The early development of concrete in the domestic architecture of pre-Roman Pompeii

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Introduction: pre-Roman Pompeii and Roman architecture

Because of its exceptional state of preservation, Pompeii has traditionally been viewed as an ideal site at which to study the early development of Roman architecture. Scholars have looked to the Pompeian evidence in order to provide parallels for periods and classes of buildings that in Rome are less well documented archaeologically. The focus of recent debate has been on the Mid- to Late Republican transition, with an emphasis on building types whose introduction at Pompeii would demonstrate a direct cultural link with practice at Rome. The prevailing view is that both the town-planning and the architecture of Pompeii in the 3rd-2nd c. B.C. were strongly influenced by Roman models or prototypes.[1] Similarly, there has been a tendency to refer to the Pompeian materials as the missing link for the high dating of early Roman concrete architecture in Rome, which would have been introduced around the same period. In a recent review of the evidence from Rome,[2] I have argued for a later chronology, which, inevitably, prompts a reconsideration of the development and cultural significance of concrete construction at Pompeii.

In the sphere of public building, a popular idea based primarily on the Pompeian pattern is that Roman-style baths, the freestanding theater, the basilica, and the quadriporticus — the most representative types of what we identify as Roman Republican architecture[3] — were all developed by making extensive use of mortar-and-rubble construction (for vaults, retaining walls and foundations). The assumption, then, has often been that at Pompeii, just as at Rome, there ought to have been a previous phase of experimentation, which would in turn suggest that the building medium was in use by the mid-3rd c. B.C. at the latest.[4] Continued research on early bath architecture (just to mention one well-understood case) is consistently showing that concrete played little rôle in the formative stages of the building type in that period.[5] On the other hand, the results of a recent

1 Most explicitly in F. Pesando, "Il secolo d'oro di Pompei. Aspetti dell'architettura pubblica e privata nel II secolo a.C.," in M. Osanna and M. Torelli (edd.), *Sicilia ellenistica, consuetudo italica. Alle origini dell'architettura ellenistica d'Occidente* (Rome 2006) 227-41; see also A. Wallace-Hadrill, *Rome's cultural revolution* (Cambridge 2008) 127-36; J. Sewell, *The formation of Roman urbanism, 338-200 B.C.* (JRA Suppl. 79, 2010) 120 and 130. For this school of thought, the pattern would reflect the political goals of the Pompeian ruling class, who wished to demonstrate to Rome that Pompeii should be recognized as a peer urban entity, refashioned along Roman lines. P. Carafa ("*Minervae et Marti et Herculi aedes doricae fient* [Vitr. 1.2.5]. The monumental history of the sanctuary in the Triangular Forum," in S. R. J. Ellis [ed.], *The making of Pompeii* [JRA Suppl. 85, 2011] 89-111) assigns key developments in the Forum to the 2nd c. B.C.

2 For an overview of the intellectual problem, see M. Mogetta, "A new date for concrete in Rome," *JRS* 105 (2015) 2-7.

3 A. Boethius, *Etruscan and Early Roman architecture* (Harmondsworth 1978) 136-215. Cf. J. B. Ward-Perkins, "Taste, tradition and technology. Some aspects of the architecture of Late Republican and Early Imperial Central Italy," in *Studies in classical art and archaeology. A tribute to Peter Heinrich von Blanckenhagen* (Locust Valley, NJ 1979) 198, who sees the architecture of Late Republican Italy as a "stream of many local currents" that can hardly be categorized as a single entity.

4 See W. Johannowsky, "La situazione in Campania," in P. Zanker (ed.), *Hellenismus in Mittelitalien* (Göttingen 1976) 270-72.

5 As demonstrated by the case-studies collected in S. K. Lucore and M. Trümper (edd.), *Greek*

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re-analysis of monuments located in and around the forum have posed a challenge to the idea of Pompeii as a "Romanized" town prior to establishment of the Roman colony of 80 B.C., suggesting that some of these "Roman-looking" building types surfaced at a later stage.[6] As a consequence, the dating of important benchmarks in the canonical sequence of the development of concrete wall-facing styles at Pompeii can be viewed as dubious.[7]

The current chronological framework of Pompeian concrete architecture, however, rests largely on evidence from the domestic sphere. Again, the appearance of canonical atrium houses and "row-houses" has been traced back to some degree of Roman influence,[8] from the impetus of the demographic urbanization experienced at Pompeii and other major Campanian sites (e.g., Capua, Cumae, Nuceria and Nola) in the period between the Samnite and the Second Punic Wars.[9] By this perspective, population increase would seem to have brought, at the local level, the need for the technological innovation of a cheaper and more efficient building medium. Building materials necessary to manufacture lime mortar were easily available in the catchment area of Mt. Vesuvius, so the notion of a phase of experimentation at these sites already in the 3rd c. B.C., whether originating independently or not,[10] seemed highly plausible. In terms of the social context of innovation, then, the problem of the origins of concrete at the site is of particular relevance because it would set the case of Pompeii apart from that of Rome. In fact, the diffusion of the new technology in the capital was associated with select building activities by the élites, and not with

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baths and bathing culture. New approaches and discoveries (BABesch Suppl. 23, 2013).

6 The full argument is outlined in L. Ball and J. J. Dobbins, "Pompeii Forum Project. Current thinking on the Pompeii Forum," *AJA* 117 (2013) 461-92. Their results would support a later date for the monumentalization of the square, implying that important Roman cultural markers were introduced only after the arrival of the Romans.

7 A full reconsideration of the problem is found in my Ph.D. dissertation, *The origins of concrete in Rome and Pompeii* (Univ. of Michigan 2013) 168-283.

8 On the "row-houses" see S. C. Nappo, "Urban transformation at Pompeii in the late 3rd and early 2nd centuries B.C." in A. Wallace-Hadrill and R. Laurence (edd.), *Domestic space in the Roman world* (JRA Suppl. 22, 1997) 91-120; Sewell (supra n.1) 127-36. F. Coarelli and F. Pesando ("The urban development of NW Pompeii. The archaic period to the 3rd c. B.C," in Ellis [supra n.1] 37-58) refer to Roman models for the canonical atrium houses.

9 C. Rescigno and F. Senatore ("Le città della piana campana tra IV e III sec. a.C. Dati storici e topografici," in M. Osanna [ed.], *Verso la città. Forme insediative in Lucania e nel mondo italico fra IV e III sec. a.C.* [Venosa 2009] 415-62) provide a useful overview of urbanization processes in Campania in the 4th-3rd c. B.C.

10 G. Lugli, *La tecnica edilizia romana* (Rome 1957) vol. 1, 382-83, suggests that local builders discovered the properties of pozzolana by observing natural phenomena caused by volcanic activities. M. E. Blake (*Ancient Roman construction in Italy from the prehistoric period to Augustus* [Washington, D.C. 1947] 312-13) argued for external influence from Greece (mediated by the colonies of Magna Graecia), highlighting the "fortunate accident" that most of the sand available locally contained pozzolana, so that even simple lime mortars (i.e., mortars composed of lime and sand) would acquire more strength. F. Rakob ("Opus caementicium und die Folgen," *RömMitt* 90 [1983] 361) established a connection with Punic architecture based on certain features of concrete construction (such as the use of wooden forms to build foundations) that can be seen also in the typical vernacular architecture of N Africa, as in "*terre pisé*". Cf. G. R. H. Wright (*Ancient building technology*, vol. 2: *materials* [Leiden 2005] 87-90), who points out that construction with *terre pisé* differs significantly from concrete construction in that it does not involve a plastic medium but rather unconsolidated earth which is made rigid by compression within shutterings by the use of a ram or pounder. Such a procedure is never used in concrete walling (although Vitruvius 7.1.3 says that concrete for paving is tamped down with pounder).

middle- and lower-class housing.[11]

Against this background, my present goal is to provide a comprehensive assessment of early concrete building techniques at Pompeii, which I analyze first and foremost in their local context, concentrating primarily on the private architecture.[12] The results of large-scale research projects investigating entire city-blocks with stratigraphic methods have greatly improved our knowledge of the urban development at the site. In addition, with a growing interest in the archaeometry of mortars, a first set of data is available to complement the evidence from excavations. In the following discussion, I will pay particular attention to how past arguments for a high chronology of the Pompeian *opus incertum* have been constructed. In approaching the new evidence, I will emphasise the interplay of the social, cultural and environmental factors that could have influenced the development of the technology there. This is a necessary first step in order to reconstruct the relationship between public and private concrete architecture at Pompeii, identify its place in the regional setting, and evaluate the broader impact of Pompeian archaeology on issues relating to the genesis of Roman Republican material culture.

The problem of 3rd c. B.C. architecture at Pompeii

The built environment of Pompeii features a great deal of architecture that, following Vitruvius (2.8.1), we would easily classify as *genus incertum*: mortared-rubble walls featuring irregularly shaped stones bonded with lime mortar, laid in courses without separation between facings and core, which Pompeian archaeologists call *opus caementicium* or *opus incertum* (depending on whether the exterior face of the stones has a finished surface). In the pre-Roman layers of the city, this class of concrete structures appears normally in combination and/or in association with ashlar architecture, which was in use at the site since the Archaic period especially for façades and foundations. Another building method that is commonly found in Hellenistic contexts is the so-called "framework technique" (*opera a telaio*), also improperly known as *opus Africanum*.[13] The development of this masonry style,

11 Mogetta (supra n.2) 29-32.

12 A preliminary re-assessment of the evidence from the public context: Mogetta (supra n.7) 228-63.

13 The term is not attested in ancient sources but is a modern definition based on the idea that the technique originated in Punic N Africa (though most of the known examples there date to the Roman period) as a "framework and fill", in which timber is replaced by stone. The common theory is that there would have been a first diffusion of the technique to the Punic sites of W Sicily, where the earliest examples (e.g., at Selinus and Motya) seem to date to the late 4th c. B.C.: Lugli (supra n.10) vol. 1, 379-82; J.-P. Adam, *Roman building: materials and techniques* (London 1994) 120-21. From there, the technique would have spread to Magna Graecia and Campania, along with other Punic cultural markers (e.g., decorated *cocciopesto* floors): A. Wallace-Hadrill, "Hellenistic Pompeii: Oscan, Greek, Roman and Punic," in J. R. W. Prag and J. Crawley Quinn (edd.), *The Hellenistic West: rethinking the ancient Mediterranean* (Cambridge 2013) at 40-41. According to S. Stopponi ("Tecniche edilizie di tipo misto a Orvieto," in M. Bonghi Iovino [ed.], *Tarquinia e le civiltà del Mediterraneo* [Milan 2006] 207-45), this construction method can be traced back to Archaic Etruria but betrays the influence of Near Eastern architects because of similarities with the *mur à piliers* (pier-and-panel technique) of Levantine origins. From there, variants of the technique would have spread to other areas of the Italian peninsula, including Campania, in the 4th through 2nd c. B.C. G. Di Luca and A. Cristilli ("Origine ed evoluzione dell'opera a telaio. Le attestazioni campane," in A. Coralini [ed.], *DHER. Domus Herculanensis rationes. Sito, archivio, museo* [Bologna 2011] 455-78) plot the distribution of the technique at Campanian sites. The typology by S. Camporeale ("Opus africanum e tecniche a telaio litico in Etruria e Campania [VII a.C.–VI d.C.]," *Archeologia dell'Architettura* 18 [2013] 192-209)

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which can be better described as "limestone-framework technique", is deemed to be particularly significant for understanding how concrete architecture came about in Pompeii. In walls of this type, ashlar blocks are laid horizontally (stretchers) and vertically (uprights) in alternation, to create rows of load-bearing piers separated by large gaps, which are then filled in with either flat blocks (an approximation of isodomic masonry) or mortared rubble. Precisely because of these mixed features, the "limestone-framework technique" has come to be described, in terms of relative sequence, as an intermediate step in the transition from *opus quadratum* to *opus incertum*, the prevailing idea being, once again, that of a steady evolution of techniques.[14] Thus there has been a tendency to link the absolute dating of *opus incertum* to that of *opus Africanum*, deriving both from the chronology of ashlar masonry. For this reason, it seems useful to start the discussion by disentangling the arguments concerning the chronology of each of these techniques.

The myth of the "limestone period" and its typological implications

Very few construction dates are available for the monuments of pre-Roman Pompeii. The historical record for the early period is indeed virtually non-existent. Strabo (5.4.8) speaks of different waves of political domination that succeeded one another in the region originally inhabited by the Oscans: Etruscan, Samnite (*c.*450-425 B.C.), and Roman. The participation of Pompeii in the rebellion against Rome during the Social War (App. *BCiv* 1.50; Vell. Pat. 2.16.2) provides the only fixed point for the period under discussion, as it resulted in the planting of a Roman colony in 80 B.C. While there is evidence that élite groups of the Samnite period retained some of their influence in the long term, the political life in the early years of the colony was dominated by the Roman settlers, who controlled the key magistracies under the new constitution (i.e., the *duoviri*; *quattuorviri* are also occasionally attested). Latin became the official language in public affairs, quickly replacing Oscan also as a spoken language. Thus, when Oscan inscriptions are found in association with standing buildings, a generic date in the period 150-80 B.C. is assumed for their construction, although some argue that the official use of Latin may have been introduced by the Samnite élites already at the end of the Social War, in the expectation of receiving Roman citizenship.[15]

In a seminal article, M. Fulford and A. Wallace-Hadrill critically reviewed the problems concerning the conventional periodization.[16] They refer to G. Fiorelli as making the first systematic attempt to link with Strabo's historical account the variety of building materials (Table 1) and techniques documented at the site. Fiorelli interpreted the diffusion of a class of houses featuring an atrium of the Tuscan type as a sign of the alleged Etruscan

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convincingly links the types attested at Pompeii with a technique documented primarily in the Greek sites of E Sicily of the 5th-3rd c. B.C., thereby questioning both the direct Punic and Etruscan connections. The complex network of interactions between Greek and Punic élites in Sicily, along with their influence on the cultures of central Italy, is explored by E. Fentress, "Strangers in the city: élite communication in the Hellenistic central Mediterranean," in Prag and Crawley Quinn (ibid.) 157-78.

14 See especially the typology in K. Peterse, *Steinfachwerk in Pompeji. Bautechnik und Architektur* (Amsterdam 1999) 36-55; J.-P. Adam, "Building materials, construction techniques and chronologies," in J. J. Dobbins and P. W. Foss (edd.), *The world of Pompeii* (London 2007) 105.

15 A detailed account of events in the period 89-80 B.C. at Pompeii is given by H. Lauter, *Die Fassade des Hauses IX, 1, 20 in Pompeji. Gestalt und Bedeutung* (Mainz 2009) 163-70.

16 M. Fulford and A. Wallace-Hadrill, "Towards a history of pre-Roman Pompeii. Excavations beneath the House of Amarantus (I 9, 11-12), 1995-98," *PBSR* 67 (1999) 37-39.

TABLE 1
STONES USED AS BUILDING MATERIALS IN PRE-ROMAN POMPEII
(nomenclature based on Kastenmeier *et al.* [infra n.18])

Archaeological term (Richardson 1988 [n.19])	*Geological term (Kastenmeier* et al. *2010)*	*Lithology*
Pappamonte	Tuff	Welded tuff with scoriae and calcite inclusions
Sarno limeston*e*	Calcareous tufa	Porous carbonate of karstic origin
Sarno limestone	Travertine	Harder carbonate with some degree of crystallization
Cruma	Basaltic Trachyandesite	Scoriaceous lava (dark purple)
Lava/*lapis pompeianus*	Basaltic Trachyandesite	Compact lava (dark grey)
Lava	Latite/Tephriponolite	Compact lava (used for road pavements)
Nocera tuff	Campanian Ignimbrite	Welded tuff

domination.[17] Because these houses were built primarily with ashlars of a local variety of calcareous tufa ("Sarno limestone"),[18] he speculated that the exploitation of this material started when the Etruscans came, only to be abandoned with the arrival of the Samnites. The argument was partially accepted by A. Mau, who proposed that this "Limestone period" continued well into the Samnite phase. He saw a major change happening around 200 B.C., when a different material, the volcanic stone known as "Nocera tuff",[19] would be introduced. This innovation would mark the start of a "Tufo period". While the "Sarno limestone" was quarried in close proximity to the site, the "Nocera tuff", which is of much better quality, was imported from farther away and, therefore, used more selectively (i.e., for façades and architectural mouldings). Given that it was a costly material, Mau was convinced that the introduction of "Nocera tuff" had happened at a time of great prosperity for the town, which in his opinion could only mean after the Hannibalic War.[20] Subsequent excavations by Maiuri below the floors of some of the limestone atrium houses, however, revealed that they were much later in date than posited.[21] Furthermore, evidence of pre-existing structures on the same orientation came to light, structures made of another kind of volcanic stone, "Pappamonte", a material that can be found at low depth in the SW area of the spur on which Pompeii lies.[22] Maiuri modified the chronology established by Fiorelli and Mau accordingly, assigning "Pappamonte" to the Archaic period and pushing the widespread diffusion of "Sarno limestone" into the Samnite phase. The same scheme was applied to the vertical stratigraphy of the fortification walls, on the assumption of a direct connection between the building phases of the circuit and Strabo's text.[23]

17 G. Fiorelli, *Gli scavi di Pompei dal 1861 al 1872* (Naples 1873) vii-xiii.

18 Deposits of this material outcrop in the river plain southeast of Pompeii: P. Kastenmeier *et al.*, "The source of stone building materials from the Pompeii archaeological area and its surroundings," *Periodico di Mineralogia* 2010, Special Issue, 50-51.

19 L. Richardson, *Pompeii: an architectural history* (Baltimore, MD 1988) 370. The deposits of "Nocera Tuff" are part of the Campanian Ignimbrite formation: Kastenmeier *et al.*, ibid., 41 and 49-50.

20 A. Mau, *Pompeji in Leben und Kunst* (rev. 2nd edn., Leipzig 1908) 38.

21 E.g., A. Maiuri ("Saggi nella 'Casa del Chirurgo'," *NSc* 1930, 381-95) dated the Casa del Chirurgo not earlier than the 3rd c. B.C., undermining the idea of an Etruscan 'limestone' phase. C. Chiaramonte Treré ("Sull'origine e lo sviluppo dell'architettura residenziale di Pompei sannitica. Spunti di riflessione dagli scavi della Regio VI, 5," *Acme* 43 [1990] 7-13) reviewed the main results of Maiuri's excavations in select houses. Cf. S. E. Bon *et al.*, "The context of the House of the Surgeon," in ead. and R. Jones (edd.), *Sequence and space in Pompeii* (Oxford 1997) 32-49.

22 For the geologic characterization of this material, see Kastenmaier *et al.* (supra n.18) 50.

23 The exterior face of the circuit at some points shows a foundation in blocks of "Pappamonte",

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The first systematic typology of the architecture of the "limestone period", by R. C. Carrington, incorporated many of Maiuri's findings. Carrington identified three techniques featuring this material: ashlar masonry; the "limestone-framework technique"; and what he defined as "dry-stone masonry", a type of *petit appareil* made of flat pieces of limestone, laid horizontally, and bigger corner blocks.[24] Based on Maiuri's chronology, he assigned these structures mostly to the 4th and 3rd c. B.C. In his analysis, he noted that, where ashlar masonry was present, it was used only in the façade, while side walls and interior subdivisions used the "limestone-framework technique". He also recorded houses built either with the "limestone-framework technique" or with dry-stone masonry in all their parts (including façades). The latter could be associated with "limestone-framework technique" façades but never with ashlar façades. An important observation was that the pattern does not imply a chronological variation as much as it depends on wealth, with the first-class houses at the top and houses where dry-stone was employed at the bottom. He viewed construction with lime mortar and limestone rubble as a practice that emerged in parallel with a generalized, if only temporary, decline in the use of ashlar masonry during the later decades of the 3rd c. B.C. In Carrington's view, this phase would be documented at recently excavated sites such as the Casa di Sallustio and Villa dei Misteri, which had been erroneously dated to that period based solely on the type of building material. These houses feature a selective use of hard mortar for the wall-facings. Ashlar blocks are used for angles and doorposts, and are laid horizontally and vertically in alternation so as to grip the rubble fill, resembling the technique seen in the limestone-framework walls. Carrington interpreted this feature as the link between the two techniques, which would confirm the high chronology of the transition.

The most recent and comprehensive study of the "limestone-framework technique" relies in part on the old methodological framework, and sets out an even more gradual sequence of development. In his survey of this class of walls, K. Peterse has singled out three types of structures (A, B, C), on the basis of variation in the spacing of the pillar-like structures, the shape of the rubble elements, and the composition of the mortar, with the expectation that each type corresponds to a chronologically bounded phase. According to this reconstruction, there was a clear evolution through time (fig. 1). The early walls (Type A, an approximation of pseudo-isodomic masonry, and Type B, which resemble Carrington's "dry-stone masonry") would feature closely spaced pillars and panels of predominantly flat blocks with no mortar. In later structures (Type C), the pillars would be more widely spaced, framing sturdier stretches of rubble laid in clay-based mortars that contain increasing amounts of lime.[25] The slow and steady evolution from Types A to C would span almost the entire Samnite phase of Pompeii, between the middle of the 5th

on top of which is a lower level of "Sarno limestone" blocks. These are part of a double-curtain structure (the "muro ad ortostati") later substituted by a fortification of the *agger* type. The upper level is in blocks of 'Nocera tuff', but a final phase in *opus incertum* is also attested: see S. De Caro, "Nuove indagini sulle fortificazioni di Pompei," *AnnAStorAnt* 7 (1985) 75-114; Richardson (supra n.19) 44-50 dates the "muro ad ortostati" in the 3rd c. B.C. The state of the debate is summarized by C. Chiaramonte Treré, "The walls and gates," in Dobbins and Foss (supra n.14) 140-49.

24 R. C. Carrington, "Notes on the building materials of Pompeii," *JRS* 23 (1933) 129.

25 Peterse (supra n.14) 19-48. Only a handful of contexts demonstrate a significant increase in the average spacing of pillars in load-bearing walls: Peterse ibid. 20-31 and 70-75, Tab. I.1-I.4. In what is perhaps the best documented of these cases (VI.11.12), the wide spacing of the pillars does not correlate with higher lime content in the clay mortar: ibid. 106, Tab. II.6.

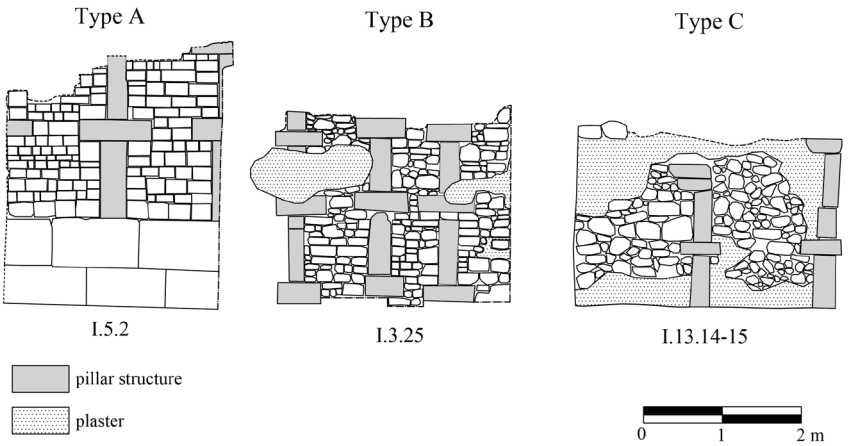

Fig. 1. Examples of limestone-framework wall types according to the classification by Peterse (supra n.14).

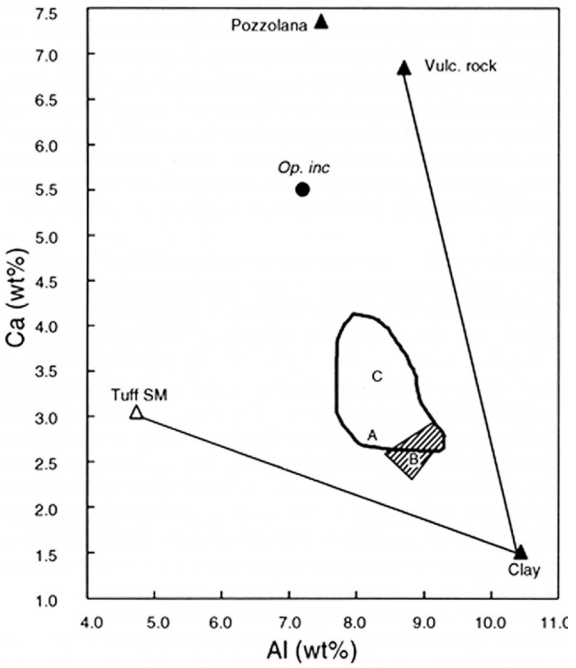

Fig. 2. Areas in which the average values of calcium and aluminum fall for the mortars sampled by Peterse (infra n.27, 376 fig. 1) for his wall types A, B, C and *opus incertum*. The plot demonstrates how the composition of the mortars of type C walls covers a larger area that partially overlaps that of type B walls. The mortar of *opus incertum* contains significantly greater amounts of volcanic material.

and the early 2nd c. B.C. As already posited by Carrington, it would also demonstrate a deterioration in the quality of the ashlar dressing (on the assumption that less refined walls ought to be later than nicely treated ones). By this perspective, Type C would represent a crucial step for the technological innovation of *opus incertum* at the town, because it would have provided a plausible context for experimentation with, and improvement of, mortared rubble architecture.[26] The suggestion is that the two techniques may have co-existed for a short period during the latter part of the 3rd c. B.C.[27] The continuous development of superior mortar recipes would eventually make the pillars no longer structurally relevant, as well as an unnecessary expense.

The relationship of 3rd-2nd c. B.C. building techniques to social status

Problems of classification affect the model described above; there is indeed ample variability within each type, especially for interior walls, with the result that in some cases the distinction between "irregular" Type B and "regular" Type C seems arbitrary. Furthermore, the fact that the placing of the pillars does not seem to depend strictly on structural requirements undermines the argument about a connection between the increases in the spacing of the pillars and the quality of the mortars.[28] Mineralogical

26 Peterse ibid. 56-63.

27 See especially K. Peterse, "Select residences in Regions V and IX: early anonymous domestic architecture," in Dobbins and Foss (supra n.14) 378.

28 There is no significant difference in the spacing between load-bearing and non-load-bearing walls: Peterse (supra n.14) Tab. I.1-I.4.

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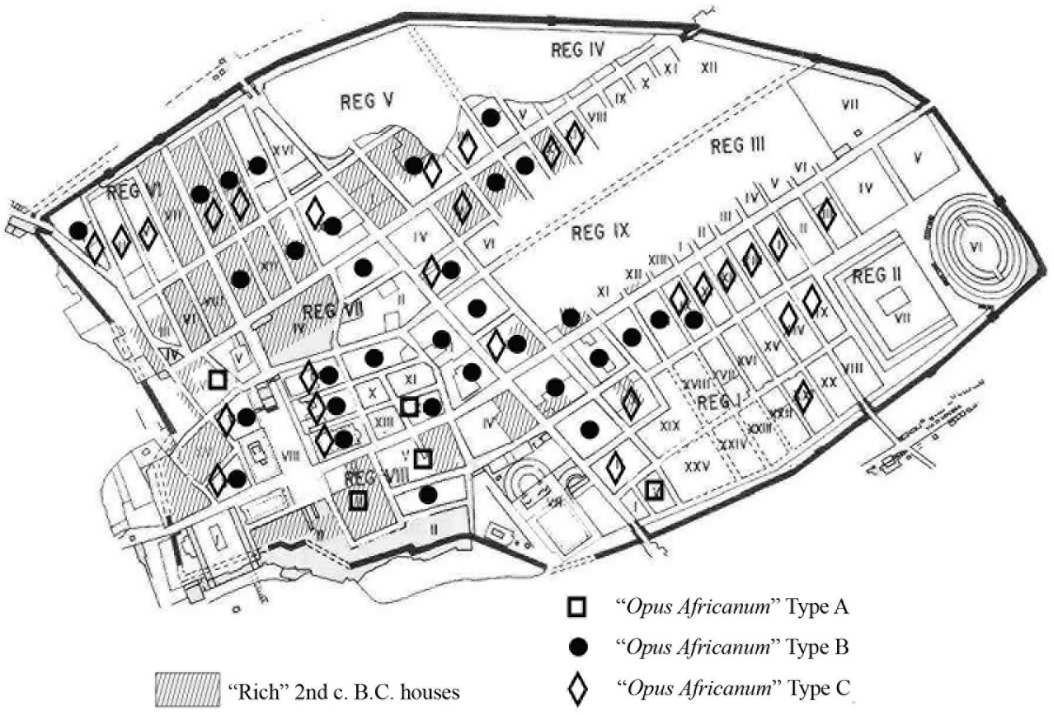

Fig. 3. Distribution of limestone-framework wall types within neighbourhoods characterized by different social status (based on Lauter [infra n.36] 150 fig. 136).

and chemical analyses of mortar samples collected from both cores and wall-facings show a substantial overlap between walls of Types B and C (fig. 2).[29] In general, the mortars associated with walls of Type C are characterized by an increasing quantity of volcanic material. Because of the heterogeneous composition of local clays, however, the tests could not determine whether separately quarried material was added to the mix. It also remains unclear whether burnt lime was used at all (calcite inclusions that could be mistaken for lime lumps are known to occur naturally in clay and volcanic ash deposits in the region).[30] On the other hand, a stark compositional difference between Type C and *opus incertum* has been detected.[31] The available scientific evidence suggests that lime-based mortar in the "limestone-framework technique" was used primarily for the rendering of rubble fills (i.e., in the form of plaster), after the wall had been built.[32]

29 Peterse ibid. 77-106.

30 The absence of lime in clay-based mortars used for "limestone-framework" architecture has been confirmed by samples from the Insula of the Centenario (IX.8): A. Bonazzi, S. Santoro and E. Mastrobattista, "Caratterizzazione archeometrica delle malte e degli intonaci dell'insula del Centenario," in S. Santoro (ed.), *Pompei. Insula del Centenario (IX, 8)*, vol. 1. *Indagini diagnostiche, geofisiche e analisi archeometriche* (Bologna 2007) 127 (mortar type D). S. Santoro and D. Scagliarini Corlàita ("Progetto Insula del Centenario [IX, 8]. Saggi di scavo 1999-2004," *RStPomp* 16 [2005] 211-56) date the first phase of occupation of the block to the first half of the 2nd c. B.C.

31 Hydraulic mortar (C-S-H) was found only in two cases, in which the lime content appeared exceptionally high (IX.1.22 and II.3; probably these walls were later repairs, so they were not included in the cluster analysis): Peterse (supra n.14) 87.

32 Richardson (supra n.19) 370 casts doubts on whether we should consider the custom of packing Sarno limestone rubble in clay as a phase antedating the standardized use of mortar, suggesting that a plaster coating in combination with the pillars would have been sufficient to hold the structure together. The technique is well-documented in the post-A.D. 62 reconstruction: J.-P.

While in Peterse's view the spatial distribution of the "limestone-framework" types would be consistent with the alleged progression of the technique over time,[33] other factors may have influenced the pattern (fig. 3). The walls of Type A do seem to concentrate near the Forum, in the area formerly known as "Altstadt", which corresponds to the sector to which the settlement shrank in the early 5th c. B.C.[34] The numbers, however, are too small to draw any firm conclusions about the date of the technique and its alleged short duration. Façades of Type B class (n=37) are attested mainly on the W side of town, while façades of Type C class (n=50) appear in greater proportion on the E side (the easternmost parts of *Regiones* I, V and IX, and *Regio* II), where the city blocks were probably laid out at a later stage of the master plan.[35] Type B walls, however, have also been found in three blocks of the new quarter (I.9; IX.10 and 14), as well as in the irregular strip of blocks that connects this area with the double row of square blocks east of the *via Stabiana* (IX.8; I.7 and 8), which was also planned later than the W side. Conversely, Type C walls are also documented in the NW sector (in blocks VI.2 and VI.5, this is the only type of limestone-framework ever attested). The overall picture, therefore, does not fully support arguments based solely on horizontal stratigraphy.

Rather than just chronology, the spatial distribution of Types B and C may reflect variation in wealth and social status, as a comparison with the distribution of elaborate Pompeian houses of the period pre-80 B.C. (including those with "Sarno limestone" ashlar façades) would seem to suggest (Table 2). The alleged early variants of the masonry style are more frequent in those blocks in which the richest and more elaborate houses are located, as is the case in the *Regio* VI.[36] Type B occurs particularly in large buildings of the canonical atrium type. While the quasi-isodomic masonry may have represented a slightly cheaper solution by comparison with ashlar masonry (individual blocks could be fitted by hand; the lack of refined dressing may also be interpreted as time-saving), the close relationship between these techniques is suggested by the fact that interior walls of houses featuring ashlar façades are often in the former technique. The alleged later type is typically associated either with small atrium houses or with the "row-houses", whose diffusion at Pompeii has been taken as evidence of an embryonic form of urban zoning.[37] Thus, the pattern

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Adam, *Dégradation et restauration de l'architecture pompéienne* (Paris 1983) 13-15. In earlier walls, the rendering has in most cases disappeared, but traces of the lime mortar used in this type of construction may remain in the exterior joints, giving the impression that the walls were composed of lime-based facings and clay-based cores.

33 Peterse (supra n.14) 64-69.

34 The current view on the problematic relationship of the so-called "Altstadt" to the early urbanization of the broader walled area of Pompeii is outlined in D. Esposito, P. Kastenmeier and C. Imperatore, "Excavations in the Caserma dei Gladiatori. A contribution to the understanding of Archaic Pompeii," in Elllis (supra n.1) 128-33. The presence of a fortification wall around the "Altstadt" has been hypothesized on the basis of a "Pappamonte" structure found under the Casa dei Postumii (VIII.4.42-43), which is perhaps associated with a ditch (J. A. Dickmann and F. Pirson, "Il progetto Casa dei Postumii," in P. G. Guzzo and M. P. Guidobaldi [edd.], *Nuove ricerche archeologiche a Pompei ed Ercolano* [Naples 2005] 156-69), but the evidence is not conclusive.

35 The separate steps of development of the town plan are analyzed in H. Geertman, "The urban development of the pre-Roman city," in Dobbins and Foss (supra n.14) 86-90.

36 H. Lauter ("Zur Siedlungsstruktur Pompejis in samnitischer Zeit," in B. Andreae and H. Kyrieleis [edd.], *Neue Forschungen in Pompeji* [Recklinghausen 1975] 149-51 and fig. 136) plots the distribution of houses of the 2nd c. B.C.

37 Nappo (supra n.8) 91-120; id., "Houses of Regions I and II," in Dobbins and Foss (supra n.14)

TABLE 2
DISTRIBUTION OF LIMESTONE-FRAMEWORK MASONRY TYPES ("STYLES") WITHIN NEIGHBOURHOODS CHARACTERIZED BY DIFFERENT SOCIAL STATUS (CLASSES) IN PRE-ROMAN POMPEII (sources: Lauter [n.36]; Peterse [n 14]).

FREQUENCY TABLE	*Type A*	*Type B*	*Type C*	*TOTAL*
Élite neighbourhood*	3	9	7	19
Non-élite neighbourhood	2	17	20	39
TOTAL	5	26	27	58
DISTRIBUTION OF CLASSES WITHIN STYLES	*Élite neighbourhood**	*Non-élite neighbourhood*	*standard error*	
Type A	60	40	21.9	
Type B	34.6	65.4	9.3	
Type C	25.9	74.1	8.4	
DISTRIBUTION OF STYLES WITHIN CLASSES	*Type A*	*Type B*	*Type C*	
Élite neighbourhood*	15.7	47.3	37	
standard error	8.3	11.4	11.1	
Non-élite neighbourhood	5.1	43.6	51.3	
standard error	3.5	7.9	8	

*elite neighbourhood here refers to city blocks featuring rich houses of the 2nd c. B.C.
In these two normalized frequency tables, I calculated standard errors for each proportion in the table from the formula sqrt(p*(1-p)/n), where p is the proportion in one cell, and n is the total count for either the row or the column (depending on which direction the table was normalized). This provided a simple measure of certainty in the values presented.

seems to correlate with quicker and more economical methods of house construction for the lower classes, using a greater proportion of rubble than of dressed blocks.[38]

The absolute chronology of the "limestone-framework" types is also problematic, especially in light of the results of a new wave of excavations starting in the early 1980s. In general, these have revealed little evidence of construction for the period from the 5th through most of the 3rd c. B.C. in both public and residential sectors of the town, posing a challenge to the very same idea of a "limestone period".[39] The progress of stratigraphic research at the site has confirmed that very few contexts can be said with any certainty to predate 200 B.C.

347-72; Sewell (supra n.1) 116-21 describes the "row-houses" as lower-class housing.

38 R. De Luca *et al.* ("Archaeometric study of mortars from the garum shop at Pompeii, Campania, Italy," *Geoarchaeology* 30 [2015] 330-51) present scientific evidence of pozzolanic mortars being used for joints at I.8.12, some characterized by hydraulic properties. The authors assign their samples to the first phase of the structure, which they date conventionally to the 3rd or early 2nd c. B.C. Based on the published plan (348, fig. 13), one could argue that the walls in question belong to subsequent modifications of an original "row-house" of Nappo's "Tipo 3", whose basic spatial organization is still legible (e.g., the position of an axial threshold on the main façade; the siting and overall dimensions of Room 3; Rooms 4, 7, 8 and 11 probably formed the original open court or *prostas*; Rooms 12 and 6 seem to reflect the presence of an axial *tablinum*). A later date in the 2nd c. B.C. is thus possible. In any event, a proper architectural study of the house is necessary to evaluate the significance of its mortared-rubble techniques.

39 Classic early works are P. Arthur, "Problems of the urbanisation of Pompeii: excavations 1980-1981," *AntJ* 66 (1986) 29-44, and M. Bonghi Jovino (ed.), *Ricerche a Pompei*, vol. 1. *L'insula 5 della Regio VI dalle origini al 79 d.C.* (Rome 1984), whose main results are placed in the broader context by Richardson (supra n.19); Chiaramonte Treré (supra n.21).

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TABLE 3
DISTRIBUTION OF "SARNO LIMESTONE" STRUCTURES
IN DATABLE DOMESTIC CONTEXTS AT POMPEII.

House	*Stratigraphic dating*	*Building techniques*
Casa del Naviglio (VI.10.11)	After 250 B.C.	Ashlar masonry; limestone-framework
Casa del Centauro (VI.9.3-5)	middle/late 3rd c. B.C.	Ashlar masonry; limestone-framework; clay-based rubblework
Casa del Chirurgo (VI.1.10)	After 211 B.C.	Ashlar masonry
Casa di Amarantus (I.9.11-12)	3rd or 2nd c. B.C.	Clay-based mortared rubble; wattle-and-daub
Insula del Centenario (IX.8)	First half of 2nd c. B.C.	Limestone-framework
Row-houses of Regio II	2nd c. B.C.	Limestone-framework

(Table 3). One of the earliest documents seems to be the Casa del Centauro (VI.9.3-5).[40] The excavators have dated the original phase of the house to the middle of the 3rd c. B.C. As they note, the unique plan features a transverse open court of shorter proportions and double street-front rooms, which would betray its relative antiquity (fig. 4).[41] The façade is in limestone ashlars, the side-walls in "limestone-framework technique", but interior walls are built with packed clay. Though the house had walls decorated with painted plaster, *cocciopesto* floors and mosaics, lime mortars were not employed for structural purposes.

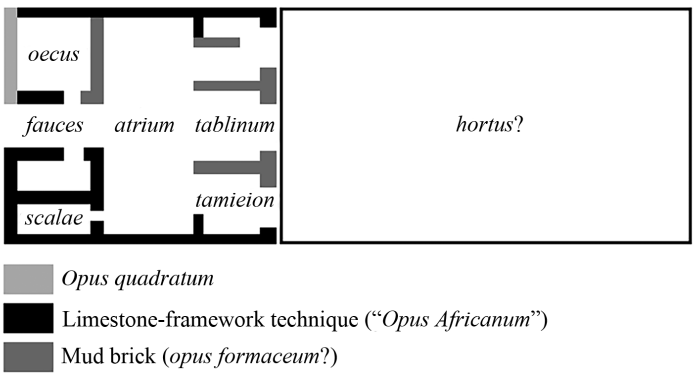

Fig. 4. Schematic plan of the original phase of the Casa del Centauro (redrawn from Pesando [infra n.42] 118 fig. 1; original without scale).

Extensive work in the rest of the city-block, as well as in the neighbouring *insulae* VI.10 and VI.13, has not produced entirely convincing evidence for earlier "Sarno limestone" architecture.[42] Two broad phases have been identified in the urban development of this

40 F. Pesando, "Il progetto Regio VI. Le campagne di scavo 2001-2002 nelle Insulae 9 e 10," in Guzzo and Guidobaldi (supra n.34) 82-88; id. 2006 (supra n.1) 229-33; id., "Case di età mediosannitica nella Regio VI. Tipologia edilizia e apparati decorativi," in P. G. Guzzo and M. P. Guidobaldi (edd.), *Nuove ricerche archeologiche nell'area vesuviana (scavi 2003-2006)* (Rome 2008) 159-72.

41 M. Giglio ("La casa pompeiana tra il III ed il I secolo a. C. Nuovi dati dagli scavi della regione IX, insula 7," in J. M. Álvarez, T. Nogales and I. Rodà [edd.], *Center and periphery in the ancient world: Proc. XVIII Int. Cong. Class. Arch.* [Mérida 2014] 1035), however, reports that in the central sector of *insula* IX.7 houses of this plan were still being built in the 2nd c. B.C.

42 Coarelli and Pesando (supra n.8) 51. A date in the late 4th c. B.C. has been proposed for the Casa degli Scienziati (VI.14.43), but it is based on material collected from levels for which no direct stratigraphic relationship with the standing masonry structures can be proven: N. De Haan *et al.*, "The Casa degli Scienziati (VI 14, 43). Elite architecture in fourth-century B.C. Pompeii," in Guzzo and Guidobaldi (supra n.34) 240-56; Peterse (supra n.27) 377-78. Another early example of the

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area, one dating broadly to the 3rd c. B.C. (especially in the second half of that century) and the other broadly to the 2nd c. B.C.[43] The second phase involved modifications of the house plans, but the same building techniques were employed, at least initially. This has been observed in the Casa del Centauro and the Casa del Chirurgo (VI.1.10), which date to the early part of the 2nd c. B.C.[44] The phenomenon finds a parallel in other neighbourhoods. Fulford and Wallace-Hadrill already observed that in the Casa di Amarantus (I.9.11-12) limestone rubble architecture without lime mortar may be as late as 200-150 B.C.,[45] while earlier structures were made of mixed materials, including "Pappamonte" and lava rubble.[46] Similarly, controlled excavation in the 'row-houses' of *Regio* II demonstrated that most of the plots in the E sector were first occupied only at the end of the 3rd c. B.C., and that there was a progressive infill in the course of the 2nd c. B.C., without noticeable changes in building methods.[47]

In sum, in light of the new discoveries a different account of the diffusion of limestone-framework architecture can be proposed. The period during which this technique spread seems much shorter than previously posited, covering only the latter part of the supposed "limestone period". The relative sequence of building techniques seems still valid, but two aspects require thorough modification. First, the continuation of this type of architecture well into the 2nd c. B.C. undermines the sharp distinction between the "limestone"

"limestone-framework technique" would be at VI.10.11 (Casa del Naviglio), where construction levels contain materials of the first half of the 3rd c. B.C. On this house, see Pesando (supra n.40); R. Cassetta and C. Costantino, "La Casa del Naviglio (VI 10, 11) e le botteghe VI 10, 10 e VI 10, 12)," in F. Coarelli and F. Pesando (edd.), *Rileggere Pompei 1. L'insula 10 della Regio VI* (Rome 2006) 322-36, for the pottery evidence. Sewell (supra n.1) 130 rightly takes this date as a *terminus post quem*. F. Pesando ("Pompei in età sannitica. Tipologia, uso e cronologia delle tecniche edilizie," in F. M. Cifarelli [ed.], *Tecniche costruttive del tardo-ellenismo nel Lazio e in Campania* [Colleferro 2013] 121-23) lists other houses datable within the 3rd c. B.C., including VI.14.40 and VI.5.5 (Casa del Granduca Michele, *c*.200 B.C.). The façade of the latter has been described as a form of *opus caementicium*, but the technique may have more in common with the "limestone-framework technique" (Peterse's type C).

43 F. Coarelli and F. Pesando ("Introduction. Proposal for a chronological sequence of the phases of occupation of the insula VI,10," in Coarelli and Pesando 2006 [supra n.42] 23-26) reconstruct a progression in the urbanization in this sector of Pompeii, moving from north to south (i.e., starting from the periphery and slowly occupying the plots closer to the core of the so-called "Altstadt"). Chiaramonte Treré (supra n.21) 24 identifies a single phase of development unfolding in the period between the latter part of the 3rd and the early part of the 2nd c. B.C., based on the results of Bonghi Jovino's excavations at VI.5.

44 Recent coin evidence has provided a *terminus post quem* of 211 B.C. for this reconstruction: R. F. Jones, "The urbanisation of Insula VI 1 at Pompeii," in Guzzo and Guidobaldi (supra n.40) 139-46.

45 Fulford and Wallace-Hadrill (supra n.16) 112-15. A re-assessment of the excavation data is given by Pesando 2013 (supra n.42) at 118-21 and 124-25.

46 This type of architecture is attested in the few known 4th-3rd c. B.C. contexts: e.g., below the atrium of the Casa delle Nozze di Ercole (M. T. D'Alessio, "La Casa delle Nozze di Ercole (VII,9,47)," in Guzzo and Guidobaldi [supra n.40] 275-82), below the Casa di Giuseppe II, and in the area of the Foro Triangolare (Carafa [supra n.1] 89-111).

47 See especially Nappo (supra n.8); A. Gallo, *Pompei: l'Insula 1 della regione IX : settore occidentale* (Rome 2001) 69-77 (Casa di Epidio Rufo, IX.1.20). Pesando 2013 (supra n.42) 123 points out that construction with packed clay and mud-brick (*opus formaceum*) continues for most of the 2nd c. B.C. See also id., "La domus pompeiana in età sannitica. Nuove acquisizioni dalla Regio VI," in M. Bentz and C. Reusser (edd.), *Etruskisch-italische und römisch-republikanische Häuser* (Wiesbaden 2010) 243-53.

and "tufo" periods: in general, a greater overlap must be admitted in terms of building materials.[48] In fact, in houses that have been dated within the first half of the 2nd c. B.C., "limestone-framework" walls and "Nocera tuff" architecture (i.e., ashlar façades, columns, impluvia, and mouldings) appear juxtaposed.[49] Another important conclusion is that stylistic variation within the class of the "limestone-framework technique" does not depend strictly on a gradual development of the technique, because it was primarily influenced by social and economic factors. The link between Peterse's Type C and the "row-houses" of Pompeii's *Regiones* I-II has important implications for the study of *opus incertum*: it suggests we should reject the idea that this came about as the result of a progressive improvement of clay-based mortars within the tradition of the "limestone-framework technique", and that we should look elsewhere for the early development of concrete at the site.

The Pompeian *opus incertum* as early concrete architecture

The interpretation of the "limestone-framework technique" and *opus incertum* as successive steps in a single, continuous sequence of architectural developments at Pompeii betrays fundamental inconsistencies in the identification of the early class of concrete walls.[50] Lugli, for example, described the fills of limestone-framework walls in the "Sarno limestone" atrium houses as "coarse *opus caementicium*", essentially because of the exterior aspect of the wall-facings, and not on the basis of the actual composition of the mortars.[51] Imprecisions like this contributed significantly to the notion that there was an early stage of experimentation. Our re-assessment of Peterse's analysis of the "limestone-framework technique" demonstrates that clay-based and lime-based mortar-and-rubble architecture in reality represented different, alternative building traditions. This pattern raises a series of issues concerning the process of technological innovation, especially whether pozzolana began to be used at the same time that lime mortar was introduced for structural purposes, as we know happened in Rome, when, and in what context. Mortar studies employing scientific methods of analysis, of course, are a quite recent (and slow-growing) development in the field of Pompeian architecture, and the available data are still limited. Early literature touched on the subject, but it includes subjective observations and confusion in the terminology, and must be approached with caution.

The conventional dating of *opus incertum* is also problematic, because it is based on the expectation that different building materials characterized different building periods in all aspects of Pompeii's architecture. This theory, which was behind the very same idea of the "limestone period", has been applied to describe the development of the concrete technique, essentially adapting the periodization of ashlar masonry. Thus, Mau hypothesized that early variants of concrete were those made predominantly of scoriaceous lavas, a material sourced from the superficial levels of the volcanic spur on top of which Pompeii

48 Ball and Dobbins (supra n.6) 463-64 question the conventional chronology of the "Tufo period", pushing most of the monuments commonly assigned to it into the 1st c. B.C.

49 As observed by Richardson (supra n.19) 376-78.

50 As A. Wallace-Hadrill ("The development of the Campanian house," in Dobbins and Foss [supra n.14] 280) points out, the term *opus incertum* in the context of Pompeii has become "no more than a catch-all".

51 Lugli (supra n.10) vol. 1, 379-83. His treatment of the subject is quite chaotic. In parts of the work that were clearly revised after the publication of Maiuri's reports in 1944-45, Lugli dated most of the known examples to the period 150-80 B.C. while maintaining the middle of the 3rd c. B.C. for the origins of the medium.

sits (as was the case with "Pappamonte" in ashlar construction).[52] Carrington, on the other hand, saw the formative phase of *opus incertum* as rooted in the "Sarno limestone" tradition. This idea was based on the high chronology he assigned to the Casa di Sallustio and the Villa dei Misteri. In his reconstruction, there would be a progressive abandonment of limestone in favour of another type of lava, more compact than the scoriaceous variety. Examples of this transition would be the Casa del Fauno (VI.12) and the Casa di Pansa (VI.6.1), where the two materials are present in equal proportions. As part of this trend, a mortar mix of good quality would also be introduced, using what was described as black volcanic sand and a higher proportion of lime. The gradual switch to compact lava rubble would be completed before the end of the century, given the association between walls made entirely of this material and First-Style paintings in some later public monuments (e.g., the Basilica).[53] Lugli envisaged the same evolutionary trajectory, not only in terms of building materials but also in terms of wall-facing styles, positing a process of progressive regularization of the mortar joints.[54]

Certain aspects of the above reconstruction have already received important criticism, which is worth recalling here. M. Blake thought that the impetus for the use of "Sarno limestone" as rubble in *opus incertum* was determined by the diffusion of "Nocera tuff" façades, in that the *caementa* could be obtained by recycling older ashlar structures that were being dismantled to make room for the new ones. Similarly, the gradual change to lava rubble would be caused by the steady decline in the supply of the recycling material, implying that limestone rubble was never quarried on purpose for concrete construction.[55] The presence of 2nd-c. B.C. "limestone-framework" architecture proves that conclusion wrong, at least in the sense that the material continued to be available throughout the period. In any case, the connection between *opus incertum* and "Nocera tuff" ashlar masonry, as well as the idea that the emergence of concrete had a connection with re-use of demolition material, both deserve further investigation. On a related note, L. H. Richardson jr questioned the idea of evolution of *opus incertum*, arguing for a direct relationship between the choice of broken lava as a building material, advances in the composition of mortar, and methods of laying the lava rubble. This harder and heavier stone being more intractable, and producing smoother fracture surfaces that were not ideal for packing, it eventually required laying the elements in heavier beds of mortar, so much so that he would hardly speak of *opus incertum* for the structures using limestone rubble. The better quality of the medium would have also determined its initial use for foundations at this stage. The relationship between technological style and structural function is indeed an important principle. According to Richardson, however, this would only be a very late development, in the last

52 A. Mau and F. W. Kelsey, *Pompeii; its life and art* (2nd edn., New York 1907) 39. Adam (supra n.14) 105 dates the introduction of lava rubble to the 3rd c. B.C. The material is known as *cruma* or *schiuma di lava*. On the geology of the local lavas, see Kastenmaier *et al.* (supra n.18) 44 Tab. 2 (note that the term "soft lava" present in this work should be avoided). No ancient quarry is known at the site, but recent archaeometric evidence has shown that scoriaceous lavas used in Pompeian concrete could also be sourced from the N slope of Vesuvius, where these deposits outcropped: L. C. Lancaster *et al.*, "Provenancing of lightweight volcanic stones used in ancient Roman concrete vaulting: evidence from Rome," *Archaeometry* 53 (2011) 720-21 and fig. 8.

53 Carrington (supra n.24) 131-32.

54 Lugli (supra n.10) vol. 1, 411-12, 447-48 and 475-76. Pozzolana would have been introduced together with *caementa* and facing blocks of what Lugli described imprecisely as "tufo vulcanico scuro".

55 Blake (supra n.10) 228-29.

quarter of the 2nd c. B.C.[56]

In light of these considerations, a thorough re-appraisal of the archaeological evidence for *opus incertum* in Pompeian houses becomes necessary. In the following sections, I will concentrate on those buildings that have been taken as fixed points for the high dating of the technique, combining stratigraphic, ceramic, epigraphic and, where available, archaeometric data. The results will then form the basis for an investigation of the social and cultural context of the technological innovation, and of the broader problems concerning 2nd-c. B.C. architecture at the site.

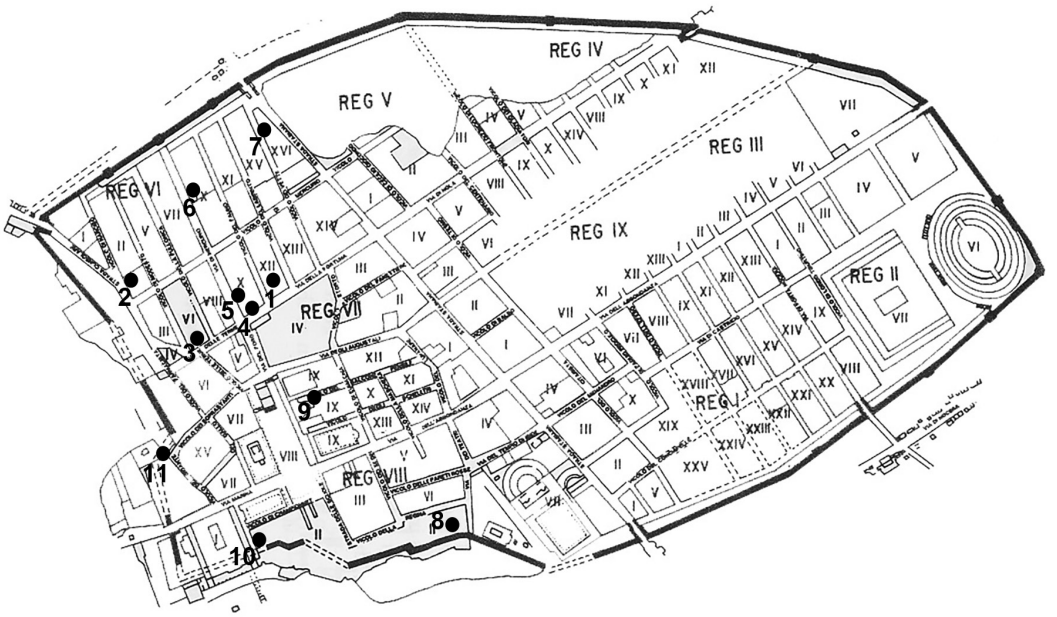

Fig. 5. Schematic map of Pompeii with location of the houses discussed in the text (1. Casa del Fauno; 2. Casa di Sallustio; 3. Casa di Pansa; 4. Casa del Naviglio; 5. Casa dell'Ancora; 6. Casa del Centauro; 7. Porta Vesuvio area; 8. Casa di Giuseppe II; 9. Casa delle Nozze di Ercole; 10. Casa di Championnet; 11. Casa di Maio Castricio).

The development of *opus incertum* in 2nd c. B.C. domestic architecture at Pompeii

At first glance, the sample size of *opus incertum* architecture in domestic contexts at Pompeii seems adequate (fig. 5), yet the dating evidence is very uneven. Many of the sites that have been taken to represent canonical benchmarks for the earliest phase of the technique, particularly those characterized by the predominant use of "Sarno limestone" rubble (e.g., the Villa dei Misteri), have not been much explored below the floor levels of A.D. 79. As we have seen, the supposed relationship with the architectural traditions of the supposed "limestone period" has influenced the interpretation of these buildings; it represents the main criterion for the high dating. The chronology of other significant monuments rests primarily on stylistic grounds, based on the association of walls with the surviving architectural decoration (e.g., Casa di Pansa), First-Style paintings (e.g., Insula of the Menander) or a combination of both (e.g., Villa dei Misteri).[57] Stratigraphic

56 Richardson (supra n.19) 376-78.

57 In *The Insula of the Menander at Pompeii* (Oxford 1997) vol. 1, 17-20, R. Ling provides a discussion of the methodological problems. Because the same building techniques were used across

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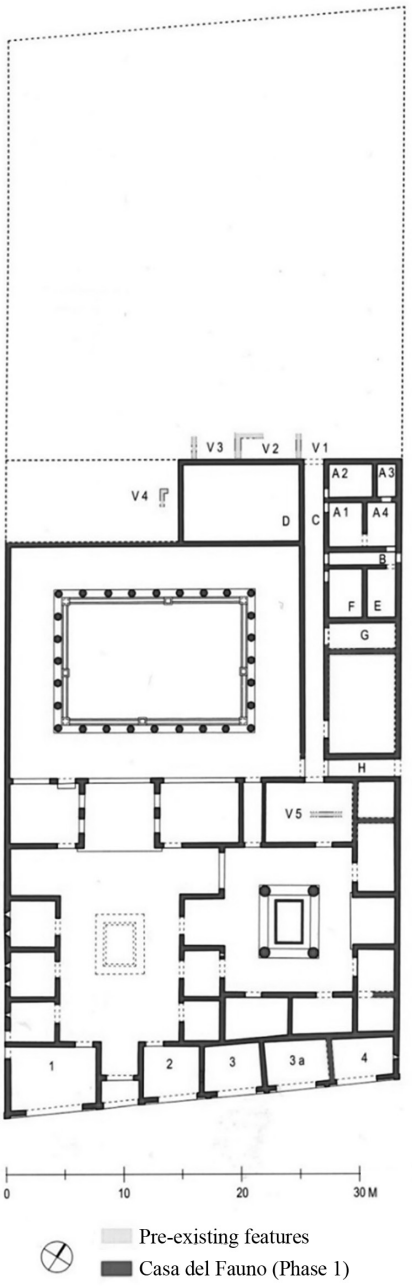

data and ceramic finds normally come from test-trenches of limited dimensions whose placement has often been constrained. Such excavations tend to result in the low recovery of artifacts, producing few diagnostic elements. In addition, most excavated deposits consist of construction fills and levelling layers, which normally contain abundant residual pottery. Ceramic assemblages collected from these levels, however, can provide a *terminus post quem* for the structures with which they are associated. In some notable cases (e.g., the "Progetto Regio VI" by F. Coarelli and F. Pesando),[58] this excavation strategy has been adopted at the level of entire blocks, although the sum total of data collected from a larger number of small trenches does not always eliminate the problem. Despite these difficulties, however, the available evidence allows us to draw a sharp demarcation with the architectural traditions attested in the 3rd c. B.C.

Early examples of the *opus incertum* technique seem to surface first in rich neighbourhoods, as demonstrated by recently published data from the Casa del Fauno (VI.12), the grandest mansion in the Late Samnite period (fig. 6). Excavations in select areas (the *fauces*, two rooms off the tetrastyle atrium, the set of 4 rooms in the NE corner of the atrium, and the S portico of the N peristyle) revealed that the Casa del Fauno was built on top of earlier structures conforming to the same alignment. These were in a flimsier technique, using rubble of "Sarno limestone", chunks of lava and tile fragments, all bound together with clay-based mortar.[59] Construction layers associated with this phase contain material of the second half of the 3rd c. B.C., while pottery of the first

Fig. 6. Phase 1 of the Casa del Fauno with indication of earlier structures in grey (modified from Faber and Hoffmann [infra n.59] pl. 9).

different periods, and different techniques could be used in the same construction phase, he maintains that masonry styles are not useful to date. According to him, the physical relationship between walls can also be problematic because there are numerous cases in which these appear bonded only in the upper parts; the safest criterion for distinguishing between building periods would be the presence of plaster on one of two contiguous walls.

58 F. Coarelli and F. Pesando (edd.), *Rileggere Pompei* vol. 1. *L'insula 10 dell Regio VI* (Rome 2006).

59 A. Faber and A. Hoffmann, *Die Casa del Fauno in Pompeji (VI 12),* vol. 1 (Wiesbaden 2009) 33-34 and 47-50.

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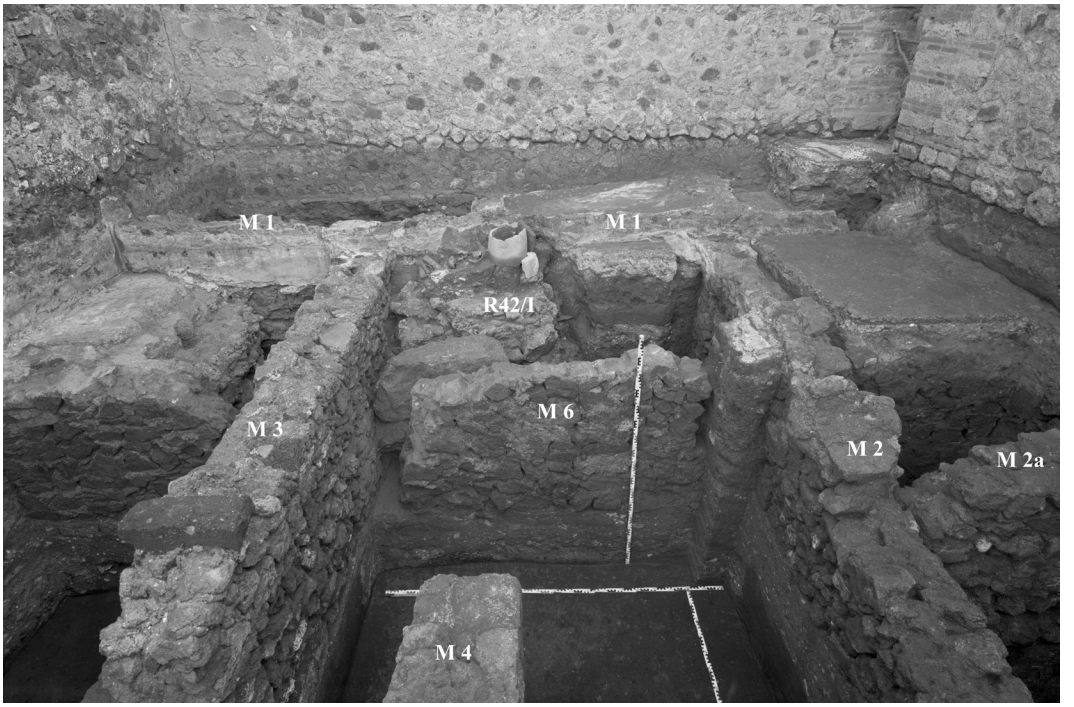

Fig. 7. Lava *opus incertum* foundations under the later floor of Room 42, northeast of the S peristyle (from Faber and Hoffmann [supra n.59] fig. 29). Wall M6, viewed from the northwest, corresponds with the E–W wall separating Rooms A1 and A4 from Room B in fig. 6 (Koppermann, Neg. D-DAI-ROM-62.2193).

quarter of the 2nd c. B.C. has been collected from occupation layers sealed by the floors of the Casa del Fauno.[60] The redevelopment of the property plot, therefore, began in the middle of the 2nd c. B.C.[61] The original phase of the Casa del Fauno featured a dressed "Nocera tuff" façade, two atria, a *hortus*, and a peristyle. The interior walls feature regular courses of mortared rubble with ashlar quoins of "Sarno limestone". The builders employed a deliberate grading of materials, selecting heavier compact lava for the lower portion of the walls (fig. 7), while using lighter "Sarno limestone" rubble with sporadic scoria and tile fragments for the upper courses. The use of compact lava instead of "Sarno limestone" in the foundations was particularly advantageous also because it provided better insulation from water and humidity ("Sarno limestone" is extremely porous). The compact lava walls served also as a retaining wall for the construction fills that were subsequently dumped to raise the floor level. Load-bearing walls have shallow mortared-rubble foundations (described by the excavators as *Mortelbankett*), laid in trenches that cut through the early deposits. This system appears to have been consistently adopted in the atria, while in the N half of the house the selection of materials seems not as uniform; the N boundary wall, for example, is made entirely with compact lava rubble, which could also suggest that, whenever available in greater quantities, a more resistant material was chosen for exposed areas.

60 Ibid. 80-81.

61 Ibid. 82-84, giving a date range of 175-150 B.C. (which perhaps should be taken as a *terminus post quem*). Most of the black-gloss pottery collected from the early level of the house dates to the first half of the 2nd c. B.C. Previous studies, based only on stylistic evidence, dated the original occupation of the *opus incertum* house to 185-175 B.C.: Richardson (supra n.19) 115-17; F. Zevi, "La città sannitica. L'edilizia privata e la Casa del Fauno," in id. (ed.), *Pompei* (Naples 1991) 47-74.

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TABLE 4
DATABLE EARLY *OPUS INCERTUM* HOUSES IN POMPEII
(SL = "Sarno limestone"; CL = "compact lava")

House	*Stratigraphic dating*	*Types of rubble*	*Vaulting system*
Casa del Fauno (VI.12)	175-150 B.C. or later	SL; CL	n/a
Casa del Centauro (VI.9.3-5)	After 175-150 B.C.	SL; CL	n/a
Casa di Sallustio (VI.2.4)	*c.*140 B.C.	SL	n/a
Casa dell'Ancora (VI.10.7)	After 140 B.C.	SL; CL	Unfaced concrete?
Porta Vesuvio (VI.16.26-27)	140/130-110 B.C.	SL	n/a
Casa delle Nozze di Ercole (VII.9.47)	125-100 B.C.	SL; CL	n/a

The creation of the Casa del Fauno was not an isolated episode in the history of that sector of Pompeii. A number of sizeable compounds datable to 150-140 B.C. or shortly after demonstrate that there was a generalized burst in construction activity at that juncture (Table 4). The date of the Casa di Sallustio (VI.2.4), which was believed to provide a late 3rd-c. B.C. example of lime-based mortared-rubble architecture rooted in the "limestone period", has been thoroughly revised in this sense, taking into account new pottery evidence.[62] The implication is that the conventional sequencing, based on the idea of a gradual change in proportions between different building materials, from "Sarno limestone" to compact lava, loses much of its chronological value.[63] In order to describe the development of the building medium, a particularly good case is the Casa di Pansa (VI.6.1), another house of canonical atrium type, to which is associated an axial peristyle.[64] The building techniques are similar to those described for the Casa del Fauno: "Nocera tuff" ashlar façade, *opus incertum* interior walls of mixed material, "Sarno limestone" corner blocks. Mortar samples collected from the original walls in the area of the atrium have been analyzed scientifically (fig. 8): the mix includes natural pozzolana, whose geochemistry is compatible with the compositional fields of the Vesuvian volcanic ash, while, most importantly, the tests detected the presence of cementitious gels (C-S-H), which means that the mortars used in the first phase of the house were of hydraulic type.[65]

The medium-sized houses of *Regio* VI also received modifications in *opus incertum*, adopting the technique introduced a short time earlier in the Casa del Fauno and other élite contexts. In the area of Porta Vesuvio, ceramic materials collected in the foundation trenches (e.g., VI.16.26-27) date to 140/130–110 B.C., while construction fills contain pottery dating to 140-120 B.C.[66] The reconstruction of the Casa del Naviglio (VI.10.11) dates to the

62 A. Laidlaw and M. S. Stella, *The House of Sallust in Pompeii (VI 2, 4)* (JRA Suppl. 98, 2014) 127-41.

63 *Opus incertum* walls made of limestone rubble are occasionally attested in houses of the second half of the 2nd c. B.C., though always in association with load-bearing concrete structures featuring a grading of compact lava and Sarno limestone rubble. An example is at VI.10.3-4: M. Zampetti, "La casa VI 10, 3-4 e la bottega VI 10,5," in Coarelli and Pesando 2006 (supra n.42) 109-11. M. Verzár-Bass, F. Oriolo and F. Zanini, ("L'Insula VI, 13 di Pompei alla luce delle recenti indagini," in Guzzo and Guidobaldi [supra n.40] 189-96) and Verzár-Bass and Oriolo ("Lo sviluppo architettonico dell'insula VI, 13," in iid., *Rileggere Pompei,* vol. 2. *L'Insula 13 della Regio VI* [Rome 2009] 496, n.14) date the diffusion of lava *opus incertum* walls to the second half of the 2nd c. B.C., taking it as a fixed *terminus ante quem* for the walls featuring Sarno limestone.

64 Richardson (supra n.19) 124.

65 D. Miriello *et al.*, "Characterisation of archaeological mortars from Pompeii (Campania, Italy) and identification of construction phases by compositional data analysis," *JArchSci* 37 (2010) 2216-18 (Group I mortars).

66 F. Seiler *et al.*, "La Regio VI Insula 16 e la zona della Porta Vesuvio," in Guzzo and Guidobaldi

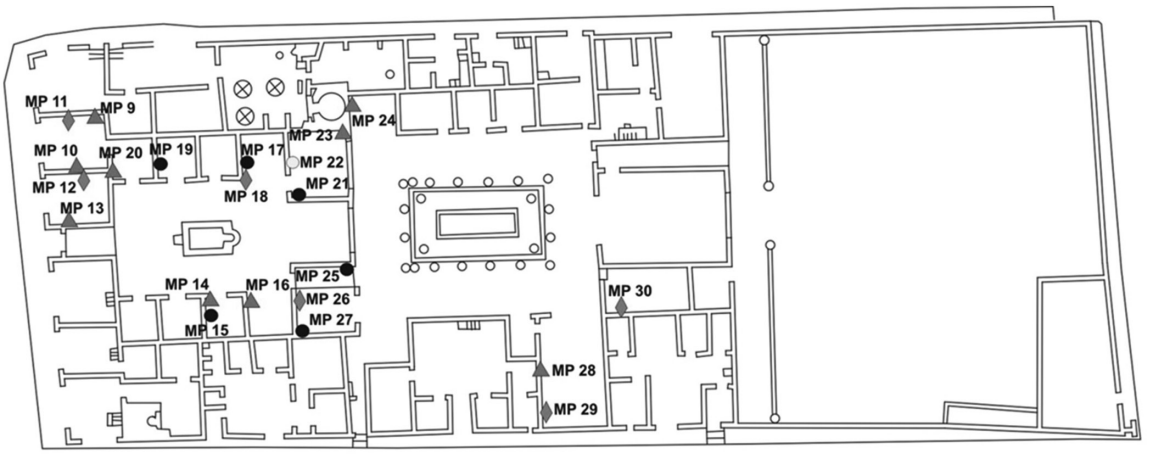

Fig. 8. General plan of the Casa di Pansa with location of mortar samples taken from *opus incertum* walls assigned to the original phase by cluster analysis (solid black dots; modified from Miriello *et al.* [n.65] 2221 fig. 12).

last quarter of the 2nd c. B.C.[67] The remodeling of the Casa dell'Ancora (VI.10.7) probably belongs to the same period. Its façade was rebuilt in *opus incertum*, though using exclusively compact lava rubble, which was also selected for the foundations of interior walls.[68] In this phase, part of the adjacent plot (VI.10.8) was added to the property, which became L-shaped. While the floor level in the area of the atrium was raised by *c.*1 m, the ground levels in the back portion of the house were maintained, creating a sunken garden delimited to the north by a set of three rooms (fig. 9). These have *opus incertum* walls of "Sarno limestone" sitting on top of foundations made with compact lava rubble, and are spanned by barrel-vaults (the largest measures 5.10 m), which support the area of the *tablinum* on the upper level.[69] This is perhaps the earliest example of concrete vaulted construction in domestic contexts at the town.[70]

The same pattern emerges in other neighbourhoods closer to the so-called "Altstadt".[71] A particularly well-documented context is the Casa delle Nozze di Ercole (VII.9.47) lying

(supra n.34) 228-29.

67 R. Cassetta and C. Costantino, "Vivere sulle mura: il caso dell'Insula Occidentalis di Pompei," in Guzzo and Guidobaldi 2008 (supra n.40) 197-208. The latest ceramic materials recovered from the floor preparation of this phase date between the second half of the 2nd and first quarter of the 1st c. B.C. The excavators suggest a date in the late 2nd c. based on evidence from other houses investigated in the same block.

68 F. Pesando *et al*. ("La Casa dell'Ancora [VI 10, 7]," in Coarelli and Pesando 2006 [supra n.42] especially 227-28 and 235) provide a broad range for this phase (150-100 B.C.). A recycled late Greco-Italic amphora was found inserted in the "*cocciopesto*" floor of one of the *oeci*, functioning as a drain; the authors date it to 140 B.C., which in my view should represent a *terminus post quem* (but the neck unfortunately is missing). A fragment of generic 2nd-c. B.C. Black Gloss pottery (Campana A) comes from the preparation. A date in the late 2nd c. B.C. is given in Pesando 2005 (supra n.40).

69 Pesando *et al*. ibid. 204-7.

70 The intrados of the vault is still covered by plaster, but the excavators ruled out the presence of voussoirs.

71 E.g., L. Pedroni, "Excavations in the history of Pompeii's urban development in the area north of the so-called 'Altstadt'," in Ellis (supra n.1) 158-68.

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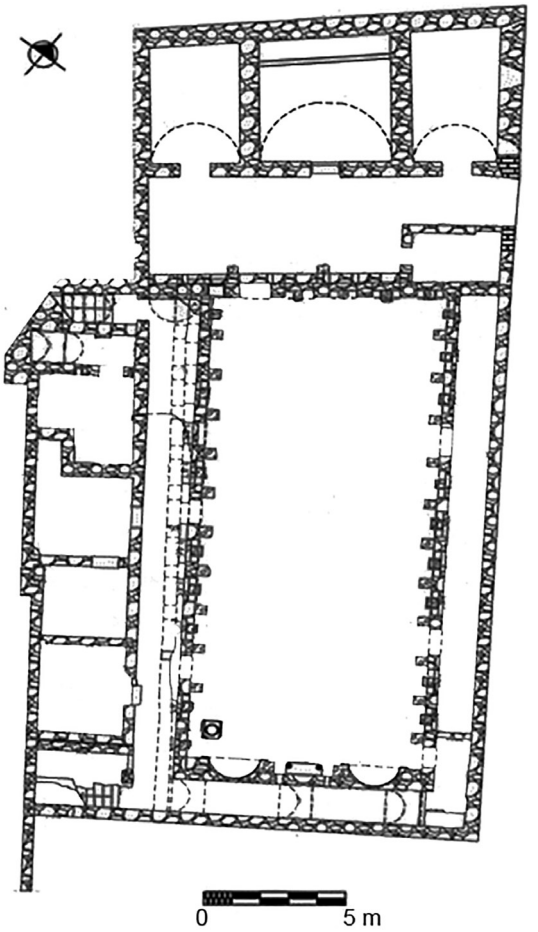

Fig. 9. Plan of the sunken level of the Casa dell'Ancora featuring concrete vaulted rooms on its N side (modified from Pesando *et al.* [supra n.68] pl. XLVII).

just east of the Forum. There, stratigraphic excavations have been carried out over an area of 540 m^2 (or almost two-thirds of the total surface occupied by the house), with the result that a much more representative sample of pottery has been collected.[72] The house acquired its standardized configuration with canonical atrium only in the last quarter of the 2nd c. B.C., as suggested by the pottery contained in the destruction layers of the prior occupation, as well as in the foundation trenches of walls. The structures show a variety of techniques: "Nocera tuff" ashlars in the pillars on the N side, "Sarno limestone" ashlars in the atrium, "Sarno limestone" and mixed "Sarno limestone" and compact lava *opus incertum* in the rest of the house.

In the so-called "Southwest Quarter" (VIII.2), occupying the slopes of the lava spur between the Temple of Venus and the Theatre quarter, there was a progressive occupation of empty lots located directly behind the fortification walls.[73] Remains in "Sarno limestone" ashlar and "limestone-framework technique" represent the first building phase in this area. Starting in the first half of the 2nd c. B.C., private structures began to encroach on the *pomerium*. In some cases, these houses were organized on terraces, featuring a basement floor that was usually covered with a flat roof and supported by ashlar retaining walls (e.g., at VIII.2.30 and 34). The Casa di Giuseppe II (VIII.2.39) demonstrates that houses of this kind were still being built in the second half of the 2nd c. B.C.[74] Examples of more extensive substructures with concrete vaults abut the fortification walls. These basement levels feature compact lava exclusively, though in some cases (e.g., VIII.2.29) they are associated with "Sarno limestone" *opus incertum* on the upper floor. By far the most elaborate example of the type is the Casa di Championnet (VIII.2.1), which incorporates an intermediate courtyard surrounded by a portico framed by arches (these are faced with "Nocera tuff" voussoirs, but have rubble cores; the vaults of the portico are later) and a lower terrace. Expansion of house construction beyond the line of the

72 D'Alessio 2008 (supra n.46) 280, Tab. 1. Note that the pottery collected from the occupation layers is earlier than that in the construction fills.

73 F. Noack and K. Lehmann-Hartleben, *Baugeschichtliche Untersuchungen am Stadtrand von Pompeji* (Berlin 1936).

74 P. Carafa and M. T. D'Alessio, "Lo scavo nella Casa di Giuseppe II (VIII.2.38-39) e nel portico occidentale del Foro Triangolare a Pompei: rapporto preliminare," *RStPomp* 7 (1995-96) 139.

old fortifications, which were re-purposed as substructures, has been dated to the Roman period because of the common association with Second-Style paintings.[75]

A similar sequence of occupation has been reconstructed for the so-called *Insula Occidentalis*, which includes the blocks between the Casa del Bracciale d'Oro to the north (VI.17.42-44) and the Casa di Maio Castricio (VII.16.17) to the south.[76] Epigraphic evidence attests that, around the time of the Roman siege of Pompeii in 89 B.C., there were houses located in the proximity of the fortification circuit.[77] The original phase of these buildings dates to the late decades of the 2nd or the early 1st c. B.C. Some of the early architectural decoration survives in the Casa di Maio Castricio (First-Style paintings, the cubic "Nocera tuff" capitals framing the entrance, and angular Ionic capitals). This house had superstructures in *opus incertum* using "Sarno limestone". First-Style paintings are preserved also in the atrium of VII.16.12-14, a house whose *tablinum* features Corinthian capitals dated stylistically to the period 110-80 B.C.[78] The building technique is the mixed type of *opus incertum*, with "Sarno limestone" in the upper part and compact lava in the lower portion of the walls. Restorations made with compact lava rubble appear at the base of the fortification walls along the entire stretch crossing the area (fig. 10). Both north and south of the *Insula Occidentalis* the outer curtain of the circuit was rebuilt up to a level corresponding to the second storey of the new houses, but this activity may date to the Roman period.[79]

The spread of structural concrete in the urban centre has a relationship with the development of villa architecture in the *suburbium*. The Villa dei Misteri (fig. 11) is among the most notable examples, as it clearly shares some features with the *opus incertum* houses discussed above.[80] The site lies off the Via dei Sepolcri, some 400 m outside the Porta Ercolano, but its orientation is at an odd angle to the road. Like other rural residences in the area, it

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75 Cf. F. Zevi ("Pompei dalla città sannitica alla colonia sillana. Per un'interpretazione dei dati archeologici," in M. Cébeillac-Gervasoni [ed.], *Les élites municipales de l'Italie péninsulaire des Gracques à Néron* [Naples 1996] 132-33), suggesting that the scarcity of Second-Style paintings from urban contexts, as opposed to the pattern observed in rural residences, is an indication that there was little reconstruction of houses in the early years of the colony, and that most Roman colonists (élite and commoners alike) lived on the outskirts of town.

76 Cassetta and Costantino (supra n.67) 197-202; M. Grimaldi, "Charting the urban development of the *Insula Occidentalis* and the Casa di Marcus Fabius Rufus," in Ellis (supra n.8) 142-45.

77 E. Vetter, *Handbuch der italischen Dialekte* (Heidelberg 1953) no. 25. One of the "*eituns*" inscriptions, now lost, was painted on the façade of a house located in *Regio* VII. The text gives indications on the route to follow to reach the specific sector of the walls delimited by the houses of Maraeus Spurius and Maius Castricius: P. Castrén, *Ordo populusque Pompeianorum: polity and society* (Act. Inst. Rom. Finl. 8; 1975) 44-45.

78 H. Lauter-Bufe, *Die Geschichte des sikeliotisch-korinthischen Kapitells. Der sogenannte italisch-republikanische Typus* (Mainz 1987) 43-44 cat. nos. 122-23, and 79. A slightly earlier date (130-120 B.C.) is given by Cassetta and Costantino (supra n.67) 204-5 with n.27.

79 The inscription (*CIL* X 937) attests a reconstruction of the fortification walls (*murus*) and of a tower supervised by the *duoviri* Cuspius and M. Loreius in the period after 80 B.C. See Zevi (supra n.75) 129. A date in the Roman period for these *opus incertum* remains is also given by Richardson (supra n.19). A rich epigraphic dossier shows that there was a spike in the construction/reconstruction of fortifications in Italy in the mid-1st c. B.C.: G. L. Gregori and D. Nonnis, "Il contributo dell'epigrafia allo studio delle cinte murarie dell'Italia repubblicana," in *Scienze dell'antichità* 19 (2013) 491-524.

80 There is much literature on this villa. The building techniques are described in A. Maiuri, *La Villa dei Misteri* (2nd edn.; Rome 1947) 42-43, 61-71 and 89-93; J. H. I. Kirsch's *Villa dei Misteri. Bauaufnahme, Bautechnik, Baugeschichte* (Ph.D. diss., Freiburg 1993) provides a more recent architectural study.

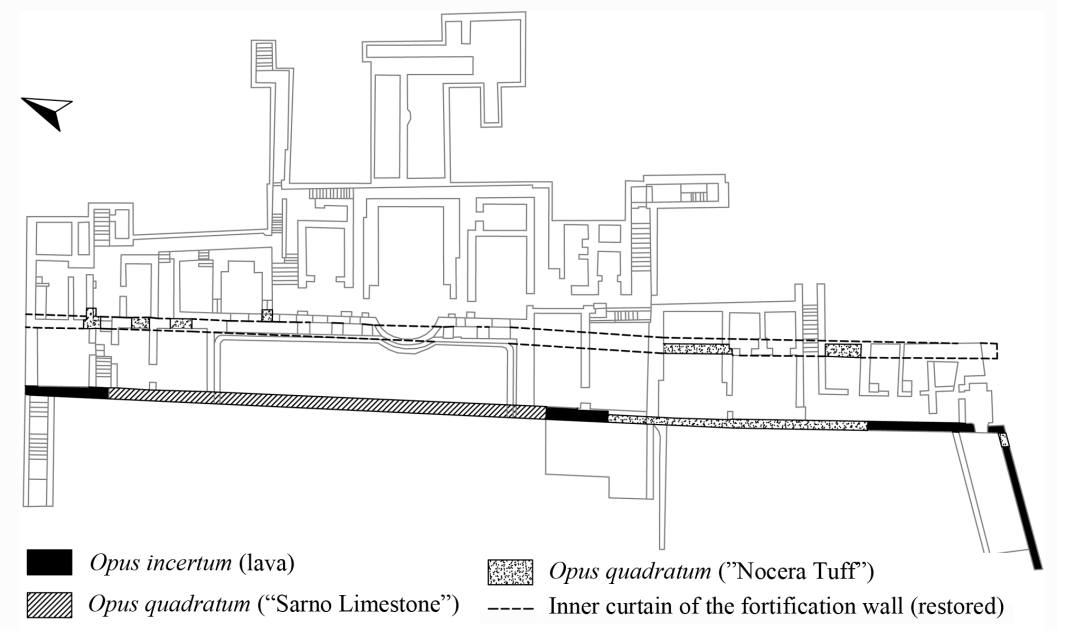

Fig. 10. Casa di Fabio Rufo and Casa di Maio Castricio, plan of basement indicating course of the original fortification wall (modified after Cassetta and Costantino [supra n.67] 199 fig. 3).

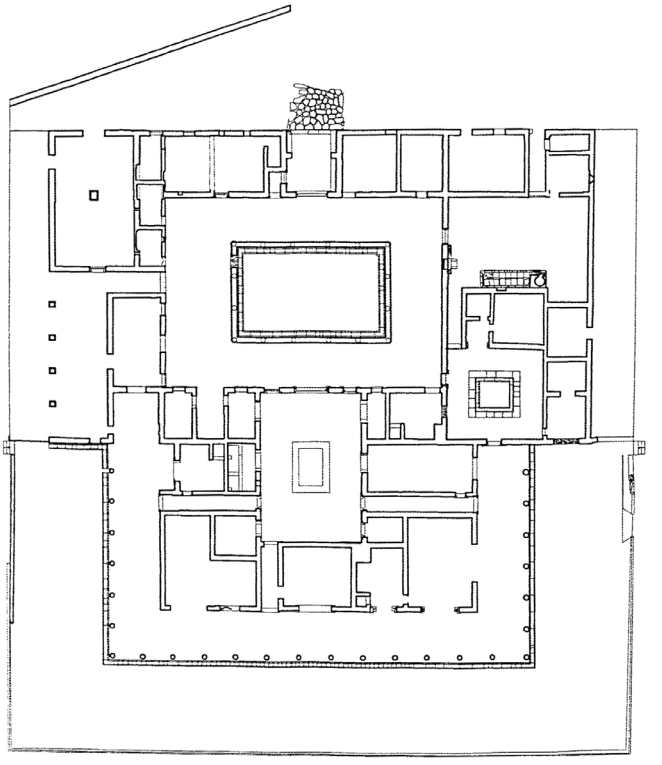

Fig. 11. Villa dei Misteri. phase plan *c.*80 B.C. (from Esposito [supra n.83] 448 fig. 8; original without scale).

follows the alignments of a land-division scheme generated by one of the main axes of the urban grid (the Via di Mercurio).[81] The villa was laid out on steeply sloping terrain, creating a square (50 x 50 m) platform delimited by a U-shaped cryptoporticus (fig. 12), which is covered with concrete barrel vaults (span of 2.65 m). The façade of the substructure is decorated with blind voussoir arches of "Sarno limestone", engaged to an *opus incertum* wall of both "Sarno limestone" and scoriaceous lava rubble (a close comparison is represented by the exterior façade of the amphi-

81 F. Zevi, "Urbanistica di Pompei," in *La regione sotterrata dal Vesuvio* (Naples 1982) 353-65. The Via dei Sepolcri has been dated to the Augustan period: V. Kockel, *Die Grabbauten vor dem Herkulaner Tor in Pompeji* (Mainz 1983) 8-9.

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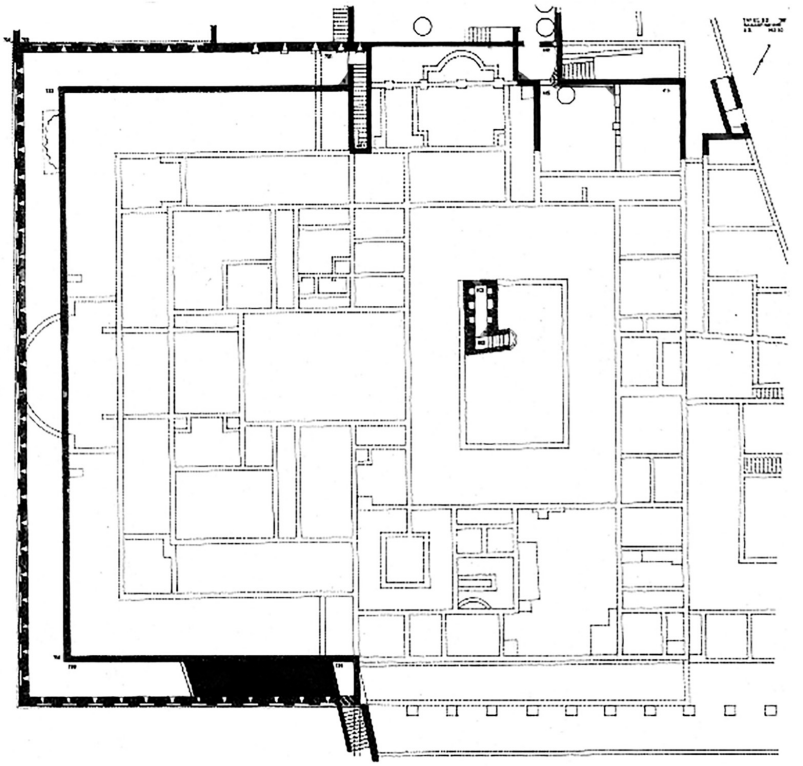

Fig. 12. Villa dei Misteri, plan of the basement (from Kirsch [supra n.80] fig. 2).

theatre, which dates to the Roman period). The inner *opus incertum* wall of the cryptoporticus is much sturdier, since facing and core are composed of compact lava. This structure retained a construction fill and supported a wide terrace on the upper floor. Behind the terrace was the atrium sector, delimited by a portico with simple Doric columns in "Sarno limestone" plastered with stucco, which sits on a stylobate of "Nocera tuff". The walls are built with *opus incertum* of "Sarno limestone", scoriaceous lava and an unspecified variety of tuff rubble, and corner stones of "Sarno limestone". Above the door lintels are relieving arches of "Sarno limestone" voussoirs (a parallel is seen in the Casa del Naviglio). "Nocera tuff" is more commonly found in the villa's E sector (e.g., the stylobate and columns of the peristyle, the *impluvium* of the secondary atrium, and door jambs). The building materials found in the rooms around the peristyle appear more difficult to classify (Maiuri speaks of different varieties of tuff). The facing blocks tend to have a flat face, and may be described as *opus reticulatum*, though the mortar joints are very thick.

A lack of stratigraphic data from the early excavations makes the precise dating of the Villa dei Misteri difficult. Maiuri thought that the difference in masonry style and building materials corresponded to two main phases, and suggested that the villa developed gradually from a more modest "Sarno limestone" core, to which the peristyle would later be added. In his first report, he dated the two phases to the 3rd and 2nd c. B.C., respectively, but he then revised his chronology, assigning the original building to the first half of the 2nd c. B.C. and the remodelling to 90-70 B.C.[82] Recent research, however, has demonstrated that the idea of a progressive development of the plan is entirely conjectural, and that the complex featured a peristyle from its establishment.[83] The variation in building techniques

82 Maiuri (supra n.80) 17 and 42-45.

83 Kirsch (supra n.80); also Richardson (supra n.19) 171-76, and D. Esposito, "Silla, Pompei e la

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should therefore be taken as evidence that different groups of builders were working at the same time in different parts of the house.[84] Wall-paintings and decorated floors are all in the Second Style.[85] Some scholars have suggested that these paintings masked a previous First-Style phase of the building, which would in turn support a date in the second half of the 2nd c. B.C. for the original construction, but the evidence is tenuous.[86] A date in the early years of the Roman colony seems more likely, although it is possible that works began in the period immediately before.[87] Thus, what was once regarded as one of the earliest monuments in the canonical series of "Sarno limestone" buildings should be placed at the end of that sequence.

Towards a new chronology and interpretation of the origins of concrete at Pompeii

A number of observations regarding the social context of technological innovation can be drawn from the case-studies discussed thus far. Our analysis of the "limestone-framework technique" shows that the first phase of urbanization of Pompeii, between the 3rd and 2nd c. B.C., was not the prime trigger for the early development of concrete architecture. At the top level of society in that phase, ashlar architecture, with its many variants, remained the preferred building tradition, while less solid types of "limestone-framework technique" were most common in lower-class housing, as demonstrated especially by the "row-houses" in the E sector of town. The clay-based mortars used to lay the rubble fills that characterize the latter technique included only small amounts of lime, and thus had a minor structural function (interestingly, these walls had thick coatings of plaster). This method of construction continued as a separate architectural tradition well into the 2nd c. B.C., undermining the idea of a gradual improvement culminating in the implementation of hydraulic lime mortars. The appearance of concrete foundations and *opus incertum* superstructures using mortar of the hydraulic type can be linked with a different phase in the town's building history that unfolded in the middle of the 2nd c. B.C. in the context of élite architecture. A number of early houses in *Regio* VI were redeveloped on a larger scale at that time, adopting standardized atrium designs and incorporating into their plans elements of Hellenistic derivation, notably the peristyle.[88] The phenomenon intensified during the second half of the 2nd c. B.C., when the new construction technique spread rapidly to other areas of the so-called "Altstadt", involving also the medium-sized properties.

Thus, the self-aggrandizement of local aristocrats seems to have played an important rôle in sparking technological change. The 2nd c. B.C. indeed represented a "golden age" for

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Villa dei Misteri," in B. Perrier (ed.), *Villas, maisons, sanctuaires et tombeaux tardo-républicains. Découvertes et relectures récentes* (Rome 2007) 441-65.

84 As noted by Esposito ibid. 446.

85 Overview: ibid. 448-53.

86 Thus H. Mielsch, *Die römische Villa: Architektur und Lebensform* (Munich 1987) 41 (still accepting Maiuri's relative sequence); Zevi (supra n.75) 135 (interpreting the Second-Style decoration as evidence that the villa was confiscated by a Roman colonist); J.-A. Dickmann, *Domus frequentata. Anspruchsvolles Wohnen im pompejanischen Stadthaus* (Munich 1999) 170-76 and 245-46; F. Pesando and M. P. Guidobaldi, *Gli ozi di Ercole. Residenze di lusso a Pompei ed Ercolano* (Rome 2004) 164-69. Esposito (supra n.83) 449 verified that under the Second-Style paintings in the atrium there is no trace of earlier layers of plaster.

87 Esposito ibid. 454-59 dates the beginning of the works to the early 1st c. B.C., while Richardson (supra n.19) 174 and Kirsch (supra n.80) propose a post-80 B.C. date.

88 Wallace-Hadrill 2013 (supra n.13) 41 advocates a down-dating of the Hellenistic phase of Pompeii to right after 150 B.C., contrasting it with the architectural developments of the 3rd c. B.C.

the Pompeian élites. Families of Pompeian origin became increasingly involved in Mediterranean trade to east and west. At Delos, numerous inscriptions naming *negotiatores* local to Pompeii have been recorded, while Aegean amphoras assemblages are frequent at Pompeii. Oscan stamps naming the Pompeian Lassii are attested on containers on shipwrecks (e.g., Chrétienne A) off the coast of Gaul.[89] The fortunes amassed in this way probably provided the funds for such an unprecedented programme of private construction. Stark variation in house sizes in this period is an index of increasing social stratification, while the diffusion of Hellenized stylistic features in their ornamentation demonstrates competition and status display within the upper échelons.[90]

This pattern contrasts dramatically with the scarcity of monumental civic architecture. Paradoxically, the distribution of the "Nocera tuff" façades may be interpreted as one of the few communal acts of urban renewal achieved in the third quarter of the 2nd B.C. to embellish the city as a whole.[91] The only public concrete monuments that can be safely assigned to this phase are the Stabian Baths,[92] and the Theatre (with the terracing structures of the Quadriporticus),[93] while the Forum area began to be monumentalized only by the end of the 2nd c. B.C., if not in the early 1st.[94] Previous reconstructions assumed a much more gradual development of the urban core throughout the second half of the 2nd c. B.C., but nevertheless interpreted the evidence as another indication that private interests prevailed over public ones until relatively late in the Samnite period.[95]

A series of Oscan inscriptions predating the establishment of the Roman colony informs us on the system that regulated public works in the town in the late Samnite period. The

89 On Pompeii's trade networks, see M. W. Frederiksen, *Campania* (London 1984) 324-25; C. Panella, "Per uno studio delle anfore di Pompei. Le forme VIII e X della tipologia di R. Schoene," *StMisc* 22 (1974-75) 149-62; ead., "Roma, il suburbio e l'Italia in età medio- e tardo-repubblicana. Cultura materiale, territori, economie," *Facta* 4 (2010) 49. For a list of presumed Pompeian traders at Delos, see Castrén 1975 (supra n.77) 39, n.6; D. Nonnis, "Attività imprenditoriali e classi dirigenti nell'età repubblicana. Tre città campione," *CahGlotz* 10 (1999) 71-109.

90 J. A. Dickmann, "The peristyle and the transformation of domestic space in Hellenistic Pompeii," in Wallace-Hadrill and Laurence (supra n.8) 121-36.

91 Wallace-Hadrill (supra n.13) 41 notes that these façades concentrate along the main urban axes leading to the Forum (i.e., the via dell'Abbondanza, via Stabiana and via della Fortuna).

92 A. Maiuri, *Alla ricerca di Pompei preromana* (Naples 1973) 44-48; H. Eschebach, "Feststellungen unter der Oberfläche des Jahres 79 n.Chr. im Bereich der Insula VII 1 (Stabianer Thermen) in Pompeji," in Andreae and Kyrieleis (supra n.36) 179-90; id., *Die Stabianer Thermen in Pompeji* (Berlin 1979). A review of the evidence is found in Richardson (supra n.19) 100-5. For the dating see also G. G. Fagan, "The genesis of the Roman public bath. Recent approaches and future directions," *AJA* 105 (2001) 408-14.

93 For the dating of the theatre see Richardson ibid. 85-90 (first half of the 2nd c. B.C.); F. Sear (*Roman theatres: an architectural study* [Oxford 2006] 49-50) gives a generic 2nd-c. B.C. date. On the *Quadriporticus*, see E. E. Poehler and S. J. R. Ellis, "The 2010 season of the Pompeii Quadriporticus Project. The western side," *Fastionline* 218 (2011) 4-5, and iid., "The 2011 season of the Pompeii Quadriporticus Project. The southern and northern sides," *Fastionline* 249 (2012) 5-6. Stratified materials from the Foro Triangolare place the redevelopment of this sector of town around 130 B.C.: Carafa (supra n.1s) 95-98.

94 See n.6 above. A significant *terminus post quem* comes from an assemblage of Rhodian amphora stamps found in the consruction levels of the Basilica: Maiuri (supra n.92) 220 no. 4 (*Arkhibios*) and no. 1 (*Aristanax II*), respectively. For the dating of these eponyms, see G. Finkielsztejn, *Chronologie détaillée et révisée des éponymes amphoriques rhodiens, de 270 à 108 av. J.-C. environ. Premier bilan* (Oxford 2001) 195, Table 21 f.

95 See P. Zanker, *Pompeii: public and private life* (Cambridge, MA 1998) 32-53.

terminology of the Oscan texts corresponds precisely to that in Latin, commonly present in Roman building inscriptions, with the legal framework of public building resembling closely the Roman *locatio-conductio operis*.[96] The Pompeian inscriptions record the involvement of local officers, the chief magistrate (*meddix tuticus*) or, more commonly, the *kvaísstur*/*quaestor*, sponsoring public projects, letting contracts for the construction of monuments, or acting as final approvers.[97] Private builders were probably hired as contractors, but there are no surviving examples of building contracts in the dossier. It is likely that magistrates let contracts for public projects to groups of builders who also worked in the private sector. Because of the many similarities in the organization of public construction, the same patrons could have employed the same skilled masons in both contexts.

The scale of construction at the domestic level can be appreciated here in all its complexity better than in Rome. The many projects progressing in parallel in this phase determined the economic need for new, efficient building methods making use of rubble, especially for the parts that were less visible (foundations and interior walls). The builders selected different building materials for different structural purposes, demonstrating an empirical knowledge of the local geology. Rubble of lighter "Sarno limestone" was normally preferred for the upper part of the walls or for vaults (a parallel in the public context comes from the N Wing of the Stabian Baths).[98] The old "Sarno limestone" structures, which are consistently found razed beneath the new houses, would have provided some recycling material. Compact lava was utilized for the lower portions, which carried the heavier loads (compact lava has a density of 2800, while that of "Sarno limestone" is 2100 kg per m^3).[99] There are, of course, exceptions to this rule, since structures built entirely in either material are also documented.[100] Furthermore, foundations made of rows of ashlars placed at short intervals, leaving gaps filled with rubble, can be found in association with *opus incertum* superstructures in place of concrete foundations (e.g., the Casa di Sallustio and Casa di Pansa; the podium of the Temple of Apollo provides a comparison in public building[101]). Scientific evidence on the use of hydraulic mortars in the early period comes from domestic architecture only. Previous experience with other types of hydraulic binders would have been instrumental in implementing the new technique: crushed volcanic material was already used as a substitute for terracotta in floor surfaces of the so-called *lavapesta* type, whose properties can be compared to those of *cocciopesto*.[102]

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96 As described in Mogetta (supra n.2) 30-31.

97 Vetter (supra n.77) nos. 13-15 (*meddix tuticus*); nos. 11-12, and 16-19 (*kvaísstur*). The two aediles of no. 8 were only responsible for road construction.

98 Maiuri (supra n.92) 32-34..

99 As noted by H. Dessales, "Les savoir-faire des maçons romains, entre connaissance technique et disponibilité des matériaux. Le cas pompéien," in N. Monteix and N. Tran, (edd.), *Les savoirs professionels des gens de métier* (Naples 2011) 50-51. See also F. Pesando, "Fundamenta sub terra. Breve nota sulle fondazioni murarie pompeiane durante l'età sannitica," *Vesuviana* 4 (2012) 76-81.

100 Most instructive is the case of the façades of block V.1 (Casa di Cecilio Giocondo, V.1.23; Casa degli Epigrammi Greci, V.1.18) showing the juxtaposition of "Sarno limestone" and compact lava stretches. A.-M. Leander Touati ("Shared structures–common constraints: urbanisation of Insula V 1," in Guzzo and Guidobaldi [supra n.40] 121-22, with figs. 5-9) suggests that different crews working at the same time on different sides of these buildings used different materials.

101 J. G. Cooper and J. J. Dobbins ("New developments and new dates within the Sanctuary of Apollo at Pompeii," *Fastionline* 340 [2015] 4-5) assign this feature to the Augustan period.

102 For a parallel development in Rome, see Mogetta (supra n.2) 31-32. The definition of *lavapesta* is given in K. M. D. Dunbabin, *Mosaics of the Greek and Roman world* (Cambridge 1999) 33;

Significant changes in the supply of building materials occurred in connection with the technological innovation. The area of Stabiae (the Lattari mountain ridge), at a distance of 5 km from Pompeii, would have been the closest source of limestone for producing lime. Other deposits found east of Sarno and Nocera lie more than 15-20 km from the site, adding to transport costs. Well-sorted pozzolana was quarried from the ash-falls distributed among the carbonate formations[103] and had to be transported. Volcanic sands and/or clays derived from the weathering of the volcanic deposits of Vesuvius near the site included large amounts of non-reactive materials, thus requiring extensive processing to become suitable for concrete construction. Compact lava deposits were found closer to the site, but the extraction of this material had to be organized *ex novo*, since it was never used intensively in the previous period.[104] On the plateau of Pompeii, a thick layer of "Pappamonte" and scoriaceous lava covers the compact lava level, but the evidence of quarrying on-site is fragmentary.[105] One of the possibilities is that the large-scale quarrying of polygonal slabs for road paving provided an impetus for the introduction of lava rubble in concrete construction. The *munitio* of the town's main thoroughfares, and their suburban stretches, is attested epigraphically for the late Samnite period, though the exact date is disputed.[106] In any case, the general raising of floor levels inside houses presupposes a similar activity on the exterior, which supports a date in the 2nd c. B.C. for the project. "Sarno limestone" rubble, on the other hand, could be obtained not only by recycling blocks from earlier structures, but also as a by-product of ashlar quarrying, which continued well into the 2nd c. B.C. to provide elements for *opus quadratum* façades and limestone-framework pillars. Overall, the evidence seems to confirm that the transition to the new construction method would have not been possible without a considerable investment of resources, bolstering the view that the innovation happened at a high level of society.

Conclusion

A closer look at the local context helps us make better sense of a phenomenon that has previously been thought of as "just happening". Far from being an accident of the local

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V. Vassal, *Les pavements d'opus signinum: technique, décor, function architecturale* (BAR S1472; Oxford 2006) 34.

103 Kastenmeier *et al.* (supra n.18) identify 4 deposits of ash falls predating the A.D. 79 eruption on top of the older Campanian Ignimbrite: Codola, Pomici di Base-Sarno, Mercato-Ottaviano, Avellino (these are mainly from the explosive activity of Somma-Vesuvius).

104 Richardson (supra n.19) 371-72 identifies this material with the *lapis pompeianus* that Cato (*De agr*. 22.3-4; 135.2) mentions as the best material available in central Italy for crafting mills. T. Kawamoto and Y. Tatsumi ("Classification and regional distribution of lava blocks in Pompeii," *Opusc. Pomp.* 2 [1992] 92-97) plot the distribution of compact lava in Pompeian masonry.

105 See P. Nicotera, "Sulle rocce laviche adoperate nell'antica Pompei," in A. Maiuri (ed.), *Pompeiana. Raccolta di studi per il secondo centenario degli scavi di Pompei* (Naples 1950) 406-16. J.-P. Brun *et al.* ("Pompéi, Herculaneum [Campanie], Saepinum [Molise]: recherches sur l'artisanat antique," *MEFRA* 118 [2006] 365 fig. 48) report recent finds.

106 For the inscriptions, see Vetter (supra n.77) no. 8 (mentioning the *vía stafiiana*/via Stabiana, the *vía púmpaiiana*/via Pompeiana, the *vía iuviia*/via Iovia, and the *dekkviarim* (acc.)/ Decuvia(?); nos. 9-10 (*terminatio* of the *via Sarínu*). B. Gesemann (*Die Strassen der antiken Stadt Pompeji: Entwicklung und Gestaltung* [Frankfurt 1996] 206) dates the road infrastructure to the pre-Roman period. Cf. Richardson (supra n.19) 372, and C. Saliou, "Les trottoirs de Pompéi: une première approche," *BABesch* 74 (1999) 196-98, both of whom assign the compact lava curbstones and sidewalks to the Roman period (i.e., 1st c. B.C.).

geology, as Lugli and Blake once too simplistically assumed, the origins of concrete technology at pre-Roman Pompeii can be seen as the outcome of significant social and cultural developments. The emergence of the new building medium occurred later than previously thought, and with little relationship to forms of vernacular architecture, thereby highlighting the pivotal rôle of local élites in the process. Technological innovation in Pompeii was driven primarily by internal social change, with which came the need to provide foundations and walls for more elaborate houses that would replace pre-existing buildings. The proposed scenario reveals an important similarity with Rome, where the implementation of concrete in the domestic context happened around the same time, and on the impetus of similar social and cultural concerns on the part of the Rome élites.[107] One notable difference, however, is that the transition to the new building technique must have been perceived as much more revolutionary in Rome than at Pompeii, given the complete lack of a pre-existing tradition of rubble architecture at the former.

The discovery of such simultaneous and convergent developments at Rome and Pompeii brings us back to our starting point, raising again the question of whether Roman influence lies behind the introduction of concrete to Campania. The issue can now be tackled in a more pragmatic fashion. In past reconstructions, the refinement of concrete technology, its large-scale application, and the rationalization of the building process at most urban sites in the region have all been interpreted as advances brought about by direct Roman presence in the region. The influx of Roman colonists at Liternum, Volturnum and Puteoli (established between 197 and 194 B.C.: Livy 32.29.3; 34.45.1-5), and the arrival of Roman *negotiatores* and rich villa-owners in the countryside (e.g., around Cumae),[108] have been seen as particularly relevant in this respect.[109] Yet there is no evidence to suggest that Roman builders were ever involved in the construction of the élite concrete houses of pre-Roman Pompeii. The redevelopment of the colony of Cosa in the early through mid-2nd c. B.C., for which direct Roman intervention is certain, provides an instructive parallel to caution us against any straightforward connections; there, structural concrete is not employed for domestic architecture, not even in the case of houses whose plan is of the canonical Roman atrium type.[110] To come back to Pompeii, it has been demonstrated that the design of one of the key sites of my investigation, the Casa di Pansa, was based on the Oscan foot.[111] This suggests that local specialists were responsible for the project.

Although it is possible that Pompeian masons learned of the new technique as this was being introduced at Rome, it is unlikely that they were adopting it so as to imitate the way of doing things of Rome's aristocratic residences. Observation of the physical properties

107 Mogetta (supra n.2) 29.

108 J. H. D'Arms, *Romans on the Bay of Naples* (Cambridge, MA 1970) 17.

109 Thus F. Zevi ("L'ellenismo a Roma nel tempo della colonizzazione in Italia," in *Il fenomeno coloniale dall'antichità ad oggi* [Atti dei Convegni Lincei 189, 2003] 80-87) links the development of vaulted concrete architecture at Rome and Puteoli. The idea is partly based on the synchronism between the foundation date of Puteoli and the construction of port infrastructures on the Tiber (the Emporium and the Porticus Aemilia, which Zevi identifies with the *opus incertum* building of Testaccio, as falling in 193 B.C.).

110 E.g., the House of Diana: E. Fentress, *Cosa* V. *An intermittent town. Excavations 1991-1997* (Ann Arbor, MI 2003) 21. Mortared-rubble architecture surfaces only in the second phase of urban development, most notably in the lower houses occupying the W block: V. J. Bruno and R. T. Scott, "Cosa, 4. The houses," *MAAR* 38 (1993) 66-67 and 71.

111 C. L. J. Peterse, "Notes on the design of the House of Pansa (VI, 6, 1) in Pompeii," *MededRom* 46 (1985) 35-55.

of *lavapesta* could easily have provided local builders with the empirical knowledge to switch from clay-based to pozzolanic mortars, allowing them to make extensive use of rubble (including recycled and waste material) also in load-bearing elements. The fact that important features of the earliest concrete houses at Rome (e.g., the use of *opus quadratum* on top of the mortared rubble foundations, even for interior partitions)[112] do not appear in the Pompeian examples undermines Romano-centric ideas of diffusion. On the contrary, it has often been remarked how the local architects and builders working for the wealthy Samnite patrons who commissioned the new houses produced quite an original class of monuments. The reason for this has been sought in the greater degree of political and ideological "freedom" that Pompeian élites enjoyed in the reception and display of Hellenistic luxury than their Roman counterparts had.[113] It was away from the metropolis, in their villas on the Bay of Naples, that Roman senators could embrace those models on a grander scale. It is indeed plausible that Romans themselves developed their technology by experimenting with the highly reactive materials available in the area in this context,[114] but the possibility that they could have relied on local knowledge should not be excluded *a priori*.

To reach firmer conclusions on the tempo, dynamics and direction of the technological transfer of concrete, a regional survey of concrete architecture in Campania, including public buildings, is needed.[115] The new reconstruction I have outlined for Pompeii, however, has potentially much broader implications for how we should conceptualize architectural change in Republican Italy, challenging the idea that this came about as the result of fashion waves radiating from the core to the periphery. The evidence suggests that a greater rôle was played by non-Roman actors in the creation of the new building style that was emerging in the domestic sphere in the middle of the 2nd c. B.C. Soon the new building medium was incorporated as a key element of the package, becoming a status symbol of its own (as is suggested by the rapid spread of concrete to villa architecture).[116] This style has come to be perceived as the material manifestation of the Roman *koine*, but the network of interaction among the élites which probably determined its diffusion was centered on Pompeii and Campania, as well as on Rome itself.[117]

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112 Mogetta (supra n.2) 24-27.

113 Zanker (supra n.96) 32-43.

114 J. P. Oleson *et al.* ("The ROMACONS Project: a contribution to the historical and engineering analysis of hydraulic concrete in Roman maritime structures," *IJNA* 33 [2004] 199-200) stress the importance of the area of Puteoli for the origins of the formula of hydraulic mortar.

115 The topic forms part of my ongoing research on Republican Roman concrete architecture. For a preliminary survey, see Mogetta (supra n.7) 264-81.

116 M. Torelli ("The early villa: Roman contributions to the development of a Greek prototype," in J. A. Becker and N. Terrenato [edd.), *Roman Republican villas: architecture, context and ideology* [Ann Arbor, MI 2011] 8-31] 19) provides examples of the mid- to late 2nd c. B.C. from Etruria, Campania, Apulia and Lucania, although he connects it primarily to a slave-based organization of construction. For Latium, see the well-documented case of Tibur: M. Tombrägel, *Die republikanischen Otiumvillen von Tivoli* (Palilia 25; Wiesbaden 2012). Interestingly, villa-owners in the *suburbium* of Rome seem to have clung to the old *opus quadratum* until at least the end of the 2nd c. B.C.: Mogetta (supra n.2) 23-24, Table 5.

117 Fentress (supra n.13) 172-78, on the development of early villa architecture, makes important observations on the spread of styles across political and ethnic boundaries in the genesis of this style, although Roman families were the main "style-setters" in central Italy.

APPENDIX

TYPE B distribution
t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.346153846	0.653846154
Variance	0.235384615	0.235384615
Observations	26	26
Pooled Variance	0.235384615	
Hypothesized Mean Difference	0	
df	50	
t Stat	-2.286647802	
P(T<=t) one-tail	0.013243275	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	0.02648655	
t Critical two-tail	2.008559112	

Observed difference is statistically significant

TYPE C distribution
t-Test: Two-Sample Assuming Equal Variances

	Variable 1	*Variable 2*
Mean	0.259259259	0.740740741
Variance	0.199430199	0.199430199
Observations	27	27
Pooled Variance	0.199430199	
Hypothesized Mean Difference	0	
df	52	
t Stat	-3.961421101	
P(T<=t) one-tail	0.00011394	
t Critical one-tail	1.674689154	
P(T<=t) two-tail	0.00022788	
t Critical two-tail	2.006646805	

Observed difference is statistically significant

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