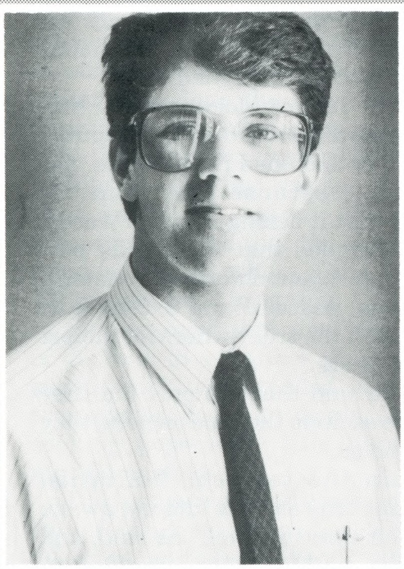
The Geodesy Corner
TEMPORAL CHANGES IN GEODESY

BY JAMES FERGUSON



I was honoured to be asked by our Executive Director, Lorraine Petzold, to speak to you this afternoon, especially on the eve of the 100th anniversary of the Association of Ontario Land Surveyors. Over the past few days I have seen much evidence of the interest shown in the heritage of the Association - historical regalia, a display of antique surveying instruments and a special viewing of Champlain's astrolabe. And I see it as fitting, that the fields of geodesy, photogrammetry and hydrography are side by each again, as they were millennia ago, but in much different forms. The history of geodesy and the changes that it has undergone over the centuries, is the subject of my talk today.

I thought it appropriate to start this out with a brief anecdote of historical interest. It was in 1492 that Christopher Columbus crossed the Atlantic ocean to seek out the unknown. Some privileged coincidence, that in the year this Association turns 100 years old, the 500th anniversary of Columbus' discovery of the New World - America, is also being celebrated.

This past December, while on survey in eastern Venezuela, I happened to visit the small town of Macuro, the town in which Christopher Columbus is claimed to have first set foot in South America. A large bronze statue is erected in his honour, and a museum, of the sort found in authentic towns accessible only from the sea, displayed what little evidence there was of his visit to this place. My thoughts went back in time, trying to imagine and capture the age of this great voyageur. How did he think? How did he talk? How did his people interact, especially with the natives? Among all these questions was a more predominant thought; what prompted explorers such as Columbus to set sail for places thought to contain demons, and evil spirits; to places known as the dreadful beyond, thousands of kilometres from their own safe ports. How did the technology required to allow such a feat, relate to the attitudes of the time? Or, what was the necessity of invention required for his journey.

G-E-O-D-E-S-Y, spells something like this; "The study of the size, shape and characteristics of the earth in both a temporal and spatial framework". Although geodesy is a "new discipline" within the Association, its roots are based in a pursuit of knowledge extending far earlier than the start of recorded history. Collaboration between men at an economic and social level extended the need to know more about the stars, the sun, and the earths' form and size. In the beginning, progress was made through mathematics and astronomy. These two facets of what we now call science were much more abstract in their infancy, and matured with the maturation of man as a whole.

In the Mesopotamium era, some 30 centuries before the birth of Christ, no one doubted that the earth was a flat disk simply because no-one new any better or worse than those "who knew".

As time progressed, various cultures placed importance on different aspects of their life. The Egyptians used primitive methods of surveying to reconstruct boundary corners and demarcate property lines after the annual flooding of the Nile river. This flooding was used to irrigate the dry lands for agricultural purposes. In this age, instruments were often standardized to a part of the body such as the Merkhet, whose size was calculated from a persons' forearm. This device utilized a plumb bob and split palm leaf for alignment on objects.

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Along with a pre-stretched wax measuring cord, this same instrument was used in the construction of the pyramids. It's hard to believe the variations in the lengths of the sides of The Great Pyramid are on the twenty (20) centimetre level, and the slopes of the sides are within millimetres of each other.

The art and science of surveying also carried over to defend titles to land in the time of the Pharoahs. Much time and effort was given to performing this task so the tax man could keep the Pharoahs' coffers filled. And when the Pharoah passed away, the survey of his tomb very often carried religious connotation, a symbol of the power of worship associated with everyday life.

In Babylonia, boundary records were large stones engraved with not only measurement details but with curses of a god on any who violated the boundary. "Cursed is he that removeth his neighbours landmark ...". Sounds a bit like certain sections of some present day legislation.

The Roman surveyors, or Agrimensors - measurers of land - have a prominent place in history for their abilities to lay out land more carefully and accurately than anyone until the late 1700's. They used an instrument called a "groma" which consisted of a series of four plumb bobs suspended from the ends of a right angled cross. The cross was in turn mounted on a rod, and when placed over a point the groma provided the capability to sight straight lines, and lines at right angles. Much of the Roman infrastructure was set out in the resultant rectangular fashion. Similar techniques were used to set out military installations, and it may be that military invention carried over into civilian usage. In those days, definite distinction was made between a civilian and a military surveyor.

Roman training of a surveyor included the study of cosmology, astronomy, geometry of areas, sighting and levelling, land law, and methods of laying out land and mapping it. A thorough education to say the least. It would be safe to say that the areas of astronomy, geometry and cosmology would have constituted the role of the geodesist. I don't believe, however, that the time was ripe for a clear or finite separation between these disciplines. Theories that may have separated astronomy from cosmology for instance, were either not thought of, or took a long time to be proved or disproved because of the lack of accurate instrumentation.

Excavations of Pompeii revealed a surveyors workshop reiterating the simplicity of his tools. But primitive tools need not imply primitive thinking, and we begin to see that the beginnings of geodesy must have developed concurrently with the development of more sophisticated thinking and subsequent tools.

Then, as now, human character continually demands more, and more means new technology and new ideas. The Romans for example needed water, and aqueducts were invented for its transport. The levelling of these aqueducts was done with twenty (20) foot long instruments called Chorobates. A water channel with markings at both ends was held in a wooden frame, and placed along the duct needing alignment. It was at the same time that the first primitive horizontal and vertical angle measurement device was introduced. This was the Dioptra, used for both surveying and astronomic observations, and was invented by the Greek scientist Hero.

As much as the Egyptians and Romans were mathematicians, the Greeks were philosophers and philanthropists. Their liberal minded attitudes set them apart from other concurrent civilizations, and little early evidence is apparent of the rigid systems employed by the Romans. This is due in part to the rugged landscape of Greece, and the absence of vast areas of arable land. The same State push to divide land was not yet there. Consequently, the greeks were more interested in planning cities, and seemingly on a more artistic and social level. Some have called their work haphazard, but this is not to say that they were lacking in technological capability. There has been evidence of tunnelling in ancient Palestine and Greece to a good degree of accuracy.

In a timeframe starting about the 6th century B.C., the need for expanded maritime trade and productive land led to a large degree of colonization. This growth extended out of a need from a society who not only had to expand, but from one in which an increased value was placed on the value of land. Founders of colonies would bring priests and surveyors to aid with allotment and settlement. One of the new cities which sprang up was the famous city of Miletus, notorious for fostering scholars who began to really put their mind to discovering the physical properties of the earth. This is the point where we can begin to separate the smaller picture of geodesy from the overall development of science and natural philosophy. Still, the motivating factors remained the same; the need for practical applications, and the motivation to seek understanding of the universe.

"The earth is a flat disk surrounded by an infinite ocean", stated the mathematician Thales of Miletus. Many of his students and contemporaries who lived in the 6th century B.C. concurred with him, while others provided variations on the theme. One such variation was the theory of a cylindrical earth having an east west axis. It wasn't until the time of Pythagoras that the earth was considered to be spherical, a notion not universally accepted at the time. To reiterate, the tools and methods of these astronomers were not sophisticated, and philosophical ideas played a major role in their visions.

Once again, proving a theory could potentially have taken hundreds of years, if in fact contemporary thinking remained in vogue for that long.

The Alexandrian greeks paid special attention to the study of geodesy, and their increasingly long ocean voyages improved their knowledge of the earth.

History tells us that initial lines of latitude and longitude were first described by the greeks in the 3rd century B.C. At this time a wider acceptance of the spherical earth theory was taking hold. Among these far thinking greeks was one of the greatest mathematical geographers of antiquity, a fellow by the name of Eratosthenes. Some have described him as the father of modern geodesy. In about 200 B.C., using the principle of arc measurements, Eratosthenes calculated the radius of the earth. This would become the first great geodetic computation of a global nature, paving the way for rapid learning and achievement amidst the relative peace of the time. But over the next few hundred years, attempts at improving his calculations were not often of superior quality or accuracy.

Other developments from the time of Eratosthenes until the first century after the birth of Christ included the first star maps of angular coordinates, the theory that the earths' axis was tilted, and the first notions that earth formed part of a heliocentric system. This latter theory was discounted by many, and it wasn't until the 16th century that it would be more widely accepted. The greek astronomer Ptolemy was the first person to compile a volume of astronomic and geodetic works done up until that time, a treatise known as the Almagest. Still, for all his insight, he failed to recognize several important theories of the time. One which stated that there were still as yet, uncharted lands on the earth.

So these were the ancient surveyors and geodesists. Plagued by a lack of technical ability necessary to learn what they wanted, hindered by, at times, non-progressive thinking, and the unwillingness to adapt to changing ideas.

This repression carried on through the dark and middle ages, and as with most events during that time, few discoveries were recorded. We are fortunate today that the Arabs fulfilled the role of record keeper. The only recorded advances made during the middle ages were not surprisingly of Arab origin, who are attributed with some of the first accurate results of the size of the earth since Eratosthenes.

By the 10th and 11th centuries, light was beginning to dawn once again over the european continent. A new age of discovery was near, albeit still under predominant theological influences. It is not so much evident that the science of geodesy per se was returning to prominence, but a broad new outlook on the world would soon lead to a revival.

Of the early great explorers, Marco Polo's exploits are significant. His adventures took him further than most of his predecessors, leading to increased discussion, controversy and a demand for facts concerning parts of the globe far from europe. The rise of cartography as a science during this period aided his voyages, and with increased geographical knowledge, was fuelled in the process. The pilgrimages and military expeditions didn't hurt cartography either, as this led to the production of travel guides. The compass came of age in the 14th century, and mariners were learning to rely on them for navigation. Exploration was the impetus for another navigational tool - charts employing the north star as a reference. With these types of charts seamen were able to plot loxodromes and rhumb lines, beneficial for following a predetermined course.

Of course all this mapping and charting was not done for nought; the profit seeking urge of rulers and merchants led to a frenzy of activity, ultimately vying for riches in the fabled east. Spreading the gospel was also of great importance, and the religious community carried much influence in travels of the day.

Some have termed the following hundred or so years the "golden age" of european exploration, with countries such as Portugal leading the way, and producing such notables as Henry the Navigator. Henry's persistent exploring opened up thinking and future expansion. He is also credited with starting one of the first schools of navigation, in Sagres in southern Portugal. Concurrent with the vast number of open sea explorations was the overdue revival of theoretical geodesy.

In the 1400's, the foundations were laid by several researchers, for the impending work of Copernicus and Kepler, two of history's geodetic giants. Copernicus published his theory of heliocentricity in 1530, stating that the earth and all the planets were centred around the sun. Kepler advanced the theory in the early 17th century, proving that the planets revolved around the sun in elliptical orbits. These discoveries were not possible without the continuing advancement of observing equipment, and the necessary mathematical tools. It is hard for us to imagine the time required for the computation, checking and analysis of the data, not to mention the difficulty of it all.

The renaissance then, not only renewed progressive thinking, but fostered a method of experimentation that can be described as the scientific process. And amid the still lingering misconceptions of diehard traditionalists, scientists were progressing in spite of them. For instance it has been noted that in Catholic countries, the Inquisition banned the work of men such as Kepler, Copernicus and Galileo until 1822. But that did not stop the works of the many who came after these unique individuals.

In terms of measurement, the age of modern geodesy probably began with the work of the Dutchman Snell. Snell carried out the first accurate triangulation survey using a primitive theodolite which probably incorporated one of the first telescopes to be used in this type of instrument. By computing latitude differences and distances between points (from triangulation), he was able to recompute the earth's radius to a fair degree of accuracy. The french "Academy of Sciences" in Paris carried on from the work of Snell starting in the mid 1600's, and dedicated themselves to finding a most accurate measure for the radius of the earth. Their efforts were successful on several occasions due in large part to their measurement accuracies, and the fact that they used the triangulation methods incorporating known baselines.

Perhaps one of the most important discoveries for science was Sir Isaac Newton's theory of universal attraction. From the geodesists point of view, he proposed the theory of the earth as an oblate ellipsoid, one of the earliest deviations from the notion of a purely spherical earth. The french astronomer Casini directly opposed Newton's theory, but a subsequent expedition by the french Academy of Science proved Newtons theory to be correct. They did so by sending two expeditions to measure two meridian arcs, one at the equator and one near the north pole. The resultant radii calculations left no doubt as to the outcome. Casini's errors were attributed to poor measurements and incorrect processing methods.

This brings us to a point which we might consider recent history; from the 1800's onward. With the publication of a book entitled "Theory of the Earth's Figure" by the Frenchman Clairaut, geodesy entered an age of its own. Including theories ranging from the relationship between geometric and gravity flattening, to the notion of physical determination leading to conclusions of a geometrical nature, it seems to me that only a geodesist would be obscure enough to care about these things anyway! At the time, US publications regarding surveying were still being reported in the magazine "Transactions of the American Philosophical Society".

Other publications would follow from a great many geodetic, and mathematical pioneers. Such genius's as Laplace, Gauss, Bessel and Stokes provided the geodetic community with more theories, tools and food for thought than at any time in history. It is interesting to me, that it now seemed possible to have differing theories on a subject, and not be necessarily right or wrong.

The earth's flat - no it's round, type of argument did not carry much credence any more. Until the middle of the 1800's, geodesy had concerned itself mainly with two dimensional horizontal thinking. Popular opinion of a geodesist at the time was that he performed terrestrial and astronomic reductions, and many saw him as a land surveyor. Serious thought of vertical computation came when Gauss created a vertical reference surface called the geoid. He defined the geoid as the best representation of mean sea level, and it has been in a state of flux ever since. Following Gauss' lead, Stokes was able to derive a formula which used physical measurements of gravity to compute the height between the geoid and a mathematical reference surface, a feat which is still considered remarkable. Linking the horizontal and vertical components of geodetic computations was put forward by a geodesist named Bruns in 1878. He suggested processing horizontal and vertical data together, but his ideas were not practically investigated until some 75 years later; a time at which geodesy gained a new vision - the vision of 3-D.

Three dimensional geodesy was to solve a lot of problems. It has solved many, but it is not yet a perfectly refined solution. Three dimensional geodesy created a much better connection between the various components, thereby eliminating the need for many numerous auxiliary hypotheses and approximations. As an end product, three dimensional geodesy gave an answer for all components simultaneously. This would prove to be of monumental importance with the introduction of satellite geodesy a short time later.

Running alongside the 3-D revolution, were continuing studies into the shape of the earth and the reference surfaces used to work with it. With increased technology and refined processing techniques, subtle changes were constantly being made.

The last thirty years have brought about enormous change in the field of geodesy. As you all know, computers have given us the ability to reduce and treat measurements which were beyond our reach not so long ago. They have allowed us to create tools that produce information in astounding volumes, and at astonishing speed. We are now able to collect information from more sources, both directly and remotely than we know what to do with. Satellite technology has been around since the middle '50's, and we now have the GPS system in place that should take us to the year 2050 at least.

It would be remiss not to mention the inertial survey technology that invaded the 1970's and 1980's, and is indeed in use today.

I have not delved into the ongoing research in the field of geodesy over the last twenty years because I believe that is another talk. I know I have left out large chunks of history, and many significant achievements in the field. But my intention today was to shed some light on the evolution of geodesy in a way you would walk along a railway line - you can't step on every one tie. Also, I hope I have given you a small insight as to what fuelled developments over the centuries.

Today and in the future, our challenge is to use our new found resources to produce a quality of service, and create a quality of information that is uniform wherever we work. As new technologies take us to different places both domestically and internationally, we must not lose sight of our raison d'etre.

Geodesy has from the outset, been a global endeavour. If we remember this, then I think we stand poised to serve the needs of a lot of people for a long time to come.

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