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Laying Out Land Parcels and the Oldest Boundary Stone in Croatia from the 4th Century BC

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Abstract: *Geographical position of the Chora Pharos (nowadays Starogradsko polje), climate conditions and brief historical development of colonization on the island of Hvar are described in the paper. Also described is how Greek from the island of Paros established the town Pharos (today's Stari Grad) and how they constructed Chora Pharos (today's Starogradsko polje). They divided the field Starogradsko polje into rectangular parcels with dimensions 1 Greek stage × 5 Greek stage (181 m × 905 m). The large project "Starogradsko polje" demonstrated that one Pharos foot equals 0.3026 m. They used the groma for pegging out orthogonal angles. Finally, there is a photograph of the boundary stone from the Chora Pharos (Starogradsko polje) from the 4th century before Christ which is deposited in the Archaeological Museum in Zagreb. This is the oldest boundary stone in Croatia and as geodesists, we can consider it a geodetic monument.*

Key words: *chora, ager, Starogradsko polje, Faros (Pharos), Stari Grad, Hvar, groma, kálamos (pole), Greeks, island of Páros, Pythagoras' theorem, Greek foot, Greek stage, right angle, boundary stone, Romans.*

1. Introduction

The island of Hvar (Fig. 1) came to be in the postdiluvial era (about 18 000 years BC) when the coast of the Adriatic Sea was formed due to deglaciation and increasing ocean level (URL 8). It is characterized by mild climate with middle temperatures:

- 8.4 ºC in January, so snow and temperatures below 0 ºC are rare, and
- 24.8 ºC is the average temperature in July.

It has the greatest insolation in Croatia, 2718 hours annually. The island receives about 780 mm of precipitation annually, most of it during the winter, while summers are mostly dry. Nowadays there are no larger water flows, while there are minor springs in places where dolomites and flysch marls meet. The only larger spring can be found near Jelsa (Šentija 1997, p. 543). There are also some brackish water streams (mixture of fresh and sea water) in Jelsa, Stari Grad and Vrboska.

The forest vegetation covered the whole island until the forest was cleared in dolomite vales and flysch areas, more suitable for agriculture. The largest fertile field

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Iskolčenje zemljišnih čestica i najstariji kamen međaš u Hrvatskoj iz 4. stoljeća prije Krista

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Sažetak: *U članku su opisani geografski smještaj faroske hore (Starogradskog polja), klimatski uvjeti i kratki povijesni razvoj naseljenosti otoka Hvara. Zatim je opisano kako su Grci s otoka Párosa osnovali grad Faros (Pharos, današnji Stari Grad) i izgradili Horu Pharos (danas Starogradsko polje). Pri izmjeri Starogradskoga polja podijelili su ga na pravokutne čestice dimenzija 1 grč. stadij × 5 grč. stadija (181 m × 905 m) koristeći dimenzije svojih "stopa". U velikom projektu "Starogradsko polje" pokazano je da su dimenzije njihovih stopa bile 0,3026 m. Za iskolčenje pravih kutova koristili su gromu. Na kraju je priložena slika očuvanoga kamena međaša iz 4. st. pr. Kr. iz Starogradskoga polja, koji se čuva u Arheološkome muzeju u Zagrebu. To je najstariji kamen međaš u Hrvatskoj, a geodeti ga ubrojaju u geodetske spomenike.*

Ključne riječi: *hora, ager, Starogradsko polje, Faros (Pharos), Stari Grad, Hvar, groma, kalamos (trasirka), Grci, otok Páros, Pitagorin poučak, grčka stopa, grčki stadij, pravi kut, granični kamen, Rimljani.*

1. Uvod

Otok Hvar (sl. 1) nastao je u postdiluvijalno doba (oko 18.000 godina prije Krista), kada se zbog deglacijacije i većeg porasta razine oceana formirala obala Jadranskoga mora (URL 8). Odlikuje se blagom klimom sa srednjim temperaturama:

- u siječnju 8,4 ºC, tako da su na njemu snijeg i temperature ispod 0 ºC rijetka pojava, a
- u srpnju 24,8 ºC.

Otok Hvar ima najveću osunčanost (najdužu insolaciju) u Hrvatskoj od 2718 sati godišnje. Prima oko 780 mm oborina godišnje, i to najviše u zimskom razdoblju, a ljeta su pretežno suha. Danas na otoku nema većih vodenih tokova, a na kontaktima između dolomita i flišnih lapora izbijaju manji izvori. Jedini veći izvor vode nalazi se kraj Jelse (Šentija 1997, str. 543). U Jelsi, Starome Gradu i Vrboskoj postoje i manji bočati potoci (mješavine slatke i slane vode).

Šumski pokrov pokrivao je čitav otok, a poslije je šuma iskrčena u dolomitskim udolinama i flišnim područjima,

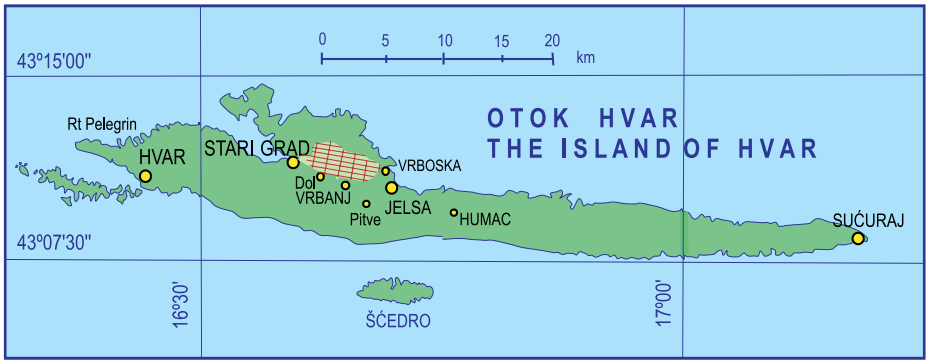


Fig. 1. The Island of Hvar is about 70 km long
Slika 1. Otok Hvar dug je oko 70 km

on the island of Hvar is Starogradsko polje, which is at the same time the largest fertile field among all Adriatic islands.

The island of Hvar was populated as early as the prehistoric era, more than 6000 years ago, which is evidenced by Neolithic findings from eneolithic period to the Iron Age in caves:

- Grapčeva Cave (in the middle part of the island, Jelsa district, about 1 km southwest of the hamlet of Humac, east of the village of Gromin Dolac), where a ship was engraved into fragments of a pot, the oldest found representation of a ship in Europe (URL 2),
- Markova Cave (cape Pelegrin, western part of the island of Hvar),
- Babina Cave, Smokova Cave and others (URL 9).

Findings of the characteristic Hvar culture from that period (3500 – 2500 BC) can be found on the island, for example coloured ceramics (grey, yellow or white ornaments on a red base, red ornaments on a black base).

The island was later settled by Illyrians, who confronted Greeks who started colonizing the island at the beginning of the 4th century. It was then that the Greek colony Faros (Pharos Greek Φαρος), today's Stari Grad came to be, established by Greeks from the island of Páros (from one of the Cyclades' islands in the Aegean Sea, southeast from Athens, Fig. 2) in 385 BC.

Afterwards, Hvar was prominent in Roman – Illyrian struggles when its administrators (Demetrius of Hvar) wanted to maintain independence. During the Roman period, Hvar lost its former importance and developed in conditions similar to those of other Roman cities in Dalmatia.

After the downfall of Syracuse (located on the southeast coast of Sicily, founded as a Greek colony in 734 BC), an important protector of the island of Hvar, the Greek reign of the island of Hvar ended. The island came under control by the old Rome in 219 BC, and Pharos became Pharia.

In 476, the Germanic commander Odoacer defeated the final emperor of the Western Roman Empire Romulus Augustus, after which the island of Hvar was included in the Byzantine Empire.

This was followed by the island of Hvar being possessed by the Neretva Principality. During the same period, the population became completely Slavic and adopted the Croatian language, culture and names. The old Slavic tribe Slavogosta populated the island at the time (URL 2).

2. Establishment of Faros (Pharos) – Stari Grad

Between the 8th and 4th century BC, the ancient Greeks established numerous colonies all over the Mediterranean, as well as in the Black Sea. Thus the Greeks from the island of Páros established Faros at the beginning of the 4th century BC (Pharos – today's Stari Grad on the island of Hvar), Greeks from Sicily established Issa, also at the beginning of the 4th century BC (Greek Ισσα – today's Vis on the island of Vis), and Greeks from the island of Knidos (island by Asia Minor) most probably established a colony on the west part of the island of Korčula (URL 10). The colony on the east part of the island of Korčula, in the place of today's Lumbarda, was established by colonized Greeks from Vis (URL 16, Belamarić 1998, Fig. 2).

During the old times, it was customary for Greeks to visit oracles to have their futures foreseen prior to making important decisions. Thus they usually went to:

- The oldest Hellenistic oracle in Dodona (in Epirus, northern Greece), which was at first devoted to Mother Goddess, and later to Zeus or
- The famous Apolon's oracle in Delphi (in the somewhat lower, southern part of Parnassus), famous by the prophetess Pythia.

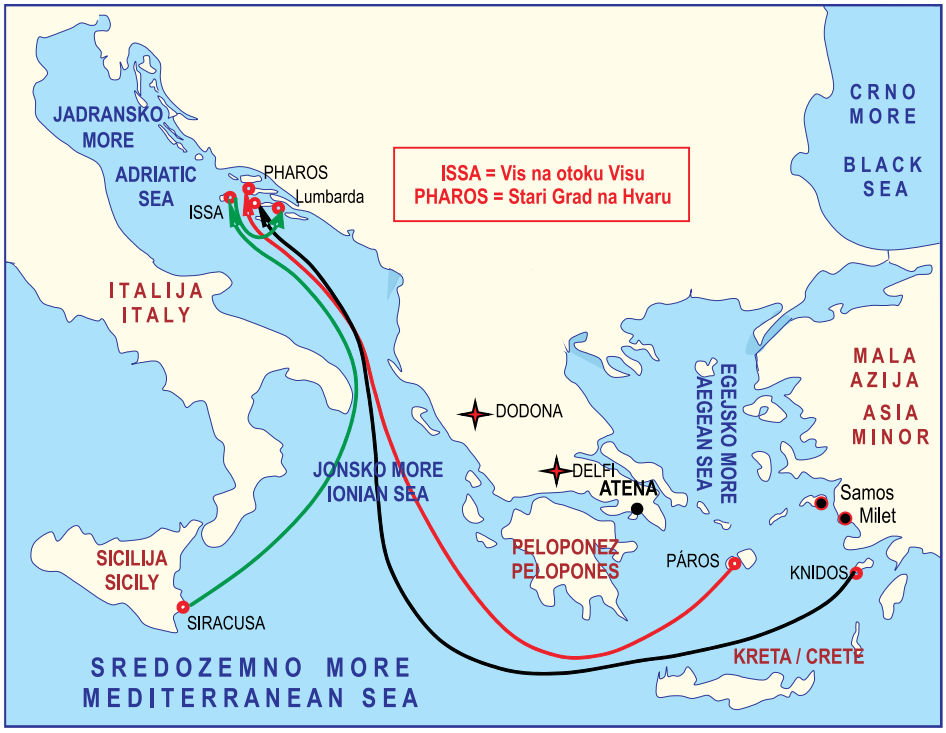


Fig. 2. Greek colonies Issa (Vis) on the island of Vis, Pharos (Stari Grad) on the island of Hvar and Lumbarda on the island of Korčula (according to Belamarić 1998, URL 10 and URL 16).

Slika 2. Grčke kolonije Issa (Vis) na otoku Visu, Pharos (Stari Grad) na otoku Hvaru i Lumbarda na otoku Korčuli (prema Belamarić 1998, URL 10 i URL 16).

pogodnima za poljodjelstvo. Najveće plodno polje na otoku Hvaru je Starogradsko polje, koje je i najveće plodno polje među svim jadranskim otocima.

Otok Hvar naseljen je već u prapovijesno doba, prije 6000 godina, o čemu svjedoče neolitički nalazi iz razdoblja eneolitika do željeznog doba u špiljama:

- Grapčeva (u srednjem dijelu otoka, Općina Jelsa, oko 1 km jugozapadno od zaselka Humac, istočno od sela Gromin Dolac), gdje je na fragmentima jedne posude urezan lik brodice, što je najstariji pronađeni prikaz lađe u Europi (URL 2),
- Markova (na rtu Pelegrin, zapadni dio otoka),
- Babina, Smokova i druge (URL 9).

Iz tog razdoblja na otoku postoje nalazi osebujne hvarske kulture (3500–2500. god. pr. Kr.), poznate po bojenoj keramici (na crvenoj podlozi sivi, žuti ili bijeli ornamenti, na crnoj podlozi crveni ornamenti).

Poslije su otok naselili Iliri; oni su se na početku 4. stoljeća prije Krista sukobili s Grcima, koji su počeli kolonizirati otok. Tada je nastala grčka naseobina Faros (Pharos, grčki Φαρος), današnji Stari Grad, koji su 385. god. pr. Kr. osnovali Grci s otoka Párosa (s jednog od otoka Ciklada, smještenih u Egejskome moru, jugoistočno od Atene, sl. 2).

Hvar se isticao u rimsko-ilirskim borbama kad su njegovi upravljači (Demetrije Hvaranin) željeli sačuvati samostalnost. U rimsko doba Hvar je izgubio nekadašnji značaj, te se razvijao u sličnim uvjetima kao i ostali rimski gradovi u Dalmaciji.

Padom Siracuze (smještene na jugoistočnoj obali Sicilije, osnovane kao grčka kolonija 734. god. pr. Kr.), bitne zaštitnice otoka Hvara, završava vlast starih Grka na Hvaru. Otok pada pod vlast starog Rima 219. god. pr. Kr., a Pharos je dobio ime Pharia.

Germanski vojskovođa Odoakar srušio je 476. godine posljednjeg cara Zapadnorimskog Carstva Romula Augusta, a nakon toga otok Hvar ostaje u okviru Bizantskog Carstva.

Potom je otok došao u trostoljetni posjed Neretvanske kneževine. U istom razdoblju stanovništvo se poslavenjuje u potpunosti i poprima hrvatski jezik, kulturu i nazive. Tada se na otoku naselilo staroslavensko pleme Slavogosta (URL 2).

2. Osnivanje Farosa (Pharosa) – Staroga Grada

Od 8. do 4. st. pr. Kr. antički Grci osnovali su veliki broj kolonija po cijelom Sredozemlju, a i na Crnome moru. Tako su Grci s otoka Párosa početkom 4. st. pr. Kr. osnovali Faros (Pharos – današnji Stari Grad na otoku Hvaru), Grci sa Sicilije su također početkom 4. st. pr. Kr.

The Greeks of Páros went to the oracle in Dodona, which is evidenced by a lead plate from the 4th century BC. It was found in Zeus's shrine with an engraved question by an unknown Greek. The Greek asked the following question in the oracle: "Is it gainful to go to Faros (Hvar) with people of Páros?" (URL 13).

Since the answer was positive, the people of Páros had to move their fellow citizens, build a city and distribute fertile land among colonists. It was a very complex task. Thus the assembly of the city of Páros chose Okist to lead them and be responsible for:

- Safe voyage
- Relations and deals with native people
- Organizing settlers as a political community with all institutions of a city-country
- Organizing a military force to defend the community from enemies
- Regular distribution of land among settlers, both within a city for living and common areas and for land for settlers to cultivate within a corresponding chora territory (URL 1).

Greek cities (countries) or poleis (Greek πολισ) had a territory under their administration with the primary purpose of organizing agriculture of the so-called chora (Greek χωρα). Old Romans called such a land ager. Old Greeks called the city centre asty (Greek αστυ), and there was also a buffer zone between asty and chora which was used for hunting, pasture, production of honey and collecting firewood, which they called aschatia.

The key operation in establishing Greek colonies was the distribution of agricultural land among colonists. Namely, even nowadays geodesists know that land distribution is a complex geometric exercise, but interpersonal relations between parties participating in the distribution can also be complex. This problem of interpersonal relations, i.e. quarrels, was solved by drawing lots, for example in Lumbarda on the island of Korčula (URL 16).

A grid of old Greeks' and old Romans' distributed parcels was usually a regular rectangular grid, i.e. composed of regular equal geometric shapes.

Aristotle introduced a word for practical geometry, geodesy, γεωδαιρία = land distribution (Čubranić 1954, page 577; Aristotle Metaphysics, book 2, 997b, 26, 31). According to him, geodesy also includes all types of surface and body surveys.

During the prehistoric era, the Hvar settlement was the main native settlement on the island, and people of Páros probably negotiated with them about them colonizing the island of Hvar. They also received a positive answer from the oracle in 385/384 BC, and settled about 100 of their families in Faros (Pharos, URL 1), i.e. about 1000 people (URL 6, URL 13).

Establishment of Faros was written about by Greek historian Diodorus of Sicily in the 1st century BC (URL 13). This is at the same time the only antique written source about the founding year of the Paros colony and events which followed it. Namely, the natives (called barbarians by the Greeks) agreed to peacefully establish a city on the island, but the following year they perceived that Greeks did not abide by the agreement. Therefore they called the Illyrians from the land who came to the island with lots of small ships, and then attacked and killed numerous Greeks.

However, the governor of Lisos (today's Lezhë in Albania) appointed by Dionysius the Elder of Sicily (about 432 – 367 BC, at the time the ruler of the Mediterranean) sailed with lots of triremes (a ship with three rows of rowing banks) versus Illyrian vessels. In doing so, he killed more than five thousand barbarians and enslaved about two thousand. Dionysius the Elder expanded his reign to southern Italy and secured predominance of Syracuse in the Tyrrhenian Sea, so he supported Greeks from Páros to establish a colony in Stari Grad (Faros).

A stone plate inscription exists from Faros and the 4th century BC which bears witness to the victory of people of Faros over Jadasi and their allies (URL 13).

The people of Páros brought grape vine and olives to Hvar. They praised grape vine on Hvar very highly, since they worshipped Dionysus, the Greek god of fertility, pleasure, intoxication and wine, and the son of their main god Zeus and goddess Semele. They forged silver and copper money (URL 13).

Interestingly, famous Alexandrian Greek astronomer and geographer Eratosthenes of Cyrene (276 – 194 BC) was aware of Pharos (Lisičar 1951).

3. Construction of Faros chora – Starogradsko polje

The Faros chora, i.e. today's Starogradsko polje is about 6 km long and extends from Stari Grad to Vrboska, and is about 2 km wide. It is situated in the middle part of the island of Hvar (Fig. 1).

Up until thirty years ago, it was presumed that the well-preserved remains of dry stone wall around parcels in Starogradsko polje were from the Roman period, because most of the other remains and artefacts were from the Roman period. However, newer systematic research (URL 17) has showed that well-preserved remains of dry stone wall around parcels are actually remains of an older Greek parcellation. A smaller number of other remains from the Greek period were also found in the area.

The field was divided into 73 rectangular parcels of 1 stage × 5 stages (about 181 m × 905 m), and some

osnovali Issu (grč. Ισσα – današnji Vis na otoku Visu), a Grci s Knidosa (otok uz Malu Aziju) osnovali su najvjerojatnije koloniju na zapadnom dijelu otoka Korčule (URL 10). Koloniju na njegovu istočnom dijelu, na mjestu današnje Lumbarde, osnovali su kolonizirani Grci s Visa (URL 16, Belamarić 1998, sl. 2).

Prema tadašnjem običaju, prije donošenja važne odluke, Grci su išli u proročišta da im proreknu budućnost. Obično su išli po savjet u:

- najstarije helensko proročište u Dodoni (smješteno u Epiru, u sjevernoj Grčkoj), koje je bilo najprije posvećeno boginji Majci, a poslije Zeusu, ili
- u čuveno Apolonovo proročište u Delphima (smješteno u nešto nižem, južnom dijelu Parnasa), poznato po proročici Pitiji (Pythia).

Grci iz Párosa išli su po savjet u proročište u Dodoni, o čem svjedoči olovna pločica iz 4. st. pr. Kr., pronađena u Zeusovu svetištu u Dodoni, s urezanim pitanjem nepoznatoga Grka. Taj Grk je u proročištu postavio pitanje: "Je li probitačno s Páranima otići na Faros (Hvar)?" (URL 13).

Kako je dobiven pozitivan odgovor, Párani su morali preseliti svoje sugrađane, izgraditi grad i podijeliti plodno zemljište među kolonistima. To je bio vrlo složen posao, pa je skupština grada Párosa izabrala Okista da ih predvodi i da odgovara:

- za sigurnu plovidbu,
- za odnose i dogovore s domaćim stanovništvom,
- za organiziranje doseljenika kao političke zajednice sa svim institucijama grada-države,
- za organiziranje vojne sile koja će braniti zajednicu od neprijatelja,
- za pravilnu podjelu zemljišta doseljenicima, kako unutar grada za stanovanje i zajedničke prostore, tako i zemljišta koja će doseljenici obrađivati unutar pripadajućeg teritorija hore (URL 1).

Grčki gradovi (države) ili polisi (grč. πολισ) imali su teritorij koji je bio pod njihovom upravom s primarnom namjenom za organiziranje poljoprivrede, tzv. hora (grč. χωρα). Za takvo zemljište stari su Rimljani koristili naziv ager. Gradsko središte stari su Grci nazivali asti (grč. αστυ), a postojala je i tampon zona između asti i hore, koju su nazivali aschatia, koja je služila za lov, ispašu, proizvodnju meda i za skupljanje ogrjeva.

Ključna operacija pri osnivanju grčkih kolonija bila je podjela poljoprivrednog zemljišta među kolonistima. Naime, i danas geodeti znaju da je podjela zemljišta složen geometrijski problem, ali mogu biti i složeni međuljudski odnosi između stranaka koje sudjeluju u podjeli. Problem međuljudskih odnosa, tj. svađa, oni su riješili izvlačenjem, odnosno ždrijebom svih parcela, kao na primjer u Lumbardi na Korčuli (URL 16).

Mreža dodijeljenih čestica (parcela) starih Grka, a poslije i Rimljana, bila je obično pravilna pravokutna mreža, tj. sastavljena od pravilnih jednakih pravokutnih geometrijskih likova.

Aristotel je za praktičnu geometriju uveo riječ geodezija: γεωδαιρία = podjela zemlje (Čubranić 1954, str. 577) (Aristotel: Metafizika, knjiga 2, 997b, 26, 31). Po njemu, geodezija sadrži i sve vrste mjerenja površina i tjelesa.

U prapovijesno doba Hvar je bilo glavno domorodačko naselje na otoku, te su Párani vjerojatno pregovarali s njima o svojoj kolonizaciji na otok Hvar. Oni su dobili i pozitivno mišljenje iz proročišta 385./384. god. pr. Kr., te su u Faros (Pharos) naselili oko 100 svojih obitelji (URL 1), tj. oko 1000 ljudi (URL 6, URL 13).

O osnutku Farosa pisao je grčki povjesničar Diodor sa Sicilije u 1. st. pr. Kr. (URL 13). To je i jedini antički pisani izvor o godini osnutka parske kolonije i događajima koji su se zbili nedugo zatim. Naime, domorodci (koje su Grci nazivali barbarima) dali su im suglasnost o mirnom osnivanju grada na otoku, ali godinu poslije uvidjeli su da se Grci, po njihovu mišljenju, ne pridržavaju dogovora. Zato su pozvali Ilire s kopna, koji su prešli na otok s mnogo malih brodova te su napali i pobili mnogo Grka.

Međutim, namjesnik Lisosa (danas Lješ u Albaniji), kojega je postavio Dionizije Stariji sa Sicilije (oko 432–367. god. pr. Kr., koji je u to doba bio gospodar Sredozemlja), zaplovio je s većim brojem trirema (lađa s tri reda veslačkih klupa) protiv ilirskih brodica. Pritom je pobio više od pet tisuća barbara i zarobio ih oko dvije tisuće. Dionizije Stariji proširio je svoju vlast na južnu Italiju i osigurao prevlast Sirakuze na Tirenskome moru, pa je podupirao Grke s otoka Párosa da osnuju koloniju Faros na Hvaru.

Postoji natpis iz Farosa, urezan u kamenu ploču, koji govori o pobjedi Farana nad Jadasima i njihovim saveznicima iz 4. st. pr. Kr. (URL 13).

Párani su dovezli na Hvar vinovu lozu i masline, a koliki su značaj pripisivali vinovoj lozi na Hvaru govori činjenica da su obožavali Dioniza, grčkoga boga plodnosti, uživanja, opojnosti i vina, sina njihova glavnog boga Zeusa i božice Semele. Kovali su svoj srebrni i brončani novac (URL 13).

Zanimljivo je da je slavni grčki i aleksandrijski astronom i geograf Eratosten iz Kirene (276–194. god. pr. Kr.) znao za Pharos (Lisičar 1951).

3. Izgradnja Faroske hore – Starogradskog polja

Faroska hora, tj. današnje Starogradsko polje dugo je oko 6 km i proteže se od Staroga Grada prema Vrboski, a poprečno je široko oko 2 km. Smješteno je u središnjem dijelu otoka Hvara (sl. 1).

Sve do prije trideset godina pretpostavljalo se da su dobro očuvani ostaci suhih zidina oko parcela u Starogradskom polju iz rimskoga doba, jer je većina ostalih

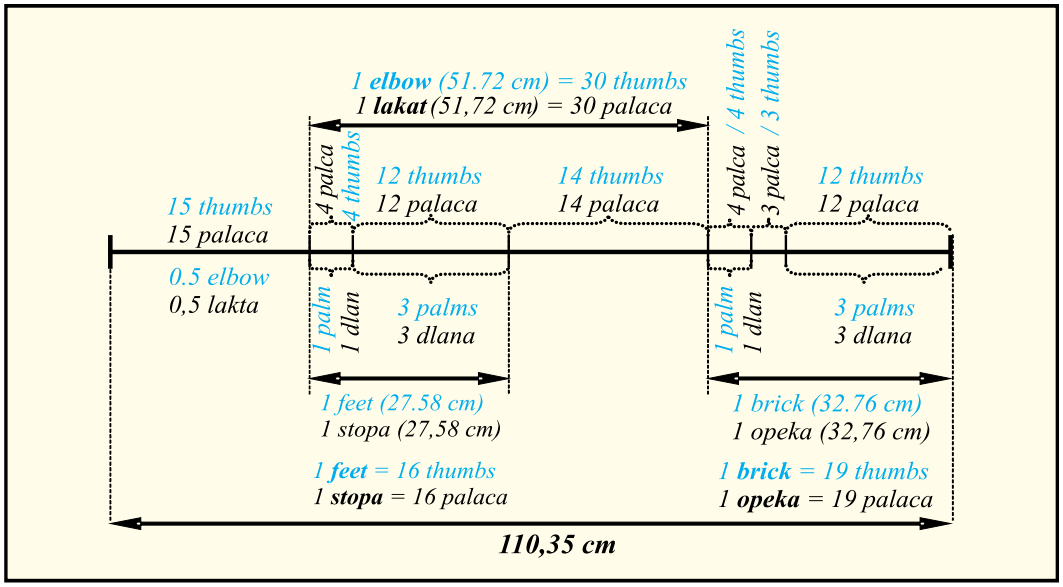


Fig. 3. Sketch of Babylonian pre-measure and used official length units. Archaeological excavations prove the copper staff was in use from about 2000 BC (Brezinšćak 1971)

Slika 3. Skica babilonske pramjere i korištenih službenih jedinica duljina. Arheološka iskapanja dokazuju da je taj bakreni štap bio u uporabi od oko 2000. god. pr. Kr. (Brezinšćak 1971).

parcels were divided into squares of 181 m × 181 m and within parcels. Old dry stone wall and field shelters are an example of antique usage of geometric system of parcellation in ancient Greece, which remained practically intact during 24 centuries, and Starogradsko polje was included in the UNESCO world heritage list in June 2008 (URL 3, URL 5).

In order for Greeks (and later, Romans) to distribute equal parts of cultivated land to their colonists, they had to have educated people who knew mathematics, geometry, surveying, but who also had the instruments and equipment necessary for surveying.

3.1. Basic measurement units for lengths

Babylonians were the first in the history of mankind to have a unique measurement system regulated by a ruler. They had special pre-measures made in a way similar to those we use today. Namely, archaeological excavations unearthed their pre-measure from about 2000 BC. It is a copper staff 110.35 cm long weighing 41.5 kg. The staff has engravings marking lengths of smaller units:

- elbow (51.72 cm) which had 30 thumbs,
- foot (27.58 cm) which had 16 thumbs,
- palm (6.90 cm) which had 4 thumbs and
- brick (32.76 cm) which had 19 thumbs

Babylonians also had other units for measuring length, for example:

- subban (29.7 m) had 60 ammatu (a),
- gar (5.940 m) had 12 a,
- kanu (2.97 m) had 6 a, where a = 0.495 m, i.e. a step (Brezinšćak 1971, pp. 178-179).

They expressed areas in burs (1 bur = 1800 square gara ≈ 63510 m^2; Kadi 1988).

Trading caused these high cultures' measures to come from Mesopotamia to Egyptians and Phoenicians, as well as to Greeks and Romans.

Egyptians surveyed land more accurately, they used measuring tape, and they also had standardized length of elbow:

- king's elbow was about 52 cm long,
- short elbow had about 45 cm.

The two units were divided into spans, palms and thumbs.

Fig. 4 represents measuring with a measuring tape 12 elbows long. Elbows were marked with knots, and the reel was adorned with the symbol of god Amon, i.e. the protector of Egyptian surveyors. In surveying, the last surveyor carried a spare reel with measuring tape (Korošec 1978, p. 17).

Sticks were made for the length of one elbow to be used as measuring units of length. Such sticks were a characteristic of Egyptian surveyors, who were buried with them (Čubranić 1954, p. 575). Namely, according to Egyptian customs, a person was to be buried with things he used in life.

Egyptians had a practical measure for area arura, which was actually a square with a side of 100 king's

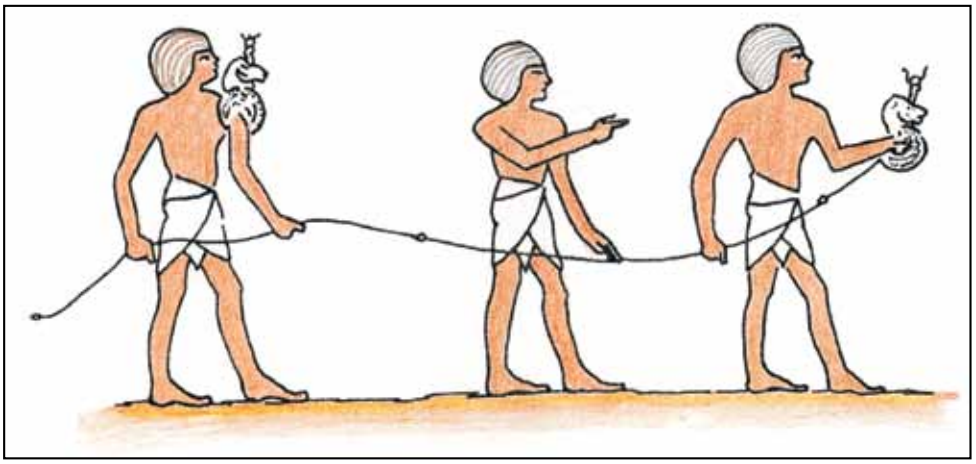


Fig. 4. Old-Egyptian measuring tape 12 elbows long (according to Korošec 1978)
Slika 4. Staroegipatska mjerna vrpca duljine 12 lakata (prema Korošec 1978)

pronađenih ostataka i artefakata iz toga doba. Međutim, novija sustavna istraživanja (URL 17) pokazuju da su ostaci suhih zidina zapravo ostaci starije grčke parcelacije. Na tom području pronađeni su u nešto manjem broju i neki drugi ostaci iz grčkoga doba.

Polje je bilo podijeljeno na 73 pravokutne čestice dimenzija 1 stadij × 5 stadija (oko 181 m × 905 m), a neke su čestice podijeljene na kvadrate 181 m × 181 m i unutar parcela. Stari kameni suhozidi i skloništa u polju primjer su antičkoga korištenja geometrijskog sustava podjele zemljišta u staroj Grčkoj, koji su ostali praktično netaknuti 24 stoljeća, te je Starogradsko polje u lipnju 2008. godine uvršteno na UNESCO-ov popis svjetske baštine (URL 3 i URL 5).

Kako bi Grci, a poslije i Rimljani, svojim kolonistima podijelili obradivu zemlju na jednake pravilne dijelove, morali su imati sa sobom obrazovane ljude, koji su znali matematiku, geometriju, mjeriti te su posjedovali potreban instrumentarij s priborom za mjerenje.

3.1. Osnovne mjerne jedinice duljine

Babilonci su bili prvi u povijesti čovječanstva koji su imali jedinstven sustav mjera, što ga je propisao vladar. Oni su imali posebne pramjere, izrađene slično kao današnje. Arheološkim iskapanjima pronađena je njihova pramjera iz oko 2000. godine pr. Kr. To je bakreni štap duljine 110,35 cm i mase 41,5 kg. Na štapu su urezane crte s međusobnim razmacima, koji označavaju duljine manjih jedinica:

- lakat (51,72 cm), koji je imao 30 palaca
- stopa (27,58 cm) je imala 16 palaca
- dlan (6,90 cm) je imao 4 palca i
- opeka (32,76 cm) je imala 19 palaca.

Babilonci su imali i druge mjerne jedinice za duljinu, na primjer:

- subban (29,70 m) je imao 60 ammatu (a),
- gar (5,940 m) je imao 12 a,
- kanu (2,97 m) je imao 6 a, gdje je a = 0,495 m, tj. to je korak (Brezinšćak 1971, str. 178 i 179).

Površine su izražavali u burima (1 bur = 1800 kvadratnih gara ≈ 63510 m^2, Kadi 1988).

Trgovinom su mjerne tekovine tih visokih kultura iz područja Mezopotamije prenesene najprije Egipćanima i Feničanima, a onda Grcima i Rimljanima.

Izmjera zemljišta kod Egipćana bila je na višem stupnju; služili su se mjernom vrpcom, a imali su i normiranu duljinu lakta:

- kraljev lakat bio je dugačak oko 52 cm,
- mali lakat imao je oko 45 cm.

Te dvije jedinice bile su podijeljene na pedlje, dlanove i palce.

Na (sl. 4) prikazano je mjerenje s pomoću mjerne vrpce duljine 12 lakata. Lakti su bili označeni čvorovima, a kolut za namatanje bio je ukrašen simbolom boga Amona, tj. zaštitnikom egipatskih mjernika. Mjernik koji je pri mjerenju išao zadnji nosio je rezervni kolut s mjernom vrpcom (Korošec 1978, str. 17).

Za mjernu jedinicu jednog lakta bili su izrađeni štapovi, kao mjerne jedinice duljine. Takvi štapovi bili su oznaka egipatskih mjernika te su s njima polagani u grobove (Čubranić 1954, str. 575). Naime, prema egipatskim običajima uz pokojnika su u grobove polagane stvari koje je on koristio u životu.

elbows. 1/2, 1/4, 1/8 and 1/16 of arura were also in use (Brezinšćak 1971, p. 179).

Egyptians had harsh punishment for traders who cheated weighing goods, and they also had an outspread network and service of pharaoh gauging office for controlling measures, which was done by leading officials of those offices.

Greeks took most measuring units from Egyptians and subsequently handed them to Romans. There are fairly reliable data about Greek measures, though they vary according to different sources.

Thus, according to (Brezinšćak 1971, p. 180), an old-Greek foot was 30.83 cm long, and an old-Greek stage had 600 feet.

According to (URL 7), Greeks had following measuring units for length:

- Athens foot, i.e. Ionian, about 0.296 m long,
- Dorian foot, about 0.326 m long and
- Normal Greek foot, 0.308 and 0.316 m long.

Greeks also had these measuring units: finger, span and elbow, as well as several shorter and longer. In addition, some locations had their own measuring units for length.

It is unknown which foot the people of Páros used. However, the large scientific project "Starogradsko polje" (URL 3) used statistical data of parcel lengths in Starogradsko polje to derive the length of their foot: 0.3026 m (URL 7). Therefore, it was neither Athens, Dorian, Normal Greek foot, nor the one noted by Brezinšćak (1971).

It can be assumed that people of Páros surveyed parcel side lengths using measuring tapes similar to Egyptian ones, which were not calibrated accurately enough, and it was possible they could deform due to changes in temperature and due to transport and work.

Greeks expressed areas in area units called plethrons, which contained 100 feet × 100 feet each, i.e. about 950 m^2 (Brezinšćak 1971, p. 181). Sources (URL 16, p. 4, URL 18) refer to pletar as an area unit.

About year 300, Romans used Greek measuring units for length, but they also cared about their own measure system. Thus they preserved standardized staves in Capitol, and they incorporated their copies in public buildings so that citizens could use them. Their measuring units for lengths were:

- Roman foot = 0.296 m
- Greek-Roman stage = 600 Roman-Greek feet = 177.6 m
- Digitus = 1.85 cm
- Iter pedestre = 28.725 km, a day of journey (Brezinšćak 1971, p. 181).

According to (Ilakovac 2002, p. 169), Romans had the following units for lengths:

- Roman foot = 0.296 m
- Double step = 5 Roman feet = 1.48 m
- Actus = 120 steps = 120 steps × 5 Roman feet/step = 600 Roman feet = 177.6 m
- Stage = 4 actus = 4 × 120 steps × 5 Roman feet/step = 4 × 600 Roman feet = 710.4 m.

Their area units were:

- Juger = 240 feet × 120 feet = 28800 $feet^2$ = 2523.34 m^2
- Centurij = 200 jugers (for Empires) = 504668 m^2 ≈ 50.5 ha.

Romans had drafts and protocols for divided colonial land (ager divisus et assignatus), and they usually divided land into parcels shaped as a square – centuriae (derived from the number 100 – centum) or a rectangle – strigae. Centuriae were most often squares with sides of 710 m (20 actus = 2400 feet), i.e. they had an area of about 50 ha. They were further divided into smaller agricultural parcels (Milić 1994, p. 184).

Their surveyors (mensores) also called agrimensores (Lat. agrimensores – land surveyors) or gromatici (surveyors, derived from the device groma for sighting and pegging out right angles) or castramensores (military surveyors, Lat. castra munita – Roman military camp) were very educated and reputable officials. The same could also be said for people who managed public books even though the books did not completely correspond to today's land books.

3.2 Pegging out a right angle using a measuring tape

Pythagoras of Samos (born about 580 BC – died about 500 BC) was a great Greek mathematician and philosopher (speculator) born on the Greek island of Samos, today a part of Turkey. One of his teachers was the famous Greek philosopher Thales of Miletus (in Asia Minor), who advised him to travel to Egypt.

Nowadays, each high school pupil knows Pythagoras and the famous Pythagoras' theorem for a right-angled triangle (Fig. 5a):

In any right-angled triangle, the sum of squared sides that meet at the right angle is equal to the squared value of the hypotenuse, as expressed by the equation: $a^2 + b^2 = c^2$.

Egipćani su imali praktičnu mjeru za površinu arura, koja je bila kvadrat sa stranicama 100 kraljevih lakata. Upotrebljavalo se i 1/2, 1/4, 1/8, 1/16 arure (Brezinšćak 1971, str. 179).

Egipćani su strogo kažnjavali trgovce koji su varali pri mjerenju robe, a imali su i razgranatu mrežu i službu faraonskih baždarnica za kontrolu mjera, koje su izvodili vodeći službenici tih ureda.

Grci su većinu mjernih jedinica preuzeli od Egipćana i poslije ih predali Rimljanima. O Grčkim mjerama postoje prilično pouzdani podaci, koji se ipak razlikuju prema različitim izvorima.

Tako je prema (Brezinšćak 1971, str. 180) starogrčka stopa bila duga 30,83 cm, a starogrčki stadion imao je 600 stopa.

Prema (URL 7) Grci su imali ove mjerne jedinice duljine:

- atička, tj. jonska stopa duga oko 0,296 m,
- dorska stopa duga oko 0,326 m i
- normalna grčka stopa od 0,308 i od 0,316 m.

Grci su imali i ove mjerne jedinice: prst, pedalj i lakat, te niz manjih i većih. Osim toga, neka mjesta su imala i svoje posebne mjerne jedinice duljine.

Ne zna se koju su stopu koristili Párani. Ali u velikom znanstvenom projektu "Starogradsko polje" (URL 3) iz statističkih podataka duljina parcela u Starogradskom polju dobivena je duljina njihove stope 0,3026 m (URL 7). To nije bila ni atička ni dorska, ali ni normalna grčka stopa, kao i ona navedena u (Brezinšćaku 1971).

Može se pretpostaviti da su Párani mjerili duljine stranica čestica nekom od mjernih vrpca sličnih egipatskim, koja nije bila dovoljno točno baždarena, a vjerojatno je i ona mogla dobiti produženje ili skraćenje zbog promjene temperature, ili doživjeti deformacije pri prevoženju i radovima.

Površine zemljišta Grci su izražavali jedinicom za površinu nazvanom plethron, koja je sadržavala 100 stopa × 100 stopa, dakle oko 950 m^2 (Brezinšćak 1971, str. 181). U izvoru (URL 16, str. 4) i (URL 18) jedinica za površinu naziva se pletar.

Oko 300. godine Rimljani su upotrebljavali grčke mjerne jedinice za duljinu, ali su brižno njegovali i sustav vlastitih mjera. Čuvali su normirane štapove u Kapitolu, a njihove kopije uzidavali u javne zgrade tako da se njima mogu služiti građani. Njihove mjerne jedinice za duljine bile su:

- rimska stopa = 0,296 m
- grčko-rimski stadion = 600 rimsko-grčkih stopa = 177,60 m
- digitus = 1,85 cm
- iter pedestre = 28,725 km, nazvan i dan putovanja (Brezinšćak 1971, str. 181).

Prema Ilakovcu (2002, str. 169) Rimljani su imali ove jedinice za duljine:

- rimska stopa = 0,296 m
- dvostruki korak = 5 rimskih stopa = 1,48 m
- actus = 120 koraka = 120 kor. × 5 rim. stopa/kor. = 600 rim. stopa = 177,60 m
- stadion = 4 actus = 4 × 120 kor. × 5 rim. stopa/kor. = 4 × 600 rim. stopa = 710,4 m.

Njihove jedinice za površinu bile su:

- juger = 240 stopa × 120 stopa = 28800 $stopa^2$ = 2523,34 m^2
- centurij = 200 jugera (za Carstva) = 504668 $m^2 \approx$ 50,5 ha.

Rimljani su imali nacrte i protokole o razdijeljenom kolonijalnom zemljištu (ager divisus et assignatus), a obično su dijelili zemlju na parcele u obliku kvadrata ''centurije'' – centuriae, dolazi od broja 100 (centum) ili pravokutnika – strigae. Centurije su najčešće bile kvadrati sa stranicama 710 m (20 aktusa = 2400 stopa), odnosno imale su površinu oko 50 ha. One su se dalje dijelile na manje poljoprivredne parcele (Milić 1994, str. 184).

Njihovi mjernici (mensores) nazivali su se i agrimensori (lat. agrimensores – zemljomjernici) ili gromatici (nazvani po spravi gromi za viziranje i iskolčavanje pravih kutova) ili castramensores, tj. vojni mjernici (lat. castra munita – rimski vojni logor); bili su vrlo obrazovani i ugledni državni činovnici. To bi se sigurno moglo reći i za osobe koje su vodile javne knjige, iako te knjige nisu u potpunosti odgovarale današnjim zemljišnim knjigama.

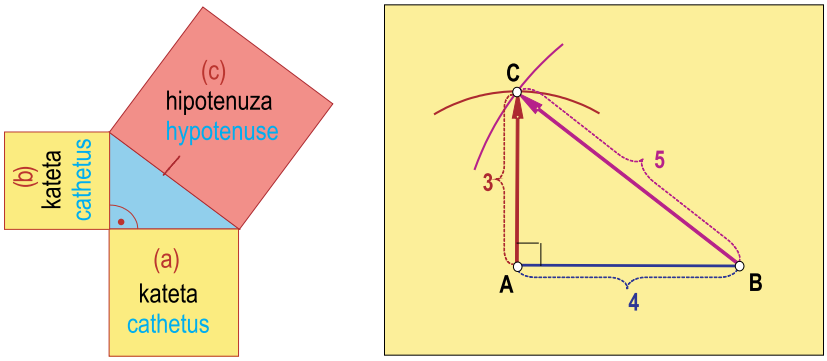
3.2. Iskolčavanje pravoga kuta s pomoću mjerne vrpce

Pitagora iz Samosa (rođen oko 580. – umro 500. god. pr. Kr.) bio je veliki grčki matematičar i filozof (mislilac), rođen na grčkom otoku Samosu, koji danas pripada Turskoj. Jedan od njegovih učitelja bio je slavni grčki filozof Tales iz Mileta (u Maloj Aziji), koji ga je savjetovao da otputuje u Egipat.

Danas svaki učenik srednje škole pamti Pitagoru po poznatom Pitagorinu poučku o pravokutnom trokutu (sl. 5a), koji glasi:

zbroj kvadrata duljina kateta pravokutnog trokuta jednak kvadratu duljine njegove hipotenuze, što je izraženo jednadžbom $a^2 + b^2 = c^2$.

Po tom poučku može se iskolčiti pravokutni trokut samo vrpcom (sl. 5b) uz uzimanje jedne katete AB kao osnovice duljine 4 mjerne jedinice, a nakon toga:



a) b)

Fig. 5. a) Pythagoras' theorem about a right-angled triangle: the sum of squared sides that meet at the right angle of a right-angled triangle is equal to the squared value of hypotenuse,
b) Pegging out a right-angled triangle with sides 3, 4 and 5 using just a measuring tape.
Slika 5. a) Pitagorin poučak o pravokutnom trokutu: Zbroj kvadrata duljina kateta pravokutnog trokuta jednak je kvadratu duljine hipotenuze,
b) iskolčenje pravokutnog trokuta sa stranicama 3, 4 i 5 samo s pomoću mjerne vrpce.

According to the theorem, a right-angled triangle can be pegged out using just a measuring tape (Fig. 5b) by taking one non-hypotenuse side AB as a basis 4 units long, and then:

- Using a measuring tape, make an arc of a circle with the radius of 3 units from the point (A), followed by
- Making an arc of a circle with the radius of 5 units from the point (B).

Point C is going to be at the intersection of the two arcs, and the angle BAC is going to be right-angle.

However, even though the theorem is named after Pythagoras, it was known to old Babylonians, and probably to Egyptians and Chinese as well, more than 1000 years before Pythagoras was born. Namely, Pythagoras was not the first to discover the Pythagoras' theorem, but he was the first to prove it.

There are indications that 1800 BC, Babylonians knew without proof what we nowadays refer to as the Pythagoras' theorem about a right-angled triangle (Gusić 1995, str. 179). Namely, it is clear Babylonians knew to peg out a right angle using only a measuring tape, without a special measuring instrument. This is supported by city of Babylon's orthogonal walls from the 6th century BC.

In China, the text Zhoubi suanjing is preserved, containing the Gougu rule, i.e. the Chinese version of the Pythagoras' theorem and its application in surveying, astronomy and other fields (Fig. 6).

Let us note that the famous Egyptian pyramid of Cheops (Khufu), built 4500 years ago has a squared base. Originally, the pyramid was covered and polished with white limestone, which does not exist anymore. Therefore, original dimensions of the pyramid can't be determined. The dimensions represented in Fig. 7 were measured by Goodman (2005) according to angles determined by Petrie. The average base side length is 231.312 m, and the average deviation is only 0.141 m, while the maximum difference between the northern and western side equals 0.30 m.

The accuracy of sides determined in such a way was quite high, considering the Egyptians did not have contemporary instruments and did not know directly about the Pythagoras' theorem.

In order for a pyramid to truly be upright and not leaning, Egyptians had to set its base as close to a square and as horizontally as possible.

Construction plans of these great pyramids were not preserved (found), but they probably existed.

Surveyors in Egypt were very famous, just like priests. In fact, cadastral supervisors, cadastral notaries, reviewers, surveyors and their assistants were educated in their temples and were required to take an oath to god Amon and the pharaoh (Korošec 1978).

3.3. Pegging out a right angle using a groma

Groma (Fig. 8) was used for pegging out right angles in the field by Greeks and Etruscans from the 6th century BC, and later Romans when they vanquished Etruscans in the 4th century BC. In 1912, archaeologists found the first remains of a groma (Ilakovac 2002). Groma was the simplest instrument (tool) for geodesists – surveyors, and it consisted of:

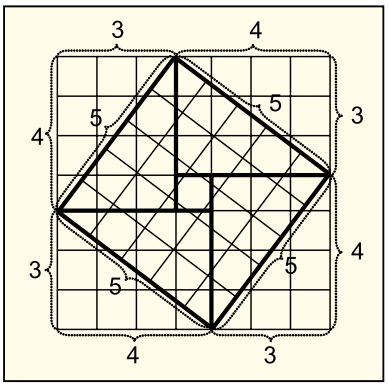


Fig. 6. Visual proof that a triangle with sides 3, 4, 5 is right-angled according to Chou Pei Suan Ching. It is a Chinese proof of the theorem later called the Pythagoras' theorem.

Slika 6. Vizualni dokaz da je trokut sa stranicama 3, 4, 5 pravokutni prema Chou Pei Suan Ching (500–200. god. pr. Kr.). To je kineski dokaz teorema koji je poslije nazvan Pitagorin poučak.

- iz početne točke osnovice (A) s pomoću mjerne vrpce povući kružni luk radijusa dugog 3 mjerne jedinice, a potom
- iz završne točke osnovice (B) povući kružni luk radijusa 5 mjernih jedinica.

U presjeku tih dvaju kružnih lukova nalazit će se točka C, a kut BAC u trokutu ABC bit će pravokutni.

Međutim, taj poučak, iako nazvan po Pitagori, bio je poznat i starim Babiloncima, a vjerojatno i Egipćanima i Kinezima, i to 1000 godina prije nego što se Pitagora rodio. Naime, Pitagora nije prvi otkrio taj poučak, već ga je prvi dokazao.

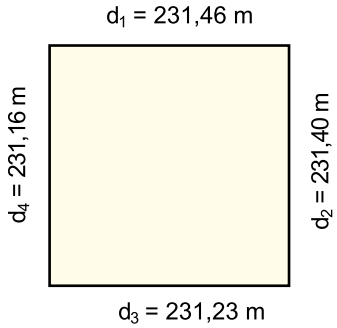


Fig. 7. Dimensions of base sides of the pyramid of Khufu (Cheops, according to Goodman).

Slika 7. Dimenzije strana baze Khufuove (Keopsove) piramide (prema Goodmanu).

Postoje naznake da su Babilonci već 1800. god. pr. Kr. znali, bez dokaza, ono što danas nazivamo Pitagorinim poučkom o pravokutnom trokutu (Gusić 1995, str.179). Babilonci su znali iskolčavati pravi kut samo s pomoću vrpce, bez nekog posebnog mjernog instrumenta. To potvrđuje i ortogonalnost zidina grada Babilona iz 6. stoljeća pr. Kr.

U Kini je sačuvan tekst Zhoubi suanjing, koji sadrži stav o Gougu pravilu, tj. kineskoj verziji Pitagorina poučka, i njegovoj primjeni u izmjeri zemljišta, astronomiji i drugim područjima (sl. 6).

Spomenimo da je znamenita egipatska Keopsova (Khufuova) piramida građena prije 4500 godina i da je baza piramide kvadrat. Izvorno je bila pokrivena i izglačana bijelim vapnencem, kojeg danas više nema. Zbog toga se izvorne dimenzije piramide ne mogu danas točno odrediti. Dimenzije prikazane na sl. 7 izmjerio je (Goodman, 2005) prema uglovima kako ih je odredio Petrie. Srednja duljina stranica baze je 231,312 m, a prosječno odstupanje stranica iznosi samo 0,141 m, dok je maksimalna razlika duljina sjeverne i zapadne stranice 0,30 m.

Točnost tako određenih strana bila je dosta visoka s obzirom na to da Egipćani u to doba nisu imali instrumente u današnjem obliku i da nisu izravno znali za Pitagorin poučak.

Da bi piramida bila uspravna, a ne kosa (nagnuta), Egipćani su bazu piramide morali postaviti kao što točniji kvadrat i točno horizontalnu.

Planovi izgradnje tih velikih piramida nisu sačuvani (pronađeni), ali su vjerojatno postojali.

Mjernici su u Egiptu uživali najveći ugled, isto kao i svećenici. Katastarski nadzornici, katastarski bilježnici i pisari, ocjenjivači, mjernici i njihovi pomoćnici bili su školovani u hramovima i morali su prisegnuti bogu Amonu i faraonu (Korošec 1978).

3.3. Iskolčenje pravoga kuta s pomoću grome

Gromu (sl. 8) su za iskolčavanje pravoga kuta na terenu koristili Grci i Etrušćani od 6. st. pr. Kr., a poslije i Rimljani kad su u 4. st. pr. Kr. pokorili Etrušćane. U Pompejima su arheolozi pronašli 1912. godine prve ostatke grome (Ilakovac 2002). Groma je bila najjednostavniji instrument (pomagalo) geodetima – mjernicima, a sastojala se od:

St – stalak (ferramentum),

K – konzole s malom izbočinom koja je služila kao osovina za okretanje gromina križa,

O – osovina okretanja gromina križa,

Kr – gromin križ (grč. asteriskos, lat. stella) koji je trebao biti u horizontalnom položaju, a sastojao se od dvije

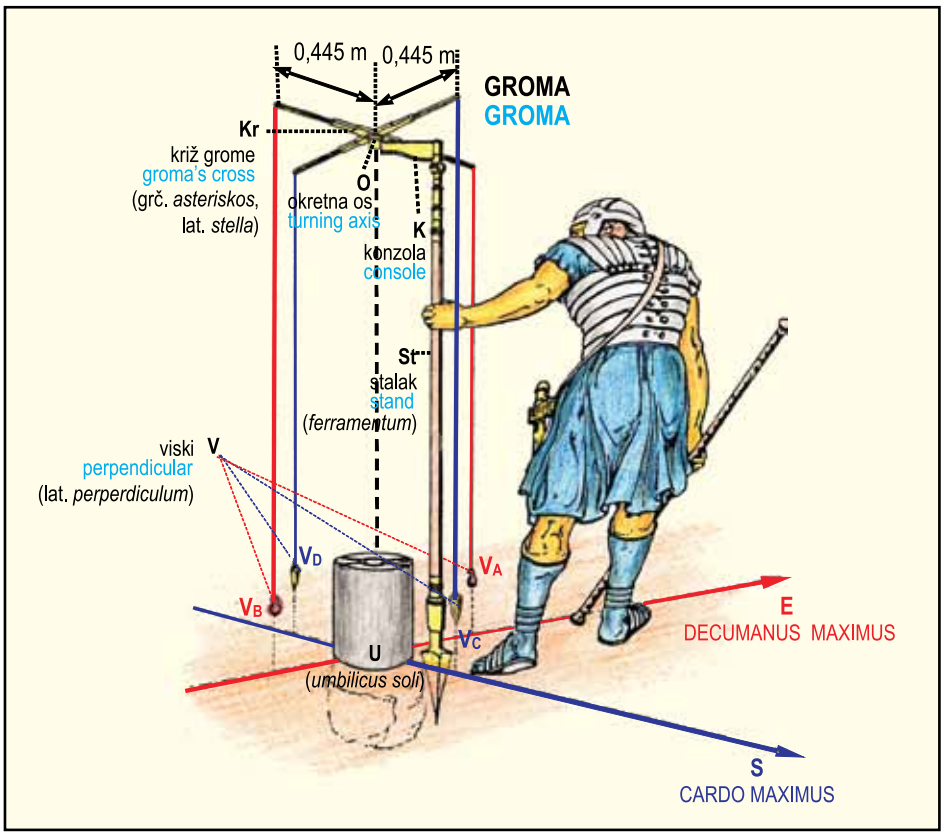


Fig. 8. Groma for pegging out a right angle in the field (according to Milić 1994, p. 209). Cardo maximus – main street in Roman cities which usually extended in the direction north-south and decumanus maximus – the main street perpendicular to cardo maximus and extended in the direction east-west (Mohorovičić 1969).

Slika 8. Groma za iskolčavanje pravoga kuta na terenu (prema Milić 1994, str. 209). Cardo maximus – glavna ulica u rimskim gradovima koja je obično išla u smjeru sjever-jug, a decumanus maximus – glavna ulica okomita na cardo maximus i išla je u smjeru istok-zapad (Mohorovičić 1969).

St – stand (ferramentum),

K – console with a small bulge used as an axis for turning the groma's cross,

O – turning axis of the groma's cross,

Kr – groma's cross (Greek asteriskos, Lat. stella) which was supposed to be in horizontal position, and it consisted of two perpendicular battens that can turn around the axis O (diameter of cross battens was 3 Roman feet = 3 × 0.2963 m = 0.889 m) and

V – two pairs of perpendiculars (perpendiculum) which hanged from batten ends and defined two perpendicular straight lines.

Groma was used to peg out a right angle in the field, like prisms were used to until recently. Groma was used to peg out a right angle in the following way (Fig. 9):

- First the surveyor centred the groma axis O above the stone marking with a cross (U), using the perpendiculum V_u (Fig. 9), and then removed the perpendiculum, so it would not hinder straight line establishment. But before that he needed to fasten the stand St.
- Afterwards, the surveyor turned the groma cross around the axis O and set it in such a way that the pair of perpendiculars V_AV_B came in the straight line in which there is a perpendicular by sighting on a flagpole – kálamos (Greek kálamos – meaning reed) T1, i.e. that the points ABT1 form a straight line.
- By sighting on strings of the other pair of perpendiculars V_CV_D, i.e. on points C and D, the surveyor attempted to move his assistant, who carried flagpole T2, into the straight line CDT2.

Unfortunately, as far as we know, no description of methods of working with groma has been found.

Groma was the simplest instrument (device) for pegging out a right angle, and one cannot expect great accuracy of pegging out a right angle in the field using a groma. In fact, while using it, one has to move his assistant with a flagpole into the straight line the surveyor can

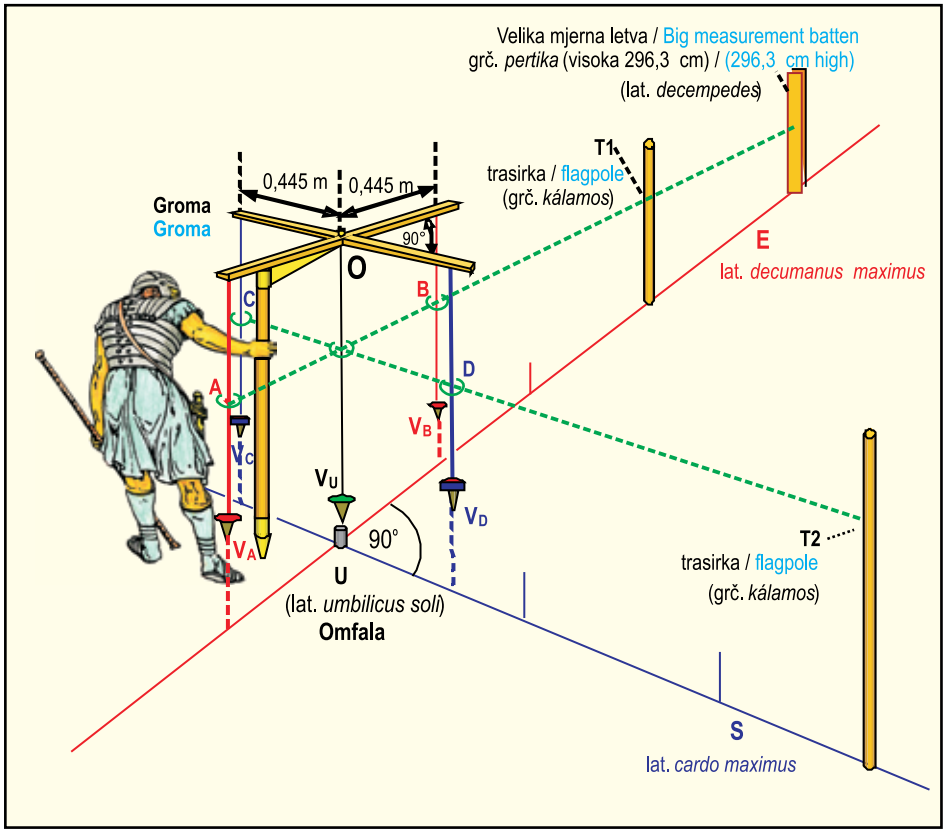


Fig. 9. Principle of pegging out a right angle using a groma.
Slika 9. Princip iskolčavanja pravoga kuta s pomoću grome

okomito učvršćene postavljene letvice, s mogućnošću zajedničkog okretanja oko osovine O (promjer letvica križa bio je 3 rimske stope = 3 × 0,2963 m = 0,889 m) i

V – dva para visaka (perpendiculum), koji su visjeli na krajevima letvica i definirali dva okomita pravca.

Groma je korištena za iskolčenje pravoga kuta na terenu, kao što su to do nedavno korištene prizme. S pomoću nje iskolčavao se pravi kut na sljedeći način (sl. 9):

- Najprije je mjernik centrirao osovinu grome O iznad kamene oznake s križem (U), s pomoću viska V_u (sl. 9), a zatim je uklonio taj visak, da mu poslije ne ometa uspostavu pravaca. Prije toga morao je dobro učvrstiti stalak St.

- Nakon toga mjernik je okretao gromin križ oko osovine O i postavio ga tako da par visaka V_AV_B dođe točno u pravac na koji se diže okomica vizirajući na trasirku – kálamos (grč. kálamos: trska) T1, tj. da točke ABT1 padnu u pravac.

- Vizirajući na užad drugog para visaka V_CV_D, tj. na točke C i D, mjernik je nastojao svog pomoćnika, koji je nosio trasirku T2, utjerati u pravac CDT2.

Nažalost, opisi korištenih metoda rada s gromom, koliko nam je poznato, nisu pronađeni.

Groma je najjednostavniji instrument (sprava) za iskolčenje pravoga kuta, te se ne može ni očekivati posebna točnost iskolčenja pravoga kuta na terenu s pomoću grome. S pomoću nje mora se utjerati pomoćnika s trasirkom u pravac koji vidi mjernik određen s užadi jednog para visaka. Budući da je razmak između jednog para visaka bio samo oko 0,90 m, pogreška od samo 1 cm u pravcu koji spaja dva viska izazvat će pogrešku na udaljenosti od 100 m već oko 1 m.

Osim toga postavlja se pitanje koliko su točno pod pravim kutom bile postavljane letvice gromina križa, tj. presjeci spojnica objesišta parova visaka. Ta pogreška može se ispitati postavljanjem gromina križa u dva položaja (sl. 10), i to:

- viziranjem u I. položaju s parom visaka V_AV_B usmjeriti gromin križ prema trasirki T1 i parom visaka V_CV_D utjerati pomoćnika s trasirkom T2 u pravac V_CV_DT2,

- zatim rotirajući gromin križ u II. položaj za približno 90° i utjerujući par visaka V_DV_C u pravac prema trasirki T1, a par visaka V_AV_B odredit će pravac kojim je definiran

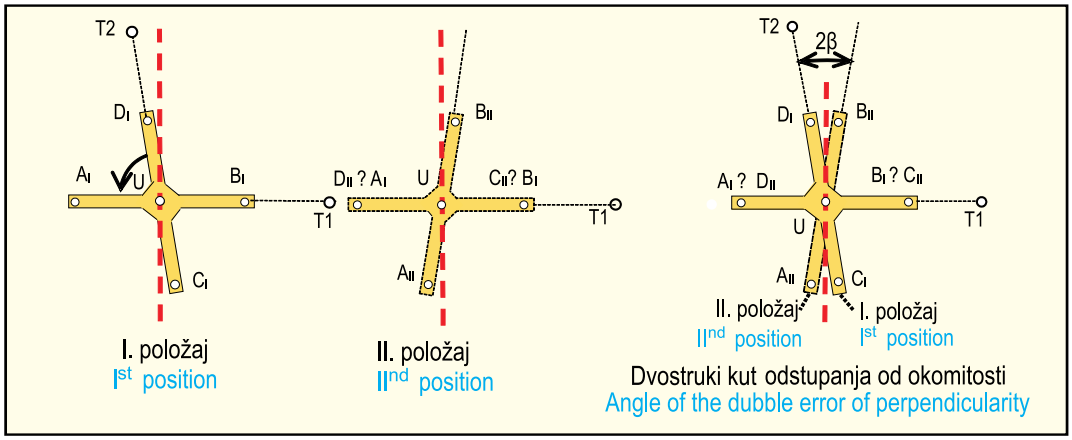


Fig. 10. Determination of the double error of right angle of groma

Slika 10. Određivanje dvostruke pogreške pravokutnosti grome

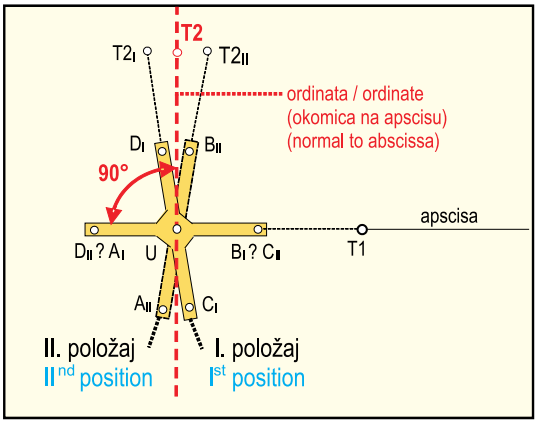


Fig. 11. Pegging out the ordinate of the point T2 using a groma in two positions.

Slika 11. Iskolčenje ordinate točke T2 s pomoću grome u dva položaja

see, determined with strings of one pair of perpendiculars. Considering the distance between a pair of perpendiculars was only 0.9 m, an error of only 1 cm in the straight line connecting two perpendiculars is going to cause an error of 1 m at the distance of 100 m.

In addition, there is an issue of the accuracy of the right angle of the groma cross battens, i.e. intersections of connecting lines of hanging points. The error can be examined by placing the groma cross in two positions (Fig. 10) as follows:

- by sighting in the 1st position with the pair of perpendiculars V_AV_B direct the groma cross toward flagpole T1 and use the pair of perpendiculars V_CV_D to move the assistant with flagpole T2 into the straight line V_CV_DT2,
- then rotate the groma cross approximately 90° into the 2nd position by putting the pair of perpendiculars V_DV_C into the straight line toward flagpole T1, and the pair of perpendiculars V_AV_B is going to determine the straight line which defines the angle of the double error of perpendicularity 2β of groma cross perpendicular pairs (Fig. 10).

This error could also have been avoided with the method of pegging out the right angle, i.e.:

- In the 1st position, in the straight line in which the perpendicular is raised, turn the groma cross so that the pair of perpendiculars V_AV_B falls into the straight line in which the perpendicular is raised, and in the straight line determined with the pair of perpendiculars V_CV_D the point $T2_I$ can be pegged out at a certain distance.
- Then, rotate the groma cross approximately 90° into the 2nd position so that with the pair of perpendiculars V_DV_C it is directed to the straight line in which the perpendicular is raised, and the pair of perpendiculars V_AV_B determines the straight line in which the point $T2_{II}$ can be pegged out at a certain distance.

The right position of the point T2, whose ordinate is perpendicular to the base (abscissa) in the point U, where the groma is centred, is going to be in the middle of the two pegged out positions in the 1st and 2nd groma position (Fig. 11).

From experience, it can be said that extending the straight line using only flagpoles is certainly more accurate than raising perpendiculars.

This fact also needs to be remembered when interpreting results of surveying Starogradsko polje by method of differential GPS surveying.

It is well-known that when land survey was performed using orthogonal method with prisms (which is more accurate than surveying with a groma), ordinate length could

kut dvostruke pogreške okomitosti 2β parova visaka gromina križa (sl. 10).

Ta pogreška mogla se izbjeći i metodom rada iskolčenja pravoga kuta:

- U I. položaju u pravcu na koji se podiže okomica zakreće se gromin križ tako da par visaka V_AV_B padne u pravac na koji se podiže okomica, a na pravcu određenom parom visaka V_CV_D može se na određenoj udaljenosti iskolčiti točka $T2_I$.

- Zatim se rotira gromin križ za približno 90° u II. položaj tako da se s parom visaka V_DV_C usmjeri u pravcu na koji se podiže okomica, a s parom visaka V_AV_B određen je pravac na kojem se na određenoj udaljenosti može iskolčiti točka $T2_{II}$.

Pravi položaj točke T2 kojoj će ordinata biti okomita na bazu (apscisu) u točki U, gdje je centrirana groma, nalazit će se u sredini tih dvaju iskolčenih položaja u I. i u II. položaju grome (sl. 11).

Na temelju iskustva može se reći da je produžavanje pravca samo s pomoću trasirki sigurno točnije nego podizanje okomica.

Te činjenice treba se sjetiti i kod interpretiranja dobivenih rezultata izmjerom Starogradskog polja metodom diferencijalnoga GPS-mjerenja.

Poznata je činjenica da prilikom izmjere zemljišta ortogonalnom metodom s pomoću prizmi (što je točniji način od mjerenja gromom) dužina ordinate nije smjela prijeći neku maksimalnu dužinu, koja je to manja što se točnije želi izvesti izmjeru. Po našim propisima ordinate nisu smjele biti veće od:

u izmjeri građevinskih rajona velikih gradova:

- za točke na uličnim frontama objekata 10 m
- za točke objekata (kuća itd.) i međa unutar gradskih blokova 20 m
- za granične točke kultura 40 m

u izmjeri poljoprivrednog zemljišta:

- za točke objekata i međa 50 m
- za točke na granicama kultura 80 m (Macarol 1977, str. 533).

3.4. Dokumentacija o Starogradskom polju

Na poticaj Lorenza Brascessija, uvaženog povjesničara grčkog razdoblja, projekt "Starogradsko polje" (koji vodi doc. dr. Branko Kirigin iz Arheološkog muzeja u Splitu) uklopljen je u međunarodni projekt "B.A.R.C.A. nell' Adrias Kolpos", koji financira Europska unija (URL 3). Tako je omogućeno stvaranje digitalne baze podataka o Starogradskom polju u koju su uvršteni: raniji podaci arheoloških istraživanja, katastarske karte (stare i nove), karte iz starijih publikacija, zrakoplovne, satelitske i ortofotosnimke (stare i nove), pedološke, geološke i slične karte.

Tako je ta baza podataka postala najsveobuhvatnija baza nekog arheološkog predjela u Hrvatskoj.

Kolege geodeti iz Slovenije prof. dr. Andrej Bilc i Jure Mlinar izveli su 1995. godine izmjeru Starogradskog polja s pomoću umjetnih Zemljinih satelita GPS-a i to po metodi diferencijalnoga GPS-a (URL 15). Ta precizna mjerenja omogućila su da se primijeti:

1. da su sve osovine parcelacije u smjeru istok-zapad vrlo pravilne i međusobno vrlo paralelne, ali da se sve neznatno lome na jednoj osovini u smjeru sjever-jug, i to onoj koja prolazi uz predjel koji se zove Dračevica,
2. da se sve osovine u smjeru sjever-jug neznatno lome na istoj osovini u smjeru istok-zapad, i to onoj na putu iz Staroga Grada u Vrbosku,
3. da su otkloni prema jugu i sjeveru od te osovine međusobno različiti.

Iz tih triju primjedaba upravo je potvrđena činjenica da je Grcima bilo lakše točnije produžiti pravce nego podići okomice.

Zato se pretpostavlja da je točka presijecanja tih dviju osovina na kojima se lome sve osi polazna točka mjerenja, tj. točka od koje su Grci počeli iskolčavati čestice u Starogradskom polju. Nazvali su ju omfala, a nalazi se na raskršću na sjeverozapadnom uglu zračne luke.

Uostalom i danas bi geodeti prije iskolčenja izveli tzv. rekognosciranje terena i s manjom točnosti izmjerili dimenzije polja ili na neki drugi način odredili njegove dimenzije. Zatim bi odredili mjesto odakle bi započeli iskolčenje. U ovom slučaju sasvim je razumljivo da su točku omfala Grci postavili negdje nedaleko od sredine Starogradskog polja.

Putovi između parcela odmjereni su posebice i upisani kao gradsko zemljište (URL 1), a njihova prosječna širina, kako je određeno u projektu "Starogradsko polje", iznosi 10 stopa (oko 3 m) (URL 12).

Na sl. 12 prikazana je arheološka karta Starogradskog polja koju je objavio Niko Duboković – Nadalini 1969. godine, a na sl. 13 satelitska snimka prema Googl Earthu, gdje se vide putovi, kao i nešto slabije ostale međe grčke parcelacije u toj najbolje očuvanoj starogrčkoj parcelaciji na Mediteranu.

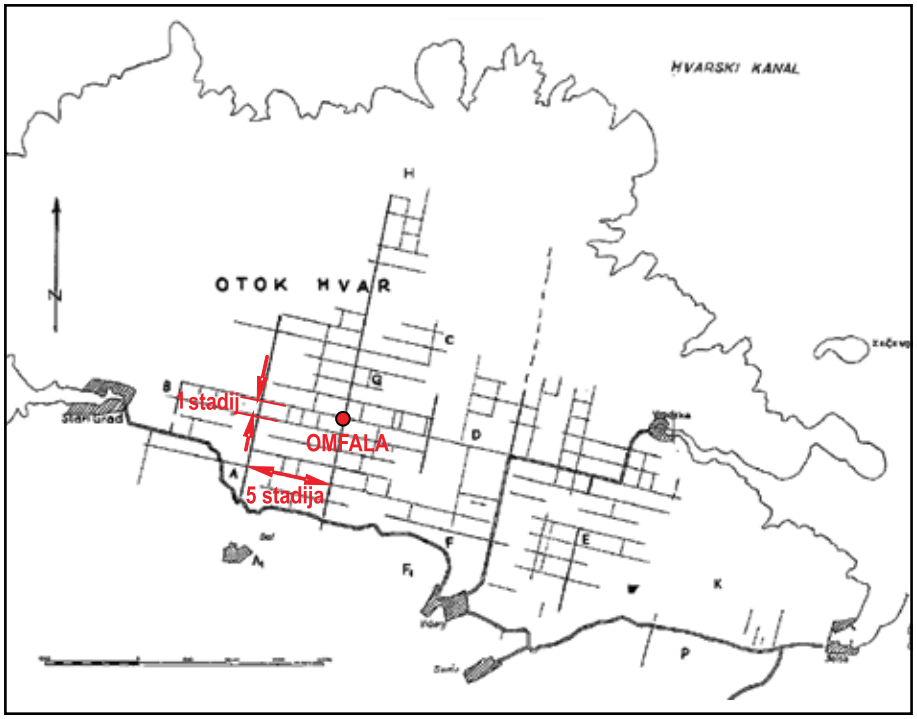


Fig. 12. First archaeological map of Starogradsko polje which was published by Niko Duboković – Nadalini in 1969. Letters indicate Roman sites in the field, and the omfala point is also indicated (URL 14).

Slika 12. Prva arheološka karta Starogradskog polja, koju je objavio Niko Duboković – Nadalini 1969. godine. Slova označavaju rimska nalazišta u polju, a označena je i točka omfala (URL 14).

Fig. 13. Starogradsko polje on the island of Hvar built at the beginning of the 4th century BC (Satellite image – Google Earth. Subsequent processing inserted markings into the image, paths can be seen clearly, while border dry stone walls are less clear).

Slika 13. Starogradsko polje na otoku Hvaru izgrađeno početkom 4. st. pr. Kr. (Satelitska snimka – Google-Earth. Naknadnom obradom na sliku su unesene oznake, pa se jasno vide putovi, dok se međni suhozidovi vide slabije).

Fig. 14. Boundary stone from the Hvar Faros Chora – Starogradsko polje from the 4th century BC, which indicates who the owner of the parcel is. It reads ''Boundary stone, Matij Pitejev" (Archaeological Museum in Zagreb, photo by Igor Krajcar)

Slika 14. Međni kamen iz hvarske Farske hore – Starogradskoga polja iz 4. stoljeća prije Krista, na kojem je označeno tko je vlasnik zemljišne čestice. Na njemu piše ''Međaš Matij Pitejev" (Arheološki muzej u Zagrebu, foto Igor Krajcar)

not have been greater than a certain maximum length, which was shorter if the required accuracy was greater. According to Croatian regulations, ordinates could not have been greater than:

In construction regions of large cities:

- for points in street object fronts 10 m
- for object points (houses, etc.) and borders within city blocks 20 m
- for cultural border points 40 m

In agricultural land survey:

- for object and border points 50 m
- for cultural border points 0 m (Macarol 1977, p. 533).

3.4. Documentation about Starogradsko polje

Stimulated by Lorenzo Brascessi, a reputable historian of the Greek period, the project ''Starogradsko polje'' (led by Assist. Prof. Dr. Branko Kirigin from the Archaeological Museum in Split) was integrated into the international project "B.A.R.C.A. nell' Adrias Kolpos" financed by the European Union (URL 3). This enabled the production of a digital database about Starogradsko polje in which the following was included: earlier archaeological research data, cadastral maps (old and new), maps from older publications, aerial, satellite and orthophoto images (old and new), pedologic, geologic and similar maps.

Thus the database became the most comprehensive base of an archaeological region in Croatia.

In 1995, geodesist colleagues from Slovenia, Prof. Dr. Andrej Bilc and Jure Mlinar surveyed Starogradsko polje using artificial Earth's satellites of the GPS and the differential GPS method (URL 15). Such precise surveys enabled the perception that:

1) All parcellation axes in the direction east-west are very regular and mutually parallel, but all of them slightly folding up on one axis in the direction north-south, the one passing through the area Dračevica.
2) All axes in the direction north-south slightly folding up on the same axis in the direction east-west, the one passing from Stari Grad to Vrboska,
3) Deviations toward the south and the north of the axis are different.

These three notes actually confirm that it was easier for Greeks to accurately extend straight lines than to raise perpendiculars.

Therefore, it is assumed that the intersection point of the two axes in which all the axes folding up is the survey starting point, i.e. the point from which Greeks started to peg out parcels in Starogradsko polje. They called it omfala, and it is located at the crossroads in the northwestern corner of the today's airport.

Even today, prior to pegging out, geodesists execute the so-called reconnaissance of the field and survey field dimensions less accurately or determine field dimensions in another way. Then they determine where to start pegging out. In this case, it is understandable that Greeks put the omfala point somewhere in the middle of Starogradsko polje.

Paths between parcels were surveyed separately and registered as city land (URL 1), and their average width is 10 feet (about 3 m), as determined in the project ''Starogradsko polje'' (URL 12).

Fig. 12 represents the archaeological map of Starogradsko polje which was published by Niko Duboković – Nadalini in 1969, and Fig. 13 represents a satellite image from Google Earth, where one can see the paths and somewhat less clearly the borders of Greek parcellation in the best preserved old-Greek parcellation in the Mediterranean.

4. Oldest preserved boundary stone from the 4th century BC

The oldest boundary stone from Croatia from the Faros chora – Starogradsko polje from the 4th century BC is preserved in the Archaeological Museum in Zagreb (Fig. 14). It reads: Boundary stone Matij Pitejev. It is the oldest known boundary stone from the territory of Croatia, and it should also be preserved with care as a geodetic monument in Croatia.

However, it should be noted that it is not a boundary stone in today's sense, because the name of owner is written on it. So, it is a cadastral description indicating who owns the parcel, and written in the nature and not on the paper cadastral plan.

Nowadays, a boundary stone refers to the stone which was placed in characteristic breakpoints on the edge of a parcel, and they do not indicate the parcel's owner, which is recorded in cadastral documentation, i.e. land books.

Acknowledgments

We would like to thank the reviewers for their helpful remarks, which contributed to the quality of this research of geodetic history of Croatia.

We are thankful to Ivan Mirnik, PhD and Ivan Krajcar for the photo of the oldest boundary stone in Croatia kept in the Archaeological Museum in Zagreb. We would like to thank our colleague Dr. Dražen Tutić for obtaining the image of Starogradsko polje from Google Earth.

We would also like to thank the Ministry of Science, Education and Sport of the Republic of Croatia for partially financing this paper, which was made within the project Development of a Scientific Surveying Laboratory for Geodetic Instruments no.: 007 – 000000(1201785) – 3539.

4. Najstariji sačuvani kamen međaš iz 4. st. pr. Kr.

Kamen međaš iz Farske hore – Starogradskoga polja iz 4. st. pr. Kr. čuva se u Arheološkome muzeju u Zagrebu (sl. 14). Na njemu piše: Međaš Matij Pitejev. To je najstariji poznati kamen međaš s teritorija Hrvatske, te ga treba brižno čuvati i kao geodetski spomenik u Hrvatskoj.

Međutim, treba napomenuti da to nije međni kamen u današnjem smislu riječi, jer na njemu piše čija je to čestica, te tako predstavlja katastarski opis komu pripada čestica, i to u prirodi, a ne na papiru katastarskog plana.

Danas se pod međnim kamenom podrazumijeva kamen koji je postavljen na karakterističnim lomnim točkama na rubu zemljišne čestice, a na terenu na česticama ne piše ime njezina vlasnika, već je to upisano u dokumentacijama pohranjenim u katastrima, odnosno u zemljišnim knjigama.

Zahvala

Najljepše zahvaljujemo recenzentima na korisnim primjedbama, kojima su pridonijeli boljoj kvaliteti ovog istraživanja povijesti geodezije u Hrvatskoj.

Zahvaljujemo dr. sc. Ivanu Mirniku i Igoru Krajcaru na ustupljenoj fotografiji najstarijeg međnog kamena u Hrvatskoj koji se čuva u Arheološkome muzeju u Zagrebu. Kolegi dr. sc. Draženu Tutiću zahvaljujemo što nam je s Googla prenio sliku Starogradskog polja.

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URL 4: Starogradsko polje http://starogradsko-polje.net/index.php?p=1 (19. 5. 2009)
URL 5: Starogradsko polje http://starogradsko-polje.net/index.php?p=64 (19. 5. 2009)
URL 6: Starogradsko polje http://starogradsko-polje.net/index.php?p=65 (19. 5. 2009)
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