

THE GREAT WALL OF CHINA: The World's Greatest Boundary Monument!

By John F. Brock

Keywords: Ancient China, surveyors, Pei Xiu, Liu Hui, *The Haidao Suanjing*, Great Wall(s) of China, Greatest Boundary Monument.

:”... in the endeavors of mathematical surveying, China’s accomplishments exceeded those realized in the West by about one thousand years.”

Frank Swetz – last line in *The Sea Island Mathematical Manual: Surveying and Mathematics in Ancient China*.

ABSTRACT

It is said that the Great Wall of China is the only manmade structure on Earth which is visible from space (not from the Moon)! The only natural feature similarly identifiable from the outer reaches past our atmospheric zone has been named as Australia’s Great Barrier Reef. This natural wonder of the sea is continuous while the Great Wall of



Fig. 1 The moon from The Great Wall instead of vice versa which cannot actually occur !!!

China is actually made up of a series of castellated walls mainly erected along ridge lines causing major variations in the levels of its trafficable upper surface. Some of the barriers built are not formed from stone but from rammed earth mounds.

The purpose for these walls was primarily to facilitate protection from hostile adjoining tribes and marauding hordes of enemy armies intent on looting and pillaging the coffers of its neighbouring wealthier Chinese Dynasty of the time. As the need for larger numbers of military troops became required to defeat the stronger opponents, which may sometimes have formed alliances, the more astute provincial rulers saw a similar advantage in the unification of the disparate Chinese Provinces particularly during the Ming Dynasty (1368-1644). In fact the earlier sections of the Great Wall(s) were constructed to delineate the territorial areas of separately governed principalities thus representing some of the most ancient continuous boundary monuments of substance still surviving to this day. This paper will investigate which portions of The Great Wall(s) of China were mainly erected as boundary demarcations and the others put up as protection as well as attempting to highlight early techniques and equipment used by the Chinese surveyors of antiquity hopefully supplemented by some translated texts and historic art.

INTRODUCTION

When it comes to the imagination of world peoples The Seven Wonders of the World holds curiosity of conversation usually when called upon to name any series of such

groups of seven including dwarfs, deadly sins and so on. Due to the magnitude of its extent The Great Wall of China quite often is put forward (wrongly) as one of these seven man-made constructions of amazement. Erected over a vast expanse of history the “Chinese Wonder” is certainly one of the most visited edifices by modern tourists but what is available for public viewing is a mere fragment of the actual 21,196 kilometres of the overall lineal coverage of the various features included among what has become known as The Great Wall. Only in the last few years from 2007 has this survey accurate total been determined through a joint project by China’s State Administration of Cultural Heritage and the State Bureau of Surveying and Mapping with the existing previous estimate at that time being less than half of the true length at a mere 8,850 kilometres ! From the popular perception the section of The Wall built of stone in the vicinity of Badaling, near Beijing, has become the vision most representative of this iconic structure due to its substantial material, excellent restoration and open accessibility for viewing. Although the steeply disparate levels of the Wall’s floor area make movement rather difficult the public authorities responsible for its maintenance and availability have had handrails installed to assist visitors to pull themselves up the demanding slopes. My thoughts instantly pondered as to how the heavily clad Chinese warriors could possibly negotiate such forbidding barriers of non-evenness as those existing along most of The Wall where it stood imposingly atop ridgelines separating the northern territories from the Chinese lands to the south. Then of course, being the inquisitive surveyor that I am, my next immediate thought was that how this famous line of walls actually separated the land of one peoples from those occupied by a rival nation thus being a visible boundary monument for the delineation of designated lands. By sheer definition both physically and notionally a wall is erected to “divide” one area from another thus representing a barrier or borderline across which incursions are only welcome by invitation or imposed by the invasion of one neighbour onto the territory of the other. Surveyors always find fascination and interest in boundary lines with particular attention directed to what has been placed to define such lines of territorial demarcation so along with concern about boundary markers comes a consideration of who actually placed them and how they were surveyed. Uncovering source material about the ancient Chinese surveyors has not been easy due to the language barrier between English and Chinese as well as the long periods of banishment of foreign inquisition

and examination imposed by the Imperial Chinese decrees of isolation intended to maintain the non-contaminated superior Chinese lifestyle. However my determination has paid off through my discovery of a brilliant English text by Professor Frank J. Swetz on Chinese mathematics as it so pertains to surveying purchased from the Pennsylvania State University Press via the internet for a very reasonable fee which also included



Fig. 2 Viktor Sikais and myself amongst the crowd atop The Great Wall at Badaling near Beijing in 2007.

packaging and postage. The much anticipated publication arrived in very quick time indeed !

CHINA'S GREAT SURVEYORS

“The Sea Island Mathematical Manual: Surveying and Mathematics in Ancient China” by Frank J. Swetz is an examination of a Chinese teaching text called the *Haidao Suanjing* (translated as the *Sea Island Mathematical Manual*) compiled in 263 AD by Liu Hui, an official during the Kingdom of Wei (220-290 AD), also known as the Three Kingdom Period, being a somewhat unsettled time under the reign of an emperor named Cao Pei. Nine problems associated with varying situations of field surveying are solved using the application of right angled triangles confining such hypotheses to micro-scale land areas within which the subject areas can be assumed to be planar and thus unaffected by any considerations of earth curvature or such spheroidal nuances. In the earliest known

Chinese mathematical text the *Zhoubi Suanjing* (translated as *Perimeter Gnomon Manual*), published between 100 BC and 100 AD, the material published represents established surveying practices including accomplished application of right triangle theorem in operation for hundreds of years. With this long history in mind the period mentioned clearly covers the lifetimes of the legendary Grecian Fathers of Geometry Thales (624-527 BC) and Pythagoras (569-475 BC) so the level and extent of mathematical knowledge and accomplishment of the Chinese is truly remarkable indeed. To clarify the subjects covered in this ancient corpus of knowledge it is necessary to define “zhou” as “perimeter” and “bi” as “gnomon” being a shadow staff for position reckoning by the sun. Also employed by the Chinese was the set square (*ju*) to determine the heights of remote objects through the proportional geometry of triangles (see Figure 3). To measure distance the ancient Chinese mensors used the customary rope which in more recent times was replaced by tapes and long wires supplemented with the use of plumb bobs for

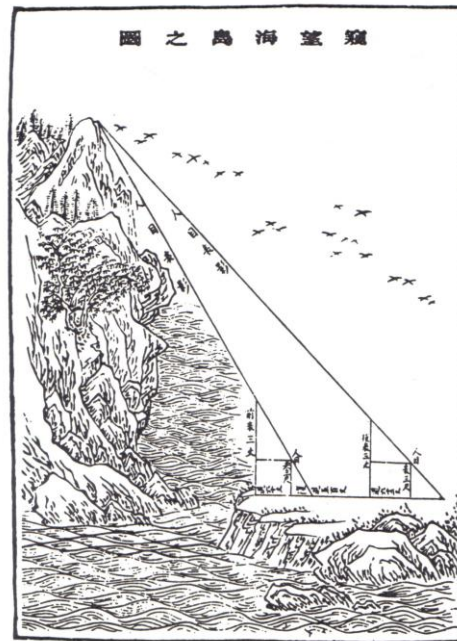
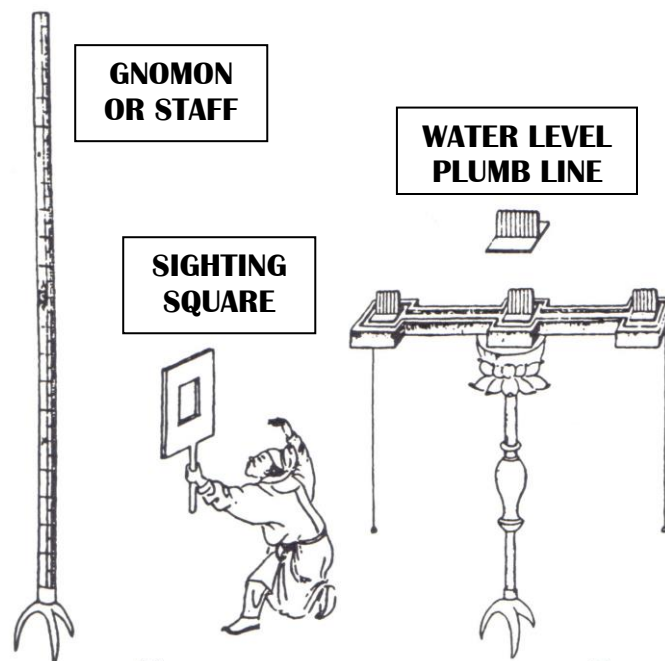


FIG. 3 A woodblock print illustrating the sea island situation. Given in the *Tu Shu Ji Cheng* (1726), an encyclopedia.

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line propagation and horizontality.

Surveying tools from ancient China are well testified

Fig. 4 Chinese surveying equipment of the ancients.

through artwork, artifacts and descriptions being sighting or reference poles (gnomons), *biao*; set square, *ju*; plumb line, *xian*; water level, *zhun*, ropes and cords later replaced by tapes, *bu che*. As more commonly known in English as “The Arithmetical Classic of the Gnomon and the Circular Paths of Heaven” dated to circa 100 BC - 100 AD, it takes the form of a discussion between Zhou duke Zhou Gong and a Grand Prefect called Shang Gao when the nobleman asks of the official: “May I ask how to use the set square?” to which the response comes: “Align the set square with the plumb line to determine the horizontal, lay the set square down to measure height, reverse the set square to measure depth, lay the set square down to determine distance. By revolving the set square about its vertex a circle can be formed, combining two set squares forms a square.” (see Figure 5) The length standards and languages adopted were quite variable before Emperor Zheng took power in 221 BC after defeating the provinces of the weaker leaders to earn the title of The First Emperor. Through his rigidly despotic regime he introduced a single currency, standards for weights and measures as well reducing the alphabet down to a mere 3,000 characters in a single spoken dialect ?? Putting into practice the new specifications of mensuration surveying devices were made to differing lengths depending on the accuracy required, with sighting poles quoted to be 20 and 30 *chi* respectively in the problems of the *Haidao* being the equivalent of 7 and 10.5 metres. The standard Chinese set square for field use had sides of 2 *chi* (0.7 metre) but could be made to lengths of 12 or 23 *chi* plus (4.2 or 9.1+ metres) to achieve finer results.

The *Haidao Suanjing* was the mathematical aid to solve the field problems which confronted the surveyors consisting of nine individual circumstances summarised as:

- 1/ The sea island problem to calculate the height of a remote island;
- 2/ The pine tree problem to ascertain the height of a distant tree;
- 3/ Size of a distant walled city problem;
- 4/ Depth of a ravine problem;
- 5/ Height of a building as viewed from a hill problem;
- 6/ Width of a river mouth problem;
- 7/ Depth of a clear pool problem;
- 8/ Width of a river problem and
- 9/ Size of a city from above problem.

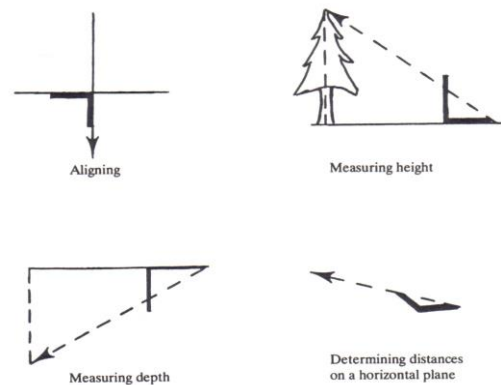


Fig. 5 Set square measurements as per

Considering Chapter Nine of this contemporary text to be inadequate for precise measurements Liu introduced a method of calculation called *chong cha* (translated as “double difference”), a concept well understood and employed by all prudent

surveyors as a mechanism to compensate for systematic errors present in monitoring equipment being readily eliminated by repeat observations at 180 degree orientation.

The essential work of the surveyors in Imperial China was directed towards the four purposes as listed:

- 1/ Mapping required for the existence and maintenance of the political state;
- 2/ Verification of cadastral land boundaries for ownership and taxation;
- 3/ Supervision of public works such as roads, aqueducts and canals and
- 4/ Warfare reconnaissance and target assessment.

Such considerations are elements of all the great civilizations in their expectations and demands upon their land surveyors with particular recognition of the skill and authority demonstrated by the ancient Egyptians, Greeks and Romans. From the most ancient Chinese classics instructions pertaining to waging war contained references to the vital need for accurate mapping and techniques to determine the position of the enemy from satellite posts. From before the Qin Dynasty (221-206 BC) such as Zhou Dynasty (1025-256 BC) classics as the *Zhou Li* (Rites of the Zhou Dynasty), *Zhan Guo Ce* (Records of the Warring States), *Guan Zi* (The Book of Master Guan), *Sun Zi Bing Fa* (Master Sun's Art of War – 5th century BC) and *Sun Bin Bing Fa* (Sun Bin's Art of War – 4th century BC) the existence and use of maps were cited on many occasions.

SURVEYING IN CHINESE MYTHICAL LEGEND

As far back as around the 29th century BC Chinese mythology has an event supporting a Noah's Ark Biblical epic of a Great Flood which wiped out the world with the only survivors being Fu Xi and his wife (who may also have been his sister?) Nu Wa who held equal status with her husband in Taoist tradition for repopulating the Earth with the tools of creation – the compass and set square! It is indeed prophetic for the future surveyors of China that these two instruments of myth would become their own devices for carrying out their survey tasks. Fu Xi is variously said to have ruled as “The First Emperor” (of folklore!) for over 115 years commencing in either 2952 or 2852 BC. As a folk legend this guy had everything useful to a surveyor in the wild bush land as he was said to have been a shaman who could tame wild creatures as well as being capable of controlling the weather. Furthermore he is credited with inventing many things among which were cooking, trapping, fishing, music, writing, the calendar and angle measurement! When images of Fu and Nu are shown Fu holds the compass and Nu the set square with their snake-like bodies intertwined. This pair would appear to me to represent an archetypal couple of Surveyor Gods to which the later surveyors may have called upon for heavenly guidance during their surveying assignments.

MAPS FROM ANTIQUITY

During 1973 an archaeological dig of a Han Dynasty tomb at Mawangdui in the south west region of Changsha discovered three silk maps of a marquissate dated to the Western Han period (206 BC to 6 AD). One of the silken charts was drawn at an

approximate scale of 1:180,000 depicting mountain ranges, rivers, occupied areas and topographical features with contours. Through a comparison with a modern map of the same area it was very clear that the surveyors and cartographers who contributed to the historic work must have been capable of reliable and highly precise map production. One of the charts was prepared to plot troop locations within the designated mapping zone.

Regarded as the Father of Chinese Cartography Pei Xiu (AD 223-271) was made Minister of Works in 267 by the first emperor of the unified Jin Dynasty (265-316). He assembled all known cartographic works at that time postulating the following set of six principles for good map making:

- 1/ The use of an appropriate scale in drawing;
- 2/ The employment of a rectangular grid system;
- 3/ Accurate measurements between major landmarks including the projection onto a plane of those with different elevations precisely executed;
- 4/ Determination of accurate elevations;
- 5/ Measurement of right and acute angles and
- 6/ Measurement of curves and straight lines.

As each of the pronounced principles required a working comprehension of the use of right angled triangles mathematically it formed the basis of the Chinese surveying and cartographic process for the facilitation of the surveying and preparation of most reliable and impressive maps from the mysterious empire. Military needs were the not the only area to which such standards of precision and accuracy were applied by the Chinese autocracy. Due to the common occupation of areas adjacent to or nearby to rivers and estuaries careful planning was carried out to design civil works for the diversion of waterways through canals and irrigation, all of which demanded a high level of correctness and skill to make preliminary reconnaissance surveys followed by the precision necessary to construct such intricate systems of water utilisation. Such respect was held for the surveying skill commensurate with the very survival of the populace translated onto the godlike qualities of the revered leaders of China when the legendary emperor/engineer Yu the Great (c.2200-2100 BC, Xia Dynasty) (also often depicted with a set square in hand!) was described in the following way:

“Emperor Yu quells the flood, he deepens rivers and streams, observes the shape of the mountains and valleys, **surveys** the high and low places, relieves the greatest calamities and saves the people from danger. He leads the floods east into the sea and ensures no flooding or drowning. This is made possible because of the *Gougu* right triangle theorem.”

During early periods the term for astronomers and surveyors were exactly the same, *chou jen* or literally “surveyors of heaven” which clearly portrays the divine status bestowed upon China’s ancient surveyors.

EMERGENCE OF THE WALL

Prior to the unification made under Zheng's dictatorship in 221 BC China consisted of a diverse group of what was termed The Warring States mainly focused on the preservation of their limited principalities from the territorial ambitions of their various not-so-friendly neighbours. Thus the first series of boundary walls were erected as defences for their own individual bits of turf, therefore truly being boundary monuments by design. This earlier epoch was known as the Zhou Period but was comprised of Qin, Zhao and Yan States who put up their walls of separation for both protection and demarcation from 350 to 215 BC.

However when Zheng took over domination of the disparate factions he soon embarked on what history has declared to be the commencement of Great Wall construction with the express purpose of keeping at bay the hostile tribes to the north of this structure and in so doing created the physical delineation of his Qin Dynasty empire in the northerly direction. Within the relatively brief reign of just over a decade up until 210 BC upon his death, The First Emperor had been successful in constructing some 4,000 miles (6400 kms) of the first Great Wall in addition to creating the other major tourist attraction of modern China – The Terracotta Warriors guarding his tomb at Xian.



Fig. 6 The First Emperor's heavenly guards in his spectacular burial place in Xian.

Contemporary accounts during the construction of this megalomaniacal monument give an estimate of around 7,500 entombed statues of which only 1,000 have so far been uncovered for public viewing.

Extending from the Ordos ranges in the west right through to the coast in the east this rather humble wall in its height and substance had been the inspiration for later rulers to build similar barriers but with more durable and impressive material along some of the most inhospitable terrain and precipitous ridgelines across the mainly northern area of the Chinese empire. As this first attempt at a "Great Wall" was clearly not impregnable to armies of horse cavalry as they only stood at heights of 1 or 2 metres for the majority of its length without ramparts or towers it was the mere concept of a physical symbol to convey the message to any potential invader that to pass across this boundary would



Fig. 7 The First Emperor's "Great Wall" boundary monument. Note the two "trig" towers atop the mountain at the top left of photo???

invoke dire repercussions by the Chinese Imperial Forces and thus it was a most emphatic border delimitation. It is interesting to note that this “first” attempt at a “Great Wall” was punctuated along its length by beacon towers or pillars which were clearly placed for determining strategic locations or other troop position points. Could they have also been utilized by the surveyors for mapping and surveying activities? It is a tantalising notion indeed!

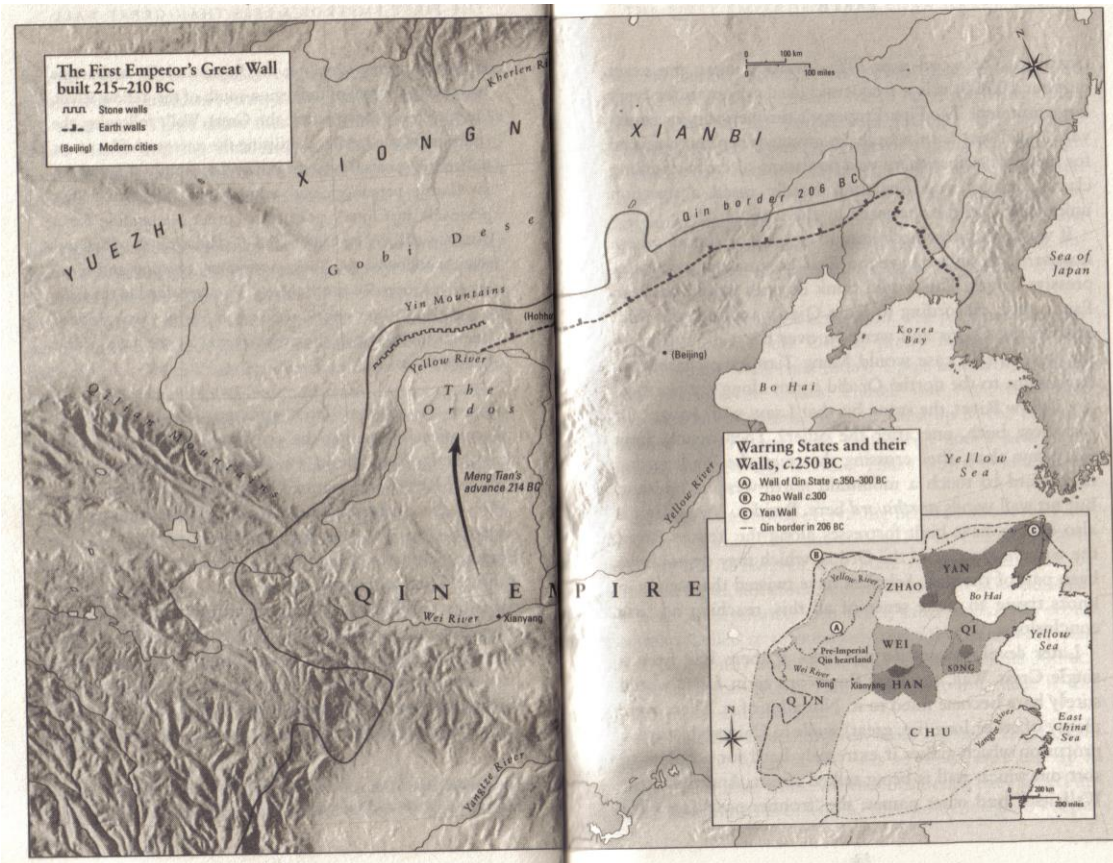


Fig. 8 The First Emperor's northern boundary line as delineated by the first "Great Wall"

The two Han Dynastic Periods from 202 BC to 220 AD saw the western extension of this Wall. From this time onwards more local walls were erected from 220 to 1234 while during the domination of the Mongols from 1234 to 1368, the latter under the leadership of the mighty Genghis Khan himself for a period, the Wall was left to natural decay and dilapidation until the rise of the mighty Ming Dynasty.

Probably more well-renowned for its treasured blue and white ceramics the Ming Dynasty was much more than just a ruling class of potters. After crushing the Mongol Army in 1368 the Ming leaders could not have imagined that their dynasty would prevail right through until 1644 when they were out-manoeuvred by the Manchus whose reign is called the Qing Dynasty lasting until 1911. The modern populist vision of a Great Wall of stone with crenellated ramparts and beacon towers running along the mountain tops as far as the eye can see is owed to the work of the Mings whose capital works program included this monumental construction. Their intentions certainly were to fortify and protect their territory and citizens from the ravaging marauders but by placing their walls along ridge lines which were already natural borders separating two different tracts of land they had unintentionally set about placing the most famous and impressive boundary monument ever created by man on earth.

During war and peace the Ming kept on building their wall despite much dissension about the cost of such a capital works program when other areas were considered to

be deserving of more priority. However up until 1568 there were still many defensive gaps in the wall and hardly any beacon towers of note at all. All was soon to undergo major improvement in these areas at the behest of one of China's heroes named Qi Jiguang who became the principal architect of the Great Wall in its iconic modern image of the grandest of designs. With an upbringing which indoctrinated discipline, loyalty, martial arts, philosophy and dedication Qi, at the age of forty, was entrusted with the duty to reinforce the northern wall to a military standard against the



Fig. 9 Qi Jiguang's statue proudly standing within view of his greatest project – The Great Wall

perceived northern savages. Embracing his assignment with enthusiastic zest Qi knew exactly how and what he was intending to achieve but as has been the custom from time immemorial the Imperial Treasury forced him to rein in his grandiose ideas with his desired 3,000 forts reduced to 1200 of which only 1017 were actually built. Any appeals for urgency to construct Qi's reinforcements greatly dissipated after the treaty with Altan in 1571. Nevertheless the resourceful soldier was able to exploit the paranoia of the bureaucratic officials convincing them that there was no better time to prepare for war than during peace time so the substantial construction scheme was allowed to carry on in earnest. Finally taking around ten years to come to fruition Qi had ultimately succeeded in facing the existing Qin Wall with bricks and stone while turning the top of the structure into a paved roadway or trafficable stepped areas where slopes became too inclined. This roadway was to be crenellated for protection while under assault as well as being punctuated with forts standing on blocks 10 to 15

metres (3-4 storeys) above the Wall itself each accommodating up to 50 men together with food and ammunition. Qi's Great Wall was a fully self-contained interactive defensive network which was never actually subjected to any engagements to practically test its effectiveness so the Chinese legend had created the future symbol of China without realising that it would never be utilised for the purpose for which he had so systematically devised it. As can be seen from the map of the Ming Dynasty this magnificent Great Wall creation did indeed follow the northern boundary of the territorial limits of the Ming Empire

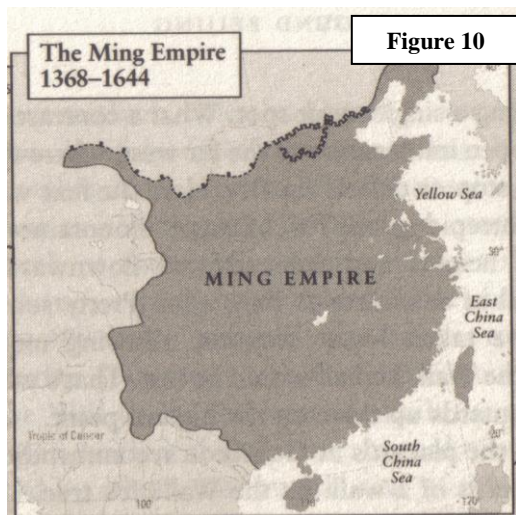


Figure 10

easterly as far as the ocean at Shanhaiguan.

For a long period after the Manchu conquest of the Mings in 1644 the dynasty known as the Qing once again subjected the Great Wall to abject neglect and inattention right

up until 1911 being over 260 years of the abrogation of required maintenance. Even between 1911 and 1949 there was a negligible effort to restore China's iconic symbol of the nation's historical accomplishments. It was left to the Communists from 1949 until the current day to set about an extensive renovation of Qi's magnificent edifice.



Through the very recent actions of the State Administration of Cultural Heritage not only has the wall been refurbished but two more areas at Huanghuacheng and Hefangkou have been prepared for touristic inspection to provide even greater accessibility to this marvel of Chinese civil construction. Both of

THE GREAT WALL

the existing viewing sites at Badaling and Mutianyu have also been upgraded in the latest improvements to further demonstrate China's enthusiasm to show off their legendary monument to the rest of the world.

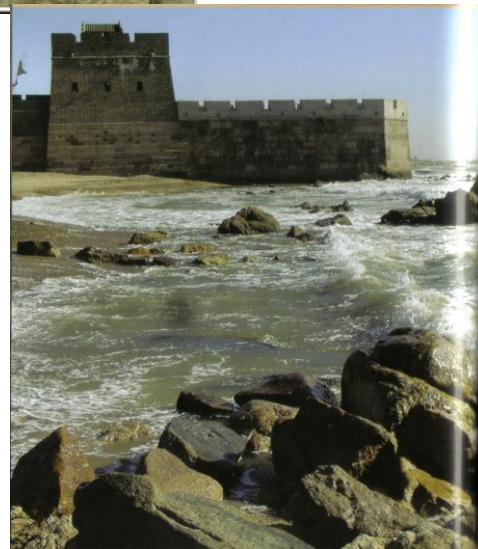
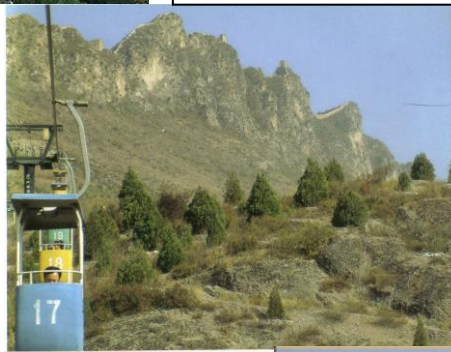


FIGURE 11

THE SEA

CONCLUSION

My journey of discovery into the surveyors of ancient China combined with the fascinating epic tale of the history of the Great Wall of China has given me an incredible appreciation for the brilliance of the great surveyors and engineers of the Imperial Eastern civilization. My Homeresque revelation of the mythological figures of Chinese folklore whose symbols were to become the future measuring devices for the surveyors of yore was most exciting and very surprising along with the amazing echelons of mathematics and measurement that were achieved by this covert culture.

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