It spread quickly, and the building was soon engulfed in flames:

> From the windows on the northwest corner there shot a tongue of flame which swept 15 feet over the sidewalk and to a level with the curbing, and then curved about and covered the north end of the school as if it were an immense fan... (Duff, 1956:2).

The alarms sounded, and fire-fighters arrived at the scene. Teachers from the school arrived soon after, and by a plan organized and led by Chute, more than one hundred teachers and students carried books and laboratory apparatus from the building. In all, about 8,000 books and the majority of the apparatus were saved. When a new school was constructed, Chutes' seniority and stature as a teacher in an important discipline influenced the establishment of a physics laboratory that was rivalled by few others in the country.

Along with the famous educator John Dewey, and others, Chute was responsible for the establishment in 1886 of the Michigan Schoolmaster's Club, and served as its inaugural President. He was also a member of the American Association for the Advancement of Science. When Chute decided to retire in 1922, the Principal was unable to convince him to stay for a fiftieth year. His resignation was accepted, and the Board of Education recognized him with an honorary high school diploma, because he had never actually graduated. Chute was spending winter with relatives in Clearwater, Florida, when he died on 1928 March 11 at the age of 80. He was posthumously honoured through creation of the Horatio N Chute Medal, which is still awarded annually to a high school student demonstrating outstanding citizenship.

9.7 John Henry Darling, Class of 1873 [1847–1943]

John Darling graduated from the University of Michigan in 1873 with a degree in civil engineering, and received an honorary Doctoral degree in 1915 in recognition of his distinguished career as an engineer.

He was born on 1847 April 15 in Lake Ridge, Michigan, to Henry and Matilda Darling. His father served as a member of the Michigan Legislature, and in 1851 was responsible for championing a law that elevated the prominence of scientific subjects in the classical curriculum. Following graduation from the University of Michigan in 1873, Darling was employed by the U.S. Lake Survey as Assistant Engineer from 1873 to 1882. During the field season, he performed primary triangulations along Lakes Ontario and Erie, and from Lake Michigan into the State of Illinois. During the winter he performed mathematical computations at the Detroit office. He also participated in the survey of the Mississippi River. In 1878, when the Lake Survey was short of funds, Darling took six-month leave to travel in Europe.

When the Lake Survey was completed in 1882, Darling took a position as a draughtsman in Major Allen's office at St. Paul, Minnesota, working on river and harbour improvement projects. Then, in 1884, he moved to Duluth, where he continued his residence the remaining fifty-eight years of his life. In Duluth, he was employed as an Engineer for the United States Government, specializing in the design and construction of water-related engineering projects. He became so well known, and so universally popular in Duluth that he was installed as a member of the Duluth Hall of Fame in 1930. He was described as "...a quiet, kindly, cultured gentleman..." (Gingrich, 1942:533).

Although Darling was an engineer, his occupation is listed in the University of Michigan's Alumni Catalogue as 'astronomer'. Astronomy was a great interest of his, and when he retired from his engineering career in 1913, he devoted himself entirely to astronomy. His was not a casual interest: in 1917, he constructed a well-equipped private observatory at considerable personal expense. He announced to the citizens of Duluth, and wrote in an inscription carved over the front door of the Darling Observatory, his desire that the facility promote "...a popular knowledge of the noble science of astronomy." (Gingrich, 1942:534). His observatory was equipped with a 22.9-cm (9-inch) refracting telescope, which was regularly made accessible to individuals and groups for observing. When Darling became too elderly and infirm to independently operate his observatory, he hired an assistant to carry on his activities for the cultural and educational benefit of the citizens of Duluth.

In his ninety-fifth year, the editors of *Popular Astronomy* paid Darling a compliment by publishing a brief article he authored titled "Meteor's and the Moon's Surface" (Darling, 1942). He died at age ninety-six, seven months after writing this article. In his will, the Darling Observatory was bequeathed to the State Teachers College of Duluth, with the caveat that they continue to provide access to the public. The building was utilized according to his wishes through into the 1960s, and was subsequently demolished.

9.8 Charles Leander Doolittle, Class of 1873 [1843–1919]

Charles Doolittle (Figure 19) was born on 1843 November 12 in Ontario, Indiana, to Charles and Cecilia Doolittle. He enlisted for service in the Civil War, and was fortunate to work in an area of personal interest: making astronomical observations for the U.S. Northern Boundary Commission. After returning to his hometown in 1866, he enrolled at the University of Michigan, and graduated in civil engineering with the Class of 1873. His training at Detroit Observatory was received under James Watson.

Figure 19. Charles Doolittle, 1843–1919 (Courtesy: Bentley Historical Library, University of Michigan).

From 1873 to 1875, Doolittle was employed with the Northern Boundary Survey, handling field assignments as well as office work, first at Detroit and later at Washington, DC. When his wife died in 1875, Doolittle relocated to Lehigh University at South Bethlehem, Pennsylvania, where he served as Professor of Mathematics and Astronomy. He remained in this position until 1895, when he transferred to a comparable position at the University of Pennsylvania. An unexpected bequest to the University provided for construction of a new observatory, which was named the Flower Observatory after the donor. Doolittle held the position of Director of Flower Observatory until his retirement in 1912, and was succeeded by his second son, Eric Doolittle. His first son Charles also followed his father's interests, making a career with the Nautical Almanac Office at Washington, DC, while another son, Alfred, became a Professor of Mathematics.

During his career, Doolittle distinguished himself in precision astronomy through his observations to determine variations in latitude. At Lehigh University's Sayre Observatory, he used a portable zenith telescope he obtained as surplus from the U.S. Coast and Geodetic Survey. The meridian circle instrument available to him at Flower Observatory offered far greater precision, yet the accuracy of the observations Doolittle initially made with the zenith telescope demonstrated his skill as a precision astronomer (Tucker, 1919).

One of the more spectacular events in Doolittle's astronomical career was his attempted observation of Halley's Comet in 1910 May – thanks to an invitation from the Philadelphia Aeronautical Recreation Society – from the basket of a balloon that had ascended to 6,500 feet. Unfortunately the clouds, even at that elevation, were so dense that the Comet was totally obscured from view (Will view comet ..., 1910:2; Balloon party missed comet, 1910:20). The press regularly interviewed Doolittle on scientific topics, including the possible presence of life on Mars, and he even speculated on the future state of the Earth's structure. Charles Doolittle died on 1919 March 3.

9.9 George Cary Comstock, Class of 1877 [1855–1934]

George Comstock (Figure 20) was another of the students trained by Watson who went on to distinguish himself as a national leader in astronomy.

Comstock was born in Madison, Wisconsin, on 1855 February 12 to Charles and Mercy Comstock, and spent his youth in Madison and Kenosha, Wisconsin, and Sandusky, Ohio. In 1869 the Comstock family moved to Adrian, Michigan, where George completed his secondary education. He gained admission to the U.S. Naval Academy, but his mother's concern over the dangers of a military career convinced him to enrol instead at the University of Michigan. The family then moved to Ann Arbor so that George could reside at home.

At the University, Comstock became a protégé of James Watson. Following the financial panic of 1873, Watson made arrangements through General Marr of the U.S. Army for Comstock to earn some money for college expenses by working as a Recorder for the United States Corps of Engineers on the surveys of Lakes Ontario, Erie and Superior, and of the Mississippi River. Comstock worked as a Surveyor during the summer and attended the University the other six months of the year. After graduation in 1877 he continued his work on the Mississippi River survey for a year, and then worked with Watson at Detroit Observatory as his private assistant, in association with Assistant Astronomer Martin Schaeberle (see Section 10, below).

In 1878, Comstock accepted appointment as Assistant US Engineer on the improvement of the Mississippi River. That same year, Watson was selected to be the inaugural Director of the Washburn Observatory, and this prompted Comstock's return to his hometown in 1879 as Watson's Assistant. Watson died unexpectedly in late 1880, but Comstock remained at Madison under the new Director, Edward Holden. Comstock spent the remainder of his scientific career at Wisconsin, with short leaves for teaching assignments as Chair of Mathematics and Astronomy at Ohio State University from 1885 to 1887, and for a summer at Lick Observatory in 1886. Although he intended to stay in California following his summer at Lick, instead he accepted the Directorship of Washburn Observatory when Holden became Director of Lick Observatory in 1886.

Comstock studied law at the University of Wisconsin to prepare for a fallback career. He was conservative and cautious, and he realized that astronomy might not always provide a reliable source of income. He received his Juris Doctor degree in 1883 and was admitted to the Wisconsin bar, although he never practised. He viewed his legal studies as perhaps the most valuable training of his education, because it taught him to apply his knack for precision to his speech and his mental processes. Comstock's surveying work with the U.S. Lake Survey gave him the expertise that led to his *Textbook of Field Astronomy for Engineers*, published in 1908.

His distinguished career is evidenced in his numerous publications, including contributions to the *Publications of the Washburn Observatory* and his seminal works on the determination of the aberration constant and atmospheric refraction. He devised various pieces of scientific apparatus, including a slat-screen device to enhance use of the meridian circle telescope, and a double image micrometer. His painstaking work on double stars led him to detect the proper motion of stars as faint as the twelfth magnitude. This prompted Comstock to reach the conclusion that the Milky Way was an absorption effect, a theory that appeared astute at the time but was subsequently disproved.

By 1899, Comstock's reputation led to his being offered the prestigious Directorship of the Nautical Almanac Office, a position he declined in favour of remaining at Washburn Observatory. In 1897, he was among the astronomers who founded the American Astronomical Society, an organization with which he held numerous offices, including President (from 1925 to 1928). Comstock was a popular instructor, teaching with dedication and inspiring his students to follow his example of hard work, high standards, and determination. He was elected to the National Academy of Sciences in 1899, and received honorary Doctoral degrees from the University of Illinois and the University of Michigan in 1907.

In retirement, the Comstocks lived in Beloit, Wisconsin. George Comstock died at Madison on 1934 May 11.

Figure 20. George Comstock, 1855–1934 (Courtesy: Mary Lea Shane Archives of the Lick Observatory).

10 J MARTIN SCHAEBERLE
Class of 1876
[1853–1924]

Martin Schaeberle (Figure 21), a German-born astronomer trained in the USA, discovered three comets, was one of the inaugural astronomers at Lick Observatory, and invented the Schaeberle solar camera to develop his theory of the solar corona.

Schaeberle was born Johann Martin Schäberle on 1853 January 10 in Oeschelbronn, Würtemberg, Germany, and immigrated to the United States as an infant in 1854 with his parents, Anton and Christina Schäberle. In America, his name changed to John Martin Schaeberle, and family and friends called him Martin. A master saddle maker by trade, Anton Schaeberle, settled in Ann Arbor, joining many other emigrants from Würtemberg who had arrived earlier (Emigration document, 1854).

Following his early education in Ann Arbor, Martin Schaeberle travelled at age fifteen to Chicago to serve an apprenticeship in a machine shop. It was in Chicago that he gained an interest in astronomy. His mechanical skills enabled him to make mirrors for reflecting telescopes, and he spent clear evenings on the roof of the hotel he called home making observations. The great Chicago fire of 1871 October caused the termination of his 3-year apprenticeship, and he returned to Ann Arbor, completed his high school course in four months, and then enrolled at the University of Michigan to study engineering and mathematics. He used telescopes of his own construction to make observations at the private observatory he built in 1872 in an alley behind a commercial building in downtown Ann Arbor. Watson's curiosity about Schaeberle's observatory prompted him to drop by one evening to see it. Schaeberle wrote to his brother:

> My own observatory is in constant use, observations being made by myself every clear night. The observations are mostly on the minor planets of which the Prof. [Watson] discovers occasionally. Two weeks ago last Saturday he [Prof. Watson] unexpectedly came to me in the evening while I was observing. And I need scarcely tell you that he was surprised to find what an instrument I had. After using the very highest powers possible he declared the diffraction excellent and made the remark that I could make very valuable observations with it. Since that time he has been hard at work putting up rooms and a work shop at the [Detroit] Observatory where he intends to have me stay to make telescopes etc. at odd hours. You would not recognize my observatory now either inside or outside. The dome is painted sky blue both inside and outside. The lower part is painted white, inside it is papered with pasteboard, and also painted white. I have just begun another instrument called the Transit Instrument which is used to determine time accurately; it will be placed in a separate building which I intend to place on the east side and close up to my present observatory and connected with it by a door so that to enter it one must pass through the main part. (Schaeberle, 1877).

Schaeberle soon became Watson's favourite pupil, and following receipt of his degree in civil engineering in 1876, he became Watson's Assistant. Two years later he was promoted to Instructor in Astronomy, and continued to serve on the Astronomy Faculty until 1888.

Figure 21. J Martin Schaeberle, 1853–1924 (Courtesy: Collection of Robert Schaeberle).

Using a 20.3-cm (8-inch) reflecting telescope of his own design and manufacture housed in his private observatory, on 1880 April 7 Schaeberle discovered the second comet of that year. The following year, on July 14, he discovered the fourth comet of 1881 with the Fitz comet-seeker at Detroit Observatory. Details of the discovery are recorded in a letter written by one of his students:

> With another woman student I had been working under Mr. Schaeberle's supervision in the smaller [Students'] observatory until the wee hours of the night and we were about to close up when someone suggested that a conjunction of the major planets would be visible later. We were anxious to see it and Professor Schaeberle with the patient, kindly courtesy which was characteristic of him offered to stay. While he was waiting for us he took a little portable telescope which was standing in the yard—I think they called it a "comet seeker"—and began to look around the heavens. Presently he hurried into the observatory and asked to use the telescope. We found that he had seen a comet and learned later that he received an award of several hundred dollars for the discovery. But the money didn't seem to interest him as much as the comet. (Greathouse, 1925).

On 1893 April 16 Schaeberle discovered a third comet, for which the Astronomical Society of the Pacific awarded him a medal (see Figure 22).

Figure 22. The comet medal presented to Schaeberle by the Astronomical Society of the Pacific in 1893 (Courtesy: Collection of Robert Schaeberle).

Under Watson's tutelage, Schaeberle received instruction in the German astronomical methods that Watson had learned from Brünnow, which stressed spherical and positional astronomy. This approach was well suited to Schaeberle's interests and abilities in precision astronomy, and this led Schaeberle to compute the ephemeredes and perturbations of minor planets Watson discovered for publication in the *Berliner Jahrbuch*.

When Watson left Michigan in 1878 to become inaugural Director of Washburn Observatory, Mark Harrington (see Section 13.1, below) took his place, but since Harrington's primary interest was in meteorology, this meant that Schaeberle was able to take responsibility for the bulk of the astronomical work at Detroit Observatory. When Harrington asked for a year's leave in 1886 on account of illness, Schaeberle was appointed Acting Assistant Professor, and his salary was increased to Harrington's Directorial rate.

In 1888, Schaeberle seized an opportunity to become one of the inaugural astronomers at the newly-founded Lick Observatory on Mt. Hamilton (California), and he remained there for ten years, responsible for observations with the Repsold meridian circle. In 1889 a total solar eclipse that crossed northern California captured his attention and prompted him to make plans to go to Cayenne, French Guiana, in 1889 December to observe the next one. In a desire to formulate a mechanical theory of the solar corona, which would expand on the prevailing magnetic theories, he devised a long-focus camera to take photographs of the Sun during solar eclipses. His design was a photographic telescope of 12.2 m (40 foot) focal length, driven by clockwork, which was portable so that it could easily be taken to remote locations. The Schaeberle camera produced the best photographs of the solar corona produced to that time, one of which revealed a Sun-grazing comet that would otherwise have gone undetected. Schaeberle travelled with his camera to Mina Bronces (Chile) in 1893 and to Akkeshi (Japan) in 1896 in order to observe total solar eclipses. He independently organized the expeditions, and recruited and trained local civilians to assist him. Astronomers continued to take the Schaeberle camera on eclipse expeditions up until 1932, when H D Curtis exposed the last coronal plates at Fryeburg, in Maine.

Schaeberle's persistent visual observations led to his discovery in 1896 of the elusive thirteenth-magnitude companion of Procyon, the 'Little Dog Star', using the great Lick refractor. He devoted himself entirely to astronomy, working diligently and methodically with disciplined, organized, work habits. He was always punctual, unusually tolerant of other points of view, and was particularly attentive to his physical health through regular exercise. He was well liked and respected, and often chose to remove himself from political disagreements. He set his ideals higher than is typically attainable, and when he came to a decision after careful contemplation and consideration of all factors, he held steadfastly to his beliefs (Tucker, 1924; Reichel, 1959).

When Edward Holden resigned as Director of Lick Observatory in 1897, Schaeberle was the obvious choice to be Acting Director. He held this position until 1898, gaining the high regard of his colleagues, and expected to be made Director. But, the Lick Trustees made a political move and instead appointed James Keeler. Schaeberle could not accept this perceived injustice, so he left Mt. Hamilton and returned to Ann Arbor, despite the protestations of his colleagues. Of his resignation, he wrote:

> The regents of the University of California urged me to withdraw my resignation and, offered me a year's leave of absence with full pay, but I could not accept their kind offer as I feel satisfied that my present course is the proper one for me to take. (Schaeberle, 1898).

Schaeberle never held another formal appointment. At first, he travelled around the world, and he then decided to carry on his astronomical work from an observatory he built at the family residence on Second Street, Ann Arbor. He constructed a 61.0-cm (24-inch) reflecting telescope, mounted equatorially, that he planned to equip with a modified bolometer to detect far-infrared radiation from the Sun and stars. Unfortunately, while drilling a hole to make a modification to the telescope, he broke his cherished mirror. In the 1930s, astronomers at the University of Michigan found one half of the discarded mirror leaning up against the Schaeberle's old barn, and they obtained it to use as an off-axis parabola for infrared spectrometry.

Schaeberle was one of the founding members and first Secretary of the Astronomical Society of the Pacific. In 1898, the University of California conferred upon him an honorary Doctor of Law, which was preceded by an honorary M.Sc. from the University of Michigan in 1893. Over the course of his career, Schaeberle published more than 100 research papers in scientific journals, some of which contained ingenious methods for determining instrumental constants.

Martin Schaeberle died suddenly and unexpectedly on 1924 September 17, while doing light yard work at his Ann Arbor home.

11 EXPLORATION OF ALASKA TERRITORY AND THE ARCTIC REGION

In the nineteenth century, great attention was paid to exploration of the Alaska territory and the Arctic region. Expeditions were organized for the exploration and identification of resources and commercial opportunities, and expedition leaders were typically trained scientists with an interest in gathering scientific data and identifying new species. Such expeditions garnered immense geographical knowledge, and amassed vast quantities of hydrological, meteorological, astronomical, and geomagnetic data. They also resulted in bountiful collections of insects, plants, birds, small animals, invertebrates, fish, rocks and minerals, and they advanced scientific knowledge in the areas of palaeontology, physical geography, meteorology, astronomy, geodesy, and ethnology.

Scientists were needed to staff the expeditions, and it was to universities that expedition leaders often turned to recruit their teams. While Director of Detroit Observatory, James Watson received numerous requests for names of suitable graduates to participate in such expeditions. These offered Michigan graduates excitement, adventure and a chance to utilize their skills and contribute to scientific knowledge, but there was also potential for danger – even death.

The United States acquired the Alaska territory in 1867, following two years of systematic exploration of the region. Interest in the area grew naturally from westward expansion, and also through a plan to establish an intercontinental telegraph. The Western Union Telegraph Company succeeded in connecting the Atlantic and Pacific coasts by telegraph in 1861, and a transcontinental railroad followed, although its completion was delayed until 1869 by the Civil War. When Cyrus Field's efforts to lay a telegraph cable across the Atlantic Ocean met with repeated failure, his thoughts turned to other possibilities for achieving his goal. The distance between the Alaskan coast and Russian territory across Bering Strait was a mere 65 kilometres (40 miles), which offered an intriguing alternative route.

Robert Kennicott, an explorer and naturalist from Chicago, was engaged to lead an exploratory mission to examine possibilities. But, news came in 1866 that the Atlantic cable was successfully laid, so Kennicott abandoned this portion of his mission. He died that same year, but his friend, William Dall, continued the scientific exploration of the Alaskan territory. Dall's official missions were to perform a hydrographic survey that would facilitate commerce, and to identify a cable-landing site for a telegraphic connection with Japan, but his true interest was in advancing scientific knowledge of the region.

There was keen interest in Arctic exploration as well. The quest for a North-West Passage, an Open Polar Sea, and a North-East Passage to reach the Orient from Europe began in America as early as the arrival of the first colonists, and persisted into the nineteenth century. Willem Baffin, John Ross, William Parry, John Franklin, and others conducted early explorations of the Arctic. The last link of the North-West Passage was achieved in 1850, followed by the North-East Passage in 1879, and the North Pole was finally reached in 1909.

During the decades of the 1850s through 1870s, explorers such as Elisha Kane, Charles Hall, and Adolphus Greely mounted expeditions to search for the missing Franklin party, and in pursuit of the North Pole. Their connections with officials at the U.S. Coast Survey and the Nautical Almanac Office led them to contact James Watson and Mark Harrington at Detroit Observatory for assistance in recruiting capable students to join their scientific corps.

11.1 Marcus Baker, Class of 1870 [1849–1903]

Marcus Baker (Figure 23) was one of the students enlisted for duty in Alaska. He was one of the most distinguished scientists trained by Watson at Detroit Observatory. His long career was launched when Watson recommended him for a post as an Astronomical Assistant for the United States Coast and Geodetic Survey's exploratory expedition to Alaska in 1873, and culminated in his role in 1888 as one of the thirty-three original founders of the National Geographic Society.

Figure 23. Marcus Baker, 1849–1903 (Courtesy: Bentley Historical Library, University of Michigan).

Baker's life began on 1849 September 23 near Kalamazoo, Michigan, where he was born to John and Chastina Baker. He grew up on the family farm, attended the District school, and in 1862 was sent to the Union School at Kalamazoo. In 1866 September he enrolled at Kalamazoo College and then transferred to the University of Michigan as a junior in 1868. It was at Michigan that he met James Watson. Baker was one of Watson's most accomplished students, and was offered employment following graduation in 1870 to assist with the preparation of Watson's Lunar Tables.

In 1870 September, Baker took an appointment as Professor of Mathematics at Albion College for one academic year. He then returned to Michigan in 1871 as an Instructor in Mathematics, working with Professor Ulney. In 1873 March, following a recommendation from Watson, Baker accepted appointment as Assistant Astronomer with Dall's U.S. Coast Survey expedition to Alaska. The position was made vacant when Mark Harrington decided to return to Ann Arbor to take a position as Assistant Professor of Geodesy, Zoology, and Botany. Baker was exceptionally well liked, and was described by Dall as having a "...kindly and cheerful nature and lively enthusiasm [that] captured our affections at the start." (Dall 1904:40).

His journey to Alaska began in Washington, DC, where Baker prepared for the trip by practising observations under the direction of Julius Hilgard, the Assistant in charge of the Coast Survey (Watson, 1873a). In 1873 March, he set out for San Francisco by way of Ann Arbor, Kalamazoo, and Kansas (where his future bride resided). Following Baker's first glimpse of the Pacific Ocean, Dall's group left San Francisco on 1873 April 28, arriving in Unalaska on May 20, then setting off in June for Alta Island in the Aleutian chain. Baker spent the summer in the islands, charting positions along the island coasts and harbours, correcting old charts, making magnetic declination determinations, gathering scientific data on tides and weather, and collecting natural history and ethnology specimens. Much of the information he gathered was utilized to prepare the *Coast Pilot of Alaska*.

After six months on assignment in Alaska, Baker took an hiatus in San Francisco, where he independently reduced unpublished data on terrestrial magnetism that had been collected between 1740 and 1880. The results of this painstaking work constituted a significant advance in scientific understanding. Baker then applied to join Watson's transit of Venus expedition to Peking, but discovered that the team had already been finalized (Watson, 1873b), so he decided to return to Alaska for another tour of duty, leaving in 1874 April. First he worked on a hydrographic survey of the coast from Sitka to the Bering Strait, and then in 1874 December he seized the opportunity to return to Kansas to marry Sarah Eldrid. But, Alaska was not yet out of his system, for he made a third trip there in 1880.

In 1886, Baker severed his connection with the U.S. Coast and Geodetic Survey to join the United States Geographical Survey. But, before this transition he was asked (in 1882) to establish a magnetic observatory at Los Angeles. With the Geographical Survey, he took a leadership role in shaping the topographic mapping of southern New

England and other regions. As Secretary and Editor, he made significant contributions to the Board of Geographic Names, a group created by President Harrison to regulate nomenclature. Mount Marcus Baker in the Fairweather Range and the Baker Glacier in Alaska were both named in his honour.

Baker also took an active role in the determination of several important border questions, including the Venezuela boundary controversy, for which he compiled a historical atlas and other materials that were essential to resolving the dispute. In 1902, he prepared a comprehensive *Geographic Dictionary of Alaska*, which proved to be an invaluable resource for cartographers and geographers.

Baker served as President, Secretary, and Editor of the Philosophical Society of Washington, and toward the end of his life was appointed Assistant Secretary of the Carnegie Institution. On 1903 December 12 he died very suddenly from heart failure while at his residence in Washington, DC. He was only fifty-four years of age.

11.2 Samuel Sharpless Green, Class of 1871 [1846-1941]

Samuel Green was born on 1846 November 13 to William Lamborn and Sarah (Sharpless) Green. When he enrolled at the University of Michigan, he was living at Media, Pennsylvania. In Ann Arbor, he studied under James Watson at Detroit Observatory. Apparently, he was one of Watson's favourite students, because when Arctic explorer captain C F Hall asked Watson to recommend an astronomer for an expedition to the North Pole, Watson recommended Green. Hall's telegram to Watson dated 1871 May 19 read:

> Can you recommend to Arctic Committee National Academy Science a competent astronomer for North Pole Expedition salary one hundred dollars per month and all expenses paid urgent need of a skillful energetic & willing volunteer to communicate with or report to me at once for preparatory training Coast Survey Washington. (Hall, 1871)

Watson sent his reply (collect) the same day:

> Yes. I can recommend Samuel S Green now with me. He is robust, active, well educated and will accept the place. Please advise me of your further wishes. He can report at once. (Watson, 1871)

Green immediately travelled to Washington for training, but on 28 May, Green wrote to Watson regarding his serious doubts about the expedition and its leader.

> …there are other discouraging circumstances: the expedition seems to be very poorly organized. There is a want of confidence in Capt. Hall; the captain is an uneducated man, he knows but little about navigation and I do not think he is a man who would preserve discipline, upon which so much depends. … Prof. Baird told me this morning that he would not consent for a son or relation of his to go on the expedition as at present organized, as it will be extremely hazardous… … Prof. Hilgard told me… …further that Capt. Hall killed a man on one of his expeditions and was only acquitted of the crime on the ground of want of jurisdiction. (Green, 1871)

Green's instinct was to decline the position. He wrote to Watson "…two men of considerable astronomical practice and experience have already declined the place after having once accepted it." In fact, Green did resign, which proved to be a fortunate decision. Hall and his expedition party did achieve a new record for distance north—only 748 kilometres (464 miles) from the North Pole—but the Hall expedition was a disaster.

Hall died aboard his ship *Polaris* under mysterious circumstances in the fall of 1872. When *Polaris* became stranded in the ice, nineteen crew members became trapped on a huge ice floe. They drifted for seven months, and suffered through terrible privation, until they were rescued about 2,903 kilometres (1,800 miles) from their starting point by a passing ship. Those left on *Polaris* were forced to abandon ship, and they suffered tremendous hardships and starvation. Five died, and the ice floe shrank to a tiny platform before they miraculously reached the Labrador coast, where they found a camp of friendly Inuits at Etah. A whaling ship rescued them that Spring.

The Navy's inquiry into Hall's death concluded that he died of a stroke. But, ninety-seven years later, Hall's biographer, Dartmouth College Professor Chauncey Loomis, became suspicious. Evidence he uncovered made him suspect Hall was murdered. Loomis had Hall's body exhumed from the frozen Greenland tundra, and an autopsy confirmed he died of acute arsenic poisoning. (Parry, 2001:296-305; Berton, 2000:408) Those responsible for the crime remain unknown.

After Green resigned from the expedition, he was an instructor in physics at Swarthmore College for a year, then returned to Ann Arbor to complete a Master's degree in 1874, and returned to Pennsylvania as an instructor at Quaker's College in Swarthmore. After a year of study at Berlin and Heidelberg, Germany, he returned to Swarthmore College in 1878 as Professor of Physics and Chemistry, where he remained on the faculty until 1886. Green retired to Florida and worked as a librarian at the public library in Bartow. He died in Florida in 1941 at the age of ninety-five.

11.3 Edward Israel, Class of 1881 [1859–1884]

Edward Israel's fascinating life was tragically short, but his contributions to science were remarkable and heroic. Israel, a native of Kalamazoo, Michigan, was born on 1859 July 1, the son of a wealthy and prominent family of that college town (At Israel's home, 1884:2). His father, Menz Israel, was the senior partner of a prosperous dry-goods firm.

Edward Israel (Figure 24) attended public schools at Kalamazoo, where he distinguished himself for his love of study and his tendency to pursue original investigations. He entered the University of Michigan in 1877, where his exceptional aptitude for mathematics caught the attention of Mark Harrington. Harrington personally provided instruction to Israel, who was far ahead of the other members of the class. Harrington wrote:

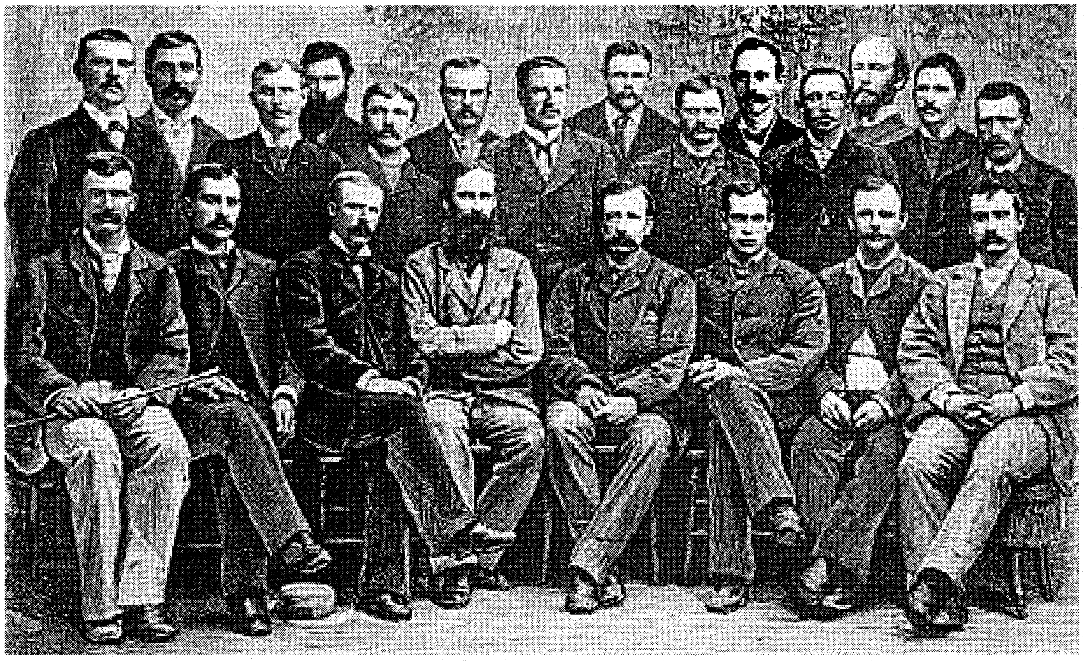

Figure 24. Edward Israel (1859–1884) is third from the right in the front row in this etching of Greely's Arctic expedition party (after Greely 1888, I: facing page 39).

> He read with me Watson's *Theoretical Astronomy*, a work so advanced as to be beyond the range of most college students, and even to offer in places serious difficulties to the professional mathematician or astronomer. Mr. Israel not only read the entire work in a half year, but he seemed entirely unconscious that he was doing anything extraordinary. (*Cyclopedia of Michigan….*, 1890:284).

Israel graduated from the University of Michigan in 1881. His scientific contributions were in both astronomy and meteorology, which is not surprising given that his mentor, Mark Harrington, went on to be the inaugural Chief of the U.S. Weather Bureau.

At the time Israel graduated from the University, Lieutenant Greely of the United States Cavalry was forming his team for the nation's first polar expedition. Greely needed an astronomer for the mission, so he sought a recommendation from Detroit Observatory. Harrington recommended Israel, who was selected over all others. Israel enthusiastically accepted this unique opportunity, and the University recognized his talents by permitting him to join the expedition prior to the end of the semester, yet graduate with his class. Israel reported to the United States Signal Service office at Washington, DC, in 1881 May for a month of practical instruction in use of the instruments, and learned to perform computations to help prepare him for the expedition.

Israel was the youngest member of the Greely Arctic Expedition (1881–1884), and the only one with a Jewish heritage. He was appointed at the rank of Sergeant, and was responsible for the astronomical observations and expected to assist with the meteorological observations.

The polar expedition was part of a larger plan adopted by the International Geographical Congress at Hamburg in 1879, with the goal of establishing a network of circumpolar stations where scientific observations could be carried out and data collected. Congress made the appropriation for the expedition in 1881 March, to establish scientific stations in the area of Lady Franklin Bay. Greely's station was to be located at the most northerly point, at Discovery Harbor (latitude 81° 44′ North and longitude 64° 45′ West).

Greely and his twenty-four man team set out from St. John, Newfoundland, on the steamer *Proteus* on July 4, and entered Lady Franklin Bay a month later. They established a base camp and named it Fort Conger to honour Senator Omar Conger of Michigan who sponsored the bill that funded the expedition. At Fort Conger, the first thing Israel did, even before setting up his astronomical and magnetic observatory, was to determine the longitude and local time of the station. Once this was done and the observatory was erected, he set about making daily astronomical observations (weather-permitting) and collecting weather data. The expedition met with many successes, and perhaps the most significant geographical milestone was the achievement by Lieutenant James Lockwood of a new northern latitude record when he reached 83° 24′ on 1882 May 13.

But, in the harsh climate of the polar region there are few certainties, and life continues to hang in the balance. Relief ships that were expected to bring provisions failed to arrive in 1882, and again in 1883, and the Greely party was forced to travel 645 kilometres (400 miles) to the south, arriving at Cape Sabine in 1883 September. Alas, the provisions they expected to find cached at this location were not there. They hoped for rescue at this more accessible location, but the relief ship did not arrive before winter set in. Provisions were rationed with precision and care, yet members of the party suffered unbearable privation that winter, and one by one they died of starvation and exposure. By April, the survivors were reduced to consuming small quantities of lichens found under the snow, and spent their time huddled together for warmth in three-man buffalo hide sleeping bags (Figure 25). With the passage of time, they became less and less able to perform even the most routine of tasks.

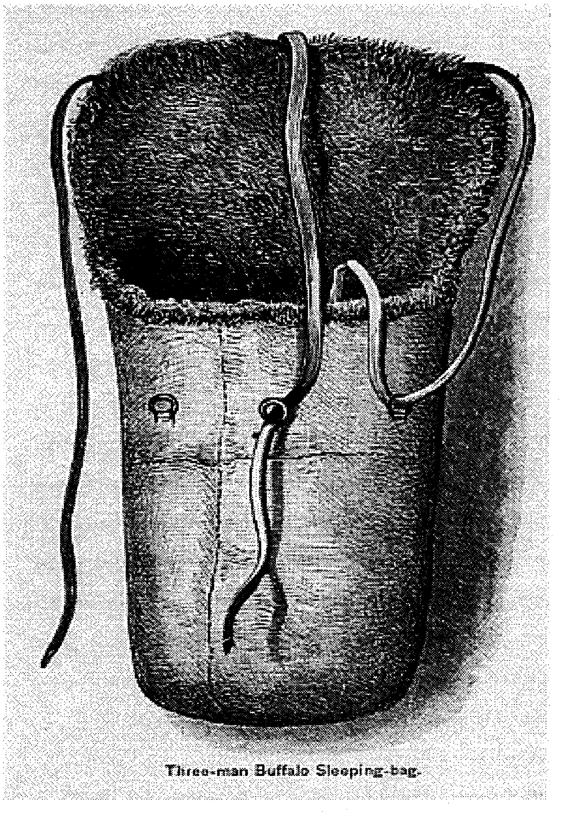

Figure 25. Arctic sleeping bag of the type Edward Israel shared for warmth with Arctic expedition leader Lte Adolphus W Greely (after Greely 1888, I: 212).

Israel, as one of Greely's favourites, received tender care and attention. When his health took a worrisome turn, a raven was seen at the camp and was killed for food. Greely gave four ounces of this scarce meat to Israel in the hope that it would help sustain him, but to no avail. Three days later, Greely (1888:519) wrote: "Israel cannot long survive the horrors of this hated place...", and the following day (1884 May 25) he wrote: "My God, this life is horrible! It is burdensome, and it plunges one into the lowest depths of despair." (Greely, 1888:520). On May 27, just after midnight, Israel died "very easily." Greely (ibid.) wrote:

> After losing consciousness—about eleven hours before his death—he talked of food, restaurants, &c. Everyone was his friend. He had no enemies. His frankness, his honesty, his noble generosity of nature had won the hearts of all his companions. His unswerving integrity during these months of agony has been a shining example...

Nearly four weeks later, on June 22, a rescue party arrived to take the seven survivors home, one of whom died during the journey.

Israel's abilities as a scientist were highly respected and valued by Greely and the other team members. The data Israel gathered were praised when examined after the expedition. About Israel's work, it was said: "...[his] computations indicate great care, even in the smallest details, exhibiting a greater degree of precision than is necessary..." (Greely, 1888:61). Israel's contributions are locked into history in the form of the important data he gathered, and in Greely's written mention of his superb abilities and personal qualities in the published account of the expedition. Israel's memory is also kept alive in his hometown of Kalamazoo, where his body was returned for burial. A State of Michigan historical marker was erected near his grave in 1972 to honour 'Edward Israel, Arctic Pioneer'.

12 BOTANICAL COLLECTIONS AND THE U.S. LAKE SURVEY

Congress established the Survey of the Northern and Northwestern Lakes (*aka* U.S. Lake Survey) in 1841, but its work began in earnest in 1851. Large teams of trained engineers and surveyors were needed to gather data in order to accurately map the Great Lakes region. Land crews performed primary triangulations, while others using various watercraft made depth soundings. Between 1863 and 1882, when the Lake Survey was completed, more than fifty percent of the civil assistants employed by the Lake Survey were students or graduates of the University of Michigan.[10] Some students worked as field assistants during the summer break, for experience or to earn money for college expenses, or both. Others took leaves of absence from their studies to earn funds so that they could continue on towards graduation. Still others launched their careers after graduation as employees of the Lake Survey.

The extensive contributions made by University of Michigan students to the surveying needs of the Lake Survey have already been documented. A more obscure yet important contribution made by some of these students was the collection and documentation of Michigan's botanical species. Orlando Wheeler and other civil assistants of the U.S. Lake Survey actively collected botanical specimens during the course of their fieldwork. One Michigan-trained surveyor, Ossian Simonds, became a famous landscape architect, and designed the University's Arboretum. In the field, botanical specimens were assembled and labelled, and data were recorded for each plant on small squares of readily available birch bark rather than on the usual paper labels. Today, many of these specimens are preserved in the University of Michigan Herbarium. For a fascinating account of the Lake Survey's contribution to nineteenth-century US botanical collecting see Voss, 1978.

13 INTRODUCING THE CONSUMATE INTERDISCIPLINARIAN

During the mid-nineteenth century, scientists had the opportunity to explore numerous disciplinary areas, because the boundaries between sciences were not rigidly defined. This is clearly evidenced in the case of 'astronomical' observatories, which in addition to traditional astronomy, generally also espoused time-keeping, meteorology, trigonometrical surveying, seismology, geomagnetism, and sometimes even tidal studies.

Scientific expeditions were necessarily limited in size, so it was advantageous for team members to serve multiple roles, such as providing both astronomical and meteorological data. One particular scientist trained at Detroit Observatory, who took interdisciplinarity to the extreme, was Mark Harrington. His interests were diverse, his curiosity hard to quell, and his energy and enthusiasm took him to the pinnacles of success. Yet, his career and his life both ended tragically.

13.1 Mark Walrod Harrington, Class of 1868 Director, Detroit Observatory 1879–1892 [1848–1926]

Mark Harrington (Figure 26) was an accomplished botanist, meteorologist, astronomer, and university president, and he pursued several other scientific disciplines, as well. He was born on 1848 August 18 in Sycamore, Illinois, to James and Charlotte Harrington. His father was a practicing physician. Mark showed great aptitude in school, and at the young age of twelve years he enrolled at Northwestern University near Chicago, where students were needed to fill spaces vacated by those engaged in the Civil War. After five years he transferred to the University of Michigan, and received his degree in 1868. He stayed on at Michigan for graduate studies, and received his Master's degree in 1871.

Harrington was a favourite of Michigan faculty members Joseph Steere and Alexander Winchell, and worked in the laboratory and museum on projects involving geology, botany, and zoology. He was particularly interested in botany, and diligently gathered and prepared specimens for the herbarium. He developed into an inspiring teacher, and in an effort to fascinate his students he suggested the use of microscopes in the botanical laboratories. In 1868 he led a group of students on a field trip to Lake Superior, and upon his return assumed his first paid position, as an Instructor of Mathematics.

In 1871, Harrington lectured on geology at Oberlin College in Ohio, and then had the opportunity to join William Dall on a U.S. Coast Survey scientific expedition to the Aleutians as Astronomical Aid. Watson opened this door by recommending Harrington for the post when Dall wrote to him asking for the name of a suitable young astronomer. Dall subsequently wrote: "I am much pleased with the prospect of having as a companion, a gentleman so highly recommended by yourself and so competent to do good work." (Dall, 1871). The expedition's objective was to examine the coast from Cook's Inlet to the end of the Aleutian Chain, and to the north as far as Cape Romanoff. Along the way, they planned to make longitude determinations, take bathymetric soundings, make astronomical and meteorological observations, take barometric measurements of various mountains they might have time to ascend, and collect animal, geological, and botanical specimens.

Harrington accepted the assignment and departed for San Francisco to meet up with Dall. In the course of this journey he truly enjoyed the scenery encountered, and a highlight was a visit to Salt Lake City to see the Morman enclave. But he became lonesome and bored in Alaska. Writing to Steere from Ilinlink, Unalaska, he complains: "We shall lie here all winter, and a miserable little hole it is." (Jones, 1978:119). But, there was one thing in particular in Alaska that truly appealed to him, and that was the opportunity to study the weather.

Figure 26. Mark Harrington, 1848–1926 (Courtesy: Bentley Historical Library, University of Michigan).

Winchell called Harrington back to Ann Arbor in the fall of 1872 to a Professorship in Geology, Zoology and Botany, and he arrived with a great many rare specimens, but the most interesting 'curiosity' was a 15-year old Aleutian boy. Perhaps Harrington was following his friend's example, because Steere had previously returned to Ann Arbor from the Philippines with a similar ethnographic 'specimen.' In 1876, Harrington developed a new course in pharmaceutical botany that emphasized the identification of drugs extracted from vegetable matter and the detection of adulterants. The course was required for students in the University's new School of Pharmacy.

Secure in a steady job, Harrington returned home to Illinois to marry Rose Martha Smith on 1874 June 30, and in 1876, with a two-year leave of absence in hand, they left for Europe where he planned to study German and learn "...the best methods in botany and comparative anatomy." His studies began at Kew Gardens near London, where he completed a study of ferns collected by Steere and published the results in 1878 in the *Journal of the Linnean Society*. This was a significant event, as it was the first research paper published by a Michigan faculty member based on the University's botanical collections (University of Michigan, 1958b:1446), and in recognition of this important publication Harrington was elected a fellow of the Linnean Society of London. In 1876 he moved to Leipzig, where he studied German and worked at various botanical gardens. The following year, he received a Ph.D. from the University of Leipzig.

After a short visit to their home in Sycamore, Illinois, the Harringtons again went abroad, Rose to Paris, and Mark to Peking, where he accepted an appointment as Professor of Astronomy and Mathematics at the Cadet School of the U.S. Foreign Office and Director of the T'ung wen Quan (Royal Observatory). This new position offered a better salary than his post in Michigan, from which he resigned.

Due to his ill health and Rose's loneliness, they decided to return to America in 1878, and Mark was appointed to a Chair in Natural Science at Louisiana State University. However, things obviously did not work out there, for the Harringtons soon returned home to Illinois, and it was there that he published an analysis of the tropical ferns collected by his friend Steere in the early 1870s.

In 1879 March, Harrington accepted President Angell's offer to return to Ann Arbor as the third Director of Detroit Observatory, given Watson's imminent departure for the Washburn Observatory. It is likely that Professor Winchell recommended him for the job, but Angell's appointment as Minister to China may have had some bearing as well. Harrington and Angell carried on a personal correspondence during the latter's residence in China, and in 1894 Angell arranged for Harrington to receive an honorary Doctor of Law degree.

During his tenure as Director of Detroit Observatory, Harrington's interests in botany and meteorology remained strong, so he decided to concentrate on meteorology and leave Schaeberle largely in charge of astronomy. Weather instruments were soon purchased, and a wind vane and anemometer appeared on the roof of the Observatory.[11] Weather records were kept and sent to the State Board of Health at Lansing. Harrington also acquired two seismoscopes, and added seismological studies to the Observatory's repertoire. In addition, in 1884 he founded the *American Meteorological Journal*, the nation's first journal dedicated solely to meteorology.

When the Federal Government reorganized its meteorological structure in 1881, Harrington left Ann Arbor to accept the post of inaugural Chief of the U.S. Weather Bureau. One consequence of this was that the University eliminated its course on meteorology, and the subject was never again offered by the Department of Astronomy.

At the Weather Bureau, Harrington led many research initiatives. Perhaps one of the most interesting was a study published in 1895 titled *Surface Currents of the Great Lakes as Deduced from the Movements of Bottle Papers During the Seasons of 1892, 1893, and 1894*. Commercial interests prompted this study. It was observed that flotsam and jetsam from shipwrecks travelled along predictable routes, and knowledge of these surface currents would permit vessels to maximize the advantage of the drift. Around the Great Lakes, Harrington deployed five thousand glass bottles into which he placed instructions to inform the Weather Bureau of the precise location and date of recovery. Only thirteen percent of the bottle papers were returned, but the data from these led to an increased understanding of surface currents. Even today, Harrington's study is viewed as a significant reference for research on Great Lakes surface currents being performed by the National Oceanographic and Atmospheric Administration (Schwab, pers. comm., May 2003).

Harrington was a gifted scientist, but he did not excel in the rigid, militaristic environment that was well established within the U.S. Signal Service, the predecessor to the Weather Bureau. In spite of his many successes and the innovations he introduced, by 1895 his position at the Weather Bureau was seriously undermined. When he was asked to resign he declined, so he was removed by action of President Grover Cleveland. His path then took him to Seattle, where he was appointed as President of the University of Washington. But shortly after his appointment, the State of Washington entered a period of political turmoil, and history repeated itself: Harrington was dismissed. His replacement resigned after six months, following altercations with the Faculty and Regents.

As always, Harrington bounced back, finding employment again with the U.S. Weather Bureau as a Section Director in San Juan, Puerto Rico. But, his physical and mental health was beginning to fail, and he was transferred to New York, where he retired. His book, *About the Weather* (1899), was published at this time, and was very well received.

But, something was amiss with Harrington's 51-year old mind. One evening in 1899 October he told his wife and son that he was going to dinner in New York, and simply disappeared. Over the course of the next ten years his family did not see him or know of his whereabouts.

It transpired that in early 1909 Harrington applied for shelter at a police station in Newark, but was unable to identify himself, so he was transferred to the Morris Plains Asylum in New Jersey. His son Mark, then a Master's candidate in anthropology at Columbia University, located his father after seeing a short note in the *New York Times* about a very learned man in an insane asylum who did not know his identity. Harrington spoke seven languages, and expounded eloquently on scientific topics, which caught people's attention and aroused curiosity.

A reporter, by pulling together past newspaper clippings, was able to determine that Harrington left New York in 1899 for China, where he suffered a long illness, but he eventually recovered and worked as a tutor to save money for the trip home. In 1902, he was living in a cheap boarding house in Chicago. In an interview with a reporter, he described from his scientific point of view the time he spent among hobos who "...migrate as regularly and completely as the birds, only they do not pass the Gulf Coast." (Jones, 1978:134). He also complained that "...universities do not want a man over fifty..." (Scholarly man's plight ..., 1902:2). At the time, the reporter did not realize that Harrington had abandoned his family, and the article escaped the notice of anyone aware of his disappearance. Later on, Harrington worked on a sugar plantation in Louisiana, and then worked as a log roller in Washington State in 1901, living in a one-room cabin he built, in which he surrounded himself with books and scholarly materials. During this time, he compiled an almanac for Alaska containing climatic and geological data, and he also worked as a labourer in a shipyard.

After a remarkable yet tragic life, Mark Harrington died at the Morris Plains Asylum on 1926 October 9.

14 WOMEN MAKE THEIR MARK

The University of Michigan did not permit the enrolment of women until 1870. The topic generated intense debate across the nation, and in Ann Arbor Tappan believed that women were a disruptive element. His own daughter was a capable student who pursued advanced study, but she attended a local school for young ladies. University students and faculty were generally sympathetic to the admission of women, but once women were admitted, it became apparent that the sentiment among townspeople was decidedly anti-women. The fear was that the University would become less attractive to students, and local business would suffer.

By 1870, the University decided to proceed with what some referred to as the "dangerous experiment", and just one woman enrolled that year. The number increased to 112 within five years, and nearly doubled over the next decade. By 1895, there were nearly 600 women at the University of Michigan. Although the majority entered the literary college, many pursued medical studies, including James Watson's sister, Catherine, who was one of the first women at Michigan to receive a degree in pharmacy when she graduated in 1876.

Once admitted, many of the women who attended the University during the nineteenth century distinguished themselves in their subsequent careers. One impressive example is Alice Freeman Palmer, Class of 1876, who became President of Wellesley College. Many of the educated women of that era found career opportunities at the women's colleges, such as Vassar and Wellesley, where the environment generally was hospitable. A digest of Michigan's women graduates compiled in the mid-1890s (see Thwing, 1895:552) identifies nine particularly successful women, including astronomer, Mary Byrd.

14.1 Mary Emma Byrd, Class of 1878 [1849–1934]

Mary Byrd (Figure 27) transferred to Michigan from Oberlin College in Ohio as a junior, graduated in 1878, and then pursued a career in astronomical science at Smith College. Byrd received her instruction in mathematics and astronomy at Michigan from James Watson and others. Of her experience at Michigan, she later wrote in response to a 1924 alumnae survey: "One of my keenest memories of college days at Ann Arbor is that the women students were unwelcome. The professors themselves, so far as I knew personally, were always courteous and considerate." (Attaway and Barritt, 2000:18).

Byrd was born in 1849 in LeRoy, Michigan (Attaway and Barritt, 2000:122), the daughter of Elizabeth Byrd, but grew up in Lawrence, Kansas (University of Michigan, 1878). Her father was a Congregational minister and staunch abolitionist who was descended from Jonathan Edwards, the noted religious philosopher and author of *Freedom of the Will*, which had a major influence in the scholarly life of Henry Tappan. Byrd's father moved the family to Kansas in 1855, where one of her mother's brothers was a prominent judge and member of Congress for a term. Mary Byrd possessed rare personal traits, including an intense resolve and inflexible moral standards, which she may have inherited from her philosopher father.

Figure 27. Mary Byrd, 1849–1934 (Courtesy: Bentley Historical Library, University of Michigan).

Following her graduation from Michigan in 1878, Byrd taught Latin, Greek and mathematics at Wabash, Indiana, and served as a high school Principal at Atchinson, Kansas, for several years. She then took a position at Harvard College Observatory, where she worked with astronomers such as E C Pickering and Henry Draper, and with a number of women who distinguished themselves in astronomy. Most prominent of these were Antonia Maury, who discovered that Beta Aurigae was a close binary star; Mina Fleming, who discovered that bright lines in the spectra of some stars indicated they were variable (Reed, 1892:167); and Anna Winlock, daughter of Harvard astronomer Joseph Winlock, who literally grew up at the Observatory. Anna began by computing the Cambridge zones while a schoolgirl, but did not complete the task until 1896, a devotion that consumed her for over twenty years and earned for her the high regard of colleagues. When she died in 1904, having only reached her late forties, Mary Byrd (1904) wrote a biographical sketch that locks into history Winlock's achievements and her dedication to science; it also demonstrates Byrd's close relationship with her departed friend. Byrd's associations at Harvard were important elements in her development as an astronomer, and she particularly valued the mentoring she received from E C Pickering, who was well known for his conviction that women should receive support and recognition in the scientific world (Jones and Boyd, 1971:413-417).

After several years at Harvard, Byrd relocated to Carleton College to teach mathematics and astronomy. And under the supervision of William Payne, she also provided time signals twice daily for the region's railroads. During this time, she pursued doctoral studies in astronomy, and received her Ph.D.

from Carleton in 1904. Her abilities then caught the attention of Smith College, and they succeeded in attracting her as Director of their new Observatory. She remained at Smith College for nineteen years, and eventually become their first Professor of Astronomy.

Byrd was recognized at Smith for her hands-on teaching methods. In 1899, she published her first textbook in astronomy, titled *Laboratory Manual in Astronomy*. Her second textbook, *First Observations in Astronomy*, appeared in 1914, written as a practical guide for the student with limited means or access to equipment. The book included instructions for making a sundial using a wooden ruler, a block of wood, a paper dial, and a carpenter's level. Other tools or instruments deemed essential for the astronomy student were a straight edge, a pocket compass, a steel scale, a transparent protractor, an orrery, a celestial globe, opera glasses and a small telescope. Byrd cautioned against the idea that a telescope was the first order of business for the energetic student:

> Magnifying power for studying the heavens is perhaps best given at first by opera-glasses. Those having a power of two or three diameters show detail on the moon, and resolve some double stars and star clusters. A telescope is the last, rather than the first instrument to be obtained. The danger is that it will be only a pretty toy, but even as a plaything it has its uses, and one can be put together with little expense... Instead, however, of making the tubes, much labor is saved by using mailing tubes, or tin tubes, of suitable size. (Byrd, 1914:11).

Three of Byrd's letters to the President of Smith College, Clark Seelye, are preserved in the Smith College archives, and they reveal the problems that she and other Directors of small college observatories faced, but they particularly characterize the challenges at a woman's college. Byrd desperately appealed for an assistant. She pointed out that she was operating the observatory alone, maintaining the equipment, making observations and teaching, and that she had to work twelve-hours days, without any vacations, just in order to keep up. These pleas eventually had the desired effect, and she was able to appoint a Smith College graduate, Harriet Bigelow, as her Assistant (see Section 14.2, below).

One of Byrd's most important contributions to astronomy, beyond her many years of college teaching and production of two text books, was her determination of the longitude of Smith College Observatory. According to Reed (1892:167), this was "... probably the only longitude campaign ever conducted wholly by women ...", and during this undertaking she teamed with Mary Whitney, who later succeeded Maria Mitchell as Director of Vassar College Observatory.

In 1906, Byrd resigned her position at Smith College as a protest against funds the College was accepting from benefactors such as John D Rockefeller and Andrew Carnegie, because she considered them to be "tainted." Deemed a "conspicuous anti-capitalist" by the media ("Tainted money at Smith," 1906:8), Byrd remained silent when the College received a series of gifts from Rockefeller, but her personal convictions became overwhelming when the Carnegie gift was announced, although it was not designated for the astronomy programme. She felt strongly that educational institutions compromised their freedom of expression on economic problems when they accepted large financial gifts from wealthy private benefactors. She retired in disgust. In submitting her resignation, she questioned "... the methods by which certain large personal fortunes were built up, and her own need for protest, even at sacrifice of her position, against such sources for college funds." (Hoblit, 1934:497).

With her principles intact, Byrd returned to her hometown of Lawrence, Kansas, where she remained active in astronomy and completed a further textbook, titled *First Observations in Astronomy*. In the acknowledgements, she extended thanks to a jeweller in Lawrence named Marks, for "... courtesy in sending accurate time by telephone render[ing] it possible to test a home-made transit instrument, and to determine longitude from local observations." (Byrd, 1914).

Byrd then relocated to New York City, and served as a Lecturer in Astronomy at Normal College and Hunter College in 1913–1914 (Dr Byrd at Normal, 1913:9). She later retired to Dunedin, Florida (Attaway, 2000:122), and died in Lawrence, Kansas, on 1934 July 30 at the age of eighty-five.

14.2 Harriet Williams Bigelow, Ph.D. 1904 [1870–1934]

Harriet Bigelow (Figure 28) received her Ph.D. in astronomy at the University of Michigan in 1904. Her educational preparation was influenced by study under Asaph Hall Jr. at Detroit Observatory, and also by Mary Byrd at Smith College Observatory. Considering the influence of such distinguished mentors, it is no surprise that Bigelow had an impressive career as a teacher and a researcher.

Born on 1870 June 7 in Fayetteville, New York, Harriett Bigelow was the daughter of the town's Presbyterian pastor. Her early education was in the Fayetteville and Pitcher community schools. The family relocated to Utica, New York, in 1878, where she attended the Utica Free Academy, graduating in 1889. She then enrolled at Smith College, where she studied astronomy under Mary Byrd. Her initial interest in astronomy was completely serendipitous: "My dormitory window faced the observatory, and I thought it would be fun to help turn the dome around." (Williams, 1934:435). She graduated in 1893.

Bigelow made an impression on Mary Byrd, and was employed as her Assistant in 1895. At the time, Bigelow was teaching at the Granger Place School in Canandaigua, New York, but she was enthusiastic about returning to Smith College. Her move to Smith in 1896 marked the beginning of a career to which she devoted the remainder of her life.

Her work at Smith College was interrupted only by her pursuit of a doctoral degree at the University of Michigan. Asaph Hall Jr., the Director of Detroit Observatory from 1892 until 1905, trained Byrd in the use of the Pistor & Martins meridian circle telescope. Her dissertation, published in 1905, was titled *Declinations of Certain North Polar Stars Determined with the Meridian Circle*. She became an expert in the determination of instrumental errors.

Following the completion of her doctoral work, Bigelow returned to Smith College as Instructor in Astronomy, and when Byrd resigned n 1906 she was promoted to Associate Professor and Director of the Observatory. In 1911 she advanced to full Professor. For the duration of her career, she carried on the tradition Byrd established at the Observatory, and like Byrd, she focused on quality instruction through hands-on observations, and respect for the mental discipline required to pursue the scientific method. Both women believed their job was "...not to turn out astronomers, but to make the girls intelligent about the universe in which we live." (Williams 1934:436). It was also important to Bigelow that every student master the English language, so that they could express their ideas in clear, proper written form.

Figure 28. Harriet Bigelow, 1870–1934 (Courtesy: John Dann).

Bigelow was active both on campus and beyond, through service to the College and to organizations such as the American Astronomical Society and American Association of Variable Star Observers. She organized at Smith the first informal meetings of women astronomers from the Eastern part of the United States, and she worked tirelessly for her science.

In 1934, following years of devoted service, Bigelow asked for sabbatical leave, and to her delight it was granted. Her desire was to spend a year of unfettered travel, free from academic responsibilities, and she made her way to Japan, then to China, and on to Manila, where she stayed six months. She then decided to visit observatories in South Africa before returning home, but between Bali and Java was found unconscious, having suffered a stroke. She never regained consciousness, and died two days later, on 1934 June 27, in a hospital in Surabaya, East Java (Williams, 1934:437).[12] Her ashes were sent home to America.

15 MICHIGAN ASTRONOMERS MIGRATE TO CALIFORNIA

During the 1880s, the pathway for students trained at Detroit Observatory shifted away from service on the topographical surveys and national engineering projects. Instead, a pattern developed, and soon became apparent, that established the University of Michigan as a training ground for astronomers at Lick Observatory (Osterbrock, 2003). The appeal of this fabulously-equipped Observatory was compelling, and Martin Schaeberle was the first to go west, leaving Michigan in 1888 to serve as one of the inaugural astronomers. But, the Michigan-California connection actually began well before Schaeberle's appointment.

James Watson was keen on becoming the inaugural Director of Lick Observatory, and began his lobbying in 1876 February, soon after Michigan's Eugene Hilgard (who was Professor of Mineralogy, Geology, Zoology, and Botany) left Ann Arbor to take up a position at the University of California. Eugene happened to be the brother of Julius Hilgard, Superintendent of the U.S. Coast Survey, whom Watson also knew. Watson corresponded with Eugene about his interest in the Lick Directorship, and in his reply Eugene noted that local salaries were decidedly better than those in Michigan, and he advised: "Be sure to find another planet soon, and Mr. Lick will want you just for the sake of having it called after himself!" (Watson, 1876). Through his connection with both Hilgards, and others, Watson gained the friendship of Joseph Henry, Secretary of the Smithsonian Institution, who wrote to the Lick Observatory Trustees nominating Watson for the Directorship. He then wrote Watson: "It will give me great pleasure to hear that they accept the nomination. If they do, as I have said in my letter to them, I doubt not you will soon make the name of the Lick Observatory familiarly known in every part of the civilized world." (Watson, 1877).

Progress at Lick Observatory was slow, but R S Floyd, the Superintendent in charge, regularly consulted Watson on constructional matters and sought his recommendations as to which telescopes to purchase. In 1880, Floyd sent Watson a photograph of Mt. Hamilton, about which Watson replied:

> [The photograph] gives me a good idea of the location of the Observatory, the slope of the mountain, &c. Mrs. Watson thinks the outlook would be superb, and a mountain residence such as you will provide not so much of a hermitage as some would suppose. We can see that the carriage road has a very easy grade. Perhaps when the time comes I may enroll my name as one of the candidates for the Directorship of your Observatory, and that too notwithstanding the ties that bind me here. I am for the best scientific opportunity while I live. (Watson, 1880).

Little could Watson have imagined that his life would end prematurely just three months after writing this letter, at the young age of forty-two.

The California-Michigan axis is fully examined in the third paper in this series (Osterbrock, 2003), but to facilitate the transition to that paper, one more Lick astronomer trained at University of Michigan during the nineteenth century, Sidney Townley, needs to be introduced.

15.1 Sidney Dean Townley, Sc.D. 1897 [1867–1946]

Sidney Townley received his early training at the University of Wisconsin under George Comstock, graduated in 1890, and went on to graduate training at Lick Observatory, where he was the first student to receive the newly created Hearst Fellowship. But, when Lick Director, Edward Holden, committed the Fellowship funds to Schaeberle in 1893 for a solar eclipse expedition to Chile, Townley was forced to seek employment elsewhere. Using his connections with Comstock and Schaeberle, he secured a position as an Instructor in Astronomy at the University of Michigan, and over the course of his subsequent, impressive career, he crossed paths with many other Michigan alumni who were trained at Detroit Observatory.

Townley was born on 1867 April 10 at Waukesha, Wisconsin, not far from Madison, to Robert and Mary Townley. His father was a minister who encouraged hard work and intellectual thought. Upon completing his high school studies, Townley's proficiency at mathematics landed him the job of clerk at the local bank. He saved his wages and enrolled at the University of Wisconsin in 1886, from which he graduated four years later with distinction, membership in Phi Beta Kappa, and one of four available graduate fellowships. His interest in astronomy did not begin until his second year at Wisconsin, and was heightened when he was given a room at the Washburn Observatory, for which he paid by working as an Assistant in the dome and helping with the time-service operation. His expertise in astronomy developed quickly under the guidance of George Comstock, who at the time was Director of the Observatory.

After graduating, an opportunity to visit his brother in California in 1891 sparked Townley's interest in Lick Observatory. Comstock provided a letter of introduction to Holden, and Townley was very impressed by the tour that Holden provided. When it came time to consider Ph.D. programmes, Townley applied to Lick Observatory and Harvard University, but he was successful in receiving an offer only from Lick (Osterbrock *et al.*, 1988:178-79). Following the loss of this Fellowship in 1893, Townley relocated to Ann Arbor to pursue graduate studies while teaching astronomy to undergraduates.

When he was a student at the University of Wisconsin, Townley started the tradition of keeping a detailed diary, to record his thoughts on everything from daily life to prohibition (Townley, 1940). At Detroit Observatory, he kept logbooks with the same regularity, and these contain a comparable level of detail (Townley, n.d.). He became widely recognized for his editorial skills, and served as editor of several scholarly journals, including the *Bulletin of the Seismological Society of America* and the *Publications of the Astronomical Society of the Pacific* (Aitken, 1946:195). During his career, he published more than 100 research papers on practical astronomy, variable stars, latitude variations, earthquakes, and other topics. He was also a photographer, and the photo albums he kept while in Ann Arbor are today an invaluable historical resource for those studying the town and the campus.[13] His research at Detroit Observatory from 1893 to 1898 was on variable stars and comets using the 32.1-cm Fitz telescope, but he also employed the meridian circle. His notebooks give an indication of the influence of his mentors, because he mentions the use of "Schaeberle's method" and refers to the sections of Brünnow's *Spherical Astronomy* that cover differential refraction.

In 1896, Townley took a one-year leave from Michigan to study in Germany, travelling to Berlin, Leipzig, and Munich, which were locations of major observatories. Upon his return to Ann Arbor, he taught astronomy for two more years, and received his Sc.D. degree from Michigan in 1897 for a dissertation on the "Orbit of Psyche." At this time, he accepted an offer to teach at the University of California-Berkeley under Armin Leuschner (see Osterbrock, 2003), which led to his appointment as Director of the International Latitude Station at Ukiah, California, from 1903 to 1907. His work at Ukiah directed his attention to the study of geodesy, and particularly seismology – following the 1906 California earthquake. In 1907, Townley relocated to Stanford University where he moved up the professorial ranks from Assistant to full Professor by 1918. His appointment at Stanford continued until his (mandatory) retirement in 1932 at age sixty-five, although he remained an active observer. He died in Stanford on 1946 March 18 at the age of seventy-nine.

16 CONCLUSION

Science and technology advanced at a rapid pace during the nineteenth century. University of Michigan President, Henry Tappan, was prescient in his understanding of the times and the role he envisioned for higher education. He believed that the advancement of science and technology for national prosperity and the betterment of society could best be achieved through intellectual cultivation. At his inaugural speech, he said:

> We aim not merely to equal, but even to surpass the old nations of the world, in our manufactures, our steamboats, and our railroads. We level the forests in a day, lay down our tracks, and startle the old world with the sounds of our engines ... substantial railroads in every direction ... lead the astonished traveler through villages, towns and cities, which have sprung up by the magic of that industry whose divine mission it is to change the wilderness into fruitful fields ... Let us make men as well a houses and railroads. Let us have eternal thoughts circulating among us as well as gold and silver. (Tappan, 1852:51).

The 'friends of science' in Detroit respected Tappan's vision and supported it, and Tappan acknowledged their financial support by naming the observatory after their city. Tappan's Detroit Observatory was the best-equipped observatory in the nation, and the recruitment of Franz Brünnow offered American students the most advanced instruction in astronomy available in America. Brünnow's appointment as the first foreign Director of an American observatory also served to heighten awareness in Michigan that prejudice against foreigners was unfounded.

Detroit Observatory contributed to the education of many of the nation's most accomplished nineteenth-century astronomers, surveyors, meteorologists, mathematicians, and physicists. It also impacted on generations of students who followed other career paths. The influence imparted by Detroit Observatory on young minds during the nineteenth century persisted for decades to follow. Evidence of this is found in the letters students wrote the University on the occasion of their class reunions. Robert Woodward, graduate of the Class of 1872, who became a distinguished geophysicist and President of the Carnegie Institution, identified the Faculty as the most important influence on University of Michigan students. He wrote:

> Some of us are old enough, also, to remember the wonderful material and intellectual progress made during the last forty years, since the graduation of the class of 1872, and how favorable have been the circumstances for the great development of this University, taking part as it has in the progress of the nineteenth century. It has been asserted that greater progress was made in that century by our race than in all previous history. But the greatest of all the influences behind the University is to be found in the great men [and women] among its Faculties. (University of Michigan, 1915:136).

Detroit Observatory stands today as a physical legacy of Henry Tappan's vision for higher education, and as a nearly perfectly-preserved nineteenth-century scientific laboratory. The historical telescopes and interpretative exhibits inform visitors about the scientific research performed by University of Michigan Faculty, and the quality of the training they offered to students.

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18 NOTES

1. The Ann Arbor meridian circle's original equipment survives complete, with the exception of its parasol and reflex basin, three of its microscopes, and its two collimating telescopes (replicas were made in 1997), which were stolen in the 1980s.
2. The author identified the location of these meridian circle telescopes in 1997, and has inspected the instruments at New York State Museum, Boerhaave Museum, and the Steno Museet. For their kind assistance, thanks are extended to Nancy Langford, Dudley Observatory and Geoffrey Stein, New York State Museum; Dr Steven Dick and Brenda Corbin, U.S. Naval Observatory; Dr George Greenstein, Amherst College; Dr Ian Elliott, Dunsink Observatory; Dr Rob van Gent, Boerhaave Museum; Dr Gerhard Hartl, Deutsches Museum; Dr Hans Buhl, Steno Museet; Jörg Zaun, Technische Universität Berlin; Dr Ileana Chinnici, Palermo Observatory, and Dr Paolo Brenni, University of Florence.
3. The restoration of Detroit Observatory (1994–1998) received the following awards: Award of Honour, American Institute of Architects-Michigan; Award of Merit, American Association for State and Local History; Preservation Award, Michigan Historic Preservation Network; Preservation Project of the Year, Historic District Commission, City of Ann Arbor, Michigan; Certificate of Recognition, University of Michigan History and Traditions Committee; Pyramid Award for Best Restoration Project Team, Washtenaw Contractors Association-Michigan.
4. This biographical sketch of Watson is an edited version of Chapter 11 of the author's book, *A Creation of His Own: Tappan's Detroit Observatory* (Whitesell, 1998). The author has in progress a full-length biography of Watson, preliminarily titled, *Michigan's Astronomer Royal, James Craig Watson, 1838-1880.*
5. Watson's personal copy of this book is now held in Detroit Observatory's collections. The book was given to Martin Schaeberle by Mrs Watson after Watson's death, then passed to Schaeberle's nephew, then returned to the Observatory library during W J Hussey's Directorship, and recently returned to the Observatory by the University of Michigan Libraries at the request of the author.
6. The Van Vleck Observatory at Wesleyan University is named after John Van Vleck.
7. E C Pickering went on to become Director of Harvard College Observatory in 1877.
8. Henry Morton became the inaugural President of the Stevens Institute of Technology at Hoboken, New Jersey.
9. The "class of six" included Snyder, Otto Klotz and Robert Woodward. Snyder could not recall the names of the others.
10. Data were compiled by the author from (Comstock, 1882:45-47) and (University of Michigan, 1923).
11. Many of Harrington's meteorological instruments and weather records have survived, and are in the Detroit Observatory's collections.
12. Bigelow's death date is erroneously reported as 1934 June 29 in *Publications of the Astronomical Society of the Pacific*, **46**:242 (1934).
13. Townley's photograph albums containing images he took while a student in Ann Arbor are held at the Bentley Historical Library, University of Michigan.

19 REFERENCES

The following references were consulted with such frequency that they are not routinely cited throughout the research paper:

Appleton's Cyclopaedia of American Biography. Appleton & Company, New York (1889).

Biographical Dictionary of American Science. Greenwood Press, Westport (1979).

Dictionary of Scientific Biography. Charles Scribner, New York (1970).

Hinsdale, Burke A., 1906. *History of the University of Michigan*. University of Michigan, Ann Arbor.

National Academy of Sciences. *Biographical Memoirs*.

National Cyclopaedia of American Biography. White & Company, New York (1893).

Tuttle, Charles R., 1873. *General History of the State of Michigan: With Biographical Sketches, Portrait Engravings, and Numerous Illustrations*. Tyler & Co, Detroit.

University of Michigan, 1923. *Alumni Catalogue of the University of Michigan 1837-1921*. University of Michigan, Ann Arbor, Michigan.

University of Michigan. Class Records. Bentley Historical Library, University of Michigan.

University of Michigan, 1958. *Encyclopedic Survey*, I-IV.

University of Michigan. *Michigan Alumnus*. University of Michigan.

University of Michigan. *Michigan University Book*. Richmond, Backus & Company, Detroit.

University of Michigan, 1837–1915. *Proceedings of the Board of Regents* (various volumes).

Aitken, Robert G., 1946. Sidney Dean Townley, 1867-1946. *Publications of the Astronomical Society of the Pacific* **58**:193-195.

American Journal of Science, **21**:65-80 (1881).

Anderson, William D., 1854. Letter to Hamilton Higginson, dated August 2. William D. Anderson Papers. Bentley Historical Library, University of Michigan.

At Israel's home. *New York Times*, July 18 (1884).

Attaway, Doris E., and Barritt, Marjorie Rabe, 2000. Women's Voices: Early Years at the University of Michigan. Bentley Historical Library, University of Michigan.

Balloon party missed comet. *New York Times*, May 22 (1910).

Baum, Richard, and Sheehan, William, 1997. *In Search of Planet Vulcan*. Plenum Press, New York.

Beakes, Samuel W., 1906. *Past and Present of Washtenaw County Michigan*. Clarke Publishing Co, Chicago.

Berton, Pierre, 2000. *Arctic Grail*. Lyons Press, New York.

Bidlack, Russell E., and Cooley, Everett L. (eds), 1966. The Kintner letters: an astronomer's account of the Wheeler Survey in Utah and Idaho. *Utah Historical Quarterly* **34**:62-80, 169-182.

Bless, Robert C., 1978. *Washburn Observatory 1878-1978*. University of Wisconsin, Madison.

Bruce, Robert V., 1987. *Launching of Modern American Science 1846-1876*. Alfred A. Knopf, New York.

Brünnow, Franz F.E., 1849. *Mémoire sur la comète elliptique de Vico*. C. G. Sulpke, Amsterdam.

Brünnow, Franz F.E., 1861. Determination of the longitude of Ann Arbor by telegraphic method. *Astronomical Notices* **27**:17-18.

Buell, Mahlon H., 1962. Some Remarks on the Teaching of Physics in Ann Arbor High School, 1873-1958. A paper presented at the Physics-Chemistry-Astronomy Conference of the Michigan Schoolmasters' Club in Ann Arbor, May 11.

Byrd, Mary E., 1904. Anna Winlock. *Popular Astronomy* **12**:254.

Byrd, Mary E., 1914. *First Observations in Astronomy*. Rumford Press, Concord.

Carter, Charles S. (ed), 1921. *History of the Class of '70*. Published by the Class.

Chute, Horatio N., n.d. Unattributed and undated newspaper clipping. DB Vertical File, Bentley Historical Library, University of Michigan.

Cincinnati Historical Society, 1944. *Centenary of the Cincinnati Observatory, November 5, 1943*. Cincinnati.

Comstock, George C., 1882. *Report Upon the Primary Triangulation of the United States Lake Survey*. Government Printing Office, Washington, DC.

Comstock, George C., 1888. Biographical memoir of James Craig. *The Sidereal Messenger* **7**:273-286.

Cooley, Mortimer E., 1947. *Scientific Blacksmith*. University of Michigan Press, Ann Arbor.

Courant, Paul N., 2003. Why Liberal Education Endures in the World of the Bottom Line. Alumni Collection Address, Swarthmore College, June 7.

Cyclopedia of Michigan: Historical and Biographical. Western Publishing and Engraving Co., New York and Detroit (1890).

Dall, William H., 1871. Letter to James C Watson, dated April 23. In James C. Watson papers, Box 1, Correspondence 1871. Bentley Historical Library, University of Michigan.

Dall, William H., 1904. Marcus Baker. *National Geographic Magazine* **15**(1):40-43.

Darling, John H., 1942. Meteors and the Moon's surface. *Popular Astronomy* **50**:169.

Dick, S.J., Orchiston, W., and Love, T., 1998. Simon Newcomb, William Harkness, and the nineteenth-century American transit of Venus expeditions. *Journal for the History of Astronomy* **29**:221-255.

Donnelly, M.C., 1972. *A Short History of Observatories*. University of Oregon Press, Eugene.

Dr Byrd at Normal. *New York Times*, March 30 (1913).

Duff, Lela, 1956. Ann Arbor High School in its earliest days: Fire-and the Phoenix. *Ann Arbor News*, October 17.

Duff, Lela, 1958. *The Pioneer School. Some Chapters in the Story of Ann Arbor High School*. L. Duff, Ann Arbor.

Elliott, Clark A., 1996. *History of Science in the United States: A Chronology and Research Guide*. Garland, New York.

Emigration document dated 1854 April 29. In Oeschelbronn Archives, Germany (sent to the author courtesy of Bernd Schlanderer).

Farmer, Silas, 1884. *The History of Detroit and Michigan*. Silas Farmer & Co., Detroit.

Fath, E.A., 1928. William Wallace Payne. *Popular Astronomy* **36**:267-270.

Gingrich, Curvin H., 1942. John H. Darling, 1847-1942. *Popular Astronomy* **50**:533-535.

Greathouse, Mary M. Curtis, 1925 (UM BA '82; AM '83). Letter from Rosslyn, Virginia to Michigan Alumnus Magazine, dated May 2. Bentley Historical Library, University of Michigan.

Greely, Adolphus, W., 1888. *Report of the Proceedings of the United States Expedition to Lady Franklin Bay, Grinnell Land. I.* Washington, DC.

Green, Lewis, 1982. *Boundary Hunters: Surveying the 141st Meridian and the Alaska Panhandle*. University of British Columbia Press, Vancouver.

Green, Samuel Sharpless, 1871. Letter dated 1871 May 28 to James Watson. James C. Watson papers, Box 1, Correspondence 1871, Bentley Historical Library, University of Michigan.

History of Livingston County Michigan. Everts & Abbott, Philadelphia (1880).

Hoblit, Louise Barber, 1934. Mary E. Byrd. *Popular Astronomy* **42**:496-498.

Jarrell, Richard A., 1988. *The Cold Light of Dawn: A History of Canadian Astronomy*. University of Toronto Press, Toronto, Ontario, Canada.

Jones, Bessie Z. and Boyd, Lyle G., 1971. *The Harvard College Observatory: The First Four Directorships, 1839-1919*. Belknap Press, Cambridge, Massachusetts.

Jones, Kenneth L., 1978. Mark Walrod Harrington (1848-1926): botanist, astronomer, meteorologist ... *Michigan Academician* **11**:115-137.

Kintner, Charles J., 1876. The Observatory. *Ann Arbor Register*, May 31.

Loomis, Elias, 1874a. Observatories in the United States–I. *Harper's New Monthly Magazine* **48**:25-52.

Loomis, Elias, 1874b. Observatories in the United States–II. *Harper's New Monthly Magazine* **49**:518-531.

Memorial of Robert Simpson Woodward. *Bulletin of the Geological Society of America* **37**:115-134 (1926).

Michigan Alumnus **3**:45 (1896).

Michigan Alumnus **9**:419 (1903).

Obituary: Franz F.E. Brünnow. *Monthly Notices of the Royal Astronomical Society*, 1892. **52**:230.

National Cyclopaedia of American Biography, 1893 **22**:287-288.

Obituary: Monroe B. Snyder. *Monthly Notices of the Royal Astronomical Society* **93**:231-232 (1933).

Osterbrock, Donald E., 2003. The California-Michigan axis in American astronomy. *Journal of Astronomical History and Heritage* **6**:120-136.

Osterbrock, Donald E., Gustafson, John R., and Unruh, W.J. Shiloh, 1988. *Eye on the Sky: Lick Observatory's First Century*. University of California Press, Berkeley.

Payne, William W., 1881. Time service of Carleton College Observatory, at Northfield, Minnesota. *Science* **2**:445.

Reed, Helen Leah, 1892. Women's work at the Harvard Observatory. *New England Magazine* **12**:165-177.

Reichel, Max, 1959. Der astronom John Martin Schaeberle. *Aus Schönbuch und Bäu* **11**:2.

Rudolph, Frederick, 1962. *The American College and University: A History*. Vintage Books, New York.

Russell, John A., 1927. *Germanic Influence in the Making of Michigan*. University of Detroit. Detroit.

Schaeberle, J. Martin, 1877. Letter to his brother Fred. Robert Martin Schaeberle, dated 9 December. Original in possession of the author.

Schaeberle, J. Martin, 1898. Letter to the Editor. *Popular Astronomy* **6**:254.

Scholarly man's plight. Ex-Chief Harrington of the Weather Bureau is looking for manual labor in Chicago *New York Times*, May 30 (1902).

Schwab, David, 2003. Personal communication with the author (May).

Seen through a hazy sky. *New York Times*, December 7 (1882).

"Tainted" money at Smith. *New York Times*, May 17 (1906).

Tappan, Henry P., 1852. *A Discourse, Delivered by Henry P. Tappan*. University of Michigan, Ann Arbor.

Thwing, Charles F., 1895. What becomes of College women. *North American Review* **161**:546-561.

Townley, Sidney D., n.d. Observer's Notebook. Observatory Records, Box 13, Bentley Historical Library, University of Michigan.

Townley, Sidney D., 1939. Diary of a student of the University of Wisconisn, 1886 to 1892. Stanford University.

Tucker, Richard H., 1919. Charles Leander Doolittle. *Astronomical Society of the Pacific* **31**:103-104.

Tucker, Richard H., 1924. John Martin Schaeberle: an appreciation. *Publications of the Astronomical Society of the Pacific* **36**:312-313.

University of Michigan, 1870a. Class Records 1870. Unattributed Clippings, Box 13, Folder 1870, Bentley Historical Library, University of Michigan.

University of Michigan, 1870b. Class of 1870, specimen drawings. Bentley Historical Library, University of Michigan.

University of Michigan, 1872a Class of 1872 Records. Class notes submitted by Monroe B. Snyder. Bentley Historical Library, University of Michigan.

University of Michigan, 1872b. Class of 1872, Fiftieth Anniversary. Bentley Historical Library, University of Michigan.

University of Michigan, 1874. *The Chronicle*, V, September 1873–June 1874. Ann Arbor, Michigan.

University of Michigan, 1878. 1878 Class Album, margin note. Bentley Historical Library, University of Michigan.

University of Michigan, 1912. Class of 1872, Fortieth Anniversary 1912. Bentley Historical Library, University of Michigan.

University of Michigan, 1915. Class note by Robert S. Woodward. Memorial of the Seventy-Fifth Anniversary of the Founding of the University of Michigan. University of Michigan, Ann Arbor.

University of Michigan, 1958a. Encyclopedic Survey, II. Ann Arbor, Michigan.

University of Michigan, 1958b. Encyclopedic Survey IV. Ann Arbor, Michigan.

Voss, Edward G., 1978. *Botanical Beachcombers and Explorers: Pioneers of the 19th Century In the Upper Great Lakes*. Ann Arbor (Michigan Contributions from the University of Michigan Herbarium, 13).

Watson, James C., 1861. Letter from James C. Watson to Lte Gillis, dated September 16. James C. Watson Papers, Box 1, Correspondence 1861, University of Michigan, Bentley Historical Library.

Watson, James C., 1871. Telegram from Watson to C.F. Hall, dated May 19. James C. Watson papers, Box 1, Correspondence 1871, Bentley Historical Library, University of Michigan.

Watson, James C., 1873a. Letter from Watson to William H. Dall, dated February 29. Smithsonian Institution Archives.

Watson, James C., 1873b. Letter from Watson to J.E. Hilgard, dated December 26. James C. Watson papers, Box 1, Correspondence 1873, Bentley Historical Library, University of Michigan.

Watson, James C., 1873c. Two-page legal agreement signed by A.W. Chase, dated August 1. James C. Watson Papers, Box 1, Correspondence 1873, Bentley Historical Library, University of Michigan,

Watson, James C., 1876. Letter from E.W. Hilgard to Watson, dated February 23. James C. Watson Papers, Box 1, Correspondence 1876, Bentley Historical Library, University of Michigan.

Watson, James C., 1877. Letter from Joseph Henry to Watson, dated July 13. James C. Watson Papers, Box 1, Correspondence 1877, Bentley Historical Library, University of Michigan.

Watson, James C., 1880. Letter from Watson to R.S. Floyd, dated August 24. Mary Lea Shane Archives of the Lick Observatory, University of California, Santa Cruz.

Watson, James C., 1881. Letter from Andrew D. White to Henry S. Frieze, dated January 2. James C. Watson Papers, Box 1, Correspondence 1881, Bentley Historical Library, University of Michigan.

Watson, James C., n.d.. Jotting Book. James C. Watson Papers, University of Michigan, Bentley Historical Library.

White, Andrew Dickson, 1905. *Autobiography of Andrew Dickson White, Volume 2*. Century Co, New York.

Whitesell, Patricia S., 1998. *A Creation of His Own: Tappan's Detroit Observatory*. University of Michigan Press, Ann Arbor.

Whitesell, Patricia S., 2000. Nineteenth-Century Longitude Determinations in the Great Lakes Region: Government-University Collaborations. *Journal of Astronomical History and Heritage* **3**:131-157.

Will view comet from balloon. *New York Times*, May 20 (1910).

Williams, Marjorie, 1934. Harriet W. Bigelow. *Popular Astronomy* **42**:434-437.

Woodward, Robert S., 1917. Letter to Edwin A. Ayer, dated February 7. Class of 1872 Records, Correspondence from Robert S. Woodward, Bentley Historical Library, University of Michigan.

Wright, Fred E., 1926. Memorial of Robert Simpson Woodward. *Bulletin of the Geological Society of America* **37**:115-134.

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