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Lines and Angles

A Historical Background to the Lore of Land measuring

by HELMUT FIALA

From the beginnings of recorded history, the major emphasis of the historian's work has been directed towards military operations and political intrigues, for these events, above all others, have a direct bearing on the affairs of all men.

Ever since the evolution of farming in the Neolithic Age — an evolution which formed the essential basis of civilization as we know it — politicians have been plotting; generals have been clashing; priests have been praying; common people have been carrying on the business of living; and (after the world had learned to write) scribes have been producing countless volumes in praise of their masters, glorifying their various achievements — with little if any mention of the men of science whose contributions made those achievements possible. Even among the specialized histories of the many fields of human endeavour there is but scant attention paid to the important field of technology.

Thus the technically-minded student finds himsslf in a peculiar situation, in which he must perforce study War and Politics, however boring he may find them; must endure learned and well-meaning discourses on Drama, Poetry, The Arts — but is left in complete ignorance of the historical background of his own chosen field, science and technology and, in consequence, has no appreciation of our rich heritage in these domains.

The hydraulic engineers and the temple builders of early Mesopotamia, the diligent officials at the Chinese Imperial Court, the priest-surveyors of early Egypt — to name only a few among the myriad servants of progress — most of these have been forgotten in the almost universal adulation of the 'great men' of history.

Behind the scenes of glory, the builders worked quietly and without fanfare, and the land measurers and geometers supplied all that was required for the work that had to be done.

Armed with as little as a *merkhet*[1] and a plumb-line, a cord with knots at intervals of 4 or 5 cubits for linear measurements, a carpenter's square, and their professional skill with the water-level, the *draggers of the rope* [1] — as surveyors were called in Ancient Egypt — helped to erect the mighty pyramids.

It seems that the principle of the *double remen* — i.e., the diagonal of the square, and with the 3:4:5 proportions of the right-angled triangle — was the sum total of their theoretical knowledge. However, they put this knowledge to excellent use. We even find a cadastral system of registration of properties in evidence as early as 3000 B.C.

For tax purposes the domain of the Egyptian god-king, the Pharaoh, was divided into nomes. The principal duty of the governor of each nome was the maintenance of the dykes and canals. A nome administration included tax inspectors and cadastral surveyors to check the position of the boundary stones. But the vital water administration kept growing, and in the end became centred in the *labyrinth,* a huge building erected ca. 1850 B.C. on the west bank of the Nile, south of *Memphis.*

The Greek writer *Herodotus,* who visited Egypt around 460 B.C., describes the labyrinth in the following words: "and having so resolved, they made a labyrinth, a little way beyond the Lake Noeris and near a place called the city of Crocodiles. I have seen it myself, and indeed no words can tell its wonders — though the pyramids were greater than words can tell, and each one excels the monuments built by Greeks, this maze surpasses even the pyramids. It has 12 courts, with doors over against each other — there are also double sets of chambers, 3000 altogether, 1500 above and the same number underground."

Thus the 'roving reporter of antiquity' describes the first *registry office* in recorded history.

Of course, water administration and elaborate irrigation systems were also the life blood of Egypt's sister civilizations in the Fertile Crescent. Here, in the Cradle of the West, the hydraulic skills of ancient Sumer and Akkad were only surpassed by the *Hanging Gardens of Babylon,* and *Sennacherib's Aqueduct at Jerwan* — both of which serve equally well as prime examples of the advances made in this field by successive civilizations. Built around 700 B.C., this 65-foot-wide canal ran a distance of 50 miles to bring water to the Assyrian capital; during its course it crossed a valley in a stone aqueduct 900 feet long, 70 feet wide, and 23 feet high, at a perfect gradient of 1:800. So vital was irrigation to this area that an ancient Babylonian curse was: "May your canal be filled with sand."

Obviously, the teaming farmland of the valley of the Twin Rivers, with its web of blue canals, ans its numerous colourful ziggurats, depended for its very existence upon the skills of competent surveyors.

Meanwhile, we witness an intellectual awakening on the distant shores of the Aegean, which would lighten the skies of scientific progress for the next 2000 years. In its wake came such prominent developments as the *mekos* and *platos* — longitude and latitude—of *Hipparchus,* [5] and the theory of the earth's curvature as laid down by *Eratosthenes*[5] before him, which in turn led to the approximately correct figure of 25,000 geographical miles for the earth's circumference. This prepared the way for notable advances in cartography. Sadly enough, after the great efforts of *Ptolemy* and *Marinus of Tyre,* in which the quantitative cartography of antiquity reached its climax, the whole system of coordinates was abandoned, and European map-making suffered an unbelieveable degeneration at the hands of the early Christian and Muslim cosmographers.[2] Religious cosmography included pictorial displays of places like Paradise and Eden, While rivers and mountain ranges strayed in wild disorder across a disc representing the world. A typical example of this practice can still be found in the first printed European map from Lucas Brandis' woodcut of 1475; here a jumble of mountains, adorned with churches, only succeeds in adding to the confusion in which Babylon appears twice, and Dacia adjoins Norway.

However, cartography was not the only discipline requiring mensuration, and the search for new mechanical and

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theoretical tools for the profession continued, Heron's Dioptra,[1,3] for instance, and his measuring rods with moveable discs,[3] were among these efforts. Unfotunately, the Dioptra was too far ahead of the times, and served only to foreshadow the development of precise levelling instruments in a more distant future. Trigonometry, on the other hand, fared much better, as we shall see later on.

So it was that the scientific stagnation which gripped the Old World after the decline of the Golden Age of Greece was also felt in the more practical disciplines of surveying. Roman road-builders advanced only to an improved version of the Graeco-Roman *groma* [1] — an instrument for laying out right angles, a simplified predecessor of which has been discovered in excavations at the early Fayum site in Egypt.[1] For linear measurements the Romans used a 10-foot rod with bronze terminals on either end;[1] but it was only in levelling instruments that any real advance was made, but it was only with devices known under the names of *Libra. Libella,* and *Chorobates* [3] (though only the last mentioned of the three applied the water-level in addition to the plumb-line).

At this point in time, when technical advances among Western centres of civilization had ground to a halt — not to be resumed for nearly 1800 years, during which the patient keepers of the flame in the Islamic world and in India kept the light of science burning bright — we turn our attention to the Far East.

There, secluded behind towering mountain ranges and vast deserts, lay the land of the *Seres,* known to the Old World only from cryptic reports trickling through the caravanserais along the Old Silk Road, but remaining a mystery not to be disclosed until the days of European expansion.

China, or Cathay as it was known to the people of antiquity, developed its own version of the *groma,* described as follows in a section of *Chou Li* [2] — which dates from about 200 B.C.: "at the four corners of the instrument four straight lines hang over the water-level and the surveyors observe with this the high and low —". Another description from 759 A.D.[2] names as the common tools of the profession a water-level on a stand, with three floating sights and two plumb-lines attached; a graduated pole; and a sighting board. The cross-staff was known already in the 11th Century, and the cross-wire grid dates back as far as 200 B.C. Around 1085 A.D., we also find a sighting-tube with a graduated scale for more precise slope measurements.

Since water control and widespread irrigation were the life-sustaining elements of this ancient civilization, it is not surprising to find the Chinese in possession of such sophisticated tools at an early point in history. These practical-minded people had little use for abstract ideas in any domain, and directed all their energies to the task at hand.

This is one reason why trigonometry never advanced significantly in China. Recognition of the importance of this subject came in early Greece, where it received its first impetus around 260 B.C., when *Aristarchus of Samos* used ratios similar to the tangent of an angle, and *Hipparchus* carried out graphic solutions of spherical triangles around 140 B.C.

However, the chief advances in spherical trigonometry were made by *Menelaus of Alexandria* around 100 A.D. in his *Spherios*[2]. During the dark centuries that followed, it was the Indians who brought trigonmetry to its modern form. Sines and versed sines appeared for the first time in the *Paulisa Siddhanta* [2] around 400 A.D. Later on, the Arabs took over from the Indians and introduced the concepts from which the tangent and cotangent were derived. Also, the first work on plane trigonometry was the *Book of Sharp Sector Figures* by *Nasir al-Din al-Tusi,*[2] who lived from 1201 to 1274 in Mongol Persia; it remained the only major work of its kind until *Regiomontanus' De Triangulis* of 1533.

The development of survey instruments in Europe, however, did not keep in step with these achievements by the East. We find that during the Middle Ages, ca. 1321, the most important instrument was the *Baculum,*[2] also known as the *Cross-Staff*[4] or *Jacob's Staff*[4]. This was a graduated rod about 4 feet long, with a cross-piece which would slide along the rod while remaining at right angles to it. It lasted till about 1594, when it was replaced by *John Davis' Backstaff*. The latter was in common use until the arrival of reflecting instruments in the 18th Century. Another 16th Century development, which would in time lead to the introduction of the transit as we know it today, had its humble beginnings in the first angle-reading instrument, called the *Recipiangle.* This was a simple pair of compasses made of two flat arms with vertical sight slots at both ends. Later in that century, the *Trigonometer* [4] or *Double Recipiangle* came into common use.

With the Renaissance and the coming of the modern Golden Age of science, the pace quickened. European instrument-makers and scientists developed hitherto unheard-of means to explore the physical universe, and thus extended the range of our understanding of its phenomena.

Scientific development in the 20th Century is riding a mountainous wave which had its humble beginnings in a mere ripple of curiosity long ago — and the crest is not yet in sight.

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Pearce Protests Ryerson Directions

Frederick J. S. Pearce of Stratford, a Past-President of AOLS and Chairman of its University Liaison Committee, expressed his views of Ryerson Polytechnical Institute's approach to survey education in a letter on April 19 to J. J. Abel, Chairman of the Institute's Department of Civil Technology. It is reprinted here at Mr. Pearce's request.

Mr. J. J. Abel, Chairman
Department of Civil Technology
Ryerson Polytechnical Institute
50 Gould Street
Toronto, Ontario

Dear Jim:

Walter Raiend has recently forwarded a copy of your News Bulletin, announcing that Ryerson has been granted authority to grant degrees. In reading it over a number of thoughts came to mind, and I felt I should forward them to you.

In 1965 a committee of our Association commenced working on a curriculum for a two year technician and a three year technology course. I met you a year or so later at a meeting with officials of the Department of Education when we were seeking support for the technology program at Ryerson. At that time you gave us full support, and even suggested to your director that he follow our program, not one which he had revamped. We appreciated the confidence you placed in our judgment.

Since that time we have been working towards a re-structured university program which should fill survey needs at another level. Each time we submitted a "white paper" on our thoughts, it was discovered some weeks later to be a part of a new proposed program at Ryerson. This, of course, annoyed those members of our Association who were aware of this "end running". If in any way you, or your director, feel you have been isolated it is probably because of this type of manoeuvring.

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