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Ambiguous evidence: earthquakes and ancient building techniques in an alpine example (4th-7th centuries)

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Abstract
Building techniques from the Roman Age using earth, stone and wood are frequently found in North Italy in town centres and in high-class residential buildings, as in smaller centres or rural villages. In Italy, a study of building techniques has begun only very recently and little is known about the response of these techniques to seismic events. This paper deals with a fortified alpine settlement, located in a highly seismic area, whose buildings were constructed with the Roman techniques and may in two subsequent stages have been destroyed by earthquakes. The archaeological evidence is, however, ambiguous: we have no knowledge of the state of repair of the buildings at the time of collapse, and the stratigraphy has been upset by subsequent reworking for the purpose of recovering the building materials.

Key words *Friuli – seismic archaeological evidence – Roman building techniques*

1. Building techniques in earth, stone and wood

The treatise of Vitruvius mentions various techniques for constructing the foundations and raised parts of buildings: along with the *opus testaceum*, which represents the technique most frequently used in the Rome of his time – among other reasons, because of legislative regulations – he recalls certain techniques of age-old tradition, such as the *opus latericium*, in unbaked bricks, the *craticium*, employing a wooden core filled with clay and straw, and the *incertum*, with prism-shaped stone pieces set in mortar. Only incidentally does he mention unbaked clay as a binding for raised parts and foundations. Thus, even the most recent studies on the archaeological traces of seismic events have concentrated on buildings constructed with «monumental», organically applied techniques.

Stone, earth and wood are the components of very ancient construction techniques: undoubtedly flexible substances, adaptable to the environment and proven by ancient protohistorical traditions but fragile, in a precarious state of equilibrium in which they always appear to be unconnected with an assemblage devoid of solid internal cohesion and prone to serious intrinsic limitations (as regards load capacity, bay lighting and durability). Above all, these building techniques involve constant maintenance ([1]).

Vitruvius [II,1,3,8] refers to them as speculative, cheap modes of construction (*opus craticium*, wattle building) or ancient and already abandoned, surviving in provincial, backward regions of the empire or in the countryside ([2]); and, in his concern to provide the fundamentals for a perfect architecture – *i.e.* endowed with *perennitas*, that indispensable feature of building in a Rome that was mistress of the world and in the empire of Augustus – he gives a negative assessment (except for *latericium*) ([3]).

However, the latest discoveries of urban archaeology in North Italy (from Rimini ([4]) to

Bologna to Milan ([5])) are beginning to evidence the presence of these techniques even in prestigious residential buildings, consisting of several floors and featuring floor and wall decoration of high quality that can be dated back to the Late Republican Age and which lasted throughout the Imperial Age. Numerous excavations of rural or minor settlements show the primacy, in alpine and subalpine areas, of «poor» building techniques having very simple living-area plans and belonging in a protohistorical tradition that survived right through the Roman Age (Santoro and Guermandi, 1994). Of course, only the latest, most thorough methods of stratigraphic investigation can reveal and recognise the fragile traces of these wallings, and this explains why, until only a few years ago, so little was known of these building techniques in Roman Italy ([6]).

The response to seismic events of buildings constructed according to the aforesaid techniques has yet to be assessed. The task is further complicated by the fact that, in antiquity, the raised parts of buildings that had decayed or collapsed were systematically despoiled and the fallen parts adapted for subsequent rebuilding, in which they were used for loose stone foundations and subfoundations.

It should also be noted that archaeologists frequently appeal to seismic events in order to account for the collapse and sudden end of a building or settlement: rather as though an earthquake were a sort of *deus ex machina* justifying the radical alteration without need of further reasons. On the other hand, although the stratigraphic method in archaeology has been considerably refined in recent years, to the point where it is capable of detailed interpretations of formative processes and of the microstratigraphies resulting from damage caused by vegetation and fauna (see *e.g.*, Leonardi, 1992), it has yet to produce a case by case documentation of the morphology of collapse that takes account of the specific nature of the techniques used in constructing the building in question and its state of repair, as well as several other variants (see, in this volume, Guidoboni and Santoro Bianchi). Where it is a case of building techniques in earth, stone and wood requiring frequent maintenance, the state of repair becomes a variable that is hard to evaluate.

Firstly, it is necessary to clarify what these «non-durable» techniques of construction are: in the opinion of Vitruvius [II.8] and Pliny [*N.H.* XXXV,48], the *opus latericium* in unbaked bricks was the best method of construction, owing to its long-lasting qualities, yet it strikes us moderns as one of the most fragile and least durable techniques, though this impression has recently been challenged by archaeological findings.

Side by side with this technique, which belongs to the most ancient Mediterranean building tradition, we have ample evidence of the following:

1) structures having a wooden skeleton plugged with (1.1) clay and straw pressed in moulds (*pisé*), (1.2) clay with a lattice core (*opus craticium*, *torquis*), (1.3) clay blocks, unbaked bricks (*adobe*);

2) structures in dry stone walling (2.1) with foundations (retaining walls), (2.1) without foundations (supporting walls for raised parts constructed in wood);

3) structures in continuous walling in stone and mortar (3.1) against earth, (3.2) *emplecton*;

4) structures in continuous clay walling (blocks, bricks, moulded lumps).

In highly seismic alpine areas such as Friuli, building techniques using natural stone in irregular shapes, with or without mortar for binding, constitute a special case. In the opinion of certain authors (Ciurletti, 1986), the appearance of this technique, together with the employment of a brick covering, marks the chronological division between the protohistorical age and the stage of full Romanization. The Rhetic tradition of construction (which can also be found on the northern side of the Alps, *e.g.* at Avanches, Lausanne, Martigny), with a lower floor built into the rock and raised parts in wood, continued to be followed throughout the Roman Age, with a series of repairs carried out on the stone raised parts and slight alterations resulting from partial rebuilding (see Santoro Bianchi, 1994).

In a few cases certain specific indicators suggest that these alterations may have been induced by seismic events which damaged the previous structures and led to more solid rebuilding: the organic cohesion of the components was strengthened by using a kind of mortar as similar as possible to the stone material employed (again, this is counselled by Vitruvius) and the corners were reinforced by alternate arrangement of headers and stretchers for the corner stones; the connection between wall and corner pillar was thus improved and detachment and overturning of the façade prevented. On the other hand, there appears to be no evidence that the anti-seismic device of a horizontal brick perimeter wall was employed in North Italy. This would enable the load to be distributed over the whole section of the structure and lateral stresses to be withstood; but even in North Italian buildings which testify to a knowledge of brick construction, *e.g.* in the outer covering, the technique does not seem to have been used, though it is amply documented at Pompei (Adam, 1990).

To sum up, even at the height of the Roman Age building technique in the alpine area continued to be dominated by the protohistorical tradition and prevented ancient builders from appreciating the advantages of applying new technologies and new products for improving the wear of buildings and their resistance to stress, including that exerted by earthquakes. Attempts have been made to identify a «local earthquake culture» from the most ancient roots; but archaeological evidence points rather to an inertia, and even a cultural resistance to the adoption of building techniques other than those sanctioned by age-old tradition, even when these latter had given ample proof of their fragility. The same opposition to innovation can even be found in quite recent times and has been responsible for the tragic events undergone by historic buildings in areas affected by earthquakes.

2. An archaeological case in a seismic area

Forgaria in Friuli, a small town that suffered worst in the 1976 earthquake that struck the Gemona area, provides an emblematic example of this situation where ancient building traditions persisted. The catastrophe was responsible for the destruction of 80% of Forgaria's dwellings constructed in the traditional way in stone pieces with a little mortar binding, and many lives were lost.

Extensive stratigraphic archaeological excavation is underway on the hill overlooking Forgaria, at the site of the ancient Castelraimondo: this site features a hill with three peaks which in Antiquity and the Middle Ages was occupied by various settlements prior to the present-day one at Forgaria. Excavation by the University of Bologna has revealed a multistratified settlement of long duration, from the IV century B.C. to the X century A.D. The buildings underwent alteration accordingly as the functions of the several buildings and the entire township changed (Santoro Bianchi, 1992). Some of these alterations may be connected with seismic events.

The first village, dated to the protohistorical age (IV century B.C.), belongs to the typology of fortified hilltop settlements, which in the eastern alpine area are known by the name of *castelliere*. The highest point of the hill was occupied by a series of alpine-type dwellings with lower floor cut into the rock, the whole surrounded by a defensive wall in earth and stones. The purpose of the village was to control the ford over the River Tagliamento and the deep, high valley of the Arzino (figs. 1, 2 and 3). At this stage it was thus the political and religious centre of an ample mountain territory and an outpost overlooking the Palaeo-Venetic plain inhabited by populations with a Rhetic culture. It was also the site of important stages in the working of iron arriving from the mines at Predil.

A large building intended for residence, but also for public and perhaps religious functions (building V) went up at the highest point close to a small fault escarpment running across the hill from east to west at this point. Here is a further instance of that attraction between settlements and earthquakes that has been so brilliantly recalled at this conference. In our case, a useful space had been created over time by the faulting and the subsequent colluvial prism: a small natural plateau, well sheltered from the cold north winds channelled from the Arzino

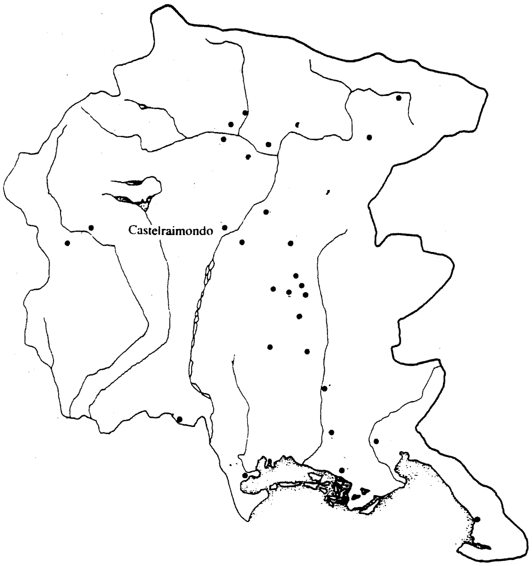


Fig. 1. Map of ancient settlements in Friuli.

valley, high enough to afford good control of the Arzino and Tagliamento valleys and having a pleasant south exposure. Karstification phenomena lent magical and cultural properties to the faulting and the sinkhole that resulted. The building constructed nearby – with a foundation ritual, as archaeological investigation has revealed – consisted of a number of rectangular rooms joined by a corridor. It had a base of large unmortared stones, which supported walls made of wood or, more likely, of a wooden skeleton filled in with clay. The roof, in some organic material (wood or straw), rested on an internal framework which was not connected with the walls and consisted of wooden poles on the corner stones. The same technique had been used in the other buildings in the village.

Whether the ancient inhabitants of the village deliberately chose to build their dwellings in light flexible structures that could stand up fairly well to seismic events, or whether the

Fig. 2. Aerial photograph taken at low altitude from south-east of the Zuc 'Scjaramont (Castelraimondo) between the valley of the Tagliamento (left) and Val d'Arzino (right). The structures of sector V are visible.

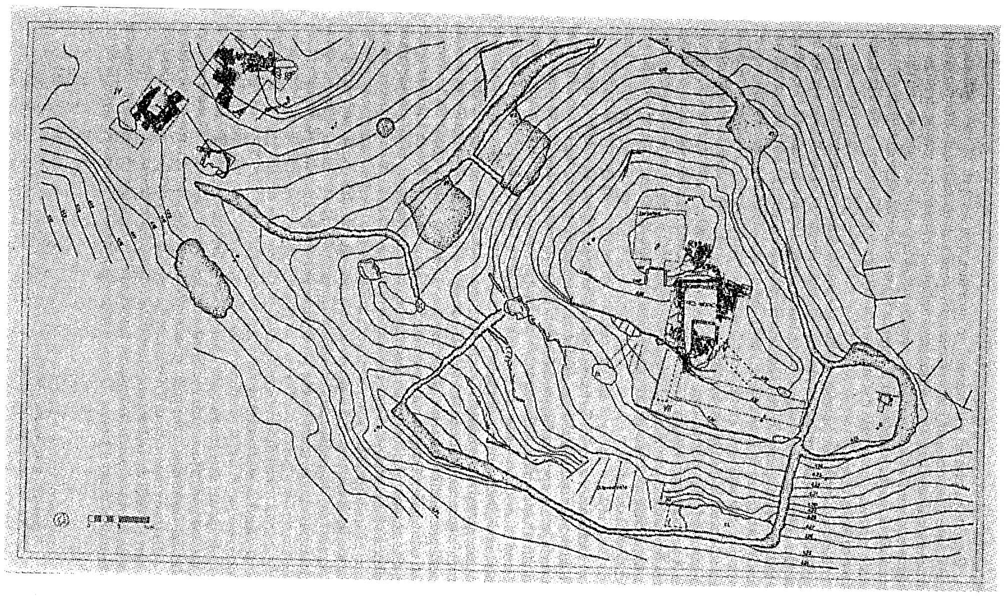


Fig. 3. General ground plan of the settlement, with indication of the ancient structures excavated.

decision was imposed by the nature of the materials available, we do not know. Certain expedients, like the framework supporting the cover unconnected with the wall structure, do indeed suggest that a «local seismic culture» existed: these features have not been found in other villages of the same period having similar characteristics but sited in areas less subject to earthquakes (*e.g.* Sanzeno, Montisei: Perini, 1969, 1978; Ruta Serafini, 1984).

The village was strengthened further during the stage of Roman conquest in the I century B.C., when it became a point in the road control system (*cursus publicus*) set up by Augustus. At least two control- and watch-towers were erected, one on the rocky cliff overlooking the main village building (building V) and a monumental one at the entrance to the settlement, connected with the fortifications surrounding the village. This latter tower was built in *opus incertum*, *i.e.* in irregular prism-shaped stone pieces bound with a thick tenacious mortar in the outer surfaces of the walls and with pebbledash on the inner surfaces. It must have been fairly high (at least six metres) and have had a facing of bricks, pantiles and flat tiles. The tower stood on foundations dug to a depth of 1.80 m and was supported on its north and south sides by buttresses; it is not known whether this was intended as a precaution against earthquakes or, as seems more likely, to improve its stability in relation to its height and to the clayey nature of the ground at that point of the hill.

During this stage, building V also underwent alterations: the top covering in organic material was replaced by a heavy twin-sloped roof of brick (pantiles and flat tiles) (see fig. 5). Since this load would have been too heavy for the wooden frame that had supported the original covering, the frame was altered and the roof was also made to rest on the side walls whose stone base was accordingly raised. In addition, the dividing walls (of wood?) were now made into retaining walls. The structure that resulted was actually much less stable than the previous one, since the walls, still of unbound material, were stressed to the limit. The technical features of both these interventions (construction of the towers and alterations to building V) are such as to make it likely that they are the work of the central Roman authorities, performed as part of a programme of military activities. The natives of the area continued to inhabit dwellings of traditional type (second stage of building IVter).

Although they represent the application of more advanced construction techniques, with widespread use of artificial components, these interventions reveal scant attention to the problem of response to earthquakes; that this problem was underestimated may have been due to a long absence of seismic events in the area, or because it did not belong in the building culture of the new overlords.

The late III century A.D. – a time of vigorous economic expansion, when the strategic role of the settlement had been appreciated and strengthened – saw the sudden collapse of both building V and tower IV. The roof of the residential building caved in when the covering of the overlooking tower fell upon it: the resulting instability caused a series of injuries to the walls (fig. 6a). Of course, this could have been the consequence of a gale that had torn off the roof of the lookout post, but the same event also damaged the walls of tower IV and caused part of its covering to collapse. Other residential buildings, constructed with traditional techniques, also suffered. In particular, the roof of building IVter, made of sandstone flags set on a wooden lattice, fell in, and, in falling, the flags smashed some terracotta vases: the house was therefore inhabited. In building V, too, we found a small vase that had been overturned in falling from one of the shelves attached to the wall (fig. 8).

All this might have been the result of an earthquake, but we have no other evidence to support the assertion. Now, it is not possible to extract any revelant information from the morphology of the collapse that caused the stratigraphy: all the buildings in the settlement were immediately reconstructed, using the stones

Fig. 4. Sector V from the south. On the rocky cliff to the north (fault escarpment) note the trace of the wooden dwelling that occupied the plateau in the IX century A.D. Below, the walls of the 4th stage, in prism-shaped stone pieces bound with mortar, and further below those of the 1st stage (in large irregular stones).

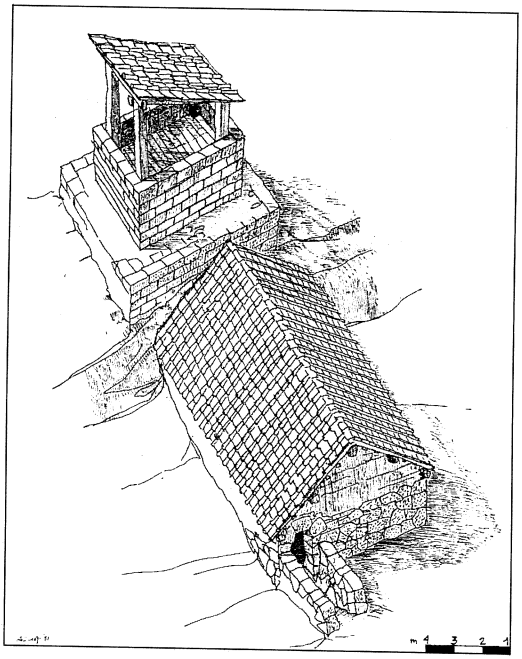


Fig. 5. Drawing of hypothetical reconstruction of building V in the 3rd stage of the settlement (early I century A.D.).

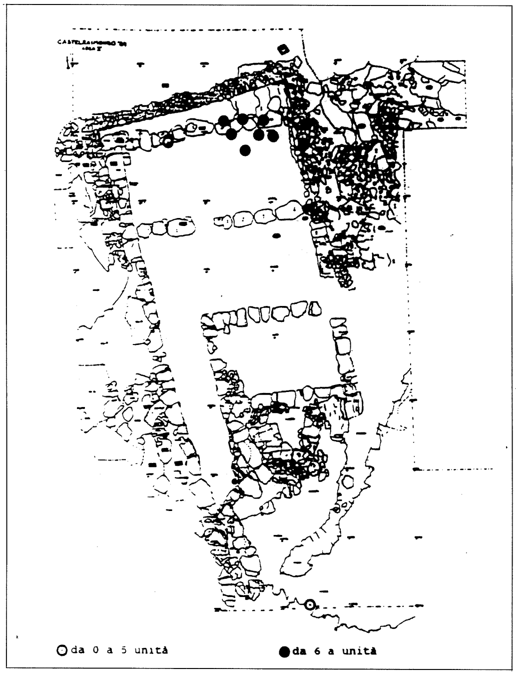
from the collapsed buildings, duly recut into regular shapes, for the foundations and sub-foundations of the new structures. The damage was certainly increased by the fact of the settlement's being positioned on a steep slope and by its terraced arrangement, which may have created an avalanche effect.

In the reconstruction of all the buildings in the settlement we can find technical improvements. In a period when the empire was in a state of extreme military tension, with raids by groups of barbarians and, above all, bands of brigands and deserters from the imperial armies frequently warring with one another, the strategic importance of the site had made the village into a fortress. Building V, in particular, was reconstructed with a walling technique in *opus incertum*, with ample use of an excellent mortar enriched with lumps of ground bricks, in continuous walling, two storeys high. The work was carried out very competently. Once again, the roof was in tiles. However, the connection between walls and corners was strengthened with cornerstones laid in alternate headers and stretchers. This characteristic arrangement was perfectly evident in the stratification of the collapse of these corners that occurred four centuries later («herringbone collapse»: Ghetti (1992), p. 352) (fig. 7).

It has been found that at a late stage, somewhere between the end of the VII and beginning of the VIII centuries, the structures still standing suffered a further violent collapse; this shows homogeneous effects and a uniform pattern running in a single direction throughout the settlement, and has been hypothetically ascribed to a seismic event. However, it may have happened when the buildings had already fallen into ruin and were only occasionally inhabited, as the dwellings were gradually abandoned.

With the passage of time, the excellent structures of the fortress that had been rebuilt in the late III century A.D. suffered serious damage from war and fires (around 430 A.D.), and were converted into refuges by the very poor civilian populations of the area. The latter patched up the ruins with light wooden structures, using a variety of materials that betray how the local economy had declined and, as a result, the quality of life. Indeed, after the VI century these ruins were occupied only seasonally or as the occasion dictated: the structure of the population of the whole area had changed owing to a marked decline in the birth rate, linked with a worsening of the climate, and owing also to the rhythms and customs of stock-raising and woodland economy, which involved locating the villages at higher or lower points.

The collapse, which took place when this stage, too, of the settlement had come to an end, is suspect since it involves all the buildings. Moreover, it would seem to have occurred not because the structures were weakened by damp and decay of the mortar, but by a sudden collapse of substantial portions of walling consisting of elements that were still strongly bound together and including the corners that were still well connected; add to this the torsion of the main tower on its founda-



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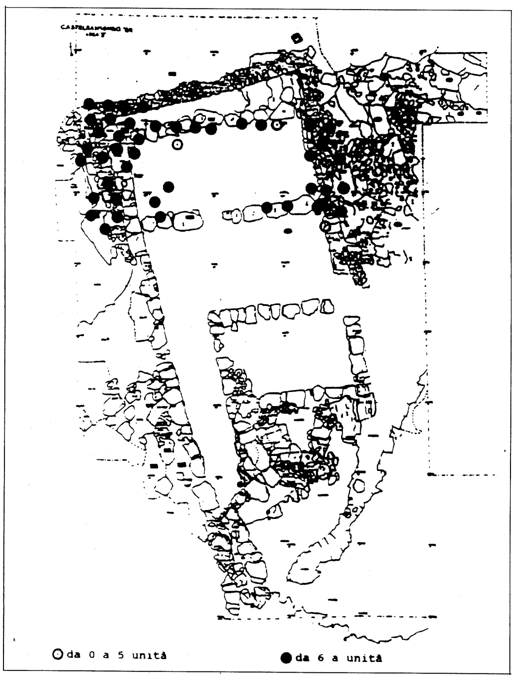

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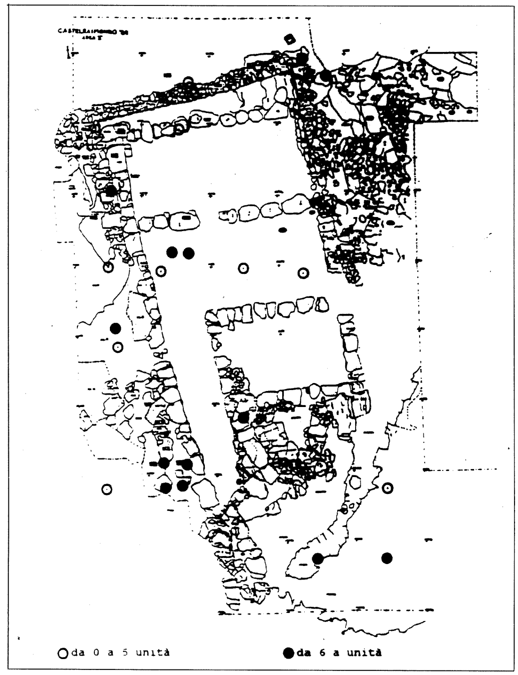

c

Fig. 6a-c. Map of distribution of collapses of bricks in sector V: a) end of 3rd stage (circa 270 A.D.); b) end of 4th stage (430 A.D.); c) end of 5th stage (630-750 A.D.).

tions, which forced out the corner stones at the base and overturned walls right from their foundations. However, the buildings were already half abandoned and the most recent inhabitants, well appreciating the building materials, had taken to scraping off the plaster wherever possible and digging trenches in order to recover the large blocks belonging to the older constructions that lay buried beneath the present ones.

Castelraimondo thus represents an obvious instance of the uncertainty that bedevils archaeology when dealing with seismic events. Several elements do, however, support the hypothesis of an earthquake: the seismic nature of the area, the homogeneity and unidirectional pattern of collapse, the characteristics of the damage to the buildings. Others would appear to contradict it: the decay of the structures at

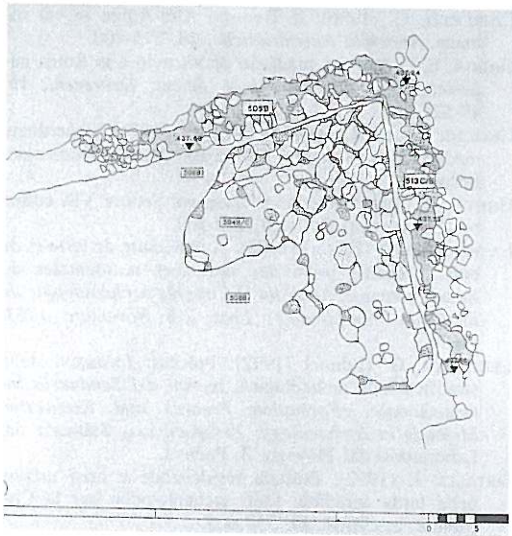

Fig. 7. Sector VB: relief of herringbone collapse (630-750 A.D.).

the time of the event, the difficulty in precisely dating the event, the absence of any historical witness, the scanty knowledge as to how these ancient building techniques would have responded to seismic stress and, above all, the lack of comparisons with other sites in the area subjected to similarly careful archaeological investigation.

NOTES

([1]) See, for example, the passages in Plautus on the use of unbaked bricks (*Truculentus*, II, 2), on the need for timely repairs to the house (*Mostellaria*, I, 100-120) and on the home manufacture of tiles to replace those blown off the seaside villa by a gale (*Rudens*, I, 85 *et seq.*).

([2]) Also Strabo (*Geogr.*, IV, 4,3; XIII, 1,67) refers to the round huts of the Gauls, in wattle and boards, with straw roofs, and Tacitus (*Germania*, XVI, 3) refers to the *materia informi* used by the Germans for dwellings. Varro (*Res rusticae* I, 14,4) speaks of the *maceria* walls and walls in earth and pebbles mixed and shaped in moulds that surround country estates; the same author – *Mennip-*

Fig. 8. Sector VC: fall of a vase (overturning) crushed by wall elements.

peae, 524 Bücheler – for traditional rustic houses prescribes a stone basement, necessary for insulating the earth or wood of the walls against damp and rot; according to Palladius (*Opus agriculturae*, I, 11 and 34; VI, 11-12; X, 13) gardens may be surrounded by walls made of unbaked clay.

([3]) On the relation between Vitruvius and Augustus and the programme of renovation of buildings inspired by *maiestas* and *aeternitas* (see Gabba, 1980, pp. 49-52).

([4]) In Rimini see, for example, Palazzo Diotallevi, excavations 1974-81 (Stoppioni, 1989, p. 29] and the «casa del chirurgo» (Ortalli, 1992, p. 591).

([5]) In Milan Via Tommaso Grossi, Perring (1983), pp. 92-93; Piazza Duomo: Andrews and Perring (1984), p. 91; S. Maria alla Porta: Ceresa Mori (1986), pp. 46-47; M3, excavations for the Milan underground. See Bishop *et al.* (1990); in Piedmont, Wataghin Cantino (1985), p. 42; in Bologna, Palazzo Albergati: Brizio (1896), p. 259; S. Domenico: Gelichi and Merlo (1987); at Settefinestre, Carandini (1985), p. 72, figs. 123, 125.

([6]) At the 1983 conference at Lyon on ancient architecture in earth and wood (Lasforgues, 1985) the editor of the proceedings regretted the total absence of Italian scholars on this topic.

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