A STUDY OF THE

HISTORY
AND
D E V E L O P M E N T
OF
TOPOGRAPHIC MAPPING

The practice of land surveying has its roots at the beginning of human life, for as soon as one man had possessions and family he had need to use land, and it became necessary for him to distinguish it from that of his neighbor's. From maps found on ancient Mesopotamian clay tablets; descriptions of land measurements and penalties for the removal of monuments in the Bible; the precise construction of the Pyramids in Egypt to within 1/16" of being square; the Greek's use of *triangulation*; the "agro centaurio" system of Roman land subdivision (division into equal rectangular plots); the Inca's surveying and construction of elaborate infrastructures using 3-dimensional models; the Chinese cartographers detailed descriptions of sophisticated mapping methods; to the founding of America and the beginning of the rectangular system of land division, a Land Surveyor's role in society has always been a prominent one.

As time and the development of new frontiers progressed, it became evident that there were elements other than the size or location of a person's land that were significant in determining its value. Physical features such as the type of terrain, amount of relief, and water or drainage features would have a bearing on whether the land was suitable to support farming and livestock or buildings and roads. So as opposed to the *cadastral* survey and map, the principal objective of which was to show a person's boundary, dimensions and area, there arose a need to show other specific features of the land in a visual format, and thus, the first topographic maps were made.

The topographic maps of yesterday hardly resemble today's maps. In fact, depending on the culture, society, and time period, maps were produced using different methods, styles and accuracy. There are also variations of opinion among writers and historians as to the exact definition of a *topographic map,* when the first map of this type was actually done and by whom. From our research we have found that although very precise methods of *surveying* were being performed at a very early date, the practice of *topographic mapping* evolved in different forms and didn't always use scientific methods. Some early maps were strictly pictorial; some used symbols to depict relief and structures, utilizing varying amounts of measured distances and elevations. Acquiring our information from a variety of sources, this study will attempt to formulate a theory, and present the reader with an overview of the *evolution* of topographic mapping from its earliest stages.

In the field of modern day surveying, a topographic map is defined as "a map which presents the horizontal and vertical positions of the features represented; distinguished from a *planimetric* map by the addition of *relief* in measurable form…usually shows the same features as a planimetric map but uses contours or comparable symbols to show mountains, valleys, and plains…."1 From the original Greek, *topography* means topos (place) + graphia (style of drawing or description) therefore – *description of a place*….2 P.D.A. Harvey, in his book "The History of Topographical Maps," defines a topographic map as "a large scale map, one that sets out to convey the shape and pattern of landscape, showing a tiny portion of the earth's surface as it lies within one's own direct experience, and quite distinct from the small scale maps that show us features of whole provinces, nations and continents."3

With this in mind, we will not limit our search for only those topographic maps that resemble the modern textbook definition, being those which show contours and are very precise in accuracy and measurement. Instead, we will search for man's earliest attempts to represent not just his boundary, but also those unique characteristics of his land such as mountains, streams, roads and structures. We will show examples that illustrate the evolution of the styles, methods and practices of early topographers with evidence that some form of measurement was being used. In all of the examples, an attempt at showing relief or elevation is evident. This succession will eventually lead to the exact measurement and location of land features with survey instruments as time and the practice of map-making advanced.

According to Harvey, the world's oldest recognizable "topographic map" (fig. 1), is a clay tablet from Nuzi in northeast Iraq, and was likely done around 2500 to 2300 B.C. It shows mountains and rivers, the size of an estate, and towns (shown as circles).

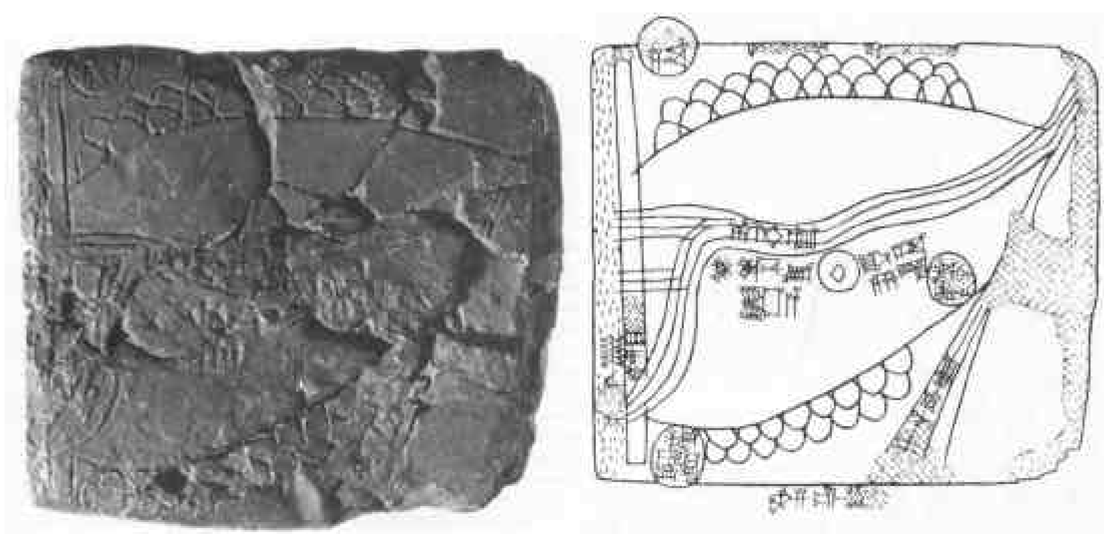


Fig. 1

The Egyptians also practiced a very sophisticated degree of surveying, as is evident by their monumental construction projects, and the fact that they had to regularly measure and re-measure their land as the river Nile overflowed its banks every year. The Great Pyramid of Khufu at Giza was built around 2700 B.C. in nearly perfect squareness north and south, attesting to their high degree of skill. There is however some disagreement among writers as to the mapping practices of the Egyptians as related to surveyed measurements. Some think that the Egyptians were the first to use what may have been the precursor to the *plane table* to make large scale accurate survey maps,[4] while other writers such as Harvey are of the opinion that maps from this period are in pictorial form only and do not show corroboration that they tied their expertise in surveying to map making.[3] Another Egyptian contribution came from the astronomer, mathematician, and geographer named Ptolemy, living in Alexandria, Egypt. In his work “Geography”, he attempted to map the known world giving coordinates of major places in terms of latitude and longitude,[5] and so an ordered method for describing the location of a object with respect to a predetermined origin. Although his concept of an earth-centered universe and the maps he made were inaccurate, his work did much to advance the study of scientific map making.

By the second millennium B.C., other maps began to show evidence that they were drawn to a consistent scale from measured surveys. A map of Bedonlina in Valcamonica, a valley located in the Alps, done around 1000 B.C. shows the framework of the town with its square fields, animals, houses, and even people on the upper floors of them (fig. 2).

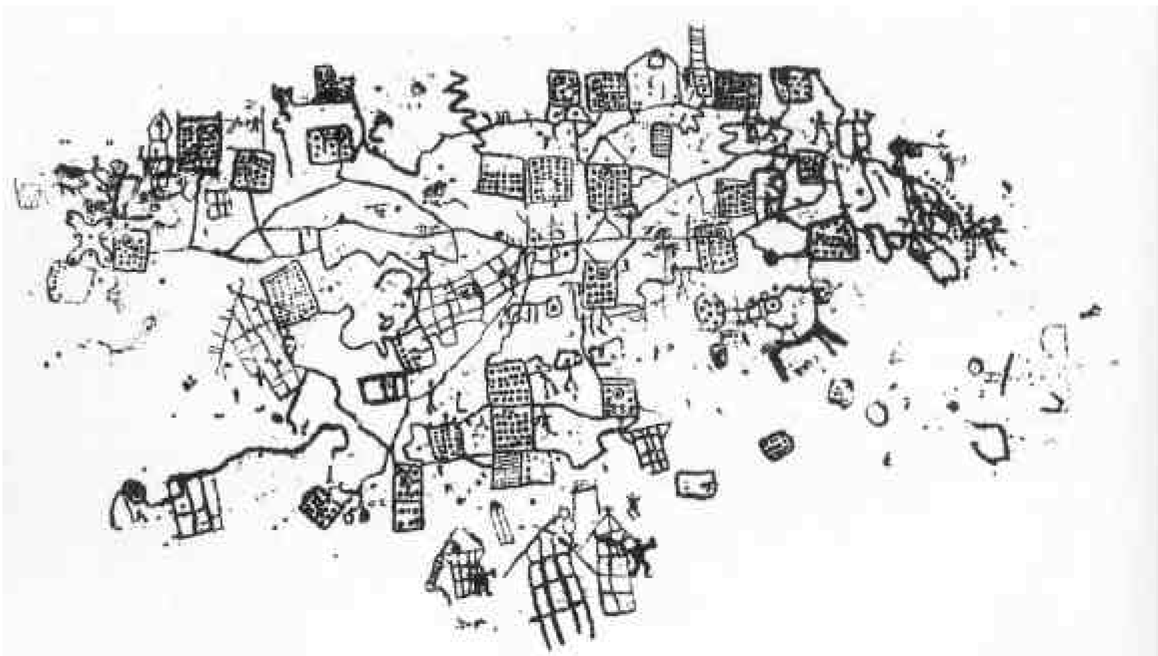


Fig. 2

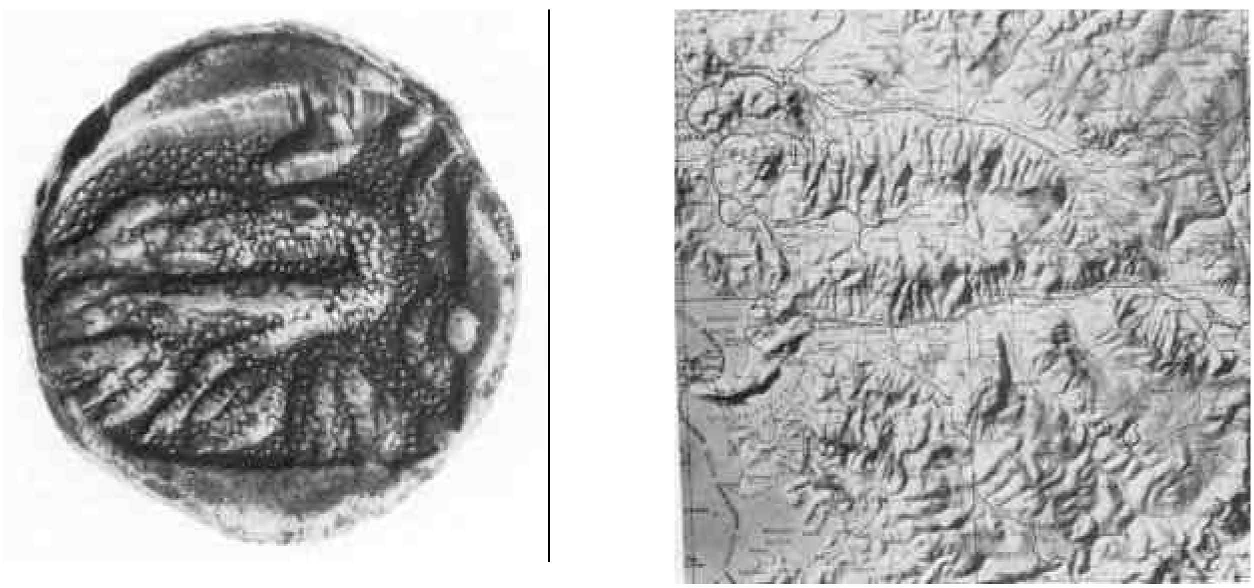


Fig. 3

Another example from Ephesus in Asia Minor is one that was thought to be an insignificant pattern on a Greek coin, issued between 336 and 334 B.C. (fig. 3). Comparison with the relief map of the area in which the coin was issued now reveals how closely the features correspond, indicating that although no other maps survived from ancient Greece, the Greeks must have had a general familiarity with the practice of *cartography.*[3] Thus the quote from the Greek historian Herodotus in the 5th century about those "who undertake to describe the contours of the land without facts to guide them…"6 It was the Greek librarian Eratosthenes in the 3rd century B.C. who, by measuring the shadow of the sun at Alexandria, arrived at a remarkably close estimate of the circumference of the world.[7] Although this does not seemingly relate to topography, it is his attempts to discover the size and shape of the earth that would later become the influence for the principle of *geodesy*, the science of earth measurement and the determination of exact positions of points on its surface; a foundational part of modern surveying. His plotted maps were drawn on a projection of parallels and meridians, with land features plotted from previously determined astronomical positions.[8] The Greeks are also credited with devising the *dioptra*; a device used to measure heights, levels and angles in both horizontal and vertical planes and for making astronomical observations.

The Romans are also famous for their amazing engineering accomplishments. Although not the first to build them, they certainly excelled at building aqueducts, tunnels, and roads. It was during the time of the Roman Empire that the duty of *mapping* was first regarded as the responsibility of the surveyor. After the surveyor prepared the map, one copy was sent to the archives and another kept in the locality of the property as a permanent record. They were engraved on bronze or stone, as shown in (fig. 4), which is a fragment of plan located near Orange done in the late 1st century A.D. showing rectangular "centuriated" fields, a list of the individual landowners, roads, and a stream with an island,[3] The Romans were also thought to have used an instrument like the plane table for setting the alignment of their roads in nearly perfect straight-line precision.[9]

Fig. 4

After the fall of the Roman Empire, scientific advances seemed to diminish for a time as the known world was reorganized. It was during this time known as the Dark Ages, from about the 7th to 12th centuries that the Arabs began their influence in the field of cartography, adopting Ptolemy's theories over the former Greek theory. Al Kharizmi, who studied trigonometry in India, was the first Arab to write on the *astrolabe,* which is an instrument used for measuring altitudes of celestial objects. It was during this time that nautical surveying essentially began as the Arabs made charts of the coastlines of the countries they visited, employing the principles of *triangulation* using compass bearings from two different locations.

At about the same time a form of scientific cartography was also being performed in China where maps drawn to a consistent scale from a measured survey were being done from about the 3rd century A.D. In contrast to the uncertain methods that the

Romans used in making their scaled maps, we do have detailed accounts of map-making procedures written by Phei Hsiu, one of the most distinguished Chinese cartographers. His map is lost, but a later example carved on stone in 1137 was done in the same tradition, as shown in (fig 5).

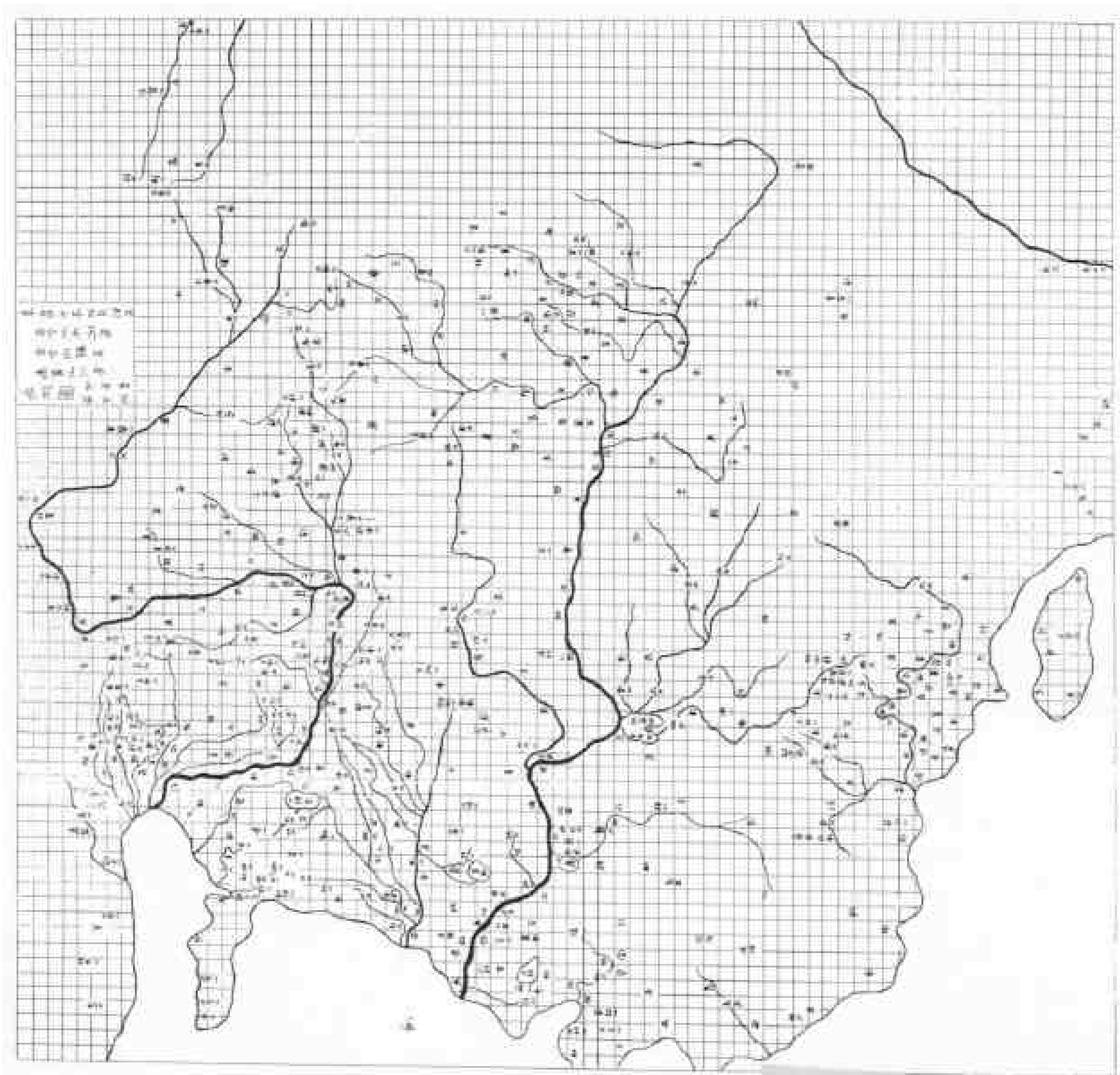


Fig. 5

In his account, Phei gives details on how to properly construct a map in six principles. The principles include: 1) graduated divisions to determine scale 2) the rectangular grid, which is the way of depicting the correct relations between the various parts of the map 3) pacing right-angled triangles 4) using calculations where obstacles were present 5) measuring elevations and angles, both right and acute 6) curves and straight lines." He then goes into a comprehensive explanation of the process of accurately preparing a scaled topographic map, the basis of which was a grid of equidistant lines forming a network of squares. Features were then placed in their proper position on the map by field measurement.[3] Although the map doesn't contain the amount of relief that would characterize a typical topographic map, it is the technical sophistication by which the survey was performed and the map produced that is indeed fascinating to the present day surveyor, considering the instruments and knowledge available at that time. It is also thought that the Chinese designed and used the first magnetic compass in or before the 11th century.

The Renaissance era brought an end to the decline of the arts and sciences and with it the dream of exploring new lands. This "Age of Discovery" brought with it a renewed interest in mapping these new territories, both for the navigator and the country claiming ownership, thus, a need for more accurate and efficient ways to measure land and to duplicate the maps that were produced. Although the process had already been developed independently in China and Europe, the invention of the printing press in 1450 made the mass publication and circulation of literature possible. In 1477 the first map was published. Further advancements in the construction of topographic maps were made with a prototype of the *theodolite*, described by Gregoriuos Reisch in the encyclopedia *Margareta Philosophica* around 1508. The instrument called the *Polimetrum,* was capable of giving a combined altitude and azimuth reading, see (fig. 6).

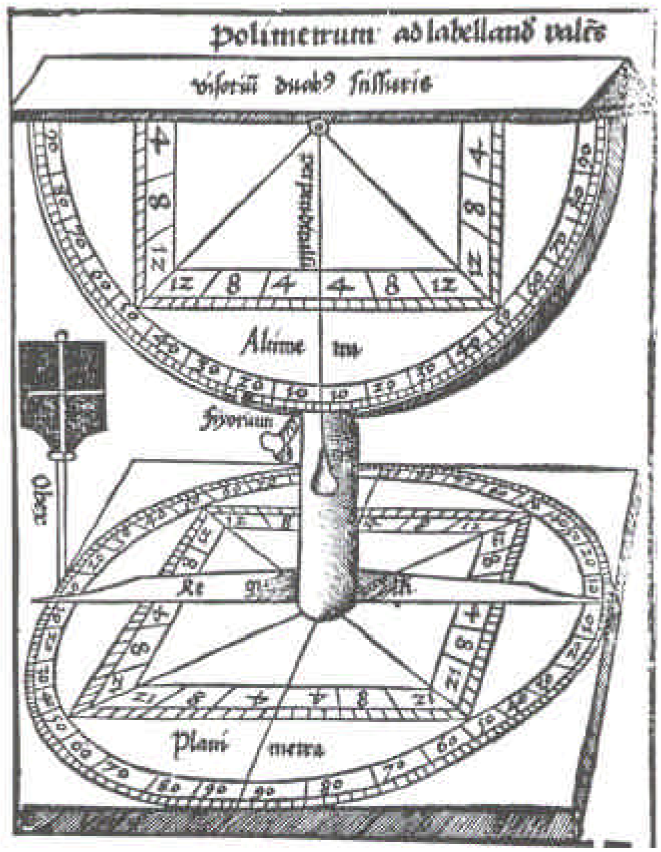


Fig. 6

The first survey books to be printed in English were written during this time and contained detailed descriptions of the duties of the surveyor. One such text by Fitzherbert, published in London in 1523 states that "the duties and functions of the surveyor were many and varied, and that he should prepare his findings in a small book; or put them on a large piece of parchment." Along with "buttes and bounds", leases, grants, and tenures, he should also state the number of buildings, location, and a description of the lands, whether meadow, grainland, or woodland.[10] This description is amazingly similar to the specifications used for the modern version of topographical survey being performed for today's client.

Other improvements to the instruments being used to perform topographic surveys and maps include a precursor to the plane table, the *holometer,* (fig. 7) of Abel

Foullon, published in Paris in 1551. His description also included the name of the instrument maker from who it could be obtained. The holometer was designed to meet the needs of the practical surveyor who did not possess exemplary skills in mathematics, science, and the use of the technical instruments of the day, making it possible for him to construct the map in the field from direct measurements.[10]

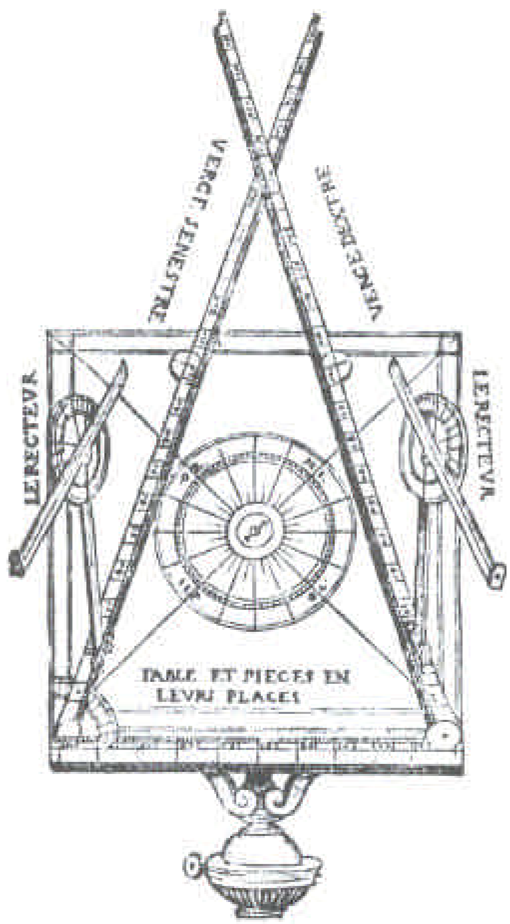


Fig. 7

The late 1560's were deemed the "golden age of cartography". Mercator, an engraver and scientist who was also thought to be the foremost cartographer of the sixteenth century, pioneered a new kind of *map projection*, which is still in use today. Known as the "Mercator projection", it uses a mathematical formula to alter the ratio between degrees of latitude on the globe and vertical measurements on the cylinder;

essentially flattening the spherical earth into a two-dimensional format. This concept revolutionized navigation techniques and earth measurements[11] and brought about a solution for mapping the curved surface of the Earth onto a flat surface with a minimum of distortion. Among the equipment that Mercator used in surveying and mapping were the compass, the *astrolabe*, the plane table, the way wiser (a wheel used for measuring distances on a map), a movable printing press, and etched printing plates.

In 1571, Leonard Diggs invented the *theodolite*, a device that combined horizontal and vertical sighting into a single instrument. By 1590 the plane table, believed to be the invention of Jean Praetorius, was being widely used. In Aaron Rathborne's book "The Surveyor in Foure Bookes" (London 1616), he describes instruments used in surveying and scaling drawings, the alidade, and the plane table, describing it as a "simple and useful instrument"[12] See (fig.8), an illustration from the book showing a plane table.

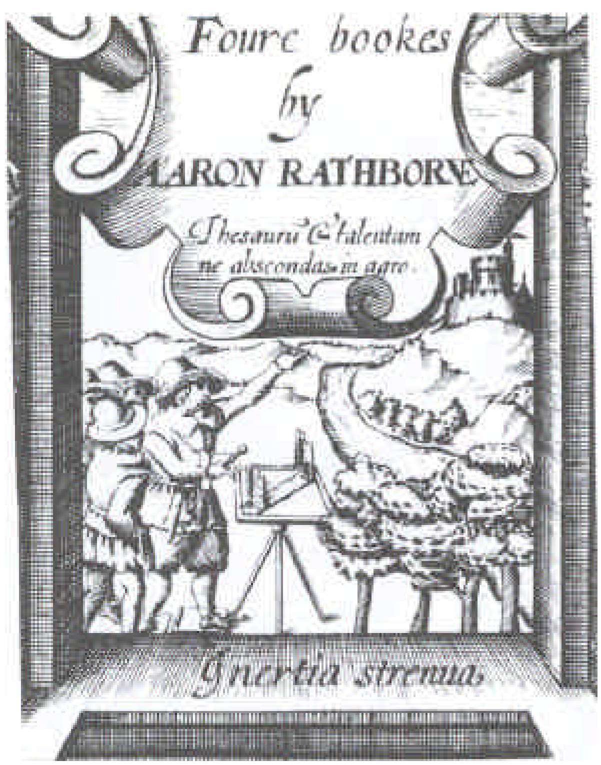


Fig.8

In the 1660's, a telescope was attached to a *quadrant* for measuring angles, further advancing the development of *triangulation*. Improvements in the mapping industry were emerging throughout Europe, most notably in France. In 1669, a surveyor, professor, and astronomer by the name of Giovanni Cassini, under the direction of Jean Baptiste Colbert, King Louis XIV's minister of finance, set about to map France for the purpose of improving their infrastructure and subsequently, their financial condition. See (fig. 9),

Fig. 9

His specifications for the project were to produce the kind of maps that detailed man-made and natural features as determined by precise engineering surveys and measurements, portraying the shapes and elevation of mountains, valleys, plains, streams, rivers, cities, roads and political boundaries. This was a huge job description for a 17^{th} century surveyor and / or cartographer. Cassini accepted the assignment, and by observing Jupiter and its satellites, was able to find longitude and use it for the basis of his new maps. (Prior to his contribution, surveyors and navigators had only been able to find latitude, the position of a point north or south of the equator).[14]

The first _dumpy levels_ appeared in the first half of the 1700's, which combined a telescope and a bubble level. Another improvement in survey instruments around the same time was a newer version of the *octant,* a navigational instrument used for measuring angles. Previously described in principle by Sir Isaac Newton and even foreshadowed by Robert Hooke in 1644, a description of the *octant* was first published (1731) in London by the astronomer John Hadley (1682-1744), and about the same time by Thomas Godfrey (1704-1749) in Philadelphia.[13] Only in the last hundred years has the octant gave place to the _sextant_, which at present time, in spite of satellite navigation and other electronic aids, is still an essential navigational instrument.

Further advancements to the field of topographic mapping came in 1740 when France initiated the first national topographic system. The British began mapping Scotland after the revolt of 1746, and in 1791 a national system was established in England. In 1772 Johann Lambert made modifications to the map projection concept of Mercator. He developed half a dozen new projections, one being the "Transverse Mercator", another known as "Lambert's Conformal Conic,"[14], which are both still used today. In 1782 British cartographers proposed that the observatories in Greenwich, England and Paris, France be tied together by *triangulation*, as well as the whole of Britain. Jesse Ramsden, an 18th century English designer and manufacturer of mathematical and astronomical instruments was commissioned to build an instrument that would be capable of such accuracy, and so he began construction on his "Great Theodolite". This first theodolite (fig. 10) took about three years to complete, incorporated a three-foot diameter horizontal circle, and weighed approximately 200 pounds![15]

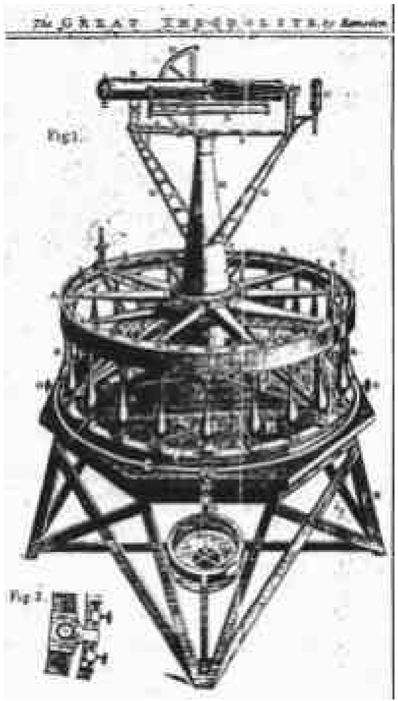
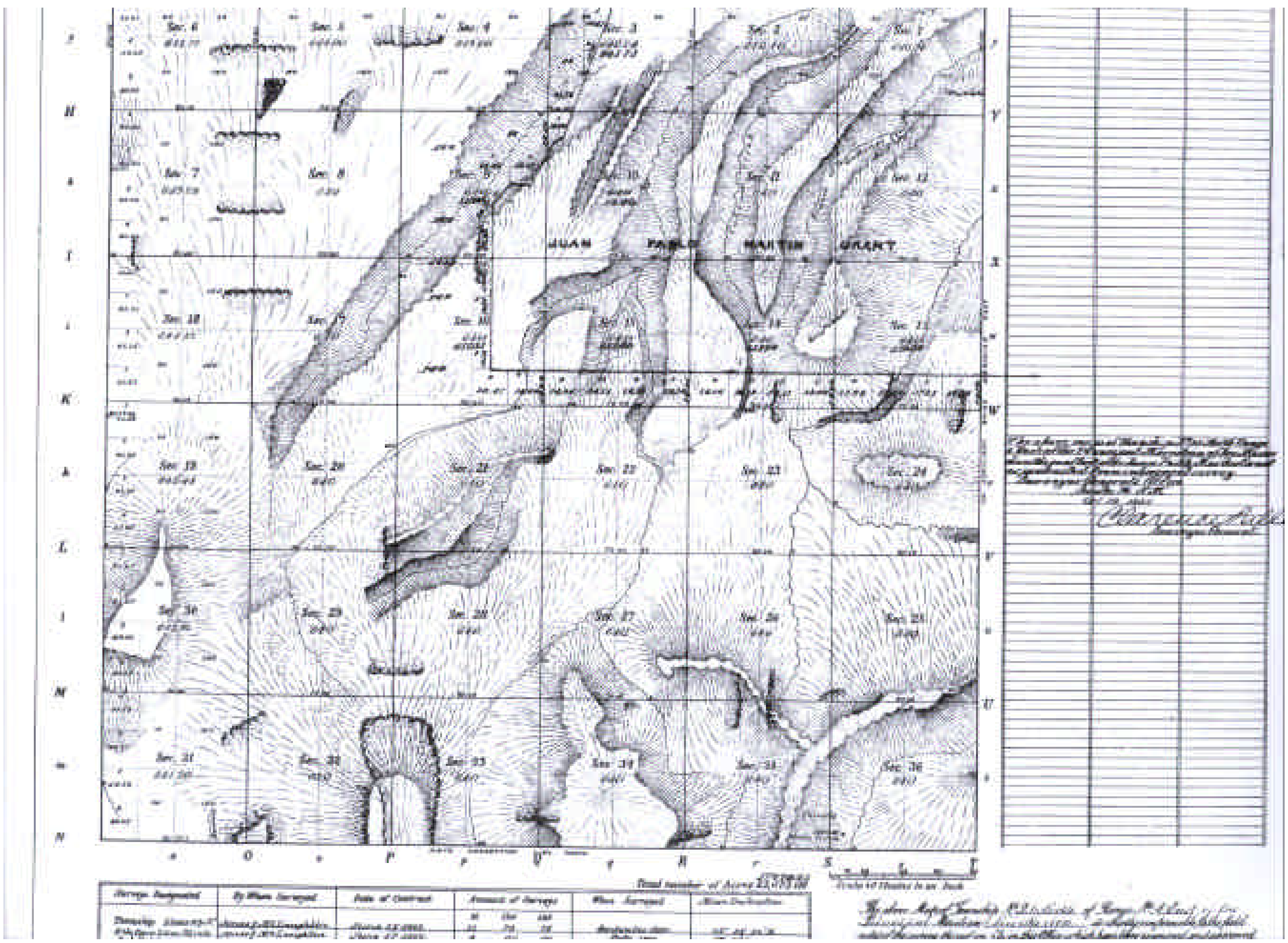


Fig. 10, drawing and model of Ramsden's "Great Theodolite"

During the settlement and great colonial expansion of America, the services of *cadastral* surveyors as distinguished from topographical surveyors were more in demand because of the emphasis on laying out property lines, boundaries and roads to settle this vast new land. These colonial surveyors had to be of a rugged, resourceful nature, have a good background in mathematics, and possess the instruments of the trade, usually at a minimum a plane table, chains, and a circumferentor, which did not come cheap in the financial system of the day.[14] There was plenty of work for these early surveyors, as there were many boundaries, both public and private that had to be laid, such as the controversial Mason Dixon Line and the selling of government land for profit after the *Land Ordinance of 1785*. They soon discovered through hardships, toil, and even death that this land, although vast and plentiful, had areas that were as diverse in nature as they were abundant. After the *Rectangular System of Land Division* was designed and the General Land Office established in 1784, these pioneers of our history had left behind as their legacy a checkerboard pattern of property lines across a continent, a pattern that is uniquely American. Most of the plats drawn by the G.L.O. contained some topographic information, as well as the dimensions and areas of the lots. Note that relief is shown with hachures, and brush or vegetation with rounded lines, as on this example of an early G.L.O. plat, done in 1882, (fig.11).



<u>Fig. 11</u>

The Louisiana Purchase of 1803 doubled the size of the new nation. In 1804, Lewis and Clark were commissioned to explore the Missouri River and lead an expedition to locate ‘the most direct and practicable water communication across this continent for the purpose of commerce.”[14] The map that was produced as a result of this expedition was not a surveyed cartographic work, but did serve as inspiration for future explorers who would continue the task of mapping the vast, unexplored territory. The *transit* (fig. 12) was invented in 1831 by W.J. Young, which improved the accuracy of surveying techniques even further.[16]

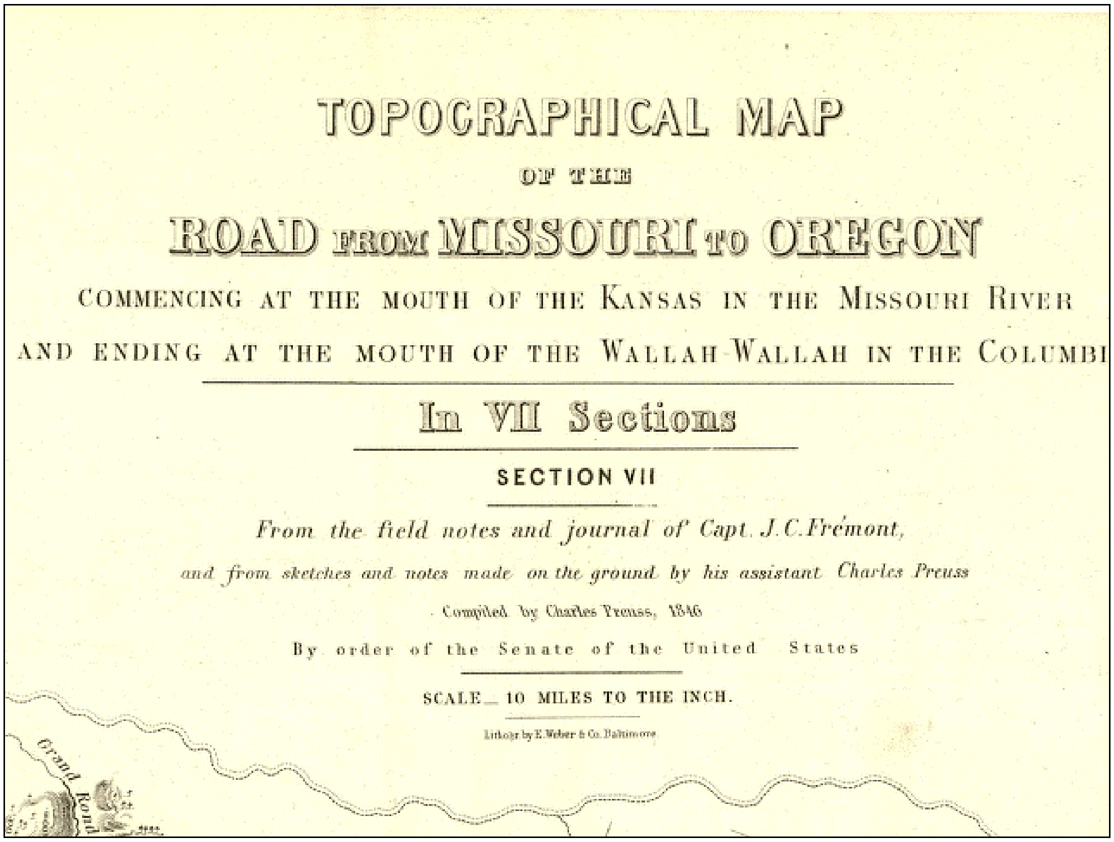
Fig. 12

Advances in the industry continued around the globe. For example, the Great Trigonometrical Survey of India led to the discovery of the highest mountain in the world, named for the man who led the undertaking, Colonel Sir George Everest. The survey began in 1806 by William Lambton, and ended twenty-five years later with a survey of the longest meridianal arc ever accomplished at the time. Because of the immense scope of the project, and the countless adaptations he made to his survey equipment, methods, and mathematics, Everest's work led to many improvements in the survey instruments that were being used to perform topographic surveys up to this time.[17] In 1830, road inspector Johann Sulzberger was commissioned to survey the entire territory of Thurgau, Switzerland. It was a plane table survey producing sheets at a scale of 1:21,600, which were eventually reduced to a scale of 1:100,000. The map portrayed slopes by means of hachures, and spot elevations that were measured with a barometer. The solar compass was invented in 1835 by the county surveyor of Macomb County, Michigan, William A. Burt and patented the next year. He designed it for surveying government public lands as a replacement for the ever-troublesome magnetic needle compass. Burt's solar compass uses a mechanical apparatus that accurately determines the true north-south direction from the sun's position in the sky. See (fig.13), early survey instruments.

Clockwise from top: vernier compass (Thomas Whitney, Philadelphia, Pa., 1820), Rittenhouse compass (Benjamin Rittenhouse, Philadelphia, Pa., ca. 1780), William Austin Burt solar compass (William J. Young, Phila-delphia, Pa., ca. 1840), transit (L. Beckmann Co., Toledo, Ohio, ca. 1885), architect's level (L. Beckmann Co., Toledo, Ohio, ca. 1911).18

Fig. 13

In 1838 the United States Corp. of Topographical Engineers was established for the purpose of performing engineering surveys for the construction of roads, canals, and other infrastructure necessary for national, military, and commercial uses. The Corp never had a staff of more than 36 officers, most being West Point graduates and having training in engineering and the sciences. One of the most famous of these early Topographical Engineers was the explorer and mapper John C. Fremont. In 1842 he began the first of three mapping expeditions to explore and map the American West: the Oregon Trail (1842), the Oregon Territory (1844), and the Great Basin and Sierra Mountains to California (1845). He was not a West Point graduate, but was trained and performed surveys under French scientist Joseph Nicollet. Being extremely passionate about beginning the expeditions, he sought trained staff with which to accomplish the monumental task. He brought experienced cartographer Charles Preuss with him on all of the expeditions, using points established on earlier surveys as points of departure. The map of the Oregon Trail, published in 1846, titled “Topographical map of the Road from Missouri to Oregon Commencing at the Mouth of the Kansas in the Missouri River and Ending at the Mouth of the Wallah-Wallah in Columbia”, was in effect the first road map of the American West.14 The map itself is an outstanding work and shows a great degree of skill by Preuss, considering that both the fieldwork and drafting were done by him in the field. It shows major routes as well as mountain ranges and other topographical features. The map was done in seven sheets. See (fig. 14) for enlarged views of sheet VII of the map.


TOPOGRAPHICAL MAP
OF THE
ROAD FROM MISSOURI TO OREGON
COMMENCING AT THE MOUTH OF THE KANSAS IN THE MISSOURI RIVER
AND ENDING AT THE MOUTH OF THE WALLAH-WALLAH IN THE COLUMBI
In VII Sections
SECTION VII
From the field notes and journal of Capt. J.C.Frémont,
and from sketches and notes made on the ground by his assistant Charles Preuss
Compiled by Charles Preuss, 1846
By order of the Senate of the United States
SCALE _ 10 MILES TO THE INCH.
Grand Rond

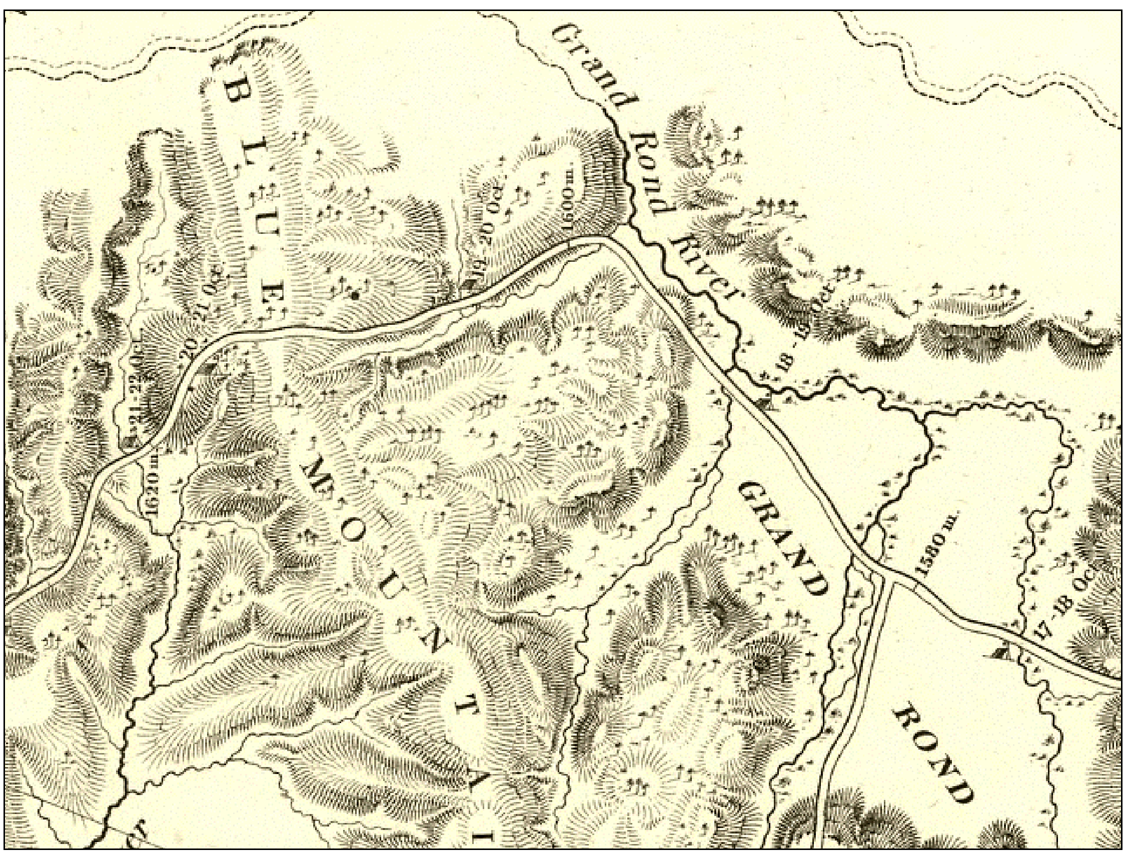
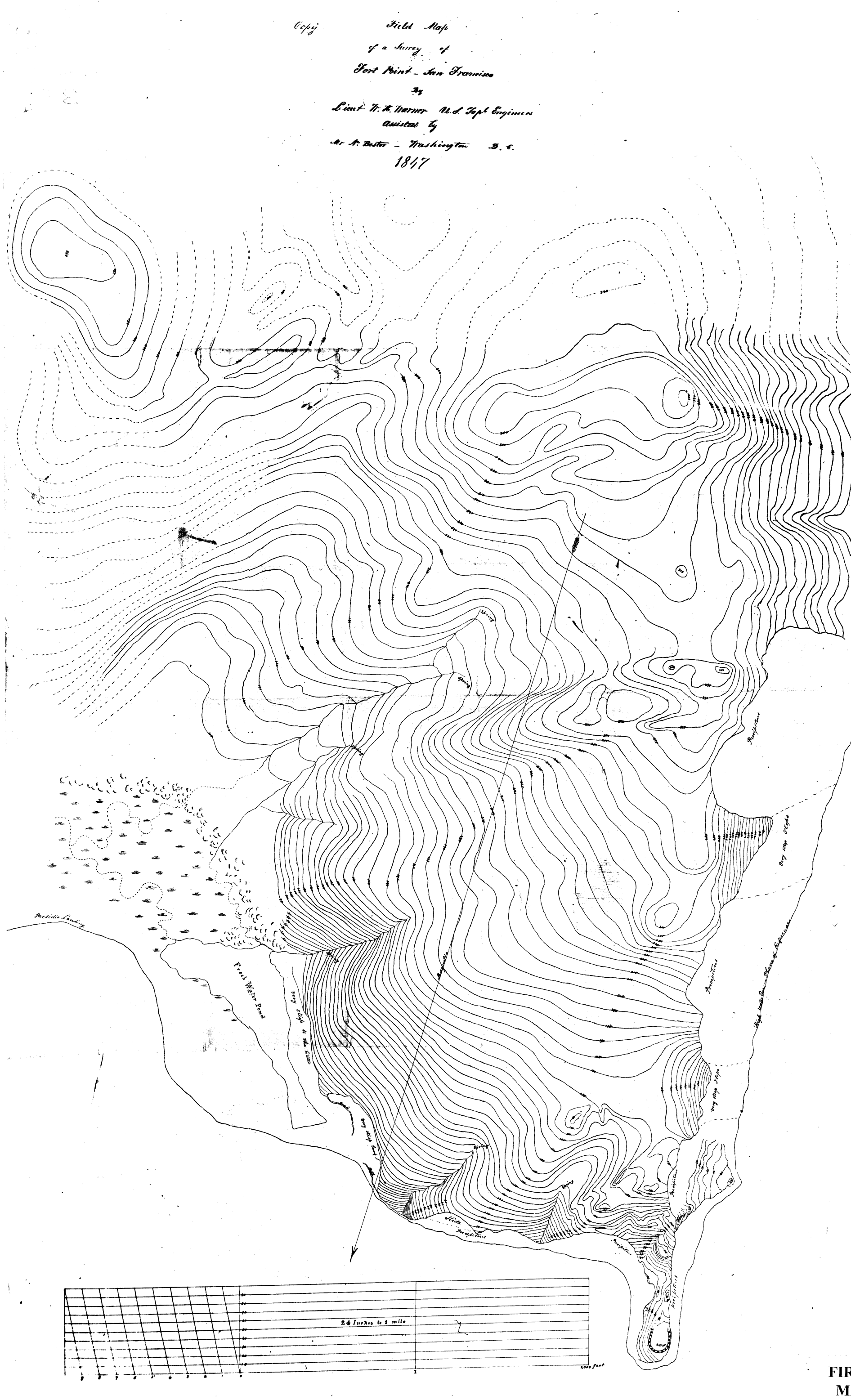

Grand Rond River
B L U E
M O U N T A I
GRAND
ROND
1600 m.
1620 m.
1580 m.

Fig. 14



FIRST KNOWN MAP TO USE CONTOUR LINES

Fig. 15

An example of the first known map to use contour lines to show elevation, done by the Topographical Engineers in 1847 is shown above in (fig. 15). In 1850 John Locke invented the “electro-chronograph”, a surveyor’s compass that incorporates a collimating level. In 1854, Kemble Warren of the Corp began work compiling the first comprehensive, scientific map of the American West, using maps and survey data dating as far back as 1800. The map, drawn on a single sheet to a scale of 1:3,000,000, was completed in 1857, and published in 1859. During the 1850’s the Topographical Engineers also began exploration for the four routes to build the first transcontinental railroad. See map (fig. 16)

Fig. 16

The outbreak of the Civil War temporarily suspended the work of the Corp of Topographical Engineers, as many not only fought in the war but also fought on opposite sides. Considered to be of great importance to the war effort, Union authorities not only enlisted them into service but gave them full support to carry out missions for the military. The Union forces were able to utilize the Corp and its existing organizational structure, an advantage that the South did not enjoy. This was a very strategic advantage, since it was well known by both sides that the any successful campaign would rely heavily on good, accurate maps, based on reliable field data. They enlisted the services of men from all of the existing Federal mapping units, including the Corp of Topographical Engineers and Corp of Engineers, the Treasury Department's Coast Survey, and the Navy's Hydrographic Office. Union forces were able to meet the demand for maps with the use of the Coast Survey's two lithographic printing presses, and so the reliance on lithography to reproduce maps in quantity grew during the war. Printing was also done via a portable photo-printing device invented by Captain Margedant, chief assistant under the Command of General Sherman, consisting of a light box and chemicals with which to make the prints. In June 1861, Union forces began the first major mapping project of the war. Employing survey personnel from the U.S. Coast Survey, two parties were formed under the direction of H.L. Whiting, the survey's most experienced field assistant. They began one the of the most monumental accomplishments in Civil War mapping, a 38 square mile plane table survey of the secured part of northern Virginia. The first edition of the map was issued on January 1, 1862, at a scale of one inch to one mile, and was engraved on stone!

The most detailed maps available prior to the war were commercially produced wall maps of selected counties, and so any maps known to Confederate forces were often confiscated, even from private citizens.[19] The need for topographical maps during the Civil War was further described in this excerpt from the memoirs of confederate Captain Albert H. Campbell, (formerly of the Engineer Corp): “the indispensable necessity of a more intimate knowledge of topographical details of regions over which troops must be maneuvered...the whole seven days campaign brought out this fact in strong colors, bloody colors, at Beaver Cam Creek.”20 Soon after this, Campbell was commissioned to take charge of organizing survey parties to carry out the duties of producing accurate, detailed maps for General Robert E. Lee and the confederate army. Campbell wrote further in his memoirs that “so great was the demand for maps occasioned by frequent changes in the situation of the armies, that it became impossible by the usual method of tracing…I conceived the plan of doing this work by photography…to me it was an original idea…but not in practical use.” Campbell took maps traced in very black india ink and photographed them to make multiple copies, and pasted together smaller maps to produce maps of an entire region. This process allowed confederate mappers to be able to provide their field officers with reproductions without the laborious process of tracing by hand or printing expensive lithographs, since funds for the Confederates were not in abundance.

It is clear that the role of surveyors and engineers in the Civil War was vital to the movement, encampment, and defense of the troops. They shared in the same hardships and dangers as the enlisted men throughout the duration of the war. Fig. 17 shows a tripod signal erected by Captains Dorr and Donn of the U.S. Coast Survey at Pulpit rock on Lookout Mountain in the Chattanooga, Tennessee area where J.W. Donn of the U.S. Coast Survey was performing plane table surveys for the Union army. He notes in his records that the “Confederates had learned the significance of the white topped instrument, and it had become a target for rifles.” Fig. 18 was taken at Camp Winfield Scott in the Yorktown, Virginia area and shows a company of Union Topographical Engineers with their instruments.

Fig. 17

Fig. 18

Fig. 18

Union forces also began the use of a new device, the stationary observation balloon, for gathering information on the location, number, and movement of Confederate troops. The balloon was also used in the preparation of maps and sketches, perhaps the precursor to the modern use of aerial photographs to produce maps. See (fig. 18) above, a picture taken in Fair Oaks, Virginia of Thaddeus S. Lowe observing the battle from his balloon "Intrepid".21 Initial surveys were made on the ground, with detailed information added later as observed from the balloons.

Wartime mappers favored the use of hachures as opposed to contours for showing relief and elevation. A field copy was often drawn with contours and later converted to hachures because they thought that the "non-expert" would read the map more easily.[19] See (fig. 19), a map produced for the battlefield of Bull Run, Virginia.

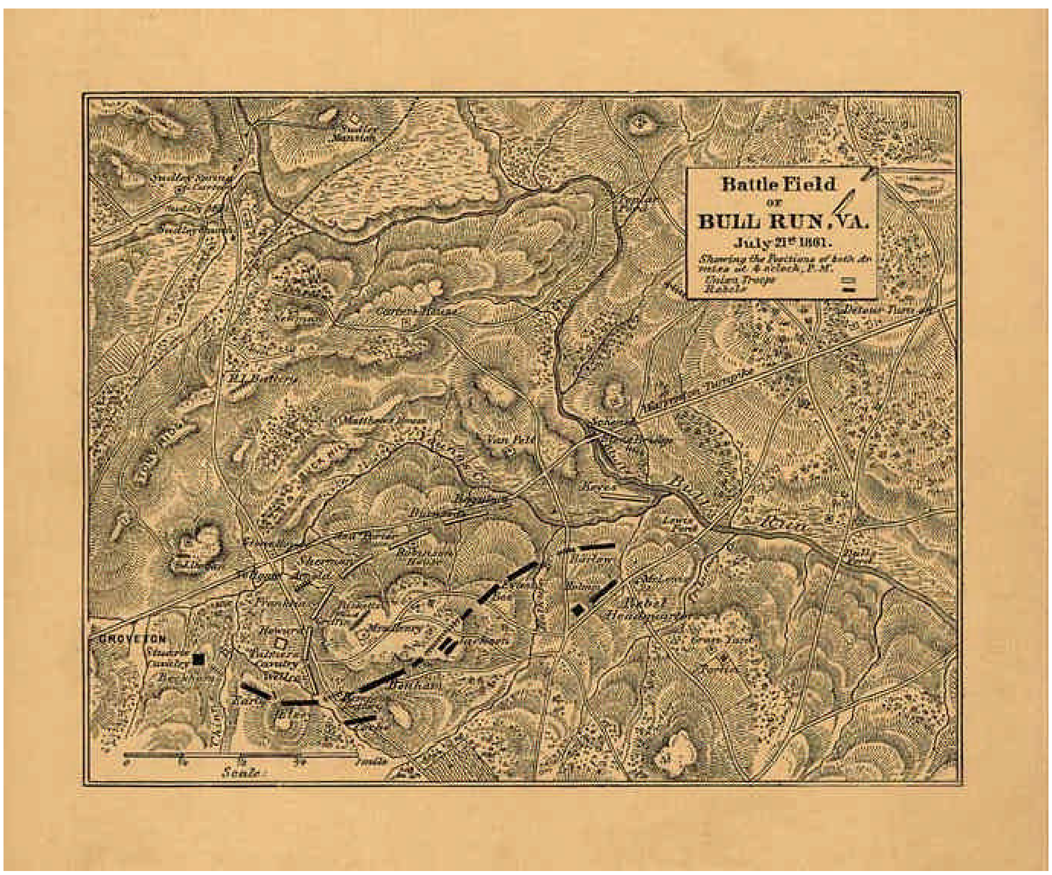


Fig. 19

By the end of the war, the concerted efforts of Federal mappers had furnished over 24,000 sheets of maps to the armies in the field. It was now possible to compile a uniform ten-mile to the inch base map of large areas. The premier cartographic work of postwar years was the “Atlas to Accompany the Official Records of the Union and Confederate Armies”; consisting of 178 plates.[22] As a result of the sophistication of the wartime mapping effort, field survey methods were improved, and better printing techniques were developed with the advent of new photo reproduction processes.

In 1870, Ferdinand V. Hayden, who had been on earlier expeditions with the Topographical Engineers, presented to Congress a plan for the geological and geographical exploration of the Territories of the United States, and the preparation of maps of each of the territories on a uniform scale. Congress gave its blessing, and Hayden proceeded with the work under the Department of the Interior. On March 3, 1879, the United States Geological Survey was established, and in 1882, under the direction of its second director Major John Wesley Powell, began its topographic atlas of the United States. Under Powell, who had previously been one of the first to survey the Colorado River, the Survey's perspective changed from an economic geology basis, to an independent basis with multiple functions to serve the greater U.S.G.S. aim. Powell’s objectives for the U.S.G.S. were as follows, as (adapted from Rabbitt, 1989):

- The development of a plan for making a complete topographic map of the United States.
- The organization of a bureau for the collection of facts and figures relating to the mineral resources of the country.
- His labors to preserve for the people the waters and irrigable lands of the Arid Region.

Powell believed geology to be independent of topography. As a director, this led him to separate geologic studies from topographic projects. Later in 1882, Congress authorized the U.S.G.S. to produce a geologic map of the United States; adversely, Powell redirected all topographic work to prepare for the geologic map, topography being the base map.[23] In 1902, a topographer for the U.S.G.S. named Francois Mathes began mapping the Grand Canyon wholly in the field using plane table and transit, on foot and mule. He utilized the method of triangulation, and this project was one of the most monumental to date producing the first detailed and thorough map of the Canyon.[14] The majority of the United States was actually mapped under the jurisdiction of the United States Geological Survey using plane table methods. See (fig. 20)

Alaskan Tundra, 1924

Mt. Constance Olympic Mountains, Washington 1931

Fig. 20

In the 1920's and 1930's, topographical surveys continued to be carried out mainly on national levels by government entities around the world. For example, the Forestry Department of Australia was performing surveys of its plantation areas using a prismatic compass and Abney level. With the outbreak of World War II, Australia realized, as did most industrialized nations, that it did not have suitable topographic maps in the event that an invasion in the country would occur. Emergency mapping organizations were set up under the Lands and Surveys Department, and maps were produced by plane table method at a scale of 1 inch to 1 mile, but did not include contours.

The military, both in the U.S. and abroad, is credited with much advancement in the field of topography, as virtually every war has brought with it the need for having maps produced in detail, to plan strategies and deploy troops. Because of their tremendous strategic value, such maps often had to be kept as classified documents, at least during wartime, to ensure that they would not fall into the hands of the enemy. These include large topographic maps of the ocean floor, and because of their use in submarine warfare, are still classified. Since many terrestrial maps today are still restricted to military use only; we actually have more detailed coverage of Venus and Mars than we do of the Earth.[24]

In the 1950's, the Electronic Distance Meter (EDM) brought about extensive changes to the process of mapping and surveying, replacing *triangulation* methods with distance methods. Data could now be transferred electronically using computers, and with the advent of new computer software, the conversion of the data into a plotted drawing. This radically transformed the survey industry, departing from the tedious and time consuming manual reduction of field notes and drafting by hand to the collection of data in the field and the finished product of the map.

As technology continues to improve, today's survey instruments are rapidly changing, the newest instruments employing the use of robotics. A typical survey crew utilizes an update of the theodolite (Total Station) for measuring angles, both horizontal and vertical. Their equipment list would also include a level, a prism, a Philadelphia (Phiily) rod, a lenker rod, a 100 foot tape measure, a compass, a magnetic locator, and a data collector. The data collector is used to store information collected in the field and transfer to the computer for the preparation of the maps and / or design.

Today, topographic maps can be considered to be the most versatile and useful type of maps produced. Engineers, scientists, industrial and urban planners, real-estate developers, hunters, fishermen, and other outdoorsmen all employ the use of topographic maps. They are widely available in printed copy, online, and in electronic formats, and are the basis for aeronautical, coastal, census, flood zoning, geologic, soil, weather, and road maps.[14] A typical topographical map of today looks completely different in format, but in reality is not all that different from the original intent. It would include any and all natural and man-made features of a site that would satisfy the intended purpose of the client. These might include, but are not limited to: mountains, bodies of water, drainage patterns, roads, buildings or structures and utility locations. Uses are varied, but can include:

- ALTA surveys, which are a survey of actual conditions on a site, so named because of the particular requirements on this type of survey by the American Land Title Association and the American Congress on Surveying and Mapping. The ALTA standards are a nationwide uniform set of standards, and require that the surveyor show everything existing on the site. Sometimes referred to as "the Cadillac of surveys." The survey is specifically designed to satisfy the needs of lenders, corporations and title companies when dealing with valuable commercial properties.

- Topographic surveys for the purpose of capturing ground elevations and the location of existing utilities, used for engineering design, construction and / or drainage study on a proposed project site.
- Mapping of sites, which have undergone some sort of disaster, whether natural or man-made, such as: the changes associated with volcanic activity at Mt. St. Helens and the crater left behind by the three-mile island disaster.
- Maps for archaeological explorations, cave exploration and mining.
- Surveys of watershed areas, to study flood zones, water pathways and sediment, avulsion and erosion patterns.
- Exploratory or historical studies, such as a topographical study attempting to provide evidence for the canal of King Xerxes, topo maps of the surface of the moon, Venus and Mars.
- Government agencies, including the U.S. Military, the Bureau of Land Management, the CIA, the National Oceanic and Atmospheric Administration, the National Park Service, the Army Corps of Engineers utilize and / or produce maps for purposes relating to their specific duties to the public.

Today's methods of preparing a topographic map vary drastically from the methods of our forefathers. Traditional methods are being replaced or supplemented with new ones, as the technology for the collection of field data and the methods of producing the finish map changes. Even the final product can vary depending on the needs and intended use of the map. The following are some of the current technologies that are rapidly changing the face of the industry as we know it.

GPS, (Global Positioning System), is a system of data collection which provides satellite-based positioning for land, marine, and airborne projects. This technology has brought about monumental changes to the industry of surveying, and consequently, to the efficiency, accuracy, and speed at which maps are produced. It utilizes national coordinate systems unique to different parts of the world, with government agencies being responsible for national standards. GPS data collection for surveys is processed in the field and can be digitally transferred to the office for map compilation. Results of a GPS survey can vary with the quality of equipment used, the techniques and field procedures used for the collection of data. Provided all variables are in perfect order, accuracies that can be boasted of are as follows: horizontal accuracy to +/- 5 mm, vertical accuracy to +/- 2 cm, efficiently reduces line cutting, and real-time positioning to +/- 2 cm. GPS technology is rapidly changing with the retirement of old systems and the deployment of new systems; the most current being the Navstar system.[25] Though GPS is not the preferred method today for gathering data for the preparation of a topographic map for design purposes, this will undoubtedly change as the methods improve.

Photogrammetry, which is defined as the art, science, and technology of obtaining reliable information about objects and the environment through recording, measuring, and interpreting photographic images and patterns.[26] In the traditional method, control is set up in the field and photos are taken from an airplane over the target area at different altitudes depending on the desired accuracy and scale of the map. By combining photographs, the aerial photographer is able to create a topographic map of a specific area at the contour interval as predetermined by the client for the intended use.

The history of photogrammetry is interesting due to the fact that it comes from different sources, starting from the private sector to the military and back to private use. In 1839, Louis Daruerre of Paris had made known a photographic method of exposing a photo on metal that was light sensitized with a coat of silver iodine, a process that is still in use today. In 1849, Colonel Laussedat of the French Army Corp of Engineers tried taking aerial photographs for mapping proposes using kites and balloons. Unfortunately, this technique did not go as planned, so he reverted back to the use of terrestrial photographs.

Various military agencies used photogrammetry between World War I and World War II for the purpose of performing reconnaissance operations preparing maps of strategic sites. It was shortly thereafter that photogrammetry was opened up to private industry, with the first aerial photograph for private use said to be taken in Tennessee in the 1930’s. Military defenses have continued to use photogrammetry and aerial photography for producing maps, however they are replacing this with the use of satellite imagery as the technology to do so produces greater and more accurate results.

The methods of producing topographic maps using aerial photography have evolved a great deal since their inception. Beginning with Analog Plotters, computerized control was combined with precision optical and mechanical components. Low-level aerial photography and subsequent photogrammetric interpretation are still the traditional method of producing high-accuracy elevation contours for topographic maps.

The next stage in aerial technology is the analytical plotter, which enables exact mathematical calculations to define the nature of the stereomodel. It is also easily interfaced with computer-aided drafting (CAD) systems, which simplifies the map editing and updating process, and also allows for collecting and sharing data with geographical information system (GIS) databases. Utilizing various CAD programs, aerial photographs are taken in, converted, edited, and / or modified.

The next method in the series is known as the Softcopy system, and operates with digital images instead of transparent photographs associated with the previous stereoplotters. This technique requires a high-speed computer system with a large memory. In the softcopy system, each digital object has assigned numerical values with characteristics that can be measured and or compared. A softcopy photogrammetric system has controls that allows the mapper to travel along the x, y, and z axis as if right on the ground level.

The newest photogrammetry technique is known as LIDAR, (Light Detection and Ranging). This technology allows the collection of high-accuracy elevation data more rapidly and less costly than any of the previous photogrammetric techniques.

Today the most accurate topographic maps are produced using photogrammetry & aerial photography. Although a considerable percentage of the budget for the typical construction project could go towards the aerial photography to produce the design, it is still the preferred method, especially on larger projects. The cost of operating an aerial photography company is substantial considering that the camera alone costs over a quarter of a million dollars. The advantages to the consumer are the detail, speed, and accuracy with which a topographic map can be produced using aerial photography, compared to the conventional methods.

This study has explored the history and development of topographic mapping from its initial stages, from crude instruments and primitive methods, to what it is today; a highly accurate scientific art.[10] As mentioned previously, the practice of land surveying itself has no specific beginning, and so it also becomes a matter of interpretation to determine the exact point at which topographic mapping first appeared on the horizon. In conclusion, to use the words of P.D.A. Harvey, we hope that reading our paper has drawn attention to this subject and aroused your interest enough that you will investigate this subject further, for yourself, and for the future of the profession of Surveying.

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Glossary of Survey Terms:*

Alidade……………..Used in topographic surveying, consists of a straightedge ruler carrying a telescope or other sighting device used in recording measurements on a plane table

Cadastral……………1 a: of or relating to a cadastre
2 a: showing or recording property boundaries, subdivision lines, buildings, and related details

Cartography………..the science or art of making maps

Triangulation……….the measurement of the elements necessary to determine the network of triangles into which any part of the earth's surface is divided in surveying; broadly : any similar trigonometric operation for finding a position or location by means of bearings from two fixed points a known distance apart

Dumpy levels………a leveling instrument which has its telescope permanently attached to the leveling base, either rigidly or by a hinge that can be manipulated by a micrometer screw

Map projection……..An orderly system of lines on a plane representing a corresponding system of imaginary lines on an adopted terrestrial or celestial datum surface. Also, the mathematical concept of such a system…

Plane table…………an instrument consisting essentially of a drawing board on a tripod with a ruler with some type of sighting instrument, generally a telescopic alidade, for plotting survey data directly from field observation

Planimetric…………A map which presents the horizontal positions only for the features represented, as distinguished from a topographic map by the omission of relief in measurable form

Theodolite…………..a precision surveying instrument consisting of an alidade with a telescope for measuring horizontal and vertical angles. There are two general types, direction instrument and repeating theodolites

Topography: 1 a : the art or practice of graphic delineation in detail usually on maps or charts of natural and man-made features of a place or region especially in a way to show their relative positions and elevations b : topographical surveying
2 a : the configuration of a surface including its relief and the position of its natural and man-made features b : the physical or natural features of an object or entity and their structural relationships

Transit………………a theodolite with the telescope mounted so that it can be transited

Sextant……………..an instrument for measuring angular distances used especially in navigation to observe altitudes of celestial bodies (as in ascertaining latitude and longitude)