SHAPING CULTURAL LANDSCAPES

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Connecting Agriculture, Crafts, Construction, Transport, and Resilience Strategies

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Marble in the mountains – econometrics of quarrying and transporting building stones for the temple of Athena Alea at Tegea, Greece

Jari Pakkanen

1. Introduction

Very little of the Late-Classical temple of Athena Alea at Tegea is preserved *in situ* above the level of the conglomerate foundations. However, hundreds of marble blocks from the building lie scattered around the archaeological site allowing for a reliable reconstruction of the monument (Dugas et al. 1924; Pakkanen 1998; 2013a: 94-109; 2014a; 2014b). The ancient traveller Pausanias visited the imposing temple in the second century CE and he recounts that its architect was Skopas of Paros, one of the most famous sculptors of the fourth century BCE (Paus. 8.45.4-5). First exploratory trenches at the site were excavated in 1879; full-scale excavations were carried out in 1900-1902 by the French School and in 1909, the final private property on top of the foundations was purchased and excavated. The next phase of major further work at the sanctuary was conducted by the Norwegian Institute at Athens in 1990-1994 (Dugas et al. 1924: x-xii; Østby 2014a; 2014b). Based on the new fieldwork at the site, the Classical temple can now securely be dated to 350-325 BCE (Østby 2014c: 341-346). The latest field documentation campaigns at the site in 2016 and 2019 have employed photogrammetry and three-dimensional intensive reflectorless total station drawing (Pakkanen 2021a: 116-117). An orthorectified and georeferenced mosaic image of the foundations and the archaeological site based on drone photography is presented in Figure 1.

Greek monumental architecture of the Classical and Hellenistic periods is characterised by the employment of durable materials. Therefore, for most buildings it is possible to present a relatively accurate reconstruction which can be used in econometric estimates of the construction *chaîne opératoire* (Pakkanen 2013b: 56-72; forthcoming; cf. also Salmon 2001: 195). The value of the preserved building accounts from Attica, Delphi, Epidauros, Delos and Didyma has been demonstrated in a series of economic studies on monumental architecture (see, e.g., Haussoullier 1926: 127-138; Stanier 1953; Rehm 1958: 62-64; Burford 1969; Haselberger 1985; Clark 1993; Davies 2001; Pakkanen 2013b) but their potential is still underutilised (Pakkanen forthcoming). The example of Janet DeLaine's pioneering monograph *The Baths of Caracalla* (1997) has been followed also in the domain of Greek building in the historical periods: these studies incorporate comparative data and labour rates from a range of different contexts to give an idea of the potential econometric impact

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Figure 1. Georeferenced orthomosaic of the archaeological site and foundations of the temple of Athena Alea at Tegea (J. Pakkanen).

of building projects (see e.g., Pakkanen 2013b; 2021b; forthcoming; Lancaster 2019). The most extensive demonstration of the utility of labour cost analyses in understanding the economic importance of building in the Greek world is Ann Brysbaert's SETinSTONE project concentrating on the Late Bronze Age (for most recent summaries with extensive bibliographies, see Brysbaert et al. 2018; 2022; Brysbaert 2020; 2021. For individual projects part of SETinSTONE: Turner 2020; Boswinkel 2021).

DeLaine (1997: 105-106) has argued that it is prudent to base econometric estimates on the principle of minimum costs since the exact date and length of building projects is in most cases unknown. Difficulties in sourcing and transport of materials and project finance did cause delays in monumental construction. However, Classical and Hellenistic building accounts indicate the contract prices and costs of monumental building. When these figures are analysed in conjunction with the preserved architectural elements, it is possible to derive actual labour rates rather than minimum ones (Pakkanen forthcoming). 19th-century architectural handbooks are also valuable sources for estimating how much work is needed to quarry and carve different types of stone. For example, Giovanni Pegoretti's volumes have been made very good use of in analyses of ancient Roman building (Pegoretti 1863-1864; see DeLaine 1997; Russell 2013; for an extensive discussion, see Barker et al. forthcoming). In a separate paper, I have analysed how Pegoretti's labour constants compare with Greek architectural and inscriptional data from the Classical and Hellenistic periods (Pakkanen forthcoming). These rates are the basis of the calculations presented in this chapter for the cost of quarrying and transport of building stones for the fourth-century temple of Athena Alea at Tegea. The sites and quarries discussed in the text are indicated in Figure 2. For architectural terms used in the text, see Figure 7.

The aim of this chapter is to present a model of how the quarry volume, supply and transport of building stones of a large-scale Classical construction project in the middle of Arcadia at Tegea can be quantified. Comparative labour rate studies can be used to gain an understanding of the size of required workforces and the timeframe of the project, the role of stone quarries

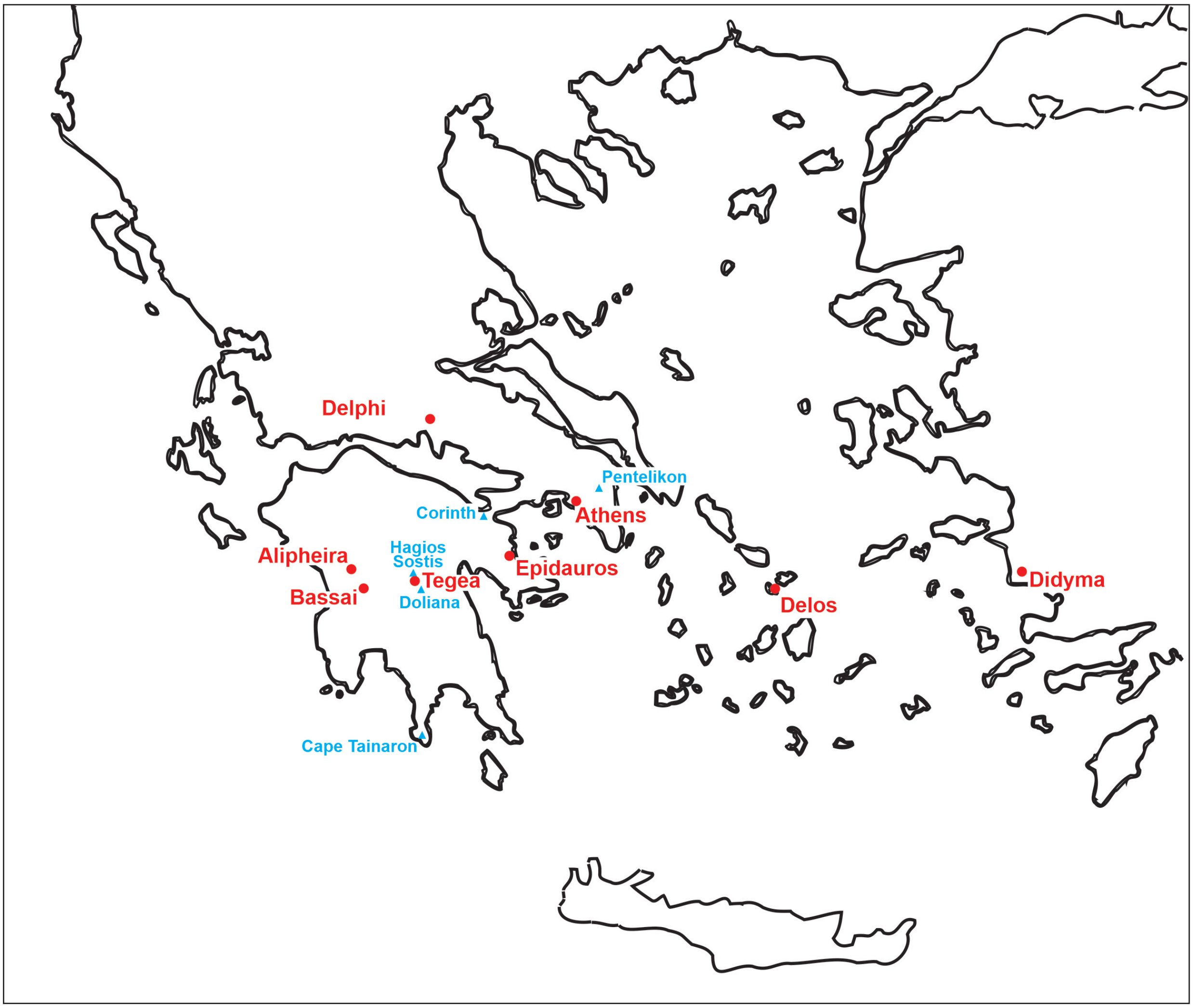

Figure 2. Map of principal sites (red circles) and quarries (blue triangles) mentioned in the text (J. Pakkanen).

and monumental construction in the economy of the city-state and the overall cost of temple building.

2. Cost of quarrying and transport of local conglomerate

The foundations of the temple of Athena Alea were built large ashlar blocks of conglomerate. The clasts of the sedimentary rock are well-rounded pebbles as is typical of conglomerates formed in coastal and fluvial environments. The nearest outcrop of this type of stone is at Hagios Sostis, c. 3.0 km north of the temple (Mendel 1901: 246; Dugas et al. 1924: 9). The hardness of conglomerates varies depending on the cement and the composition of clasts (Himus et al. 1972: 169-170). The temple builders at Tegea considered this the best locally available material for the foundations.

The horizontal dimensions of the foundations based on the 1996 fieldwork are presented in Figure 3 (Pakkanen 2013a: 102-103). The depth of the outer ring foundations supporting the exterior peristyle order of the temple varied: in the northeast corner, they comprise nine courses and have a depth of c. 3.1 m; in the southeast corner the five courses are c. 1.5 m deep; on the south side, the depth is c. 1.3 m, the west c. 1.6 m and on the north c. 1.9 m. The depth of the east ramp and north platform foundations is c. 1.1 m. The depth of the inner ring is c. 1.5 m and the foundations supporting the east and west walls of the cella are slightly shallower with a depth of c. 1.2 m (Dugas et al. 1924: 10). In the corners of the temple, the courses were stepped. However, some marble blocks from the Archaic predecessor were also recycled into the Classical foundations (Østby 1986: 91-92), so these two factors largely cancel each other in the calculation of the total volume of conglomerate needed for the temple foundations. The volume of stone for the outer ring can be estimated as 771 m^3 and

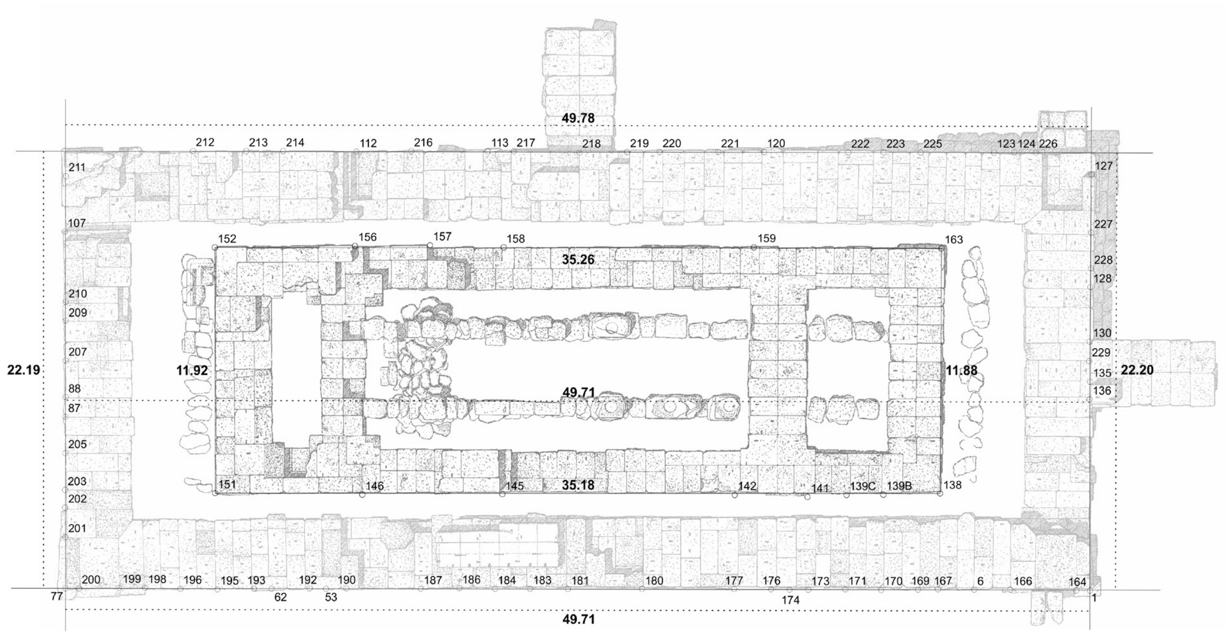

Figure 3. Foundation dimensions of the temple of Athena Alea and locations of new measurements taken in 1996 (J. Pakkanen; foundation drawing based on Dugas et al. 1924, pls. 3-5).

the inner ring as 325 m^3. The volumes are based on a combination of previously published figures and new fieldwork.[1]

Table 1 presents a summary of limestone quarry, transport and construction costs based on the contracts recorded in the building inscriptions of the early fourth-century BCE temple of Asklepios at Epidauros (*Inscriptiones Gracae* IV^2 102; Pakkanen forthcoming). The table corrects the labour rates presented by Alison Burford (1969: 248-250). The contract prices are adjusted on the basis of Sebastian Prignitz's reinterpretations and the stone volumes based on Georges Roux's architectural monograph (Prignitz 2014: 18-85; Roux 1961: 83-130). The function and general characteristics of the local soft limestone recorded in the first two contracts are comparable to the conglomerate at Tegea, and the combined quarry, transport and construction costs give a baseline for the cost estimates of the temple of Athena Alea. The location of the local Epidaurian quarries is not known, but the foundation stone would have been sourced close to the sanctuary keeping the transport costs as low as possible. The rates for Corinthian stone in Table 1 include both land and sea transport, but in another instance the cost of oxen cart transport for Pentelic marble coffers from the harbour to the sanctuary can be calculated as 2.3 Aiginetan drachmas per cubic metre and kilometre (Burford 1969: 186; Pakkanen forthcoming). I have also estimated that based on Pegoretti's figures and taking the length of a working day as 10 hours, the rate for quarry costs, including rough shaping, of good-quality limestone column drum blocks at Corinth can be calculated as 6.8-18.3 Aiginetan drachmas per cubic metre, and most likely towards the lower end of this range. The large range based on Pegoretti is primarily the result of different types of limestones he takes into consideration. The daily wage of a skilled craftsman at Epidauros can with quite high degree of certainty be taken as one Aiginetan drachma a day, so conversion of Epidaurian rates into skilled person-day rates is very straightforward (Pakkanen forthcoming). In order not to complicate matters in the following, I will keep expressing the costs in terms of Aiginetan drachmas. Comparison between the Epidaurian contracts and Pegoretti's rates shows that the Corinthian limestone quarry entrepreneurs made, in most cases, a healthy profit by getting at least twice the price of daily wages they would have needed to pay for the extraction of the blocks.

The two first contracts, 1 and 2 in Table 1, show that the rate for quarrying soft local limestone was considerably less expensive than Corinthian stone, so the quarry costs for the conglomerate at Tegea were also likely below the range established based on Pegoretti's limestone rates: 5 Aiginetan drachmas per cubic metre seems a reasonable estimate. Therefore, to quarry and roughly cut into shape the c. 1,100 m^3 of conglomerate needed for the foundations

1 West outer ring (width × length × depth): 3.40 m × 14.44 m × 1.6 m. North: 3.40 m × 49.78 m × 1.9 m. South: 3.35 m × 49.71 m × 1.3 m. East: 3.40 m × 14.45 m × 2.3 m. East ramp: 3.20 m × 6.10 m × 1.1 m. North platform: 5.83 m × 3.03 × 1.1 m. Opisthodomos foundations of the inner ring: 2.75 m × 7.82 m × 1.5 m. West cella wall: 2.15 m × 7.82 m × 1.2 m. East cella wall: 2.65 m × 7.82 m × 1.2 m. Pronaos: 2.65 m × 7.82 m × 1.5 m. North: 35.26 m × 2.05 m × 1.5 m. South: 35.26 × 2.05 m × 1.5 m.

Table 1. Temple of Asklepios at Epidauros. Cost rates based on contract prices in the inscriptions and reconstructed stone volume (probable day wage of a skilled craftsman: 1 Aiginetan drachma per day; c. 6.1 g of silver per drachma).

Construction task and quantity	Q, T & C	Q & T	Quarry (Q)	Transport (T)	Construction (C)
1. Local limestone for foundations of peristasis, 176 m³	4,068 dr. 23.1 dr./m³				
2. Local limestone for foundations of cella, 96 m³	1,385 dr. 14.4 dr./m³				
3. Corinthian stone for peristasis from steps to pediments, 258.7 m³		5,700 dr. 22.0 dr./m³			
4. Construction of visible steps & stylobate, 66.9 m³					888 dr. 13.3 dr./m³
5. Construction of colonnade & entablature, 191.8 m³					3,068 dr. 16.0 dr./m³
6. Corinthian stone for cella (half), 135.1 m³		6,167 dr. 45.6 dr./m³			
7. Corinthian stone for cella (other half), 135.1 m³			4,437-4,455 dr. 32.8-33.0 dr./m³	1,712-1,730 dr. 12.7-12.8 dr./m³	
8. Construction of the cella, 270.2 m³					3,209-3,500 dr. 11.9-13.0 dr./m³
9. Fluting of exterior and interior columns, 574.5 m²					1,336 dr. 2.3 dr./m²

would have cost c. 5,500 Aiginetan drachmas. Possibly half of the quarry workers would have been unskilled labourers paid half the wage of a skilled craftsman (cf. DeLaine 1997: 209-210), so a group of 12 skilled and 12 unskilled quarrymen would have been needed to produce this volume of stone in c. 300 days.[2] Even though the quarries were very close to the temple, the cost of oxen transport of the blocks at c. 7,600 Aiginetan drachmas was very likely more expensive than quarrying the stone.[3] Conglomerate and marble were already used for the Archaic temple (Østby 1986: 79), so the road network between the quarries and the sanctuary must have already been developed in late seventh century BCE.[4]

3. Cost of quarrying and transport of marble

The marble for the superstructure of the temple was quarried at Doliana, c. 12 km southeast of the site (for an extensive discussion of the Doliana quarries, see Bakke 2022 in this volume). The quarries are located c. 1,100 m above the sea level and the route in the beginning descended steeply to the Tegea Plain (c. 650 masl). The few euthynteria blocks on the south flank are the only *in-situ* pieces of marble of the Late-Classical temple (Figure 4), but more than 800 blocks from the temple have been documented at the site (Figure 1; Pakkanen 2014b).

The marble from the temple has not been scientifically studied and the different strata at Doliana have not been documented in detail, so in this chapter I have taken the cautious approach that all marble used in the building could originate from these nearby quarries. The material of the temple sculptures is discussed in some detail by Charles Dugas and Jules Berchmans, and they conclude that there is no specific reason to suggest that the marble would have been imported to Tegea from further away (Dugas et al. 1924: 78-80). However, the possibility of imports cannot entirely be excluded for the Tegea temple. For example, the marble, which was used for the rooftiles, coffers and sculpture in the temple of Apollo at Bassai, could have been an option. The Cape Tainaron quarries are located at the south end of the Mani peninsula (Cooper 1996: 108-111), so the material would have needed first sea transport along the west coast of the Peloponnese and then more than 40 km on a winding road to Bassai up to a height of 1100 masl. The route to Tegea would have been similar but along the east coast to modern Astros and then over the mountains. Translucent marble allows sunlight to filter inside the building, so the temple builders did not shy away from transporting large quantities of stone to the mountains for specific purposes. Similar marble is used more widely to the west and north of Bassai, for example in the Late-Archaic temple at Alipheira (Orlandos 1967-1968: 79-89; Cooper 1996: 107-108).

Table 2 summarises the rates for quarrying, transport and construction of marble blocks based on the building accounts of the Hellenistic temple of Apollo at Didyma (Rehm 1958: 40-64; Pakkanen forthcoming).

2 $1{,}096\ m^3 \times 5\ dr./\ m^3 = 5{,}480$ dr. With 12 skilled and 12 unskilled, 5,480 dr. / (12 dr./pd + 0.5 × 12 dr./pd) ≈ 304 pd. For the argument that the physically arduous tasks of quarrying and construction would have been carried out by a workforce consisting of mostly men and not women and children, see DeLaine 1997, 106.

3 $2.3\ dr./(m^3 \times km) \times 1096\ m^3 \times 3.0\ km \approx 7{,}562$ dr.

4 Pikoulas (1999, 306-309) discusses the dating of the road network in Arcadia: he dates the beginning of a systematic cart-road construction to the seventh century BCE based on political and military factors. Forsén 2003, 70 discusses the late sixth century temples of Vigla and Agios Elias at Asea and connecting these construction sites with cart roads from Doliana. On the complexity of dating and establishing the road network between Doliana quarries and the Tegea Plain, see Bakke and Bakke-Alisøy 2020.

Figure 4. Detail of the south flank of the temple of Athena Alea. The marble euthynteria is on top of the foundation conglomerate blocks, and the column drum is not *in situ*. The red lines are part of the 3D total station drawing (J. Pakkanen).

The currency and day wage are different than at Epidauros, so in order to convert the rates into person-days of a skilled craftsman they need to be divided by two. The land transport rate per cubic metre and kilometre at Didyma is strikingly high, approximately four times more than at Epidauros. This could partially be explained by the colossal scale of the temple and the very large marble blocks which were difficult to handle. Since the unfinished column drums at Didyma record the ordered sizes of blocks and it is possible to measure their actual sizes with the extra mantle of stone, the building accounts make possible differentiating between the ordered and delivered rates: the volume of delivered stone is greater than what was ordered, and in many cases the drums are placed lower in the shaft than originally intended making good use of the extra delivered material. The two different rates for quarry stone take into account the stratification of marble in the quarries: blocks with a height of less than 0.5 m were easier to find and extract, and taller blocks could only have been quarried from specific places.

The quarry rates based on the building accounts at Didyma, 131.8-192.4 dr./m^3, can be compared with the range based on Pegoretti's data. I have calculated that using Pegoretti's time and volume estimates and the same day wage of two Alexandrian drachmas as at Didyma, the range is only 35.8-43.7 dr./m^3 (Pakkanen forthcoming). The colossal size of the temple, difficult handling of the very large blocks, and high degree of quarry wastage are likely the largest factors behind the differences between the rates. Therefore, Pegoretti's range is used in the following as the rate for the cost of quarry stone at Tegea. However, it should be kept in mind that Pegoretti gives potentially a low baseline for marble quarrying: in the 19th century, extraction of marble in the main Italian quarries was a highly professional operation aimed also at export market. When the range is converted into fourth century Epidaurian day wages and the Aiginetan currency used in the previous section, the range becomes 17.9-21.9 dr./m^3, which is 3.6-4.4 times higher than the conglomerate rate used in this chapter.

Table 2. Temple of Apollo at Didyma. Cost rates as outlined in the inscriptions and based on ordered sizes and actually delivered blocks (likely day wage of a skilled craftsman: 2 Alexandrian/Attic drachmas per day; *c.* 4.3 g of silver per drachma).

1. Task	2. Rate	3. Rate ordered	4. Rate delivered
Quarry stone (H < 0.5 m)	4 dr./ft^3	153.6 dr./m^3	131.8 dr./m^3
Quarry stone (H ≥ 0.5 m)	5 3/6 dr./ft^3	211.2 dr./m^3	192.4 dr./m^3
Land transport		19.2 dr./(km × m^3)	17.4 dr./(km × m^3)
Loading to ship	1/6 dr./ft^3	6.4 dr./m^3	5.8 dr./m^3
Sea transport		1.6 dr./(km × m^3)	1.4 dr./(km × m^3)
Unloading from ship	1/6 + 6/72 dr./ft^3	9.6 dr./m^3	8.7 dr./m^3
Lifting & positioning	1 dr./ft^3	38.4 dr./m^3	38.0 dr./m^3
Fine dressing	2 dr./ft^2	22.8 dr./m^2	21.6 dr./m^2
Fluting	2 dr./ft^2	22.8 dr./m^2	22.2 dr./m^2
Carving Ionic capital	5 dr./ft^2	56.9 dr./m^2	54.5 dr./m^2

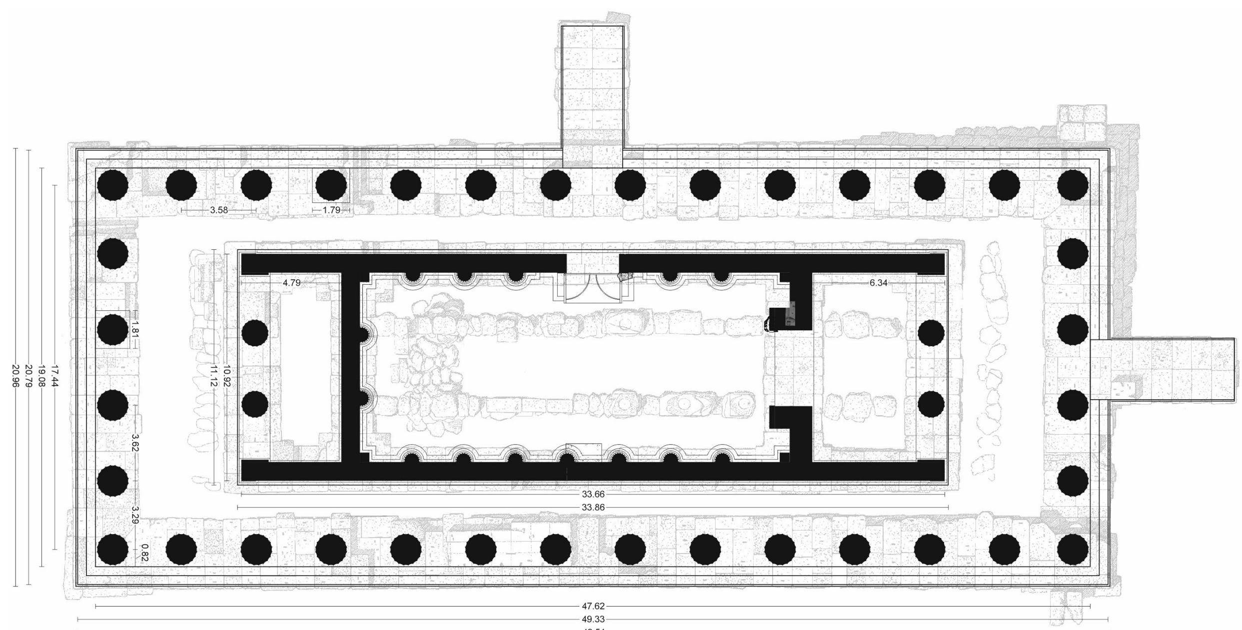

Figure 5. Reconstructed plan of the temple of Athena Alea superimposed on the foundations (J. Pakkanen).

The calculation of the volumes of Doliana marble used in the temple of Athena Alea is based on fieldwork and reconstructions presented in Figures 5-7 (for further dimensions of the different elements, see Dugas et al. 1924; Pakkanen 1998; 2013a: 94-109; 2014a). The volume of marble in the euthynteria and the three steps of the krepis is c. 449 m^3, the exterior order columns c. 549 m^3 and the entablature[5] c. 455 m^3. The exact layout of the cella interior is still a work in progress, but the minimum volume of Doliana marble for the cella can be estimated as 1,095 m^3. The coffers and their supporting beams of the ceilings had a volume of c. 252 m^3, and, finally, the marble roof c. 148 m^3.

To sum up, the minimum total volume of Doliana marble used in the temple is c. 2,950 m^3. Using the range calculated on the basis of Pegoretti's figures, the quarry cost of this volume is c. 53,000-65,000 Aiginetan drachmas. With 24 skilled quarrymen and 24 unskilled labourers working at the marble quarries, they would have been able to quarry the stone in five to six years.[6] Halving the size of the quarry workforce would have doubled the length of this part of the building project. If funds for temple construction at sanctuary of Athena Alea were limited, this

5 The total volume of the entablature includes the architraves (178.4 m^3), the frieze course (163.4 m^3), the horizontal geisa (91.7 m^3), the tympana (14.7 m^3) and the raking geisa (7.2 m^3).

6 2,948 m^3 × 17.9 dr./ m^3 ≈ 52,770 dr; 2,948 m^3 × 21.9 dr./m^3 ≈ 64,560 dr. With 24 skilled and 24 unskilled, 52,770 dr. / (24 dr./pd + 0.5 × 24 dr./pd) ≈ 1,470 pd; 64,560 dr. / (24 dr./pd + 0.5 × 24 dr./pd) ≈ 1,790 pd. The calculation of years assumes that a working year comprised a maximum of 300 workdays.

Figure 6. Reconstruction of the east façade of the temple of Athena Alea (J. Pakkanen).

might have been the preferred option.[7] As in the case with the conglomerate, the cost of carting the stone from the quarries to the building site was larger than extraction: the sum can be estimated as 81,000 drachmas.[8]

4. Conclusions

The econometric analysis presented in this chapter is just one step towards understanding the role stone quarries and monumental construction had at ancient Tegea. Craftsmen from Tegea are recorded in the building accounts from Delphi and Epidauros (Burford 1969: 199 n. 2; on construction in Arcadia, see Roy 1999: 336-338) but further work on the volume of stone extracted from Doliana is required to get a more thorough picture of how important the quarries were (cf. Bakke 2022 in this volume).

The 1,100 m^3 of foundation conglomerate could have been extracted by a team of 12 skilled craftsmen and 12 unskilled labourers in about a year, but even though the quarries were only 3 km from the sanctuary, the cost of land transport was more expensive than quarrying. Extracting marble is more time-consuming than conglomerate, but because of the further distance of the quarries from the sanctuary, the cost of carting the blocks was again more expensive than sourcing the stone. The minimum volume of marble used in the temple is nearly 3,000 m^3. With twice as many people working at the quarries at Doliana, it would have taken five to six years of work to quarry the necessary volume of stone. If the building funds were limited, the work in the quarries could have extended over a much longer period and with fewer craftsmen.

One of the most significant economic decisions the temple commissioners and Skopas as the architect had to make was choosing the different types of material and scale of the monumental building project. At Epidauros, the temple builders decided to use Corinthian limestone for most parts of their rather modest monumental structures at the sanctuary of Asklepios. At Didyma, even though the temple of Apollo could be built using

7 According to the preserved building inscriptions, the relatively small limestone temple of Asklepios at Epidauros took 4 years, 9 months and 12 or 13 days to build; the larger Tholos did not proceed as promptly, and the project took 25-40 years to complete; see Prignitz 2014: 248-249. On the costs at Epidauros, see also Burford 1969: 81-85.

8 2.3 dr./(m^3×km) × 2948 m^3 × 12.0 km ≈ 81,360 dr.

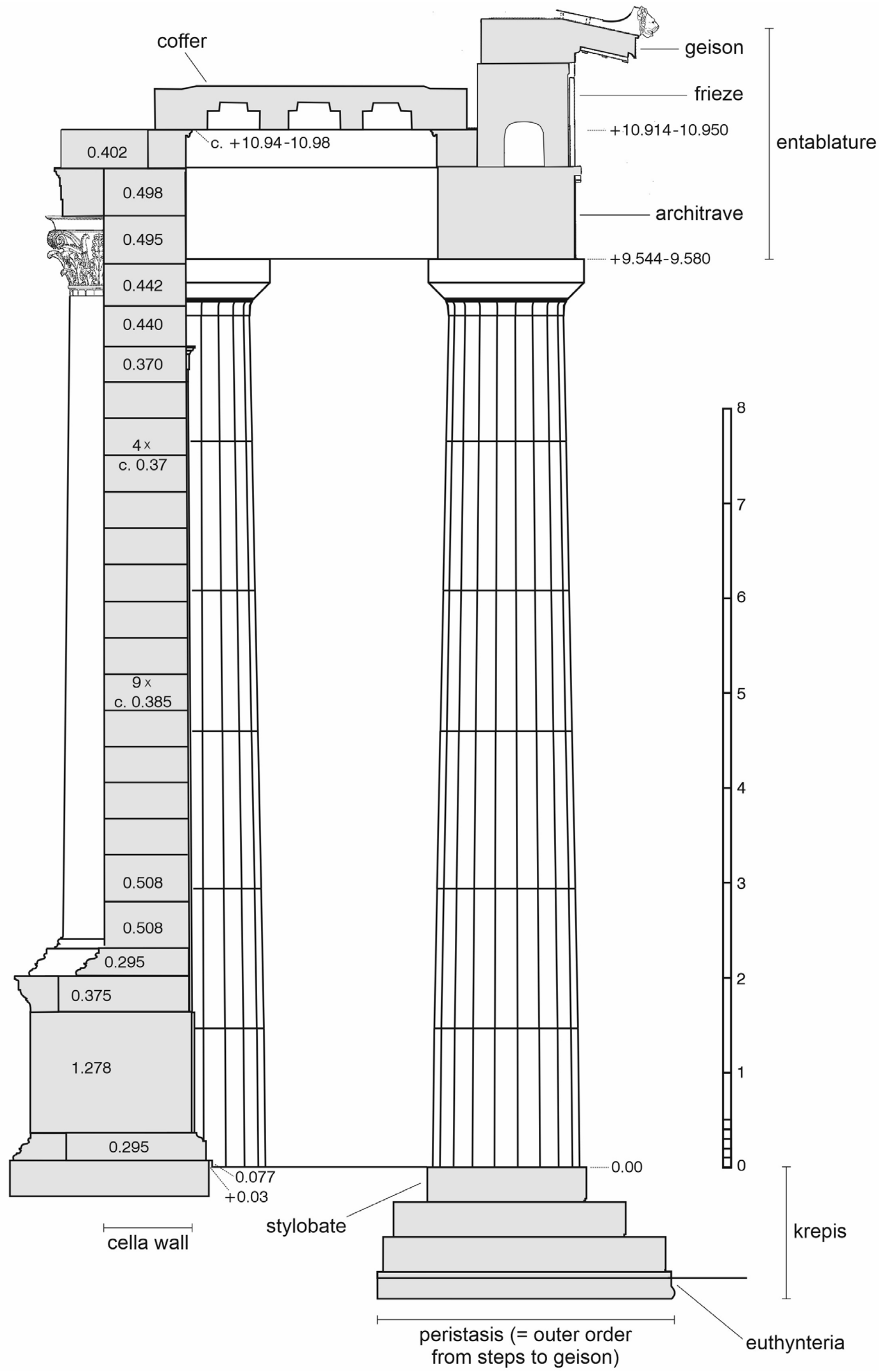

Figure 7. Section of the flank order of the temple of Athena Alea with architectural terminology indicated (J. Pakkanen).

locally sourced marble, the colossal scale resulted in very high costs. I have calculated that the choice of material and scale resulted in more than four times as high expenses at Didyma than at Epidauros per cubic metre of stone (Pakkanen forthcoming). At Tegea, the builders opted to use the most prestigious stone, marble, for the temple of Athena Alea. However, it was also a local stone from quarries with a long history of exploitation, so it was an economically rational choice: the commissioners could trust that the supply was constant and not coming from too far away.

5. Acknowledgements

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