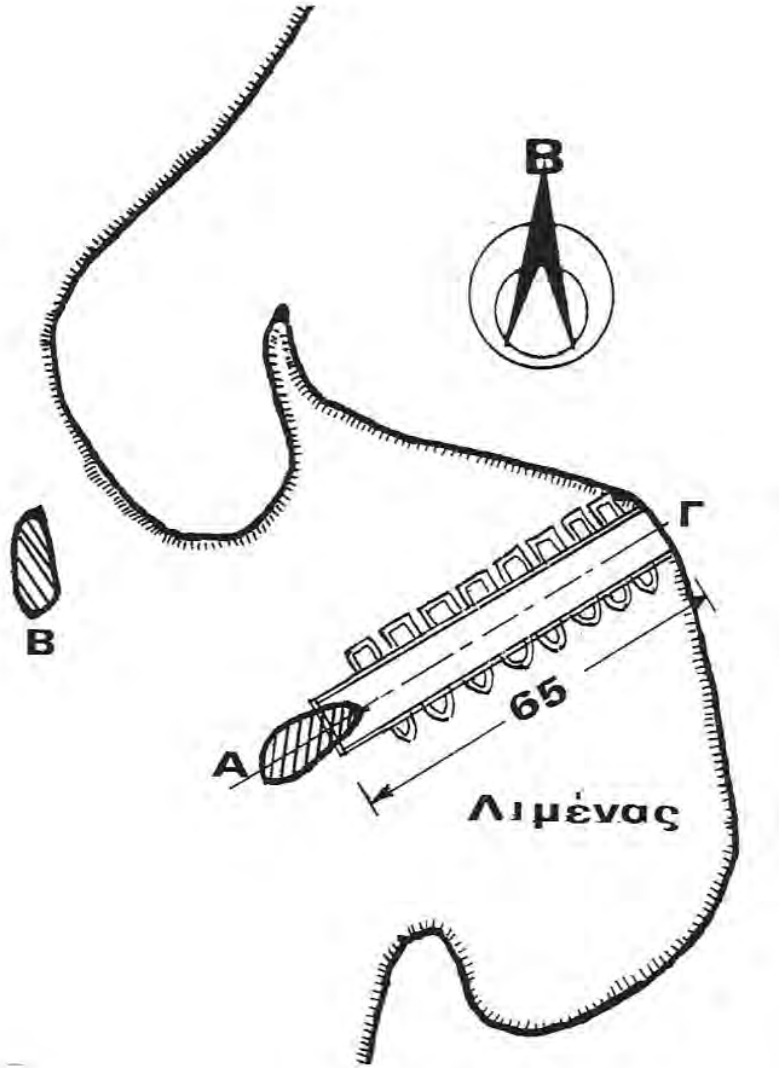


Fig.7. The pontoon-bridge of Nikias at Delos, (Makres, p.248).

3. HELLENISTIC PERIOD

- Since the 4th c. BCE, the corbelled system of bridges was abandoned

  The use of key-stone vaults was generalised
- Removable timber bridges continued to be built

Fig.14. Rhodos bridge, (316 BCE), (Bougia, p.14, fig.9).

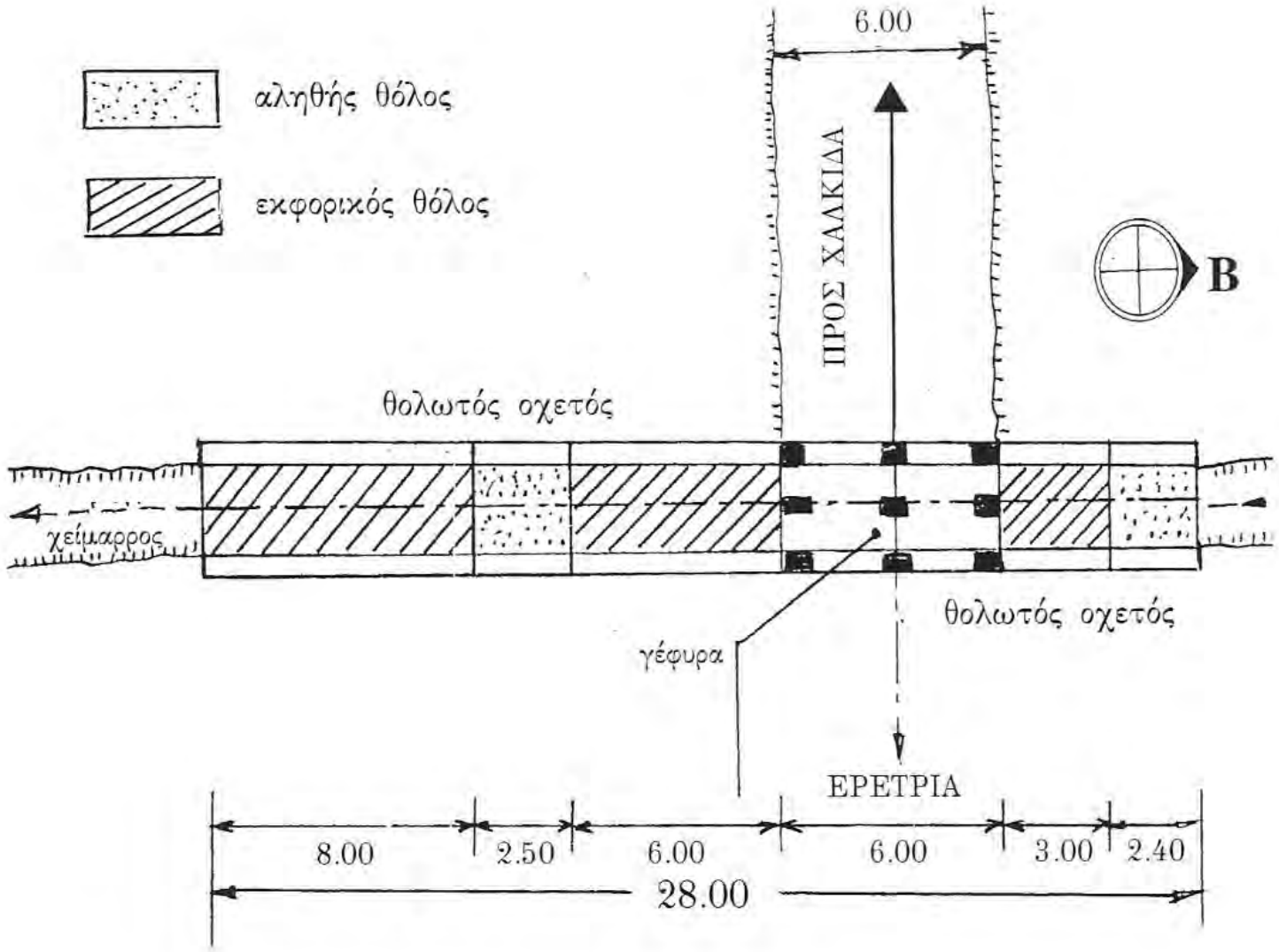


Fig.17. A segment of a vaulted channel was purposely modified into a remountable timber bridge. Eretria, 192 BCE, (Makres, p.214).

Extensive **repair** programme of existing timber bridges in the region of Nile (by the Ptolemies)

[greek papyrus P. Petr. 3.43(2)]

4. LONG MILITARY BRIDGES

made by Greek Engineers

- **Bosporos**, L = 740 m, pontoon bridge, Mandroclēs, 513 BCE, (Fig. 18)
- **Istros**, pontoon bridge
  Ionian Greeks, 513 BCE
- **Hellispontos**, (674 ships), pontoon bridge
  Harpalos, 480 BCE

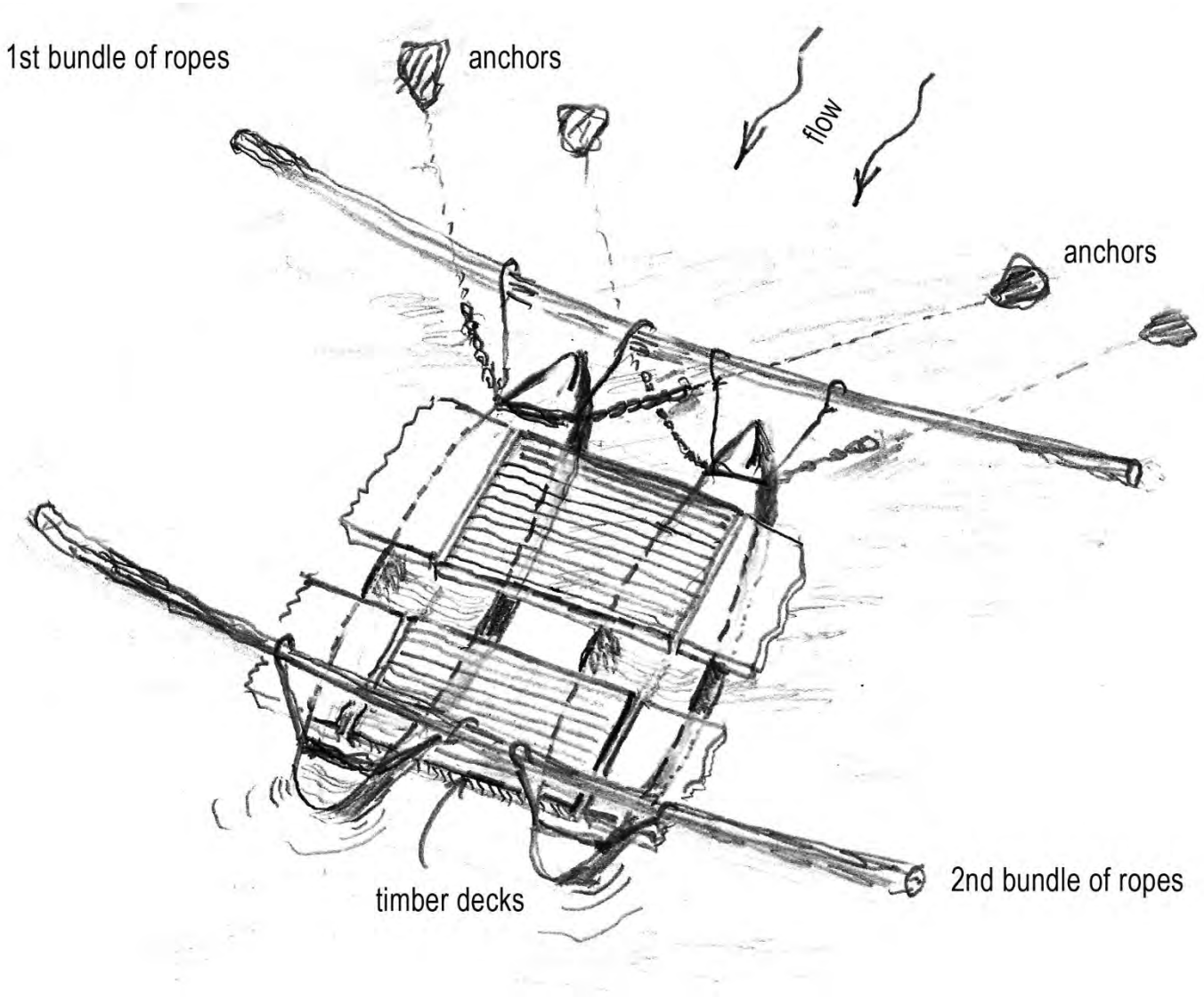


Fig.18. Assumed arrangement of ships, tensioned ropes, anchors and added decks, of the pontoon-bridges described by Herodotos and Arrianos, (Author).

- **Strymon**, pontoon bridge
  [Phoenicians], 480 BCE
- **Euphratēs**, pontoon bridge
  Alexander's Engineers, 331 BCE
- **Indus**, pontoon bridge
  Alexander's Engineers, 327 BCE
- **Danube**, masonry piers, timber trusses
  Apollodoros, 105 CE, (Fig. 19, 20, 21)

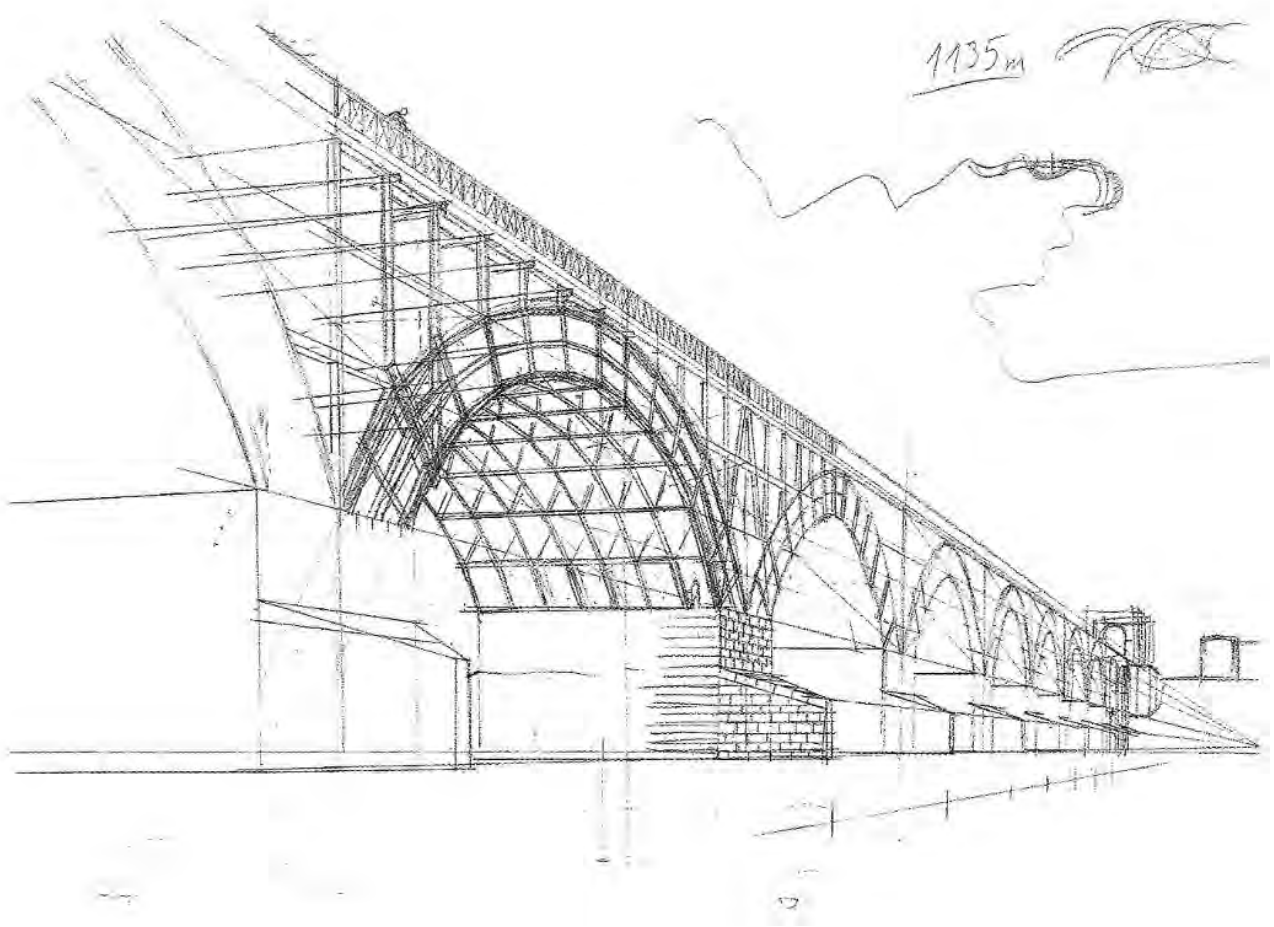


Fig.19. Possible composition of the superstructure of the Istros bridge (105 CE), (Korres, p.177).

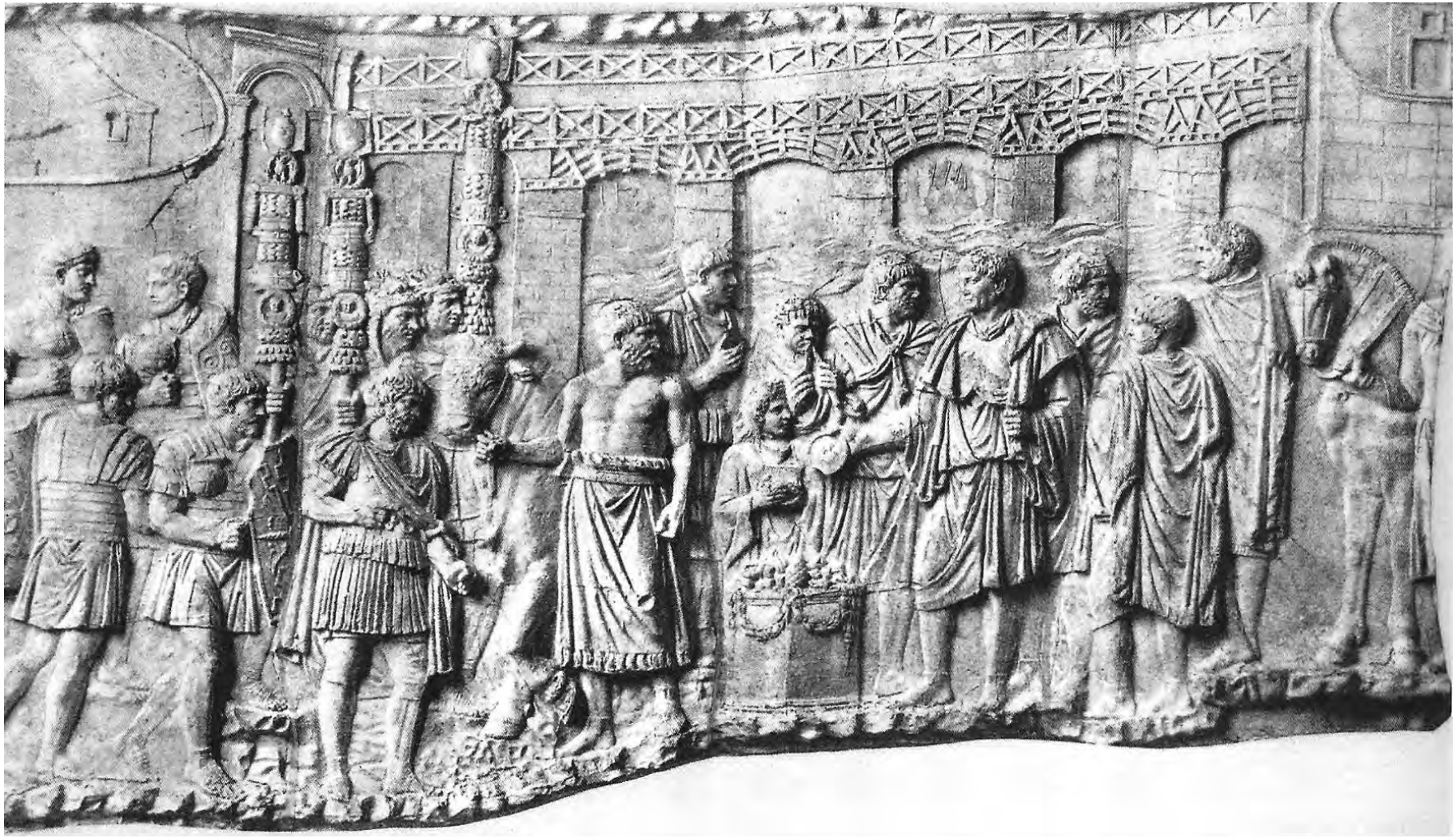


Fig.21. Representation of the Istros bridge on the Trajanus Column in Rome, (Korres, p.166).

III. GEOTECHNICAL ENGINEERING

Fig.1. The need to adapt to the morphology of the ground (Hephaesteion, Athens).

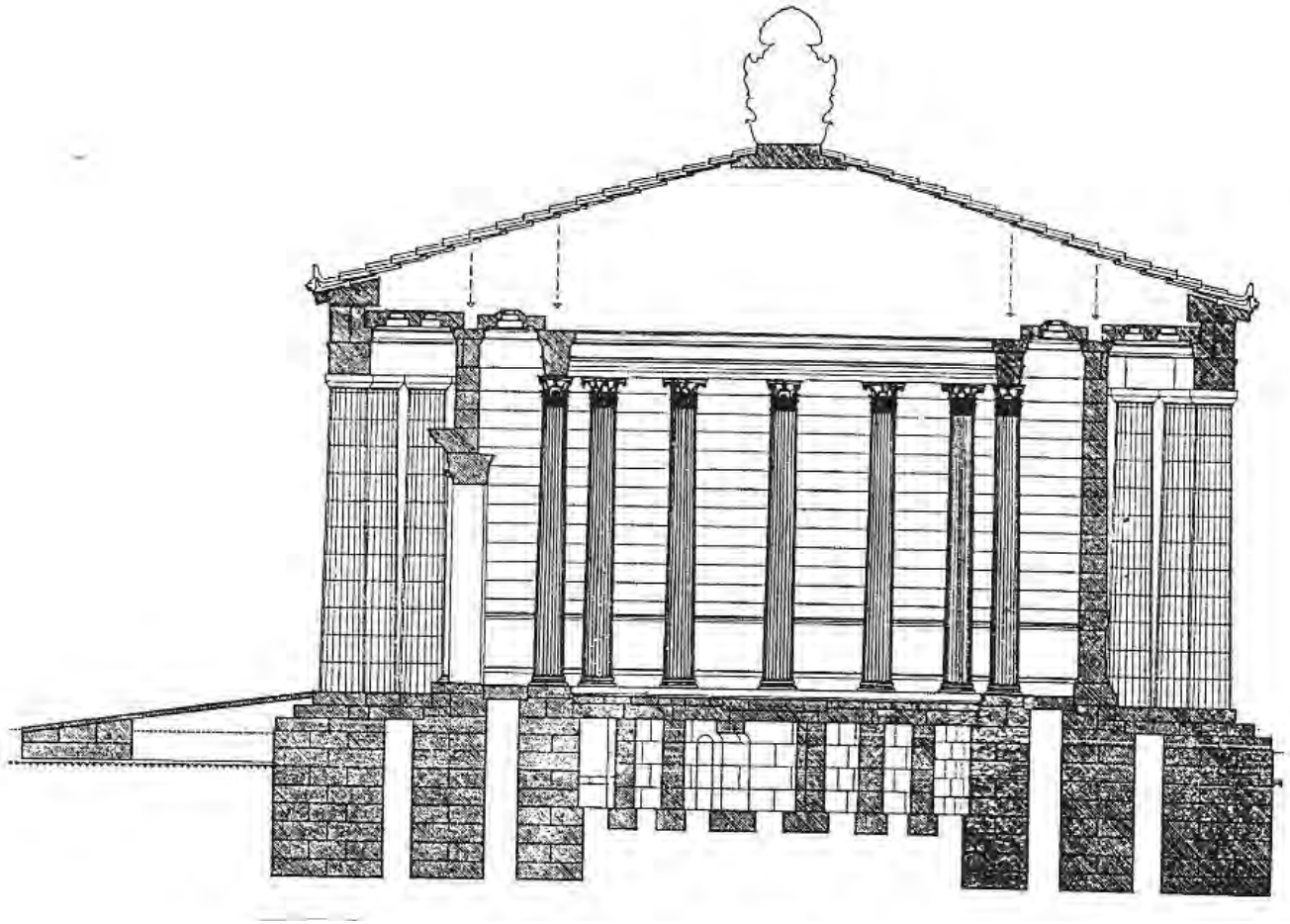


Fig.2. Variable width and depth of foundations of columns depending on their load, (Tholos of Asklepoeeion, Epidauros).

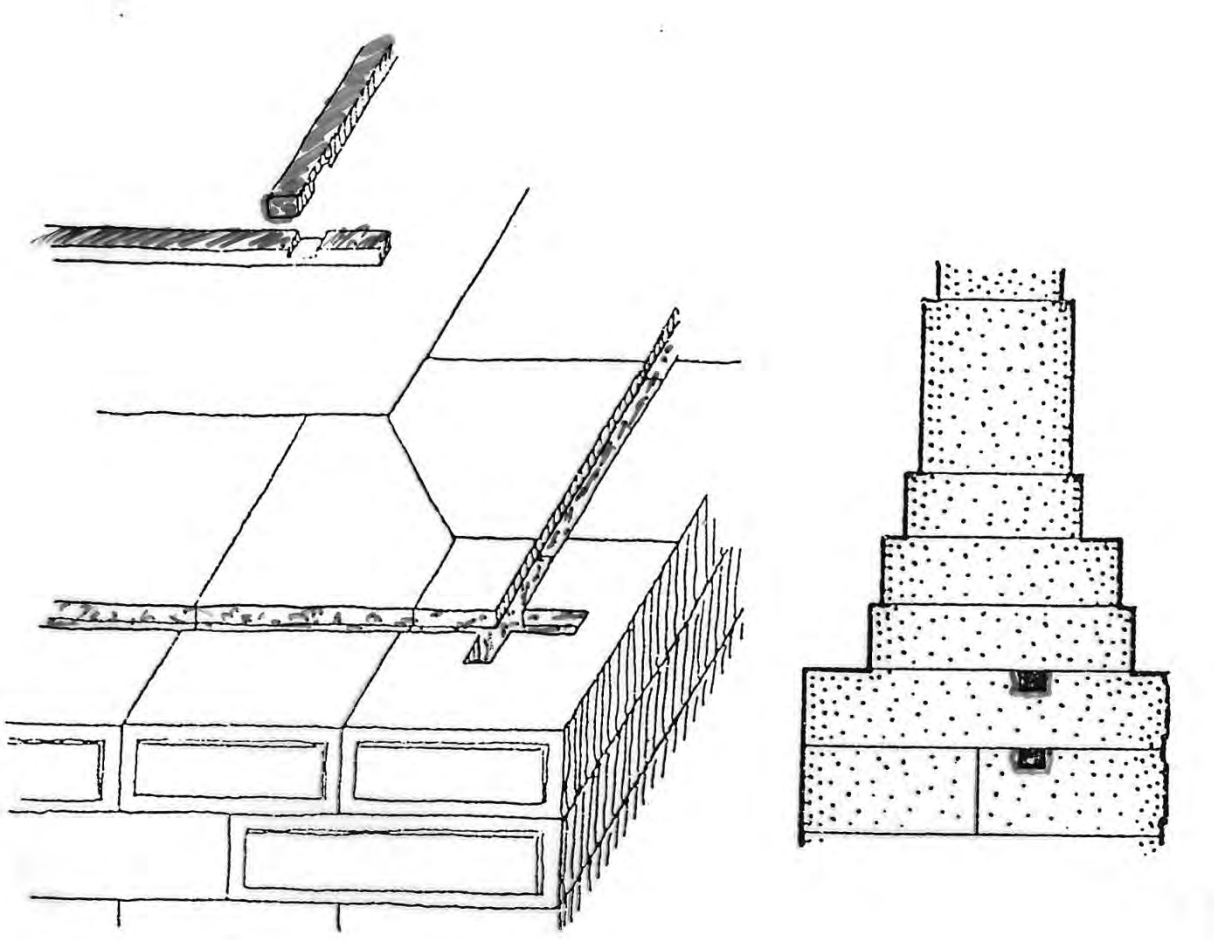


Fig.5. Iron reinforced foundation beam (Delphi – Thebean Treasure) (Dinsmoor, in Orlandos).

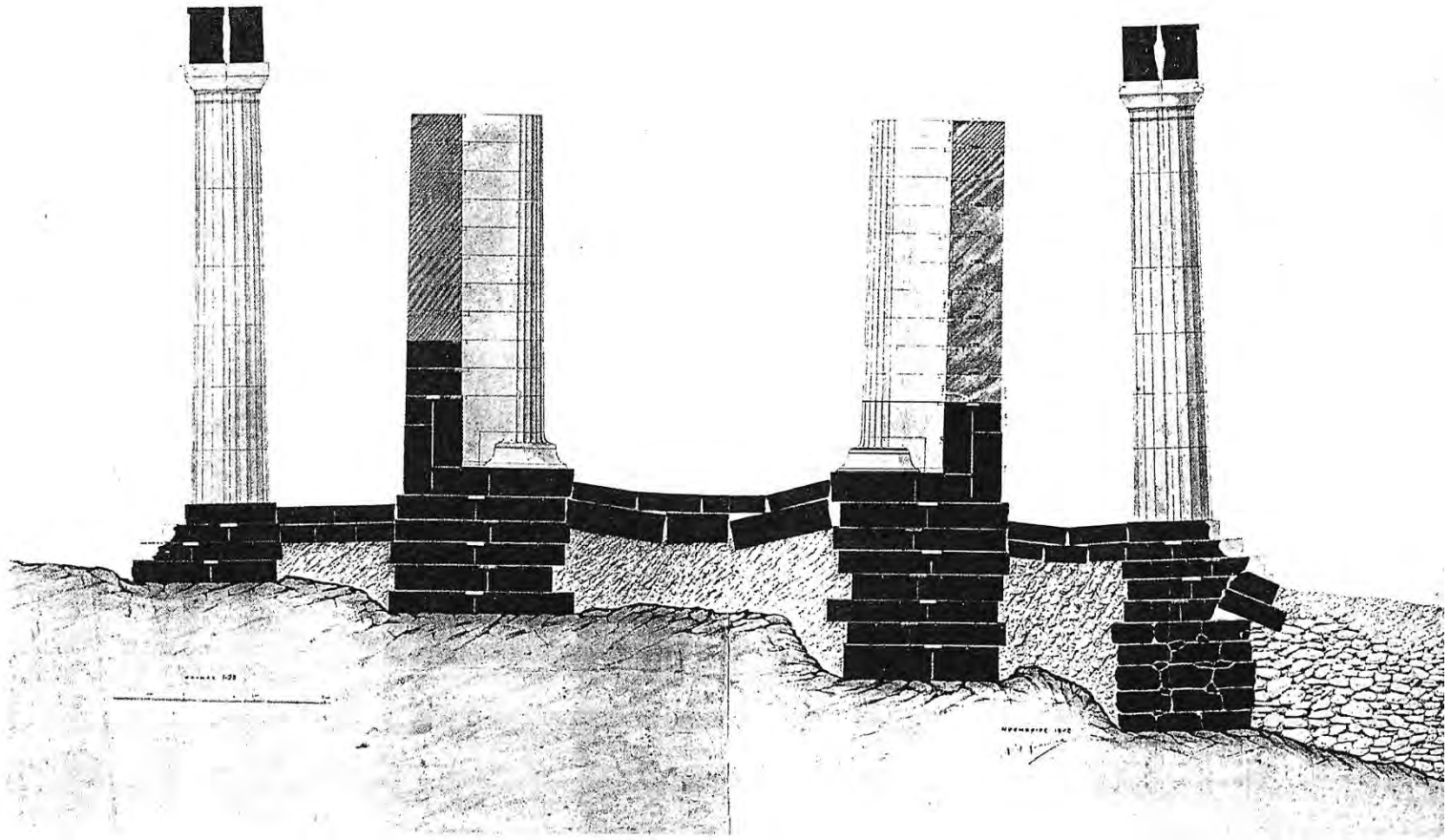


Fig.7. Consequences of differential settlements (Temple of Apollo, Phigaleia).

2. PILING

- Old examples
- Piling in bridges
- Stone-infilled large wells

Fig.9. Timber piles at the Neolithic lake-settlement of Dispelio.

Fig.11. The piling of the Amphipolis bridge on the Strymon bridge (4th cent. BCE, Lazarides).

3. SOIL IMPROVEMENT

- Feeding-in with appropriate materials

  Ex. marshy soil ⬅ lime + stones
- Special surface coverings

  Ex. Temple of Ephesos (~ 356 BCE)

  “packed charcoal + fleeces”
- Soil replacement

  (see Fig. 13)

4. SLOPES' STABILITY

a) Greek Theaters

b) Retaining walls

- Sophistication (Eleusis, Fig. 14)
- Extrados' inclination (Fig. 15)
- Increased thickness (Fig. 16)
- Daring records (Fig. 17)
- Daedalus in Sicily!

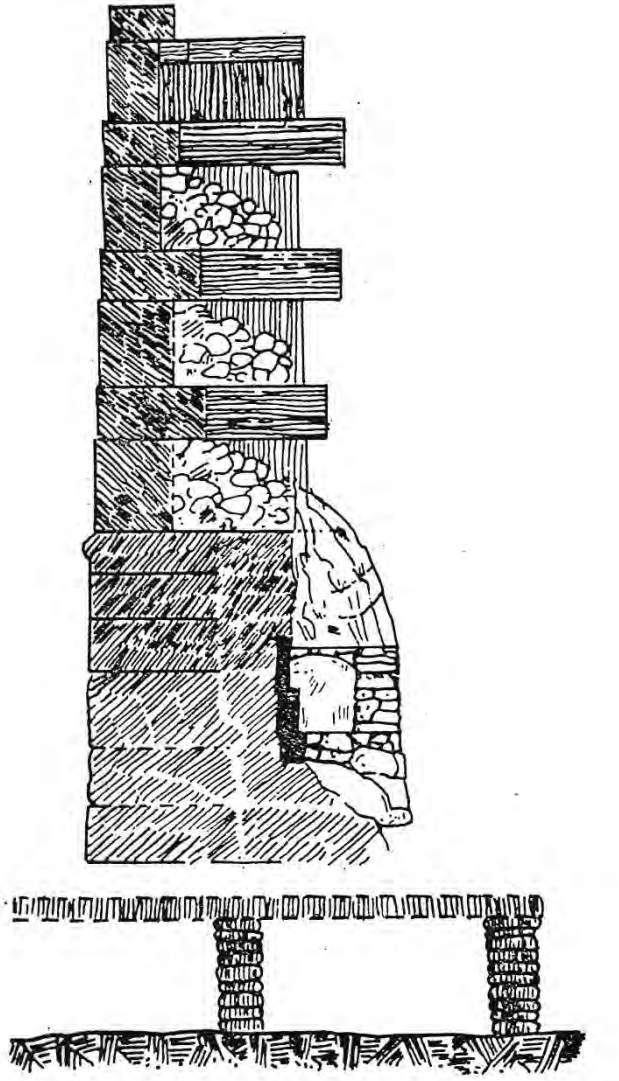


Fig.14. Sophisticated retaining wall (Eleusis, Martin, p.374).

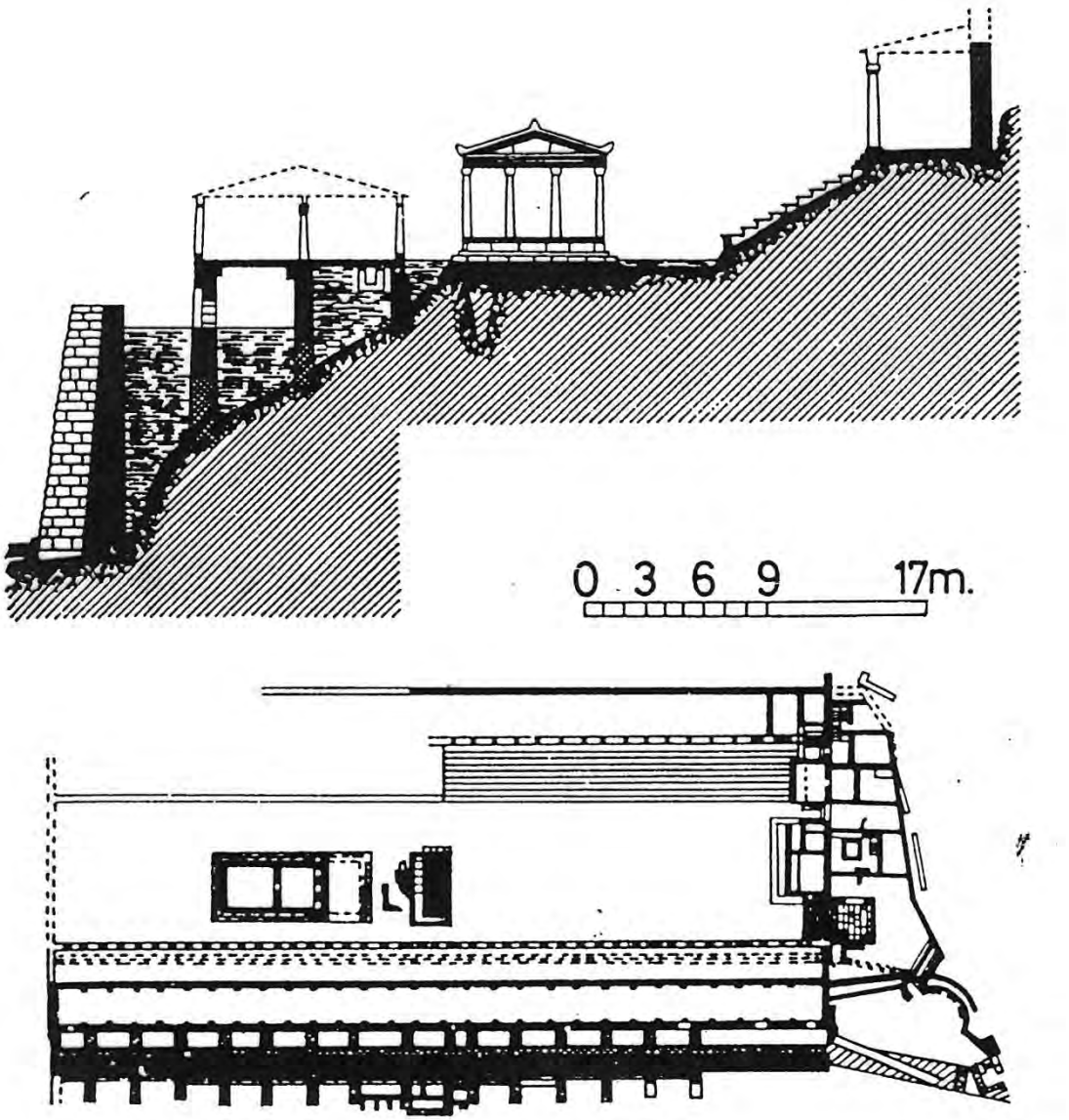


Fig.17. The enormous retaining wall at the Temple of Demeter, Pergamos (2nd cent. BCE) (…….).

c) Unsupported slopes

- Cuts of roads (Fig. 18)
- Xerxēs Canal at Athos (481 BCE)
- The Elikē tsunami (373 BCE)

5. EMBANKMENTS and DAMS

- Kopaïs lake drainage (14th c. BCE)
  Large impermeable fills (Fig. 19)
- The deviation of Klados (Olympia)
  (Fig. 20)
- The fill of Tyros Siege by Alexander the Great, (332 BCE, Fig. 21, 22)

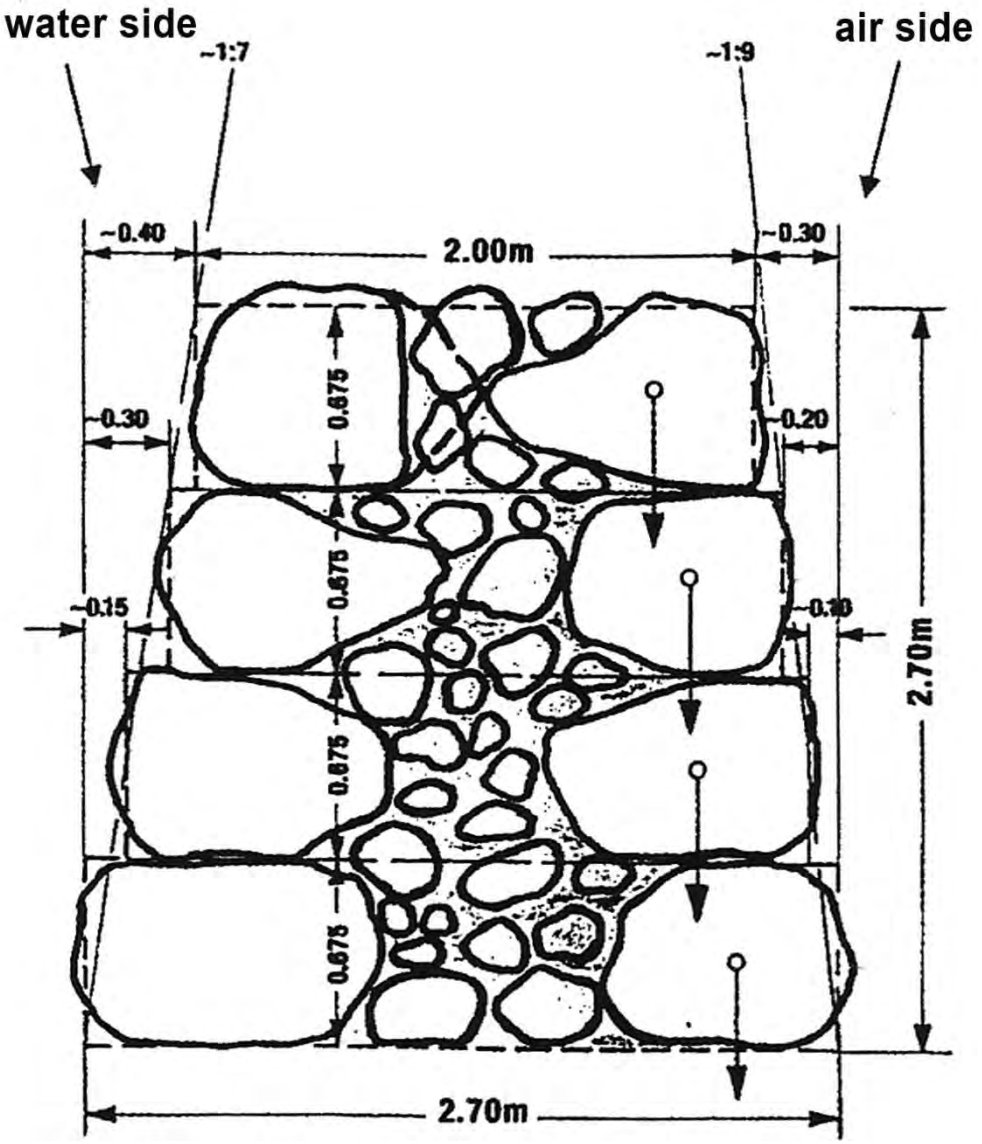


Fig.20. Cross section of wall for the deviation of Kladeos tributary of Alpheios, Olympia (14th cent. BCE) (Knauss).

- Tiryns earth dam (13th c. BCE)
- Alyzeia dam (Fig. 23)
- Samos jetty (rip-rap), 370 ^{m} long (Fig. 24)

6. TUNNELS

a) Mines since ~ 3000 BCE (Thorikon, Lavrion)

b) Eupalinos tunnel, Samos, (6^{th} c. BCE)
1 km long, 1,80 x 1,80 m
Possible tracing, Schoene, (Fig. 25)

c) The hellenistic Kopaïs tunnel (Fig. 26, 27)

d) The most applicable tunneling in water supply of greek Cities (Fig. 28) and Asklēpoeia (Fig. 29)

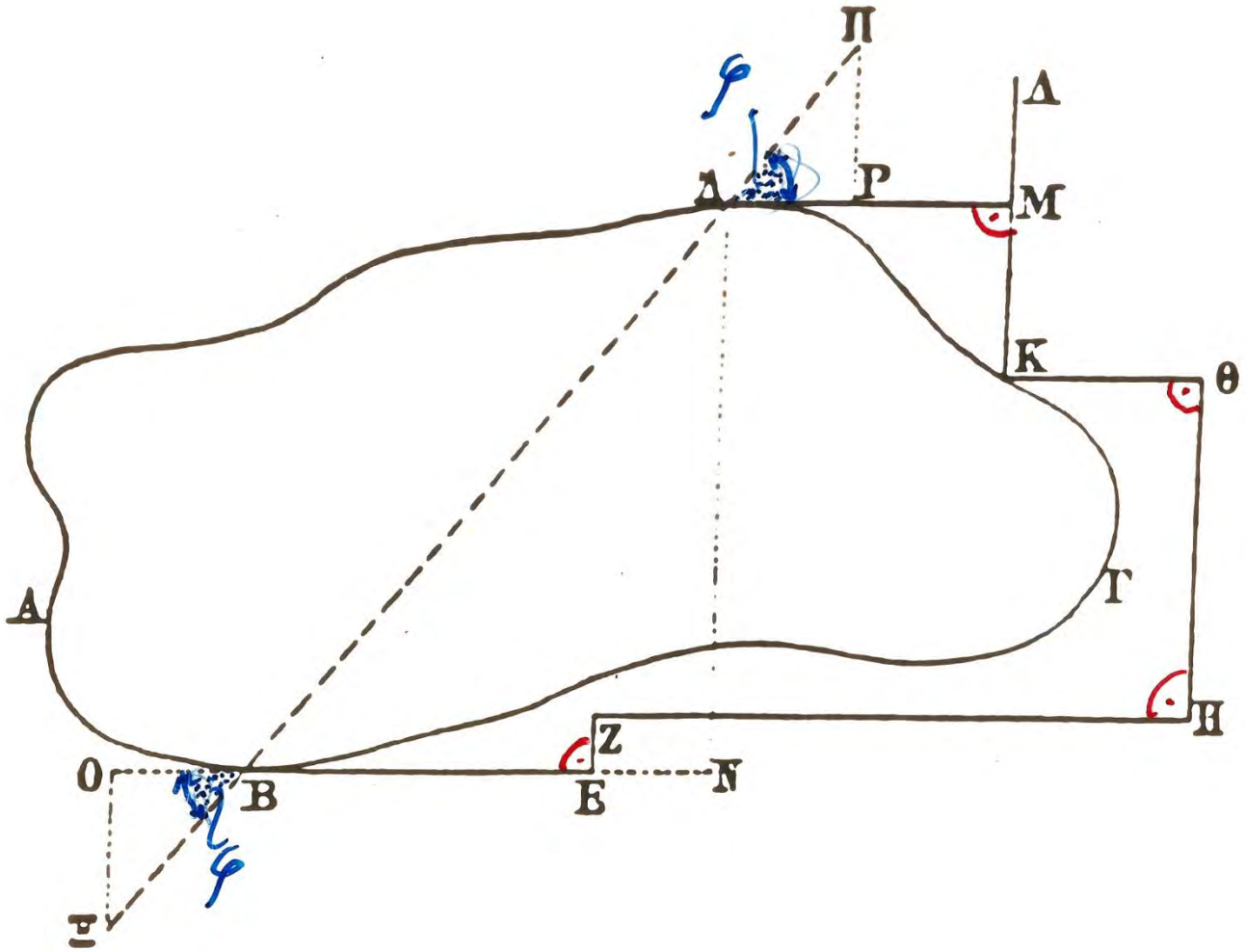


Fig.25. Representation of the survey-example XV of Heron (Schoene).

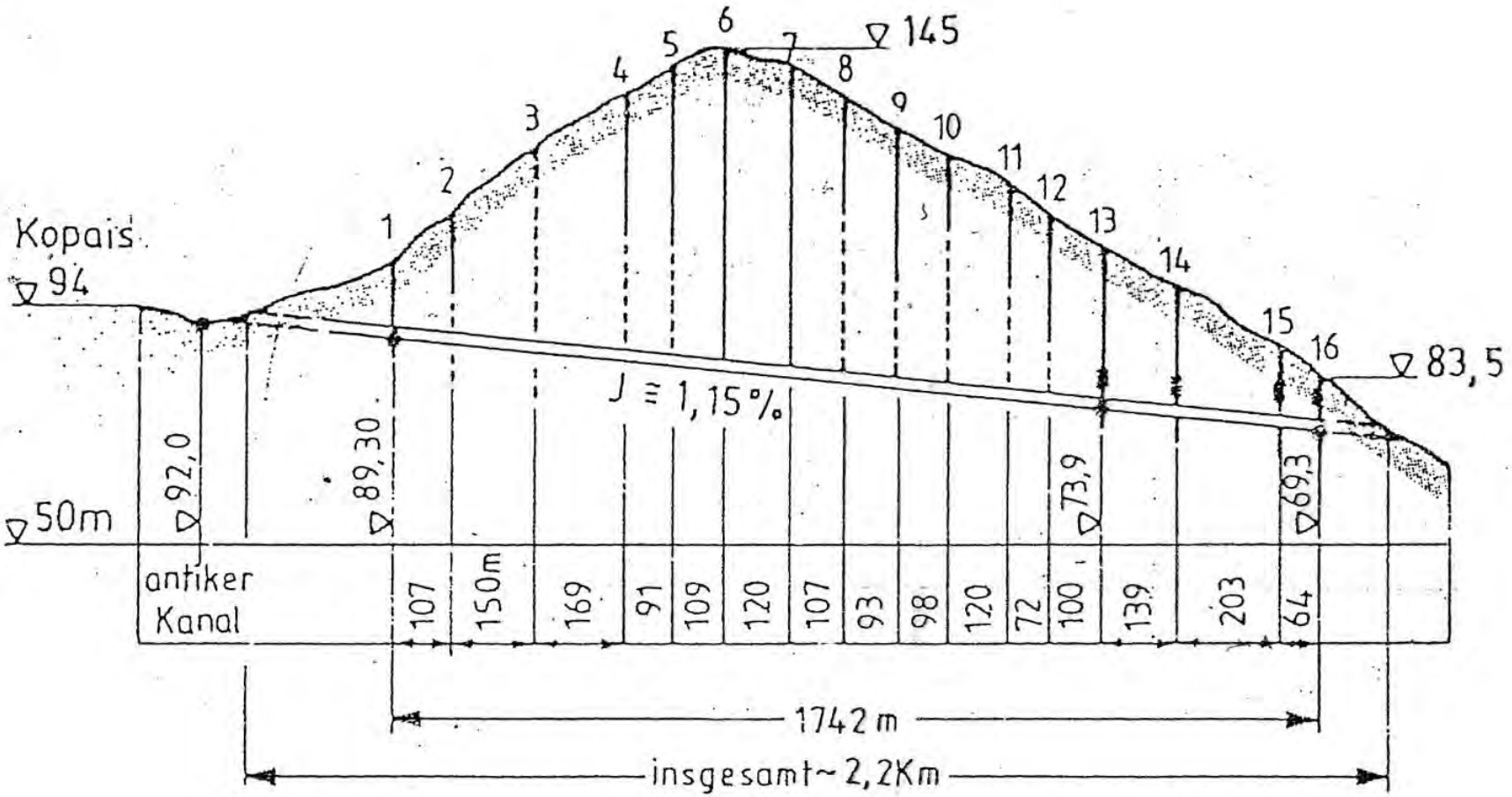


Fig.26. The Hellenistic tunnel at Kopais lake (Knauss)

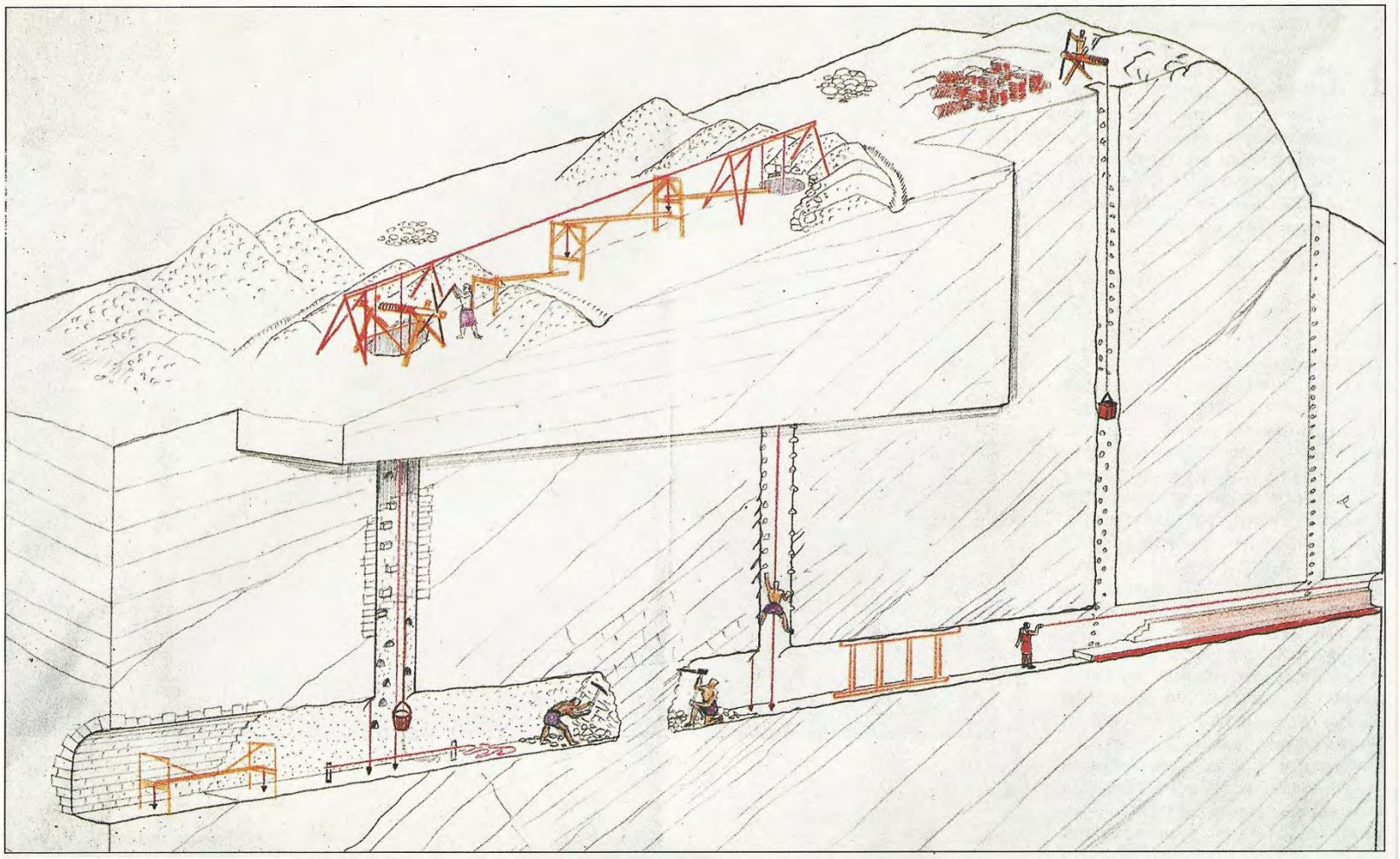


Fig.28. The typical construction method of the underground water-supply systems of the greeks (Korres).

IV. HARBOUR ENGINEERING

1. Introduction

- Distinction: “commercial”, “military” (Fig.1)
- External harbour
  Inner harbour (Fig. 2)
- Layout and construction materials
  Naval yards
  Auxiliary installations
  Particularities of Inner harbours
- Maritime Canals and Diolkoi

2. Layout, Materials and Construction

a) Moles: Underwater (Fig. 3)
upper works (Fig. 4)

a) Entrances (mouths)

b) Fortifications: Walls, Fig. 5
Watchtowers, Fig. 6

a) The revolution of Dikaiarchia (pozzuolanas)

b) Quays (Fig. 7, 8)

c) Deepening, dredging (Fig. 9, 10, 11)

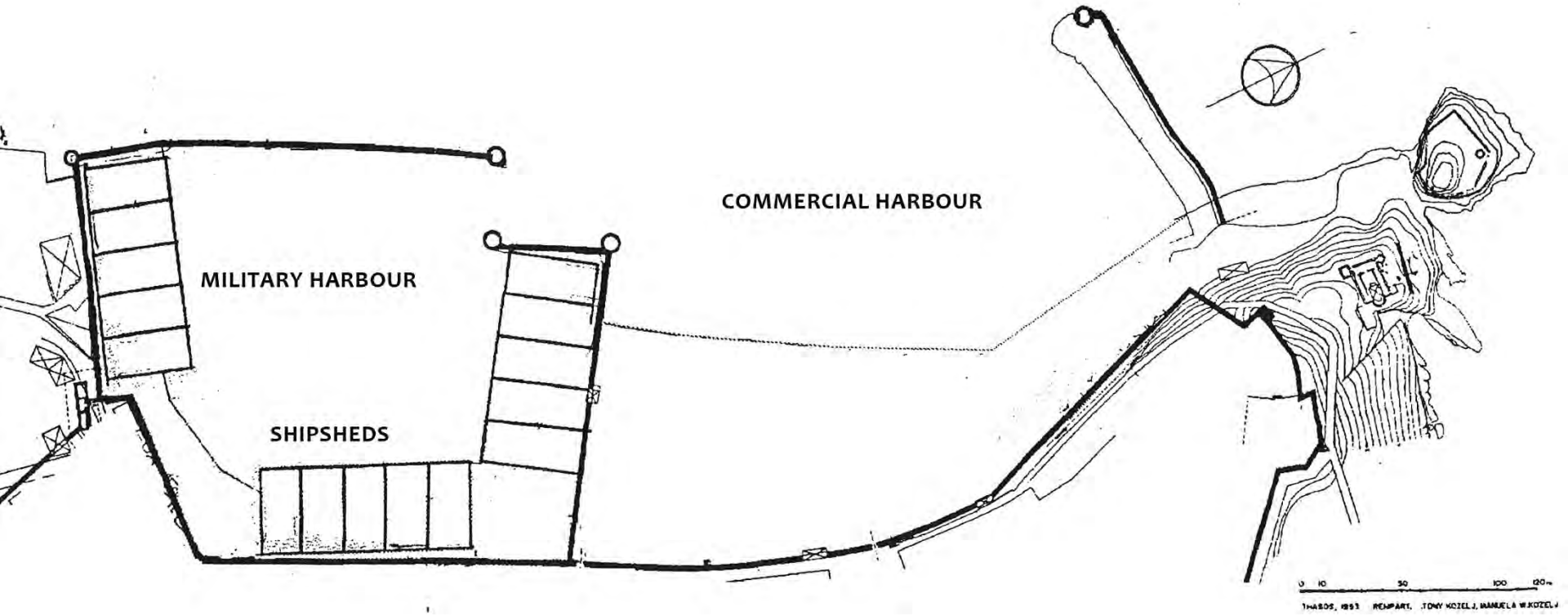


Fig.4. The ancient harbours of the island of Thassos, [Zēros, p.24, from Kozelj]

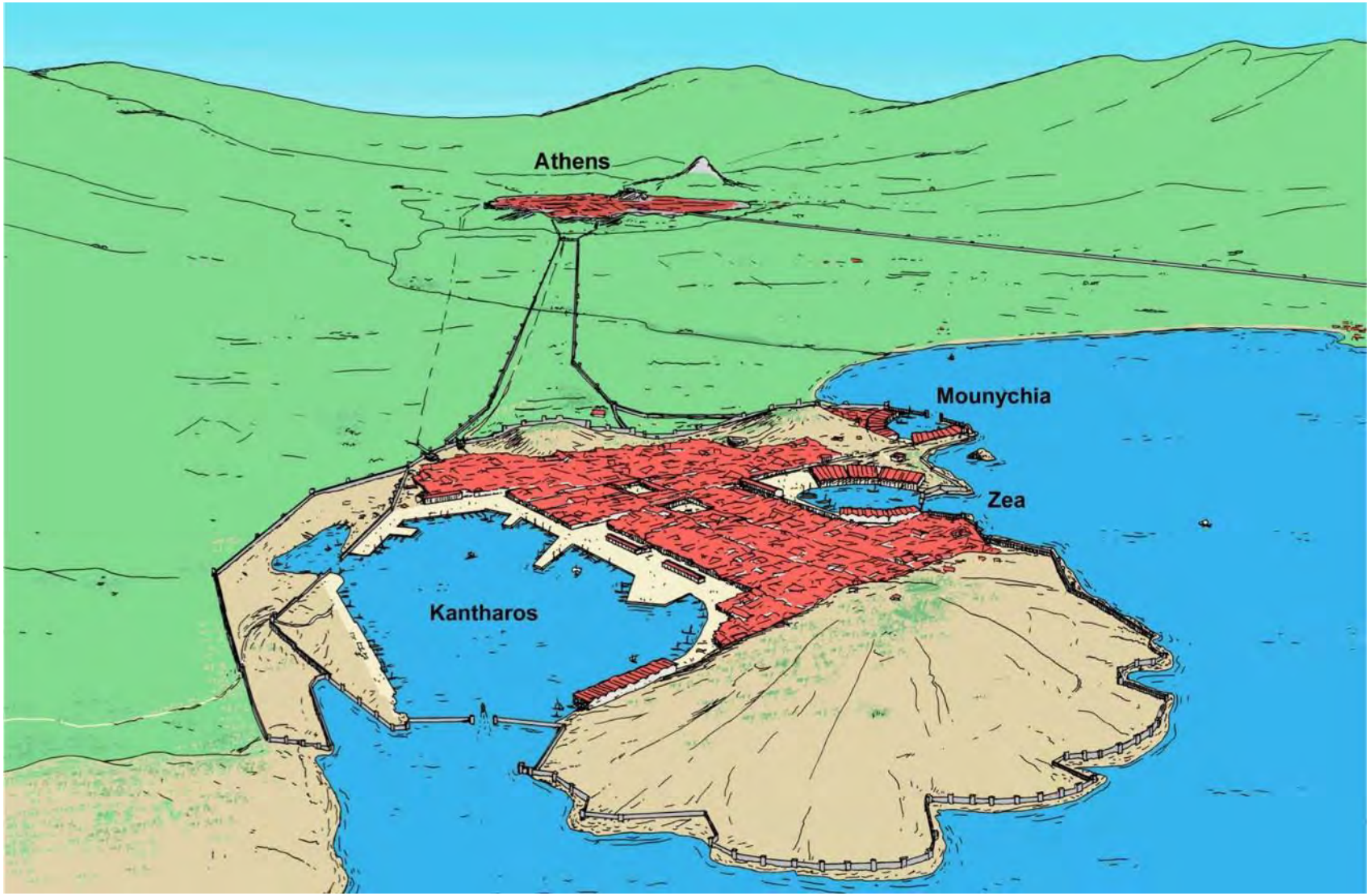


Fig.5. The fortification walls of Athens and Piraeus were extended to include the military harbours as well, [Nakas……-kourkoumelis…Loven]

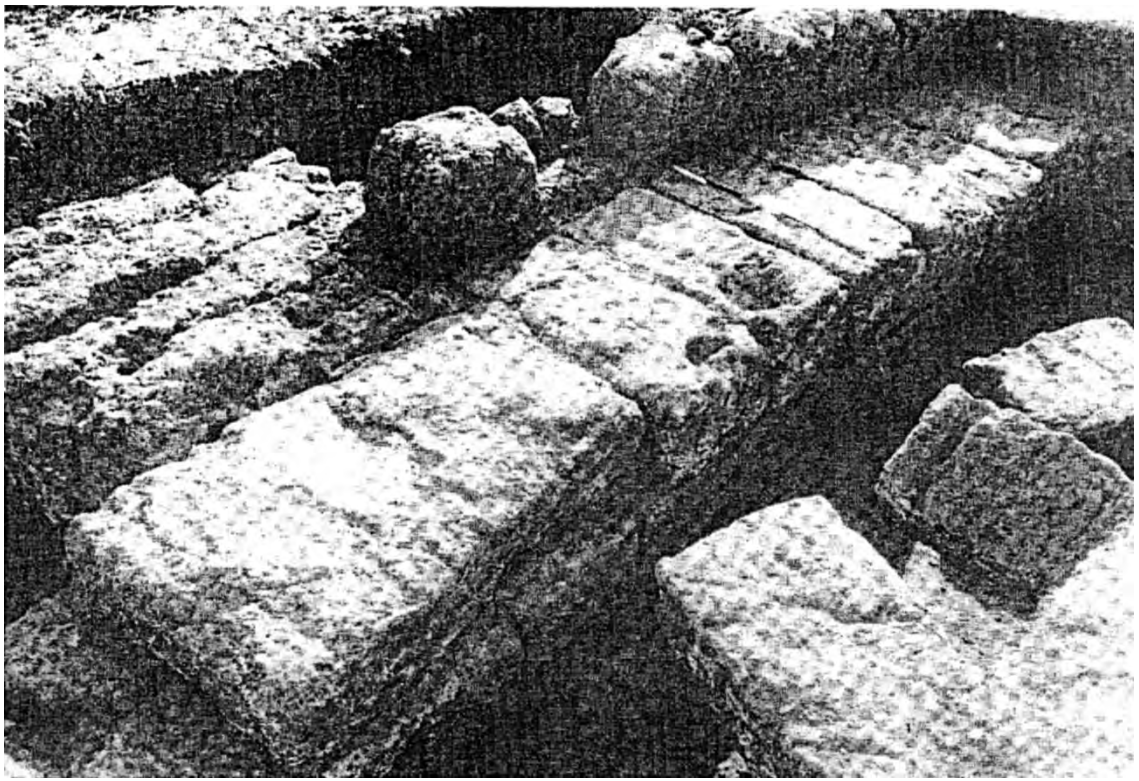
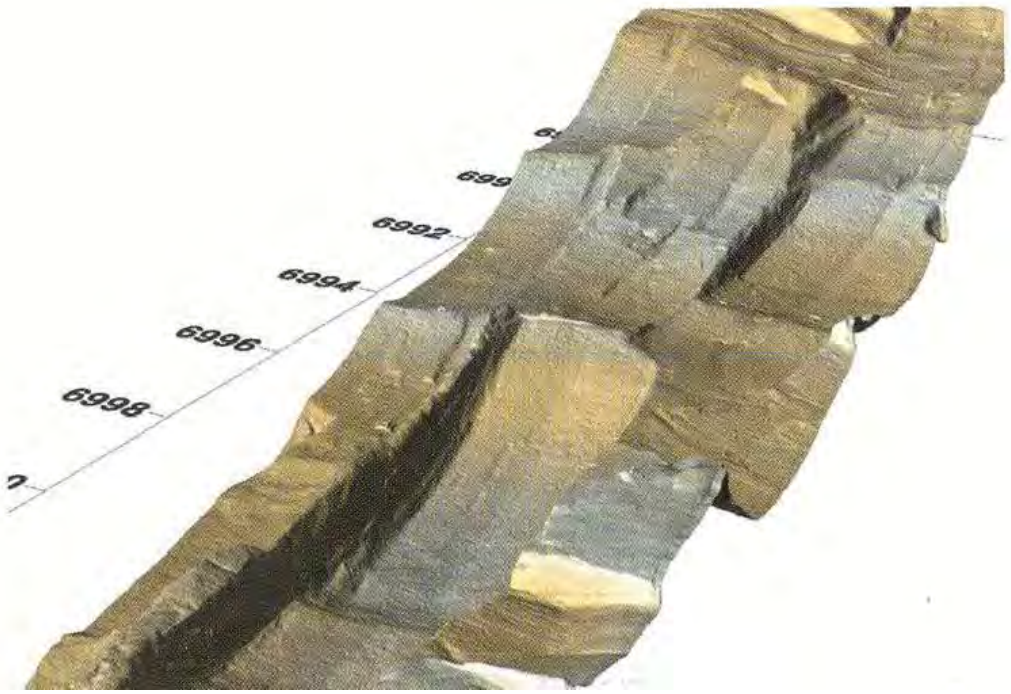


Fig.7. The quay-wall at Phalasarna harbour.



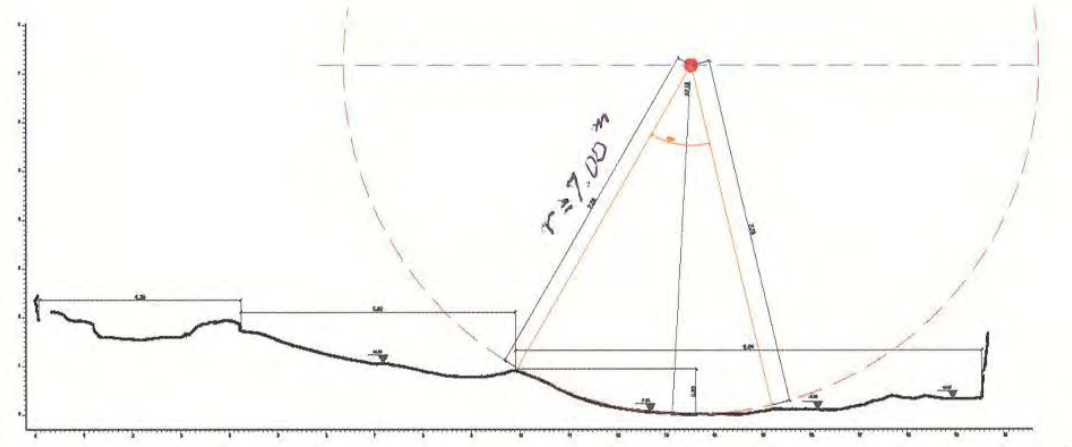


Fig.10. Geometrical statistical study of the dredging traces of Fig.9, [Giampaola et al.].

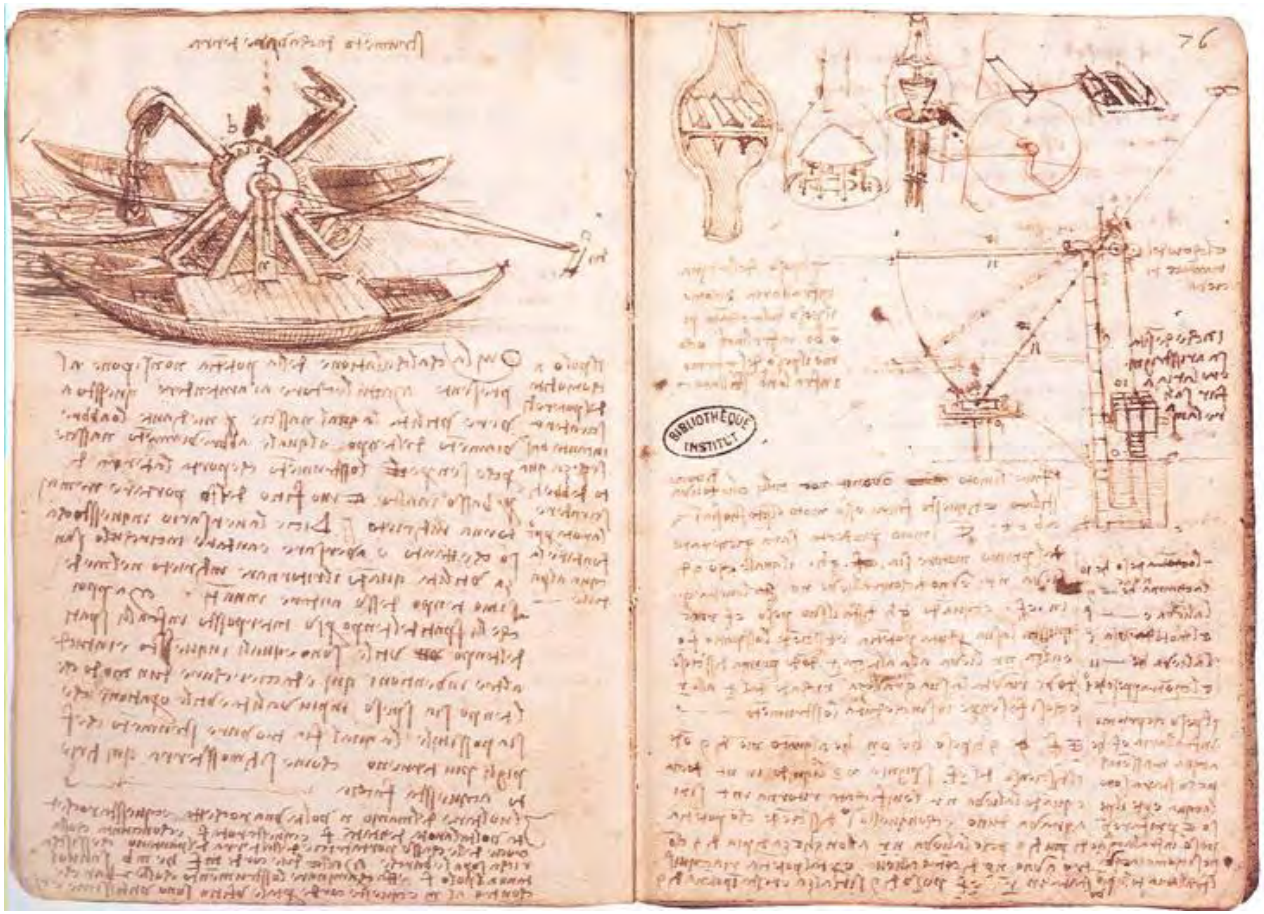


Fig.11. The floating dredger of Leonardo da Vinci, [Giampaola et al.].

3. Shipsheds

a) Sheltering of warships

(Fig. 12, 13, 14)

b) Slipways: ships hauled out (Fig. 15)

Fig.12. An artists' view of two triremes hauled out and housed in two shipsheds, [Zea Harbour Project].

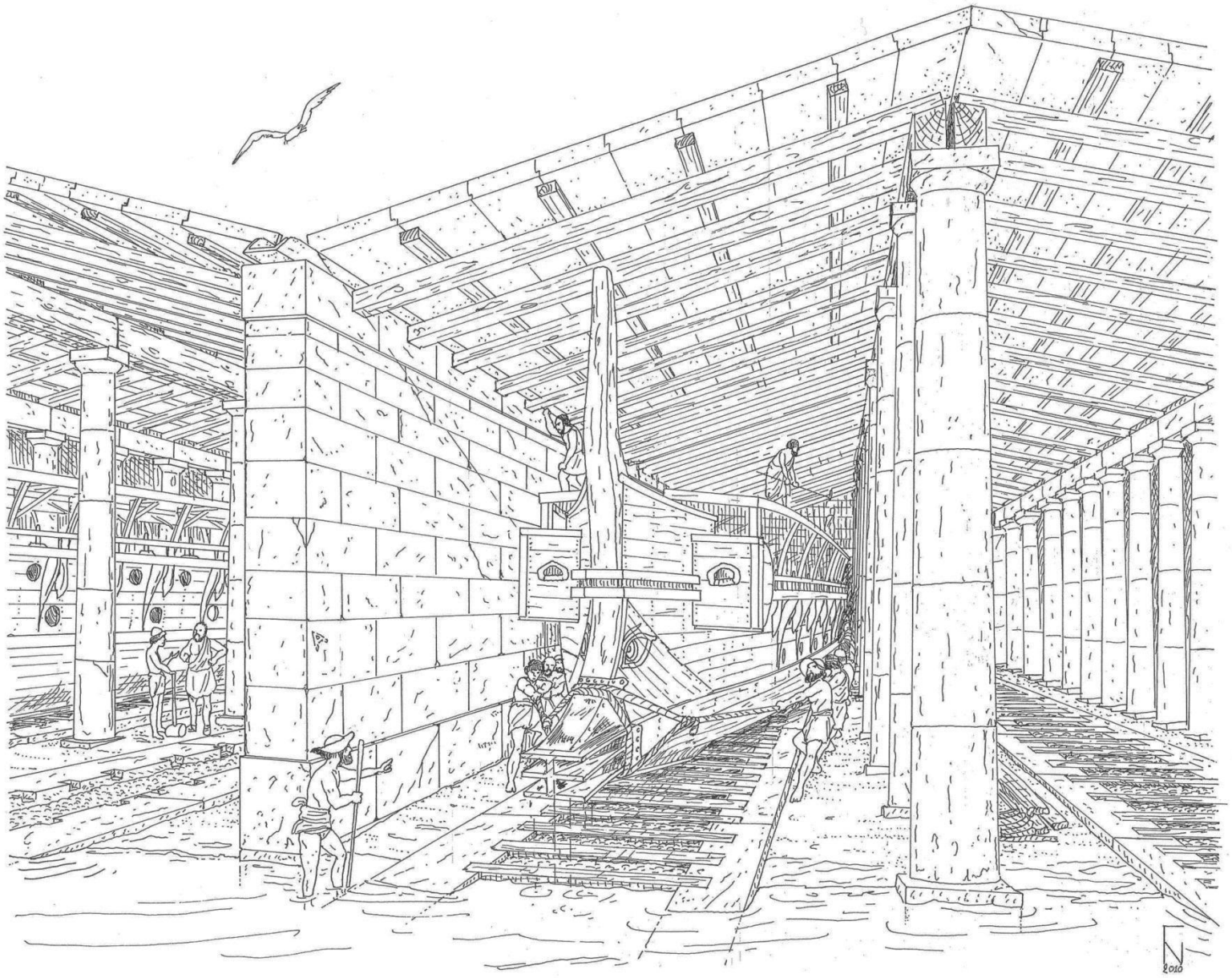


Fig.15. Artists' view of a shipshed at Zea, [Nakas, in Loven].

5. ARTIFICIAL INNER HARBOURS

- Several greek inner harbours were studied: Gytheion, Lechaion, Alexandria (Kivotos), Phalaserna
- **Lechaion**, actual remnants, (Fig. 17)
- Outer jetties, (Fig. 18)
- Long mouth canal (100,0 m) 4th c. BCE, (Fig. 19)
- Two mounds of ancient dredged sand and pebbles (5,0 and 15,0 m high), (Fig. 2)

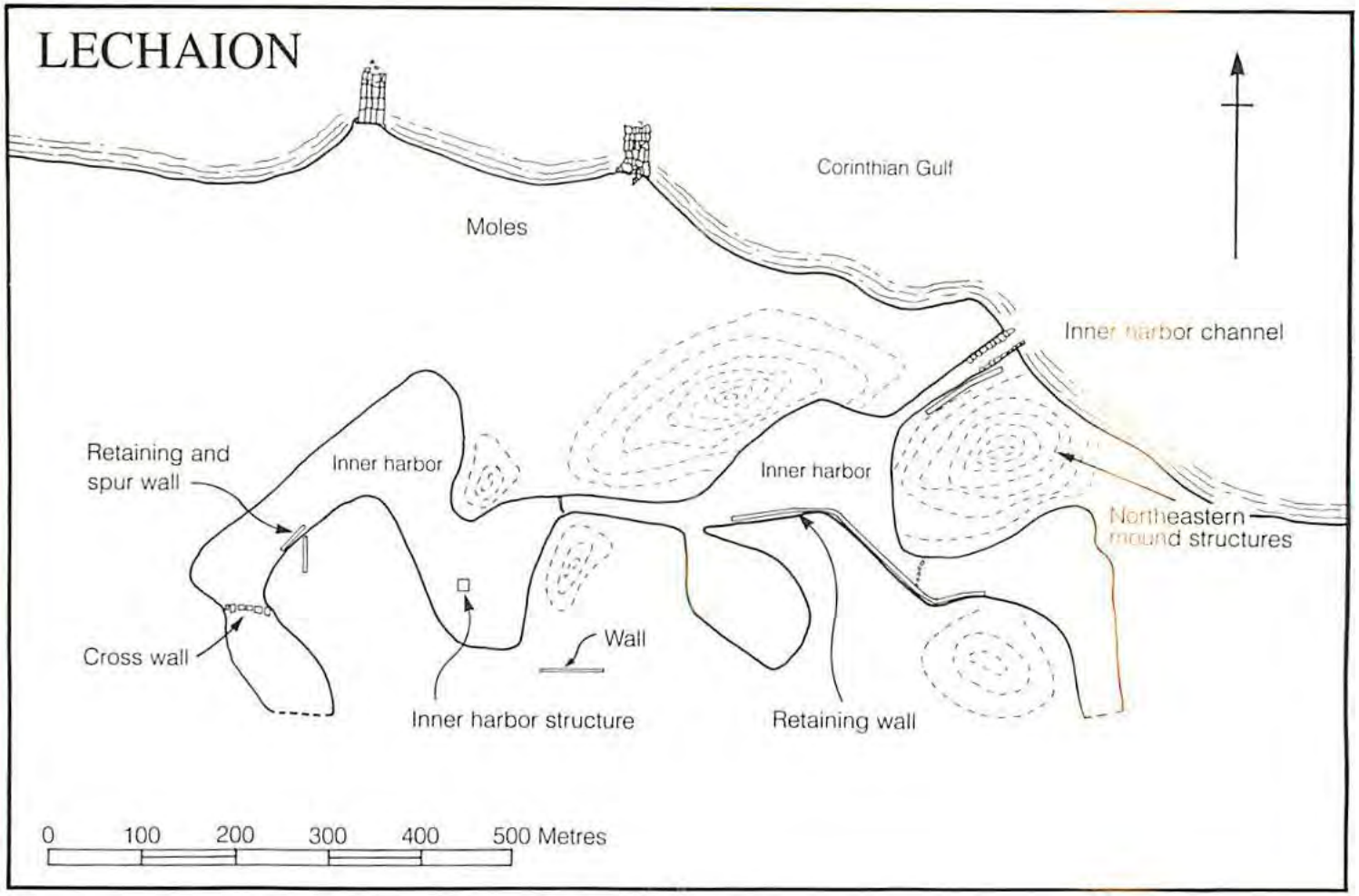


Fig.17. An approximate layout of the actual remnants of the inner basins of the Lechaion harbour, [Rothaus].

Plutarch: “The Dinner of Seven Wisemen” was organised at Lechaion, next to Corinth and Diolkos!

4. MARITIME and RIVER CANALS

Sea-to-sea **artificial** Canals, inevitably connected to Harbours, should also be described here.

a) **Along the Corinthian Isthmus** (Fig. 20)

- Convey ships from Corinthian to Saronikos Gulf (6,0 km), avoiding to sail around Peloponnese
- Periandros: intention ~ 550 BCE
- Dēmētrios Poliorkētēs: started digging (308 BCE); wrong levelling measurements

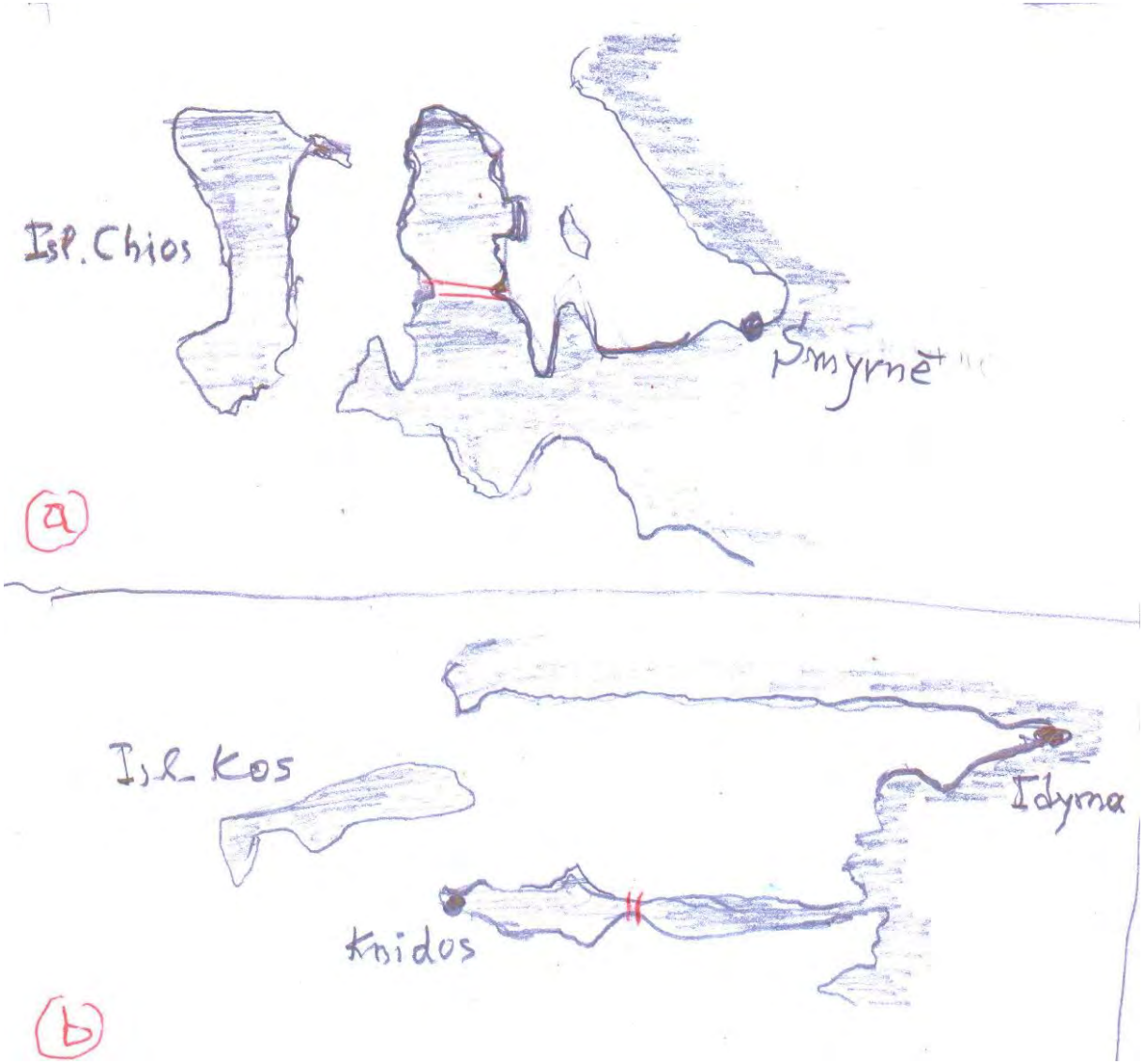


Fig.21. The location of the Canals attempted to be dug by the Greeks in Ionia, the coastal area of Asia Minor. B) in the Peninsula of Knidos, A) In the peninsula of Mimas, [Author].

c) The Ancient Greek "SUEZ CANAL" (Fig. 22)

- Lechos (ca. 600 BCE) started, (Herodotus 2, 158/159)
  - A little south of Boubastis
  - Heading from West to East and then to South (to the Arabic Gulf)
- It begins at Phacussa and empties to Arsinoē, (Strabo 17.1.25 + 17.1.26)
  Breath 50 m, sufficient depth
  - Dareios continued the works
  - Ptolemaic Kings "Cut through the Canal"

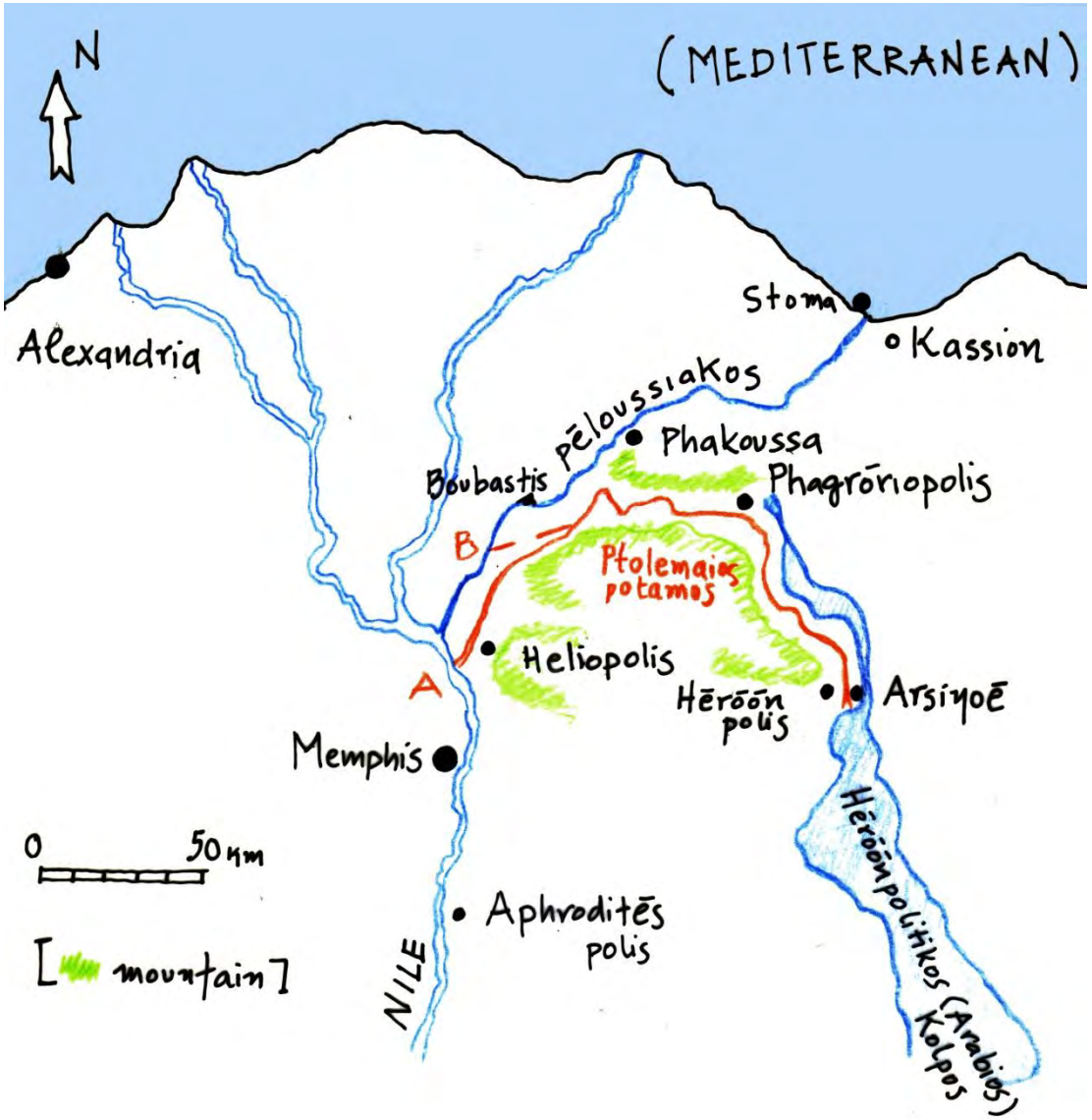


Fig.22. The region of the artificial canal from the vertex of Delta of Nile up to Arsinoe harbour (Suez) at the Arabic Gulf. (This approximate map was drafted on the basts of Heinen/Schomer and Harvard U.P)

DIOLKOS (6th c. BCE up to 1200 CE)
(the substitute of the Corinthian Canal)

- Well paved land-road 6,5 km long
- Ships hauled up overland (Fig. 23)
- Loaded on a track, (Fig. 24)
- Pulled along the “Diolkos” (Fig. 25, 26)
- Launched again to the other Gulf, (Fig. 27)

Fig.23. Ships were hauled up near the Lechaion harbour, [Tassios et al.].

Fig.25. Transfer of the ship along the Diolkos, [Tassios et al.].